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It is my hope that you find the file of use to you personally – I know that I would have liked to have found some of these files years ago – they would have saved me a lot of time !

Colin Hinson
In the village of Blunham, Bedfordshire.

FERRANTI
Defence Systems Limited

RADAR

[REPRINT - Limited Edition]

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA

PSD

RADAR

[REPRINT - LIMITED EDITION]

Preface by

R.P.F. Lauder, B.Sc., C. Eng., FIEE, FIERE

Engineering Manager

This set of eleven historic documents was discovered by PSD's Contracts Manager, bound in book form, in a secondhand bookshop in Tucson, Arizona in 1984. Ferranti's extensive printing and publishing division in PSD has been employed to make a reprint of these volumes in a strictly limited edition of numbered copies. These are to be distributed to special customers and friends, one volume at a time, on a monthly basis, which will build up into a book of great historic significance within one year. PSD's Engineering Manager has contributed an introduction to each volume in the form of a meditation on one or more of the themes within that volume.

The original volumes were issued by the direction of Brigadier General H.M. McClelland, the Air Communications Officer of the United States Air Force, and were originally classified confidential or secret. This classification was downgraded to restricted by May 1946, and today, almost 40 years later, are completed unclassified.

Ferranti has been in the business of military radar design and manufacture since 1947. In peace time, we are accustomed to a comparatively leisurely approach to design, model building, bench, environmental, reliability and maintainability trials, flight test, manufacture and in-Service support, extending over a period of several years. In these volumes, the editors are reporting to military men engaged in a shooting war and are receiving despatches in the form of photographs and commentary from the front line, of actual user experience in the bloody business of war.

As a result, these volumes have an immediacy and an urgency. Men's lives could be saved by broadcasting a good idea, or exposing a potential danger.

As we shall see in Vol.3 the first installation of the MEW radar in Southern England, instantaneously saved the lives of 140 men and 14 B17 bombers who were lost over western Europe and heading out into the Atlantic, with insufficient fuel to make safe landfall. Radar saved both men and machines and the volume rightly exults in this triumph.

At times, the editors are clearly struggling with new concepts, perhaps imperfectly understood. It is easy for us with 40 years of hindsight to smile. The continuing preoccupation throughout the volume is with antenna design and radar map displays. In the days when 10 cms. was a very short wavelength indeed, it was difficult to get sufficiently narrow beams to give good discrimination.

The radar map was the eyes of the bombardier in cloud and darkness and he was to lead his pilot to the target with no other aids.

The keynote is the ingenuity flowing down from the designers through the fabricators, to the users; the overcoming of obstacles, and the achievements, in spite of the limitations of the available components. The excitement and the enthusiasm are infectious. Even in the short period of 17 months covered by these volumes, the new equipment coming into Service, the novel ideas being employed, are impressive.

We in Ferranti with our own traditions and experience in Radar, salute the early workers in the field, and commend their brave history to our readers.



March 1985

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

PSD

FERRANTI Defence Systems Limited

RADAR

Issue No.1 APRIL 1944

INTRODUCTION



R.P.F. Lauder
Engineering Manager
Product Support Department

The extraordinary feature of this volume of RADAR is that it is only 40 years old. When one looks at the techniques used in 1944, the radar displays, the antennae, the transmitters and receivers, and compares them with what is available today, the progress over these 40 years is truly remarkable.

Transport one of the young radar operators pictured here, instantaneously across 40 years to one of Ferranti's radar laboratories, and he would be both astonished and baffled by what he saw. He would be searching in vain for the "tubes lit up" (see page 18), and power supplies of ±5V d.c. would totally confuse him, because if they were not to light up filaments, what could they possibly be for? His power supplies would be in the range +350V, +500V, +750V together with EHT supplies of a few kV.

To him, silicon was something you lay on, on the beach at Guadalcanal, and if he had heard of germanium at all, it was in the chemistry class as a pretty useless rare earth element found inside coal-fired chimneys. The idea that silicon could be fashioned into a crystal capable of amplification would be totally foreign, and he probably wouldn't believe it. Show him the detailed schematic of an IC inside a TO-5 can, and he would mentally translate this into a chassis of vacuum tube diodes, triodes etc., and his credibility would widen even further.

However, this first volume of the series has all the excitement and enthusiasm of a brand new art, where every day new ideas were being generated, new experiences were being exchanged, and new capabilities were being discovered.

We have to remember that in April '44 the emphasis, in both the European and the South Pacific theatres, was in relatively long range, high density bombing raids, with large, slow aircraft flying in formation at about 3000 feet altitude. The problem was to find, and to bomb the target by day through cloud, or man-made smoke, (see the photograph of Bremen on page 12) or by night with blacked out cities. The radars depicted in these pages were primarily to allow the pilot to navigate to the target and, hopefully, to identify it when he got there. The AN/APS-15 radar used was a descendant of the UK H2S radar, and had the capability of 360° PPI display or sector scan to increase the data rate.

Another British derived radar – the SCR 521 was descended from the UK ASV Mk II as an anti-U boat, or shipping radar, and is depicted on page 29 et seq.

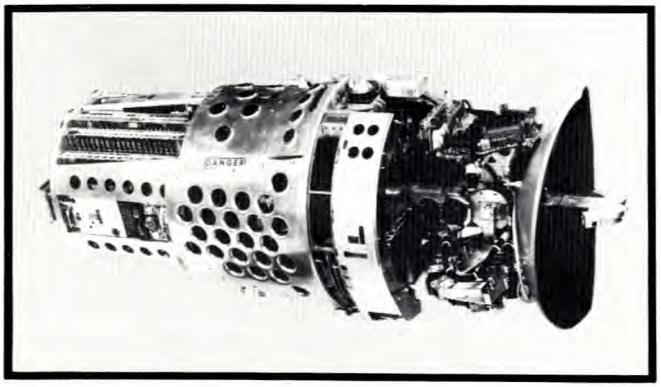
It is also interesting to note the early realisation of anomalous propagation, or the ducting effects of temperature inversion and moisture layers, (see page 31); the effects of large masses of water vapour in the atmosphere on radar (page 27) but surprisingly little about sea clutter.

Ingenuity appears in overcoming the problems of display photography (page 28), and in blind landing improvisation (page 24).

Many of us may be surprised that ECM was in use by both sides in 1944, even though it was in the rudimentary form of window chaff.

We in Ferranti started our major contribution to military radar technology in the early 1950's, but we salute the early users and maintainers shown in these pages.





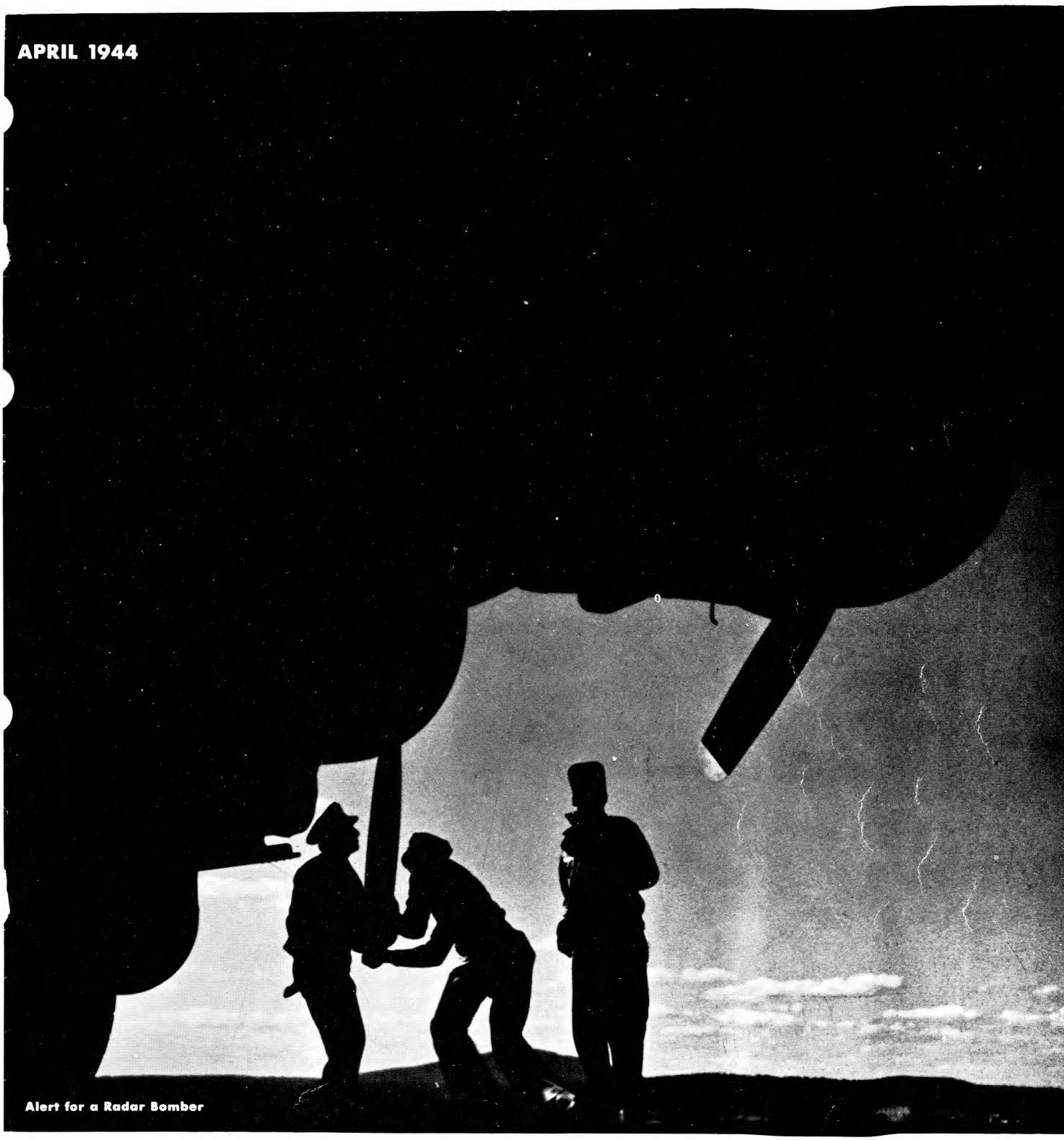
AIRPASS 1
AI AND GROUND ATTACK RADAR

Designed in the early 1950's, Ferranti's AIRPASS 1 Radar is fitted to the English Electric Lightning aircraft for both the Royal Air Force and the Royal Saudi Arabian Air Force. Based entirely on vacuum tubes, this highly versatile radar was the first high power, monopulse radar to enter squadron service in the world.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

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APRIL 1944



Alert for a Radar Bomber

RADAR

RADAR

In This Issue

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RADAR is issued each month for confidential distribution to all qualified personnel. It is published with the technical and editorial assistance of the Radiation Laboratory of the Massachusetts Institute of Technology, and by official direction of

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EDITORIAL ADVISERS: Maj. Gen. Barney M. Giles, Chief of Air Staff; Maj. Gen. Roger B. Colton, Chief, Engineering and Technical Service, Office of the Chief Signal Officer; Brig. Gen. Thomas D. White, Assistant Chief of Air Staff, Intelligence; Dr. Edward L. Bowles, Consultant on Communications to the Commanding General, Army Air Forces; Dr. Louis Ridenour, Assistant Director, Radiation Laboratory.

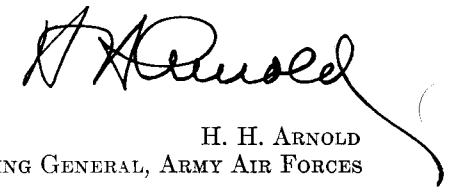
PUBLICATION DIRECTOR: Chief of the Radar Branch, Office of the Air Communications Officer—Col. W. M. Canterbury.

EDITOR: Dexter W. Masters **ASSOCIATE EDITOR:** Nancy Newton.

You'll get more out of this publication if you put something into it. Information and photographs on operations and maintenance of equipment in the field are requested. Submit material to Radar Editor, Office of the Air Communications Officer, Headquarters of the Army Air Forces, Washington, D. C.

RADAR: " . . . make solid use of it"

The personnel of the Army Air Forces must know as much as possible about radar, and make the greatest possible use of both their knowledge and their equipment, for the perfectly simple reason that by so doing they will be able to fly better, fight better and deal with the enemy more effectively in general. Anything which contributes to these ends is of the first importance, and the publication RADAR clearly comes under this heading. I am glad to see it in production, I wish it well, and I strongly urge Air Force personnel to make steady and solid use of it.



H. H. ARNOLD
COMMANDING GENERAL, ARMY AIR FORCES

RADAR: " . . . a tool of war"

RADAR is a magazine which is a weapon. It has one purpose: to improve the tactical and operational use of radar equipment among Air Force personnel, thus to increase the AAF's fighting effectiveness.

This publication will work to achieve its purpose by making itself a clearing house for news and thinking about radar — by reporting radar developments on the fighting fronts — by clarifying problems that arise in the handling of radar equipment — by analyzing tactical potentialities of these vital and complicated devices. RADAR is being produced in answer to a known need, and General Arnold states that need very plainly.

Starting with this issue, RADAR will be going out to you every month — shortages and the rigors of transportation permitting. I urge you to think of each issue as a tool of war, and to judge it by the cold standards that must be applied to any tool of war. If it helps you to do your job not only better but enough better to warrant our effort in producing it and your time in using it, put it to work for all it's worth. And if at any time you see ways to increase its usefulness, speak up.

The staff of RADAR is asking no quarter and making no bones about their intentions: they intend to do a good job. I am convinced that they will.



HAROLD M. MCCLELLAND
BRIGADIER GENERAL, U.S.A.
AIR COMMUNICATIONS OFFICER

RADAR: " . . . criticize . . . participate"

General Arnold and General McClelland set forth their hopes and expectations concerning RADAR before this first issue was put together. It has been put together with those hopes and expectations steadily in mind. An important job has been laid out for RADAR. An important help in doing it will be the criticism and participation of RADAR's readers.

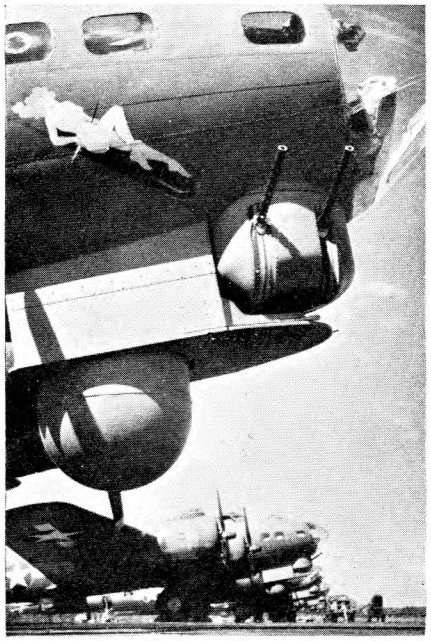
THE EDITORS

12 RADAR BOMBERS

. . . lead 8th Air Force to record operations



WILHELMSHAVEN-BOUND B-17'S FOLLOW PATHFINDER ON THE FIRST COMBAT TRIAL OF HIGH ALTITUDE RADAR BOMBING EQUIPMENT



ESSENTIALLY, APS-15 is adaptation of high frequency sea search equipment to land navigation and bombing. Double chin housing for antenna (above) marked all early installations. Housing is now in belly turret.

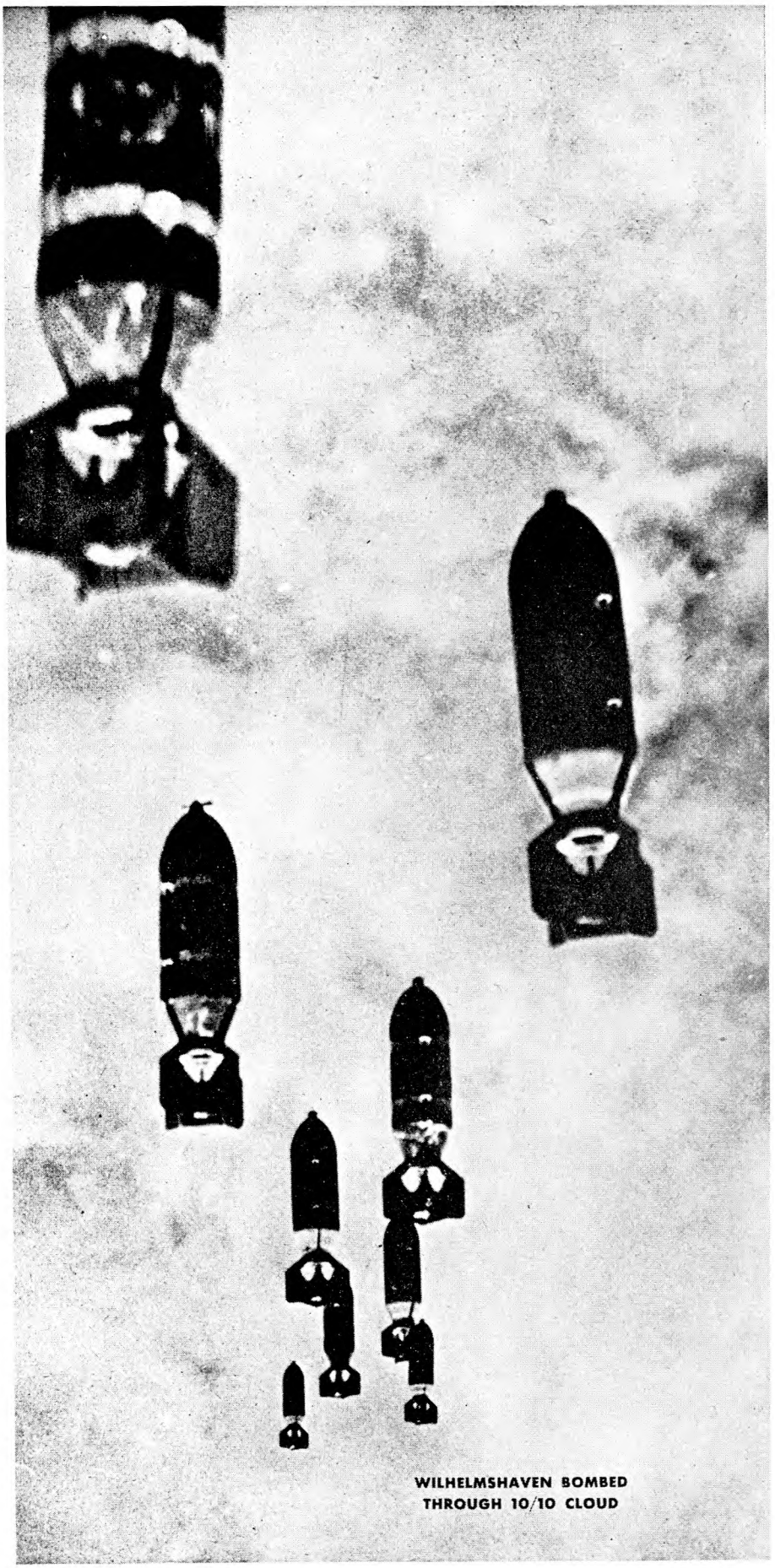
New radar sets keep Europe's skies open

Basically, there is nothing very new about radar, which is by now securely tagged as No. 1 technical achievement of World War No. 2. Developmentally, something new in radar happens almost every time two physicists get together. If emphasis is put on development, it is clear enough how component principles can be old while their embodiment in a given piece of equipment can be a sensation. Radar equipment has been a sensation in many forms since war started, and each time it has been the work of development — *i.e.*, an adaptation or new arrangement of familiar components — which has made it so.

Of all the radar systems put into production to date, the APS-15* high altitude bombing equipment involves probably least that is individually new and most that is collectively sensational. Work to develop it started at a long-term tempo and was promptly converted into a crash project under field pressure. First APS-15 equipment installed in planes was compounded of old parts almost literally bent into new shapes, and there was not much of it. But the idea that gave point and purpose to the shapes was there, and in combat the equipment proved its worth. For the last two months of 1943 and the first month of 1944 the 8th Air Force bombed at a record-breaking rate and most of its bombing operations depended on exactly 12 B-17's equipped with pre-production APS-15 systems.

The enemy might have profited greatly by knowing this a few weeks ago Now he can't do anything about it. For now there are many more than 12 planes providing eyes for the 8th Air Force, and the equipment is coming out of production in steadily increasing quantity.

**Early, pre-production installations of this equipment — the only installations used for the operations reported here — were called H_2X. That designation has become a general term of reference for high altitude, high frequency radar bombing, whether done with U. S. or equivalent British equipment. Official designation for U. S. equipment is now AN/APS-15 (APS-15 for short) and that designation is used here.*



WILHELMSHAVEN BOMBED THROUGH 10/10 CLOUD

Four months of getting

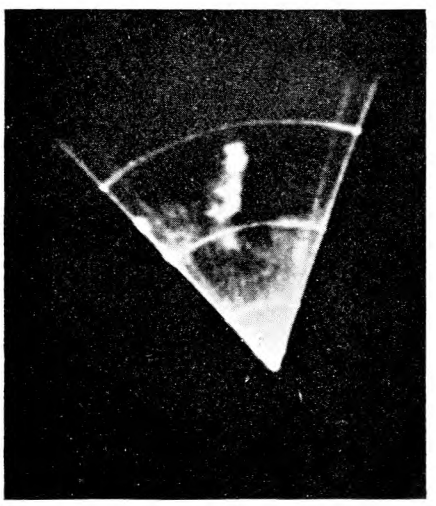
APS-15 moved from U. S. laboratories to the air fields of England in three months — from July, 1943 to October. In that brief time 12 sets of equipment with minimum spares were put together and installed in 12 planes, and 12 crews got a highly concentrated preliminary training. On 1 October the crews put the planes down at the base of the 482nd Group (Pathfinder Force) of the 8th Air Force Bomber Command.

Neither planes nor equipment nor crews were ready for operations but Bomber Command was more than ready. For a month solid Bomber Command inquired and prodded almost daily: "Are you ready now?" said Bomber Command. "Now . . . now . . . now?" And each time the APS-15



IN TYPICAL OPERATION each Pathfinder with APS-15 flies from its base to field of group it leads, usually between 2200 hours and 0500. By 0900, after briefing, all bombers take off.

WILHELMSHAVEN at 16 miles. Actual presentation is much clearer than this photo but even here target characteristics are visible. Bright end of long signal is city's industrial section.



ready = three months of 8th's best bombing, with more to come

group explained that the planes were not yet operational, that the navigators had to have more training. "Maybe the navigators can train over Germany," said Bomber Command, "with 60 planes behind each of them." The navigators kept on training over England, and the radar technicians kept on getting rid of bugs, and parts broke and were repaired, and lights burned late at the Pathfinder base.

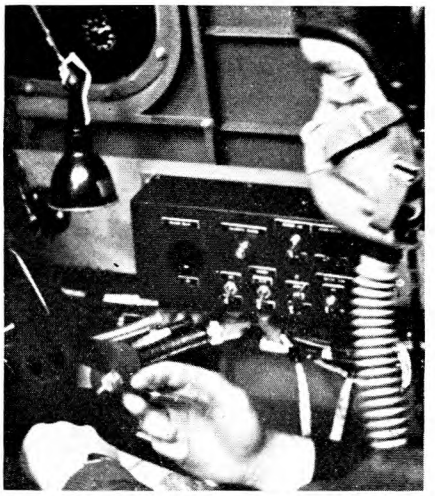
On 30 October came the first standby. It was scrubbed. On 2 November came the second standby and then the alert. On 3 November nine wings took off in the first combat trial of the new equipment (see below). The target was Wilhelmshaven — nine months earlier it had been the target for the first raid ever made over German territory by the then young 8th Air Force.

During November, the 8th made more raids than it had ever made in a month before. During December it dropped its greatest tonnage of bombs and for the first time carried as big a bomb load as the RAF — 24,000 tons. On 13 December the biggest force of bombers ever to go out from England in daytime up to then — some 740 heavies — raided Bremen and Kiel. On into January the 8th flew and struck with heavier forces than ever. The 8th had never before been able to operate in bad weather, let alone on this record scale. And the weather was no better than winter weather ever is over Europe; throughout November and December there were only four visual raids. APS-15 Pathfinders led virtually all the others.

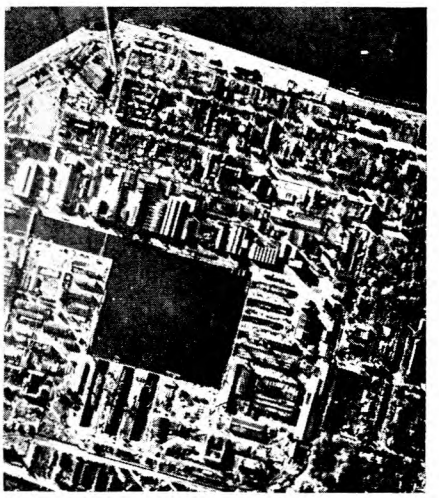
They did not lead all the others. The older, lower frequency British H_2S (in B-17's) served as deputy leader on most raids, ably took over when APS-15 failed, and led several raids on its own. Maintenance troubles, arising in part from high altitudes flown, dogged APS-15 throughout November and were not under control until the beginning of this year (for the first 25 days of January the equipment was 89% operational). Before that time APS-15, like the 8th Air Force itself in its early days, met its full share of doubters and critics. It won out against them just as the 8th had won out: despite difficulties, despite pressure, it got the results.



FORMING OF WINGS takes about two hours. In picture above formation is on way to target. Mickey (radar) operator's main work does not begin until formation hits enemy coast.



MICKEY OPERATOR charts course through overcast below. APS-15 as navigation aid helps avoid flak areas and is valuable, even on visual raids, in lining up bombardier on target.

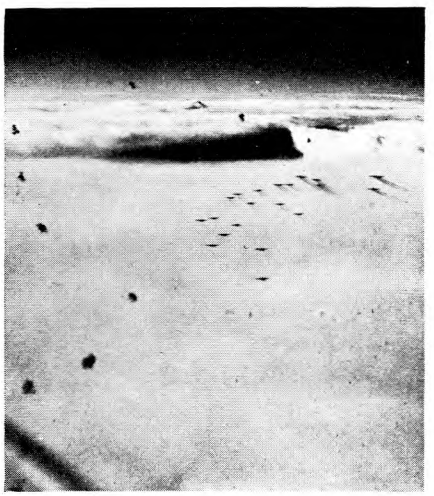


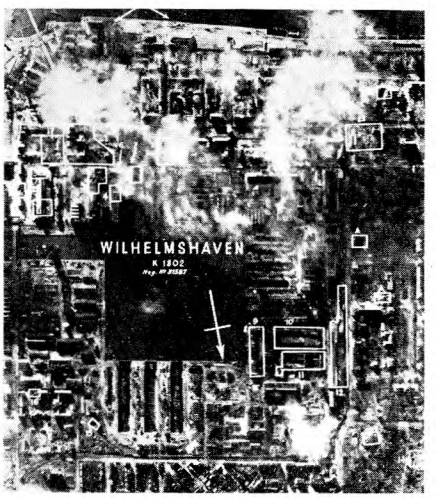
"MEDIUM PRECISION" of APS-15 can't equal eye on pinpoint targets. But skilled navigators can pick target area as small as Wilhelmshaven's Bauhafen (above), 400 yards across.

OVER TARGET formation runs into flak. But an important advantage of radar blind bombing is that AA and fighter opposition are often weaker because overcast complicates defense.

DAMAGE PICTURE shows mean point of impact on target. Bomber Command was impressed; eight raids without APS-15 had missed. Crews cannot see results, so pictures boost morale.

NEW ALERT MAY COME in few hours. First two months, because of short crews and equipment, schedule was especially stiff, with little time in between. Schedule is improved now.









Smoke from fires set by bombs dropped on Bremen boils up (A) through cloud blanket over city. Map (below) shows course of the three wings that made this diversionary raid.

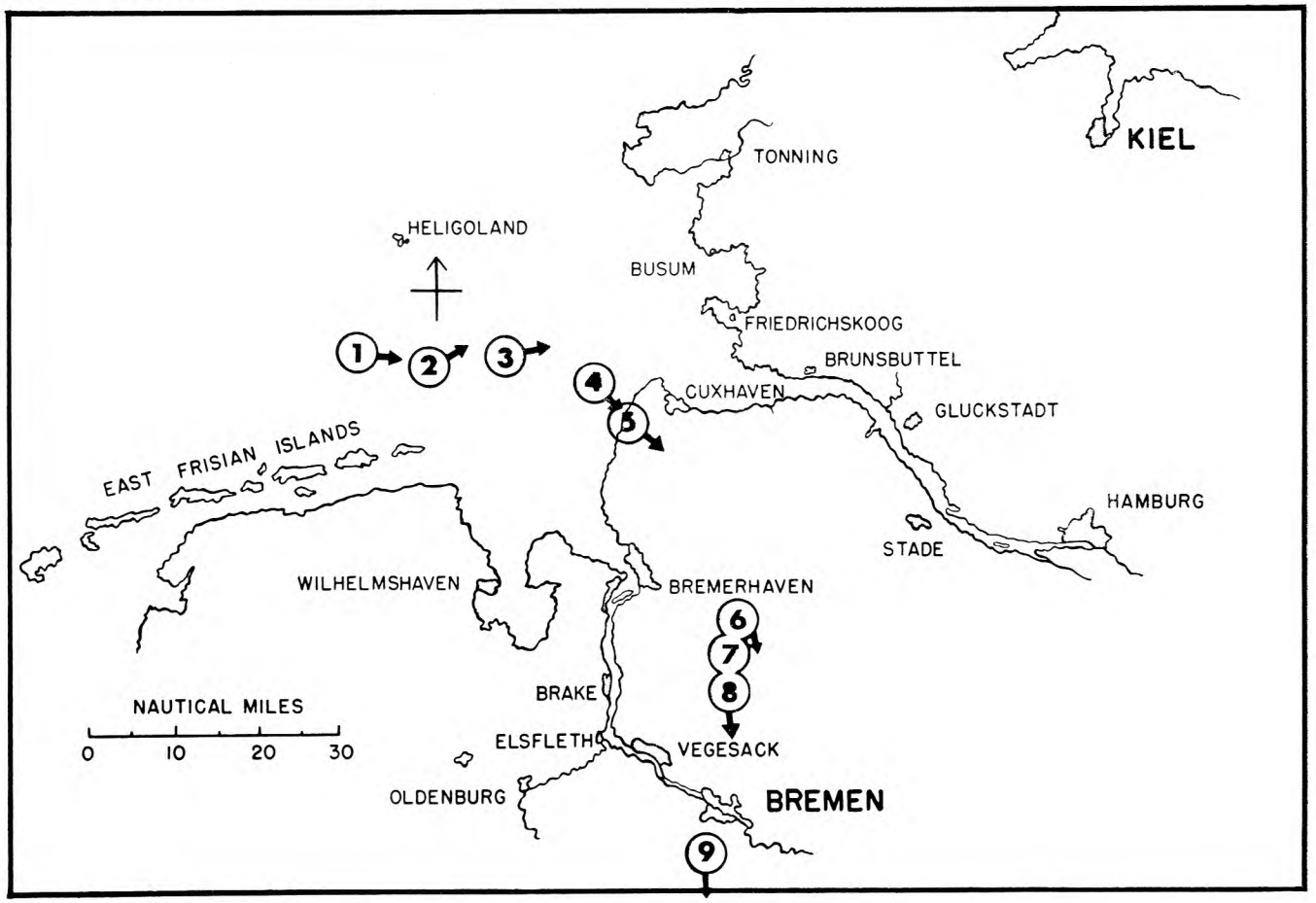
Raid on Bremen

All of Europe was covered with a cloud blanket on 13 December 1943. Yet on that day the 8th AF sent out the greatest force of bombers ever to take off from England in the daytime. The force was led by APS-15. Its objectives: Bremen (*diversionary*) and Kiel (*main*).

The story of the Bremen mission is shown in the pictures at right, the first of their kind ever published. They are pictures of Nazi Germany as seen on the scope of a plane that bombed it.

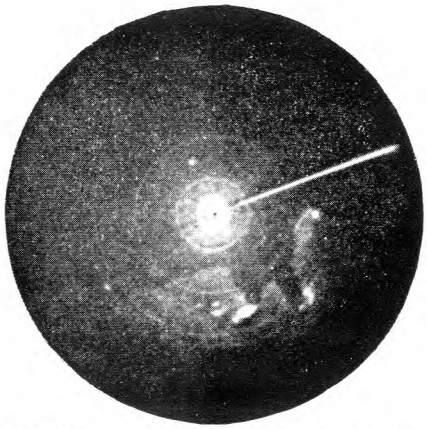
To a skilled navigator, the scattered flecks of light in these pictures are landmarks as familiar and almost as positive as the highway signs of home. APS-15's scope is stabilized, so that north is always up and reference to the map (below) is easy. Radial line on scope shows heading of plane. Key numbers plotted on map show how the plane cut between Heligoland and the Frisians, kept bearing south till course marker lay squarely on the target.

The last picture (No. 9) shows Bremen dead astern a few minutes after 270 tons of bombs had been dropped. Planes returning from Kiel reported "great clouds of smoke" over the city. Photograph at left shows smoke from burning Bremen pushing through the clouds.

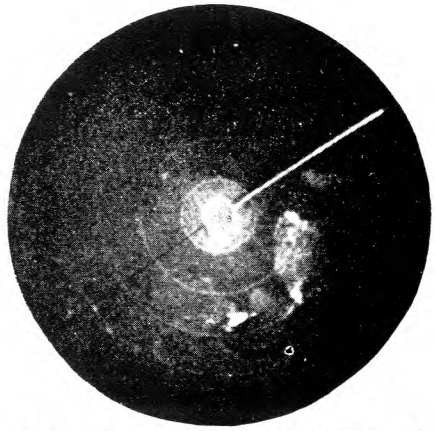




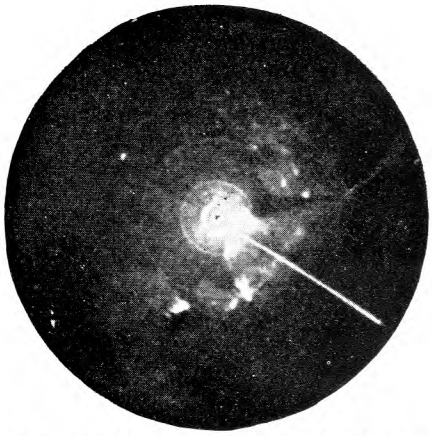
1 Over enemy waters. Radius of circle here is 50 miles. Plane is heading east between Heligoland Island (12 o'clock) and Frisians. Mainland is clearly visible below the Frisians, Wilhelmshaven coming in at 4 o'clock, 30 miles.



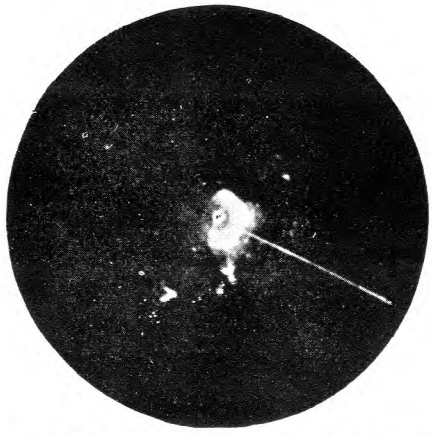
2 Cuxhaven comes in at 3 o'clock, 25 miles; Bremerhaven at 4:30, 30 miles; Wilhelmshaven at 5:30, 25 miles. Note characteristic "W"-shaped outline of the bay. Heligoland is still visible at 11 o'clock, some 15 miles off.



3 Plane has edged up north. Heligoland is astern at about 10:30. Cuxhaven is still at 3 o'clock, now 18 miles. Bremerhaven is now about 4 o'clock, Wilhelmshaven at 6, on west shore of Jade Bay. Range of both, 28 mi.



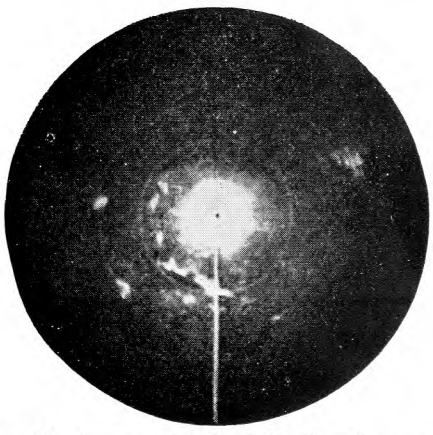
4 Approaching coast just south of Cuxhaven, heading southeast. Bremerhaven and Wilhelmshaven coming in strong. River Elbe bearing off toward 3 o'clock, with several towns visible above it, at about 20 miles.



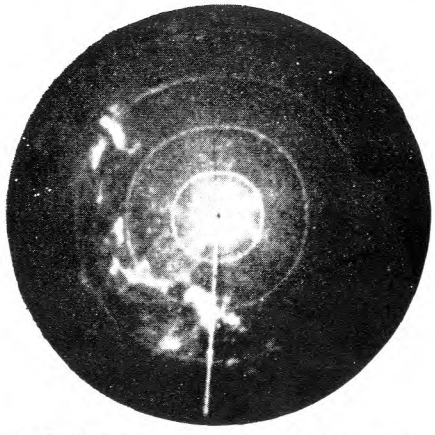
5 Crossing coastline. General signals weaker, but Bremerhaven and Wilhelmshaven are still strong at 6 and 7 o'clock respectively. Heligoland clearly visible dead astern at 10 o'clock, 38 miles. Brunsbuttel at 2:30, 20 miles.



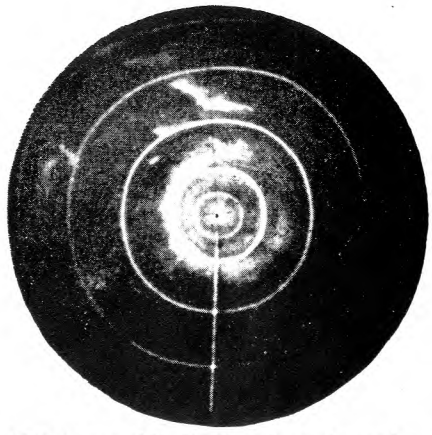
6 Bremen starts coming in at 5 o'clock, 25 miles, near course marker. Bremerhaven at 9 o'clock. Other cities are strung down along river Weser, from 9 to 8 o'clock. Cuxhaven at 10 o'clock, faintly visible astern



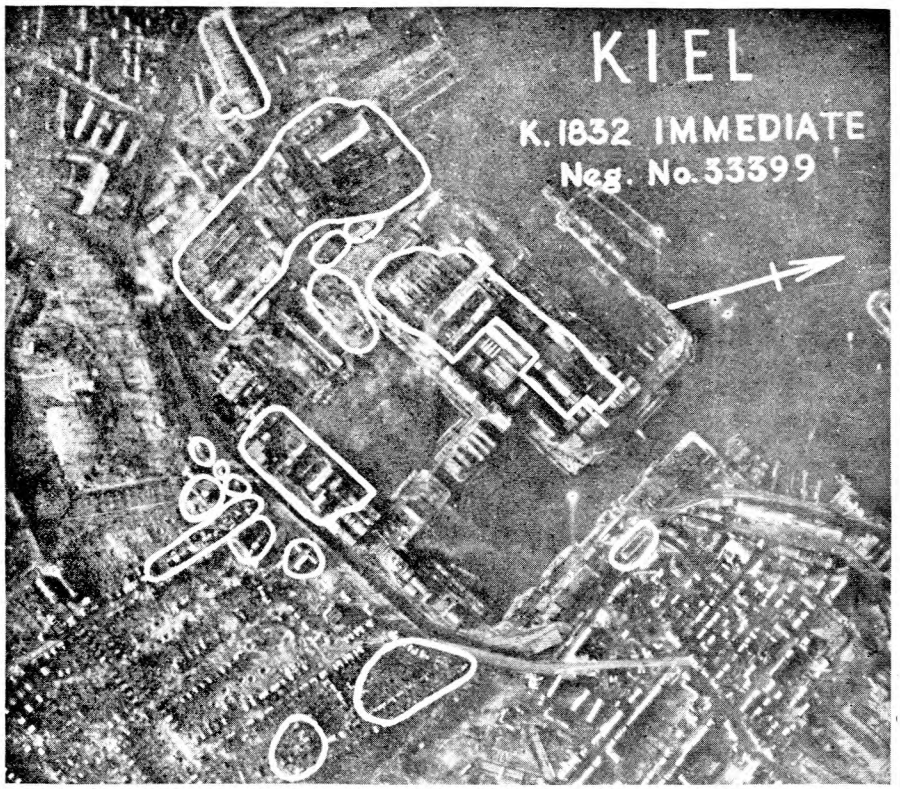
7 Hamburg at 2:30, about 40 miles; Bremen at 6 o'clock directly on marker. Wilhelmshaven at 9 o'clock, 30 miles; Oldenburg at 8 o'clock, 30 miles; river cities running from Bremen to Bremerhaven, from 6 to 9 o'clock.



8 Navigator switches to shorter sweep. Radius of circle is now 20 miles. Bremen shows large at 6 o'clock, about 12 miles, on marker. River cities visible up the Weser to Bremerhaven. Bombing run about to begin.



9 270 tons of bombs have been dropped on Bremen. The city shows dead astern at 12 o'clock, 12 miles, Vegesack at 11 o'clock, 18 miles. The plane is still heading south, but will shortly swing west and head for home.



Bomb damage after APS-15 raid of 13 Dec. 1943. Some dispersal; damaging concentration. Map below shows course of plane in "strayed" wing that saw error in time to alter course.

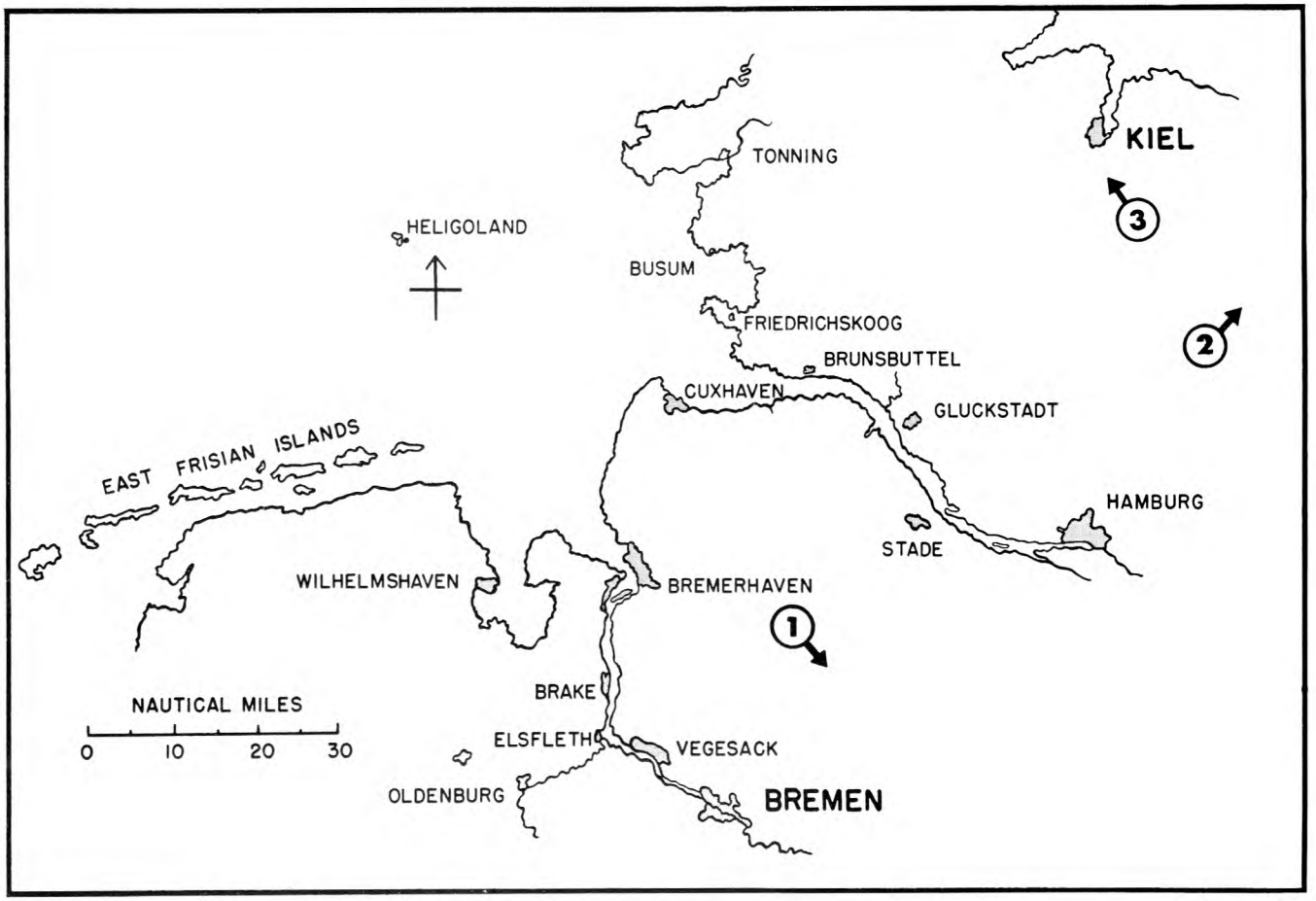
Raid on Kiel

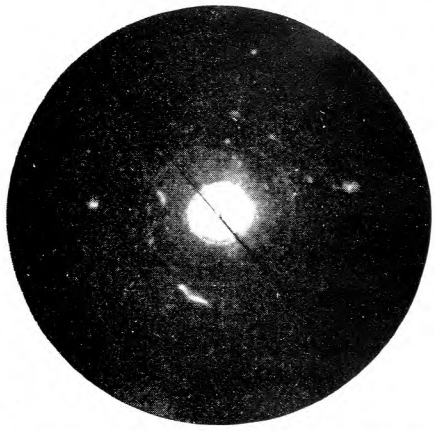
Kiel was a different story from Bremen (page 6).

After three wings of the record 10-wing mission had set off for Bremen, the remaining seven headed up to plant the main load on Kiel. But faulty navigation led three of the seven too far south. As soon as they hit the coastline, the lead wing's Mickey operator called the error. An argument with the wing navigator followed: Mickey lost. Two of the three strayed wings bombed Hamburg by mistake — with apparent effect, since later planes reported smoke.

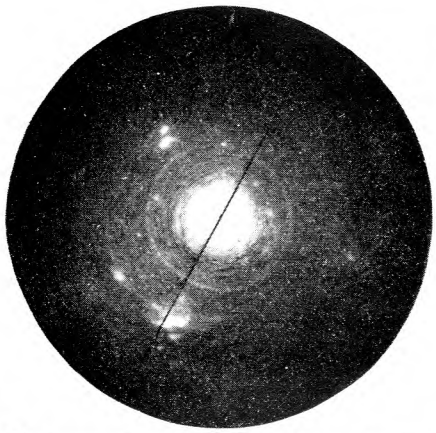
But the last of these three, bringing up the rear, had a Mickey operator who didn't follow the leader. Though bomb run was started, he reported that target was clearly Hamburg. Accordingly the leader took his wing up and around Hamburg, ran on to Kiel, dropped his bombs with heavy damage.

Path of this "independent" wing is shown on map below. It underlines an important fact: with APS-15, you can shop around over the map, hit your target from any angle. Path of lost wings, if shown, would point up equally important fact: improper operation or distrustful leadership can lead APS-15 to make a mistake as serious as bombing Hamburg for Kiel.

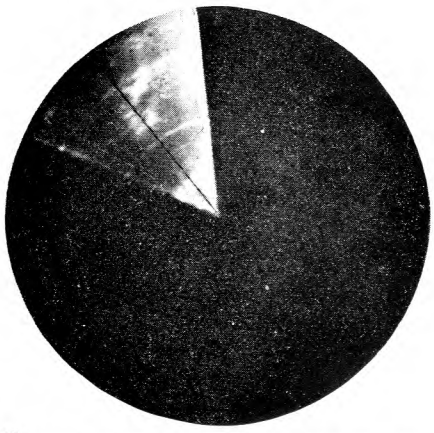




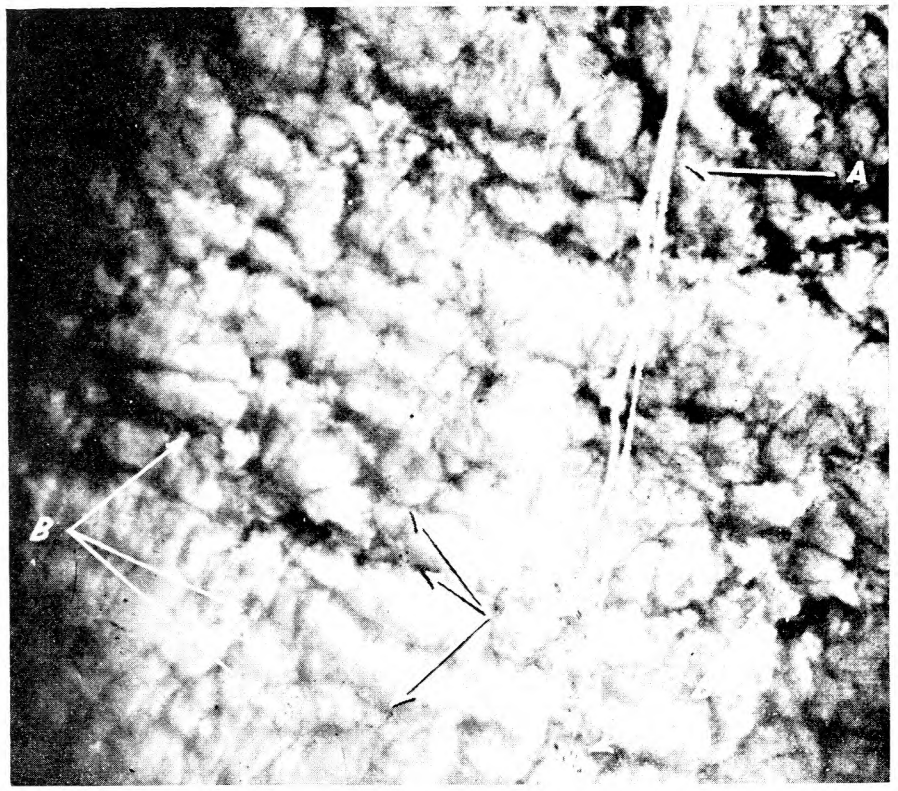
1 Getting lost, though Hamburg, Bremen and Bremerhaven are clearly visible in their characteristic triangle. Course marker not working, but black line from drift marker shows that the plane is heading southeast.



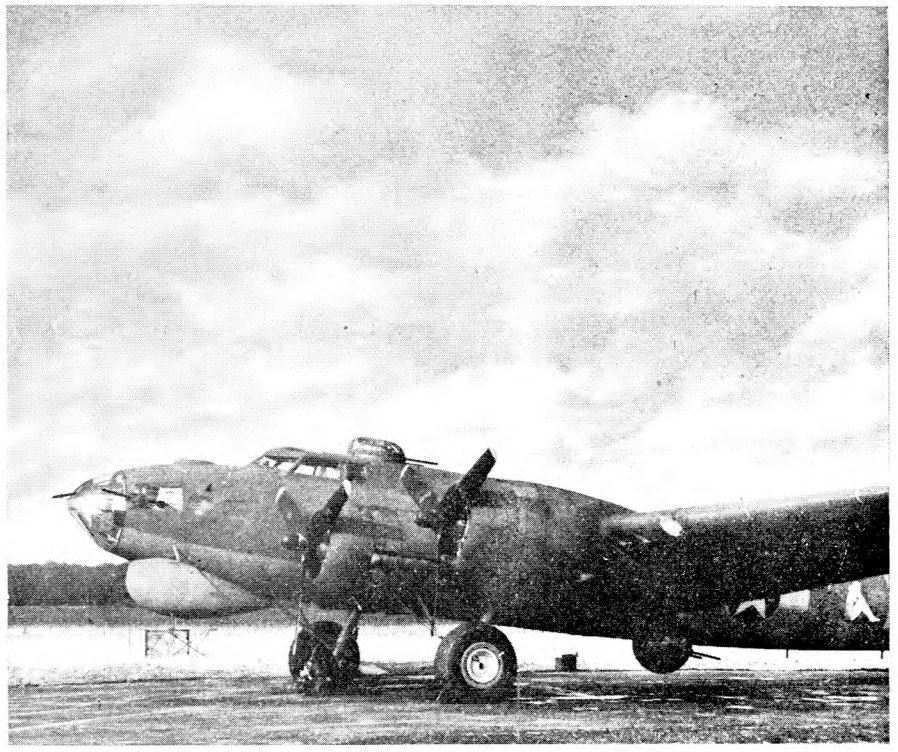
2 Operator has seen his mistake and headed north. Hamburg astern at 6:30, 18 miles. Lubeck and Travemunde are the two small signals just above 3 o'clock, 10 miles. Kiel is now visible at about 11 o'clock, 28 miles.



3 Start of bomb run on Kiel. Indicator has been switched to sector scan to permit greater accuracy in guiding plane. Note "U" which corresponds to buildings and installations along the curved harbor line of the city.



Smoke Trail above (A) is one of several devices used by Pathfinders to mark bomb release point for planes following. This trail was laid over Bremen. Note bombs in transit at B.



Immediate Ancestor and Present Teammate of APS-15 is British H_2S, also installed in B-17's, one of which is shown above at base in England. The H_2S — older and with lower frequency — backs up APS-15 on most missions and also leads many missions on its own. Nacelle for scanner is tear-drop housing (compare with APS-15's dome) just back from nose.

APS-15 at Work

Artist and camera show what happens at three highpoints of bombing run

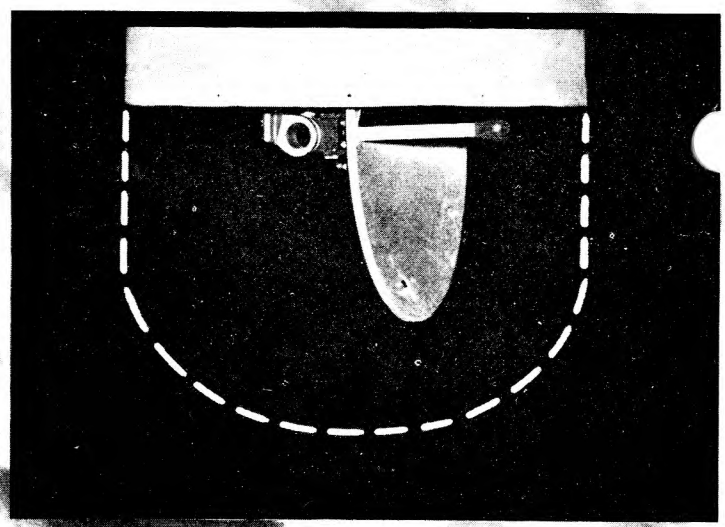
APS-15, as preceding pages suggest, serves the purpose of a badweather bombsight. An optical bombsight is more accurate than a radar bombsight, hence on a clear day Bomber Command may give APS-15 a rest or use it for navigation only. One reason for the quick success of APS-15 is the lousiness of Europe's winter weather.

The bombing functioning of APS-15 is clarified by reference to the makeup of a combat element. Bomber Command is divided into three Divisions, each of which includes three to six Combat Wings. A Wing, consisting of two Combat Boxes each with 60 planes (formed into six Groups of 20), is smallest combat element. Each Wing has a lead Group, that Group has a lead plane, and that plane is Pathfinder for the whole Wing. In operations described on these pages Pathfinders equipped with APS-15 led as many as nine Wings in a single raid, although most of the raids were smaller than this.

The Pathfinder technique, developed first by the RAF and adopted by the 8th Air Force, was instituted to serve several purposes; notably, it allowed maximum utilization of a relatively small amount of radar equipment. The amount of APS-15 which reached the 8th last October was so small as to be virtually useless except with Pathfinder technique. In turn, it extended the technique's usefulness by opening the skies to the Air Force on days when the weather would otherwise have kept bombers on the ground.

Panels to right show three highpoints of APS-15 at work. It is at these points during a bombing mission that APS-15 most graphically and most distinctively makes its contribution to the war effort.





FIRST PANEL

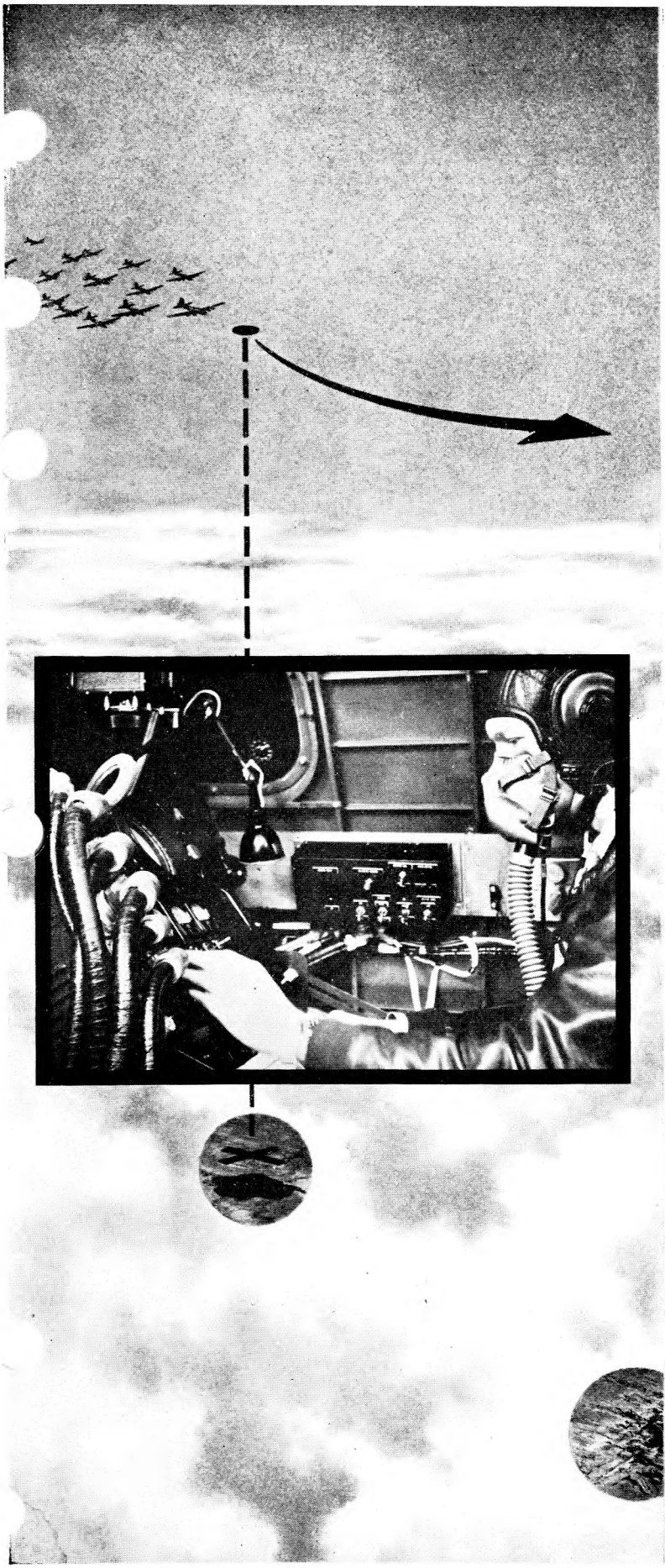
Formation reaches enemy coast. Coastal cities appear on scope and Mickey operator takes over. Inset shows APS-15 dish. Its size and special shape (cosecant^2, as physicists say), in conjunction with very high frequency, give the greater area coverage and higher resolution needed for the job to be done. At altitude flown (25,000 feet plus) the contrast between cities and the land around them is marked.

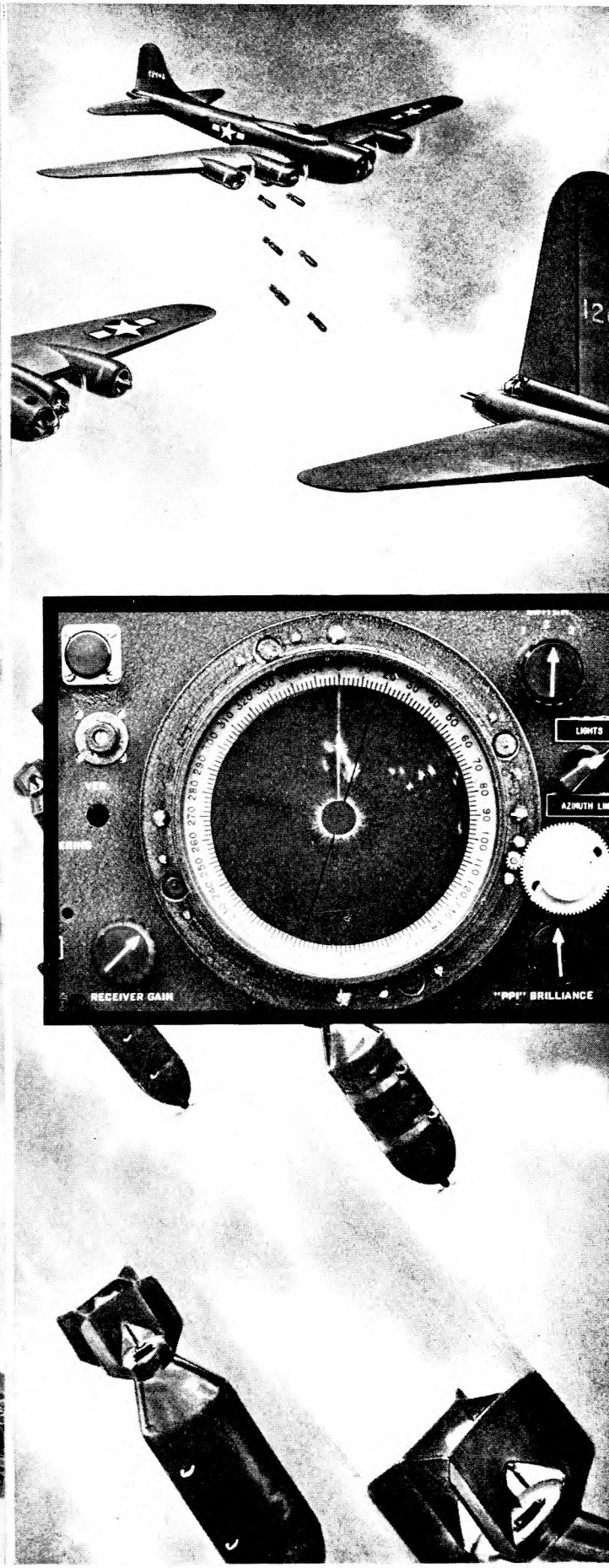
SECOND PANEL

Formation reaches Initial Point (about 20 miles from target) and turns into bombing run. 10/10 clouds cover area but artist has drilled through to show what APS-15 sees: lake which serves as IP and target just jutting into panel. At this point Mickey operator sets up computer, cranks in altitude; that done, he will set in air speed. Computer puts bombing circle onto PPI scope (Plan Position Indicator).

THIRD PANEL

Pathfinder plane, moving out of picture, has dropped bombs and remainder of formation drops on that signal. Inset takes time back 10 seconds, shows scope just before bomb release. Target is coming down drift line (on this day drift is 18° right). When target crosses bombing circle — bright line around center — operator toggles bombs out. At the same time flares or smoke markers (see page 9) are dropped to indicate release point for planes too far behind to see Pathfinder's bombs drop.




LIGHTS
RECEIVER GAIN
"PPI" BRILLIANCE

The Future of Radar Bombing

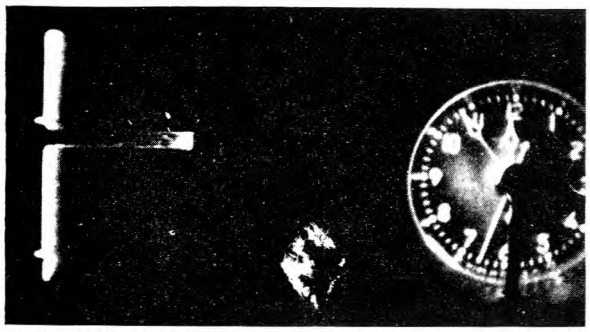
In the photograph below, if you look closely, you can see written the future of radar bombing or, for that matter, the future of daytime bombing; the two futures have much in common. Somewhere under the layer of smoke in the photograph lies Bremen. The eye cannot see it; the memory cannot place it, for the pots that make the smoke extend 14 miles in one direction and 18 in the other, much more than Bremen, and the Germans do not guarantee that the pots will not be moved next time. But this smoke does not exist in radar's world; APS-15 can see the targets of Bremen plain, smoke or no smoke.

As APS-15 is pushing aside the natural overcast which has been one of Germany's staunchest allies, so will it push aside the artificial overcast which Germany has devised to protect its war potential on clear days. The theory of doing so is established, and so is the fact — to the extent of the very limited amount of radar bombing equipment which has gone into operation. But two things remain to be done before the limited fact becomes a big one:

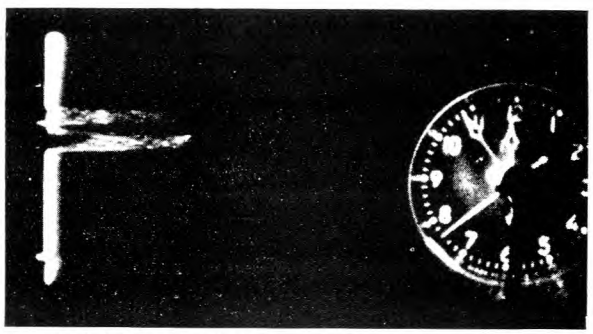
1. **PRODUCTION.** There must be enough equipment to meet the demand, even if the demand calls for equipping every plane in the 8th Air Force.
2. **TRAINING.** There must be enough trained personnel and replacements to man all the equipment that goes into use. And training schedules are not as well in hand as production schedules.

It may be assumed that the speed with which these things-to-be-done will get done will be in direct ratio to the intensity of support for radar bombing in the 8th Air Force. The support had manifest chinks in it when radar bombing was being started, a long three months ago, and high-pressure preparation was paying off with mechanical breakdowns and inefficient operations. The chinks closed and acceptance soared as difficulties were ironed out and APS-15 turned in the cold evidence that it could hit what it could see. Acceptance soared — to coin only a small figure — on the wings of 12 B-17's, whose crews and equipment did the work which can grow into a bombing barrage to cover Germany more completely than overcast or smokepots ever did. The future of radar bombing — which is that — will be realized as acceptance now generates action to make the future possible.

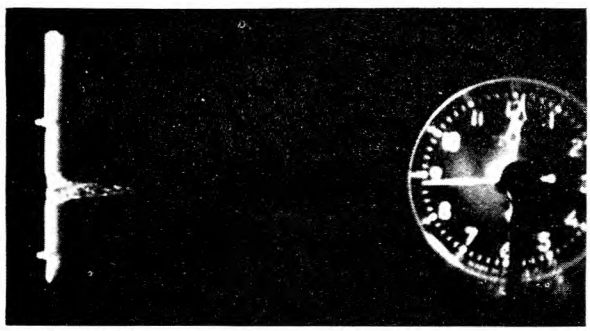




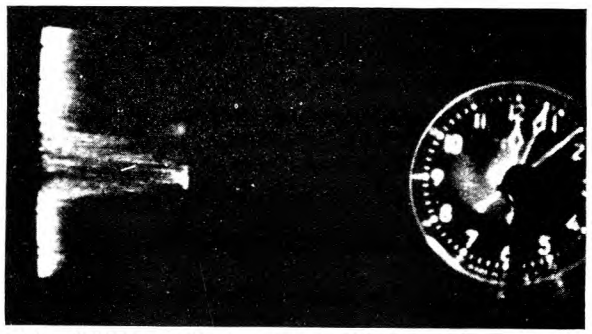
TEST PICTURES show how window's deception works with "A" scope. Above, no units of window have been dropped. Plane's signal is clear, moving upward as plane moves out in range.



FIVE SECONDS later. Plane has dropped window (lower signal) and is now 400 yards away from it. Both signals fluctuate; skilled operator tells window by faster *rate* of fluctuation.



SEVEN MINUTES and 11 seconds later. Window dispersing. Plane has moved off scope, which is still centered on window. In operation plane would have dropped more window by now.



NINE MINUTES and 35 seconds later. Window no longer useful as deception, still obscures scope. By now plane would have dropped much more window, creating many more false signals.

WINDOW works for US

This radar deceiver serves the offense best

The fundamental fact about the little foil and paper strips which are called window (or chaff) is that they are a *defensive* tool for *offensive* aircraft. That fact is also the key to the effective use of window. And that is why the British, who were experimenting with window as long ago as 1941, kept it in the dark until last July, by which time they no longer had to send their airpower up to defend but could send it out to attack.

On the night of July 24th 700 bombers dropped 2300 tons of bombs on Hamburg — and along with the bombs went 30 tons of window. This was the first operational use of window and it worked. Average losses on that and three succeeding heavy raids on Hamburg, all window-protected, were 2.8%. Average losses on six comparable Hamburg raids, without window, had been 6.1%. Window is no sure cure for losses, of course. But after using it for little more than two months the RAF estimated that it had been responsible for saving at least 200 planes and 1200–1500 men. Since then the material has gone into wider use and techniques have improved.

Simplest explanation of how and why window has worked is found in intercepts from German fighter and GCI radio chatter picked up by RAF listeners during raids in which window was being dropped. Samples:

"Search well in your area — there must be many hostiles near you."

"Break off contact — hostiles are multiplying."

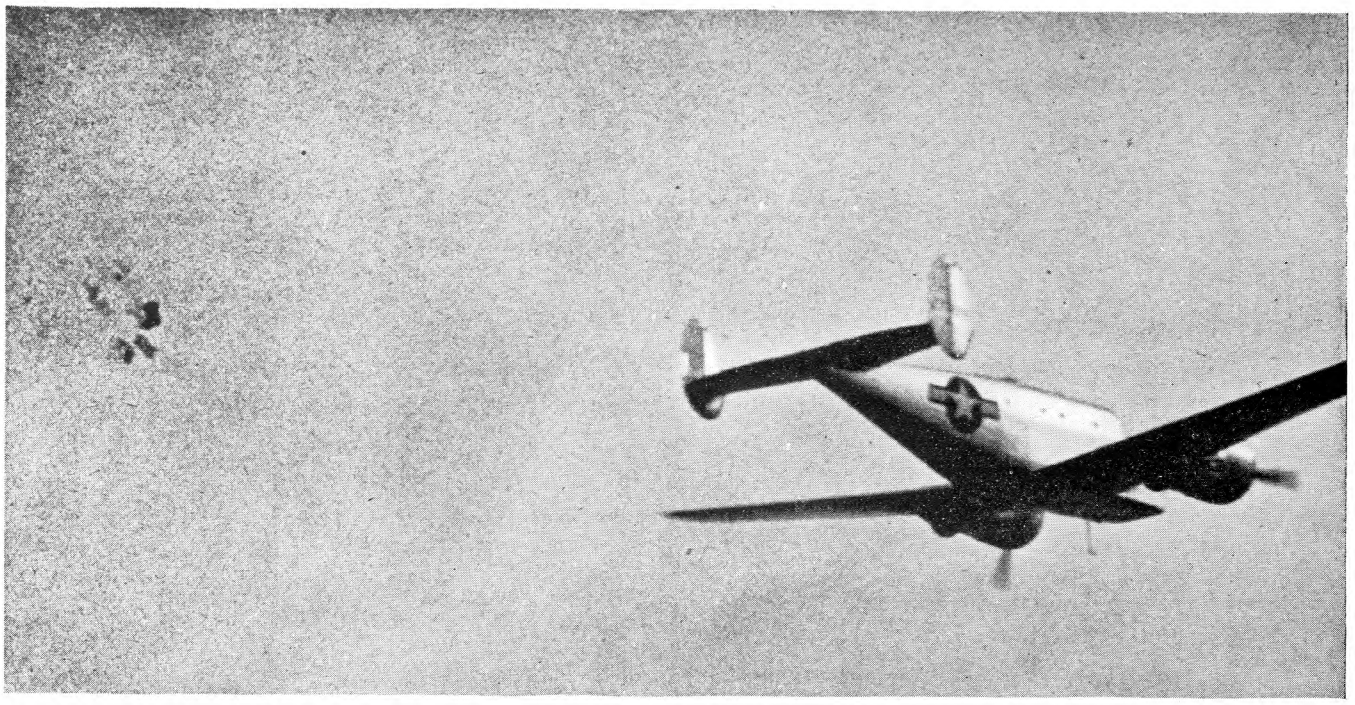
"Everything has gone wrong."

"It's a sorry mess — I'll explain everything when you come down."

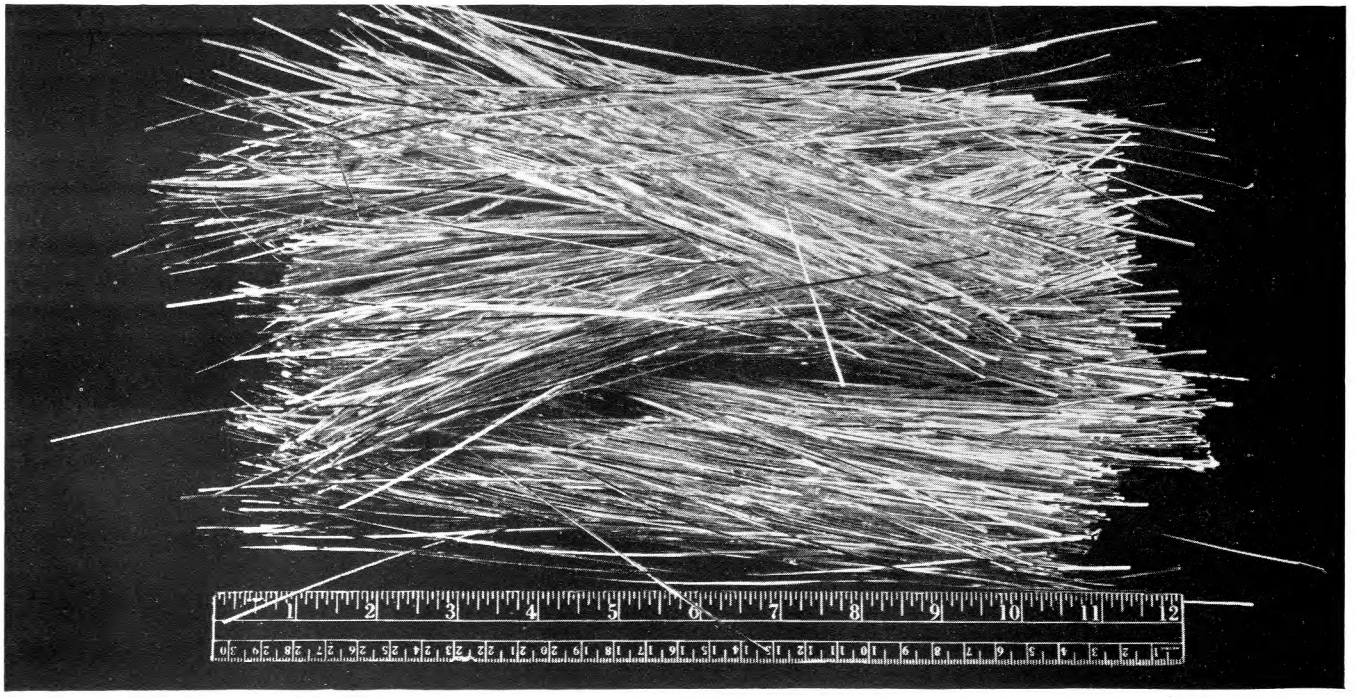
Window, like any other tool of war, fights for no flag; its advantages to its users become disadvantages as soon as it's used by the other side. And the idea behind the window — to fill the air with reflecting material which will confound enemy radar — is so obvious that U. S.-British technical workers have assumed from the beginning that they didn't have anything the enemy didn't know about. First proven use of window by the Germans was over Bizerte 6 September 1943. They have been using it off and on ever since and, according to recent cabled reports from the area, all major enemy night raids in the Mediterranean are now window-protected.

But window is a far less potent tool in the German's hands than in ours, and for a very good reason: window is best adapted to offense, and we have the offensive.

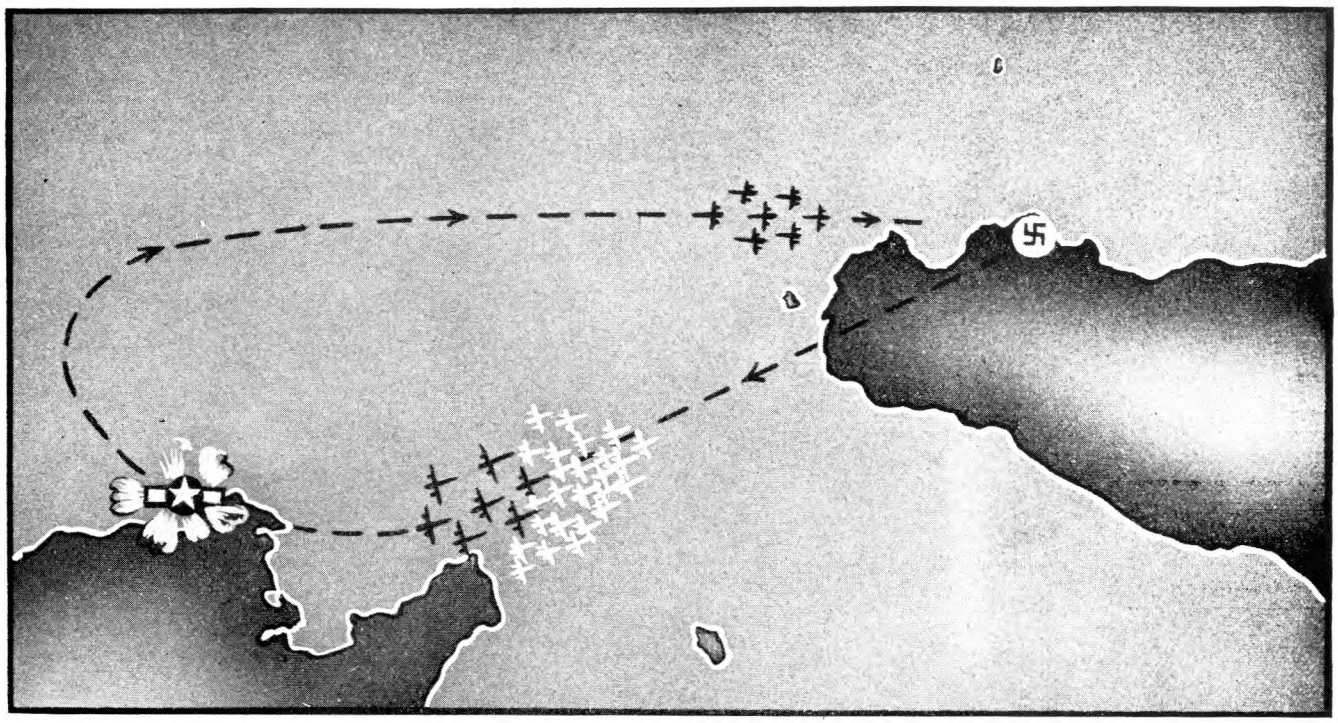
For this advantage to be triple riveted in our favor, so that window may work as a more influential factor in our air victory, it is necessary to improve both our tactical understanding and use of it and our techniques for discounting the enemy's use of it. For comment on these and other aspects of the subject, see following pages.



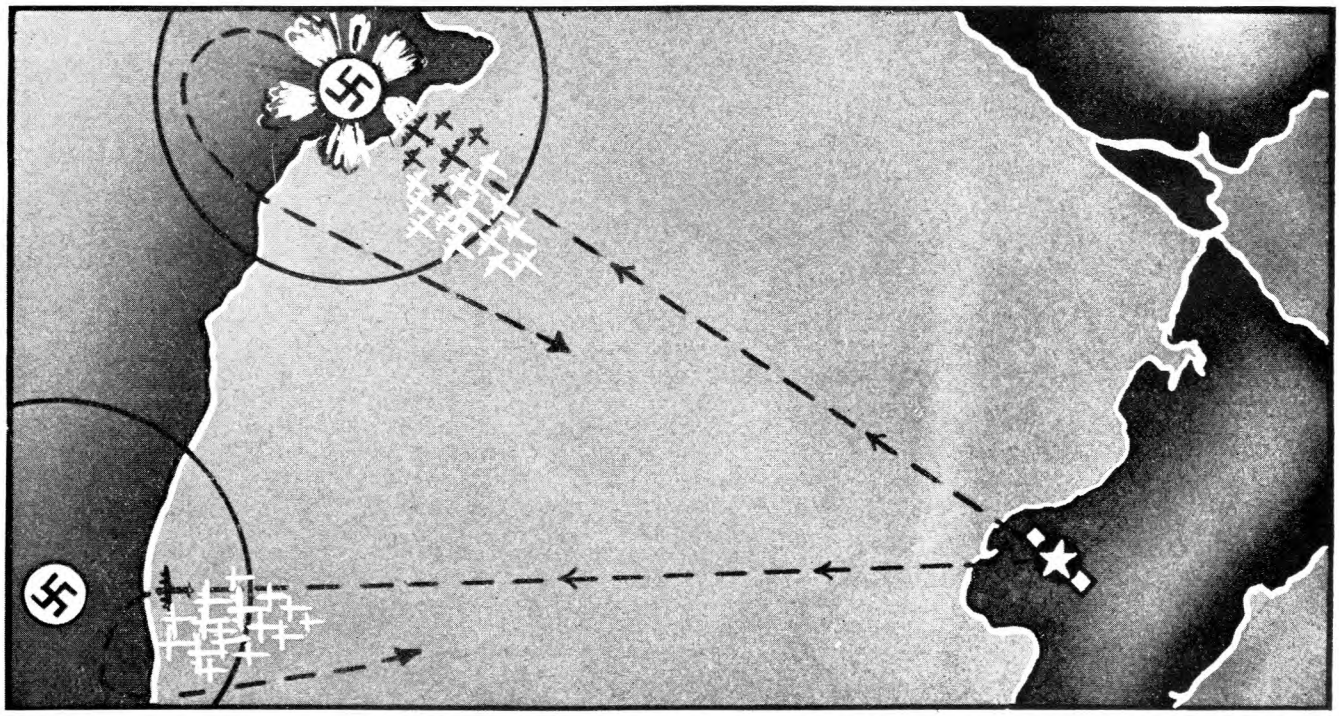
Window "Whites Out" Planes. Attacking aircraft are hidden by window only when actually in it; radar can see through window to targets beyond. Once in air (picture above was taken immediately after release), window works by filling enemy scopes with clouds of fake signals in which real ones — from planes — are difficult or impossible to distinguish, hence cannot be counted or tracked. Window proved its worth in the European theatre where it has been used primarily to protect against German gun-laying Wuerzburg radar. Over AA areas, window upsets the pip-matching of the Wuerzburg, knocks out the assembly of range data for fire control. Tight U.S. daylight formations were once thought to require prohibitive amounts of window; tests showed otherwise. Nearly ready is automatic release chute.



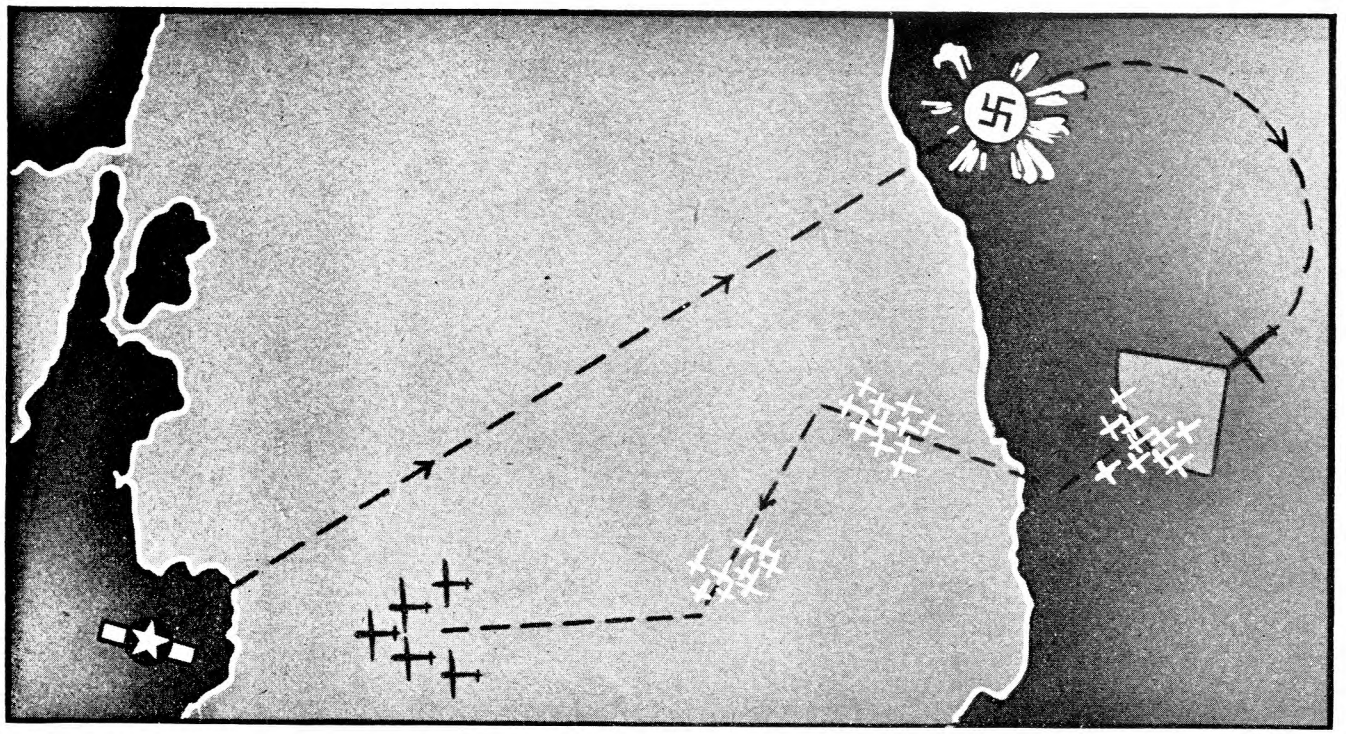
Window Looks Like Jackstraws, is made of foil and paper. Several types of window have been and are still being tried; the narrow, creased paper-backed foil strips above have been adopted by the USAAF. They are cut to about one-half the wavelength of the radar against which they are to be used, and are effective over plus or minus 10% of that wavelength Big factors in the effective use of window are (a) its rate of fall, which is controlled by its weight and, for type shown, is about 260 feet per minute; (b) its rate of dispersal, which should be as slow as possible; (c) its response quality, which is determined by its dimensions, conductivity of the metal foil used (much the same as foil you used to get around cigarettes) and density of material in air. Many trials have determined best materials and techniques.



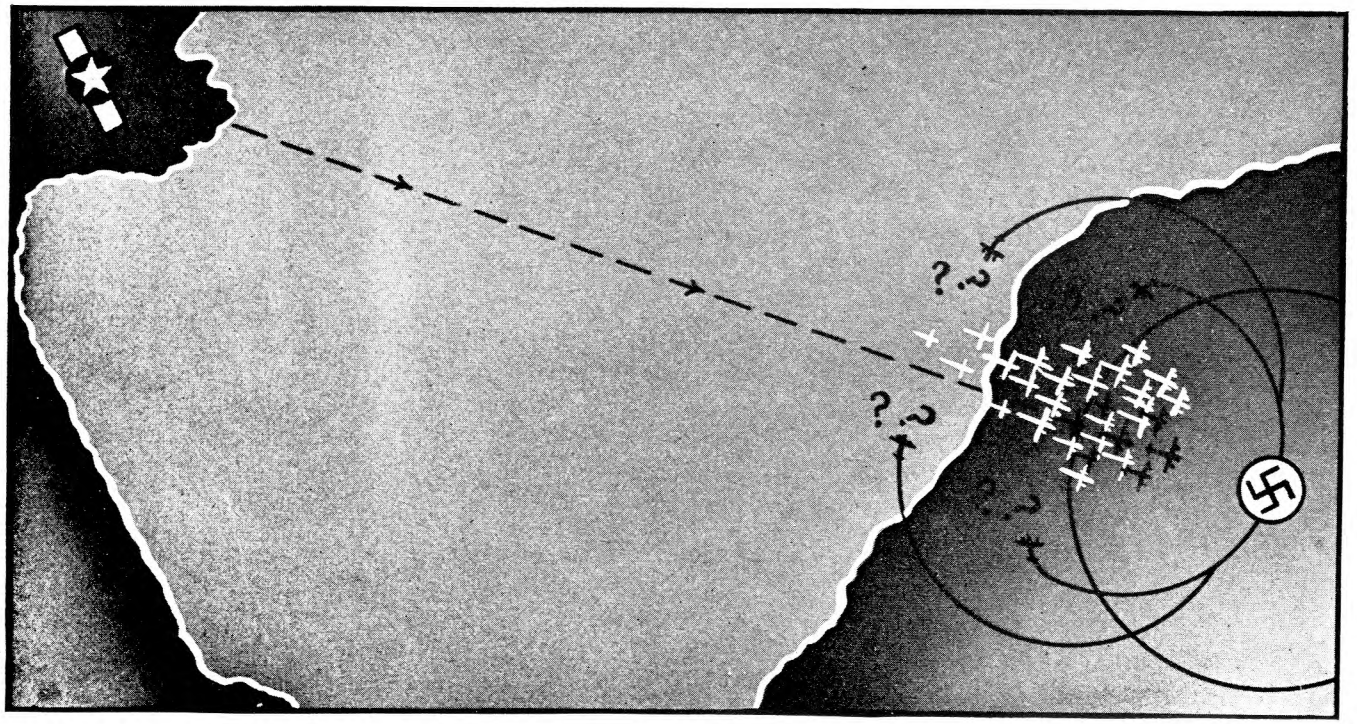
First Known Enemy Use of window was at Bizerte, 6 Sept 1943 (above). Early warnings reported 200 aircraft attacking but U. S.-British fighters vectored onto the supposed formation could find nothing. Actually, less than 50 planes are believed to have participated, flying in on the deck to evade early radar detection. Near the coast they climbed sharply to bombing altitude, released their window (Dueppel) in one big cloud cut for 200 mc, and made for the target. This was about the simplest possible use of window but, thanks to the surprise, it worked pretty well. Good training in detection can usually nullify such simple tactics, and at least minimize more complicated tactics. A well trained operator can often see through window under conditions which, to an untrained one, make the job impossible.



Against Early Warning Radar, window can be used to confound the enemy's alerting and to split fighter strength. A few planes might spread window to simulate large rendezvous, while actual formation could come together elsewhere. Or, as in diagram above, raids themselves can be simulated by putting out a few planes to sow a lane of window along a possible route of attack while the main striking force proceeds through another window lane to actual target (rings around targets indicate enemy radar range). The enemy's radar will make similar presentations of both lanes and enemy operators may have to toss a pfennig to decide whether it's two fake raids, a real raid and a diversion, or two real raids. Diversions of this sort are most profitable where enemy relies heavily on radar for alerting.



Against AI Radar — as when a homing night bomber might try to throw off an enemy fighter (above; beam in front of fighter indicates his AI range) — window ups the chances of successful evasive action. Window effectiveness here depends considerably on the type of indication in the fighter. On a circular A-scan (used on the FuGe 202, German AI) confusion can be much greater than on the indicator of our SCR-720. The closer the enemy radar — airborne or ground — the more precise must be the handling of window. Anything less than a given amount released at a given interval will produce something less than maximum deception. In recent trials 250 units (2000 strips per unit) dropped every minute gave 18 heavy bombers most protection against GCI radar of Wuerzburg type. But circumstances alter cases.



Against GCI Radar, window may be used either in a diversionary way or to cover actual formation (above), thus preventing accurate vectoring of fighters onto individual attacking bombers. Eloquent testimony to effectiveness of this use is found in Intelligence report on reaction of German GCI officer to a flight over his area. Excerpt: "The Officer-in-Charge was mad with rage and declared he would prefer to be bombed by 100 aircraft rather than submit to that flood of paper. He is supposed to have detected 700 machines without having been able to locate one." As with all countermeasures such as window, counter-countermeasures are to be expected sooner or later and experiments to develop them are well along. Operators can help by reporting all experiences, even the slightest, with enemy window.



COL. STUART P. WRIGHT

How and why radar bombing got its start in South Pacific

SINCE Coral Sea and Midway the enemy has learned better than to send out ships in such concentrations as made those wholesale wreckings possible. Japanese ships now move among the islands in ones and twos and threes; make more of the cover of darkness, of overcast and of fighters. Consequently balance sheets on strike missions have had to be drawn up very carefully indeed. Risks worth taking to blast a convoy might or might not be worth taking for a couple of fog-covered barges, or a fighter-protected ship cargo. Search missions for targets so isolated or so protected could be prohibitive.

What we needed to meet the problems thus presented was obvious: precision — precision in finding the targets and precision in striking. What provided the answer was a new adaptation of radar — a low altitude, high precision bombing attachment. It is now five months since the night when three B-24's took off from an island in the Solomons to give this equipment (APQ-5) its first combat trial. At this writing bombers equipped for such operations are flying regularly with the 5th and 13th Air Forces, and regularly paying their way.

Development of APQ-5 started back in 1942, when laboratory work got underway to crystallize ideas that Japanese dispersal tactics had set in motion. By June of 1943 pre-production models were being put through their paces in experimental flights. And at Langley Field Col. Stuart P. Wright and a selected group of pilots, navigators, bombardiers and radar technicians were readying themselves and 10 B-24's to take the new equipment into combat.

In words and pictures on this and the following five pages, RADAR summarizes a question-&-answer session with Col. Wright concerning his project, for the success of which he has been awarded the DFC. In future issues RADAR hopes to report further on operations in the area.

LOW ALTITUDE, HIGH PRECISION

Radar bombing blends them to strike dispersed Jap shipping

Question: There's been a lot of talk about your low altitude project in the South Pacific, Col. Wright. But no report has been made generally available to date. We'd like to tell the story through RADAR, so Air Force personnel all over the world can know what went on. To begin with, is the project continuing?

Col. Wright: Stronger than ever. The operational period I had charge of — which is all I can talk about here — started on 27 August last year and wound up on 2 October. But many of the people who worked with me are still in the area, and more besides. And there's more of the bombing equipment there now and more use of it, than ever.

Question: About how many equipped bombers have been sent out?

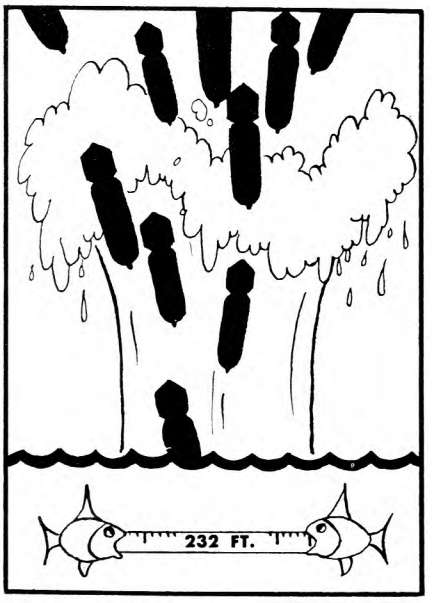
Col. Wright: All told, about 22 planes equipped for this type of bombing have been sent to the South and Southwest Pacific together. Incidentally, these planes are called Snooper planes out there.

Question: What are they proving? That is, what have the results of this bombing been since you first gave it a try?

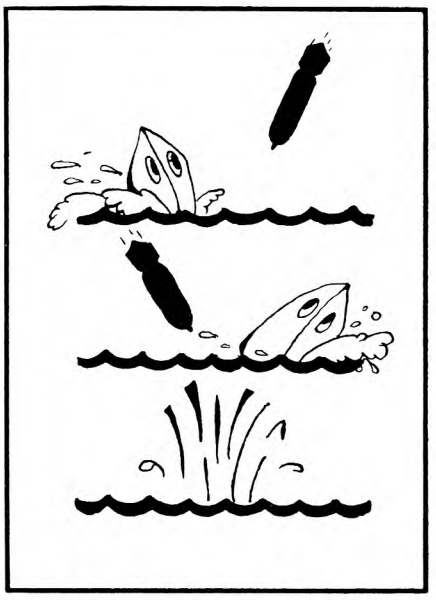
Col. Wright: The results have been the destruction of dozens of Jap ships that wouldn't have been touched, except for this



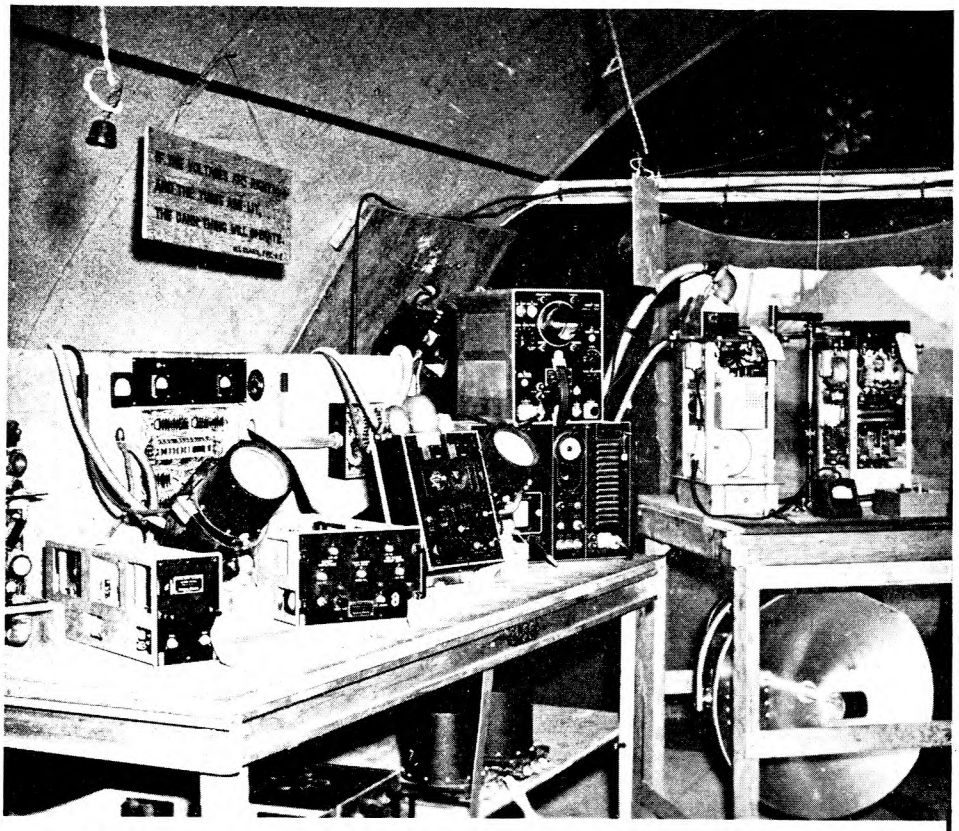
IN TRAINING at Langley Col. Wright's bombardiers dropped 100 lb. practice bombs on this half-submerged wreck just off Atlantic Coast.



CIRCULAR ERROR of practice bombing for whole training period averaged 232 ft. Each of bombardiers rehearsed with 100 trial bombs.



DIRECT HITS made during training averaged about one out of three attempts. Combat results later bore out this score almost exactly.



Bench setup in one of two Quonset huts constructed to house radar equipment on Guadalcanal. Note sign above equipment, suggestive of the universal trials of maintenance men: "If the voltages are right and the tubes are lit, the damn thing will operate."

Good personnel & equipment . . . .

More than 100 trained men participated directly in the low altitude radar bombing operations highlighted on these pages. The men:

Col. Stuart P. Wright, in charge of the project
Capt. E. R. Barriere, Radar Officer
Combat crews for the 10 B-24's involved
Ten radar mechanics for maintenance of all equipment
Mr. E. H. Sharkey, manufacturer's engineer specializing on blind bombing attachment
Mr. H. L. Clark, manufacturer's engineer specializing on radar search equipment

Each plane was equipped with SCR-717-B (radar search equipment), APQ-5 (blind bombing attachment), SCR-729 (Interrogator-Responser) and ARN-1 (Radar Altimeter, 0–400 feet). Complete spare components plus loose spares for all this equipment were taken along, as well as test equipment.

The 10 planes taken on the project had neither nose nor bottom turrets, which made them too vulnerable for day operations. The radar antenna was installed in the well normally occupied by the bottom turret and nose turrets were left off so that planes could leave sooner.

Men and materials together left Langley Field, Va., on 5 Aug 1943, and reached Espiritu Santo, New Hebrides, Headquarters of 13th Air Force, two weeks later. The squadron then proceeded to Guadalcanal, where first step in preparation for combat operations was to erect two Quonset huts — one for shop facilities, test benches, etc., one for squadron communications and storage. By 27 August all facilities were set up and three planes were ready for operations.

At the conclusion of the 67 combat missions flown in next five weeks the following notable record of satisfactory performance percentages was compiled:

SCR-717-B:	92.9%	SCR-729:	97%
APQ-5:	92.2%	ARN-1:	97%

bombing, or even known to exist as targets. You can say that for five months the Snoopers have been extending the range and striking power of the Air Forces operating in those areas — extending them by a lot, too.

Question: Before we go any further, how about a thumbnail sketch of what you mean by "this type of bombing"?

Col. Wright: What I mean is low altitude precision bombing by radar instruments alone. By low altitude I mean 1000–2000 feet. By precision I mean planting a bomb on or close to a ship target every time we let one go. By radar instruments alone I mean the whole job was done automatically and without visual means from beginning to end — from locating the target right through to the bomb release. The equipment that made this possible was a standard radar search system, the SCR-717B, plus the APQ-5 blind bombing attachment which had never been used in combat before. It's adaptable to any microwave ASV set such as the SCR-717B, and it works with the Norden bombsight. Other equipment was involved in our mission, but this was the guts of it.

Question: Is the bombing attachment good only at low altitudes and for ship targets?

Col. Wright: It was designed for use against ship targets at low altitudes and that's how we used it. It employs a computer up to 2000 feet and within that altitude it's precision equipment. However, by extending the slant range release distance you can use the equipment against *shore-based* land targets at any altitude. We tried this out over there but not in combat (see page 22).

Question: Why not?

Col. Wright: Because we were there to get ships and there were plenty to keep us busy.

Question: Have results been good enough in the five months since you went over to represent a real threat to Japanese shipping?

Col. Wright: Not in the quantities in which the equipment's been used. On the other hand, proper use of this equipment in sufficient quantities could pretty nearly disrupt Japanese shipping lines. That's my feeling about it and it's based on the record.

Question: What do you mean by "sufficient quantities"?

Col. Wright: I'd say that if each Air Force operating in the Pacific had one Heavy Bombardment Group equipped for this blind bombing, that would be minimum.

Question: Is the equipment as useful for other theatres as for the Pacific?

Col. Wright: Draw your own conclusions. It was designed for ship targets and that spells Pacific to me. Situations certainly arise in other theatres in which this type of bombing can achieve important

gains not otherwise possible. But in the Pacific it may some day emerge as a really decisive technical factor working for us against the Japs.

Question: Is much special training necessary for the personnel using the equipment?

Col. Wright: Well, the blind bombing attachment does a job that nothing else before it did. It was brand new when we took it over, with the usual quota of bugs to be ironed out. Everyone concerned with the use and maintenance of APQ-5 had to have special training, including first of all the bombardiers who operate it. The rest of the equipment involved was standard and required standard training.

Question: How did the group you took over get its training?

Col. Wright: It got it by going through a special training period at Langley Field. This lasted roughly two months — from early June to the end of July. Each bombardier, for example, worked a total of five hours on a blind bombing trainer during this period and dropped 100 practice bombs blind at various altitudes. We simply figured out all the angles we could think of and trained ourselves as well as we could along those lines.

Question: Had any of the men had any of the necessary training before you all got together?

Col. Wright: The technical men knew their particular phases and the combat crews were already trained in all normal operations. Most of them had some radar experience, although not with APQ-5. Only one bombardier was up on the blind bombing technique; he was bombardier on all test flights I conducted during the initial development of this equipment.

Question: What were your conclusions at the end of the training period as to the effectiveness of the equipment?

Col. Wright: We figured we had something. We figured we could get a hit out of three tries pretty consistently.

Question: And when you got into combat?

Col. Wright: We improved; direct hits during the operational period I'm covering averaged 39%.

Question: How does 39% compare with results from other types of bombing?

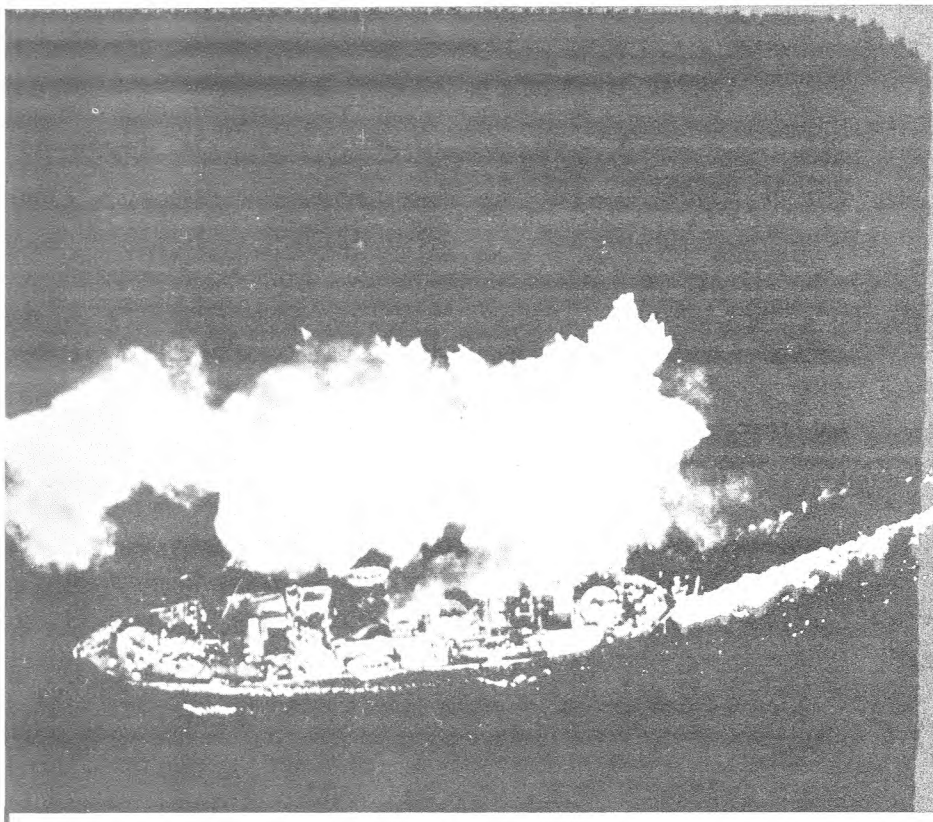
Col. Wright: 39% is good in any league. But no other bombing is altogether comparable.

Question: How about other types of blind bombing? How about the blind bombing that the 8th Air Force is doing for example?

Col. Wright: That's done under entirely different conditions and with a different type of equipment (see page 3).

Question: O.K. One more question. Can you tell me exactly what happened during one typical mission with APQ-5?

Col. Wright: Sure. I'll tell you about the first one we ever flew. It was on the night of 27 August . . . SEE NEXT PAGE



No photographs were made of APQ-5 hits; no method of taking them was found. This is a stock picture but it conveys the impression of APQ-5 operations two-thirds of the time. Move bomb flash onto ship and you'll get impression for other third.

. . . . can produce good results

During the period covered in this report on South Pacific radar bombing operations — from 27 Aug 1943 to 2 Oct — 67 combat missions were flown in the course of which 46 bombing runs were made against water targets found by radar methods alone. These runs yielded 18 direct hits of one or more bombs, which comes out to 39%.

Inasmuch as all missions were flown at night or through heavy overcast, it was impossible to get photographic records of the hits for use in identifiying targets and assessing bomb damage. But at the low operating altitudes — 1000 to 2000 feet — it was easy enough in most cases to determine when a direct hit had been made: the flash could be seen, the explosion heard, the concussion felt.

With 13 of the direct hits, visual observation in the light of the bomb flashes revealed the following targets:

4 barges	2 transport or cargo ships
1 heavy or light cruiser	5 destroyers or corvettes
1 submarine	

Of these targets, all of them hit directly, two barges and one destroyer were seen to sink, another destroyer was set afire and a third blew up about one minute after the hit.

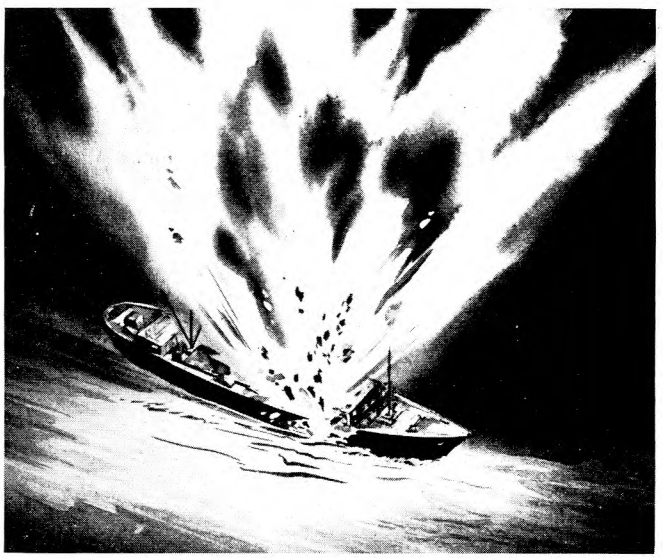
In the case of 5 of the 18 direct hits, the targets either could not be identified accurately or else turned out to be small islands.

In a majority of the attacks, on both merchant and naval shipping, neither evasive action nor AA fire was met on the first run over the target — probably due to the complete blackout and almost complete lack of noise of the APQ-5 bombers. Second and third runs, made where necessary, ran into both evasion and fire.

Some experience was found necessary for distinguishing between ship targets and small islands, and during most of the operational period reported on here such experience was lacking. Subsequent reports from area say operators have learned.



3 Three 500-pound demolition bombs were released in train, spaced at 75 feet. Each had a 1/10 second delay fuse. Conditions were such that even at the low altitude nothing could be seen optically. Squadron Intelligence Officer who had come along waited on catwalk watching for bomb flash below. Crew members waited to hear what Intelligence Officer would report. During training period direct hits had been scored in average ratio of 1:3 (see page 17). On which side of that ratio would the results of this first actual combat run fall?

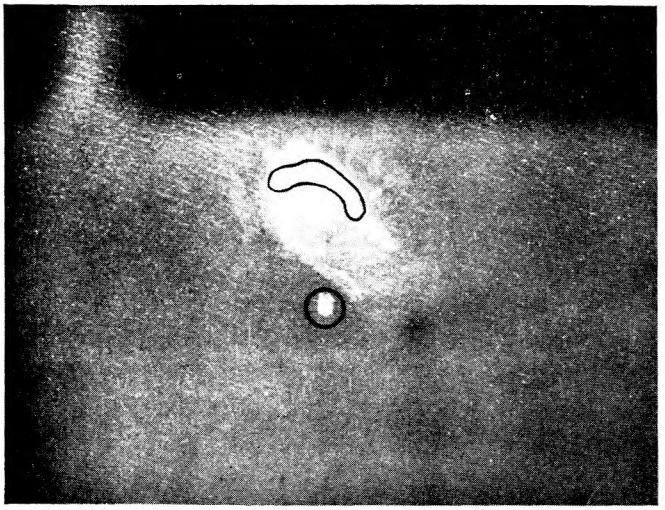


4 In light of bomb flash Intelligence Officer saw small Japanese cargo vessel ripped by a dead-center hit. Back at base, Bomber X learned that one of other two bombers had located target and made two bombing runs, one of which had scored hit on unidentified target. Third bomber had located no target in its area. Thus, on first combat missions, radar low altitude bombing worked even more accurately than in training, with two hits out of three tries. For results of all 67 missions flown during five weeks of Col. Wright's project, see page 19.



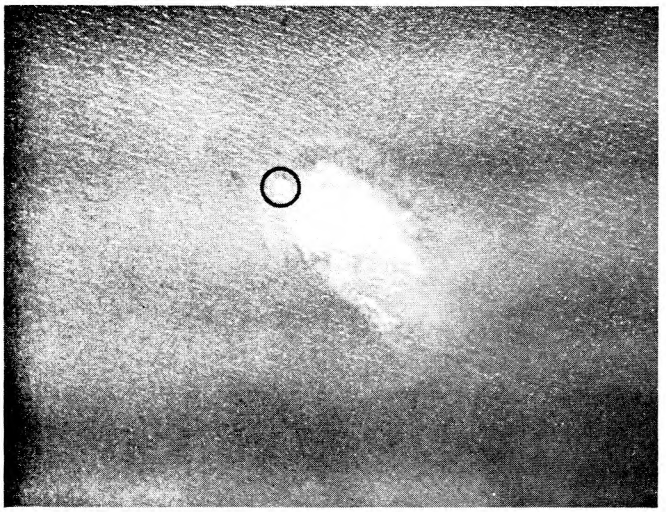
One of top crews during the introduction of APQ-5 to South Pacific was this one, here standing in front of its plane, Madame Libby, at Guadalcanal base. This was the crew which got two direct hits out of two tries on one mission. Aids to such results were precautions taken to make planes as inconspicuous as possible. Checks at far end of runway during takeoff showed that planes were invisible and practically noiseless beyond half a mile under better detection conditions than would prevail in combat. Snooper flights take 10–14 hours as a rule, mostly deep in enemy territory at low altitude, which means heavy strain on crew; radar operators were one line poorer on Snellen test after operations than before. Lessons learned during first five weeks are being applied to improve conditions of present operations.

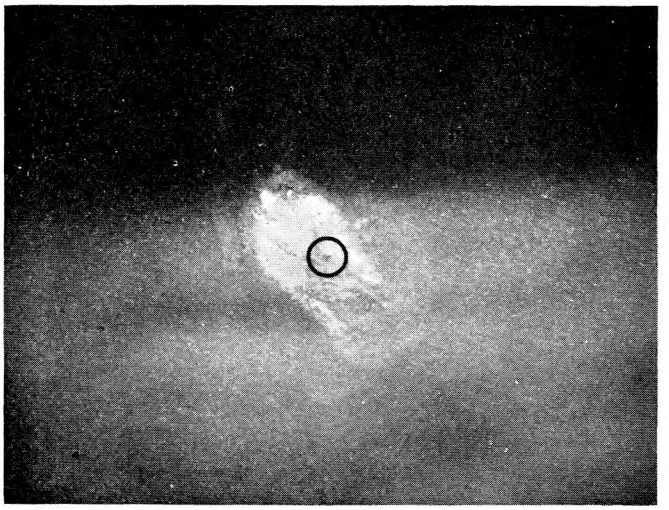
• Low Altitude Bomber Does Pretty Well Up High



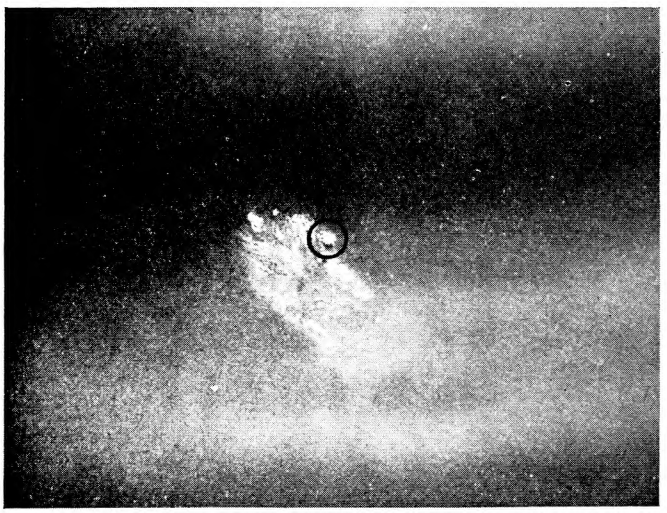


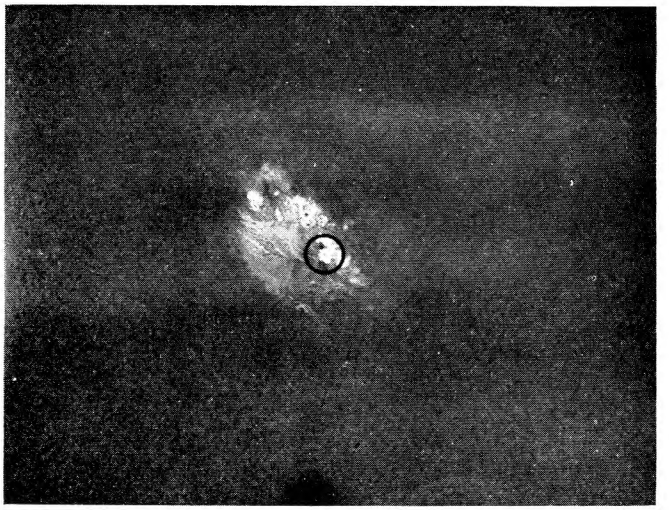
APQ-5 BOMBARDIERS DID NOT BOMB IN COMBAT AT HIGH ALTITUDES BUT TRIED EQUIPMENT AT 10,000 FT. WITH THESE RESULTS





LEFT TO RIGHT, TOP TO BOTTOM PICTURES SHOW SIX (1, 2, 4, 6, 7, 9) OF NINE DROPS. ISLAND (RINGED AT UPPER LEFT) WAS 1200 FT.



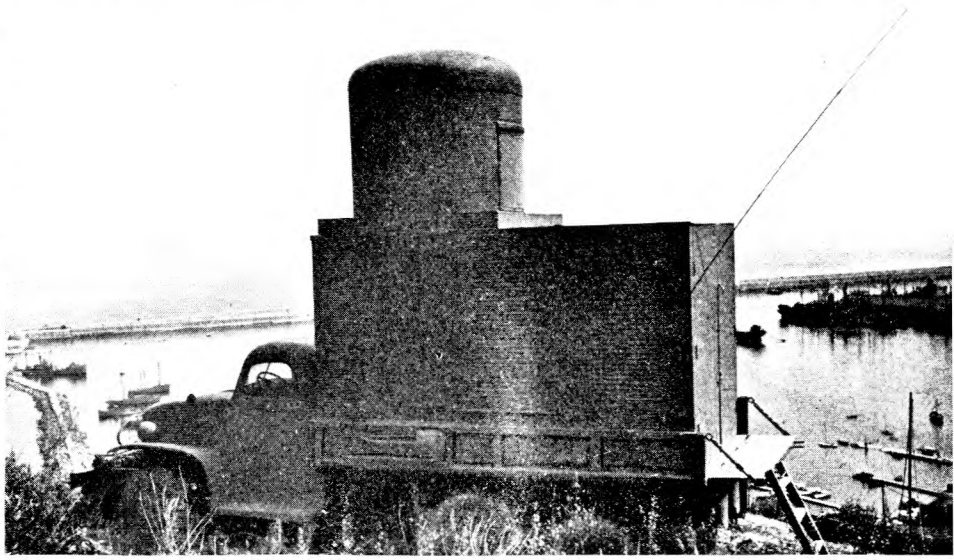


TEST WAS TOO SPECIALIZED TO PROVE APQ-5 A HIGH ALTITUDE BOMBER BUT DID DRAMATIZE OPERATORS' SKILL AT HANDLING IT

Ingenious Operators Improvise to Meet Needs

A radar set is designed to fill a specific purpose. But in the field, and in a pinch, equipment is sometimes put to uses never dreamed of by its designers. Partly this happens because radar production has not yet caught up with radar needs; equipment may be forced to perform extra jobs simply because there isn't enough equipment yet for all the jobs to be done. Partly it happens because Yankee ingenuity is as active with a radar set as with anything else.

One of the important jobs that RADAR can do is to tell about useful field improvisations so that operators who might not otherwise know of them can put them to work or get leads for further ideas. On this and the following two pages RADAR tells about four ingenious improvisations developed on both sides of the world during past months.



OPERATIONS TRUCK OF MOBILE SCR-582, ANTENNA RAISED AND PROTECTED BY BLISTER

Harbor Set Put on Wheels

In the normal course of things, SCR-582 is a house-bound set fixed to a site overlooking the harbor traffic which the set is designed to survey. But for a time in North Africa the Army was moving pretty rapidly from one harbor to another. There was need for a fast-moving radar, and Casual Detachment 0285, C.A.C., met the need by putting three SCR-582's on the road.

When these sets came off the supply ships at Oran, they were loaded into 2½-ton cargo trucks, and the six trucks required for each set conveniently furnished the Detachment with mountings.

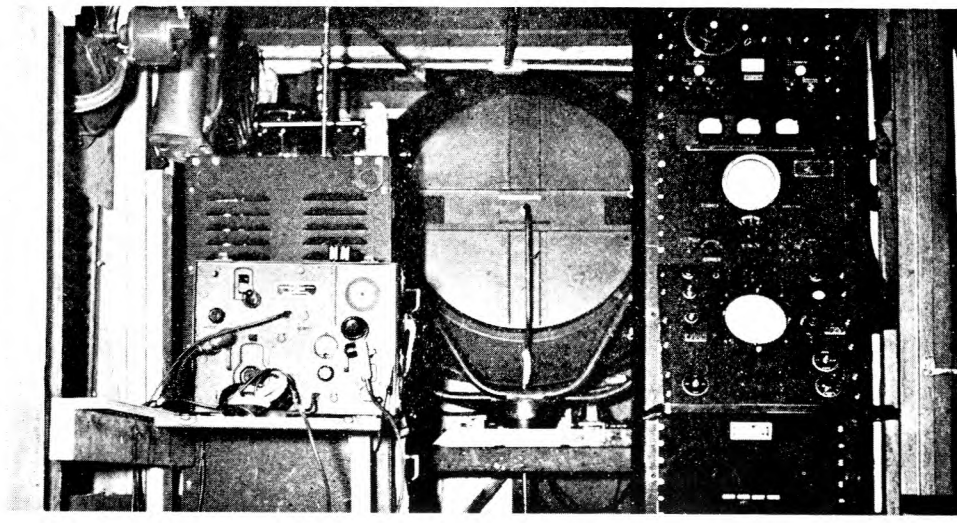
Into one truck went the radar proper — antenna and spinner assembly, transmitter, receiver, amplidyne motor generator — plus radio set SCR-284, plotting table and two telephones. These were covered by the plywood supplied with each set for construction of the engine house. In operations, the dish was projected through a hatch in the roof covered by a removable blister. In travel, the dish was lowered into the van on a vertical track.

Two more trucks accommodated the two power units, reserves of gas and oil, spare parts and tools. A fourth truck was fitted out as a workshop. That left two vehicles of the original six, and into them went personnel, baggage, rations, cookstove and the various impedimenta of a radar crew.

Thus the complete caravan of six trucks formed a self-sustaining radar station. For short operations two trucks sufficed — the radar and one power truck.

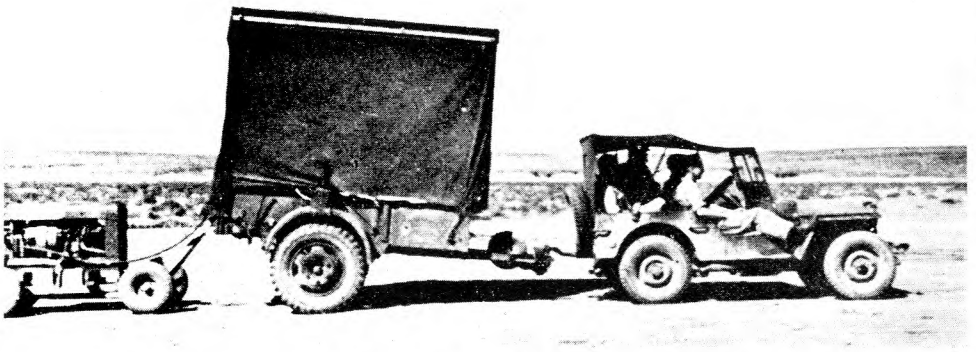
In the Bone-Philippeville area, these mobile sets kept war channels free of mines, guided convoys and directed fighter planes to convoys under attack. Later, one truck-mounted 582 moved to Sicily. There it was used for early warning against low-flying planes.



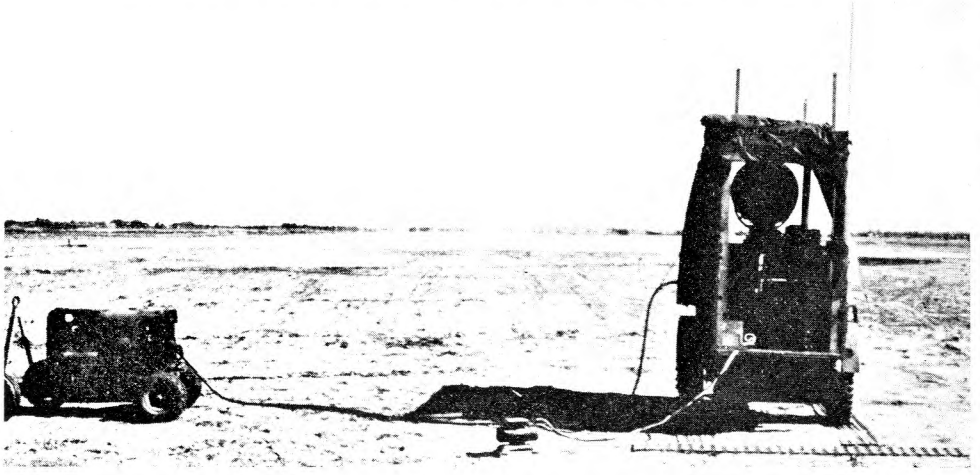


FOR TRANSPORT, ANTENNA LOWERS (above); RADAR UNITS (below) ARE PUT FORWARD

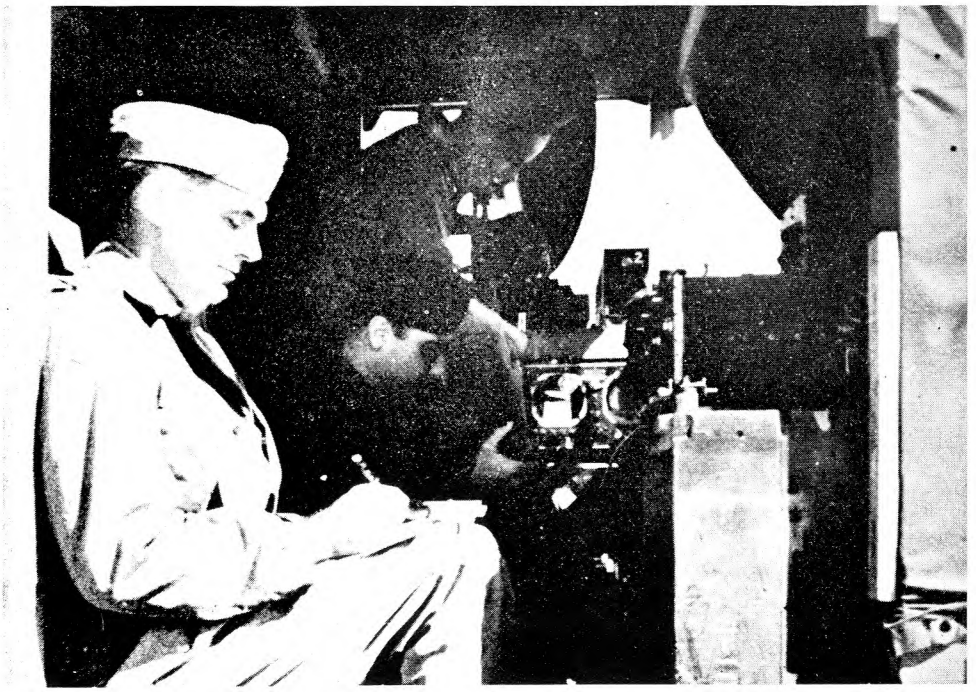
Trailer-Rigged ASV Brings Planes Home



TRAILER-BORNE SCR-517-C WITH ITS POWER SUPPLY EN ROUTE TO THE OPERATING SITE



RADAR LOOKS DOWN RUNWAY (above); BELOW ARE PLOTTER, CONTROLLER, OPERATOR



At Port Lyautey, N. A., a plane of the 480th Anti-Submarine Group, its radar damaged by enemy action, flew aimlessly over its airfield, waiting for a break in the overcast to come in. Meanwhile, on the ground, radar men testing equipment had picked up the plane and were watching its course on the scope of an SCR-517-C ASV system. The scope gave them all they needed to direct the plane onto the right approach but, with the means of doing that at hand, there were no means of communicating with the plane. And that, figured the radar men, made no sense.

What made sense was to mount an SCR-517-C on a trailer, fit in radio communication to planes and to the control tower, and then line up the works at the end of the runway so that the runway's center line would coincide with the center line (zero angle) of the radar scope. Then the position of any incoming plane, as shown by the scope signal, could be observed, its course plotted, and corrections radioed direct to the pilot from this mobile ground station. Thus the radar men's proposal and, since it made sense, it was forthwith done.

Of several procedures tried with this setup, the following proved most satisfactory:

(1) The plane is directed over the airdrome and onto the center line of the runway heading away from the radar.

(2) At about 10 miles distance, the plane is put into a procedure turn and returned on center line.

(3) In final stages, pilot is given letdown instructions. Controller specifies the rate of descent, announces distance to the end of the runway at every mile and the altitude at which the plane should then be. (Since the radar does not measure angle of elevation, glide angle must be established from altimeter readings relayed by the pilot to the controller.)

Only real problem in this procedure is to get the plane onto the runway-line and keep it there. Accordingly, the Group worked out a device which automatically determines proper plane heading from any position on the field. The device is a rotatable plexiglass disk marked with a fan-shaped array of lines. Each line is marked with a compass heading giving the correct bearing which a plane crossing that line should take in order to make a smooth tangential approach to the center line. The disk is put over the plot and turned as necessary to allow for drift corrections.

In 87% of the trial attempts made with this system, pilots judged their approaches successful on the first run; in 98%, by the second run. Advantage of the technique is that it requires no special equipment in the plane, and demands of the pilot only the ability to navigate within radar range of the airfield.

Guadalcanal: APQ-5 crated for work on line

Radar men of the 5th Bombardment Group, responsible for the maintenance of first operational installations of APQ-5 (see page 17), had a big job cut out for them. Early equipment had plenty of bugs and the South Pacific is far from supplies.

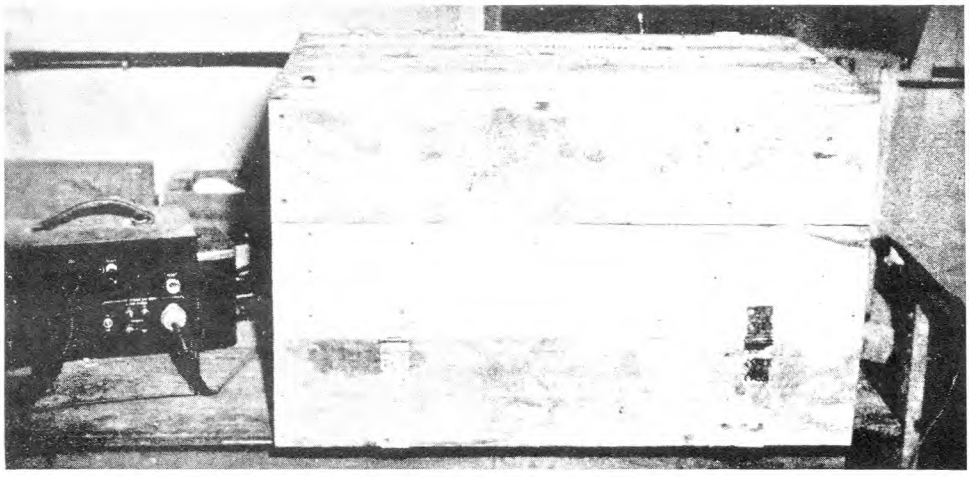
In their favor was an ample store of replacement units to begin with, and of these they made the most. Kept in perfect running order, reserve components were available at a moment's notice to replace a faulty unit in a plane. This substitution method had the advantages of tying up operational equipment for the minimum period and saving maintenance men from the super-heat of ships on the line.

A gadget which helped them do this job even more quickly was the improvised portable service set shown in the pictures at the right. In this salvaged crate is a complete APQ-5, mounted so the box can be closed for transport, wired so as to operate. When an ailing APQ-5 is reported, the boxed equipment can be taken to the field, plugged into the plane's power and set in operation. By substituting components from the ship's radar for components in the box, the damaged unit can be located.

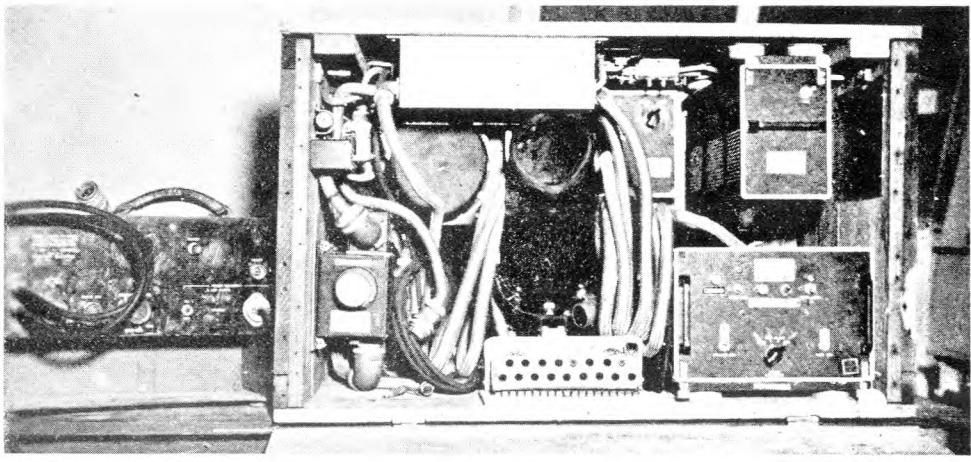
The crated APQ-5 serves, too, as an easily transportable servicing unit for use at advanced bases.

Another improvisation of the 5th Bombardment Group was a truck-mounted SCR-717B, set up originally in an attempt to meet an urgent need for an aircraft interception control system. The equipment was mounted in a closed communication truck, with antenna on top and modifications to permit (1) elevation control by drum-operated cables, and (2) limited sector scan over any arc. Though the short ranges attained discouraged attempts at interception control, the experimental set was put to good use. Driven to a beach or headland, it afforded a good radar view of ships, buoys, barges and islands; in an emergency, it could function as a harbor control set. On top of all this, the truck-mounted SCR-717B turned out to be a first class trainer for operators and navigators.

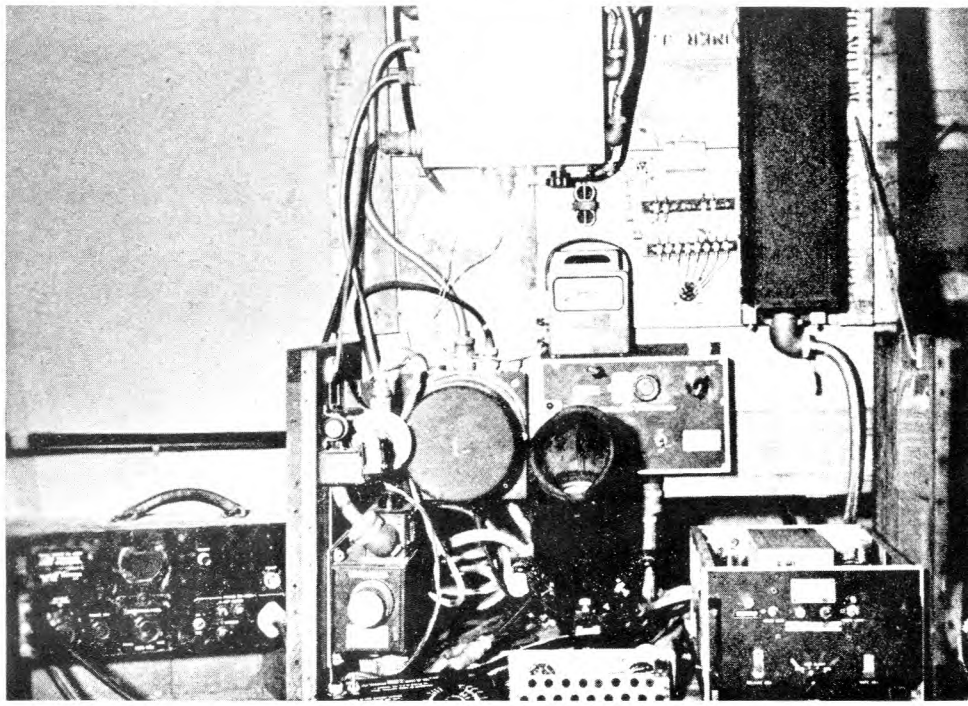
The improvisations that many radar operators and maintenance men work out in the field can be of high interest and value to operators and maintenance men generally. Rigged up devices of the kind shown on this and the preceding two pages will win no prizes for fancy construction and pictures of them will win no prizes for dramatic photography. But in a modest way, and sometimes not so modest, these improvisations are in the main stream of things that help win the war. RADAR wants to report on as many as it can find out about. Will RADAR readers help by sending in data and photographs?

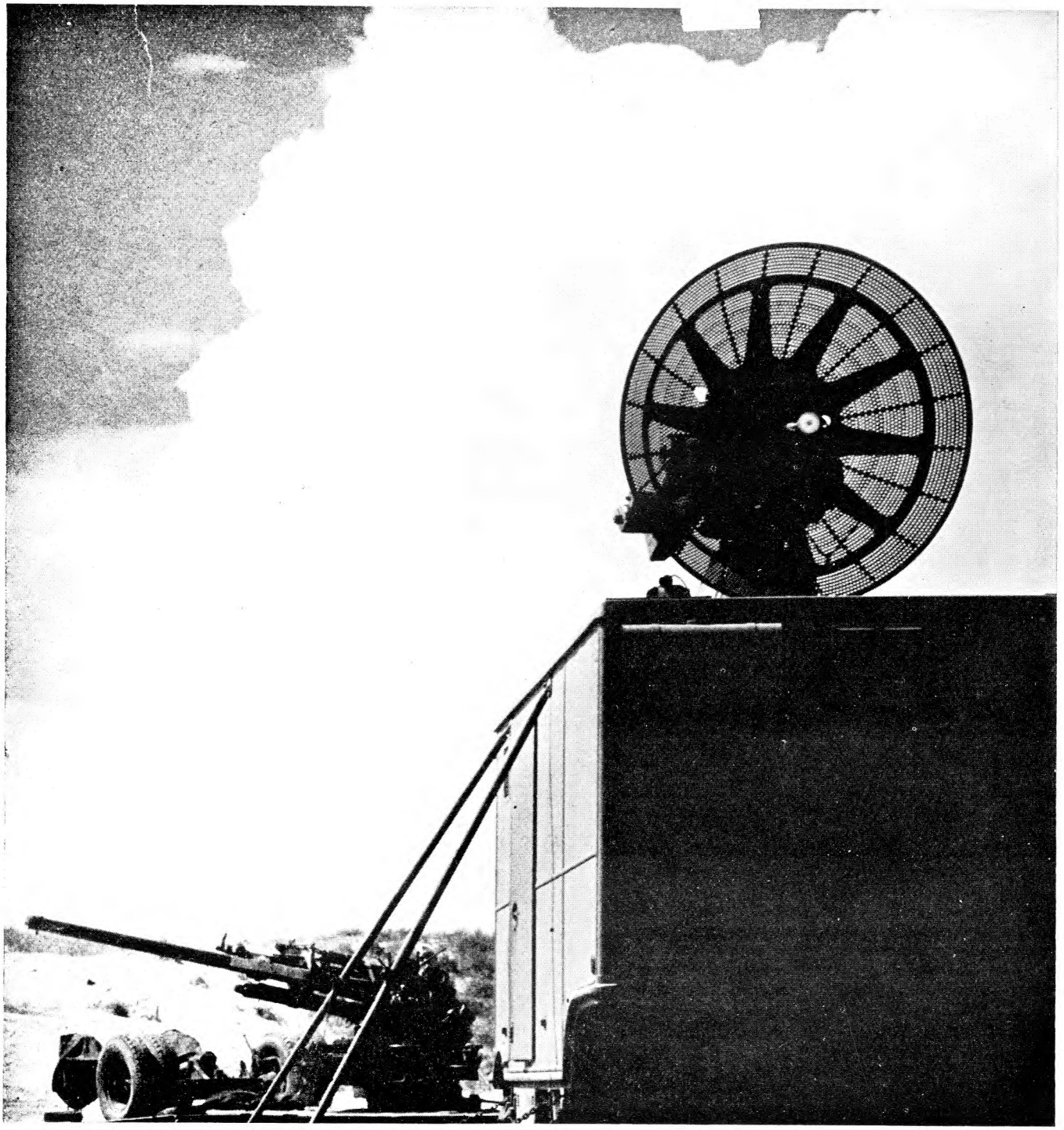


HOMEMADE PACKING CASE ABOVE CARRIES COMPLETE SERVICING EQUIPMENT OF APQ-5



THE COMPACT ASSEMBLY (above) DIAGNOSES TROUBLE ON LINE WHEN OPENED (below)





"CLOUD CLUTTER" IS NOT USUALLY A PROBLEM, SINCE CLOUDS HEAVY ENOUGH TO CAUSE IT ARE USUALLY HARD TO FLY THROUGH

RADAR vs WEATHER

Once, when fighters patrolling off Panama got cut off from their base by quick tropical storms, there wasn't much that anybody could do. Planes often crashlanded in the jungle, or were lost at sea. But about a year ago, when radar SCR-582 was sent down to keep watch over sea approaches to the Canal, operators looking at their scopes began to notice an interesting thing: thunderstorms often painted fairly clear pictures of themselves on the PPI. Thereafter, guiding fighters around heavy storms became part of the radar operator's day-to-day routine. Planes lost to weather thereafter diminished in number.

To research people, who knew that radar was literally born out of atmospheric studies (measurements of the ionosphere by electronic means), it was no news that radar and weather are intimately related. Reason that the relation was not more fully investigated was that right from the start of the war the big push was to make radar into a fighting tool. But experiences like that of the Canal Zone, repeated from the Solomons to Africa, have swung attention back. Today on many radar fronts studies have been started to do something about the effects of weather on radar, the fighting tool.



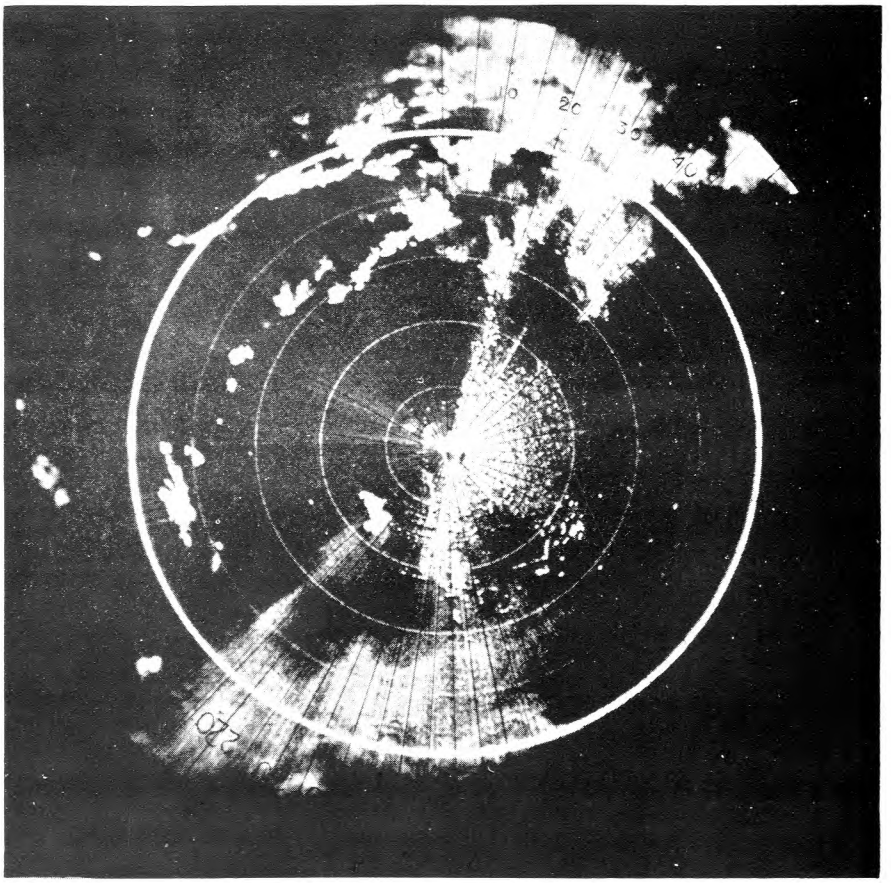
RADAR SEES THROUGH OVERCAST AND MOST CLOUD. BUT SOME THUNDERHEADS ARE DENSE ENOUGH TO HIDE SIGNALS WITHIN THEM.

. . . and vice versa

Atmospheric conditions are both friend and foe of radar: sometimes they can give abnormally long ranges; other times they can create almost a "blackout." Cause of this phenomenon is rather simply stated: changes in temperature, pressure and water vapor content of the air make changes in the dielectric constant. And vertical dielectric constant gradients are directly related to radar ranges. Frequently conditions are found that trap a part of radar energy near the earth's surface and produce a two-dimensional guided wave.

This generalization is known; consequences flowing from it are not. The main job now is to evolve useful data; to draw up charts so that radar performance can be accurately forecast from ordinary weather information. The value of this is obvious: task forces, foreseeing a radar blackout, could go in with less risk of detection; tactical use could be made of storms.

Studies to these ends are now going forward at both Army and Navy centers. Meantime, operators are daily learning and reporting more about how clouds look on scopes. No promises, obviously, are made. It may be some time before operators will be able to repeat the experience of the legendary research man working on an experimental set, who looked up from his scope and reported, "Light rain coming across the harbor," and a moment later added, "A few seagulls flying in ahead."



Two storms; both are heavy but largest is at top. Coastline at center, 20°. Plane could be tracked through lower storm, parts of upper one. Light storms do not show on the indicators.

Photographing a Radar Scope

Pictured in this issue of RADAR (pp. 6, 7, 8, 9, 31) are the beginnings of the newest kind of map in the world; a *radar* map, made of a mosaic of scope photographs taken over enemy territory. The map is small now. There are only a few pieces. But there will be more and still more, until all of the enemy's territory lies spread out, its glowing targets permanently visible.

It is clear that radar reconnaissance must some day be as important in its way as visual reconnaissance. And it follows that scope photography will be as important as recco photography. At present neither technique, training nor equipment for scope photography exists; but as always, skilful improvisers can cobble up something to do the job. The picture at right shows the improvised camera (*center*) used by APS-15 operators to take radar-map pictures of Germany.

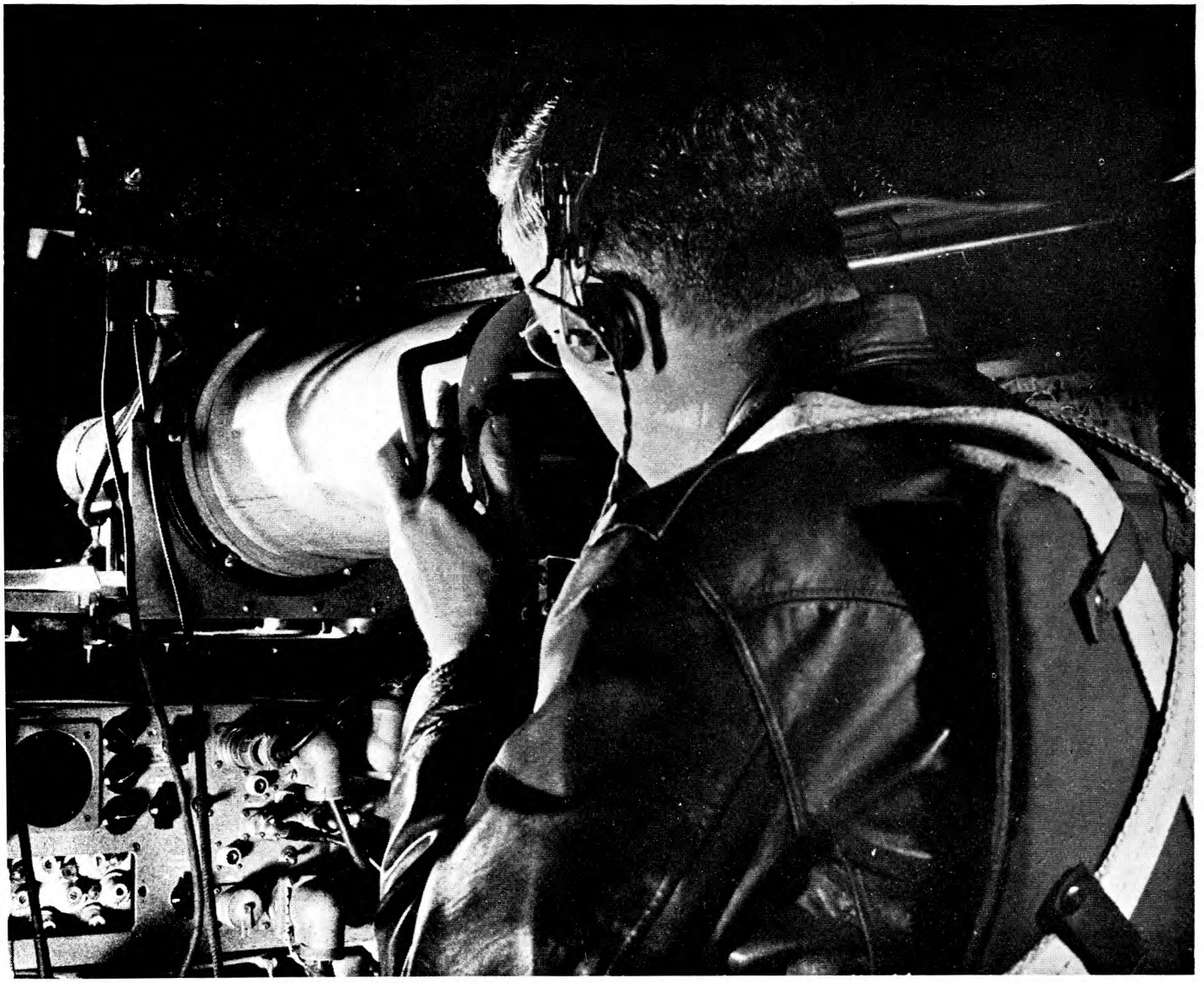
Basically, the thing is no more than a piece of stovepipe and any 35-mm candid camera. The stovepipe does double duty as camera support and light excluder. An eyepiece is introduced at the back so the scope can be viewed while it is being photographed. The camera has a cable release which is led out at a convenient place near one of the handles on the stovepipe.

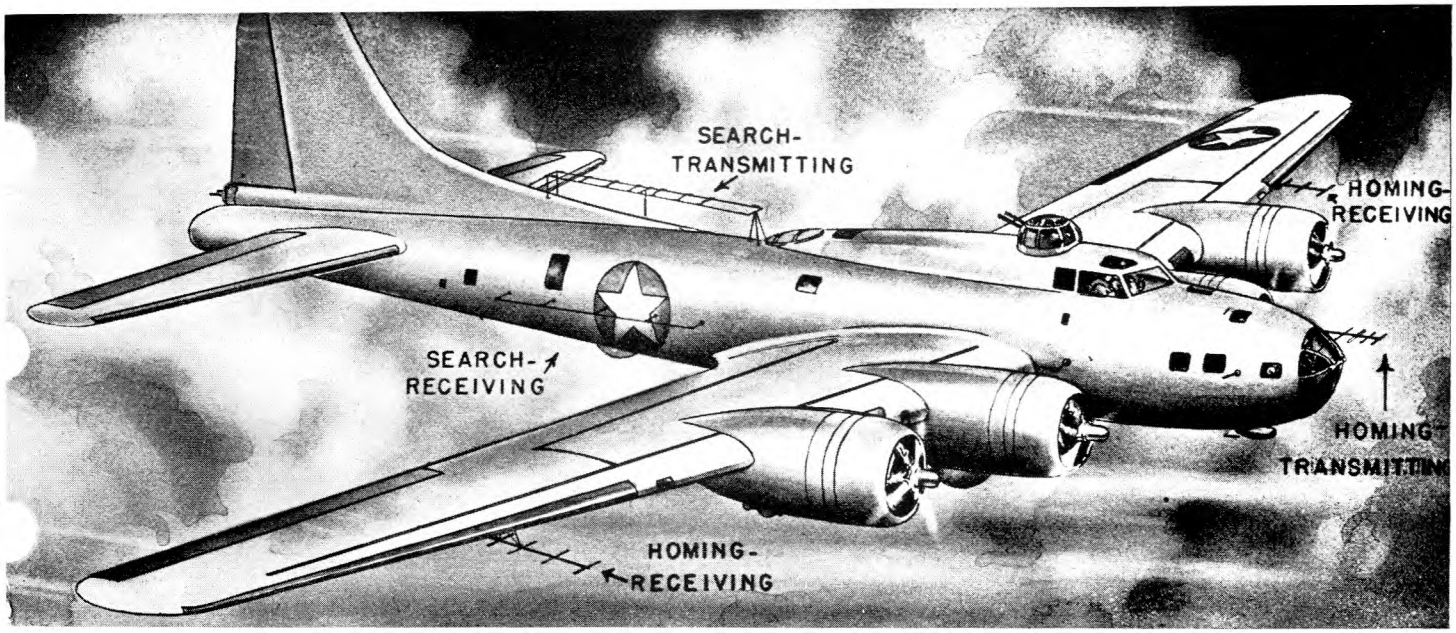
Building a camera like this is obviously easy. There are only two tricks: (1) shimming out the lens so the distance to object can be short, the image on negative large; and (2) cutting the tube to correct length. Thickness of shim and length of tube can be ascertained by taking the back off the camera, taping on a piece of ground glass and trying various distances. Pictures are taken by "bulb" exposure: shutter open for one complete revolution. Correct exposures will come with practice. These stovepipes will eventually be supplanted by GI jobs, both for movies and stills. Meantime, they can do invaluable work.



"STOVEPIPE" CAMERAS for 3, 5 and 7-inch indicators. Three-inch camera uses viewing hood instead of the usual eyepiece.

Need for Scope Photographs is evident — both for record of mission and for future briefing. But navigators already need six hands for work they do. Simple fixed-focus "stovepipe" camera helps. Fast pan film and an aperture of f/5.6 are generally used.





TYPICAL INSTALLATION OF SCR-521 ANTENNAS ON B-17. SOMETIMES AS MANY AS 10 ARE USED FOR SEARCH, HOMING, RACONS.

"ONE SINGLE INVENTION"

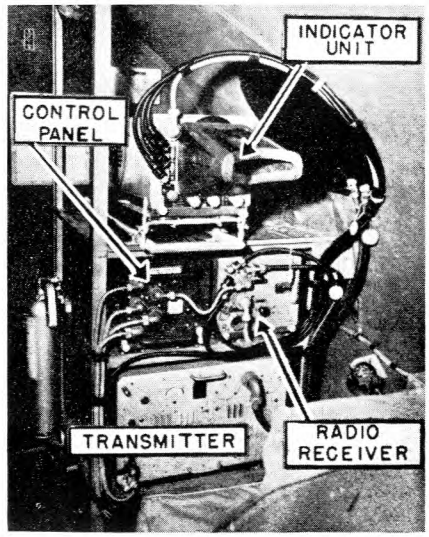
SCR-521, old U-boat buster and patriarch of radars, still earns its keep

When Adolf Hitler told the Germans that "one single Allied invention" had smashed his U-boat campaign, he was wrong. It was not one invention but several, all knit together into one broad attack. But Hitler was half-right, too. In the early days of the Battle of the Atlantic one device drove the marauders back from their furthest reaches, broke up and forever weakened their striking power. The device that did that was a radar set known as SCR-521, and it got no honorable discharge for doing it. It's still around, a four-year-old patriarch of radars, and still doing a variety of jobs. In the stories of radar sets which RADAR will tell in this space, issue by issue, SCR-521 warrants the first mention.

Of British parentage, SCR-521 began life in England under the name of ASV Mark II. It cut its teeth on surfaced U-boats in Atlantic waters, in the Channel, in the Bay of Biscay. It vastly extended the range of Coastal Command patrol planes, enabled the patrols to work round the clock. Further, it made for good hunting at night, when hunting was best — when unsuspecting U-boats surfaced for air and battery-charging. It was a surprise weapon and it did good work.

By the time the U. S. joined the war, ASV Mk. II had seen close to two years of service on the other side of the Atlantic. Less than two months after Pearl Harbor, Canadian-built models were going into a squadron of LB-30's and were on their way to guard the Pacific approaches to the Panama Canal. By September 1942, over 2600 SCR-521-A sets had been delivered to the U. S. Army by Canadian manufacturers. American manufacturers were well along in the production of an equivalent set for the Navy.

The sets went immediately into planes and into action. In B-17's and B-24's they did anti-sub patrol duty, first in the Caribbean and off the Atlantic coast, later in the Pacific. Those were the days of smoking tankers off Florida, of severed tanker lines between South America and the U. S. In a few months the lines were open to traffic again.



COMPONENTS are installed in B-17 at operator's position in radio compartment. Sometimes a second scope is supplied to navigator. Total weight of SCR-521 comes to 225 lbs.

Already, however, other forms of usefulness were apparent for SCR-521. In B-25's the sets went to Alaska, helped pilots navigate over mountainous terrain and through continuous fog. In North Africa they were even diverted from planes, erected on the ground as temporary detection equipment to provide early warning of approaching enemy aircraft.

By current standards, the SCR-521 looks like a frowsy set. Instead of the compact dish of modern microwave systems, it has as many as ten antennas projecting from wings, nose and fuselage. Separate antenna systems are used for: 1) searching, 2) homing on targets, 3) homing on racons. And in addition to all this each antenna system consists of separate transmitting and receiving arrays.

Some later installations use a device called a polyplexer, which allows a single antenna to transmit and receive, thus eliminating the special transmitting antennas. Some omit the long-range search antennas; others substitute short stub "dog-leg" antennas for the heavy homing receiving Yagis under the wings. But no matter how they're shuffled, assorted antennas, decking the aircraft like a camouflaged Christmas tree, are the identifying mark of SCR-521. Aesthetically, the effect is almost as un-

fortunate as that of the German Funkgerat 200, the sea search radar used on Junkers 88's and Heinkel III's.

Within the fuselage, SCR-521 looks respectable enough. It consists of six components, packaged so as to stow conveniently into most medium and heavy bombbers. The British used it in Wellingtons, Whitleys, and Sunderlands as well as in American-built patrol planes. The U. S. Navy put it into PBY-5's; the Army into B-24's, B-17's, B-34's, B-25's and A-29's. The sleek-bodied B-34 is, in fact, about the only Allied bomber that couldn't be made to accommodate the equipment.

Installed, the SCR-521 adds about 225 lbs. to the plane's weight. Generally the units are assembled around the radar operator, stationed in or near the radio compartment.

In operation, the SCR-521 is a simple set. Granted good maintenance — and the set is not difficult to service — the operator has only to watch the scope, report suspicious-looking signals to the pilot. The scope he watches has a presentation resembling two vertical A scopes lined up back to back. Signals appear as pips, or deflections, on the luminous trace.

As on an A scope, the range of a reflecting object is indicated by the distance of the pip from the base of the trace, and can be read to within 10% accuracy from calibrations marked on the face of the scope. Position of the reflecting object to right or left of the plane's line of flight is shown by the corresponding projection of the pip to the right or left of the trace.

In searching, the radar lobes extend at right angles from the line of flight. When a surface object is swept by a lobe, a pip appears on the side of the trace where the target actually is. When this occurs, the radar operator notifies the pilot, directs him into a turn and a head-on approach to the target. The radar is then switched to "homing," and the lobe extends forward in a fan-shaped path along the line of flight. Objects lying in this path appear on the scope as two opposing pips.

As the plane heads to the right or left of the object, the corresponding signal on the scope grows larger. By directing the pilot onto a course which brings the two pips to equal size, the radar operator can put the plane in a straight run to the target. The final phase of the run is made by the pilot visually, however, as the base of the scope is covered by "sea return" — signals reflected directly by the water — and the target signal frequently becomes lost in it.

Range & Altitude

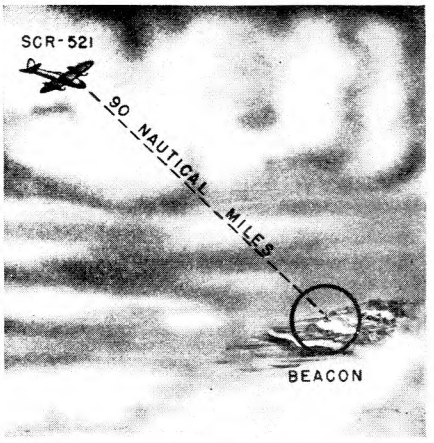
The range at which surface vessels can be detected by SCR-521 depends on the altitude of the plane. Most satisfactory for ASV work is an altitude between 1500 and 3000 feet, and from this height the equipment can be depended on to pick up surfaced subs at 8 miles, convoys at 34. In such operations, two range scales are used: a 36-mile sweep for searching, a 9-mile sweep for closer viewing as the plane approaches the target.

When homing on an SCR-621 racon, the radar, at increased altitude, picks up the signal at a maximum of 90 miles, limit of the third range scale. SCR-521 uses a special set of antennas for racon operations, transmitting a beam which triggers the racon. The racon responds by sending out coded pulses which are received by the radar in the plane and appear on its scope as a special type of opposing pip display. From the relative size of the right and left pips, the direction of the racon can be determined; from the number and spacing of the pips, the identity of the racon can readily be established.

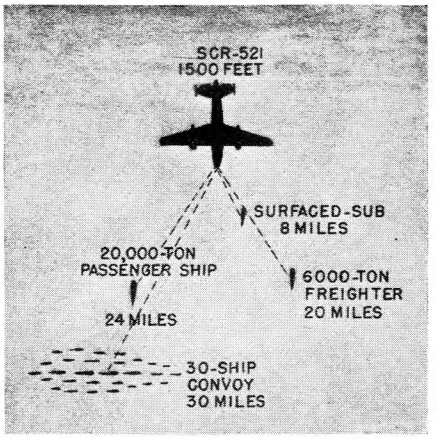
Like many a military device, SCR-521 was eventually caught up with. By the fall of 1942, German subs came equipped with a receiver which enabled them to detect the approach of SCR-521 in time to dive and escape attack. As a U-boat menace, the set had seen its day. The job it had begun was handed on to newer radars against which the Germans had no defense — first the SCR-517, early microwave ASV set; later, the SCR-717.

Thus SCR-521 has been twice succeeded by newer, more modern equipment. A year and a half have passed since the last SCR-521 came off the production line for the U. S. Army Air Forces. Including the Navy version, ASE (installed in PBY-5's), close to 4000 of these sea search sets were produced in all.

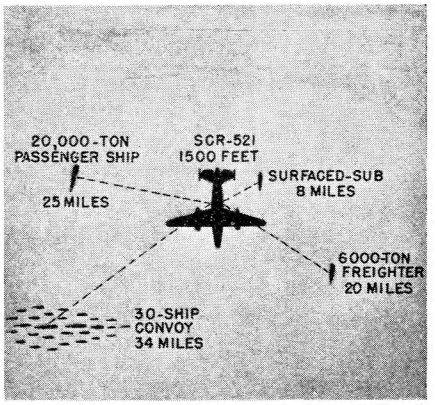
They were a good investment. They did the job they were assigned to do, and did it well. Today, old but far from worn out, SCR-521's are still at work, tracking down surface vessels, patrolling coastal waters, helping planes to navigate over strange and distant areas.



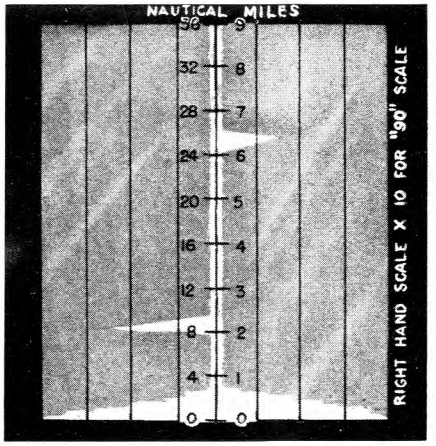
RANGE on racon SCR-621 is to the limit of the scope — 90 miles. Triggered by pulses from the radar, the racon sends out coded signals which give its range, direction and identity.



HOMING ranges are shorter on small targets. Compared to newest ASV sets — which pick up surfaced subs at 18–20 miles — SCR-521 is near-sighted, but it saw enough to do the job.



MAXIMUM SEARCH ranges of SCR-521 are indicated above. When searching, radar lobes extend from fuselage at right angles to line of flight. When homing, the lobes point forward.



SIGNALS on scope appear as above when set is searching. With 36-mile sweep, scope shows a ship to right of plane at 24 miles, another to left at 8 miles. When set is homing, one target makes a pip on each side of the trace.

While We're on the Subject

Good Thing

"Having the crews believe so strongly in radar," writes a technical specialist with a bombardment group in one active theatre, "can be too much of a good thing." The reason, he says, is that after getting results from radar on a few flights, the bombardiers begin to feel that unless they hit the target dead center the equipment must be out.

Radar, let it be said plainly, is not as good as all this. It's not good enough to cover up errors, uncompensated evasive action by the target, or other factors beyond its province. But when the technical specialist investigated a number of trouble reports turned in by crews he found the causes, with only two exceptions, to be just such factors. In one classic case, the bombardier toggled the bombs out because he just figured they should have dropped by then, although the radar said no. They dropped, all right — short.

Long Range

The editors of this learned journal know of no special record of long range radar performances of the sort achieved from time to time under unusual meteorological conditions. It may be that there is such a record unknown to us and it may be that the studies on weather now in progress (see page 26) will provide one. Meantime there are isolated reports and some of them relate truly prodigious performances. Most prodigious we have come across is described in a report prepared by the M. I. T. Radiation Laboratory and quoted recently in *Radar Information Notes* (Navy Dep't Bureau of Ships). Excerpt:

"On June 30, 1943, the SC-2 radar on the USS JAMES O'HARA at Mers-El-Kebir observed a moving target at a range of 329 miles, bearing 18 degrees true, and mountains at 272 miles, bearing of 40 degrees true. Between the 29th of May, 1943, and the 12th of June, 1943, the USS JOSEPH T. DICKMAN's SC-1 radar at Mers-El-Kebir saw fairly constantly the island of Majorca at 294 miles, mountains northwest of Barcelona at 378 miles, the islands of Iniza and Formentera at 230 miles, and other mountains at ranges of about 190 miles and 120 miles. These signals were steady in nature, becoming somewhat weaker in the afternoon, but never fell below a 2 to 1 signal-to-noise ratio. Also at one time the island of Corsica was seen at about 400 miles."

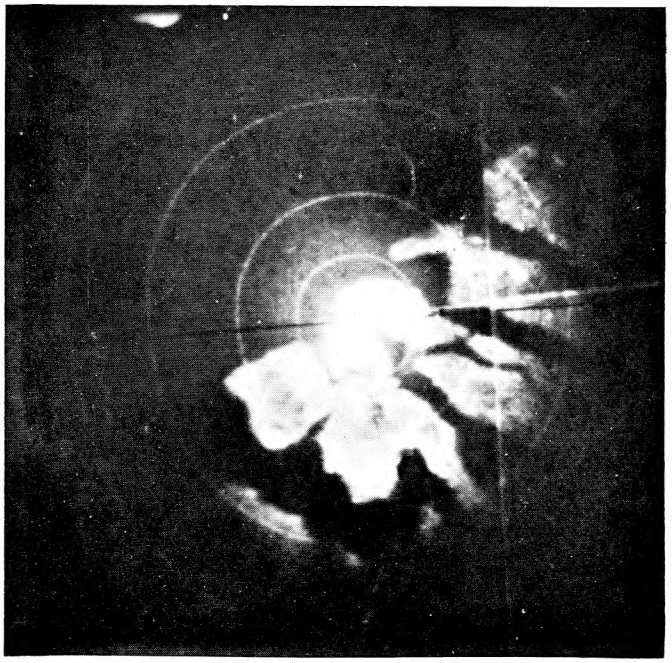
Says the report, in explanation:

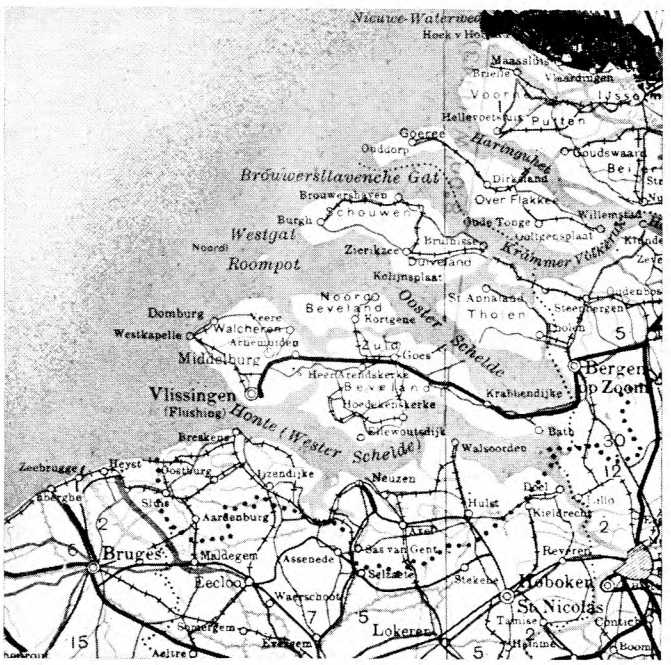
"This type of long range performance is not surprising in June in the Mediterranean since meteorological conditions are particularly favorable for production of vertical gradients of the atmospheric index of refraction which trap energy from the radar beam in the first few hundred feet and confine it near the surface of the water for great distances."

If you know of a range performance better than the 400 miles cited above, give us particulars. Maybe we'll compile the record ourselves.

Foreign Correspondents Wanted

As this first issue of RADAR goes to press, and thence to AAF squadrons all over, a second and a third issue are being shaped up and plans for many more are in the making. Preview of contents: radar evasion tactics; interpretation of scope signals; continuing reports on radar systems; how to recognize enemy installations; navigation techniques; and anything else we can think of that might be of use or interest to you. If you've got any ideas to suggest, please let us have them. If you can submit more than ideas — articles, items, photographs — by all means let us have them. The pay is nothing much — in fact, nothing. But your hours are your own and you can be a foreign correspondent just like in the movies.





APS-15 is a navigational set as well as a set for bombing of inland cities (see p. 3). Picture of Netherlands coastline above on scope shows clearness with which main shapes are resolved (compare with map). Even without computation or use of fixes, a skilled navigator could locate himself quickly. Scope shows radial distortion, or "stretching" of shapes as they recede from center. But range circles, which indicate accurate intervals (in this case, 5 miles each), give the radar operator a ready check at all times on such distortion.

New kind of soldier



Military history, as much as it is the story of battles, is also the record of new weapons, new devices. The tank created the tank corps; the airplane spawned an army of over 2,000,000 men. And each new weapon brings its own organizational problems. Shall it have a branch of its own? Shall existing units each sprout their own specialist groups? How? Radar, the outstanding new weapon of this war, is already calling for answers to such questions. In the main, radar brings a new kind of soldier: part mathematician, part electrician, part fighter. RADAR aims to make a running report on radar men and where and how they fit. Coming in an early issue:

"Radar Personnel in the Air Forces."

FERRANTI Defence Systems Limited

RADAR

Issue No.2 MAY 1944

INTRODUCTION



R.P.F. Lauder
Engineering Manager
Product Support Department

Ferranti is pleased to issue this second volume in the 11-volume series covering the last 18 months of World War II as seen by the USAF's experience of radar.

This volume concerns itself mainly with active ECM jamming, passive ECCM, IFF and an examination of German long range surveillance radars, and short range GCI.

It is more than probable that the spur for active EW jamming techniques to be developed, by both the US and the UK, was the occasion on a night in February 1942, when the Germans so successfully jammed British radars, that the two German battleships *Scharnhorst* and *Gneisenau* were able to make their escape through the English Channel, undetected. Their subsequent fate is of course another chapter of history.

This active EW jamming was called "carpet" by the Americans and consisted of both AM and FM modulations as well as noise. Although the German Freya and Wurtzburg radars only covered a band of some 15 MHz centred on 550 MHz, the techniques available at the time sometimes required three separate overlapping jammers to cover this modest band. The success was judged by the first ten missions, where a saving of 210 men and 21 aircraft was realised, compared with ten missions without carpet.

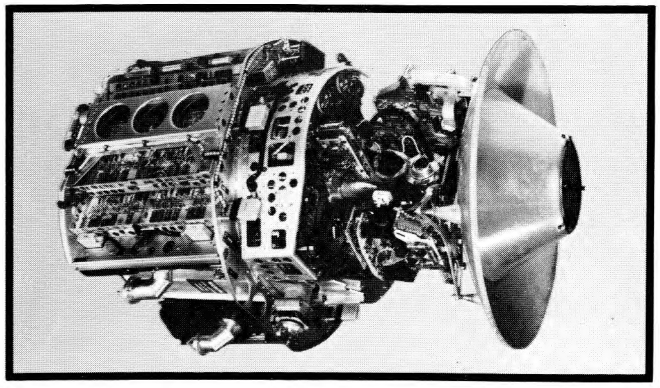
Looking at the reverse side of the coin – the passive ECCM, we find the allied operators with little defence beyond intelligent use of the gain control. Modern techniques which Ferranti has used many times, such as frequency agility, jamming, avoidance, defences against inverse gain jammers, range and velocity gate stealers and angle deception jammers were simply not available. Most transmitters were fixed frequency, or manually tuned – rather slowly. Fortunately, the sophisticated techniques of RGPO, VGPO and IG were not employed by the enemy.

IFF seems to have been regarded as a very mixed blessing; it had maintenance problems and unreliability, and was treated with little respect by pilots who frequently forgot to switch it on. Interrogation of the unknown aircraft was initiated from the operations room on the ground and both fighter control and anti-aircraft control would inform their respective forces that the aircraft was friendly or not. Interrogation/response in the air to air situation does not seem to have been practised at this stage. It was evidently so controversial a subject that the USAF found it necessary to employ the AAF's cinema unit to make a 40-minute film about IFF to punch home the point that ignoring it meant that you were shooting down your own aircraft.

By this time, intelligence was beginning to come in about Germany's early warning radars deployed in massive numbers along the westward-looking coast of Europe, which had been over-run by the Germans. The Freya was the major version for long range surveillance. At 550 MHz the antenna consisted of dozens of half wave dipoles mounted on a huge vertical earth plane to provide an azimuth beam width accuracy of 1°. The range limit was 120 miles for targets at 20,000 feet. The task of manufacturing these huge structures was given to the Zeppelin works, and the German steam shovel company. The Freyas handed targets over to the Wurtzburg radar at about 25 miles and allowed the GCI job to be done. Wurtzburgs had a parabolic dish (folding, in the case of the mobile radars) and came in two sizes, the larger of which was at a fixed location and weighed 12.7 tons.

Even in the month elapsing since the issue of the last volume one can sense the growing awareness of the potentiality of radar, and an understanding of its problems.



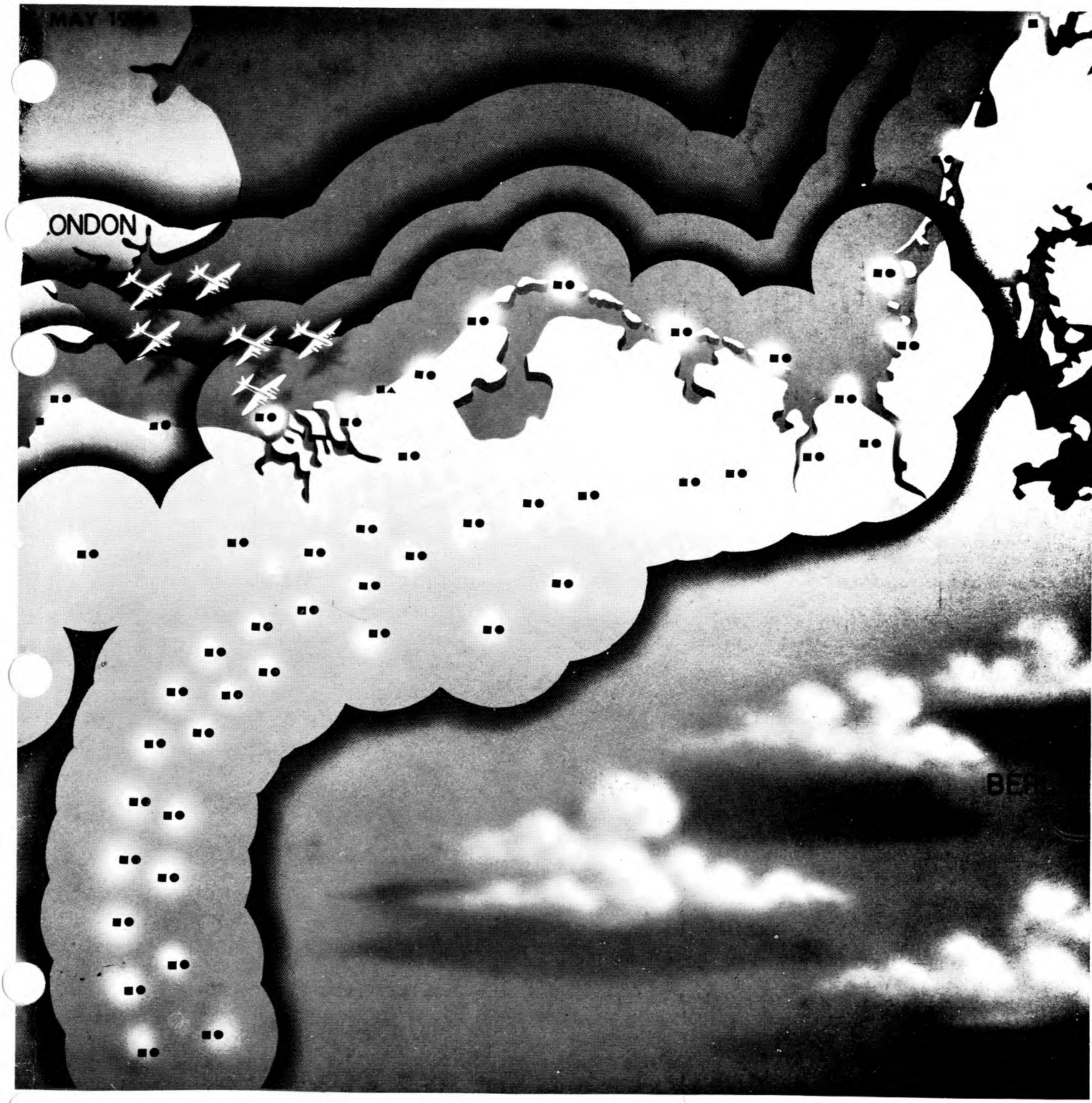


BLUE PARROT

This long range search, ground mapping, and air to surface strike radar designed by Ferranti, originally for the Royal Navy, was later dedicated to RAF IDS roles and currently is on duty as deep water maritime strike with a variety of weapons. It is in the line of succession to Airpass 1.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

PSD



RADAR

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In This Issue

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CONFIDENTIAL

GERMAN RADAR

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EDITORIAL ADVISERS: Maj. Gen. Barney M. Giles, Chief of Air Staff; Maj. Gen. Roger B. Colton, Chief, Engineering and Technical Service, Office of the Chief Signal Officer; Brig. Gen. Thomas D. White, Assistant Chief of Air Staff, Intelligence; Dr. Edward L. Bowles, Consultant on Communications to the Commanding General, Army Air Forces; Dr. L. A. DuBridge, Director, Radiation Laboratory.

PUBLICATION DIRECTOR: Chief of the Radar Branch, Office of the Air Communications Officer—Col. W. M. Canterbury.

EDITOR: Dexter W. Masters **ASSOCIATE EDITOR:** Nancy Newton.

You'll get more out of this publication if you put something into it. Information and photographs on operations and maintenance of equipment in the field are requested. Submit material to Radar Editor, Office of the Air Communications Officer, Headquarters of the Army Air Forces, Washington, D. C.

Radar is like rabbits

There is a story — probably apocryphal — about a recent meeting of three men in Washington, at which the tactical application of a certain type of radar was up for discussion. One of the men was a Squadron Commander fresh in by plane from a combat zone. He said that the problem they were talking about had been settled in favor of *such-and-such* a procedure just before he left. The second man thereupon said that apparently it hadn't because only a couple of days ago a new order had been issued supporting *such-and-such* a procedure. Whereupon the third man announced he'd received a cable the day before reporting that a new angle had been introduced which turned the whole picture around. At this point a fourth man came into the room and told the other three that he'd just had an exchange of radiograms with London on a brand new development which changed everything.

Apocryphal or not, this tale is truth itself so far as its implications go. The truth is that radar developments multiply like rabbits and it's a brave fellow who'll set up to speak with authority on how things stand at 9 o'clock on Tuesday or any other given moment.

One of the main reasons for this is the kind of restless, unofficial research that goes on in the field. The centers for such field research may be the work bench in a Quonset hut housing Third Echelon maintenance men, or the operator's compartment in a B-24, or a command HQ, or a barracks. Out of such laboratories comes the basic experience, or the shop talk about it, which is refined into criticisms of prevailing equipment and operations, into ideas for improving either or both, into realizations of functions which radar could be and is not performing. The distillation of field experience into those criticisms, ideas and realizations is a never-ending process, a highly important one, and one which—to bring all this back to RADAR'S home base — poses a terrific job of information gathering.

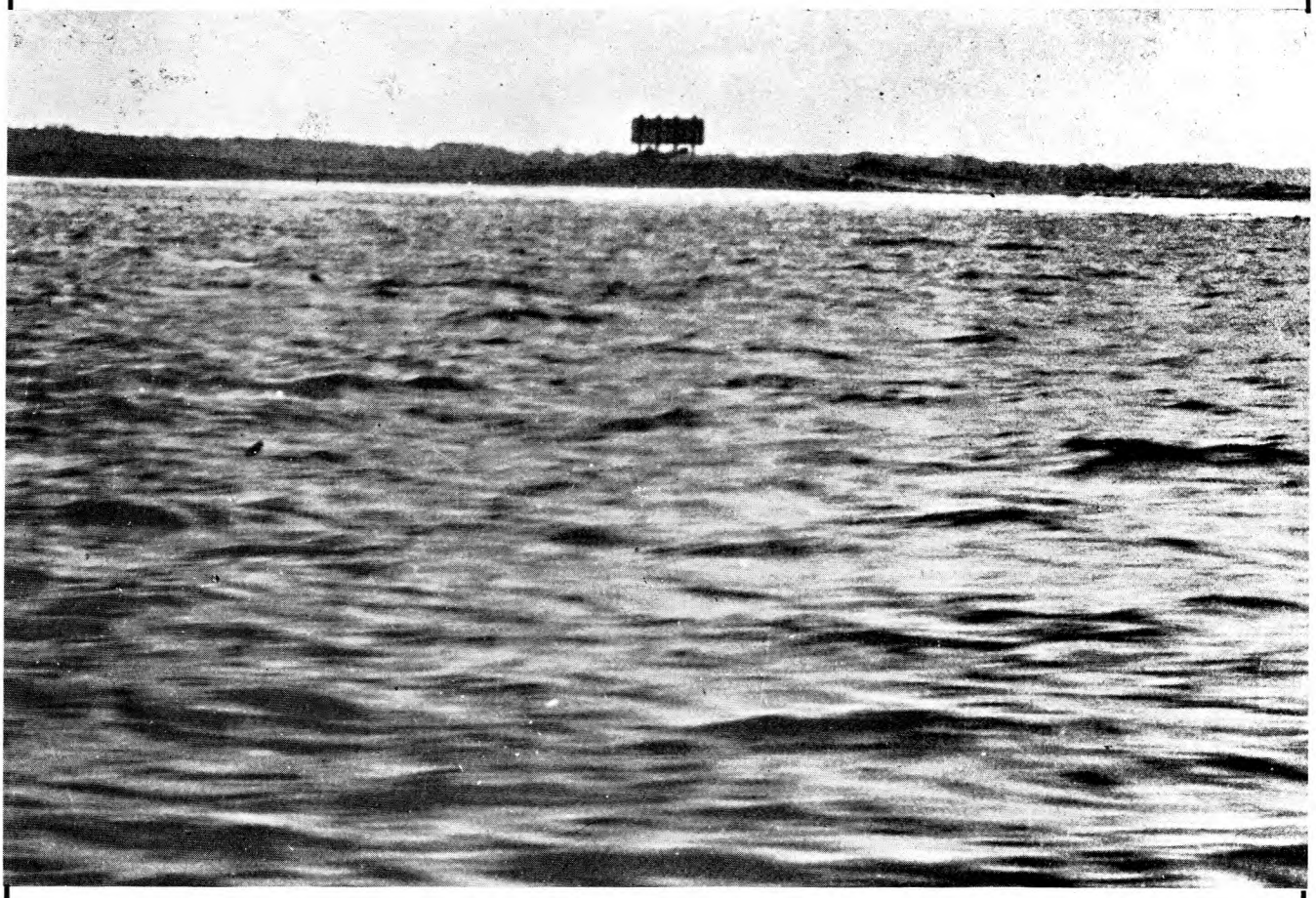
The aim of this journal is to tell as much as it can find out as well as it can as fully as security allows. In pursuit of this aim RADAR will spot correspondents in enough places to keep it directly informed of all the developments that a normal correspondent can be expected to keep an eye and an ear on. But the operator's compartment in a B-24 is not quite big enough to accommodate a RADAR correspondent and, in a word, much is bound to happen in the field that no correspondent alive can keep tabs on. The Third Echelon maintenance men, the operators, the command HQ staff and the barracks shop-talkers have got to come through direct.

Field response to the first issue of RADAR was first-rate — voluminous and full of compliments. That is fine and we wouldn't have it otherwise, but from now on we'll be happy to let the compliments go and take articles and items and photographs. Reports of operations and smart uses of radar and more photographs. Local radar news and dumb uses of radar and still more photographs. Read, for instance, the report on IFF beginning on page 20 of this issue. There is doubtless much on the subject which you know about from direct experience and which is not there. OK, let us have it. You'll get it back all dressed up and combined with a lot of other things from others which will be as useful to you as what you know about will be to them.

RADAR, as befits any self-respecting journal, has a slogan, of course. It goes: "Remember . . . when you spell RADAR backwards it spells RADAR." But we've got another, too. It goes: "RADAR is your friend . . . speak to it."

"THE WHOLE OF GERMANY IS ENVELOPED by a CLOSE NETWORK OF ECHOLOTS★"

"Anglo-American attempts to destroy the effectiveness of the German electric pylons have failed completely. Pylons function according to the echolot process . . . night fighters employ the same methods. In fact, the whole of Germany is enveloped by a close network of echolots so that each single enemy machine, let alone formation, is under constant observation. By these means German defenses can operate with extreme rapidity and effectiveness." — From a German broadcast to England, 31 March 1944.



A GERMAN "ECHOLOT" (HOARDING TYPE) LOOKS OUT ACROSS CHANNEL WATERS FROM THE WEST WALL OF EUROPE

GERMAN RADAR

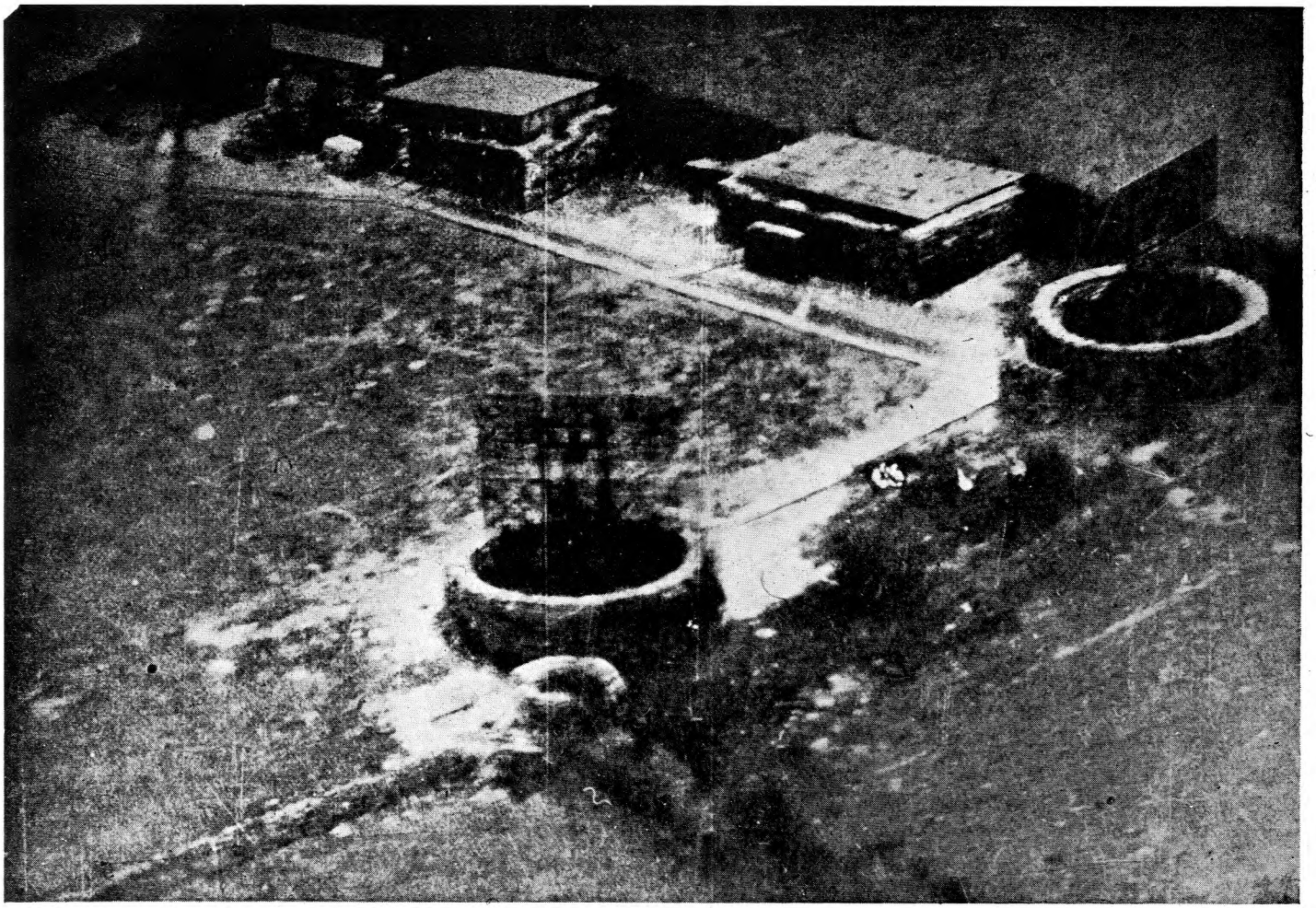
Authorities differ on German radar. The words above constitute one view. Another was found in the captured files of an Italian base commander: "It must be borne in mind that in technique, organization and experience of use of radio location, the Allies have arrived at a state of progress notably superior to that being attained by Germanic means."

The crews flying against Germany's radar network — who may be as authoritative as any on the subject — are not inclined to belittle it. Whether attempts to destroy its effectiveness have "failed completely" is a point safely left for decision to the same crews, and to the German operators who have tried to track them through clouds of Window and blankets of Carpet.

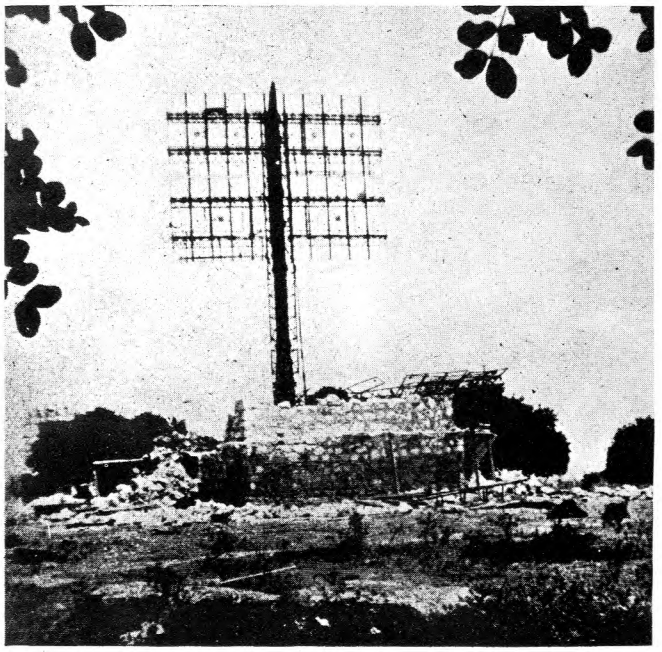
With respect to fundamental effectiveness it can be argued, and often is, that German radar runs about a year behind Allied. Most German equipment captured has not been up to ours technically. More significant, no German equipment as yet even makes use of some of the potentialities which have been developed by the Allies into highly effective instruments — microwave equipment, for one. Some of the German lacks, and notably their lack of anything comparable to our APS-15 for bombing (see RADAR, April), may be explicable in terms of their forced emphasis on defense. But the lack of, say, a German PPI scope is harder to account for; except in terms of backwardness.

Nonetheless, there is no denying that German equipment works and, for some functions, is as good as it needs to be. The whole system is at least effective enough to require our constant disruptive efforts. And it is at present in a great state of flux just because of those efforts. How it will work out of this state remains to be seen. For some time at least, if only because of the vastness of its installation, it will probably not get far away from its basic components. What those are and how they fit together are the subjects of the next eight pages.

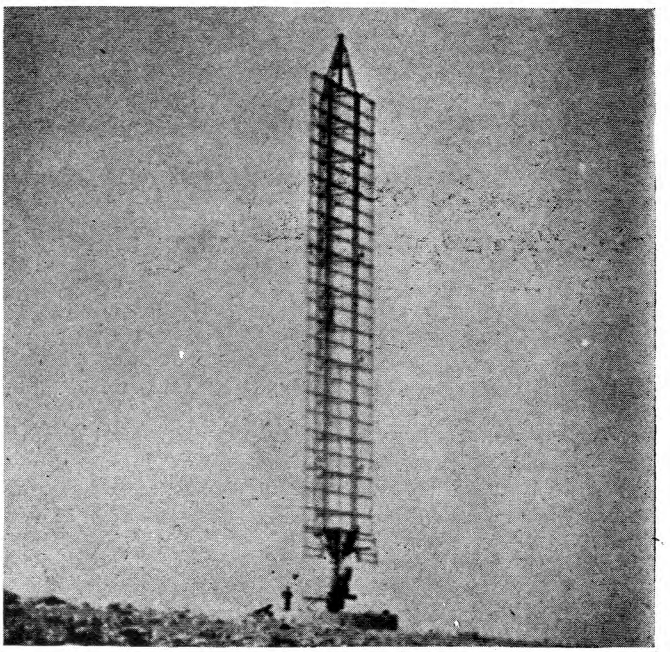
★*Echolot: from* echo (*meaning just that*) *and* lot (*a plumb or measuring device*). *The word has been used before to designate an instrument for sounding water depths.*



Easily recognizable to Allied pilots on cross-channel sweeps are these two old-type ("Limber") Freyas. Characteristic points of Freya coastal site are: high, clear, flat terrain; nearby obstructions that might cover ground attack cleared off; the entire installation circled with wire. Protective walls are sandbag or stone, 25 feet in diameter. *Bullseye for strafing* is operators' box, in center below the antenna.



Pole-type Freya captured in Sicily. A second Freya, also left standing, is visible behind clump of trees at left. Freya network in Sicily was fairly complete, covered Malta and other Allied approaches.



Another Sicilian capture: Chimney, also called Wasserman. It is newer than Freya; range is estimated to be half again as great. Some versions can give height as well as range and azimuth of aircraft.

Freya: for warning

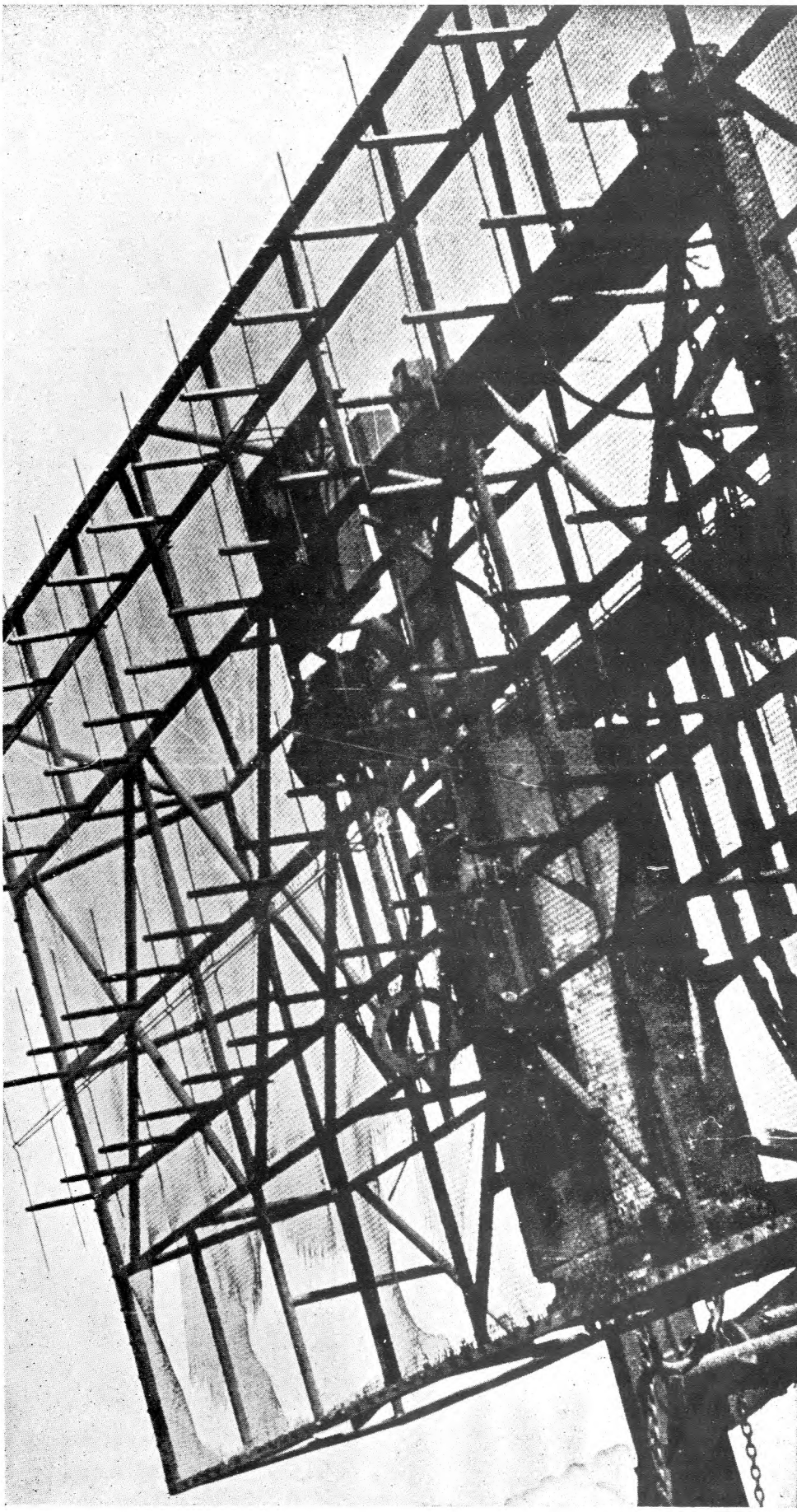
Freya (named for the Norse goddess of love and beauty) looks like a bedspring sitting on a box. Scattered in considerable numbers over coastlines, islands, and inland areas, it is the basic German aircraft warning set, comparable to our SCR-270, for example. It is also one of the oldest, dating back to 1939. Several other common German radars are essentially variants of the Freya, among them the Hoarding and the Chimney. These are the radars that account for the coastal coverage shown on the map on the front and back of this issue.

Freya can work alone, but usually doesn't. Its job is chiefly to spot remote planes — plot them in to about 25 miles range — and then hand them over to gun-laying or GCI Wurzburgs. Within its limits, Freya does this job reliably. It supplies *range* with a probable accuracy of plus or minus 100 meters, and *azimuth* with an accuracy that is probably better than 1°. Limit on range is usually stated as 120 miles maximum, but this figure is qualified by altitude of approaching planes. It is probable that planes at 20,000 feet elevation can be seen out to 160 miles or more; planes at 10,000 feet at 120 miles; and planes at 2,000 feet, 55 miles. Since low cover is so poor at extreme range, the German prisoner of war's claim — "With Freya it is possible to spot enemy airplanes as soon as they leave an airfield near London" — is undoubtedly inflated.

Besides range limits, Freya is hampered by inability to give height. Good operation can correct this to some extent. An alert operator can at least make a height estimate based on the range of a signal when first seen. Any greater accuracy in height-finding must be left to other sets, and is usually left to Freya's partner, the Wurzburg.

At present, there are probably around 1,000 Freyas in use. Several hundred of them are the original 1939 "limber" type — built on a mounting similar to that for the 88 mm Flak gun. The others are the demountable LZ "pole" type introduced around 1941. Built by GEMA (Zeppelin works at Friedrichshafen build the frames), this type is a 5-ton transportable affair that scans about 1 rpm and presents its information on three A-scopes viewed through magnifying lenses. It has provision for identifying targets. Some Freyas were sold to the Italians and re-named Felino; the Italians planned to make their own version before they surrendered.

A major weakness of Freya is that it can easily be jammed. P/W's have in past reported that their most reliable notice of a British raid is sudden jamming of coastline Freyas. An anti-jam device (Freya-Halbe) is supposed to be under development and test at Werneuchen.





Wurzburg: for GCI

Flakmessgerat* 39-T is the proper name for Germany's Wurzburg. The set came out in 1940, and is variously used for searchlight control, AA fire control, height finding, GCI. It was a pretty good set to start with, and has been improved.

There are two main types of Wurzburg: small and Giant. The small ones have a bowl-shaped reflector 9 feet in diameter. Giants measure 24 feet across the dish. Circuits of both types, designed by Telefunken, are roughly similar.

There are probably a couple of thousand small Wurzburgs spread over Europe. The latest known version is the FmG 39-TD, which is probably being produced now at the rate of about 100 a month.

Like most German devices, FmG 39-TD is an excellent mechanical job: simple, robust and straightforward. Light alloy is used throughout. Weight is around 2.2 tons. Convenience has sometimes been sacrificed for simplicity: the dish, which must tilt often, tilts by hand-crank.

Two operators work the system. These men observe four scopes — coarse range, fine range, azimuth and elevation. The scopes giving azimuth and elevation show "split" presentations, i.e., display two pips which, when equal on each side, indicate that the target is on the beam.

Range of the small Wurzburg is about 24 mi. maximum, 1 mi. minimum. Accuracy in range is probably plus or minus 15 meters. Accuracy in angle may be within about 0.2°.

The Giant Wurzburg came out in 1941 — almost two years after the first small Wurzburg. The Giant is a fixed installation weighing 12.7 tons. On search, the set swings around at the rate of about a circle and a half a minute.

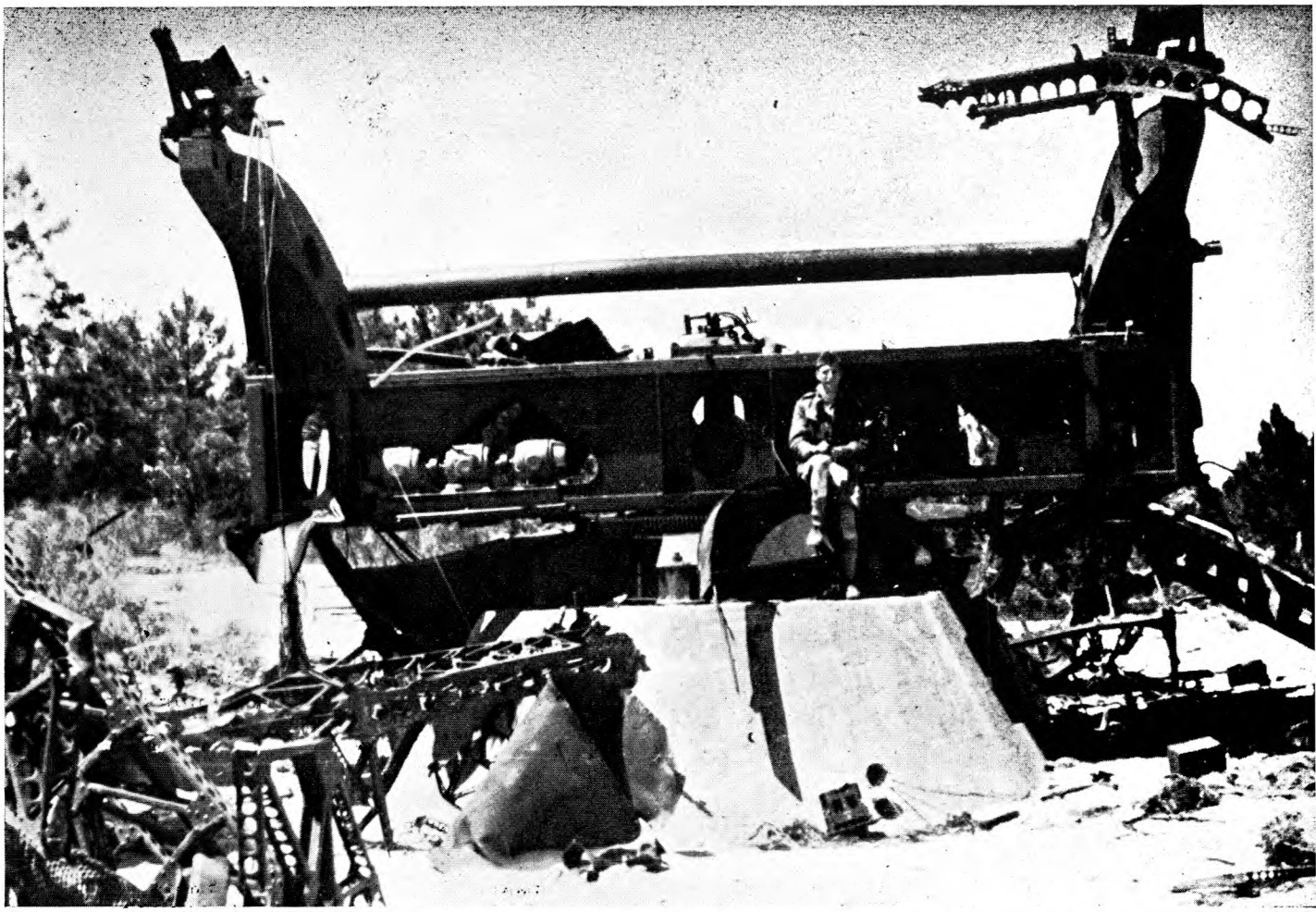
The Giant has double the range of the small Wurzburg: about 45 miles. Its beam is narrower, too. These characteristics suit it for its chief role, which is ground control of interception.

Both small and Giant Wurzburgs have IFF, which works with a small transpondor that is carried by nearly all German aircraft. When the Wurzburg operator wishes to know the identity of a plane whose signal appears on his scopes, he switches from "Measurement" to "Interrogator." If his headphones carry a tone, it's German.

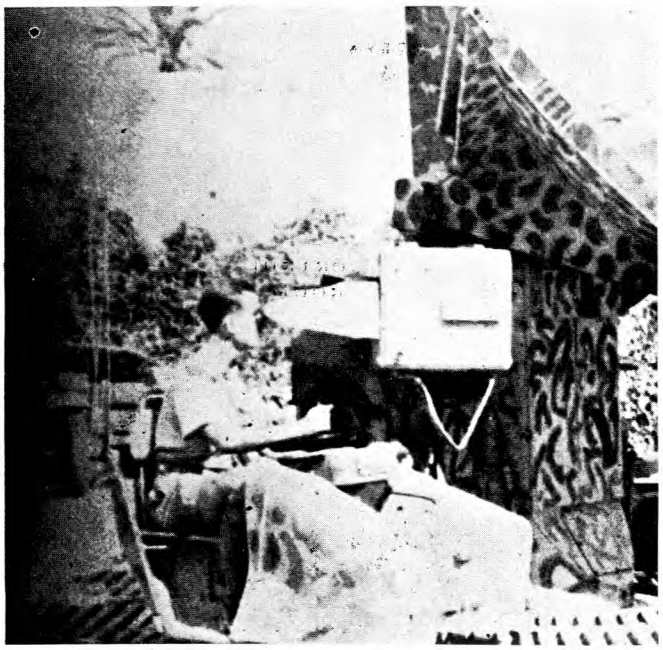
Wurzburg has two main weaknesses. The first is that the set has no PPI (Plan Position Indicator, as on our SCR-584, for example) to facilitate plotting.

The second is that we have learned pretty well how to jam it. As to the PPI: the Germans are expected to have one soon (see page 10). For more on jamming, see page 12.

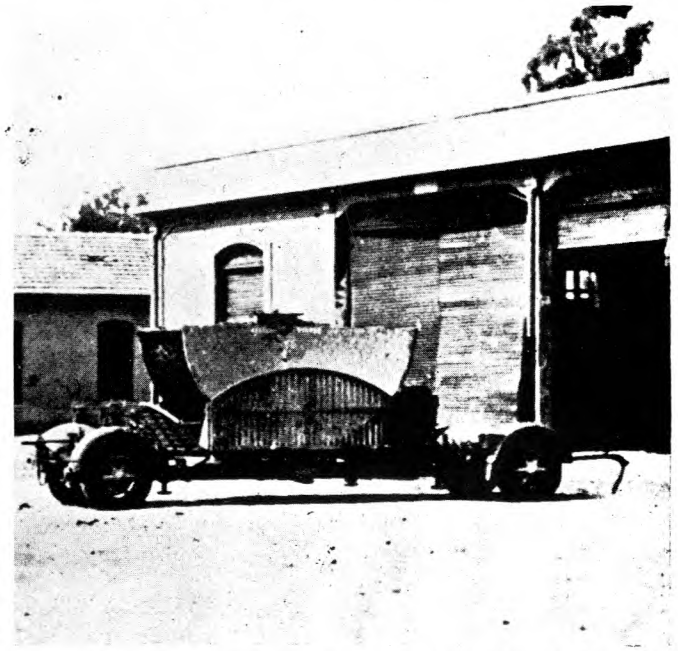
* Flugzeug-Abwehr-Kanone-Messgerat, *or airplane-defense-cannon-measuring device: another way of saying fire-control radar.*



Expensive junk. One of Germany's big steam-shovel concerns is said to make parts for Giant Wurzburg, and the Zeppelin works also sub-contract components. Remains are shown here, in Mediterranean theatre. It is probable that there are almost a thousand Giants in Europe, with about ten to twenty more a month coming. Chief job of the Giant is GCI. Small Wurzburgs usually control lights and guns.

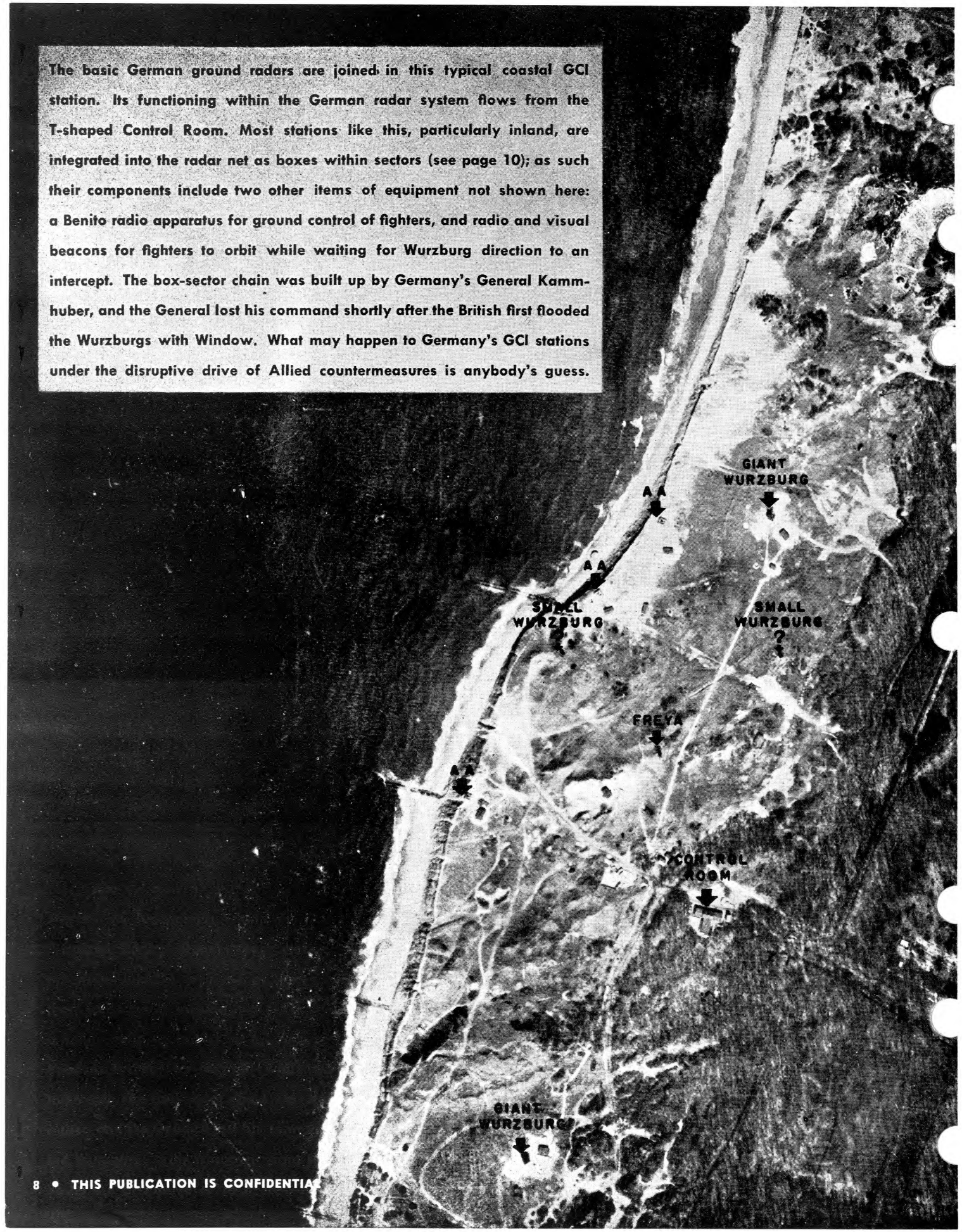


Operating position for small Wurzburg, with dish erected for search. Note leg shields. All these sets are mounted on a trailer something like that of 88 mm flak gun. Trailer is steerable at both ends.



Plane killer. Just below the top edge of the half-dish here can be seen a line of painted trophies: kills claimed by this small Wurzburg. The split-and-fold dish gives lower clearance, better roadability.

The basic German ground radars are joined in this typical coastal GCI station. Its functioning within the German radar system flows from the T-shaped Control Room. Most stations like this, particularly inland, are integrated into the radar net as boxes within sectors (see page 10); as such their components include two other items of equipment not shown here: a Benito radio apparatus for ground control of fighters, and radio and visual beacons for fighters to orbit while waiting for Wurzburg direction to an intercept. The box-sector chain was built up by Germany's General Kammhuber, and the General lost his command shortly after the British first flooded the Wurzburgs with Window. What may happen to Germany's GCI stations under the disruptive drive of Allied countermeasures is anybody's guess.

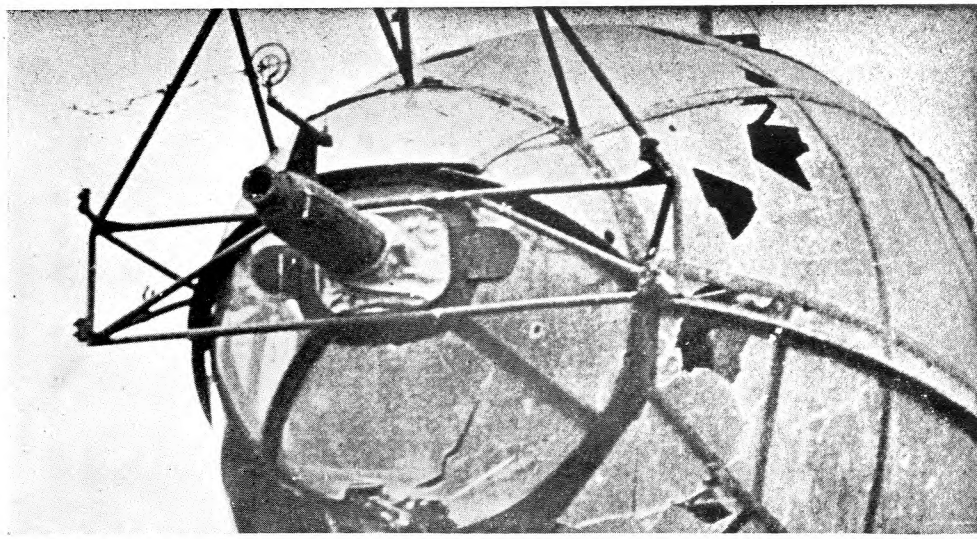


Hohentwiel: for ASV

Hohentwiel (FunkGerat 200) is found in most types of planes used against shipping: Ju 88, FW 200, Ju 188, He 177, Do 217, He 111. As in the Lichtenstein, the antenna is carried ahead of the nose in a large array. Targets are presented on a single cathode ray tube — a double-A type — calibrated to 50 miles, but effective range is probably less. New versions have two range-sweeps: 50 miles and 5 miles. Basically, the Hohentwiel is a rather rudimentary device. In performance, it has not been too bad. Used with a bomb-release clock (X-Gerat) and altimeter FuG 103, it is fairly reliable in bombing attacks.

A new set intended for ASV work and designated FuG 213 may now be in use on Do 217's. It has its receiving antennas on the wings, and it has two scopes: one showing range on a circular sweep and one showing azimuth by pip-matching.

Either this or the better-known FuG 200 is used in control operation of guided missiles; but little is now released on this application. So far as general knowledge goes, the basic German ASV set is the Hohentwiel. It has a long way to go before it can equal the record of Allied ASV's, even the old SCR-521 (see RADAR, April).



All elbows is the antenna support for Hohentwiel. This is one of planes abandoned by Germans in Sicily. Radar was stripped out, mountings alone were left on Junkers, Heinkels.

Lichtenstein: for AI

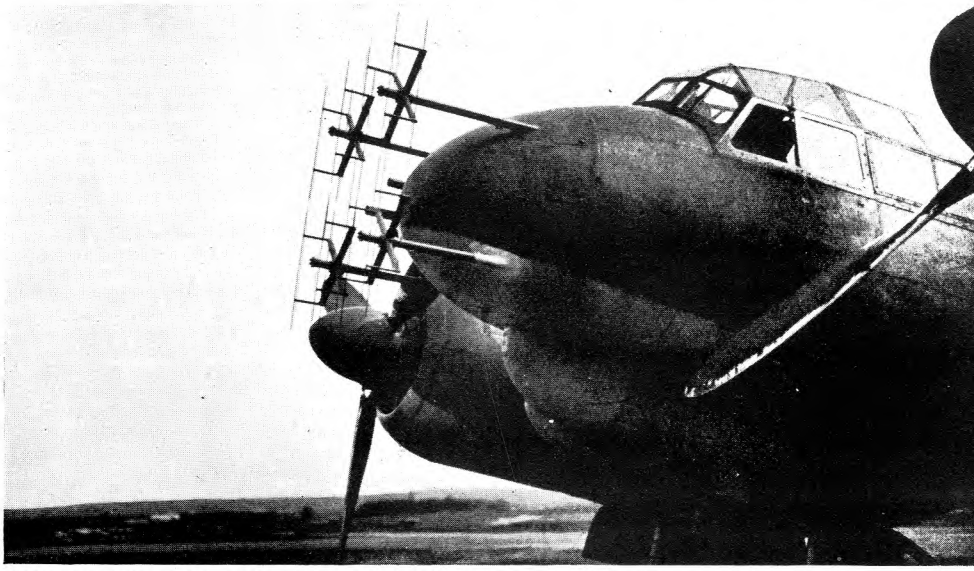
At the start of the war, the Germans had no AI radar, but instead an infra-red device, *Spanner*. Crude, short-ranged, narrow in beam and heavy in power-demand, Spanner was replaced when A(ircraft) I(nterception) was worked out in 1941.

Lichtenstein AI is very similar to the early British AI — so much so that you could almost say the chief difference was timing. The British came out sooner, and came out when it counted.

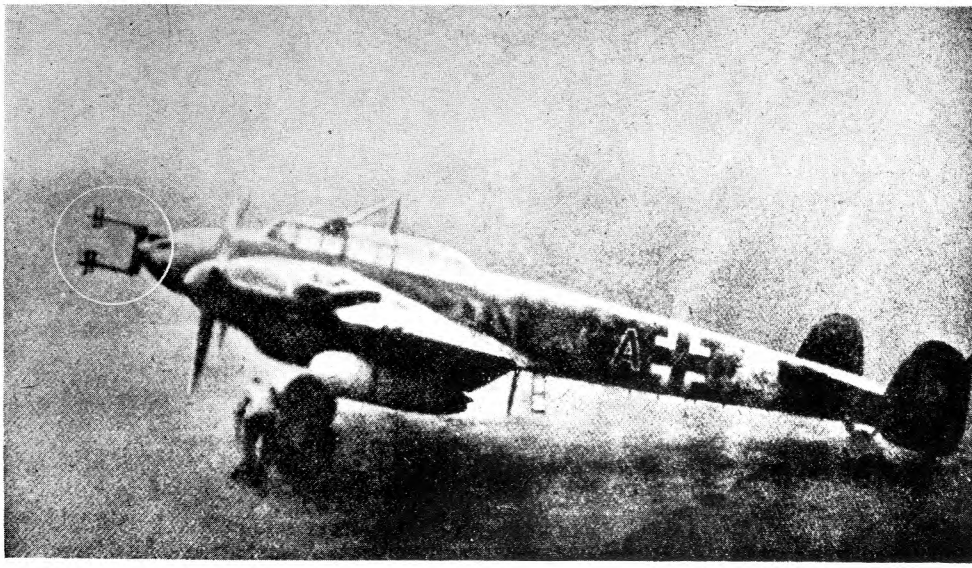
Outside, the Lichtenstein AI is clumsy and awkward. The antenna array reduces speed about 15 mph. Inside, the display is conveniently arranged: three scopes in a flat box. The set weighs 110 pounds, not counting antennas and cabling.

Range of the Lichtenstein was designed to be 8 km. It has tested 3½ km maximum, and can probably be depended on for 1¼ miles at altitude. Like its British counterpart, the Lichtenstein loses targets in ground clutter at low altitudes. It is extremely sensitive to small changes in bearing of its target.

Today, the Lichtenstein AI is regarded as "obsolescent." Rumors of a new AI set have been coming through regularly. One P/W (ticketed as being "given to exaggeration") has said the new AI will have 10 km range, 180° search angle, and an airborne interrogator-responsor like our SCR-729.



Lichtenstein, old and new. The whole nose-cap on the newer model (above) can be removed, antenna and all, for servicing. Note clumsier array on the older model below. The Lichtenstein is about 3 years old, is expected to give way to an improved model soon.



PPI & Microwave

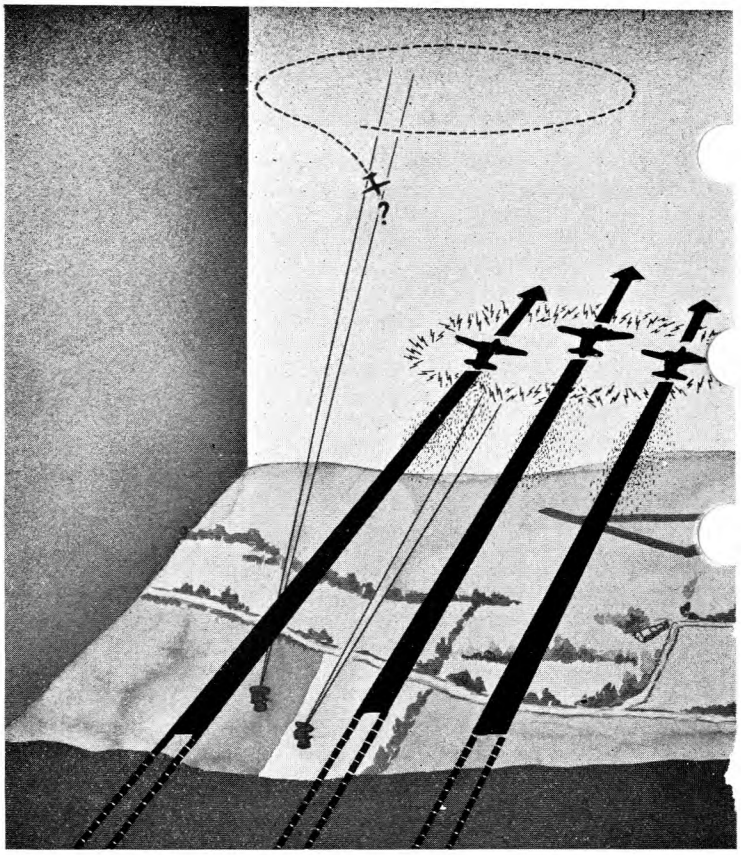
How soon can Germans produce them?

There are two schools of thought concerning the deficiencies of German radar. One has it that the Germans are a good deal further advanced than they seem to be and are simply holding off their radar treasures for a later day. The other believes that captured equipment, P/W information, intelligence, reconnaissance and operations fit together to make a picture which shows the Germans making full use of all they've got.

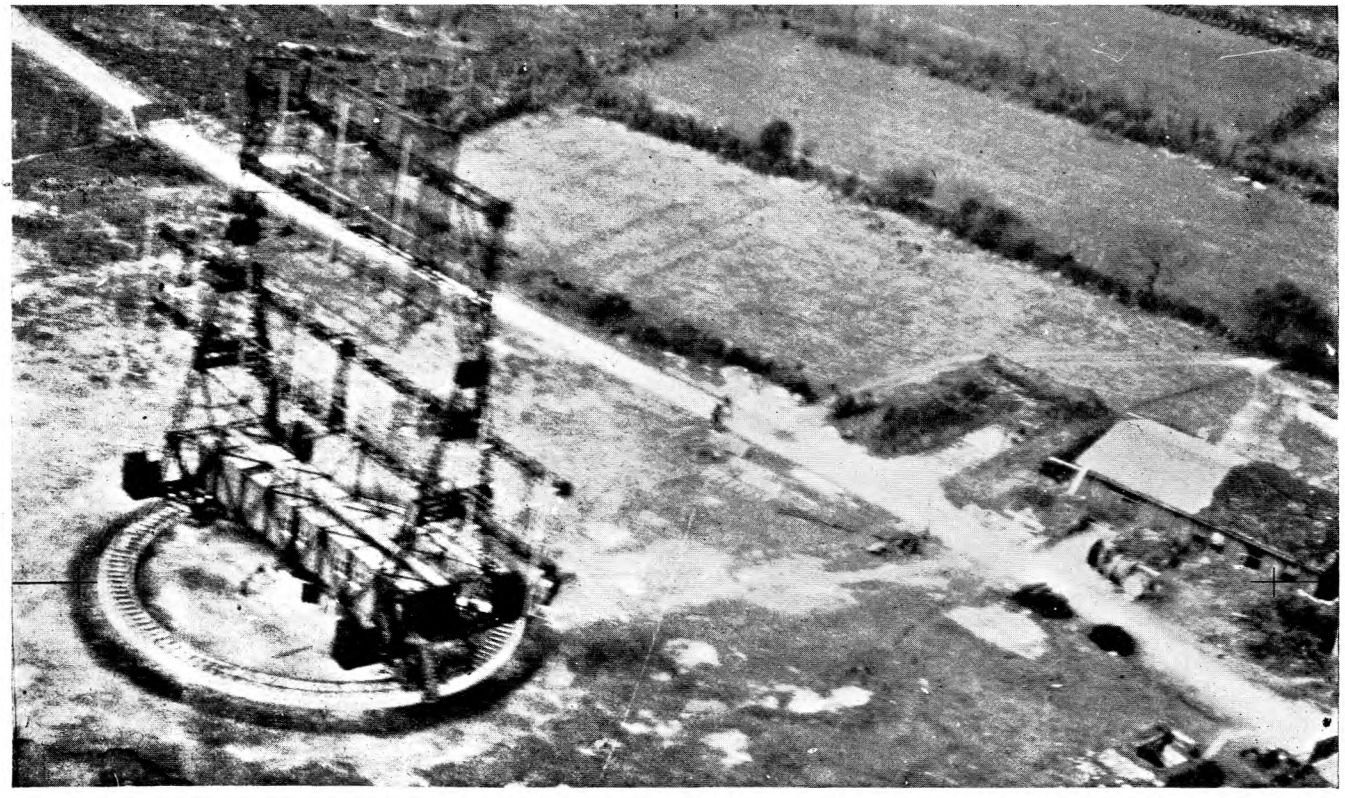
The division between the two schools, and the tentativeness of both, are natural enough: it's no cinch to find out the precise state of the enemy's resources in any field, let alone the fluid field of radar. But even here glimmers of certainty show through.

Thus it is quite certain that British losses of H_2S equipment and U. S. losses of H_2X (the APS-15 sets) have presented the Germans with the PPI technique and, in the case of the latter, with the microwave principle. If they didn't know the workings of these before, it can be fairly well assumed that they do now. Chief question remaining is how long it will take the Germans to turn knowledge into production.

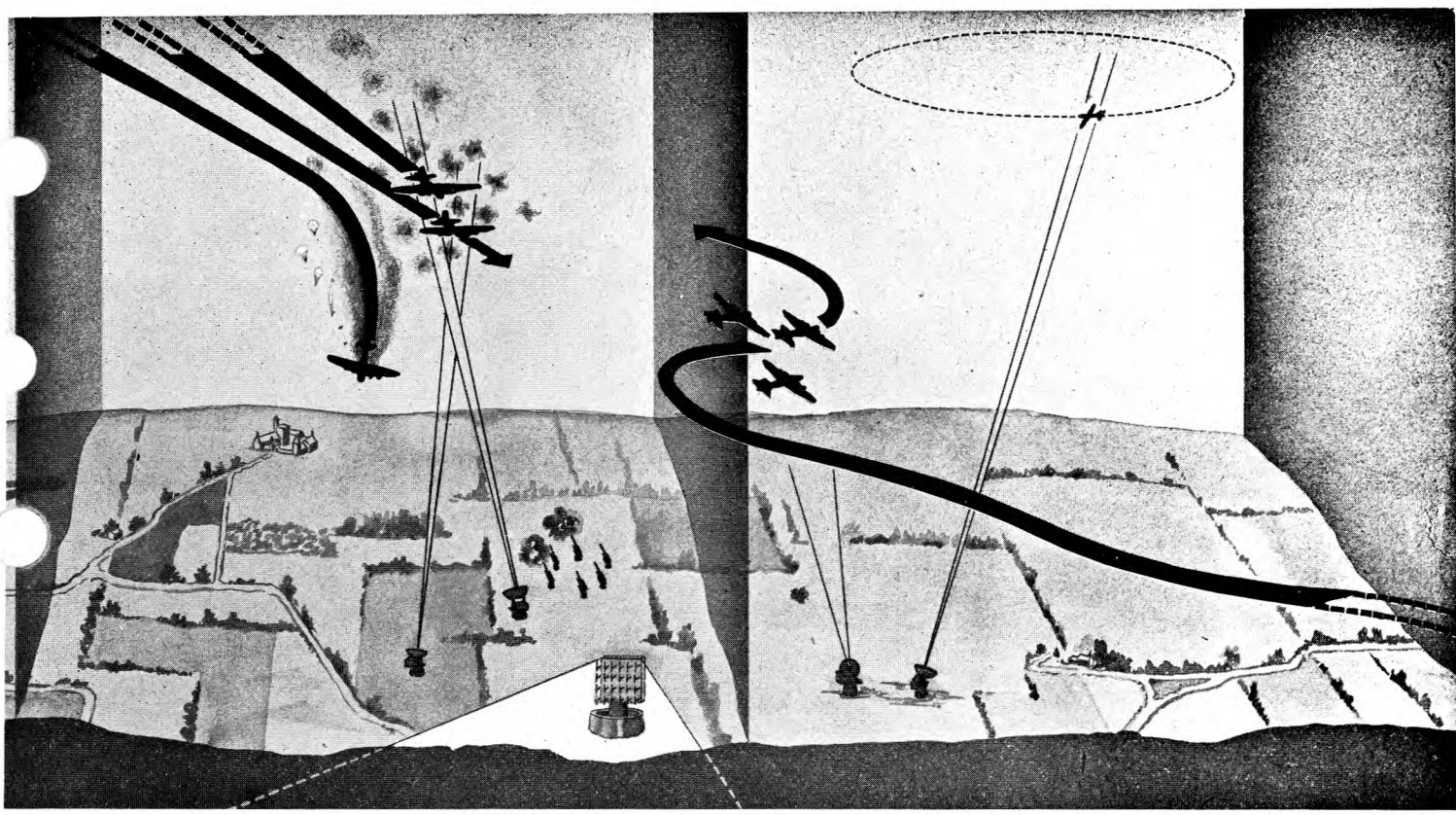
Characteristics and advantages of H_2S and H_2X were dealt with at some length in the April RADAR. Microwave and PPI functionings serve, of course, many purposes other than bombing and navigation, and their contribution to German use may be made most notably in GCI operations. The German method of putting their GCI radar data into map position and height for plotting has been ponderous, cumbersome and time-consuming, and most of the involvements come from the need to work out mechanically and indirectly the information which the PPI technique provides directly. Microwave radar is just better radar. To put both to work will cost the Germans vast overhauling of present installations and procedures. It is expected that the cost will be paid.



Three adjacent GCI stations constitute one sector in Germany's radar interception belt. Sector headquarters (chateau in middle) gets warnings from coastal Freyas, directs whole setup. Only key equipment is shown; small Wurzburgs, etc., are not included here.

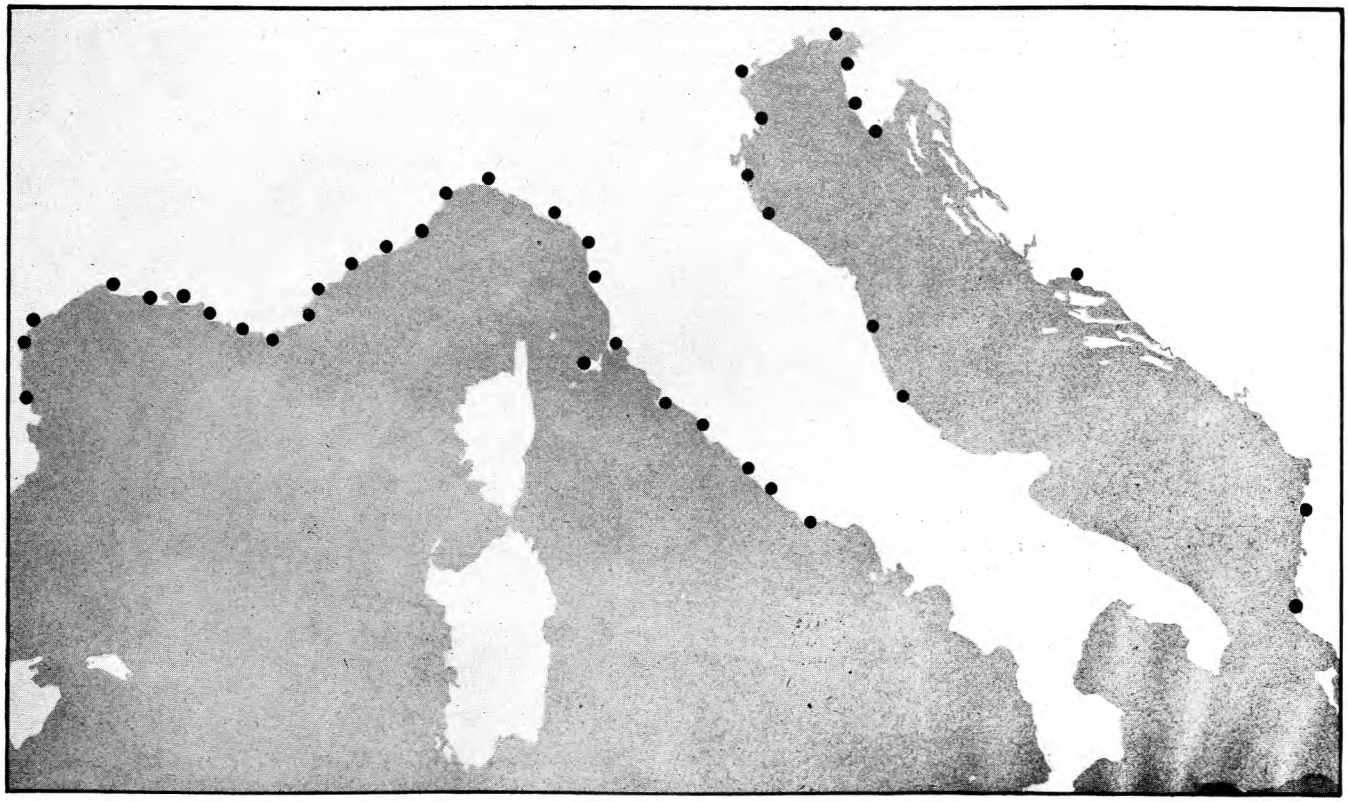


Benito, not often photographed, has been appearing in increasing numbers at German GCI stations. Radio rather than radar, it is unaffected by much jamming and can take over fighter control from Wurzburg. Benito control gives slant range and bearing of aircraft.

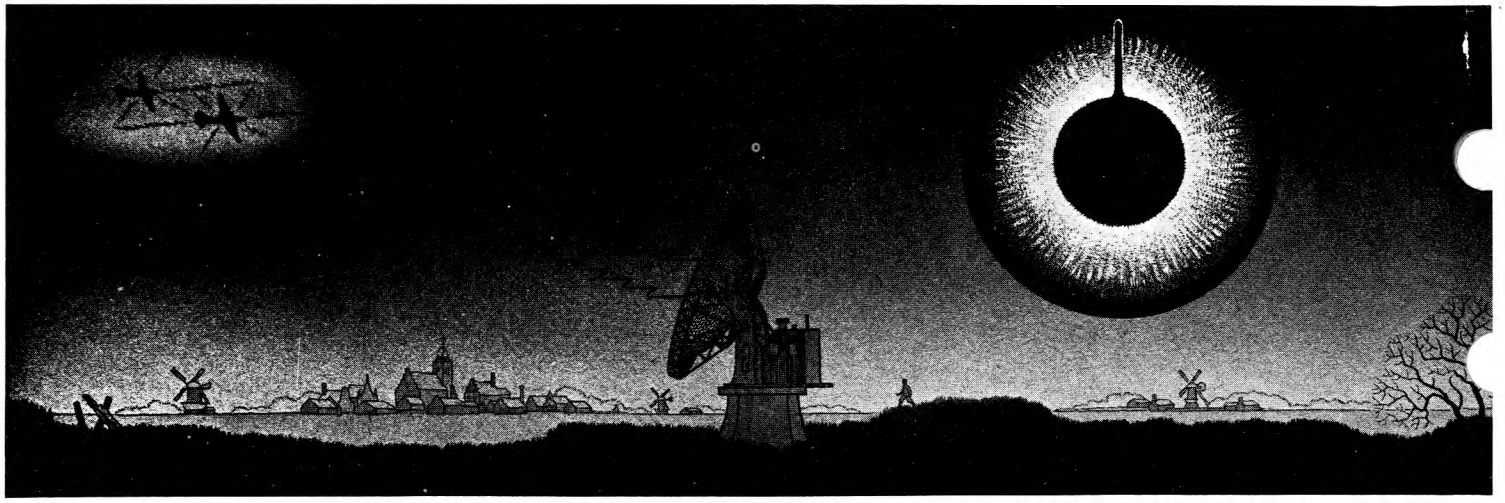


In this hypothetical sector more things are happening at once than normally would. Guns are usually some distance away but middle formation's trouble is clear. Flying in straight through Freya's range it has put itself on Wurzburg's beam with no evasive action.

Formation at far left is jamming with Carpet and Window to confuse Wurzburg-directed fighter. Formation at right is snaking along box boundaries, a stunt to gain time while boxes decide who should take target. Box measures minimum of 20 mi. frontage, 60 mi. depth.



Germanitaly's radar system is not so intricate as West Wall network, makes a solid pattern even so. Dots indicate only presence of equipment, not types. Work of reconnaissance squadrons in covering enemy's radar activity will be reported in an early issue.



PLANES PROTECTED BY CARPETS IN FIRST TWO MOVE IN UNSEEN BY WURZBURG. INSET: CARPET'S EFFECT ON WURZBURG SCOPE

LAY THAT CARPET DOWN

Jamming German radar, no pushover, is Carpet's job. It does it

The most direct way to combat an enemy's radar defenses is to bomb out his installations — that is, if they can be located with exactness, knocked out with regularity, and all without too great a cost, which is a lot of ifs. The most indirect way is to plot the gaps in his coverage and then by-pass the coverage by exploiting the gaps — that is, if the gaps can be plotted accurately and if they're big enough to make exploitation feasible, which is also a very iffy proposition.

No radar system can be perfect, and certainly the German system is not. Even so, it's too strongly put together to be bombed out and too well put together to be by-passed. Although both of these methods are permanent parts of the whole strategy devised to over-ride German radar, the answer to the problem is not found in either method nor both together. The likeliest answer to date is found in jamming, which may be described as a kind of direct-indirect method.

For a working definition of jamming, you can say that it is any process which serves to blot out on the enemy radar the target signal which would be seen without the jamming. To put it another way: jamming gives the operator of an enemy radar more or different signals than he wants to see when he looks for a target.

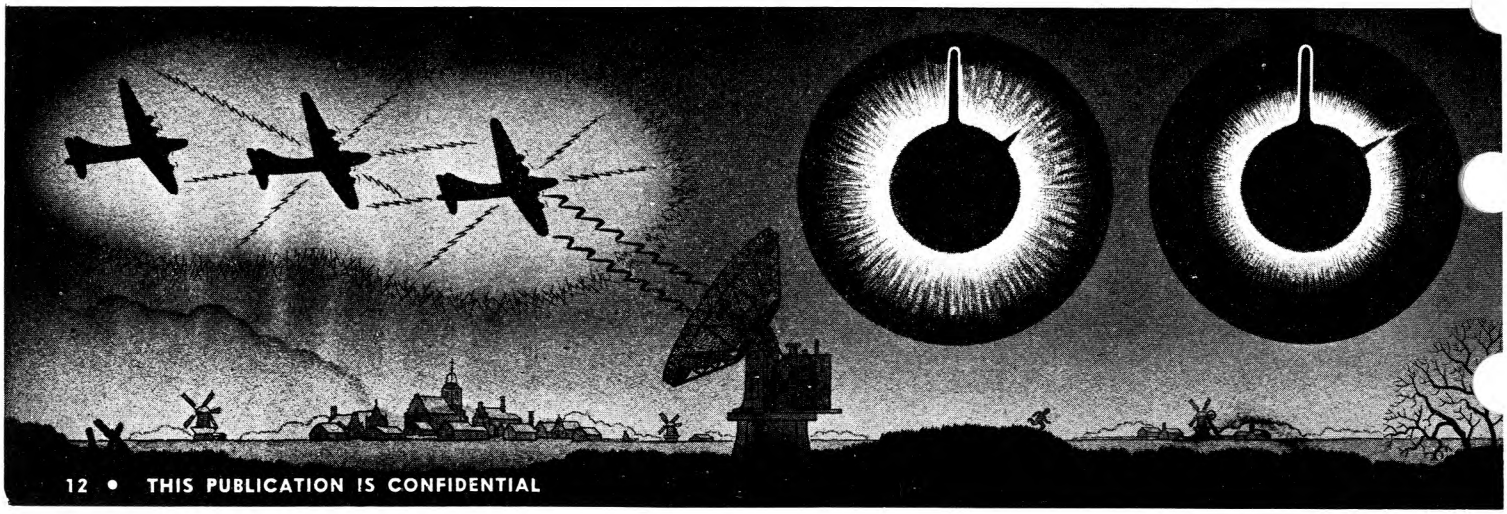
Jamming was used early by the Germans. And on a night in February, 1942, they gave British radar operators so many more and different signals that the German battleships Scharnhorst and Gneisenau made their getaway through the English Channel while every British radar in operational use searched wildly and saw nothing.

It is no secret now that Germany's clean success in this operation spread alarm among British and U. S. commands. But lots of work, already under way, began to come to a head very fast — lots of research, lots of development, lots of training. The net has been that in the past two years U. S.-British achievements in the jamming art have put us in a position not only to combat enemy jamming but to take the lead in dishing it out.

Against the German radar defenses shown on the preceding pages, two jamming devices in particular have proved effective. One is Window — the foil-and-paper strips which, when dumped from our attacking bombers, fill the Wurzburg scopes with fake echoes (see RADAR, April).

And the other is Carpet — a transmitter which, properly used, blots out the Wurzburg's target indications with jamming energy. Window provides a cover for the followers of the lead planes in a formation but not for the lead planes themselves. Carpet is designed to take care of them or of a whole formation, if need be. For Carpet, Window's teammate, can work on its own.

TOO CLOSE, FIRST PLANE BEGINS TO SHOW (INSET 1). SKILLED OPERATOR MAY THEN BUILD UP PIP BY ADJUSTING GAIN (2)



Carpet is an electronic raspberry

You can put the basic principle of jamming into action by doing precisely as the gentleman to the right is doing — making a noise, Bronx style, for transmission. The British have jammed certain German radars almost that simply. They have put microphones on plane engines and transmitted the roar.

The jamming done by a highly specialized piece of equipment such as Carpet is no more than an electronic raspberry — a powerful, carefully directed and carefully controlled interference, put in a form specifically designed to get a rise out of a Wurzburg. The form that this interference takes is spelled out in terms of sine waves, frequency or amplitude modulated signals, noise modulation, and the like. And the secret of Carpet, or of any electronic jammer, is the precise combination of such forms that it uses.

The merits of any given jamming transmitter — assuming that it is technically capable of doing the requisite jamming — are measured on two main counts:

1) To what degree will its first use take enemy operators off guard?

2) To what degree will its continued use out-reach the enemy's capacity to work out a means of balking it?

On the first count, there is no question that the operational debut of Carpet last October took the Germans by surprise. Ample proof thereof emerged from data compiled by the 8th AF Operational Research Section (see chart on page 15).

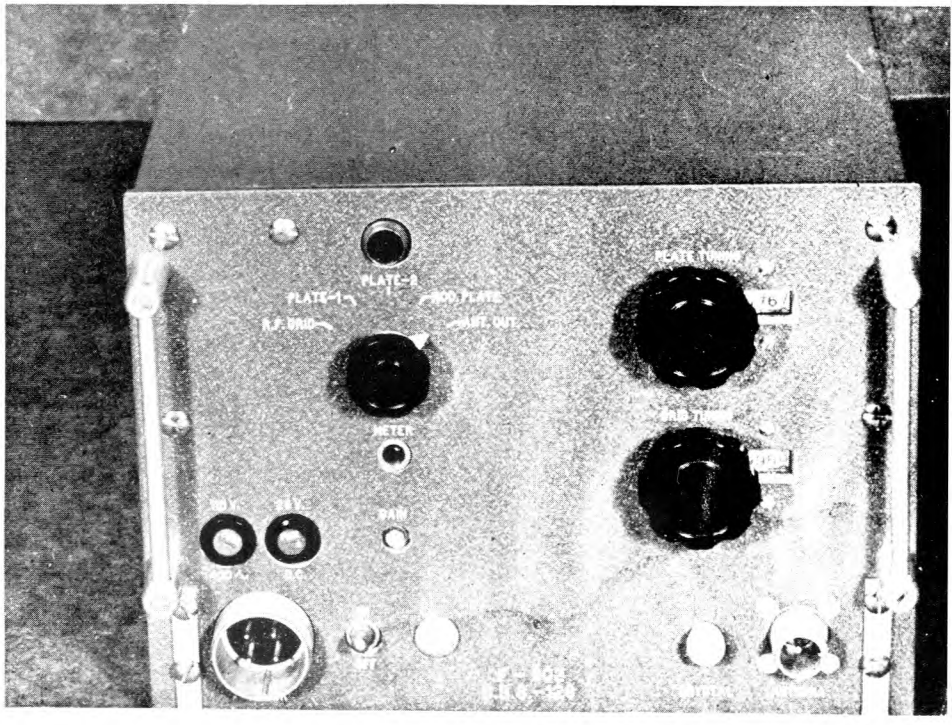
On the second count there is no such clearcut answer. Obviously, once the surprise is over, results from any new piece of equipment can be expected to fall off. And Carpet is not as effective now as it was last fall. On the other hand there is continuing evidence of the kind shown in the chart on page 15 that the Germans are relying less on their radar than they did in pre-Carpet days. (The recent German use of daytime searchlights — presumably as a kind of height-finding method — may be an effort to outwit Carpet.) And from that it is a fair, if not final, conclusion that a counter-countermeasure still eludes the Germans.

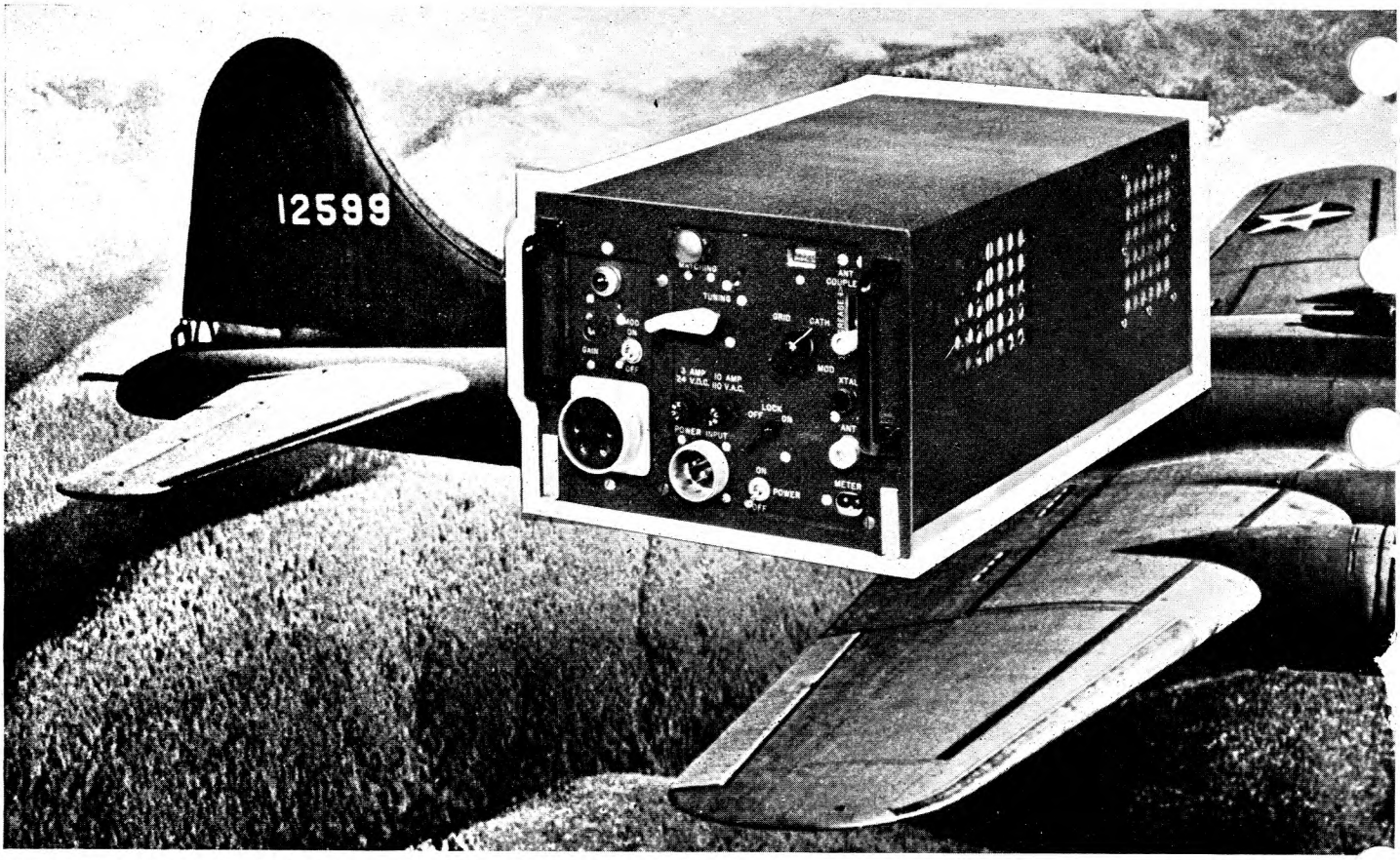
All of which, if true at all, may be true today and not true tomorrow. The only way to keep a countermeasure out in front of the possible counter-countermeasures is to keep improving the countermeasure. Improvements on the Carpet equipment which stood the 8th AF in such good stead last fall have already been worked out along two lines. As fast as production permits, a new and more efficient antenna will supplant the old one in operational use. And Carpet I itself (its official name is AN/APT-2) will give way to a new and more powerful Carpet III (AN/APQ-9).



Human raspberry wouldn't bother a radar but does illustrate basic principle of jamming

Electronic raspberry is provided by Carpet I, whose jamming energy worries the Wurzburg





CARPET III (ABOVE) HAS FOUR TIMES THE POWER OF CARPET I, STILL WEIGHS LESS THAN ANY MEMBER OF A BOMBER CREW.

Carpet jamming is one thing in theory and another in practice

A squadron back from a mission over Germany on one occasion in Carpet's early days griped that the equipment hadn't provided any protection that any of them could notice. Look at the flak damage, they said. It was true enough. Carpet hadn't worked that day, and for a very good reason; it was a bright, clear day and Carpet regrettably can't jam optical fire control. Only night or overcast — in a word, God — can do that.

Carpet's role in the scheme of things is better appreciated now, after some months of use. It is hardly likely that anyone who has had anything to do with it remains unaware that its jamming powers are directed at radar. But its limitations within this framework still need clarification. A fair cast-up of Carpet at work can be stated as follows.

At its best Carpet will so jam a Wurzburg that the Carpet plane's signal will be totally buried right up to within a very few miles of the radar. And a Wurzburg that doesn't show an attacker's signal before then is of little more value for fire control, fighter direction, etc. than a Wurzburg that isn't working at all.

But Carpet is not always at its best. Like any electronic equipment, it has a relatively delicate constitution, subject to upsets and breakdowns. Like any jammer, it often leaves a few gaps through which an expert and conditioned enemy operator can get at least a glimpse of what he wants to see.

On top of all this Carpet is used in different ways, as determined by tactical considerations and by such homely factors as a plane's load and space capacity, and these ways are not equally effective. A jammer, in short, is one thing in theory and another in practice, one thing under ideal conditions and another when the conditions change.

Thus it would require five Carpets in a bomber to insure complete protection from the most common Wurzburg frequency ranges.* Space and weight considerations discount this ideal five to a practical three. But Carpet's availability in a given theatre, or the maintenance status of the available sets, might well not permit even one Carpet per bomber needing protection. The effectiveness with which Carpet shields more than the plane carrying it is a moot point. The simple truth is that no one seems to know for sure and the simple fact is that Carpet is often called on to do the job.

Carpet can be used for either spot or barrage jamming — that is, its jamming spread (about seven megacycles) can be centered exactly on the frequency of a given Wurzburg or the jamming of several Carpets can be overlapped through a broad band covering, with less precision, all frequencies within that band. For spot jamming a skilled operator must go along to keep the Carpet sharply tuned. And a receiver must be carried to keep check on the frequency of the radar to be jammed.

These requirements for spot jamming are usually enough to make it impracticable. Moreover, spot jamming is not so good where tight formations fly over numerous enemy radars spread through a wide frequency range, as in Europe.

Over Germany, consequently, Carpet has been used mainly for barrage work.

For example, Carpets in a formation may be so set that the Carpet in plane A will jam Wurzburgs in the 535–542 megacycle range, the Carpet in plane B will jam

** It is estimated that the great bulk of Wurzburgs operate in the 550–565 megacycle range. Expansion of the Wurzburg's frequency range since Carpet's introduction, however, has produced frequencies as low as 525, as high as 595.*



IT IS JUST GOING INTO OPERATION NOW

in the 538–545 range, the Carpet in plane C will jam the 541–548 range, and so on.

Before the formation takes off, skilled technical personnel must pre-tune the Carpets. Tests have shown that Carpet is susceptible to some frequency change after take-off, and such a change — on top of a tuning error — could throw the jamming all off. Once in the air, Carpet requires no attention. Any of the personnel in the plane can turn it on at the proper time by flipping a switch on a remote control box.

That there is a proper time to turn Carpet on is clear from the fact that Carpet's jamming is much stronger than a plane's echo at all outlying ranges. If the jammer goes on before the radar could get an echo from the plane, the enemy is simply given an extra early warning. He can't figure range nor size of the formation but he can get the bearing.

The circumstance can be used, of course, to trick the enemy. Carpets in diversionary planes can be turned on ahead of time to distract him while aircraft actually doing the raiding come in to the target from a different bearing.

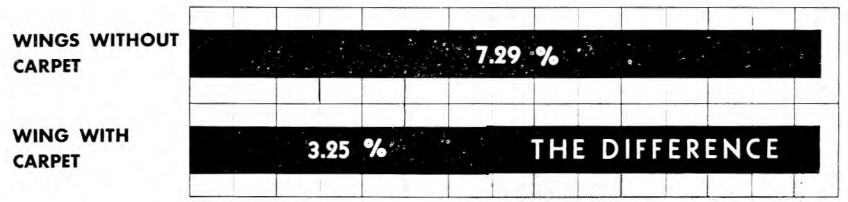
What Carpet's future may be is pretty unpredictable. Countermeasures are notoriously short-lived as a rule, but Carpet is a cagey item and may be doing business for quite a while.

FIRST TEN MISSIONS PROVED CARPET'S WORTH

Only 70 pieces of equipment were available to 8th AF Bomber Command for Carpet's operational start. Equipped with these, one Combat Wing flew 10 missions during two recent months along with other non-equipped Wings

AIRCRAFT LOSSES* FOR THESE MISSIONS WERE

*In % of total sorties and not counting losses from accidents



CARPET HELPED TO SAVE



210 MEN AND 21 PLANES

Based on data compiled by 8th AF Operational Research Section

GERMANS DIDN'T LIKE CARPET HERE ARE 3 REACTIONS



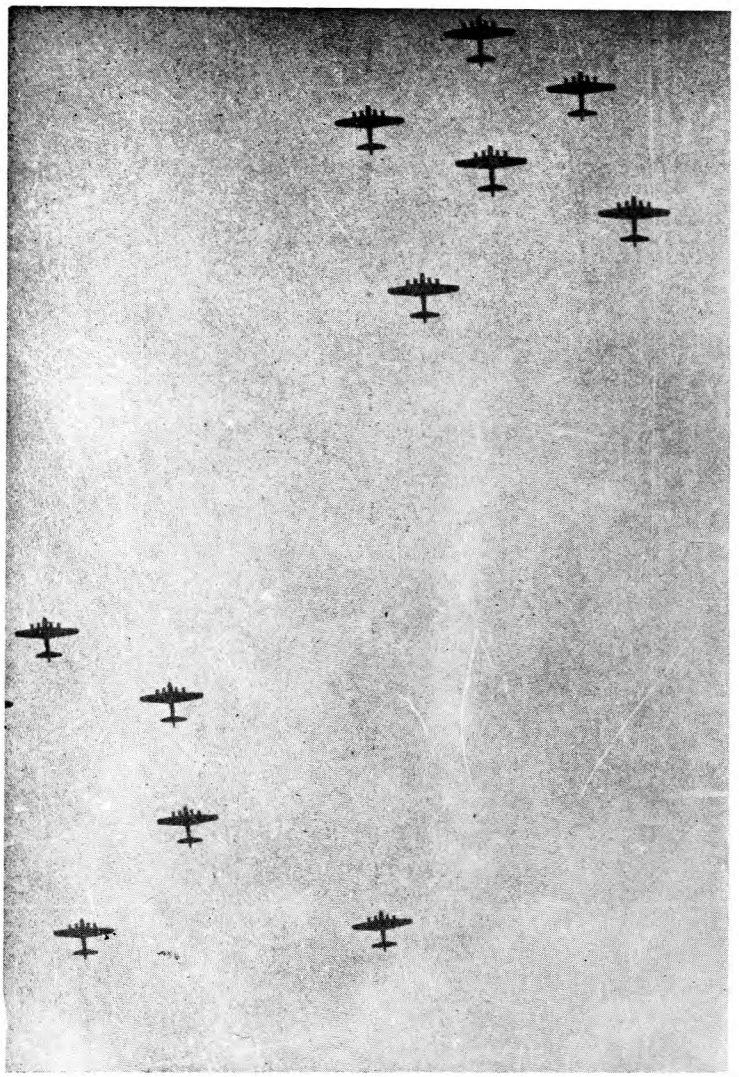
Barrage AA fire has been reported taking the place of fire controlled by radar



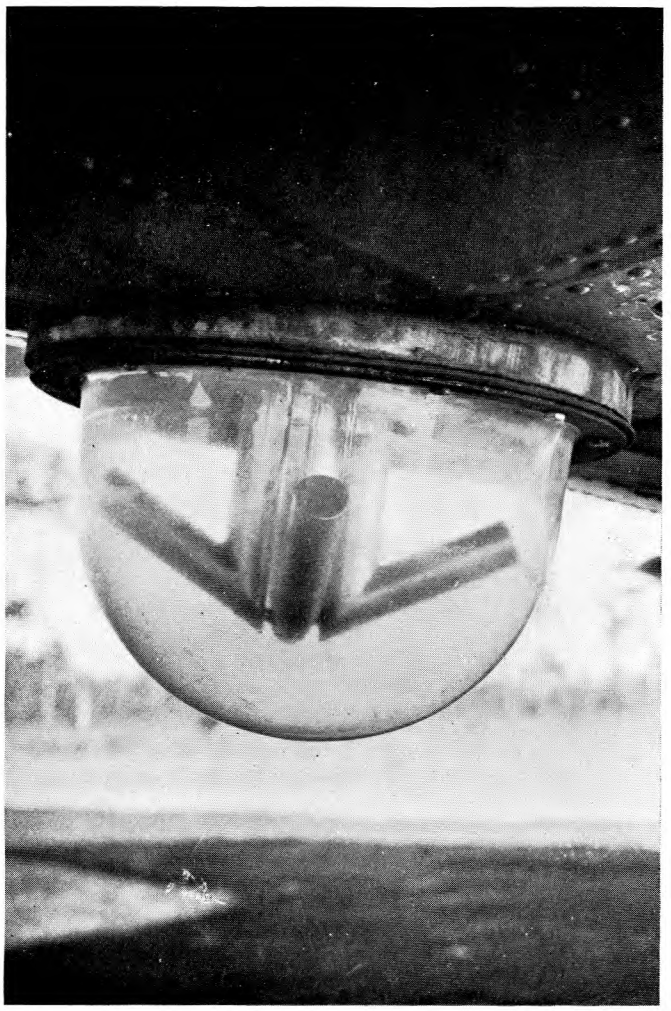
Observor planes have given height data unobtainable with the jammed Wurzburgs



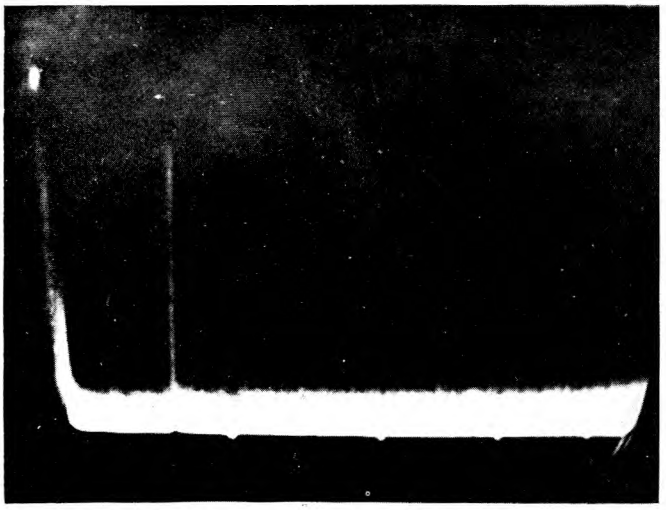
Wurzburg frequency spread has been expanded in effort to make it outreach Carpet



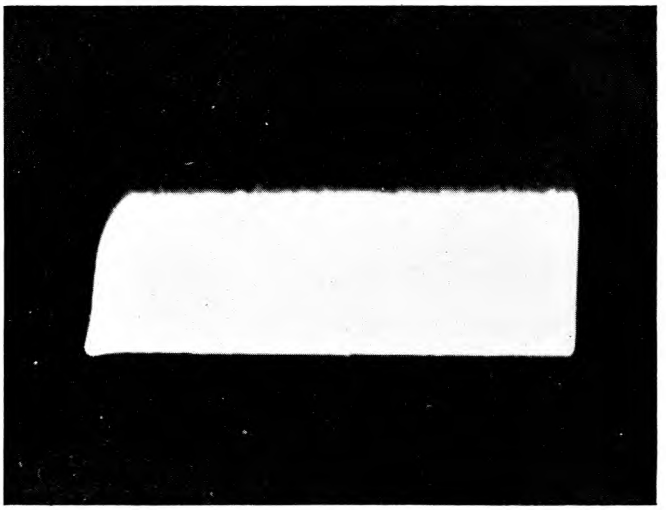
Carpet's first job is to protect bombers in lead combat boxes of formations. In this way it supplements protection given by Window, dispensed from lead bombers for following planes. But Carpet, unlike Window, can be used in proper quantity to cover whole formations.



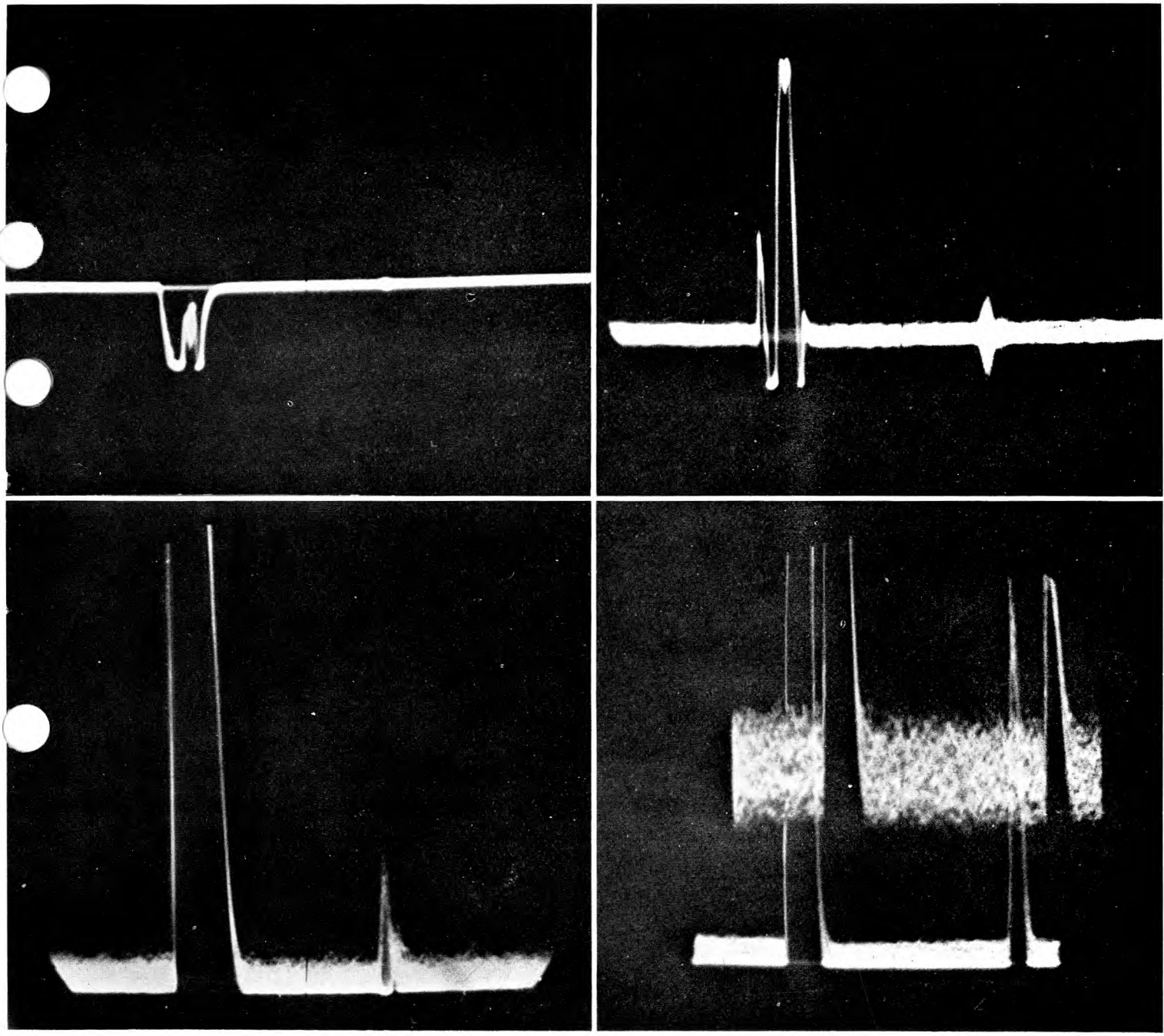
New antenna, designated M-2201, complements Carpet III's greater power by eliminating downward radiation null of old antenna AN-132A. No less usable with Carpet I, it can be assembled in simplified form by Maintenance Units pending delivery of production models



Simulated Wurzburg, a modified SCR-648, was used in tests of Carpet I conducted at Orlando, Fla., by Army Air Forces Board. The scope before Carpet's jamming energy was turned on looked like this.



During jamming the scope looked like this. Precise effect of jamming on Wurzburg is speculative but intelligence after one early Carpet mission reported that "Jamming saturated the trace at all ranges."



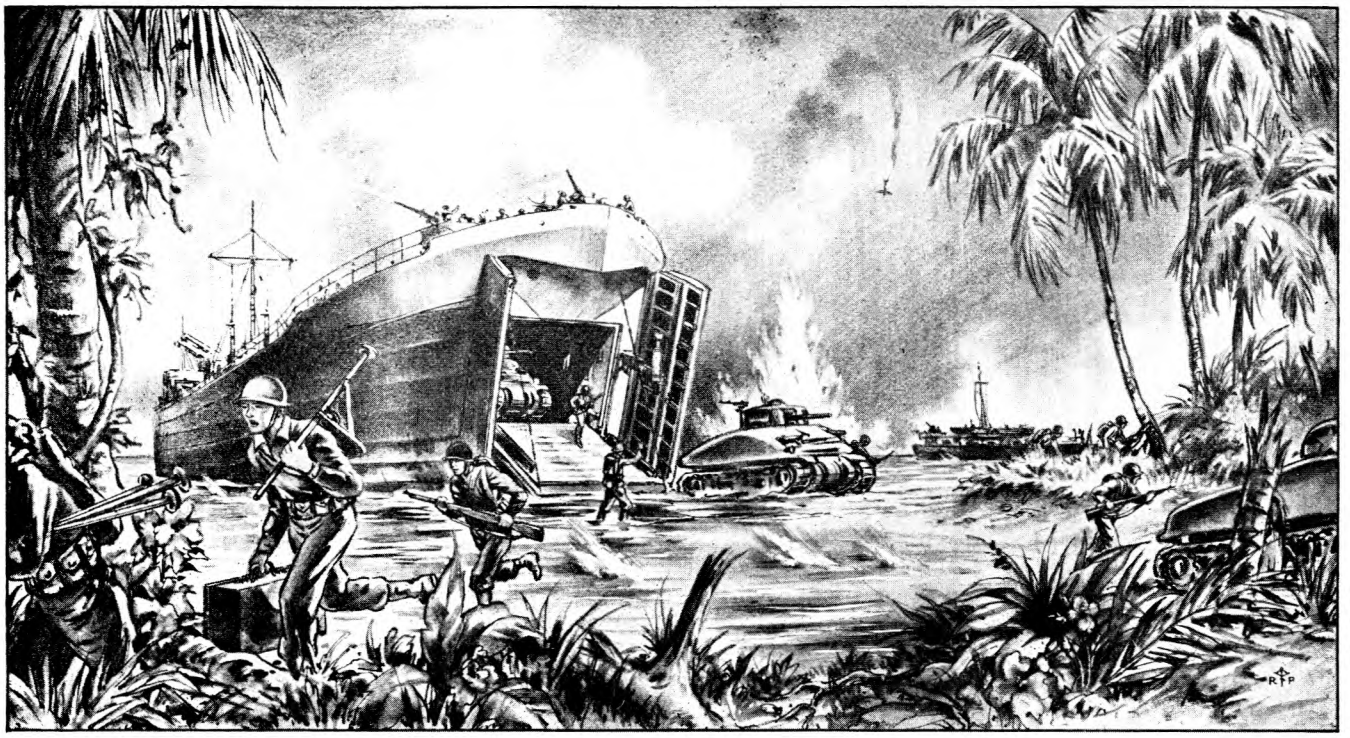
ANTI-JAMMING IS AN ART

Germany, as early in the jamming business as the Allies, is, of course, still in it. Both the Germans and the Allies are therefore in the anti-jamming business, only this isn't a business, it's an art. It's an art which we were not prepared to practice when the Germans moved the Scharnhorst up the Channel, jamming British radars as they went. It's an art in which, since then, much work has been done to keep the Germans from doing to our radars what we are doing to theirs with Window and Carpet and other jamming devices. It's an art, finally, in which the skill and determination of the radar operator are decisive.

The photographs above illustrate some jamming and anti-jamming effects on the scope of a common U.S. radar, SCR-268. *At top left*, the signal is barely visible (right of center on time base) under very strong CW (Continuous Wave) jamming. *At top right*, same jamming but gain is turned back to best setting; signal shows. *Lower left*, same jamming but receiver retuned and gain on full. *Lower right*, effect when jammer and target are not on same bearing.

These photographs are a laboratory reenactment of just one simple type of jamming out of many and a couple of equally simple things to do about it out of many, the whole with reference to just one type of radar out of many. Too limited to mean anything in themselves, the photographs nonetheless make the most important point of all: more than any other department of radar operation, anti-jamming requires that the operator be on his toes. For he has to achieve something approaching normal by the delicate process of playing off one abnormal effect against another. To succeed takes plenty of know-how.

In an early issue RADAR will look into anti-jamming techniques more fully.



1 The Gloucester Airdrome area in New Britain had been bombed and shelled for two weeks before the landing; first Marines off the LST's swarmed across the narrow beach, meeting little resistance. The first wave was followed by tanks, field artillery, radio and radar equipment. Meantime, at second beachhead 15 miles away, more troops landed, including a Radar platoon with four SCR-602 early warning sets. The platoon and other radar teams were all part of Drew Field-trained unit, which took part under the command of Capt. Eugene J. O'Neill.

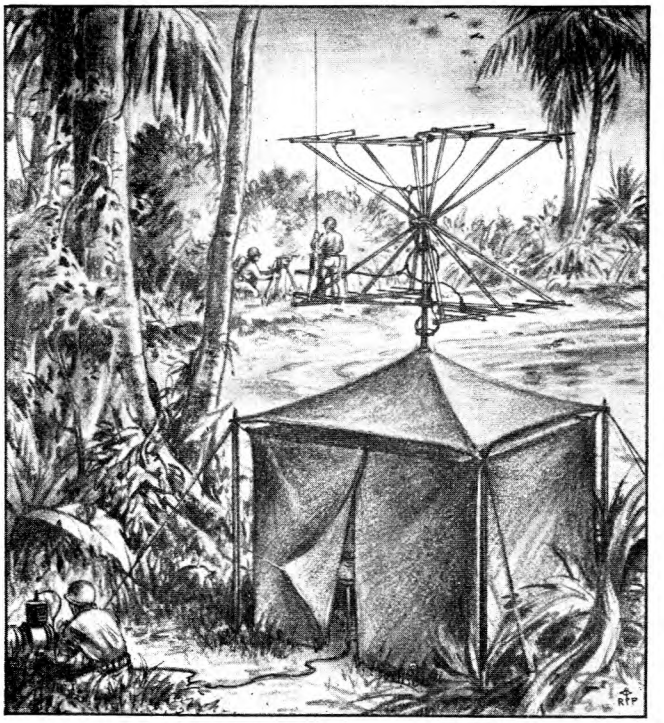
LANDING AT GLOUCESTER

Drew Field's Aircraft Warning training pays out in seizure of Jap airdrome

THE long-range aircraft warning radar set SCR-270 requires approximately 50 men to operate it, of whom at least 15 need special radar training. Medium-range SCR-268, used also for searchlight control and gun-laying, requires 12 scope operators alone for a 24-hour watch, in addition to other personnel. It takes six weeks to train maintenance men, four weeks to train operators for the equipment. The portable early-warning set SCR-602 needs a crew of 14 for 24-hour operation during assault, and they have to be relieved after two or three weeks.

All of this adds up to a lot of manpower, a lot of hours and a lot of effort. In a variety of centers the necessary effort is being made. One of the most active of the establishments is the Aircraft Warning Unit Training Center, which does its work at Drew Field, Florida.

On this and the following page RADAR tells in words and pictures how some of Drew Field's training paid out in actual combat. This is the story of the Allied landing at Gloucester Airdrome in New Britain and the part that was taken in it — nothing special and all in a day's work — by an Aircraft Warning unit that was put together and received its training at the Drew Field center.



2 Four men can operate SCR-602, specially adapted to use on beachheads; it is portable, easily set up. Range is not as great as SCR-270's, but it provides limited warning until heavier equipment can be installed. At Gloucester it picked up enemy flights the 270's had lost.



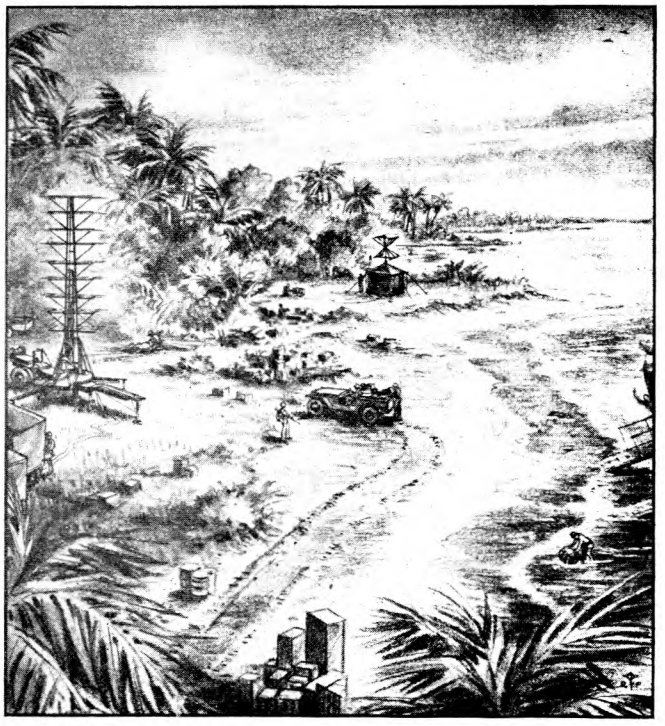
3 A mountain separated the two beachheads from each other but communication was established by a Ground Observer team's radio set. Later, an Information Center was established to coördinate reports from observers and radar, transmit data to fighters and AA units.



4 The job of setting up the radar equipment and getting it in operation was finished just in time to catch Jap raid. Radar's early warning gave fighters a chance to get into action. Result: 31 out of 61 Jap planes shot down, the rest driven off. One unloaded LST was sunk.



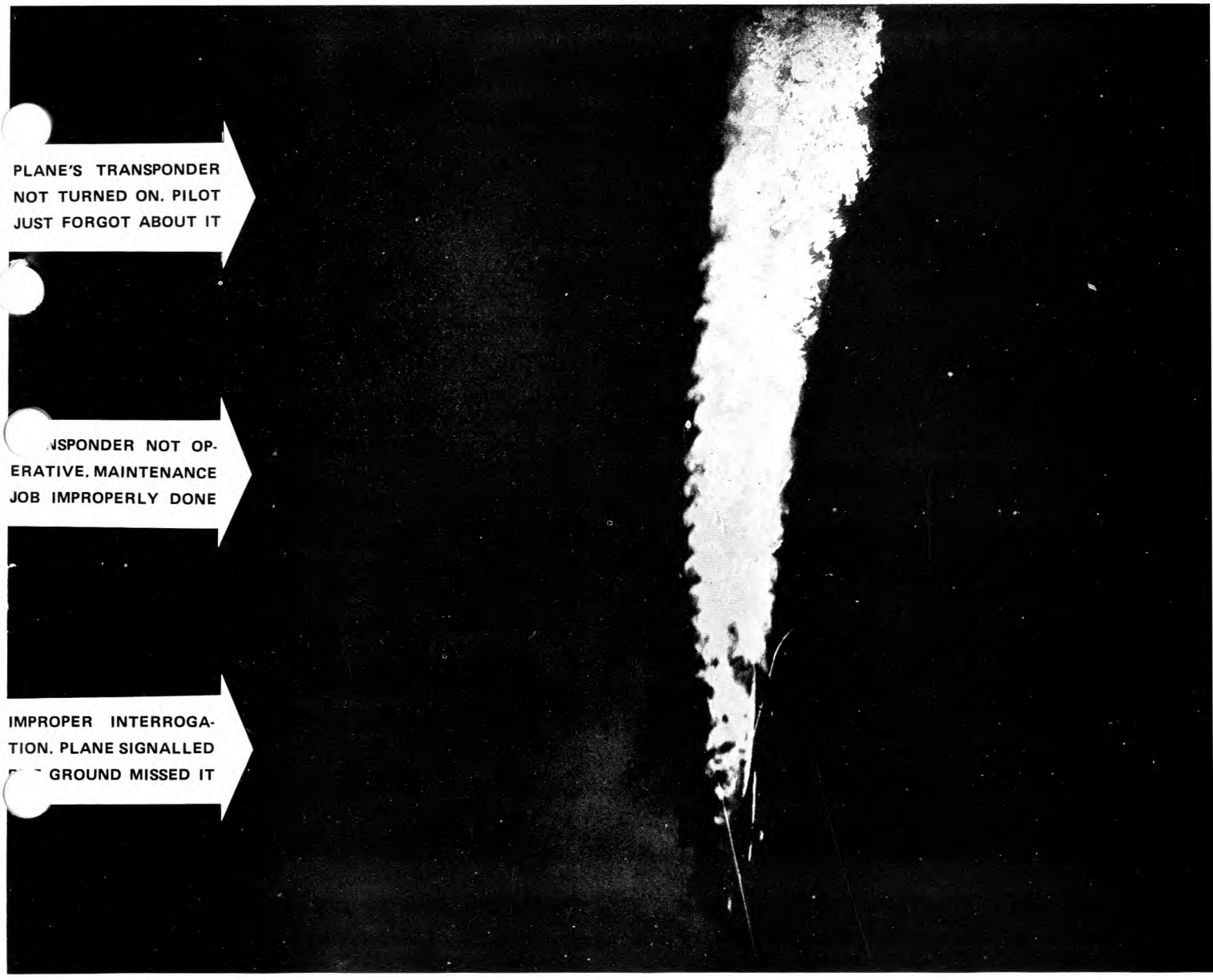
5 Long range and early warning radar kept up a round-the-clock search for enemy aircraft, while Marines made progress on beachheads. After attempt to dislodge the Japs from a strategic dugout had failed, the Marines sent over a bulldozer—wiping out dugout and Japs.



6 A week after initial landing, nine Army and Marine radar units were operating for aircraft warning, searchlight and gun-directing Mountains made radar siting difficult, caused interfering echoes on scopes; despite this handicap not a single enemy raid got through.

A plane downed by AA guns from its own side is one of the saddest wastes of war. In the arrows: three avoidable causes.





IFF: IT'S NOT DOING ITS JOB

. . . and training, rather than equipment or the system, seems to be at fault

You can take either of two points of view about the way IFF (Identification of Friend or Foe) equipment is being used in the combat zones. You can argue that equipment of this type necessarily presents difficulties and can't be expected to operate at 100% efficiency. Or you can argue that it can be expected to operate a lot better than it is and something ought to be done to improve the situation. There isn't any argument about the main premise: which is that in too many areas IFF isn't doing the job it was set up to do.

It is a known fact that mis-use and non-use of IFF in circumstances where it should have been in full operation have led to losses of our own men and planes. It is a known fact that wholly unnecessary expenditures of manpower and equipment have followed false alerts or failures to alert which proper use of IFF could have prevented. It is a known fact that IFF is good for an argument any day in many theatres, that there has been much grousing and griping about it, that plenty of operators who know how to use it don't and plenty who don't do.

For a system whose sole point is to save friends and trap foes, IFF's erratic use is very funny indeed. But the picture above isn't funny. Nor is it funny for misunderstanding of the workings of IFF to get in the way of the workings of entire radar interception systems, of which the IFF system is or should be a natural and integral part.

It isn't funny, nor is it necessary. For if IFF is not a perfect solution to the identification problem — and nobody ever said it was — it still can do a job that nothing else yet devised can do. What's more, unless every effort is made on the part of all concerned to help it do this job, Allied radar operations have got one strike on them before they get started.

There are some plausible reasons for the troubles IFF has had. There are far better reasons for getting past the troubles and putting IFF to work. Look again at the picture above, and look at the newspaper clippings reproduced on page 23.

IFF Can Answer the $64 Question — If It Gets a Chance to Do It

At nighttime in a combat zone, with unidentified planes in the radar beam and AA guns on target, comes the $64 question: to fire or not to fire? On the answer may hinge the success of a crucial defense, the outcome of a long-planned mission, the lives of those involved.

There are other questions that hang over combat zones when visibility is low: just how valuable is a system that detects planes and ships before they can be seen if it can't tell friend from enemy? Of what real use is equipment that directs guns in the dark if the guns are going to fire on friendly planes?

IFF is one answer to the $64 question, one means of resolving the gunner's doubts. It is not the only one, and there are limitations to it. But it is the only one whose capacities at identifying can match radar's capacities at detecting, and it has less inherent limitations than any other answer. It is, finally, a relatively simple device, as such devices go.

If IFF has the greatest capacities and the least limitations, why its spotty record of use, why the griping about it, why its failures?

There are at least five general explanations of this:

1. The fact that there are other methods of identification — plain radio communications, flight scheduling, etc., — means a divided reliance on any one, even the best one, which is IFF.

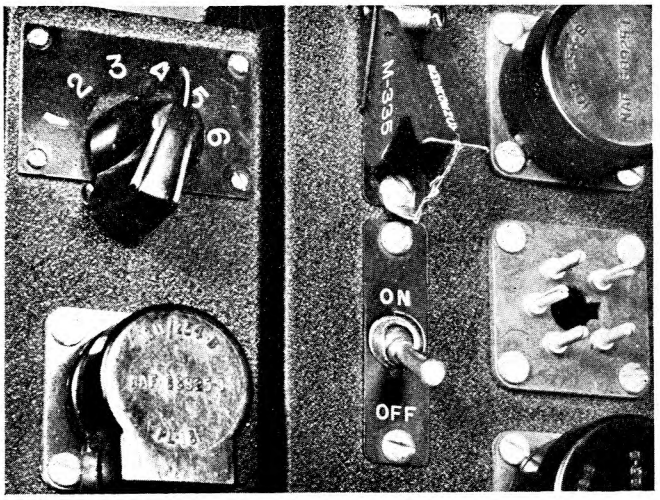
2. It's an all or nothing proposition. One squadron operating with faulty IFF can disrupt the IFF program for a whole theatre. Gun crews have to *know* that planes which are not identified are hostile planes; doubt or debate ends IFF's effectiveness.

3. It requires a fair amount of maintenance and checking, particularly for the component in the plane, and so it's a bother.

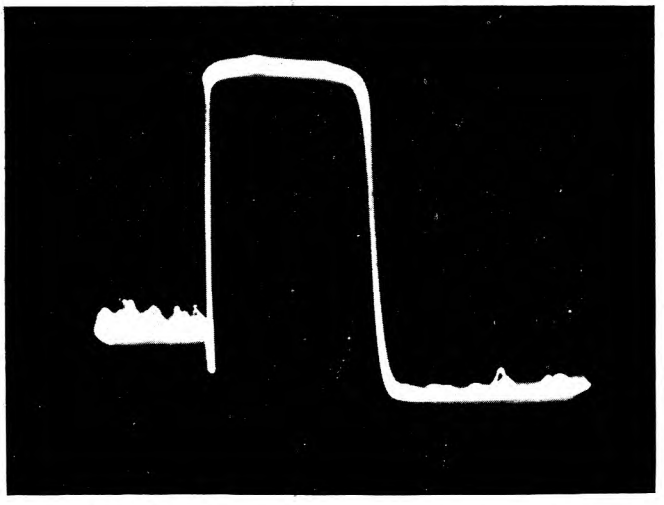
4. Since it's largely automatic so far as a pilot is concerned, and since it simply avoids something that might or might not happen, it makes no initial appeal to either consciousness or interest.

5. Gunners have a natural hesitance to fire on what might be one of their own planes, even when there's no signal. So when a pilot ignores his IFF often nothing happens — except that the pilot may very well be hostile and raise hell with the gunners' base without drawing a shot from the gunners.

The worst thing about these barriers to



Accidental bumping of emergency switch can cause general confusion. Guard wire, breakable by hand, should be put on as shown.



Emergency signal is not the same with all equipment but in general shows as a broad pip like this. Identification signal is narrower.

IFF: How & What

IFF positively identifies only friends. Foes are inferred from the absence of signal.

That's why consistent use of IFF in combat zones is imperative. To radar operators on the ground a friendly plane is one that returns an IFF challenge; a plane that doesn't must — if IFF's purpose is to be realized — be considered hostile.

In principle, IFF is a miniature radar beacon device. Its components are three: (1) an *interrogator* or transmitter at the ground radar station which sends out pulses to challenge the (2) *transpondor* or transmitter-receiver in the plane, which receives the challenge (i.e., is triggered) and returns an answer to (3) a *responsor* or receiver on the ground. Interrogator and responsor, used together, are known as an IR unit.

In the Mark II system, the ground radar itself served as interrogator. As types of radar systems increased, as Army, Navy and British radars began to be used in the same theater, conflicts in frequencies necessitated a revised IFF system. The one now in use is the Mark III system. It employs a universal frequency band which permits identification of all Allied planes and ships.

At some stations a special operator mans the IFF interrogator, challenging targets according to established operating procedures. At others, the radar operator himself works the interrogator. In the plane, the pilot has no scope or dials to watch. He does his part simply by switching on the transpondor at the proper time. But if he forgets to do this, the whole system breaks down.

The standard IFF airborne component is the SCR-695, essentially a little box with an on-off switch, a code switch and an emergency switch (see cut). When the set is turned on it will respond to any IFF interrogator in whatever code the code switch has been turned to. This response—the "I" band of the 695—is supplemented in fighter planes with a "G" band, the effect of which is to bulge out the fighter's signal on a GCI radar scope so that ground operators can vector the pilot.

In a special category of its own is the SCR-729 radar, which puts the IR functions usually associated with ground radar into a plane. Thus a night fighter, for example, is enabled to interrogate a target plane. The 729 functions just as well in the role of beacon interrogator and as such is much used as a navigational aid.

effective IFF operation is that they're cumulative. Thus the pilot who ignores IFF finds his inaction compounded in the gunner's failure to fire and the gunner's inaction tends to make the pilot even less likely to use his IFF next time. At the root of this spiraling is a basic fact about the whole IFF system which sets it off sharply from a radar system.

With radar, the failure of a piece of equipment or of an operator's functioning is reflected at once in the loss of the target. Immediate corrective action can be taken. With IFF, lack of response may result from a variety of malfunctions — either on the ground or in the air — and hence necessary corrective steps can't so readily be figured out. On top of this, the ground station has no control over airborne equipment. And on top of that it is as true here as anywhere that, where two factors are involved, each tends to blame the other and both grow more lax.

What emerges from this is a steady increase in unidentified flights and a steady decline in checking the causes thereof. And as checking relaxes some of the airborne personnel will assume that this means everything is OK, and some of the ground personnel will assume that a high per cent of failures is to be expected, and some of both will assume that IFF is a lot of nonsense.

There is nothing anywhere along this line which an emphatic program to make IFF work — both at home and in the field — couldn't fix in short order. Chiefly lacking to date has been an adequate emphasis on the over-all aspects of IFF; there is plenty of evidence that too many operators think of IFF in terms of one or another box with a couple of switches on it, too few think of it as a system. It is, in fact, a highly integrated system, as the pictorial presentation of an IFF system on the next page shows.



BAD PRESS recently on identification breakdowns has put heat on drive to improve IFF.

IFF: Pro & Con

A regular literature is growing up around IFF and by and large it doesn't read well. The clips above are a part of it. Operations reports are a big part; typical ones go like this:

> Failure of airborne IFF confused the radar picture badly. The Big Headache right now is the non-use of IFF in friendly planes. All day and night reports of planes come in, but failure to show IFF creates a war of nerves.
>
> A plane was sighted apparently making a bombing run . . . observation was difficult and no IFF could be obtained. When the plane was nearly overhead firing started. After several rounds the plane was identified as a B-24.
>
> About 50% of fighter effort is wasted on raids that turn out friendly.

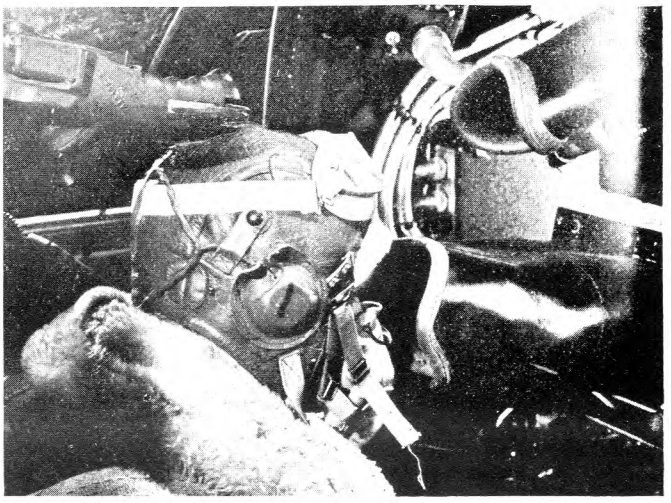
There are plenty of similar reports and along with the reports a kind of rumor wave has spread. You are apt to hear that Mark III IFF is shortly to be supplanted with an improved version. And that the new one will practically run itself. Conclusion: why bother with Mark III, long live the new Mark.

The facts are that there isn't going to be any new Mark in use for a long time. In any case, vastly more important than the equipment, old or new, is the IFF system. If the system is made to work, Mark III will work. It worked in the operations covered by these excerpts:

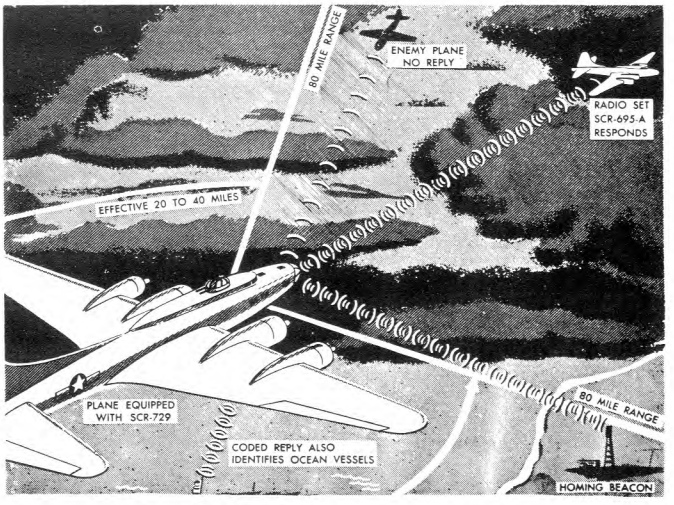
> The IFF was a godsend. With literally hundreds of planes milling about, radar was able to single out enemy groups.
>
> Aircraft kept IFF on at all times. It is believed that this contributed greatly to the few unidentified planes.
>
> When IFF is used it is excellent.

The last one tells the story.

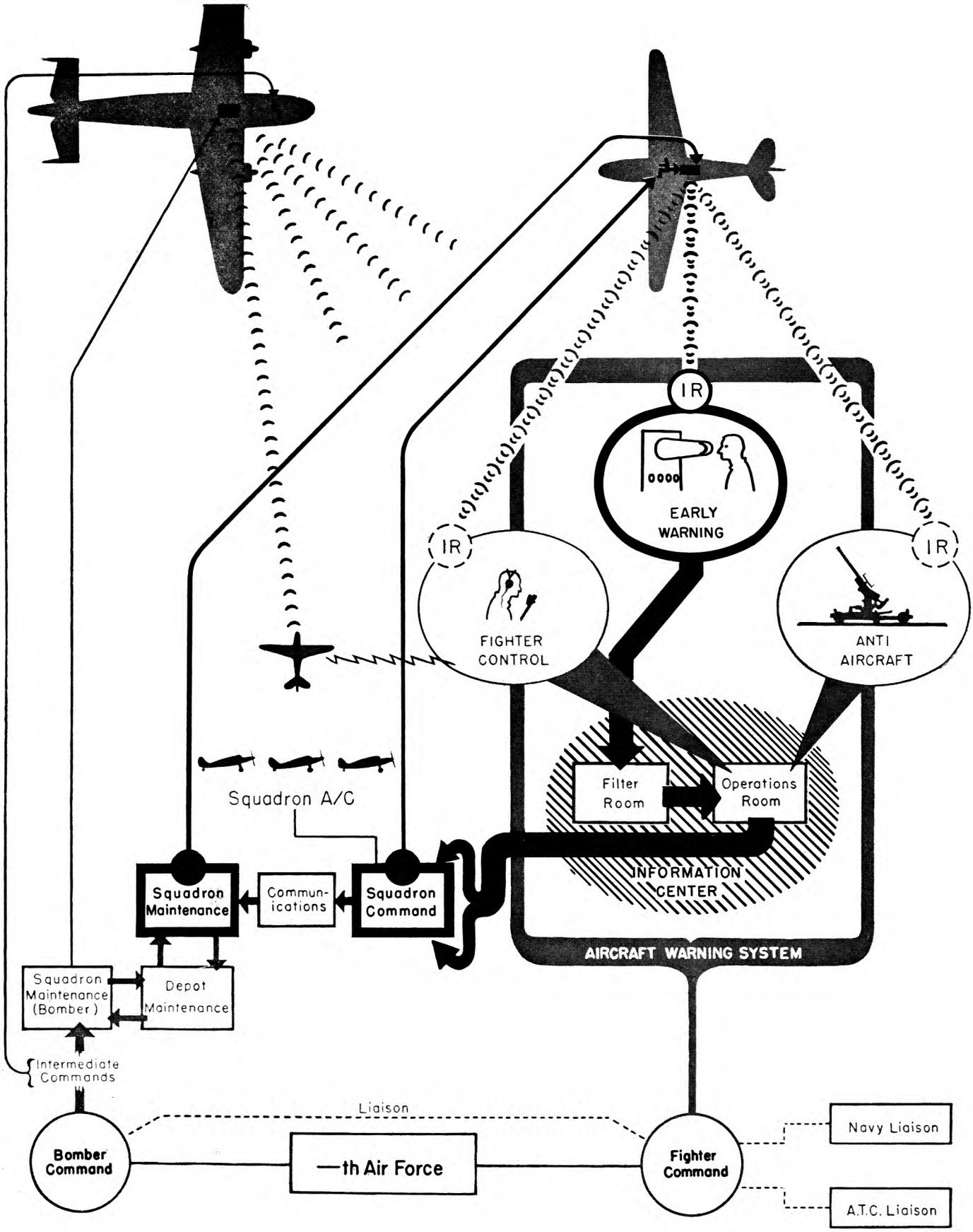
Inherently, Mark III does have two faults: enemy planes can sometimes get bearings on ours by triggering our IFF, and enemy raiders sometimes succeed in faking an IFF response. Proper training and use of the system can overcome both faults. There is a time for a plane's transpondor to be on or off, and every theatre has its regulations. As for the faking, it takes a very classy job to get by a really well trained operator; there are almost invariably differences. Some transpondors have been captured, but not enough to cloud the picture seriously. The picture won't get clouded if every IFF that falls anywhere within reach of the enemy is destructed per instructions.



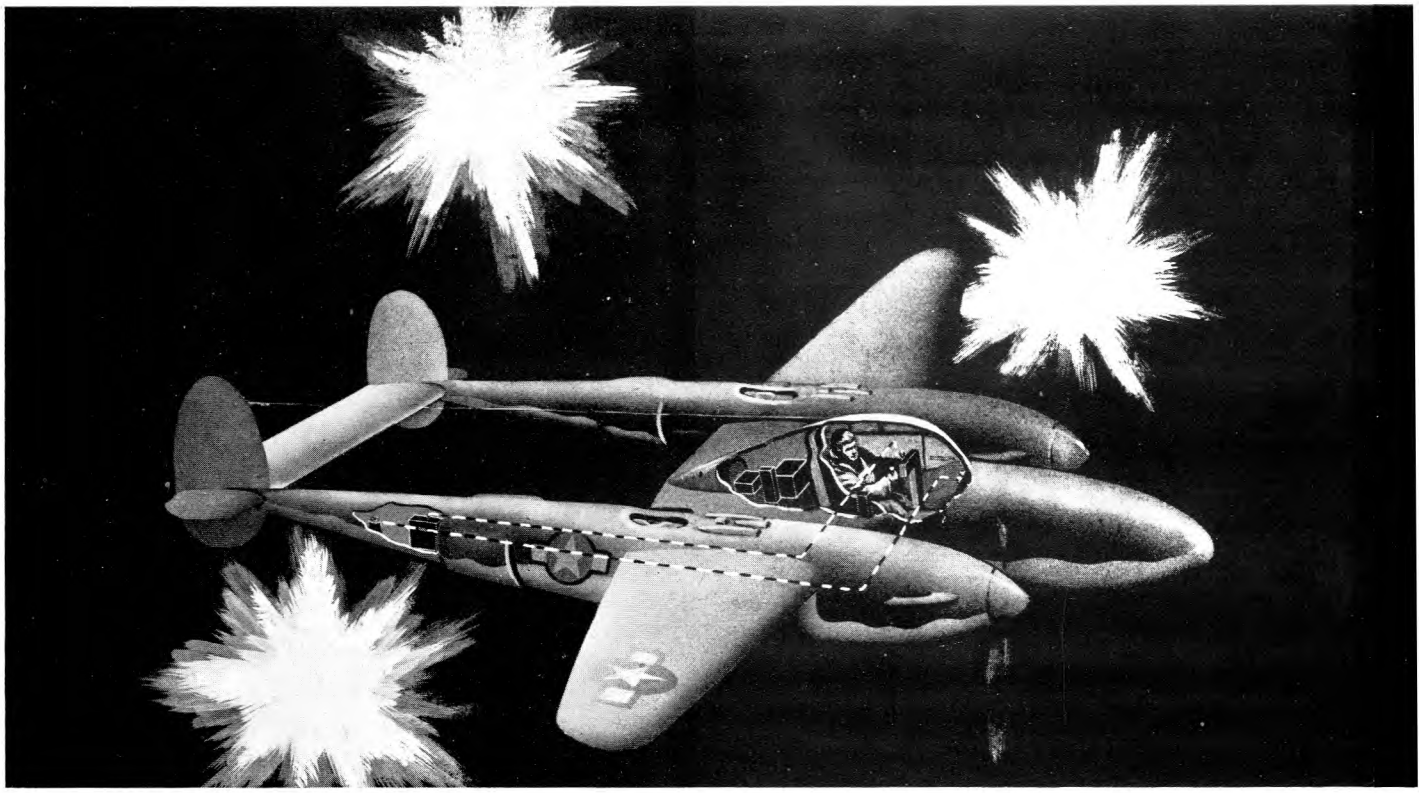
In cramped quarters of this night fighter 729's viewing hood projects out above regular AI's. Range of 729 is about 50 miles.



Varied uses of SCR-729 are shown in this training drawing. Beacon interrogation (i.e., navigation) is most staple function.



The ingredients of an IFF System make a pattern like this



IFF transpondor (SCR-695) fits into P-38 like this. Outer line connects switch box (front) and inertia switch for detonator; inner line connects control unit (front) and receiver, below which is antenna. Flak comes from U.S. guns; pilot forgot to flip switch to let equipment work.

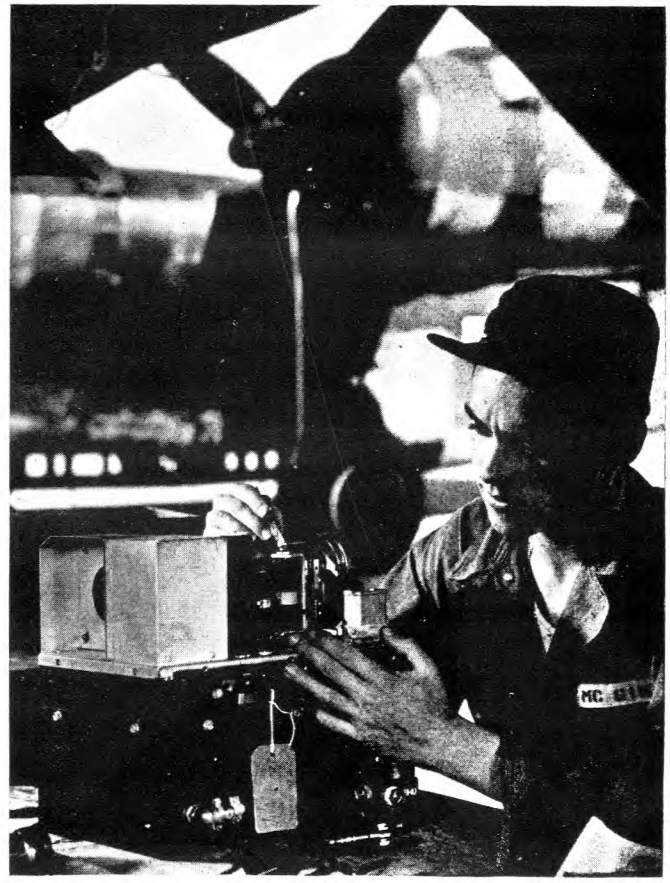
← How to read the diagram

The diagram to the left is an attempt to get down on paper the ingredients of a more or less representative IFF system. IFF systems aren't necessarily set up the same way from one theatre to another, but the big point is that they are set up; essentially, they will not differ much from the pattern of the diagram.

The way to read the diagram is to start with the two black dots. Fighter Squadron Command's emphasis on IFF as transmitted to its pilots determines whether they will operate their transpondors intelligently. The work of Fighter Squadron Maintenance determines whether the equipment will work at all. From the transpondor (black box in the plane) the main flow is through the early warning radar's IR unit on to the Filter Room, thence to Operations. From here, if action is indicated, alerts go up the funnels to Anti-Aircraft and to Fighter Control, out along the red line to Squadron Command. (Anti-Aircraft and Fighter Control may or may not have IR units; if they do, results of their interrogations are sent down the funnels direct to Operations.) The other prong on the arrow from Operations to Squadron Command is one of the most important paths in the whole flow; over this route should go all reports of malfunctioning, orders to check, etc.

The fighter plane at the top is showing its IFF signal but the bomber is not. So a night fighter is going up for an intercept, interrogating the bomber through its airborne IR unit (SCR-729), maintaining contact with Fighter Control via radio. As the gray lines at far left show, the bomber belongs to the Air Force's Bomber Command. Its failure to identify itself is traceable down those same gray lines; either the pilot or the equipment was not properly prepared. The consequence will be all the waste of a needless alert and intercept, to say nothing of what may happen to the bomber.

If the Aircraft Warning System is on its toes it will undertake to see that hell is raised about this waste, and if Fighter Command is on its toes, it will use its direct liaison to Bomber Command to do the hell-raising. In the end it should be the Air Force Headquarters which brings everyone and everything to book; IFF starts working, or breaking down, right there.



Proper maintenance and regular attention are prerequisites if IFF is not to break down before it gets started. This happy scene showing a 695 getting the works is from new IFF film (see next page).

IFF in the movies

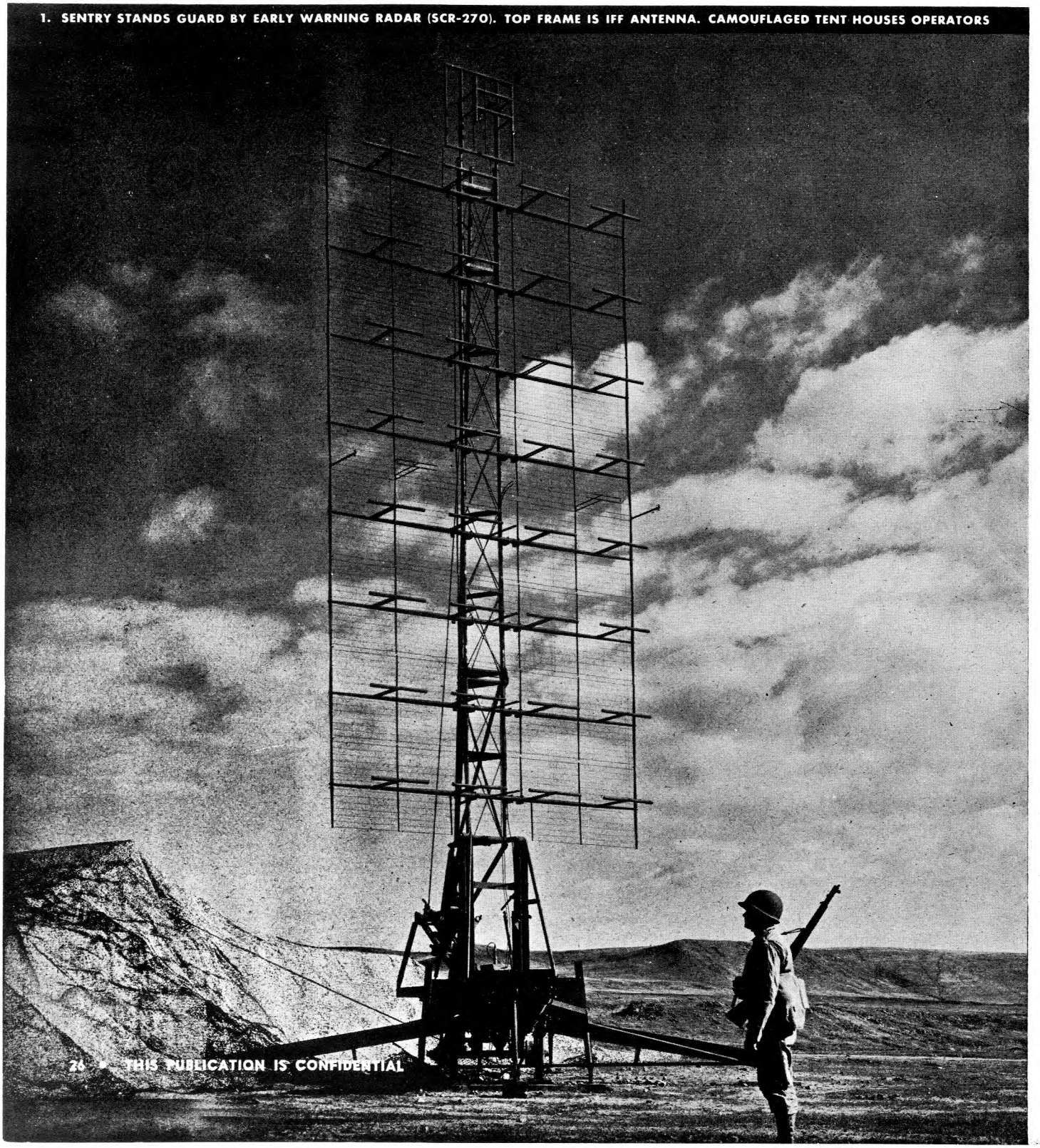
Two main points emerge from the report on IFF on the preceding pages:

1) More concentrated training in its uses is needed.
2) Effective training must emphasize IFF as a system.

Well aware of both points, the Army and Navy alike have been giving growing attention to the IFF problem.

One solid contribution to the cause of better IFF will be made about the time this issue of RADAR gets out: a joint Army-Navy film on the Mark III IFF System. Produced by the 1st Motion Picture Unit of the AAF (as Project 1700), the film is earmarked for confidential distribution to all personnel of all the armed forces who have anything to do with IFF operations.

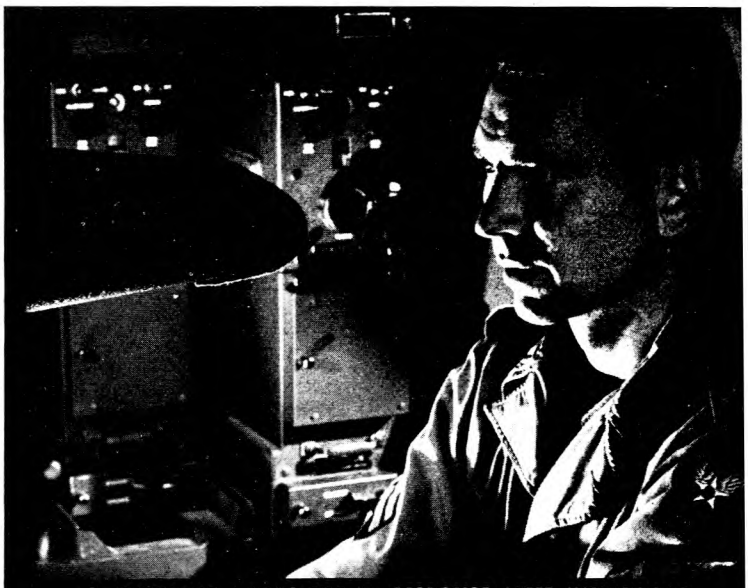
The photographs on these two pages are advance stills from the film, excised from one part of one sequence. The whole job covers all possible applications of IFF (it will run about 40 minutes) and does it with considerably more oomph than these stills — no duller than most movie stills — might indicate.



1. SENTRY STANDS GUARD BY EARLY WARNING RADAR (SCR-270). TOP FRAME IS IFF ANTENNA. CAMOUFLAGED TENT HOUSES OPERATORS



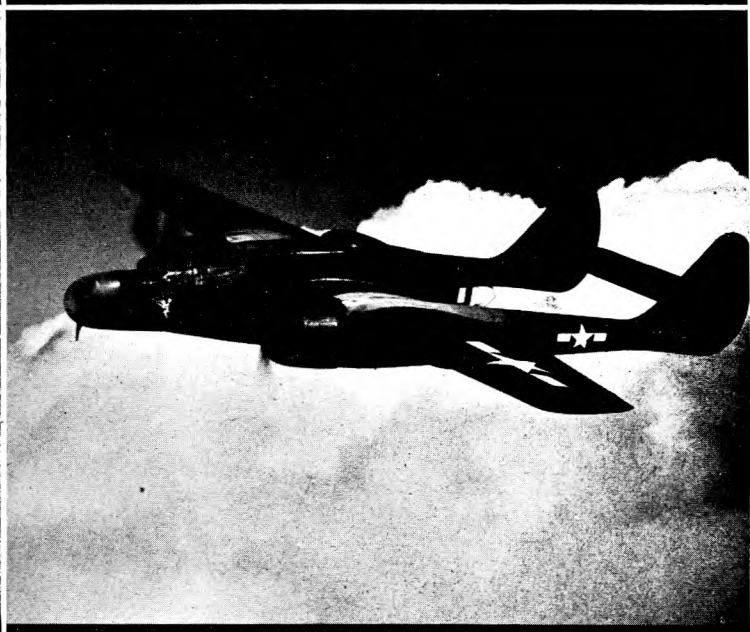
2. PLOTTER (LEFT) MARKS COURSE OF TARGET ON BOARD AS RADAR OPERATOR (CENTER) CATCHES AND TRACKS SIGNAL



3. OPERATOR LOOKS FOR IFF RESPONSE AFTER INTERROGATING TARGET VIA INTERROGATOR-RESPONSOR (BACKGROUND)



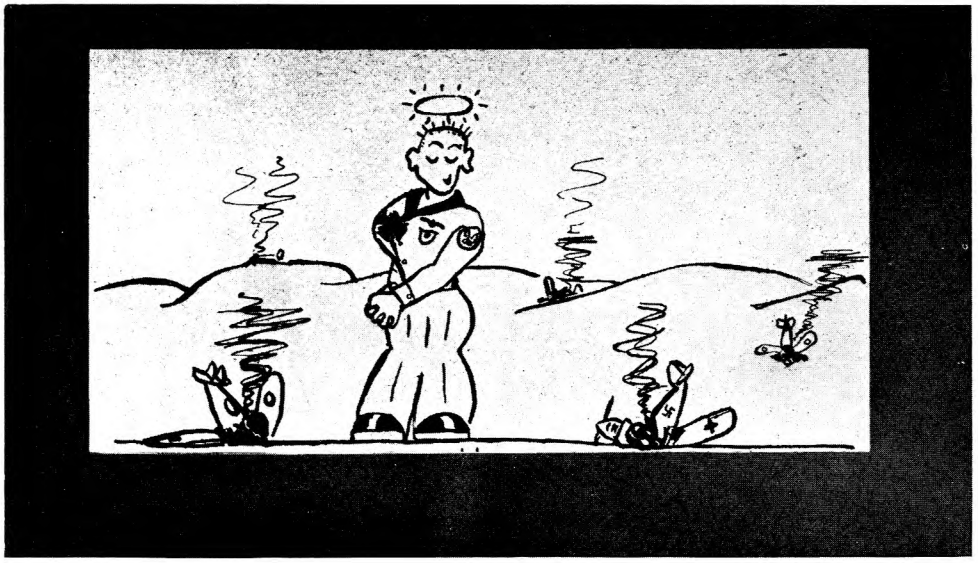
4. IN THE MOVIE NO IFF SIGNAL IS RECEIVED SO FIGHTER CONTROL CENTER IS INSTRUCTED TO MAKE AN INTERCEPT



5. P-61 NIGHT FIGHTER IS SENT OUT, EQUIPPED WITH ITS OWN I-R UNIT (SCR-729) FOR QUERYING TARGET IN AIR

6. CONTROL BOARD SHOWS POSITIONS OF PLANES WITH NIFFS (TABS) INDICATING FRIENDS & FOES. SET IS PURE HOLLYWOOD





How to Succeed in Combat

Or how to antagonize the enemy and get back

NOTE: This document is "must reading"; meaning that after you read, and pass it on to all your subordinate officers and enlisted men, you should do something about the dope contained herein. *If you're a guy that knows everything and can't learn anything more, quit reading now.*

EXAMPLE: You are flying an OA-10 on reconnaissance. You spot an enemy carrier off Rabaul!! You know of a squadron of B-17's enroute to bomb Lae, and you want to tell them, and the boys back at Guadalcanal what you saw. You tell the radio operator to send the message.

The radio operator thinks (*any one of these or all*):

a. "My radio doesn't work; I forgot to check it before taking off."

b. "I forgot what frequency the squadron is on."

c. "The home station won't work me because I forgot my radio authentication."

d. "I don't know how to use my frequency meter — so I don't know if they can receive me."

e. "Besides, my code speed is so slow I doubt if I can work back home."

f. "Moreover, I forgot the call signs of the squadron and the home station; and they won't answer."

g. "Furthermore, this is new equipment. I don't know how to tune it, or change frequencies."

So the operator tells you, "We're out of radio communication."

You yell, "God-damn Signal Corps equipment! It never works when you need it!"

I. So you go in and attack the carrier single-handed, and get shot down. (You have made the enemy very happy.)

Under the title above a sprightly little booklet issued a few months ago by the Commanding General, 6th Air Force, has been circulating in successive reprints. The airy technique it employs to make its solid points is not new, but not often is the technique used to such good effect. Because other Commands may want to adapt the manner to presentations of their own problems, and because the matter will be of direct interest to many RADAR readers, RADAR here excerpts the highlights of "How to Succeed in Combat."

CONCLUSION: You, not the radio operator, are at fault. You as commander of your airplane are just as responsible for the radio communication on your ship as you are for the proper operation of your machine guns, bombs, navigation, etc.

Or

II. SO you decide to beat it home and tell the boys. You run into bad weather.

a. You tell the radio operator to ask for homing signals, or the radio range to be turned on. He doesn't know how — this is still your fault.

b. You know that there are homing stations in operation along the islands. You tell the radio operator to use the radio compass and get you a few bearings.

(1) He doesn't know how to use the compass — or — (2) He knows how but left the radio facilities chart home — so he gets bearings — but he doesn't know where they're from. So you run out of gas, and crash into the sea — or parachute into a jungle and take six weeks to get back with the news of the carrier.

CONCLUSION: This is still your fault. (And is Tojo pleased!)

Or

You land and rush over to the C.O. with news of the carrier. Instead of smiling and patting you on the back, he gets mad as hell.

"I could have headed off that squadron over to the carrier! Why the hell didn't you radio me right away?"

You reply, "My damn radio wouldn't work."

The C.O. then replies, "I wonder when the hell they're going to send us radio stuff that will work." So you and he go over to the canteen for a beer and decide to attack the carrier tomorrow.

The next morning after you check up, the bombers and fighters from the carrier have caught 12 out of 15 B-17's on the ground at daybreak — knocked out your AW Radar, your base engineering, your gas storage, etc. You have lost many friends — killed or wounded — many airplanes and essential supplies — you have weakened your defenses. (You have succeeded in making friends with your enemy.)

Why?

1. Command is communications — without the second you can't have the first.

2. You, as an aircraft commander, a flight commander, a squadron commander, a group commander, a base commander, or a CG — are just as responsible for your communications as you are for your fire power. (*You wouldn't dream of flying a bombing mission unless you checked the bombs, the bombardier, your machine guns and/or your machine gunners, before you took off — would you? Why? On account of you want to get back sometime.*)

3. You can command and control yourself — but it is only with communications that you can control others. Note: *A leader is one who controls others.*

Are you a leader? Are your means for controlling others in good shape? Start learning and checking now!!

4. You do not pay sufficient attention to your communication facilities and personnel. You treat communications as a necessary evil — and you leave yourself at the mercy of a subordinate for things for which you are responsible.

5. There is nothing mysterious about radio communication. You can believe this — an instrument panel on an airplane looks just as mysterious to a radio operator as the panel on his radio set does to you.

6. You don't have to be a radio mechanic to know how to handle your radio communications — any more than you have to be an airplane mechanic to fly an airplane. And you don't have to be a radio engineer to know if your communication equipment

and personnel are properly operating and trained, respectively.

Truth or Consequences

Master of Ceremonies: "Imagine that you are the senior or command pilot of a flying fortress — (*the audience will please refrain from applauding*)."

QUESTION 1: "My good friend, just what do you expect from the command radio set in your airplane?"

ANSWER 1: "I, sir, expect to be able to talk to all the other airplanes in my flight at all times. I expect to be able to talk to the control towers at the various fields from which I operate. I expect to be able to talk to friendly naval vessels on kcs when we are both engaged in fighting Jerry or Nippy in the same area. We, sir, call this last little game 'Scene of Action'."

M.C.: "You are correct! Absolutely correct! !"

QUESTION 2: "And now my merry monarch of the upper zone — What do you want your liaison radio set to do?" To the audience — "I guess we'll stump him on this one."

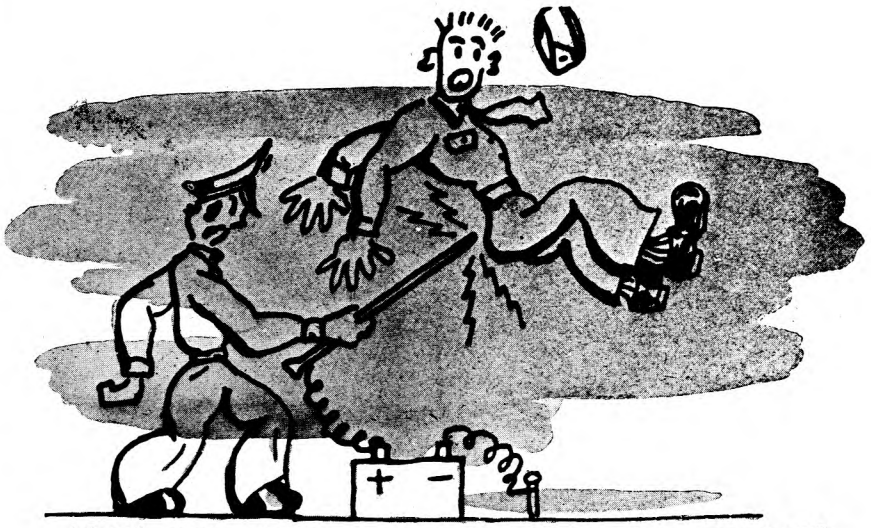
ANSWER 2: "I expect my liaison radio set to be able to communicate back to my squadron station — and/or my bomber command station — and/or any AACS station in my area for weather, or navigational aid — *at all times.*"

M.C.: "Wow! ! This man is good. — But, my admiring friends of the American radio audience, *I bet we get him on this one! !*"

QUESTION 3: "The third and last question, my winged protector of civilization — Can you always do what you said in answers 1 and 2? If not, why not?"

ANSWER 3: "Well, not always — because my radio equipment doesn't always work. I don't know why — because I don't know much about such stuff — but that is what my radio operator tells me. It's a damn nuisance because a lot of times I can't accomplish my mission."

M.C.: "Ah hah! He missed the $64 question! *H forgot that I told him he was the senior or command pilot.*"



JACK UP YOUR COMMUNICATIONS OFFICER

CONSEQUENCE: "The next time you take out the B-17 on a flight — you will strap up one leg, tie one arm behind your back, blindfold one eye, and plug up one ear — you're only 50% effective anyway — *catch on?*"

Anecdote

Once upon a time (and this really happened) — the CG, ... Bomber Command sat with his staff and evolved a marvelous plan. Seven B-17's from ..... field, and eight B-24's from ..... field were to take off, rendezvous over ..... Island at ..... hours. Upon assembling the flight group would be directed by radio to:

a. Either search by individual plane in a radial pattern from the rendezvous point, to locate, or

b. Comprise a task force for the purpose of attacking —

AN ENEMY CARRIER

All elements were briefed the night before. The planes were fully armed and bombs loaded. The take-off was on schedule (except for one plane which got stuck in the mud). The rendezvous over ..... Island went according to schedule. The flight group commander then waited for radio instructions —

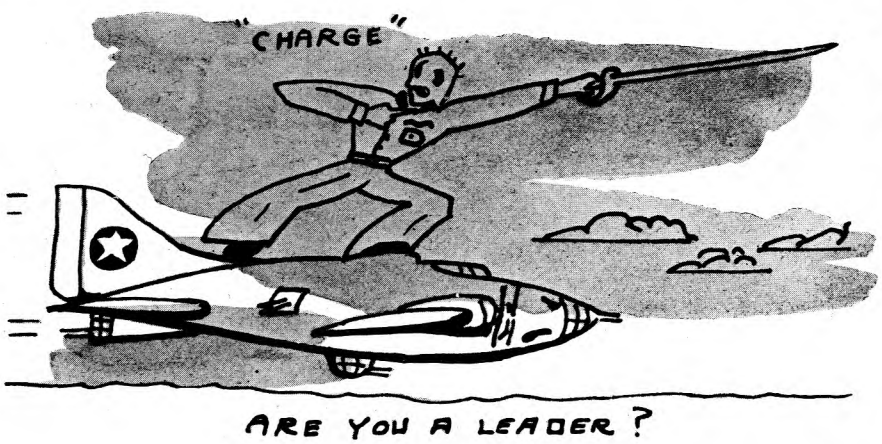
— and he waited
— and he waited
— for 72 MINUTES!!

Valuable time lost — and valuable gas expended. Why?

Because his radio operator's set was 100 kcs off frequency and the latter couldn't establish communications with the Bomber Command ground-to-air radio station.

Note: Another operator from another plane in the flight finally woke up and called him and told him he was 100 kcs off frequency — about 70 minutes later.

P.S. *They never found the carrier.*



ARE YOU A LEADER?

If You Are a Squadron, Group or Higher Commander

You should be the most jealous man in the world about your communications. Why? *Because it is the only means you have to run your show with.* The only means you have to receive info — contact your airfields, dispatch your aircraft, direct them in flight, and bring them back, is communications. If you don't pay particular attention to your communications, you place your sole tool in the hands of a subordinate, the communications or Signal Officer. Of course, he is doing his best, but you are the C.O. You should know your communications facilities, their powers and limitations, how to improve them, and how to improve your operating personnel. The chief complaint in our active operations has been "insufficient communications." It should be "Improper management and handling of available communication equipment."

Remember, the communications equipment of the U. S. Army Air Forces is the best in the world! Ask the man who knows.

Our weaknesses lie in the insufficient training, or lack of supervision of training of communication personnel. Take a personal interest in it.



LT. BOLSTRIDGE SMILES FOR THE CAMERA. SCENE: BOCA RATON AIR FIELD. OVER HIS SHOULDER: BABS ANTENNA STRUCTURE

Maine Farmer on Attu

The following is the first of a series of write-ups of radar personnel in the Air Forces, scheduled to appear in RADAR from time to time.

First Lt. Leslie J. Bolstridge, HQ Det. 15th Academic Group, Boca Raton Field, Fla., was a farmer when he enlisted. He came from a good Maine farm, liked farming, and planned to return to it after the war. Today, he is a radar officer and he means to stick with radar.

How this transformation came about is typical; and typically, its roots go deep. About the time Lt. Bolstridge got out of short pants, he began tinkering with radio. Before long he had a shop in the attic of a shed and was building broadcast receivers, short-wave receivers, 5-watt to 65-watt transmitters. A builder rather than an operator, he didn't bother to learn code. But through high school and into college, he built and fixed sets for miles around.

In the summer of '41, after two years of dairy husbandry at the University of Maine, he enlisted. He asked for radio duty, and hoped to be a bomber's radio operator. Accepted, he was shipped to Air Corps Technical School at Scott Field, to study radio operating, basic radio theory and aircraft radio. He graduated with an 86 average — held down by his slow word-rate in code. He didn't get flying duty; instead he got an instructor's job.

Not long after this Bolstridge applied for appointment as Aviation Cadet, Communications Branch. Appointment came in July 1942, and he was commissioned as 2nd. Lieutenant in October — a little over a year after he enlisted. This time, he ranked number three in his class, with an average of 96.

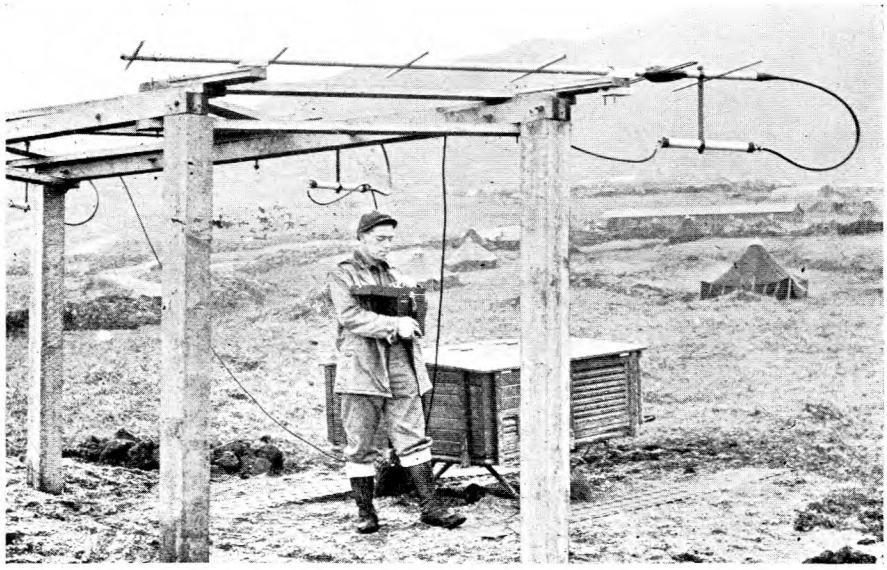
It was this grade that jumped Lt. Bolstridge into radar. Washington sent down to pick the top men and send them to radar school. Men with calculus were slated for M. I. T.; those without went to Boca Raton. Lt. Bolstridge, who had high-school algebra, geometry and physics, went to Boca, where he studied basic radar for two months and existing sets for one. And he beat his Cadet School record by graduating top man in his class. He was now (February '43) a radar officer, and at this point he was made a supervisor in the school.

Good radar men have a way of turning into instructors; and Lt. Bolstridge might have stayed on at Boca Raton, teaching, if Maj. Gen. Davenport Johnson, Commanding General, 11th AF, had not requested a chain of blind approach beacons (BABS) for his fog-bound Aleutians airfields. Lt. Bolstridge, who had done considerable work in 176 megacycle beacons and search equipment, was assigned to the project with Malcolm S. Morse, a civilian engineer from Wright Field, and a crew of three sergeants.

Working up to 18 hours a day, this group put together beacons for the next few months. On 13 September 1943, six of these beacons arrived in Adak, along with Lt. Bolstridge and his three sergeants. Six days later, the first beacon was operating on Adak. Three weeks later, another one was going on Attu. From there on Lt. Bolstridge and his crew worked the islands.

If they didn't have a beacon ready-made, they built one. In all, they installed six imported jobs and six hand-made ones, trained about 100 flying crews to use them. On 14 January 1944 — four months after arrival — the job was done and Lt. Bolstridge left for the U.S., with a commendation from Gen. Johnson, addressed to his whole group, and a First Lieutenancy awaiting him.

Lt. Bolstridge likes all this. He also likes the prestige of radar. He has found that it commands respect and, what is more, priority — an important item when you want nuts, bolts, planks or travel. Most of all, Lt. Bolstridge likes the future of radar. As a good radio man, he knows that today's radar, with its ponderous transmitters, its hodgepodge of boxes and cabling, is as primitive as was the communications radio of War I. He sees illimitable peacetime applications for radar. And he is anything but starry-eyed about all this. He is dead-cold-serious and matter-of-fact as a Maine potato. He is saving $75 a month right now; and after the war he is going back to college to study electrical engineering. A lot of radar men will be there with him.



BABS INSTALLATION ON ATTU. SOME INSTALLATIONS WERE COMPLETED IN 6 DAYS

While We're on the Subject

"Basic English" for Radar Operators

Following are some of the terms that make up a radar man's shop talk. Not all the terms — just some of those that haven't yet made Webster's. Some are official designations. Some are pet names, some are abbreviations, a few are enemy aliens. In fact, the list is hardly English at all. But it's Basic.

A SCOPE — An "A" scope shows the range of an object as the distance along a flat line from the transmitted pulse to the signal.

AI — Short for Aircraft Interception. AI radars such as SCR-720 guide nightfighters to interceptions.

ANGEL — A reflecting device for creating false echoes. (See Window.)

ASV — Short for Air-to-Surface-Vessel. ASV sets (SCR-521, -517, etc.) detect objects on the surface of the sea.

AW — Aircraft Warning.

B SCOPE — Scope that shows range vertically and relative azimuth horizontally; SCR-717A has a B scope.

BLIP — British for pip.

BLISTER — Housing for a paraboloid antenna. Officially a radome.

BTO — Bombing through overcast. APQ-5, APQ-13 and APS-15 are BTO sets.

C SCOPE — Shows azimuth angle horizontally and elevation angle vertically. Used in microwave AI sets.

CARPET — An airborne transmitter for jamming enemy radar stations (see page 12).

CH — Chain Home. British early warning radar.

CHAFF — See Window.

CHL — Chain Home Low. Early warning against low flying aircraft.

COL — Chain Overseas Low. Early warning against low flying aircraft. Designed for operation at overseas bases.

DISH — Paraboloid reflector of an antenna. (See spinner.)

DF — British for Direction-Finding. Also used as a verb.

EUREKA — A portable ground-based radar beacon that responds to an airborne interrogator, Rebecca, to permit homing. Especially useful for designating landing zones in troop carrier operations.

FREYA — German early warning radar set. Rhymes with hiya (see page 4).

FUNKGERAT — German for radio and radar apparatus.

GCA — Ground Control Approach. The technique — and sometimes the set — for directing aircraft into approach for landing.

GCI — Ground Control of Interception. GCI stations vector fighters to within visual or radar (AI) range of enemy planes.

GEE — British navigational system, similar in principle to Loran.

GL — Gun Laying. Range, bearing and elevation supplied by GL equipment are used to direct guns and control their fire.

GRASS — Noise on an "A" scope.

H — Navigational and bombing system in which a plane carries an interrogator to pick up signals from two ground-based racons, and thus get a "fix" for bomb-release point.

HOHENTWIEL — German ASV set (see page 9).

IFF — Identification of Friend or Foe (see page 21).

J SCOPE — A circular "A" scope.

LAB — Low Altitude Bombing. A radar attachment (APQ-5) adapting an ASV set and a Norden sight, for low-altitude high-precision blind bombings.

LICHTENSTEIN — German AI set (see page 9).

LORAN — Long range navigational system for ships or planes, using pairs of high-power ground-based transmitting stations.

MAGGIE — Short for magnetron.

MAIN BANG — Big signal on "A" scope caused by the transmitted pulse.

MATTRESS — Type of long-wave antenna, used by SCR-270, -271, etc.

MICKEY — H_2X radar, used for BTO. (Also Mickey operators, Mickey planes.)

MICROWAVE — Radar using wavelengths of less than approximately one meter. A large proportion of the newer radar sets are microwave sets.

OBOE — Navigational bombing system in which two ground-based stations interrogate an airborne racon. A sort of "H" system reversed.

PIP — American for blip.

PLUMBING — The radio frequency line.

PPI — Plan Position Indicator, a circular map-type display showing range as the distance of the signal from the center and azimuth directly by compass-markings on rim of scope.

RACON — Officialese for radar beacon.

RADOME — Officialese for blister or antenna housing.

RCM — Radio Counter Measures. A radar jammer is one kind of RCM.

RDF — Radio Direction Finding. Old British term for all radar.

REBECCA — See Eureka.

SCI — Ship Control of Interception. Carrier-based version of GCI.

SEARCHLIGHTING — Directing the radar beam steadily on a target, either manually or automatically.

SHF — Super High Frequencies: 3,000–30,000 megacycles.

SLC — Search-Light-Control. SCR-268 is an SLC set.

SNOOPER — In the South Pacific, a plane equipped with LAB (APQ-5).

SNOW — Noise on a PPI or "B" scope.

SPINNER — Paraboloid antenna assembly, including antenna, reflector, mount, motors, etc. Also called scanner.

STINKY — H_2S, a British navigational and bombing set, predecessor to American Mickey (APS-15). Clue: H_2S also stands for hydrogen sulfide, the "rotten-egg" gas.

TCI — Terrain Clearance Indicator. An absolute altimeter.

TURNSTILE — Type of antenna used on such long-wave sets as SCR-621.

UHF — Ultra High Frequencies: 300–3000 megacycles.

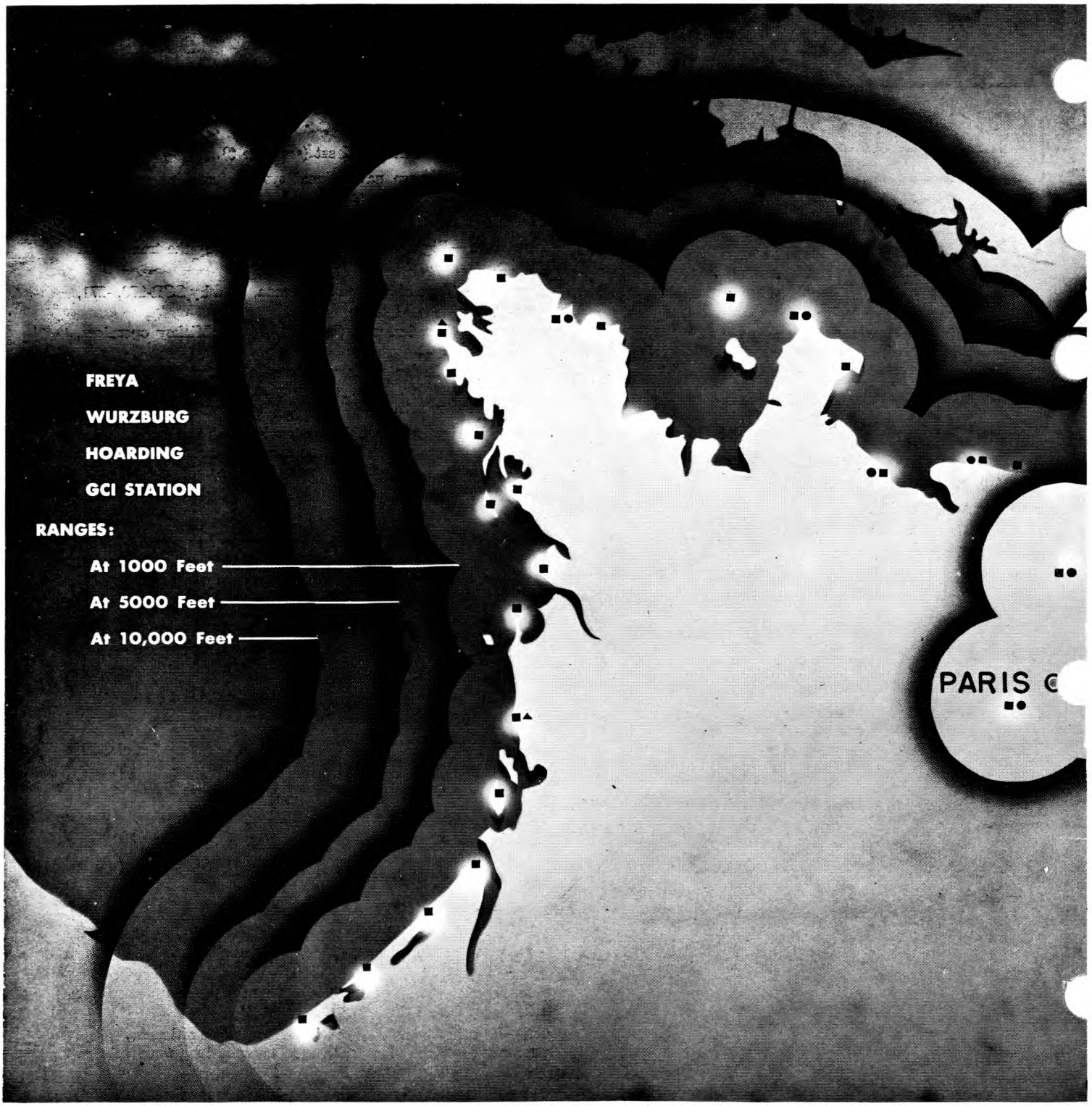
VHF — Very High Frequencies: 30–300 megacycles.

VLF — Very Low Frequencies: 10–30 kilocycles.

WINDOW — Any of several mechanical reflecting devices which create false signals on enemy radars when dropped from planes. Used particularly for the foil-&-paper strips which are technically known as Chaff.

WURZBURG — German radar set used variously for aircraft warning, searchlight control, anti-aircraft fire control, and GCI (see page 7).

YAGI — Type of antenna used on long-wave sets. Named for its designer, Professor Hidetsugi Yagi of the Tohoku Imperial University, Sendai, Japan.



German Radar

No map of Germany's radar defense system can be wholly accurate and the map above is no exception. Changes come too fast, as new tactics force new developments, for any static presentation to keep up with them. But this map is essentially correct as of two or three months ago and so far as it goes. It does not pretend to show every German radar station. What it does show is the main pattern of coastal and inner radar lines, approximately accurate locations of major installations forming the pattern, the outward range of the coastal system and the full coverage of the inner system. Here is the skeleton of German radar defense on the ground. For the flesh around the skeleton, see pages 3 to 11.

FERRANTI Defence Systems Limited

RADAR

Issue No. 3 JUNE 1944



R.P.F. Lauder
Engineering Manager
Product Support Department

INTRODUCTION

The third volume in this Ferranti-presented series of historic documents went to press just as the allied invasion (D-day) of continental Europe was starting. It is therefore too soon to record the part played by radar during those heady days. However it is clear that massive off-stage work had been going on in anticipation of D-day, not least of which was the development and pilot production of the microwave early warning (MEW) radar which was to play such a vital role in the control of the airborne support of the actual invasion.

Working in the 10 cm band, MEW overcame the problem of combining long range horizon search, with shorter range high altitude cover, by having two antennae, one directed along the ground and the other providing a higher altitude fan beam. The photograph on page 4 shows the parabolic low angle reflector, and the more empirical cosecant-squared beam, merged together. Later versions were placed back to back. The long range antenna was vertically polarised, whereas the fan beam was horizontally polarised to minimise cross-talk.

The MEW radar was used in conjunction with the British Type 24 height finder radar since the MEW was incapable of determining height.

Dozens of raids were plotted simultaneously by a large number of manual plotters occupying the many displays. The correlation of the signals from low and high beam plus the Type 24 must have required considerable interpretive skill.

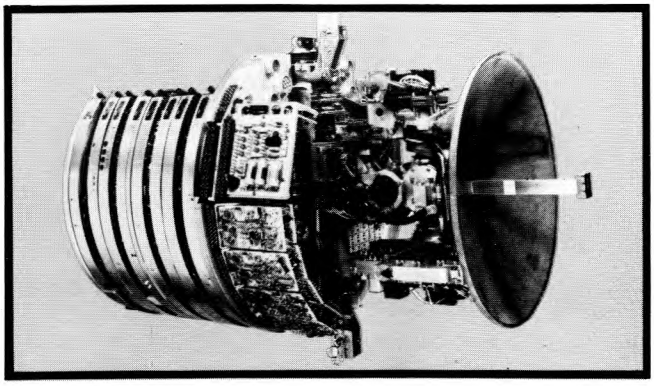
Mentioned only briefly is the Senior Controller's main PPI display, the Skiatron. This was in fact a dark trace CRT with an accurate spherical face placed at the focus of a spherical mirror. Through a hole in the centre of this mirror, a high intensity mercury vapour lamp was focussed on to the face of the CRT. The resulting image was focussed by the spherical mirror via a front face 45° mirror on to the underside of the viewing screen carrying a map of the coverage area. A Schmidt correcting plate surrounded the CRT, approximately at the position of the deflection coils.

The resulting signals appeared as magenta coloured patches against a white background. It was thus possible to produce a large radar display from a small diameter CRT. The dark trace tube had the unsatisfactory feature of burning-in signals on to the screen. These could be removed by occasionally raising the temperature of the tube, and scanning it with a weak electron beam. The contrast was also poor and probably as a result it has not persisted in radar designs.

Allied airmen, unfortunate enough to be shot down over the sea, had an inflatable rubber dinghy to sit in until rescue arrived. The picture on page 12 dramatically illustrates the problem faced by the rescue pilot in spotting this very small object, even in relatively calm water, and under clear conditions. The dinghy was a virtually invisible radar target, but here we see the first steps taken to enhance the radar echoing area of the craft. Very pistols had been around since 1910 – named after their American inventor – it is surprising that their radar analogue of a chaff shell fired by the same pistol had not been considered.

Wartime aircraft were equipped to measure true air speed, but not ground speed or drift angle. Estimations of wind speed and direction were done by the navigator making a double drift determination. This issue describes the realisation that the position of a target on the ground displayed by radar in azimuth and range, and successively plotted over measured periods of time could, with the aid of a simple calculator, yield ground speed, and wind velocity and direction. The more elegant radar solution of measuring the doppler shift of main beam clutter with respect to aircraft heading had to await the end of the war.

In this volume we also see the beginnings of mechanisation to the dispensing of chaff or window, and attempts to sow corridors without 'holes' in them. It is interesting to note the comment on page 31 that the US airmen use tight formations of bombers, require steady release of window for cover compared with the UK's looser formations where a more individual protection was used.



STRIKE AND TERRAIN FOLLOWING RADAR

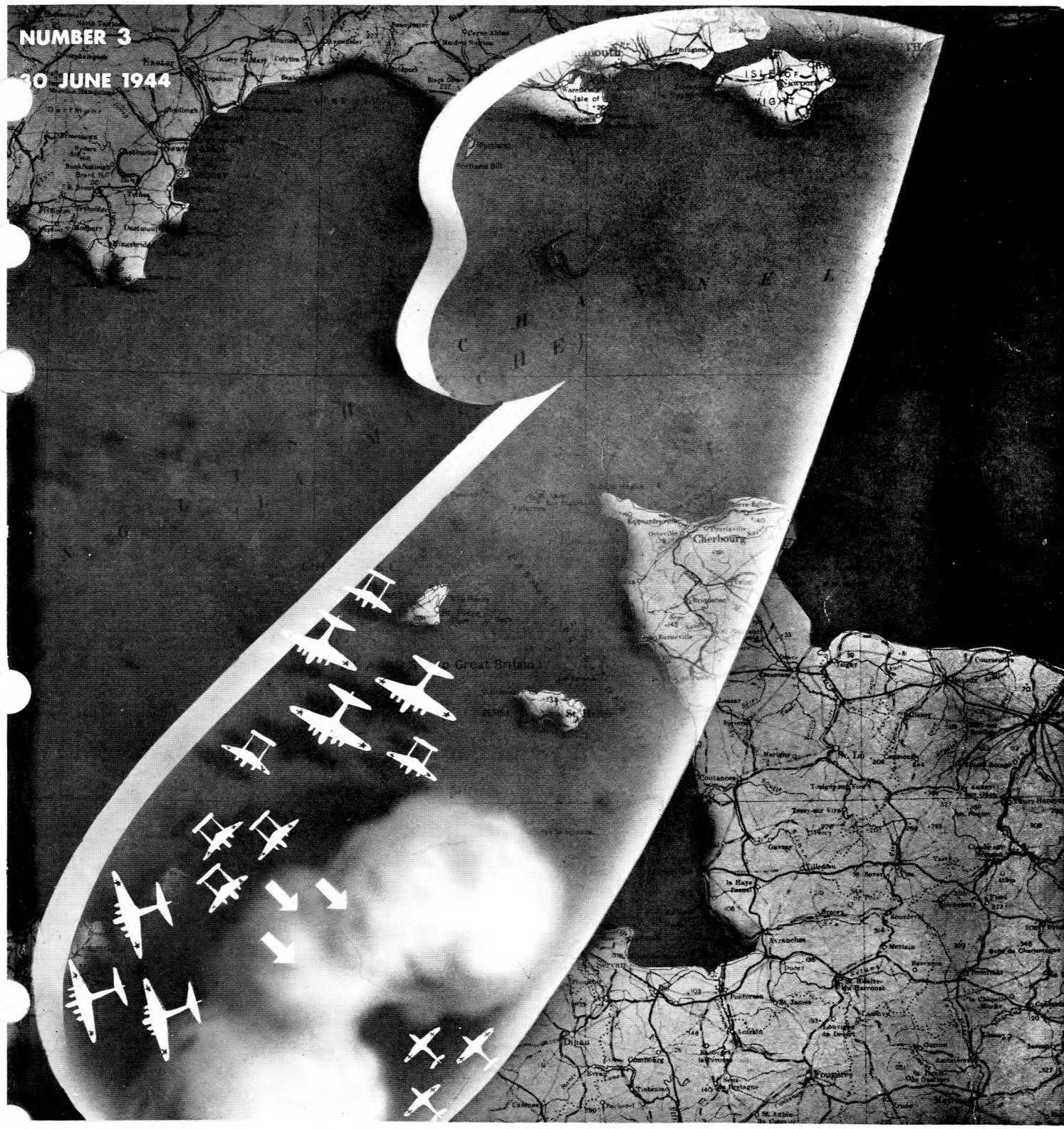
This excellent multimode Ferranti radar was designed to equip the TSR2 aircraft which, unfortunately, was never built. Radar trials by Ferranti showed that a pilot quickly built up confidence in flying over mountains in cloud at 50 feet clearance in level flight without ballooning.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

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MEW over France

RADAR

RADAR

In This Issue

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EDITORIAL ADVISERS: Lt. Gen. Barney M. Giles, Chief of Air Staff; Maj. Gen. Stephen G. Henry, Director, New Developments Division, War Dep't Special Staff; Maj. Gen. Roger B. Colton, Chief, Engineering and Technical Service, Office of the Chief Signal Officer; Brig. Gen. Thomas D. White, Assistant Chief of Air Staff, Intelligence; Dr. Edward L. Bowles, Consultant on Communications to the Commanding General, Army Air Forces; Dr. L. A. DuBridge, Director, Radiation Laboratory.

PUBLICATION DIRECTOR: Chief of the Radar Branch, Office of the Air Communications Officer—Col. W. M. Canterbury.

EDITOR: Dexter W. Masters **ASSOCIATE EDITOR:** Nancy Newton.

You'll get more out of this publication if you put something into it. Information and photographs on operations and maintenance of equipment in the field are requested. Submit material to Radar Editor, Office of the Air Communications Officer, Headquarters of the Army Air Forces, Washington, D. C.

★ INVASION REPORT

The intricate pattern for invasion was heavily threaded with radar. On the beaches, in front of the beaches, and beyond, radar of many kinds and forms worked on D-day — searching, intercepting, directing, bombing. How it did on the bombing is the subject of the following report to RADAR from an on-the-spot radar specialist, close to what went on and thoroughly familiar with radar-bombing equipment and its uses.

Radar bombs the beaches

The first wave of the assault force to land found the going definitely easier than had been expected. This was particularly true on the beaches assigned to the British which got the greatest weight of 8th AF H-hour bombing. Gun emplacements and obstructions were shattered; the enemy, in many areas, was literally stunned by the concussion of hard, heavy bombing. All of this softening-up bombing, in the 30 minutes before H-hour, was by H_2X.*

Before D-day there had seemed to be about a 50–50 chance for weather that would allow visual bombing. Ground forces asked the 8th AF to be ready with blind bombing in case of cloud. Preparations to this end were more thorough than for any H_2X operation ever. Five practice missions took 8th AF heavies equipped with H_2X to the French coast against targets simulating invasion beaches, and results were good. Since none of the Mickey (H_2X) operators had ever seen a beach with boats offshore in such quantities as were to be expected on D-day, radar photo reconnaissance was done over invasion barge areas. Scope pictures resulting were presented to each operator along with a general plan of distribution of assault forces as it would be around H-hour. Operators also had scope photos of the actual invasion beaches.

Right up to take-off time — from 0230 to 0330 — distribution of forces was on the visual bombing plan. Then south of London the clouds closed in, covering the invasion area. Clouds were 10/10; except in a few places, not even the beachline could be seen. That put it squarely up to H_2X.

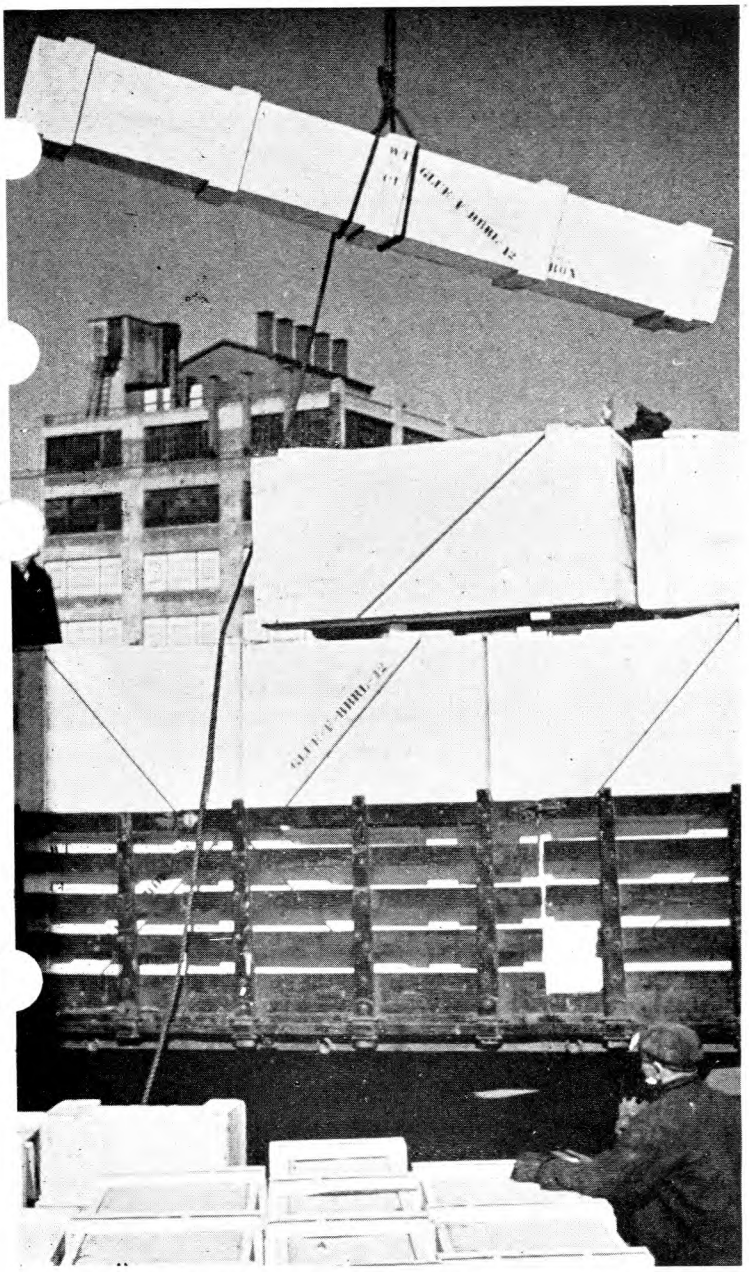
At H-hour minus 30 minutes, landing forces were scheduled to be about a mile offshore; at H-5, about 500 yards. Since a man can recover from heavy bomb concussion in just about 30 minutes, all of this bombing had to be done in that time. It had to be intensive and accurate. It was both.

On their scopes the Mickey operators were able to make out the assault forces in all their profusion. The water line between assault boats and beaches was consistently clear. Bombing was just plain damn good. Photo reconnaissance later showed that, on the whole, very good patterns were laid down accurately—as the High Command has noted.

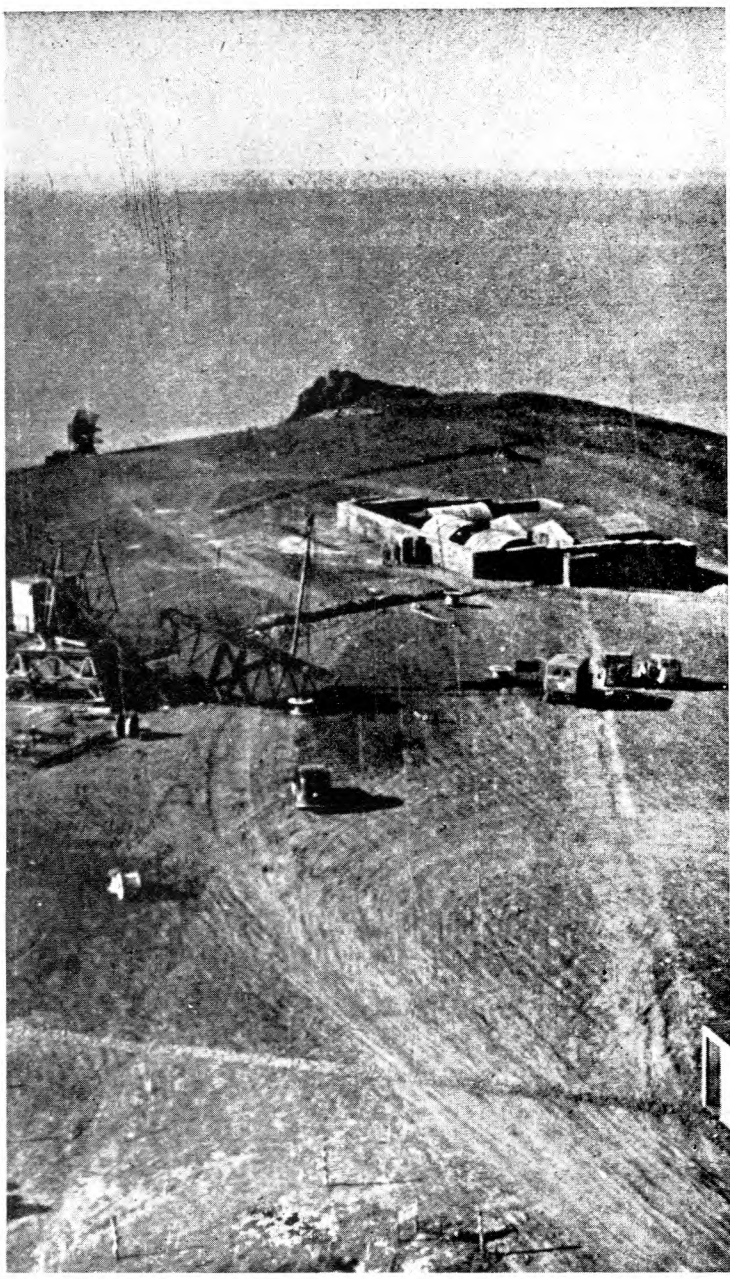
. . . and the enemy's radar

Bombing blind with Oboe, 9th AF and RAF Bomber Commands raised hell with enemy radar installations. The fact of this matter is that more than 190 coastal installations—including Giant Wurzburgs, Hoardings, Chimneys, etc. — were hit so hard that only a handful were operating a few minutes before H-hour. Disorganization was so great that spoofing actions also carried out were probably unnecessary. Some new thinking on vulnerability of radar installations to heavy bombing seems called for; it's much greater than had been figured.

H_2X: radar equipment for high altitude blind bombing — specifically APS-15 radar (for a full report on this equipment and its operational use, see RADAR, April).



IN THESE CRATES MEW's 66 TONS LEFT U. S. FIVE MONTHS AGO



FROM HERE (COVER LOCATION IS FAKED) MEW COVERED D-DAY

SIXTY-SIX TONS of MEW

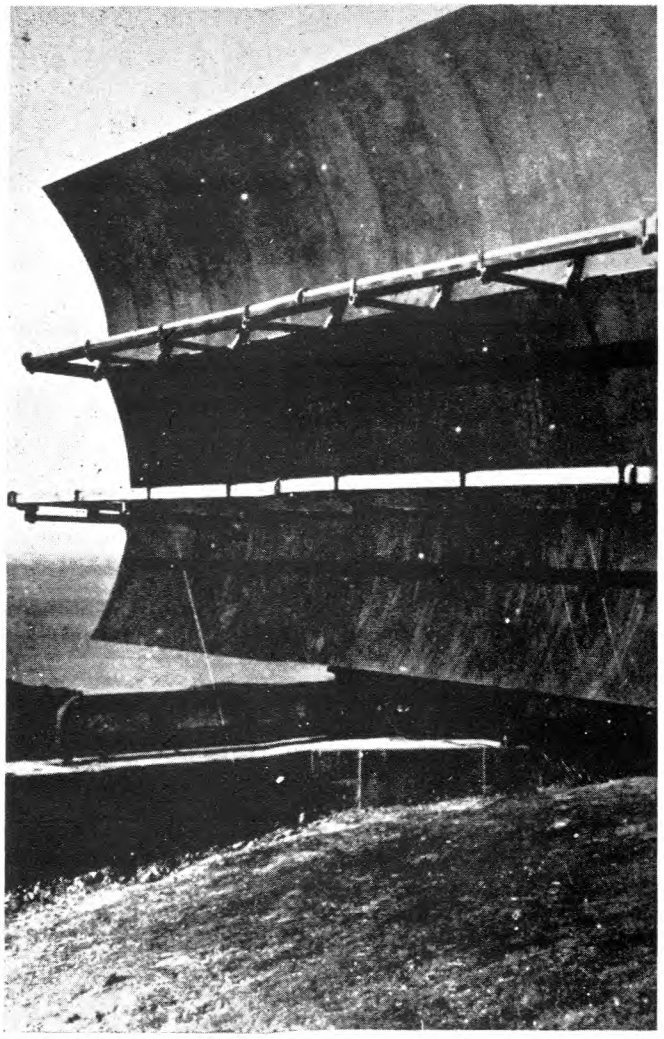
New Microwave Early Warning was ready for D-day

The first Microwave Early Warning* radar to be used in a theatre of operations sits on the coast of England facing Le Havre, Cherbourg and the whole curve of the Normandy coastal line. On the 6th of June its big snowplow-like antennas swept this area all day and a radar map of what was going on fed piece by piece into its battery of PPI and B scopes. MEW, most powerful and sharp-sighted of radars, sat right where the looking was best on D-day.

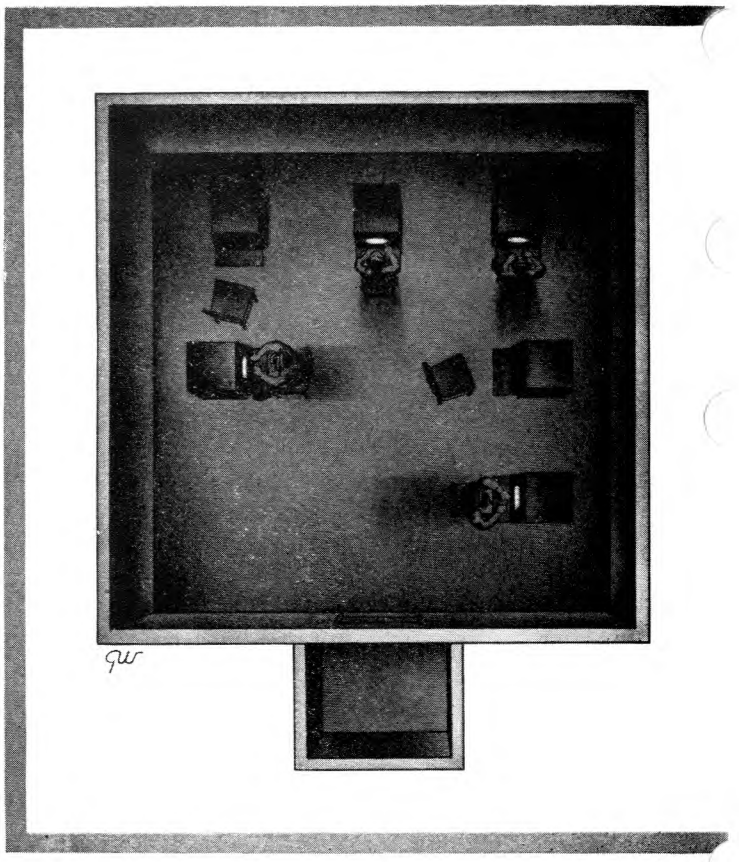
**MEW for short and AN/CPS-1 officially.*

It had been sitting there, and not idly, ever since 28 January, when the crates carrying its 66 tons of parts and fittings arrived from the U. S. Eight weeks after its arrival the installation was finished and MEW went into action. The work it did between then and D-day was just about enough to get the bugs ironed out, the crews broken in and procedures set. Considering the varied and valuable uses that MEW has for such operations as constitute an invasion, you might have made a fair prediction of the time and place of invasion from the time and place of MEW's installation. Of the details of its use on D-day more in an early issue.

Here — and for two reasons — RADAR reports on what MEW is, how it works, what it is designed to do. The first reason is that MEW is slated to play a potent and continuing part in many of the operations that began with D-day, hence the greater the understanding of it the better. The second reason is that the handful of MEW's now in existence, pre-production models all of them, will soon be joined by production equipment for all theatres. It takes considerable planning to utilize effectively the full capacities of 66 tons of MEW, and the sooner the planning begins the better.



Antennas for high and low beams are thus joined at first English station; later MEW's have them back to back. Whole antenna system weighs about 5 tons, is 25 feet long, knocks down for transporting

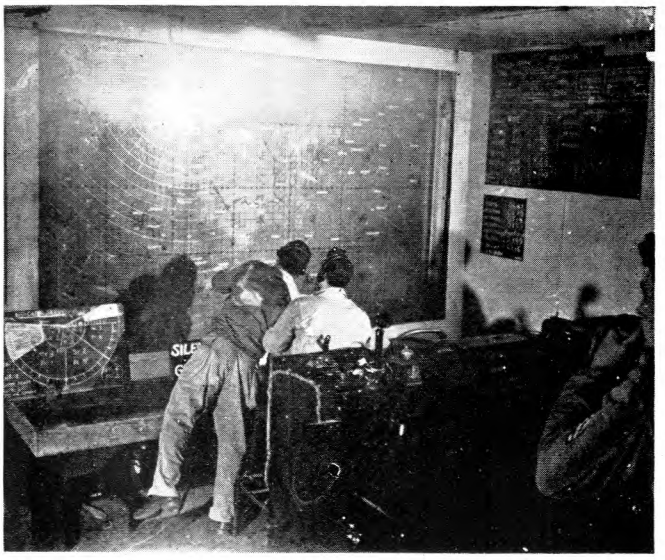


MEW: Its shape and look

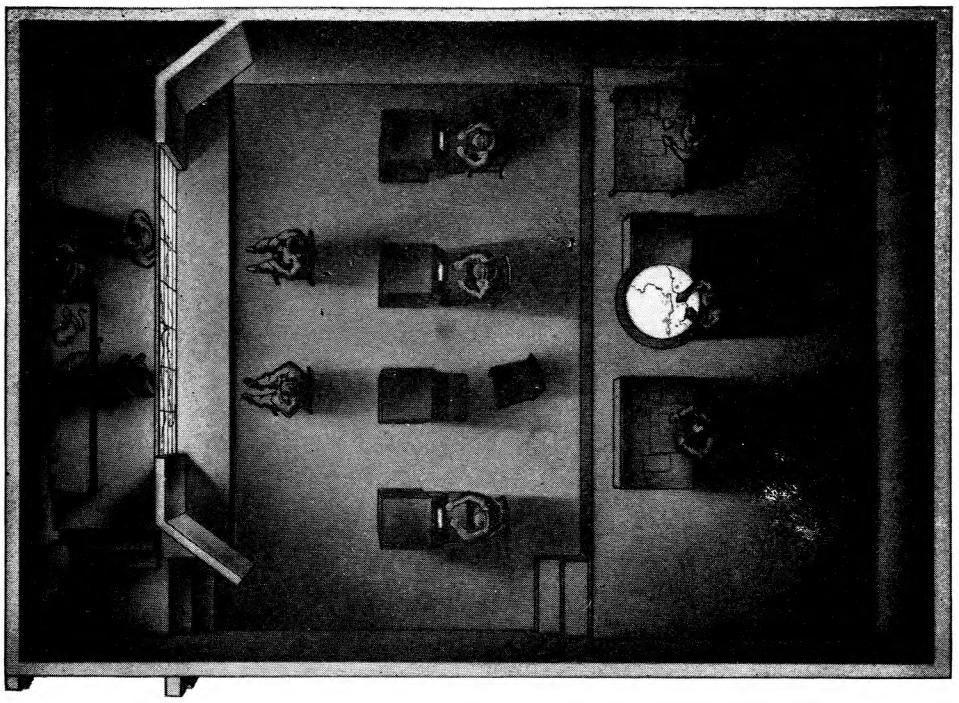
There are at this writing five MEW's in existence. One, the model for much of this report, is the installation in England overlooking the area in which the invasion began. Two more are in England; one, a fixed installation, was scheduled to begin operations on the 6th of June; the other is being converted into a mobile set for use on the Continent. A fourth MEW has been installed in the Mediterranean area, is about to become operational. The fifth is still in this country being readied for use in the Pacific.



Plotter marks all tracks on ground glass back of screen, thus leaves front view unobscured. White chalk indicates friend, red means hostile



Plotting screen, vertical glass, is innovation of this station. Coast lines, azimuth and range lines, grid squares are painted on in colors



Operations Room and (on opposite page) Scope or Indicator Room of first MEW installation in England concentrate a lot of men, equipment and activity into small space. Entire operations block includes, besides these two nerve centers, a maintenance hut, an operations office and a hut for crew rest room, telephone and power facilities. A blast wall encloses the whole layout. (See photo of site on page 3.) Personnel required for an MEW installation can vary a good deal depending on uses to which equipment is put and activities in area. A dozen men can do the traffic-handling alone under light conditions. An organization of approximately 150 is needed to take care of all functions, including administrative, operational, maintenance, etc. The English installation given in general plan view here (for accurate detail check with actual photos below) is functioning primarily as a fighter direction station.

MEW is no simple gadget; it's a very hefty, complicated layout and production in any quantity comes slow. That is why, to bridge the production gap, a crash project was ordered to turn out the five sets now on hand. Because they were crash-built they are not all alike, as the production models will be; details of antenna structure, plotting and display arrangements, etc. vary from one to another. Modifications have been made and more modifications are in process. But MEW has about two years of development work behind it; it has been tested and tried; it has been probed and handled. By now, in all essentials, it is a pretty definite commodity.

MEW is, in strict fact, two commodities. It is two radar sets brought together on one mount, each having its own transmitter, receiver, antenna and indicator and both sharing a common power console and modulator. One of the sets operates at high angles, the other at low, which gives MEW its distinctive double-lobe coverage pattern. Coverage, wedded to the great power of the microwave transmissions and the high sensitivity of the receivers, makes MEW the versatile thing it is. Of its character and its uses more is told in following pages. Photos on these pages are first to be shown of the first installation in England.



Plan of attack board displays pending operations, provides identification references while operations controlled by station are going on



Dais at far end of room from plotting screen has Senior Controller, with Skiatron in front, assistants at sides and all data in plain view

Saved—
Fourteen Forts, 140 Men

Almost before the first of the preproduction MEW sets was out of its wooden packing crates and installed at its station in England it had paid for itself handsomely. In one brief and unscheduled shepherding it saved 14 B-17's and their crews, which you can value at about $2,500,000 plus almost any amount of money.

The story on these two pages tells of this first serious assignment for MEW, and thus merits special attention. It happened on 20 March, while the set, though installed, was still non-operational because of missing communication lines. On that day the station was host to several RAF communications officers who had come to inspect the setup. As it turned out, they were treated to a full dress rehearsal.

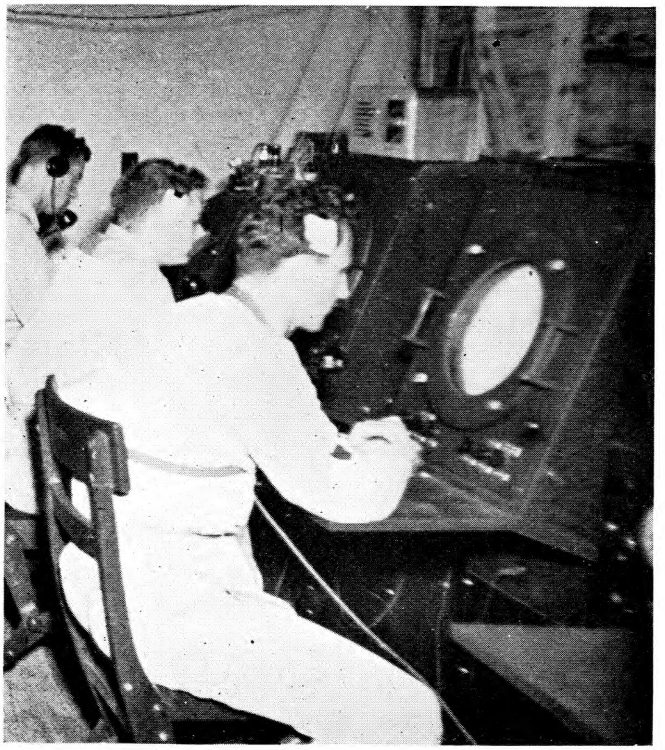
One big point this unscheduled operation underscored was MEW's versatility — its handyman ability — a consideration which was given special emphasis by the AAF Board during the equipment's trials at Orlando, Florida. No. 1 installation in England was and is intended to direct fighter sweeps — its primary function — with GCI and early warning as supplementary roles, among others. On 20 March it did a special air rescue job. Another MEW, installed elsewhere, might be asked to direct air support for landing parties, do duty as a weather observer, or control area bombing. More early experiences should be coming in soon from MEW installations. And as these become available they will give further keys to what can be counted on from MEW in operation. As more and more of the equipment moves into the theatres, its work-a-day and tactical potentialities can fairly be expected to tax the ingenuity of its users.



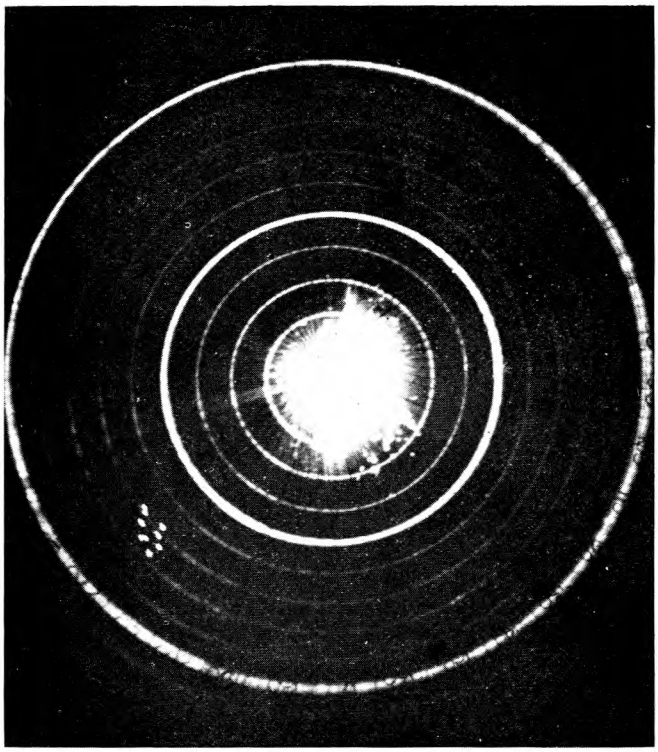
1 Fourteen B-17's were lost over the Atlantic. Some had been damaged by flak, engines were out on others, all were down to the last of their gas supply. They had been lost for several hours. Analyzing the situation the flight leader saw only one thing to do — ditch



2 A navigational slip had led the formation astray. Homeward bound from a mission over Germany they crossed the coast below Brest, thought they were crossing the bulge below Belgium (*arrow*). England was nowhere around. Before ditching the leader radioed for a fix



3 Meanwhile, an MEW crew in training picked up the flight, thought it was hostile, called chief controller to check. Before he could report the formation's track for action, the DF station used with MEW reported the distress call, on frequency used by 8th AF heavy bombers



4 On the PPI scope the flight showed as bunched white tracks about 170 miles off; and position checked with the DF fix. Unprepared as yet for communication on 8th AF frequency, MEW operators began phoning plots to nearby GCI station which, in turn, started vectoring



5 In quick talk with planes, instructions were given for them not to ditch, to try to make it in as close as they could. Air/sea rescue plane was started out to meet them. MEW operators, keeping steady watch, continued passing on plots; this was training with a capital T

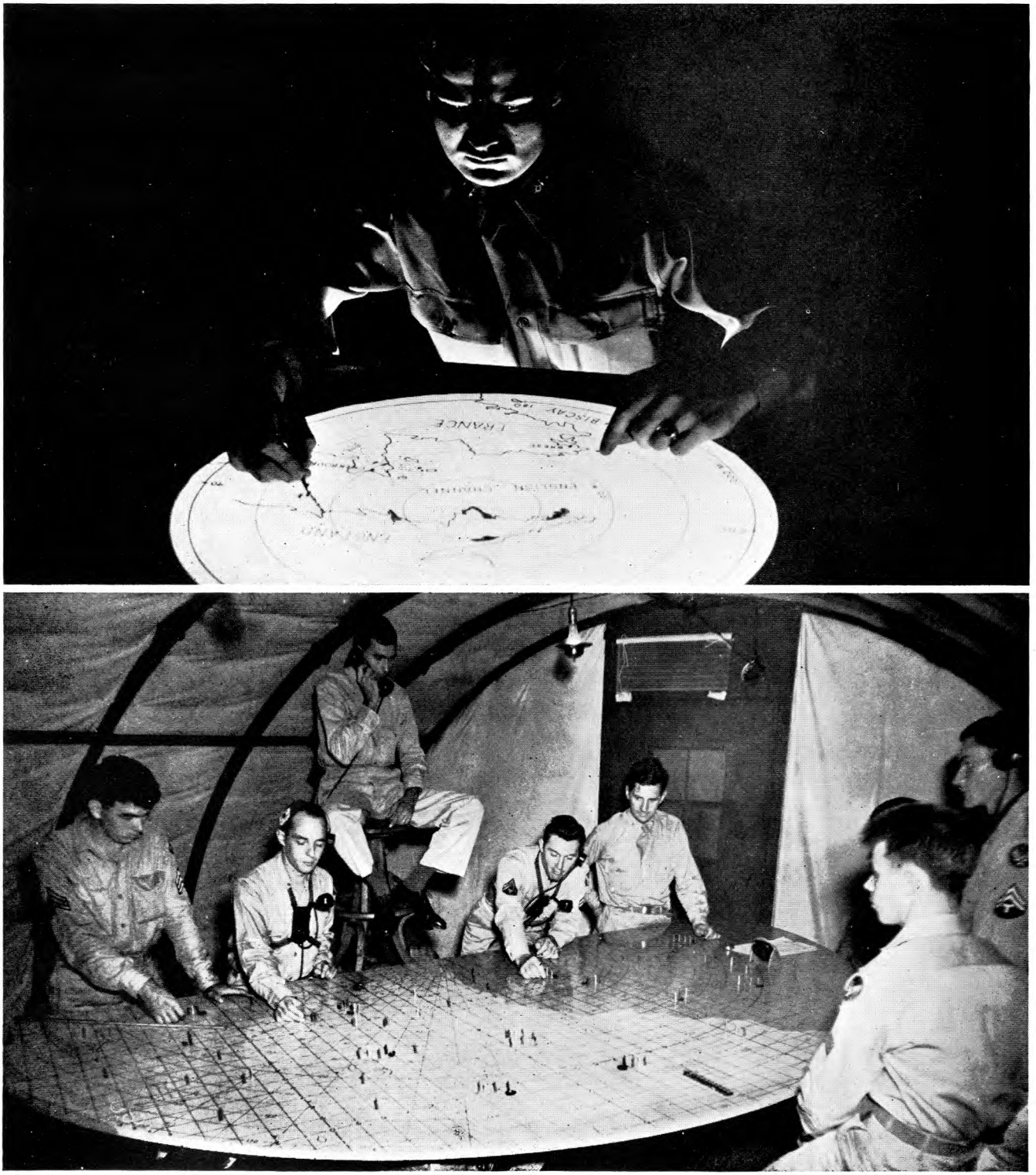


6 It was tough going for the Forts. They coughed and spluttered. More engines gave up; two were burning on one plane. But they all kept on, getting closer and closer to home. And MEW kept on tracking them, brought them into range of the GCI station which then took over



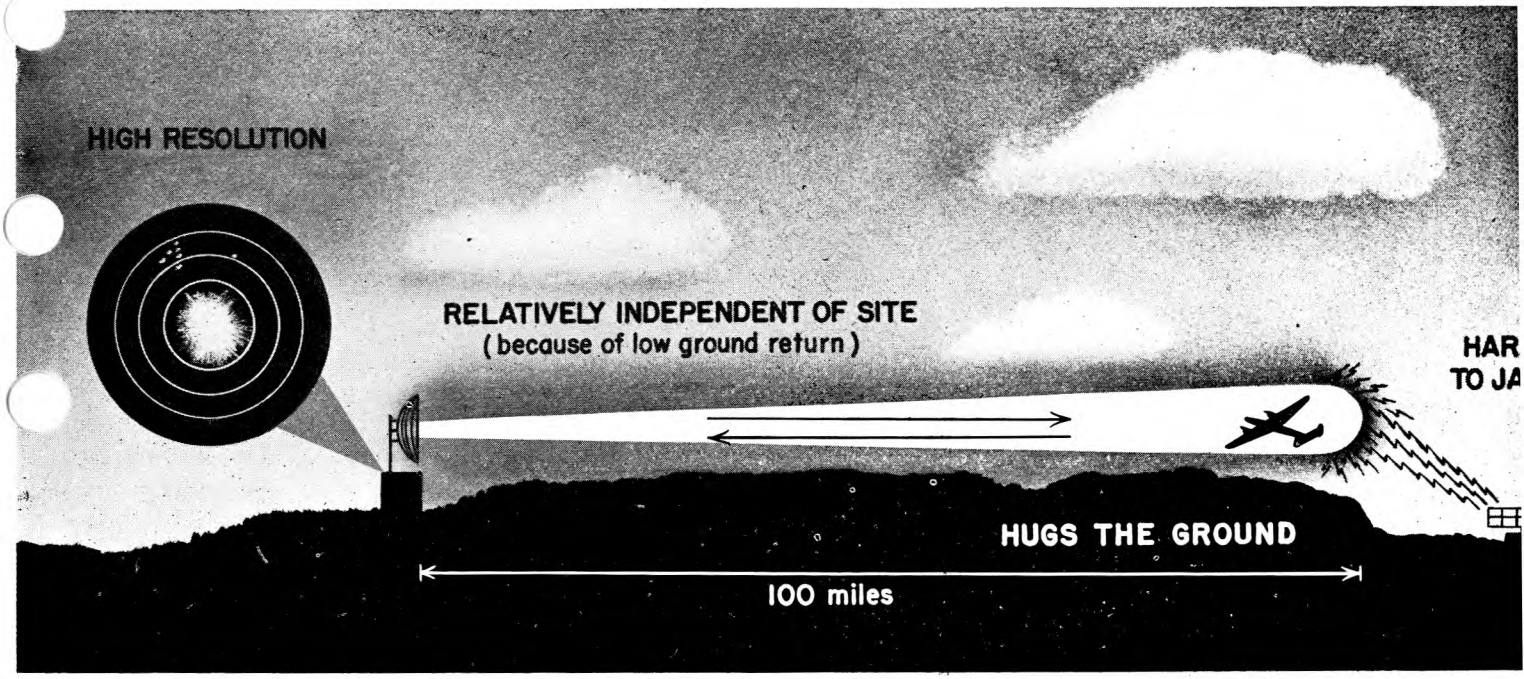
7 Thus guided, the formation made its way in from the ocean, came safely to rest on English soil without losing a single plane. And thus ended the new MEW's unscheduled operational debut. Seven days later the installation was complete and MEW started fulltime work

Different MEW set-ups use different plotting equipment . . .

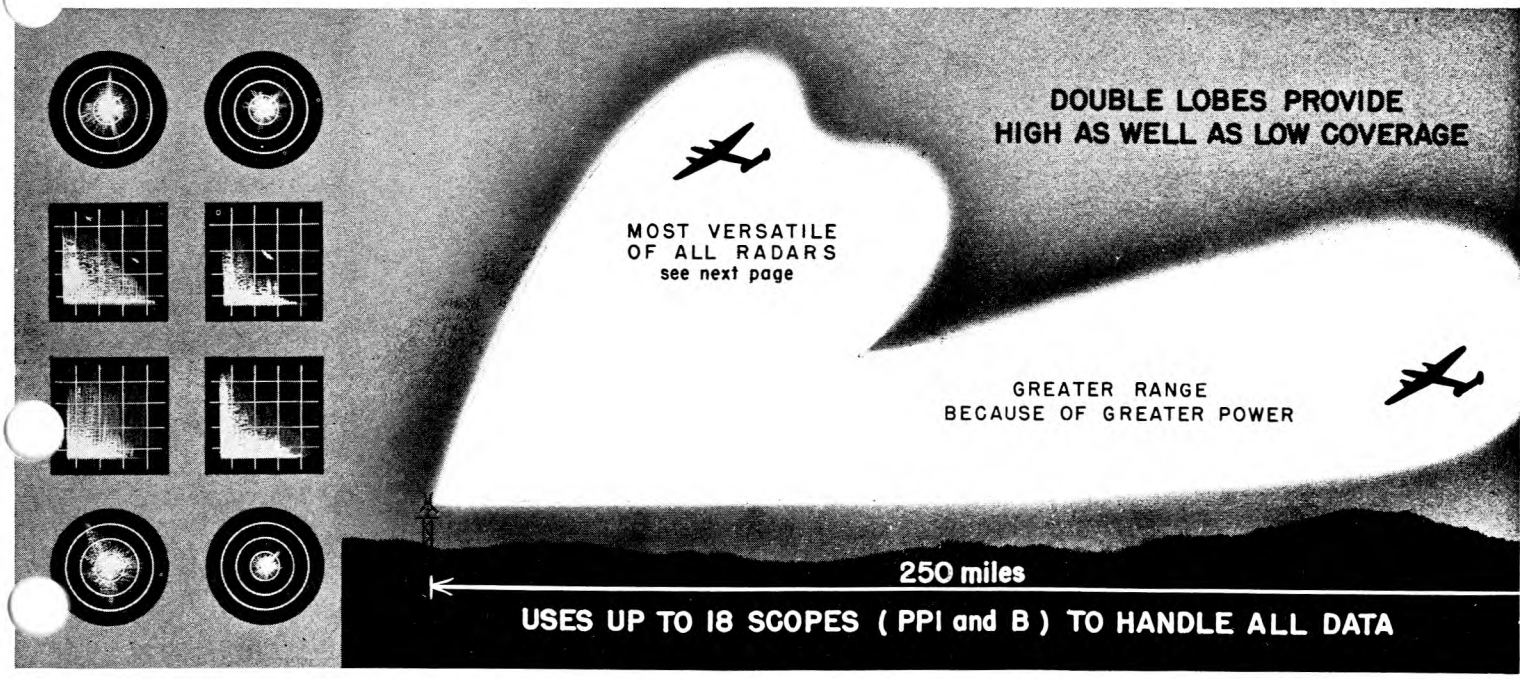


Traffic-handling capacity of MEW, which requires the use of more scopes than any other radar uses, requires also elaborate and varied equipment for display and control of data provided. Two devices are shown here. Skiatron (top above), a kind of outsize PPI arrangement, provides Senior Controller with expanded display for checking accuracy and progress of plotting. Newly-developed PPI, in which center of area scanned can be moved off-center to provide equivalent of 4 ft. scale at any given position, may take place of delicate, heavy Skiatron, particularly with mobile MEW's planned for use on Continent. Plotting table (directly above) was original display for MEW, has been supplanted by large glass screen in English installation (see pages 4 and 5) because table plotters obscure what they're plotting

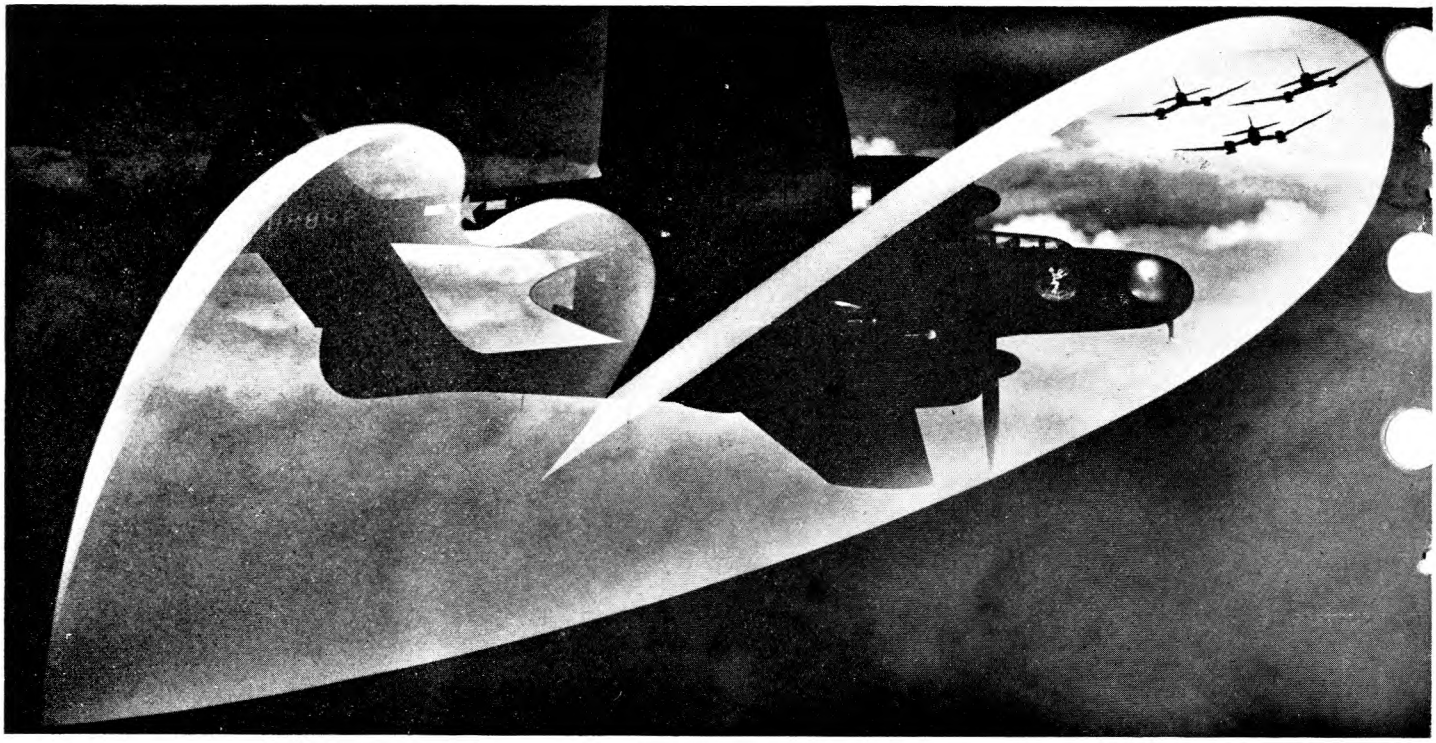
. . . but all MEW uses one formula: microwave, power, coverage



Microwave radar was successfully adapted first to airborne equipment (as in SCR-717, APS-15, etc.). For any kind of installation, air or ground, its two big advantages over longer wave sets are its higher degree of resolution and its much greater resistance to most jamming. On ground equipment these advantages are coupled with the further one that the beam can sweep very low without losing signals in ground clutter. Hindrances to the development of ground microwave equipment centered around the difficulties of building enough power into the transmitters, overcoming poor receiver sensitivities, getting adequate vertical coverage — all within a framework of providing long range needed. MEW is not first successful ground microwave equipment but has greatest range and adapts itself to most uses



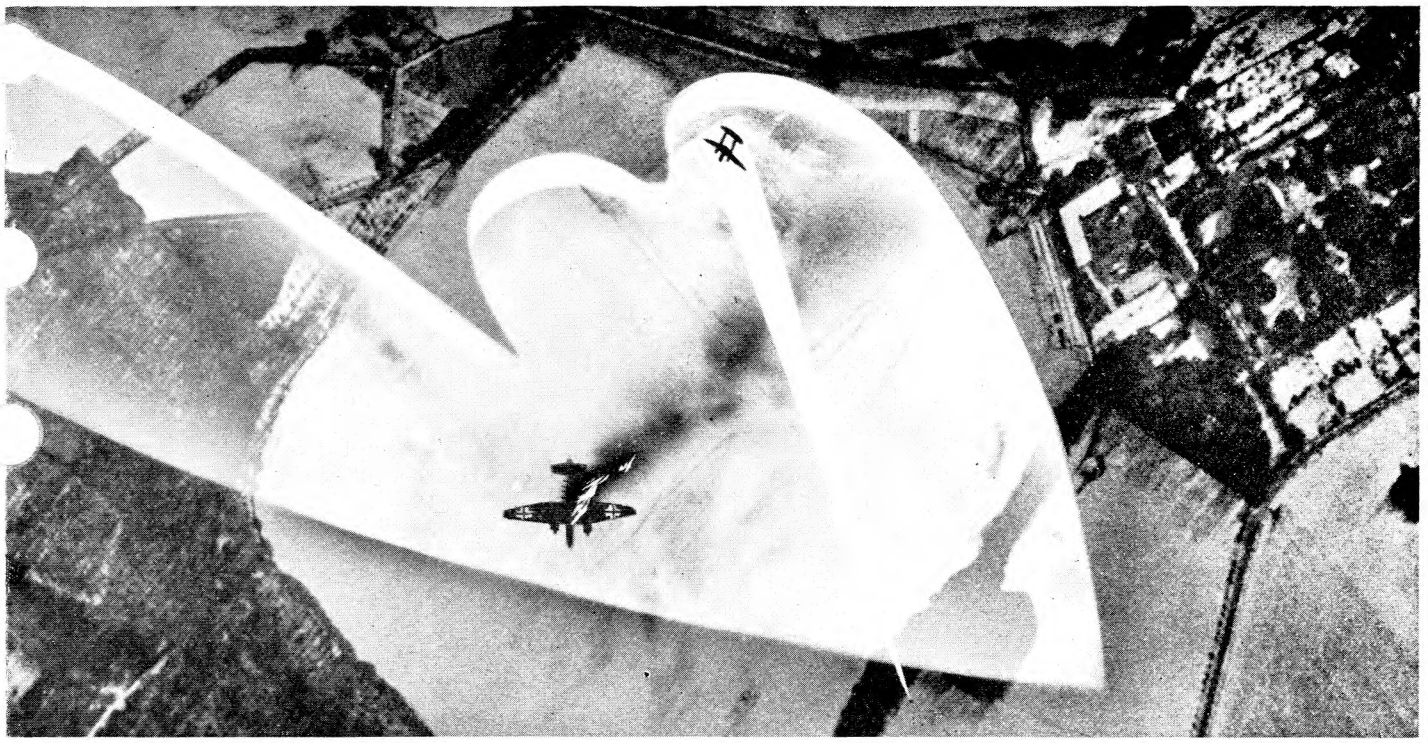
"Microwave plus" is as good a description as any of the category that MEW falls into. As the cover and the next two pages illustrate graphically, MEW is a spirited and versatile performer, and some of the factors in this performance are shown above. It is safe to say that the technical developments out of which these factors emerge will be reflected in search radar production for some time to come. On the debit side, experience with MEW to date has revealed inefficiencies in the upper beam coverage that may call for modifications; since the lower beam normally provides bulk of information this is a relatively minor debit. MEW's sensitivity to heavy overcast and rain clouds is both debit and asset: cloud return can sometimes blot out signals and reduce range, can also provide valuable meteorological data



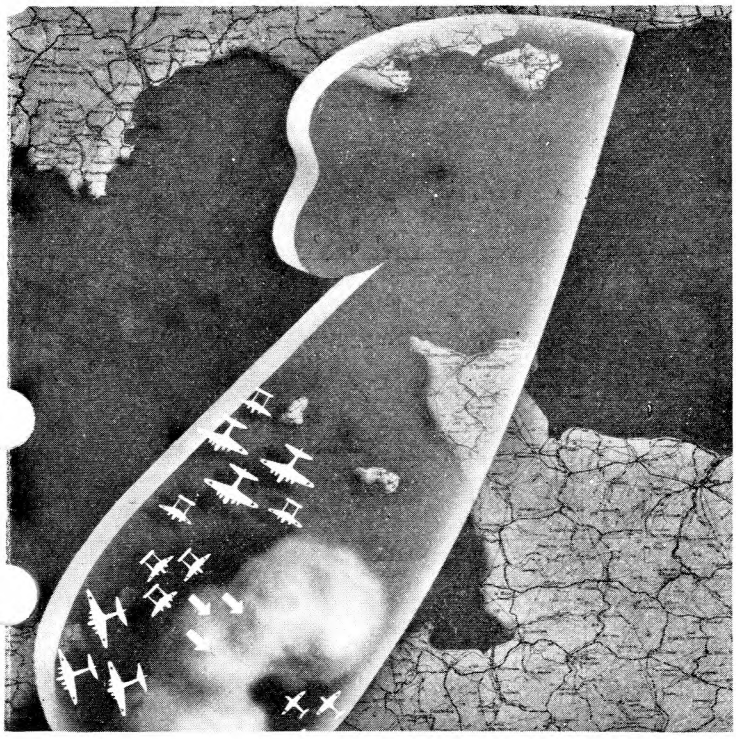
Early Warning is the basic function for which MEW was designed, and the equipment's long range and high resolution put it at the top in this class. Under good conditions MEW can pick up a heavy bomber at distances over 200 miles and at altitudes up to 30,000 feet or more, all with a high degree of range and azimuth accuracy. It can also catch and track a practically infinite number of raids at once, which necessitates allocation of the scopes to given sectors of the search area — sectors geared in size to the reading tempo of the operators; a good one can handle about a dozen plots per minute. Early warning can be a continuous operation during which control operations can go on, too



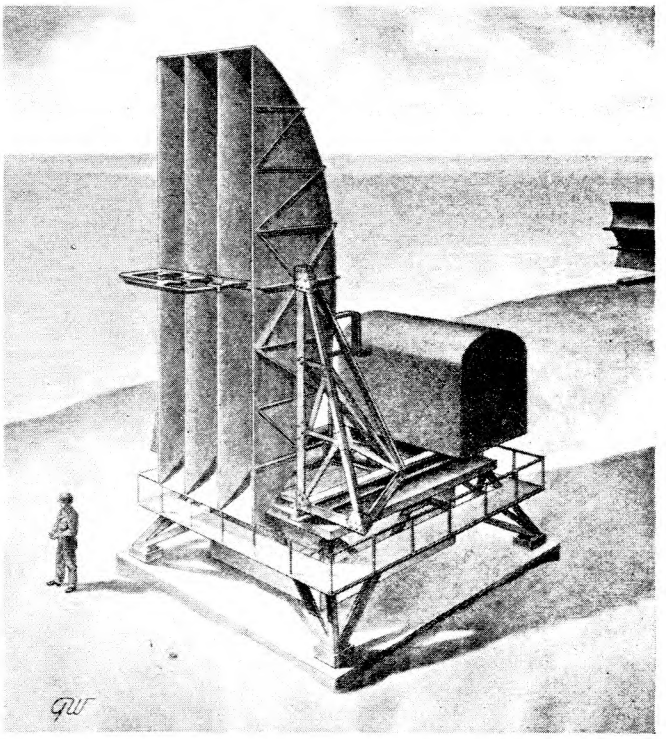
Air cover for landing operations is a function on which MEW will probably be working overtime as invasion operations — which began just as this issue of RADAR was going to press — proceed. In periods of anomalous propagation considerable stretches of Europe's coastline appear clearly on indicators of England-based MEW. Under normal conditions MEW can see all it needs to direct fighters toward enemy aircraft approaching landing area. MEW's range on small fighters may fall off from its range on heavy bombers by as much as half. But for many a cross-Channel operation this will be enough. Use of MEW for bomber direction has been tested, not yet tried operationally



Ground Control of Interception is not a job which MEW was designed to swing alone. Since it cannot determine height directly it must — with some exceptions — perform GCI work in collaboration with height finding equipment such as the British Type 24 (see below, right) or SCR-615. The exceptions arise from the fact that the height of a heavy bomber or tight formation can often be estimated with fair accuracy from the range of first detection. Such estimates provide reasonably usable data for daytime interceptions, are wholly inadequate for nighttime. As senior partner in GCI team, providing all data but height, MEW works well, though better with lower beam than upper



Fighter Direction is what the first English MEW installation has been called on to do most since it started operating. The photo-drawing on cover and above shows one type (location of station is faked): the MEW operators, seeing U. S. formation, Nazi raiders and clouds all at once, are vectoring detachable fighter escort over for an intercept



Height Finder now going into use with MEW in England is this British Type 24, an ungainly and highly effective instrument with good range and high accuracy (MEW site photo on page 3 shows it being installed). Other height finders, British and U. S., are also being used; a more maneuverable set will go with mobile MEW being readied



Find the Dinghy. Visual range on an emergency dinghy is generally not greater than about 500 yards from an altitude of 500 feet (approximately the range and altitude here) which gives a search plane only five seconds or so of flying time to see it. That's the problem

RADAR FOR RESCUES

Among the purely visual devices designed to extend an emergency dinghy's negligible visibility (see cut), some, like reflecting mirrors, are as old as dinghies. Others, like sea dyes, are comparatively recent. All of them are obviously limited.

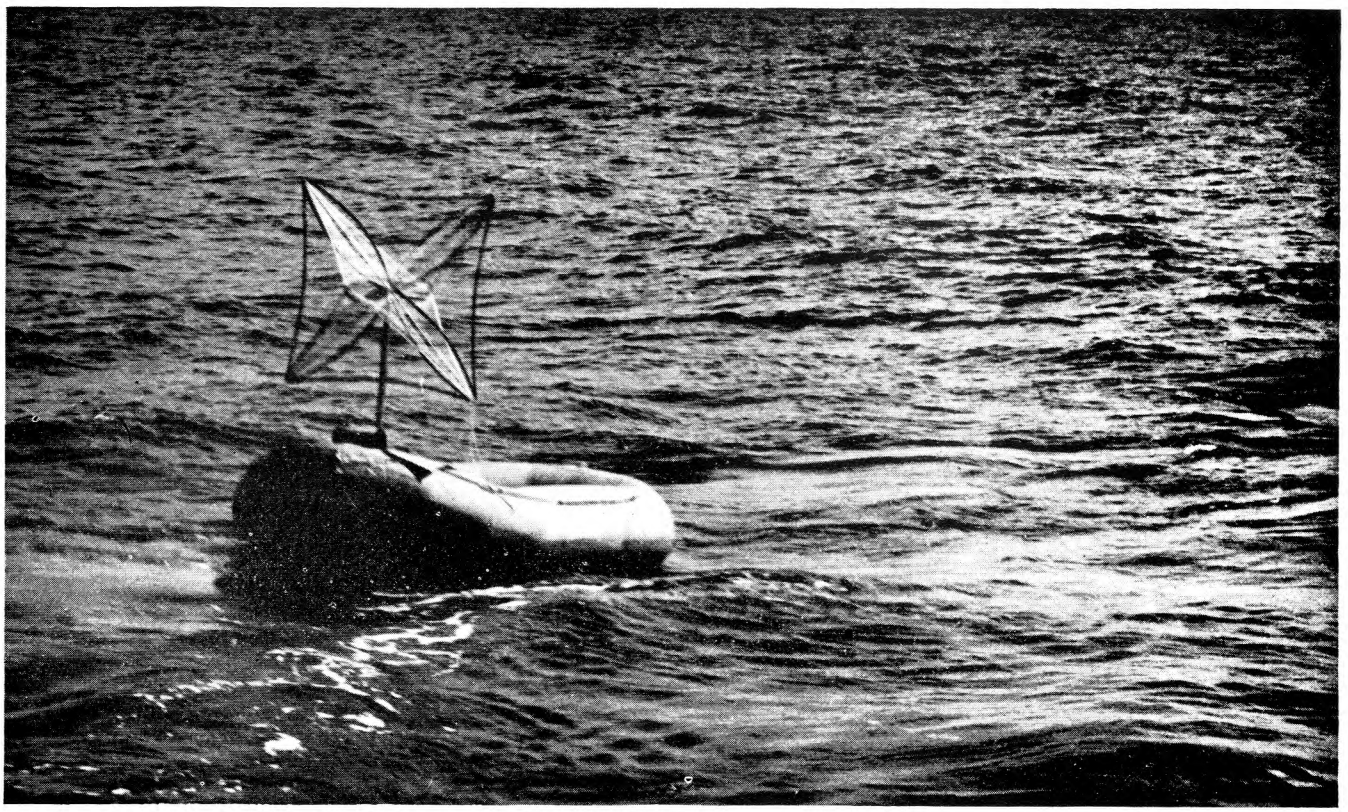
Radar's contribution to the problem is still in the making. But extensive experimental work in both the U. S. and the U. K. is far enough along by now so the outcome is beginning to take shape. It seems fairly definite that one or maybe both of two kinds of radar devices will be getting into production in the very near future. Tests are going on to set performances; but enough is known to allow a general picture. Electronic devices (radar and communications) for Air Force use are being coördinated by AAF Emergency Rescues Branch.

The one-man dinghy presents a special challenge to radar. Large multiple-seat rafts carried by all bomber and cargo planes over sea use a portable radio transmitter (Gibson Girl). But the single fighter pilot can't use equipment of this weight. The radar devices in the works now are meant primarily for the one-man type raft.

One of these two devices is a small, self-powered transmitter, a British development known generally as "Walter" (a modification of it is being worked on in the U. S.). In its present form it weighs 41 oz. and is designed for the fighter pilot's dinghy parachute pack. Search planes equipped with radar of the same frequency (British ASV Mark II, our SCR-521) can home on its signals. Though obsolete for most purposes, radars of this frequency are in fact installed in all British air/sea rescue planes.

The other device — Corner Reflector — (Corner for short) is a very light-weight, collapsible set of intersecting planes, made of metallized cloth or screen-like material on an aluminum frame. Corner's function is simply to reinforce the dinghy's radar echo which, without reinforcement, is almost negligible. Maximum detection range — which at this writing seems to be about 12–15 miles — is not dependent on altitude of the search craft but on the type of radar used, weather, sea return, etc. Corner is easily carried in the dinghy parachute pack, easily set up. It can be detected efficiently only by microwave radar, which means that widespread use would require such equipment in search craft which don't have it. Most ASV sets now are microwave; SCR-521 is not.

Though production problems affecting Walter may dictate immediate emphasis on Corner, it is likely that any decision to use one will not preclude use of the other. RADAR will report developments.



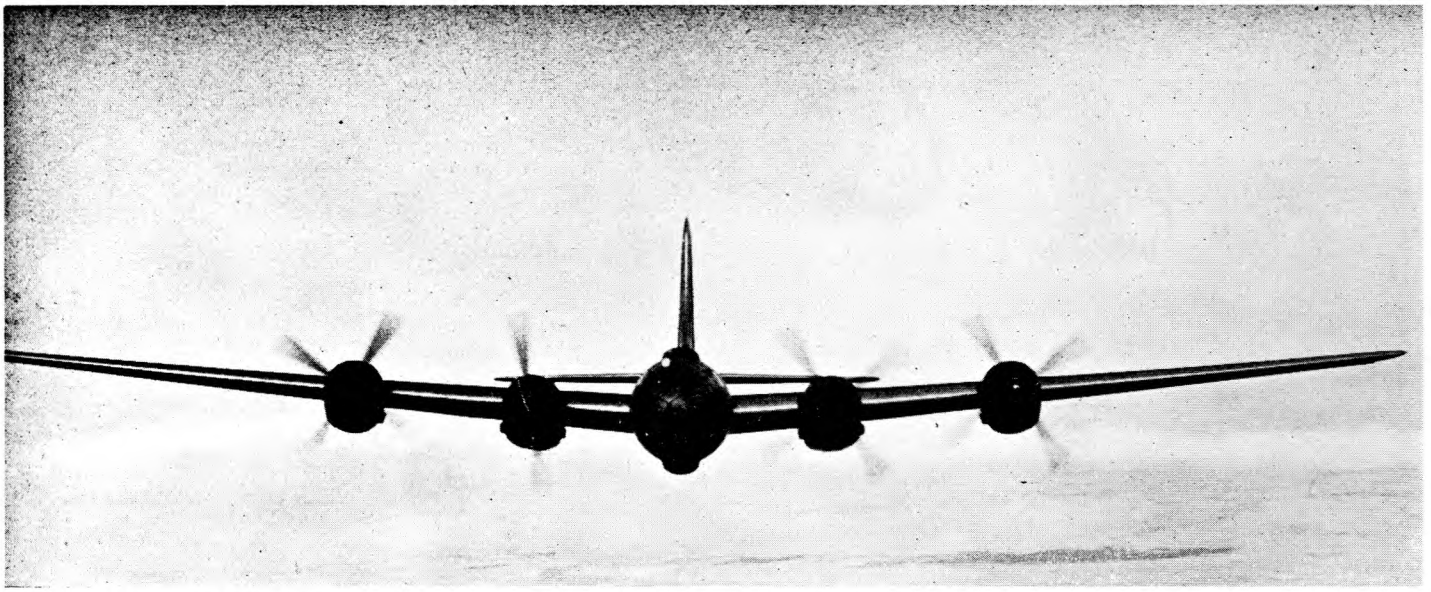
Corner Reflector (Emily to the Navy) is still subject to change, so far as construction details go. Likeliest version at this writing is one above, which weighs not much over 1 lb. Corner's signals are not distinctive, as are Walter's (see below), hence search planes can lose time tracking wrong signals. And Walter's range—limited by its own power to about 23 miles— is considerably in excess of Corner's 12 to 15 miles



Walter, sketched here in operating position, folds into a neat little package for dropping in the dinghy parachute. Its merits for sea rescue are obvious (see text) but production difficulties may hold it back



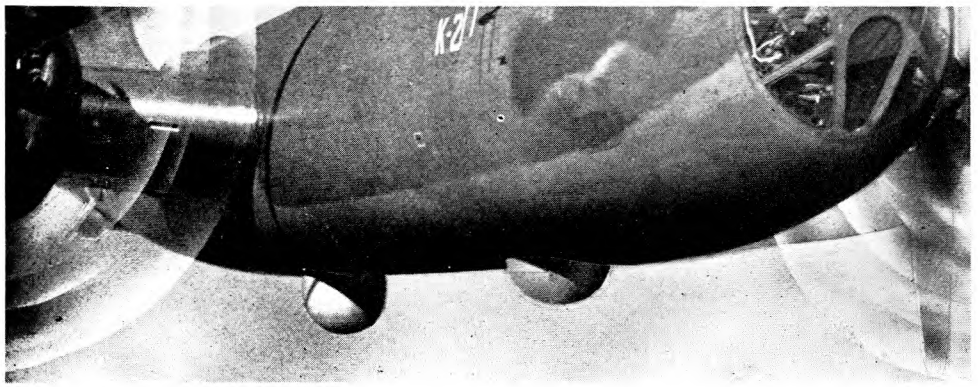
Rigid Corner, far heavier than light Corner above, gives little more range. Patterns of range for Corner and Walter are being determined by tests while problems of productiom and use are being worked out



APQ-13 (RADOME SHOWN BELOW) HELPS MAKE B-29 EFFECTIVE OVER ENEMY TARGETS, AS ALREADY DEMONSTRATED OVER JAPAN

Know-How for Radar Bombing

New Officers to provide it are trained for XXth BC

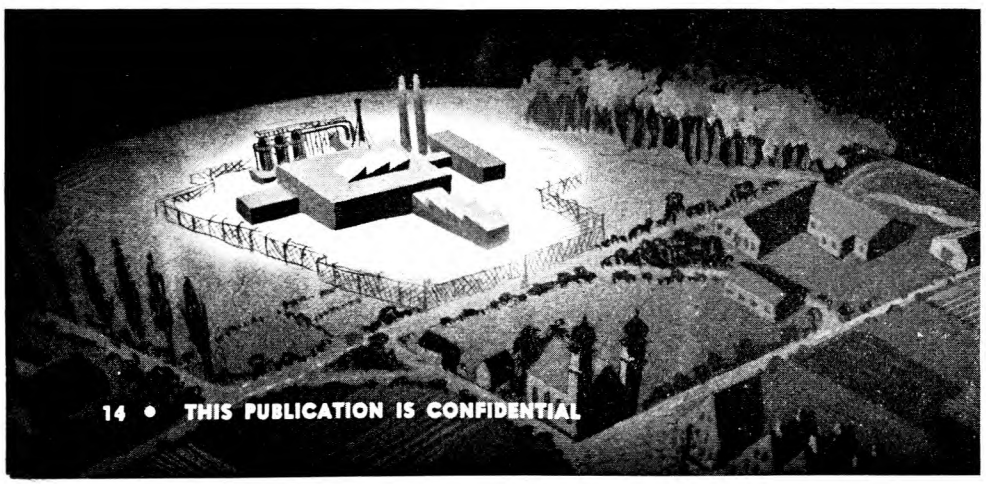


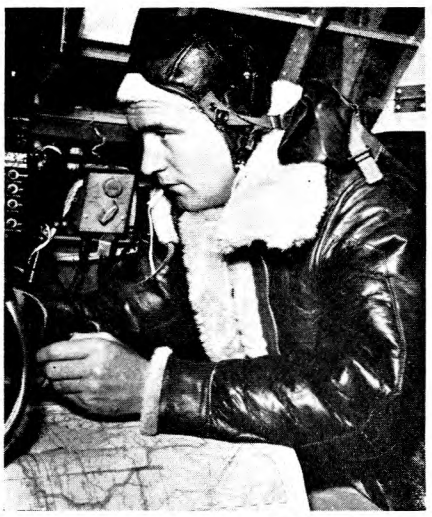
The officers pictured across the page are the newest thing in radar — the first-born of a special training project to develop Intelligence Officers to handle the problems and techniques involved in radar bombing. Their training will be over and they will move into their jobs about the time this issue of RADAR gets out. Their jobs will be with B-29's, the newest thing in bombers, and particularly with the B-29's radar equipment APQ-13, newest thing in bombing.

The beginning of all this, so far as the five Officers are concerned, came last Fall in England. It was then and there that the 8th Air Force first began to bomb through the overcast with radar in the form of the then new APS-15 (see RADAR, April). In the process of doing so the 8th discovered that radar bombing was not to be fitted neatly into normal procedures and routines; by trial and error the 8th learned that new ways had to be devised to handle the new technique. It took precious time, and it involved serious waste, to learn the facts of radar bombing by trial and error; at the time that was the only way it could be done. But the 8th's experience showed what was needed. Shortly after the XXth Bomber Command was organized, with its B-29's, training of special Radar Intelligence Officers began.

The job of these specialists will be to know the new factors that radar introduces into the bombing business, and to see that they are taken care of expeditiously in operations. If the bombing is through the overcast, navigation to and from a target must be through the overcast, too. And so the Radar Intelligence Officer will have to figure out adequate check points for radar navigation, will have to work out approaches which provide the best radar aiming points, will have to brief navigators and bombardiers on what to look for and how to recognize it. The Radar Intelligence Officers will do considerable to earn their keep, and the duties cited here are only a few. On the following pages the requirements of their jobs are outlined in some detail.

Because the work involved parallels normal Intelligence work, the Officers are attached to the A-2 Section of the XXth Bomber Command. Organizers of the training program were AC/AS, Intelligence, and AC/AS, O C & R. The Air Communications Officer did the supervising. In weeks to come more officers will be emerging from the training to take their places along with the first five, to help ensure that the most is made of radar's bombing and navigating potentialities.





CAPT. J. E. BOYD, JR.
At Washington, Salina and Bedford . . .



CAPT. R. N. NIVEN
. . . over cities, flatlands and mountains . . .



CAPT. R. G. FITZSIMMONS
. . . they trained to know for future use . . .

First Radar Intelligence Officers

. . . graduate from special crash training course

The first group of Radar Intelligence Officers (see cuts) came together in the Office of the Air Communications Officer late in April. There they got a high-speed course in fundamentals of the things they would have to know to perform the functions of radar intelligence. Specifically, they covered the following subjects: basic radar, radar scope interpretation, dead reckoning navigation, radar navigation, radar bombing techniques, the preparation of radar approach and target charts, characteristics of selected target areas.

The group then proceeded to the radar training unit of the Second Air Force in the midwest. It took daily flights, with special emphasis on high altitude, in B-17's equipped with APS-15. It studied the flat country of and around the area and it flew over the mountains of Colorado to learn how to pick check-points for over-mountain navigation. Latest radar bombing techniques were studied and put into practice on missions over several cities and towns. Radar navigation techniques and radar scope photo interpretation took much of the time between missions.

Next stop was the First Electronics Experimental Detachment at Bedford, Massachusetts. In the west most of the work had been done while viewing repeater scopes; now the Officers actually operated the radar equipment in performing various missions from Bedford, going through each of the steps required of regular radar operators on a mission. In contrast to the flat midwestern country and the mountains of Colorado, most of the targets bombed were targets along the coast. Briefing folders and target charts were prepared for Portsmouth, Providence, Boston and other targets; and then missions were flown to determine just how well the briefing material had been prepared.

For any particular mission, the following procedure was followed: First, radar briefing material, target and approach charts were prepared for the particular target selected, without benefit of any scope photographs of the target area. Second, the mission was performed, and radar scope photographs taken during it were analyzed to determine how well the mission was accomplished. Third, using the scope photographs obtained on the first mission, a second set of briefing material was prepared. Finally, another attack using the new material was made, and results compared with results of the first mission.

Thus, in highlights, the record of the crash training that produced radar's first Intelligence Officers. On the next page are more explicit descriptions of six major items in the curriculum.



1ST LT. A. H. NORDHAUSEN
. . . what many an 8th AF operator . . .



2ND LT. R. A. RUCKMAN
. . . had to learn himself by trial and error

Here are six things a Radar Intelligence Officer has to learn

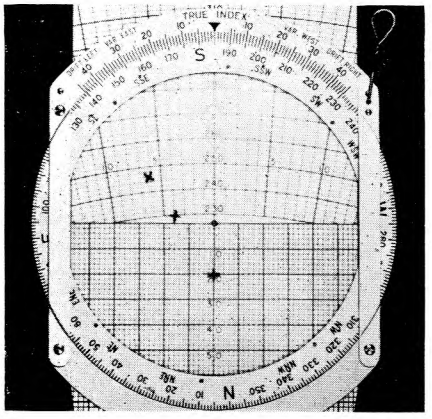
● He learns more than is described below, but these are high-points of special training project worked out for XXth Bomber Command. Following five pages give more detail on two of subjects: Radar Photo Interpretation and Radar Navigation



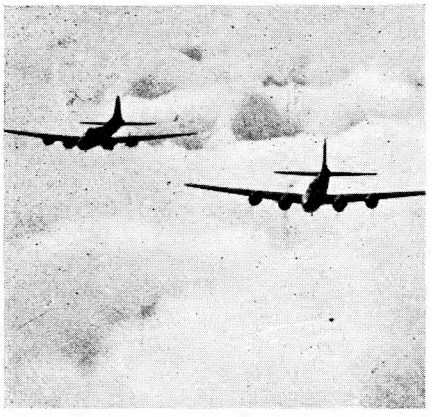
RADAR EQUIPMENT for bombing through the overcast allows the employment of new tactics and operations against the enemy. At the same time, it has definite limitations which must be understood and taken into consideration in the planning of missions. The Radar Intelligence Officer must know from actual experience just what these limitations are. He gets it from flying with the equipment, pinching and poking it to get its feel, learning to make like a radar operator. In the end he must be able to monitor the radar briefing material so that it will reflect the point of view of the radar operators.



RADAR NAVIGATION is an important part of radar bombing. Successful navigation to the target area depends very largely on the selection of a route which will pass near good radar check points. The Radar Intelligence Officer must be able to pick them. Whenever the aircraft passes near a good radar check point, the radar equipment may be used to determine wind. So methods of wind determination by radar, using the standard E-6B computer, must be understood by the Radar Intelligence Officer and applied to planning of missions (see page 21 for sample).



RADAR BOMBING techniques differ widely from the techniques associated with visual bombing. Radar bombing is much more difficult, requires careful and precise planning before each mission. Details of the actual target are often not discernible, and the bombing must then be done with reference to some recognizable object in the vicinity. When this is necessary, the Radar Intelligence Officer must work out special tables and course beforehand to enable the radar operator to release his bombs at the right instant. Much training time goes into the study of all the relevant techniques.



HIGH ALTITUDE operations with their attendant cold and fatigue, often make even the simplest calculations and operations assume gigantic proportions. To understand the degree of simplicity required in any work which must be done by the radar operator, the Radar Intelligence Officer must have a number of hours of high altitude flying to his credit. While flying at high altitude, the Officer must make attacks on a variety of targets, so that he will go through each and all of the operations which are required of the radar operator on an actual combat mission.

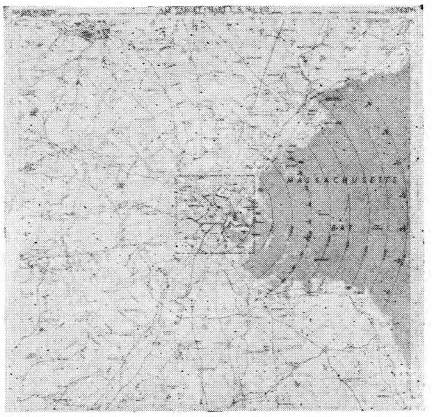
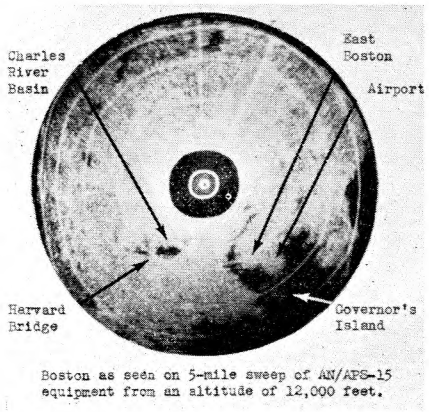


PHOTO INTERPRETATION is basic to effective radar operations. From radar scope photographs taken on previous missions a trained interpreter can obtain valuable information which will aid and simplify the task on future missions. Often the only way in which the success of a mission can be judged is by careful analysis of the radar scope photographs taken on the bombing run. The Radar Intelligence Officer is trained to develop all the skill he has in radar scope interpretation, must in addition to that know something about the techniques of scope photography. On next four pages: a portfolio of scope photos.

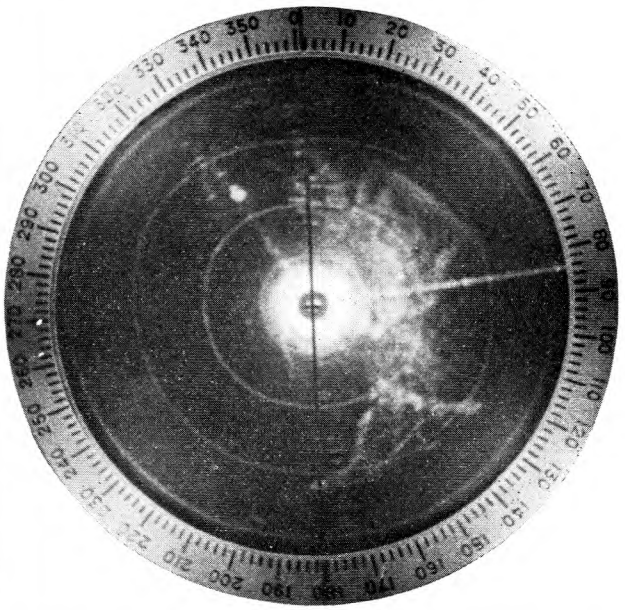


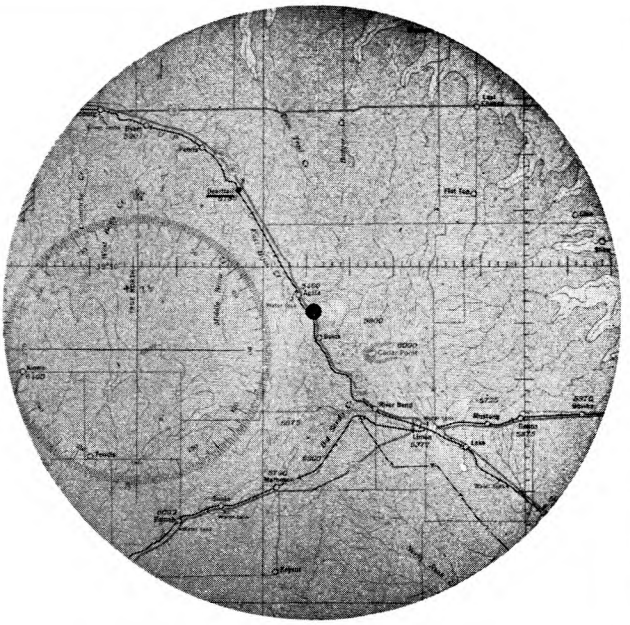
Boston as seen on 5-mile sweep of AN/APS-15 equipment from an altitude of 12,000 feet.

TARGET INTELLIGENCE of all the important targets in the intended theater of operations must be part of the required knowledge of the Radar Intelligence Officer. An important part of the training is designed to make him thoroughly familiar with the details and geography of each target area, prepare him to know just how well each target can be attacked by means of radar. He must compile radar target charts for the most important targets in the area covered, showing the best method and angle of attack and the most useful radar check points which can be used on each of the missions flown.

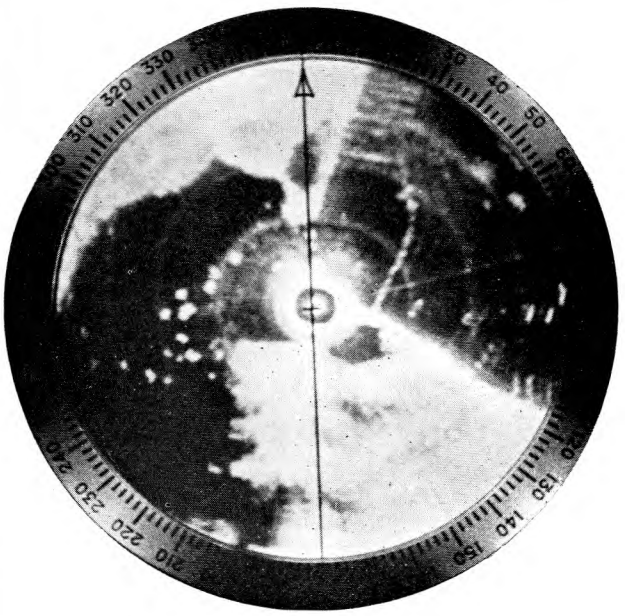
It takes practice to interpret a radar scope: these are cities

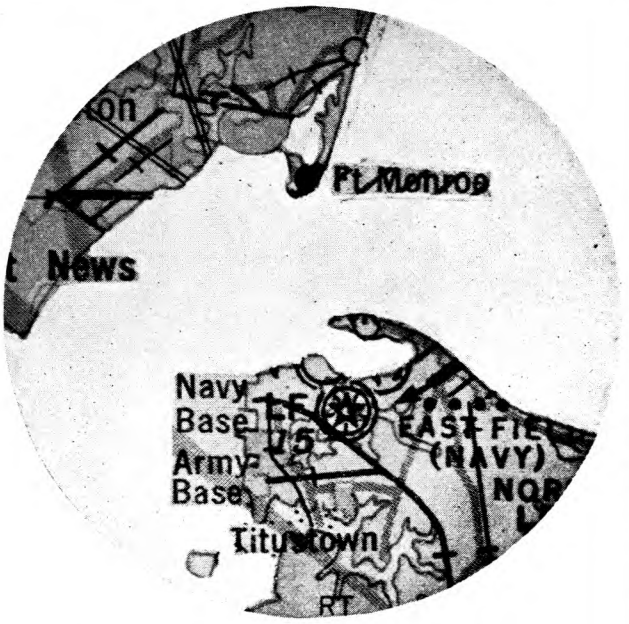
● Scope interpretation is vital in many functions of Radar Intelligence Officer, hence looms large in his training program. Cities show up bright in contrast to surrounding land when radar is properly adjusted, serve as good check points on missions.





Deertrail, Colorado, appears here brightly to the NW. Note "Cardinal Point Effect" in series of dots bearing 175°. This indicates magnetic variation may not be properly set into flux gate compass. Highway appears clearly at bottom cutting bend of railroad

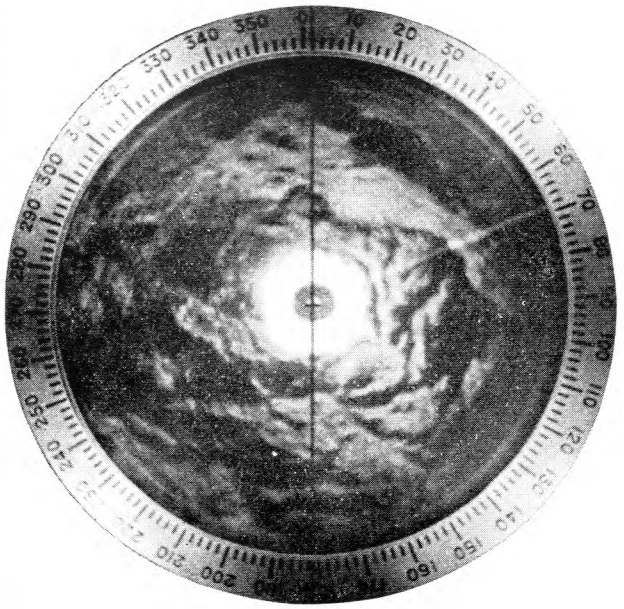




Low altitude photo shows built-up areas at entrance to Hampton Roads. Submarine nets guarding entrance are sharply visible at right; ships and docks within the anchorage can be seen in large numbers. Most of this area is built, giving strong contrast to water

These are mountains

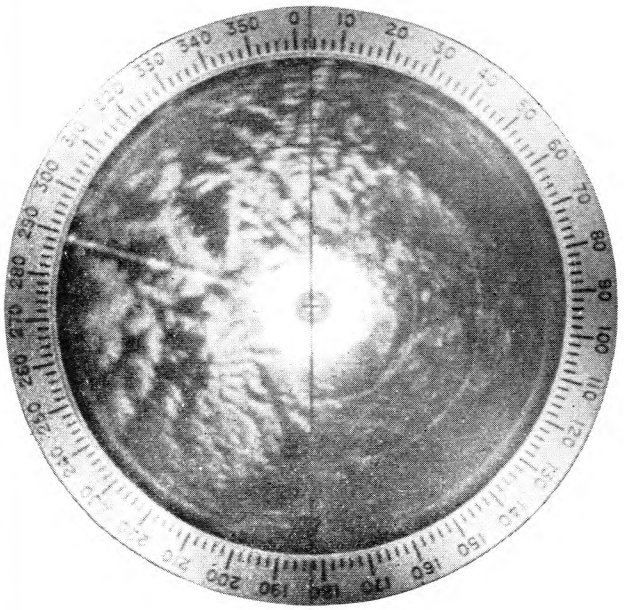
● Mountains often show characteristic patterns which can be used as radar check points. Dark areas are radar shadows; near sides of mountains reflect strongly, hence are bright. Dark area coming from shadow of isolated ridge can be distinguished



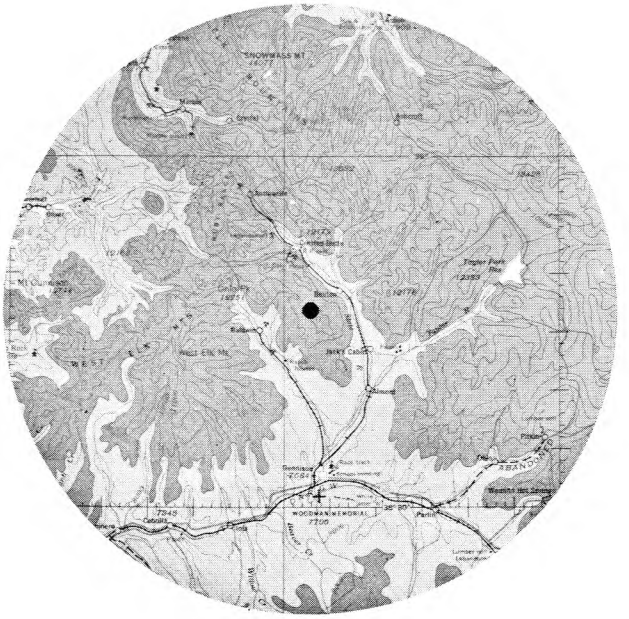
This scope photo taken over Colorado Rockies turns up several useful check points for trained observer. Most recognizable pattern



for future reference is probably distinctive shape of bright signal returned from steep slopes on north bank of curving Eagle River



Taken over another section of Rockies, this scope photo is notable for sharp triangular shadow caused by canyon beyond ridge. The



shape appears at wide range of positions, serves as excellent check point. Radar is more informative than map on such conformations

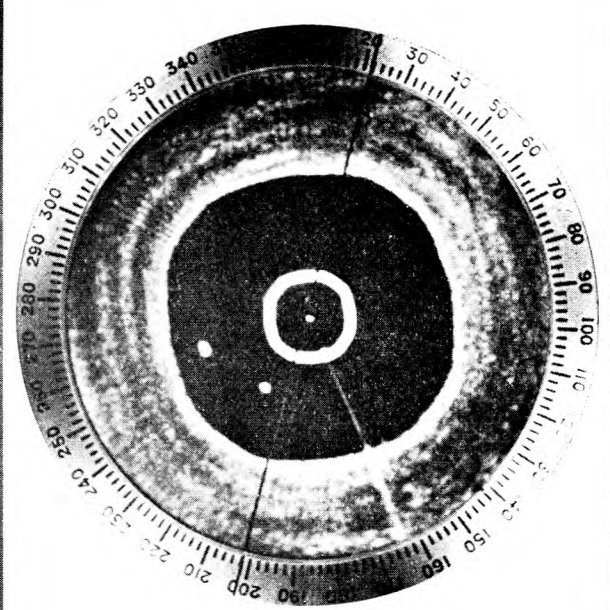
from dark area caused by wide river if basic rule is applied: near side bright means a ridge, far side bright means a river.

These are bombers

● Radar's uses in formation flying have just been touched. The two scope photos below are among the first of their kind.



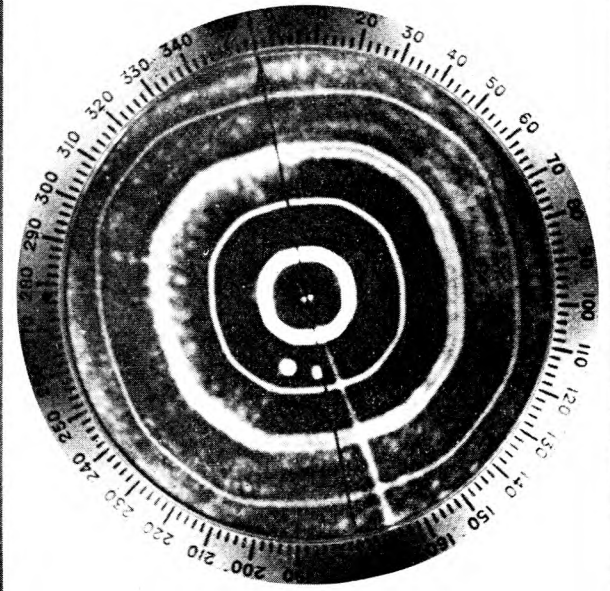
Relief model of area, used for training by XXth BC and also for Intelligence Officers' course, resembled map and photo strongly



The two companions (B-17's) to plane from which this photo was made are clearly visible at ranges of about 1 and 1.5 miles



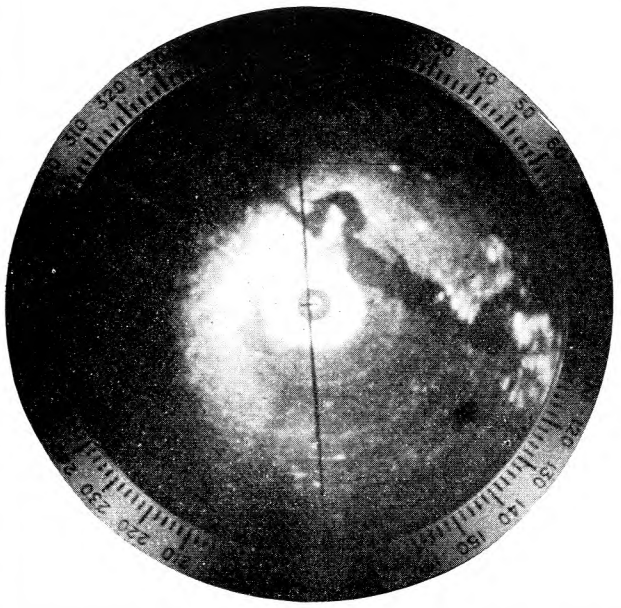
Relief trainer, which jibes closer here than above, can furnish checks for areas not flown over. Its use will be reported in early issue



In this photo the planes have moved ahead and together. Operational use of radar in formation flying is untried but promising

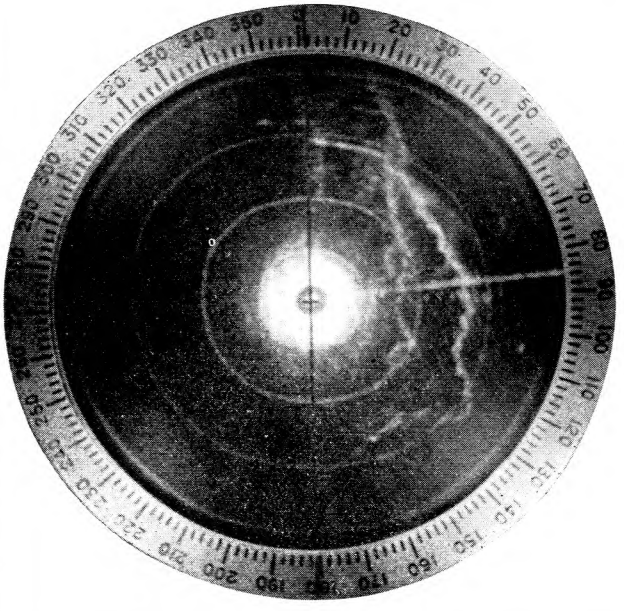
These are rivers

● Rivers provide easily recognizable radar pictures. Radar beams glance off water, are not reflected back to aircraft. Land gives good return and river bank is outlined by contrast. But small river and large river may show up differently, asphotos below show.

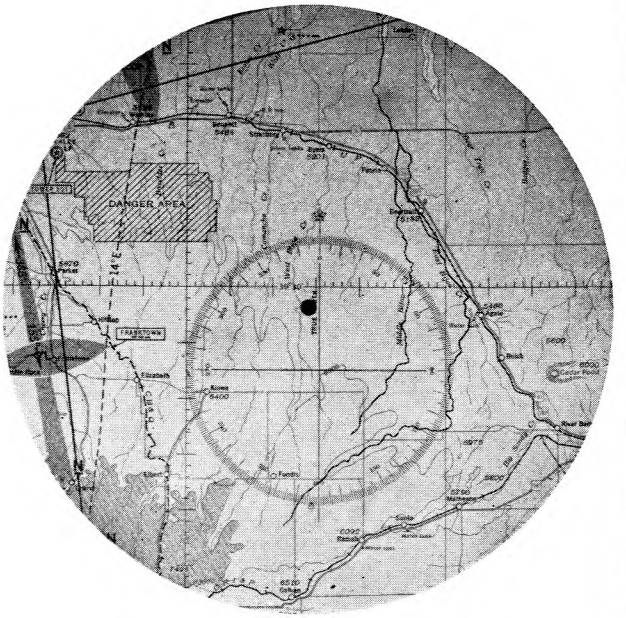


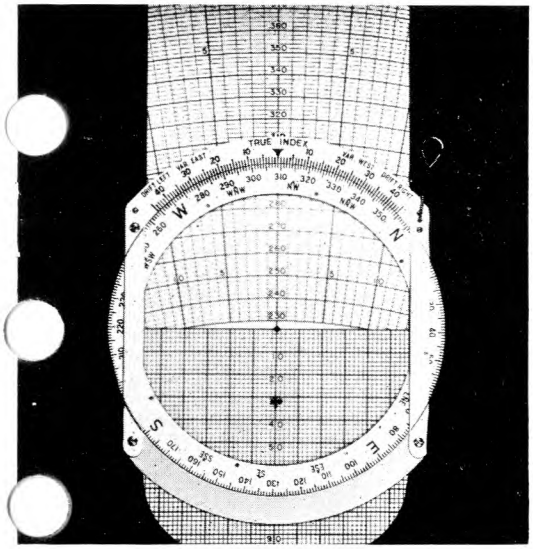
James River from 15,000 feet is crystal clear and typical example of broad river. Also clear in this photo is sharp contrast of Norfolk and Newport News compared to land and water masses around them. Spot north of Newport News at 75° is reflection of Langley Field



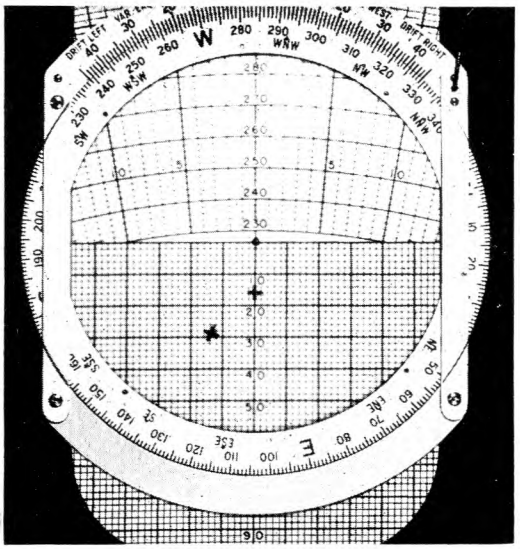


This little river — forked Bijou Creek, southeast of Denver — is as typical of its type as James River of its. Flatness of land (giving poor return) plus sharp cut banks make the response bright. Straight line visible at top is combination of highway and railroad

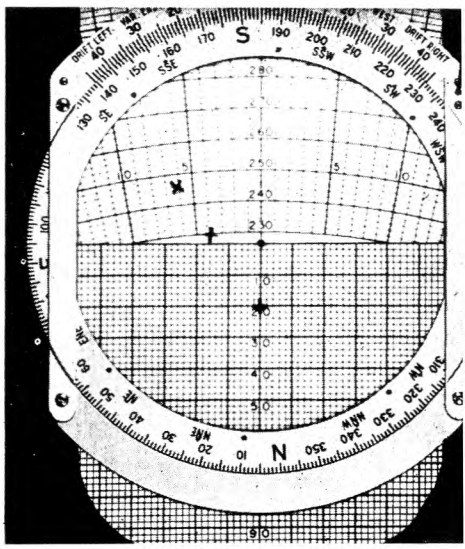




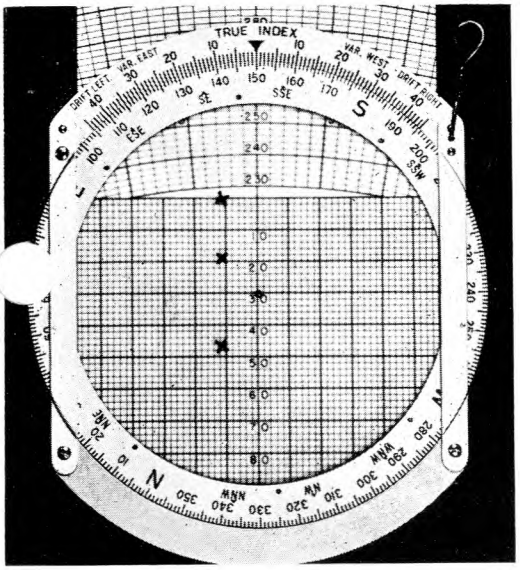
1 On this standard E-6B computer small circle at center of plotting disk represents radar signal. Plotted at first observation (20-15-10), signal shows at 32 naut. miles, bearing 309°T



2 At 20-22-20 plane's position has changed so that the radar signal now is seen at 16 nautical miles, bearing 284°T. As second step in problem, make plot for this as illustrated above



3 Final observation on this signal is taken at 20-32-21 and at 20 nautical miles, bearing 185°T. Rotate disk and plot this position. All three points plotted lie on plane's actual path



Radar Officers learn how to use standard E-6B computer to estimate wind by radar

Dead reckoning navigation, one of the things a Radar Intelligence Officer has to know, requires knowledge or determination of wind direction and velocity. Under conditions of good visibility the knowledge can be acquired by making a double drift determination. When visibility is poor the navigator must rely entirely on forecast winds with the consequent chance of large errors — unless he knows how to do the job with radar.

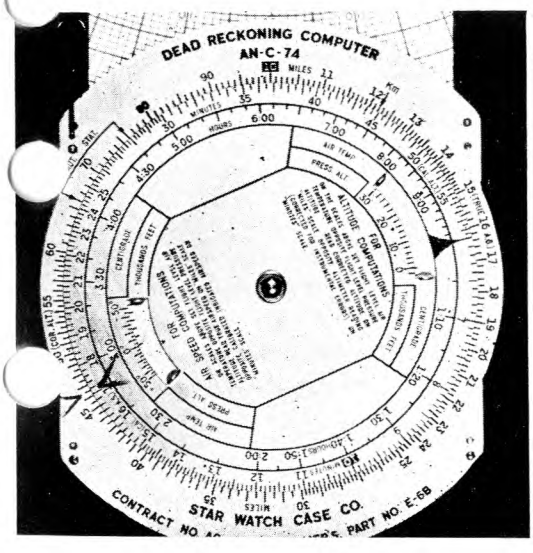
By allowing a series of observations on range and bearing of a ground object, whatever the conditions of visibility, radar has made itself a potent aid to DR navigation. And wind determination by radar is even simpler than it is by visual methods. The double drift method calls for changes in course but radar wind determination does not.

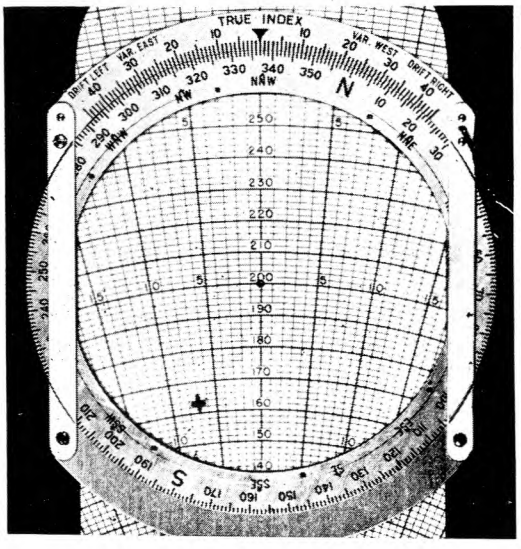
On this page a typical problem in wind determination is set and solved, precisely as it was worked out by the five Radar Intelligence Officers whose training is described on preceding pages. Heading is taken to be 337°T and the T.A.S. (True Air Speed) to be 200 knots. Grab an E-6B and work it through for yourself.

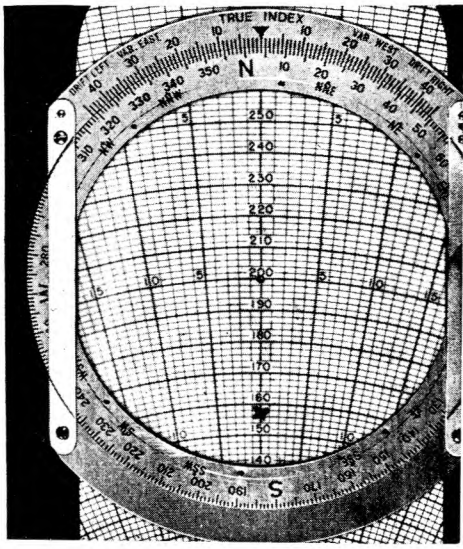
4 Line up plots with axis to get plane's track: 150°T+180°T=330°T, or 7° left drift. Distance traveled shows as 46.5 naut. mi. Ground speed is now computable (below): 163 knots

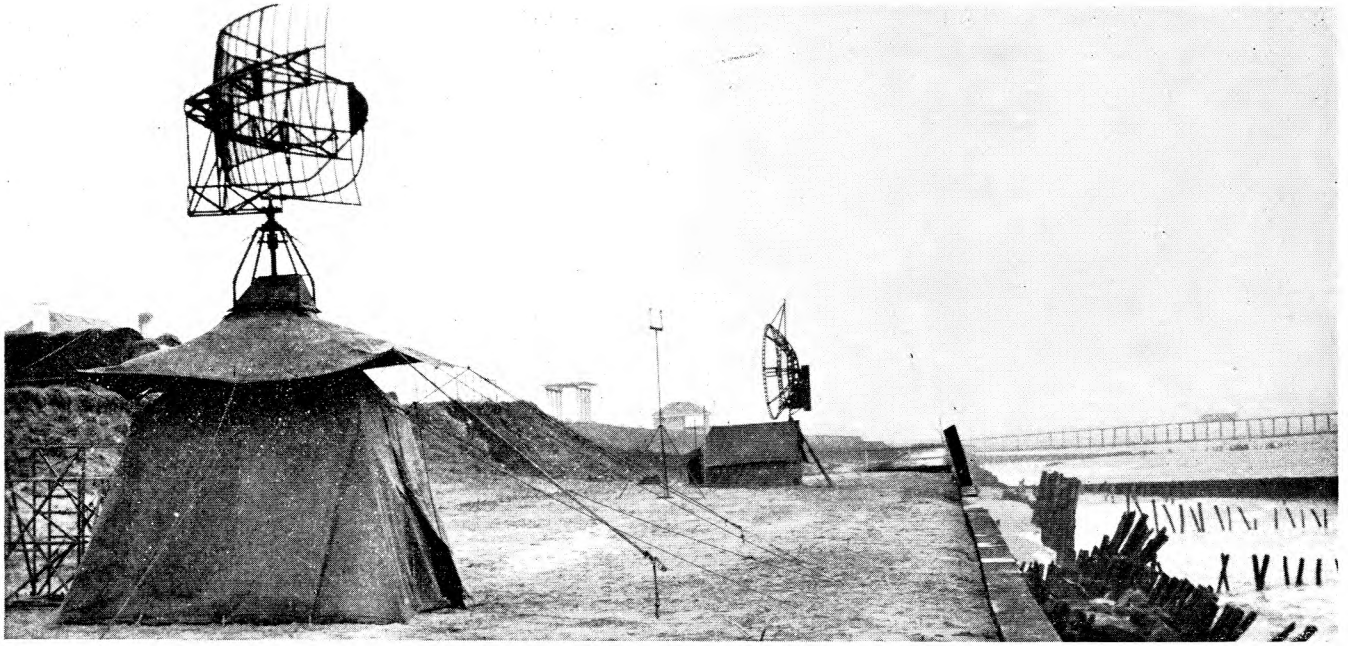
5 To obtain wind, set center of plotting disk at the T.A.S. of 200 knots and heading of 337°T. Ground speed can then be plotted on 7° left drift line at 163 knots ground speed

6 Difference between air speed vector and ground speed vector is wind vector. Rotate disk to bring wind vector into line with axis. Wind is shown to be 43 knots from 04°T









TPS-1 AND -3 ARE SHOWN HERE AT TEST SITE. PRE-PRODUCTION MODELS PROBABLY ACCOMPANIED FIRST TROOPS INTO FRANCE

Portable Radar Gets Better

About the best way of all to give a beachhead aircraft warning protection is to put several thousand friendly planes in the air over and around it. That was the situation with the beach head staked out on the Normandy coast. And along with the biggest air cover in history that beach head also had the watchful eye of MEW (see pages 3 to 11) looking out for it. From less than 100 miles in back of the beach head MEW's range was enough to cover more than 100 miles beyond.

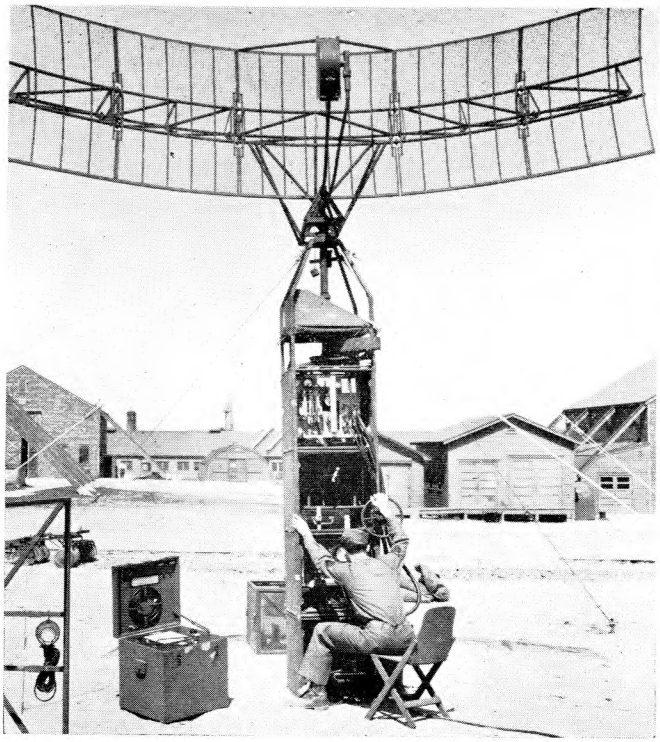
That's a fine setup if you can get it. It happens about as often as the invasion of Europe happens. The boys who ploughed ashore to set up beach heads at New Britain, New Guinea, or even Salerno, had very much less. Many a beach head has been established without any more protection than could be provided by what was carried along.

For its work on such occasions the portable search equipment known as SCR-602A has made a good name for itself from North Africa to the South Pacific. It has been around and it has done a lot of early warning (for one job it did at New Britain, see RADAR, May) but range has been limited, susceptibility to jamming high, low-angle coverage not too hot and raid-handling capacity small.

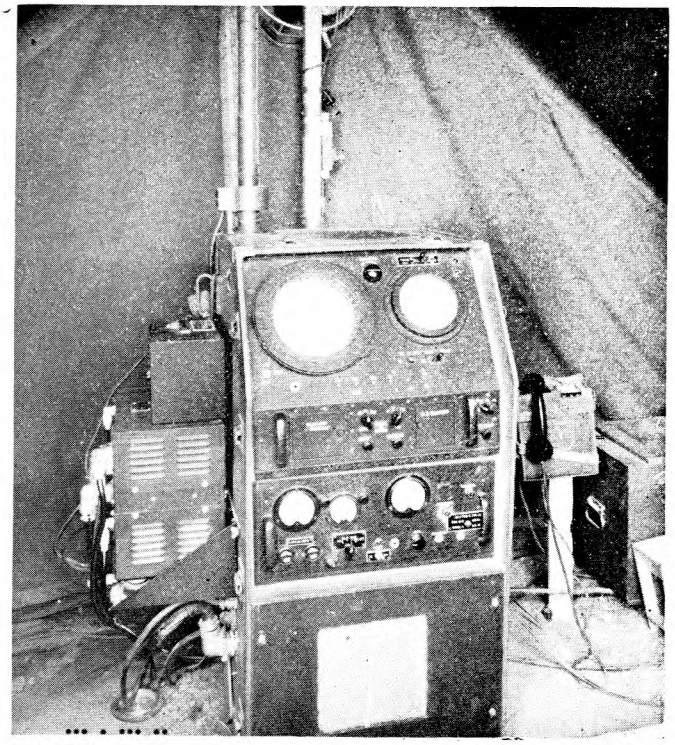
Something better is now available in the form of a whole new family of radars — AN/TPS-1, -2 and -3. In limited production now, these sets will take over from 602A in months to come and, for that matter, early models probably worked on D-day for all the air cover. On these two pages RADAR discusses the equipment briefly.



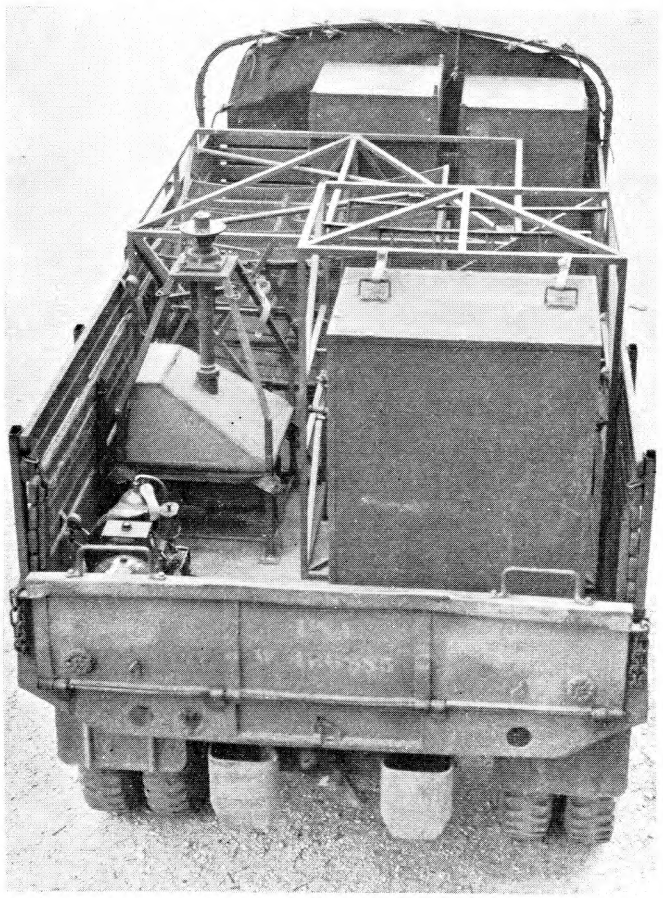
Portability and light weight are achieved by all three TPS sets at some sacrifice of durability and performance. TPS-2 sacrifices most but whole works (except spares) can be thus carried by 8 men. Total weight is about 700 lbs., to TPS-1's 2,300, TPS-3's 1,600



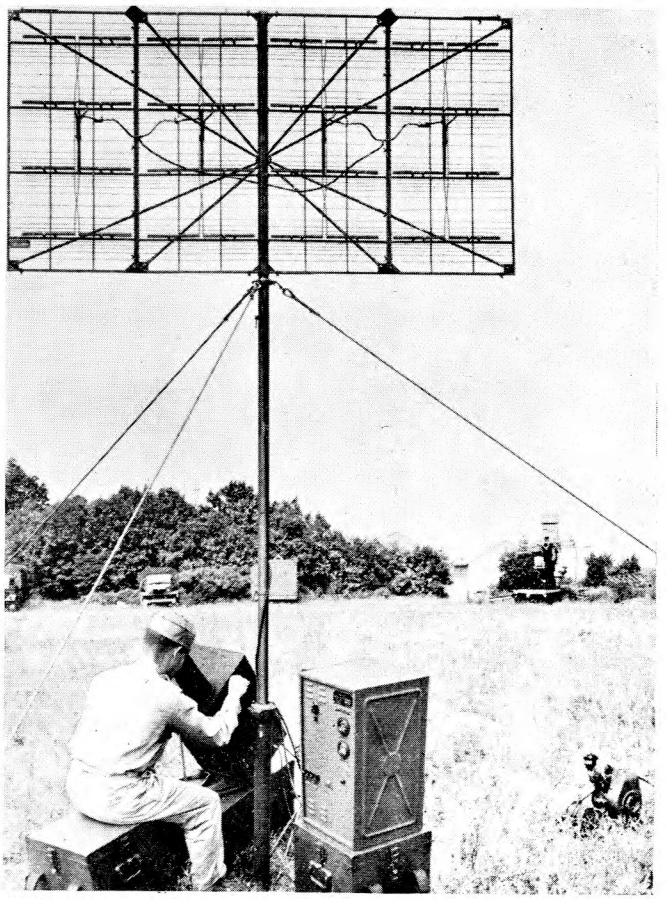
TPS-1's narrow beam enables high raid capacity. Low back and side radiation simplifies siting. Both, plus high frequency, cut jamming



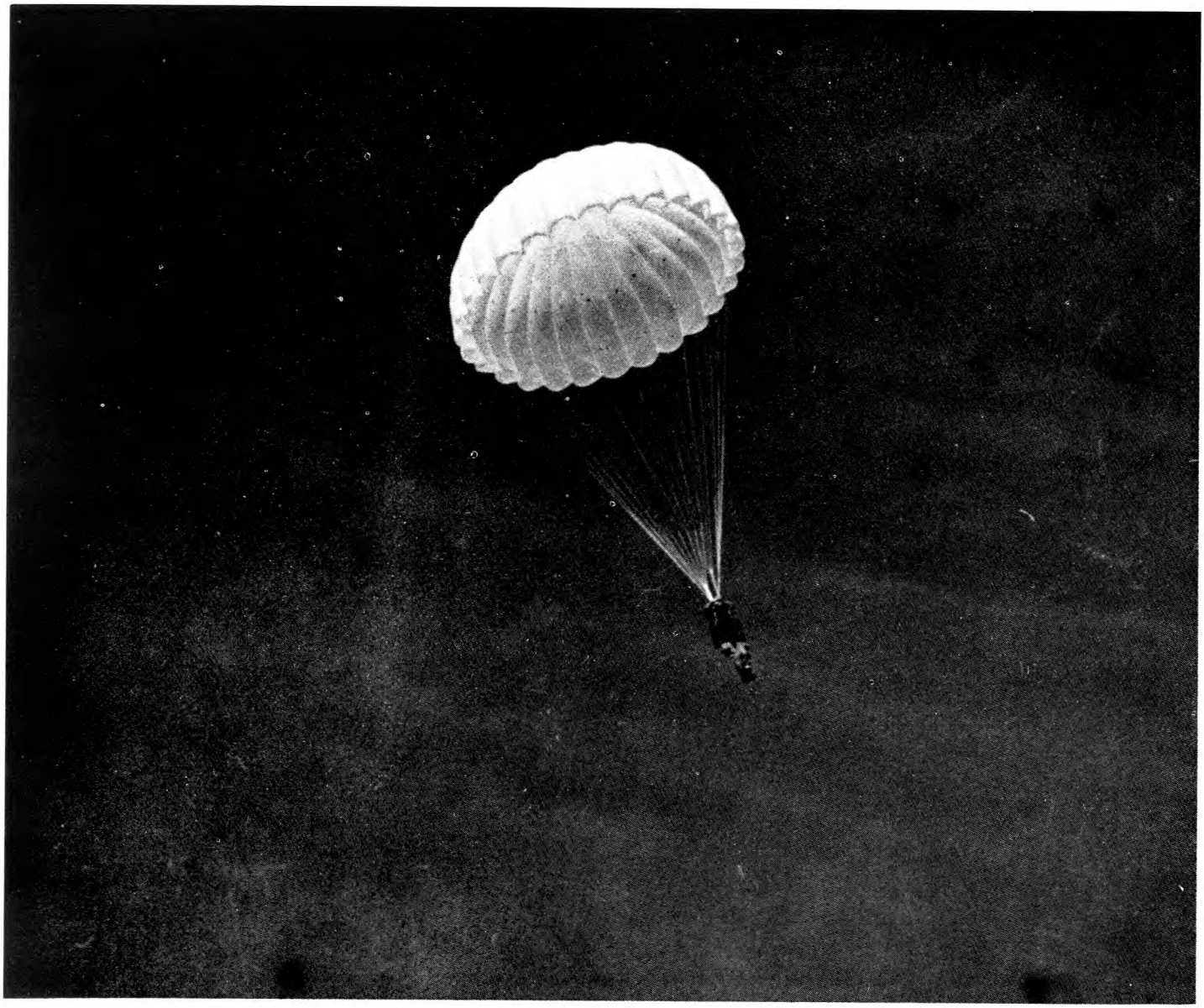
TPS-3 has longest range (over 100 miles to TPS-1's 70 odd, TPS-2's 60) and 7″ PPI. TPS-1's 5″ PPI is due to be enlarged to 7″ in future



Components of TPS-1, packed for transport in 19 cases including spares can be carried in army truck shown, also operated from truck



TPS-2 has no IFF, no PPI, no automatic rotation, but 2 men can operate it (4 for others) and it can be set up to operate in 20 minutes



TROOP CARRIER COMMAND PHOTO TAKEN FOR RADAR SHOWS PARATROOPER FLOATING DOWN WITH EUREKA STRAPPED ON

TROOPS BY AIR

9th Troop Carrier Command had every navigational aid in the books on D-day

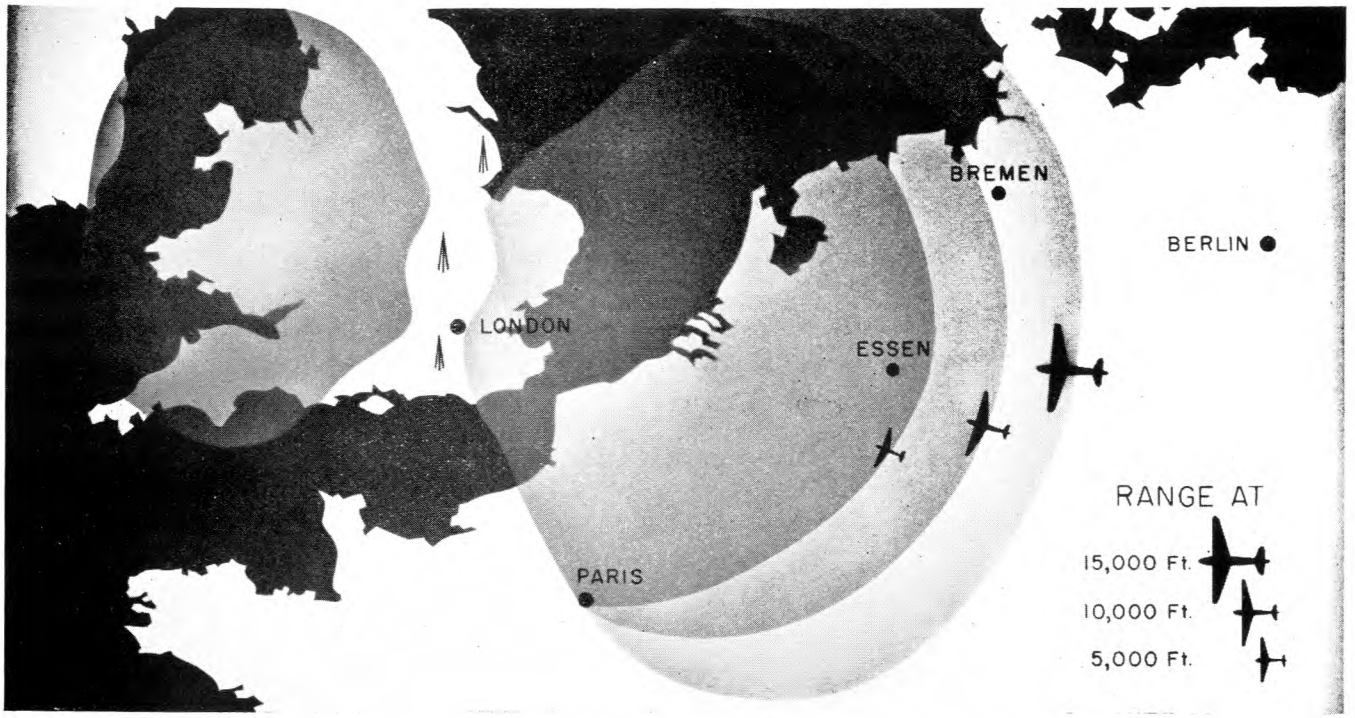
LONDON, June 7 — *More than 1000 troop-carrying aircraft at dawn yesterday dropped the largest airborne force in history into France.*

When the time is night, the terrain hostile, the cargo a load of paratroopers and the destination a Dropping Zone not much bigger than a football field, a troop carrier operation is one of the world's most ticklish jobs. Since those are usually the conditions the job is usually just that ticklish. And those were precisely the conditions at dawn on the 6th of June — plus very poor visibility.

It is no secret that troop carrier operations were done badly in early Allied attempts. In two operations against Sicily, 50% of the airborne soldiers failed to reach their goals. Nor were these the only failures by a long shot. The reasons were varied: inexperienced operators, inadequate amounts and quality of equipment, faulty plans, uncertain navigation. In the early days such factors had inevitably to affect the picture. But they did not apply on D-day. A lot of work had been done, a lot of equipment installed, to cut them out of the picture.

At the bases of the 9th Troop Carrier Command in England every navigational and directional aid in the books had been called on and tuned up. The force of transport planes which took off for France — Pathfinders to lead the way, carriers to follow with men by the thousands — flew their courses with more to guide them than had ever been dreamed of in earlier operations.

It is too soon to know full results of this biggest troop-carrying job or to know, in any detail, the ways and means by which it was actually done. On the following five pages RADAR reviews the tools which the 9th Troop Carrier Command had for the job, tells briefly of their operational qualifications for what they were called on to perform the 6th of June.



British Gee System played basic navigational role in 9th TCC operations. Approximate coverage of original chain of transmitters is shown (our Loran system is modeled after Gee). Other chains have been added in England and one is in Mediterranean. Gee transmitters (master and two slaves) send pulses to airborne receivers. Measurement of time difference in arrival of pulses enables planes to plot fixes on special maps. British supply ground service, have equipped all their bombers, turned over several thousand sets for U. S. planes.

The 9th TCC's navigational equipment for the D-day operations, accumulated over many months, added up to this:

1) GEE — basic British navigational system.

2) SCR-717C — microwave search equipment.

3) Rebecca-Eureka — interrogator & beacon system.

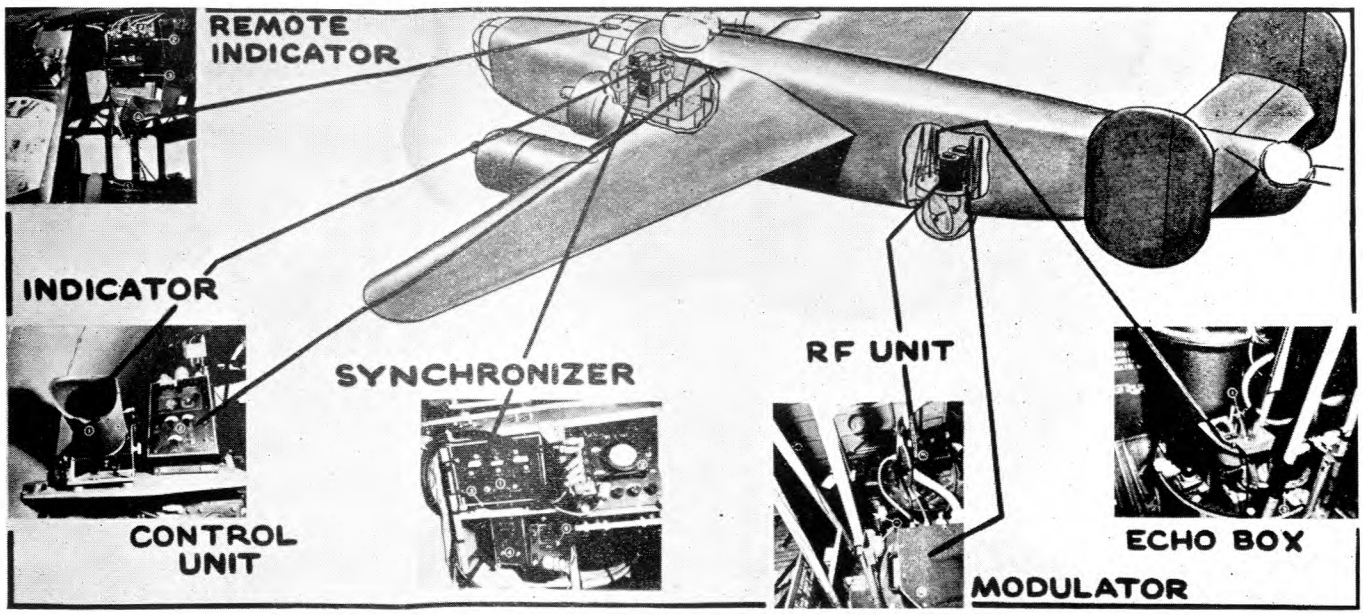
4) BUPS and BGS — small marker beacons for use with SCR-717C.

5) APN-1 — altimeter.

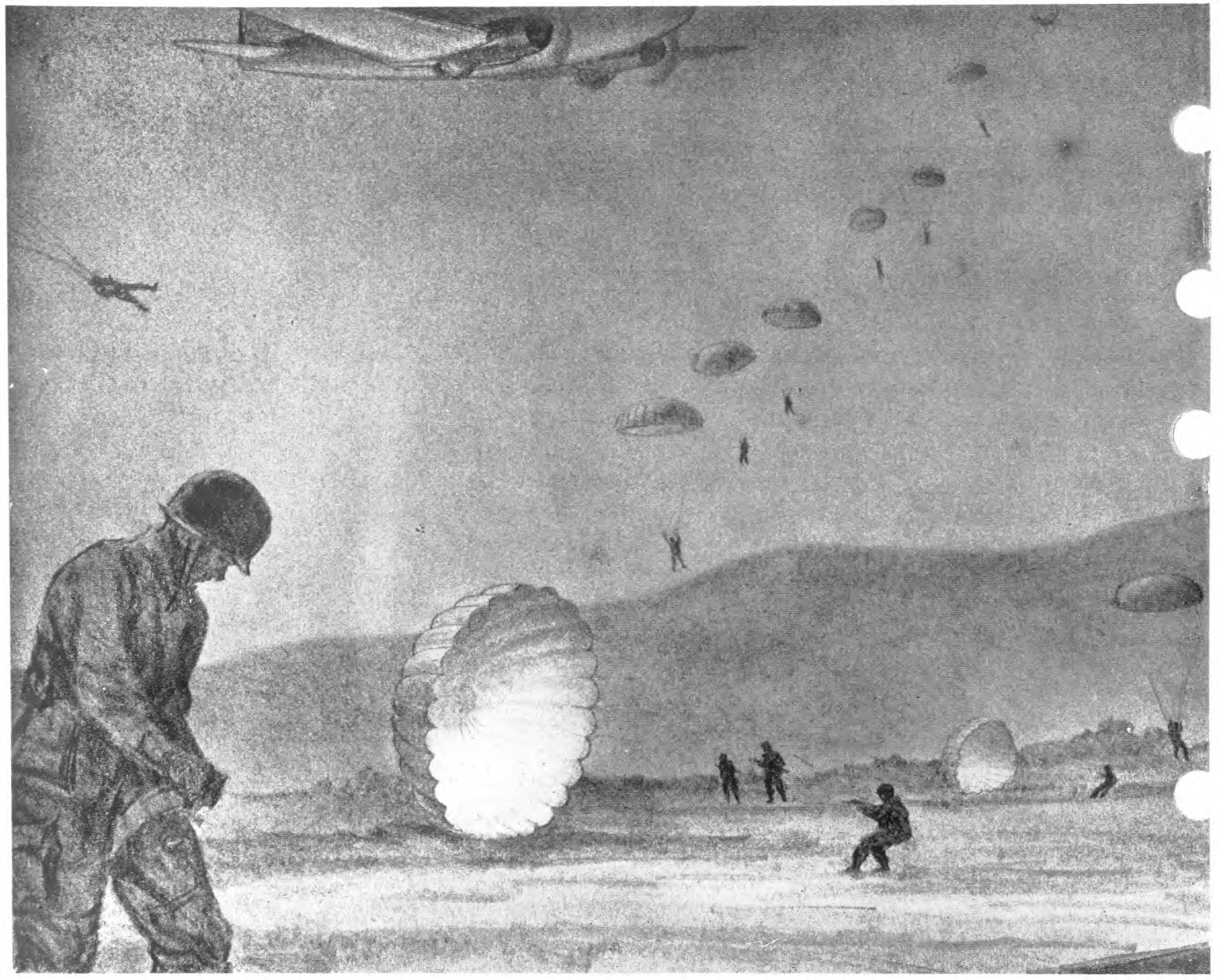
6) A whole slew of flares, lights, radio transmitters, smoke signals, etc.

In the pattern of 9th TCC operations Pathfinder planes, getting fixes from Gee and using SCR-717C's scope presentation as a radar map, found their way to selected Landing or Dropping Zones, there dropped trained paratroopers to mark the zones with flares and signals and set up radio and radar beacons for main force troops following.

At all stages of a carrier operation navigation must be precise or close to it and coöperation between air and ground is a prime requisite. At the final stage, where the whole operation comes to a head, it is the particular function of Rebecca-Eureka to make this navigation and coöperation as automatic as possible. A high per cent of 9th TCC planes were equipped for Rebecca-Eureka functioning and it may be assumed that the functioning was strong on D-day.



SCR-717, as used for navigation by TCC, actually can give better PPI picture than shorter-wave APS-15, as used for 8th AF blind bombing; low altitudes flown by C-47's make difference. 717B shown is same as 717C, but a truncated dish on latter permits less bulky dome.



HOMING ON EUREKA (FAR RIGHT) DROPPED BY PATHFINDER, REBECCA-EQUIPPED CARRIERS FLY MAIN FORCE TO DROPPING ZONE

Rebecca and Eureka do their jobs in critical last 20 miles

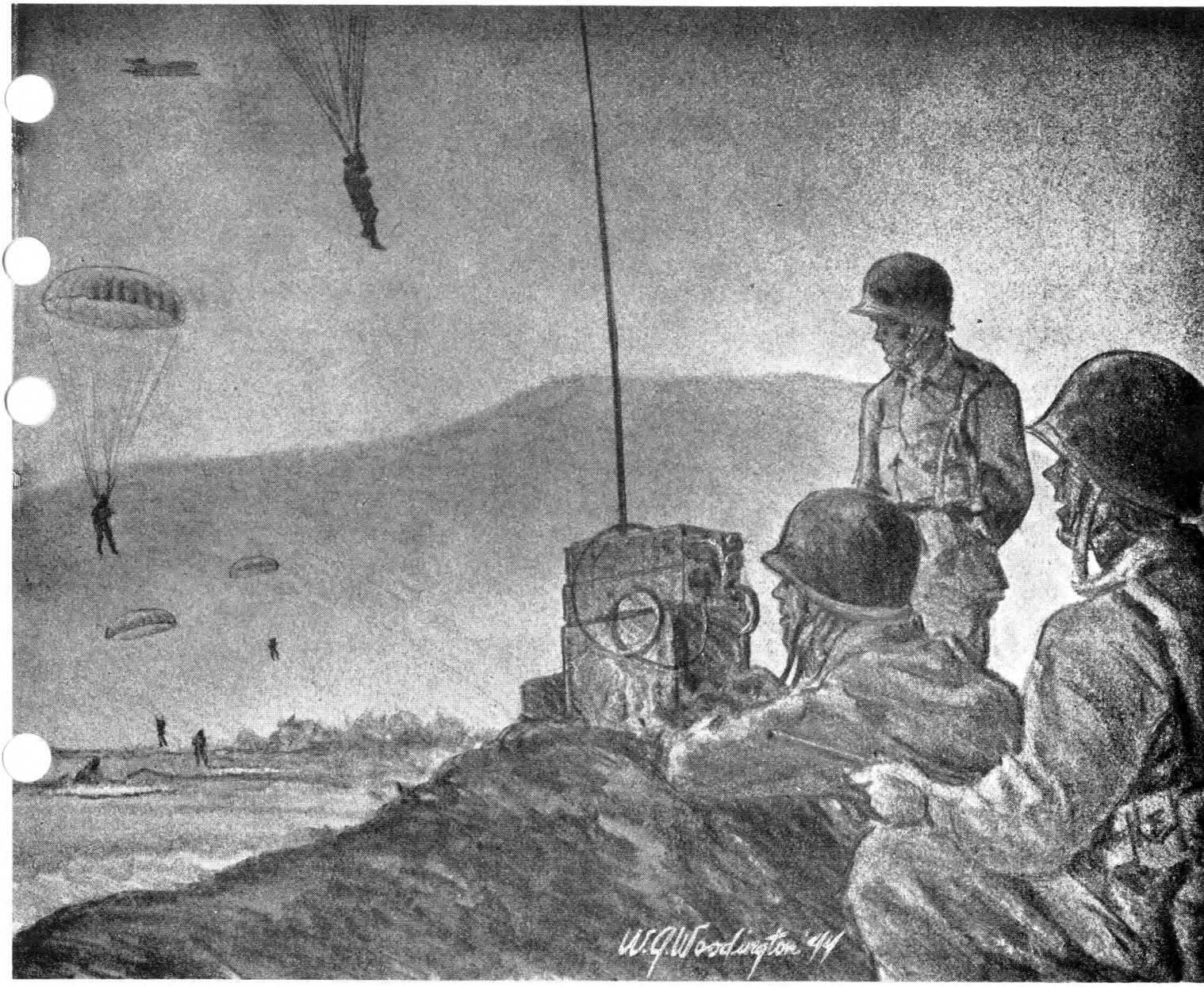
Under favorable circumstances Dropping Zones can be located and marked well enough as a rule with flares, radio beacons, lights and other such devices. For such landings behind enemy lines as took place on the 6th of June, or in any conditions of poor visibility, the Rebecca-Eureka radar beacon system offers big advantages. It is less subject to enemy detection; it enables troop carriers to get to a small DZ at ranges up to about 20 miles; it is easy to handle, light in weight, less subject to damage than comparable radio equipment.

The Rebecca-Eureka system operates like any other radar beacon: The Rebecca (APN-2) sends out a pulse which "triggers" the Eureka (PPN-1), causing it to return pulses which are received by the Rebecca in the plane. The pulses appear as signal pips, from which the operator can tell range and direction of beacon.

A form of communication between Rebecca and Eureka operators is also provided. The Eureka operator above is listening for triggering through his earphones, might well be trying to send Rebecca operator a coded message by depressing the key provided for that purpose. Such messages are read on the Rebecca indicator as a blinking of the signal pips. This kind of communication, though slow, can be used to notify Rebecca planes of any last minute changes caused, for example, by change of wind direction or surprise enemy action.

Chief difference between Rebecca-Eureka and other racon systems lies in the size and weight of the units. Rebecca is designed solely to interrogate a Eureka; it serves no other function and requires no other radar in the plane. Hence Rebecca can be installed in a troop carrier plane at a cost in weight of only 85 lbs., compared to an installed weight of 400–500 lbs. for an ASV radar. A microwave fixed ground racon weighs about 900 lbs. Eureka weighs only 30 pounds.

Two Eurekas are carried by the first Pathfinder team that sets out for the DZ. They are strapped to paratroopers in the plane and parachute to the ground with them. As soon as a Eureka has been set up (usually it can be done in less than 10 minutes) it is ready to be triggered and to signal in return to incoming Rebecca-



NORMANDY FIELDS SAW THIS SCENE TIME AND TIME AGAIN ON JUNE 6TH AND DAYS AFTER AS TROOPS DROPPED, THEN SUPPLIES

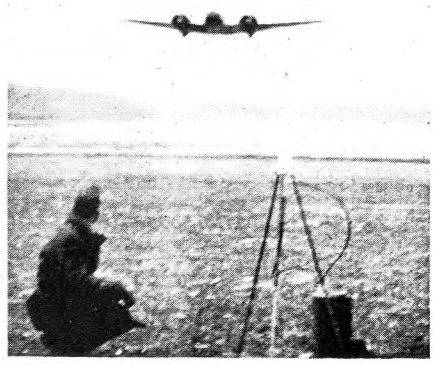
equipped troop carriers. These craft may also be equipped with a radar altimeter (APN-1), which enables them to know when they have reached proper altitude for releasing the paratroops.

Rebecca and Eureka must each use the proper frequency channel — i.e., Rebecca interrogates and Eureka is "triggered" on one frequency; Eureka responds and Rebecca receives the response on another. Available choice of frequencies allows, in practice, for 6 different channels, enough to act as a safeguard against tapping by the enemy. If the operator suspects that the enemy is catching on to one frequency, he can change the combination to other prearranged channels. Physical security of Eureka is protected by a destructor unit, which can make the set useless to the enemy if it has to be abandoned.

Some 56 squadrons in the 9th TCC were scheduled to be equipped with Rebeccas. Mechanics and maintenance men for them were trained in the U.S. at Boca Raton, Fla. In England, training for mechanics and operators has been carried on along with training of Pathfinder crews and paratroop teams at a training center set up near 9th TCC headquarters.

Past performances of Rebecca-Eureka in action have not been uniformly satisfactory, and there have been instances of serious failures.

They have not been the fault of the system, but of the same factors of inexperience and inadequate supplies of equipment — and, quite as much to the point, lack of testing apparatus to keep what equipment was available in condition — all of which interfered with airborne troop operations generally in the past. The system itself works. On the next page RADAR tells about one operation in point. The activities which began on D-day will provide other examples, a great many of them.



BUPS is microwave beacon providing check or homing point to SCR-717's on Pathfinders

Operation at Salerno: one that worked

THE SITUATION Fifth Army forces holding a 7-mile beach-head at Salerno found themselves threatened by a German counter-attack driving down toward the coast. If successful, the drive could have cut U. S. forces in two. Reinforcements were badly needed, and paratroops of one of the Airborne Divisions then in Sicily were sent over on two successive night missions, to land on a prepared Dropping Zone about 5 miles behind the front lines, between the main road and the sea.

THE OPERATION Shortly before dusk on the first night three Pathfinders took off from Agrigento, carrying advance paratroops to mark the Dropping Zone with Eurekas and other signalling devices. The Pathfinders found the area by DR navigation aided by check points along the coast of Italy. Their troops parachuted down with two Eurekas, a radio transmitter (5G), Krypton lights and Handie-Talkies. The radio transmitter was damaged in landing and knocked out. The first Eureka, set up and going in three minutes, was triggered continuously for the next three hours by incoming Rebecca-equipped troop carriers. Flares had to be extinguished after each group landed its troops to minimize detection by enemy aircraft in the vicinity.

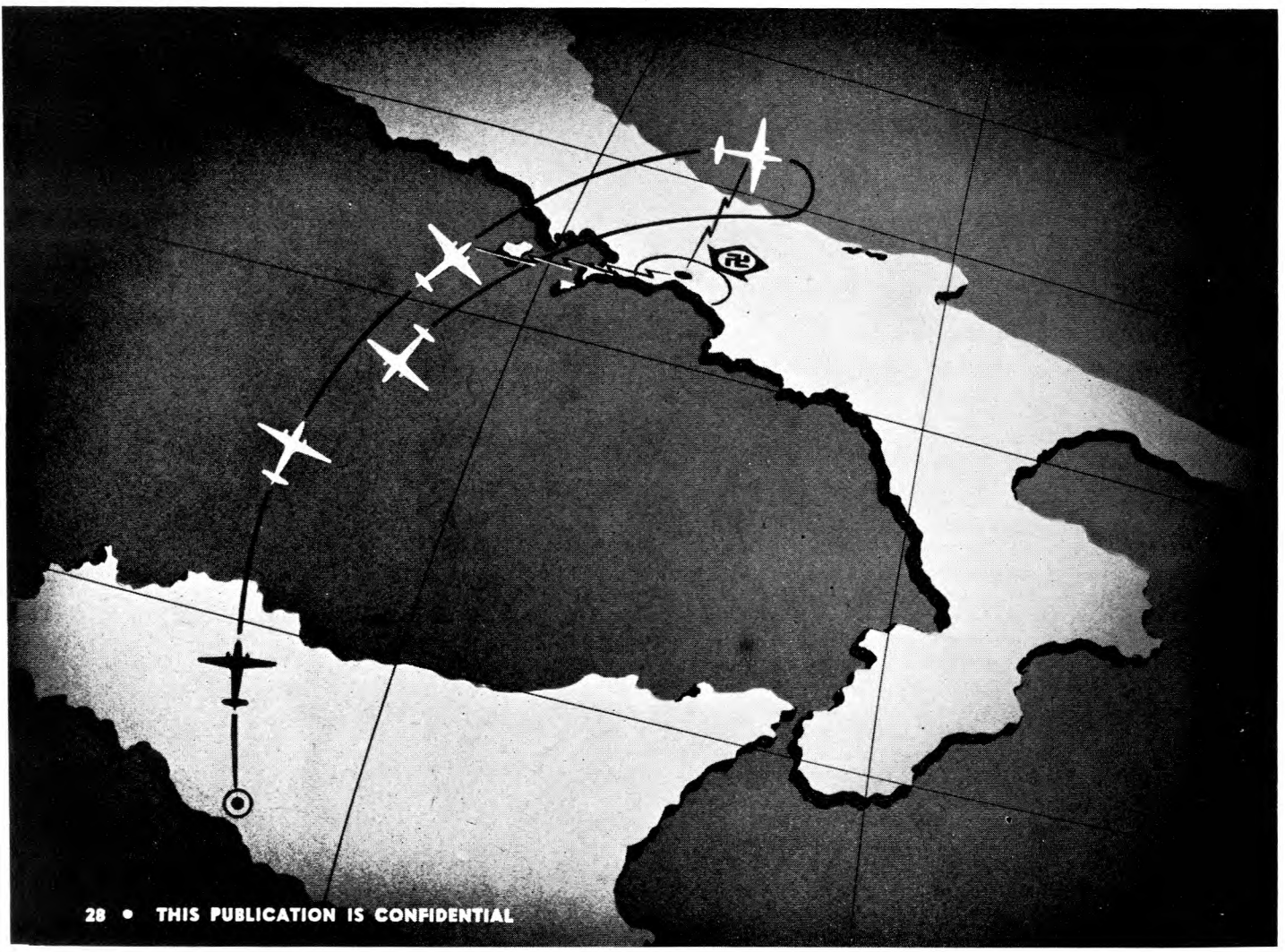
Most of the lead planes in each group equipped with Rebeccas dropped their loads within 200 yards of the Eureka, after catching the Eureka's signal at ranges of 7–13 miles. Within one hour after the last drop 800 paratroopers had collected and the DZ was cleared.

Next night Pathfinders again led the way successfully to the DZ. One Eureka was set up and going within 5 minutes: Rebecca-equipped planes picked up the signals at ranges up to 17 miles. Most of the troops were dropped within 200 yards of the beacon, the furthest less than 1½ miles away, except for two groups whose planes missed the way altogether and dropped 20 miles from the Zone. But 45 minutes after the last drop, 2100 troops were on trucks on the way to protect the threatened flank. No troops and no planes were lost in either night's operations. About 80% of the Rebeccas worked without hitch.

POST MORTEM The Rebecca-Eureka equipment available for these operations was very much on the makeshift side. There were only 16 Rebecca-equipped aircraft at the time in the entire Troop Carrier Command in the Italian theatre; the Rebeccas had been hastily put together and had a low power and small range. Eurekas were of the British MK II type, weighing 50–55 lbs. as compared with the AN/PPN-1 now used, which weighs about 30 lbs. They were less sturdily built and had a smaller range than the current model. Operators had been trained on the spot in the few weeks before the mission.

Despite these handicaps, R-E supplemented other signal aids by giving accurate range data. And by confirming other directional signals it demonstrated its usefulness for circumstances where these might not be available.

The Salerno operation was in marked contrast to one about the same time at Avellino, where the mission failed in its objective because troops missed the DZ by many miles. Failure was due to a variety of reasons (poor navigation, a breakdown in intelligence, etc.), but it is also a fact that here no R-E was used, and at least some of the troops which were not able to identify the DZ might have been able to if they had been equipped with R-E.





On paratrooper Eureka (AN/PPN-1) adds about 30 pounds to already heavy load, is sturdy enough to stand any landing paratrooper can stand. New model will be lighter, will strap on in smaller case



On ground after dropping Eureka can be set up for operating within 10 minutes. Site is important since effective range of transmitter may be several times greater from high ground than from lower blocked area



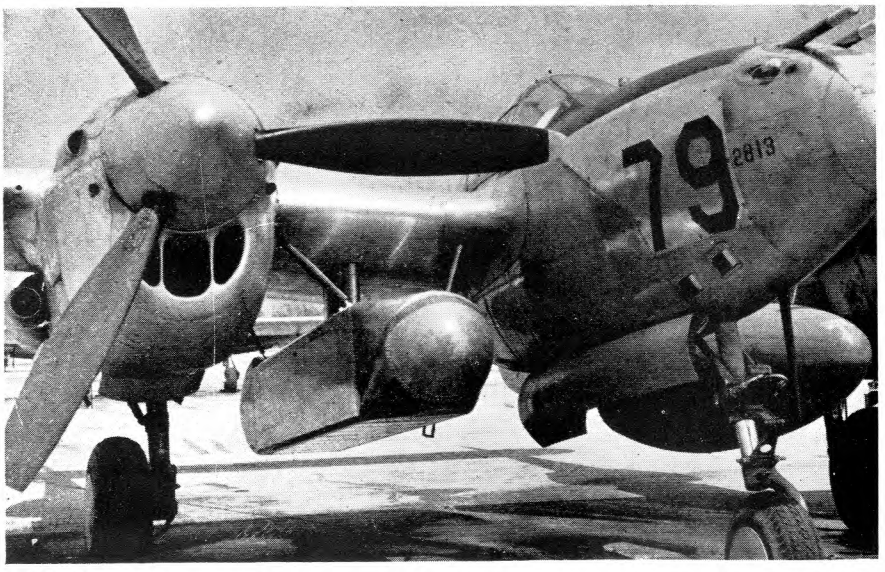
New Eureka (AN/PPN-2), not yet out of production, will be more compact, lighter by about 10 pounds and will have greater range — up to 40 miles or so when Rebecca-equipped plane is at 5,000 feet



Big Eureka (AN/TPN-1), transportable by plane but too much for a paratrooper, weighs 150 pounds, can be set up in about ½ hour. Used for Glider Landing Zones, etc., it requires no operator once it's turned on



Automatic dispenser, developed by AAF Materiel Command, holds up to 850 units of window of the U. S. CHA-3 type. Made of aluminum, it weighs 185 lbs. empty, is 12 feet long. Electrical mechanism detaches packages from tape, breaks seals before strips are released



Attachment to fighters (P-47's, P-38's) is by means of standard bomb rack. The dispenser can be jettisoned if necessary. On bombers the dispenser is located in fuselage. Control mechanism allows pilot (or other crew member on bomber) to regulate the dispensing speed

JERRY GETS THE WINDOW

Practically every bombing mission sent out from England nowadays — RAF by night, 8th AF by day — is a window (chaff) operation. But gone is the time when Jerry's fighters would break off attack at mere sight of the window, and the ground operator throw up his hands in despair. It has been almost exactly a year since the RAF first introduced Jerry to window over Hamburg. And after that much experience with the stuff Jerry has learned some of the tricks of the trade. He is quick to exploit gaps in even well-used window. And he can be counted on to make the flak hot if the window is improperly dispensed.

On ways and means for improving the dispensing mechanically, considerable work has been done since RADAR last reported on window operations (see RADAR, April).* Before then, pending completion of launching chutes, B-24 waist gunners were instructed simply to "open the window and toss the stuff out." For a short while the window was expelled through flare tubes, standard bomber equipment. Launching chutes of the type shown on the opposite page are now in wide use. For their simplicity and efficiency they have got the nod over more complicated devices.

Newest development is the automatic dispenser shown at left. Created originally for bomber use, it is now being tried with fighters. It may prove a means of working the fighter's high speed and maneuverability into new tactical applications of window.

The basic job that any dispensing device has to do is to get the units (packages) of window out so that they will open up, clear the plane and fall free. Each unit may contain as many as 2000 of the foil strips that do the business of jamming Jerry's radar, but they won't do it unless they float down separately. Of all the things that can go wrong, "birdnesting" — twisting and inter-twining of the strips on release — is most common. But present chutes minimize that pretty well.

They do not minimize the considerable time and effort that have to be put in by crew members to get proper amounts of window out at the proper intervals. This is the point where effective dispensing begins or breaks down and at the high-point of a big mission the crew members doing the dispensing are as busy as a one-armed paperhanger ever was. If the automatic dispenser gets into general use it can save a lot of muscle work. Current tests should discover whether it might also do the job more efficiently.

** In an early issue RADAR will report again on operational and tactical use of window.*

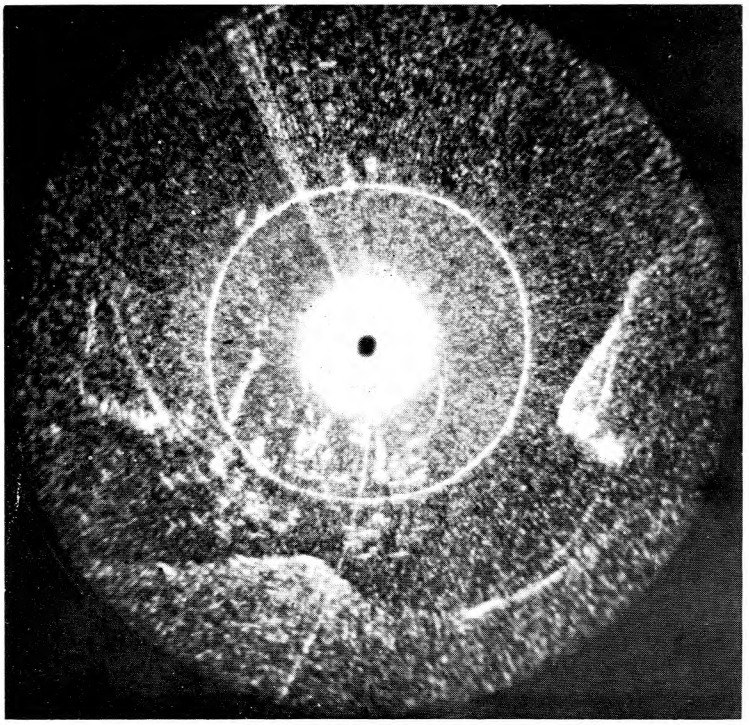
8th AF, RAF drop window differently through similar chutes



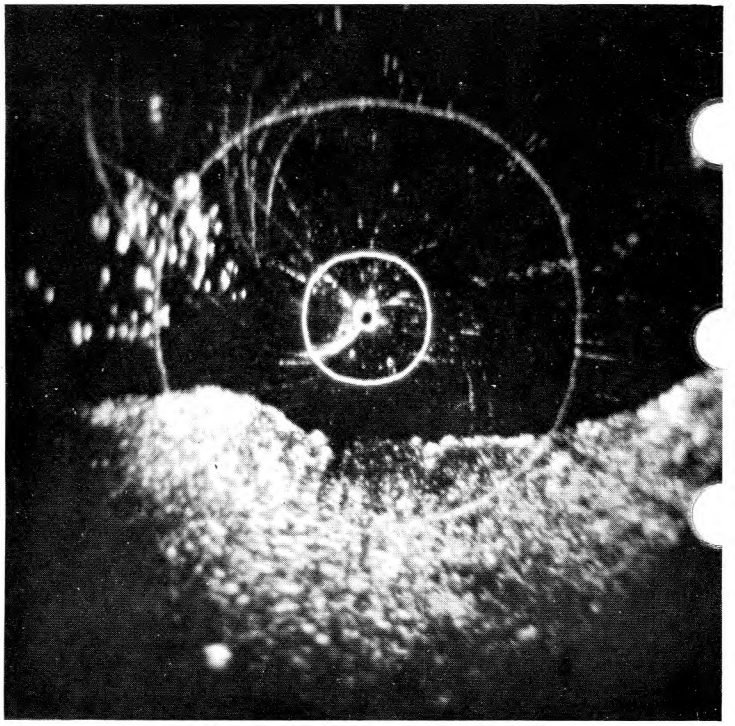
Launching chute in widest use is the type shown above. Here crew member puts out four units of U.S. CHA-3; the foil strips in each unit will put one fake heavy bomber on the scope of a watching Wurzburg. Use of window is now almost standard for 8th AF, RAF, Nazi raids alike



With British window you have to "pull the string" before shoving the unit through the chute. Since RAF loose formations require only occasional releases, as opposed to the steady releasing needed for tight formations, extra step doesn't interfere. Chute is much the same



At H-hour minus 20 minutes invasion area north of Caen looked like this on scope of APS-15 radar in bomber overhead. Several British assault forces are shown offshore. Havre shows bright, right

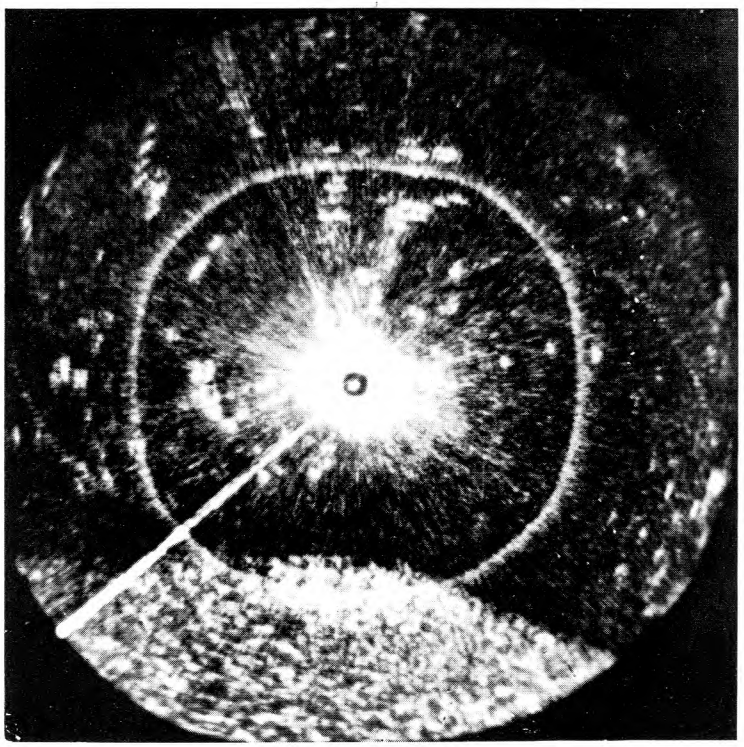


Nearing the beach, invasion craft here can be seen less than one mile off the Normandy coast. The town of Caen, about 10 miles inland, is the bright spot just left of center at bottom of the photo

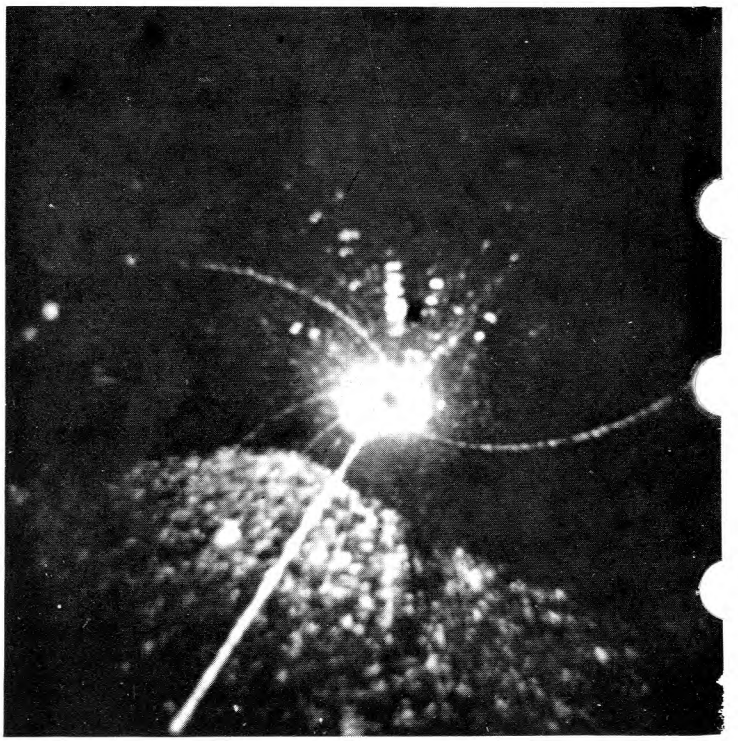
Time: H-hour minus 20 minutes. Place: Normandy beach head

The four photos on this page were taken from the scope of APS-15 radar bombing equipment in one of the heavy bombers which blasted out opposition just before invasion forces landed. Because clouds closed in on the invasion area as operations started, virtually all of this pave-the-way bombing had to be done blind — that is, by radar. These photos show the picture the men upstairs got through the overcast from down below as they did their bombing — a scene that nobody saw visually. The spiral lines and streaks are interference from nearby radar sets, both friendly and enemy. For more on radar bombing at H-hour, see page 2, inside front cover.

Assault forces are directly underneath. Line between first wave and beach shows clearly. Channel and invasion area were closed in by 10/10 cloud so that not even beach line could be detected visually



Smaller task force shows on scope as bomber nears release point To achieve maximum effect, H-hour bombing was tightly geared to movement of forces and all of it was done within 30 minutes of H-hour



FERRANTI Defence Systems Limited

RADAR

Issue No. 4 AUGUST 1944



R.P.F. Lauder
Engineering Manager
Product Support Department

INTRODUCTION

Since the last issue by Ferranti of this historic series, the allied invasion of Europe had taken place. Prior to the actual beach-head landing, the enemy's coastal defences were pounded relentlessly by wave after wave of heavy bombers. A graphic account of this scene is reported here, not by a military man, but by a civilian – Dr C. Pollard of the Radiation Laboratory staff who had been seconded to the UK. Dr Pollard recounts sitting down in front of a spare display of the MEW on the evening of the 5 June '44, and unknowingly witnessed this important bombing raid going out. His story is shown on the inside front and back covers of this volume.

With the relatively long wavelengths, and wide radar beams in use at the time, the problems of relating the low resolution radar map to the real map, particularly over totally unfamiliar terrain, are becoming obvious. However, in this volume, for the first time, radar is being taken seriously as a means of weapon aiming, under conditions where the traditional visual methods are impossible. This is shown here by the fact that radar maps are being simulated for the purpose of briefing the B-29 bomber crews prior to the mission.

Great ingenuity and energy was applied to this problem of map matching, and two methods are described here. The use of an actual 3-D relief map, traversed by a camera, allowed simulated actual flight paths which were then transferred to an enlarged PPI. A more sophisticated, and probably more realistic, approach was to submerge a glass map in water, and to use an ultrasonic transducer under water to simulate the radar transmitter beam. This would equate more nearly to the relative physical dimensions of wavelength and beamwidth used by the radar. Today, of course, Ferranti has overcome this problem with its COMED (combined map and electronic display). Here an optical map is driven by the inertial navigation system to show the aircraft's position and course, and a radar map suitably scaled is superimposed. In this way, precise radar pictures can be correlated with the actual map.

The radar planning device shown on page 14 et seq had the dual purpose of predetermining suitable ground radar sites without actually siting a radar on these points and, secondly, plotting suitable approach paths to enemy targets by making most use of ground shadowing of the enemys radars. If intelligence did not have precise knowledge of enemy radar positions, the device could also predict where the enemy was most likely to have located his radars. Again the method depends on a reasonably accurate 3-D model of the ground being considered for attack, and a light pen to simulate the radar beam.

This volume also marks the first mention of offset bombing using an identification point (IP). This is, of course, related to the fairly crude radar map, which can only show dominant features such as headlands, small islands and the like. A small island off the coast carrying the target is ideal since it would show up well on the radar PPI. Provided the navigator had pre-planned an approach to the target directly in line with his IP, and knew the horizontal distance between the target and the IP, he could calculate the bomb release time and measure it with a stopwatch. His table was based on a fixed ground speed run into the target with the bomb doors open, because of their influence on drag. Nowadays Ferranti's inertial navigation and attack systems, with the HUDs (Head Up Displays), can use IPs and attack targets blind with automatic weapon release to a high degree of accuracy.

The work of the "Ferrets" or radar reconnaisance, or ESM (Electronic Surveillance) as we would call it today, is first described here. It is to be a recurring theme throughout the rest of these volumes. Basically, a variety of bombers are crammed with equipment to measure radar frequency, pulse width, p.r.f. and output power over quite a wide range, and to plot the position of the enemy radars. They also carried jammers to cause the radars to move to another frequency if they were capable of that, and the new frequencies were also recorded. Judging by the pictures in pages 24-27, much of the equipment was commercial, or came from other sources. It was also clear that new items were added almost on a sortie basis.





TYPE 86 CODENAMED INDIGO CORKSCREW

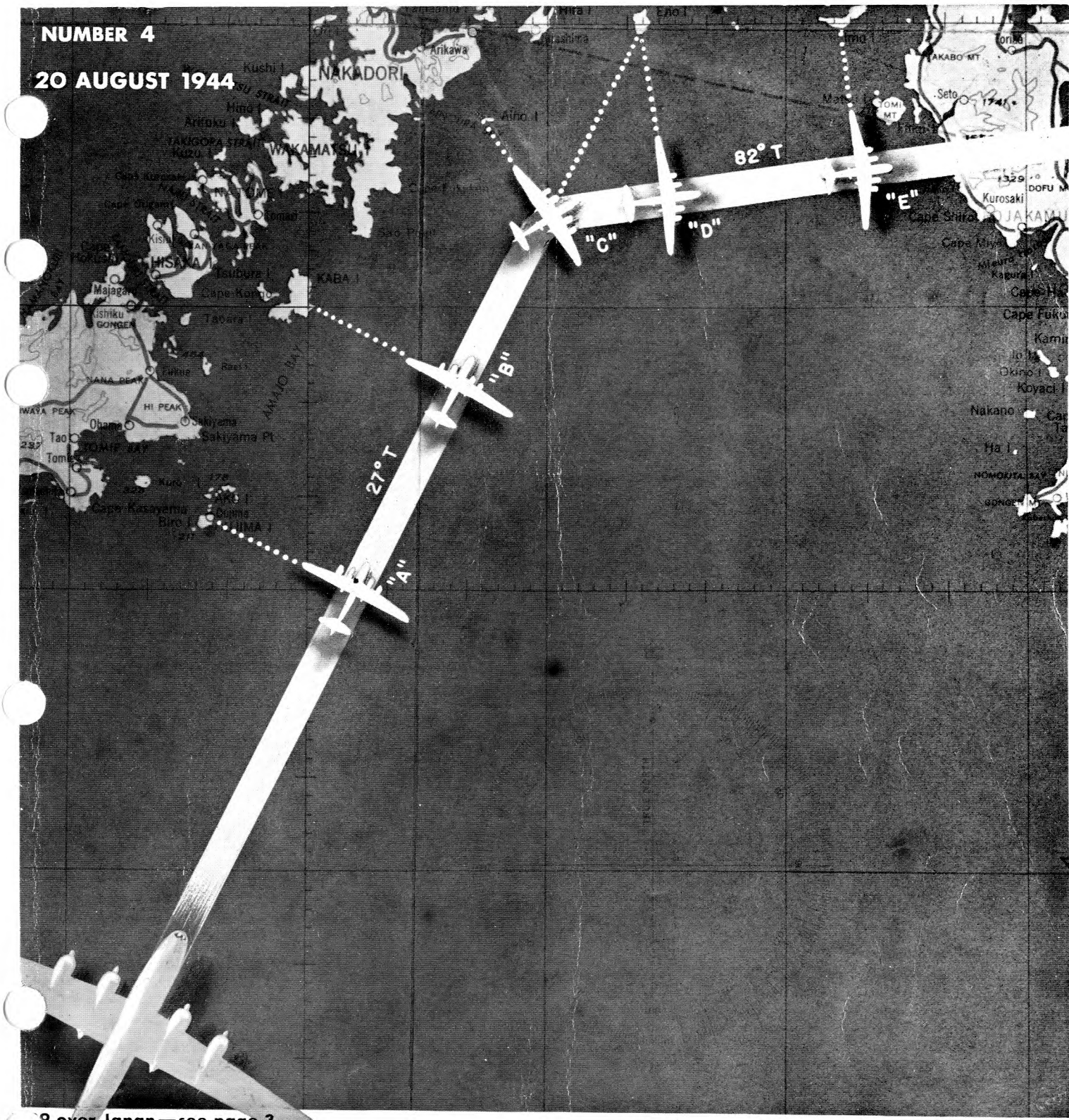
This ground based FMCW Ferranti radar entered service about 25 years ago with the RAF, and a similar system called AD 10 Mk I with the Army. They are both target illuminating radars for the Bloodhound SAM system in the RAF, and the Thunderbird SAM system for the Army. The latter is no longer in service but the AD 10s are being converted to T86s. A similar version was sold to the Royal Swedish Air Force for Bloodhound. All are still providing yeoman service.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

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20 AUGUST 1944



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RADAR

RADAR

In This Issue

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EDITORIAL ADVISERS: Lt. Gen. Barney M. Giles, Chief of Air Staff; Maj. Gen. Stephen G. Henry, Director, New Developments Division, War Dep't Special Staff; Maj. Gen. Roger B. Colton, Chief, Engineering and Technical Service, Office of Chief Signal Officer; Brig. Gen. Thomas D. White, Ass't Chief of Air Staff, Intelligence; Dr. Edward L. Bowles, Consultant on Communications to Commanding General, AAF; Dr. L. A. DuBridge, Director, Radiation Laboratory.

PUBLICATION DIRECTOR: Chief of Radar Branch, Office of Air Communications Officer — Col. W. M. Canterbury.

EDITOR: Dexter Masters. **ASSOCIATES:** Ruth Copland, 2nd Lt. Norman Goldman, Nancy Newton, Nancy Perkins, 2nd Lt. Robt. Wright.

★

MATERIAL AND PHOTOGRAPHS on operations and maintenance of radar equipment in the field are requested. Submit to Radar Editor, Office of the Air Communications Officer, Headquarters Army Air Forces, Washington, D. C. **IN EUROPE:** submit material to Signal Communications Officer, U. S. Strategic Air Forces, London.

"Something big was on . . . "



On the evening of 5 June Dr. E. C. Pollard, staff member of Radiation Laboratory attached to its British Branch, sat down before an idle MEW scope at a Fighter Direction station in England. He did not know the Invasion was coming off that night. When he finally got up from his scope he had seen it happen. The following report was prepared by Dr. Pollard shortly after. Pictures of the station — reported on in RADAR No. 3 — were taken on D-day plus 3.

June 5 was a clear beautiful night. It was a bit windy a little after midnight; the moon was up bright and nearly full. The sea was much calmer than previously. After the operation had started it really was a night to set your blood tingling.*

The station at —— does not normally carry out operations in fighter direction at night; it was functioning as a recording station, turning its plots over to a special table at Fighter Control which had a reproduction of our tracks only.

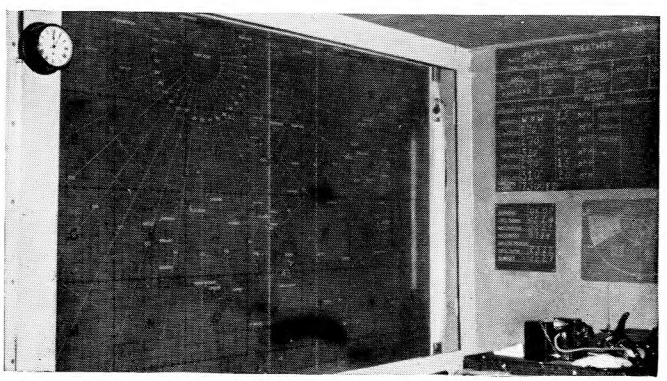
The radar setup at the station is elaborate. The MEW is down the hill and looks quite insignificant beside the Type 24 height finder, which is most impressive. The associated VHF equipment is placed something like a quarter of a mile away from the rest of the station. In addition, the Admiralty has a very imposing tower carrying a 10′ paraboloid which rotates slowly keeping a check on shipping.

The stand-out thing inside is the large ground glass screen with map, polar coördinates and grid squares on it. Behind this plotters receiving the data from the scope operators chalk in the tracks for the various raids or targets. The procedure is somewhat similar to a standard filter room technique, but there is no doubt that this vertical screen which shows in so dynamic a way what is going on is a great advantage over anything previously seen anywhere.

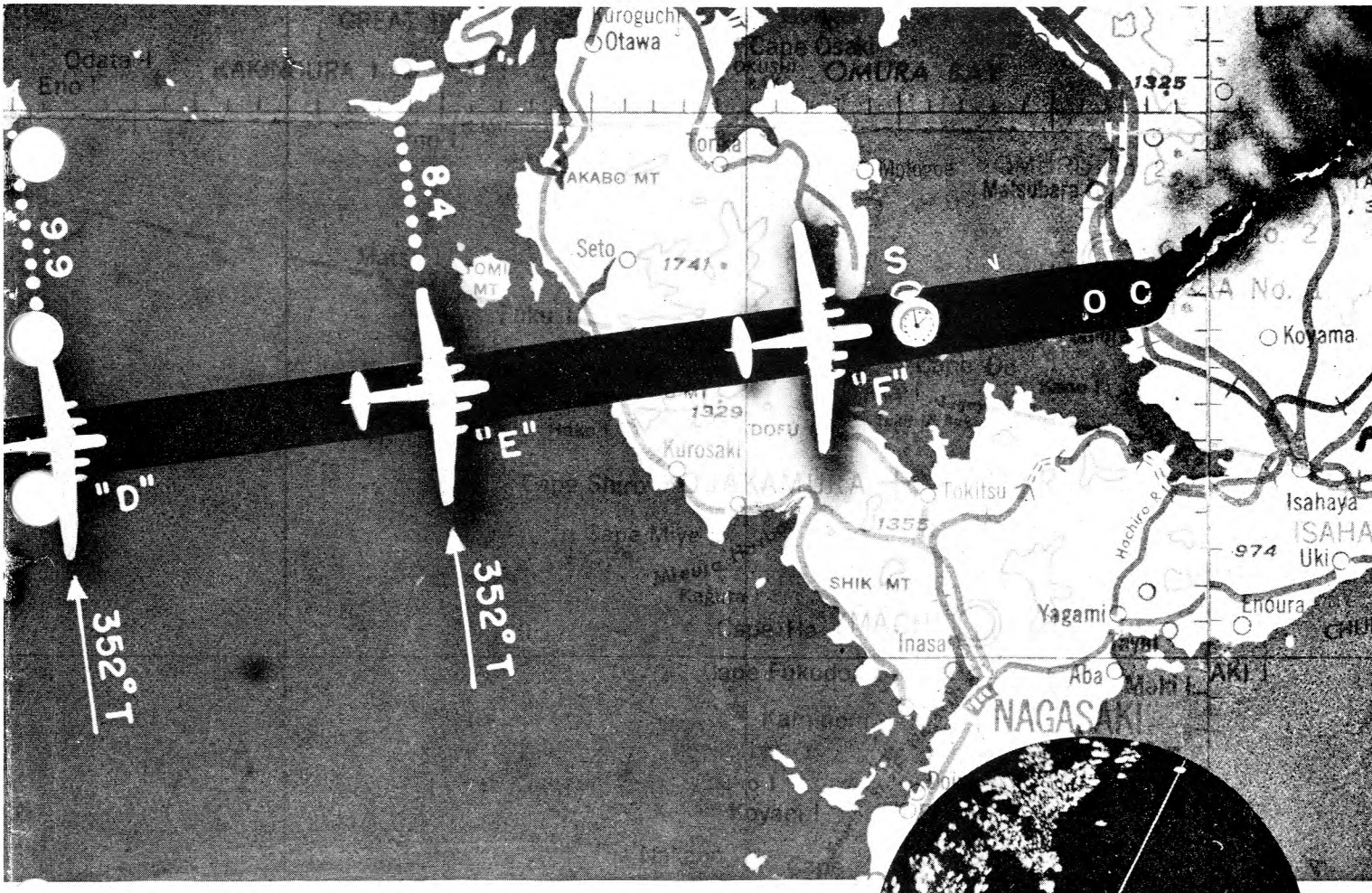
Also of great value is the VHF direction finding board. Two operators can call up the VHF station and ask them to give a fix on some plane to which the controllers are talking. The fix is remarkably good, never more than 1 degree or so out. The range of the VHF is well over a hundred miles, invaluable for keeping on targets which have faded and for distinguishing particular planes in an area where there may be several raids.

CONTINUED ON INSIDE BACK COVER

** But cloud closed in on the invasion area as operations started; invasion bombing and navigation had to be largely by radar. — Ed.*



"STAND-OUT THING INSIDE IS A LARGE GROUND GLASS SCREEN"



B-29 Flight paths are secret but path shown on cover and above, worked out for RADAR by 20th BC briefing experts, shows technique applied to fictional target. Watch (S) shows "stopwatch point" and black dot marks "aiming point" for offset bombing. Simplified versions of similar maps are included in briefing folders. Simulated scope photo for Point B (front cover) was made with supersonic trainer (page 10)

RADAR OVER JAPAN

APQ-13, the big radar stick on each B-29, is as new to combat as the Superforts themselves, which is to say that — as this issue of RADAR goes to press — it is four missions old. And the first of these was only a shake-down raid over Bangkok. Not until middle June, when the 20th Bomber Command first aimed its B-29's at the Japanese homeland, did the equipment have its real operational debut. That was the debut for everything and everyone — the 20th BC, the B-29's, the specially trained crews, and APQ-13.

The debut, and the second mission over Japan which followed last month, were both navigated by radar and the bombing of the targets was radar bombing. APQ-13 got the planes there and back through the night over unfamiliar territory and put the bombs away.* Radar navigation aided the latest mission, daylight over Southern Manchuria.

**Two planes were lost to enemy action on first mission; all returned from second.*

This was a large assignment for a new piece of equipment, but nobody had doubted its ability to perform. For if APQ-13 was new to action it was going in far better prepared than any other radar like it had ever been for a first action. The B-29 operations are, in fact, the first operations anywhere in which navigation and bombing by radar were integral parts of the planning from the beginning.

The special factors that radar brings into navigation and bombing were learned the hard way — by trial and error — everywhere else. They were learned with shortages of equipment to make the job harder. And often they had to be learned by personnel not too familiar with basic factors of radar, let alone special ones. For some of the difficulties the 8th Air Force had, see RADAR No. 1 (April.)

On all of this early spadework the 20th BC capitalized fully. The radar planning started with the equipment itself; APQ-13 is a carefully-built job compared to the crash built APS-15 which was rushed out for the 8th AF a year ago.**

Most importantly, the 20th BC got its project going with full emphasis on training personnel in the capacities and limitations of radar navigation and bombing. And it saw to it that proper radar briefing — i.e., briefing with reference to these capacities and limitations — preceded operations.

This emphasis on training and briefing is the significant part of the story of the B-29's over Japan, so far as radar is concerned. In its last issue (No. 3) RADAR reported on the training. On following pages RADAR presents a highlight report on the briefing, plus some words and pictures on equipment used in both training and briefing, and in the B-29's as well.

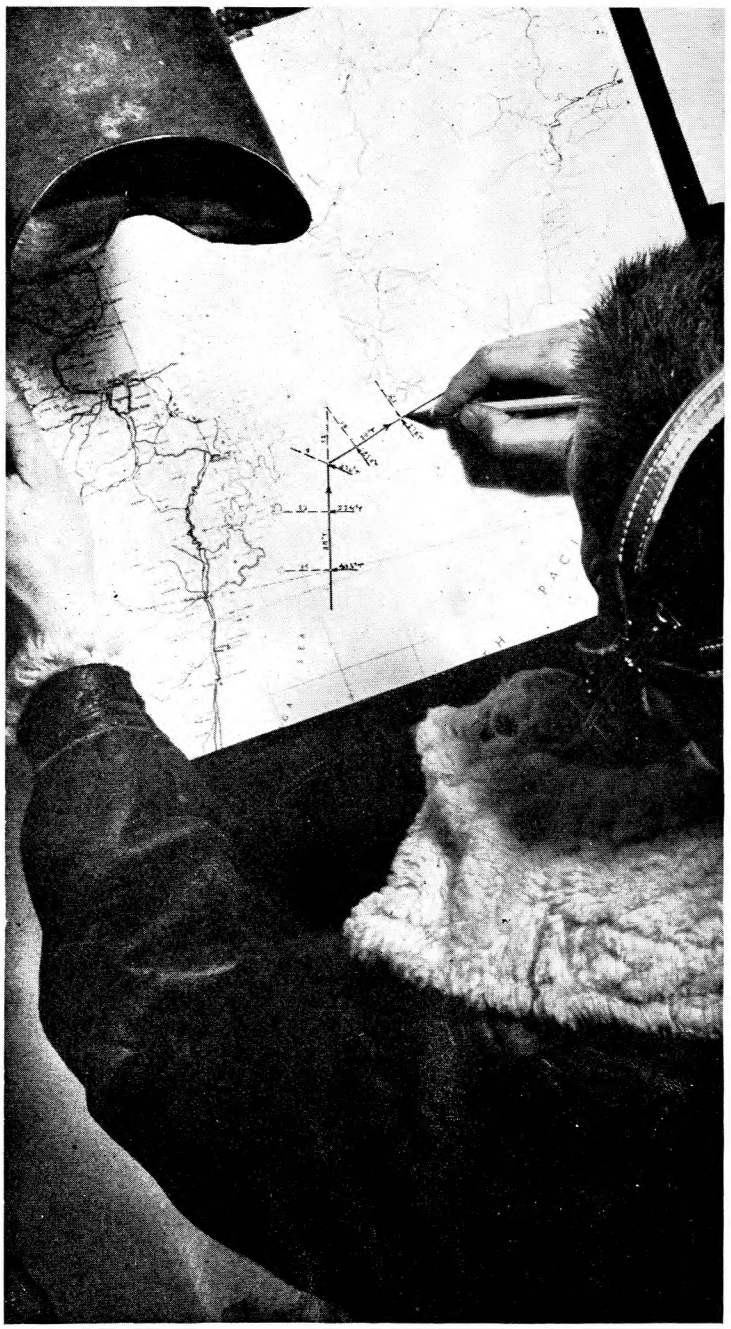
***APQ-13 and APS-15 are two versions of same equipment, both for high altitude blind bombing.*

B-29 briefing is tricky; here's a sample

The need for very special briefing for a mission in which navigation and bombing are done by radar grows partly out of the crudity of radar's presentation as compared to what the eye can see. Features on the ground as they appear on a radar scope are blurred together unless they're pretty well separated. A structure clearly resolved when viewed from one direction may disappear completely from another direction.

On the positive side, radar makes available check points that low visibility or distance or both deny to the eye. And radar is not crude when it comes to measuring range — which is, in fact, the basis for its use as a bombing device.

Radar briefing is a process of working out the best approach to a given target in terms of all these factors — best in the sense of getting the mission most surely and safely to a point where it can release its bombs most effectively. That point is not necessarily the point at which the target crosses the bomb release circle. On





B-29 Operators see Japan with one eye on APQ-13 scope and the other glued to the briefing folder. Japanese targets, usually near coastlines, are highly "scopogenic" — made to order for offset radar bombing. Path to one such target (fictional) is laid out together with radar check points on map which this B-29 radar operator is studying

Simulated scope pictures, to show operators what to expect, are prepared for key points on flight path. Sketches have been used so far for simulations, but pictures can be made with H_2X relief trainer (p. 8), supersonic trainer (p. 10) and RPD (p. 14). Actual photos are best but Jap homeland has been untouched by radar until recently

the Japan missions to date, in fact, the targets have not been seen even by radar. Good briefing makes this possible. Offset bombing is the end to which the briefing is the means.

In offset bombing an "aiming point," picked for ease of recognition and located somewhere in known proximity to the target, is set up. It may be a distinctive section of coast line, an island, a point of land, or the like. It must be something which gives a characteristic and isolated signal and, in the Island Empire, where targets are usually located near coastlines, that is not hard to find. With such an aiming point established, it makes no difference if the target itself is observed, camouflaged or lost in signals from built-up areas around it. Operators are briefed to clock a time delay predetermined with reference to the aiming point's location; and the target gets the bombs which are released at the end of the time delay.

Out of the infinite calculations involved in thus working out a B-29 mission for the long and tricky run from base to destination and back again, the 20th BC's briefing experts emerge with a neat leather-bound folder for the operators to take with them. An exact simulation of the pages used in the briefing folder, including classification, especially prepared for RADAR, appears on these two pages.

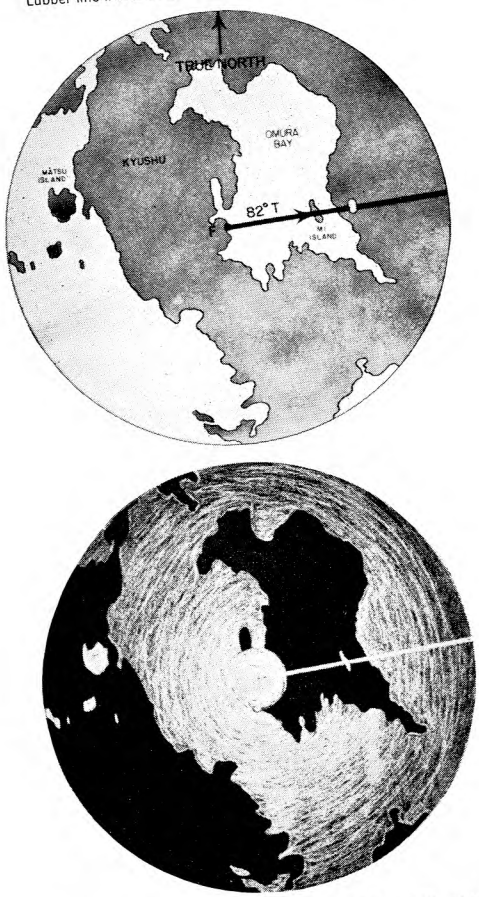
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PROBABLE APPEARANCE OF THE SCOPE AT POINT "F"

Altitude: 20,000 feet*

Sweep Length: 10 miles

Lubber line indicates a "no wind" heading of 82° True.

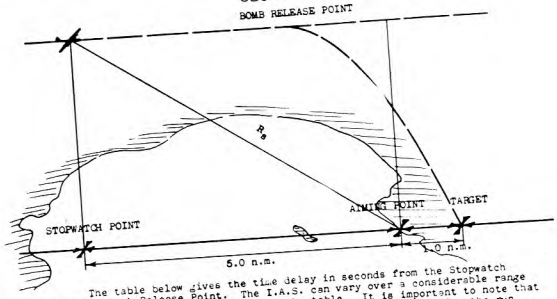


*Although the calculations for slant range and for the distortion of the scope pictures were made for an assumed altitude of 20,000 feet, there is no significant difference between 15,000 and 25,000 feet.

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BOMB RELEASE POINT



The table below gives the time delay in seconds from the Stopwatch Point to the Bomb Release Point. The I.A.S. can vary over a considerable range without introducing appreciable error in the table. It is important to note that these delay tables were calculated for a constant ground speed during the run from the Stopwatch Point to the Bomb Release Point. The bomb-bay doors should be opened before the Stopwatch Point is reached, and the correct ground speed with the bomb-bay doors open should be used when entering the table to determine the delay time.

The Stopwatch Point is located by setting up the slant range marker to the slant range, R_B, shown on the bottom line of the table. When the slant range circle crosses the Aiming Point, the stopwatch is started to measure the time delay before bomb release.

DELAY TIME FROM STOPWATCH POINT TO BOMB RELEASE POINT FOR AN-M59, 1000 LB BOMB

GROUND SPEED KNOTS	ALTITUDE FEET	13,400	14,600	15,800	17,000	18,300	19,500	20,700	21,900	23,100	24,300	25,600	26,800	28,000	29,200	30,400
	N.M.	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
130		2-19.4	2-18.5	2-17.7	2-17.0	2-16.3	2-15.7	2-15.2	2-14.6	2-13.9	2-13.4	2-12.9	2-12.5	2-12.1	2-12.0	2-11.8
140		2-07.4	2-06.6	2-05.9	2-05.0	2-04.1	2-03.5	2-03.0	2-02.3	2-01.6	2-01.0	2-00.4	2-00.0	1-59.7	1-59.5	1-59.3
150		1-57.2	1-56.1	1-55.2	1-54.3	1-53.4	1-52.8	1-52.2	1-51.4	1-50.6	1-50.1	1-49.6	1-49.2	1-48.9	1-48.6	1-48.2
160		1-48.0	1-46.9	1-46.0	1-45.1	1-44.3	1-43.5	1-42.7	1-42.1	1-41.4	1-40.8	1-40.1	1-39.6	1-39.1	1-38.9	1-38.6
170		1-39.8	1-38.7	1-37.7	1-36.8	1-35.9	1-35.2	1-34.5	1-33.8	1-33.1	1-32.4	1-31.6	1-31.1	1-30.7	1-30.4	1-30.0
180		1-32.6	1-31.5	1-30.5	1-29.5	1-28.6	1-27.9	1-27.2	1-26.5	1-25.4	1-24.9	1-24.3	1-23.6	1-23.0	1-22.7	1-22.3
190		1-26.2	1-25.0	1-23.9	1-23.0	1-22.1	1-21.3	1-20.6	1-19.8	1-18.9	1-18.2	1-17.4	1-16.8	1-16.3	1-16.0	1-15.6
200		1-20.4	1-19.2	1-18.2	1-17.1	1-16.1	1-15.4	1-14.7	1-13.8	1-12.9	1-12.1	1-11.3	1-10.7	1-10.2	1-09.8	1-09.4
210		1-15.4	1-14.2	1-13.1	1-12.1	1-11.1	1-10.4	1-09.7	1-08.8	1-07.9	1-07.1	1-06.3	1-05.7	1-05.1	1-04.6	1-04.1
220		1-10.4	1-09.1	1-08.0	1-07.0	1-06.1	1-05.3	1-04.5	1-03.6	1-02.6	1-01.9	1-01.1	1-00.5	59.9	59.4	58.8
230		1-06.2	1-05.0	1-03.9	1-02.9	1-01.9	1-01.0	1-00.2	59.3	58.4	57.7	56.9	56.2	55.5	55.0	54.5
240		1-02.2	1-01.0	1-00.0	58.9	57.9	57.0	56.1	55.3	55.4	53.6	52.7	52.0	51.4	50.9	50.3
250		59.4	57.2	56.2	55.1	54.1	53.2	52.3	51.5	50.6	49.8	49.0	48.2	47.5	56.9	56.3
260		55.1	53.8	52.7	51.6	50.6	49.7	48.9	48.1	47.2	46.3	45.4	44.6	43.9	43.4	42.8
270		51.9	50.7	49.6	48.5	47.4	46.4	45.6	44.7	43.8	43.0	42.1	41.4	40.7	40.1	39.5
280		49.0	47.8	46.7	45.6	44.5	43.6	42.7	41.8	40.9	40.1	39.2	38.4	37.7	37.1	36.4
290		46.3	45.0	43.8	42.7	41.7	40.8	39.9	39.0	38.0	37.2	36.3	35.5	34.8	34.2	33.6
300		43.8	42.6	41.5	40.4	39.3	38.4	37.5	36.6	35.6	34.7	33.8	33.0	32.3	31.7	31.0
310		41.3	40.0	38.9	37.8	36.7	35.8	34.9	34.0	33.1	32.2	31.2	30.5	29.8	29.1	28.4
320		39.2	37.9	36.8	35.7	34.6	33.6	32.7	31.8	30.9	30.0	29.1	28.3	27.5	26.9	26.2
330		37.1	35.8	34.7	33.6	32.5	31.5	30.6	29.7	28.7	27.8	26.9	26.1	25.3	24.6	23.9
340		35.2	33.9	32.8	31.6	30.5	29.5	28.6	27.7	26.8	25.9	24.9	24.1	23.3	22.6	21.9
350		33.3	32.0	30.8	29.7	28.6	27.6	26.7	25.8	24.8	23.9	23.0	22.1	21.3	20.6	19.9
360		31.6	30.3	29.1	28.0	26.9	25.9	24.9	24.0	23.0	22.1	21.1	20.3	19.5	18.8	18.1
370		29.8	28.5	27.4	26.2	25.1	24.1	23.2	22.3	21.3	20.4	19.5	18.6	17.8	17.1	16.3
380		28.4	47.1	25.9	24.7	23.6	22.6	21.7	20.8	19.8	18.9	17.9	17.1	16.3	15.5	14.7
390		26.8	25.5	24.3	23.2	22.1	21.1	20.1	19.2	18.2	17.3	16.3	15.4	14.6	13.9	13.1
400		25.4	24.2	23.1	21.9	20.7	19.7	18.8	17.8	16.8	15.9	14.9	14.0	13.1	12.4	11.7
	SLANT RANGE TO AIMING POINT NAUTICAL MILES															
	R_B	5.46	5.55	5.64	5.73	5.83	5.94	6.05	6.16	6.28	6.40	6.54	6.67	6.80	6.93	7.07

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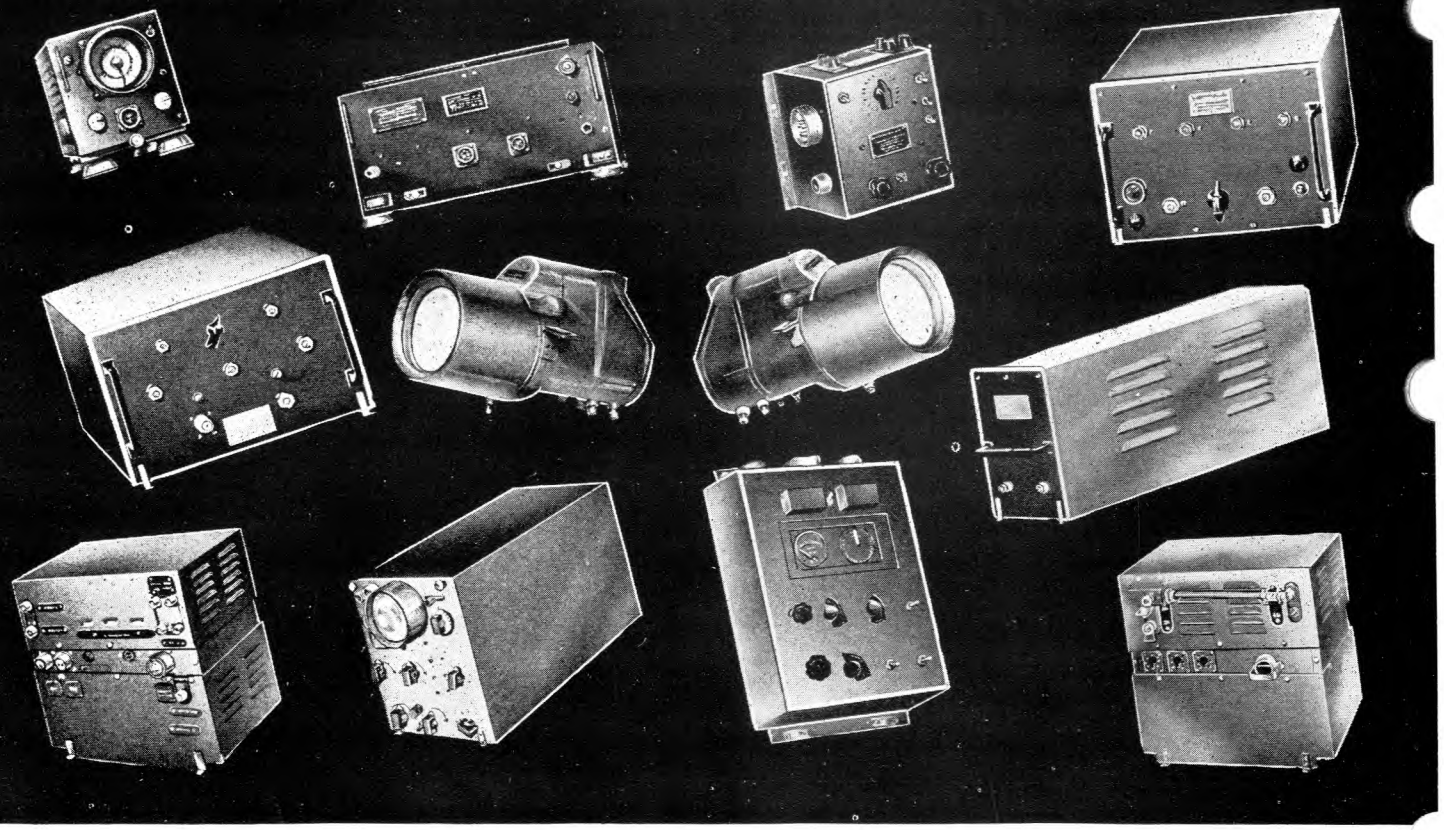
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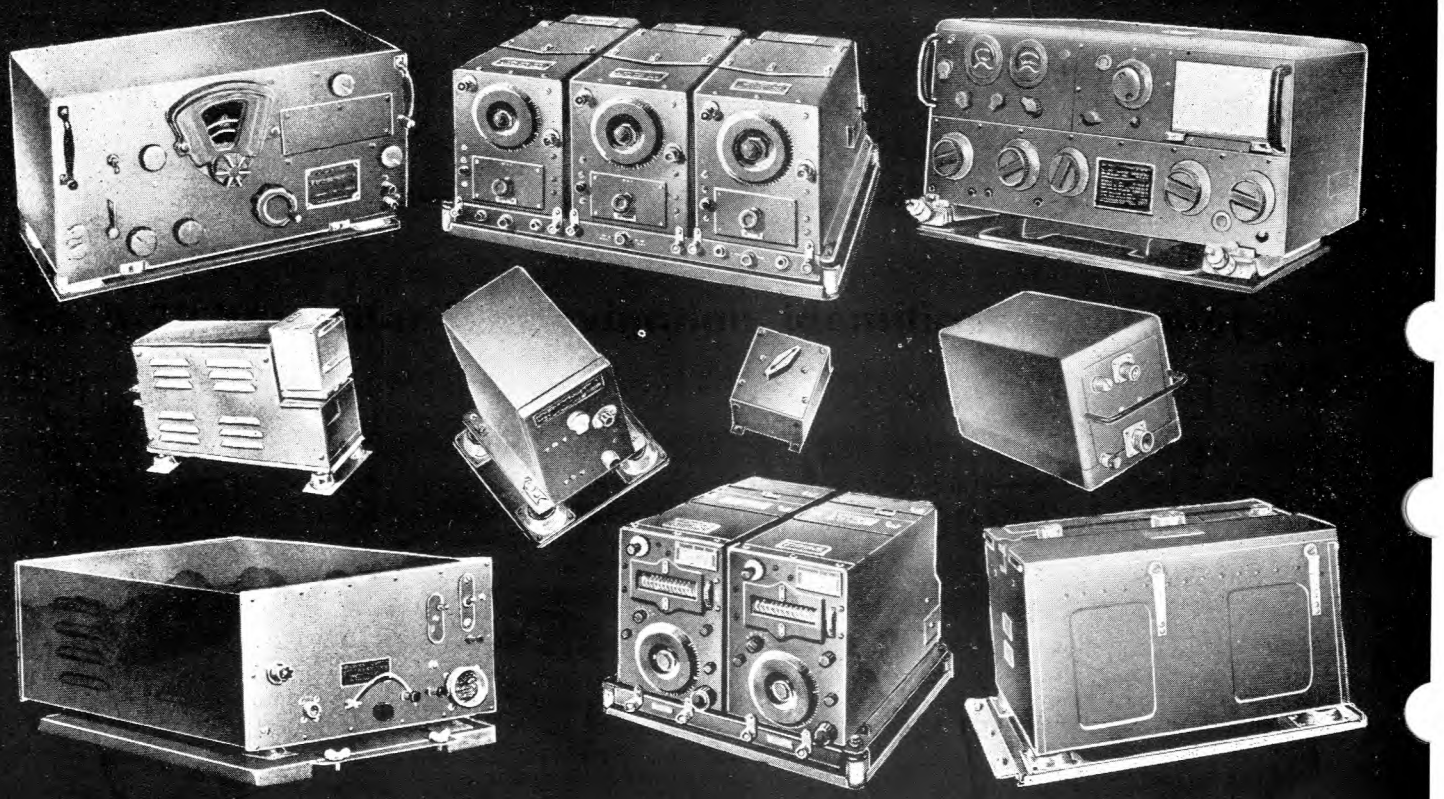
Accurate distortion is introduced into these scope sketches. The effect of a three degree beam width is created by making two tracings on the same paper three degrees apart. The use of a distorted protractor takes care of the misrepresentation caused by differing ground and slant ranges. Sketches are drawn to line up with actual scope sweep

Bombing table and sketch of the target approach area provide crucial last minute information. At a glance operator can, on reaching stop watch point, determine setting for slant range marker and time delay to allow for reaching bomb release point. Readings are not taken over aiming point; signals are better recognized from a distance

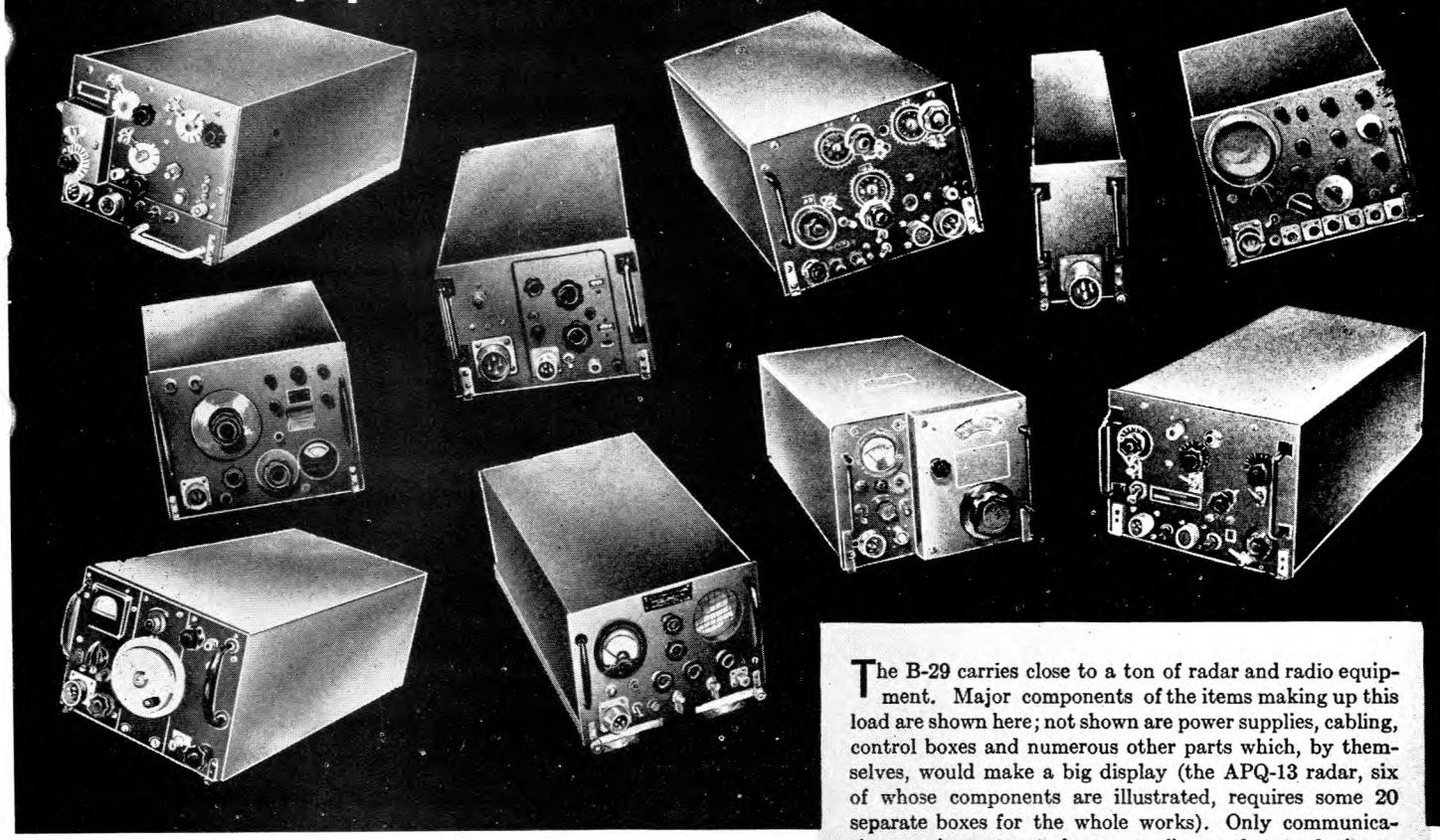
The B-29 has radar for navigation, identification, bombing . . .



. . . all standard radio installations plus a few special ones



. . . RCM equipment for detecting and jamming enemy radar



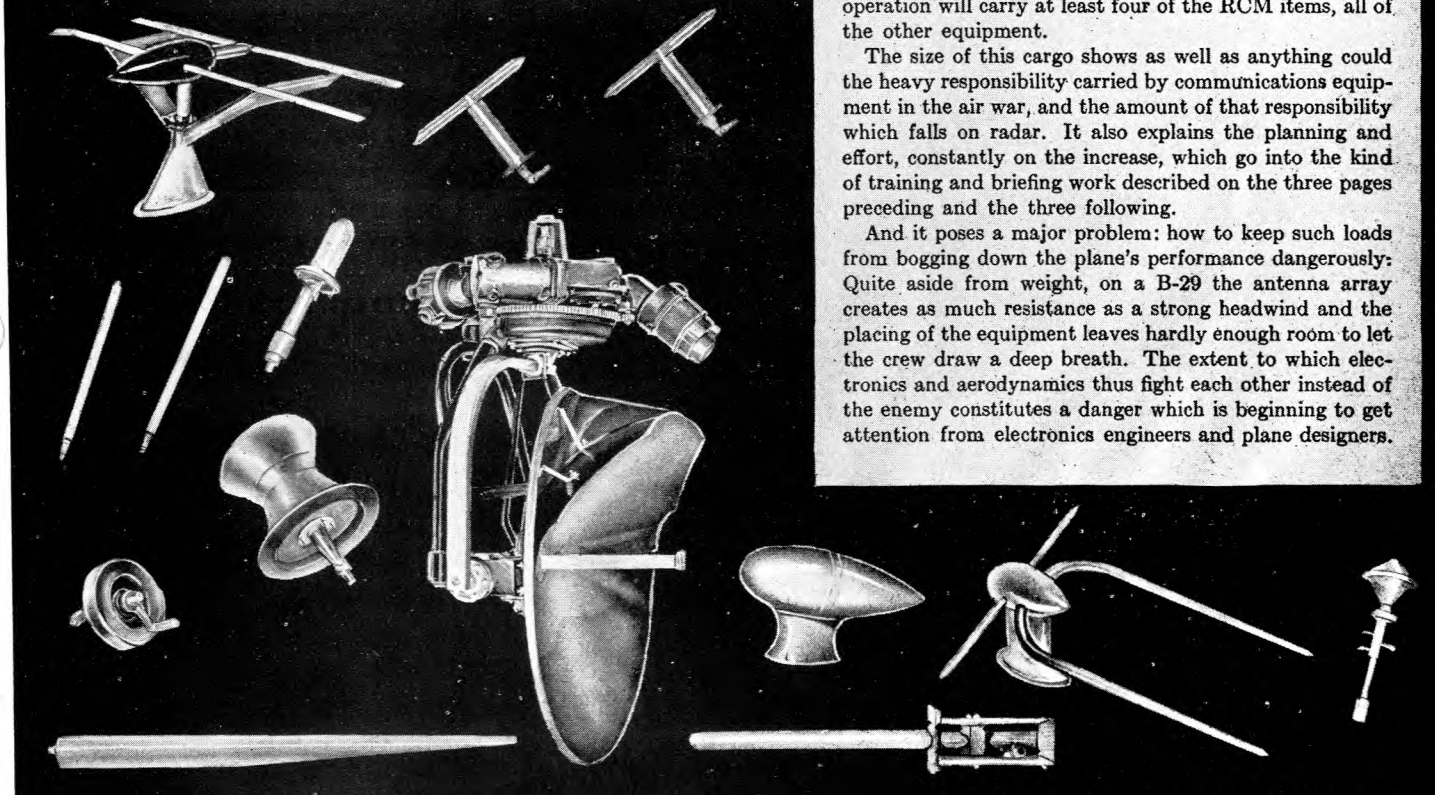
The B-29 carries close to a ton of radar and radio equipment. Major components of the items making up this load are shown here; not shown are power supplies, cabling, control boxes and numerous other parts which, by themselves, would make a big display (the APQ-13 radar, six of whose components are illustrated, requires some 20 separate boxes for the whole works). Only communications equipment not shown at all are the staple interphone system and Gibson Girl.

Depending on what the B-29 is going to do it will take along or leave behind certain of the RCM pieces; others are now allotted two to a squadron. But most B-29s in operation will carry at least four of the RCM items, all of the other equipment.

The size of this cargo shows as well as anything could the heavy responsibility carried by communications equipment in the air war, and the amount of that responsibility which falls on radar. It also explains the planning and effort, constantly on the increase, which go into the kind of training and briefing work described on the three pages preceding and the three following.

And it poses a major problem: how to keep such loads from bogging down the plane's performance dangerously: Quite aside from weight, on a B-29 the antenna array creates as much resistance as a strong headwind and the placing of the equipment leaves hardly enough room to let the crew draw a deep breath. The extent to which electronics and aerodynamics thus fight each other instead of the enemy constitutes a danger which is beginning to get attention from electronics engineers and plane designers.

. . . and this array of antennas



By such means as this, planning begins

One of the surest signs of radar's coming-of-age is the emphasis currently being put on advance planning. Along this line there have been major developments in recent months and a definite change in the state of mind of those who work with radar.

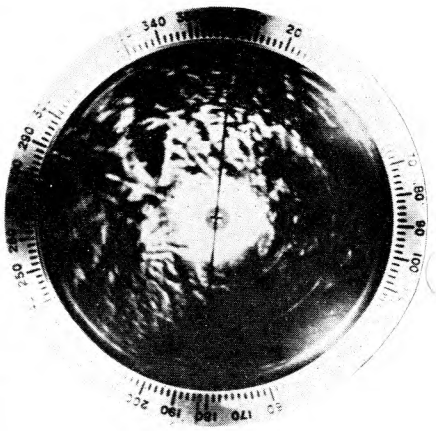
The essence of today's state of mind is that with radar, as with any other complex and high-potential instrument, effective use comes in direct ratio to intelligent preparation for use. This is a simple thesis, but it is new nonetheless — at least in general acceptance and in terms of something being done about it. Radar has, for a fact, been widely abused in the past out of a sort of mystic assumption that you don't have to do anymore with it than turn it on for results to pour out, like music from a juke box.

The report in RADAR No. 3 on the training of Radar Intelligence Officers was a report on the new state of mind. The report on B-29 briefing in the preceding pages is another. The relief trainer shown on this and the next page is part of the same picture. And so are the devices described on page 10 and pages 14–19.

The common denominator here is the effort to start radar operations with concrete plans rather than with assumptions, mystic or otherwise. With respect to the trainer and the two devices, the method is to reproduce on a small scale elements of an operation, and then to simulate what happens. Equipped with the results of such simulations, the actual operators know, at least in miniature, what they're getting into when the operations begin, and also why. One of the interesting conclusions to be drawn from this is that operational intricacies of radar are in a fair way to being resolved at the hands of model-makers.

The Navy's RPD, on which work started about a year ago, was the first undertaking in this direction. But the relief trainer, developed out of the same formula as RPD's about eight months ago, has been most intensively applied to navigation. For its uses in that field it was espoused by the 20th Bomber Command to assist in meeting the vast navigational problems faced by the 20th BC's B-29's. The Research Section of the Command worked out the trainer under the technical direction of Dr. William Shockley of the Secretary of War's Office.

Simulating actual flight with a guided camera running over a relief model and putting the views on an enlarged PPI scope, the trainer familiarizes 25–30 students at once with scope interpretation and radar navigation. RADAR No. 3 showed some of its results. On these two pages is a two-shot view of the trainer at work.





Close relation of simulated PPI photo to real one makes value of the trainer plain

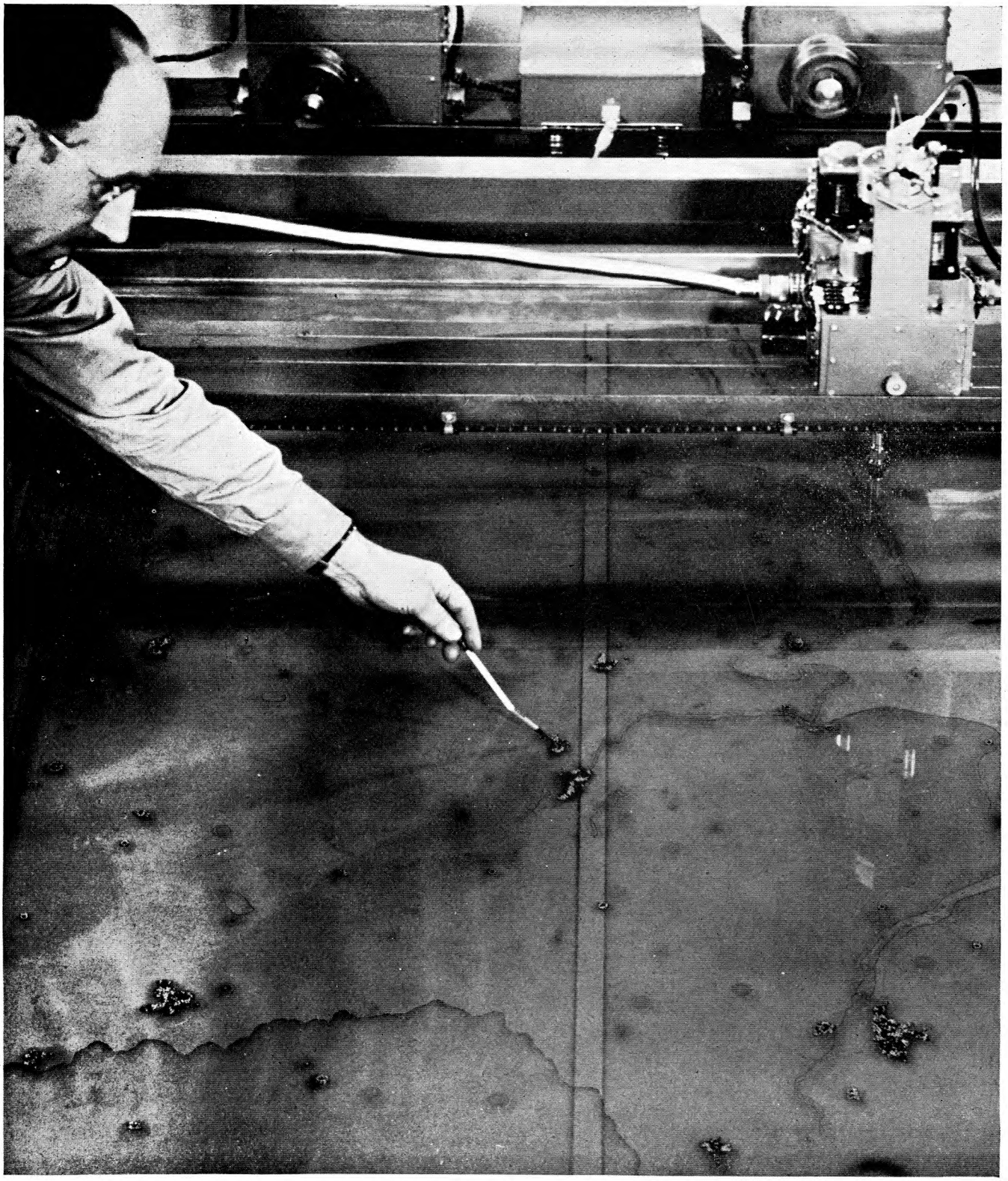
Trainees, with navigator's logbook and sectional chart of area covered by model, "fly" 2-hour missions. Watching big PPI, they have to solve problems of sort met in real flight





Guts of trainer are relief model and camera, which moves to simulate plane flight, transfers what it sees to enlarged PPI. Interchangeable models let trainees practice over various terrains, including future target areas. Portable version using maps is being made ready

Supersonic device, useful as trainer and briefing aid, has helped in study of enemy territory for bombing in ETO, is now being used in preparation of B-29 briefing photos. A layer of water covers a glass map (scale is 1:200,000), in which land areas are simulated by sand on glue, water areas by the plain glass, cities by small beads sprinkled with carborundum to imitate rooftops. Supersonic waves, emitted from scanning head under water, go out and bounce back in same way as radar waves travel through air to and from real terrain. Signals are presented on APS-15 indicator, of which photos are taken. The map can accommodate large variations like parks and big plants and — one special advantage — can be readily altered if radar reconnaissance shows that city shapes, etc. are different than the initial predicted model





HOW THEY GOT THERE

Results of the 9th TCC's D-day mission

THE MISSION

The mission of the 9th Troop Carrier Command on D-day was to drop the 82nd and 101st Airborne Divisions in an area five by eight miles in the Saint Mere Eglise section approximately five miles from the coast.

For this mission, greater dependence was to be placed on radar than in any previous airborne movement. And to this end the 9th TCC's radar program had been set up three months before.*

A Pathfinder School, located on a new field that was a sea of mud most of the spring, was set up with personnel drawn from TCC squadrons. No Table of Organization was made for the school. Men were placed on detached service from their organizations; radar officers were drawn on temporary basis from Air Service Command. Only a few mechanics arrived prior to D-day.

Lack of a Table of Equipment was as serious a handicap as lack of a T/O. Test equipment was short for both shop and plane work. Equipment had to be requisitioned for the School from 9th TCC groups not using it for critical work.

Despite all the handicaps, by D-day 56 Pathfinder crews had been trained and three major practice missions carried out.

For three days prior to D-day mechanics worked nearly 24 hours a day testing all equipment to be used. The last aircraft was OKed just 12 hours before paratroopers loaded up for the Invasion.

THE RESULTS

In four hours on D-day the 9th TCC moved in 844 C-47 transports and 105 gliders and dropped or landed some 15,000 airborne infantry, all within the general Landing Zone. Average drops were accurate within 400 yards of the pinpoint Dropping Zones. Maximum error appears to have been one mile.

Twenty C-47 Pathfinders equipped with GEE Mark II, SCR-717C and Rebecca preceded the main force (30 lead ships of which were similarly equipped) to the DZs by about 30 minutes. For each of the six DZs the Pathfinders carried six Eureka beacons — one for operation, five for assurance. Most Eurekas were operating within the prescribed 10 minutes and triggered within 15. Signal lights were unusable; they immediately attracted German fire. Radar was relied on for nearly all drops.

Ground fire, as the Pathfinders came over the DZs at 500 feet, was very hot. Because of it, some pilots dropped somewhat away from the exact pinpoints, upped flying speed from 90 mph at the DZs to around 150 mph and went up to 2000 feet from the planned 500. At one DZ a Pathfinder pilot veered off and dropped his team about a mile away. The Eureka was set up there but of 150 ships coming in later only 20 dropped on it. The others, recognizing by GEE and the 717 that the Eureka was off base, dropped on the exact DZ.

* *A general report on the 9th TCC's radar program for D-day, with special emphasis on the navigational equipment used (GEE, SCR-717 and Rebecca-Eureka), appeared in RADAR No. 3.*

THE EQUIPMENT

GEE Mark II. In the Pathfinders and lead and deputy lead planes of the main force there were two GEE failures. In one plane a fuse blew out three minutes before the DZ but was replaced in time for the drop. In another an oscillator tube was faulty but still serviceable. All in all, GEE was the major reliance for navigation and some operators made drops by it.

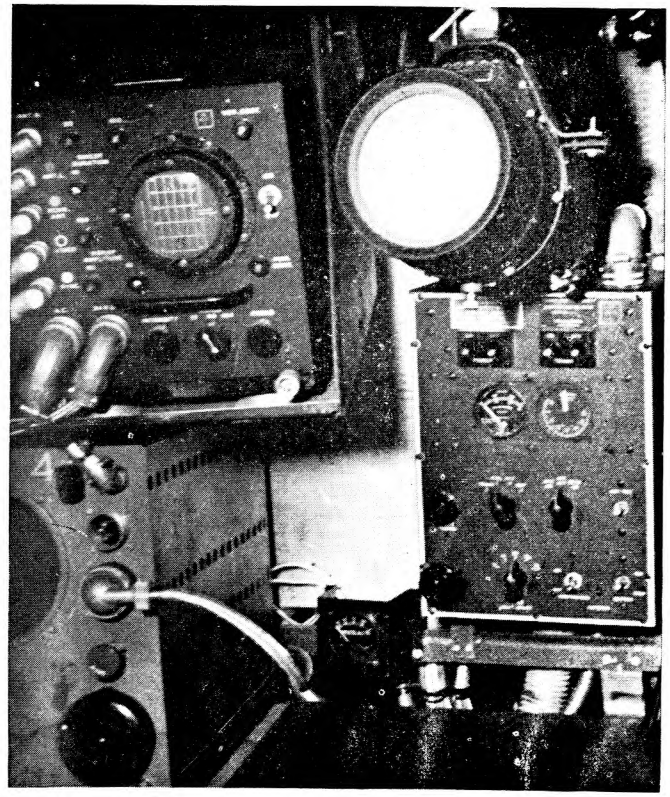
The new GEE frequency put into use for the Invasion was not jammed, though GEE frequencies used prior to D-day had been. Signal strength came through even at 500 feet over the targets.

SCR-717C. Both Pathfinders and main force navigators used the 717 to check landfall and general position. But GEE worked so well that 717 was used less than planned.

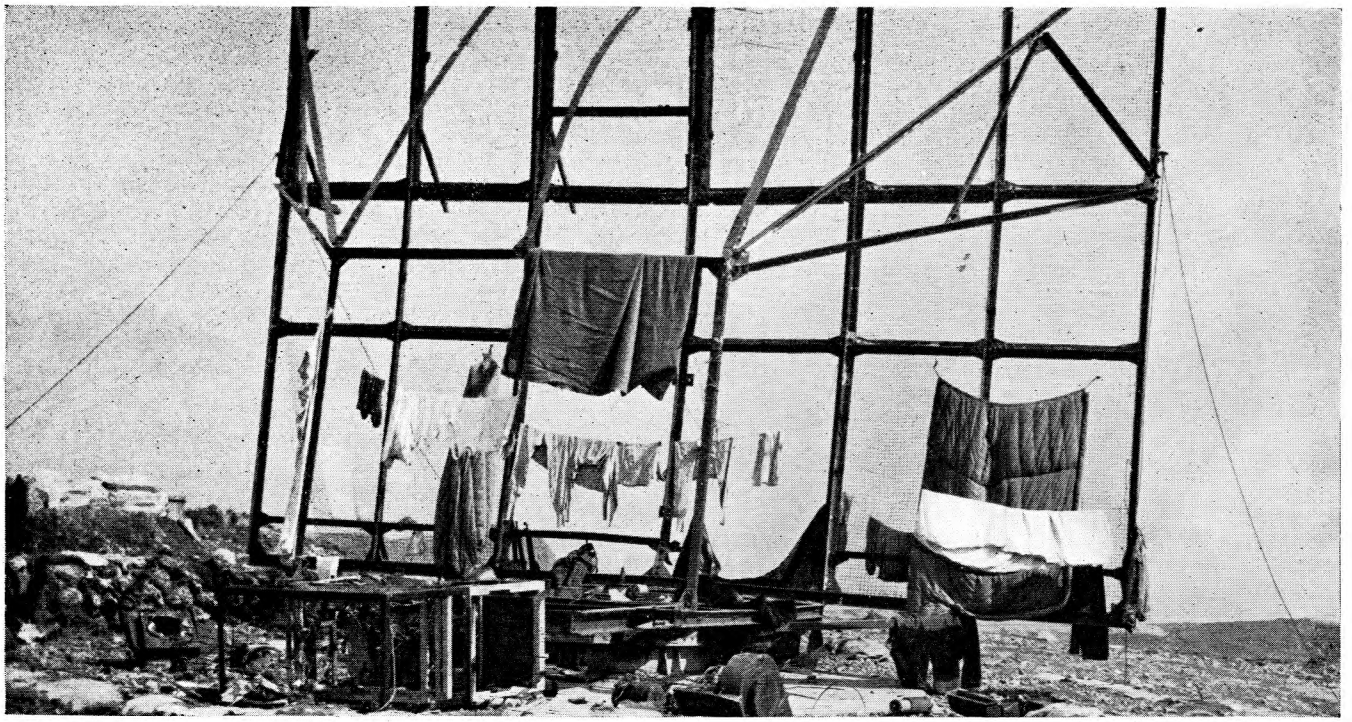
Most dramatic use was by one of the 20 Pathfinders, forced by engine trouble to turn back. The plane was losing altitude fast and orders were given to lighten ship; everything not nailed down was tossed out except 717. But shortly after, and smack over the Channel, ditching became inevitable. At this point the 717 showed a surface vessel 20–30 miles north which might be friendly, since it was larger than the E boats constituting practically the only shipping in that area. Homing on the signal, the pilot brought the plane down by a British destroyer. All on the C-47 were saved.

Rebecca-Eureka. At least three groups of the main force, about 150 planes, dropped entirely blind on R-E. It was planned that only one in nine Rebeccas would be operated at any one time, to avoid over-interrogation. Actually about one in three was operating, because ground fire dispersed formations and individual ships turned on their Rebeccas to help find the DZs.

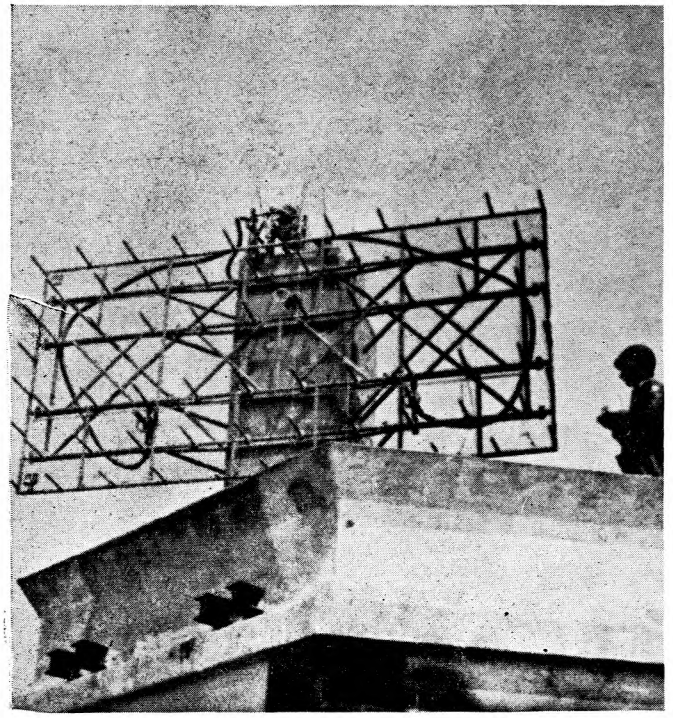
BUPS and BGS. These beacons, for use with the 717, were used very little inasmuch as navigation, dropping and landing were done largely with GEE and Rebecca-Eureka. The altimeter (APN-1) was used plenty and worked fine.

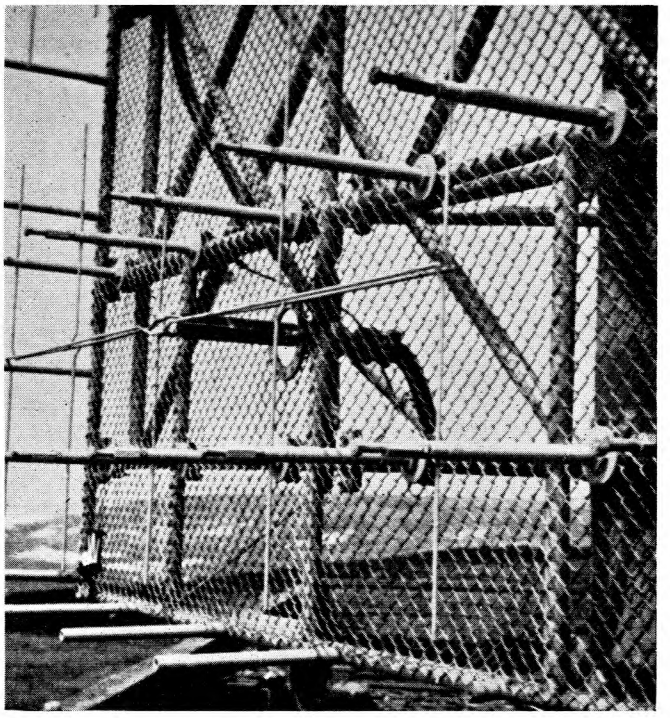


Big three of the radar navigational aids used to get paratroops across to Normandy are shown here as installed in C-47 Pathfinder of 9th TCC. At right is indicator of SCR-717C, with control panel beneath. Rebecca is at upper left. Set on navigator's table is GEE Mark II. Pathfinders and main force leaders used all three to good effect.



THIS BATTERED JAP RADAR WAS TOO FAR GONE TO PROVIDE MUCH INFORMATION. GI LAUNDRY IS KEEPING IT WELL JAMMED





PRE-INVASION BOMBING BLASTED OUT MANY GERMAN RADARS IN NORMANDY BUT THIS COASTWATCHER WAS TAKEN ALMOST INTACT

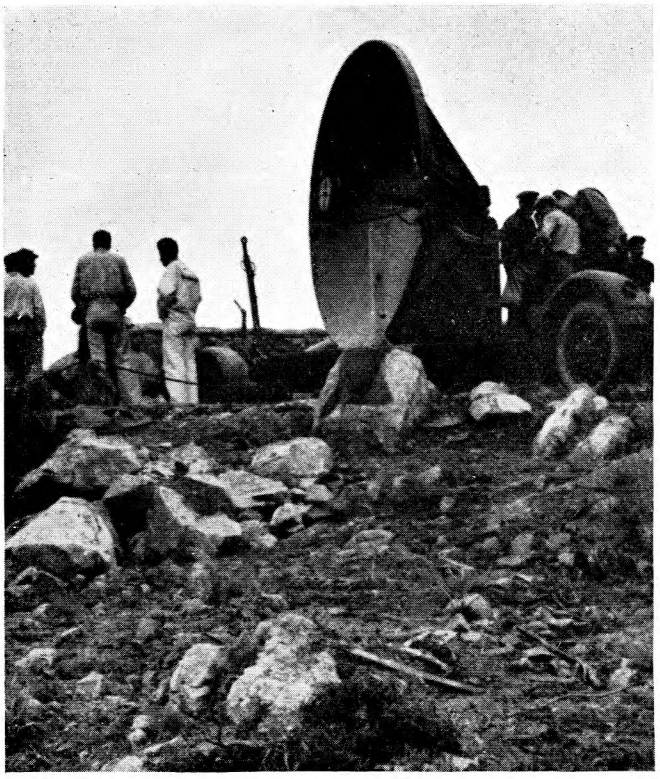
Useful Booty

Allies are getting good collection of enemy radar

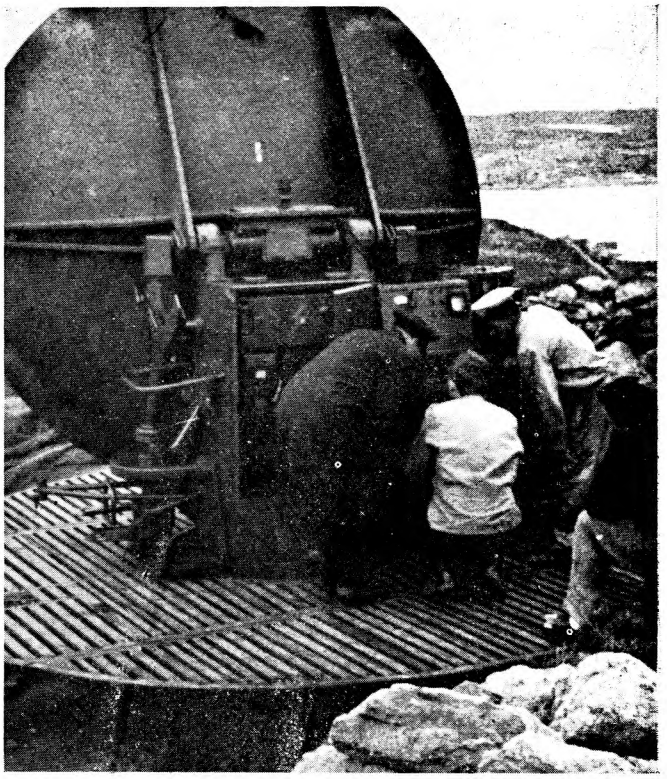
It used to be, and not so long ago, that the characteristics of enemy radar had to be figured out by guesswork, trial and error and elaborate sliderule sleuthing. One of the happy consequences of pushing the enemy back is that such labors are minimized. Captured equipment can answer a lot of questions.

Recent drives in the Pacific, Italy and France have added considerably to the Allied collection of second-hand radars. Some of the items gathered up on all three fronts are shown here. Any equipment taken in reasonably good condition, like the Wurzburg across the page, goes at once to testing centers. But even badly damaged radars have their uses, as the picture at the top of this page plainly shows.

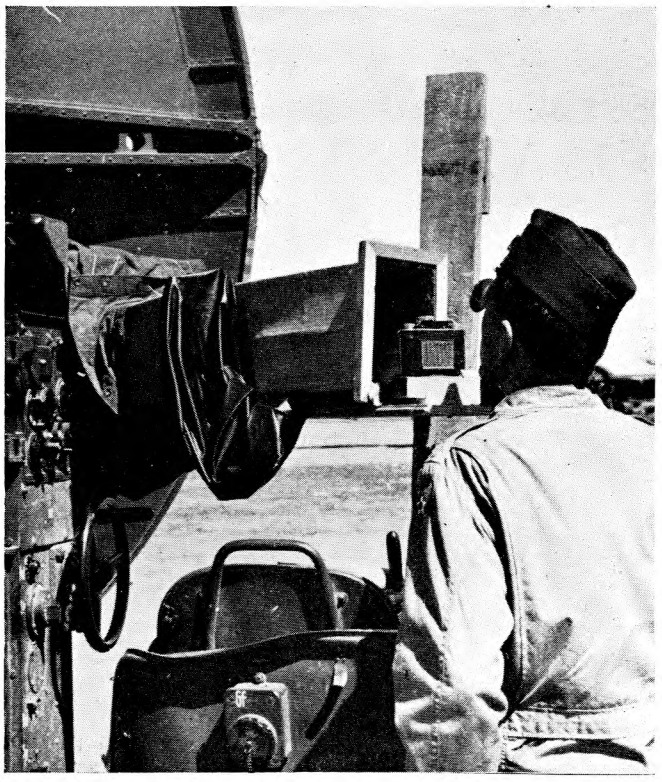
The stock of captured Wurzburgs is growing fast



Mobile Wurzburg is inspected by members of 16th Reconnaissance Squadron (see page 21), called in to help Italian operators make set tick



Many Wurzburgs were sent to Italy by Germans before surrender. This one, sited on Madelina Island, has since been sent to U. S. for tests



Scope photos were made by Squadron members before set was shipped. Before testers are done captured sets are probed all over



Italian sailor once worked Wurzburg against us, later worked with us in fixing it up. Some Wurzburgs are now in use against former owners



BEFORE SAIPAN STRIKE MODEL MAKERS REPRODUCED THE ISLAND SO NAVY COULD MAKE RPD PREDICTIONS TO GUIDE FORCES

RPD DOES IT BETTER

Navy's Radar Planning Device simplifies siting

If you want to be 100% sure about a radar site, the thing to do is to go to every possible location in the area, set up a radar and see how it works. If the area isn't too big, you might reach a decision in a year or two. Obviously, radar siting can't be done that way.

Precisely because siting is a troublesome business, many a siter has gone to the other extreme. He has stood on a hill, like stout Cortez, looked around and said: "OK, let's put it here." Maybe he has stood on two hills and then flipped a coin.

SITING BY THE PROFILE METHOD (BELOW) IS A MOUNTAINOUS TASK; RPD STREAMLINES THE PROCESS AND SPEEDS IT UP



There have been exceptions. Conscientious siting officers have sweated for days with contour maps, working out profiles and predicting good sites by a laborious process of elimination. The profile method is widely known, regularly taught, and irregularly used. Often there just isn't time to use it. But the chief indictment of the method is that, out of its shortcomings, has grown up a widespread disregard for the whole concept of siting. In more than one theater, siting has been decidedly a hit-or-miss proposition, with appropriate effects on the workings of the radar equipment thus sited.

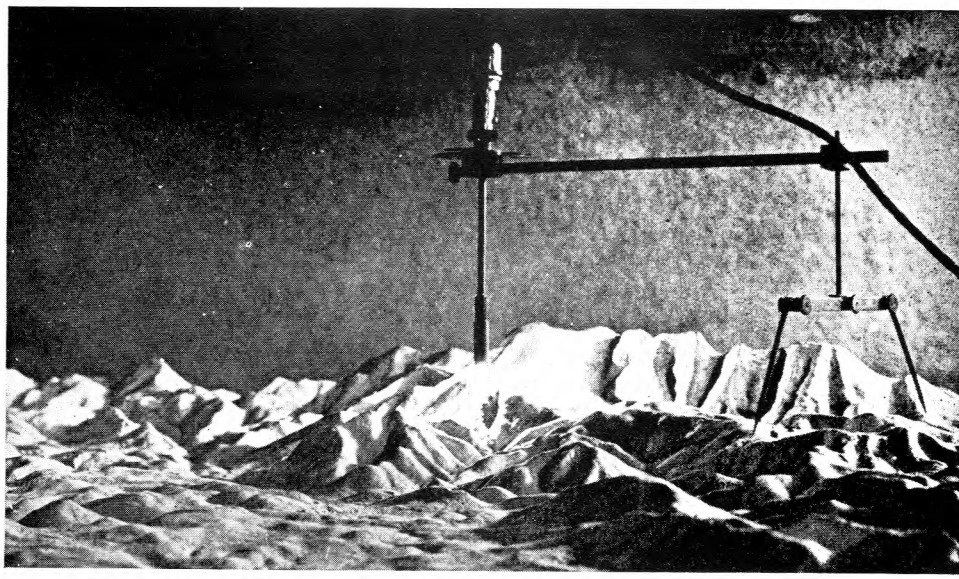
The Radar Planning Device pictured at the right gives promise of changing all that. Developed by the Special Devices Division of the Navy's Bureau of Aeronautics, it is finding its way into use by Army Ground and Air Forces as well as by the Navy and Marine Corps. It has given a spurt to general interest in the whole problem of site prediction.

It is being put to use not only at working out sites for new equipment but at repositioning old equipment which was badly sited. And not only at siting problems but at evasion planning and navigational problems as well.

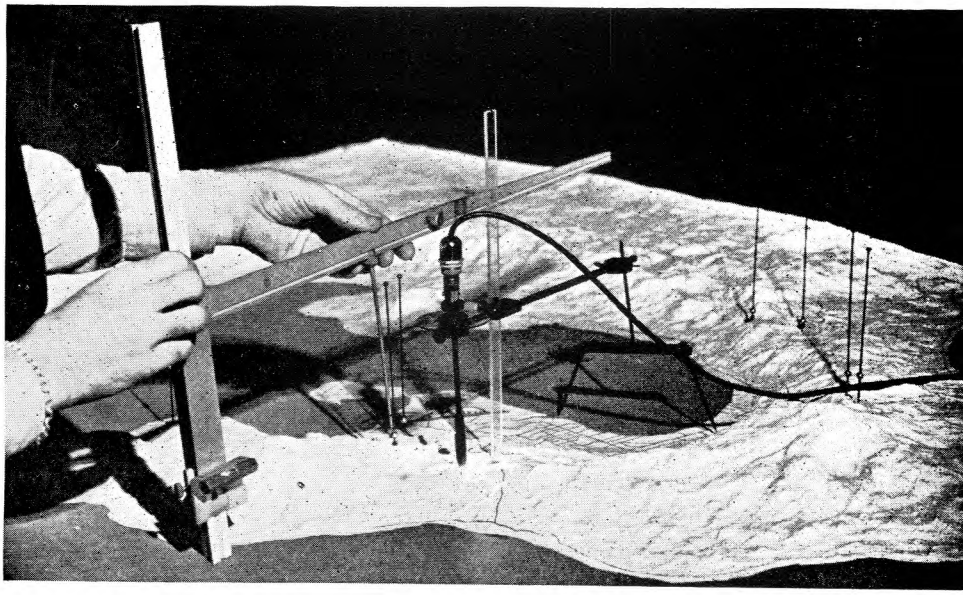
Actual operational knowledge of RPD is still scant and may, as it becomes available, show up weaknesses which no one has been able to find to date. But RPD has done well in numerous tests. It was too new to get in on the preparations for the Normandy invasion, but was called on just before D-day to check and to supplement navigational plans worked out by British profile methods; and it did this to general satisfaction. Its big operational debut was at Saipan, where it was put to work charting approaches for amphibious and carrier task forces. Results of RPD's contribution to the Saipan operation are not in as RADAR goes to press.

RPD is more than a device; it's a technique, and the RPD tools themselves are useless without considerable advance work. In effect, the technique brings down to manageable scale all the elements involved in a real-life siting (or navigation or evasion) problem. A relief model simulates the area to be surveyed; the RPD tools simulate the radar; when they are made to work upon each other they show up exactly what would show up if a real radar were tried out on a real piece of terrain. (For comment on two devices which provide similar results in a similar way, see pp. 8 and 10.)

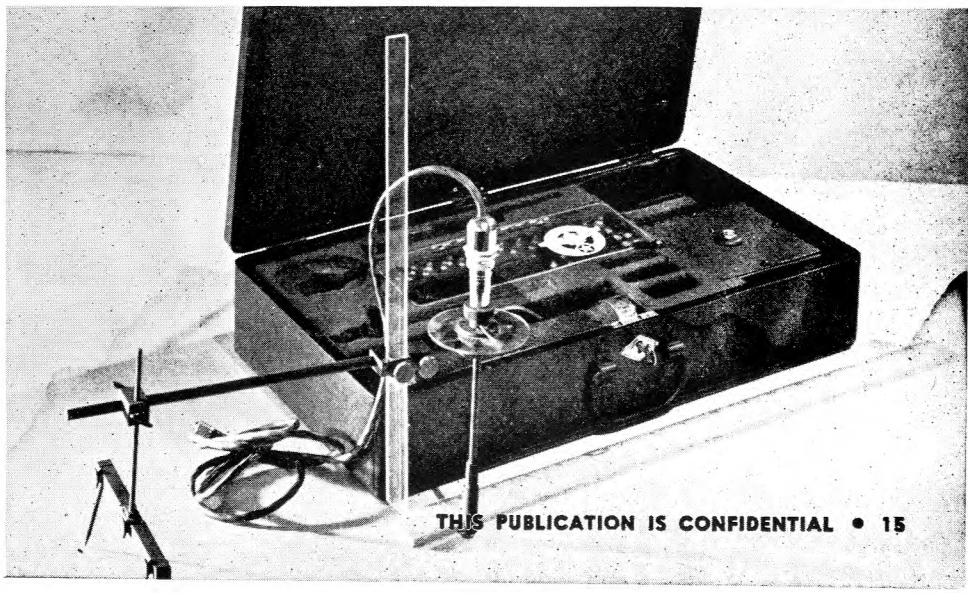
What makes RPD possible is that the skills and personnel for making the basic relief models exist and are fast being extended. What makes RPD the hot item it appears to be is the fact that, once the preliminary model work is done, every radar coverage problem presented by a large area can be worked out in short order. For what RPD does and how it does it, see the next four pages.

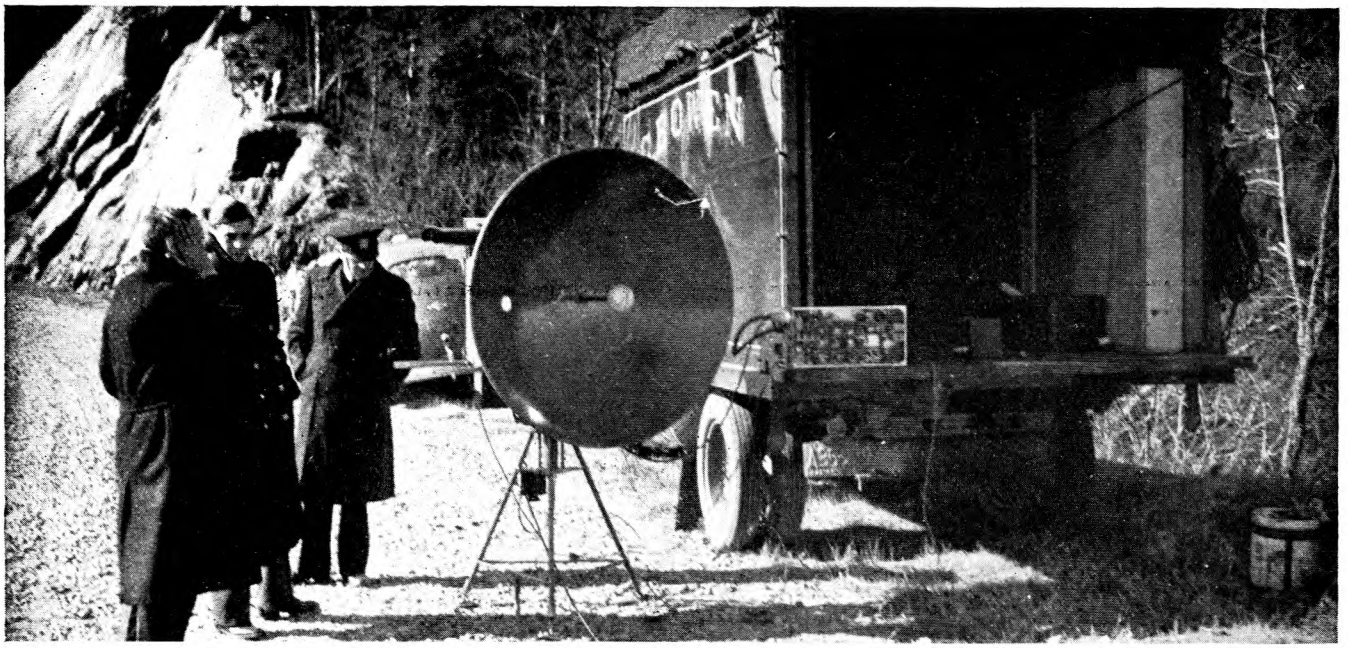


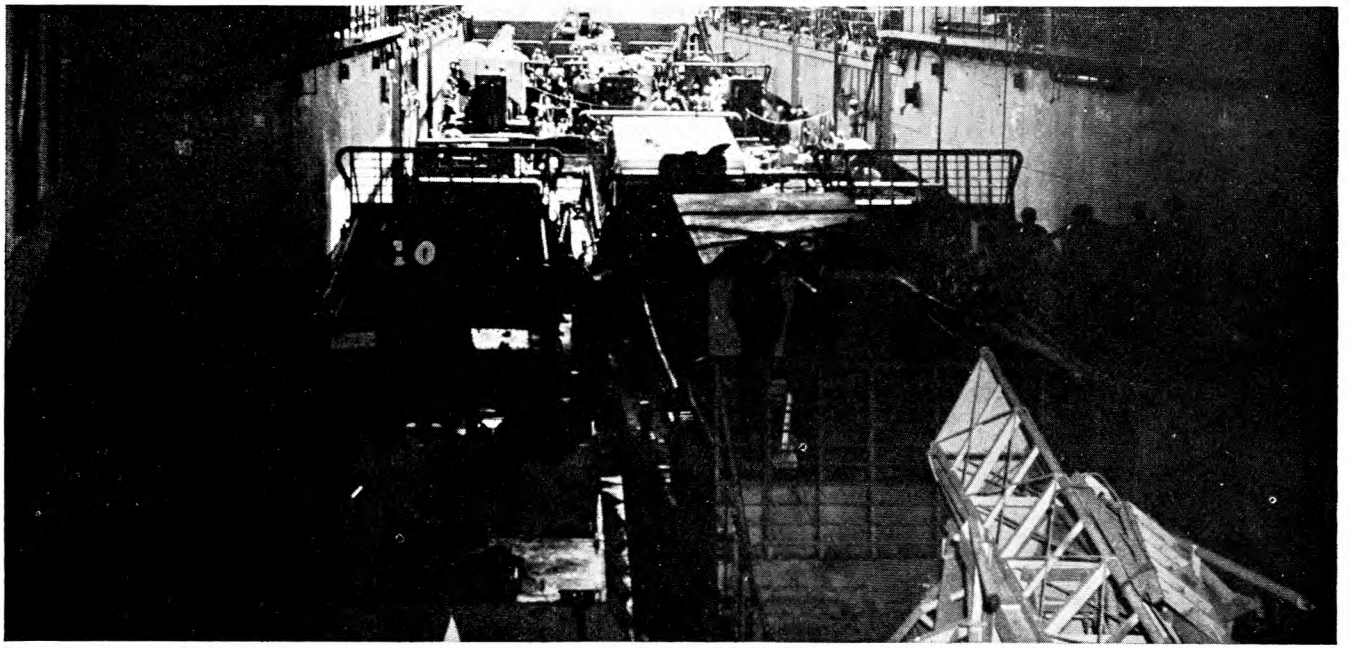
Basic components of RPD are relief model and point source of light representing radar antenna. Light and shadow pattern shows coverage, blind spots, permanent echoes



Beads on pins are adjusted to mark extent of ground clutter and shadows, measured by Map Conversion Scale (above). RPD Kit (below) is both light and compact. Requests for the unit should be directed to O C & R, Fighter & Air Defense Branch, HQ, AAF







First field tests of RPD were in North Carolina's Smoky Mountains last fall (top). On strength of good results the project mushroomed

Final step in RPD siting job is getting radar to predicted site. Here knocked-down SCR-270 moves ahead into RPD-planned position

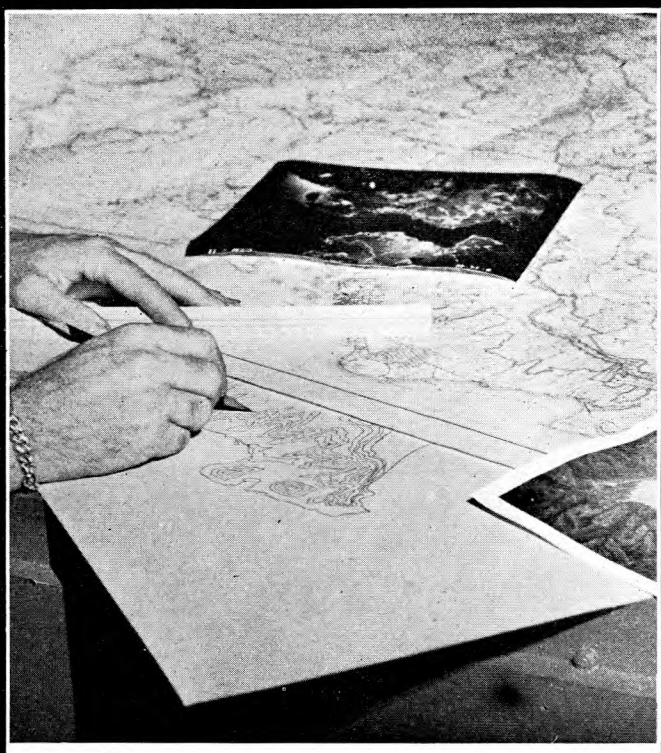
The method makes sense

The AAF got interested in RPD some time ago when the problem of siting the big Microwave Early Warning radars (see RADAR, No. 3) came up. To date the AAF has ordered 112 sets of the equipment, and requests for it have come in from the South Pacific theater, the European and the Mediterranean. RPD-trained officers are already attached to the 5th and 9th Air Forces and are being sent to other AF's.

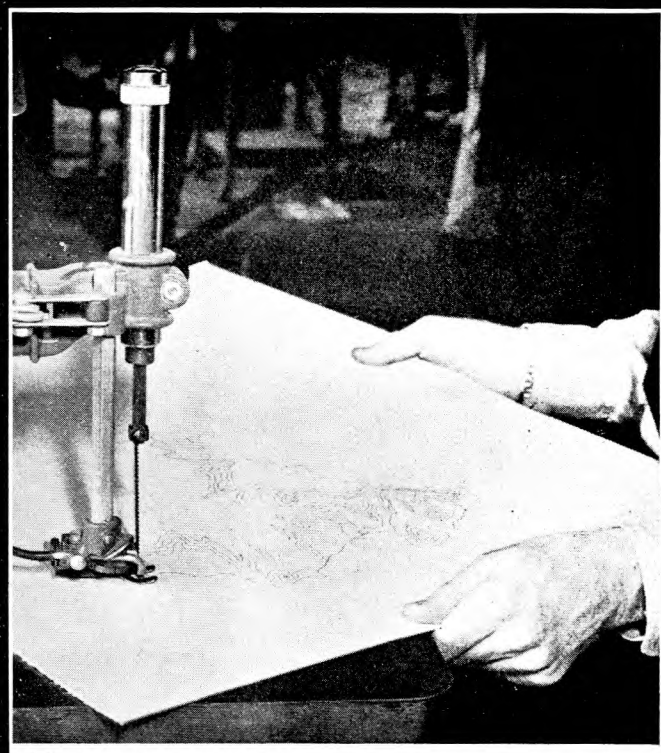
As with many new techniques, the full scope of RPD's potential uses isn't really known. Site prediction, an obvious staple job, is getting the biggest play from the AAF now. But application of RPD to the planning of evasive missions is very much in the picture (see page 19). And the ease and accuracy with which the RPD technique can simulate PPI pictures from flying altitudes assure its increasing use as an AAF navigational aid. (A specialized version of this same technique, worked out by the Research Section of the XXth Bomber Command for navigational training, is described on pages 8–9.)

In all of these applications — others may emerge as inventive field officers get the feel of the equipment — one of RPD's biggest assets is that it is an apt convincer. The siting officer, for example, who has to sell both himself and his superiors on his selections, can do it faster and better with an RPD display to back him up; which is only to say that the method makes sense.

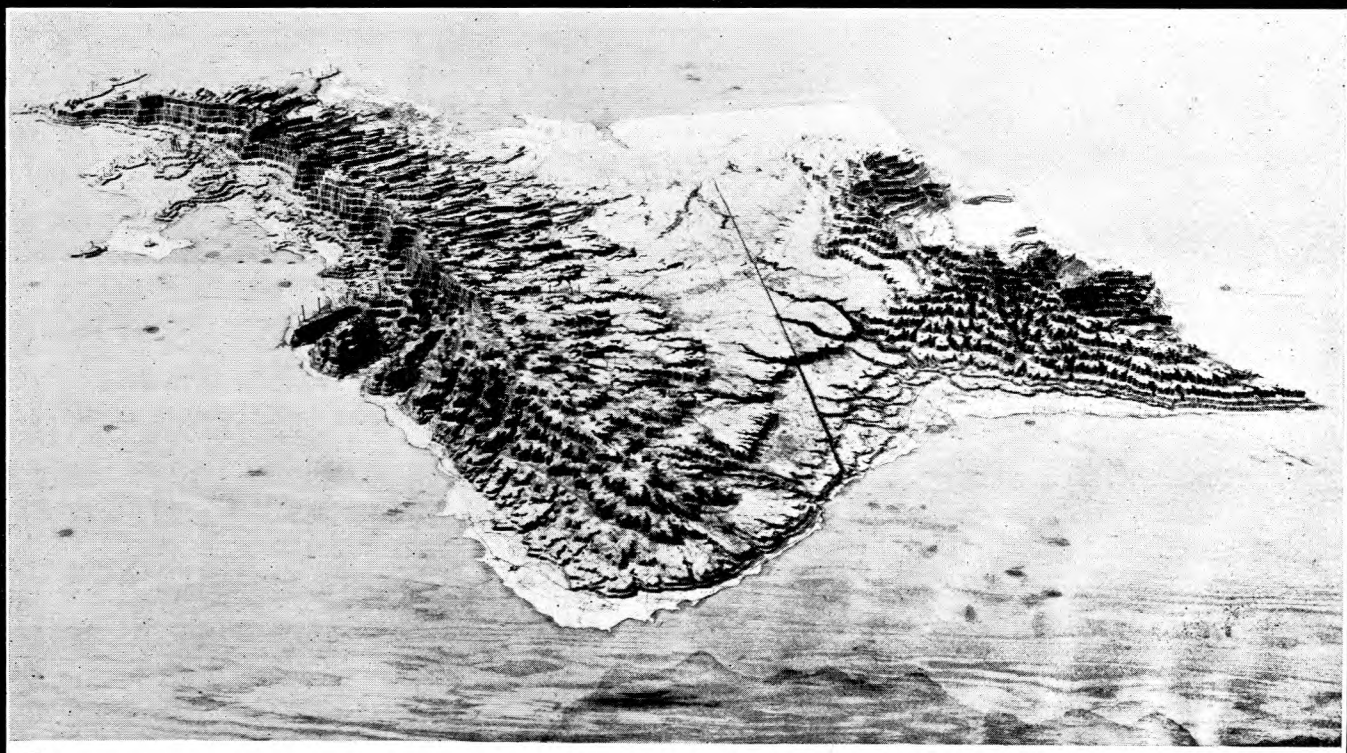
First you make a model . . .



1 Topographical maps and photos contribute to contour tracing, first step in preparing RPD model. At this stage RPD technique requires same work as profile method; but latter requires many drawings whereas one tracing serves all RPD purposes

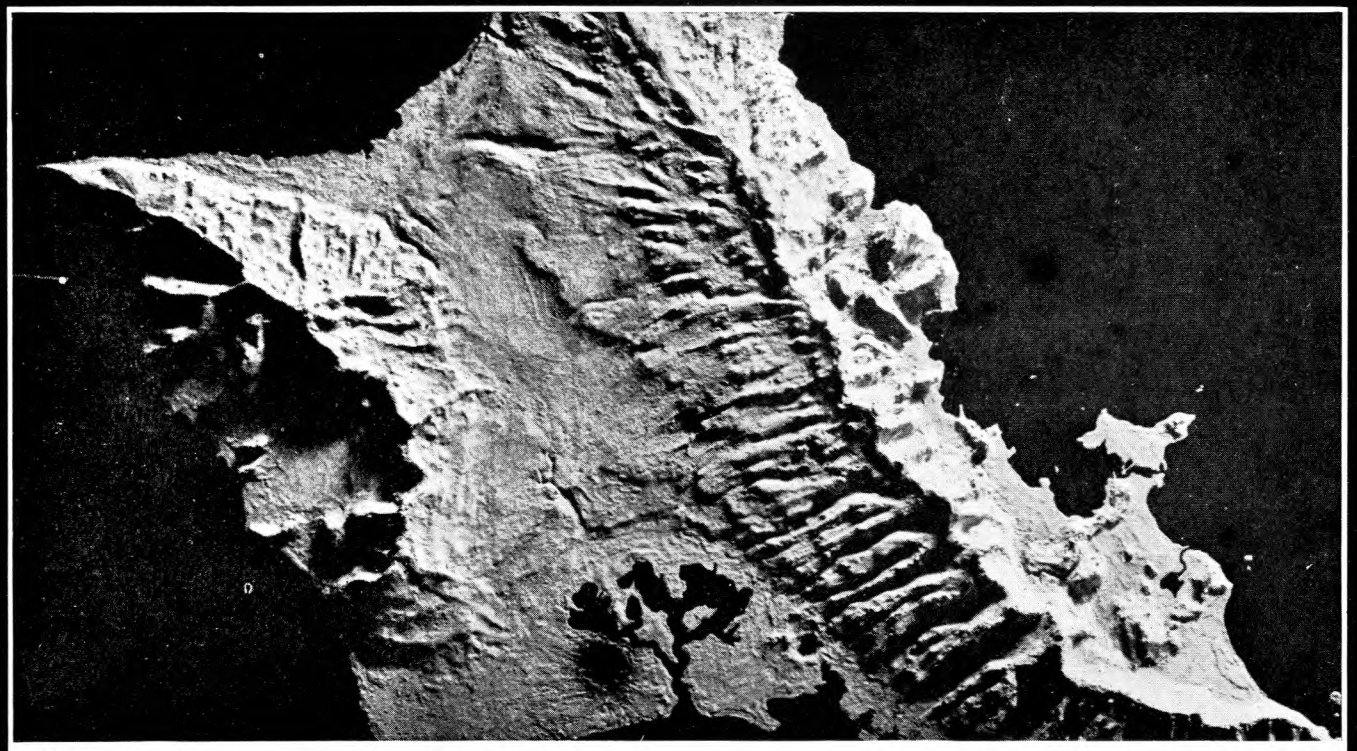


2 Biggest job in preparing RPD model is sawing out cardboard contour sections based on tracing. Facilities for making RPD models will soon exist in most theaters and trained men are becoming available to turn them out on emergency basis if needed



3 Built-up contour sections make this skeleton, which needs only a modelled coating — white for land, black for water — to become a finished model. At this stage most of the hardest work is done with. Depending on complications of the area and skill of the technicians, it may take 2–8 days to reach this point. Once reached, every possible site in the area can be doped out in a day or so. Accuracy of detail in the model is imperative but level of present skill and training has proven as good as it needs to be

. . . then you see what you can see



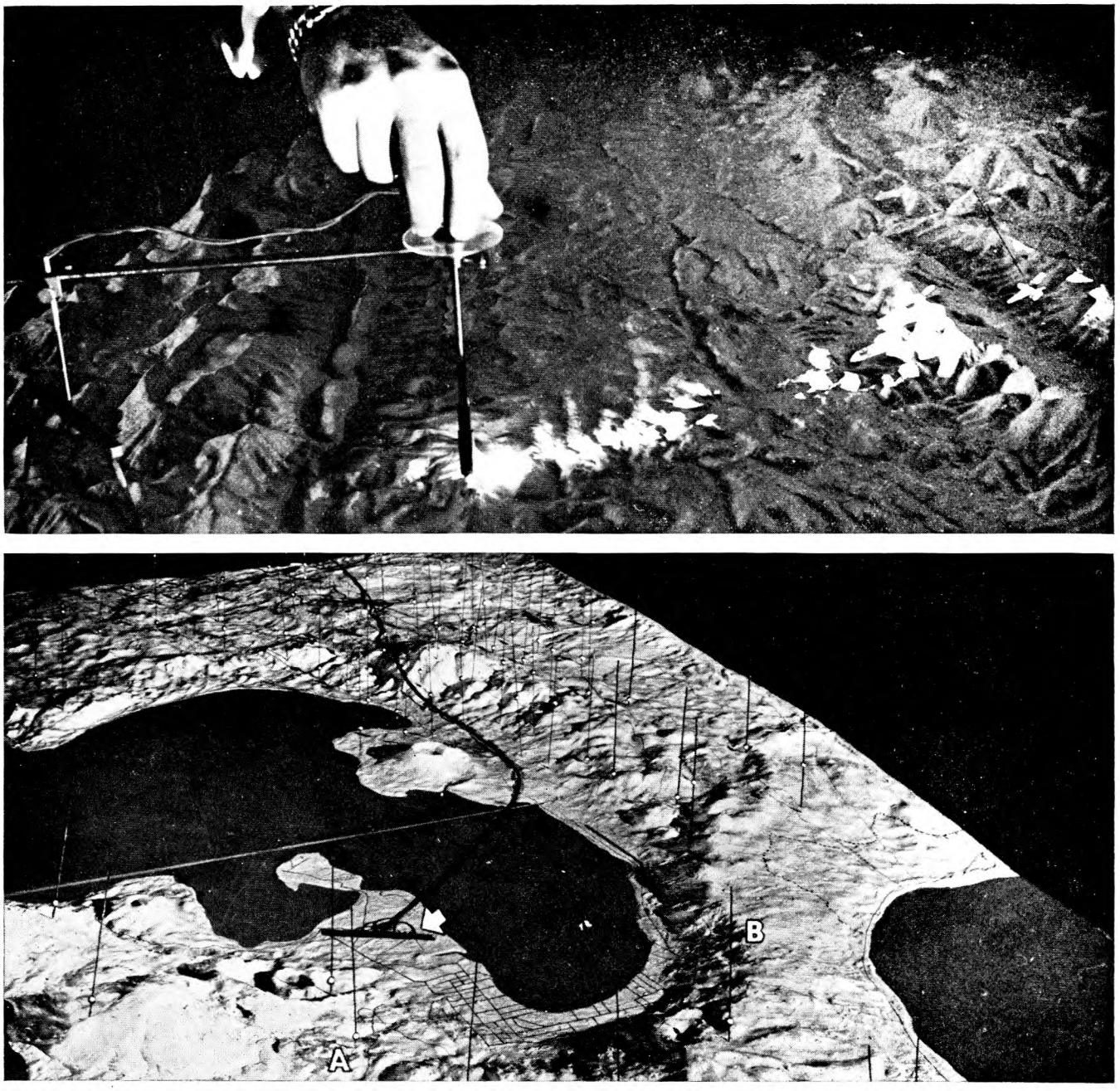
4 Skeleton model on preceding page looks like this finished (area is Oahu Island, where Navy maintains a complete RPD unit at its Pacific Fleet Radar Center). The RPD paraphernalia can now be set up, as shown on page 15, and site characteristics, recognition features, check points for navigation, etc. determined. A special marker to orient signals in range and bearing and a photo easel to provide for beam spread distortion are used in making up the simulated PPI photos of what the RPD lighting reveals



5 Simulated PPI photo of the model taken to represent radar at 150 feet altitude and 5 miles off shore shows most of island lost in shadow of ridges along coast. RPD point light source placed in same position would show the same pattern directly



6 Actual PPI photo taken from same position relative to the island shows almost exactly what simulated photo made with the model showed. Such close resemblances, duplicated in many tests of RPD technique, have firmly established its accuracy



To chart flight through enemy radar coverage (top), RPD light is put in turn at estimated sites A and B. Evasion Indicator pins are set for each location to show area and elevation of blind spots due to ground clutter and shadows. Evasive path to enemy base is then laid (bottom)

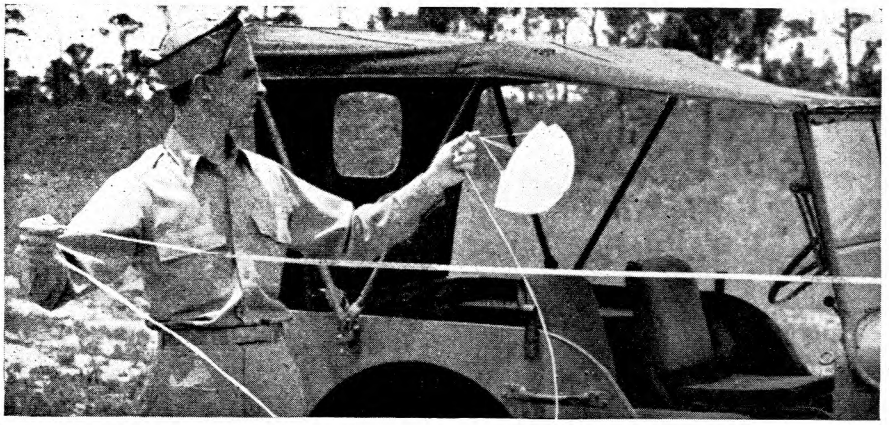
Evasion is siting in reverse

The offensive use of RPD in working out flight paths to evade enemy radar coverage is as much to the point as its defensive use in working out sites for our own installations. The job is the same in either case: to make a model and then to work out coverage patterns related to given locations. In siting, the patterns determine what the locations will be. In evasion planning, the locations of the enemy's radars determine the patterns.

Reconnaissance and intelligence usually must be relied on in locating enemy radars, but even at this RPD can help. An RPD survey of a model of enemy terrain will disclose logical sites as well as impossible ones, thus provide a rough guide to where the enemy's installations are likely to be.

When blind spots in the enemy's coverage have been measured, they can then be exploited so that our attacking forces can get in with minimum risk of detection. Aside from the fact that such planning can save men and planes and add greatly to a mission's effectiveness, it goes well with the crews doing the flying. The objective testimony of an RPD layout showing why a flight path leads where it does can be a considerable morale factor at briefing time.

**For a report on RPD from a Navy point of view see the August "C.I.C.", confidential publication of Chief of Naval Operations.*



NEW ROPE TRICK

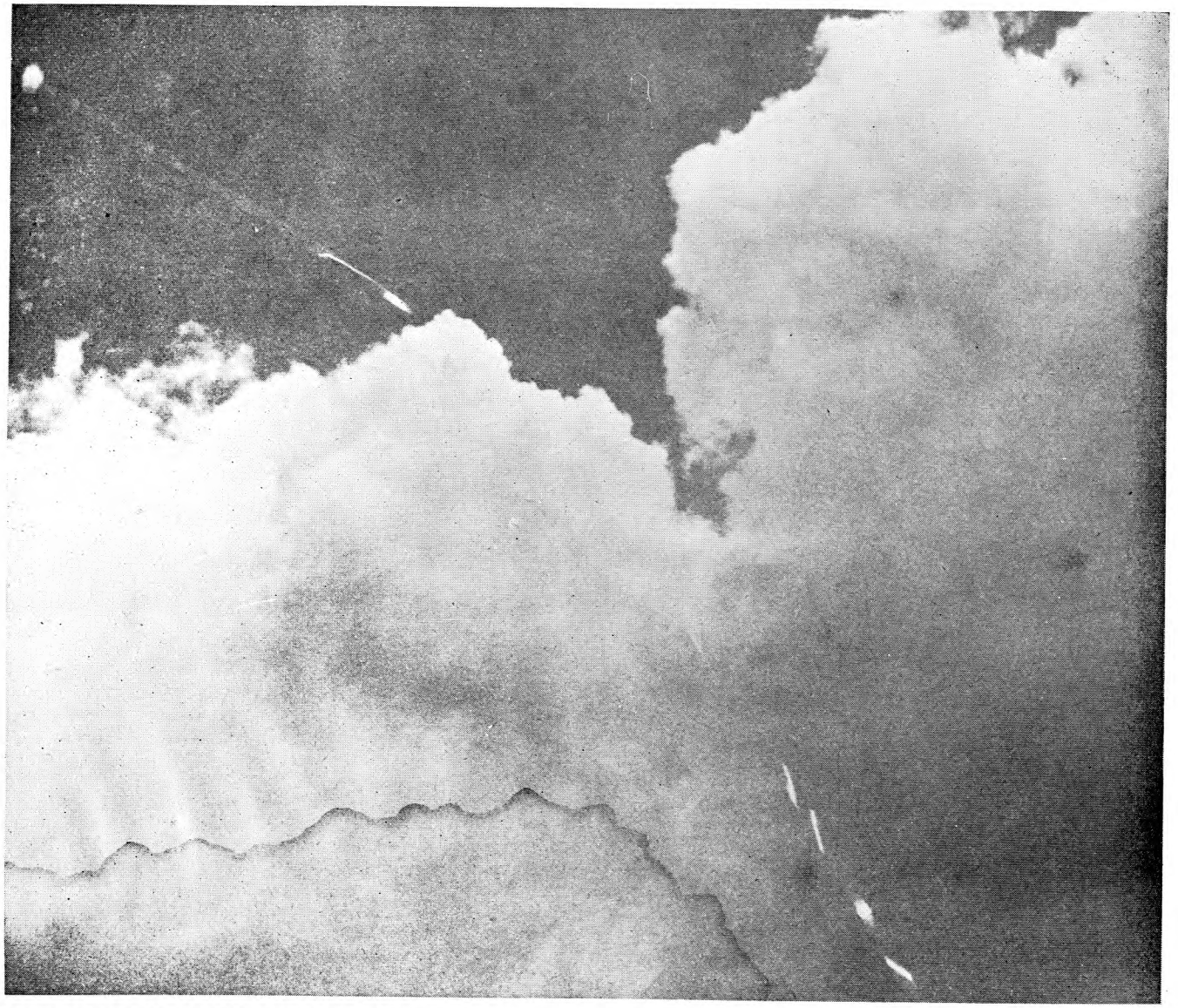
Untuned rope, shown here in the hand and in the air, is window with eye-appeal. Newcomer to the window family, its 400 feet of aluminum foil looks like glorified confetti, acts on opposing radar something on the order of Irish confetti.

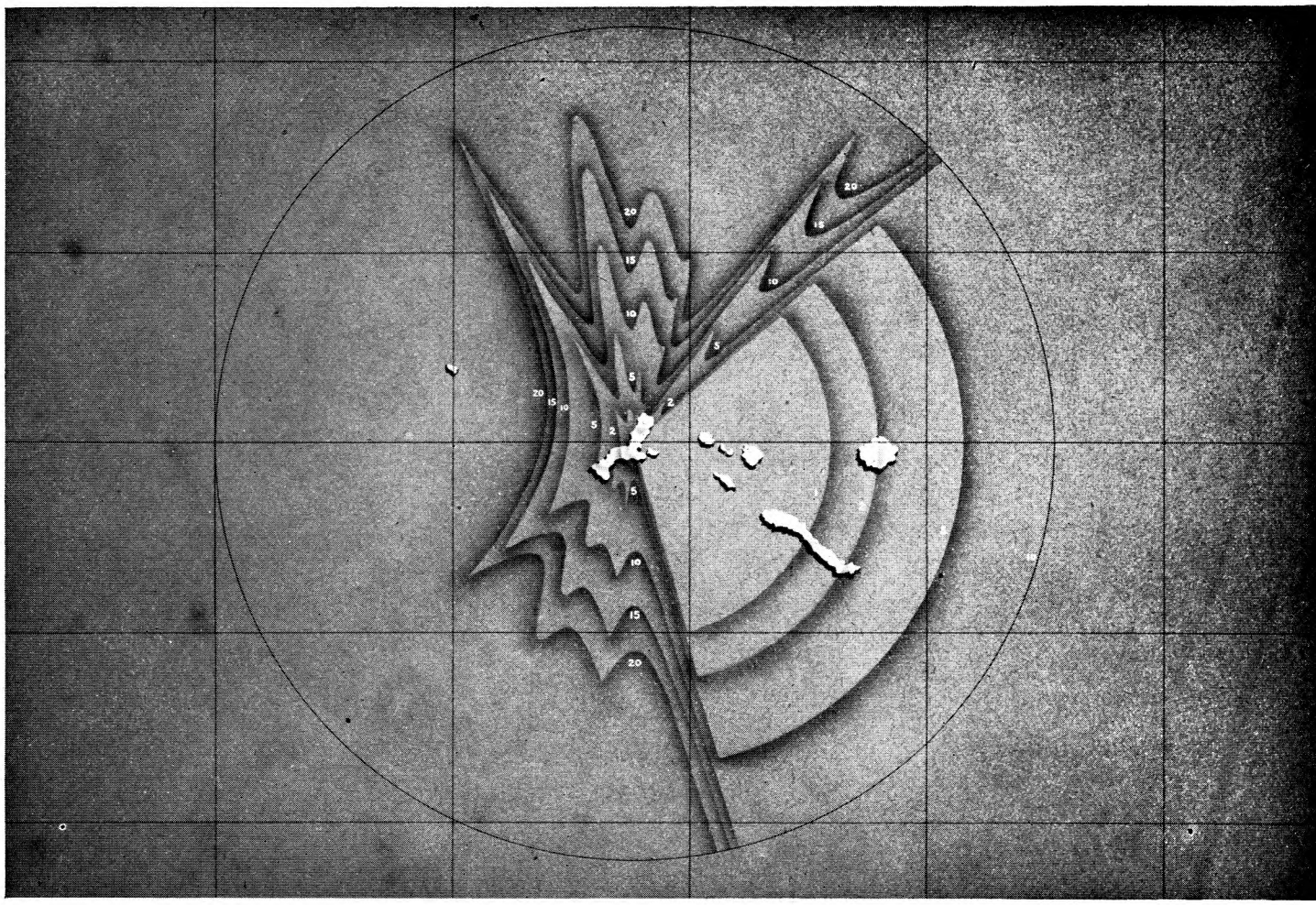
Rope does its trick against the enemy's low frequency radars and over a broad band. It is a logical teammate to chaff (see RADAR, No. 3), various types of which cover various parts of the higher frequencies used by enemy radars.

The echo from a given amount of rope has a varying value depending on the radar frequency; the lower the radar's frequency the greater the echo created by the rope. One bundle of three rolls gives an echo at 150 Mc equivalent to the echo of one heavy bomber.

Launched in a neat roll, rope is joined by a cloth strip to a paper parachute 1′ in diameter or to a 3″ square card; the roll opens on contact with the slipstream. The parachute type is for use against vertically polarized radars; the card type for horizontal polarization.

Parachute rope falls about 4 to 5 miles an hour. Card rope goes down a bit faster. Both types are just now getting into operational use.





FIRST FERRET CHECKED JAP KISKA RADAR COVERAGE PREDICTED ABOVE. SUCCESS OF THIS JOB GOT FERRETING OFF TO GOOD START

The work of the Ferrets

Ferret is a code name which has become part of the language of radar. It entered the language unobtrusively in the smallest of the war's theaters, in connection with a mission to find a single radar installation. The mission involved one plane with two 2nd Lieutenants fresh out of a radar school in charge — and, uneventfully, it succeeded.

This was some 18 months ago. Ferreting — which means radar reconnaissance — is by now an established institution and the flying laboratories which are the Ferrets have probed hundreds of enemy radars. They have done most in the Mediterranean, where they have been steadily active for over a year. Not until a few months ago did the Pacific get Ferrets. Currently a pair of B-24's, more completely equipped than any other Ferrets in the business, are covering Jap radar in the South Pacific, helping to round out island invasion plans.

Ferret planes are loaded down with all the countermeasure devices that can be crammed into them. But, more to the point, Ferrets are countermeasures themselves — almost the original countermeasures, since the big emphasis on getting at enemy radar by radar methods started with the Ferrets.

A photo reconnaissance mission in the Aleutians, which revealed a probable Jap radar installation on Kiska, started the Ferrets. With the situation coming to a head in that theater, if Kiska had a radar it had to be eliminated. But first it had to be identified and studied — to learn from it what could be learned, to find out how best to knock it out.

The theater had neither equipment nor personnel for the job. But back in the States some 2nd Lieutenants were just coming out of a new RCM course at Boca Raton, Florida. When the call came from the Aleutians, Lieutenants Edward Tietz and William Praun were assigned to get the information.

At Patterson Field a new B-24D with the bomb bays rebuilt to house the latest radar investigational equipment was readied. In January 1943 Ferret I began a series of solitary missions against a probable Jap radar on Kiska. The Ferret found the signal, homed on it and confirmed the photographic report. It logged the station's frequency, power, PRF, and provided data for checking coverage (see chart above).

As a result of their findings the two 2nd Lieutenants found themselves sitting in on a staff meeting with Major General Butler, then commanding General of the 11th Air Force. Ferret findings were of tactical value in the General's coming offensive. He wanted to know how to approach the radar with least risk of detection, where bomb hits on it would do most good, etc. As Lieutenants Tietz and Praun answered the questions, plans were laid for the elimination of Kiska radar.

Thus the history of the first Ferret mission.

As it has developed, Ferreting has been by and large a job without the drama that goes with much radar activity. With an eye to the importance of its undramatic contributions, RADAR reports on the following pages what the Ferrets are, what they have been doing since their quiet start a year and a half ago.

16th Reconnaissance Squadron: the Mediterranean Ferrets

The challenge offered by German radar in the Mediterranean theater was accepted by three Ferret-equipped B-17F's shortly after the first Ferret mission countered Jap radar in the Aleutians. Aboard these three Ferrets were six RCM officers from the Boca Raton school — Lieutenants Mathew Slavin III, R. L. Ihle, John K. Pheley, Norman Weed, Harrison A. Lehmann and James E. Magnuson.

Their mission was to locate and investigate all radars along the Mediterranean coast from Spain to Crete — an intensive assignment, as it turned out, since they found a radar site every 30 miles along that coast.

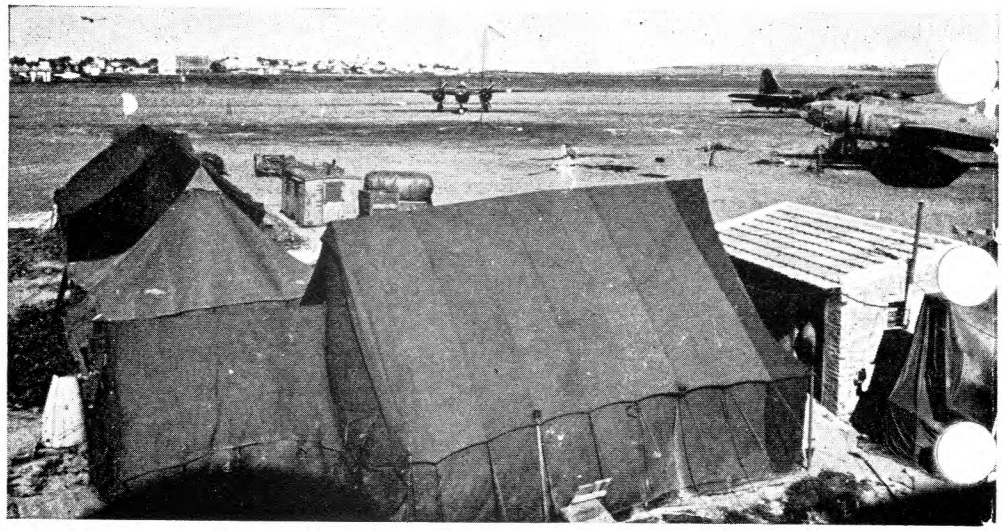
But Ferret operators and crewmen found more problems in the theater than those offered by enemy radar. Since Ferreting was a new activity without benefit of squadron organization, such essentials as food, bedding, supplies and maintenance had to be found the hard way. Having no official designation, the Ferreters named themselves — the GR (General Reconnaissance) Squadron — to receive mail. By a careful winning of friends and influencing of people (with emphasis on supply sergeants) these countermeasures orphans survived.

After three months the Ferret crews were finally adopted by the 16th Reconnaissance Squadron, with Lt. Col. N. J. McGowan commanding. Life became less rigorous after that. C rations were abandoned in favor of a squadron mess, and overdue promotions were forthcoming. Later the command was turned over to Captain W. W. Redman.

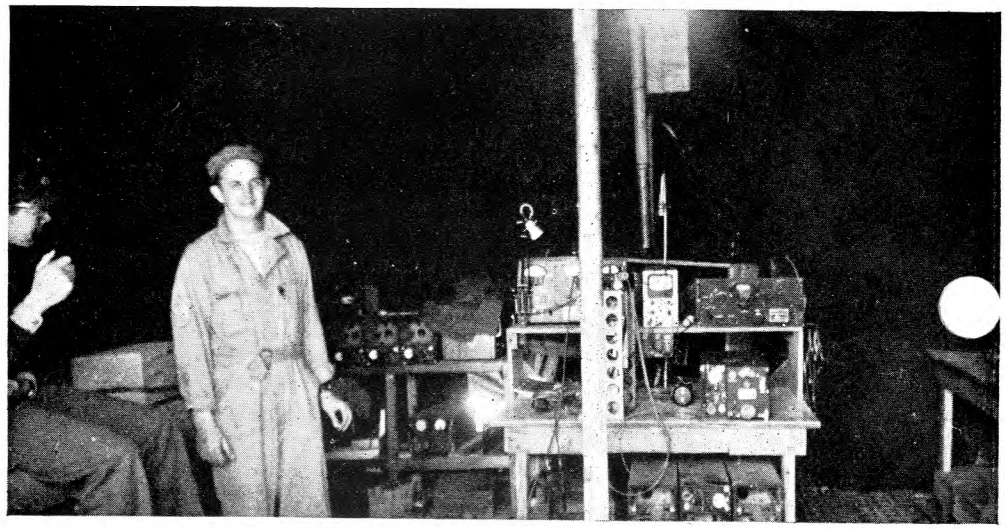
With more than a year's activity in the Mediterranean behind it, the 16th Reconnaissance Squadron is on the record as having constructed and maintained a comprehensive picture of enemy radar in that theater through its investigational missions. Its findings have laid the basis for an expanding and efficient countermeasures program.

The work isn't all done in the RCM room. Pilots, navigators, bombardiers and crewmen share pretty much alike the credit for safe and profitable Ferret flights. The crew fights a special enemy — boredom — for a Ferret flight isn't spectacular, provides few thrills and little contact with the enemy as a rule. But any Ferret aircraft is vulnerable and demands an alert crew to insure the safety of its specialized personnel and equipment. Enemy or no enemy, missions at 500 feet at night are tricky, especially over waters dotted with island hazards.

In addition to flying their search equipment, RCM personnel usually have man-



MEDITERRANEAN FERRET MISSIONS WERE FLOWN FROM THIS NORTH AFRICAN FIELD



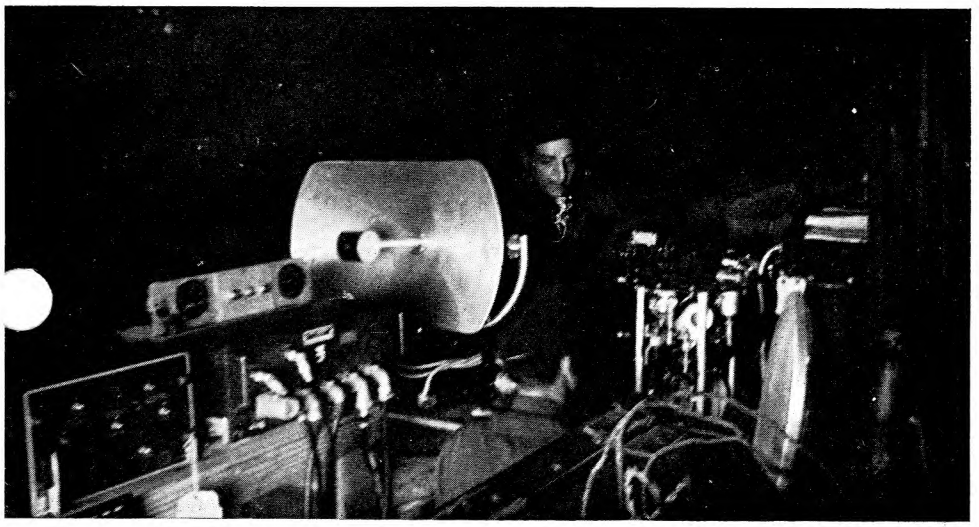
SCR-717 MAINTENANCE IS HANDLED IN A TENT BY 16TH RECONNAISSANCE CREWS



MOST EXPERIENCED FERRETS: 16TH'S OFFICERS HERE ASSEMBLED IN SQUADRON MESS



. . . FROM WHICH THE FERRET CREW ABOVE IS JUST GETTING READY TO TAKE OFF



. . . AND RCM MAINTENANCE IN ANOTHER. COMPLETE REPLACEMENTS ARE KEPT ON HAND



FIRST FERRETS: CAPTAINS PRAUN AND TIETZ, WHO RAN PIONEER MISSION AT KISKA

aged to expand the scope of their work. They have modified and built equipment, developed antennas, tested captured sets (see page 13), made new installations and done general laboratory work. And their main job doesn't leave them any too much time, either.

The Ferret operator's assignment in the theater is, in fact, a round-the-clock affair, with a little of everything thrown in.

A day of Ferreting begins with a mission over an area subject to future offensive action. It may run to eight or ten hours. On the way out the search equipment is operated, positions recorded, notes taken; even before coming back the RCM officer starts writing up a detailed report.

On landing, and without any time out for changing clothes or eating, he is rushed to be questioned by intelligence officers wanting to know what he saw and did on the flight. By the time he has eaten supper, photographs taken of the same area by another reconnaissance plane have been developed, and he is called in to coördinate his findings with photo intelligence. This may turn out to be an all night job. In a photograph a radar can look like anything but a radar.

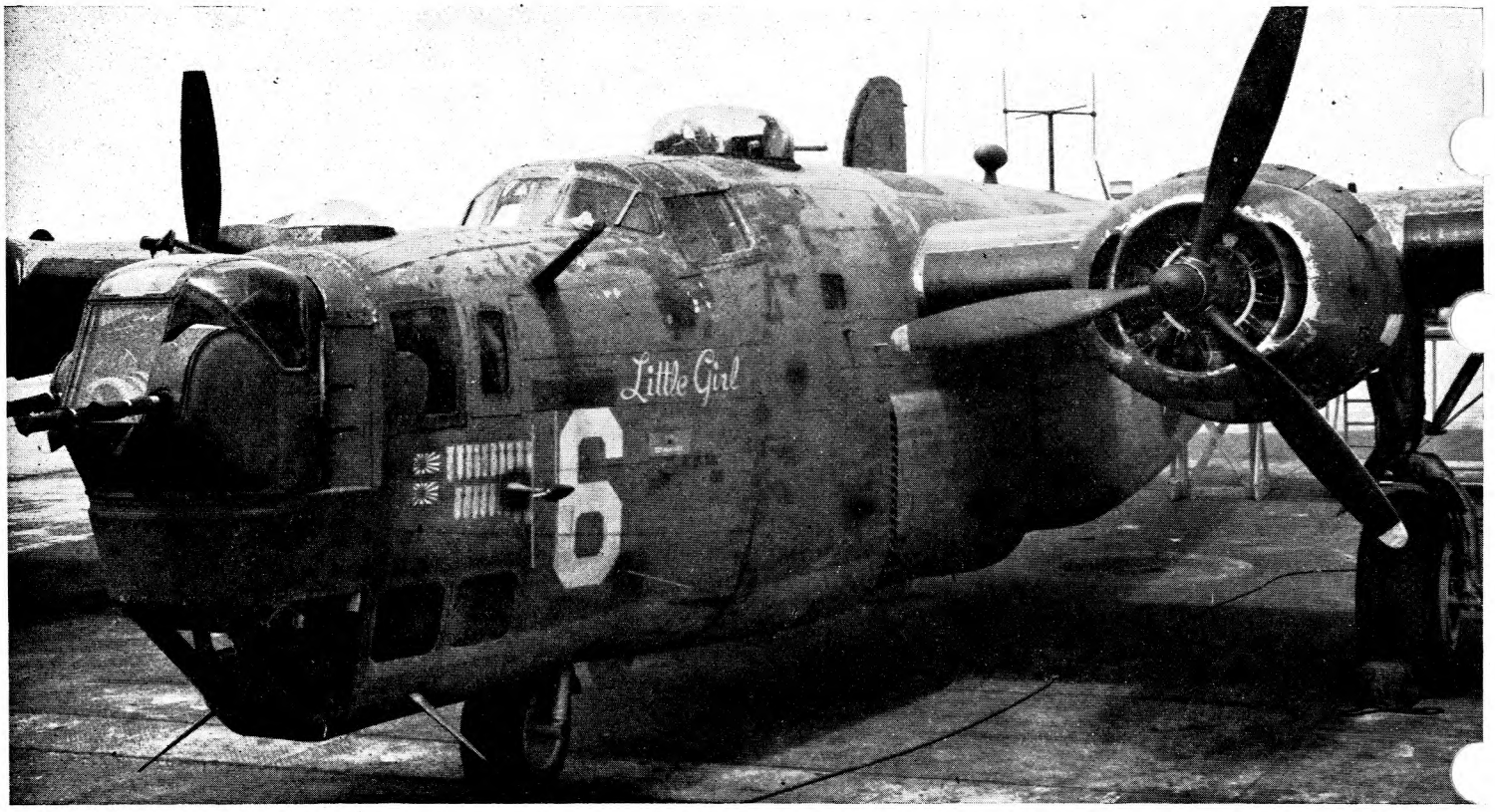
Then the RCM officer is expected to construct a shadow map of the investigated area based upon his Ferret findings (see page 21). From this, paths of approach and traffic can be laid out to circumvent enemy radar coverage and the efficient application of specific countermeasures can be determined. In such maps — one end product of Ferret missions — the combined data provided by all the Ferret equipment and all the operators' skill are put to work. On the accuracy of such maps may depend the success of many a future action. New developments in plotting coverage patterns (see page 14) may alter or even lighten this work of the Ferrets. But the main job — to find the enemy's radar and to test out its capacities and characteristics — is a never-ending one.

Each Ferret plane carries a complete crew, plus one or two of the specially trained RCM officers. The latter plan the missions, operate the equipment and are responsible, not only for the missions, but for tactics, maintenance, intelligence, interpretation.

Ferret operators are RCM officers who have run the gauntlet of radar schools. Most of them, after graduating from the communications school at Yale University or Scott Field, studied radar fundamentals and electronics for six months at Harvard and MIT. From there they went to Boca Raton for practical experience with airborne radar equipment. Following this training, officers selected to become RCM experts take a special four-week course for an aeronautical rating as Aircraft Observer (RCM). Early officers went into the field at this point; now their training is supplemented by an operational tactical course at Eglin Field.

Ferreting calls for these conglomerations of equipment

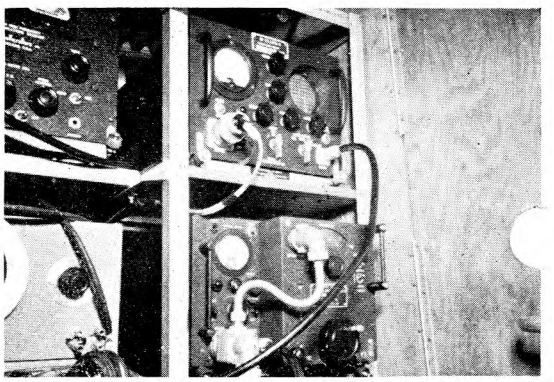
Typical Ferret installations in B-24 and B-17, the two planes used for Ferret missions, are shown on this and following three pages. Most of the installations are made at Wright and Patterson Fields, Ohio, whence the planes are flown to the Electronics Section of Eglin Field, Florida

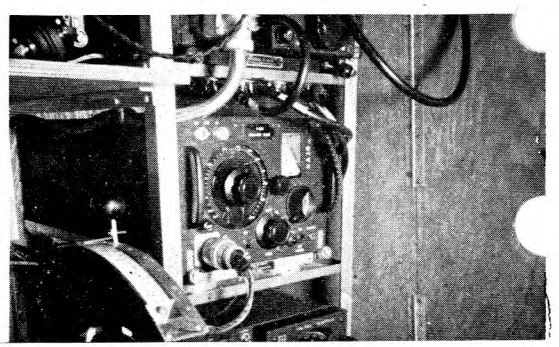


B-24 Ferret has RCM equipment in bomb bays, carries up to 20 antennas. Installations provide data on locations, frequencies, ranges of radar or CW stations; on signal power, pulse widths, VHF frequencies, etc. B-24's are best for long range work

RCM room in rear bomb bay houses Panoramascope with S-27 receiver (top); SX-28 receiver and HP Audio Oscillator (bottom); Pulse Analyzer, APR-4 receiver & spare, APR-2 autosearch receiver (all at right); lever for DFing (lower right); fluxgate compass (top at left)



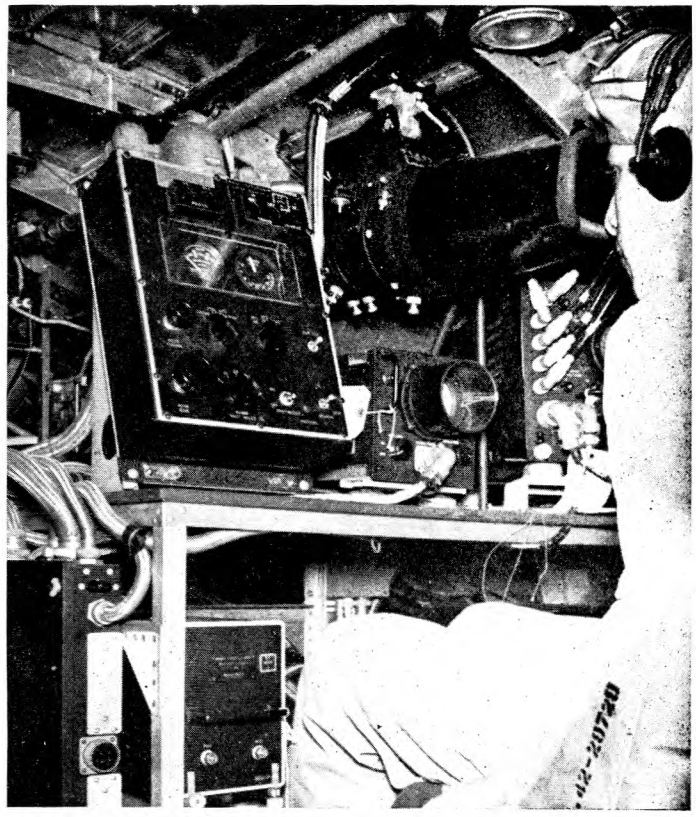




At Eglin, shakedown runs and calibrations of equipment are made; crews are picked up and Ferrets are then ready. Since theater requirements give varying emphasis to various equipment combinations, Ferret installations are often changed. Crews do this work in field



717 antenna structure in up position. Looking toward bomb bays, door to RCM room is seen right center, radar room door top center

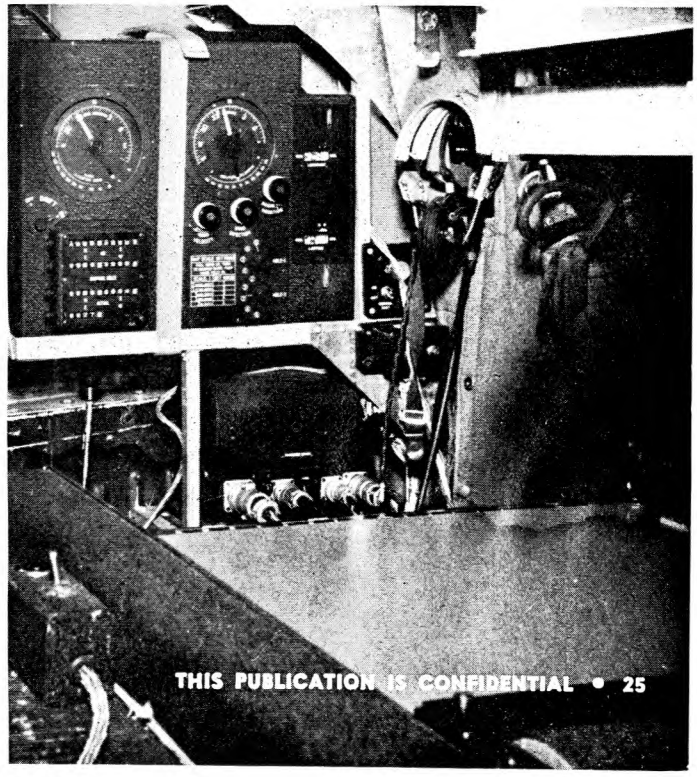


Radar operator is on top deck above RCM room. Radar altimeter shows below the 717 hood; indicator for SCR-729 is at extreme right

Loran receiver is important part of Ferret's equipment as aid in solving the tricky navigational problems peculiar to Ferreting missions



Odograph, not yet installed in all Ferrets, surrounds navigator's position, automatically traces flight path and marks key positions

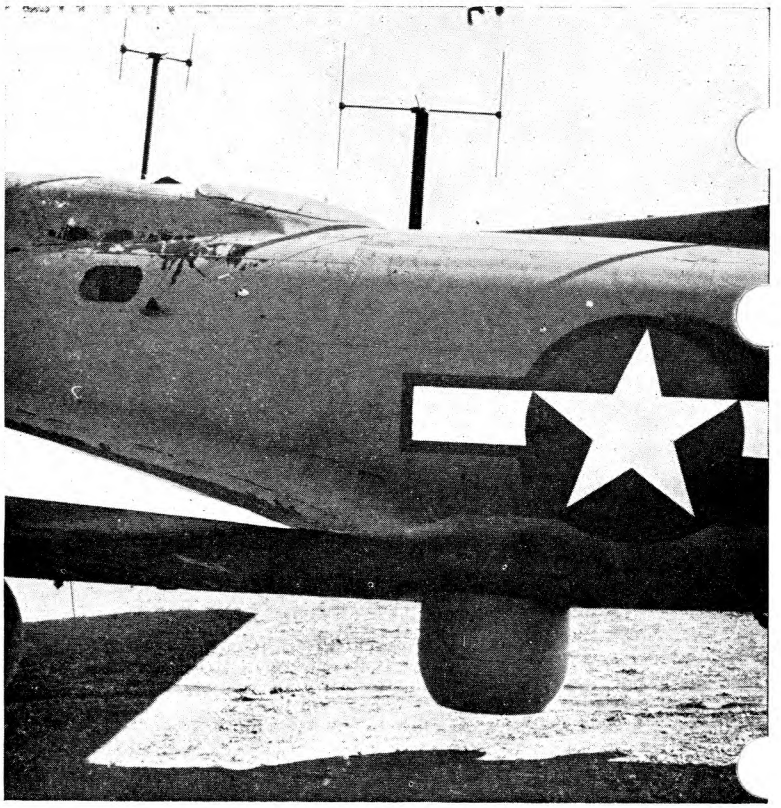


Ferrets are most crowded of combat planes

By the time all the search and investigational equipment used for the Ferreting is installed, plus complete replacements, tool sets and extra gas tanks, there isn't much room left. But all of this load is crammed in without excluding any crew member or eliminating essential armament



B-17 is fitted for Ferreting without much overhaul. RCM sets are in radio room, which is big enough for two operators

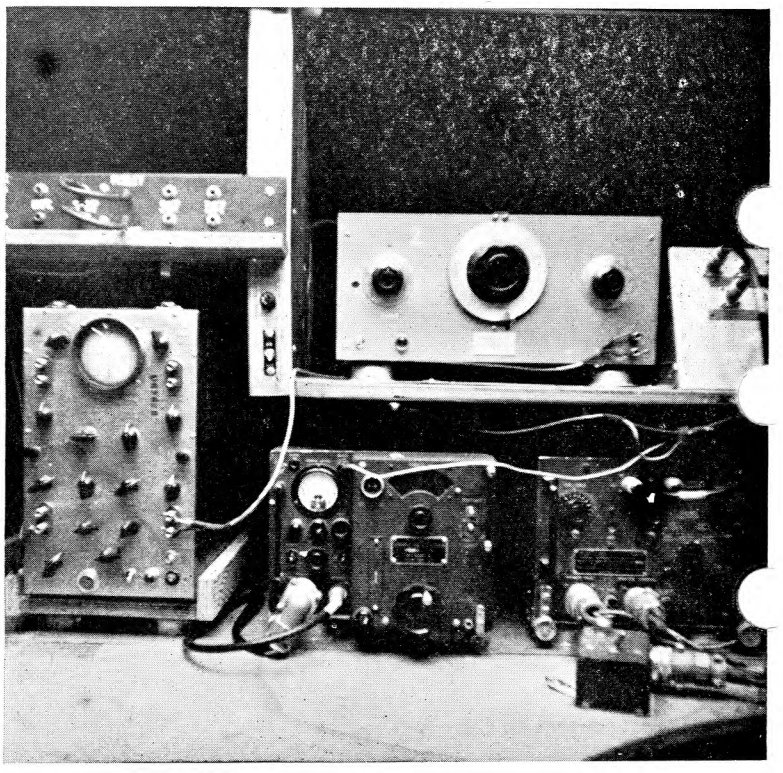


DFing antenna, shown on a Mediterranean B-17 Ferret, is trademark of all Ferrets. It was designed specifically for investigational planes

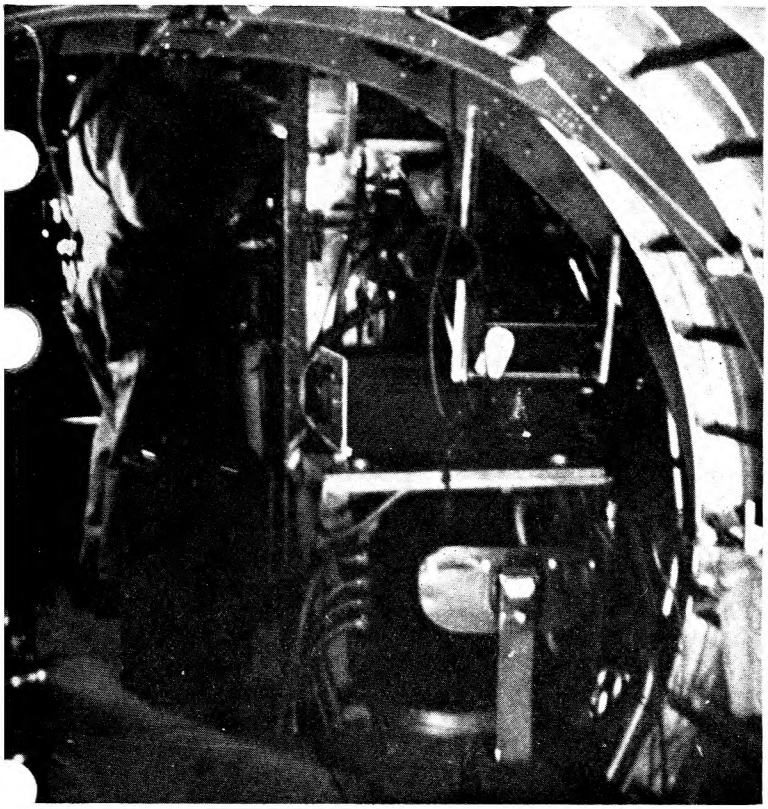
Interior of radio room on the B-17 flying solitary mission above shows following RCM equipment: HP Audio Oscillators (top); APR-4 receivers and APT-3 (Mandrel) jammers (bottom); two oscilloscopes (center). Equipment varies from mission to mission, is easily changed



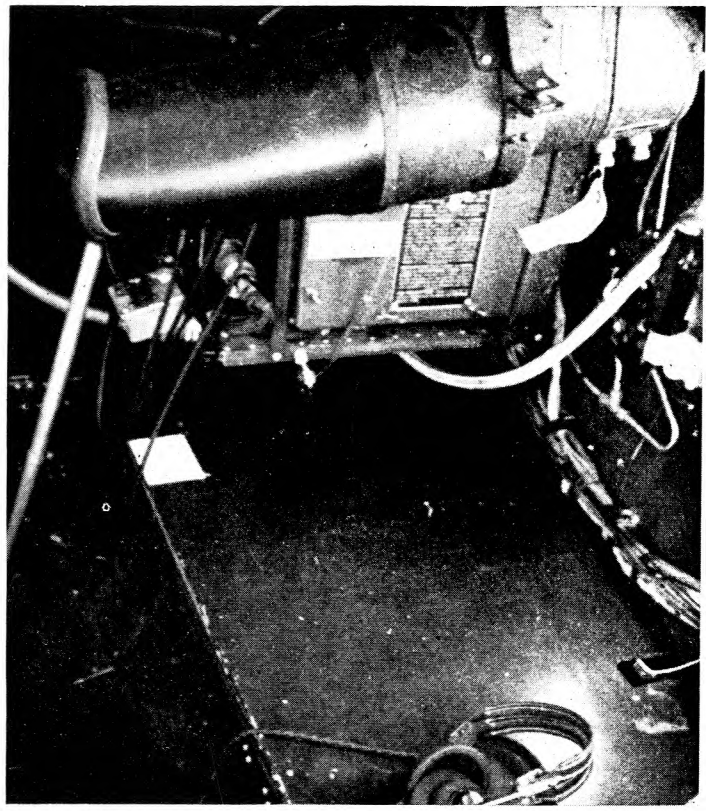
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B-24's and B-17's converted to Ferreting carry same equipment but installation is easier in B-17. Liberators are most used where their longer range is important, as in Pacific; Forts where range is less of a factor, as in Mediterranean. Ferreting work in ETO has been done by RAF

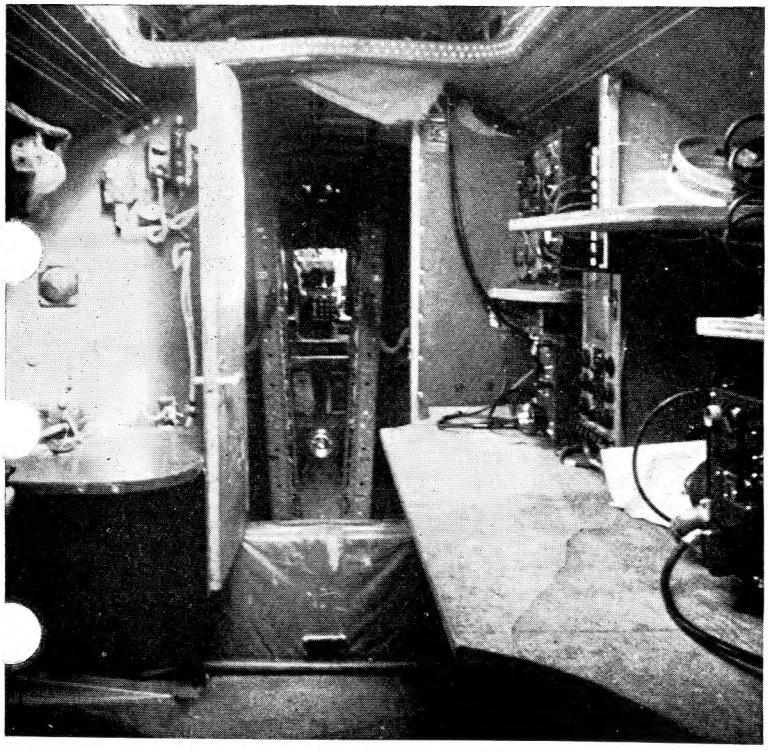


717 installation on this Fortress Ferret was made in the theatre by crew members. The 717 is standard ASV radar for all Ferret aircraft

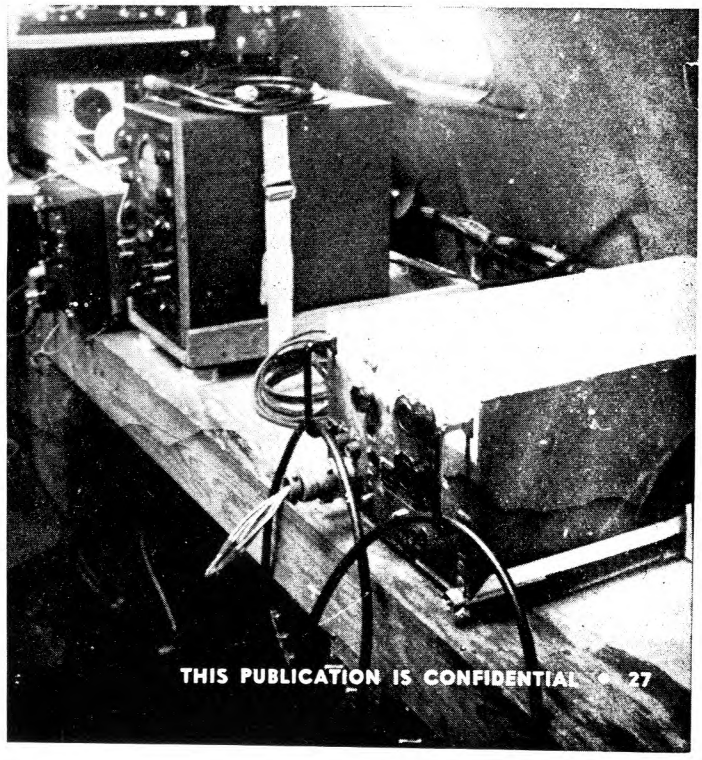


Navigator's table is equipped with repeater 717 scope. In midst of special equipment, spares, etc., Ferret crews have little room

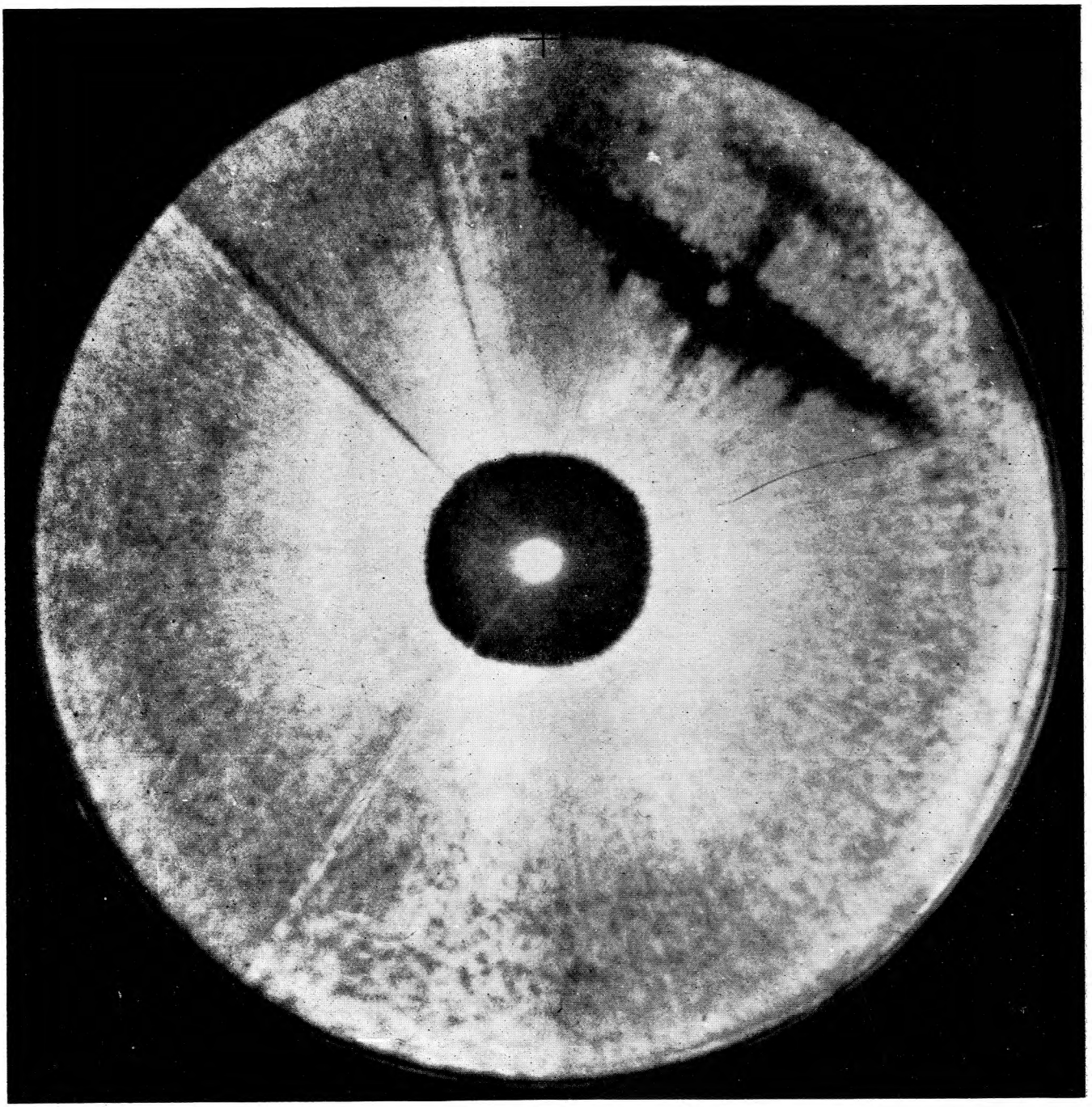
Radio room is just behind bomb bay. Not shown in these equipment photos is new tape recorder for taking down audio signals received



Carpet jammer is here installed for use on Wurzburgs. Its function is to force enemy activity on additional channels for detection purposes



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NEEDED: MORE PICTURES LIKE THIS

The B-24 limned in such fine detail on an APS-15 scope above is a radar shadow of a type occasionally reported by radar operators but seldom pictured. The photo came in from the 8th AF — one of the few places it could come from, since it takes a tight formation of the 8th AF variety to produce the proximities which can produce such effects. No special phenomena, shadows like this can be expected on the scope in a plane whenever another plane gets into a relative position comparable to that of the B-24 here. Position can be determined if some dimension of the shadow-casting plane is known, since the plane's slant range, horizontal range and height separation are in the same relation to those of the shadow as are the dimensions of the plane to the shadow's dimensions. The B-24 whose shadow shows here was about 80 feet away from and some 75 feet below the plane in which the scope picture was made.

Possibilities of exploiting radar shadows like this tactically — e.g., for identification during interceptions — would seem to warrant attention. First need, however, is for some careful scope photography under operational conditions. Inadequacy of the scope photographs which have been made to date, rather than any particular rarity of the subject matter, is what makes the picture appearing on this page such a unique one.

What happened at Anzio beachhead

Herewith the first published report on how 16 radars helped save the day

The movement of a piece of radar equipment from factory to combat zone is frequently so fast that such matters as tactical employment, crew training, maintenance and general know-how have to be taught on the combat end of the line. It is up to the crews and equipment to find and prove themselves for better or worse in actual operations. That is a tough assignment. The pressure is great and results, under the pressure, are not always wonderful.

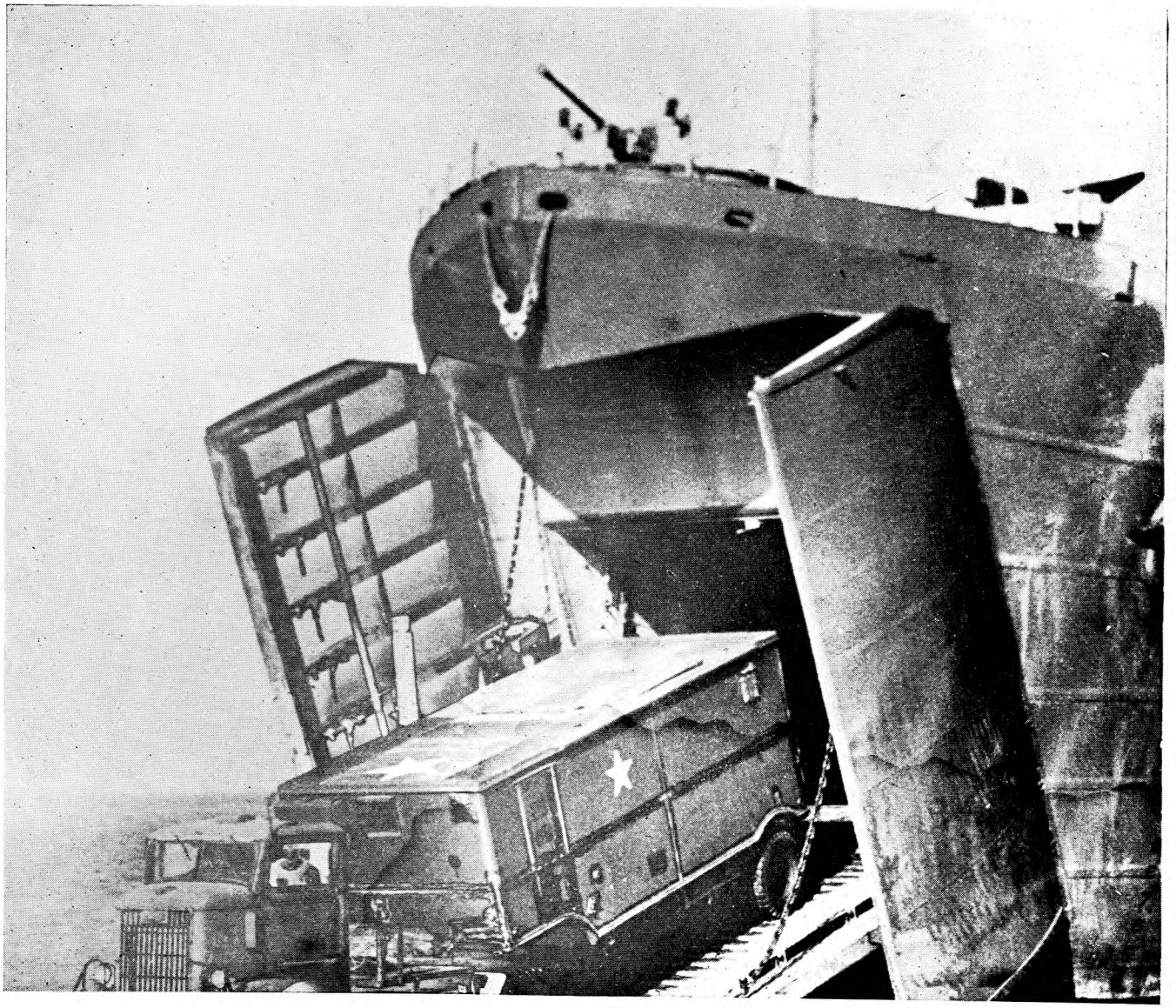
The remarkable thing, in these conditions, is that results are as good as they are as often as they are. They were of the best at Anzio in the period just before the big push started up Italy; and the Anzio assignment was an unusually tough one. For the situation on the beachhead was tight enough to put very special demands on the radar fire control while tested or even trained personnel, so far as most of the equipment went, was just non-existent. On these pages RADAR gives the first general report of what went on.

Leading roles at Anzio were played by some relatively untried radars and their neophyte crews, which took over the AA gun defense of the area from mid-February to May, after an assembly of SCR-268's had been blinded by enemy window and land jammers. Sixteen batteries — twelve SCR-584's, four SCR-545's — were involved. Not one man of the enlisted crews had seen previous action. Only a handful had previously seen a 584. The 545 crews were in better shape; they had trained with their sets.

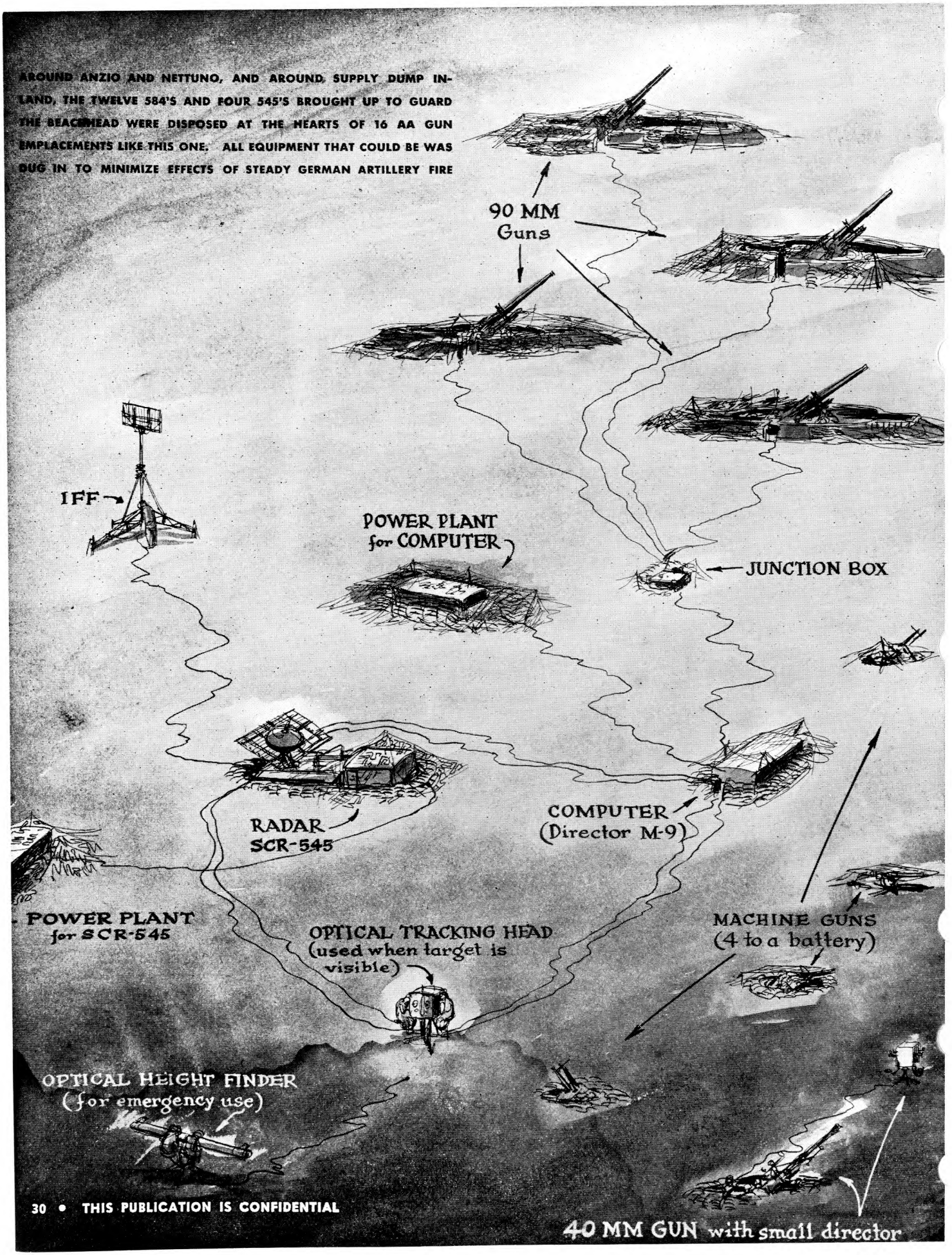
All of them, after moments of uncertainty, did well. So well, in fact, that the following was written into an official report: ". . . without a doubt they are largly responsible for the successful AA defense of Anzio." They helped to knock down 46 enemy aircraft. They discouraged enemy raids in an area so congested that the enemy could hardly avoid hitting some equipment or personnel whenever he dropped a bomb. They stopped formation bombing entirely and they took the worst of the sting out of an extra heavy barrage of jamming thrown at them.

What happened at Anzio is a case history in what can happen on any front when the radar shipment arrives and an odd and unfamiliar assortment meets the eye. For the story, see following pages.

LST'S BROUGHT RADARS FOR ANZIO UP FROM NAPLES. BOWL-SHAPED ANTENNA OF THE SCR-584 BELOW RETRACTS IN TRANSIT



AROUND ANZIO AND NETTUNO, AND AROUND SUPPLY DUMP INLAND, THE TWELVE 584'S AND FOUR 545'S BROUGHT UP TO GUARD THE BEACHHEAD WERE DISPOSED AT THE HEARTS OF 16 AA GUN EMPLACEMENTS LIKE THIS ONE. ALL EQUIPMENT THAT COULD BE WAS DUG IN TO MINIMIZE EFFECTS OF STEADY GERMAN ARTILLERY FIRE



The background to combat

Two 584's and one 545 radar reached the hard-pressed Anzio-Nettuno Beachhead on 24 February, 1944. They were the first to arrive of 16 mobile, microwave, AA fire control radars attached to the 68th, 72nd, 216th and 108th Gun Battalions. Their Anzio assignment: to guard the skies above the Fifth Army's 100 square miles of beachhead; to discourage the formations of enemy divebombers that were raising nightly hell. They were taking over from some tired and discouraged 268's, on which enemy jamming had done a very thorough job.

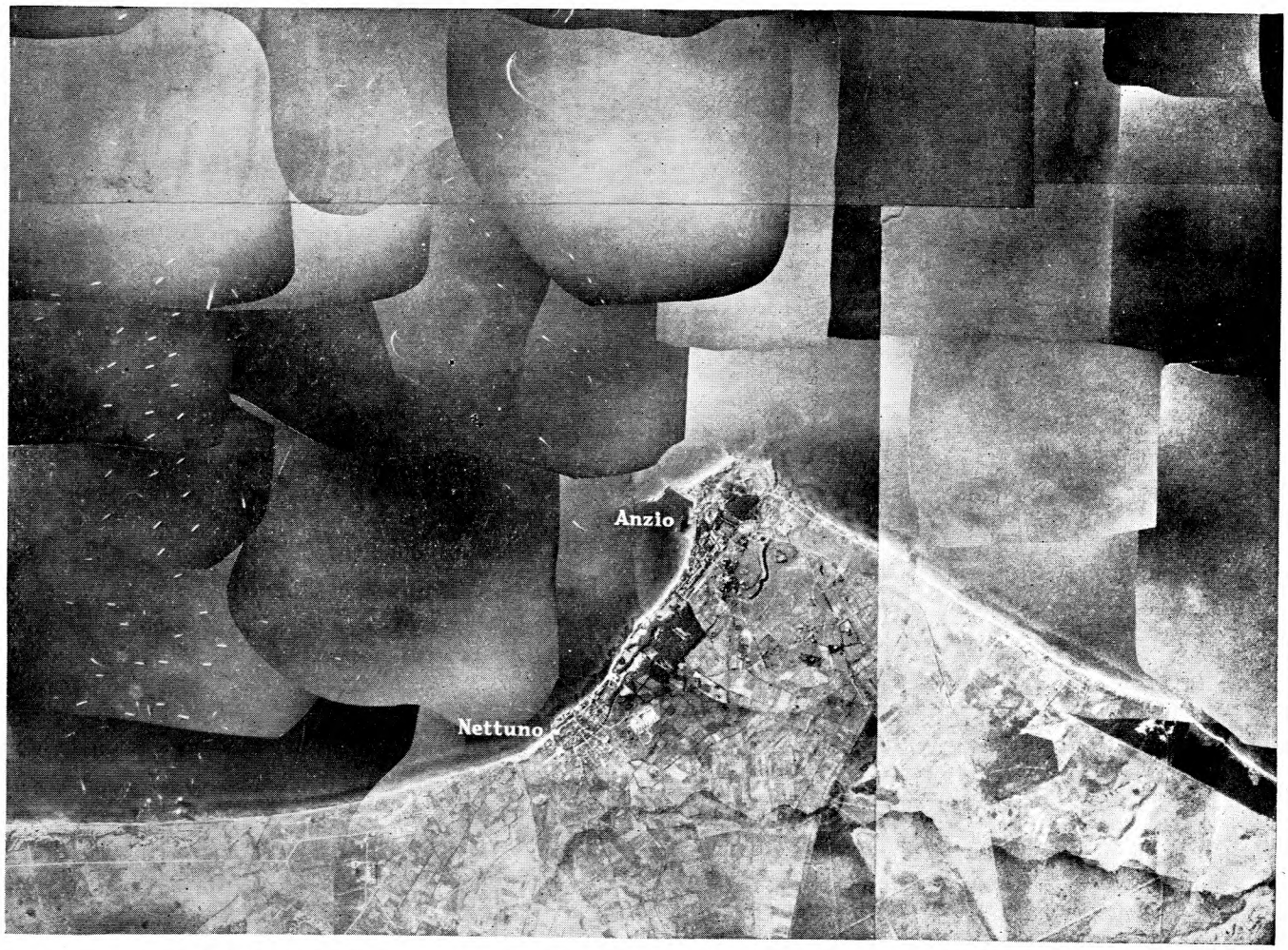
The three radars came by LST from Naples. Both types had been tested thoroughly under target-practice conditions by the Antiaircraft Artillery Board. But antiaircraft experts crossed their fingers. The first real action was only hours away.

Inside each 584 van were a chief of section, PPI operator, range operator and maintenance technician. The 545 crew consisted of a chief of section and three operators (range, azimuth and elevation). In the case of the 584's, all but a few men were seeing them for the first time. And this fact soon became so evident that Lt. Helm, radar officer for the 108th Battalion, in charge of the 545's, came to their rescue during the early action, running back and forth between installations for 24 hours at a stretch. While enemy planes approached, he coached them in tracking through window, introduced them to the equipment, helped them with repairs.

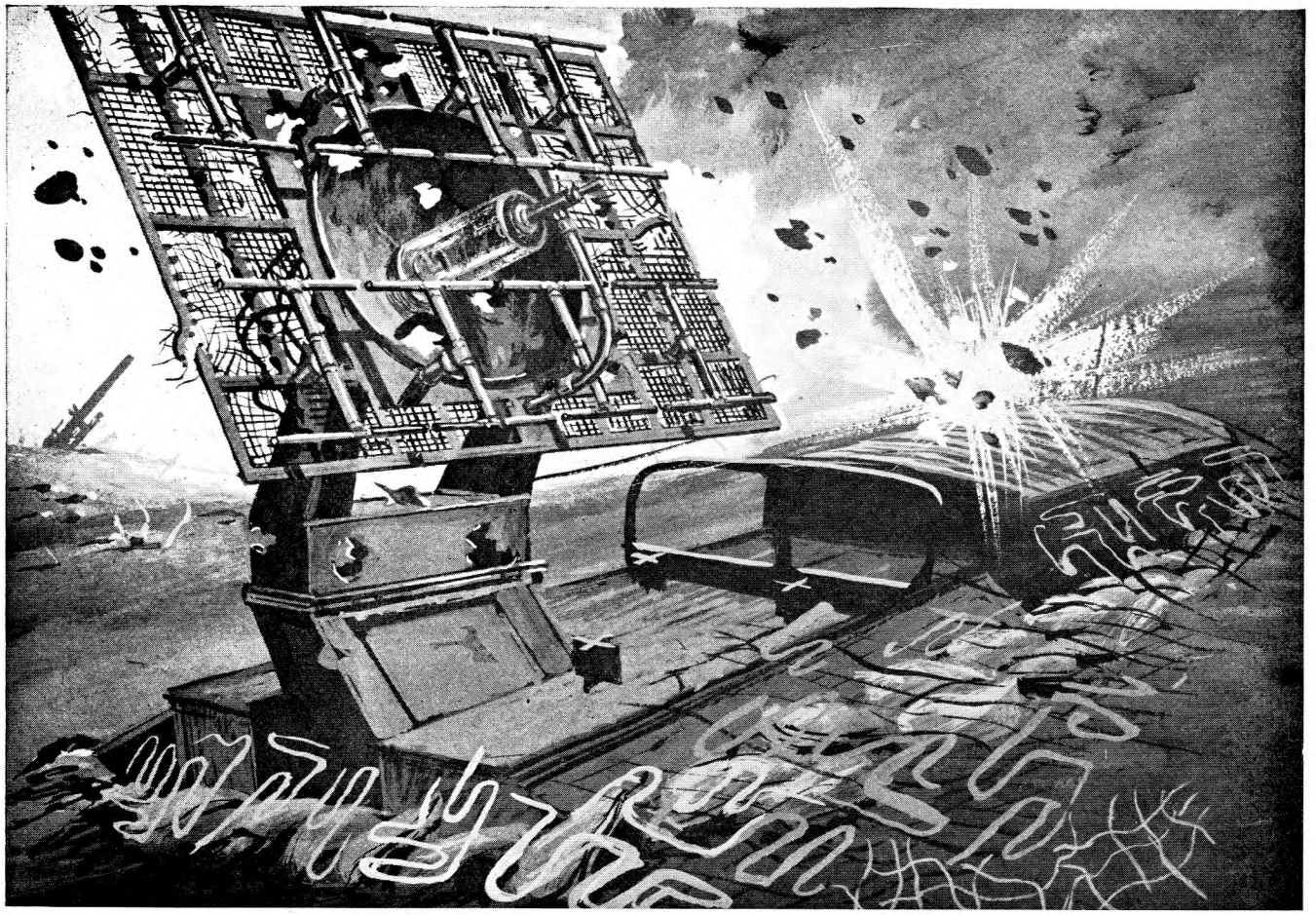
Yet there was a great deal that could not be taught in a few nights. On one occasion later, disgrace almost eclipsed the outfits when all 12 of the 584's had been installed and reported by their crews to be operating satisfactorily. An inspecting major, with a nose for radar trouble, came calling. Before long he presented his report: nine units were out of order. Of the remaining three, one was in bad shape.

In contrast, the 545 crews had trained for months at Oran, Algiers and Naples. Back in the States they had been exposed to models being tested by the Antiaircraft Artillery Board at Camp Davis, N.C. At a staging area in Oran a school was established for the maintenance men while the operators busied themselves with tracking friendly targets flying between Algiers and Oran. After two months the 108th Battalion moved to Algiers where the British lent a hand by flying practice tracking and firing missions. Late in 1943 ropes were slung around the big trailers and they were hoisted aboard Liberty Ships, two to a hatch. Ashore at Naples, they tracked aircraft and participated in many alerts. Even so, the battalion had never fired at the enemy before its arrival at the beachhead.

This was the background to combat. At Anzio each of the radar units was assigned a primary and secondary operating sector and at least four sets were allotted to each sector during an alert. It wasn't long before the alerts were coming at the untried crews thick and fast.

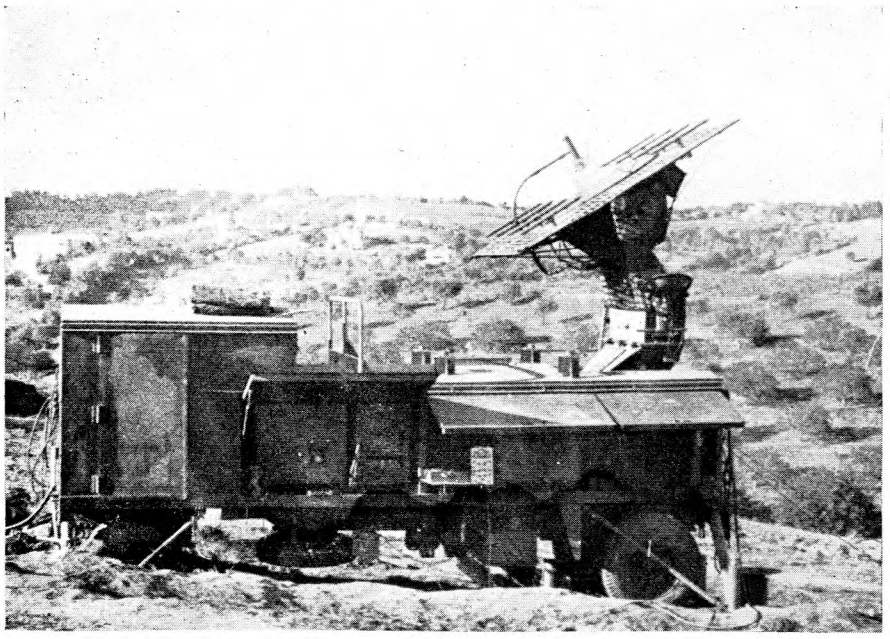


Compact Anzio-Nettuno area is shown here in this D-day (22 January) mosaic. For first month longwave 268's fought a losing fight against enemy jamming. When 584's and 545's moved in formation raids stopped fast. Crews learned plenty on this beachhead



AN ARTILLERY SHELL THAT EXPLODED FIVE FEET AWAY KNOCKED 54 HOLES IN THIS 545'S ANTENNA. IT KEPT RIGHT ON WORKING

In one night protection of beachhead advanced a big step . . .



The 545 had trained crews, but 584 held the edge against jamming. In the end both sets did solid work. This is one of Anzio's 545's, shown in North Africa where much of training was done

Nothing happened the first night the two 584's and one 545 were installed at Anzio. But on the second night the raw crews became veterans. Early that evening 12 enemy bombers came over in formation, their usual procedure against the easily-jammed 268's. In a few minutes five were down in flames and the enemy bombed in formation no more. Thereafter they scattered before coming into gun range, attempted violent evasive action, discarded their bombs fast and less accurately than before. The protection of the beachhead in this one night's action was advanced a long step.

Enemy bombers, however, were not all the opposition that the radar crews faced. Siting of the sets, predetermined by a reconnaissance group, was on good level ground with the mountains 30,000 yards away. And the smooth terrain afforded the enemy an opportunity to observe and get the artillery range. The shells began to pour over.

To meet this, the installations dug in. When the digging was completed the tops of the vans were level with the ground, a thickness of sandbags walled the vans, the



BEACHHEAD JAM MAKES INVITING TARGET FOR ENEMY, HARD WORK FOR DEFENDING RADARS. ANZIO CONGESTION WAS EXTRA HEAVY

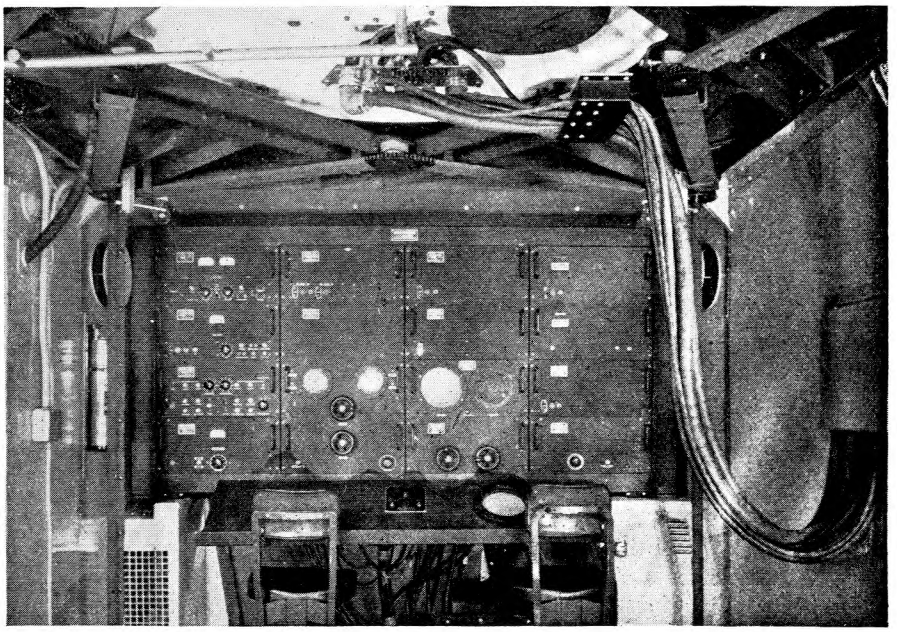
. . . and from then on it got better; final score — 46 down for sure

bottoms of the antennas were about a foot above ground.

On 29 February eight 584's were on hand and, along with four 545's, were waiting for action when another raid developed. The 72nd Battalion with the four remaining 584's had not yet arrived. All 545's except one, which was restricted in search sector, were promptly on the target, but the 584's were having trouble. That night the 108th Battalion (545's) fired 650 rounds of 90 mm while the 68th and 216th (584's) expended only 160 rounds between them. The next morning the wreckage of seven E/A littered the beachhead. The Navy claimed two.

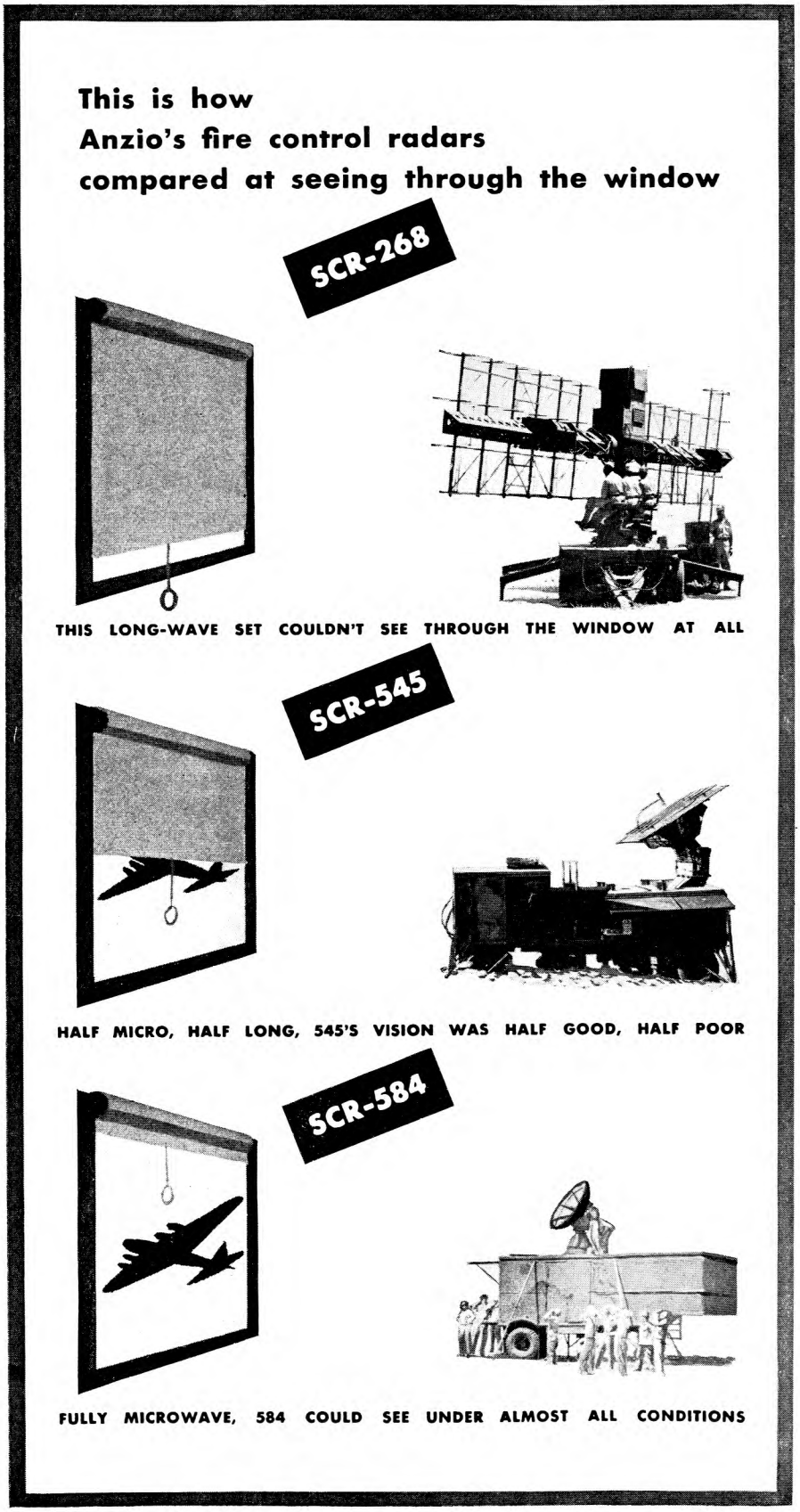
These early episodes did not fully mirror the future. The 584 crews, despite their slow start, kept improving. By 6 May, when the certified count of downed planes was 46, the 584 batteries claimed 37 and the 545 batteries claimed 9. Most E/A were fired on at long range and, when downed over their own lines, could not be confirmed as kills. The actual count was almost certainly well above 46.

How the 584's and 545's reacted to enemy countermeasures, what their operators learned, is told on the following page.



Interior of dug-in 584 housed a four-man crew. Unlike the trained 545 personnel, most members of 584 units were looking at sets for first time, getting introduced under fire

It took microwave and lots of savvy to beat German jamming



The best defense against enemy jamming, aside from all-important savvy of the operators, is equipment that isn't vulnerable to it. Against the countermeasures which the Jerries piled on the Anzio radars, none of the equipment operated without disturbance. But the microwave radar *did* operate, and that was the measure of the fire control success of Anzio.

The 268's were long-wave. The 545's were long-wave search and microwave fire control. The 584's were all microwave. Once their frequencies were detected, the 268's were no match for Jerry. The 545's had trouble with long-wave search as a by-product of the enemy's insistence on jamming the oft-abused facilities of the retired 268's. The design of the 545's long-wave, however, was good enough to permit fairly efficient search under most conditions. Its microwave direction finding system was much less affected. And the 584 was affected least of all.

Practice that the 545 crews had received on fixed echoes proved invaluable when, in their first real action, a huge quantity of low-frequency window was dropped by each raider. The crews continued tracking throughout the deluge by maintaining the search receiver gain at minimum level and using aided tracking. Later in the same raid, as the hostiles increased, window saturated the area so completely that the greatest scrutiny and concentration were required to pick up targets on the search system. First-rate performance by the operators under their first combat conditions was responsible for the tracking done that night.

In a later engagement, low frequency jamming was encountered from one sea and two fixed ground locations. It caused some confusion on the 545's battery of A scopes, but the crews didn't let it affect performance. Window again caused trouble, but careful scanning prevailed.

The 584 and the microwave tracking system of the 545 invariably saw through all but the worst concentrations of window. 584 operators learned that under severe conditions the high-precision J-scope was a handy instrument to have around. The 545 operators, trained in the use of aided tracking, were able to coast through bad patches of window while maintaining smooth firing data.

As the Battle of Anzio progressed, the enemy used ever-increasing quantities of window. Tracking became progressively more difficult but by then the operators had developed to a high point their ability to detect and track on cluttered scopes.

In their dug-in vans they went about their work, ignoring an almost constant rain of artillery fire, putting the guns on target.

CONTINUED FROM INSIDE FRONT COVER

IFF will be incorporated on the Type 24, but that was not operating while I was there. Nevertheless, by calling up sector it is easy to identify targets provided only that an accurate plot on them is available. An unidentified track is plotted in blue, and I would estimate that not more than one track in thirty or even fifty got carried as blue for more than ten minutes while I was at the station.

Being a confirmed scope watcher, I sat down at one of the vacated controller's scopes and started looking. The time was 2320 on June the fifth.

First thing was two area raids leaving Portland and swinging out, one of them going north from Cherbourg. An area raid is really a fearsome thing to see if you have not seen one before. Something like 100 planes are scattered over a range of 20 to 30 miles and a width of 10 miles or so. The MEW would really let you count individually if there was some long persistent scope to permit such counting. As it was, I felt sure that I could estimate the planes correctly to about 50% and in these area raids something like 80 to 120 planes were involved.

At 2345 something new appeared on the scope; a kind of target I had never seen before. It was a long streak moving directly south, having a length upward of four miles and the width of a single plane. In my notes I put the guess that this was either a very accurate line of planes or a plane with a window trace behind. A second group appeared at 2355 looking almost the same and at 2356 the first group turned straight East. I had no longer any doubt that something big was on. At 0005 June 6 teletype gave the information that gliders were on the way over. Four tracks were visible by now. At 0010 Squadron Leader Cherry Downes told us the Invasion had started, that we were taking part in it and had to do our job as well as possible. Sgt. Maas detailed two men to each of the guns.

Shortly after this, in a maddening routine, the station went off the air for maintenance. Nothing could be done about this since they are a daytime station and maintenance must be done. However, I took a dim view of it. As soon as the station was back many more of these streaks appeared, with more area raids. My notes say that "the glider lines were about 10 miles long and sharp as hell — looks like perfect flying."

A little later, at 0050, the lines seemed to separate a little. Then we saw a long line which we associated with the gliders, and a compact block moving faster, weaving around the line. This looked like the Germans were sending up interceptors but apparently they were carried as white tracks, not hostile, and now it seems likely that they were fighter cover. These fighters crossed and recrossed the glider tracks. More area raids appeared. One could see now the broad plan so far as the station was able to perceive it.

Raids were visible going down across the channel, rather hard to pick up at a range of over 150 miles. These flew south, faded a little, then came in crossing the Cherbourg peninsula. This circular bombing continued all night. Pictures later showed quite clearly the almost ceaseless pounding with raid after raid of 100 Lancasters, Halifaxes, and so on.

At about 0145 long streaks of returning tow planes began to appear. These long 20-mile streaks would fall in line one behind the other and at one time there was a streak something like 80 miles long. It gave us a good feeling because these were our boys coming back from the job.

At about 0200 I took a look around the room. Everything was unflurried and the plotters were going on as usual. The group behind the skiatron sat there nearly motionless. The phone would ring now and again, papers were scattered on top of the glass screen of the skiatron. Everyone seemed cool and calm. It is always the civilian that really works at fighting the war; the army takes it in stride.

There was a continuous howl on our "Y" broadcast line but we fixed it and in a little while the howl stopped. A call would go through to the liaison center: "Is the filter table a little bit swamped?" "Yes, it is." "That other stuff they call an area raid we have as a solid line." "They have area raids there."



"THE GROUP BEHIND THE SKIATRON SAT NEARLY MOTIONLESS"

All this time the long lines of troop carrier planes continued to show and area raids ran around their course. Not till 0735 was there a cessation of area raids on the screen. Over what we thought was the beachhead we could see no air cover, but that was probably due to the low height. We heard steady thumping, which may have come from the naval bombardment or from the 2000 pounders when the 8th AF took over.

During the day the controllers had to use all the PPI's. As evening came, area raids began again and more troop carrier planes went in. A bright pink plot showed where someone had been 10 miles off the French coast and one of the jobs of the station was getting the rescue planes out. At 2342 an area raid came on flying south from inside Portland. The raid was about six miles wide and 50 miles long; I estimated 300 aircraft. The fact that the raids were flying a GEE course was quite clear. I could see them fly down to the intersection, then carry over on the other line. Still no hostile plots.

Off the tip of Cherbourg a type of stationary echo appeared that might have been balloons or atmospheric refraction showing some ships. At 0300 on the 7th news came through that a Halifax was down nearby. Later more troop carriers could be seen going in. Type 24 gave the height at about 3,000.

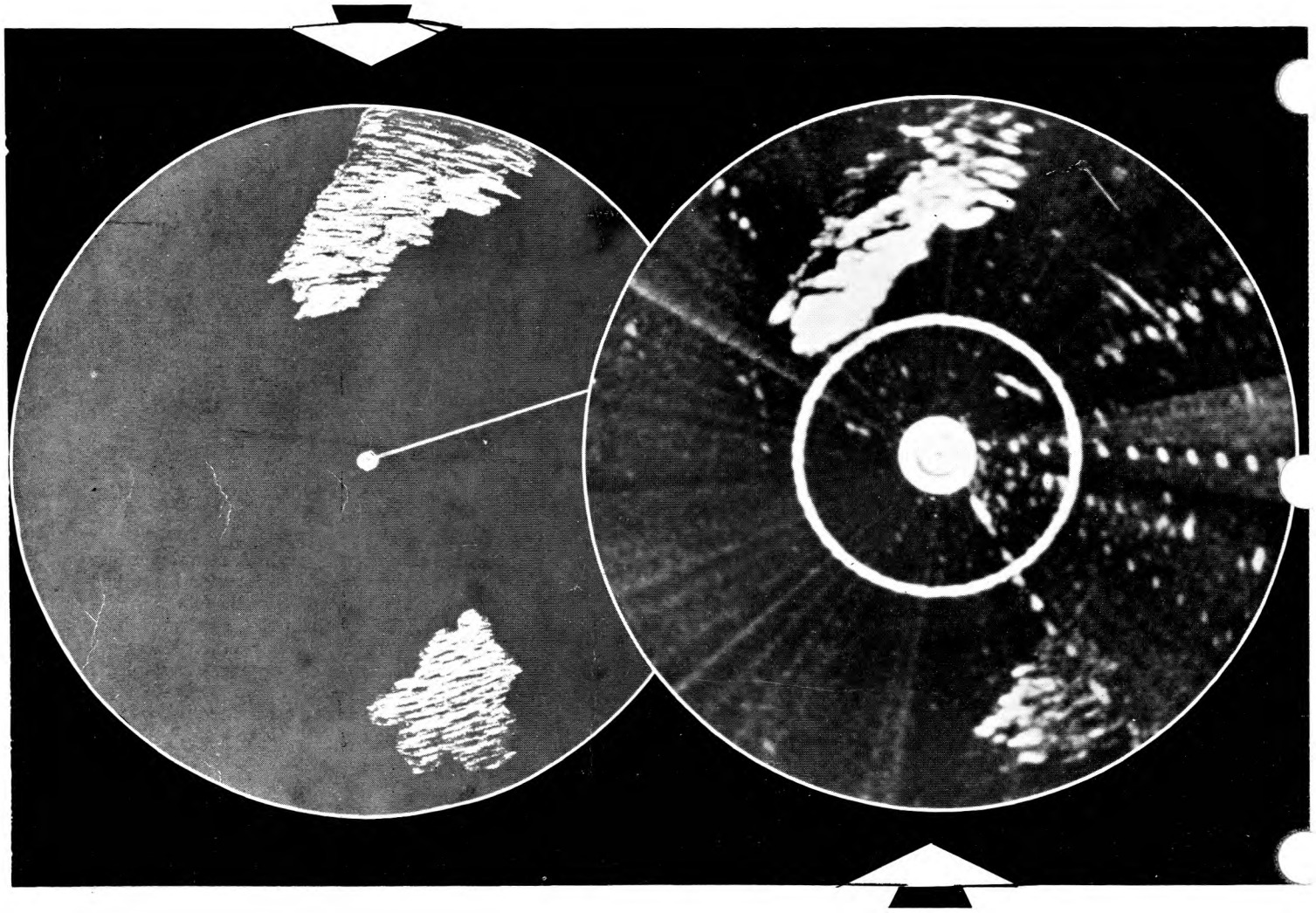
Around now the BBC made itself heard. A new stepped-up transmission beamed in the direction of the Invasion beachhead came on the air and got into our VHF. I heard the following conversation on the phone: "Hello, Marlborough, Marlborough, is that you? There's something wrong with our VHF. We've got the BBC on it. All we can get is some girl singing, 'Everything I have is yours.' " A moment later — "Can't we get that boogie woogie off the air?" And from the second controller: "Blow it up. Just vector somebody over there and tell him to hit it."

The most continuous operation in the fighter control functions of the MEW was maintaining a patrol of Thunderbolts flying off the Brest peninsula to protect Coastal Command, looking for submarines coming up the channel. A flight of four Thunderbolts could not stay out very long and ultimately four sets of four had to be maintained; two would be present at any time, one flying one way, one the other; two would be either on the way out or back; all would be under control. It was difficult because the Thunderbolts were at a range of 110 miles, flying very low, moving to look at whatever interested them and generally being quite active on their own initiative but returning every now and again to ask for a fix. It was also the job of the station to assist the GCI station in getting the rescue planes out. And a third job was sending fighter bombers over various targets and getting them back. All this and reporting, too.

It turned out that our board at Fighter Control was the only that out of which any sense could be made and they were using one entirely for passing on information about what was flying.

First radar view of Japan shows the B-29 briefing was good

Below is a simulated PPI presentation prepared in advance of the first B-29 raid on Japan. Along with similar presentations for other positions on the flight path, it was given to the B-29 navigators as part of their briefing material



Above is the photograph of what actually appeared on the PPI scope of one of the attacking B-29's at approximately the position used for the simulated presentation at left. The scene is near Japan on the way in to the target — Yawata

FOR FULL REPORT ON ROLE OF RADAR IN B-29 MISSIONS SEE PAGES 3 TO 10

FERRANTI Defence Systems Limited

RADAR

Issue No. 5 SEPTEMBER 1944

INTRODUCTION



R.P.F. Lauder
Engineering Manager
Product Support Department

To those of us who were actually present in South East England during the German invasion by their V1 Buzzbombs (or doodlebugs as the English called them), the first few pages of this volume induce a considerable state of nostalgia.

Despite the fact that the Buzzbomb was the AAA man's ideal target – it flew well within artillery range, at constant speed and unvarying course, and advertised its presence both audibly and visually–the AAA 90mm gun success was very low. This was due to the fact that angle tracking, target velocity and predicted track were simply not available to an accuracy commensurate with the gun/shell capability. The V1s were attacked by Spitfires, but their performance was also poor, and they were needed as escorts for allied bombing raids.

The advent of the SCR 584 radar made a dramatic and instantaneous improvement. If a personal note may be forgiven, I remember one day shortly after the SCR 584s were deployed in SE Kent, seeing a line of 4 Buzzbombs coming in, in line astern, in the direction from Folkestone to London and being picked off one after the other by the AAA guns after the manner of the expert shot picking off clay pipes at the fairground booth.

This is the first recorded instance of a radar capable of tracking a single aircraft target out to a maximum range of 34 miles, where the angular errors, in both azimuth and elevation, off the boresight were not presented to operators, but used to derive both the amplitude and phase of the error, and to cause this to drive the antenna in a direction to reduce the error. In other words, it is the first recorded instance of the use of an angle tracking servo loop.

Range was displayed on the little-used J-scope. Here the time base was deflected circularly, and the target painted radially by the use of a central electrode. Two displays were used, one to display the whole range, and the other, 1/16 of the first, which could be moved anywhere over the whole range. A range gate coupled to the range handwheel caused a bright-up to allow accurate setting on to the leading edge of the target echo. A six foot diameter paraboloid at 10 cm wavelength gave a beamwidth of 4 degrees, and allowed tracking accuracy of ± 25 yards in range, and ± 1 milliradian in angle to be realised.

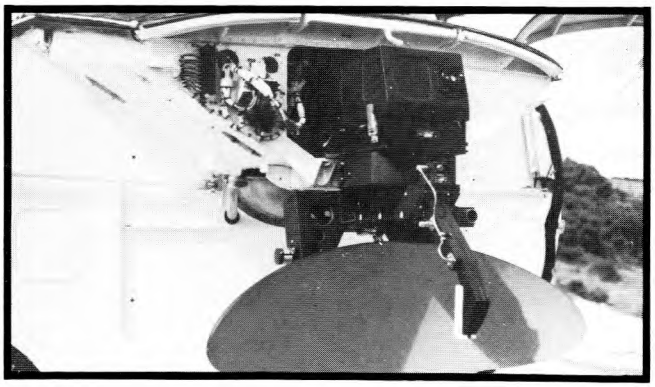
Automatic range tracking was also available with a range servo, but the operators tended to use manual tracking, since the tracking gate could be deduced by the small target passing other, larger signals.

The SCR 584 had no "putting on" radar, and did its own limited search. The British CHL (Chain Home Low), and the U.S. MEW provided early warning of the approach of Buzzbombs, and the U.K. gun operations room gave rough slant range and azimuth to the radar operators. The SCR 584 was capable of a helical scan of the patch of sky indicated by the GOR (Gun Operations Room), and on finding the target, went into conical scan angle tracking, passing continuously measured pointing angle, range and sightline spin rate to the guns. If Ferranti's helmet pointing system had been available in these early days, this would have been a useful adjunct to the system.

Also in this issue is the first record of the so-called "anti-jamming medicine show" in New Guinea. The Americans had obviously found it necessary to equip a Hudson aircraft with whatever jamming gear was available, and to fly it round the South Pacific to demonstrate the effects of jamming, and how to counter it. Some messages were learnt very quickly, like the six SCR 268s all operating on the same frequency within 500 kHz, and all simultaneously taken out by jamming.

When the fighting war is in process, these lessons are easily learnt, but in peace time they tend to be forgotten. With the proliferation of EW techniques nowadays and their greater sophistication, the allies must be ever vigilant that radar operators can recognise the various types of jamming, and know how to combat, and work through them. This kind of training should never be left until the shooting starts.

Robert P F Lauder



SEASPRAY

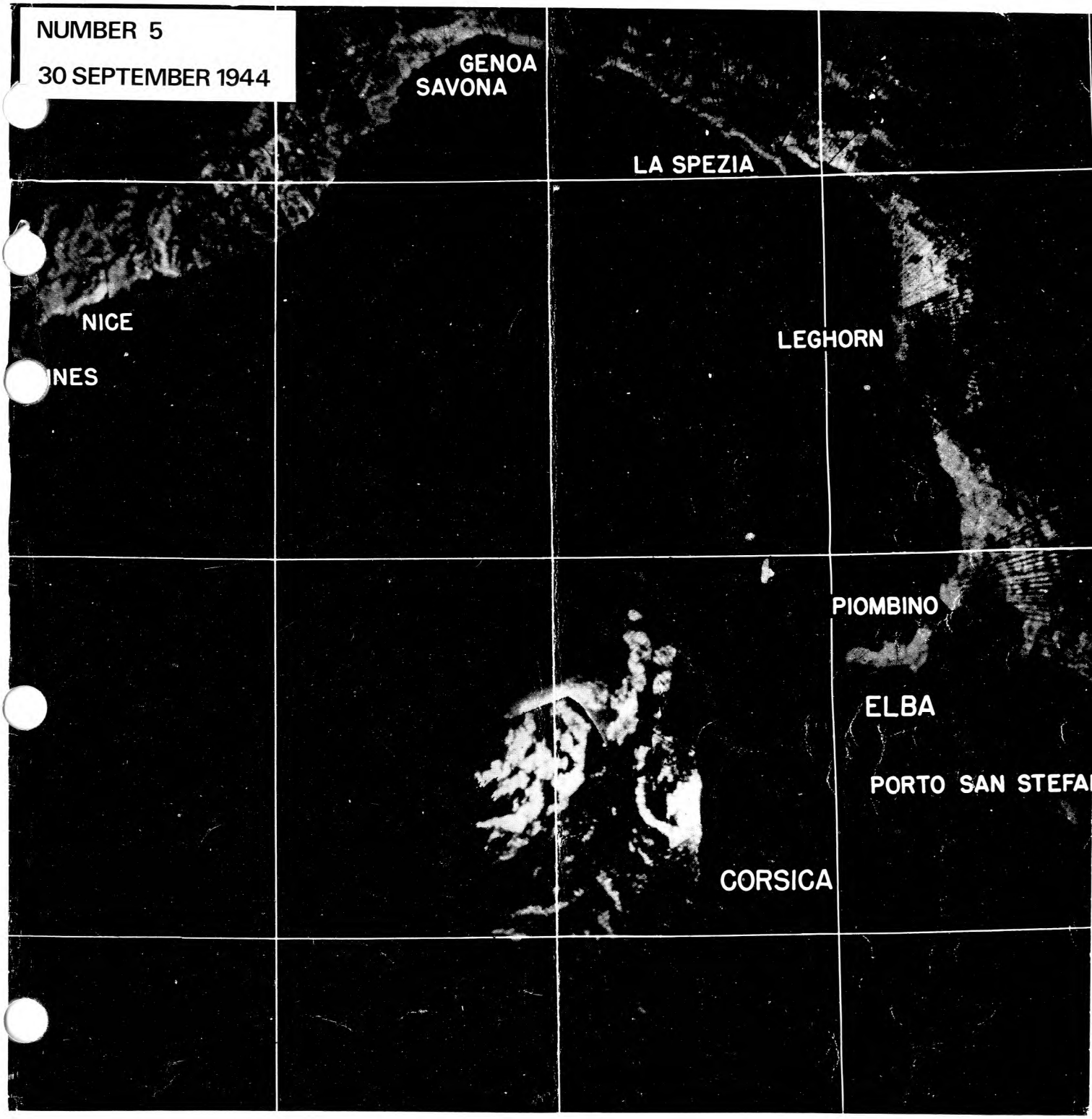
Ferranti's Seaspray radar was designed and first built for the Royal Navy in its Westland Lynx helicopter, but today it sees service in eight other countries, and has been fully combat proven in the Falkland Islands crisis. It carries out sea surveillance and missile guidance functions, and is compatible with a wide range of aircraft and ship platforms. A Mk. III version uses advanced digital signal processing and offers 360° search, multiple target Track-while-scan and many other new features.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

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EDITOR: Dexter Masters, Office of the Air Communications Officer.

FOREIGN EDITORS: Dr. L. J. Henderson, Advisory Specialist, Hq. U. S. Army Air Forces, MTO; Dr. L. C. Marshall, Chief, Operational Research Section, Hq. U. S. Army Forces, POA; Dr. Louis N. Ridenour, Advisory Specialist, Hq. U. S. Strategic Air Forces.

ASSOCIATES: Sgt. John Caldwell (England), Avis Clarke, Ruth Copland, 2nd Lt. Norman Goldman, Lucie Sewell, 2nd Lt. Robert Wright. Drawings by Presentation Branch, Office of Strategic Services.

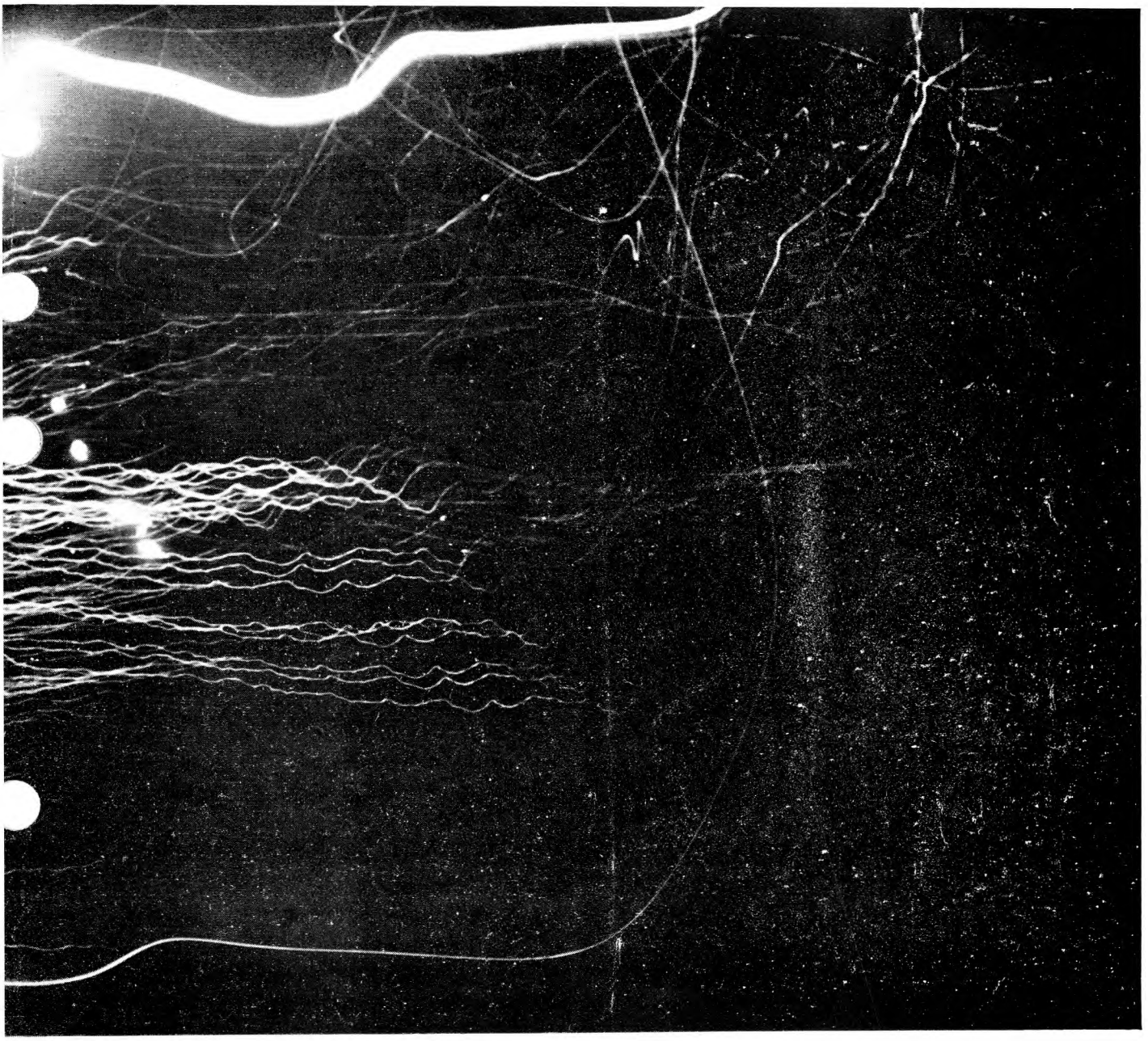
ADVISERS: Lt. Gen. Barney M. Giles, Chief of Air Staff; Maj. Gen. Roger B. Colton, Chief, Engineering & Technical Service, OCSigO; Dr. E. L. Bowles, Consultant on Communications to Commanding General, AAF; Dr. L. A. DuBridge, Director, Radiation Laboratory.

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584-CONTROLLED FIRE DOWNS BUZZ BOMB AT CHANNEL

The cameraman who took this picture for RADAR was standing 600 feet from where the buzz bomb lit after a 90mm. shell, directed by SCR-584, knocked it dow The wide bright track coming in at the right is the pre-h path of the bomb. Flash at the end of this track marks the spot at which shell struck. Burning fuel probably accounts for some of this flash and for the bright spots below. Trajectory of the warhead down to the Channel water is shown by the thin curving line ending in the accordion bursts of th final explosion. Wobbly tracks of the almost solid sheet tracer fire and strange curves in path of bomb result from movement of camera; considering the nearness of the goings-on, cameraman can hardly be blamed. For a considerable time now, U. S. 584-controlled AA batteries working in cooperation with the British system have been intercepting flying bombs and bringing them down like this before they reach targets. If military progress at RADAR's press tim continues, this may be last as well as first picture of its kin



The 584 earns its keep

The SCR-584 has now come out from behind its sandbags, so to speak, and is playing on the offense as well as the defense. In other words, it is no longer a special purpose set. On the defensive side it continues to bring down enemy aircraft, and these days—so long as the Germans have a place from which to launch their buzz bombs—it is a number one protection against them. On the offensive, in the big push against the Germans, it is acting as radar link between ground forces and their air support.

SCR-584 was introduced into the European theater of operations about 8 months ago, after running up a solid record in North Africa and confirming it at Anzio (see RADAR No. 4). Thirty-nine sets reached Normandy on D-Day. Defense of the beach was divided between the British and the Americans, and the 584's worth was spelled out when the Germans pulled their aircraft out of the American sector after a few days when they discovered the damage the 584-controlled AA fire was doing.

It is doubtful whether the Germans had any idea how effective AA fire would be as a countermeasure against their buzz bombs. And it took a while, in fact, for the fire to get good enough to make a real dent. It took just long enough to get the 584's and their crews into working trim. Thereafter the number of thwarted buzz bombs rose well into the thousands. Some very classy interception work by the fighter pilots contributed greatly to the score but the AA battalions—and especially those with 584 control—accounted for a truly remarkable number. The 90mm. guns could work on continuous shifts whereas fighter action was necessarily restricted by weather conditions.

For a brief report on the 584 as used for fire control, see following two pages; on the 584 as used in air support of ground forces, see pages 6-9.



U. S. anti-buzz bomb battery near Channel had to be in instant readiness at all times. Bombs gave maximum of 3 minutes between alert and fire. 584 is at center and dug-in M-9 director is barely visible to right. In one 5-hour barrage 90mm. guns of this battery fired 1600 shells at bombs with visibility so low that not even the flash of explosions could be seen

It is doubtful that the Jerries knew how good the AA fire would be

On the night of the heaviest buzz bomb attack of the first two months, fog, low clouds and a miserable drizzling rain made visibility so poor that even the flames from the jet propulsion units could not be seen. The 584's really sold themselves that night. Firing would have been virtually guesswork without them. Prejudice on the part of some of the battery personnel against 584 as an extra piece of cumbersome equipment soon disappeared.



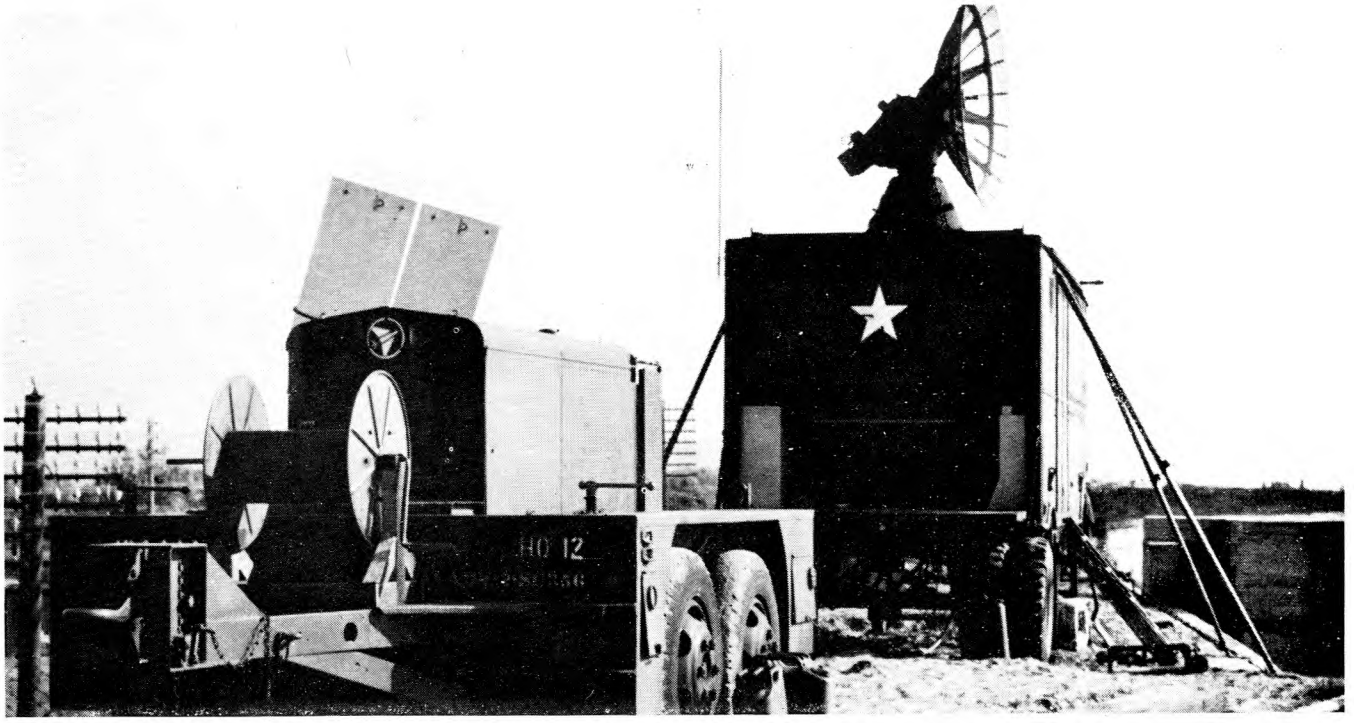
All American battalions were integrated with the British anti-aircraft defense system. The British directed the employment of the AA and the method of fire, assigned the sectors and looked to other details of AA policy in the defense against flying bombs. The AA units are located across the lanes along the English Channel over which the greatest number of bombs approached. There were 5 American AA battalions equipped with 90mm. batteries. And the array—supplemented by British batteries using 3.7 inch guns—provided what was probably the most concentrated and sustained anti-aircraft fire to be found anywhere in the world.

Early warning of the approach of the "divers" was given within a matter of seconds after they left the launching ramps by the efficient British aircraft warning net. Equipment used for this was the CHL (Chain Home Low) and the U. S. MEW (see report on pages 31-33). The AA units were then alerted by the British GOR (Gun Operations Room) and provided with an indication of slant range and azimuth.

The 584 operators had to be good at (1) tracking a quickly moving target, and (2) tracking through spurious echoes. Ground clutter and fixed echoes were caused by the coast of France and the Channel, but some of it could be cut out by digging in the sets or screening where possible.

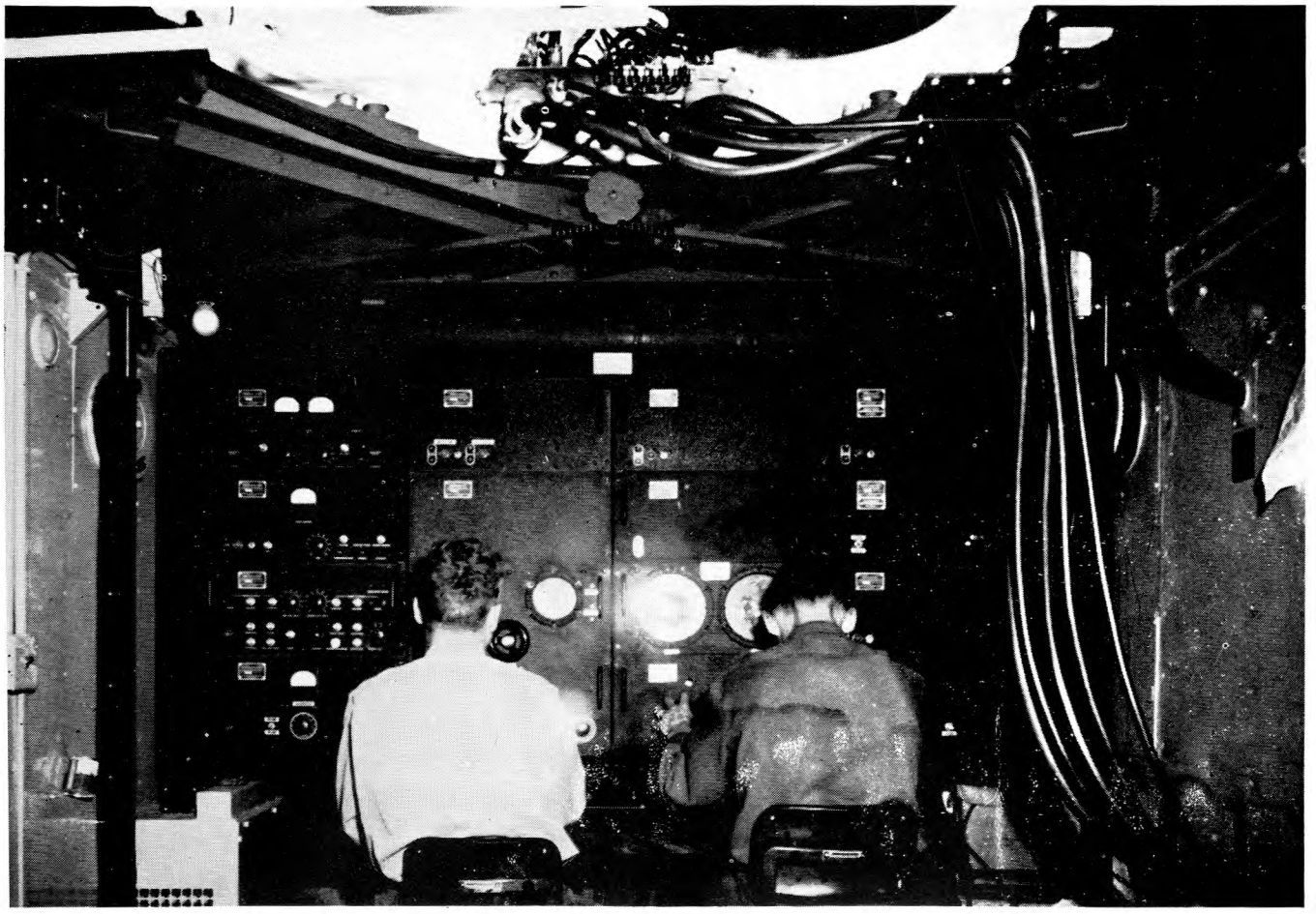
The bomb or diver produces a small but sharp echo on the 584 scope, slightly smaller than that of a Spitfire and moving very fast in range. But the antics of the bombs soon become so well known that identification was not too hard. They travel at a high speed and have an unusually constant flight pattern due to their inability to take evasive action. To do any real good they had to be brought down before they reached the coast of England and a hit had to be scored on one of the detonators (in the nose and belly) to explode the bomb in the air.

The 584's and guns alone were not enough to do this. It took plenty of guts to sit unprotected in the path of a buzz bomb and it took cool, calculated skill to track and fire on such a target when the whole job had to be done in a few seconds. But the feat has been performed day and night. It may be that the feat will be unnecessary by the time this issue of RADAR gets out.



This 584 was not dug in, thus permitting dish to look over 20-foot seawall toward Pas de Calais. 584 at this battery swept a sector about as wide as area shown on opposite page

In position, PPI operator (right) picked up echo at about 35,000 yards, range operator locked on selected target at 20,000 yards. Search started on alert from early warning



10 miles behind the front: camouflaged 584 in quiet French wheatfield directs P-38s, P-47s, P-51s, to pinpoint targets



In tactical operations in France SCR-584 has contributed greatly to close air-ground cooperation. This type of mobile installation can be set up for combat operation in an hour; it is sited (as here) on the highest point of land in the vicinity to avoid permanent echoes. Fighter-bombers, as well as photo and tactical reconnaissance planes, are vectored out to targets 35 miles or more away and back again. The controller with the 584 can signal pilot via VHF when and where to drop bombs to do most good.

It was in July, a few miles east of St. Lo. Three P-47's took off and the leader made contact by VHF with a 584 controller stationed 10 miles behind Allied lines. The planes carried no radar but, from that moment on, it was a radar-controlled mission.

The Thunderbolts were on their way to dive-bomb a bridge behind German lines. On directions from the controller, they approached the bridge at 9,000 feet. Positioned over the target by the radar, they were directed first into a 90° turn, and then into a 45° angle dive. They dropped 6 bombs and they scored 4 hits.

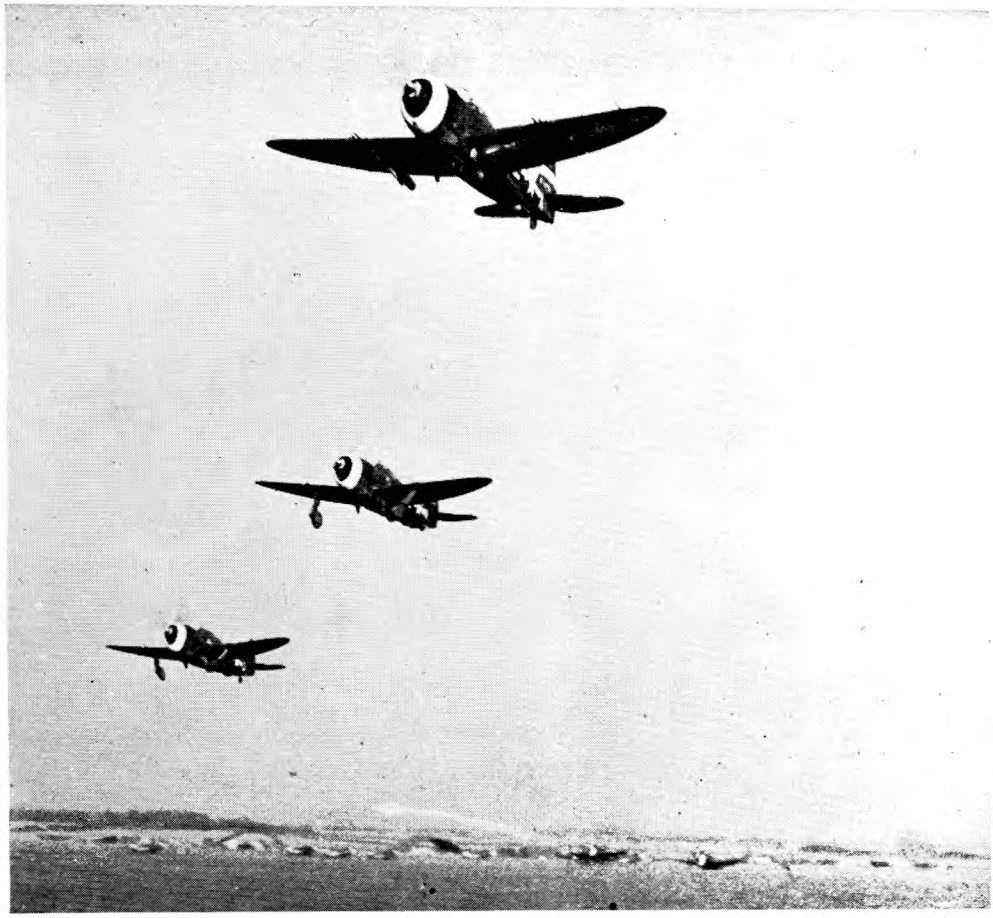
That mission was the first battle test of a modified SCR-584 in controlling air power in joint air-ground operations. Sponsor of this auspicious pioneering was the 9th Tactical Air Command. It has used the 584 for such operations enough since then to convince itself—and others—that it has something.

There have not been enough missions, on the other hand, to allow a full evaluation of the system's capabilities and limitations. One reason is that once our forces got started in France they maintained such a pace that there wasn't much need for this type of mission. Also, during most of July and August, weather was good and daytime bombing could be done visually. Finally, there just weren't many modified sets available for the job—in fact, only 3.

Some 20 additional equipments have since gone into construction in the U. K. If and when the front becomes more static, there is small doubt that the 584 will be brought into fuller play. Tactical commanders who have worked with the system are apparently ready to use it whenever it's needed.

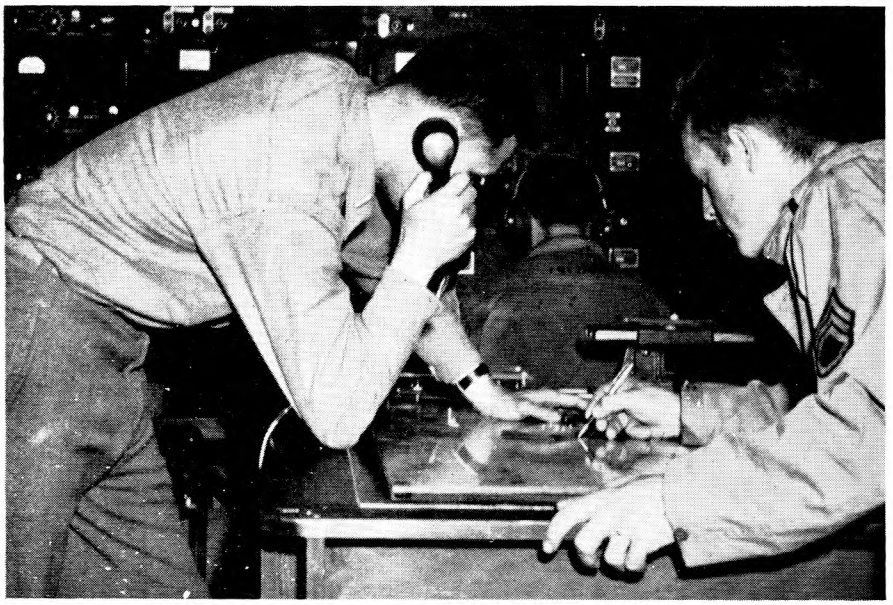
The 584 got started in its new role when a standard model was given a shot in the arm by improving its range. Then it was modified so that a semi-automatic plotting table could be linked up with it. The result was a set-up capable of controlling and positioning aircraft in tactical operations.

With a mission under control, the beam of the radar is used to keep an accurate check on range, azimuth and elevation of the lead plane: position is plotted on the map of the plotting table. The controller, with all necessary data supplied by the table and associated gadgets, gives VHF instructions to the pilot to put him right on top of his target. See next pages for details.



584's control of a flight begins shortly after planes take off, lasts right through the bomb release. Still unproven in its new role, 584 has turned in enough results like those below to justify 9th TAC's pioneering and greater use in months ahead





Plotting table, here shown in 584 van in France, is what gives the radar its control capacities. While plotter (right) marks flight path, controller directs pilot by VHF. The table, like the radar, is undergoing steady changes to improve usefulness

How a 584-controlled mission develops

To begin with, the ground forces call the Fighter Control Center to have the tactical air force knock out a column of armor, or some such choice target, 20 miles or so from the radar installation and about 10 miles ahead of our troops. Fighter Control Center in turn assigns control to the FDP (Forward Director Post). Because visibility is poor, FDP directs the 584 to set up for a mission. One or more fighters are assigned by FDP. Thus, typically, might the mission originate.

The aircraft are dispatched to an assembly point, where the lead plane (flying far enough out front for the radar to track its signal) reports to the 584 controller for directions by VHF. To control a plane, the 584 uses its normal search function to pick up the signal—for identification the plane can dispense window cut to 584 frequency.

After the aircraft has been spotted and the radar is tracking it, the controller has a continuous record of its course. On the plotting table he has a map of the target area oriented to the radar's position. As the controller vectors the plane toward the target, the line of flight appears on the table as a dot of light showing through the map. In effect, the controller sees the flight approaching the target as the pilot might see a car below him approaching a town. If the flight goes off course, the dot of light moves off, too. The controller can promptly tell the pilot the correction necessary.

While the 584 controller is taking the flight to its target, FDP watches for any aircraft in the vicinity (the mobile MEW—see page 38—has been helping with this, too). So the pilots are free from the distraction of looking for enemy aircraft. The pilot does not have to keep a check on his position nor fly a straight course; he can take evasive action and enemy flak concentrations can be marked on the plotting table and the planes vectored around them.

As the flight nears the target, a second controller with the 584 puts corrections into a Norden bombsight, precisely as a bombardier would in the plane, so that the radar controller may give data and bomb release point to the pilots (this type of control is only for level bombing). After bombs are away, the flight is vectored back or against targets of opportunity.

In normal procedure, the 584 relinquishes control to FDP or to the MEW immediately after the planes finish their work, so that it will be ready to pick up the next mission.

When and how the 584 functions as a controller

Maintaining isolation of the battlefield is one of the cardinal points of field operations. It is much harder to make a successful push forward if there are odds and ends of enemy resistance pecking away at you in the immediate battle area. These may not be major stumbling blocks but their nuisance value can be high and they can cost lives. Field artillery is usually called upon to remove such obstacles but the difficulties of night operations or overcast still remain.

It is at this point that the 584's new use comes into play. With radar supplying a link between ground and air, darkness and weather are no longer such obstacles and the weight of air power can be used effectively when otherwise it couldn't.

Through 30 August, the 584 handled only dive and level bombing missions—and not too many of those—but that isn't the extent of its capabilities. In general, its future probable uses will be as follows:

1. Control of bombers and fighter-bombers operating above undercast, at night or under any conditions of low visibility. For level bombing the controller indicates bomb release point, and for undercast conditions the pilot is told when to break the cloud cover. In dive bombing operations the pilot is given turn and dive information.

2. Control of night photographic reconnaissance aircraft. Here the controller indicates time when the photographs should be taken.

3. Day tactical reconnaissance. Aircraft controlled by the 584 have an accuracy in pinpointing a target comparable to that of photo reconnaissance.

The system is not limited to the above functions nor, on the other hand, has its worth in all of these been fully proven. Another slightly different use, not yet proven operationally, is the precision marking of battle lines or the positions of special ground force units by means of mortar shells or rockets fuzed for airburst and loaded with **window** cut to

the frequency of the 584. This stunt could materially reduce the danger of bombing our own forward lines in areas of quickly changing fronts.

Good communications organization, considering the importance of the VHF link, is essential in this game. Siting is equally so, but there wasn't much time for that in the big roll through France. Ordinarily, the radar is not more than 10 to 15 miles behind the front lines, and at times it is closer. During one maneuver in France, the 584 was moved into a pocket created by an armored force thrust even before the infantry came in to occupy the territory.

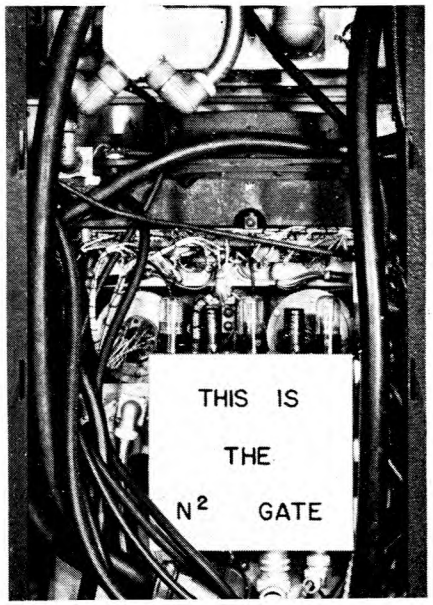
A 584 can be moved into location and put into operation, or shut down and put on the road, within one hour. The plotting table now in use weighs about 150 pounds and can be easily transported along with the rest of the equipment.

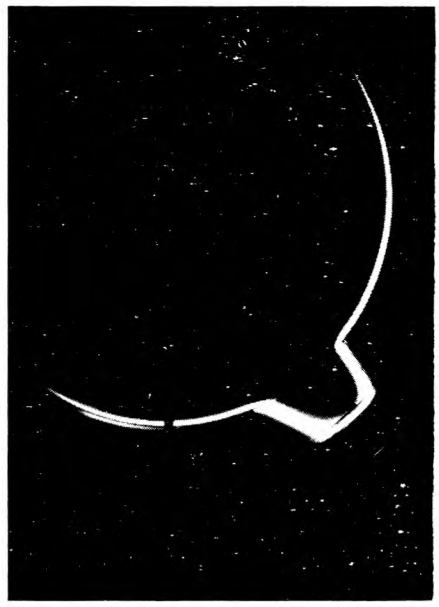
THE PLOTTING TABLE

Approximately 4 feet square, the table is arranged to show a 90° sector. (Recent modifications of the table will allow a 180° sector; in some operations in Normandy two 584's were employed as a team to give that coverage.) An arm whose pivot represents the position of the radar follows the antenna in azimuth, and a carriage bearing a small light is driven along the arm by the range output of the radar. Thus a spot of light showing through the map overlaid on the glass top of the table indicates the position of the plane. A plotter continuously follows the light-spot with a pencil so he can supply the controller with an indication of ground speed and other data. A Craig Computer or Norden bombsight is used with the plot for the bomb run and bomb release information.

A more complicated, more elaborate plotting table is currently under construction, although it will be a number of months before it gets out. It will be considerably heavier than the one in use at present but the excess weight will be used to good advantage. Among other things, it will show a 360° plot with the location of the radar in the center of the board. Also two scales will be available, the normal scale of 1:250,000 and an expanded scale of about 800 yards to the inch.

All in all, the 584 control setup looks like a promising baby. RADAR will report on future developments.





N^2 gate (left) doesn't take up much space in innards of 584, makes a big difference in performance. A picture can't show it, but with the N^2 gate on operator would see thickening and brightening of target signal at outer rim of normal narrow gate (right)

New modifications improve 584's range, tracking

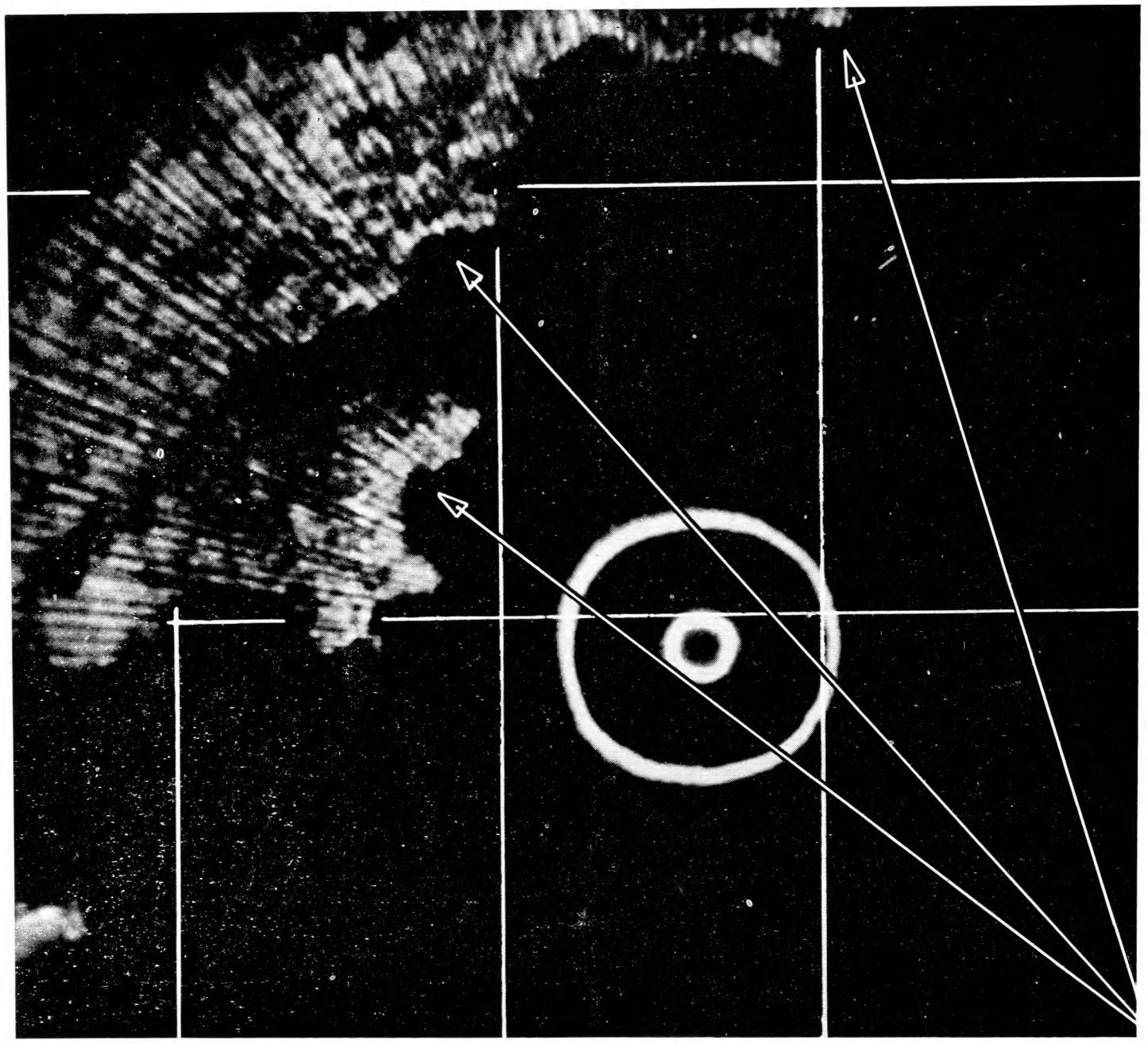
The development of a new gating circuit for the SCR-584 makes precision tracking of individual targets feasible, even in areas full of aircraft and flak bursts. Before this, the set had two gating circuits for measuring range: a wide gate to illuminate the 32,000 yard range and a narrow gate to show up a smaller portion of that range. Automatic tracking for azimuth and elevation worked only if the selected target could be kept well separated from other signals. If the radar saw another comparable target within a sector slightly greater than that covered by the narrow gate, it might lock on the new target or, for that matter, it might lock on some point in space between the two.

The new narrow-narrow (or N^2) gate turns on the servo channel of the receiver for a time interval corresponding to only 50 yards in range, and the consequence of this is a very considerable increase in the discriminating capacity of the set.

Operation of the gate requires more than usual skill in tracking. The appearance of the cathode ray tube trace changes very little: an increase in brilliance at the top of the target signal is about the only indication. This higher intensity represents a sector 50 yards wide and is displayed on the 2000 yard J-scope so that the operator may have a continuous check on the gate's position.

The N^2 gate is by no means the answer to all tracking and interference problems but it is the answer to a number of them and it makes the 584 just that much more competent. Before long, it will be standard equipment on all SCR-584's.

Meantime, an improved coverage has been obtained by modifying gearing and circuits, slowing down pulse repetition rate, putting in a higher sensitivity crystal to give a better signal-to-noise ratio. The changes make possible a tracking range considerably greater than that of the standard 584. Further improvements to increase range are being tested. Simplest yet most effective trick seems to be the use of an ordinary responder beacon, such as UPN-2, in the aircraft; the 584 has to be modified to allow for time delay. The beacon acts as a sort of booster station, serves as a means of identification as well. Enlargement of the 584 dish is also contemplated as a means of extending the range.



SPECIAL TRAINING FOR RADAR NAVIGATION AND BOMBING PRECEDED D-DAY IN SOUTHERN FRANCE. ARROWS SHOW WHERE BOMBING WAS DONE

Radar on the Riviera

Operations of the 15th Air Force, which swept over the French Riviera on 15 August, followed the Normandy pattern (see RADAR Nos. 3 and 4). So did other operations on that day, which meant radar bombing of the beaches (Pathfinders and H_2X). Troop Carrier drops with Rebecca-Eureka and SCR-717, RCM precautions.

Extensive preparations began more than a month before this second of the D-days to assure effective air operations regardless of weather. The 15th compiled a radar mosaic of the Mediterranean beaches all the way from Rome to Spain (see covers and page 34). Its invasion aircraft completed many a practice mission and ran off a simulated D-day. Its Pathfinder crews trained constantly in the 15th AF's Pathfinder Synchronous technique of bombing (on which RADAR will report later).

Pathfinders did the navigation on D-day. The bombing runs from the IP (Initial Point) onward, it was thought, could be visual. But after the night takeoff some groups learned that their IP's were covered by 10/10 clouds, putting it up to the Pathfinders to determine the crucial turns.

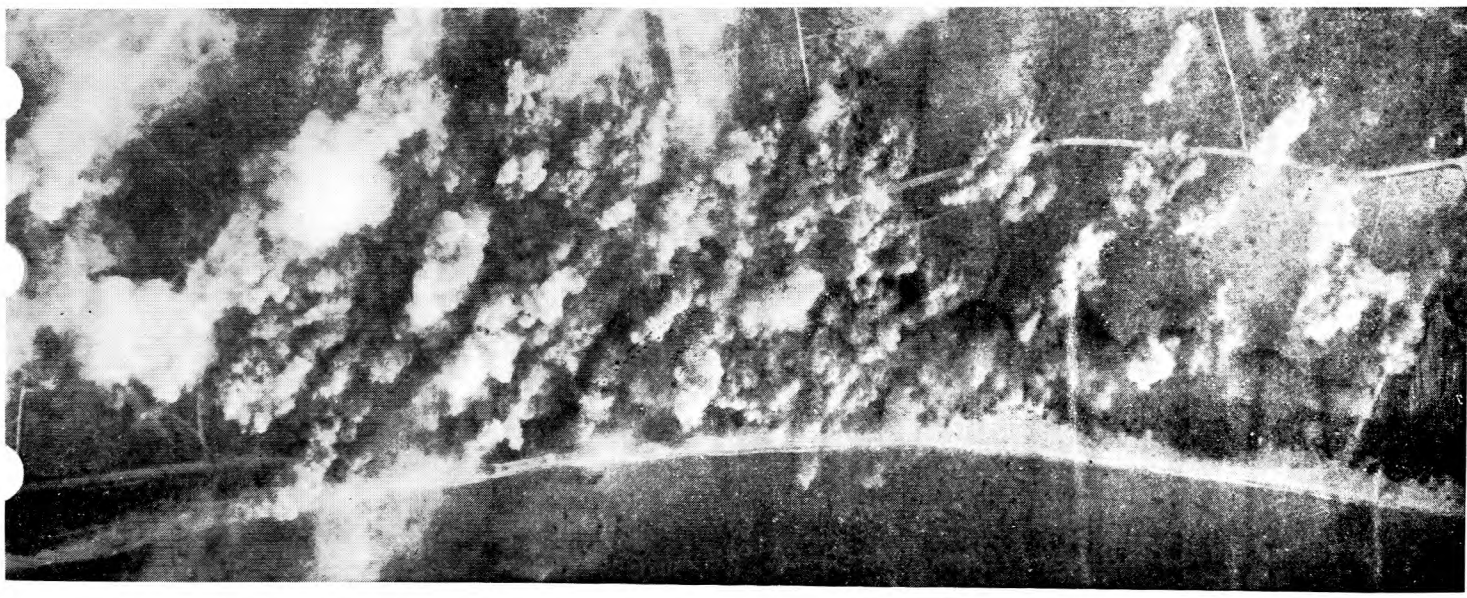
Troop Carrier Pathfinders, working with R-E and the 717, had a good day. Said the CO of the leading Group: "Radar permitted the flight to pass over six check points, locate the proper point between strongly defended zones, locate the DZ (Dropping Zone) and drop paratroopers through a solid blanket of ground fog. We were only 30 seconds late, after a 2 hour, 55 minute flight."



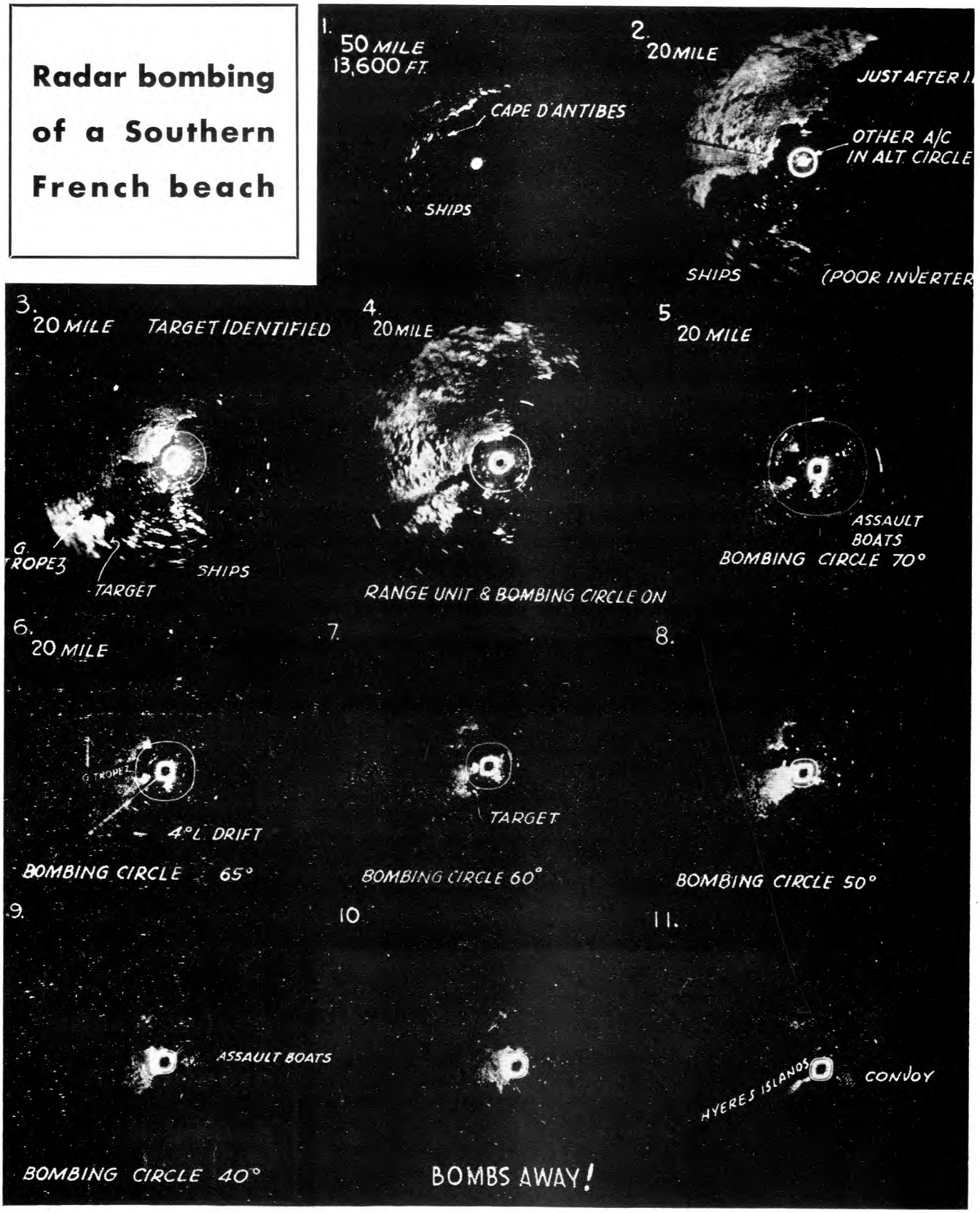
PATHFINDERS OF 15TH AF (NOW NUMBERING 130) LED WAY TO SOUTHERN FRANCE, PINPOINTING BEACH TARGETS AFTER 200 MILE HOP OVER WATER



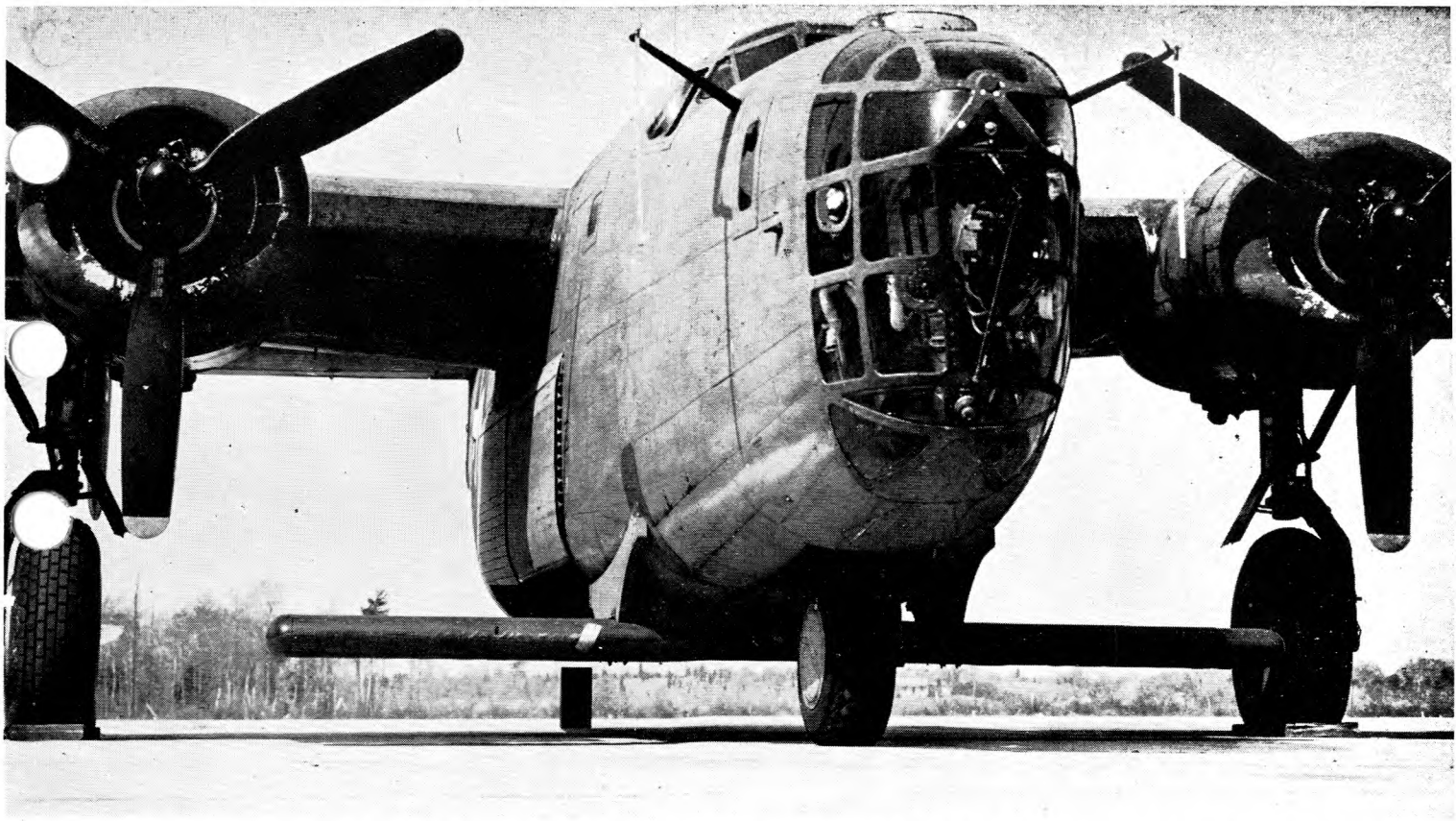
OVERCAST REQUIRED RADAR FOR ALL NAVIGATION, 50% OF BOMBING. PATTERNS WERE WELL LAID, AS PHOTO (BELOW) OF ONE STRIKE SHOWS



Radar bombing of a Southern French beach

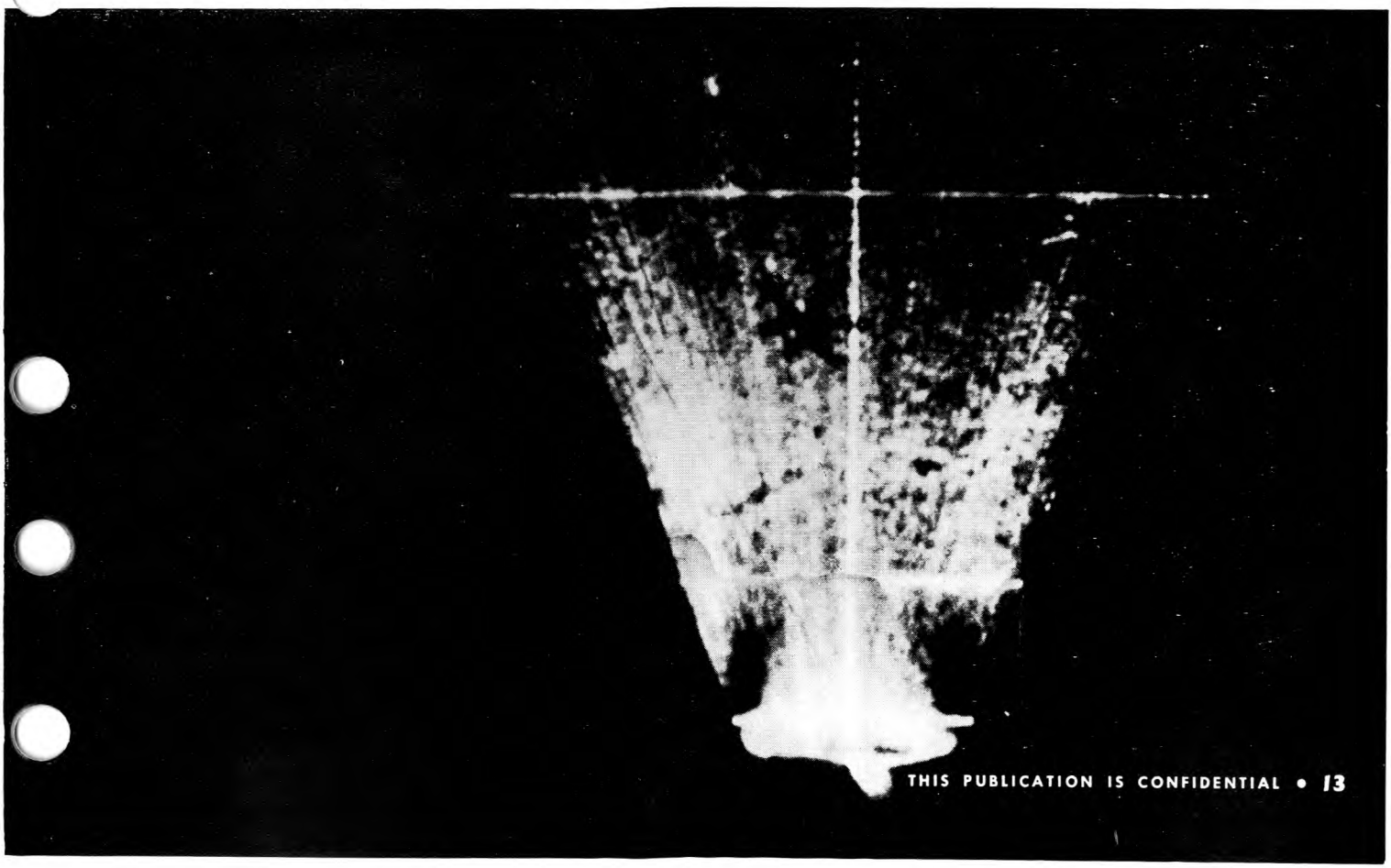


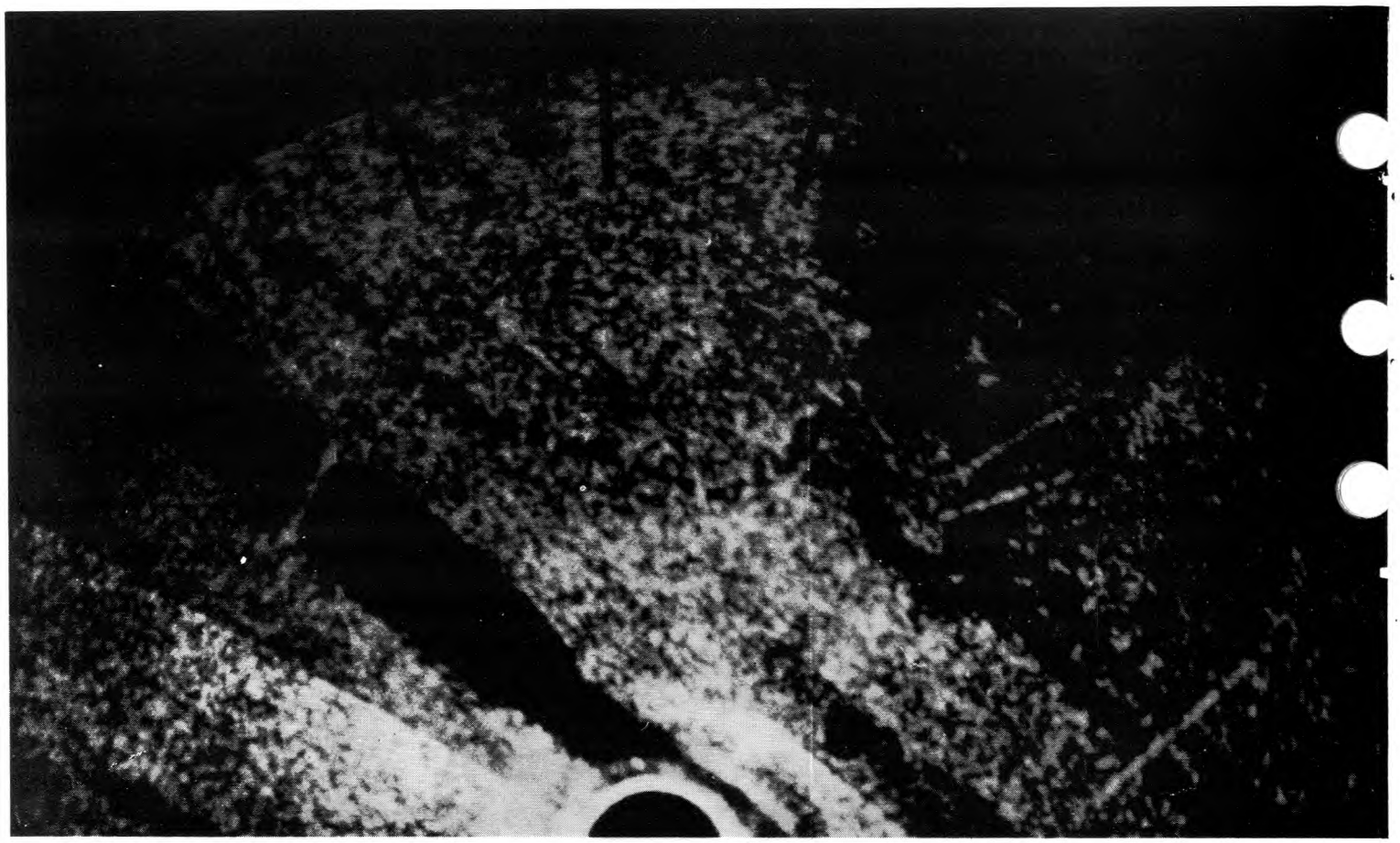
D-day series of APS/15 scope photos from IP (Initial Point) to bombs away. Bombing circle narrows as accurate slant range indication is reduced to synchronize optical bombsight with target. In this series of photos, taken and put together by members of the 15th Air Force, shoreline contours, assault boats and convoys are visible. Note frank apology on photo No. 2.



TO COME:

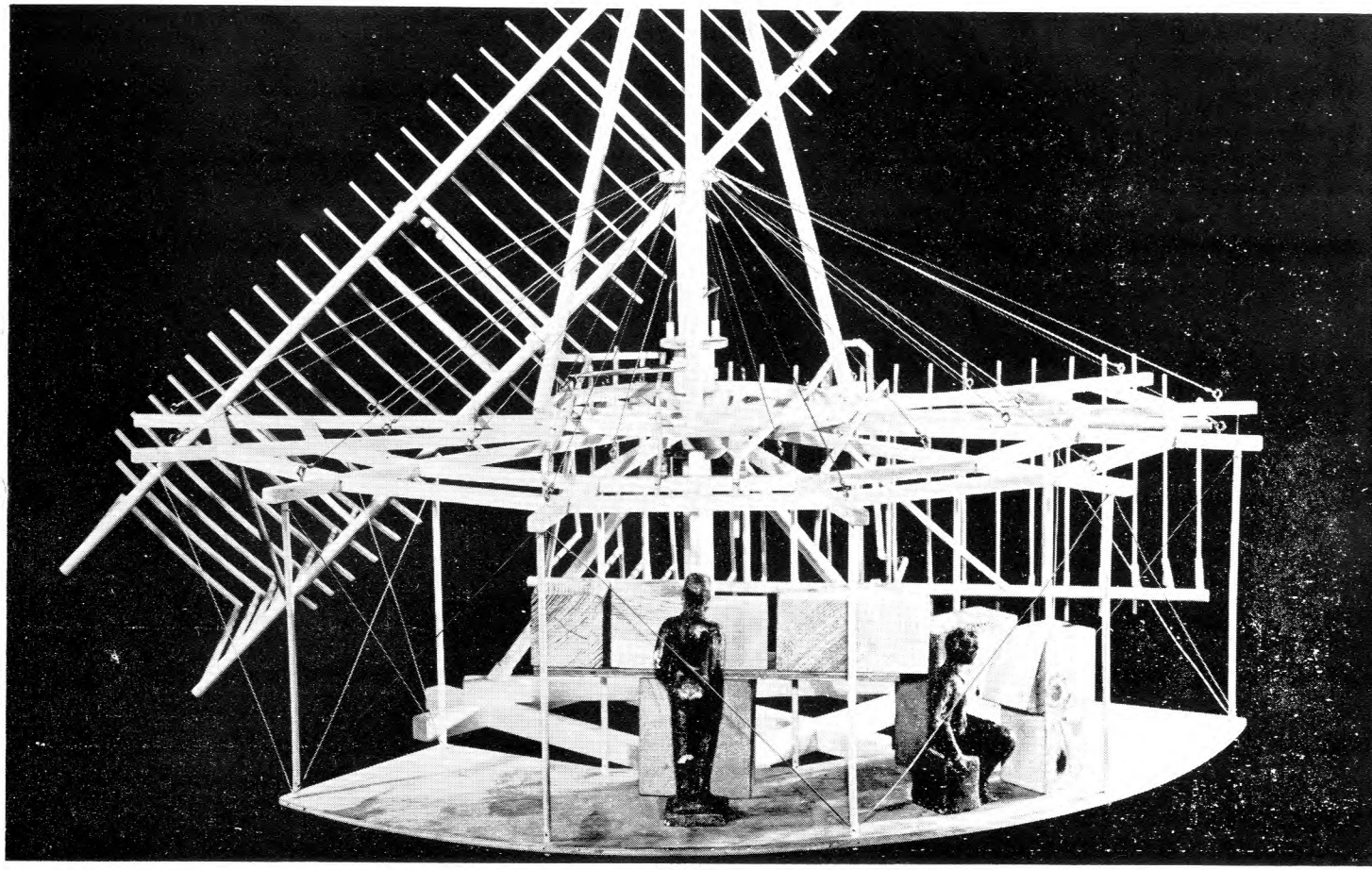
Radar shown on this and next 3 pages will not be in use tomorrow, is latest thing in development at home. Below the PPI of Eagle (AN/APQ-7), designed for navigation and bombing, paints Bedford Airbase runways clearly from 10,000 feet. Improved resolution comes from special narrow beam antenna, odd shape of which is visible in B-24 mounting (above)



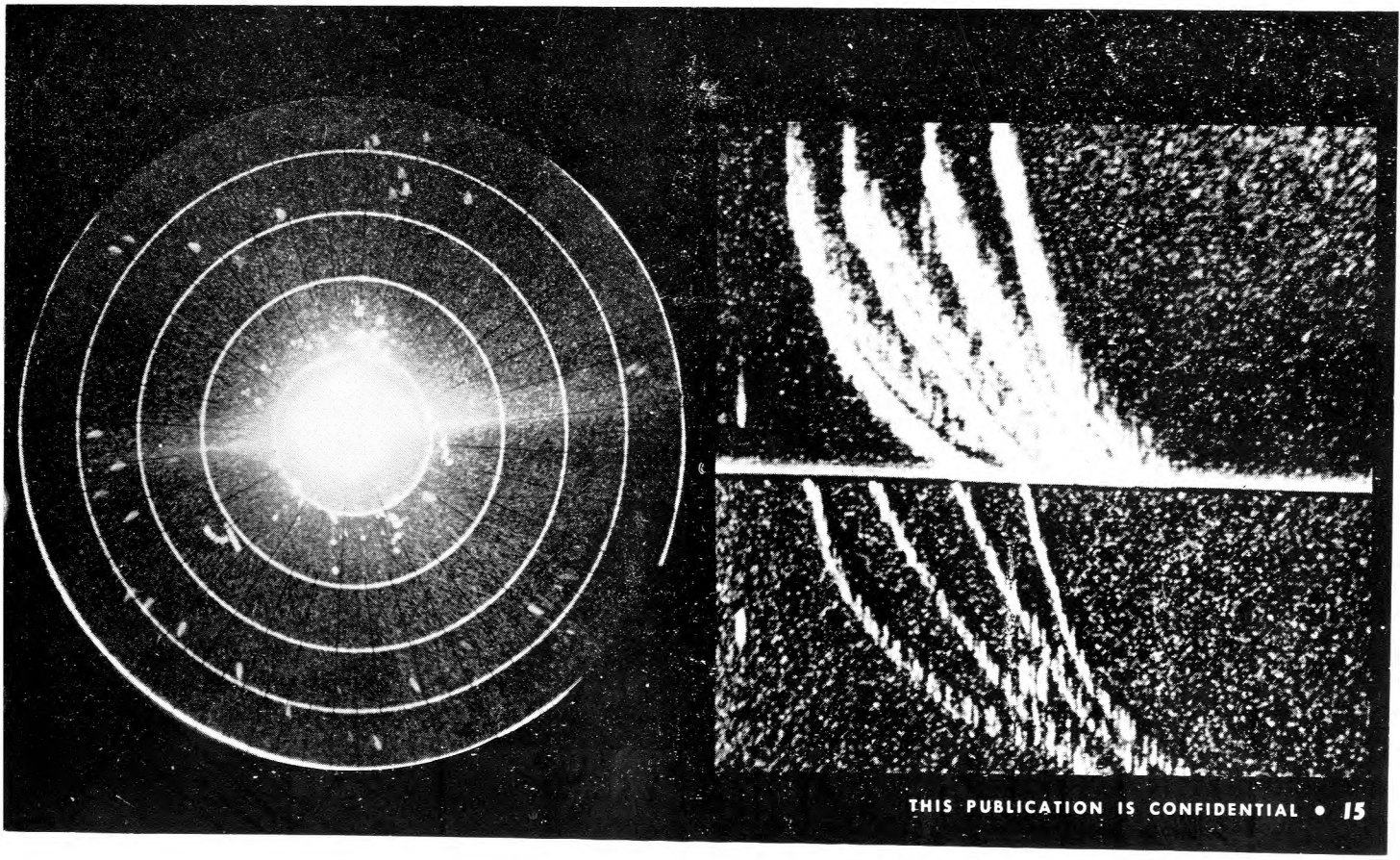


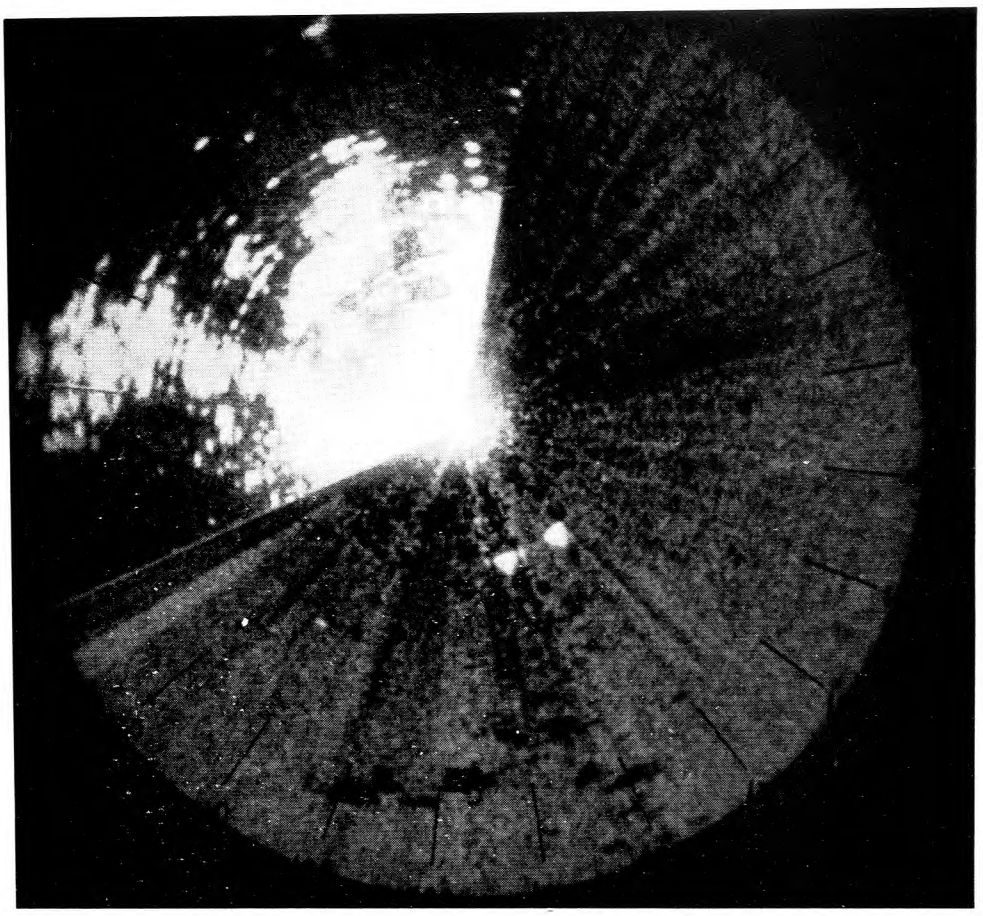
K-band radar gets its unusually brilliant resolution from very short wave length. For navigation and bombing it will be undoubted successor (along with Eagle—see page 13) to present H_2X. But not for some time. Production problems plus complexities always involved in change-overs of equipment and operating procedures must be met first. This picture of the shape of things to come shows what a trial equipment saw from 8,000 feet over Manhattan. Note the docks along North River





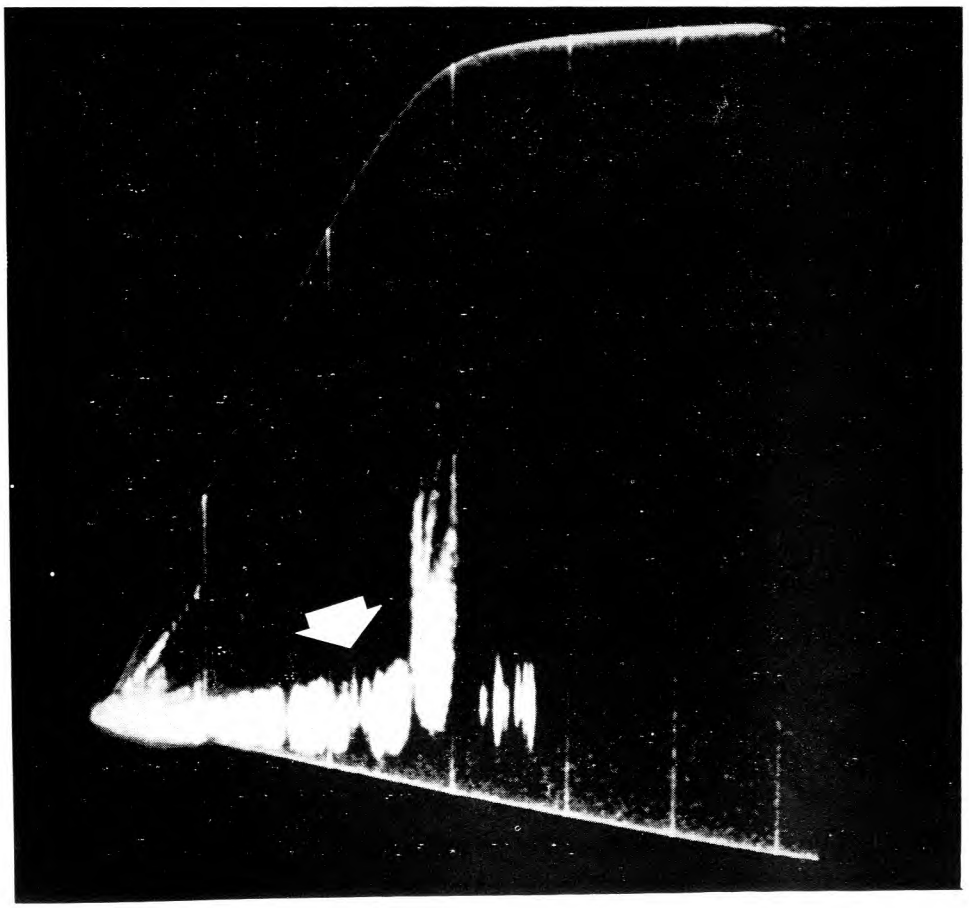
V-beam radar performs search and height finding functions both, is good for fighter or bomber control, tracking through window, storm detection, etc. Its 2 antennas (model above) are mounted merry-go-round style. The whole equipment, cumbersome though it looks here, will be air-transportable. V-beam's high discrimination shows in PPI photo below: fighter (8 o'clock) is being vectored onto target. Height scope's vertical beam (right, bottom) shows targets plainly in window trails (top half is slant beam)





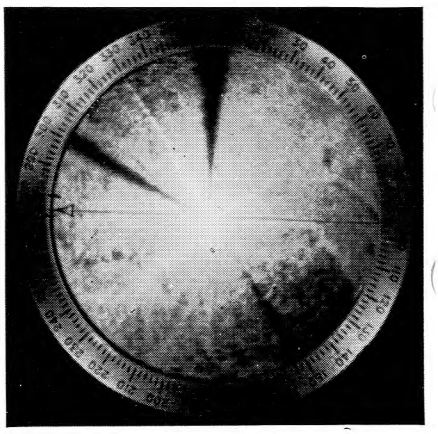
MTI (Moving Target Indicator) circuits wipe out fixed echoes, leave targets well displayed. On scope above 0°-240° sector shows MTI effect; 240°-360° is normal

Li'l Abner (TPS-10), whose special scan and narrow beam fit it to mountains, will soon be Pacific bound. Arrow shows B-25 at 23 mi., 1700 ft. through fixed echoes

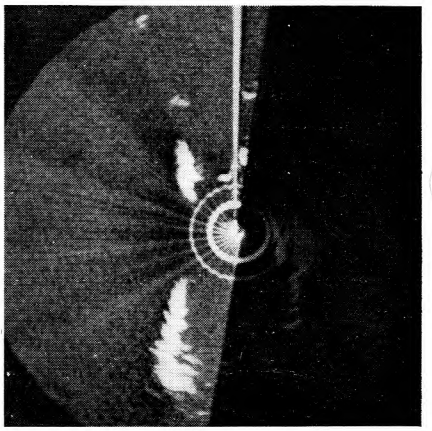


...and some oddities

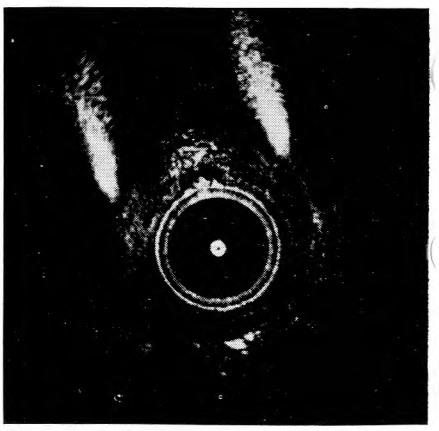
Presentations from developmental radar on preceding pages are matched by curious effects from present radar, below



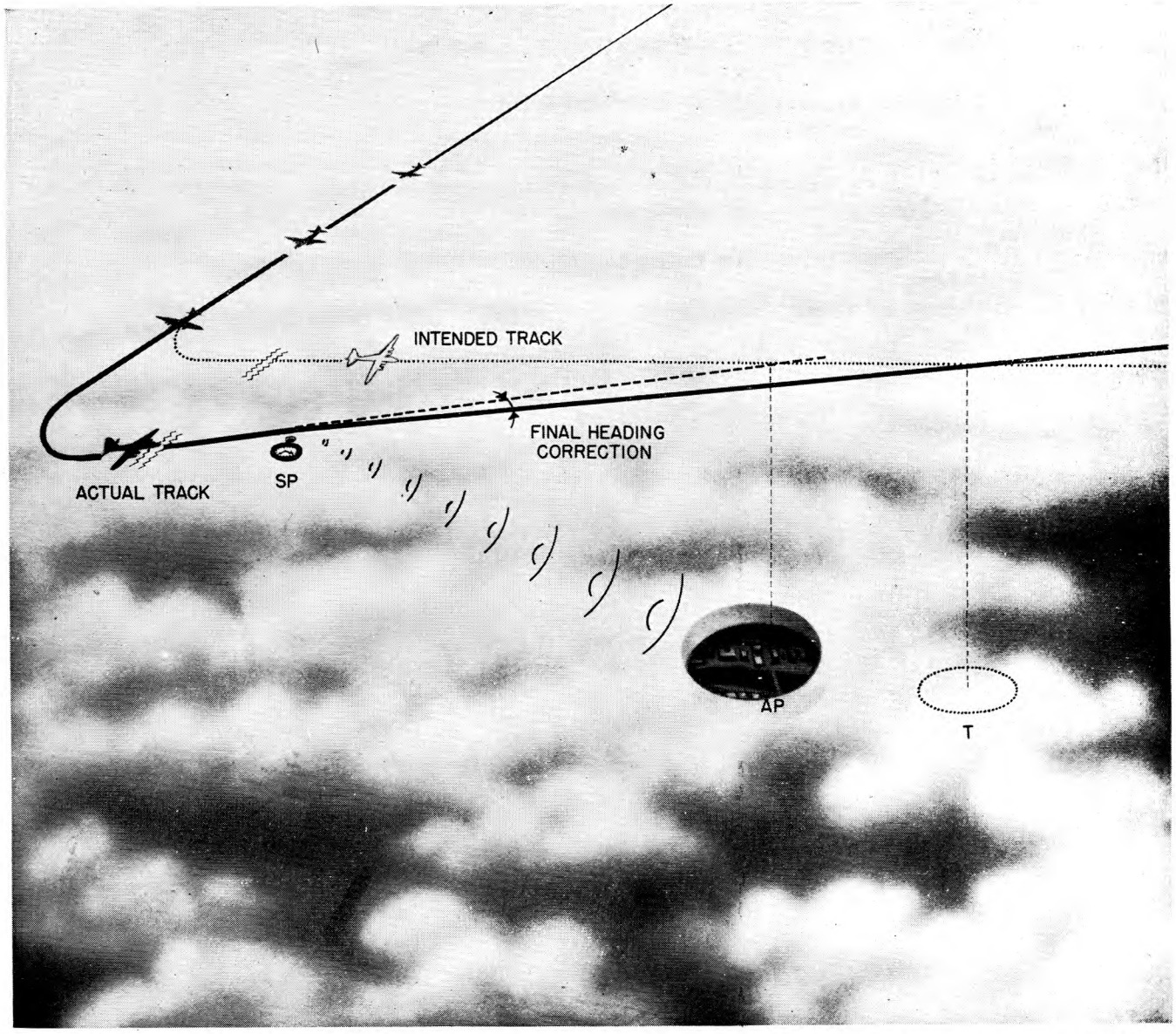
LANDING GEAR of B-17 puts 3 wedge-like shadows on scope of APS-15 as pulses bounce back from front and rear wheels



CLOUDS show so sharply on this APQ-13 scope (at 7 and 11 o'clock) that they're virtually indistinguishable from land echo



DOORS of rear bomb bay on B-29, when opened for the bombing run, show up as 2 fiery plumes at top of APQ-13 scope



NEW OFFSET TECHNIQUE ENABLES ACCURATE BOMBING AGAINST HARD-TO-SEE TARGETS. FOR DETAILED EXPLANATION OF METHOD SEE PAGE 20

Radar bombing: offset

First of a series on developing techniques

Visual daylight bombing can't be beat for accuracy—that is, if there is daylight and visibility. Direct H_2X bombing is a good alternative—that is, if the target can be distinguished on the scope. Since much of current bombing is blind, and many targets present poor scope signals, both methods together still leave precision bombing appreciably limited. Offset bombing by radar is a leading candidate for the job of cutting down the limitations.

Growing out of necessity, offset radar bombing involves techniques which are slightly different for every theater—according to the needs of each. The 8th Air Force achieves accuracy with its H_2X by using the "Micky" operator and bombardier as a team, and has multiplied their effectiveness by introducing certain offset methods.* The B-29s in their jaunts over Japan use a form of offset (see RADAR No. 4). A new offset technique on which much work has been done in the States offers added precision and might be pretty generally adaptable.

Basically, all offset methods treat the problem of bombing accuracy with simple logic. They are technical applications of such common practices as golfers use in aiming for the cup by sighting on the flag. From the fairway a golfer can't see the cup, but can place his shot accurately because he knows where it is in relation to the flag. Similarly, on a scope, when the radar operator can't get a good return from his target, he aims at a point he can see, which is in a known position with respect to the target.

Thus the simple theory of offset. For more detail and a discussion of the new offset technique, turn the page.

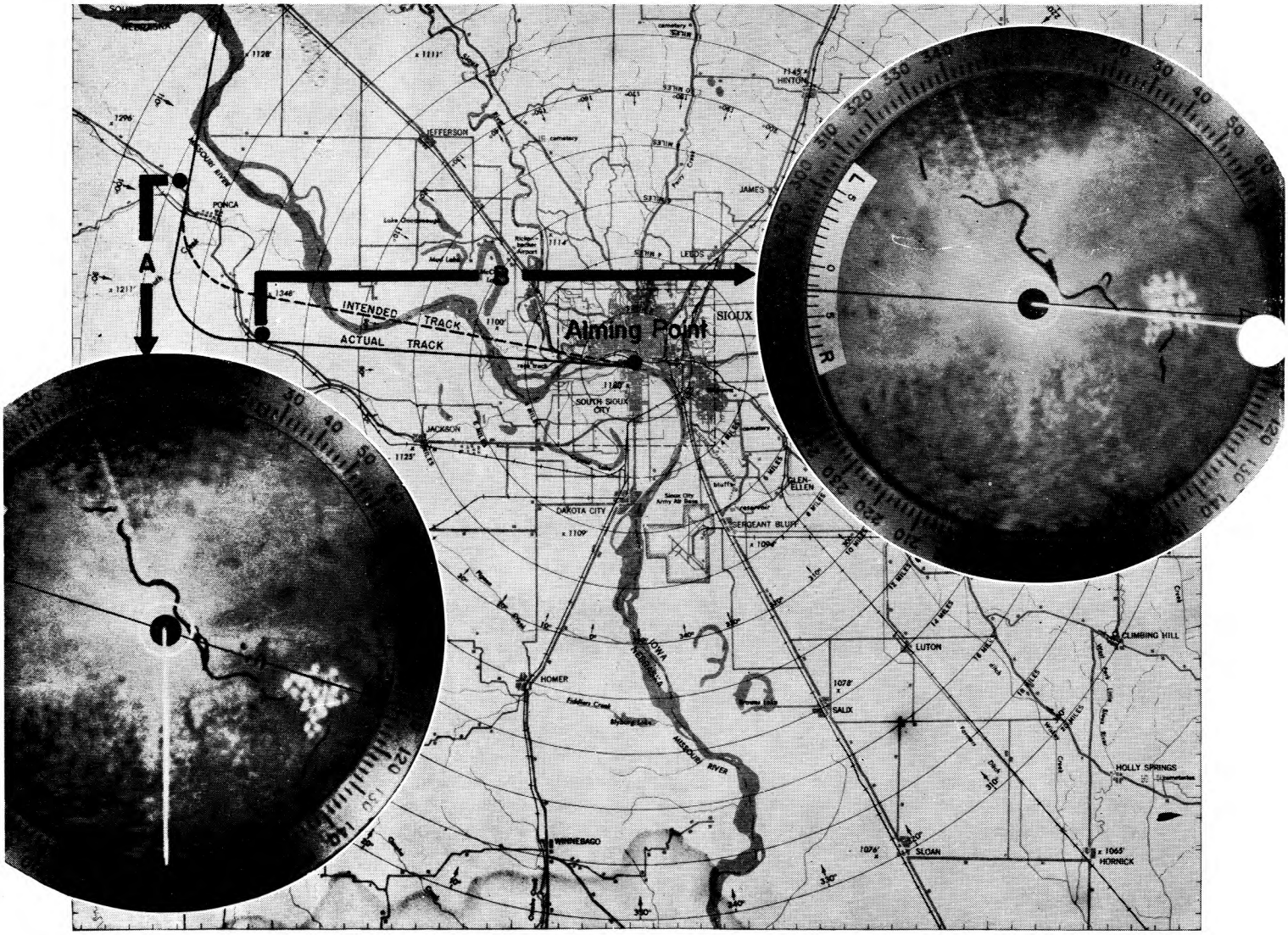
* *Future issues of RADAR will discuss bombing techniques of 8th, 15th and other Air Forces.*

A good AP is the sine qua non; what happens thereafter is largely mathematics

The various offset practices have certain technical differences, but common to all is the necessary "aiming point" (AP). That can be any outstanding coastal projection or indentation, island, large bridge, or other feature which will produce a good signal on the scope, and is near the target. Once the mission is set up, its execution can be boiled down to flying a track connecting aiming point with target. At "stopwatch point" (SP), where bombing circle coincides with aiming point, a predetermined time delay is clocked, after which bombs are away.

But offset bombing is more than this. For one thing, aiming points aren't picked just because they look good on a map—their selection is a technique in itself, involving such factors as distortion, stability of signal, etc. An example of a perfect aiming point is the small island of Ailsa Craig in the Firth of Clyde, between Scotland and Northern Ireland—a solid rock 2,000 to 3,000 feet in diameter and extending 1,100 feet above the sea. Steeply sloping sides make it visible on the scope at a range of 30 to 35 miles. Since it's several miles from the nearest coast, its signal never blends with that of the coastline. It gives such a good return that it can't be mistaken for a ship. From every direction it gives back a steady signal which doesn't change. It is small enough so that accurate ranging can be done on its signal, and it provides an excellent means of determining wind with the E6B computer. It's too bad there isn't a target near it.

Aiming points aren't often as good as Ailsa Craig, but the more like it they



Actual mission pictured on these pages illustrates offset tactics discussed above. Three simulated scope photos cover key points along the track. At (A) aircraft is approaching Initial Point—20 mile scale—track 190°—heading 182°—right drift 8°—bearing line 109°. Procedure turn is started when point estimated as bridge (AP) is under bearing line. Operator has put mark on plexiglass disc indicating a 3° left drift for final run. At (B) procedure turn is completed—target region now about 12 miles away—20 mile scale. As aiming point has not yet appeared operator tracks point he estimates to be the bridge.

are, the better. It's a job for radar intelligence officers to know the possible aiming points that exist around real targets and to pick the best one when the occasion arises. The successful planning and briefing of an offset mission pretty much start with the selection of a good AP.

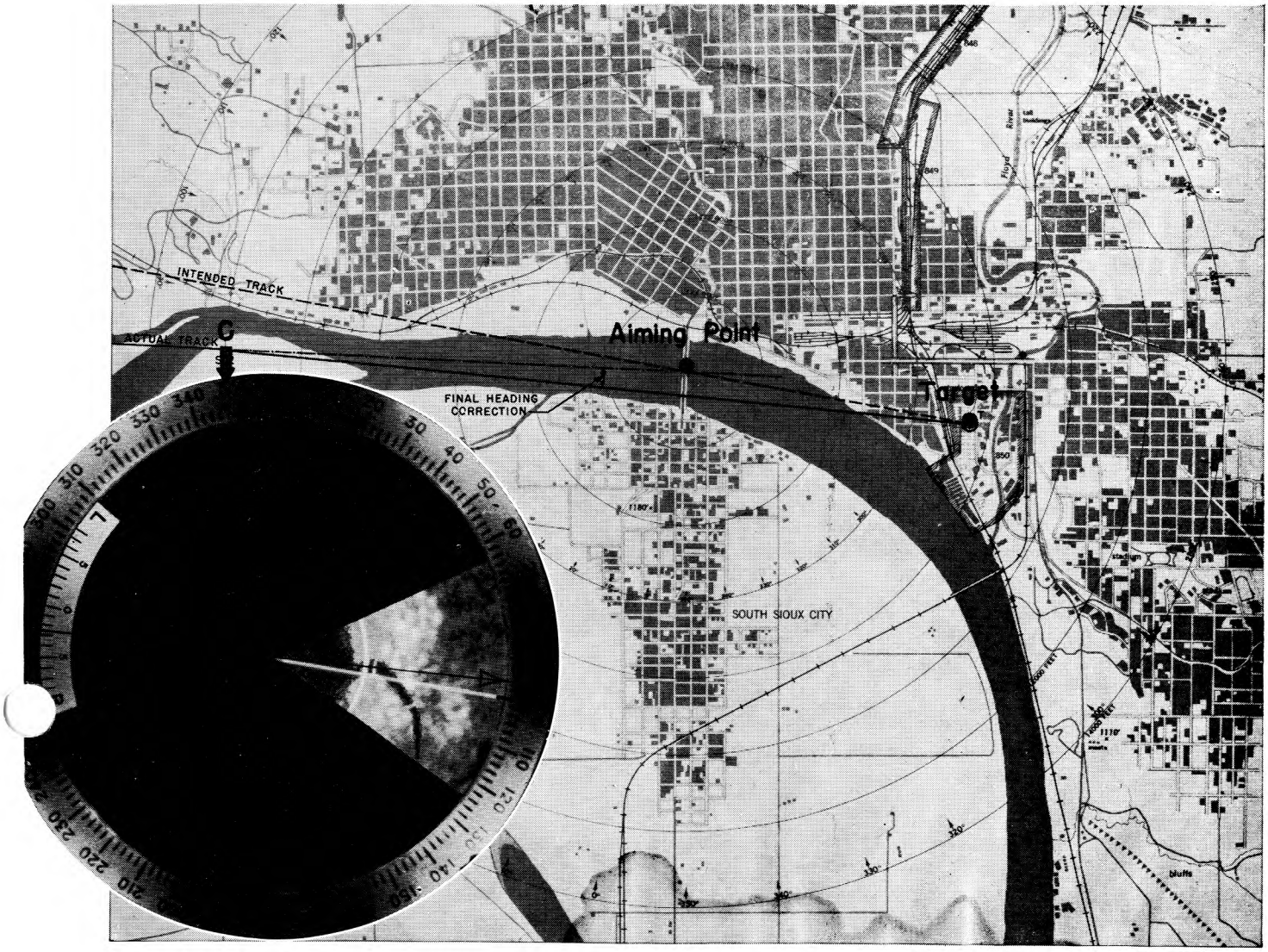
The newest offset technique—for which many Midwest and Pacific Coast cities have been serving as guinea pigs—was developed by the 2nd (now 4th) Air Force Radar Instruction Unit, recently moved from Kansas to March Field, California.

Recognizing that the less work done in the air, the less chance of error, the Unit's method has placed the burden of computation on the ground. Tables, charts and scales for each mission can be prepared in advance—in less than an hour—so that even final corrections can be made without actual calculation while in flight.

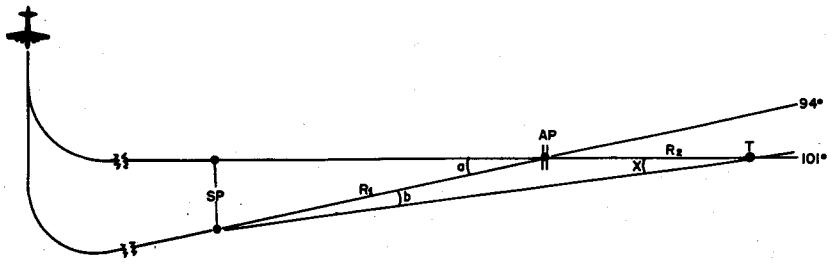
Opportunity for error could be minimized if the operator knew in advance where the aiming point would appear on his scope—if the plane could be put on course at the beginning of the run. A procedure turn technique was developed to accomplish this.

The aircraft is navigated to approach an initial point on a track 90° to the desired final track. At a predetermined distance from the course line, which connects aiming point with target, the turn is begun. The appropriate bank angle to use is determined from a table involving speed of aircraft and radius of turn desired. Enroute to this turning point wind drift is calculated by any one of several methods (for one radar method using the E6-B, see RADAR No. 3).

If this turn could be made perfectly and if there were no error in drift computation, the rest would be simple. Just a matter of flying on course through stopwatch and bomb release points. But turns are never perfect nor drift calculations accurate—hence a need for a final heading correction (see page 20).



Stopwatch point is reached at (C) where bombing circle and bridge coincide—5 mile sweep. Final heading correction is made here as indicated by tail of bearing line on scale centered at 281°—reciprocal of 101° desired heading (see next page for details). Delay time determined from bombing table starts from this point—after required number of seconds bombs are away. Note lubber line, since turning, has been on the grease pencil mark which was placed 3° right of bearing line. Range circle is set for 12,000 feet ground range which is 23,320 feet or 3.84 nautical miles slant range for an altitude of 20,000 feet.



Some Offset Mathematics

Final heading correction—a crucial step in the offset method described on these pages—is simplified in the air because it is predetermined on the ground. Here's how, for the mission shown above:

R_1 = Distance from SP (Stopwatch Point) to AP = 12,000 ft.

R_2 = Offset Distance from AP (Aiming Point) to T (Target) = 7,500 ft.

a = Degrees aircraft is off course

b = Degrees change in Heading necessary to bring aircraft over T

$$\frac{a-b}{12000} = \frac{b}{7500}$$

$$b = .38a$$

Desired track connecting aiming point and target in this case is 101°. Aircraft approaches an Initial Point, 15 miles from AP, on a track 90° from desired track. After execution of a procedure turn aircraft is not on course, but flying a collision track on AP at 94°. This track is maintained until Stopwatch Point is reached, as indicated by the coincidence of bombing circle with AP. The final heading correction is made here.

From the geometry of the diagram angle (x) is seen to equal angle (a) minus angle (b), and (a–b) is to R_1 as (b) is to R_2. Substituting the figures for R_1 and R_2 corresponding to the mission at hand, angle (b) can be identified in terms of (a)—in this particular case, b = .38a.

This information is presented to the operator on a final heading correction scale, and is available at a glance. Scale is placed along rim of scope with 0° on scale at the reciprocal of desired heading (281° in this case). Markings from 0 on the scale correspond to the ratio of (b) to (a). On this mission a 7° error means approximately a 3° correction, as indicated by the tail of the bearing line (see simulated scope photos on pages 18 and 19).

ALTITUDE	SLANT RANGE
19,000	3.70
20,000	3.84
21,000	3.98

GROUND SPEED (KNOTS)	ALTITUDE		
	19,000	20,000	21,000
150	44.8	44.2	43.5
160	39.8	39.2	38.5
170	35.4	34.8	34.1
180	31.4	30.8	30.1

Excerpts from slant range and time-delay tables needed for this offset bombing method are shown above. Slant range from SP to AP in nautical miles is used for positioning bombing circle according to altitude. Delay times in seconds from SP to bomb release point depend upon altitude and ground speed. Portions of tables shown above are based on characteristics of M-43 500 lb. GP bomb and a constant indicated air speed of 155 miles per hour.

Final correction is polishing touch

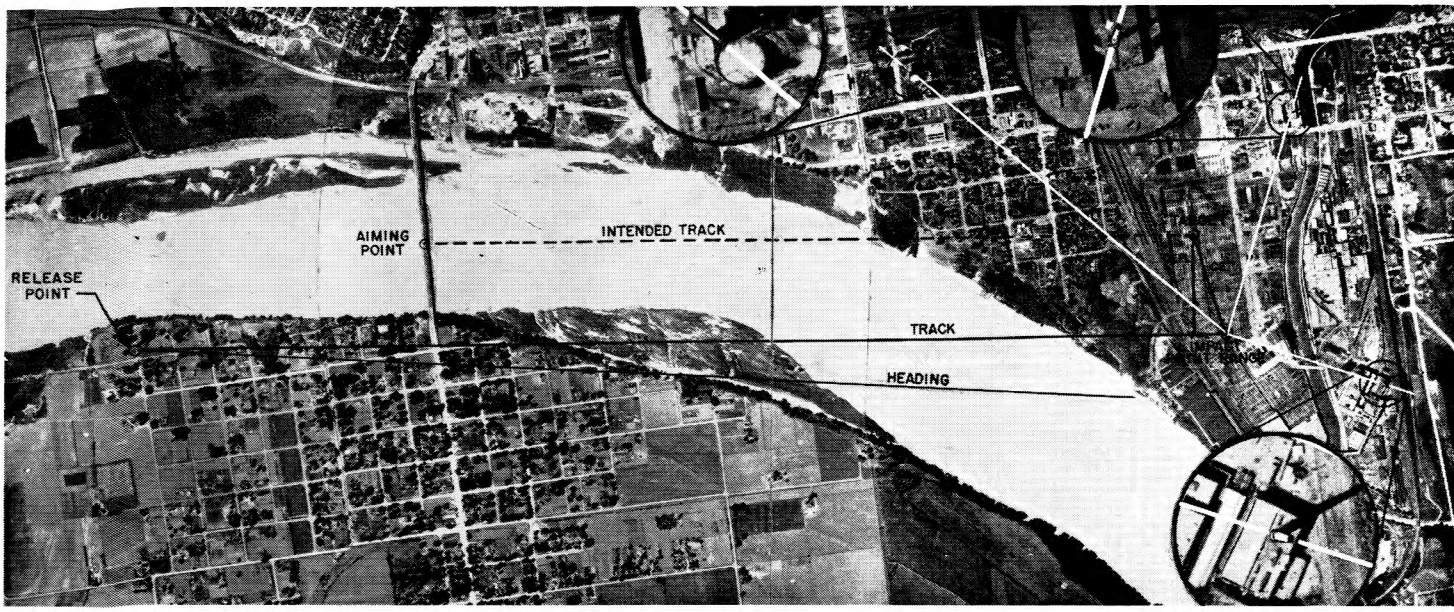
The final heading correction is the last minute touch in the offset method which socks the bombs in on the nose. This correction is made at the stopwatch point. It is based upon a geometric ratio between the amount the plane is off course and the amount it must change heading to fly a collision course on the target. The perspective drawing on page 17 and the map on page 19 show pictorially what happens. The adjacent box describes the process in detail.

Thorough pre-flight preparation—as exemplified in the final heading correction scale—is an outstanding characteristic of this offset bombing technique. The stopwatch point must be placed at a distance from the target and aiming point consistent with equipment limitations and tactical considerations. Slant range data—based on ground range between stopwatch point and aiming point—must be compiled so that the bombing circle can be properly set for whatever the altitude may be. Delay time (the time for the aircraft to travel from stopwatch point to target, plus time to travel trail distance, minus time of bomb fall) must be worked out for the various speeds and altitudes that might be flown.

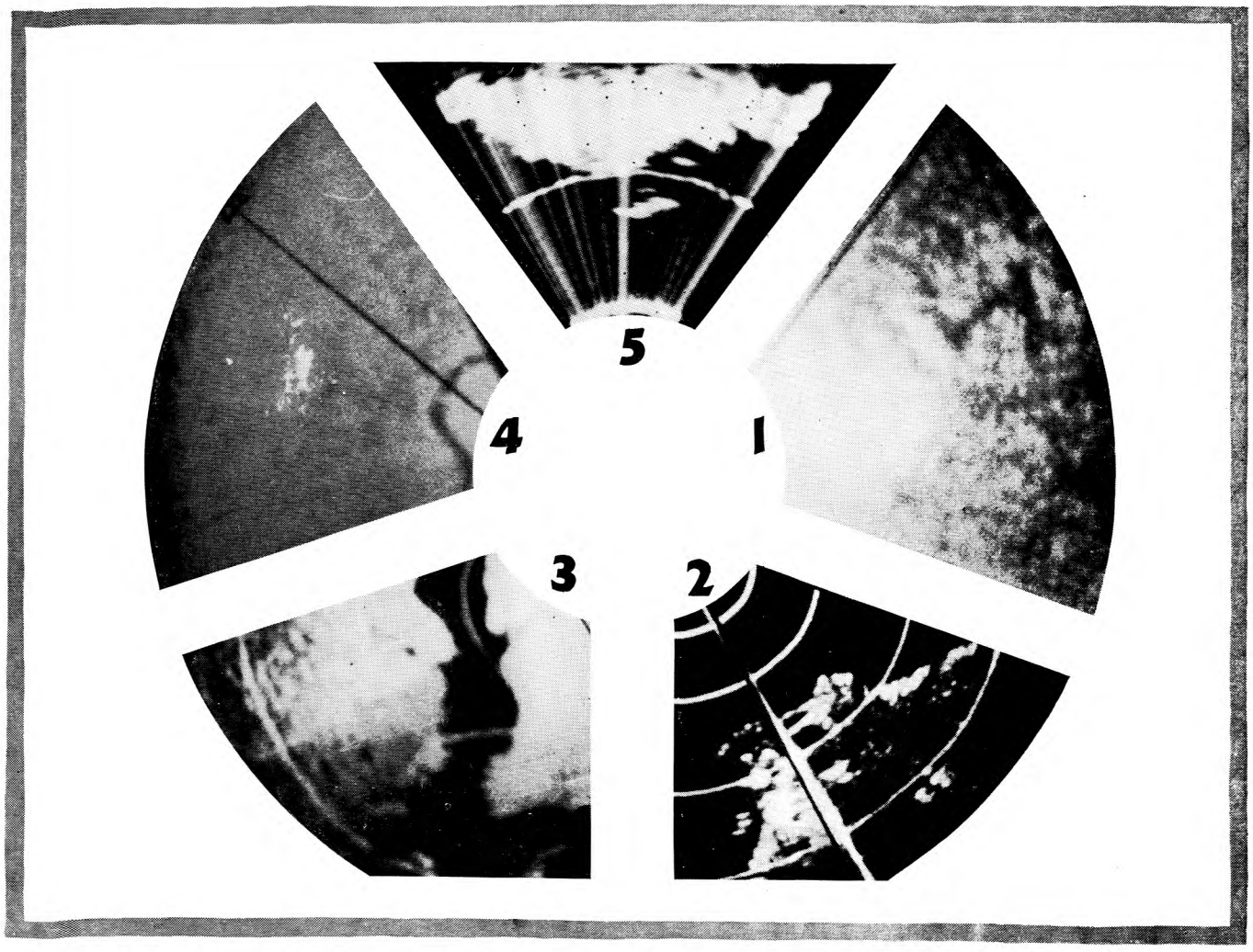
All of this information is made up in tabular form before the missions start (see excerpts from tables at left). It means more work for radar intelligence and operations officers, less work for radar operators. And it also means that errors may be eliminated before they can affect results.

This particular offset method has yet to be initiated operationally. It is intended to supplement—not by any means to replace—methods of H_2X bombing which use the actual target signal as a guide. Officers trained in the offset technique are confident that it can provide a satisfactory means for bombing many a target which offers little or no signal return.

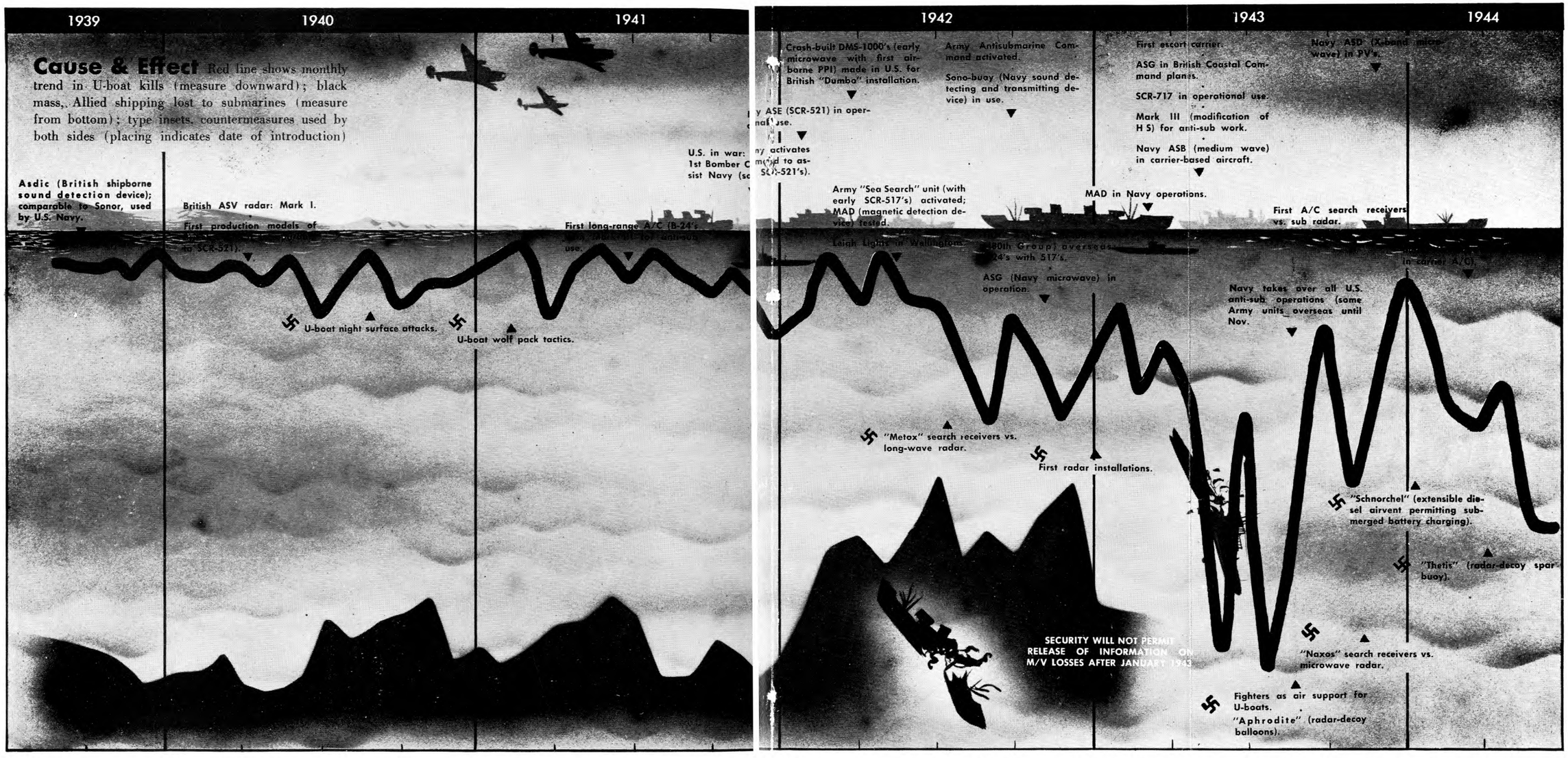
Results compiled to date indicate that well trained operators using proper methods on a correctly calibrated set, can drop half their bombs within 1500 feet of the target. That isn't quite pinpoint precision but it's far from bad bombing at that.



Photographs score the bombless missions run in offset training. At intervals from SP photos check calculations for drift, ground speed. On photo taken directly over impact point hits are located by nadir method: extending vertical lines of nearby structures to vanishing point (above). Impact point is determined by time of bomb fall minus trail distance divided by ground speed



Aiming points may be provided by coastlines (2), bridges (3 & 4), islands (5), etc., so long as definition is good and point is near target. These keys to offset bombing are sometimes hard to find. Japan has plenty—Europe fewer. The number increases as radar resolution, training improve. Runway (1), shown from low altitude, will be good at greater heights as equipment improves



In the U-boat war the AAF pitched in to help the Navy during the worst months, estab hed the offensive power of the aircraft-radar team. Here for the first time the full story is told

War against the U-boat

4 AUGUST 1942: *"The aeroplane can no more eliminate the U-boat than a crow can fight a mole."*—Admiral Doenitz. • **APRIL 1943:** *"The enemy possesses no means of defense against our U-boats. Not even in his growing air fleet, although it must be admitted that aircraft . . . give our men some trouble."*—German home report. • **9 AUGUST 1944:** *". . . the U-boat remains the hunted rather than the hunter. They have been attacked from the Arctic to the Pacific, aircraft playing a great part. . . ."*—President Roosevelt and Prime Minister Churchill.

Between the first statement and the last the battle against the U-boat was fought and won.

Hitler had reason to expect a different result. The U-boat was a big hope, it rated top priority in naval construction, probably total construction. In 1942 the fleet numbered nearly 700, daily averaged 16,000 tons of shipping sunk.

What happened to the U-boat campaign is in considerable measure the story of the "crow" that learned to fight the "mole," and the story of ASV radar. Together, long-range aircraft and airborne radar drove the U-boat down.

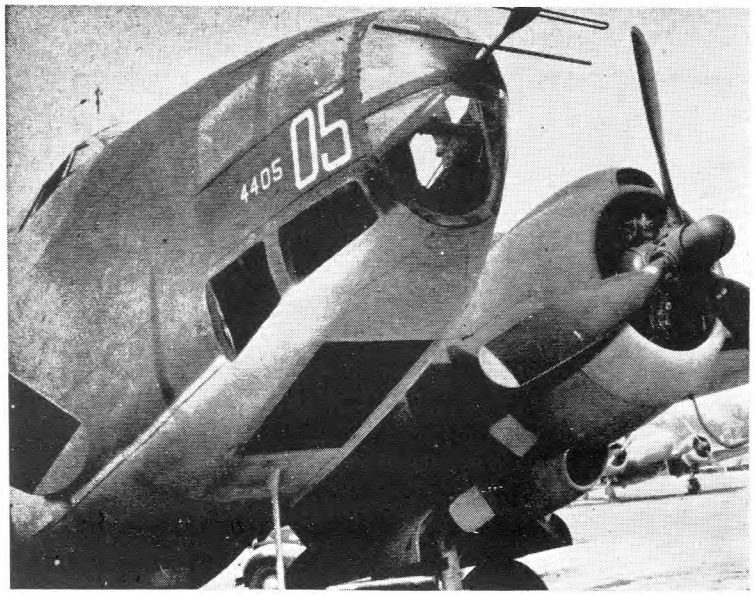
"Hunt and kill" was the basic concept of the aircraft-radar team. This was something that the enemy, sure of Allied faith in the defense creed of convoy coverage, had not expected. The defensive concept held until mid-1942, when ships were going down like tenpins.

Meanwhile, the aircraft-radar team, key to offense, was gaining strength.

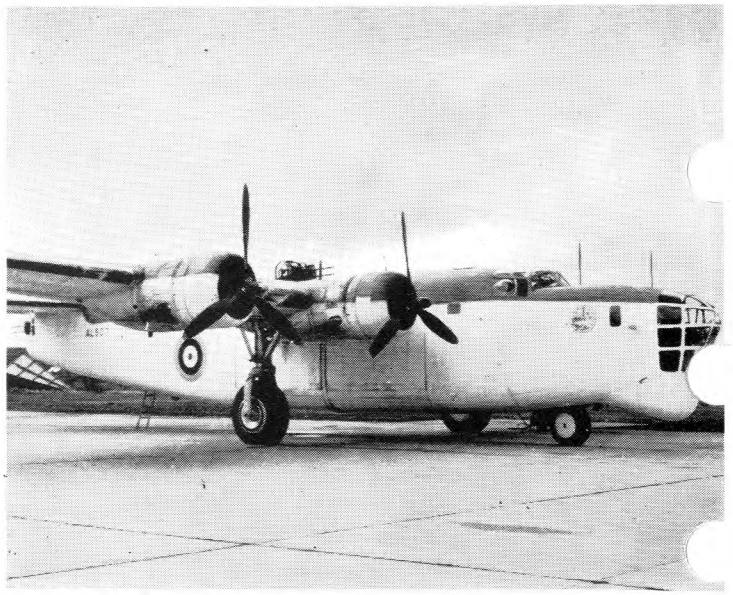
In mid-'43, during the peak months of the submarine battle, "hunt and kill" tactics decided the issue. Nearly 100 U-boats succumbed during May and July, aircraft accounting for two-thirds. More important, merchant mortality kept dropping. Bettering a pre-1943 ratio of one sub sunk in 40 sightings, British Coastal Command and USAAF aircraft-radar teams in July brought the kill-to-attack ratio to 1:4.

The Navy was ready to carry the whole anti-submarine load by August 1943. Its efforts since, coupling surface escort coverage with land-based and carrier aircraft, have been aggressive and fruitful.

Now—one year after the AAF stepped out—RADAR tells the story of its contribution as a notable chapter in the history of radar. See next 6 pages.



Eight U-boat fighters are shown here. SCR-521 (antenna on B-25 nose above) was radar mainstay prior to microwave



British DMS-1000 and B-24 were joined in famed Dumbo I, granddaddy of microwave and long range aircraft combination

First phase: radar linked the chain

Until the decisive months of 1943 the submarine struggle was a seesaw affair, mostly in favor of the U-boat. The expansion of the German effort was felt in merchantman sinkings; Allied growth in a chain of countermeasures and counter-countermeasures that forced the U-boats to greater risks and ever-shifting tactics. Many of the links in this chain were radar.

At the start, which is to say September 1939, it was a case of the prepared vs. the unprepared. Against a small but ready U-boat fleet, fast swelled by a mass-production program, the British threw a hasty defense of convoy escorts, mostly destroyers, and short-range Coastal Command planes. Installed in a few Hudsons and Sunderlands were some early, nearsighted, longwave ASV Mark I's. This was the only radar, neither numerous nor potent enough to provide a threat, much less stop daylight attacks.

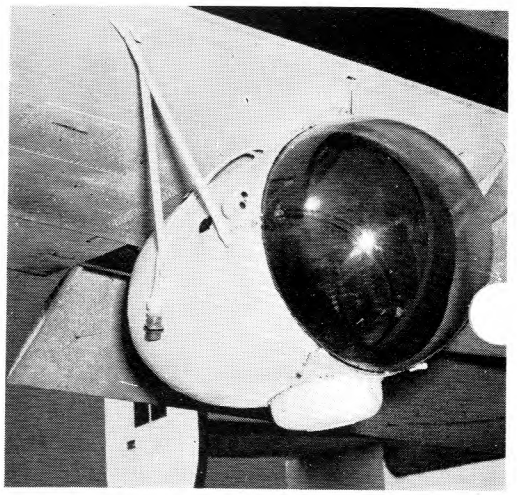
Asdic, a shipborne, non-radar, British device for spotting submerged submarines, tried to do that. The U-boats hit back by attacking on the surface at night, a strategy that enabled them to escape without submerging in the darkness and could only be countered by a substantial radar effort. Before the British installed ASV Mark II in ships and aircraft late in 1940, the U-boat roamed free and wild. Mark II was a surprise weapon, longwave and short-visioned like its handmade predecessor. It was known in the U. S. as SCR-521.

Mark II celebrated its first successes, in assessed sinkings, in March, 1941. It made night patrol possible; took some of the cockiness out of U-boat crews. It drove the intruder from the shores around Britain, where the Coastal Command flew, and forced him seaward.

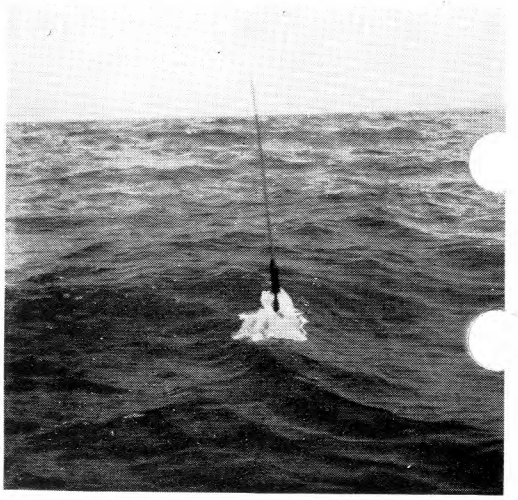
But it couldn't track and follow far into the Atlantic without long range aircraft. And British convoys, loaded with lend-lease, were plowing across the North Atlantic. In March, 1941, U-boats formed wolfpacks far at sea. Using long range Focke-Wulfs as spotters they pounced on whole convoys at night, risking reprisal by surface escorts in the knowledge that long range aircraft would offer no opposition.

Midway in 1941 the British scraped together a squadron of long-range planes —new, untried Liberators rejected by the U. S. Air Forces. Fitted with Mark II they did a dual job, ranging far out on patrol, giving air cover to convoys that asked for help. At the same time the H.M.S. *Audacity*, first auxiliary aircraft carrier, joined the anti-submarine ranks. Its career was short-lived. It succumbed to U-boat action shortly after making its initial kill in December, 1941. The *Audacity* might have lived longer with radar.

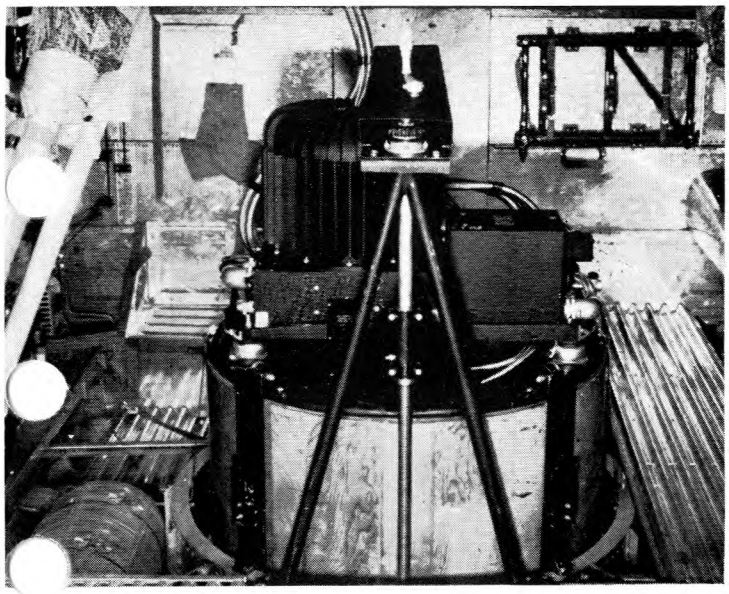
By the end of 1941 there were some noteworthy examples of cooperation between British surface and air escorts. But surface guardians still accounted for most of the kills. An inventory of Coastal Command fighting strength at the end of the year showed 306 planes,



LEIGH LIGHT, 5,000,000 candlepower, was aid to British night bombing in '42-'43



SONO-BUOY is parachuted to suspected U-boat location, detects, then transmits



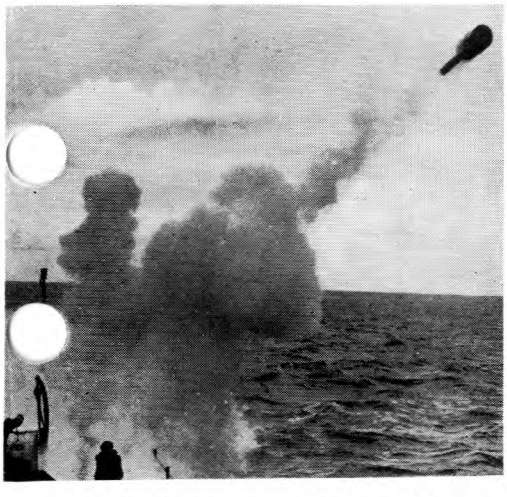
Navy's APS-2 (ASG), antenna structure above in PB4Y, is quantity built, widely used microwave. British got many



X-band ASD antenna is housed in this teardrop nacelle on wing of carrier-based F6F. This is latest Navy equipment



MAD (on tail of this "Sea Search" B-18) detected submerged U-boats magnetically



DEPTH CHARGE, after sub is found by one means or another, is still the big killer

including 192 Hudsons, 36 Catalinas, 32 Whitleys, 18 Sunderlands, 16 Wellingtons, 9 Liberators and 3 G-boats, nearly all Mark II equipped. One in four usually was ready for action. Many were unsuited for the job, which made one expert U. S. observer comment: "I'd hate to ask our boys to fly them."

In December, 1941, the U. S. entered the War and the character of submarine battle changed. The U-boat high command stepped up the activity in keeping with increased ocean traffic, particularly turning its attention to U. S. coastwise routes, where the pickings were easiest. Unarmed and unescorted, U. S. ships died like flies. The Navy sent available odds and ends of patrol boats, blimps and planes to do battle, but it was sheer improvisation. Deep in convoy defense and other worries, the Navy was glad to get help from land-based bombers of the Air Forces.

The 1st Bomber Command, initial AAF contribution, was activated in December, 1941. It was made up of an assortment of B-17's, B-18's, B-25's and other types, some with SCR-521. They patrolled and escorted under the operational control of the Navy, but they were novices in submarine warfare. Mostly they were learning what to do and gathering tools to do it with. Yet their mere presence over submarine-infested waters helped keep many a U-boat in hiding. The 1st Bomber Command stayed on the job until late in 1942, when it was inactivated to form a nucleus for the new Antisubmarine Command (see page 27).

A second AAF unit broke into the anti-submarine picture in the spring of 1942. This was the 1st Sea-Search Attack Group, known to Washington as the Seasearch—Attack Development Unit or simply as SADU. Col. William C. Dolan headed the outfit, which was based at Langley Field, Va.

SADU was activated 17 June 1942, when U-boat devastation was at its worst, with a combination mission: (1) to develop tactics and techniques for using submarine devices; (2) to conduct general sea search. For maximum flexibility, SADU reported directly to the Commanding General, AAF, just as the XXth Bomber Command does now. Operationally, it was under the Navy.

Added to SADU's scant starting quota of 11 B-18's, fitted with pre-production SCR-517's, were two British-loaned B-24's—Dumbos I and II. In these had been installed two early British microwave sets known as DMS-1000 and equipped with the first airborne PPI's.

SADU worked hard on microwave, daily putting it through its paces. Microwave was urgent because longwave radar was in danger of being compromised by U-boat radar search receivers.

SADU learned while fighting. Not numerous enough to join the 1st Bomber Command in day-in-day-out patrols it became an emergency unit. It sent "killer" detachments hopping down the coast, to Miami, Key West, Trinidad, wherever U-boats concentrated, at the Navy's beck and call. From activation to 15 July 1943, SADU sank and damaged 4 U-boats, made 18 sightings.*

**To accomplish this SADU flew 209 hunts and patrols totalling 1274 hours*



Second phase: the chain tightens

On both sides of the Atlantic, in mid-'42, the battle seethed. Among the U-boats there was cause for optimism. Though they felt the hot breath of the aircraft-radar setup, by now they were more than 600 and the morale of their crews was high. In May and June they sank over 200 vessels in the U. S. Atlantic strategic area alone.

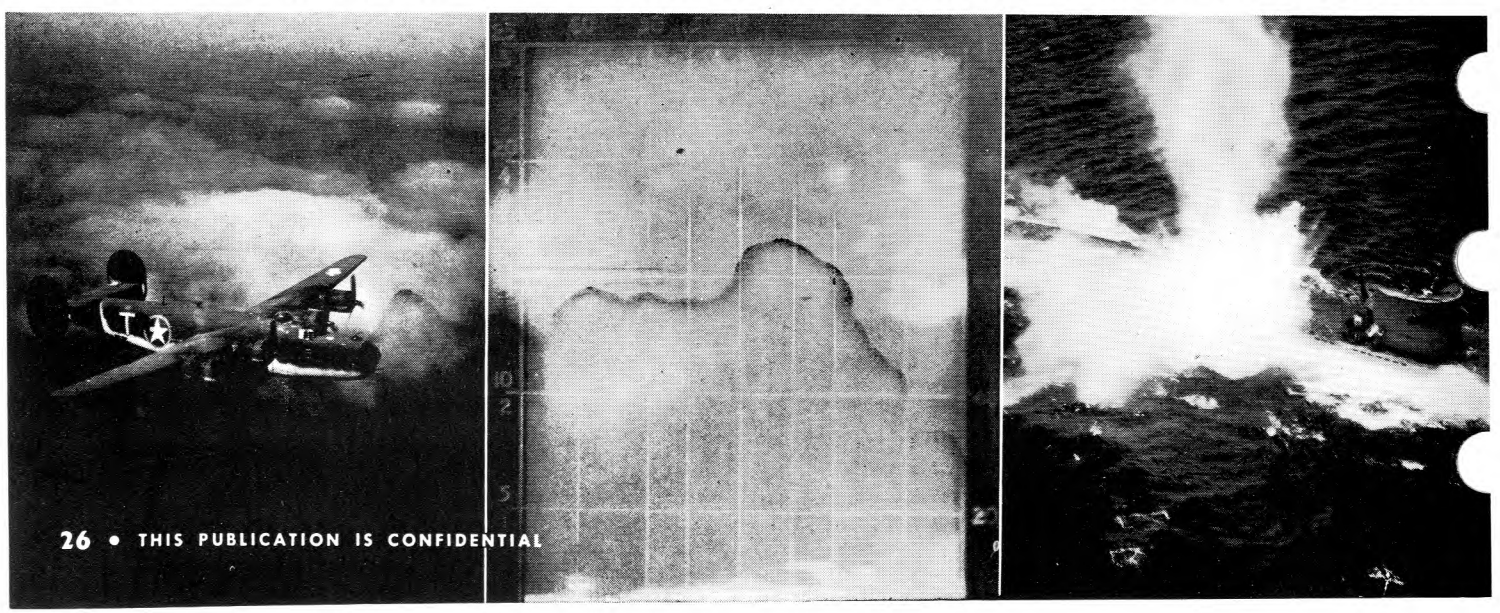
Then came a series of countermeasures and counter-countermeasures that helped the struggling forces in turn, but slowly worked to Allied advantage.

June of 1942 brought the British Leigh Light, a 5,000,000 candlepower searchlight designed to keep U-boats from night surfacing in the Bay of Biscay. At first there was only 10 of them, but in combination with ASV Mark II they made a remarkable impression. They made it possible to bomb accurately at night after the target was sighted.

During the 3 months following its introduction the Coastal Command's sightings of Bay of Biscay U-boat traffic zoomed to an estimated 50% of total.

The submarine countered, in August, 1942, with the long anticipated radar search receiver (Metox), which detected ASV Mark II longwave pulses in time to submerge, and thus temporarily neutralized the Leigh Light that worked with it. That made microwave a "must."

SEQUENCE IN A SUCCESSFUL U-BOAT HUNT. THE B-24'S SCR-517 PICKS UP A TARGET AT 18½ MILES, HOMES, STRIKES AND KILLS



West and north of "Coffin Corner" at Spain's northwest tip U. S. Squadrons killed or probably killed 4 and damaged 3 U-boats one week in July, 1943, as they waited on the surface for convoys Mediterranean-bound. From England, British Coastal Command and more U. S. aircraft hunted far to the south. Thereafter, U-boats hid below the surface

As a stop-gap 14 DMS-1000's were crash-built at a U. S. laboratory and rushed into British service. By the end of the year the Navy's AN/APS-2 (ASG), a useful member of the microwave family, and British Mark III, a modification of H_2S, were coming to the rescue.

For the U. S., meanwhile, the Navy was carrying most of the load. It worried over its convoy charges, defending them from wolfpacks as a mother hen does her brood. But its equipment was growing and it was readying for offensive action.

What the Navy needed in late 1942 was more bomber coverage. The Army was anxious to help. Thus came the 1st Antisubmarine Army Air Command in October, an expansion of the 1st Bomber Command (see page 25).

The Antisubmarine Command was on the job during part of the decisive period of submarine warfare, but for the most part its 16 squadrons operated on the wrong side of the ocean. Growing strength in the West Atlantic plus the opening of North African operations had resulted in the U-boat tribe flocking east. So while big bombers of the Command, strong with radar, patrolled from Newfoundland to Trinidad, elsewhere things were happening.

The record of the stay-at-home squadrons bears this out. They accounted for 86% of the total flying hours of the Command, yet in their lifetime, which lasted 10 months, they made only 5 damaging attacks and never sank a sub. The few squadrons sent to England and French Morocco did all the "hunt and kill" (see next page).

Of the 235 aircraft assigned to the Command at home and abroad as of March 1943, more than 50% were radar-equipped, many with microwave.

This was the background in March 1943, as the death struggle began.

That month the U-boats launched their heaviest wolfpack attacks, sinking at a prodigious rate. But in turn they were so badly mauled by aircraft-radar teams and support groups, including escort carriers, that they were largely driven from the North Atlantic.

In May and July the sub-killers really hit their stride. Nearly 100 U-boats perished, two-thirds to aircraft. The breaking of the U-boat's spirit came so abruptly that in secret anti-submarine disposition rooms in London and Washington it seemed hard to believe the charts.

After that the enemy writhed and sweated below the surface. They stole back to their bases and were fitted with radar, although many a captain refused to use it for fear that it would reveal position. An improved microwave receiver ("Naxos") was introduced, then temporarily withdrawn because of the same fear.

Allied devices came in quick succession. And in the first half of 1944, well over 100 U-boats were killed against a small, steadily declining merchantman mortality (security forbids exact data).

Around D-day, and since, the record has been good. The 9 August 1944 statement issued by President Roosevelt and Prime Minister Churchill stated: "A total of 17 German submarines were sunk attempting to interfere with our cross-channel traffic since June 6. The number of U-boats sunk during the war now exceeds 500."



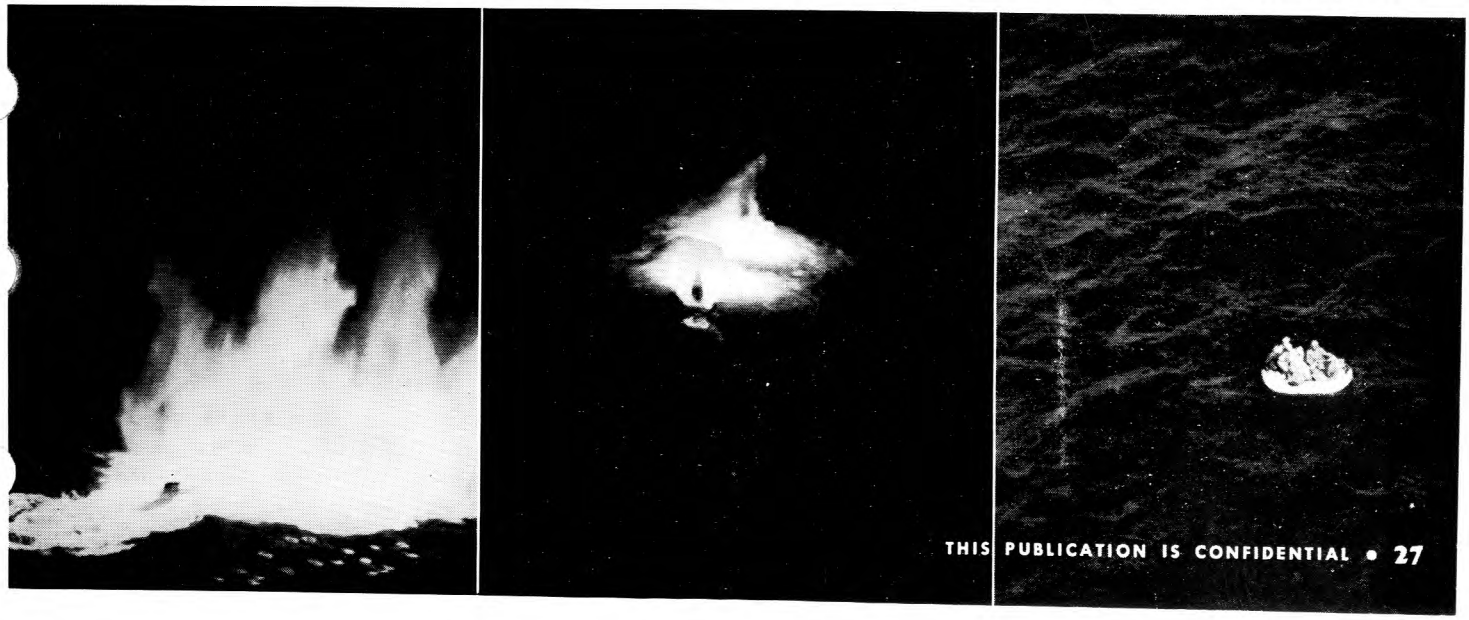
"Das Flugzeug kann das U-Boot genau so wenig ausschalten, wie die Krähe einen Maulwurf bekämpfen kann."

Admiral Doenitz am 4. August 1942



FACTS of U-boat warfare are given by British in this propaganda leaflet dropped over Germany. Below Admiral Doenitz' "crow" and "mole" fancy (see page 22) is an account of a plane killing a sub and this statement: "In 31 days of a month 31 successful attacks on U-boats were accomplished"

THIS IS A SURE KILL, PROVED PHOTOGRAPHICALLY. ASSESSMENTS, BY NAVY'S COMINCH, HAVE BEEN FOUND REMARKABLY ACCURATE









FROM COL. ROBERTS' SCRAPBOOK. Left: Gen. Spaatz and Col. Roberts. Above: Lt. Salm's crew (see next page). Right: bringing in a battle casualty.

War against the subs: story of a unit

Liveliest progeny of the Antisubmarine Command (see preceding pages) were the 1st and 2nd Antisubmarine Squadrons, which tangled with the enemy in the East Atlantic while their less happy brothers quietly patrolled U. S. territory.

The 1st and 2nd were capable of conducting their own U-boat blitz. They were fitted with the cream of the aircraft-radar combination, which meant VLR B-24's and microwave radar. And they happened to be where, periodically, U-boats clustered.

They came to St. Eval, near the southern tip of England, in November and December 1942. Their CO was Lt. Col. (later Col.) Jack Roberts, a youthful, quiet West Pointer. Altogether, air and ground officers and men, they numbered around 800.

They left the U. S. with a combined strength of 21 B-24's equipped with SCR-517. The weather was bad; during the crossing two planes were lost. St. Eval, where the others landed, was a Coastal Command base for several Whitley squadrons doing antisubmarine patrol over the Bay of Biscay. The 1st and 2nd Squadrons here became the 1st Antisubmarine Group (Prov.).

During the first six weeks action was light, although a radar contact was made on a German blockade runner bearing enough vegetable oil to supply all of Germany for several weeks. The B-24 vectored a British destroyer to the scene and the Nazi vessel was sunk.

Early in February, 1943 Col. Robert's squadrons were called on to play a leading role in a Coastal Command campaign called the "Gondola" operation. The strategy was devised to take advantage of the anticipated traffic of U-boats travelling to and from their Bay of Biscay havens following two heavy convoy battles. U. S. B-24's were assigned to patrol the area known as the "Outer Gondola" while the shorter-range British planes covered the "Inner Gondola." From February 6 to 15 fourteen sightings were made and 9 attacks attempted, 90% by the big U. S. bombers.

There was nothing skillful about these early attacks and they were largely unsuccessful. But the 1st and 2nd had their full baptism under fire.

In March, 1943 the two squadrons were ordered to Craw Field, Port Lyautey, operating under the Navy as the 2037th Antisubmarine Wing (Prov.).

From their Moroccan base their job was to help the Navy protect the Mediterranean approaches, patrol the southern reaches of the Bay, strike at U-boat concentrations westward.

They were flying patrols and convoy coverages before their ground echelons had reached Craw Field. For a few months convoy work was an almost daily diet and "hunt and kill" figured little.

In early July, the biggest month for U-boat killings, a new opportunity arose. Coastal Command, assisted by the 479th Antisubmarine Group now at St. Eval, were patrolling the Bay so completely with their increased forces that the U-boats were making submerged transits. Outside the Bay, they waited for Allied convoys streaming to the Mediterranean.

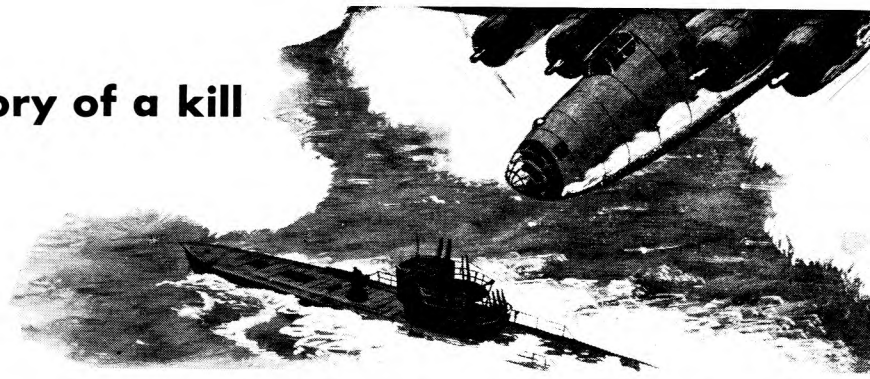
The 1st and 2nd, by now called the 480th Antisubmarine Group, seized the chance. By now they had newly-operational, long range SCR-717. In the one week between 6 and 14 July they sighted 15 U-boats, attacked 12, sank or probably sank 4 and probably damaged 3.

And then, while the submarines hid below the surface, the U-boat high command dispatched Focke-Wulf 200's to do their work. From July through October the 480th had 10 air battles, destroyed 8 planes and themselves lost 5.

The last job for the 480th was at Tunisia, protecting shipping participating in the Italian invasion. In early November the 480th went home, where it received a Presidential citation.

In all, the 480th had done 319 convoy coverages, 847 hunts and sweeps, 19 air sea rescue missions. It had **made** 43 sightings, sunk 6 and damaged 7 U-boats by strict official assessment. It suffered 112 fatalities—none from U-boat combat—and 31 injuries. It lost 16 aircraft.

War against the subs: story of a kill



Up to 12 July 1943, 2nd Lt. Ernst Salm, pilot of B-24 aircraft "C" of the 1st Antisubmarine Squadron, never had sighted a submarine, much less made a kill. That day he did both in an almost perfect example of the business.

He told the navigator that he wanted to go as far out as possible, and he added 400 gallons of gasoline to the 2,300 gallon load usually carried on a standard 11-hour mission. In his bomb bay he loaded twelve 250 pound Torpex depth charges. At 0851 he took off.

At 1439 he was 1250 miles out, near the extreme limit of his run. He was flying at 5600 feet above a 10/10 overcast when T/Sgt. Billings, the radio operator taking a turn on the SCR-517C, reported a contact at 23 miles, 165° right. Lt. Salm turned to close the contact, ordering the radar operator, Sgt. Williams, to guide the plane to the target.

Near the target, Lt. Salm dived steeply through the clouds. When the altimeter read 400 feet there still was nothing but thick cloud but he kept going. At 200 feet he broke out and saw the surfaced submarine straight ahead.

The bombardier dropped 7 depth charges. Five hit just short, the sixth exploded forward of the conning tower, the seventh on the after deck. The men on the bridge were tossed into the sea. Neglecting his training procedure, Lt. Salm put his plane through a vertical turn a bare 100 feet above the water and returned for a second run.

But there was no need to drop the other depth charges. The conning tower of the U-boat below was missing. Then the stern went down and the bow almost straight up and the U-boat slid under. Huge blue oil bubbles erupted. About eight survivors in yellow life jackets tossed in the water.

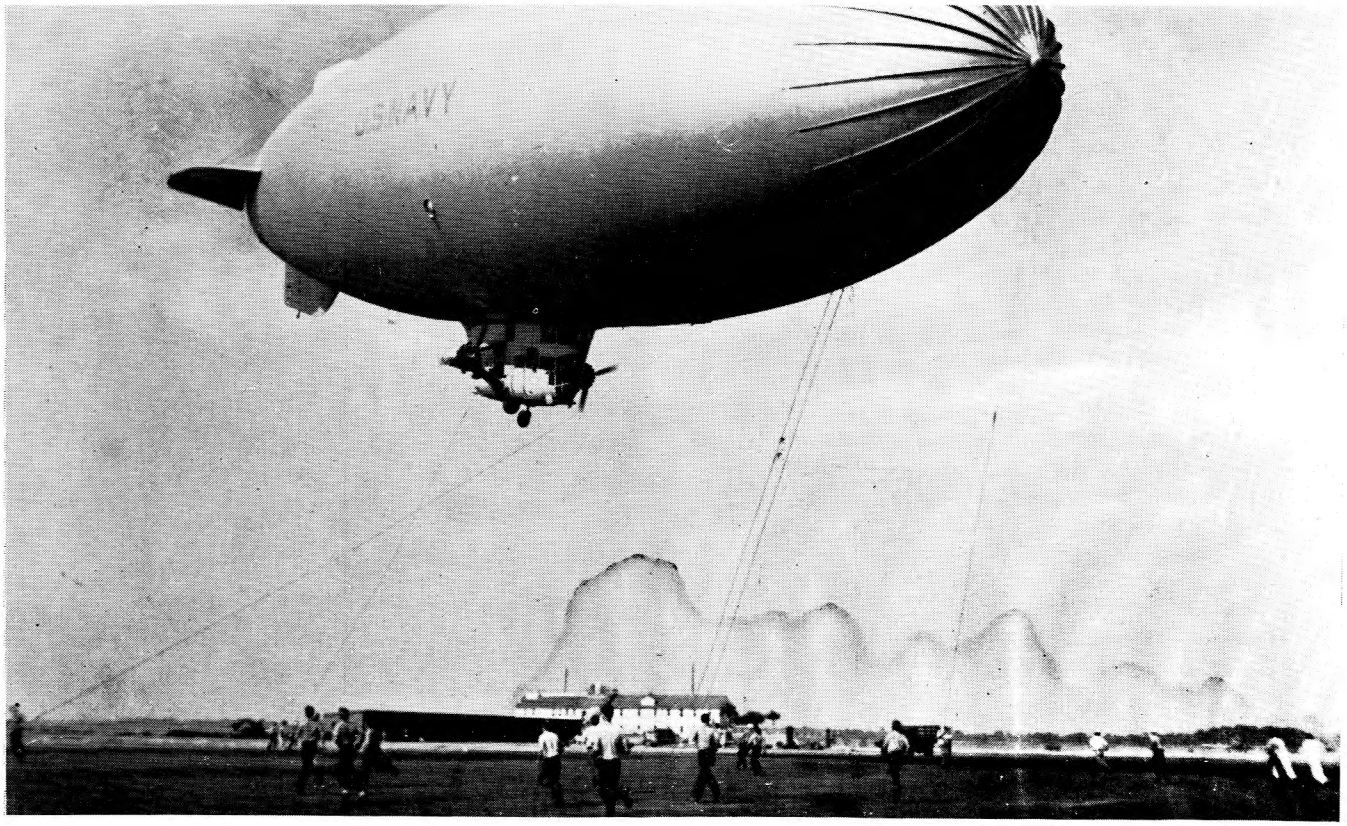
When the first excitement was over Lt. Salm slowed down to 110 miles and instructed the engineer to drop the rubber dinghy. Two days later another B-24 from the 480th located the survivors and signaled their position to a British destroyer, which rescued them.

On interrogation, the survivors identified their submarine as the U-506, a 740 tonner, with 17 victims to her credit.

In commenting on the kill the Squadron Commander said: "Particular credit is due both the radar operator and the pilot, the former for the unusual nature and distance of the sighting, and the latter for the extreme aggressiveness with which he drove home the attack. . . ."

Said Lt. Salm: "It was all up to Williams. I ordered him to take the radar and take me there. I was on instruments then. He deserves the credit. I told him to take us to it, and, by golly, he took us."

U. S. ANTI-SUB WAR IS NOW ALL-NAVY JOB. BLIMPS, AS OLD TO JOB AS NAVY ITSELF, STILL CRUISE. NOTE ASG RADOME ON CABIN



How's your IFF?

IFF has been pushed around for a long time now. Efficiently employed in a few areas, it has been widely criticized or just plain forgotten in many others. In May a 3-man Army-Navy team, appointed by the IFF Sub-Committee of the Joint Communications Board and accompanied by the Sub-Committee Chairman (Dr. W. L. Everitt of the Signal Corps), went to the South Pacific to do something about it.

At one air base they found only 75% of the plotted aircraft using IFF. They spent a week straightening out pilot non-use and mis-use of IFF—figured as No. 1 problem (see RADAR, May 1944)—and sent the percentage up to 90. During the second week, devoted to preventive maintenance, the percentage went on up to 97. And these findings were confirmed by more investigations.

The team, reporting back, stated as its conviction that the IFF equipment is perfectly sound and any CO interested enough to apply the corrective procedures can expect good results. But the interest is all-important and the team found that too often lacking.

To meet that problem, the Sub-Committee has recommended that highlights of the team's report be issued in pamphlet form to area commanders. Beyond that it hopes to prod pilots and maintenance men with a series of posters.

The procedures worked out by the team are perfectly straighforward. For example, pilots are briefed on IFF before takeoff; a sign reading "IFF ON?" is held aloft at the end of the runway; pilots taking off without IFF are reminded by radio; equipment is checked and maintained regularly.

The team's report makes these overall recommendations: (1) full-time IFF officers should be appointed to headquarters of each appropriate command; (2) air personnel should be educated in use of the equipment; (3) regular maintenance of all equipment should be provided; (4) regular reports from Information Centers regarding presence or absence of IFF on all aircraft plotted should be required. Detailed recommendations and instructions are spelled out in the pamphlet being readied.

●



IFF POSTERS (right), prepared by Presentation Branch of Office of Strategic Services at RADAR's request, show possibilities of focusing interest on IFF in the theaters

THE MOBILE MEW

Its first 10 weeks in France are reported on below



RADAR CORRESPONDENT Sgt. John Caldwell (left) got data for this report on special trip to France. Others: Lt. Col. C. L. Devendorf, wire officer, ASC, USSTAF; Capt. Doyle Hicks, pilot of C-45 shown

Microwave Early Warning radar (AN/CPS-1) is rolling through France—10 trucks carrying its tonnage from site to site on the heels of advancing Allied armies. It has been rolling since almost the start of the invasion, and from the 6 sites that it has so far had (as of 30 August), it has brought down 36 Jerries for sure (out of very few in the skies during most of this time), damaged others and saved at least as many Allied planes.

The MEW and its impedimenta can be put on the road in about 1½ days, and on site can be put up in the same time. The moves to date have not impaired the technical operation of the installation to any great extent. For all the moving, it has averaged 21 hours a day on the air for the whole period since its arrival in France.

Even before it was known for a fact that MEW could take to wheels its use was being planned for the protection of invasion beaches. Converting the equipment from fixed to mobile was accomplished in April—in 11 days—at the British Branch Radiation Laboratory. Five days later, after trials, MEW was ordered into a concentration area for the invasion, and soon after that orders came to get it crated and waterproofed for the cross-Channel trip. There was no time for warm-ups with fighter groups or tryouts with the British Type 13 Heightfinder. Operators and pilots both had to get their practice together on the Jerries.

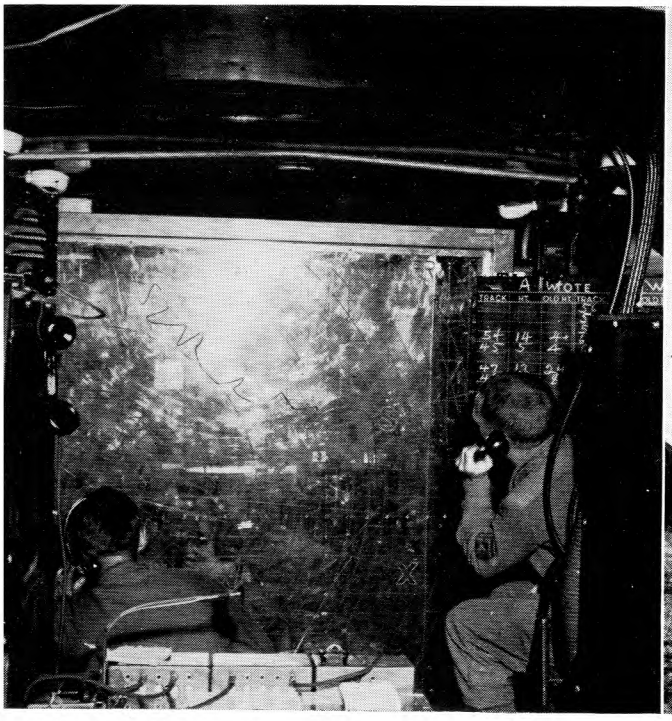
D-day plus 6 found the mobile radar unloading intact and on schedule on Omaha Beach in 6 inches of water. The crossing and 10 mile trip to the site were accomplished without damage to any equipment in spite of 88mm shell fire, mines and a rammed LST. In addition to 10 trucks for MEW proper, there were 6 for VHF equipment.

On D plus 7, in a driving rain, the first mobile MEW was being put into position on a selected site 90 feet above sea level and with a clear view of the area it had to protect. Only permanent echoes came from 30 miles inland. Three days later the first operational flight was directed in the thick of battle around Omaha and Utah beaches in Normandy.

Here pilots had their first taste of long range control by ground radar. They were sceptical until MEW led them to targets 75 to 100 miles away—once was enough to sell them and they came back for more leads. More than one came calling to have a look at the site and what went on.

MEW was put into the campaign with the main purpose of directing day and night fighters against anticipated large scale German attacks on invasion beaches—but the attacks never came.

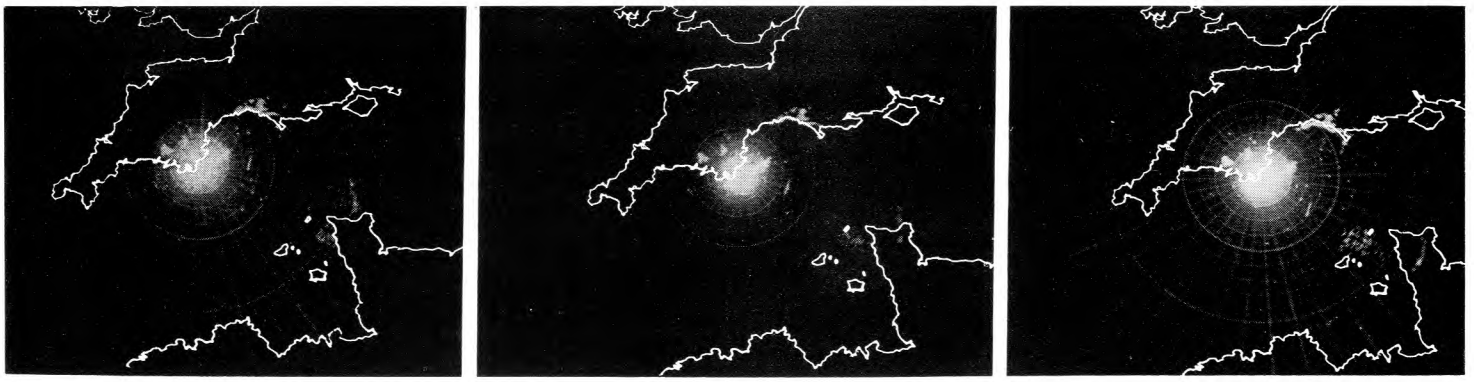
It was not until 18 days after opening for business that MEW claimed its first



Operations room of mobile MEW, mounted on 6x6 truck, houses PPI scope (side shows at right) for controller, another for deputy, plotting board (teller in front), tote board and operator (with phone), switchboard for calls to flights, etc.



Combat layout of operations vans shows only part of the whole. Heightfinder van is off to one side. Plotting board van is behind one at right here, which contains B-scopes; 2 PPIs are on connecting platform. Center truck holds phone system and teleprinter



Sequence of photos taken at first fixed MEW installation in England shows what the big set saw during pre-invasion shuttle bombing on night of 5-6 June. At 2348 (first photo) two groups of heavies pass at 100 miles, one homeward, one outward bound

kill—an ME-109 downed by P-51's; Huns were scarce. With Germans sending up so few planes the radar's main job was as a traffic filter for the ceaseless Allied air movements.

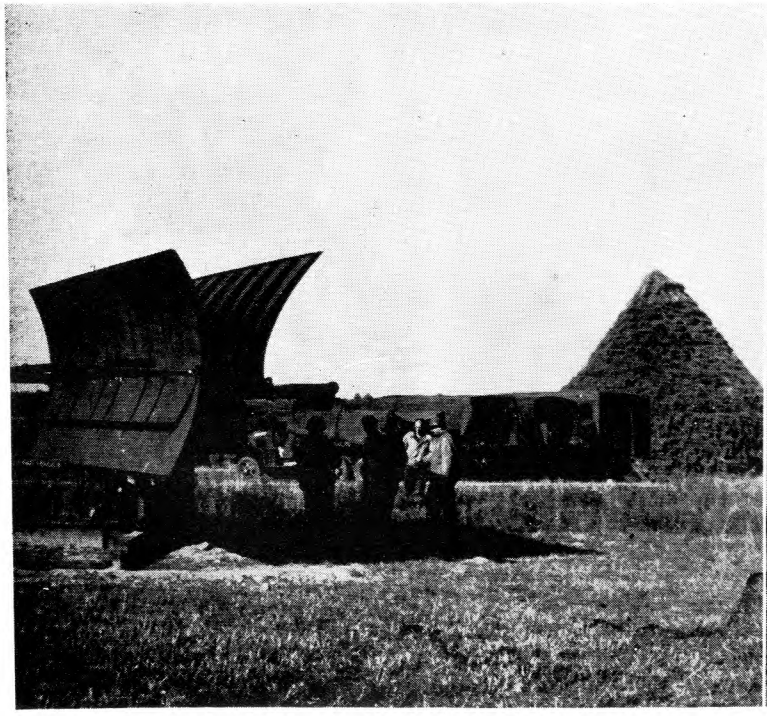
But it did one very fancy job of getting a kill right on the ground from this first site. Some 33 miles away, in the area around Caen, the MEW controller one night noticed some suspicious blimps. They were moving slowly and at a very low altitude. British rocket-equipped planes investigated, found and destroyed a column of German armor.

By 11 August Cherbourg was ours and MEW had moved to a new site—750 feet above sea level and ideal for low coverage at long range. Most control from this site was at 2000 feet or so at 60 miles.

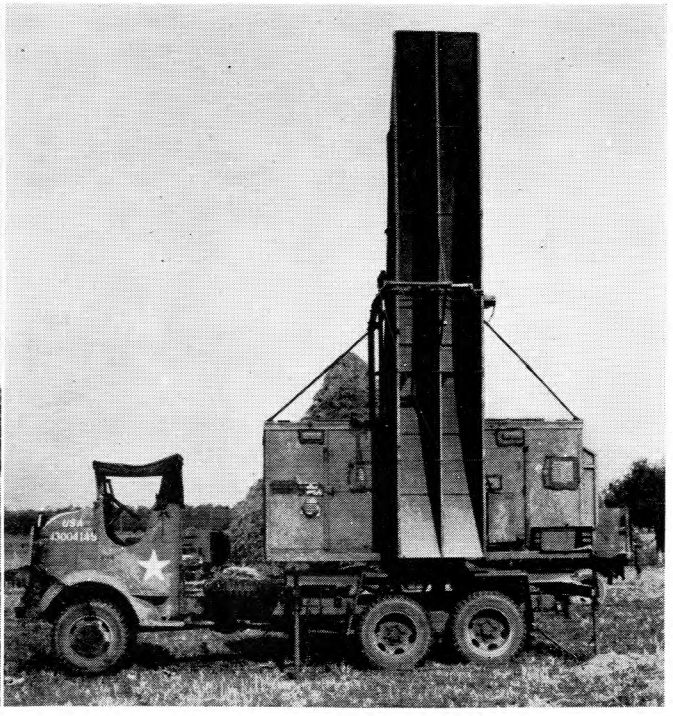
With the Huns still absent, MEW took P-51's on long range free-lance sweeps over Paris. On several nights at this site MEW could see the Isle of Wight 115 miles away, and the Eiffel Tower in Paris, 150 miles east.

By 24 August the Allied armies were sweeping across France and the mobile MEW was on the air near Paris. Weather was good and enemy activity still slight. The radar's big job continued to be reporting of aircraft movement.

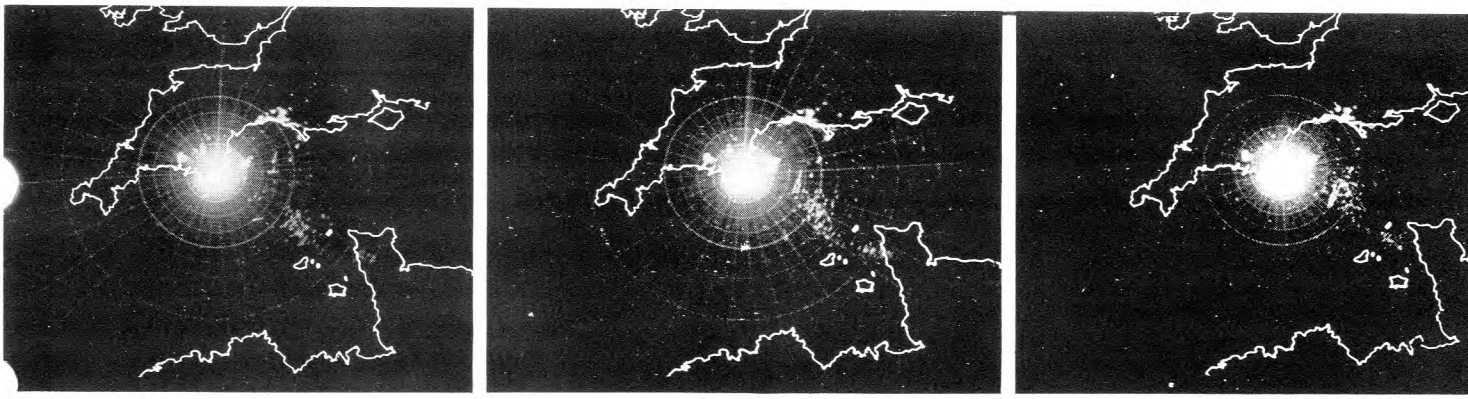
It does its reporting to the Fighter Control Center of one of the 9th TAC's Fighter Wings. But the FCC may turn over control of special missions to the Wing Controller stationed with the MEW, in which case the whole mission is handled from the site. Since the FCC control plan was well established before MEW got into the field, there's been less control from the radar than there might be or probably will be in the future. Big advantage in controlling from the radar is that the bulk of spot information on aircraft movements—on which decisions largely rest—is available right there, and it is rounded out by information fed back by Ground Observers stationed close to the front (usually 30-40 miles from the site). There are 5 teams of 6 men each, and out of their ranks have come the only MEW casualties to date. One GO officer was killed by



MEW antenna, minus steel platform used at fixed locations, rests on ground—requires added care in siting. One site pre-chosen from contour maps proved unsuitable because of trees. Only the antenna is carried disassembled; other equipment can be mounted



British Type 13 heightfinder used with mobile MEW was procured too late for pre-invasion tryouts. It has worked well in interceptions, accounted for at least one kill by bringing a fighter patrol down through thick cloud cover directly behind enemy flight



Just over France (third photo above), formation of outward bound group tightens as bombing run approaches. Both groups, returning, start to leave formation as they get closer to home. By 0041, right after last photo, both groups were home, missions done

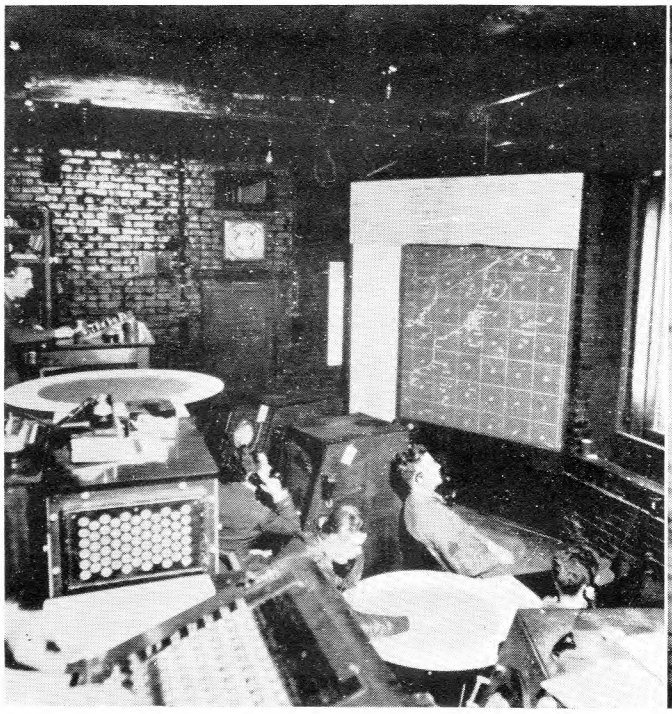
enemy action and 2 GO enlisted men are missing.

Adding up everything, the 9th TAC in France could count a dozen or more ways in which the mobile MEW had been put to use from 13 June to the end of August.

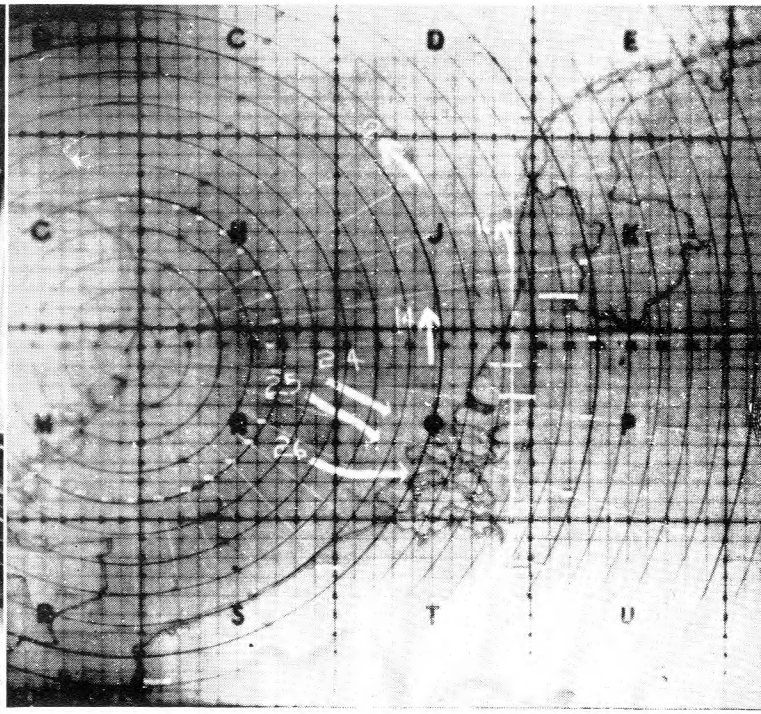
(1) Reporting all aircraft movement to Forward Director Post and Forward Control Center occupied most of MEW's time. In the first month 2000 interceptions were made—10 hostile. (2) Control of free lance fighters accounted for the first MEW kill and many others. On one occasion a flight of P-51's was vectored to 4 FW-190's for 4 kills. (3) MEW helped fighters to rendezvous with bombers. (4) Control of night fighters was effective, and most enemy air activity put the emphasis on this. (5) Beachhead patrols were controlled even though the set was designed for long range work. (6) MEW was used to position fighters over specific targets. (7) Much time was saved by fighters who could depend on MEW to vector them home. (8) With thousands of planes in the air MEW's over-all picture of aircraft movement prevented accidents and warned against the enemy. (9) Just before the St. Lo break-through Germans sent over day fighters at dusk; MEW directed enough kills to nip this tactic in the bud. (10) Cooperation of MEW with SCR-584 (see page 3) was a minor use; the pace was just too rapid.

Other uses of MEW were (11) to mark the bomb line, (12) vector fighters to friendly stragglers, (13) control armed reconnaissance, (14) direct dive bombers on free lance sweeps after their primary mission. An anticipated use of MEW is for photo reconnaissance.

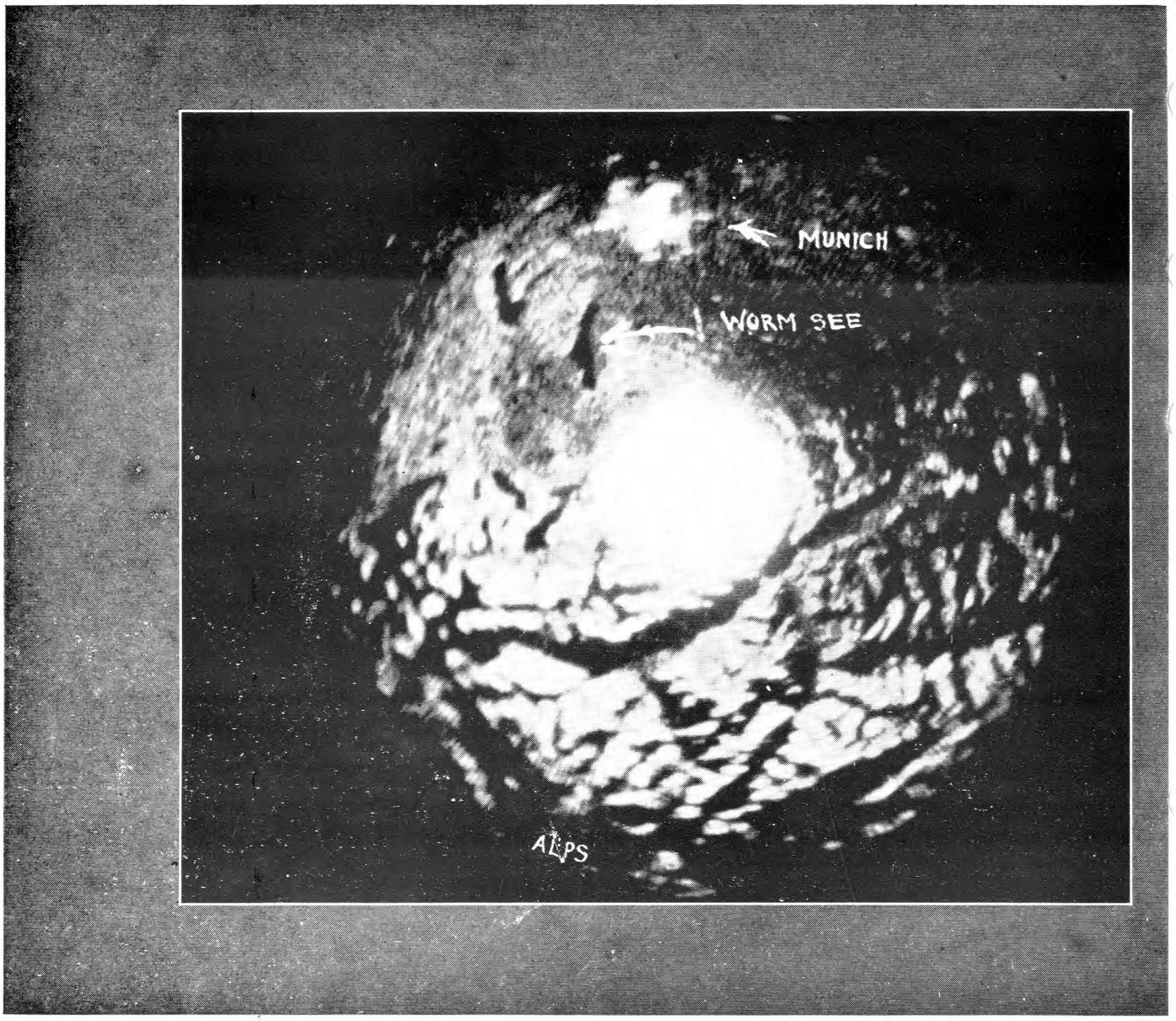
The "all-purpose" nature of MEW was further illustrated when the installation which covered the Normandy invasion (see RADAR No. 3) was moved in 4 days to bolster buzz bomb defense. In the process the set became mobile. It was used largely for controlling interceptor aircraft, and it was soon possible to bring the interceptor into firing range at proper height completely by MEW and its associated British height finder.



Airborne invasion of Holland went off under watchful eye of this fixed MEW on British east coast. Operations room is shown above. First fixed MEW in England, which covered Normandy invasion (see top of page), was made mobile to fight buzz bombs



Numbers on big vertical plotting board at east coast installation are tracks of flights under control. Making MEW mobile means cutting down, putting wheels under such installations as this; control and reporting functions continue, but mobility extends them



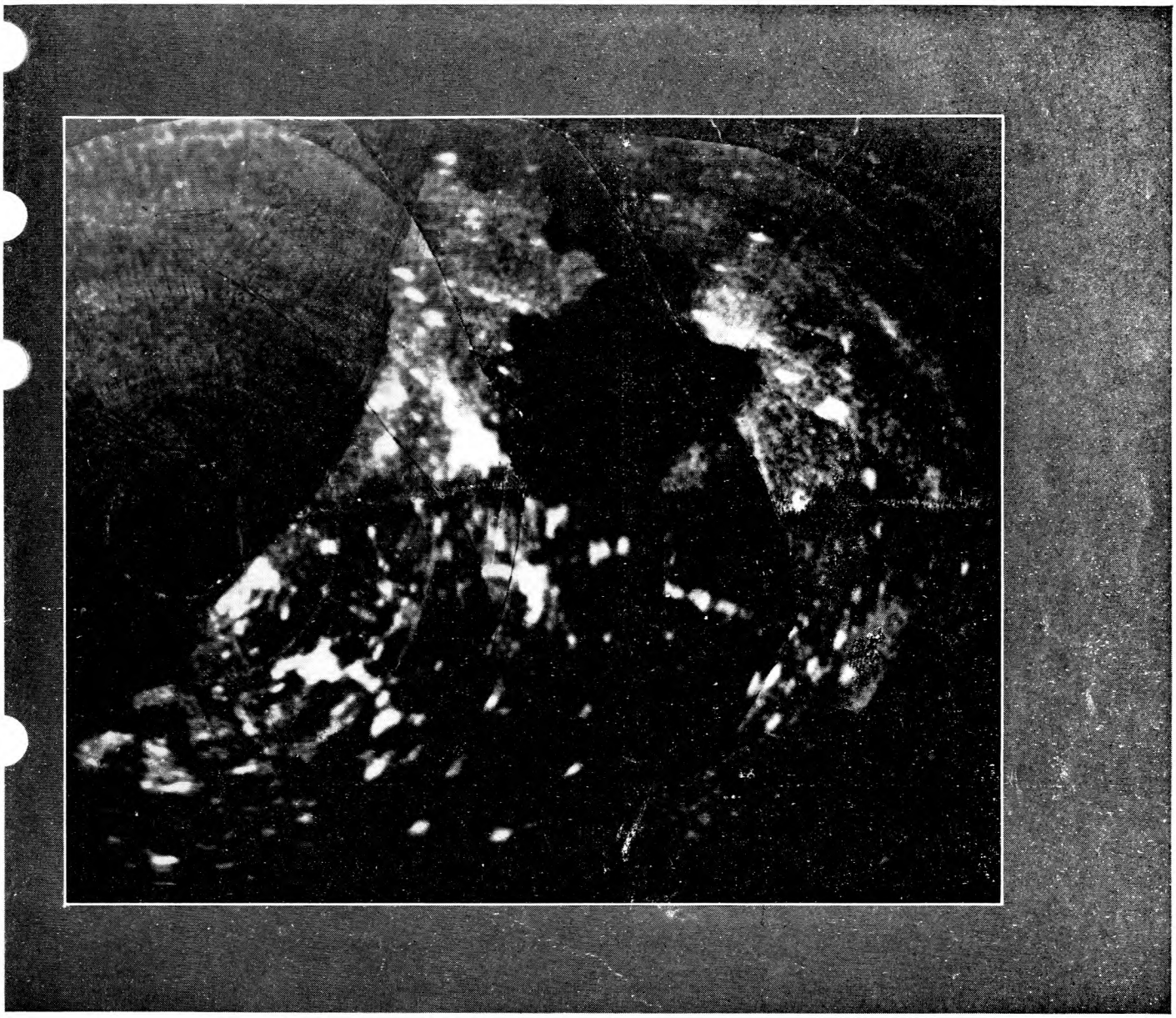
H₂X photography at its best. More photos like this one—contributed to RADAR by Lt. G. O. Mickelson of 305th Bombardment Group—are needed to improve and extend mosaics like those on opposite page and covers. Compare with pages 38-39

Maps for radar's world

By now a very considerable effort is being expended to help radar navigators bridge the gap between two worlds. One might be called the world of Rand McNally and the other the world of Pulse & Cathode. The gap is big, and any radar operator who has ever tried to relate a scope presentation to the forms and figurations of a standard map knows just how big.

From its earliest days radar has been handy for "pinch-hit" navigation. More than one crew has been saved because an alert 521 operator could identify island echoes or a piece of coast line. It took the finer resolution, better antenna patterns and PPI presentation of such equipment as APS-15 and APQ-13 to let radar realize its real potentialities for navigation. But while these developments gave the navigator more and more to go by, there were no comparable mapping developments to let him make full use of it.

Radar reconnaissance on a large scale was the logical need; i.e., a true radar map provides the best briefing material, the best guide to use with a scope. The results of radar reconnaissance reproduced on the covers and above show why. But a really good scope photograph is still far from common; this one of the Munich area is remarkable enough to cause excitement among connoisseurs of PPI photography. As for mosaics, few have been compiled to date. The one above was the first real radar mosaic and it was made only a few months ago. Despite improved techniques, limited equipment and personnel have kept radar



Radar mosaic of Holland made from seven 8th AF scope photos. Portions between 15 and 35 mile limits of 50-mile scan were used, lubber lines and range marks were eliminated, and photos taken not less than 6 miles apart. This was first radar mosaic

reconnaissance from developing into the standard practice it will eventually be.

Meantime, something had to be done. In the beginning ordinary aeronautical charts were used, but the use of these was precisely what indicated the size of the problem. Not only were their forms and tones wholly unlike those which appear on a scope, but they were too cluttered for efficient radar use. And so revisions were made to screen out irrelevant data—the heavy overlay of contour lines, communications data, gradient tints, navigational information, etc., as well as the numerous small roads, rivers and towns which would never show on a scope.

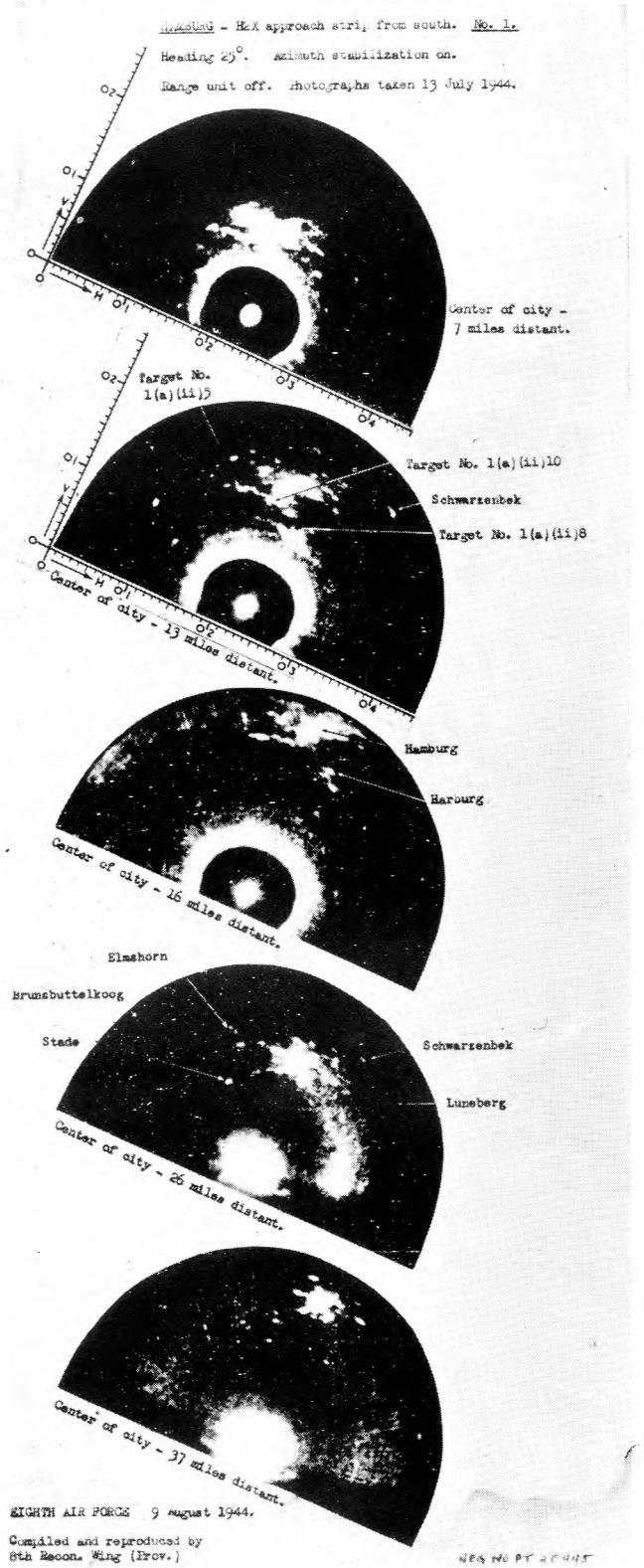
Such stripped down maps came closer to matching what a scope might show, but they still didn't talk in radar terms. More work has been done to achieve a closer comparison. In some attempts land-water contrast has been heightened by blackening the normal blue of an aeronautical chart's water areas, by using the airbrush to simulate degrees of brightness for cities, roads and topographic relief. For rugged country, actual relief models have been made.

With all these efforts there has been no great success at taking into account the many variables introduced by radar navigation. Constantly changing light patterns, unpredictable returns, blinking, distortions, variations in scale and gain settings, and in altitude, have proven hard to account for.

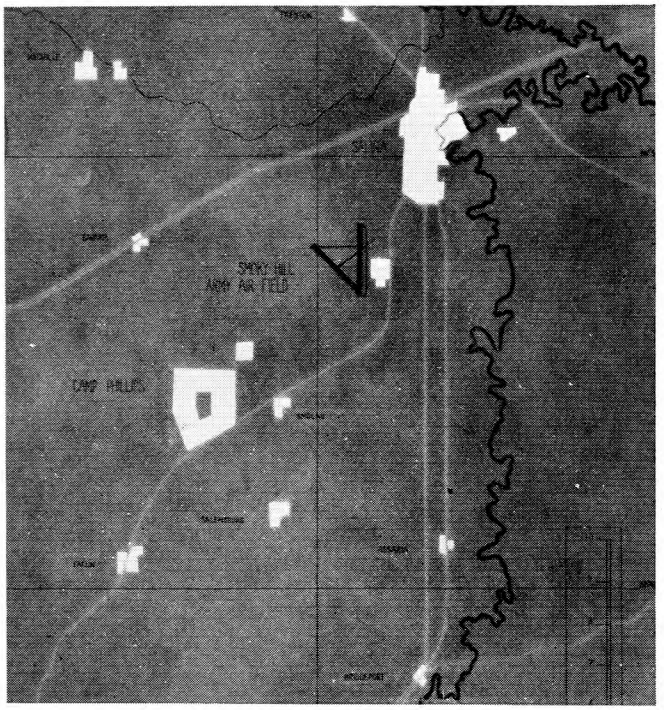
Enough radar reconnaissance is now going on so that actual scope photos of key points on a known route can be worked in to supplement a map. And there has been enough development in the art of imitating scope photos so that satisfactory simulations can be used similarly (see RADAR No. 4).

On the following pages RADAR reviews some of these mapping processes that are taking up the slack until full-fledged radar reconnaissance takes over.

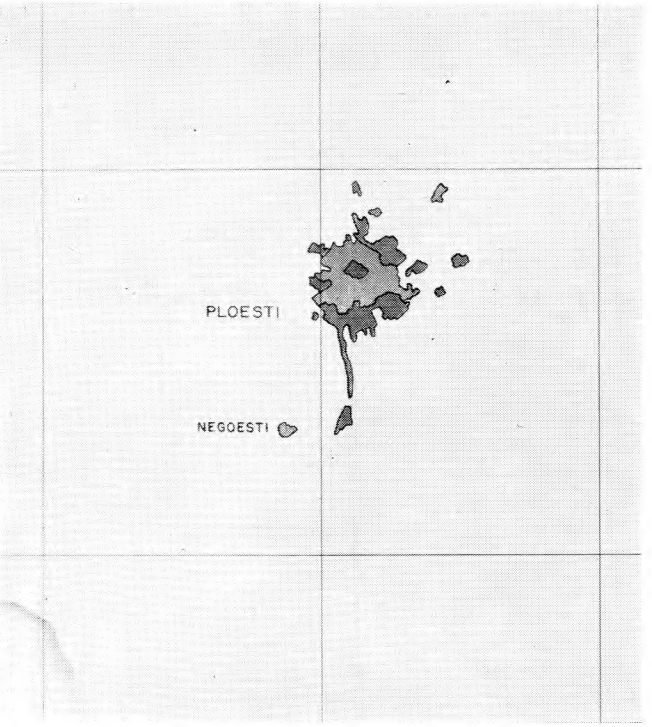
One of these works, one may work, one didn't



Navigation strips composed of actual scope photos supplement maps, are useful for briefing. Pictures may be obtained from previous missions or by radar reconnaissance. Or simulated photos may be used as in missions over Japan (see RADAR No. 4)

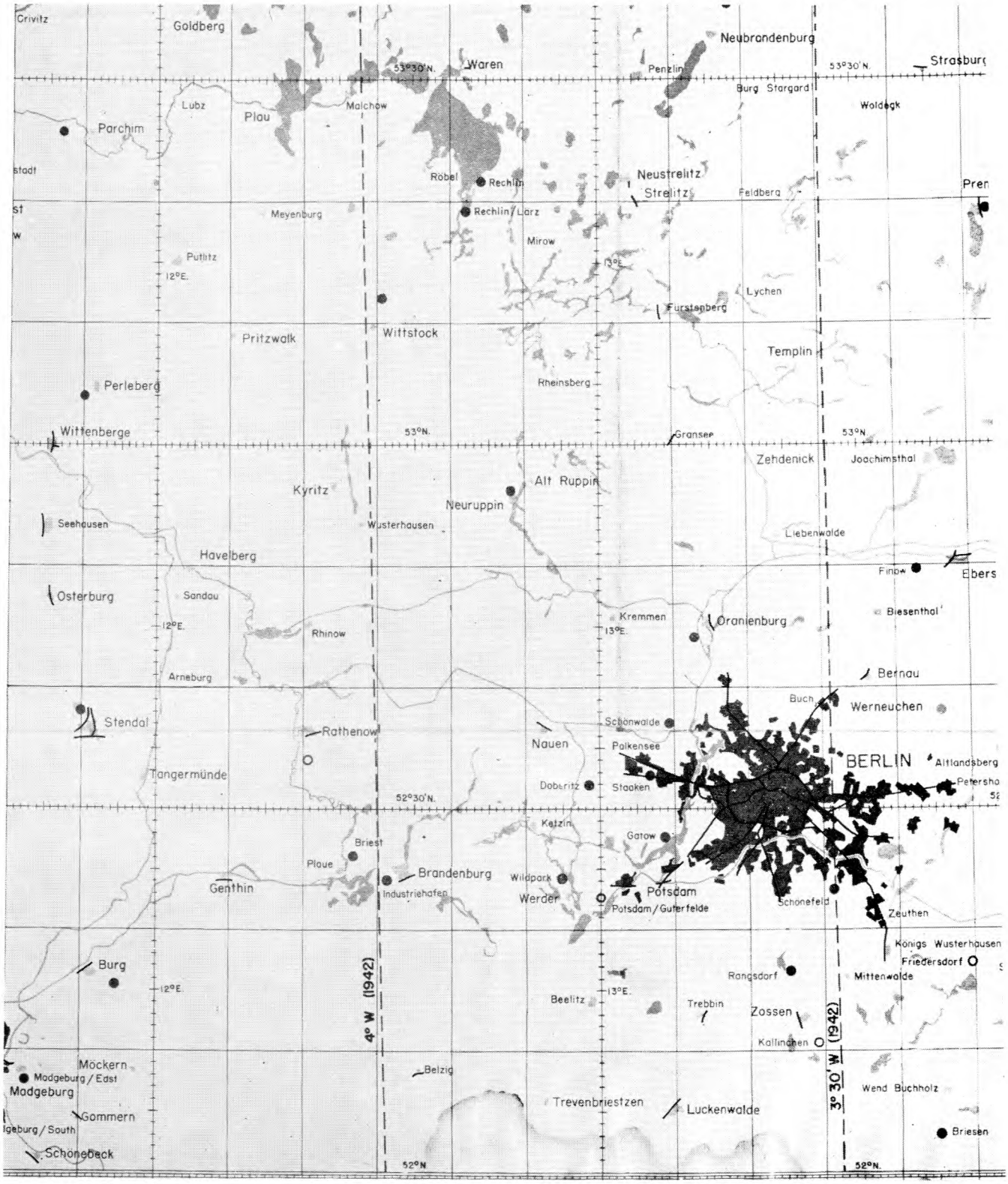


Radar target chart, still in experimental stage, presents only features which might show on scope. Tones of chart imitate scope tones (white for strong signal, etc.). Kansas flatlands show here. For similar treatment of broken terrain, see page 38



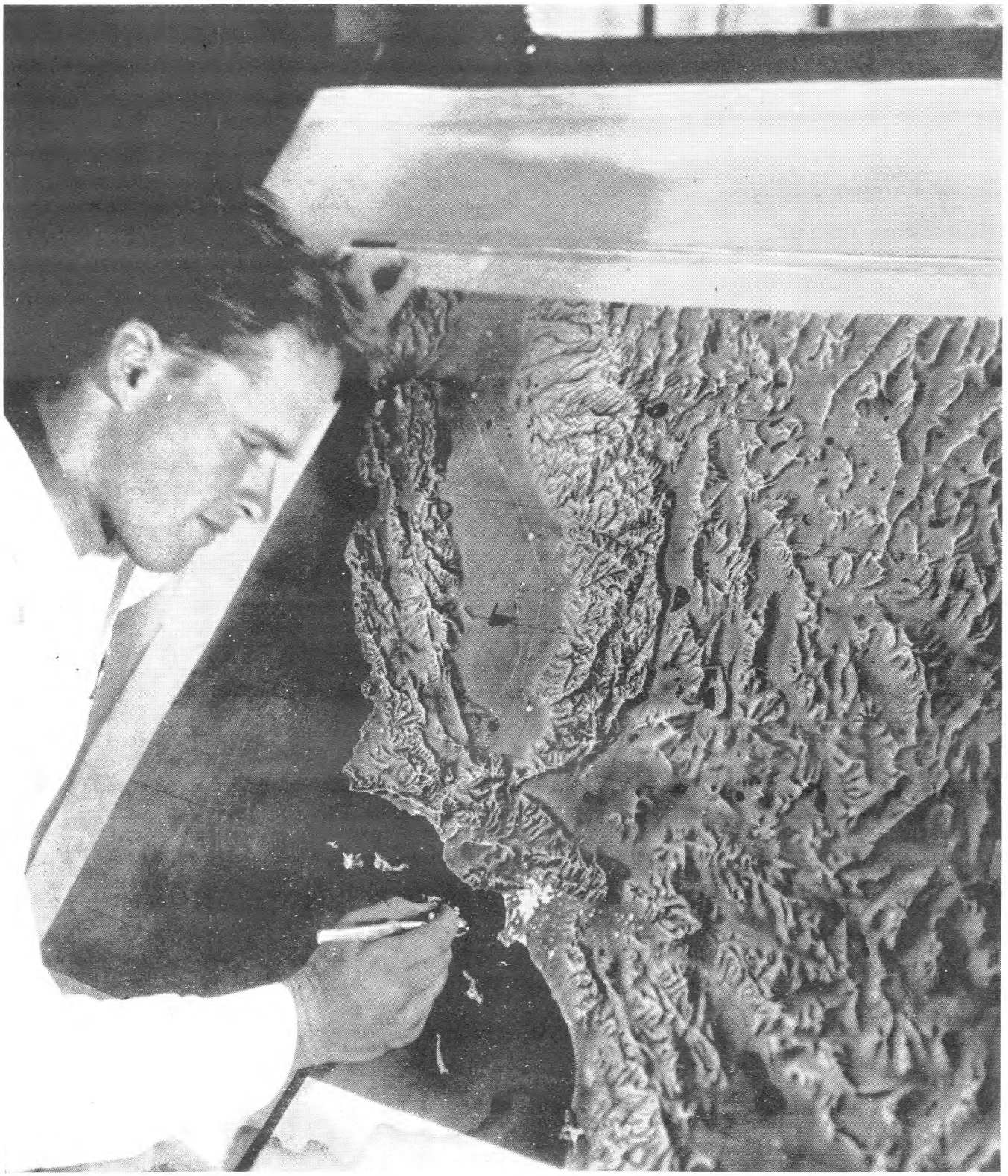
Early attempt to produce a radar map didn't get quite enough on. Aeronautical charts are too cluttered—this map is too vacant to help. Major function of a good radar map is to show up not only target but reference points in identifiable form

8th AF map screens irrelevancies, shapes cities



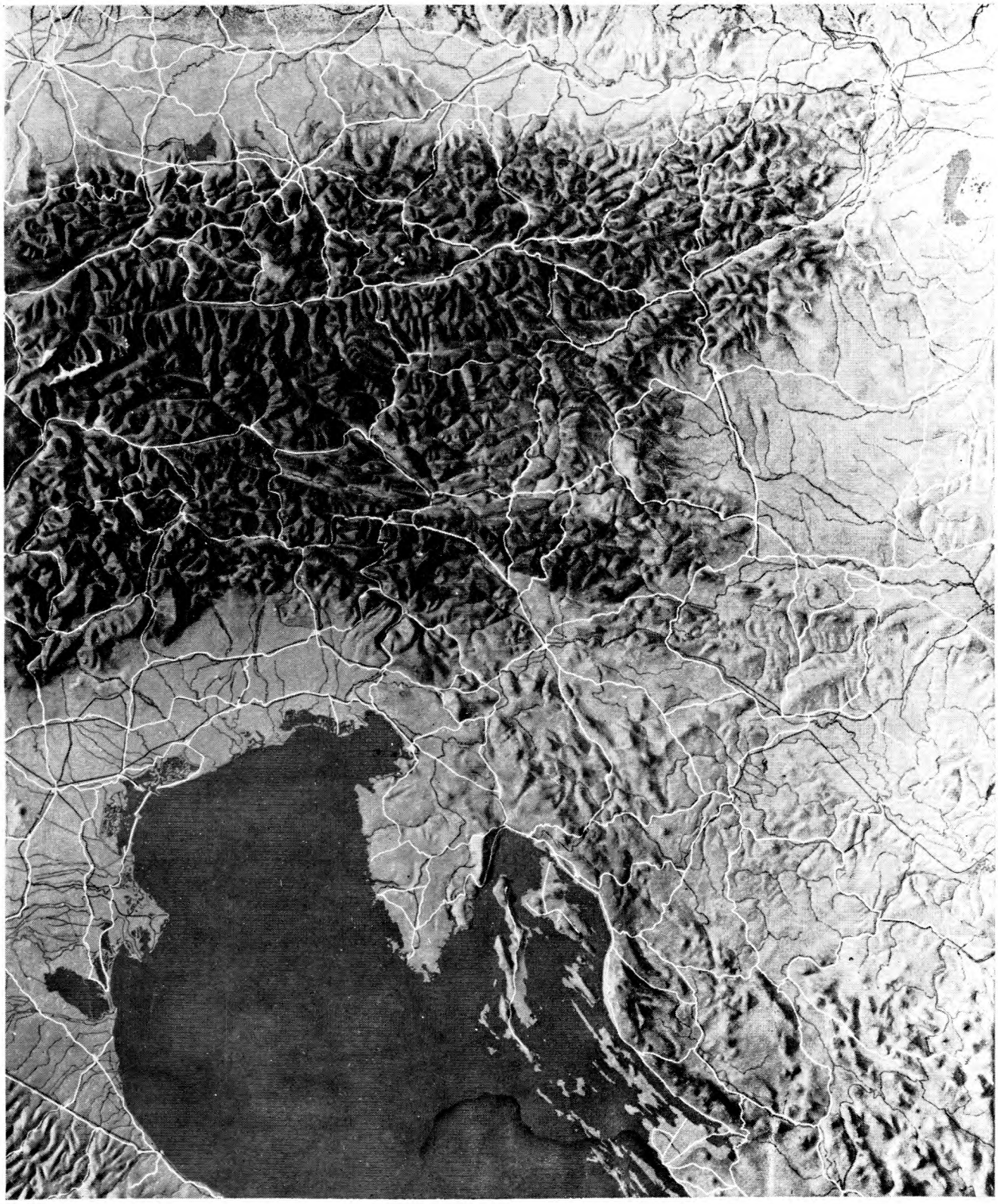
8th Air Force answers radar navigation problems with this special map, developed and printed in the theater. It is essentially an aeronautical chart with unnecessary information screened out, cities shaped to resemble radar signals and land-water contrasts emphasized. Map is based on scope photos taken on H2X missions; as more and better pictures come back the chart is revised. Late editions substitute Lambert Conformal Conic projection for Mercator to simplify the use of scope protractors

This experiment gets relief effect with air brush

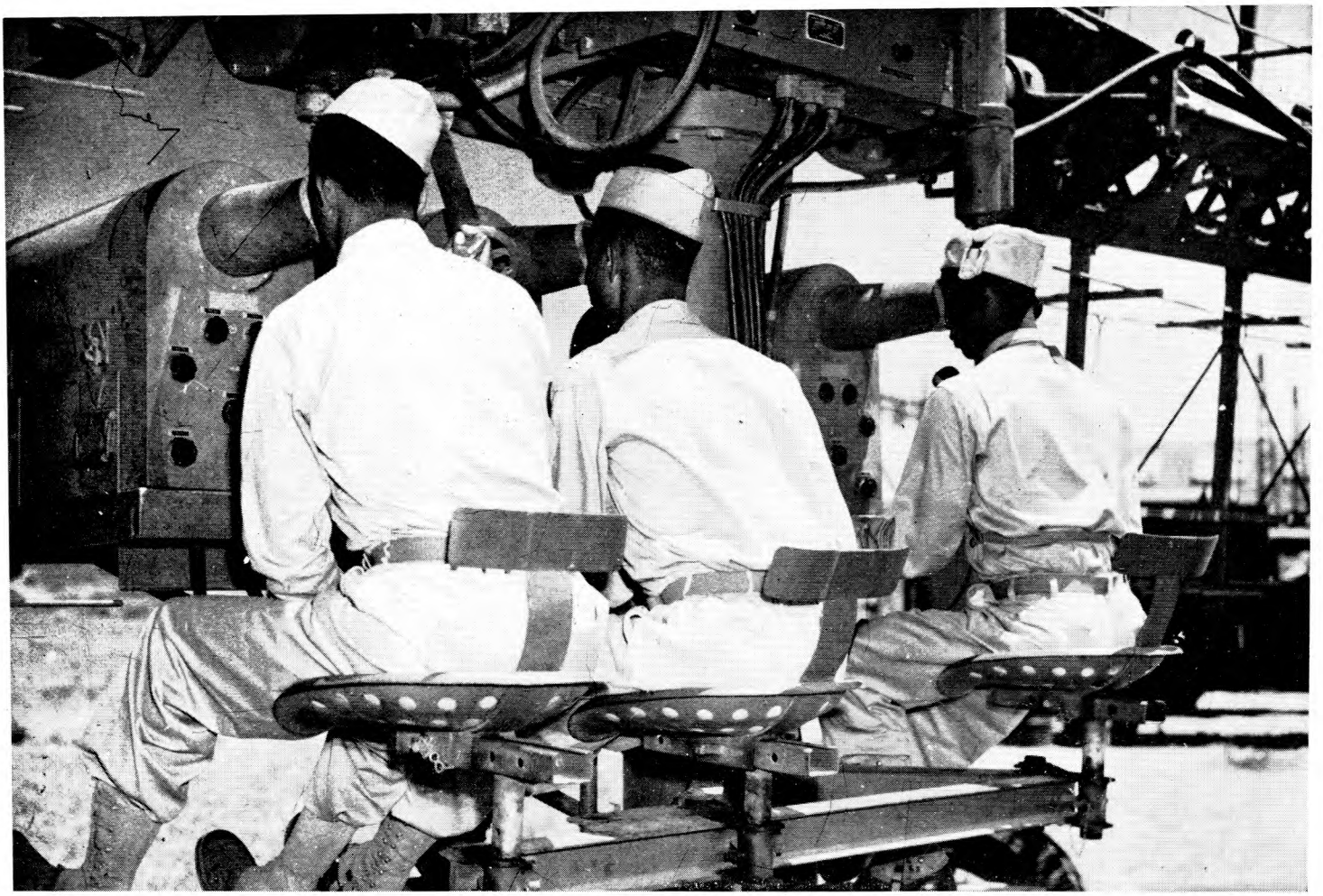


Nearing completion is this latest radar map experiment, sponsored by AAF Aeronautical Chart Service. Artist and air brush make flat paper look like a very sharp relief model and achieve tones similar to those of a scope presentation. A map of this scale can't take care of distortion and variables, but with features thus well defined operator's skill and imagination are counted on to do that. RADAR urges readers to submit comments on this technique, will pass them on to Chart Service

Transportable relief model is realistic but bulky



Rubber relief model that can be rolled up and taken into the air imitates the scope when illuminated by a point source of light corresponding to position and altitude of aircraft—gives a true picture but is hard to handle. Relief models have been used successfully for radar training, siting, briefing (see RADAR No. 4). Their use for radar mapmaking is still experimental and has involved not only rubber but plastic surfaces and a variety of photographic schemes—none of which is as yet operational



HEIGHT, RANGE, AZIMUTH ARE WHAT THESE 268 OPERATORS SEEK. THEY'LL MISS OUT WHEN JAMMING STARTS—UNLESS THEY KNOW THEIR A-J

A-J MEDICINE SHOW

How to recognize jamming on a live scope is something every young radar operator should know. He should also know what to do about it. The logical place to get the knowledge is in radar training back in the States. But until fairly recently every available bit of jamming equipment was rushed to the theaters for use against the enemy. Many a radar operator had to learn about jamming on the receiving end of the line.

Bridging this gap, a training unit popularly known as the Anti-Jamming Medicine Show has been making two-night stands all the way from Brisbane to the north coast of New Guinea since mid-April. Strictly an SWP Theater project, the Show consists of one weatherbeaten RAAF Hudson, an assortment of jamming equipment and a miscellaneous cast of one USNR lieutenant, two AAF assistants and an Australian crew. The Show was planned, rehearsed and readied under the direction of Lt. Col. P. W. Albert, Acting Asst. Director, Section 22, GHQ, Southwest Pacific Theater.

As a performance, the Medicine Show has gotten a rapt audience wherever it has gone. As an educational feature, it does a digestible, double-quick job. Operators have shown up for the Show from mainland, islands and Navy forces afloat, sometimes after many days enroute from their posts. The unit makes prearranged stops, scheduled to accommodate a maximum of the radar operators in the Theater. Reconstructing a typical stop, the routine goes somewhat as follows:

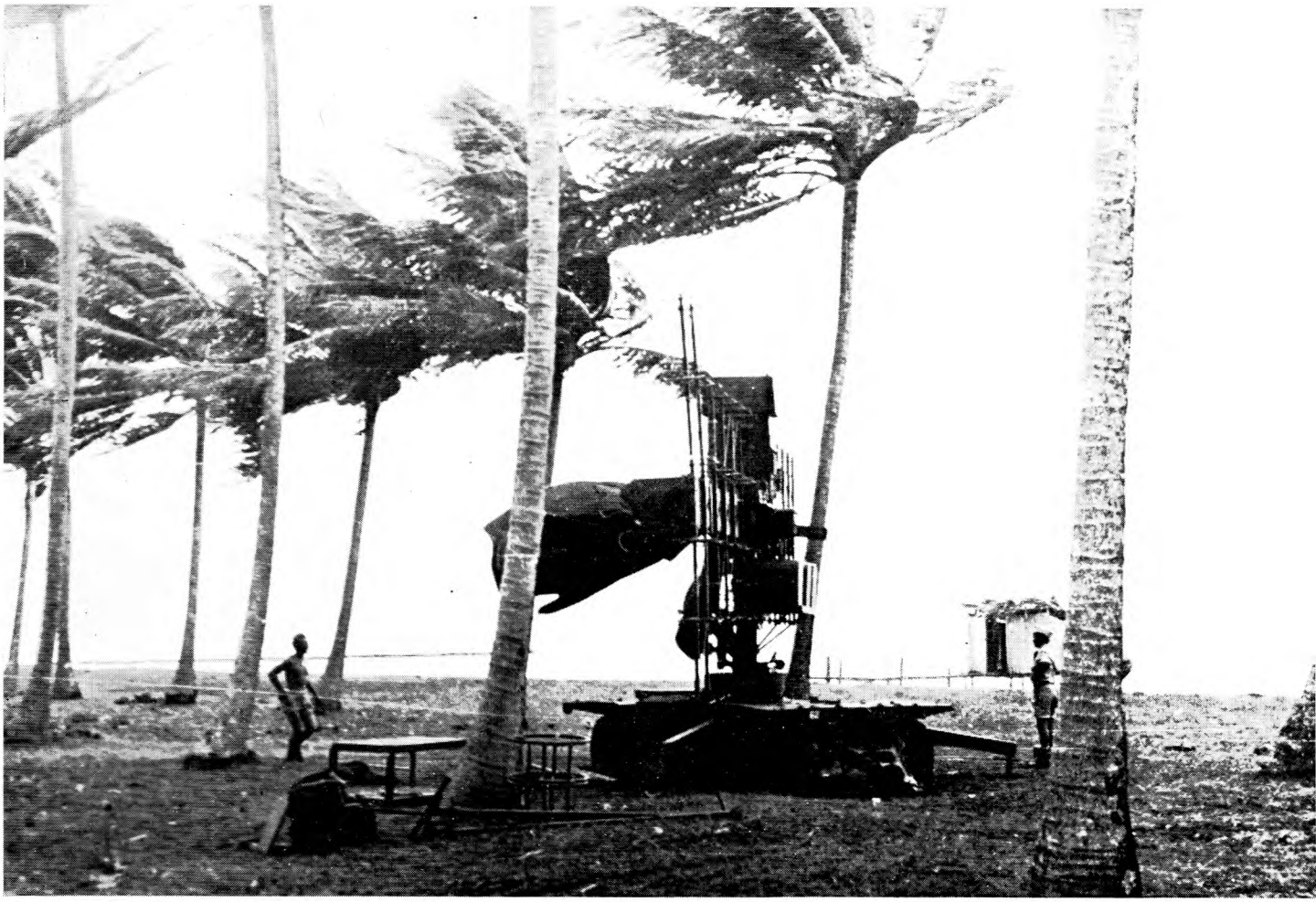
•

Late one afternoon the Hudson landed on an airstrip in New Guinea. Eight radar operators, on temporary duty from their posts throughout the region, were waiting. One sergeant had been 9 days enroute, coming by muleback and native fishing boat.

It was too late that day for a jamming demonstration. After supper and a brief get-acquainted session the cast of the Medicine Show, led by Navy Lieutenant McCaa, filed back to the Hudson to make sure everything was in order. While the Australian crew checked the plane the three Americans serviced their equipment: two Mandrels; one Dina; one CXCD, a Navy practice jammer; one Australian-built practice jammer covering 150 to 250 mcs; two ARC-1 Navy Intercept Receivers; one portable jamming simulator for lecture purposes; several varieties of window.

The next morning the Hudson took off on its first demonstration flight, while on the ground the radar operators huddled around several SCR-268-A scopes. This was electronic jamming. During the two-hour demonstration they sweated and fumed, trying to track through the noise. At first the job seemed impossible, but by the time the run was over they were catching on, seeing through the grass and railings.

In the afternoon they saw window. Several kinds of chaff were launched



JAMMING SQUALLS CREATED BY MEDICINE SHOW WORKED ON MANY AN OPERATOR LIKE AN SWP HURRICANE HERE WORKS ON 268 INSTALLATION

from the plane, first in small batches, then in big ones to show different tracking effects. The men at the scopes found themselves profiting from their morning noise-jamming baptism. The window symptoms were different, but the general idea was the same. They did tracking that afternoon that would have sent them yelling for the maintenance man 24 hours earlier.

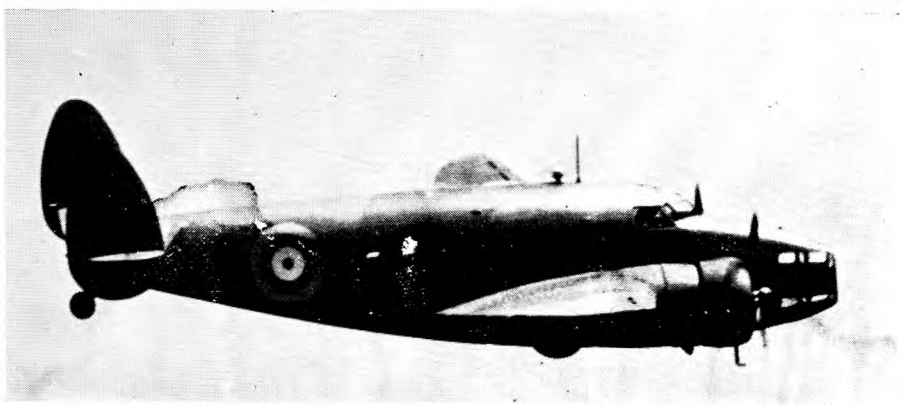
In the evening they asked questions, and well into the night. Next morning the Hudson was on its way to another rendezvous.

Anti-jamming demonstrations are not new. In August, 1943 a group of counter-measures experts watched operator reaction to some surprise electronic jamming tests at Orlando, Florida. At first the men were woefully confused and unable to cope with the situation. But subsequent tests showed improvement. On the third day they were able to track and identify targets on scopes that looked hopelessly jammed, succeeded so well that they tracked jamming aircraft by taking bearings on the jammers. These were all-electronic tests; window, newly operational, was taboo because of security.

The Navy, since mid-spring, has been emphasizing pre-combat A-J training. Each month quantities of window are dropped during the Exercises at Pearl Harbor.

One taste of real jamming will do wonders for the operator. It shows him what to expect; provides confidence born of understanding. Most of all, it eliminates surprise. The practice method is considered dangerous in combat zones, disrupting operations and exposing relatively unarmed planes to enemy fire, but most theaters can use it tellingly.

While operator training is the reason the Medicine Show Unit exists, at least one valuable by-product has resulted. The demonstrations serve to put the finger on faulty radar set-ups, convince COs of the importance of improvements. This happened at a showing in New Guinea, as told on the next page.



AN RAAF HUDSON WAS HOME TO THE SHOW. IT HOUSED THE JAMMERS, THE CAST AND CREW

A-J demonstrations needed: 2 reasons

1 Six SCR-268's were pitted against the Medicine Show during one demonstration somewhere along the New Guinea Coast. The maestro of the Show, Navy Lt. McCaa, and his AAF assistants knew the system didn't stand a chance against jamming, and with good reason. Bunched within a 6 mile radius, all six 268's were operating within plus or minus ½ megacycle of the same frequency—the most vulnerable kind of geographical and frequency deployment. The situation had come to official attention earlier, but without result.

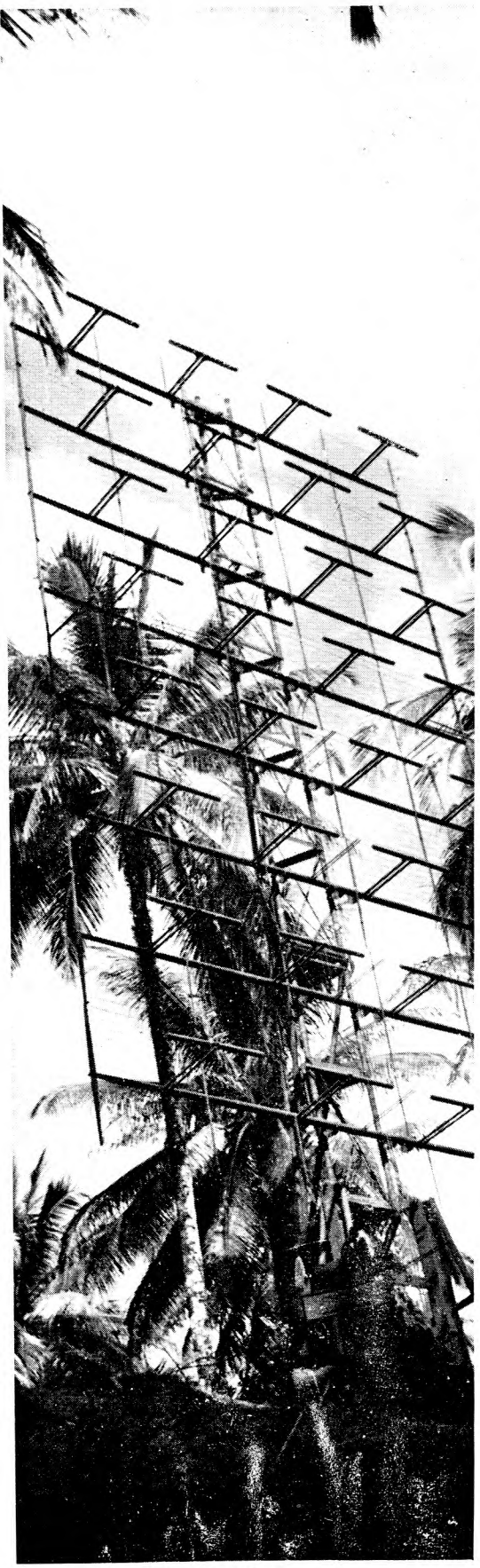
Lt. McCaa asked ranking officers of the Command to attend the electronic jamming demonstration, assuring them of an interesting performance. What they saw was one Dina transmitter knocking out six 268's. Changes, the officers promised, would be made.

2 This summer, in the U. S., SCR-268's, 270's, 271's and 296's guarding an east coast control area extending hundreds of miles were reported jammed to saturation.

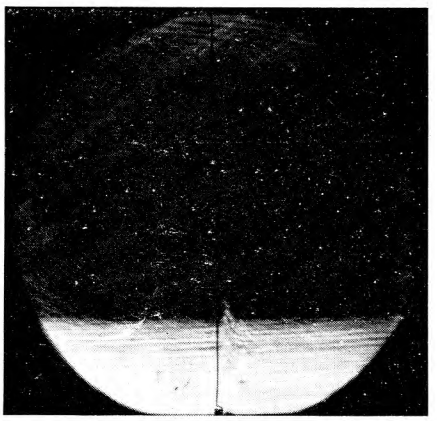
There was quite a scare and some investigators went out to probe the trouble. What they discovered was that it wasn't jamming at all, but interference among radar sites probably due to anomalous propagation. The radar operators had neither recognized the symptoms nor made corrections. The investigation report expressed "an urgent need for A-J training on operational sites."

It recommended "visits of demonstration crews equipped with training devices to simulate jamming or, if possible, actually to jam certain stations so that operating crews may gain experience in anti-jamming techniques."

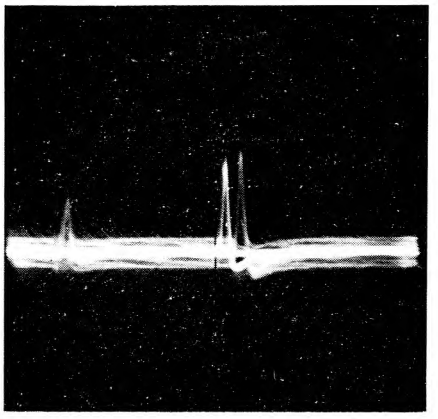
Jamming shows up in many forms and patterns; few can be regarded as typical. The shots below, of a 268's A-scope, are some examples of what an operator may see.



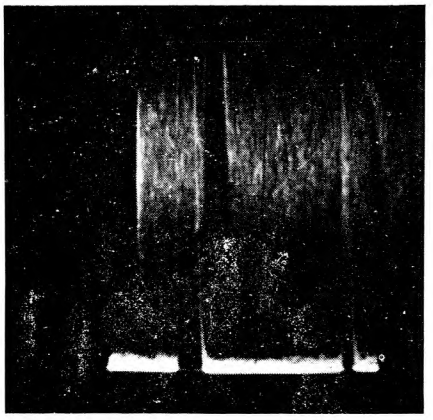
BEAUTIFUL BUT DUMB against jamming was the verdict on some of the radar systems seen during the Medicine Show's travels



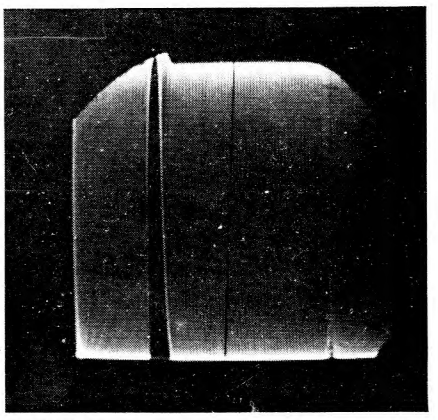
BEFORE: This low frequency modulated CW on the SCR-268, which might have come from a Jap jammer, looks hopeless here



AFTER: Treated with a high pass filter, installed in the SCR-268, the distortion reduces, the pips show bright and clear



NOISE-MODULATED CW, characterized by irregular effect, often has been called "grass" jamming, could come from Mandrel



"RAILINGS" jamming, likened to a picket fence, could be emitted by the Medicine Show's Australian-built practice jammer

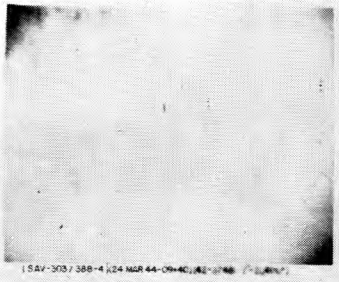


1. DUAL PERSONALITY OF RANGE MARKS ASERTING ITSELF IN THE FORM OF LIGHTER COUNTERPARTS. THIS PITFALL CAN BE AVOIDED BY REDUCING INTENSITY OF RANGE MARKS.
2. SPIRAL INTERFERENCE FROM NEARBY H_2X SET. CANNOT BE AVOIDED, BUT SHOULD NOT BE A DISTURBING ELEMENT.
3. UNDER THE SIGN OF STATICORN, STATIC ELECTRICITY WITHIN CAMERA CAN BE PREVENTED BY GROUNDING CAMERA CASE. CRESCENT DUE TO A/C IN BANK.
4. NERVOUS TENSION IN RANGE MARKS DUE TO VOLTAGE FLUCTUATION. REQUIRES MAINTENANCE MAGIC.
5. THE SHADOW OF YOUR PAST PURSUING YOU. H_2X VIBRATIONS PREVENTED FROM REACHING GROUND BY NEARBY A/C. NO CAUSE FOR ALARM.
6. EXCESSIVE NOISE PROBABLY DUE TO LISTLESS INVERTOR. CONSULT MAINTENANCE MEDIUM.
7. HALO DUE TO LOW TILT AND PROBABLY AGGRAVATED BY POOR POLAR DIAGRAM. BOMBING CIRCLE TOO FAT. SLIGHT SPIRAL IN EXPERIENCE FROM NEARBY H_2X SET.
8. INTERFERENCE IN THE FORM OF LIGHT DOTS CAUSED BY NEARBY H_2X SET. RADIAL DASHES PROBABLY TEMPORARY INTERNAL NOISE FROM TILT MOTOR. DO NOT BE CONCERNED.
9. ALL VIBRATIONS FAVORABLE. EXCELLENT GAIN SETTING, FOCUS, POLAR DIAGRAM AND RANGE MARK INTENSITY. PROFITABLE RETURNS PREDICTED.

EIGHTH AIR FORCE 27 June 1944

8th AF puts H_2X experience on posters

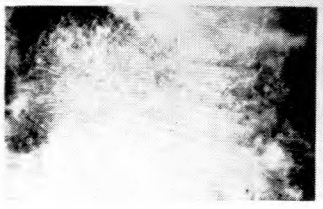
After nearly a year of bombing through the overcast with H_2X radar (APS-15), the 8th AF has come to know the ins and outs pretty well. Some pitfalls are shown in the Horrorscope above, with the gleaming scope in center portending profitable returns on future missions. This poster and a series telling about previous H_2X achievements were circulated to 8th AF radar personnel by the Operations Section. One of the series, depicting H_2X bombing Frankfurt through cloud and smoke, is shown below.



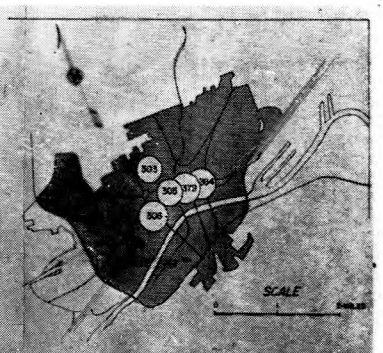
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(SAV-303/388-14)(24 MAR 44-09+40)(42-37681-7-21,000')

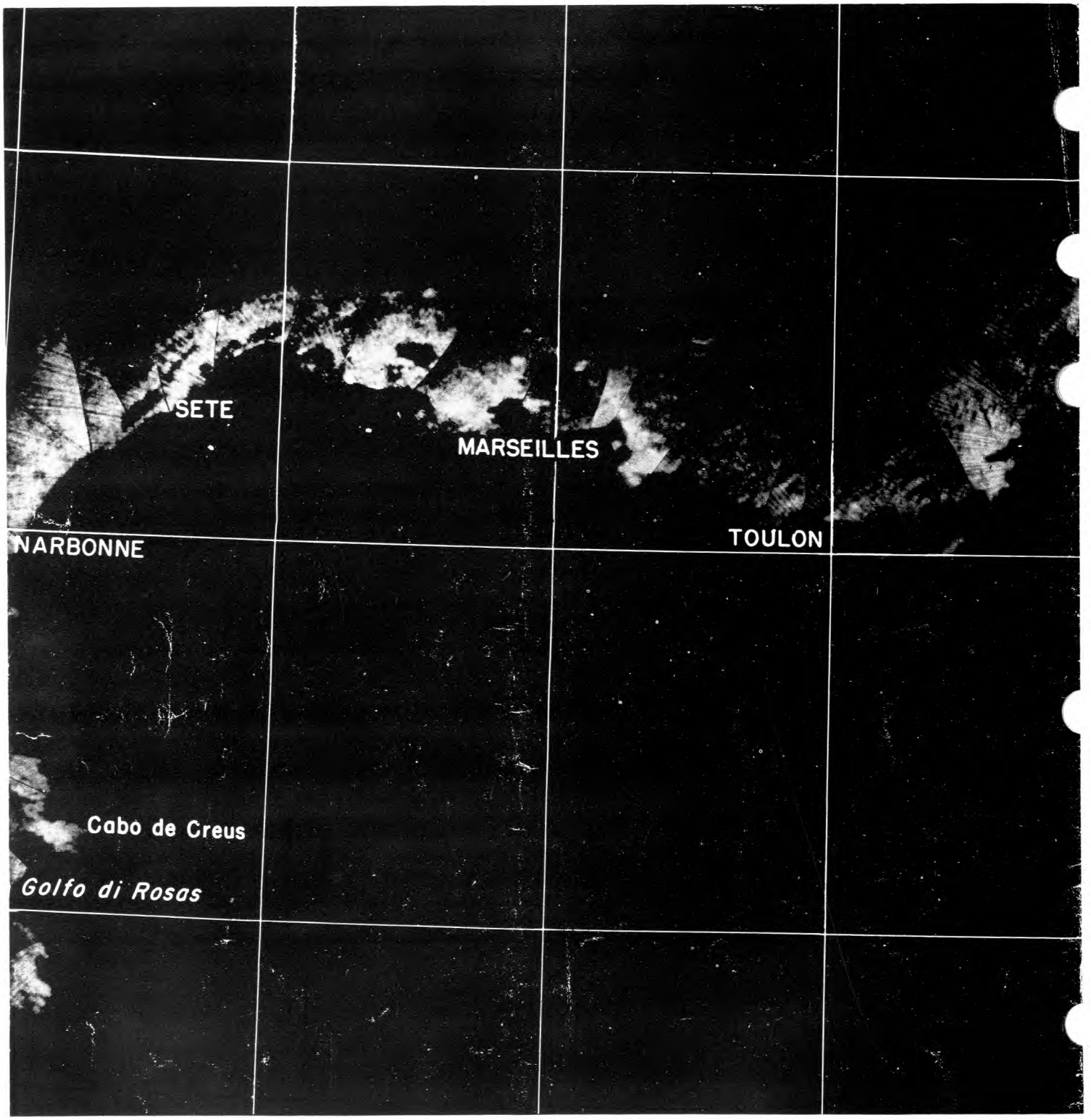


THE 40th AND 41st COMBAT WINGS ATTACKED *FRANKFURT* 24 MARCH 1944 AFTER THEY HAD BEEN FORCED BY WEATHER TO ABANDON THEIR PRIMARY TARGET. THE MAP ON THE RIGHT SHOWS THE LOCATION OF FIVE OF THE SIX GROUP BOMBFALLS. THE FALL OF THE 92nd GROUP WAS LOST IN THE CLOUD AND SMOKE. THE SIGHTINGS WERE MADE BY H2X. THE STRIKE PHOTOGRAPHS ON THE LEFT SHOW BOMBS AWAY *(Note the cloud)* AND THE STRIKES OF THE INCENDIARY BOMBS OF THE 303rd GROUP AS WELL AS THE STRIKES OF H.E. BOMBS OF SEVERAL PRECEDING GROUPS. THE OLD WALLED CITY OF *FRANKFURT* SUFFERED HEAVILY FROM THIS ATTACK.



H2X BLASTS THE CENTER OF FRANKFURT





The radar mosaic of the great curve of the Northern Mediterranean above and on the front cover was put together by the 15th Air Force as part of the preparations for invasion of Southern France. Biggest job of its kind yet produced, this mosaic **must** be supplemented by many more on even bigger scale before radar reconnaissance can make its full contribution to radar navigation. For more on navigation, see page 34. For more on Southern France invasion, see page 10.

FERRANTI Defence Systems Limited

RADAR

Issue No. 6 NOVEMBER 1944

INTRODUCTION



R.P.F. Lauder
Engineering Manager
Product Support Department

The war has now moved to the stage where the USAF's main theatre is in the South China Sea. Their task; to attack Japanese shipping in the archipelago running south from Formosa, the Phillipines and New Guinea to the Solomon Islands.

At first, shipping was attacked in force by day, largely with visual bombing. The attacking aircraft were vulnerable to AAA fire, particularly when they steadied into the bombing run, or they flew above the range of the guns, with bad effect on accuracy. Clearly what was needed was equipment which would allow them to place their weapons on the target at low altitude, under cover of darkness.

Several of the bombers were equipped with the SCR-717B radars and the APQ-5 attachment. The effect was swift and dramatic. Almost half the enemy tonnage was sunk by 20% of the bombers which were LAB (Low Altitude Bombing) equipped. The SCR-717B operated at 10 cm, and presented a PPI or sector PPI picture of the terrain ahead. The APQ-5 used two yagi antennae, one on either side of the aircraft, so that their overlapping polar plots allowed the aircraft to be pointed directly at the target. Clearly, harmonisation of these beams with the aircraft axis was important, as were the effects of drift angle. The bombardier took over control of the aircraft at 8 miles from the target, and flew it by remote control. A predetermined air speed was flown, and range and altitude were fed continuously to an analogue computer which solved the release equations for the ballistics of the bombs being carried, together with automatic release. One of the radar operator's problems was that at 30 or so miles, each of the thousands of small islands in the South China Sea looked exactly like a large ship.

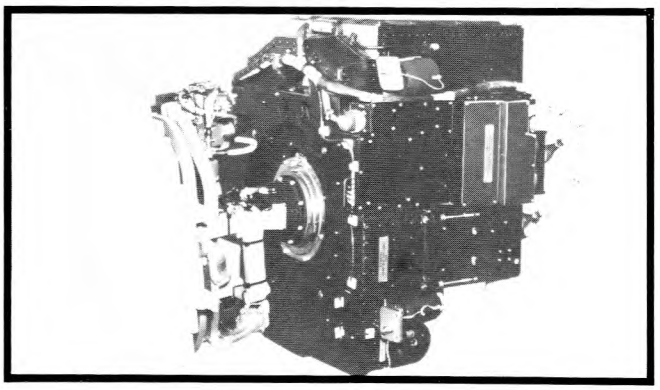
In February 1941, the allied high command was asking the question 'Do the Germans have radar?" Included in these pages are some quite remarkable photo-reconnaissance pictures of German installations of long and short range surveillance radars, gun control radars and Electronic Warfare jammers. Armed with this knowledge, together with that gleaned from electronic surveillance of the details of frequency, pulse width, p.r.f. etc., the allies covered the D-day Normandy landing with massive countermeasures. These pages describe the diversionary tactics where window (or chaff) was used to simulate a raid on Calais, complete with dummy parachutists. Surface ships and aircraft poured electronic noise against the German radars which were left after the allied bombing.

Again in these pages, we see the start of the long game of leap-frog where jamming is improved, then radar counter-counter measures get better, and so on. The game is still being played today. The lesson has been learnt, that if your spot jammer is tuned before take off, and the enemy radar changes frequency, you have no jamming capability. However tuning in the air demands a warning receiver with sufficient bandwidth to listen to the enemy radars and to tune the spot jammer appropriately. We also see the beginning here of prioritisation. With the plethora of radars sprinkling the path of the bombers, only those enemy radars which posed a physical threat to the aircraft were jammed, i.e. those controlling AAA fire.

Fortunately, the long range surveillance radars had to use low p.r.f. whereas the gun-laying radars achieved a higher data rate with high p.r.f. at short range. It was therefore a simple matter to feed the detected signal from the warning receivers to the operator's headphones which allowed him the easy distinction between the growl of the surveillance radars and the 1 kHz signal of the gun-laying radars. The idea is just surfacing as well, that it should be possible to angle track on jamming.

Earlier volumes have shown the awareness that water droplets in active convective clouds act as reflectors of radar energy, and show up on radar displays. Hitherto this has had only nuisance value, but now we see the beginning of positive use being made of the phenomenon. Remembering that the 1940s were long before the days of the weather satellite, metereological information, in the midst of a shooting war, was not easily acquired. Radar was a powerful means of plotting, at least the potentially dangerous cloud and storm centres, and providing this information for the benefit of one's own troops.





BLUE FOX

Ferranti's Blue Fox lightweight high performance radar is fitted to the Sea Harriers of both the Royal Navy, and the Indian Navy. It saw service in the Falkland crisis where it was fully combat proven. It is designed for air-to-air interception, air-to-surface attack, target acquisition and accurate weapon aiming.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

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RADAR ROUND THE WORLD: WHAT'S IN USE WHERE Covers

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EDITOR: Dexter Masters, Office of the Air Communications Officer.

FOREIGN EDITORS: Dr. L. J. Henderson, Advisory Specialist, Hq. U. S. Army Air Forces, MTO; Dr. L. C. Marshall, Chief, Operational Research Section, Hq. U. S. Army Forces, POA; Dr. Louis N. Ridenour, Advisory Specialist, Hq. U. S. Strategic Air Forces.

EDITORIAL ASSOCIATES: Avis Clarke, Ruth Copland, 2nd Lt. Norman R. Goldman, Lucie Sewell, 1st Lt. Robert Wright. **CORRESPONDENTS:** Sgt. John Caldwell and S/Sgt. Robert Carlson (European Theater). Drawings by Presentation Branch, Office of Strategic Services.

EDITORIAL ADVISERS: Lt. Gen. Barney M. Giles, Chief of Air Staff; Dr. E. L. Bowles, Consultant on Communications to Commanding General, AAF; Dr. L. A. DuBridge, Director, Radiation Laboratory.

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What's coming

Sometimes the staff of a publication like this can work a few issues ahead, figuring out from what it knows about the developmental, supply and operational status of equipment when best to report on same. Sometimes nicely planned issues are knocked sky high by developments that transcend anything else—for instance, D-day. Most of the time we plan ahead what we can, hold ourselves ready to junk it to make room for something we couldn't have planned, and end up using both.

This is not a sob story on the troubles of editors but a cautious approach to a listing of some of the material scheduled *at this writing* for future issues. We are doing the listing because in the far-flung areas where radar is operational, people are working, day in, day out, with the radar we'll be writing about. If they know in advance what's scheduled it may be that they will send along relevant data and photographs. And if they do the stories will be better stories. So: in the next 4 or 5 issues, as planned and among other things, there will be reports on the following:

1. Radar bombing methods.
2. Operations and uses of navigational aids and beacons, from BABS and YJ to Shoran and Micro-H.
3. Causes and effects of scope distortion.
4. Uses of ground radar for weather determination.
5. Night fighters and operations of the SCR-720.
6. Airborne fire control radar.
7. Field experience in preventive maintenance.
8. Problems and procedures involved in introducing new radar equipment into a unit.

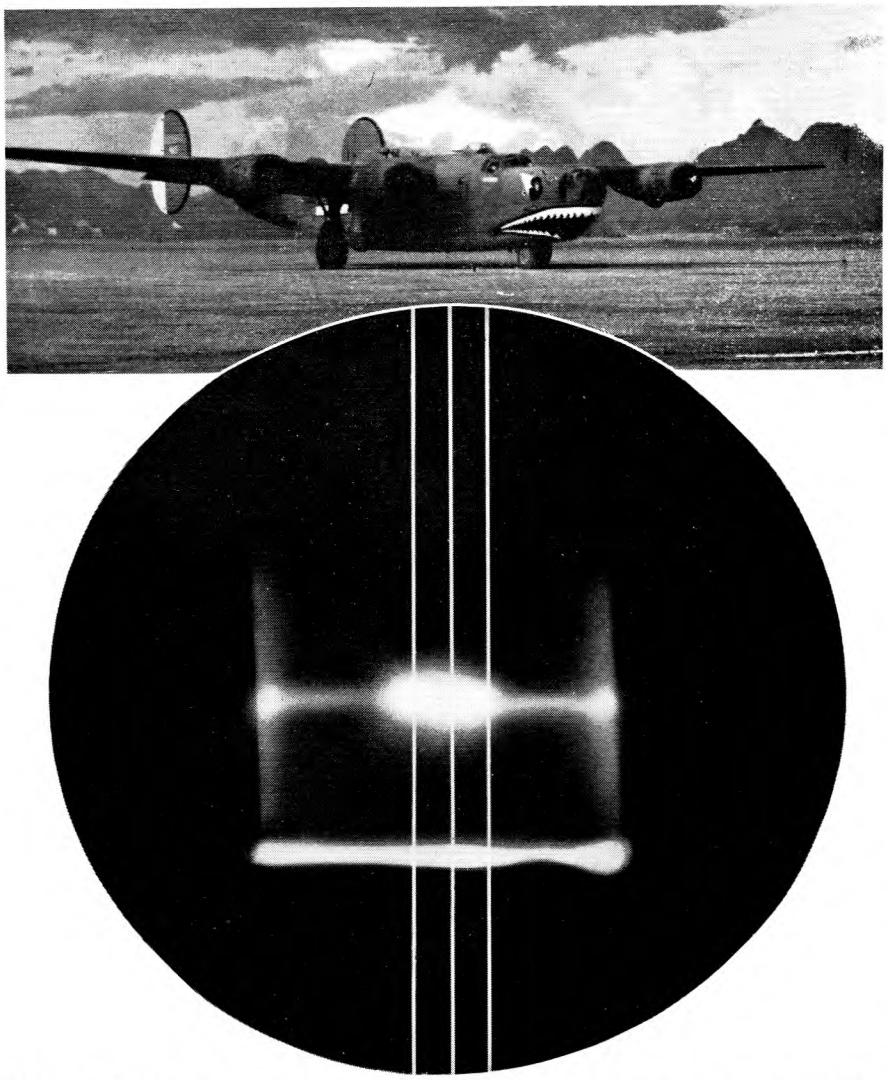
Along those lines we would welcome memos, notes, reports, documents and photographs. Also along any other lines that will serve to maintain RADAR as the compendium of useful information it aims to be.

Report from Tokyo

The Japanese Home and Empire Service of Tokyo last month broke all security regulations affecting radar with a broadcast telling all to the Japanese home front. Since the secret is now out, we quote:

> On the night of June 15, enemy B-29s took off from Chengtu and flew directly eastward. It is 2,560 kilometers to Yawata. What enabled them to fly this long distance and successfully reach north Kyushu was electrical waves. 'Guiding waves' are to a plane lost in the great skies what a stick is to the blind.
>
> Next, among the crew members of the B-29, there is one in charge of the instrument which is a short wave finder known as radar, and the B-29 is equipped with this topographical instrument. It is possible to know the topography of the land, whether water, land, mountain or (city) with this (shortwave).
>
> Next, its use in enemy night raids on ships. Enemy B-24s and B-29s are bombing our ships sailing in the South China Seas and waters off Taiwan with the view to smashing our supply lines. In such cases, enemy planes do not detect our ships with their naked eye, but utilize an **electric** wave (word missing) instrument which locates them.

We can't imagine what that missing word could be.



LAB bombardier's scope shows blip centered on range line and hairlines half mile from target (Jap ship). Bombs will drop automatically when release line, moving up from bottom, touches range line. Bombardier, at APQ-5 in nose of B-24, guides flight for last 8 miles. **At top:** 14th AF B-24 warms up at Kweilin for China Sea LAB sortie

LAB vs. JAP SHIPPING

In 14 months a handful of LAB planes have sunk more than 500,000 tons; with the invasion of the Philippine Islands the record in months to come may be even more impressive

LAB radar* has been pecking away at Jap shipping for over a year now. Three LAB projects operating under as many different air forces have in this time sunk 500,000 tons of cargo craft, damaged another 200,000, besides accounting for some carriers, cruisers and destroyers. Off Formosa in October a lone LAB bomber out on a sea sweep lent a little help to Admiral Halsey by sinking a cruiser.

For the Japs, LAB has been hard to get at. But lately they've had success in their drives on Kweilin and Liuchow, forward bases in China. Kweilin has been abandoned and LAB bombers may be forced to withdraw from Liuchow. Until the base problem is solved LAB aircraft are going to have a hard time hitting the bustling China Sea traffic.

The solution may not be far off. With the invasion of Leyte, bases near Jap shipping lanes and a way to bring in quantity supplies—essentials of large-scale activity—seem to be coming up.

China Seas targets have kept LAB aircraft busy all through the summer. The territory has been patrolled since May 1944 by a special LAB force under Lt. Col. William D. Hopson, attached to the 14th AF. A year earlier, the 13th AF pioneered LAB in the Solomons area with Col. Stuart P. Wright in charge (RADAR, April 1944). Late in 1943 the 5th AF extended it (under Lt. Col. Edward W. Scott) westward into the Bismarck Sea, then upward and westward all the way to Mindanao.

The record of LAB in the 13th and 5th AF's is good, but it's better in the 14th. The first two averaged one sighting, 350 tons of sinkings per sortie. The latter, "fishing" where the fishing is best, has been clicking with 3 sightings and a 1200 ton average from May through September. LAB results can be pretty well predicted if traffic is known. Thus, an 850 ton average per sortie for China Seas operations had been foreseen and this figure was on the nose for the first 2 months. Statisticians lost out when the enemy's drive to neutralize East China bases kindled the crews. During September 110,000 tons of shipping were sunk—1700 tons per sortie.

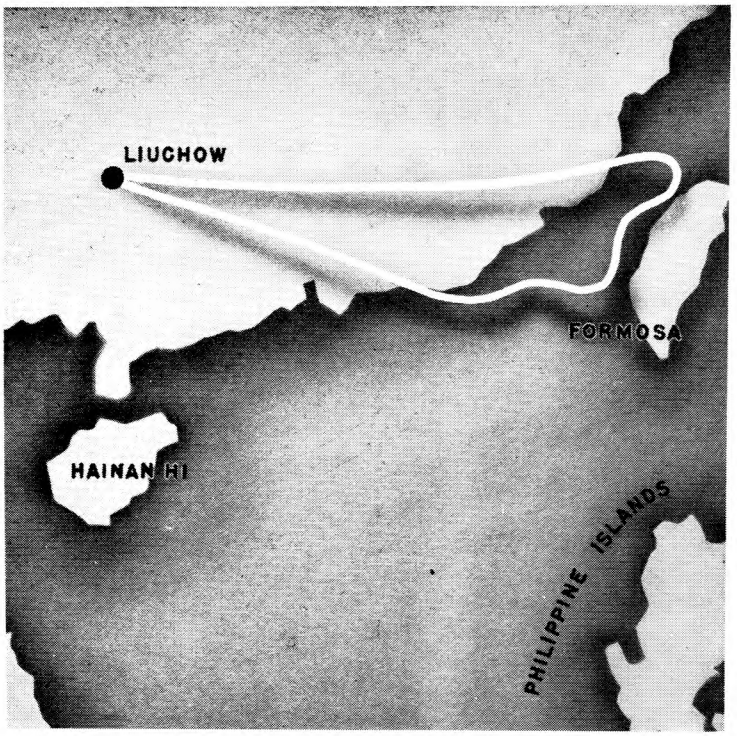
Of late LAB crews of the 13th AF have been outside the big target zone, but they've kept their hand in with frequent practice. The 5th AF has better hunting, though hardly to be compared with what they expect before long.

Big LAB doings are looked for in the 7th AF, which will be able to throw well over 100 equipped B-24's against the Japs by the first of the year. The 11th AF has a few LAB bombers, hasn't used them much yet.

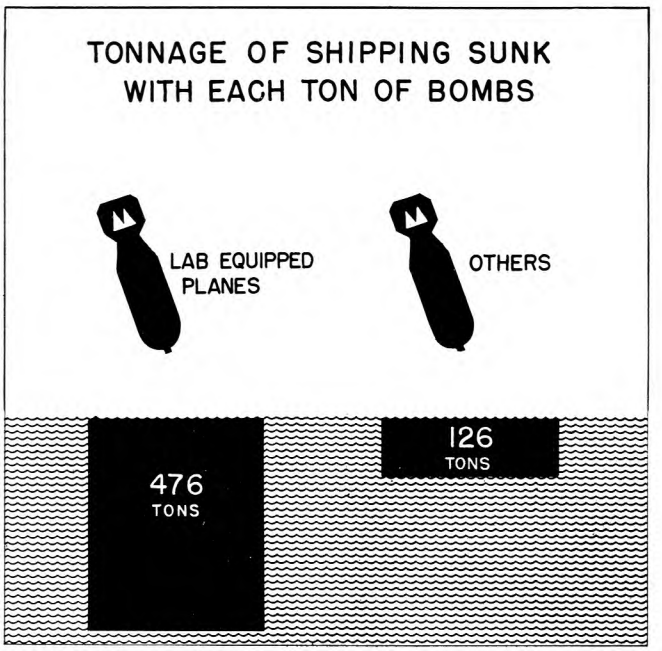
As a method, LAB today is no different than reported 6 months ago. Crews come better trained, learn more from the veterans; maintenance is better; refinements have come in. While it can't do everything that LAB planes in combat zones are called on to do, it does everything that it was built for. The following pages tell what and how.

---

* *APQ-5 bombing attachment with SCR-717 or other microwave ASV radar for Low Altitude Bombing—hence LAB.*



14th AF has sunk many ships on sweep shown, also around Hainan. Philippines may provide successors to threatened China bases



Margin of LAB over non-LAB planes is strikingly put in data compiled by 5th AF, on which this and next chart are based

All the damage to date has been done by a handful of planes

As an anti-shipping weapon, LAB combines high precision with low combat loss. Besides the efficiency of the bombing attachment for its special job and a definite last-second knack that some LAB bombardiers seem to acquire, the high precision stems from the inability of targets to take effective evasive action against the low altitude bombing. Low combat loss results in the main from the protection of nighttime operations.

The whole works out to this sort of record: one LAB squadron accounted for 47% of all tonnage sunk during 4 months by one bomber command. The rest of the command used 4 times as many aircraft, bombs and personnel in strikes against shipping.

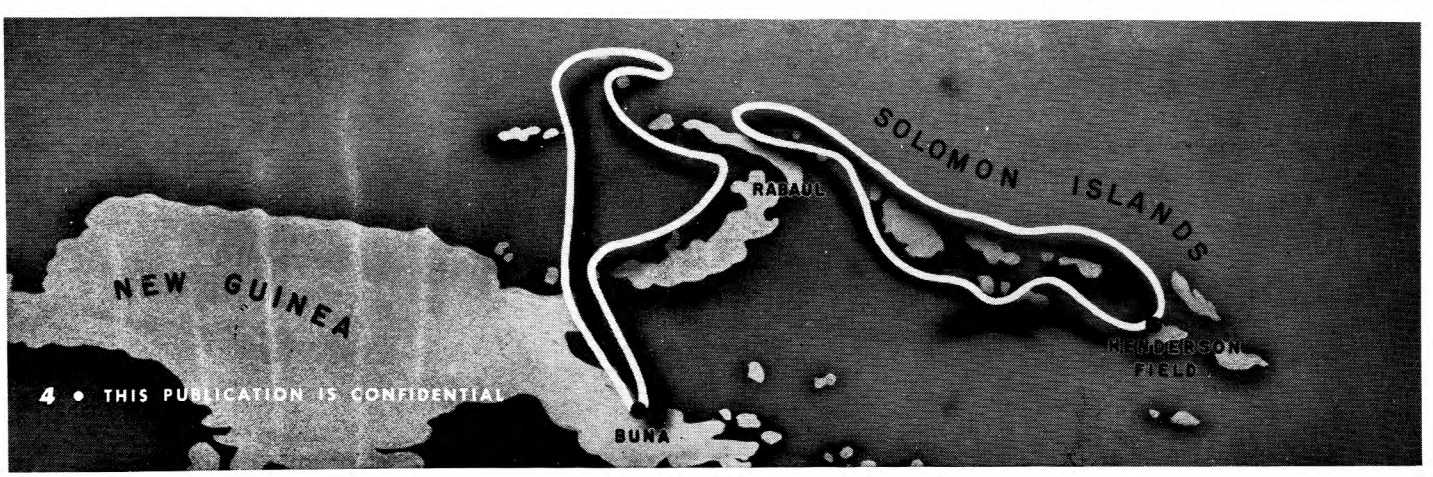
The Wright Project in the 13th AF opened plenty of eyes with its results. The Scott Project and its 5th AF successors, in 233 missions over a 6-month period, sank 122,050 tons and damaged 65,650. The Hopson Project, with the best hunting of all, in its first 3 months (134 sorties) sank 113,400 tons of cargo shipping, damaged 54,300 and, additionally, bagged 7 warships. Then, in the month of September, it downed 110,000 tons.*

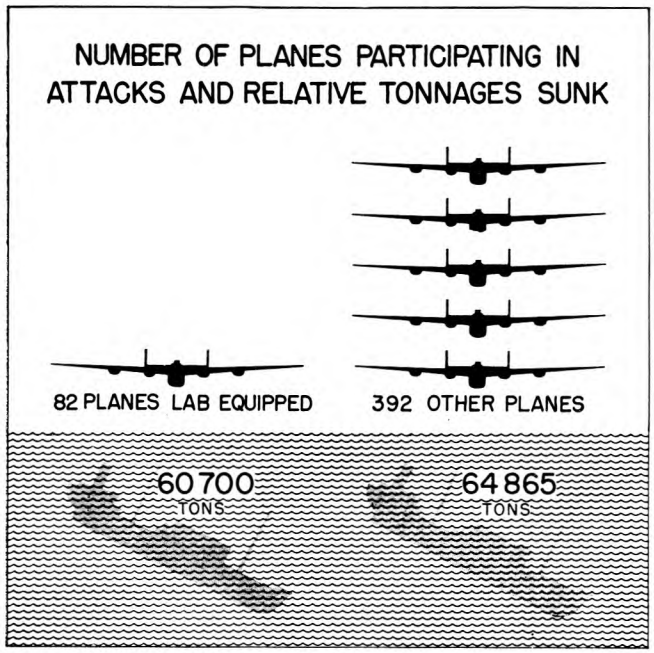
The combined sinkings by LAB action to date can hardly be called a major Jap disaster. But all the damage has been done by a handful of planes. One bombardier has sunk 75,000 tons. Two out of every 3 legitimate targets located in the China sweeps had to go untouched because there was just more work than a lone B-24 could do. One out of every

** Confirmation of sinkings is based on the following: (1) disappearance of target blip from PPI scope after bombing although radar is still known to be operating perfectly; (2) visual verification; (3) evidence of survivors, visually or by radar, on return for verification.*

5th AF initially dispatched LAB missions northward into Bismarck Sea, then shifted westward, now bombs around Mindanao

13th AF had good hunting around Solomons last year, currently does practice missions to be ready for LAB action elsewhere





LAB results are predictable if ship traffic is known. In China Seas 14th AF, as expected, has surpassed these 5th AF results



Theater art by member of an LAB crew. The cloud cover denotes night operation. Crewmen respect LAB and don't mind saying so

4 ships attacked in Chinese waters goes down.

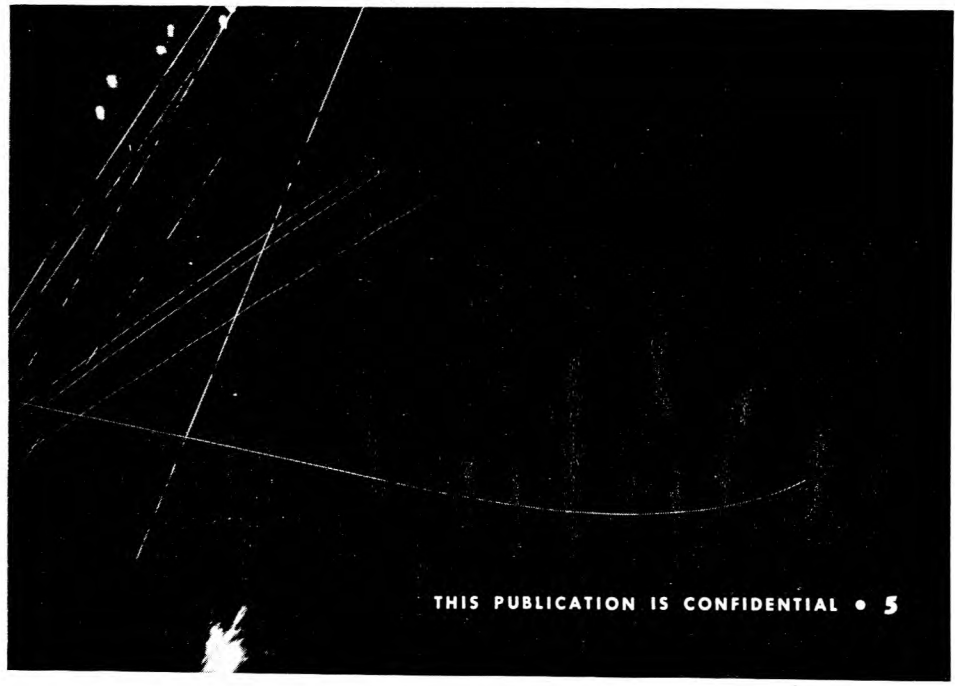
The LAB technique calls for bombing moving targets at low altitude and the equipment was designed with that in mind. Improved versions of the APQ-5 have been suggested providing accuracy at low, medium and high altitudes, particularly in combination with the better resolution of X-band APS-15, which is already going into some replacement aircraft. But at its favorite low altitudes APQ-5 performs so expertly that it seems destined for quite a long and useful life.

Where heavy bombers are scarce, and that includes China, LAB aircraft are sometimes integrated into general-purpose squadrons and called on for a variety of odd-jobs. As Pathfinders in Group operations they haven't worked too well; their SCR-717-B radars lack necessary discrimination. With APS-15 or APQ-13 this drawback may vanish. River sweeps haven't been very fruitful for the same reason. Buoys, lighthouses and small islands look like logical targets.

LAB sorties are night missions. In this rests much of their surprise and their safety. Prior to the arrival of LAB aircraft in the 14th AF, most sweeps were done in force and during daytime hours. Just a few days before the Hopson Project began functioning one such operation lost 4 bombers in combat with an escorted 10-ship convoy. But in 4 months of LAB night sorties there hasn't been a single traceable combat loss; losses from other causes (weather, navigational errors, running out of gas, etc.) come to about 5%. Today most sorties are carried out by a single B-24, although sometimes they take off in pairs and maintain fairly close support, if necessary, during separate hunts throughout the night. A lone B-24 usually carries twelve 500 pound bombs, enough for 4 runs. With the heavy amount of China Seas traffic lately, it takes pretty keen selectivity to pick the best targets.

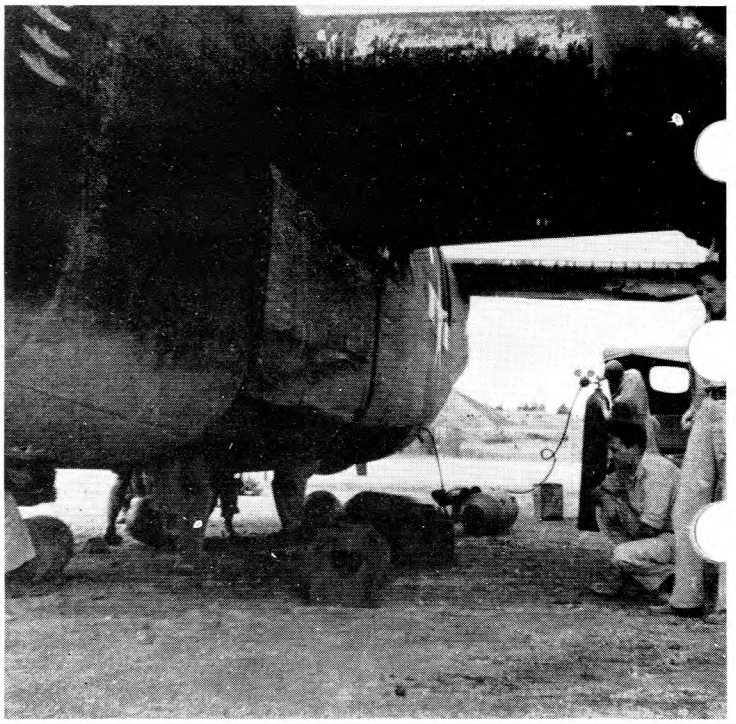
Though target opportunities improve as we close in on Japan, the cost goes up, too. LAB successes in China have been achieved against tough obstacles that are getting tougher. Some of what it costs to keep LAB going in China is told on the following pages.

Jap ship flak has hard time locating attacking LAB plane of 5th AF in pitch darkness. This photograph shows what the crew saw looking down through night





Trained crews like this one are hard to replace in China. Bombardier (left) has sunk 75,000 tons. Note frag-marked radar hut



Bombs and other LAB essentials are cargoed in over the Hump. This ex-African U-boat hunter takes on twelve 500 pounders

"Every undertaking must be measured in pints of gasoline and ounces of bombs"

The history of LAB in the 14th AF from May to September 1944 provides a working sample of the kind of problems AAF units are likely to encounter as they make the adjustment from other theaters to the Far East scene.

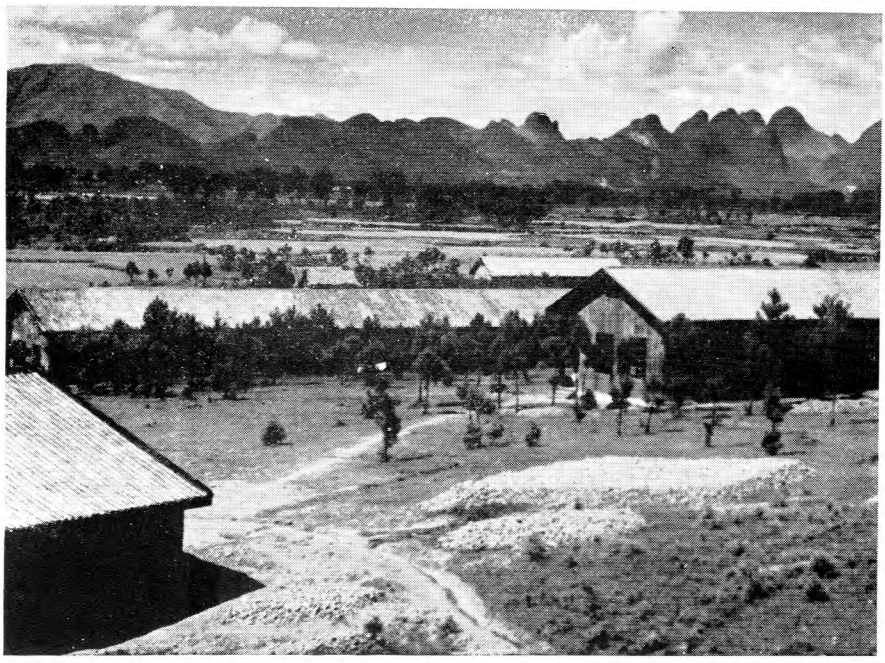
Chinese operations and tough supply problems go hand in hand—especially when you're dealing with heavy bombers, which drink gas almost faster than it can be brought in. "Get that gas-hog out of here," cried a base Commander in China when the first LAB B-24 came in. First LAB results changed his mind. But, as Lt. Col. Hopson (LAB project officer) observed, it is still true that "every undertaking must be measured in pints of gasoline and ounces of bombs." In 4 months LAB sorties, excluding other activity, swallowed up 400,000 gallons of gas and 800,000 pounds of bombs, all of which had been flown in over the Hump.

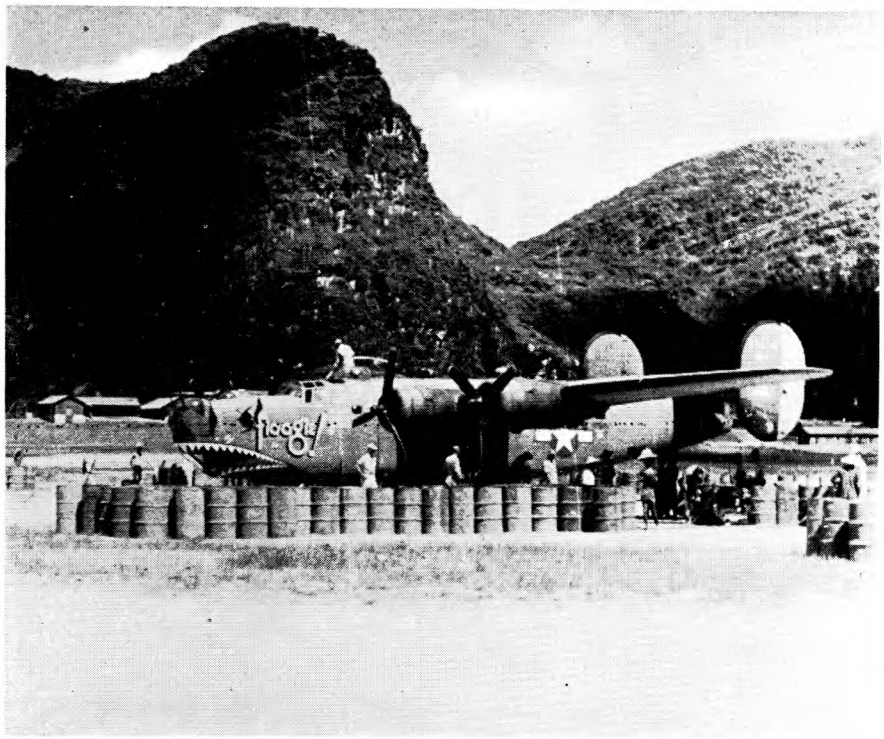
Lack of fuel prevented practice flights and for several weeks stopped regular missions altogether until LAB bombers, serving as air tankers, could haul gas from West China to the forward base at Liuchow. They'd haul fuel 2 trips and do LAB work the third. It was a good investment. One ton of Jap shipping was sunk for about each 1.7 gallons of gas expended.

All types of equipment, sorely needed, were on the do-without list. The forward detachment at Liuchow, representing one Bombardment Group, was the envy of all airmen in East China for its 6 x 6 truck. "There is nothing here but what we bring," wrote the Radar Officer. "We are grateful for many of the simple things we insisted on carrying out, saws, hammers, etc."

Right now the problem of bases is the biggest headache. Kweilin is gone, Liuchow is far from secure. And even these big forward bases, providing nearest entry to the China Seas, have meant a minimum sortie of 1500 miles, 65%

Hostel at Erh Tong Field, Kweilin, housed LAB crews, was abandoned when Jap land drive threatened base. Field was bombed often, slit trenches were always popular





Gas hauling was regular LAB B-24 job in July. Plane would haul gas to Liuchow twice for each mission. 2750 gallons is the average sortie load, enough for 1650 miles

over land. Westward bases are used today, but the overland percentage is even higher, some of the best hunting ground is inaccessible, gas usage is heavier, flights are longer at night over mountainous terrain in areas of practically no alternate bases.

This last means a greater operational menace. Even from East China the tough terrain, lack of emergency fields, weather hazards and navigational problems combined to destroy one LAB bomber and damage another every 20 missions. One crew was lost every 40.

LAB crews, forming at Langley Field, Va., are trained as a unit, with the navigator-bombardier-radar operator performing as a closely integrated team. So tightly do their jobs dovetail that spot replacements are out of the question. Three teams were out of action simultaneously not long ago because in each case one of the radar team was missing.

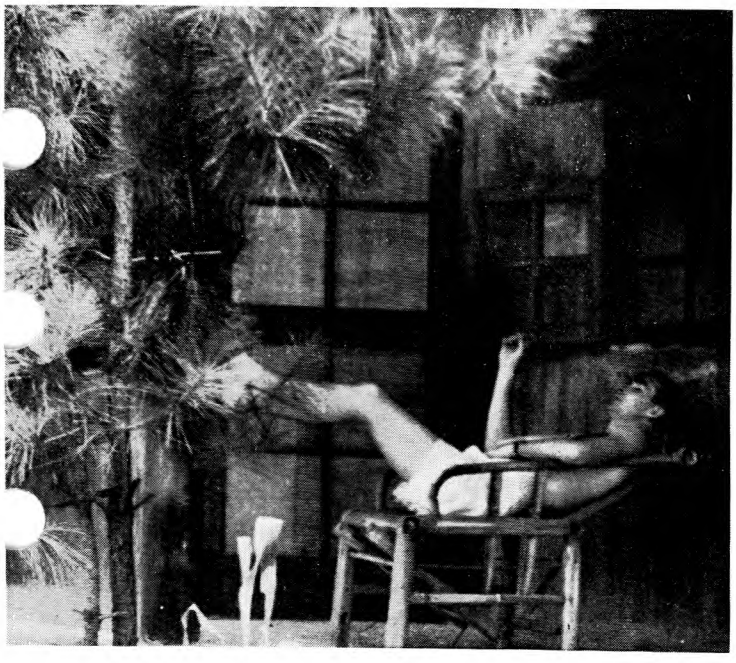
LAB men in China have the advantage of lessons learned by the 5th and 13th AF and better training by the LAB Training Squadron at Langley, whose officers are veterans of many LAB sorties themselves. Maintenance is improved, though the Jap land offensive means relocated setups and even heavier strain on equipment.

All sorts of odd jobs cut into LAB operations. That's one of the laments of LAB crews, who develop a downright affection for their basic work. But they recognize the necessity for pitching in on Group operations in a land where heavy bombers are scarce and multipurposed. But the consequence is further diminishment of the anti-shipping assignment and that helps to explain why 4 months of operations in China showed less than 200 LAB strikes.

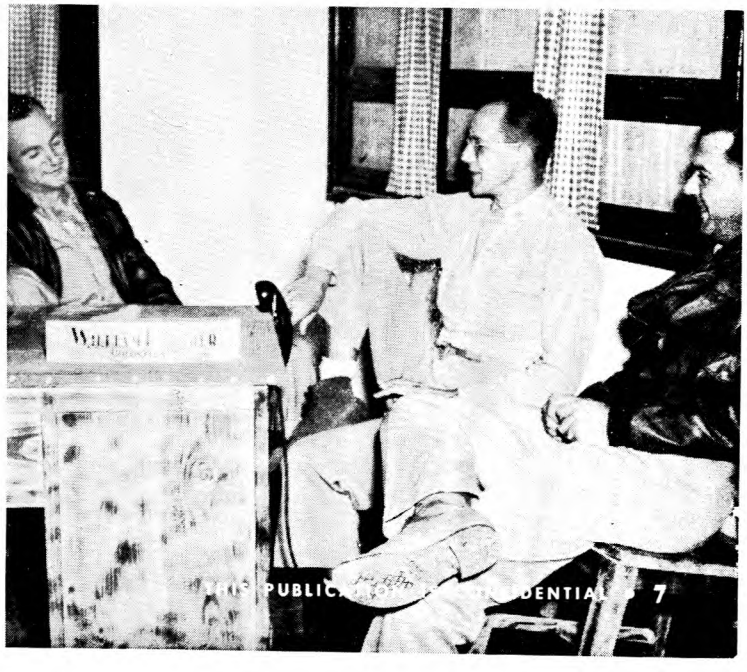
Crews talk of the day when they can work exclusively on LAB, can stop worrying about getting hold of gas for the next mission and can operate from bases that aren't under enemy assault and 500 miles from the scene of action as well. That seems to point to the Philippine Islands, smack in the middle of Jap shipping lanes. When they get there the lanes will be contracting northward, but not so fast that the crews won't be able to get their fill of hunting.

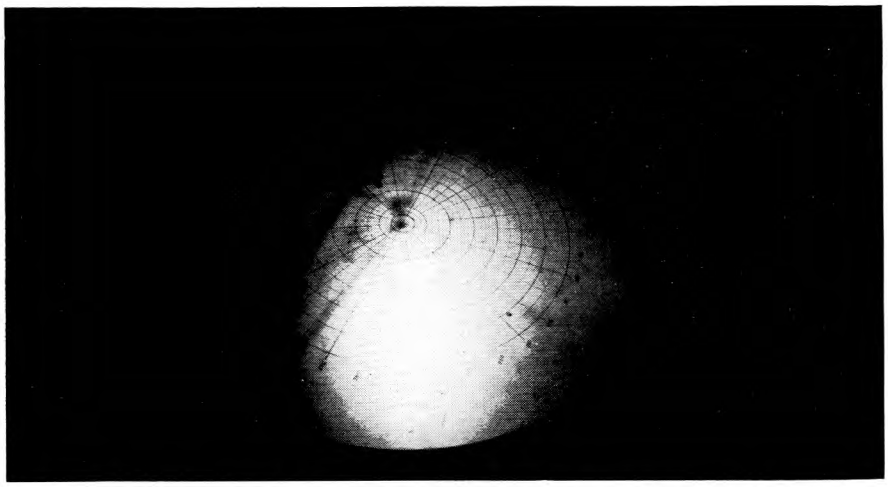
For all the troubles, things might have been much worse. Forewarned, the 14th AF's LAB unit came well stocked with essentials and joined a veteran bomb group whose morale was high.

Intelligence Officer can "sack it" from 1000 to 1300. Rest of day—and night—he briefs, interrogates, shapes combat data

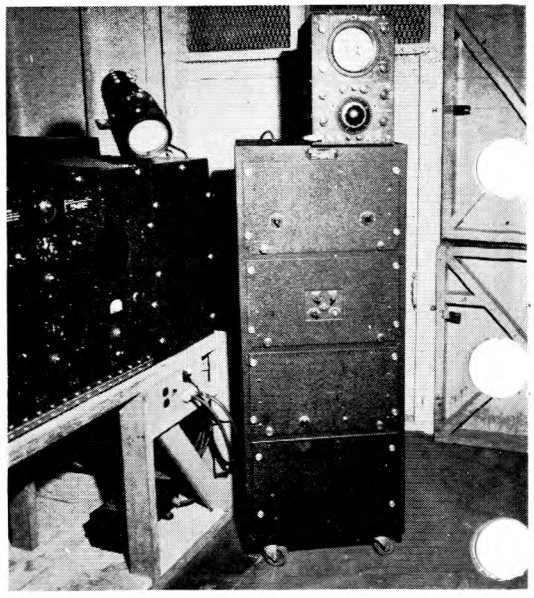


Headmen of China LAB (l. to r.): Col. Fisher (Group CO), Lt. Col. Hopson (Deputy), Lt. Col. Wm. H. Smith (Detachment CO)





LAB Training Squadron at Langley Field uses special trainer to ready radar operators, bombardiers. Trial results show on bombing map above, which instructor watches



SYNTHETIC TARGET for bombing problem comes from Echo Simulator Unit (above)

Target off Formosa: a typical sortie

It is 14 September 1944. Plane No. 715, brought up that day to a forward base near Liuchow, lifts heavily into the early evening dusk and heads for the South China coast.

In its wing are 2750 gallons of gas. It carries twelve 500 pound bombs, good for 4 runs against Jap shipping. Its IAS is 165 miles. If all goes well it will be out some 9 hours and cover about the same mileage as from Washington, D. C. to Denver.

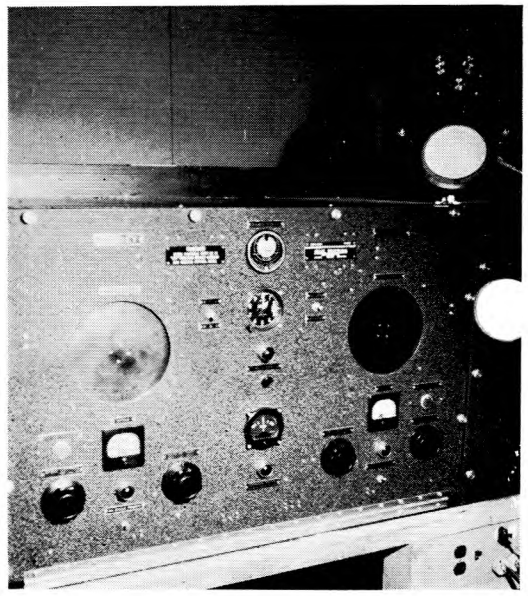
This is familiar territory, mountains and all. The navigator reads his PPI scope like a memorized map as No. 715 leaves the Jap-held coast and flies eastward into the hunting zone. The pilot heads down, way down, to check the pressure altimeter against the radar altimeter. Then up he climbs to search altitude and the radar operator starts looking. On other sorties the operator has spotted shipping as far off as 70 miles, but usually it's closer to 30 miles.

Not far off Formosa the radar operator calls, "Looks like something!" and focuses on it with his sector scan. He gives direction to the pilot, range and direction to the bombardier. But 15 miles away he says, disgustedly. "Sorry, gents, it's just an island."

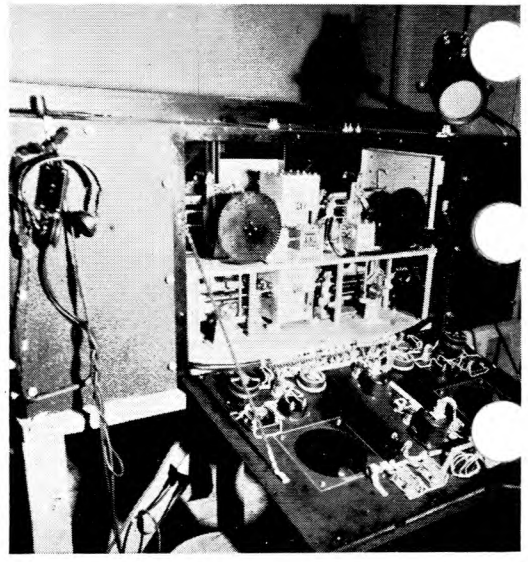
It's like deep sea fishing, waiting for something to hit the bait. At 34 miles the scope shows something. "This is it, sure," says the operator, and quickly furnishes the data. He calls off the miles as they move up through the night, and 8 miles away sounds off with the half miles. This is for the bombardier, who meanwhile has been tracking in range and bearing. The plane belongs to the bombardier as they hit the 8 mile mark and the bombing run starts. He flies it with automatic controls and he leads directly toward the blip. On his LAB scope the target area ½ mile to each side is magnified 8 times over the search position. Altitude is set in the LAB equipment, a predetermined air speed is maintained and everything is synchronized for bombing.

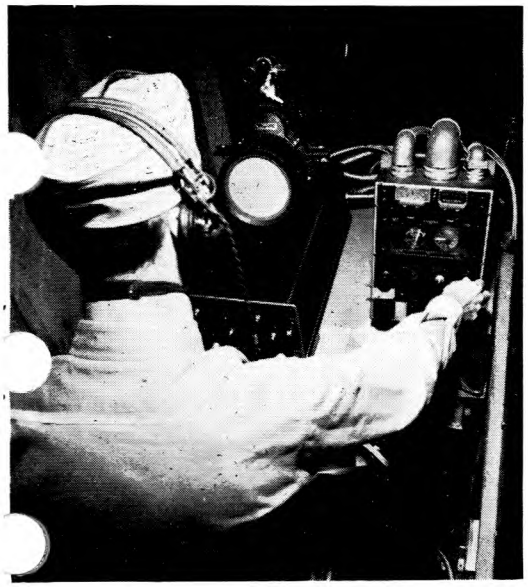
Three miles from the target the operator reports, "It's a big boy." The crew gets grimmer and more eager at the same time. The bombardier is glued to his screen, making his adjustments to keep the target centered and motionless on the crosshairs. The APQ-5 does all the computing as course and range corrections are cranked in.

With the blackness and the overcast there's nothing to see visually. Now they're only seconds off. Then: "Bombs away," sings the bombardier, though the actual release is automatic. The crew is quiet as three 500 pounders plunge seaward, one after the other. They can't see a thing, but several seconds later they hear the explosion and see a burst of light. That means a strike. They don't strafe and they use a flame-dampener so their own position won't be revealed. Now comes a tremendous secondary explosion that fills the sea and sky. They duck out, while the tail gunner yells over the intercom, "I saw her. She's big and fat, and she's going down sure."

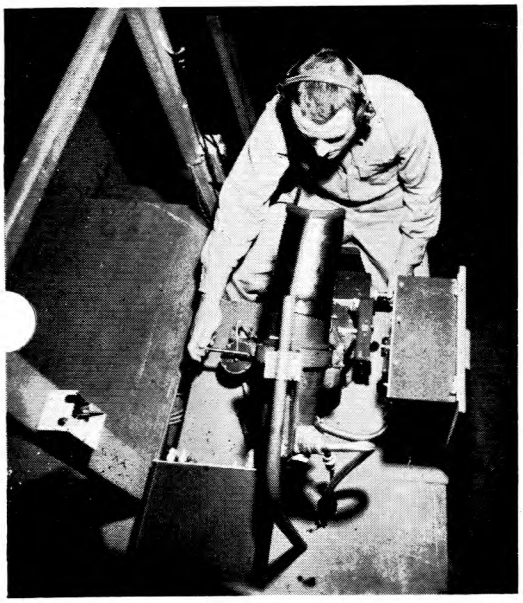


TARGET motion, wind, IAS feed into an Equation Solver Unit; innards below





RADAR OPERATOR (above) puts bombardier (below) on target. Then APQ-5 gets busy



BOMBING MAP traces plane's position by spot of light. Target is dead center



Training and practice get the results

UNDER the strain and split-second timing of LAB operations the most effective crews are invariably those with most training and seasoning; lucky strikes by green crews are few and far between. LAB squadrons get their training both at home and in the field, as the pictures here show. They get their seasoning from flying many a sortie like the one described on the opposite page. And then the interrogation officers get reports like those excerpted below (from 14th AF records, May-September 1944):

THREE SUNK, ONE DAMAGED

Four targets picked up 10 to 12 miles apart east of Hong Kong. The biggest was bombed first and sustained a direct hit. The blip disappeared in about 6 minutes. Thirty minutes later a run was made on the second largest for another direct hit. There was a secondary explosion, seen by rear gunner. The blip left the screen. The third ship was attacked and sustained a direct hit. The blip disappeared. New targets were seen, but these were identified as an island and 2 reefs during bombing run. Four ship convoy located. Salvo straddled lead ship about 30 feet astern. Target stopped while convoy continued.

ONE SUNK

Object appeared on the screen at 20 miles. Aircraft approached through overcast; indication was identified as a large vessel. Following LAB run crew observed 2 bomb flashes and heard an explosion. After 3½ minutes the blip faded out.

SUNK: TWO SHIPS, ONE JUNK

One hundred miles east of Kowloon made run on indication and discovered it was a 50 foot junk too late to hold release. Junk sunk. No damage claimed on second target. Third target took direct hit, exploded and sunk. Fourth got direct hit. Crew saw lifeboats in water, then ship go down.

CRUISER SUNK

Blip near Hainan was light cruiser. Direct hit on first run but didn't sink. Another bullseye on second run. Third run against heavy AA fire; third direct hit. Cruiser sank while aircraft was climbing to bomb again from higher up.

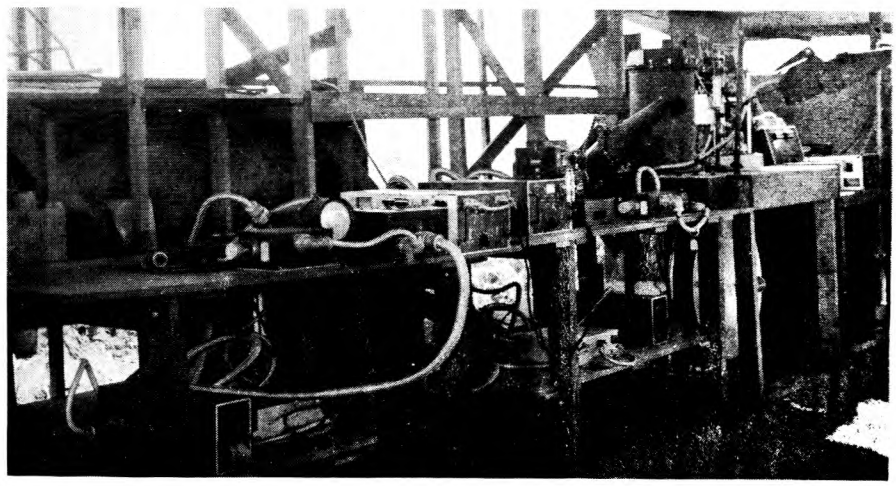
SHIP SUNK

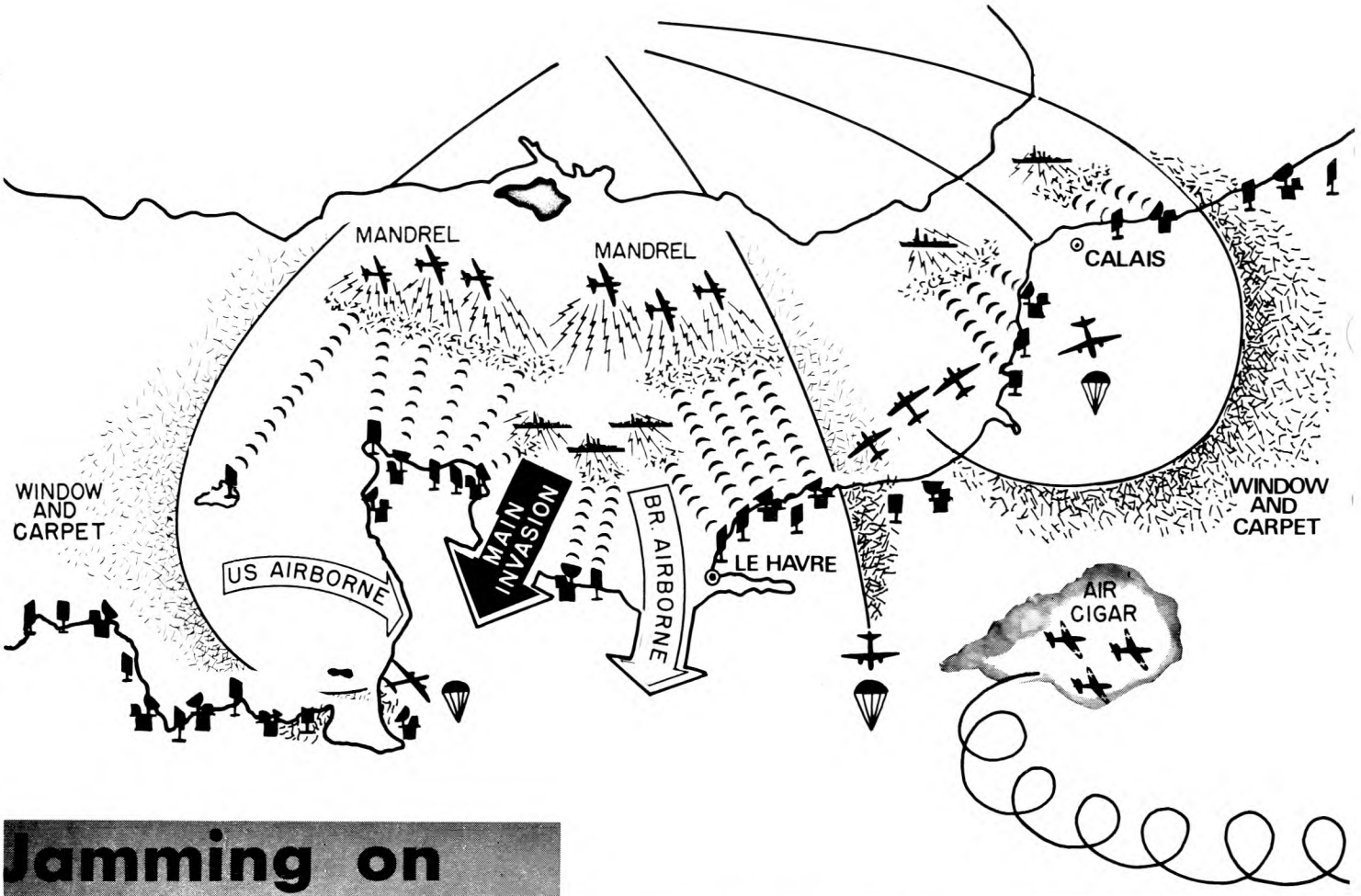
Dropped 3 bombs on 250 footer west of Liuchow Peninsula and confirmed sinking when blip disappeared from the target screen.

SUNK: ONE CRUISER, ONE TRANSPORT

Picked up convoy at 30 miles. Biggest blip in center bombed. Secondary explosion, sunk. Identified by rear gunner as 600 foot transport. Twenty minutes later made run on outside target (second biggest). Two bombs hit amidships. In light of secondary explosion seen as light cruiser. AA fire heavy.

5th AF trainer is abbreviated version of Langley setup, is credited with quick success of novice teams. L. to r.: target-controlling APQ-5, bombardier's APQ-5, SCR-717B





RCM pattern for the Normandy invasion is generalized in this diagram showing the extensive jamming of Jerry's radar defense. Window and Carpet diversions along with R/T jamming diverted enemy fighter opposition while air and seaborne jammers screened early warning radars. Similar RCM tactics were successful in Southern France.

Jamming on D-day: how it upset Jerry's radar front

● *So far as German radars were concerned, the invasions of Northern and Southern France were, among other things, very noisy affairs. Particularly in the north a large weight of explosives blasted coastal radars out of existence; north and south, the scopes of unbombed German radars filled with jamming noise as Allied forces threw the book of Radio Countermeasures at them. The RCM program for both D-days was built around the oldest of tricks—the feint. The maneuvers, significant as examples of the tactical role radar has come to play in the war, can now be reviewed in general. A detailed analysis of what went on will have to wait awhile.*

On D-day minus 2 the coast of Northern France presented a solid radar front—an active threat to invasion operations. Between Ostend and Cherbourg there was a major German radar station approximately every 10 miles. Actual count from Brest to Calais showed 6 Chimneys and 6 Hoardings for long range early warning; 38 Freyas for medium range EW and night fighter control; 42 Giant Wurzburgs for night fighter control, coast gun control and for use against low flying aircraft; 17 Coastwatchers; and Small Wurzburgs, one per flak battery.

Reduce this line-up by 82%—by more than that in the area around Cherbourg—and you have the German radar picture for D-day minus 1. The reduction was achieved by a blistering attack with bombs, rocket projectiles and machine guns. So thorough was the job that, according to one report, only one site was left operating within gun range of incoming invasion ships.

The first big task for RCM on D-day was to confuse what remained of the German EW radar system, which was still enough to constitute a special threat to operations of Allied troop carrier and tug aircraft.

On the night preceding D-day the confusion was accomplished by Mandrel (anti-Freya) jammers carried in 8 Sterling aircraft along the South Coast, and in 4 B-17s spaced to give cover as far as the island of Guernsey. Flying at 18,000 ft. for 5 hours these squadrons screened the approach of airborne forces to the French coast.

Meantime British Bomber Command aircraft carried jammers and dropped Window and dummy parachutists inland from the Dover-Calais area. Reacting

to these countermeasures German fighter strength spent most of the night circling over the Calais area. There were no fighter attacks on the 844 transports and 105 gliders of the 9th Troop Carrier Command, which landed or dropped some 15,000 troops with only 2% loss—and that due to heavy ground fire.

There were several other diversionary raids—each with personnel trained in the use of Window to simulate a full airborne invasion with only a few aircraft. In response, the Germans sent out numerous aircraft east of Cap d'Antifer, but none west of the Cap where the real threat existed.

A second D-day mission for RCM was to disrupt German R/T control of fighters. Initially German fighters were ordered to orbit Chartres, southwest of Paris and well back of the actual invasion area, to await hostile aircraft southwest of Evreux and Beauvois. Because of effective jamming with Air Cigar, the Jerries were unable to tell fighters the true area of attack.

Third RCM mission was to disrupt EW and gun control radar directed against surface operations. Thanks to 600 pieces of RCM equipment carried by the fleet, the seaborne invasion forces approached well within anticipated radar range before German coastal shelling began.

Countermeasures were prepared to interfere with navigational and bombing aids for German bombers in case of attack; unexpectedly, there was little such activity.

This large scale disruption of German radio and radar meant a lot of "jam", both U. S. and British, distributed in a relatively small area. To avoid interference all RCM activities were coordinated in a Combined Countermeasures Advisory Staff.

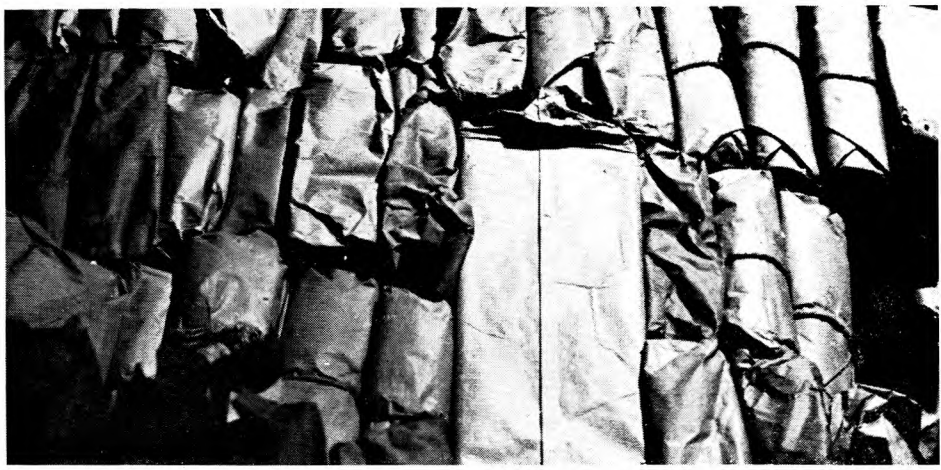
An operational RCM staff functioned prior to and on D-day to make immediate decisions on the employment of RCM and to make immediate changes if necessary.

Southern France

RCM activities in Southern France duplicated those in the north but involved more complicated diversionary activities and more RCM installations on U. S. ships.

Well in advance of D-day preliminary reconnaissance was undertaken by the 16th Reconnaissance Squadron (see

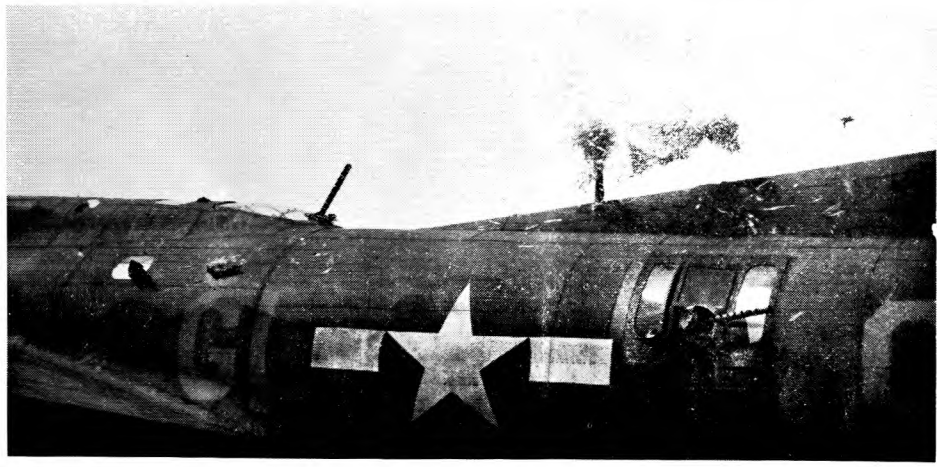
D-day or any day, Window does a job



Paper jam for Jerry's GL radar is in these packages of Window. Large package is U. S. type (CHA-3), small ones British. Both were used heavily for D-day deception

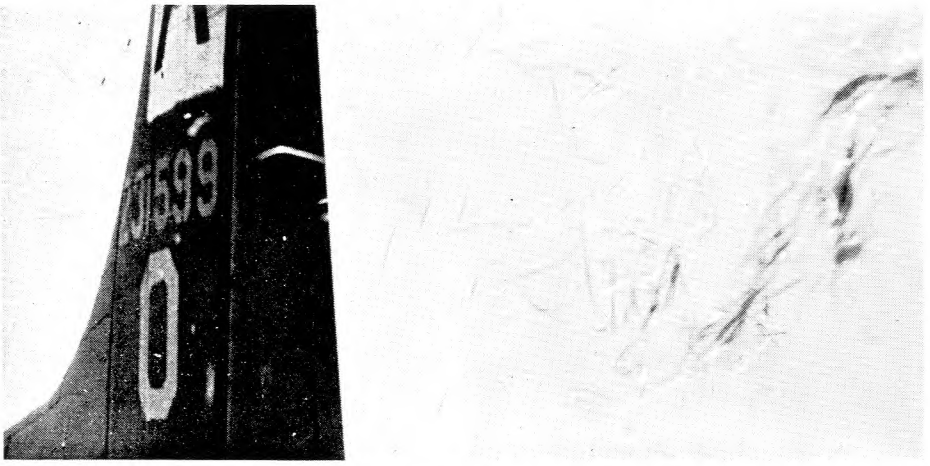


Bundles from Britain for jamming and spoofing German radar must be opened and units dispensed separately. Each package has 72 units, each unit hundreds of strips



Dispensing is done through chute at left (from radio compartment). One unit is just leaving chute here, another has formed "bird's nest", must break up to be effective

Window at work (continued)



Each floating strip, cut to German GL radar frequency, is now sending signal to operator. Signal from unit appears as dot of light which resembles heavy bomber



Enough Window to protect a squadron is here discarded, damaged on mission to Europe. Techniques to avoid waste and improve effectiveness are being worked on



Useful data for improving techniques come from interrogations. Here radio operator and navigator tell just how they used Window. Most crews say, "Give us more"

RADAR No. 5), the 1st Signal Service Platoon (Special) based on Corsica and photographic reconnaissance planes. There were major sites approximately every 30 miles along the beach with the usual dispersal of Small Wurzburgs around flak batteries. Coverage of these stations was plotted and the radar system analyzed so that jammer frequencies could be assigned to stations most threatening.

Because poor weather held up Allied fighters until D-4 the pre-D-day bombing of radars was not as effective as it had been in Normandy.

Of two diversionary operations, one on the left flank by the "Western Force" was by far the most emphatic. Just prior to H-hour this unit followed a complicated course leading in close to shore in the region of Toulon, then turning away again and finally going eastward to join the other forces. It was intended that this force put on a really good feint—and it did just that, as evidenced by a German broadcast that thousands of paratroops had landed near Toulon, that a large amphibious force west of the city had been repulsed.

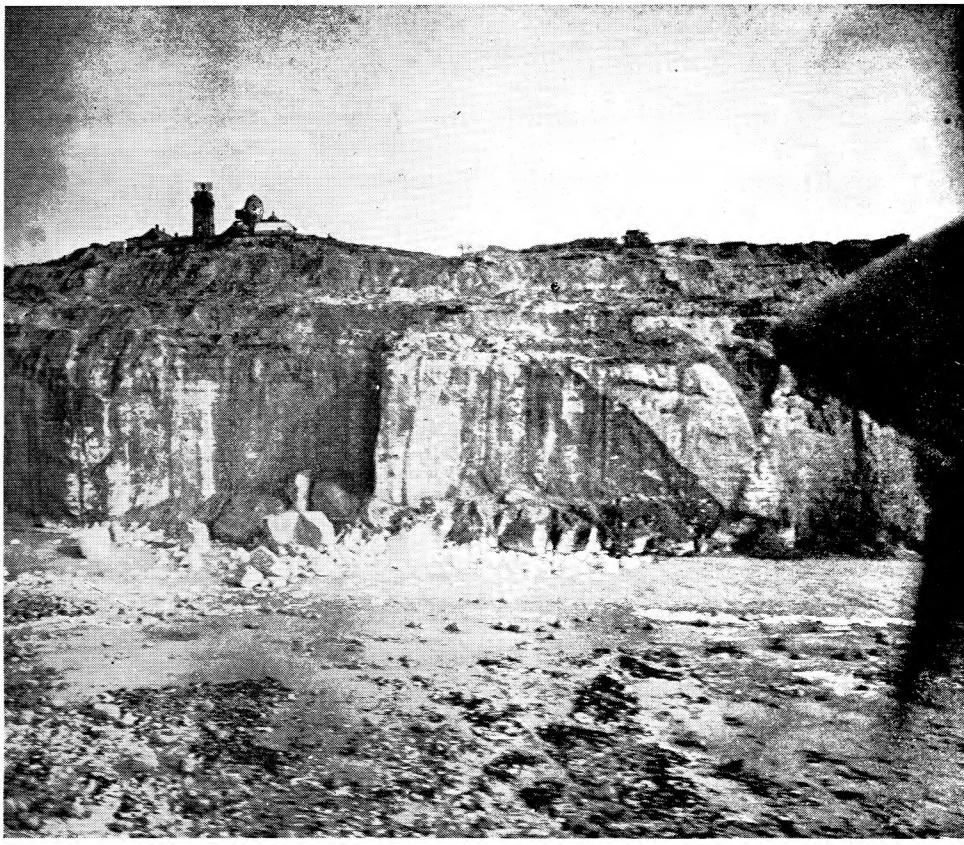
Naval forces approaching LaCiotat Bay were provided with an abundance of balloon reflectors, rocket Window and jamming transmitters. Other RCM equipment was installed in minelayers and even PT boats were equipped. Five C-47s came in between Marseilles and Toulon dropping Window and dummy chutists.

A second diversionary action, intended as a fairly obvious spoof, was carried out by an "Eastern Force." Prior to H-hour this force approached the region of Monaco and attempted to create the illusion of a large convoy with a few British gunboats carrying balloon-supported reflectors and jamming transmitters. It was fully expected that this fake would be recognized by the time the ships were within 20 miles of the coast, by which time the tactical purpose of the action would be served.

Support of the main assault forces in the Frejus area, where Troop Carrier operations were substantial, was accomplished by an airborne Mandrel screen similar to the one used in Normandy. In addition, ships were installed with Carpets and Rugs to jam Coastwatchers, Freyas and Wurzburgs. Listening posts reported that Coastwatchers were neutralized and 5 out of 6 went off the air altogether.



CHIMNEY type radar in Belgium was blasted by Typhoons in pre-D-day attack. Germans started rebuilding at once. Now construction of Chimneys is being rushed to serve inside Germany in place of lost coastal net



Just before D-day this still-life of German Coastwatcher and Giant Wurzburg was made by daring PRU pilot. Since D-day over 500 Nazi radar sites have been taken

Allies have been hitting German radar for quite some time

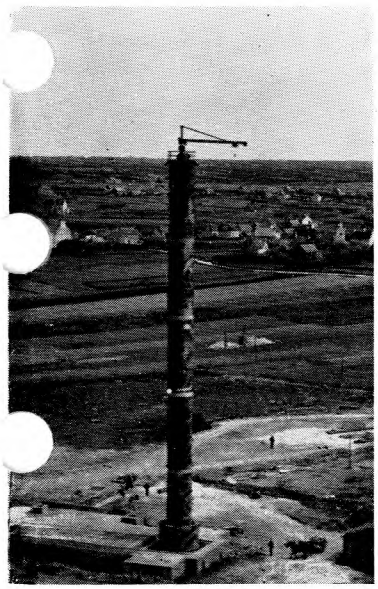
Between Cap de la Hague on Cherbourg peninsula and the Holland border, the Germans had approximately 75 major radar installations close to the coast. In circles crossing the main approaches of Allied aircraft the Germans studded permanent radar sites. The preceding 3 pages tell what was done about all this for D-day. More has happened since.

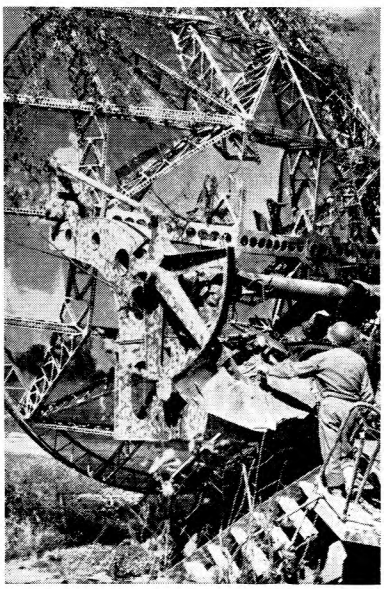
From 6 June to 1 October it is calculated that Allied armies overran more than 500 of the permanent sites in France, Belgium, Luxembourg, Holland —some 175 for Freyas, some 250 for Giant Wurzburgs. The number of Small Wurzburgs can't be calculated, but there was one for every 4 heavy AA guns.

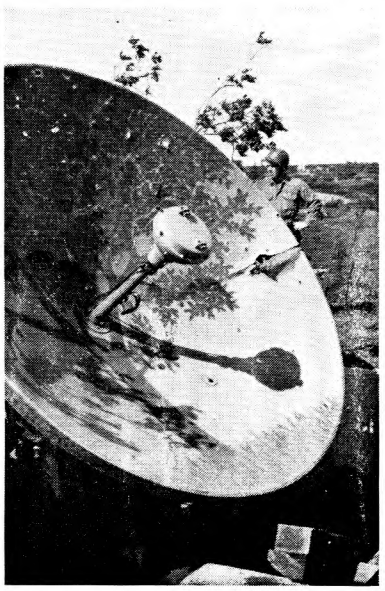
The Germans have now lost all of their early warning system right up to Germany. They are rushing construction inside Germany of additional Chimneys to take the place of those used previously along the coast. What else they may be able to do to recoup their losses remains to be seen. Some equipment, of course, was pulled back before it could be captured or destroyed. But they couldn't pull the ground back with them. And the consequence is that for many border targets early warning is no longer possible to the Germans.

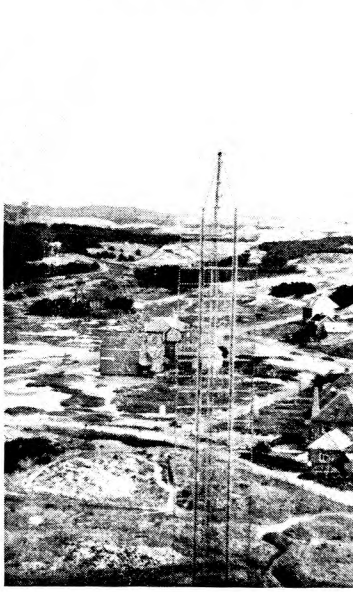
For more on German radar and Allied countermeasures, see page 17. For some highlights out of the history of the campaign against German radar since its first detection, see next 3 pages.

HAUL OF COMMON ITEMS LIKE THESE (CHIMNEY, WURZBURGS, WASSERMAN) HAS BEEN BIG. NOTE INGENIOUS CAMOUFLAGE ON SMALL WURZBURG





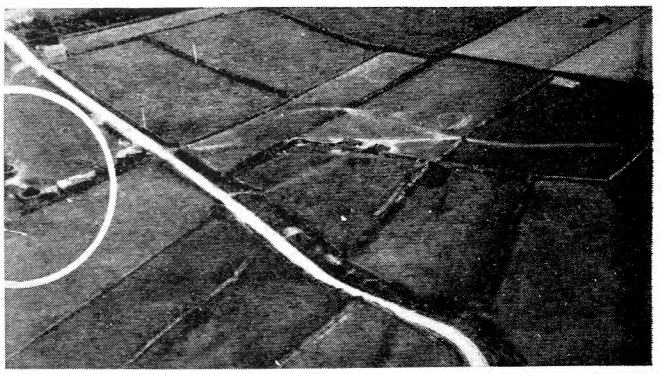




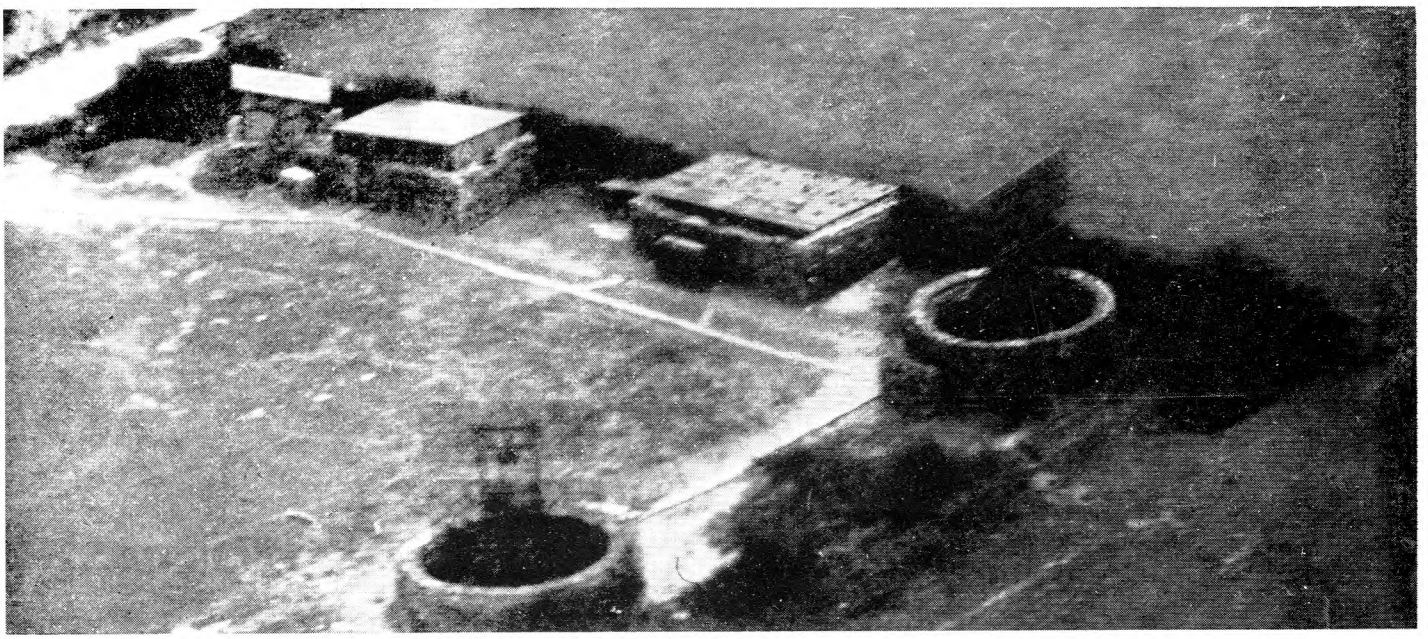
These historic photos show first detection of German radar



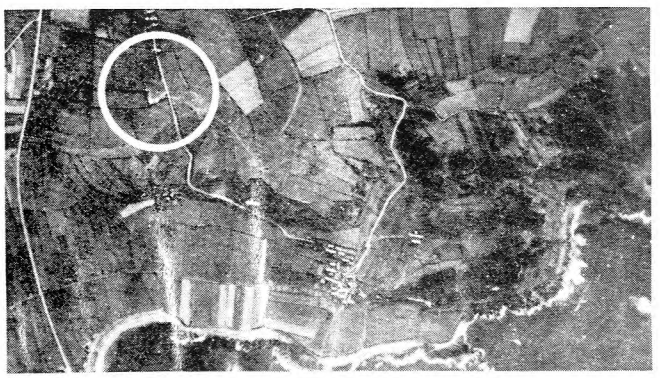
Circled objects in British PRU photo (22/11/40) could not be explained. To identify, special low altitude shot was ordered



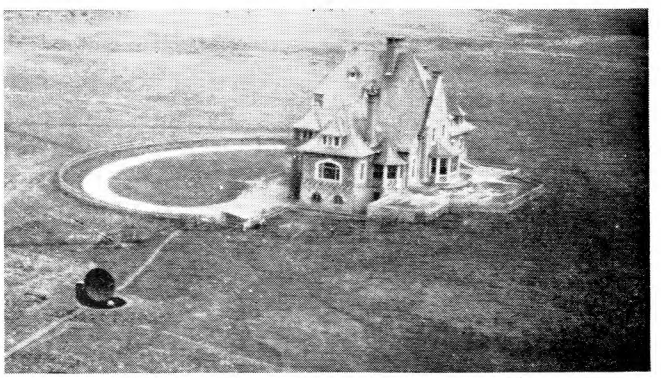
Partial success on first low altitude attempt (16/2/41) showed enough to prove Jerry had something, warranted another try



Courageous PRU pilot obtained this important picture 6 days later (22/2/41), just in time to answer question "Do Germans have radar?" being discussed at Air Ministry meeting next day. Details of picture provided data on frequencies and wave forms

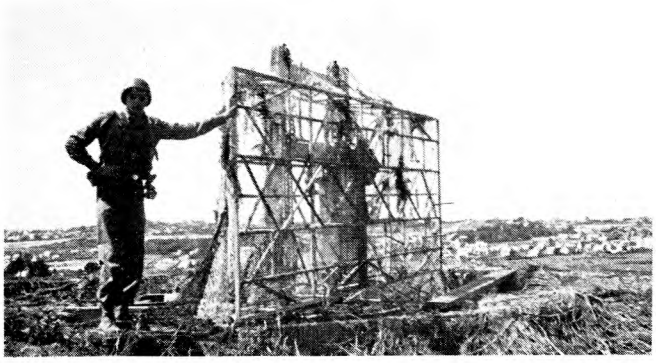


Two weeks later (5/3/41) reconnaissance showed Germans had moved their radar away. Site was at Auderville, near Cherbourg

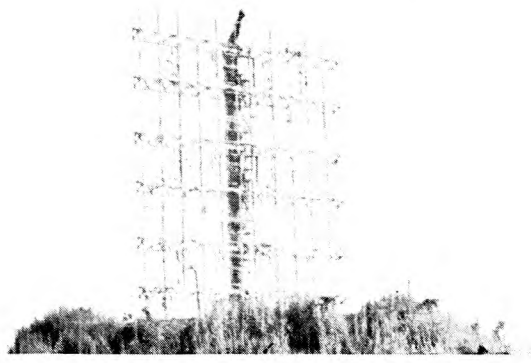


Soon after this photo was made (5/12/41) initial Commando raid brought back parts of Wurzburg shown, first of many captured

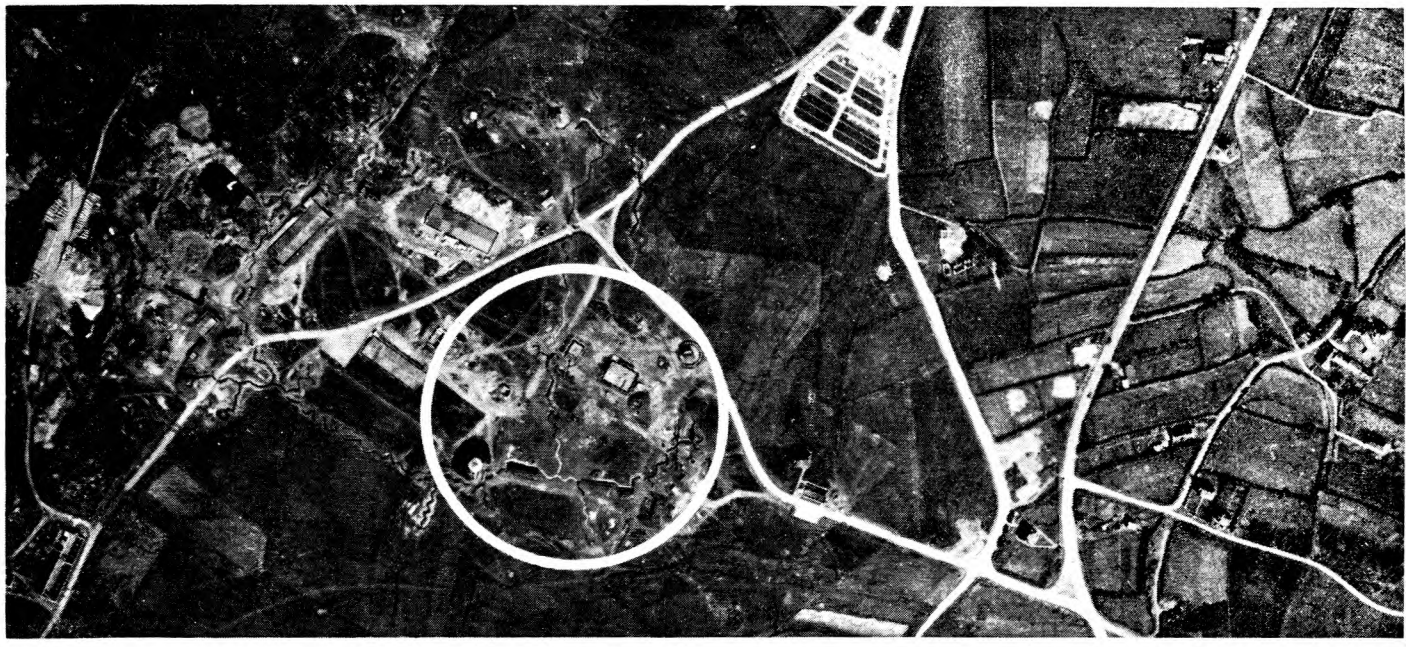
. . . and these were taken on capture of second known site



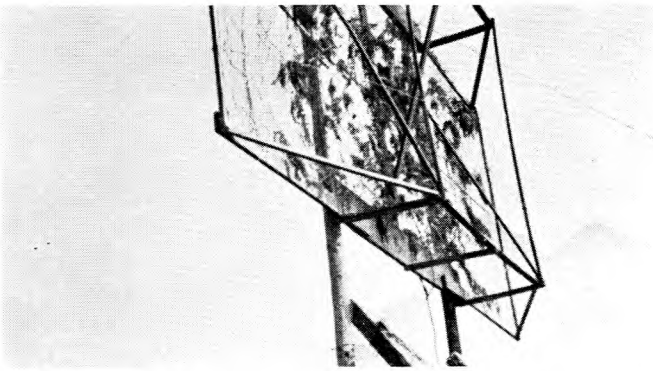
Well camouflaged Coastwatcher was part of Nazi setup bagged near Brest 12 August by AAF officers and civilian specialists



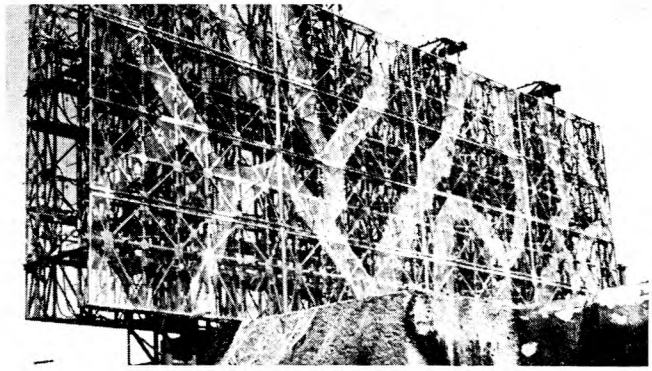
Early warning Freya, pole type, was captured, too. So were 450 Germans who insisted on surrendering to U. S. rather than FFI



Site, outside Lannion, was known to Allied intelligence long before this reconnaissance photo taken 24 July. This is one of earliest German radar installations in France, the second identified by intelligence. Location is 500 yards from Coast

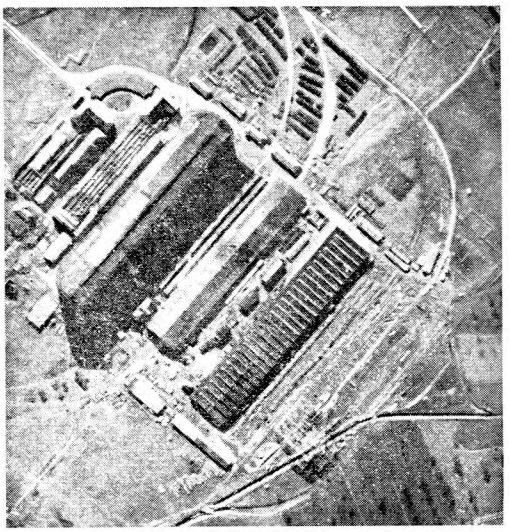


Decoy Coastwatcher was among finds, probably was constructed after Nazi garrison figured site was due for Allied attention

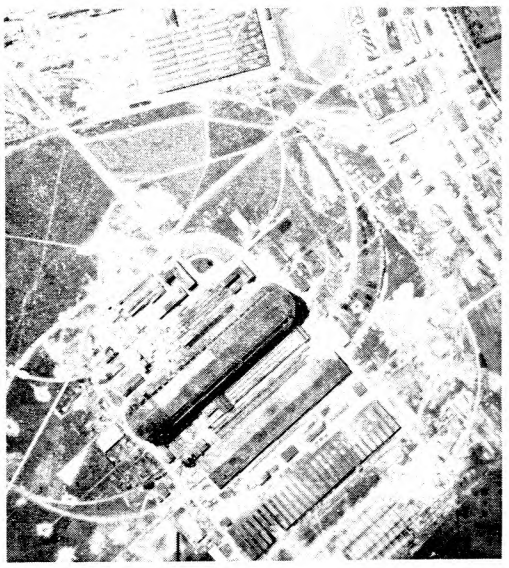


Hoarding, for long range aircraft reporting, was recovered in good condition. Since 12 August captures have been very heavy

RAF Zeppelin raid hit Nazi radar at source

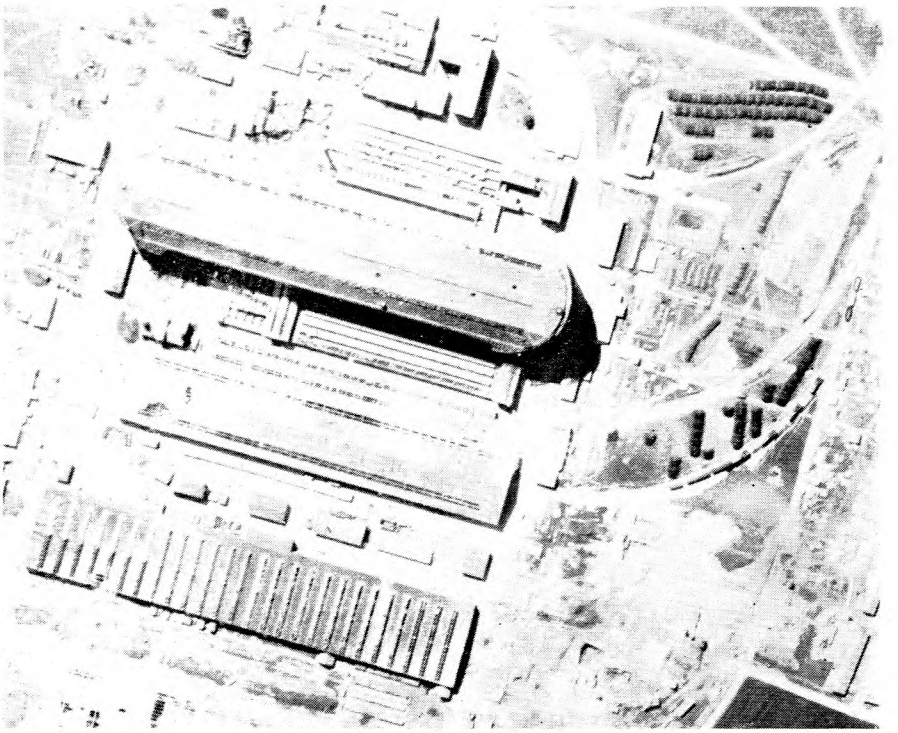


ZEPPELIN WORKS at Friedrichshafen were busy producing aerial arrays for the Giant Wurzburgs in February 1943. "Baskets" are neatly stacked at rear of plant

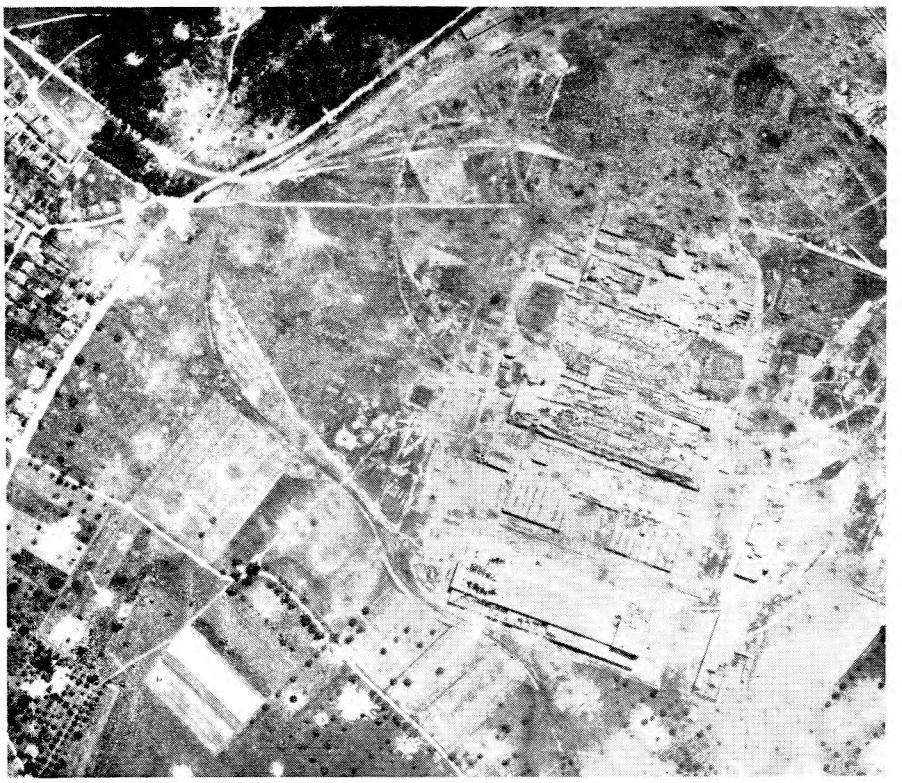


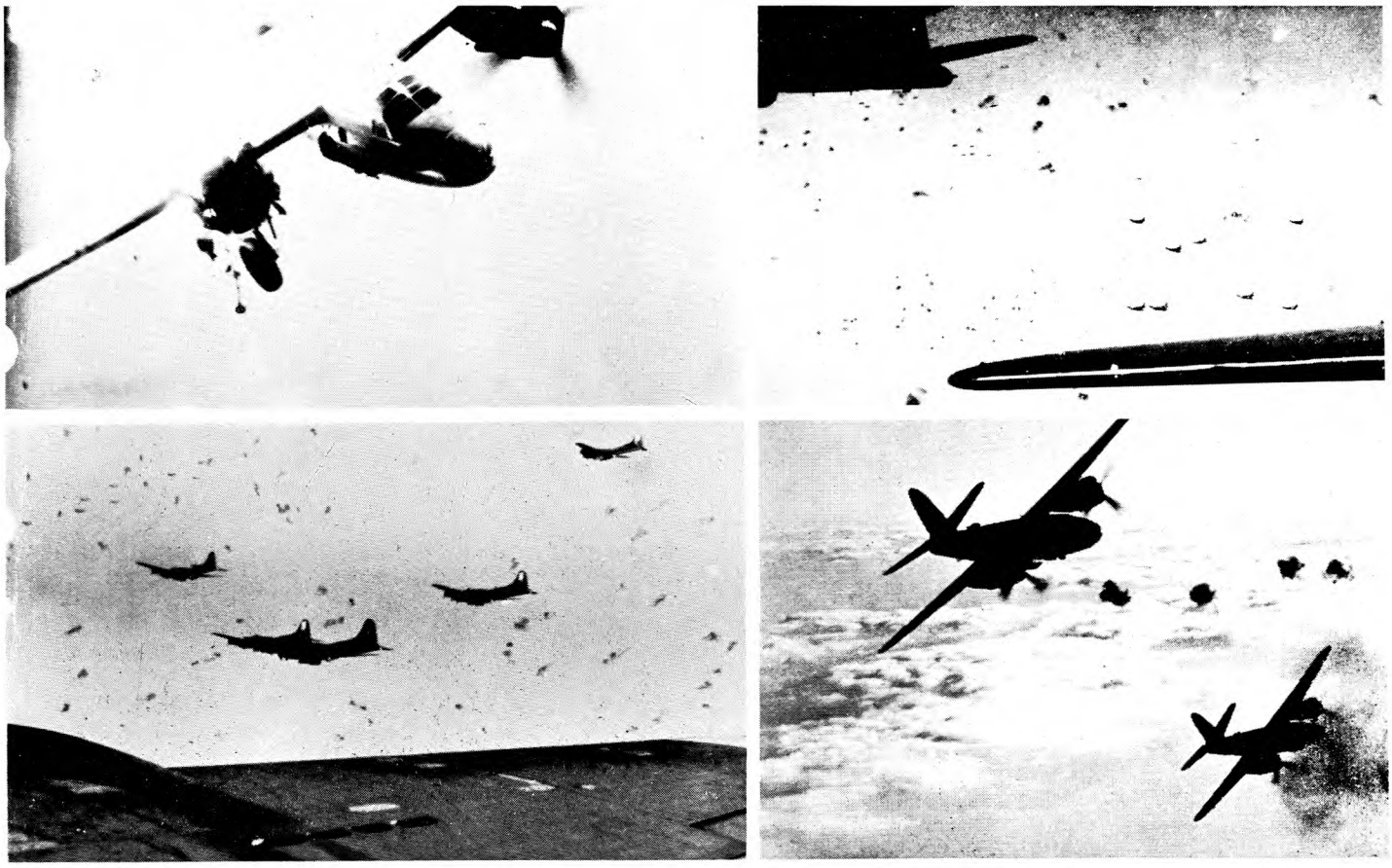
RAF RAIDS in July 1943 (above) and May 1944 (below) slowed, then stopped production, as seen by diminished stacks. But stacks soon started mounting again





Cue to PI Officer was rib-type light metal construction employed in making both Wurzburgs and Zeppelins—he measured diameter of stacked objects, found it matched that of Wurzburg basket. Finally, after partially successful raids shown at left, the RAF completely blasted Zeppelin Works in July 1944. Results are shown below





PLANES OF 8th, 9th, 12th AND 15th AFs FEEL STING OF GERMAN RADAR CONTROLLED FLAK. BUT JAMMING POWER AGAINST IT IS GROWING

Countermeasures war

A report on new developments in the Carpet-Wurzburg fight

To give the devil his due, the Germans have developed a first rate system for anti-aircraft fire control—for which Allied bomber crews have developed a healthy respect, and for good reason. Too often they have watched it punch substantial holes in their formations—night or day, clear or cloudy.

This consistent accuracy under both "seen" and "unseen" conditions is the handiwork of radar—most particularly, the Small Wurzburg. It is standard equipment for all German AA positions, and it is effective equipment. Angular accuracy is high (in one test of a captured set 80% of the readings were within .2° and 60% within .1°) and elevation accuracy above 17° is equally good. Effectiveness of the Wurzburgs has been bolstered further by plenty of practice on the part of their crews and by the very multiplicity of them.

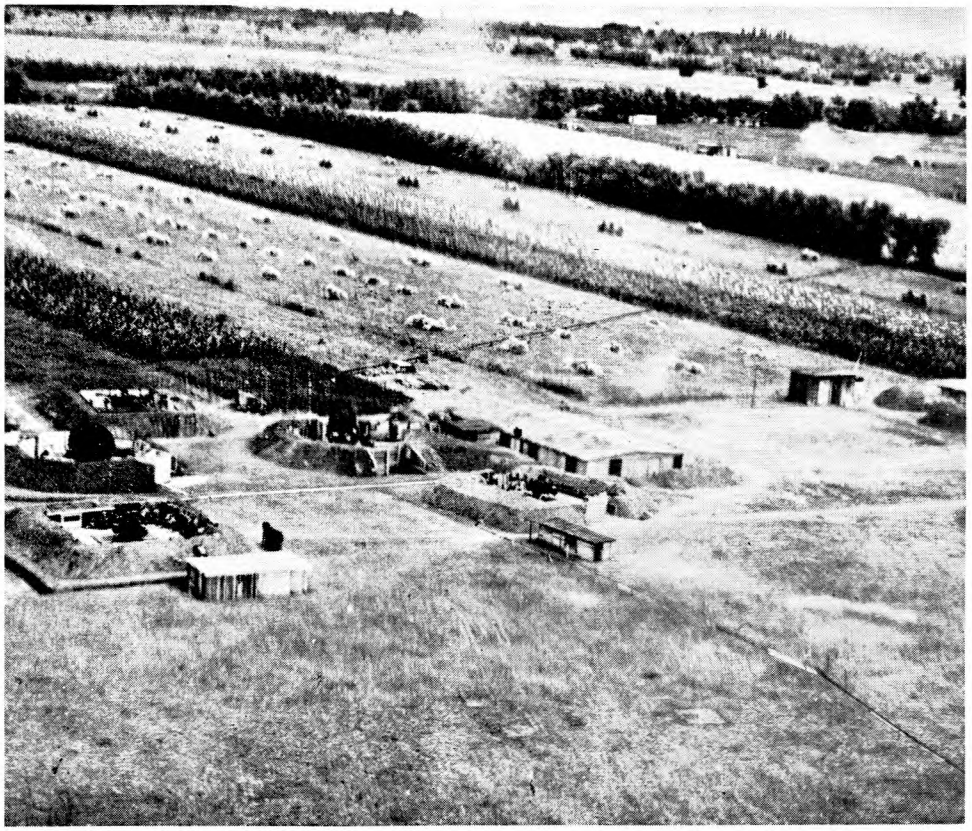
The Wurzburg "seeing eye" is good enough to pick up a single heavy bomber at 35 km. and transmit continuous range, bearing and elevation data automatically to the computing device. Originally produced in 1939, the Small Wurzburg—a mobile decimeter radar (wavelength 50-60 cm.)—has been modified several times. The latest edition, Type D, owes its accurate direction measurement to an off-focus rotating dipole giving split in both azimuth and elevation.

German flak is most deadly when it can combine Wurzburg range data with optical angular data—which means that radar has the added job of searchlight control for night attacks. When optical DFing is impossible radar takes over for complete control.

The density of these radars is such that Allied bomber groups are normally tracked simultaneously by half a dozen, while 12 or 14 may be brought to bear over the target. There is little wonder that our bombers run into flak trouble over targets like Hamburg, where 240 guns were arranged within an 11 mile radius, or Kassel, with 110 guns in a 4 mile radius. That's a lot of flak for any formation to dodge, and there's even more now that Germany has concentrated its defenses in the Reich.

Allied Air Forces haven't taken German flak sitting down. The situation has given rise to what might be called a war within a war where anti-flak and anti-aircraft procedures vie for supremacy. We jam their GL radar—they counter with new frequencies and techniques—we reply with higher powered jammers and improved tactics—and so it goes.

The following pages report on this countermeasures war in the light of some new developments in it. Its pros and cons might well be borne in mind as military emphasis shifts to the Pacific, for hard earned anti-flak experience against the Hun can be effectively used against the Nip. It is increasingly evident that Japanese flak is losing some of its inconsistency—our planes aren't getting as many free rides as they used to. As the noose tightens in Europe, lessons learned there will have to be applied more and more in the Pacific. These pages tell what some of the lessons have been.



Master site for radar control of German heavy AA battery near Ploesti, Rumania. Two Small Wurzburgs and 3 Kommandogerat directors control the guns which can be seen firing at upper right. Radar at left is probably the one tracking flight from which this photo was taken. B-24 flying through heavy flak is visible just above horizon.

Spot jamming with modified Carpet is good antidote for improved Wurzburg

The German fire control radar system continues to be a major threat because it is both accurate and fluid. Under fast changing battle conditions the Germans have been able rapidly to adjust their radar pattern to meet new situations. Because of that the flak problem has continued to grow in spite of effective countermeasures and impressive victories.

Though the Allied occupation of France took away from the Germans their elaborate advanced early warning and GCI radar network, the flak control has been, if anything, improved. Allied advances have occasioned a shift of emphasis—Small Wurzburgs have been wheeled from France and the Balkans back into the Reich and are now placed en masse around important industrial targets. Flying over these targets Allied crews are meeting just about the heaviest flak concentrations ever thrown into the air.

Against Allied advances in the laboratory the Small Wurzburg has been equally versatile. Our countermeasure program has been met by improved operating procedures and by at least 6 ingenious modifications of the Wurzburg to enable operators to read through jamming. In addition to this the frequency band has been extended so that now it covers more than 100 mcs. Wurzburg frequencies were formerly concentrated in a band 10 mcs. wide.

Several of the modifications were designed to aid operators in distinguishing between true and false echoes. One method used the Doppler effect (radio frequency of the blip is altered by an amount proportional to speed of the target along line of sight) by locking the transmitter with a small oscillator ensuring coherence of RF phase between the pulses. Another device used an audio presentation of propeller modulation of blips to identify the true target. Subsequent trends were toward simplification of the procedure for changing frequency, and alteration of the split presentation to enable split DFing on an airborne jamming signal.

Initially these modifications were thought to be ineffective owing to a serious loss in range involved in making them. According to evidence from prisoners of war captured in Normandy the modifications have been considerably improved and are held to be of real value by the enemy. Practically all Type D Small Wurzburgs in the Cherbourg area were fitted with some or all of these modifications.

Effective jamming of Wurzburgs has also encouraged the enemy to experiment with altogether new devices. His latest is the Mannheim, already beginning to appear in the field. It seems to be a development of the Small Wurzburg with more power. Its range, bearing and elevation operators look at meters rather than scopes, and track planes by turning controls to keep pointers at the center of dials. It is highly probable that Germany is working on still newer types of fire control.

Expectations now are that German radar with PPI presentation—at long last—will be operational in quantity very shortly. The advantages of microwave still seem to be out of the German radar world. There is evidence of a microwave point-to-point communications system in the range of 15 to 23 cm. but no conclusive indication that such wavelengths are in current use for radar.

Allied countermeasures, in meeting the German flak problem, have brought about enough reduction in flak losses and damage to constitute a major victory. They cannot, of course, stop flak completely. Their use has generally forced the enemy to use his less accurate visual range finders under "seen" conditions of fire control, and to fall back on less effective barrage fire against many blind attacks.

The resort to visual range finding is more of a handicap than it might seem at first blush. It makes for a substantial cut in the length of time one of our formations may be engaged, provides only spot readings instead of a continuous measurement of range to the predictor, and gives a less accurate measurement of slant range. Sharpest reductions have come when the target was smoke or cloud covered, but they have been considerable even in good visibility.

Responsible for the results are Chaff (aluminum strips for creating false

echoes—see page 11) and noise modulated transmitters for electronic jamming (see RADAR No. 3).

And along with these measures time-proven tactical procedures are in constant use. Formations flying over flak protected targets pay particular attention to spacing between planes, altitude and axis of attack. It is the combination of tactical and radar countermeasures that has made our anti-flak program effective.

Of the transmitters, Carpet has been able to deal the most telling blows to the Small Wurzburg. Carpet seems to be about the best answer yet to Germany's accurate fire control and recent applications and improvements indicate a considerable rise in its effectiveness.

An all-out Carpet program has been held up heretofore by a lack of equipment. But equipment is now arriving in the theater in substantial quantity—enough to allow a current installation rate in excess of a group a day. Installation crews have been set up to speed the job. Carpet I, the original jamming transmitter, has been supplemented by a big brother, Carpet III, with about 4 times the power and jamming ability. And equal quantities of both sets are about ready for action in the biggest countermeasure program yet attempted.

Prior to Wurzburg improvements, "barrage" jamming was the accepted Carpet procedure. With this system the transmitters are pre-tuned to a fixed frequency before take-off, each Carpet on a different frequency throughout the Wurzburg spectrum, in an attempt to blanket the entire band. This makes for effective jamming, but to accomplish it each plane must be equipped with several transmitters—a large order.

The lack of sufficient quantities of equipment in the theater—and the effects of German anti-jamming work—encouraged the perfection of the "spot" jamming technique. With this system Carpets are tuned *in the air* against exact Wurzburg signals, as detected by an airborne radar search receiver. The point of the spot technique is to produce a maximum jamming of the most dangerous GL radars with a rather limited number of operational installations—and it does just that.

During July sorties over flak-defended targets one bomb group using Chaff and barrage jamming with Carpet I had a 2.55% loss to flak, and 5.5% major damage. During August spot jamming went into effect in the group and loss fell to .4%, major damage to .8%.

As barrage jamming is analogous to shooting with a shotgun, spot jamming is like shooting with a rifle. The rifle is Carpet I and its sight the "Blinker" search receiver—Wurzburg serves as the rabbit. The jamming procedure amounts first to detecting the GL signal with the search receiver (sighting the rabbit), then tuning the jammer to that signal (drawing a bead and firing). If the Wurzburg changes frequency when the jamming starts (rabbit starts to run) the operator can follow with the receiver and still fire effectively.

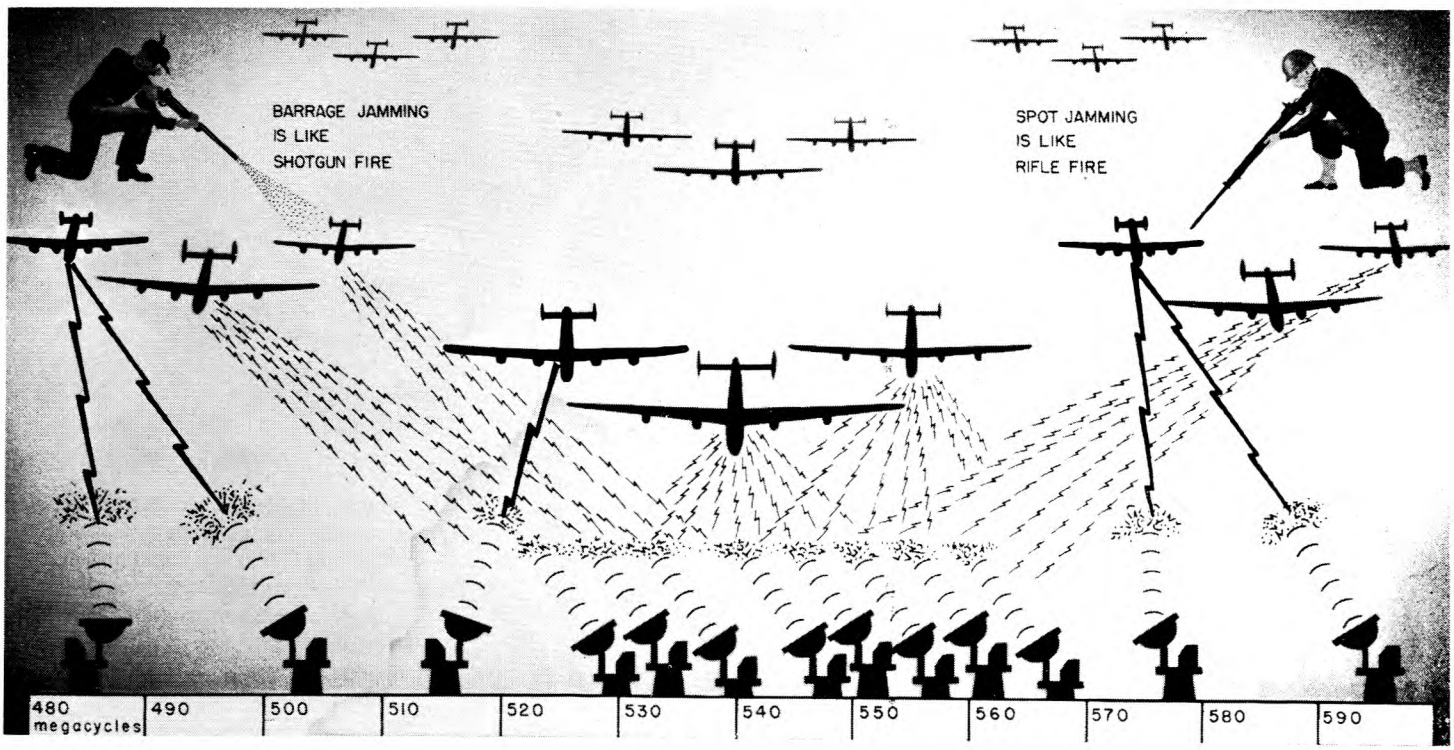
Using the search receiver and a bank of 3 Carpets adapted for spot tuning, the 3 strongest GL signals can be picked out and jammed. As the plane moves beyond range of one jammed radar the RCM operator retunes the Carpet to new stations emitting stronger signals.

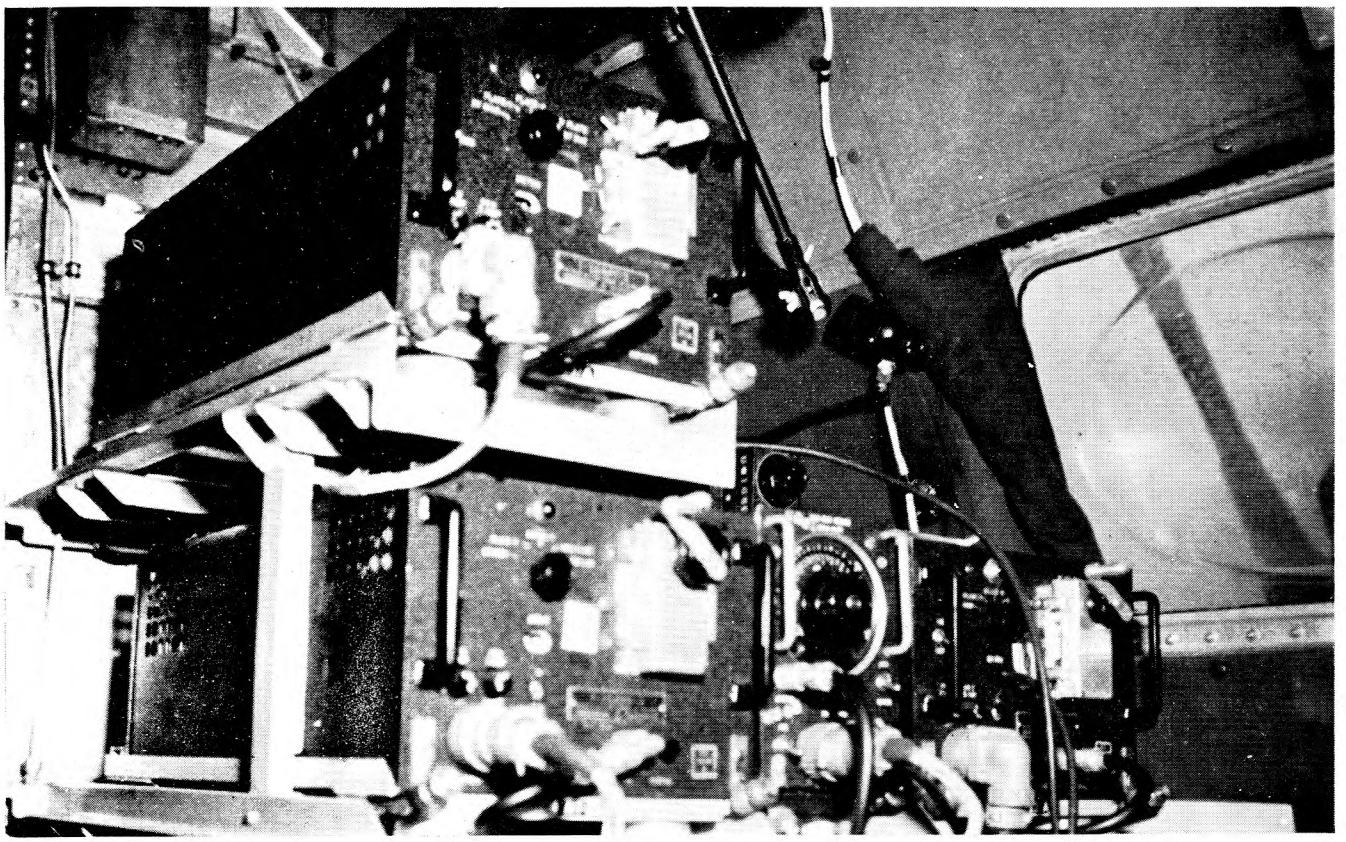
It was once thought that barrage jamming with 2 transmitters in every plane would more than blanket the Wurzburg band; now, in view of the Wurzburg frequency spread, and our tendency toward smaller formations, it appears that barrage alone on such a scale would be inadequate.

A large scale spot program might provide a quicker solution to the problem, but such a plan would require an additional specially-trained man for every Carpet plane.

The solution lies in a combination of barrage and spot jamming, as pictured below and described on next page.

Jamming pattern to screen all planes in a formation against gun laying Wurzburgs is shown below. 2 or 3 spot jamming planes per combat box, each with 3 transmitters, jam straggler frequencies while 2 Carpets in every other aircraft barrage crowded parts of the spectrum around 560 and 530 megacycles. This desirable situation is rapidly becoming fact with special teams in the theater installing Carpet I and III in a group per day—one 8th AF division is already equipped





Spot jammers installed to right of radio operator in B-26 medium bomber. Two Carpet I's modified for spot jamming are at left: third is at extreme right with "Blinker" receiver between. Window is covered in flight so neon light indicating enemy radar signals can be seen. B-24 installation is in cramped radio room with the Carpet sets stacked vertically

Barrage-spot combination blankets GL radar with minimum equipment

Eighty to 90 percent of the Wurzburg signals are still in the original band (560 mc.), and most of the others are in the secondary band centered around 530 mc. With a high powered barrage coverage of these frequencies and spot jamming of the stragglers, the entire Wurzburg spectrum could be effectively blanketed with a minimum of equipment and personnel.

Carpet programs of various designs are under way in the 8th, 9th and 15th Air Forces, but they are generally similar. The present plan in the 8th Air Force is to have 2 planes for every combat box of 12 equipped with 3 transmitters for spot jamming—the other 10 with 2 Carpets for barrage jamming. Since boxes will be separated by 3 to 5 miles, mutual protection will be impossible and each box will have to protect itself.

At this writing, however, the plans are still plans and operations are going on under the following Standard Operational Procedures. Three planes per group, or one per squadron, are Carpet-equipped and each has a bank of 3 Carpets plus search receiver. The special RCM operator in one plane searches the high frequencies—another the low—and a third tries for full band coverage. If squadrons of the group attack different targets each operator guards the entire band.

No jamming is carried on at a distance of more than 30 miles from enemy territory. By aural discrimination of PRF the operators avoid GCI Wurzburgs (low pitch) and concentrate on the more dangerous GL sets (high pitch). Since GL radar gets its most important information during the first 5 minutes of tracking, and it normally takes the RCM operator one minute to tune in, identify and jam, he should



SPOT JAMMING is made possible by this crank arrangement on Carpet I geared to tune both grid and plate. Ground adjustments can be made to enable rapid tuning in flight on the desired part of the band

know his job well enough to reset each of the 3 transmitters every 3 minutes to jam new frequencies. Transmitters are frequently turned off to determine if the radar is still tracking.

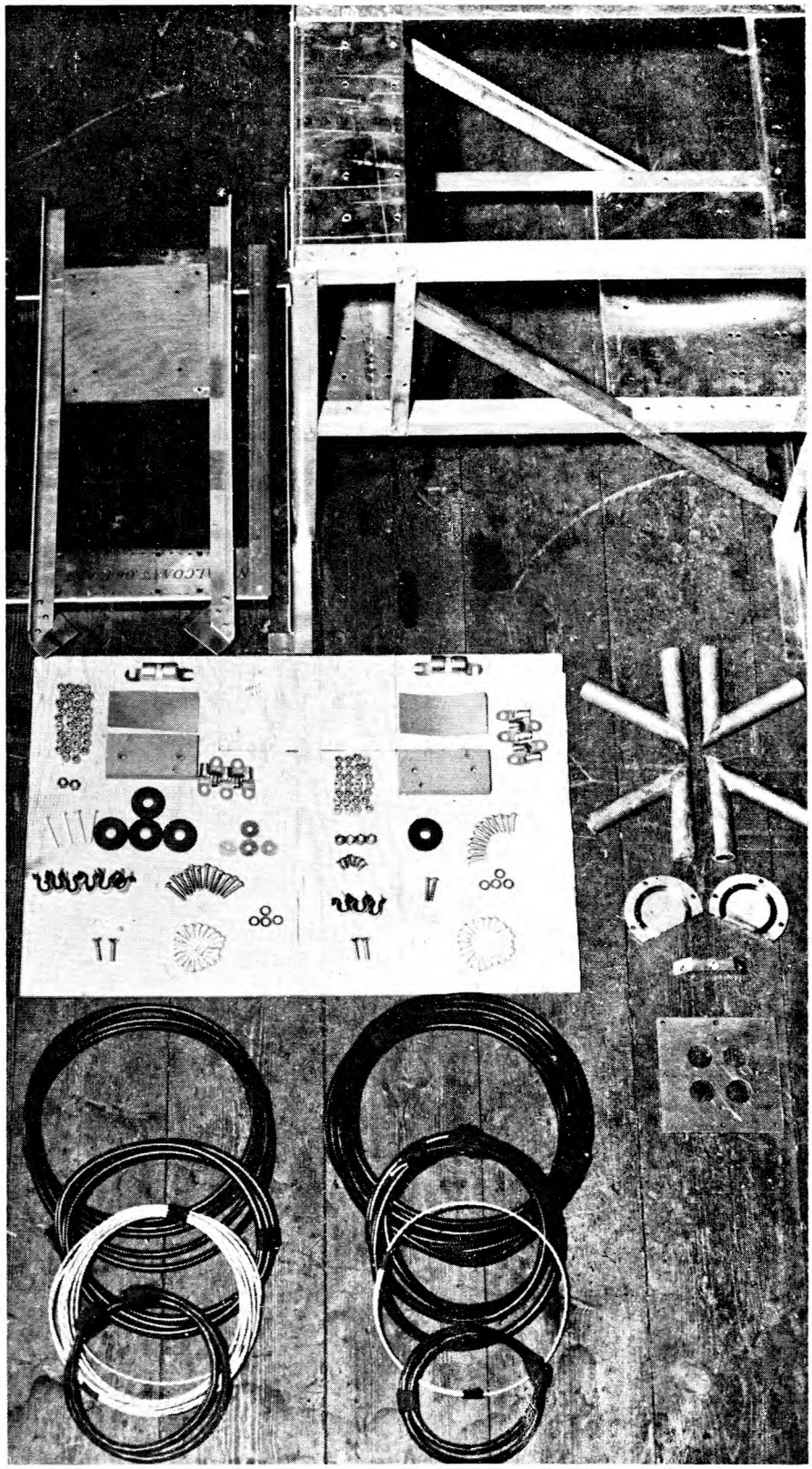
The jamming signal of Carpet prevents enemy AA gunners from obtaining a radar range, and also reduces the accuracy of bearings obtained on either a formation of Carpet-equipped bombers, or non-equipped planes flying within a half mile. The recommended procedure is for Carpet to be flown in leading positions, so it can protect the otherwise vulnerable leading edge.

Actual tests of Carpet I against a Small Wurzburg show that a single set can reduce the range against a B-17 to about 3 miles, with the transmitter tuned within a half megacycle and equipped with the improved AS-69/APT (fishhook) antenna. On this basis it may be expected that an operation could reduce the maximum range against a formation to 5 or 6 miles.

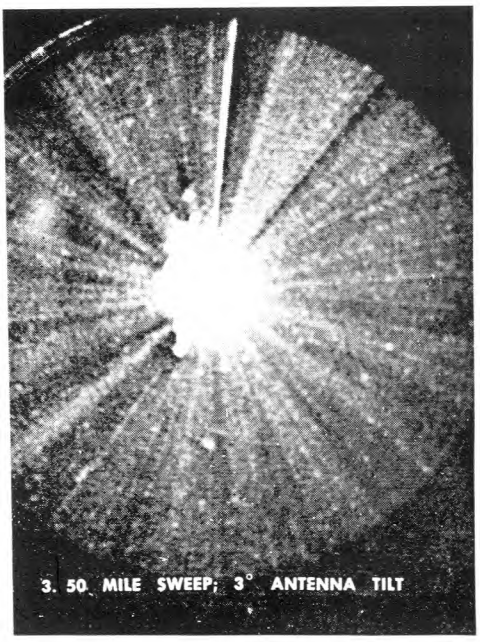
Now moving into the theater are still newer and better RCM equipments to supplement the jamming program. The new AN/APT-5, with about the same power as Carpet III, will be suitable for either barrage or spot jamming up to about 1200 mc. in case GL frequencies go that high. Another transmitter, especially suitable for barraging crowded parts of the spectrum, is AN/APT-4, with about 40 times the power output of Carpet I. It can jam the Wurzburg down to about one-sixth the maximum range obtained against the Carpet I.

Although two-thirds of our flak losses occur over the target area where batteries are highly concentrated, and most counter efforts have been designed with this in mind, attempts are constantly being made to save some of the one-third lost enroute. One experimental program which promises to do much toward this end involves the use of receiving and DFing equipment for determining the location of gun laying radars in the path of Allied formations moving over. With the advance warning thus provided it may be possible to make minor changes in route to avoid flak.

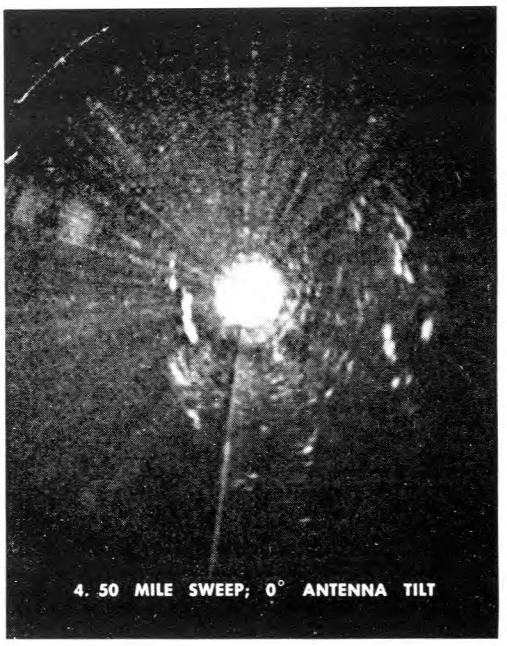
Generally speaking, past efforts in the Allies' RCM battle against German GL radar have kept the odds fairly balanced. What with present plans and a better flow of equipment with which to execute the plans—and this report does not cover the whole picture—it looks like the scales are about to be sharply tipped in our favor.



Manufacturing ingenuity at base depot in England speeded Carpet activity in ETO. On-the-spot production of mounting racks, antennas, screws, washers, bolts, nuts helped keep Carpet flying until supply schedule could be met—such hardware is lost more than sets themselves. One group lost all or part of 50 setups before a single transmitter was used and 13 jammers had to lie idle until parts could be made for them



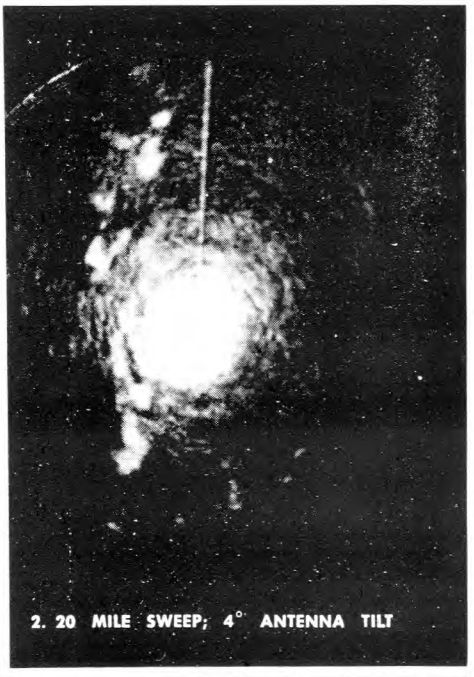
3. 50 MILE SWEEP; 3° ANTENNA TILT



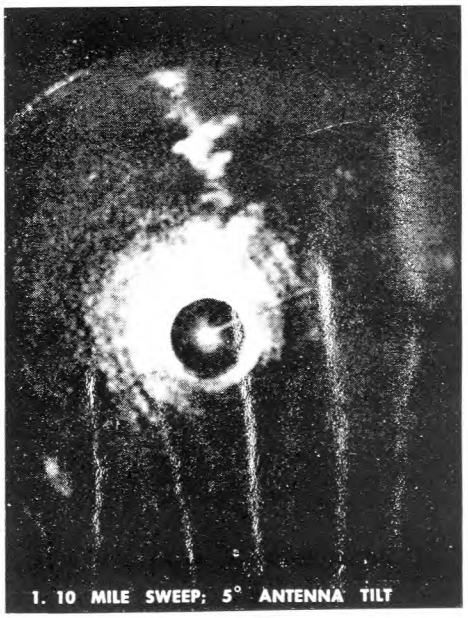
4. 50 MILE SWEEP; 0° ANTENNA TILT



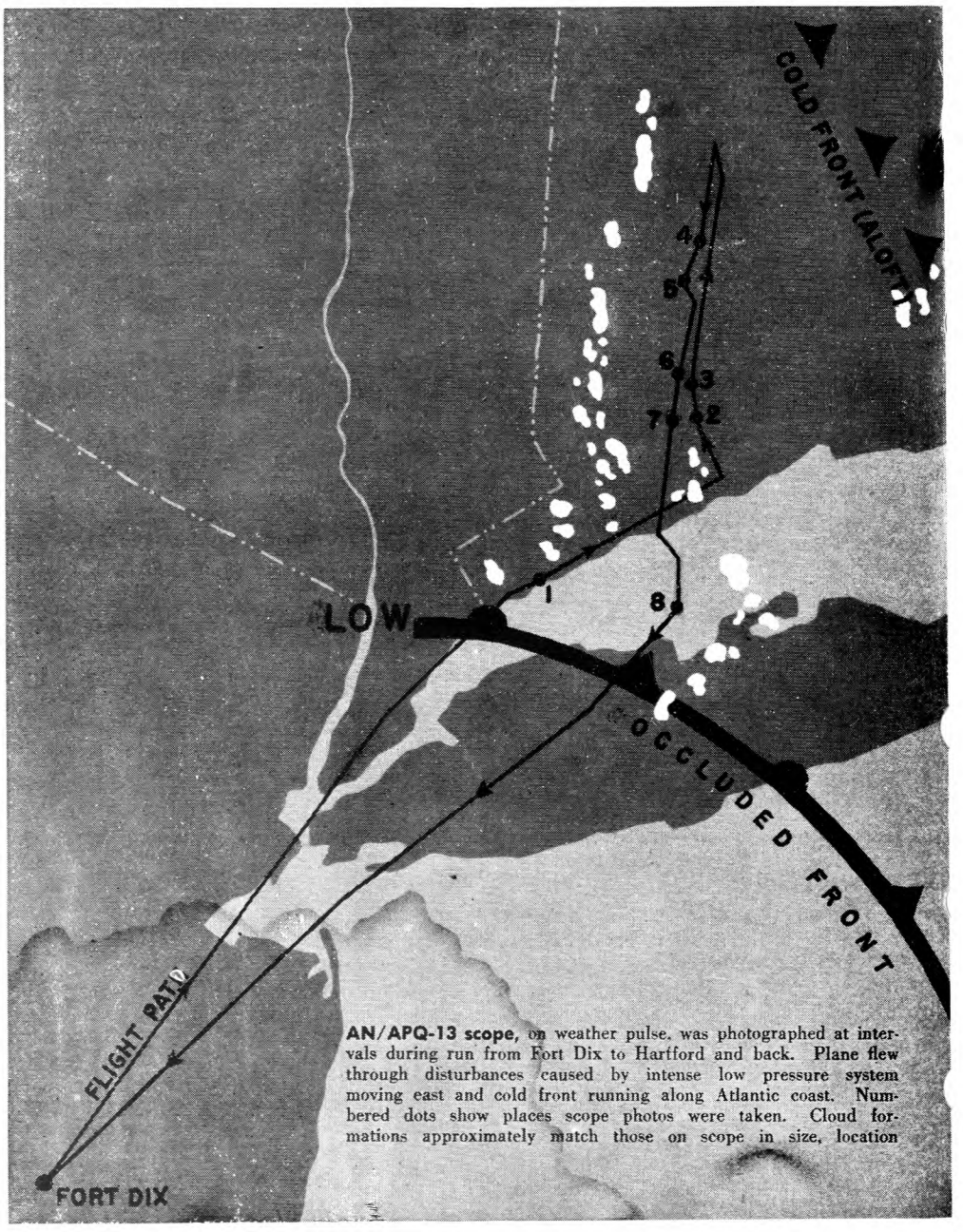
5. 20 MILE SWEEP; 0° ANTENNA TILT



2. 20 MILE SWEEP; 4° ANTENNA TILT



1. 10 MILE SWEEP; 5° ANTENNA TILT



AN/APQ-13 scope, on weather pulse, was photographed at intervals during run from Fort Dix to Hartford and back. Plane flew through disturbances caused by intense low pressure system moving east and cold front running along Atlantic coast. Numbered dots show places scope photos were taken. Cloud formations approximately match those on scope in size, location



6. 20 MILE SWEEP; 0° ANTENNA TILT



7. 10 MILE SWEEP; 6° ANTENNA TILT



8. 20 MILE SWEEP; —3° ANTENNA TILT

Radar for storm hunting

Weather checking by airborne radar, long planned, begins

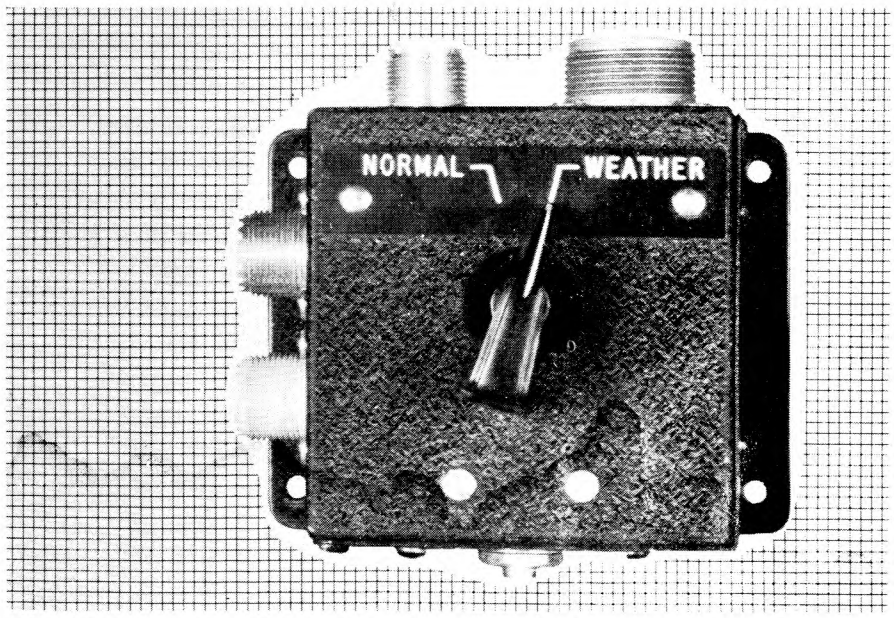
On a ramp at the Washington National Airport a few weeks ago sat a B-24, fresh from the modification center. You had to look hard to tell where the work had been done. It looked like any other B-24J. Inside there was a not unusual amount of radar equipment —Mark III IFF, 2 radar altimeters, SCS-51 blind approach system and the AN/APQ-13. Only clues to the plane's true mission in life were a 6″x6″ black box marked "WEATHER" located just left of the PPI and a manual entitled "Modification of AN/APQ-13 for Weather Reconnaissance" which had been left at the radar operator's position.

Three months ago not one radar-equipped weather reconnaissance plane was to be found. First experimental installation, a mock-up in a B-25, was started in May 1944 but the first real radar-weather planes didn't make their appearance until the middle of August. By now there is a squadron of B-25s for weather work, part of which has been assigned to the CBI theater. As for the B-24, it's a member of the 655th Bombardment Squadron which will be providing weather information to units of the 20th Air Force in the very near future.

Weather reconnaissance missions are flown for the very good reason of getting meteorological data which otherwise wouldn't be available. Useful in compilations of current weather reports, the data may further be used to construct weather maps over ocean areas or enemy territory. Information gained by radar means supplements the standard methods of weather measurement.

A cloud is just another airborne target—but not all clouds are radar targets. One big objective in radar weather study right now is to determine which are and which aren't. It is going to take increased knowledge of the mathematical and physical aspects before complete answers can be given. Meantime, it can at least be said that it is the presence of water droplets within a cloud which causes reflection of part of the energy passing through them. Only clouds of considerable density will scatter enough energy for detection at microwave frequencies—drops contained in fog or drizzle are too small to give any appreciable indication. In general, strong radar echoes are returned only from very active convective clouds. Since these are the clouds that spell trouble, the weather planes are going to work.

Drawings on opposite page and page 26 by W/O Ralston Crawford, Weather Division, HQ, AAF



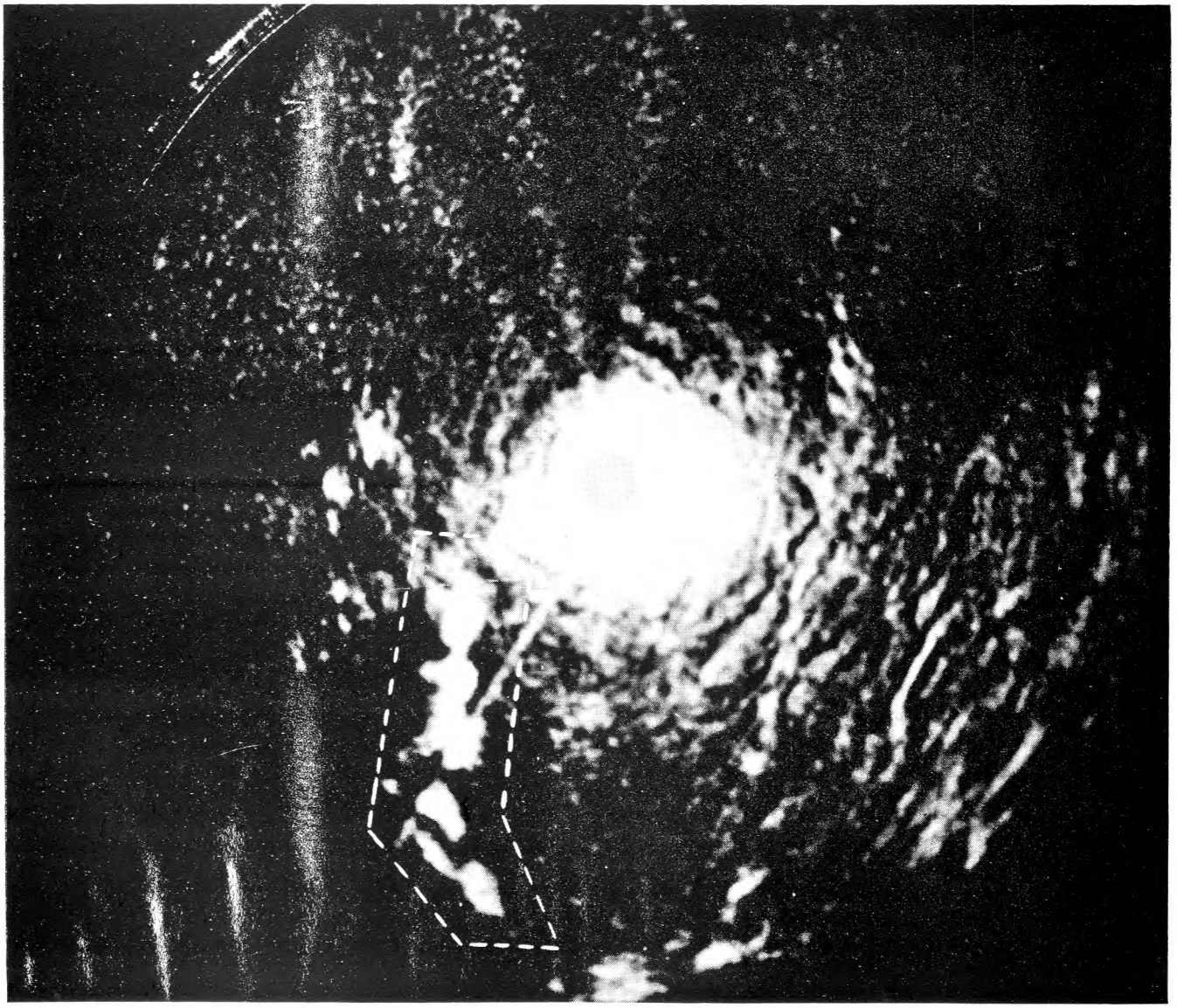
Little black box that makes it easier to see what kind of cloud a cloud is. Switch changes ordinary APQ-13 operation to longer pulse, turns on A-scope presentation

Modified APQ-13 gets most from clouds

All things being equal, the radar sets using the higher frequencies are the best storm detectors. Some of the early longwave radars are relatively insensitive to clouds; on the other hand, attenuation caused by absorption and scattering takes place at extremely high frequencies. On any X-band set, attenuation effect is negligible but at higher frequencies it becomes progressively greater.

Atmospheric echoes may sometimes confuse a radar operator who is looking for something more concrete than a cloud on which to drop his bombs. They are, however, easily enough recognized by a trained weather-radar operator who is familiar with their usual appearance and habits. Most cloud echoes show motion with respect to the terrain and their velocity is usually equivalent to that of the winds aloft. They are picked up at distances varying from the minimum range of the set to far beyond the normal range for fixed ground targets. On the scope, a cloud usually has a fuzzy and irregular appearance with indistinct boundaries. On occasions, cloud echoes have been known to mask even relatively strong land signals.

For weather reconnaissance, the APQ-13 is modified to include A-scope presentation. The additional scope is installed a few inches to the right of the PPI and can be cut off when the radar is being used for navigation only. This is done by a two-position switch marked "Normal" and "Weather." Most recent A-scope modification (APA-36) acts almost like a microscope for weather detection. It is possible to take a 5 mile section anywhere on the range scale, from 0 to 100 miles, and put it on the A-scope in order to get a really good look at it.



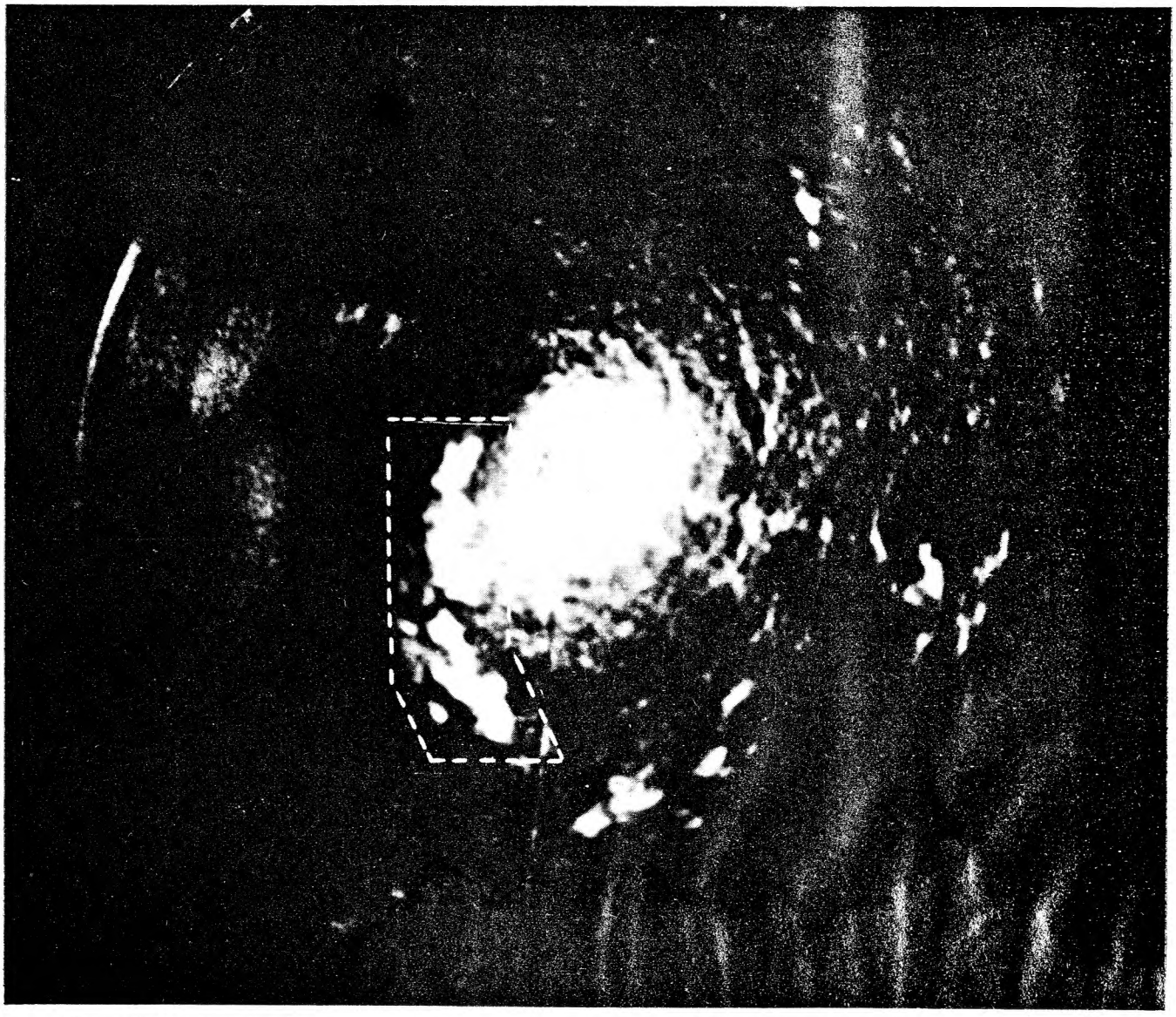
Outlined area shows concentration of storm echoes. Aircraft equipped with APQ-13 do not require modified version of the set to pick up and avoid storms. In this case, the plane was heading directly into disturbance at an altitude of 9500 feet

A-scope indication is important because of the nature of weather echoes. Cloud echoes, for instance, are characterized by very rapid fluctuations of signal strength and very often it's these fluctuations alone which identify them. Because of the persistent properties of the PPI scope, quick changes in signal strength are not apparent—the brightness of the echo appears constant. The A-scope, on the other hand, is non-persistent so the same type of echo appears as a flickering brightness, revealing the nature of the cloud target. Generally, a cloud echo shows on the horizontal time base of the A-scope as a large number of pips of unequal height forming a lacy pattern that is easily recognized (when using the A-scope for identification, the antenna is pointed and held in the desired direction for as long a time as is necessary).

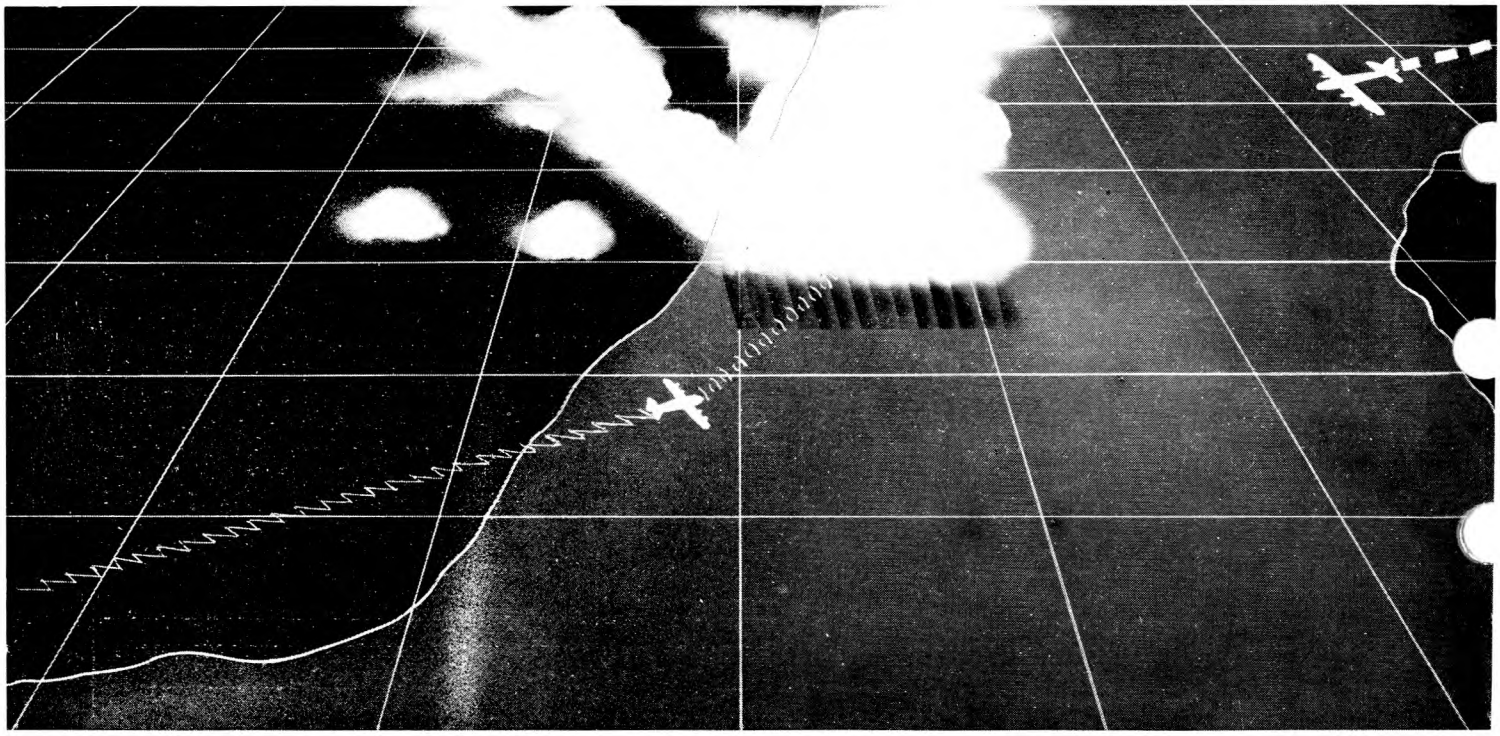
A second modification of the APQ-13 is a change in pulse length. The echo from a cloud increases in strength with increasing pulse lengths—therefore, longer pulse for APQ-13. On normal operation this set has a pulse length of $1\frac{1}{2}$ microseconds for the 5, 10 and 15 mile ranges, $1\frac{1}{8}$ microseconds for 50 and 100 mile ranges. Modified for weather reconnaissance, a $2\frac{1}{4}$ microsecond pulse is employed for all of the ranges.

Radar identification of storms is easier over water than over land since there are no fixed targets on water surfaces. In order to eliminate somewhat the ground clutter received from land areas, the antenna is tilted upward. With APQ-13 equipment it is possible to tilt up the antenna 10°, although unobstructed coverage above the horizontal is possible in all directions only at small angles. For storm detection with APQ-13 an altitude of at least 10,000 feet is generally used, high enough to put the plane above most storm centers.

How weather reconnaissance planes with the modified APQ-13 are scheduled to operate in combat areas is told on next 2 pages.



Five minutes later: the pilot has changed heading enough to avoid storm altogether. In some cases large gaps in storm areas which would not be visible to the naked eye can be picked out by the radar and planes can vector themselves safely through



One logical use of weather reconnaissance squadrons is shown in drawing above. Radar equipped aircraft, ranging out from a VHB base, detects heavy storm area moving in toward path of returning bombers, reports size, nature and velocity of the disturbance back to base. Safest action for the bombers to take is determined and transmitted to them before they reach the storm area

B-29s benefit by radar reconnaissance

In Pacific areas weather is an enemy second only to the Japs in treachery. There are too many tragic tales about too many planes lost—not due to enemy fire but to weather. Ground weather services can't begin to give meteorological forecasts to cover vast areas where there is ocean, and then more ocean, with no observations available. What is more, it isn't a case of layer-type overcasts moving in at a regular rate. Treacherous turbulent areas and quickly changing frontal cumulus that seem to come from nowhere are a constant threat to air operation.

Radar-equipped weather reconnaissance squadrons sent to the Pacific and CBI theaters will supplement, through aerial observation, the AAF ground weather service. B-29 units in particular should benefit from the improved weather product. Due to increased range of VHB aircraft and the fact that B-29 bases are few and far between, it is difficult to tell by ordinary means whether the big bombers will run into storm conditions during a mission. The danger can be greatly reduced by sending out weather reconnaissance aircraft before the mission, and that's precisely the plan.

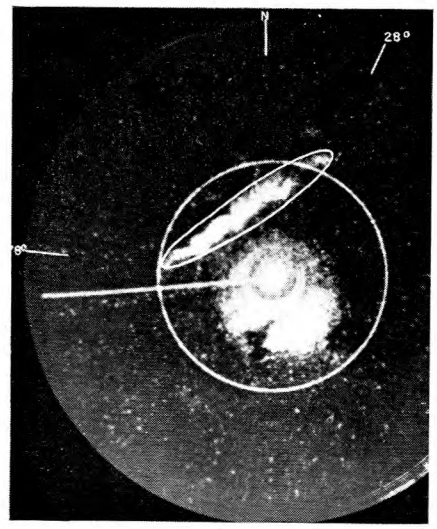
The area covered by these storm hunters is increased approximately 100 miles by their radar so that storms within a considerable range can be detected. (APQ-13 will detect the presence of severe thunderstorms up to 100 miles, weak cumulonimbus and well-developed convective clouds to at least 50 miles). The information, together with a knowledge of the characteristics of weather in a particular area, enables a sufficiently accurate check on disturbances at any given time. With such details provided, the timing and flight plan of a bombing mission may be planned accordingly.

Just as important is the task of getting the bombers safely back to their bases. Weather squadrons equipped with APQ-13 will be able to get information to determine whether or not home bases will remain open, whether the bombers can be given a different heading around the "weather" and safely routed in or should be sent to other bases.

On reconnaissance flights, radar storm observations are taken simultaneously with the usual weather observations at 30 minute intervals. The approved procedure is to report time, position of aircraft, position of storm area relative to aircraft, size and shape of storm area, fraction of area covered by echoes, and intensity of echoes.

Storm echoes may often be scattered all over the face of the PPI, making individual echo reporting impossible. Signals can be examined and identified singly on the A-scope but they are reported to the ground station in groups along with a description of the area and extent of the group.

It has been found that an ellipse serves to describe position of weather indications as received on the PPI. Intensity of the echoes within the ellipse is esti-



Ellipse drawn around storm echoes on PPI is used to report location of disturbance to ground weather station (see text)

mated qualitatively—as strong, medium or weak—by the brightness of the signal on the PPI. The operator determines his coordinates for the ellipse in accordance with the following rules:

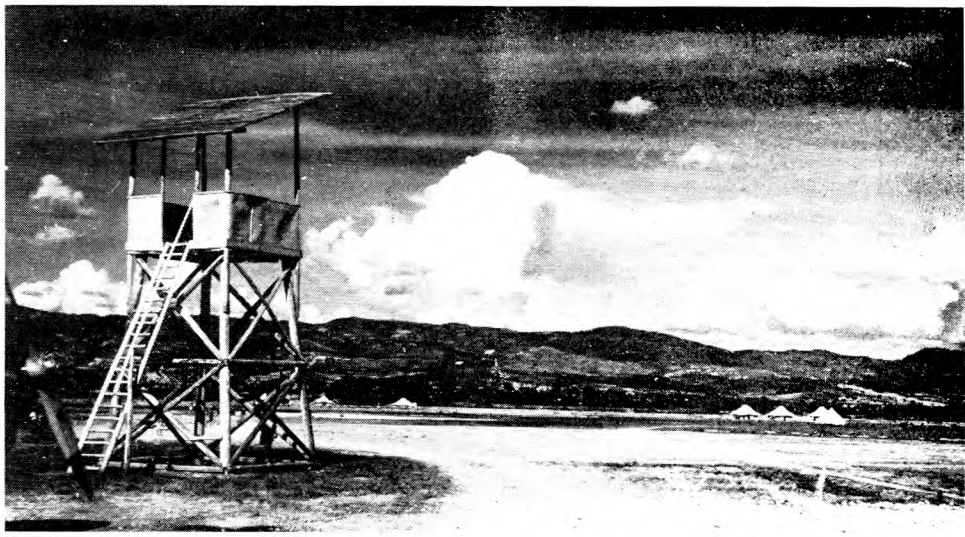
1. When a few widely scattered echoes appear they are reported individually.
2. Echoes within the ellipse should be of uniform intensity whenever possible.
3. Prominent echoes are reported individually rather than grouped with scattered, weaker echoes.
4. Concentric or overlapping ellipses may be used, in which case the intensity and coverage in the area common to both will be given by the greater values.

The program for aerial weather reconnaissance using radar is, in large part, still in the formative stage. First weather aircraft went to the theater only 2 months ago and their experiences will serve as a basis for final operating procedures to be set up for this relatively new project. Meantime, training has gotten well under way at Will Rogers Field, Oklahoma, and another weather reconnaissance squadron will soon be off to the theater.

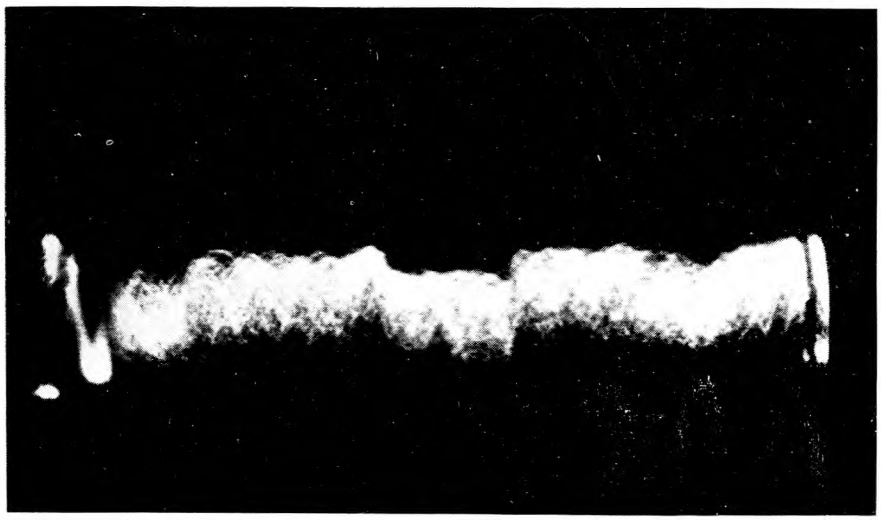
RADAR will report new developments in the radar reconnaissance program. Future issues will also carry accounts of the part played by various ground radar equipments in the business of weather observation and storm detection.



Most B-29 base areas provide a good market for radar weather squadrons. Missions are flown over terrain and water where storms are tricky, plentiful



No up-to-date control tower or ground weather station for planes on this airstrip in China. Aerial weather reconnaissance does double duty at such bases



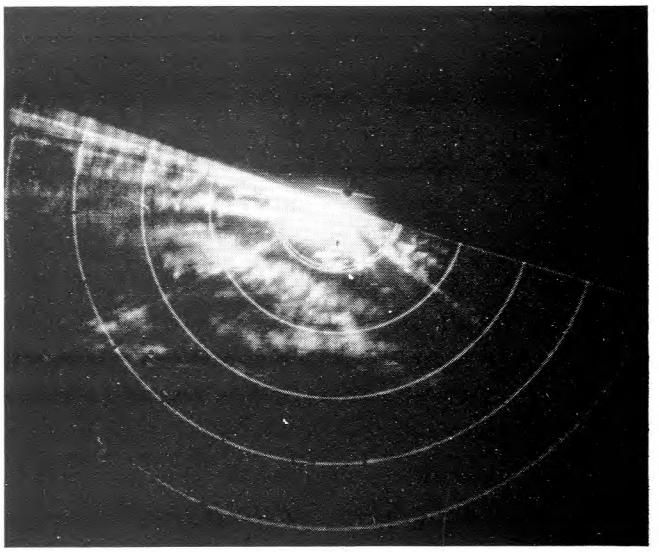
Close examination of portions of cloud echoes appearing on PPI is made possible with A-scope presentation, which emphasizes fluctuating nature of cloud signal. Expanded A-scope of SCR-615 shown is similar to that used with modified AN/APQ-13



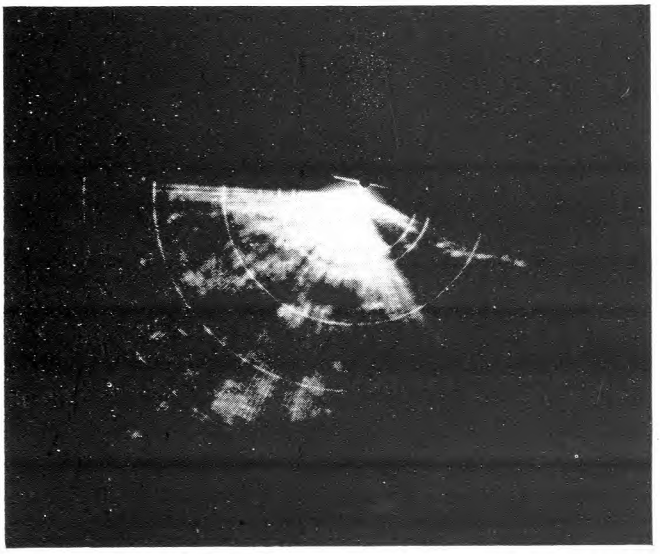
While modified APQ-13 is best adapted to show cloud character, regular set can pick up storm echoes readily (9 to 11 o'clock)

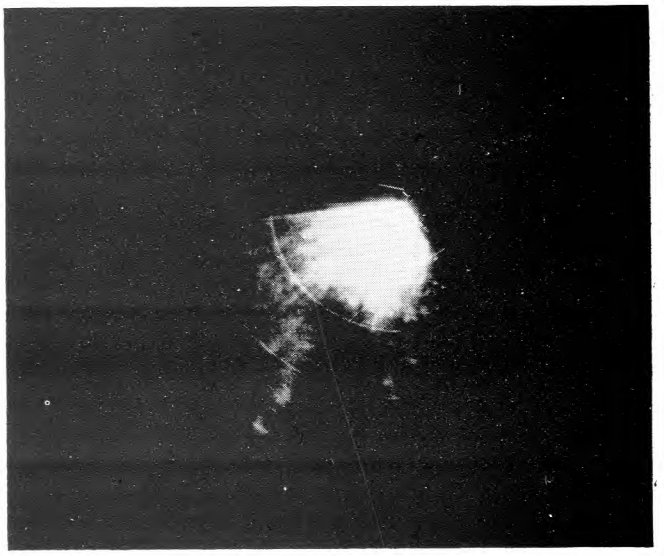
Hurricane

Here is what a hurricane looks like on the scope of an experimental, high-power S-band radar that was set up on roof top. Photographs were taken when the storm hit near Boston the night of September 14. Hurricane weather reconnaissance aircraft equipped with SCR-717C will soon be used to locate and follow these typical disturbances which form in the Caribbean area and swing north along Atlantic seaboard.

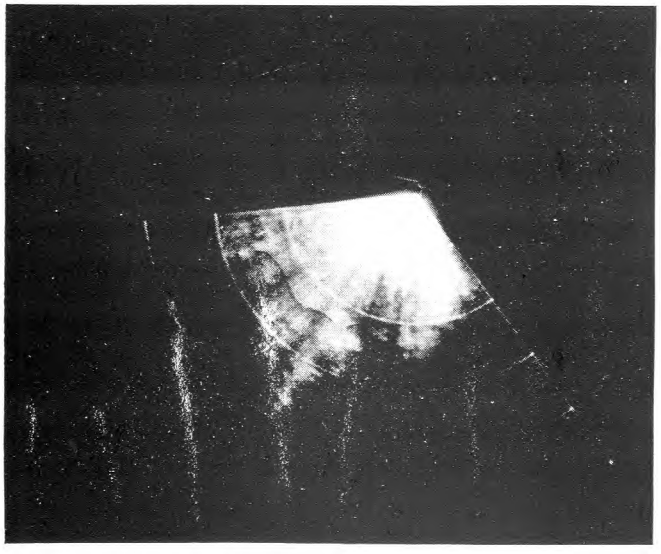


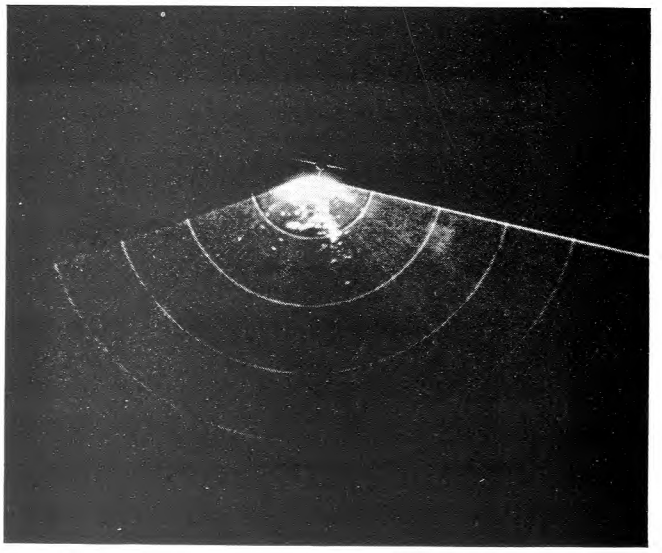
PHOTOS HERE ARE FROM SERIES TAKEN AT INTERVALS AS PART OF HURRICANE PASSED WITHIN RANGE OF THE RADAR. SWEEP IS 50 MILES





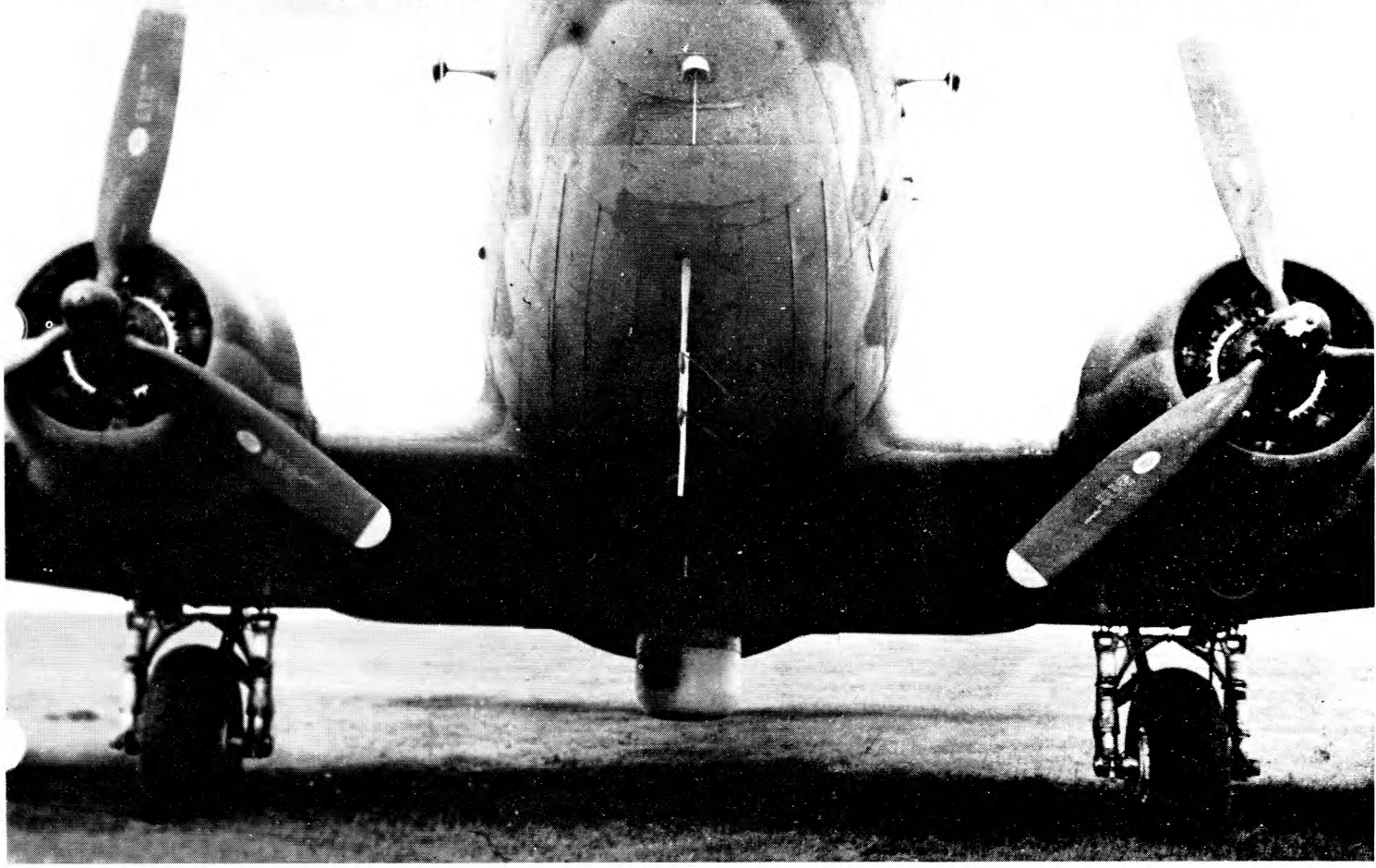
WAVE-LIKE FORMATION (UPPER RIGHT), NEVER SEEN BEFORE, BAFFLED EXPERTS. AS STORM MOVED ON, THE ECHO WAS SOLID, VERY BRIGHT



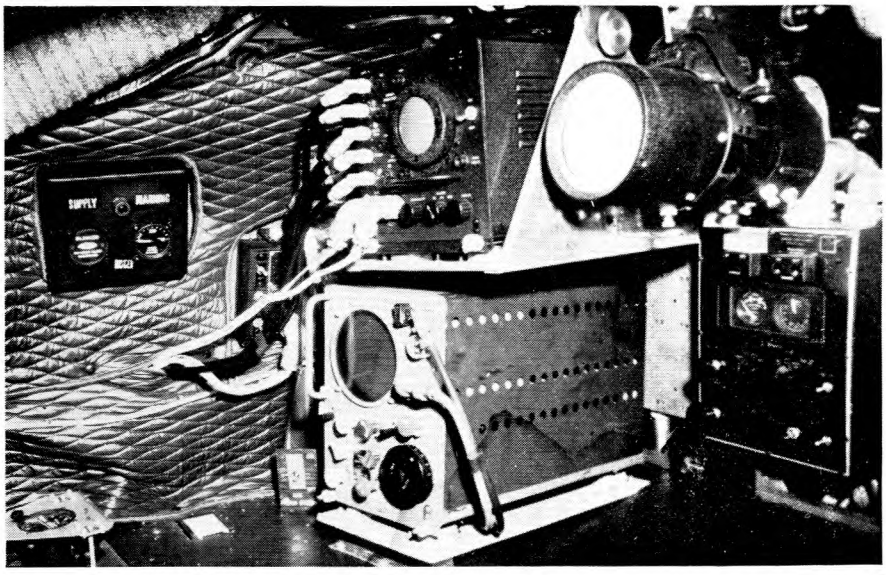


The Dutch Drop

The 9th TCC was better equipped for this job than for Normandy, where the pattern was set



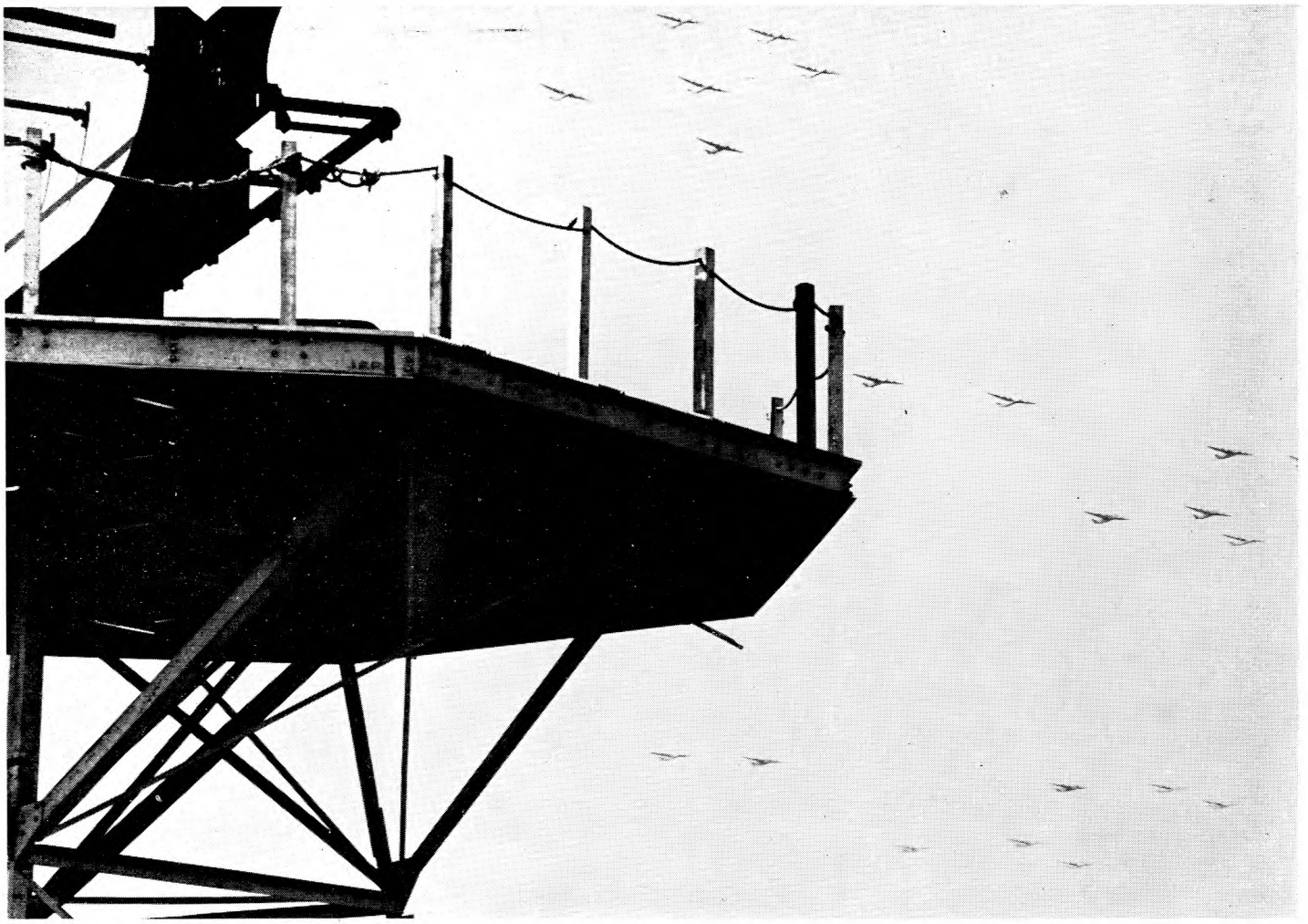
THIS C-47 PATHFINDER PARTICIPATED OVER NORMANDY AND HOLLAND. REBECCA ANTENNAS PROTRUDE FROM NOSE. RADOME HOUSES SCR-717C



Pathfinder navigation used these radar aids in Dutch Drop: left (on Navigator's table), Gee indicator; above, Rebecca; right, SCR-717C indicator with hood removed. Below 717 indicator is the control panel. Installation is on the left facing front

Dropping an airborne army around and behind enemy lines is, by now, established Allied procedure, with its own set of tools and a well-integrated formula. The radar tools in the kit were assembled and tried out in several practice missions before Normandy. And on 6 June they performed so well (see RADAR No. 4) that scant changes were required for the airborne invasion of Holland, reported on here. In between, the Mediterranean Command used pretty much the same radar and the same methods for Southern France (see RADAR No. 5).

The 9th Troop Carrier Command, working with British Troop Carrier units as a part of the First Allied Airborne Army, spent a busy afternoon on 17 September 1944—and for several days thereafter—exploiting the formula. From 1300 on through most of the daylight hours of 17 September the 9th



8TH AF MEW CONTROL CENTER OPPOSITE HOLLAND (ANTENNA ABOVE) KEPT EYE ON CARRIERS, BOMBERS, FIGHTERS ALL THROUGH OPERATION

TCC dropped paratroopers and glider units of the 82nd, 101st and British 1st Airborne Divisions in the Nijmegen-Arnhem sector of Holland. If the operation as a whole ran into difficulties, it was no fault of the 9th TCC and its radar.

The radar tools used in the Dutch Drop were (1) SCR-717C, (2) Rebecca-Eureka, (3) Gee Mark II, (4) AN/APN-1 (absolute altimeter). Except for Bups beacons which couldn't be gotten for this operation, the lineup was identical with that of 6 June.

For the 9th TCC the operation unfolded about as follows. It was a daylight job, with Rebecca scheduled to put the finger on Eureka-marked DZs and LZs, as usual, and with other navigational radar backing up the earlier parts of the trips in case of poor visibility. After swarms of bombers had swept the invasion areas all morning, 6 Pathfinders, equipped with SCR-717C, took off to mark dropping and landing zones for the main force. The weather was fine and everything proceeded per schedule. SCR-717C and Gee were mostly used for time to time checks. The first afternoon the 9th TCC put 92 serials totalling 1150 aircraft over the target.

The weather turned bad later. On D-plus-2, for example, when anywhere from 45 to 1000 paratroop and resupply aircraft were heading into the DZ/LZ area, radar aids sometimes did all the seeing. On the way back several serials had to rely solely on radar navigation.

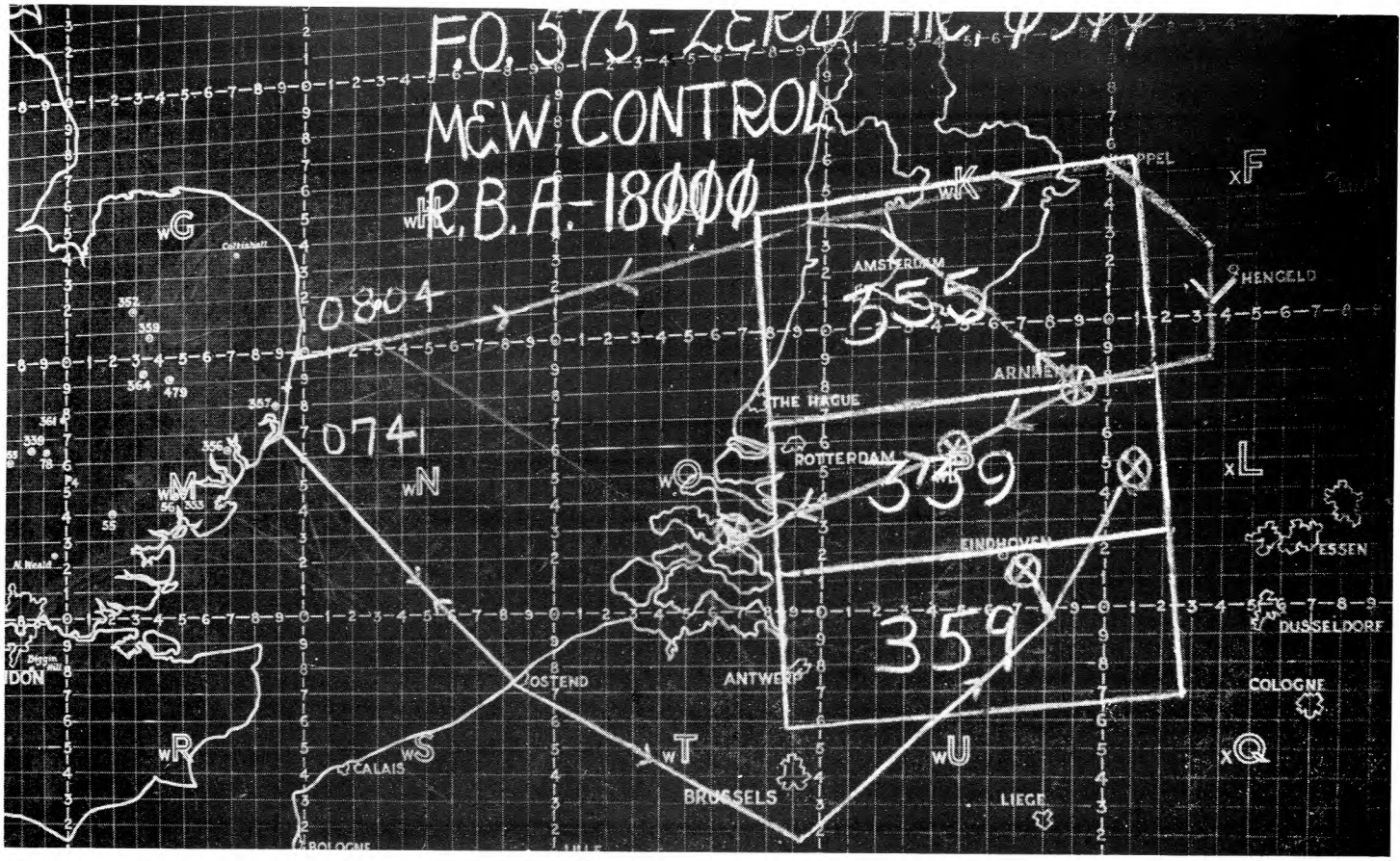
The only radar failures came from damage by ground fire and flak. The enemy tried to jam Gee but didn't hurt operations at all. Rebecca-Eureka, which had undergone considerable modification since Normandy, showed a marked improvement in range and sensitivity. Pulse width had been reduced from 10 to 5 microseconds to facilitate pinpointing.

Compared to the radar headaches of past airborne operations, the Dutch Drop was relatively easy. For the first D-day the 9th TCC had been plagued by a shortage of spare parts, spare equipment, test equipment, trained radar personnel. That had all been cleared up. Normandy and Southern France had done a real selling job on radar-shy unit commanders, which meant that all through the summer radar equipment—especially Gee and SCR-717C—had been requisitioned and installed.

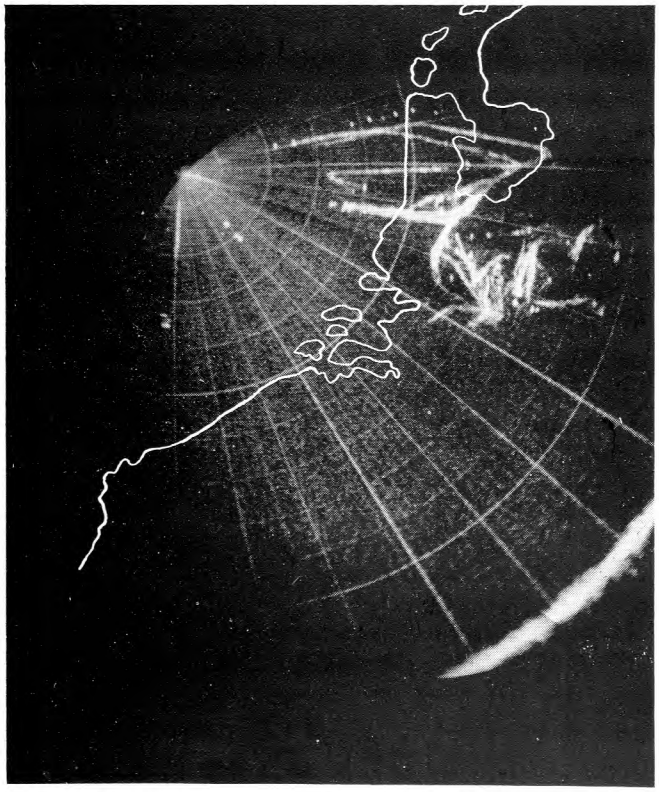
While the 9th TCC was buzzing back and forth a watcher stood on the English Coast surveying the scene. This was the 8th AF's big MEW (AN/CPS-1) Control Center.

Looking deep into Holland, the MEW did steady reporting and directing, as another MEW had done during the Normandy invasion and still another during the invasion of Southern France (see page 38). As a reporter, it kept tabs on everything in sight. As a fighter controller, it directed sweeps and interceptions more than 150 miles away.

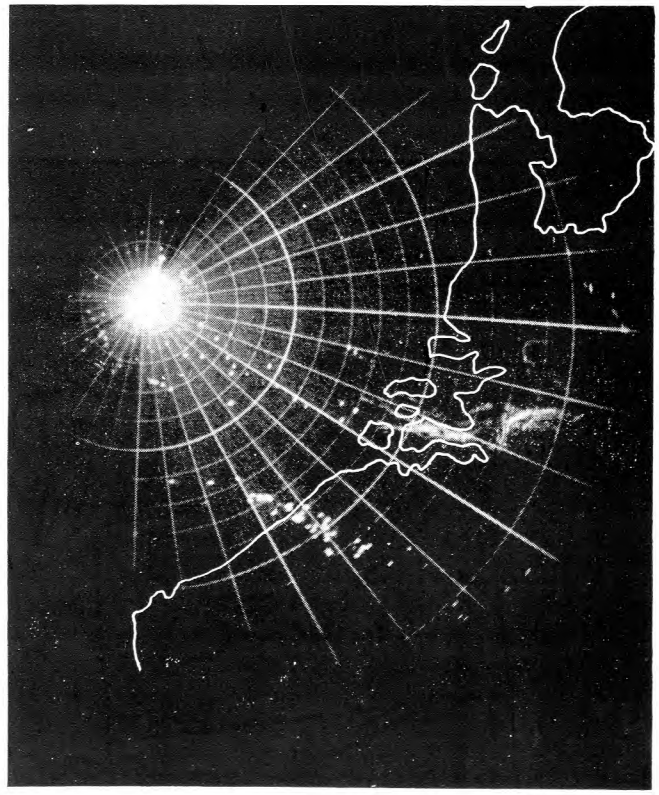
Observers who wanted a good clear look at what was going on in the air picked the MEW as their vantage point. Some of what MEW saw on 17 September is reproduced on the next 4 pages.



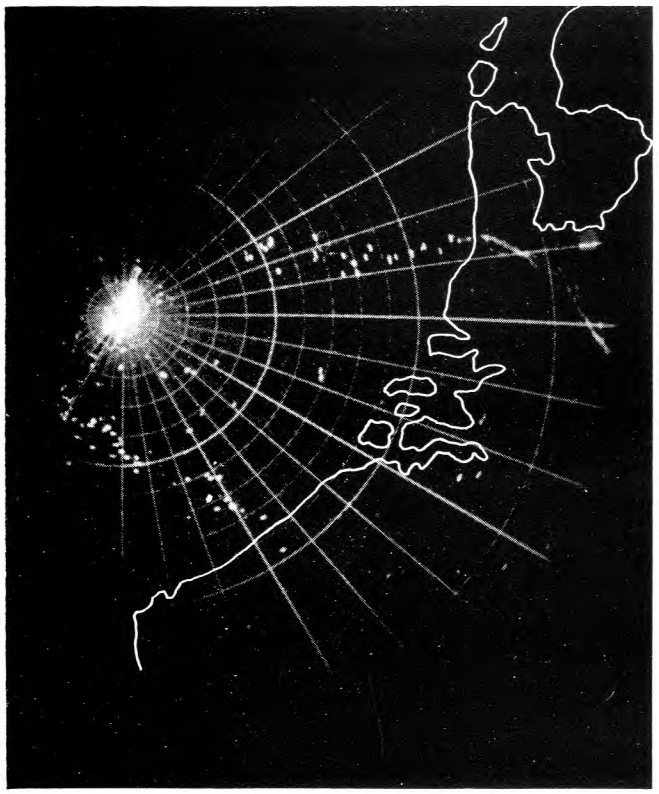
Operations board at 8th Air Force MEW control center charted paths, target areas as softening-up for Dutch airborne invasion began. Rectangles are fighter control sectors. From 0900 to midafternoon on 17 September MEW saw this plan take form



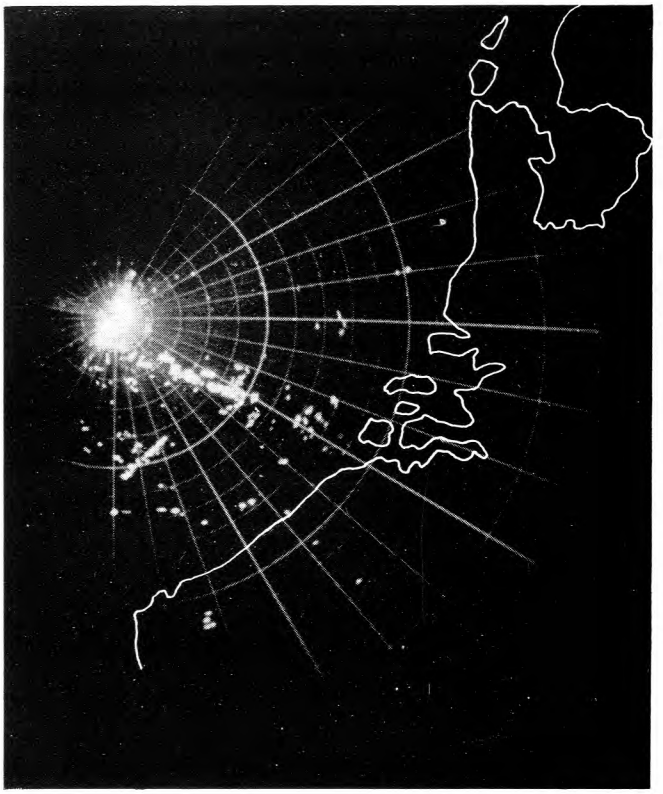
0950 Morning sweep puts 900 bombers over target and trail of window over North Sea. Scope has 50 mile delay



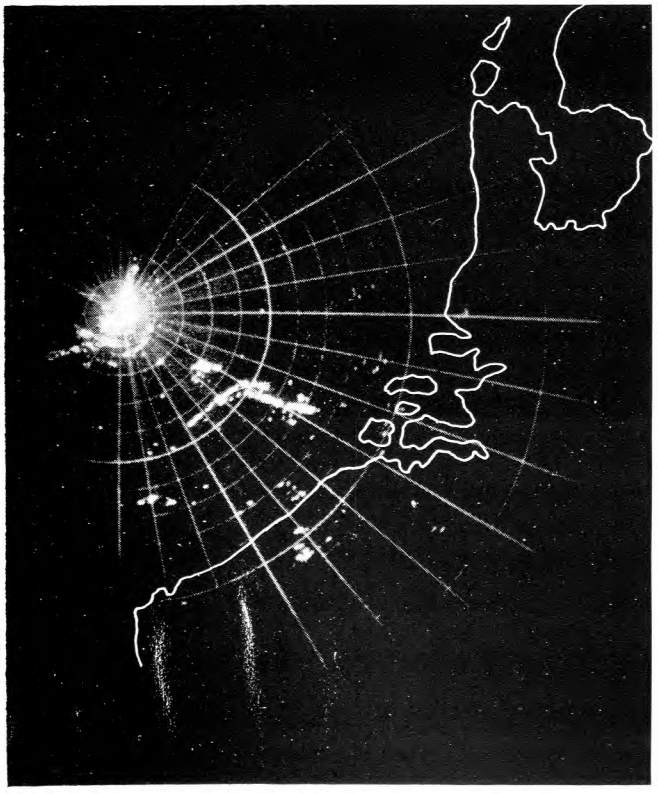
1035 Bombers head for home while fighters carry on. Scope is now normal. White line approximates Holland coast



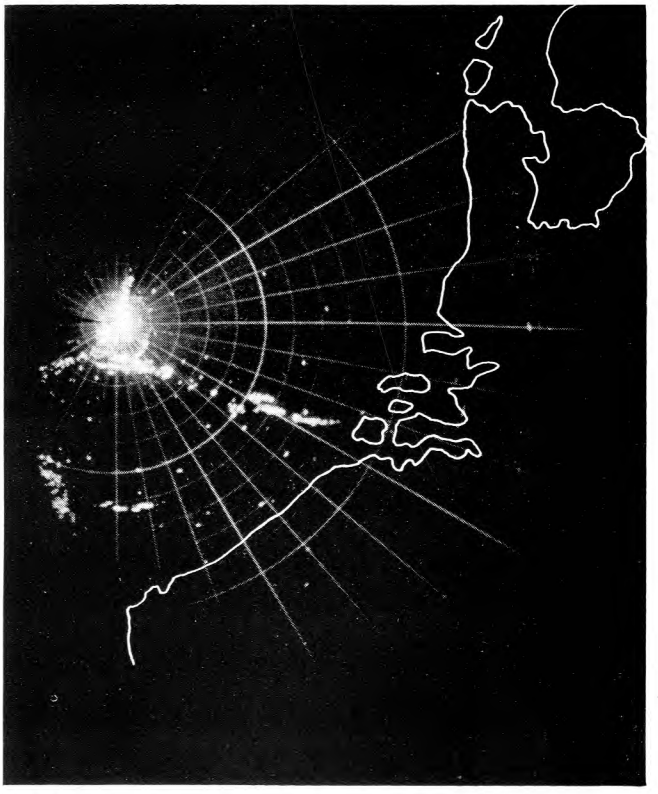
1100 Mixture of bombers and troop carriers is on the way over. First bomber group is now back over England



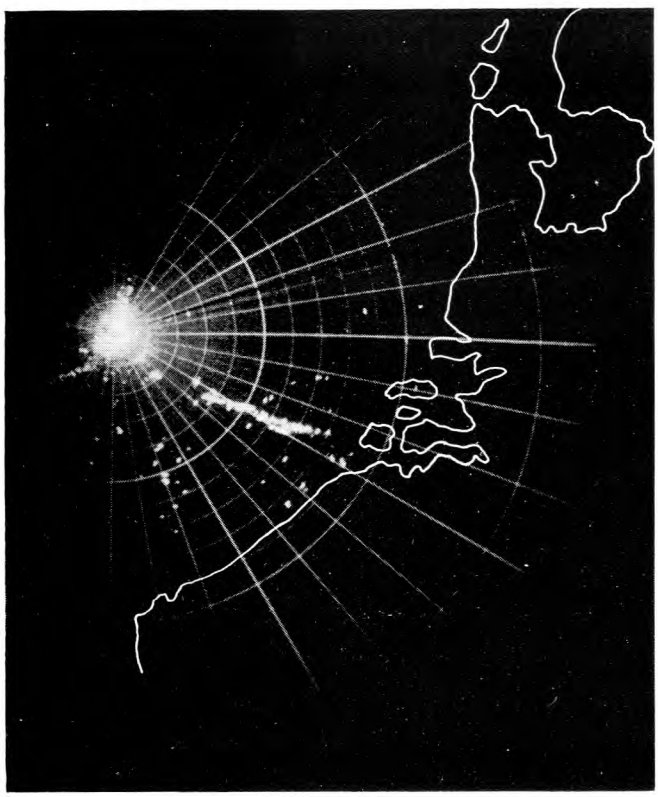
1204 Sky fills with fighters, carriers, gliders. "What's this," radios a returning bomber pilot, "another invasion?"



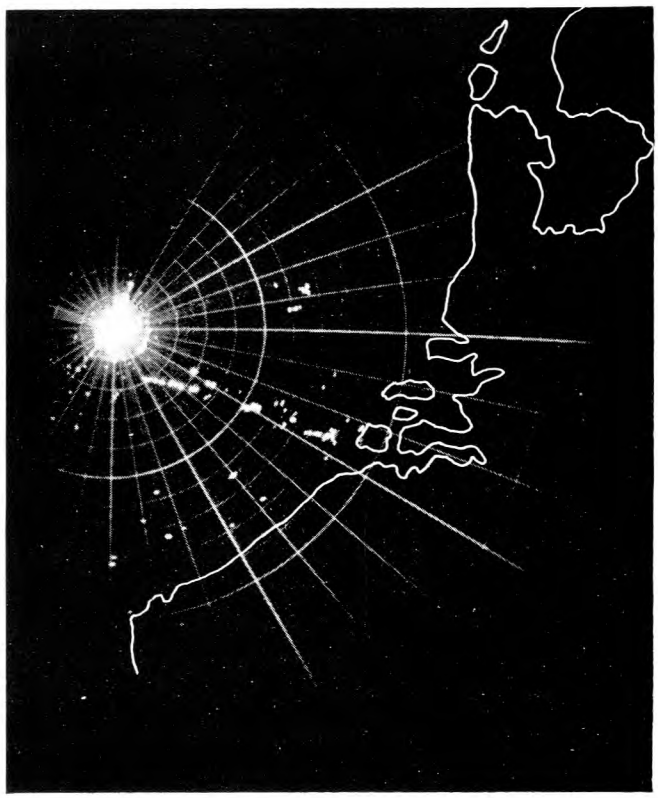
1215 Main body of 9th TCC is now out over North Sea. Note force that has come up from 5 o'clock in previous shot



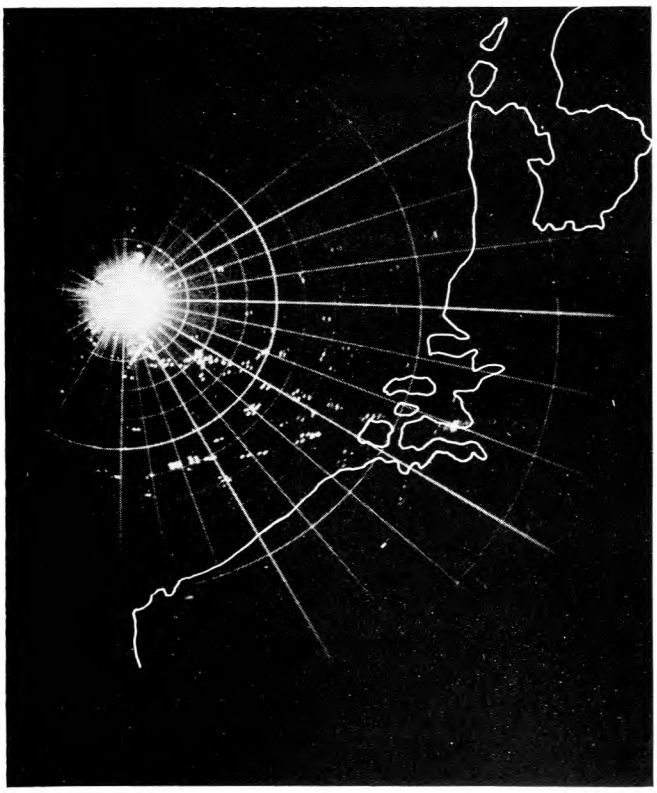
1230 Another concentration comes into picture at about 7 o'clock and still another just below the radar site



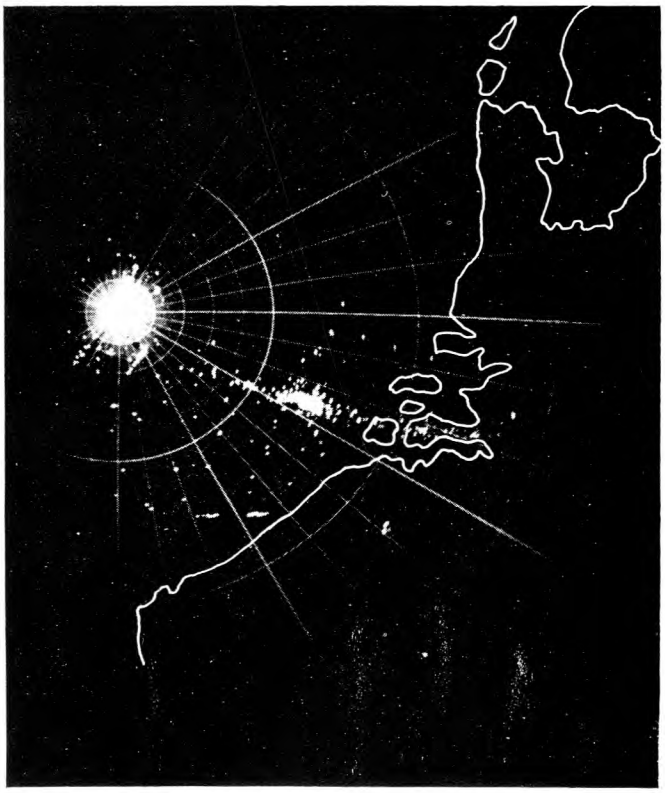
1245 Air armada stretches 50 miles over North Sea nearing Holland coast, points toward Nijmegen-Arnhem area



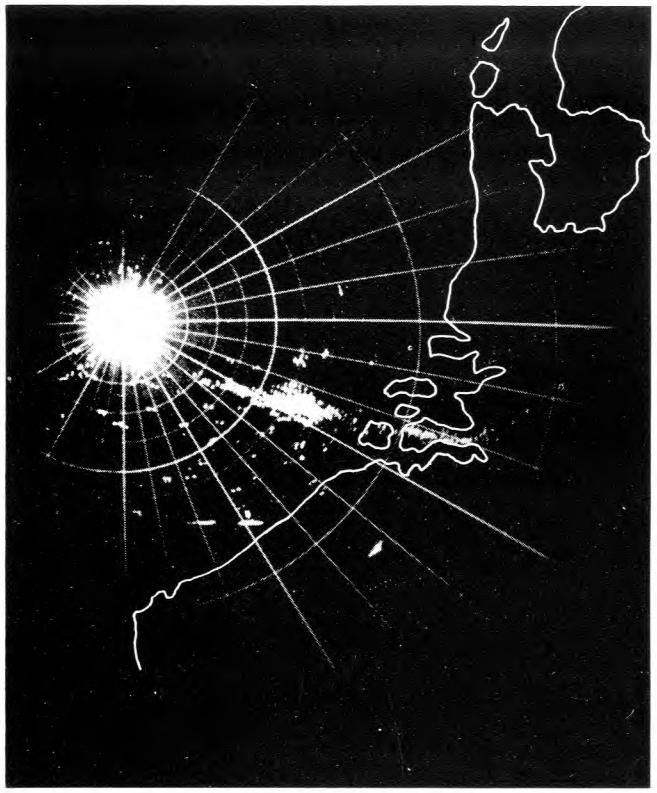
1300 Jumps and glider releases begin. Most aircraft are now down on deck over Dutch lowlands, don't show up



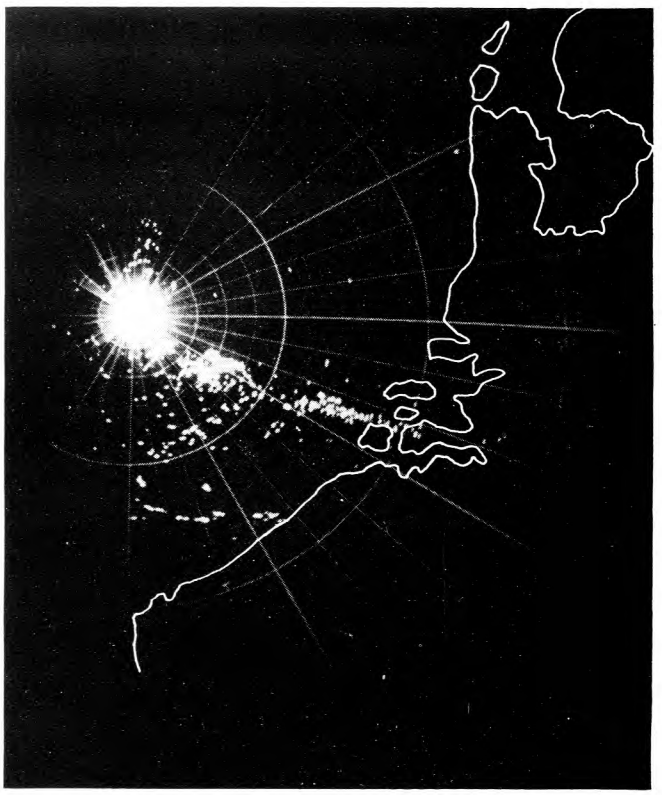
1345 Blips reappear as carriers finish chores over DZs. While these head back other serials are on the way



1400 Bombers going and carriers returning stretch all the way from airfields of England to heart of Holland

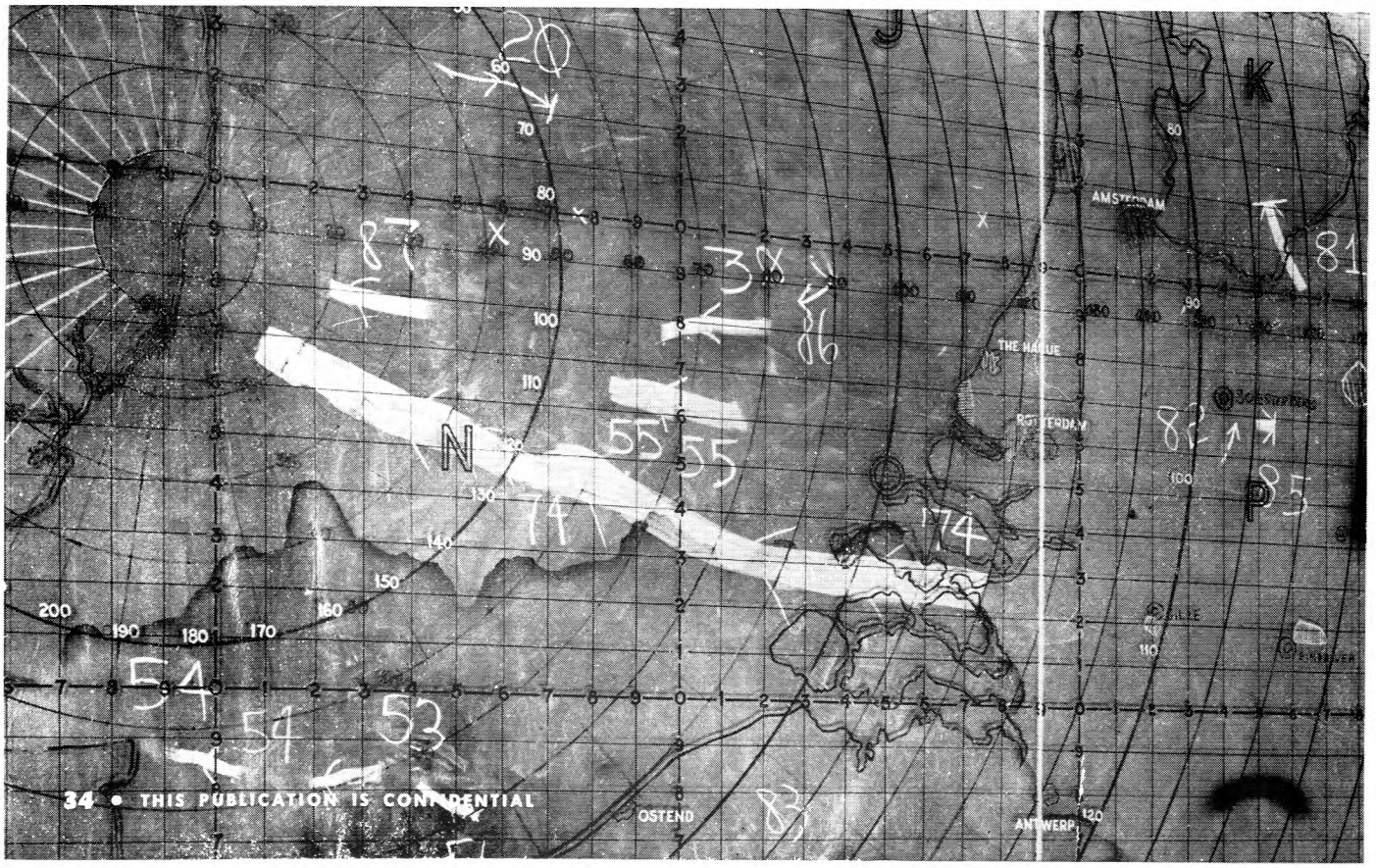


1405 To spectators outside the MEW station this display looked like a faint haze hanging over the horizon



1420 Planes bunch near finish while other serials follow on behind. Scattered units are trekking targetward

At 1405 MEW plotting screen (marked by 3 plotters behind) looked like this, corresponding to scope photo at left above. MEWs used to report Normandy and Southern France invasions have subsequently been mobilized to move with troops; this one may be





AT PEAK of buzz bomb war English skies were white with AA fire. Buzz bomb path here is line coming in at top left. Radars at MEW site are limned against the fire

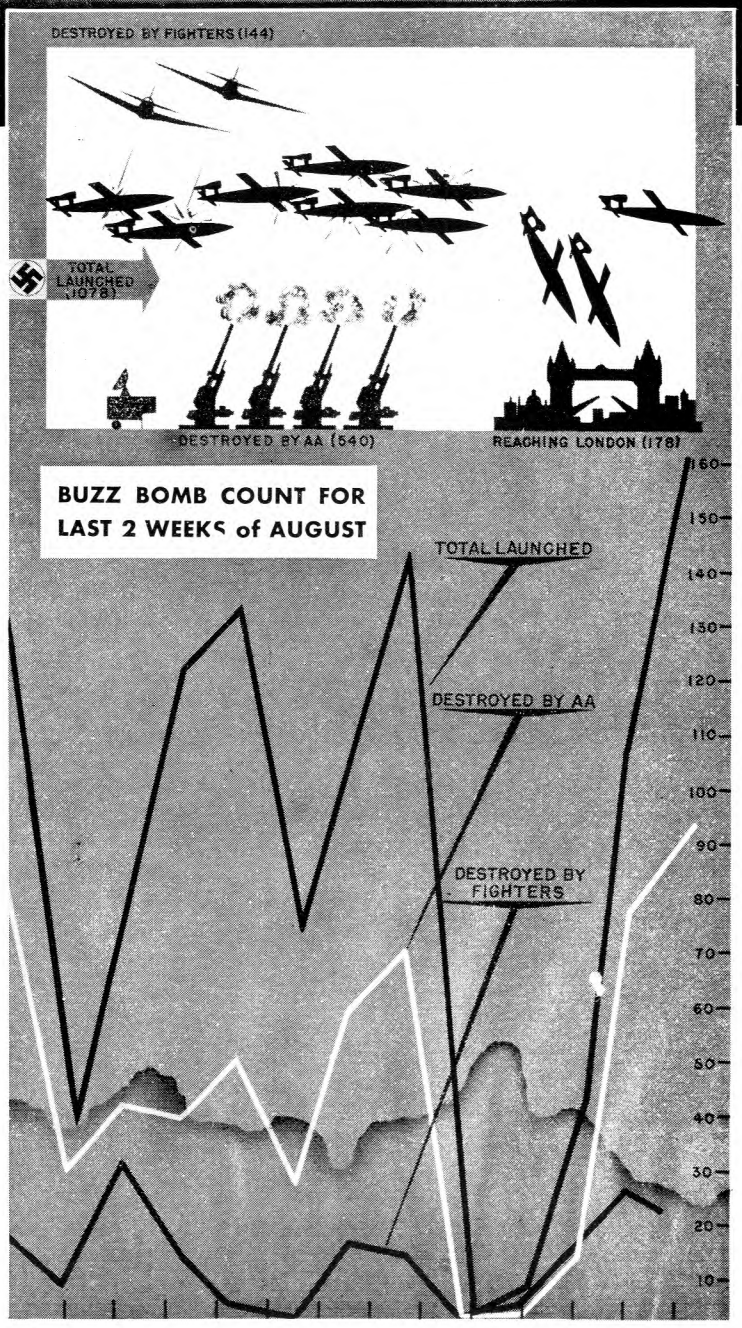
Postscript on buzz bombs

The once mighty roar of V-1 is down to a whisper. Although V-2 is now a reality, it can't be told as yet just what form Allied defense has taken. Meantime, however, the record of V-1 is pretty well in and the success story of the two types of defense used against it is of considerable interest.

V-1 lost its sting with its bases. But before that it was being defanged, anyway. When the first buzz bombs came over, intercepting fighters knocked down quite a few. AA batteries chimed in with a lot of fire and a few kills. The fighters got better, but in the meantime the slow-starting AA came along with a tremendous rush and finally developed into top defense. In the last 2 weeks of August AA units were stopping one out of every 2 bombs that left the launching area across the channel (see chart opposite).

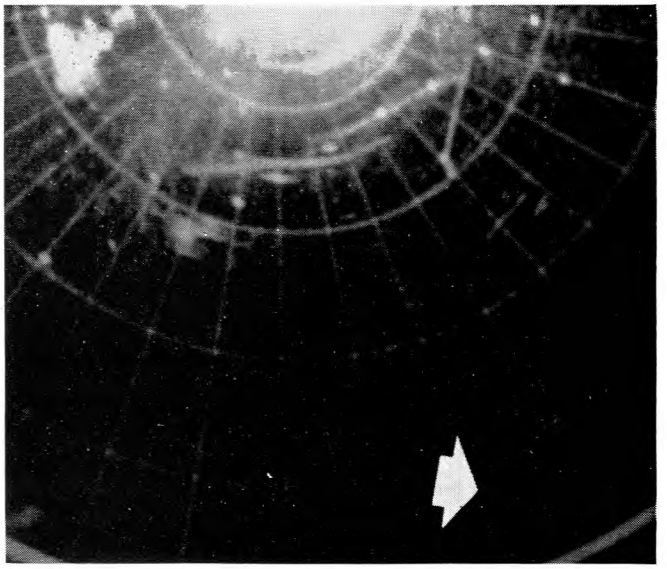
It was the MEW, British CHL (Chain Home Low) and SCR-584 installations that gave the blocking techniques their touch. The first two vectored diving fighters onto the targets over the channel and simultaneously furnished slant range and azimuth to AA units along the English coast. SCR-584, an AA specialist, came into its own as crews picked up skill and gun units learned how the bombs could be expected to behave (see RADAR No. 5 for full report).

The remarkable pictures of AA fire in pursuit of buzz bombs shown on this and the next page were taken outside the MEW buzz bomb station on the English coast.



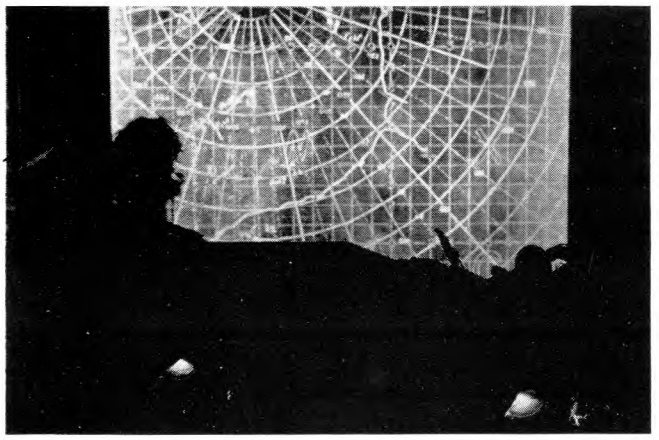


Buzz bomb had 50-50 chance of surviving AA fire (see chart on page 35). Display made odd patterns, like Daliesque legs here



Vectored fighter (arrow) chases buzz bomb across channel. Picture was taken from scope of MEW which did the vectoring

Meantime, more MEWs are put on wheels









Only one of the four early-edition MEWs rushed to England and Mediterranean remains at fixed site, namely, the 8th AF's Control Station which worked in Holland invasion (see page 31). MEW that tagged buzz bombs has gone to France on wheels. Two top pictures show plotting board and operations room inside one van. Bottom left is mobile caravan before it left England. Bottom right shows stump of Corsican installation, now on wheels in Italy. See RADAR No. 5 for report on first mobile MEW



LCVP, loaded with men and radar equipment, comes in through the surf of enemy waters to land on unoccupied atoll in the Pacific



Lightweight knock-down construction enables TPS-3 to employ a large antenna. Wire netting of dish makes camouflage easier

Task force radar

New TPS series, in action all over, also makes the movies

Although reports aren't in at this writing, it's a fairly safe bet that the lightweight warning sets of the new SCR-602 series were present—among other radars of all varieties, shapes and sizes—at the Philippine invasion. The old 602T-6 has appeared on almost every front since the days of North Africa. Its offspring, the AN/TPS-1, 2 and 3, are now carrying on in France and wherever our springboards in the Pacific are set up.

The TPS sets made their first theater appearance when they were sent to the UK for the entry into France—there were about twenty TPS-1, sixty TPS-2 and twenty-five TPS-3. As soon as European demands were supplied, the first sets were started on their way to the Central Pacific, Southwest Pacific and CBI theaters. In most cases the TPS-2, baby of the series, has been most in demand; it can go more places in the least space.

Within the next few months the new lightweight series will be taking part in every new step forward and making it easier for the men who are doing the stepping. Meantime, the shadows of future operations have been cast both in training and in a new training film.

The film, "Lightweight Radar Equipment—AN/TPS 1-2-3 (SCR-602 Series)", shows the operational use of the

This Jap plane apparently didn't know about the TPS-3 operating on the island. Antenna can be seen through screen of palm trees

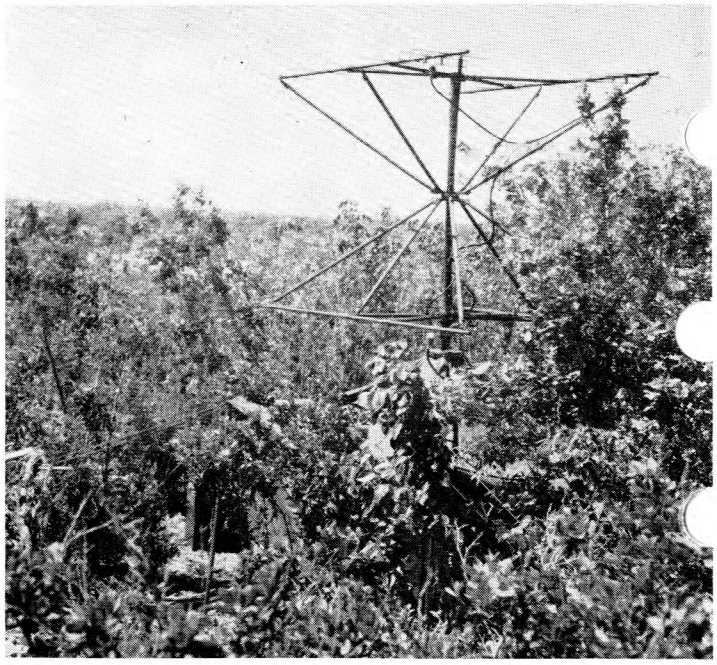


Waterproofed TPS-2 is here hauled through jungle stream. These pictures are taken from a new training film on the TPS series





For 3 days, four C-47s made 2 trips daily to Marathon Island, Pacific-like atoll off Florida, in Drew Field training maneuver



Coral rock made slit trenches impossible. Rock emplacements erected on ground surface gave individual cover for each set

TPS-3 in the Pacific, at the same time manages to give a good technical description of all three TPS sets and how they compare to the older 602. Technical adviser for the film, Capt. S. M. Whalen of the Aircraft Warning Unit Training Center, Drew Field, had real experience to fall back on—he was with a task force which took part in the invasion of Attu using the SCR-602.

Another picture of Pacific operations was acted out not long ago by Drew Field's AWUTC, where all the lightweight warning units are trained. In an airborne maneuver, several crews with ten SCR-602s (no TPSs were available) set up radar coverage on one of the islands in the Florida Keys to protect it from supposed attack by carrier-based enemy aircraft. The idea was to give the men final training under conditions which simulate the semi-tropical weather and coral formations found in a Pacific atoll (see pictures).

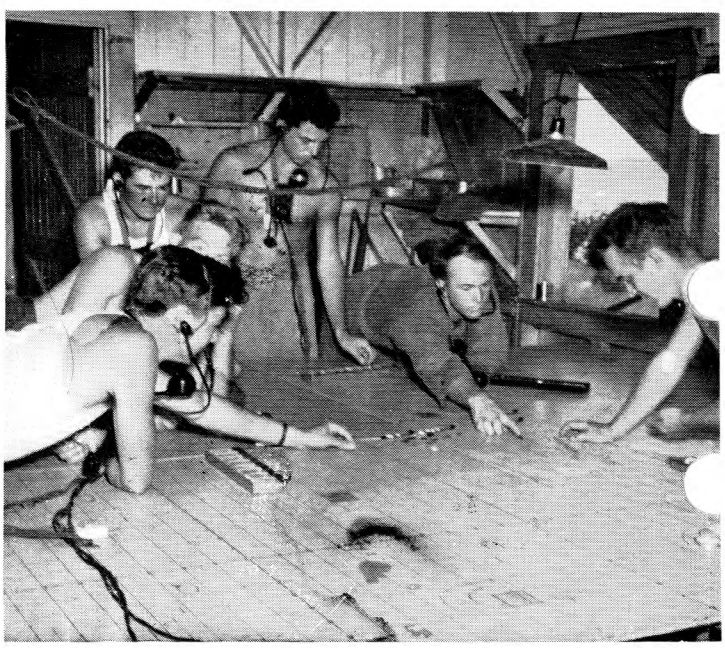
The 3 TPS sets have been designed particularly for use in initial assault operations where weight of the parts and time required to assemble them must both be at minimum.

Although the TPS-1 is heaviest of the series—about 100 lbs. lighter than the older SCR-602—it has the advantage of being the least susceptible to jamming. The real lightweight is the TPS-2, only true pack set of the series; it doesn't take many men to carry its 700 lbs. Its general performance doesn't match that of the other two but such refinements as durability, automatic antenna rotation and PPI are left at home to produce a set that can be slugged through the jungle where a man is his own pack horse. TPS-3 weighs a little over 1600 pounds when packed and has a range of 100 miles or more.

Abandoned shack and adjoining estate became HQ, Information Center, radio room. Man-size mosquitoes were only inhabitants

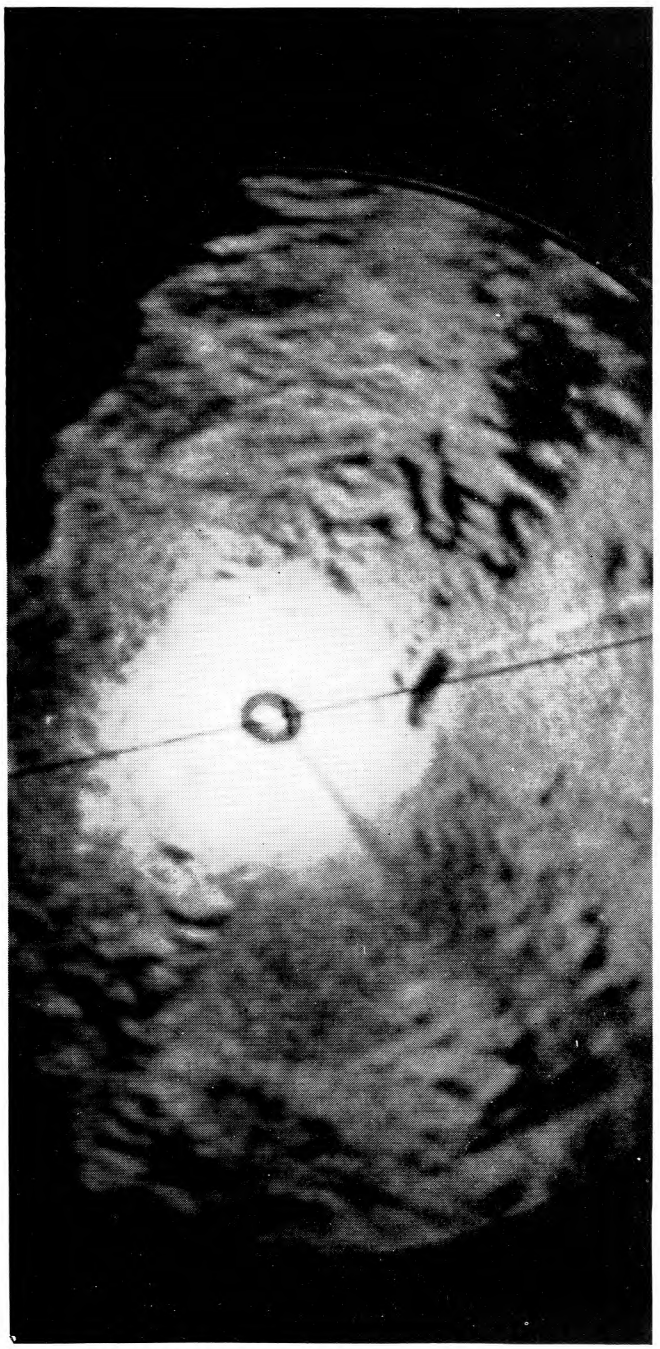
Information center crews followed strict 24-hour schedule, while the ten 602s operated on an average of twenty-two hours a day



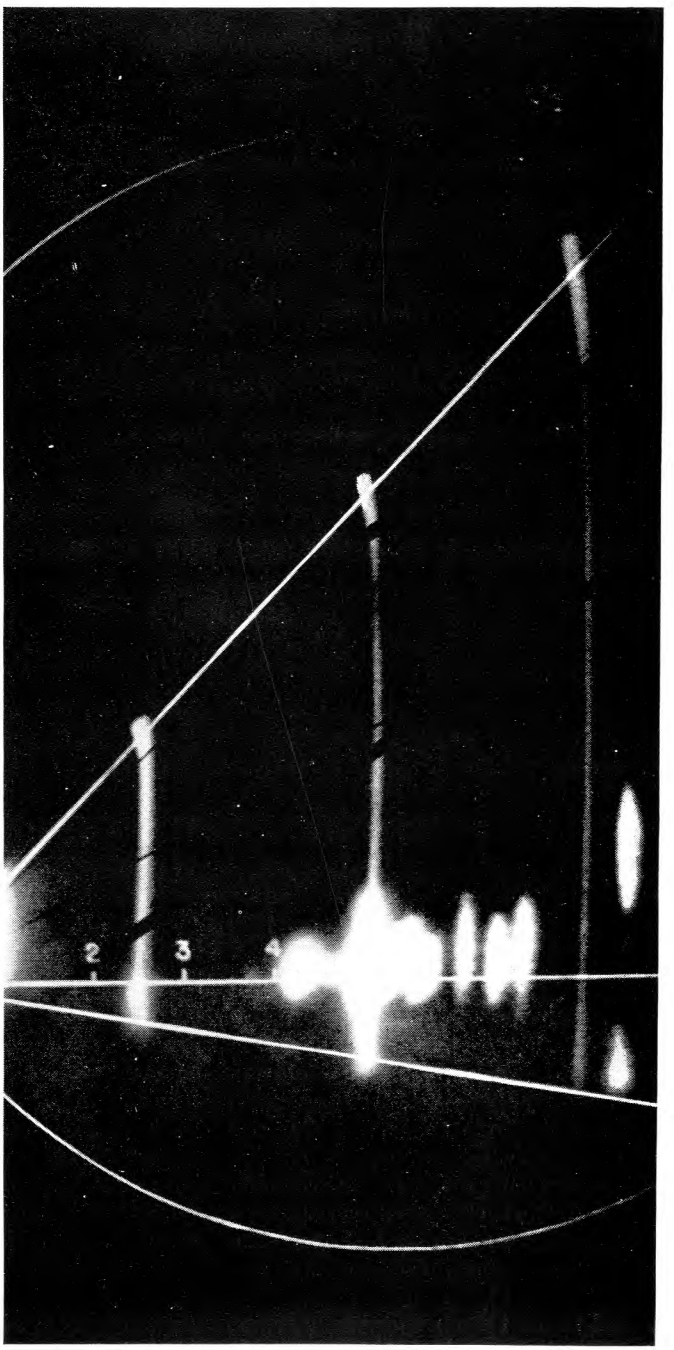


Scopes

The scope of any radar, whether it's airborne or ground, whether it's in Kiel, Karachi or Kansas City, can be counted on to come up with some unusual presentations from time to time. RADAR herewith urges its readers to watch for them, photograph them and send in the results. Some scope photos are no more than oddities; some can shed useful light on functions of radar still in development; some exhibit levels of performance from which many an operator can learn much. For all of these reasons, including the first and probably others, RADAR is anxious to get and to publish noteworthy scope photographs. A number have been presented in past issues. Two appear below and elsewhere in this issue. RADAR will run more, with credit, as received.



Large "U. S." is formed on APS-15 scope by Santa Ana Mountain Range, California. This patriotic phenomenon, found by crew from West Coast Radar Training Center, Victorville, was photographed on way back from training mission over San Diego



Signal image, which sometimes occurs at low angles due to ground reflections, is shown here on GCA 2-mile elevation scope. The signal, at extreme right, is from a water tower; the image is visible below ground level line, directly underneath the signal



What's where Magnitude of the part taken by radar in every theater of operations is pictured by symbols on the two hemispheres above. Each symbol shows approximately the area of use of one or more installations currently operational. Picture is not wholly complete: beacon coverage and IFF have not been included. Dotted lines show present Loran coverage, dot-dash lines show Gee.

RADAR

Issue No.7 JANUARY 1945



R.P.F. Lauder
Engineering Manager
Product Support Department

INTRODUCTION

In vol. 7 of this historic series which Ferranti is proud to present to special customers and friends, we see an increasing sophistication being applied to the problem of accurate bombing. Targets are still difficult to distinguish on the radar display because the wavelength is too long to provide a sufficiently narrow antenna beam for good discrimination. There is also the lingering feeling on the part of bombardiers that you really ought to see the target visually to get an accurate hit. Weather and darkness combine to make this unrealisable for much of the time.

Our attention is now drawn to the happily named "synchronous bombing" which combines the virtues of radar and the bombardier's optical sight. The highly successful H_2X radar is giving way to the 3 cm AN/APS 15 radar with its obvious capability for greater discrimination and accuracy. The "synchronism" refers to the combined activities of the radar operator and the bombardier working in concert to guide the bomber to its target.

The AN/APS 15 was unusual in that a planar triode (the so-called "lighthouse" tube because its physical shape was reminiscent of a lighthouse) was used as a pulsed oscillator developing about 500W power. This allowed the transmitter, receiver and filtered power supplies all to be housed in the lightweight cylindrical LHTR shown on fig.17. This unit was also used in other radars as a common module.

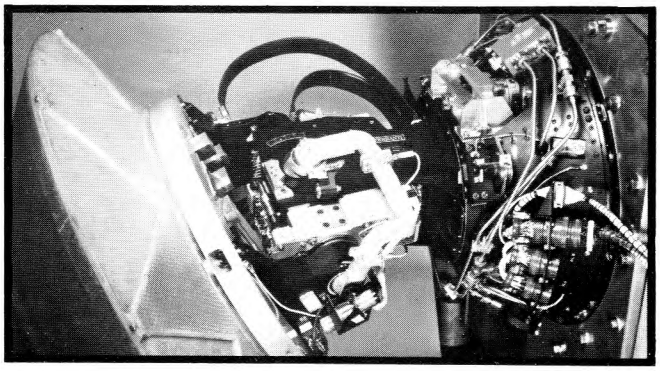
Bomber navigation in those days was largely a matter of dead reckoning assisted by radar. There were no universal aids such as GPS, satellite Navstar, Omega, etc., but the aircraft flew to the general area of the target without too much difficulty. However, these methods would get them home again but were not nearly sufficiently precise to allow actual landing in adverse weather conditions. It must also be remembered that there was often a degree of urgency and danger about landing due to airframe defects from AAA gunfire, and the stacking of aircraft, or even diversion to other landing sites which were not affected by fog or low cloud, was simply not possible.

There was therefore a clear need for a ground control of approach (GCA) system and radar was the obvious candidate for the job due to its ability to see clearly through fog or cloud. The AN/MPN-1 filled this need and was the only radar developed during the war for GCA by rapid scanning.

GCA was in fact three radars working in concert. The S-band part rotated through 360° and was a general surveillance radar similar to a modern air traffic control radar. Two other radars had shaped beams which were rapidly scanned in their narrow directions normal to each other and provided azimuth and elevation errors of the approaching aircraft from the ideal glide path to the runway. The errors were relayed to the pilot in two ways, one by straightforward voice communication from the ground, and the other by a left/right deviation signal in azimuth only, which was controlled by the ground operator's cursors fed directly into the communication system. The signal was coded to indicate the sense of the error and varied in pitch to show the amplitude of the error. A similar British system used morse symbols for the letters 'A' and 'N' i.e. dot-dash and dash-dot. These signals when equally received, fitted together so that a single tone was heard. Deviation left or right allowed one of the letters to predominate and thus indicate the corrective direction to fly.

Page 35 shows an extremely ingenious method of making antenna polar plots visible to the naked eye. A single dipole transmitting a few milliwatts at the defined frequency of the antenna under test is received by the test antenna which is rotated in azimuth. The test antenna sends signals to the rotating coil of a PPI in sympathy with its own rotation, and the modulation (10kHz, AM) is painted on the tube. An excellent visual representation of the polar plot is shown on the PPI. The effects of directors and reflectors and their positions are immediately obvious. If this volume does nothing else than resurrect this splendid training aid, then it will have justified its existence.

In vol. 5, we saw the first use of the SCR 584 as a target illuminating radar, now we see its secondary role as a vectoring means to guide our own troops to the target area, and to give them precise co-ordinates of the target with respect to their own present position.



FOXHUNTER

Ferranti's Foxhunter radar is a joint venture project with the Marconi Company to provide an advanced radar for the Air Defence Variant of the Tornado aircraft. Ferranti design the transmitter and scanner mechanism and the radar is an advanced multi-mode pulse doppler system for Skyflash guidance, and TWS and ground mapping features.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

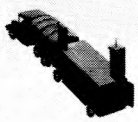
PSD

NUMBER 7 1 JAN. 1945



Coming in through ceiling zero

See page 19



RADAR

RADAR

Number 7 1 January 1945

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EDITOR: Dexter Masters, Office of the Air Communications Officer.

FOREIGN EDITORS: Dr. L. J. Henderson, Advisory Specialist, Hq. U. S. Army Air Forces, MTO; Dr. L. C. Marshall, Chief, Operational Research Section, Hq. U. S. Army Forces, POA; Dr. Louis N. Ridenour, Advisory Specialist, Hq. U. S. Strategic Air Forces.

EDITORIAL ASSOCIATES: Avis Clarke, Ruth Copland, 2nd Lt. Norman R. Goldman, Dallas Johnson, Lucie Sewell, 1st Lt. Robert Wright.

CORRESPONDENTS: Sgt. John Caldwell and S/Sgt. Rob't Carlson, ETO.

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EDITORIAL ADVISERS: Lt. Gen. Barney M. Giles, Chief of Air Staff; Dr. Edward L. Bowles, Special Consultant to the Commanding General, AAF; Dr. L. A. DuBridge, Director, Radiation Laboratory.

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"You can't build a box that will do everything"

When General Claire Chennault reported that his bombers, using precious gas hauled over the Hump, sank a quarter of a million tons of Jap shipping in August, he added a significant note: "We have done this with 19 of the 44 (radar) crews we have got—those are the experienced crews. The ones coming in now are so inexperienced that we are not getting results. You have got to give me better trained crews."

It has been several months since General Chennault said that, and since then the situation has been improving. However, it's still a fact that training of radar operators and mechanics is often left behind in the scramble to develop newer radar and to find better uses for old; often enough they're trained for one job and put to work on another. A lot of people have griped about this for a long time. Partly it's in the nature of war on a world-wide scale. Partly it's in the nature of radar's fast and fluid development. Still, a case can be made out for better coordination of training. It may be that something is to be done about it.

With the purpose of so doing, a new Radar Training Standardization & Advisory Board, headed by Brig. Gen. L. A. Lawson, CG of the Eastern Technical Training Command, in November held the first of a series of monthly meetings at St. Louis. The Board is made up of specialists in training, equipment and operations. It has permanent committees on various aspects of training. And now it has a program.

Immediate goals, as they emerged from the first get-together, are: 1) to get new equipment to training commands before it goes to the theaters; 2) to develop standardized training procedures based on current methods in the theaters; 3) to coordinate radar training with Air Force training and operations.

But both the official speeches and the general corridor talk were concerned with something that went beyond these 3 immediate objectives. And this was the simple fact that overconcern with individual pieces of radar equipment has led to underconcern with the whole system of radar. To put it another way, the trees have been obscuring the forest.

Brig. Gen. H. M. McClelland, Air Communications Officer, said it this way: "You can't build a black box that will do everything. More attention to training and less effort to build better and better gear all the time is the thing we should work for now. . . . We are too equipment minded. We should be more system minded. We must start out with all the gear that can contribute to the solving of a problem and see how far toward our goal we can go with what we have."

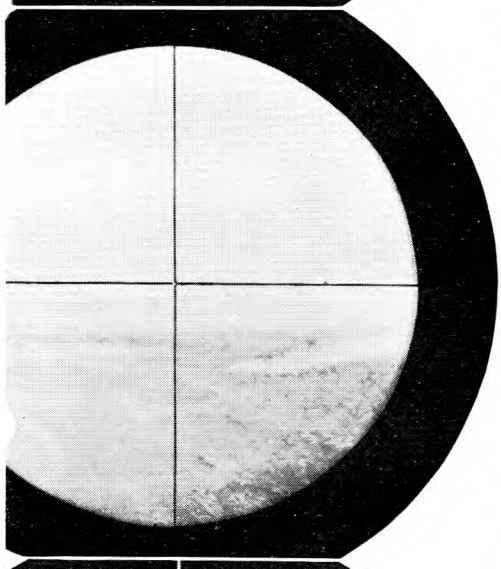
Dr. Edward L. Bowles, Special Consultant to General Arnold, said it this way: "It seems to me that our real objective in this whole program is not so much to interest ourselves in the technical intricacies of radar, as to bring radar to bear on the enemy." And he added: "I have a hunch that in training these boys our big problem is to get the end result."

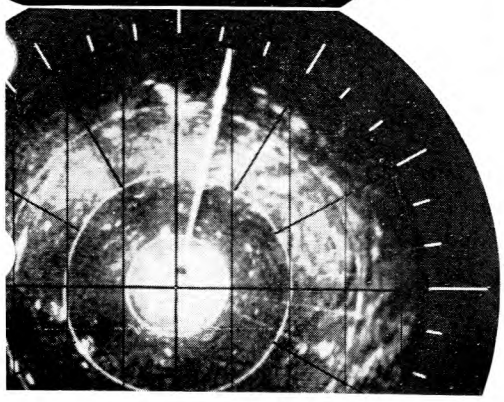
It will take a while for a program of these dimensions to take shape. Meantime, it's out in the open and on the record, where it can be prodded, supported and fed.











H_2X synchronous bombing

Success of radar operator-bombardier teamplay has made this technique standard for AFs with H_2X. Radar, bombsight overcome each other's lacks in varying visibility

With bombsight as partner, H_2X radar starts second year

Last month high altitude radar bombing—H_2X—was getting a good start on its second year. On both sides of the world, in 4 theaters of war, H_2X in conjunction with the Norden bombsight was building up as the primary tool of heavy bombardment.

H_2X bombing got under way on a cloudy November day in 1943 when 9 double-chinned B-17s took off for Wilhelmshaven leading 9 wings of the 8th AF. The second chins carried 9 preproduction AN/APS-15 radars (all but 3 of the 12 then in existence.) When the planes got back, Wilhelmshaven had been hit without being seen and a new era in aerial warfare had begun (see RADAR No. 1).

Now, a year later, the AAF has received almost 2000 APS-15 equipments and 3500 are on order, scheduled for delivery at 200 a month. In 12 months 12 equipments have thus multiplied.

From the record of this big year H_2X pioneers were last month recalling the following highlights:

¶ Crippling of Hitler's aircraft and ball bearing production in one month of record 8th AF bombing last February, with APS-15 leading the way although the bombing itself was visual.

¶ Development of H_2X bombing in the 15th AF which, in March, got 25 sets and in due time put them to work in the relentless pounding of Ploesti.

¶ The 8th AF's highly accurate radar bombing that softened Normandy coastal defenses minutes ahead of our invasion.

¶ Extension of H_2X techniques to the Japanese war with the first B-29 raids.

¶ The 15th AF's assault on Southern France beaches, with APS-15 leading the way to most targets, bombing half.

¶ Any number of particular, memorable missions through the year's worst weather—missions which wouldn't even have been flown except for H_2X.

All of this, and more besides, doesn't add up to infallibility for H_2X. Along with its successes, it's done some pretty poor bombing. But it's getting better and the future points toward average results as good as the best to date.

Aside from the all-important fact that the equipment is now getting into the field in quantity, there are three major justifications for faith in H_2X's future:

1. The equipment itself is accepting continuous improvement. As of November, 106 sets of a new model—AN/APS-15A—were out of modification centers on their way into combat. Higher resolution equipment (Eagle, or AN/APQ-7) is well on its way.
2. The H_2X training program, long behind schedule, is gradually rounding into shape.
3. Synchronous bombing, worked out by the 8th and 15th AFs, for the first time makes full use of both radar and visual methods.

For more on APS-15A, see page 10. For more on H_2X training, see page 27. For more on synchronous bombing, see following pages.

Radar's vision, bombsight's precision work together in synchronous bombing

The two basic components in an H_2X system are an orthodox microwave search unit plus a range unit providing the wherewithal for aiming. Acting somewhat like a slide rule, the range unit determines the point at which a particular type of bomb will strike the earth from a given altitude and ground speed. By positioning the computer drum the radar (Mickey)* operator coordinates this information. His adjustment positions a spot of light on the sweep line which corresponds to the correct slant range. As the sweep rotates, this point generates the bomb release circle, which corresponds to the horizontal crosshair found on the visual sight.

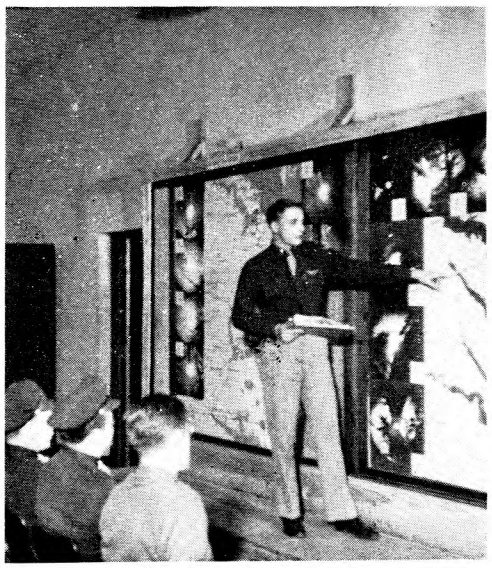
The plane's track represents the vertical hair, and bombs are toggled when the target image and release circle coincide. Such releases in the past year proved good enough for area bombing with all of the Air Forces which were using H_2X equipment.

However, complaint got to be quite universal that something better than area bombing was necessary. An analysis of "unimproved" (i. e., pre-synchronous) radar bombing in the 15th AF indicated that only about 12% of the bombs could be expected to fall within 1000 ft. of the target, given first class operation.

The figure is not too impressive, and it results from the inherent handicaps of radar sighting. In the first place, since the target image is not very sharply defined, considerable judgment is required of the Mickey operator to make accurate releases. To make it harder, this handicap intensifies during those decisive moments when the aircraft nears its target. At close ranges the release circle and target image become confused in the center clutter and distortion, which inevitably are found on the PPI scope.

As a matter of fact, in May of this year the 8th AF had its H_2X equipment 80% operational over the target but regarded bombing performance as unsatisfactory. Seventy navigators who were quizzed for reasons laid most of the blame on the difficulty of determining

* *"Mickey" was a code name given to H_2X equipment in the days when it was Secret; it has since gone into general use as a sort of nickname for H_2X radar, which covers both APS-15 (in B-17s and B-24s) and APQ-13 (in B-29s) as well as the forthcoming APQ-7 (Eagle).*



Radar briefing is vitally important first step getting synchronous mission started



Radome housing APS-15 spinner antenna is fixed by radar mechanics before take-off



Pathfinders warm up to lead bombers. H_2X still requires Pathfinder technique except with fully equipped B-29s. Synchronous bombing is best with H_2X **in all** planes

when the target had reached the bombing circle.

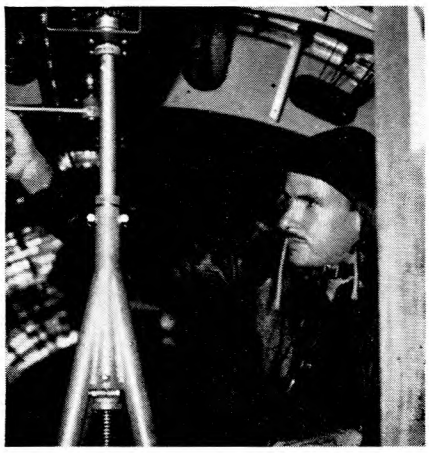
Which is why real precision bombing, until a few months ago, was pretty well confined to daylight missions utilizing the proven accuracy of visual bombsights.

The bombsight has precision if it can see. Radar can see but is less precise. Used independently these two valuable bombing instruments were doing about half the job they could have been doing combined. Synchronous bombing was developed in order to get the most out of both equipments. The combined use of radar and sight provides a workable bombing system which affords a high degree of accuracy under all conditions of visibility.

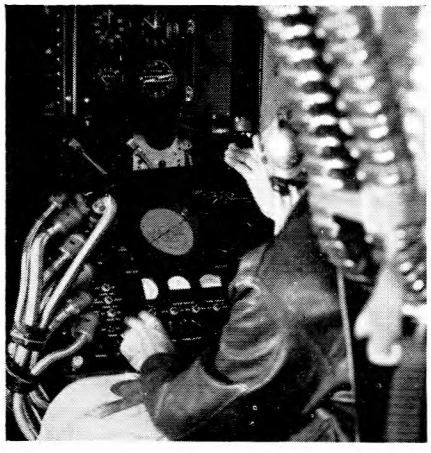
A typical synchronous mission is highpointed in the pictures below. Turn the page for a detailed presentation of radar-bombsight synchronization and how it works out.



Bombs are released by bombsight after bombardier has synchronized sighting angle index with readings given by Mickey operator. In cut-away section: the radar setup



APS-15 antenna must be lowered to operating position as soon as plane is airborne



Computer drum is adjusted after IP turn, setting bomb circle at 70° sighting angle

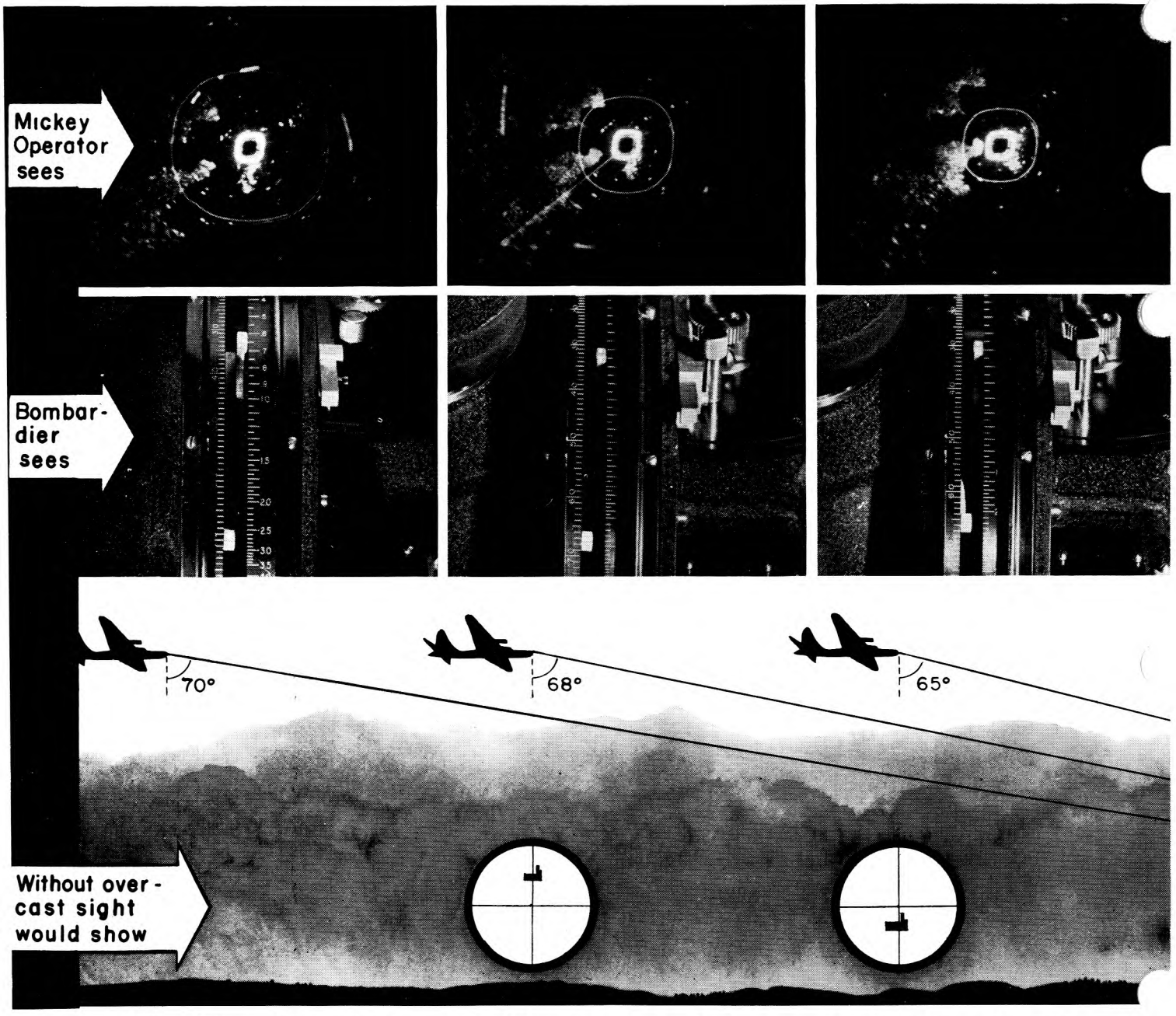


Via interphone operator tells bombardier when target coincides with bomb circle



Bombardier clutches in his sight which is pre-set with rate, trail and disc speed

This is what happens on synchronous H_2X mission. Bombsight



Essentially, H_2X synchronous bombing is little more than the stimulation of a high degree of Mickey-bombardier coordination. Without visibility the Mickey operator can determine more or less accurately everything a bombardier needs to know to set up his bombsight for a precision release—drift, trail (bomb ballistics), disc speed (altitude), rate (ground speed) and sighting angles. So the Mickey operator tells the bombardier, who sets the data up in his sight, which drops the bombs automatically and accurately.

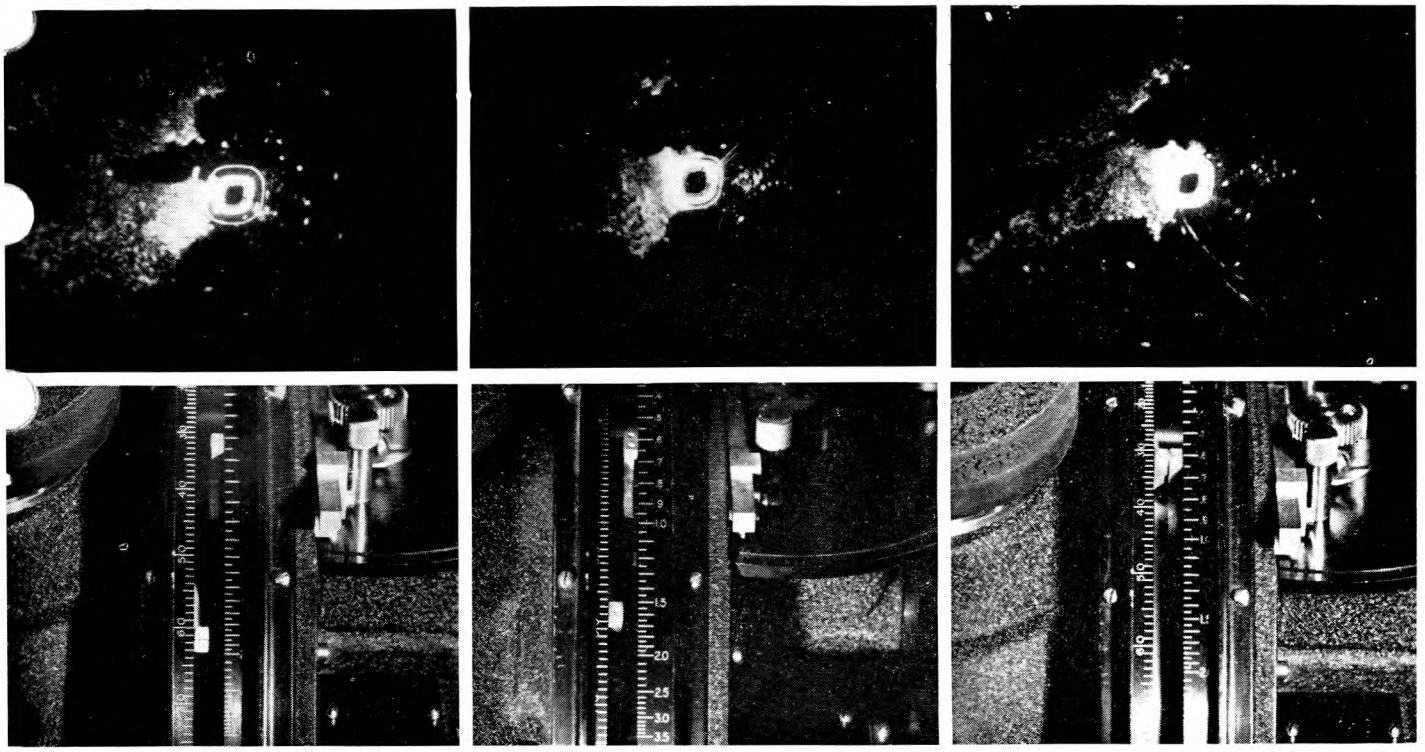
Since H_2X equipment is usually limited to Pathfinders flying lead positions, following planes must bomb on the Pathfinder's release.

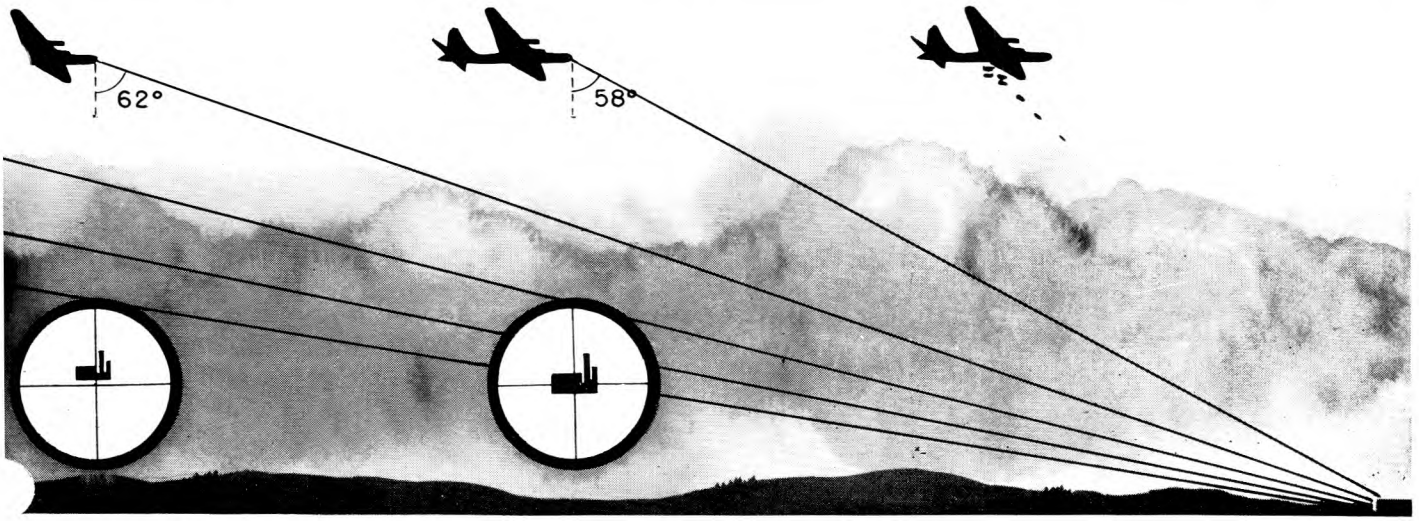
The synchronizing procedure begins after the plane is on its target run following the IP turn. The Mickey operator maintains a true track to the target and sets his bomb release circle to intersect the target image when the plane is at a 70° sighting angle from the target. This he does by using a special chart for the computer drum, which permits positioning of the bomb release circle according to sighting angles to the target inside of slant ranges (see computer drum picture, page 9).

The bombardier also has set his sighting angle index at 70° and has preset his dropping angle from rate, trail, disc speed, etc. At the coincidence of the circle and target image the Mickey operator notifies the bombardier, via interphone or signal light or both, and the bombardier immediately clutches in his telescope rate synchronizing motor.

If the pre-set data were correct and Mickey's first reading were absolutely

errors and corrections are exaggerated for this presentation





accurate the job would be just as simple as that. But such is never the case and unavoidable errors must be accounted for.

To do this several additional synchronizing checks are made. The radar operator positions his bombing circle as the plane approaches the target for 68, 65, 62, 58, 53 and 46° sighting angles (this separation between readings each represents one mile ground range or 20 to 30 seconds), and notifies the bombardier of the moment of coincidence in each case. By adjusting the rate knob the bombardier synchronizes his dropping angle index and adjusts the sighting angle index so that it agrees with the sighting angles determined by the Mickey operator.

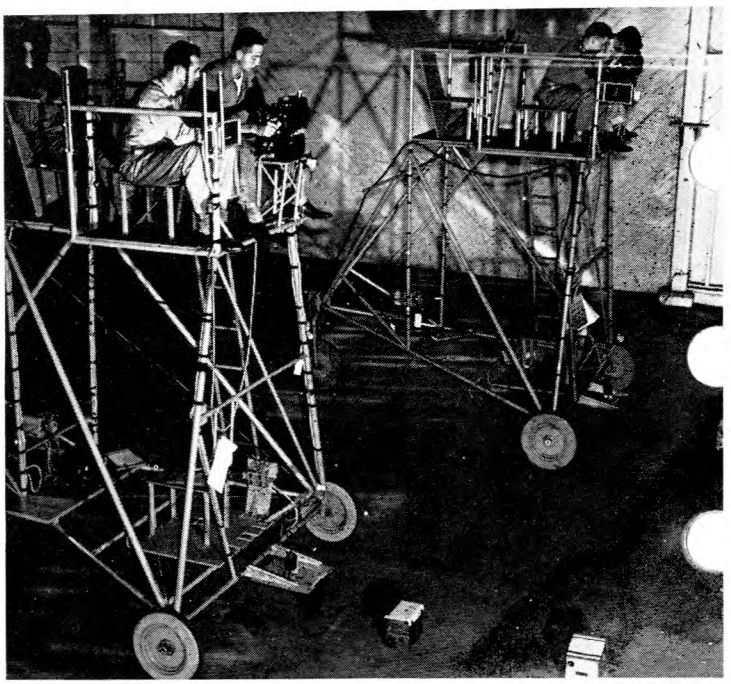
Synchronization is usually complete after four sighting angle checks. As soon as it is accomplished, the operator sets up his radar equipment for direct bombing and follows through on the run to be able to take over in case of bombsight failure.

For more on synchronous bombing, see following pages.

● *In bombsight photos above sighting angle index is left, dropping angle index right. At 70° left index starts moving up scale—has gone too far when Mickey indicates 68°—is immediately moved back to 68° and right index moved to slow down rate. At 65° overcorrection has made index slow—it is moved ahead to 65° and right index again moved to correct. At 62° left index is a little fast but at 58° it's on the nose—bombs are away when the two meet. Scope photos are taken from 15th AF D-day mission.*



H_2X training begins in the classroom and ends in the air. The Langley Field school for H_2X bombing furnished these pictures



Bombardiers practice the synchronizing procedure here—radar operators practice on the supersonic H_2X trainer (see page 27)

Synchronous bombing is now standard

All Air Forces which now do H_2X bombing (i. e., the 8th, 15th and 20th, including the latter's 21st Bomber Command) do it by coordination with the bombardier. And all bombing operations of these AFs will be led by H_2X aircraft as soon as enough are available. The use of the synchronous method as a standard operating procedure has been especially valuable this winter over Europe. A report from the 15th AF tells of weather conditions which have prevented visual sighting on 90% of the missions during the past few weeks.

Radar techniques are, of course, generally associated with night missions or poor visibility. But bombsight coordination gives H_2X an important job even on daylight missions. Experience to date has indicated that visual bombing operations are much improved when H_2X aircraft are leading.

One of the great advantages of synchronization is that it permits the bombardier to complete a run should the target become visible at the last minute. Under conditions of 9/10 overcast this technique has been extremely effective. Visual synchronization can be accomplished in the last 20 seconds if the bombsight has been previously coordinated with the radar.

Insurance against equipment failure is another by-product of the synchronous technique. If the radar goes out in the midst of a run the bombardier is able to carry on and drop his bombs with data preset from the radar.

Responsibility for the success of an entire mission used to rest on the accuracy of a single radar reading of bombing circle and target image coincidence. There was no chance for correction. The several readings made in synchronous bombing provide the means for checking initial errors.

Substantial errors are eliminated because critical scope readings are made some distance from the target where center clutter and distortion of the PPI are not a handicap.

When the target is too weak or fuzzy to be used as an aiming point the bombsight also comes in handy as a checking device. Previously Mickey used a stop watch to measure the offset distance from an aiming point to the release point. Automatic timing with the bombsight eliminates possible human errors.

Teamwork is the decisive factor in synchronization. Closely assisted and checked by the DR navigator, Mickey and bombardier do the big job in the air; but they have to get plenty of help from the pilot and crewmembers—more than on ordinary missions.

On the ground, the radar intelligence officer, aided by special maps and scope photos, helps the operations officer select a route, IP and bombing approach which will aid H_2X processes. Scope photos are particularly useful for determining reliable ranges on built-up areas, unique coastline features, lakes and the like. Routes are planned to insure that one or more of the known checkpoints will be at all times within radar range so that H_2X fixes can be taken constantly. The IP is put at least 40 miles from the target to allow time for drift correction, and a bombing approach selected to pass near radar landmarks.

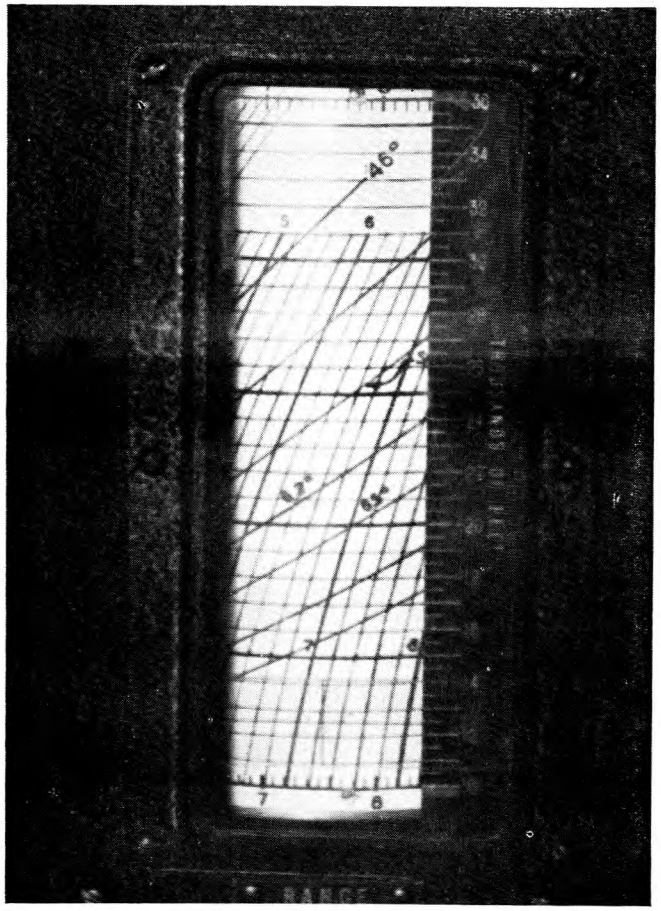
The idea of radar-bombsight coordination is really just getting started, and steps are already under way to make the tie-in closer. The point-to-point synchronization now practiced may soon be replaced by a system which provides continuous synchronization. With this system—called Nosmo (from NOrden Sight MOdification)—a Norden bombsight rate end is used to drive the H_2X bomb release circle potentiometer so that the bomb release circle tracks the target signal continuously.

Rate and sighting angle information thus obtained is automatically compared with similar information set into the bombsight on a meter in front of the bombardier, who simply adjusts his rate and position knobs until the meter hand remains stationary at zero—signifying accurate adjustment.

Synchronization with this system eliminates the cumbersome interphone or signal light arrangement between Mickey operator and bombardier. Early trials are encouraging, and a B-17 equipped with Nosmo is already enroute to the ETO for field trials.



Sighting angles are represented by horizontal lines and are called up to bombardier by officer representing Mickey operator



Computer drum for positioning the slant range circle indicates altitude (side) and slant range (bottom). Sighting angles were added diagonally for the synchronous procedure. To position the slant range circle, crosshair finder is adjusted for true altitude and drum is rotated so as to give the desired angle reading

8th and 15th AFs cut deflection errors with Quadruple Drift Correction Method

Deflection errors account for many of the inaccuracies of radar bombing, as demonstrated in both practice and combat missions. Efforts to minimize these errors have resulted in several drift correction procedures. RADAR No. 5 discussed the Final Heading Correction Method. The 8th and 15th Air Forces now do about the same thing with their Quadruple Drift Correction method.

This was derived from the Off Course Drift Correction Method, the principle of which is as follows: to make good a course to a target, the course correction needed is equal to the change in bearing of the target divided by the fraction of the total distance to target travelled while measuring change in bearing.

For example, if the fraction of the distance travelled is ½ and the change in bearing is 5°, the correction would be 5° divided by ½, or 10°.

For convenience the Quadruple Drift Correction Method is set up for a travelled distance of ¼ the total to allow as much time as possible for a check and another correction if necessary. Here's how it works.

Two short lines or tick marks are made on the rotating filter of the PPI scope at predetermined distances from the center. After the plane is on a proper heading following the turn at the IP, the rotatable track line is placed to bisect the target. Sweep amplitude is then expanded so that the target to be followed rests under the outer of the two marks, and the bearing is noted.

When the target has moved to the nearer mark, or ¼ the original distance between the plane and the target, the track line is again placed on the target and the bearing noted. The difference between the two bearings, when quadrupled, gives the proper correction. This is given to the pilot as a change in course in the same direction as the change in bearing.

Ideally this would bring the plane over the target. However, since it takes time to turn, the target will not be under the track line after the turn is completed. Drift has been killed but the plane is still off the desired track although flying parallel to it. This small error is corrected by the following rule of thumb: the additional change in bearing is measured, doubled and given to the pilot as a change in course.

If the first corrections are made some distance away from the target, the entire procedure should be repeated. The change in bearing cannot, in practice, be measured closer than ½° off and therefore initial corrections may be as much as 4 times ½° or a total of 2° in error.

With azimuth stabilization "off," the procedure is the same except for those changes needed as a result of the PPI picture rotating on the turns.



Bombs away through clouds and smoke to hit Ploesti refinery in first synchronous mission by 15th AF. Bad weather broke up formations twice enroute but target was hit despite intense AA and rocket fire. 39 Pathfinders led 80% of the 15th Air Force

One mission sold the 15th

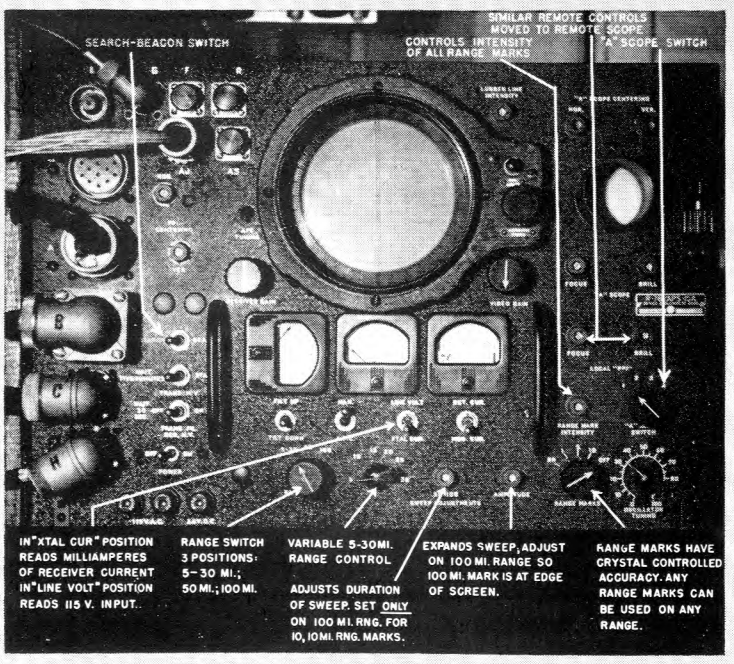
It took only one mission to sell synchronous bombing to the 8th AF—that was D-day, when synchronous H_2X bombed the beaches (see RADAR No. 3). And one mission sold it to the 15th—the Ploesti raid last July that brought forth a citation to the 461st Bomb Group (H), 15th AF Pathfinder unit. Excerpt: "With full realization of their responsibility . . . the Pathfinder operator and lead bombardier skilfully coordinated their instruments and dropped their bombs on the obscured target enabling the formation to lay down a perfect pattern. . . ."

For 3 weeks a special H_2X crew from the 461st got special briefing in the synchronous technique. Then it went back, briefed the whole Group. And on 15 July, 39 of the Group's B-24s led 80% of the 15th AF through bad weather, heavy flak and 2000 smoke generators to lay bombs on the Creditul-Minier refinery in the beautiful pattern at right.

More recently 15th AF Pathfinders have engaged in a promising new H_2X activity. Teaming up with bad weather, small formations of H_2X aircraft have been bombing individually under cloud cover so heavy as to prevent any other form of attack. Early trials are encouraging. Opposition has been slight because of the weather and damage has been great because of surprise.



Strike photo was made through last minute hole in clouds. 125 visible hits on refinery, 18 in storage yard and 21 on marshalling yards reduced by 1,500,000 tons the dwindling oil supplies of the Axis and established synchronous bombing technique



New member of the family

Most recent addition to the H_2X family is AN/APS-15A. The equipment is essentially APS-15 with revitalized circuits providing a more linear sweep, greater band width, shorter pulse and overall modernization. Outstanding changes in the indicator unit are pointed out at left. The most significant change was from a drum (page 9) to the dial computer shown across the page.

The new computer uses the H plus B method for positioning the bomb release circle and divides slant range to the target into components: (H) absolute altitude; and (B) an increment of range dependent upon ground speed. The drum and dial computers do the same thing but the dial does it more efficiently and with greater precision.

For direct bombing the H factor is set in by turning the altitude control until the release circle just touches the first ground return on the PPI. Setting in the B factor positions the circle for correct slant range to the target, and is done by turning the GS dial to the correct ground speed in knots. Trail for

Mixup on facts has given Jerry his best H_2X countermeasure; facts are that he can't make effective use of H_2X against us

Radar, like all new technical subjects, has a marginal area in which rumors and misunderstandings abound. Most of them are harmless or even funny; some of them can do great harm if they're not spiked before they become serious.

A case in point is the rumor that H_2X equipment (APS-15) in heavy bombers in the ETO exposes planes and men to enemy action. As a consequence, some air commanders have ordered H_2X sets turned off with the idea of preventing enemy locators from getting early warning of our attacks or in the belief that listening devices were being used to furnish tracking information for enemy AA batteries.

Such action is understandable in a way, if only because air crews in the ETO have a tough and wearing job and enemy defences around the dwindling list of strategic targets are increasingly concentrated and formidable. Nonetheless it is action based not on the facts, but on misunderstanding of the facts. And its net effect is to injure our own cause and help the enemy just as surely as if the Germans had been able to develop countermeasures to nullify our H_2X bombing.

The facts are that under present daytime bombing conditions in the ETO, Jerry cannot possibly get information from H_2X radiation which will be as useful and accurate for his purposes as information he already gets from several other sources—early warning radar, gun laying radar, and VHF intercepts. It is possible that the enemy has receivers which are capable of tuning in H_2X radiation. The reception, however—if he actually is getting it—would not give him a radar picture as it is seen on a Mickey scope; it would give him only the line of position from his receiver to our aircraft.

So far as early warning is concerned, the enemy gets more useful information from his own ground radar sets and from his interception of our interplane VHF talk than H_2X radiation can give him.

For ground control of interception by enemy fighters, Jerry's regular GCI procedure is much more efficient than any system based on picking up our H_2X could be.

With flak control, the case is even clearer: no data useful for flak control can be gained from monitoring Mickey. AA control requires tremendously fast and accurate data on azimuth, elevation and range of the airplane target. Such data is supplied to German flak batteries by the small Wurzburg radar. To get similar information from H_2X intercepts, a widespread group of ground stations would be required and the procedure would be so slow, cumbersome and inaccurate that it would be useless.

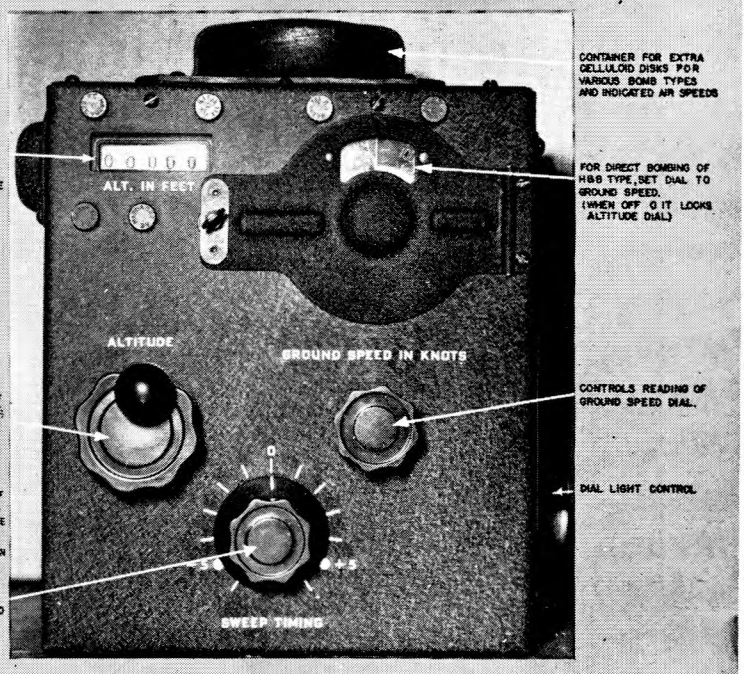
There is no doubt that flak damage to our heavy bombers has increased, but it comes from increased concentrations of flak batteries around strategic targets, not from monitoring of Mickey in our planes. Nor does the monitoring possibility serve to explain the fact that lead ships in a formation sustain more flak damage than following ships. Among several reasons for that are the relative clearness of the target image given on German radar by lead ships and the fact that following ships get extra protection from window dropped by the leaders.

Development and use of enemy countermeasures of all kinds are closely followed and even anticipated by Allied technical experts. Under present conditions they have no reason to believe that Jerry is capable of making effective use of our H_2X against us.

various bomb types and air speeds is accounted for by using one of 12 different B factor discs.

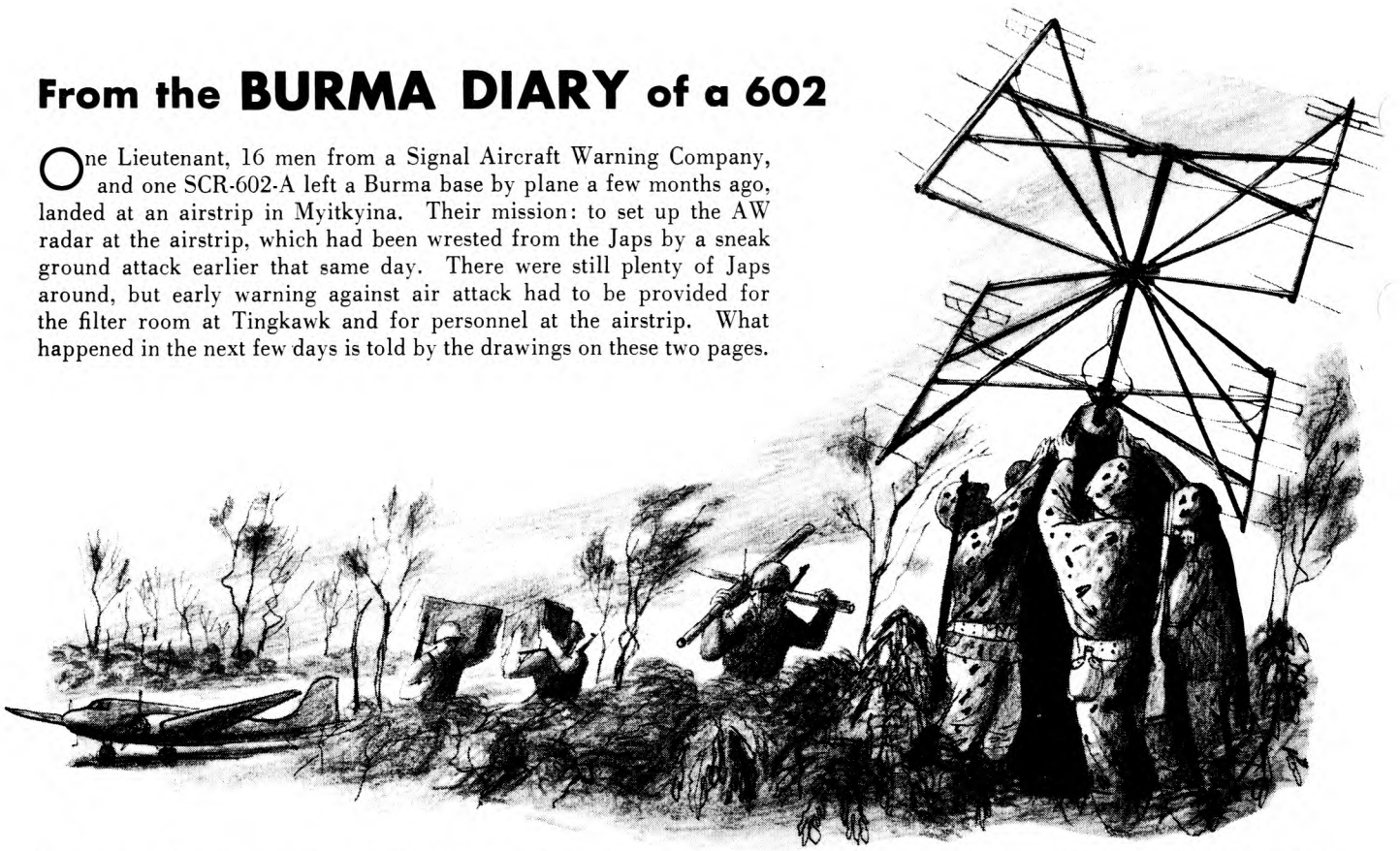
Although the dial computer was designed initially for direct H_2X bombing, it is easily adapted to the synchronous technique. For this a special sighting angle chart is used enabling the operator to set up distances in feet for various sighting angles. There are separate charts for different altitudes and each includes ground ranges and changes in range between sighting angles for quick checks of ground speed.

After the release circle is set for the correct altitude, in the same manner as for direct bombing, the value determined for a 70° sighting angle is turned into the altitude counter, positioning the circle for that angle. The same thing is done for the other angles and coordination with the bombardier is the same as before. With the synchronous procedure the ground speed counter is always kept at 0.

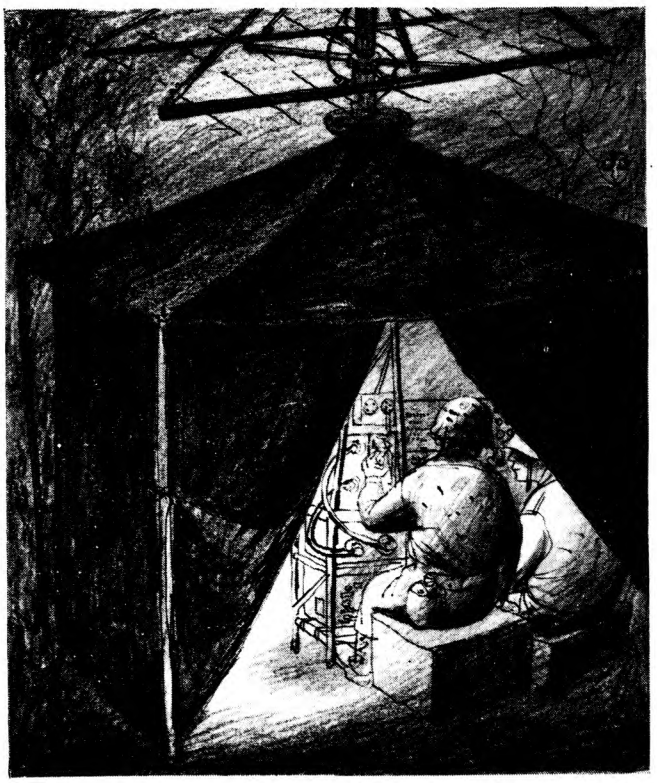


From the **BURMA DIARY** of a 602

One Lieutenant, 16 men from a Signal Aircraft Warning Company, and one SCR-602-A left a Burma base by plane a few months ago, landed at an airstrip in Myitkyina. Their mission: to set up the AW radar at the airstrip, which had been wrested from the Japs by a sneak ground attack earlier that same day. There were still plenty of Japs around, but early warning against air attack had to be provided for the filter room at Tingkawk and for personnel at the airstrip. What happened in the next few days is told by the drawings on these two pages.



1 In spite of enemy patrols and sniper action, all equipment was hauled from the airstrip to the site without mishap. The site chosen was about 300 yards from the edge of the strip and fairly good camouflage was afforded by short scrubby bushes



2 By nightfall of the first day, the radar unit, having withstood an air attack, was set up and being tested on the air



3 Enemy snipers and artillery were active. Sniper action was worst at daylight as Japs sneaked into position at night



4 On third day the radio team made contact with Net Control Station and the filter room began to receive plots from the 602



5 Artillery barrages soon became heavier, more frequent; radar was sandbagged, radio and plotting board set in shell hole

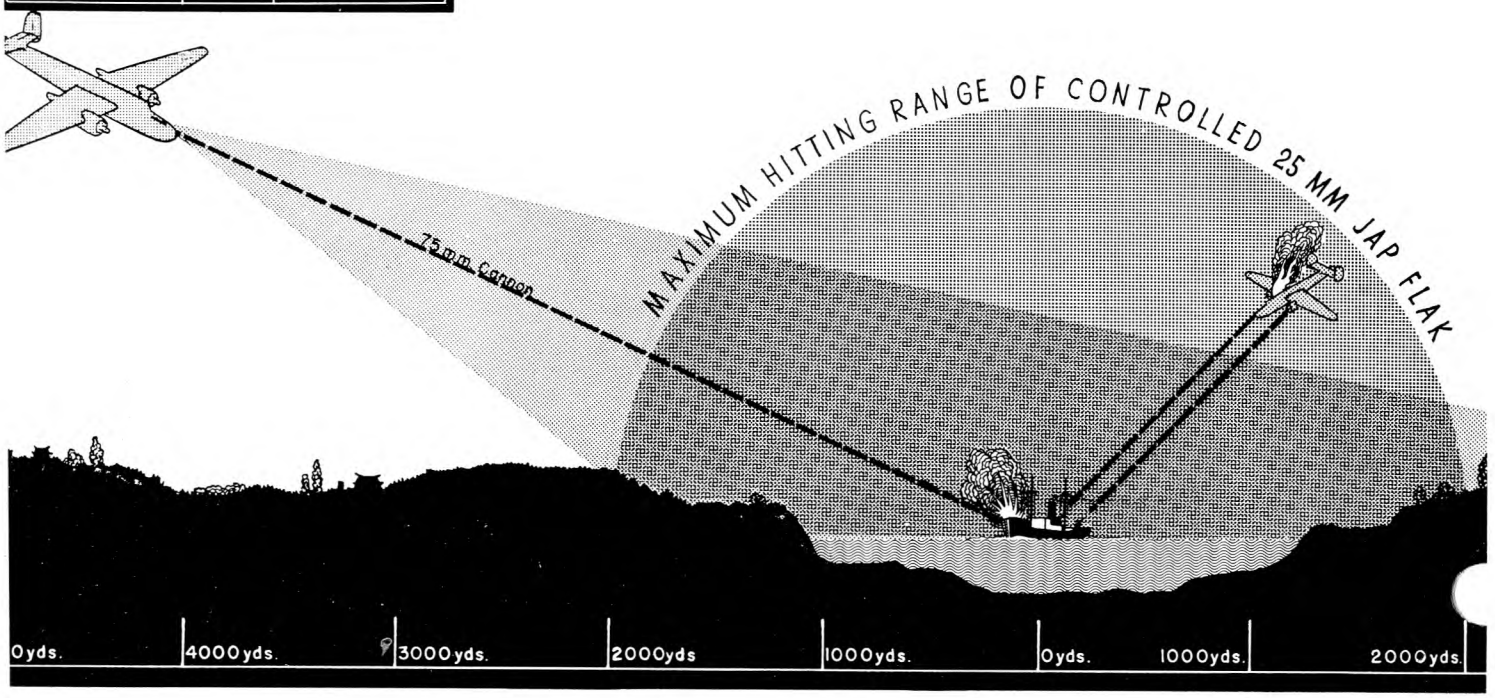


6 One morning operator reported flight of planes circling above undercast, showing no IFF. Crew tried out new method of defense—fake message broadcast to non-existent fighter over air-ground liaison net, then fake answer. Japs left without attacking

FALCON FOR FIRE

B-25H—75mm. cannon test results

WITH FALCON			WITHOUT FALCON	
HITS	MISSES	Range(yds)	HITS	MISSES
33	4	5000 to 4000	0	40
36	4	4000 to 3000	8	38
25	2	3000 to 2000	5	31
10	3	2000 to 1500	3	51
104	13	TOTALS	16	160
Boca Raton, June 1944 Concrete boat, 245' X 20' 90 % OF HITS IN CENTER THIRD		Place Target	Eglin Field, October 1944 Barge, 120' X 30' HITS SCATTERED ON TARGET	



Not long ago the fixed 75mm cannon in the nose of the B-25H was regarded as a handy anti-shipping weapon that ought to be handier. With a range of over 5000 yards, the B-25H and its 763 lb. cannon represented a unit of highly mobile artillery that could stay clear of the light flak thrown up by Jap shipping while hammering away at the target.

But the cannon had no way of getting accuracy at long range; instead it had to be fired on the optical judgment of the pilots, which is a particularly tough ASV assignment. As a result, B-25H pilots worked mostly at short distances where optical range errors were small but the danger of getting shot down high. What was needed was something to give range data to the gunsight so that the necessary superelevation correction, allowing for the gravity drop of the 15 lb. projectiles, could be accurately applied.

The answer was AN/APG-13 (Falcon), radar range finder introduced early in 1944.* Falcon eliminates guesswork all the way from 5100 down to 300 yards, keeps the gunsight continuously corrected for range.

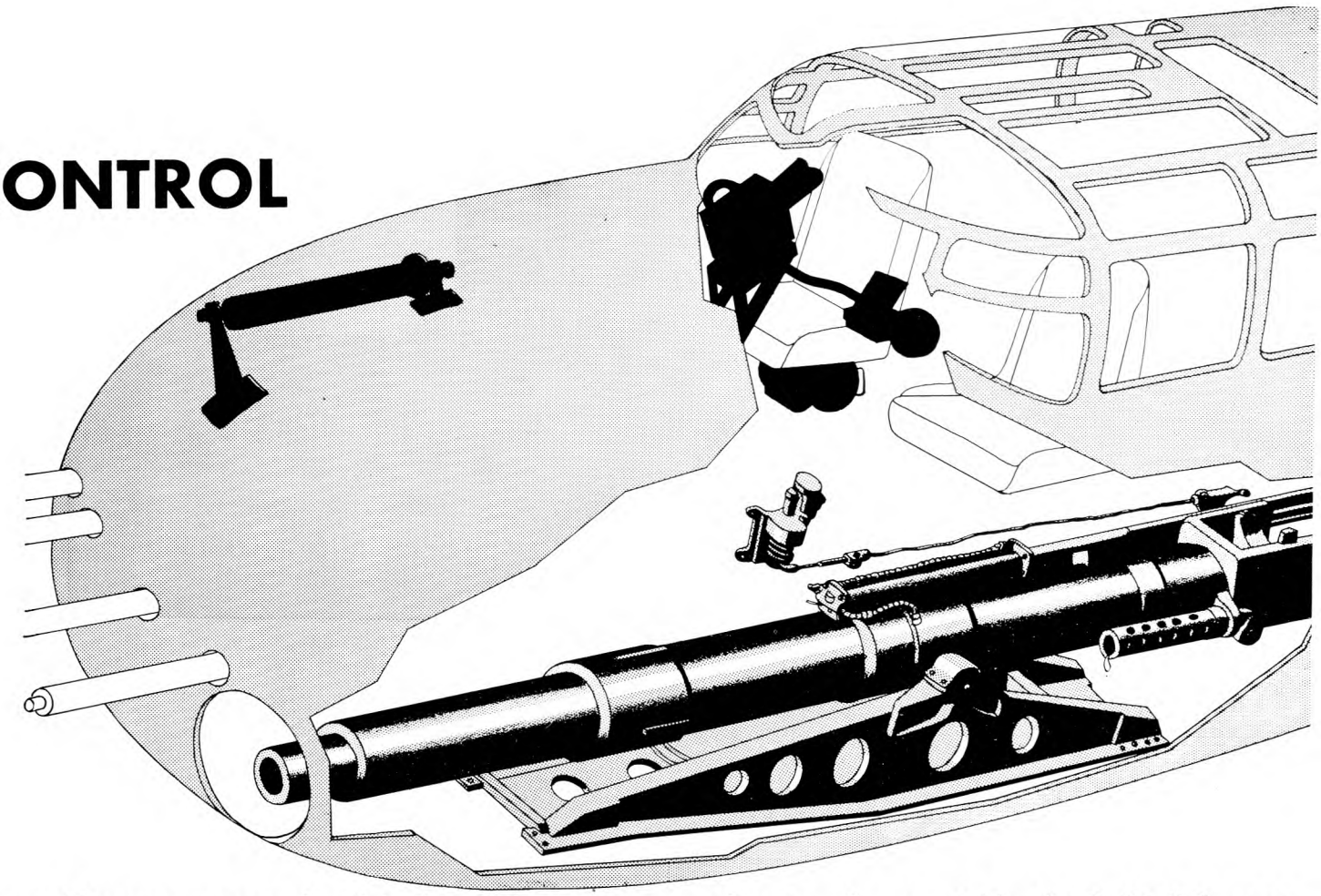
It turns out that pilots take readily to Falcon, and ring up good scores with little or no training in 75mm firing. Their performance isn't surprising, since their job—providing the gunsight is fed correct data by the radar operator sitting alongside—is stripped down to flying so that the hairlines in the sight window are properly positioned on the target and then pushing the firing button as fast as the cannon is loaded.

** AN/APG-13 was the crash-built, pre-production Falcon; test data mentioned in this report refer to that. The production model, incorporating several refinements, but essentially the same equipment, is designated AN/APG-13A.*

Falcon now has been theater tested by the 5th, 13th and 14th Air Forces. Only the 14th was able to give it a real workout. Its performance in China (mainly along the Yangtze) resulted in a heavy requirement, fulfillment of which has been affected by the critical China base problem, though Jap river traffic still offers targets from existing westward bases. The 5th and 13th just didn't have the shipping to pit it against. But a Marine squadron fitted with Falcon now is in the Pacific and 6 more will follow.

The fact that the Japs have taken to using small, flimsy cargo vessels in substantial numbers (partly for reasons of cargo dispersal, partly because of the increasing dearth of larger ships) gives the B-25H-75mm-Falcon team added value. Against light shipping the 1.5 lbs. of TNT in the 15 lb. projectile is powerful enough to kill. It isn't enough to hurt a heavily-constructed vessel or

CONTROL



provides accuracy and safety by giving range on shipping from outside the light flak zone

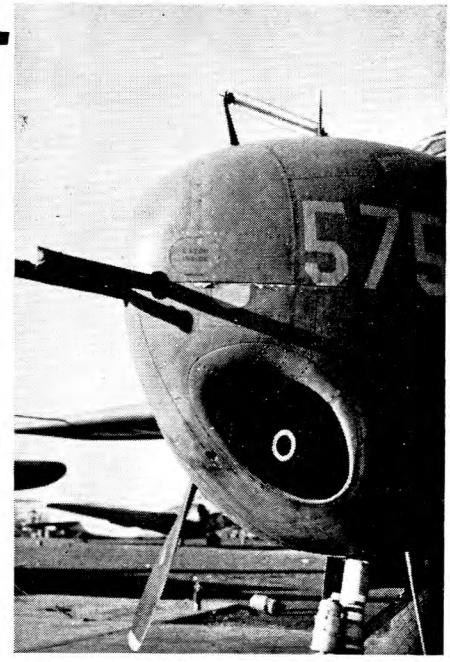
a warship. And in comparison, the 500 lb. bomb dropped by an LAB B-24 (see RADAR No. 6) carries 250 lbs. of explosive. That may be why the 5th Air Force sees the Falcon-fitted B-25H as best suited for armed reconnaissance.

Another possibility for Falcon is its adaptation for 105mm cannon in the A-26, which would require an increase in the radar sweep to 12,000 yards or more.

The theater tests have proved Falcon inept against most land targets because the rough terrain often encountered in Jap warfare doesn't allow good target discrimination at ranges above 1500 yards. But a "range-over-land" development (Vulture) is under way which may see the equipment modified to give range data against tanks, motor vehicles, trains, ammunition dumps and other non-isolated land targets.

Falcon is just one of 10 or more airborne fire control radars on their way into operation. It is the first scheduled for extensive use, with both Army and Navy participating. Others, however, are fast following. AN/APG-15, a combined ARO and AGS type (see page 18) for the B-29 tail turret, has been delivered to the theater in small quantities and should be in use about the time this issue is being read. AN/APG-5, similar to Falcon but needing no radar operator, will soon be used in bomber turrets to feed range to computing sights. Additional systems are being designed and built for tail defense of various aircraft, for use with fighter computing sights, for blind fire control in the Black Widow. Most of these are more complex and weigh more than Falcon (a 100 lb. baby). In return they handle more complex assignments. They will be reported on in an early issue; for pictures of 2 of them see page 18.

For more on Falcon and how it operates, see following pages.



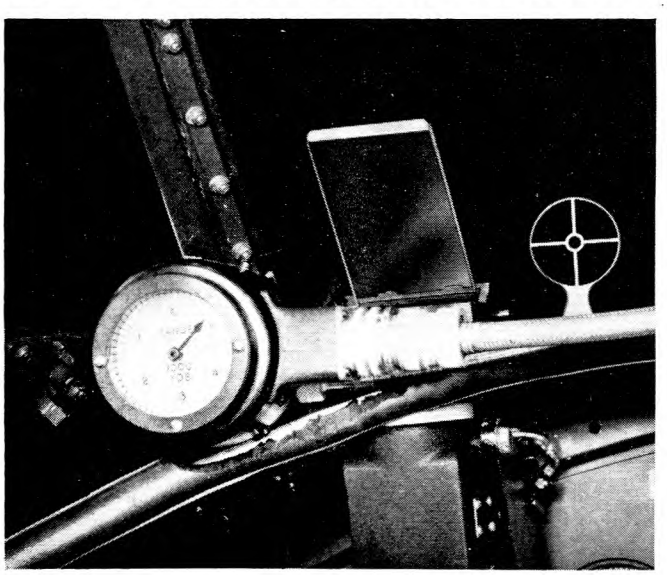
Endfire antenna is on axis of 75 mm cannon, gives 28° in azimuth, elevation. **Above:** drawing shows the cannon and Falcon parts—antenna, indicator, lighthouse Tube Receiver (LHTR), range dial



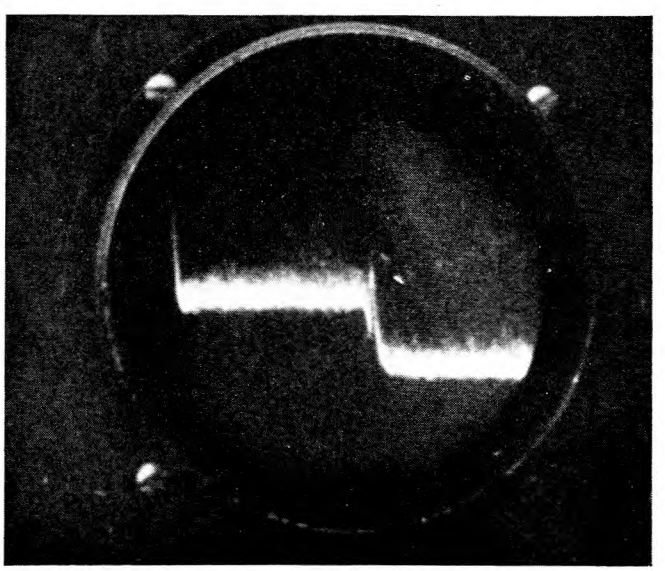
ALL B-25Hs HAVE 75 MM CANNONS, MANY ARE GETTING FALCON. WITH RADAR, FIRING STARTS AT 3 MILES, BREAKS OFF GENERALLY AT ONE



14TH AF TESTS IN CHINA GAVE CANNON-FALCON TEAM GOOD SCORE AGAINST JAP RIVER TRAFFIC. B-25H VICTIM ABOVE IS TYPICAL EXAMPLE



Reflector sight tilts as range data feed in. Pilot keeps target in aiming circle, reads range dial to determine breakoff point



"M" scope is what radar operator, alongside pilot, sees. He tracks manually, turning crank at side of scope to adjust sight

In combat and elsewhere Falcon looks the same—good shooting at long range

Without Falcon the fixed 75mm cannon in the nose of the B-25H is airborne artillery useful at pointblank range. With Falcon it can knock out a Jap supply ship at 3 miles. In operation, the procedures unfold as follows:

WITHOUT FALCON: The pilot presets the gunsight for a certain range by rotating the adjusting knob. As he flies, his line of sight is on the target as seen through the gunsight. When he estimates his range to the target to be equal to the prescribed distance he pushes the firing button. He then quickly resets the sight to a shorter range and repeats.

With this technique, about 3 shells can be fired per run. The big trouble is that estimating ranges is tricky practice, so the pilot flies in close where his judgment is better but the flak thicker.

WITH FALCON: The radar operator and the pilot, sitting side by side, work as a team. The pilot homes on a target. He motions the operator. When the target becomes visible the operator is ready. Watching it on his 6000 yard range sweep he begins tracking, keeping the range step lined up with the left hand side of the target echo by turning a crank on the side of the indicator unit. This automatically turns a cam that varies the elevation angle of the optical reflector sight to provide the required superelevation. Coincidentally, the data is fed into the range dial mounted near the sight, enabling the pilot to open and break off fire on the basis of his range readings.

The pilot, for his part, keeps the target positioned in the reflector sight, computes windage as usual, and fires as often as the loader can ram the projectiles (20 in the rack and maybe more on the floor) into the breach. With Falcon constantly providing range data for the gunsight, 10 or more rounds can be fired during a single run.

In its young lifetime Falcon has undergone a number of tests at home and abroad, all of which add up to pretty much the same thing. The picture is one of accurate 75mm firing as far as 3 miles from the target and the fuller realization of B-25H as an offensive weapon. It's also a picture of increased understanding of Falcon's applications and limitations, particularly based on its tests.

AAF BOARD TESTS. Official trials at ranges from 5,000 down to 2,000 yards resulted in 56% hits on a destroyer silhouette. Between 5,000 and 4,000 yards the average was 35%.

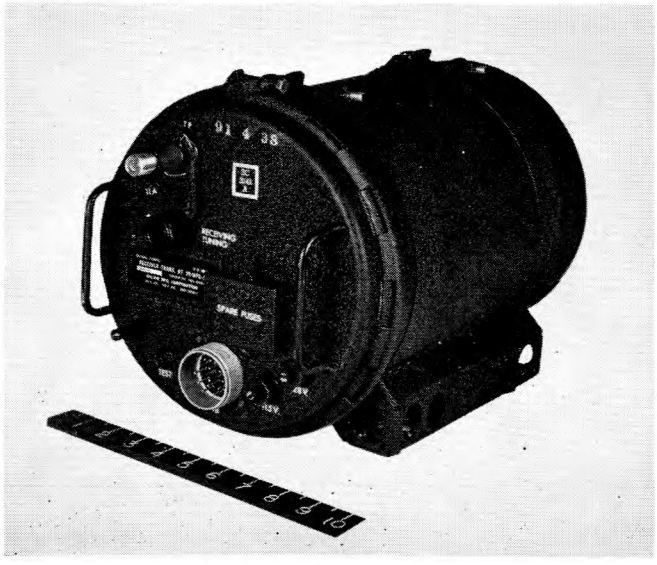
BOCA RATON (FLA.) TESTS. Three pilots handling the 75mm for the first time fired 117 times, making 4 to 5 shots on each pass on ranges between 4800 and 2000 yards. They made 104 hits, 13 misses (see chart, page 14). Here is what they reported:

Lt. Col. John J. Mullen: "Any pilot with a minimum of training can be expected to fire an almost perfect score. The operation of the radar is quite simple and should require little training. The test results were amazing. Each time the cannon was fired while the target was in the sights a direct hit was registered."

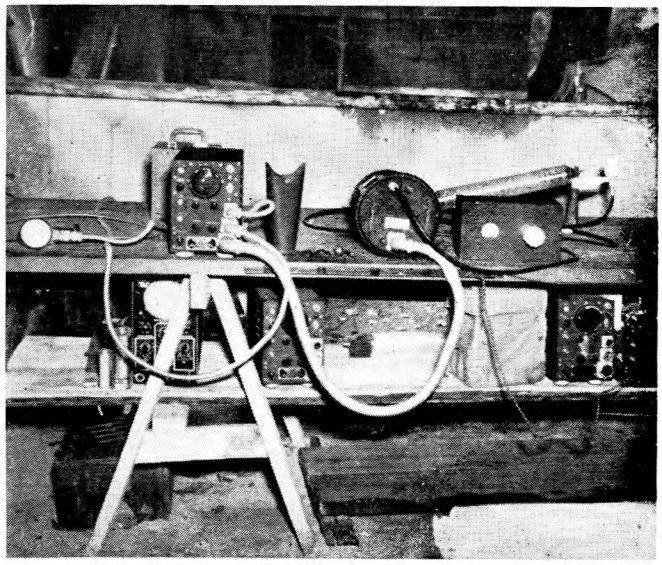
Capt. F. J. Muskus: "I consider the equipment very satisfactory . . . this was my first experience in this type of firing and the high percentage of hits proves its effectiveness."

Capt. R. S. Bowditch: "After firing 46 rounds, my first aerial gunnery, I consider my score remarkable. Use of the sight involved no skill or experience, and after firing a few rounds even the most inexperienced pilot should have no difficulty getting a high percentage."

5TH AF PROJECT. Sixteen B-25Hs, commanded by Lt. Col. Neil A. Newman, tested Falcon in June 1944 for its tactical value in the 5th AF theater. Most missions, due to the scarcity of enemy shipping, developed into training and practice flights. Good scores were counted against small rocks and islands in most of the 19 such operations. Three missions failed because of radar electrical and mechanical failures, two because of radar operator inexperience. Two additional missions that started as anti-shipping developed into land-strafing which found Falcon useless. In the



Lightweight LHTR weighs 28 lbs., is coming into operational use after long development. It makes airborne fire control possible



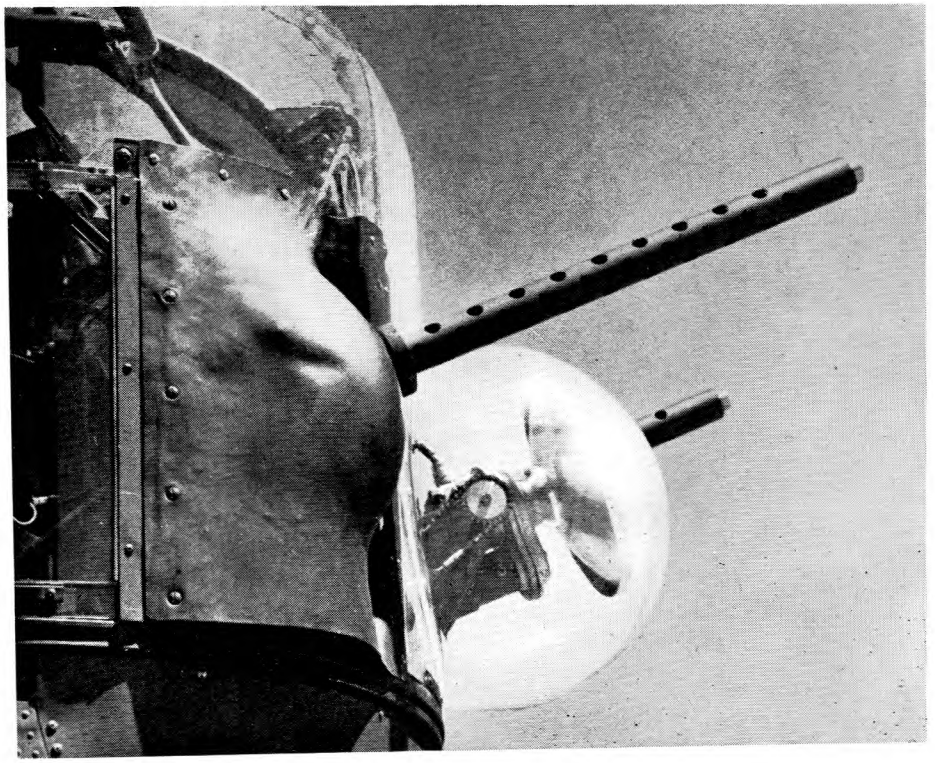
5th AF bench set emphasizes Falcon's compactness, simplicity. Ease of installation and maintenance are big Falcon advantages

First showing of two airborne radar fire control types now becoming operational



AN/APG-5, on B-17 turret above, is one of ARO (Airborne Range Only) group; it does for flexible gunnery what Falcon, another ARO, does for fixed gunnery

AN/APG-8, below, is AGS (Airborne Gun Sighting). Improved version, APG-15, is being installed in B-29 tail turrets to give pointblank machine gun protection



lone operation that found an enemy transport, the pilot failed to fly at the airspeed required for the gunsight computation, and all shots fell short. As a result of this error, the production Falcon now allows the pilot to set his own speed so long as he maintains it throughout the firing run.

14TH AF PROJECT. Three B-25Hs got operational tests in China during June 1944 under Major P. J. Riemar. Two were fitted and flown from Eglin Field, another was fitted with spare equipment in the field. Major General Claire L. Chennault, who saw Falcon as a way to get at Jap river traffic supplying the central China invasion, briefed the crews first. He acquainted them with the Jap strategy, moving shipping along the Yangtze after dark, anchoring during daytime with large gunboats hovering nearby. Long range firing seemed a likely answer. Against such opposition 3 test missions were flown, the following results noted:

1. Against gunboats on the Yangtze, with fighter cover by 13 P-38s, firing began at 6,000 yards and broke off at 2,000, with most firing around 4,700. Forty-two rounds were fired by the 3 aircraft and a considerable number of hits recorded. The gunboats, about the size of small destroyers, were heavily armed with AA guns up to 40mm. During 35 minutes over the target no sinkings were noted.

2. Twelve hits seen, many probables, out of 61 rounds against Changsha shipping. One cargo ship, 1 fuel boat and several small motorpowered cargo boats sunk.

3. Two B-25Hs, the pilot of one firing the 75mm for the first time, made a one hour sweep along the Yangtze. One large steamer and 4 river boats destroyed. Total damage to all B-25Hs on all missions was 1 flak hole.

Falcon's tests are finished now. The present job is to figure ways—the base problem being what it is—to get planes into combat. The 14th AF, striking against Jap river traffic deep in China's provinces, has the best chance. Other AF's are primed for its use as soon as takeoffs become possible. With Falcon by day and LAB (see RADAR No. 6) by night, they have a double-barreled menace against Jap shipping that is slated for plenty of action as the forces come to closer grips in the months to come.



ORDINARILY AN AIRFIELD WOULD BE CLOSED TO INCOMING PLANES IN WEATHER LIKE THIS. GCA's JOB: TO CUT A PATH THROUGH THE WEATHER

All-weather glide path

A new approach to the old problem of beating the weather with ground radar—specifically, GCA

There was overcast from 100 feet up to 25,000 and some fog. Visibility was ¼ mile at the most. The B-17 had been cleared from Savannah to Fort Dix, but the weather came up and the plane got lost. Finally the pilot managed to get in touch with Lakehurst Range and was handed over to Dix, where crews in training with the new GCA system were just waiting to handle this kind of business.

By now the No. 1 engine was acting up badly. But now the situation was in hand. The GCA controller brought the big ship into the normal pattern, onto the final approach—necessarily short because of the emergency—and right down to 100 feet over the centerline of the runway. "From there on," the pilot was explaining happily a few minutes later, "it was easy. All I want to do now is kiss that controller."

Poor visibility over airfields can do more than give a pilot a bad time; it can crash planes, smash up crews and badly disrupt operational schedules affecting many flights. Consequently, a lot of emphasis has been placed on the development of blind approach and landing equipment.

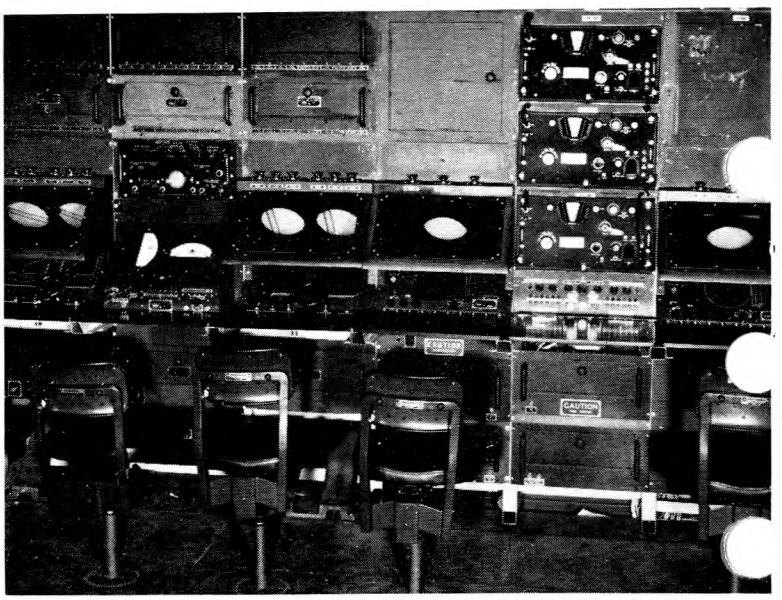
GCA,* radar's best contribution to the problem, is distinguished from other systems by the fact that it requires no special equipment in the aircraft; nor is pilot training necessary. As a result, a pilot can make use of it coming into a strange field no matter what type of plane he is flying. If he is the worse for wear after a combat mission, the GCA crew can bring him in first without confusing or endangering other aircraft about to come in. The GCA operators on the ground have a continuous indication of the position of planes within a radius of 30 miles. They can give a pilot accurate range and azimuth data at all times, and precise elevation data from 10 miles, to place him within 50 feet over the center of the end of the runway. The system can handle several aircraft at once and is capable of limited traffic control.

GCA is new, but sufficiently tried to warrant the go-ahead that has been given it. In the months ahead it will be going into the theaters in quantity. For details see following pages.

* *Ground Control of Approach. Official designation of GCA equipment now in production (Mark III) is AN/MPN-1.*



Success of GCA depends greatly on highly skilled, competent crews. Operators must give pilot confidence, also accurate data

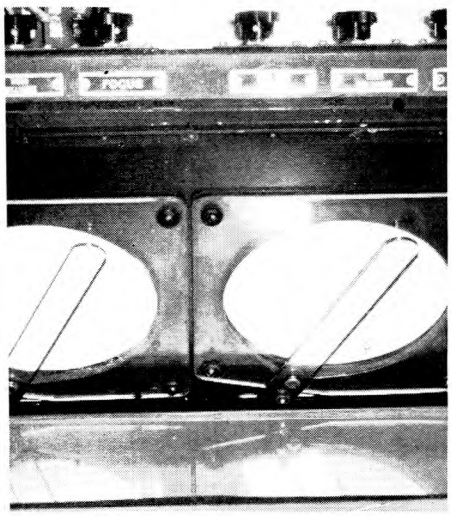


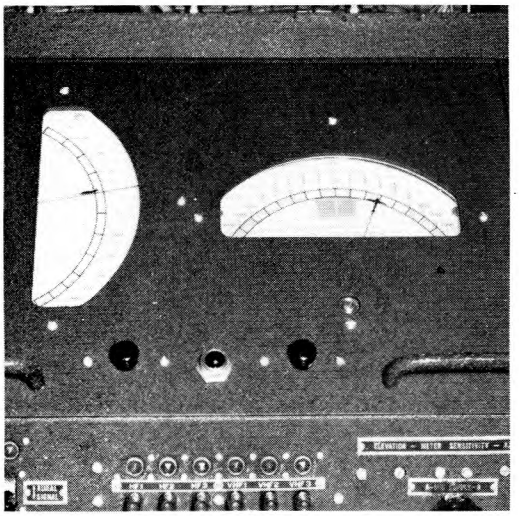
Compact indicator rack is housed in trailer. Set-up of search, precision and communication systems makes for efficient operation

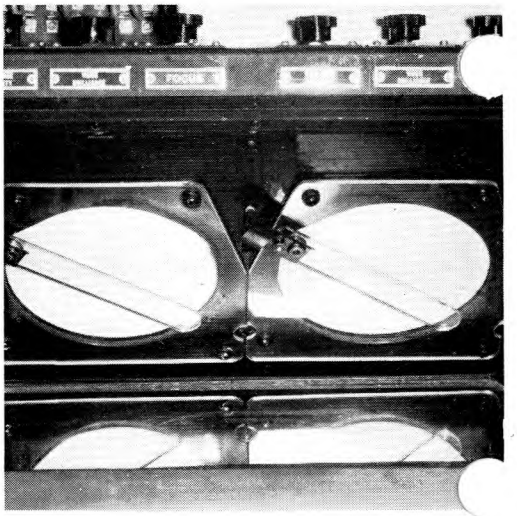
GCA gets ready for a big job

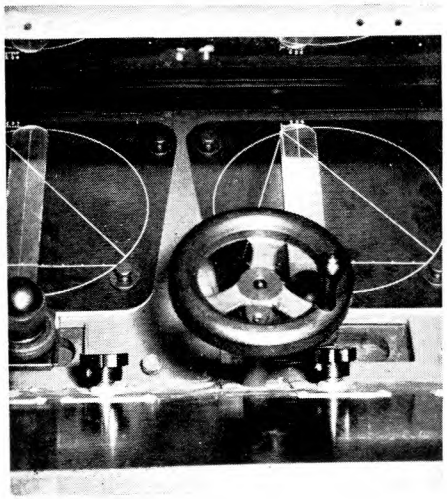
Mark III GCA will soon be able to prove its full operational worth. Production, after early difficulties, is well under way and several sets have been delivered for training at U. S. centers. Based on theater experience with some preproduction equipment, a versatile operating procedure has been worked out. Requests for equipment and personnel have come in from most all of the overseas air forces and with the start of the year the first production sets and trained crews to operate them will be on their way to do a job.

First equipments will go to the European theater where, now that the war has entered the winter phase, the old game of beating the weather is tougher. It would seem likely that GCA will have a full-time job over there.



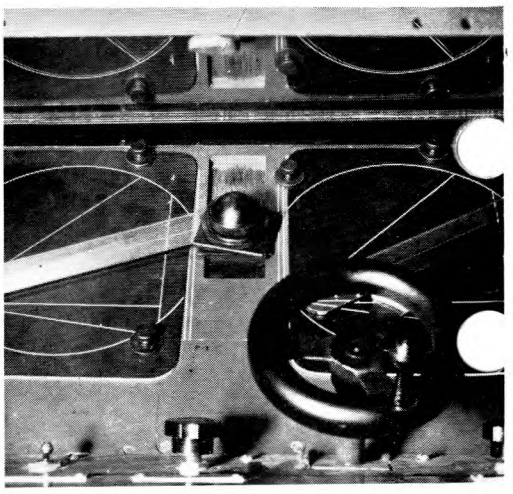


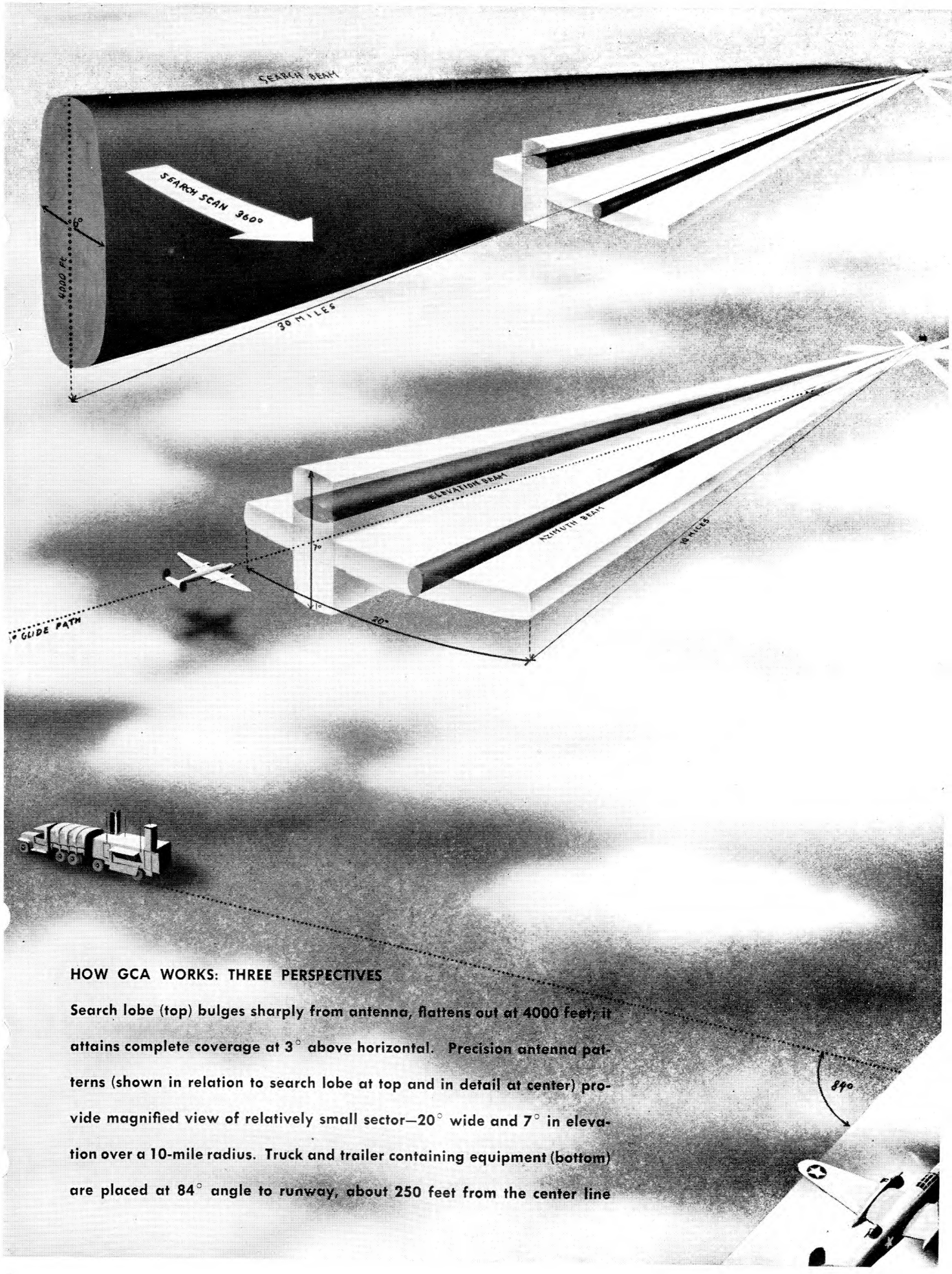




SPECIAL PRESENTATION ADDS TO PRECISION OF GCA

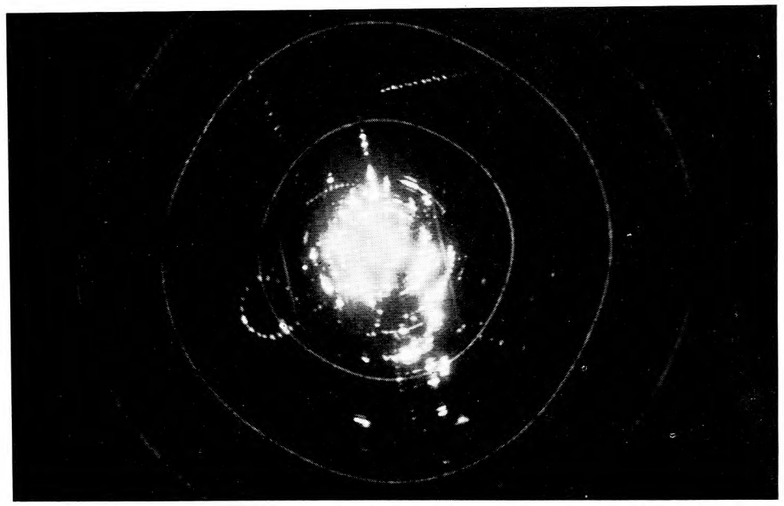
Error meters (center) show the GCA controller whether plane is directly on ideal flight path. Handwheels operated at azimuth tracker's position (left) and elevation tracker's position (right) keep cursors mounted on precision maps directly over echo, which automatically controls meter indications. 10 mile scopes are on right at both positions and 2 mile scopes are on left. Here precision maps and scopes have been photographed directly. What the operator sees is ingenious combination of the two on half-silvered mirror; the purpose of this is to give a perfect correlation of the scope and map data including the positions of cursors



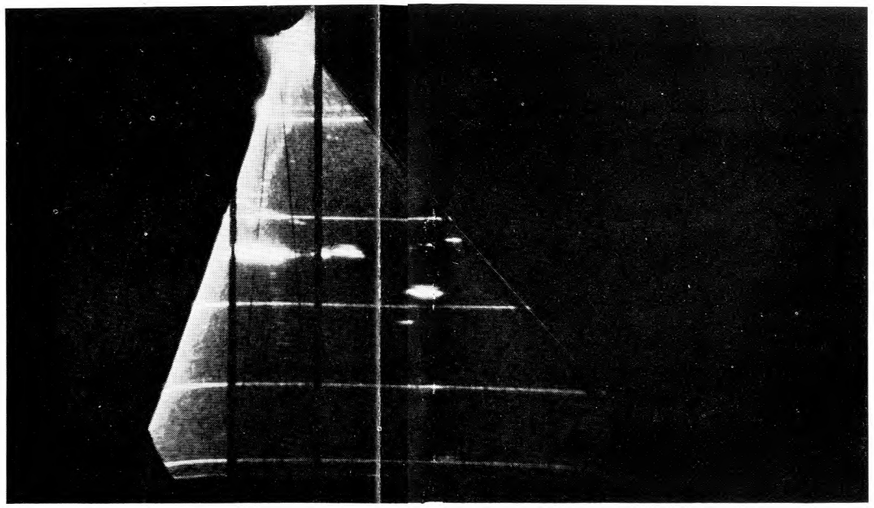


HOW GCA WORKS: THREE PERSPECTIVES

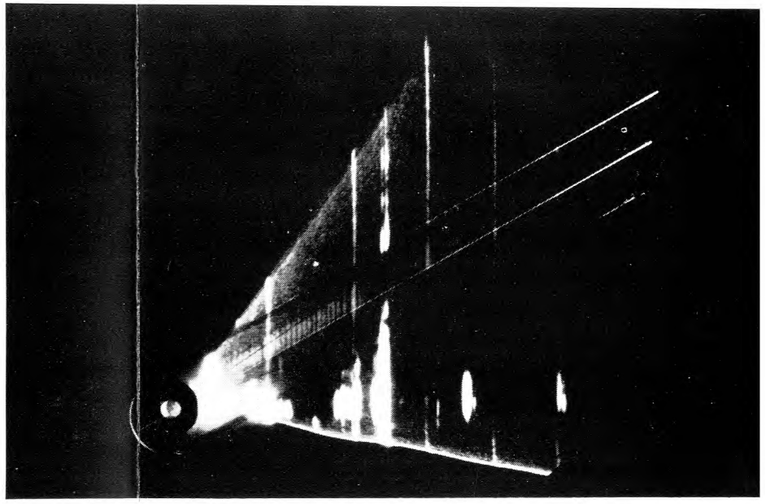
Search lobe (top) bulges sharply from antenna, flattens out at 4000 feet; it attains complete coverage at 3° above horizontal. Precision antenna patterns (shown in relation to search lobe at top and in detail at center) provide magnified view of relatively small sector—20° wide and 7° in elevation over a 10-mile radius. Truck and trailer containing equipment (bottom) are placed at 84° angle to runway, about 250 feet from the center line



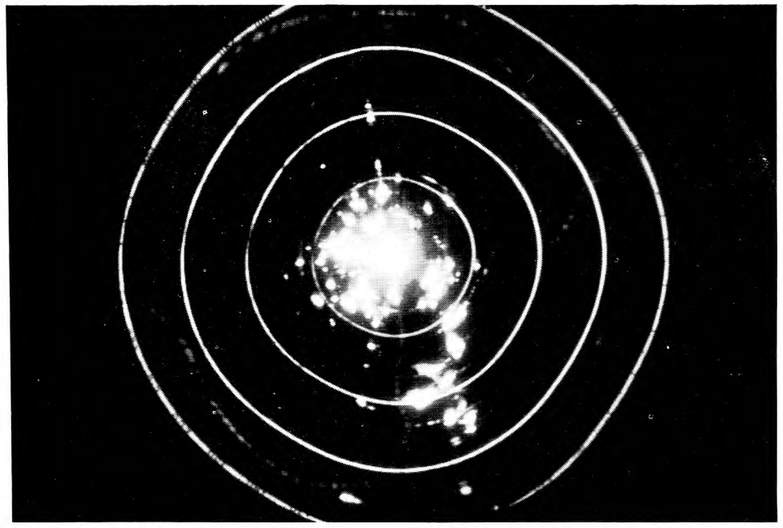
PPI on 15 mile sweep shows tracks of 5 planes—4 circling airfield and one coming in. Ground return is heavy since successive exposures were taken on same frame



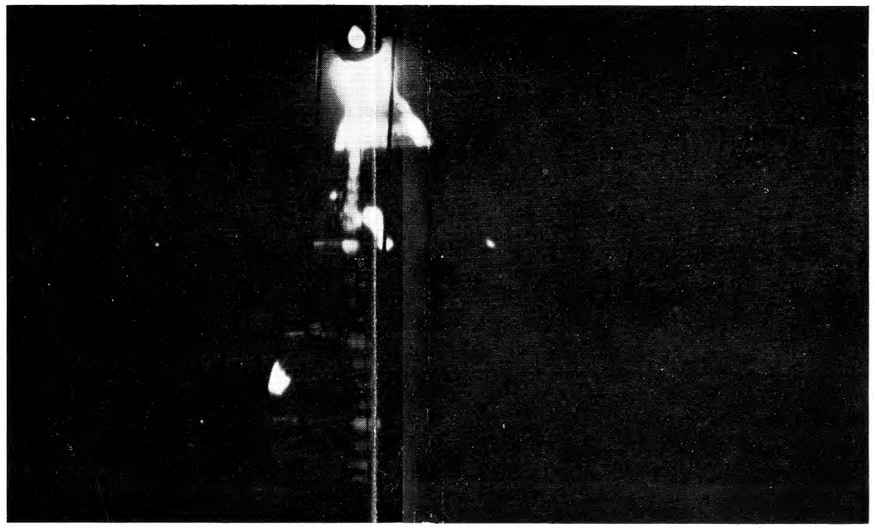
Ten mile azimuth scope shows series of echoes of plane being brought in from about 7 miles out and several corrections in azimuth as plane leaves the correct path



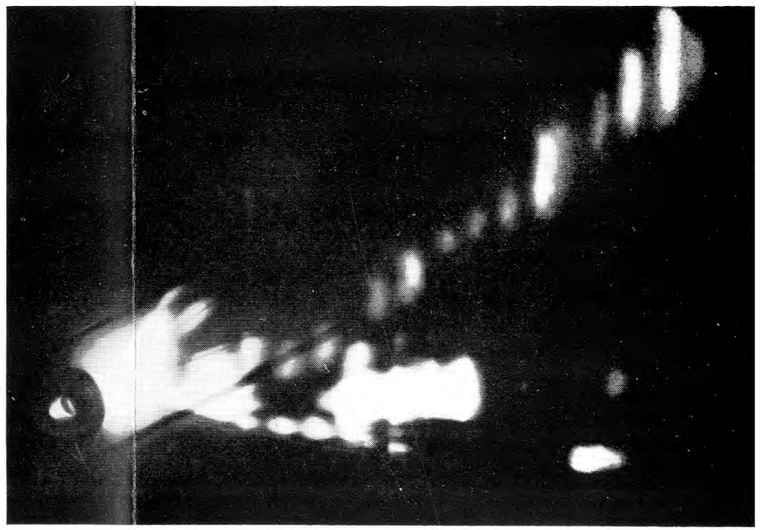
Ten mile elevation scope shows aircraft maintaining altitude from 7 to 6 miles, then starting glide at 6 miles, flying at proper glide angle but slightly above glide path



PPI on 8 mile sweep with 2 mile range marks shows track of plane coming in and 2 corrections made in its heading. Long track at top is aircraft waiting to come in



Two mile azimuth scope shows final approach track—range marks 2500 feet apart. Signal left of track is permanent echo from tower; other echo is from island in harbor



Two mile elevation scope shows plane descending slightly above path and leveling off at 4000 feet range to 50 feet above the ground. Normally gain is considerably reduced

GCA sees plane's every move

Completely mobile, GCA is a self-contained unit that can go wherever it's needed—by land or by landing craft. Siting in relation to the runway must be accurate, but is not a difficult job. The equipment is a combination of two specialized radars, an X-band precision system and an S-band search system plus a multichannel radio communications system. To bring in a plane, the "talk down" method is used. Operation of GCA requires a 6-man team, 5 on the ground and one—the pilot—in the air.

The search system locates incoming planes as they come within 30 miles of the airfield. The echoes received from the 360° scan of the search beam are shown on PPI scopes for both a traffic director and a plane selector. The scopes are mounted at a 45° angle, reflecting the radar echo information down onto a horizontal semi-transparent mirror which combines with map information reflected up through the mirror. Thus the plane's position is given both in space and in relation to the surrounding terrain.

The traffic director gets one or more planes into a traffic pattern until he can turn them over, one by one, to the plane selector. The selector, watching a plane's flight on the No. 2 PPI, then can direct the pilot into the ideal flight path. When the plane gets to within 10 miles of the runway, its echo is tracked on the precision system.

For this 4 scopes are used. The azimuth tracker gets his information from two expanded partial PPI scopes (Expanded Position Indicators or EPI), which are a major feature of GCA. The special type of indication provided gives a much larger and clearer version of the echoes to be tracked—deviations of a few feet can be detected. The azimuth tracker has one EPI that magnifies a 10-mile section of the area and one that further expands the last 2 miles. The elevation tracker follows the incoming aircraft on a similar pair of scopes.

The 2 trackers manually operate cursors or transparent rules mounted over the face of the precision maps. They keep these cursors constantly over the center of the echo, tracking any deviation from the prescribed landing path. And every movement of the cursors is recorded in the error meters in front of the approach controller. It is the controller who, studying the meters, talks to the pilot and gives precise directions to keep him on the correct approach.

Along with the verbal instructions he gets from the controller, the pilot is advised of every azimuth deviation by an audible signal in his radio. This aural signal device is automatically controlled by the azimuth cursor and transmitted to the pilot through the communications channel. The sound is coded so that the pilot knows whether he is on course, off to the right or off to the left. Degree of deviation is also indicated by a change in pitch.

All in all, the GCA system does its useful job with accuracy and efficiency. It remains to be seen how it will stand up under high pressure, under all conditions, and through sustained operation.

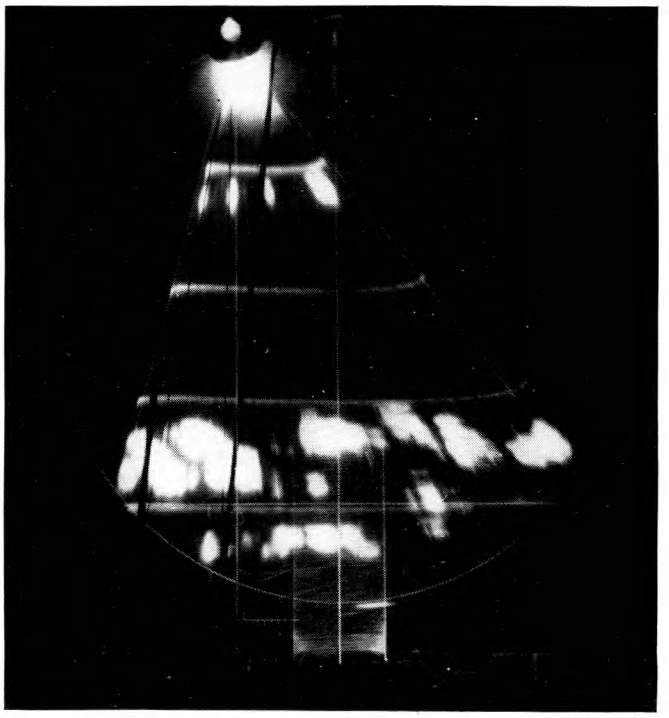
GCA is newest of 3 systems now in use



Complete GCA equipment consists of cargo truck and single trailer which can be easily moved from one runway to another. Power and air conditioning units are mounted on truck. Trailer takes care of all electronic equipment including the antennas. Search antenna (left), elevation precision antenna (right), VHF stubs and HF whip antennas are set up on roof of trailer. Azimuth precision antenna is fitted into left side of trailer body. All this equipment can be dismantled, housed within during transit



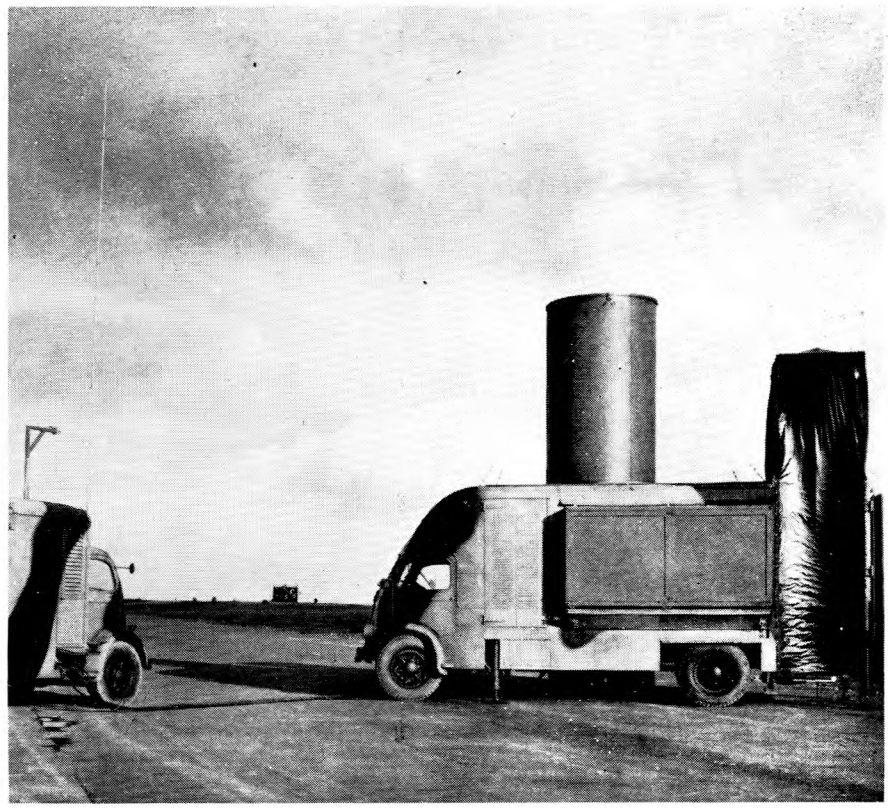
Four corner reflectors are set up as close as possible to end of runway for final alignment of GCA—they appear on precision scopes as permanent echoes, thus marking position of the runway



Echoes just below top range mark are from reflectors—second from right is from reflector located on extension of runway center line. Map cursor is always kept directly over runway position



Energy from dipoles in sleeve is directed by parabolic reflector to form special antenna pattern peculiar to GCA search beam, which is designed to avoid ground clutter



One and only model of Mark I GCA, photographed during trials in England. Over 250 controlled approaches were made with various types of aircraft in tests. This system consisted of two trucks—one carrying search and precision radar antennas and the prime power supply, the other the indicating and communications sections

The reason GCA didn't come out of the development stage some time ago is that the system had to be highly precise in order to be of any real value. At first engineers were stopped by the problem of antennas. An SCR-584 type antenna was used in the first attempt at a GCA system. It was ruled out because of its inability to obtain low angle coverage over land. An entirely new antenna had to be evolved to give such coverage for the glide path of a landing aircraft. The precision indicating system also turned up a lot of bugs which had to be ironed out.

The one and only Mark I GCA, an experimental model, was sent to England in 1943 to test its effectiveness with operational planes and pilots. Then five preproduction models of the Mark II equipment were sent to the UK in early 1944 for operational tests with the RAF. There were only five other Mark IIs, and these went to both the Army and the Navy, principally for training purposes. By the time Mark III came on the scene, Army, Navy and RAF commands had each made more than 2000 controlled approaches with these preproduction models. And most of the approaches were handled—successfully—by crews new to the equipment.

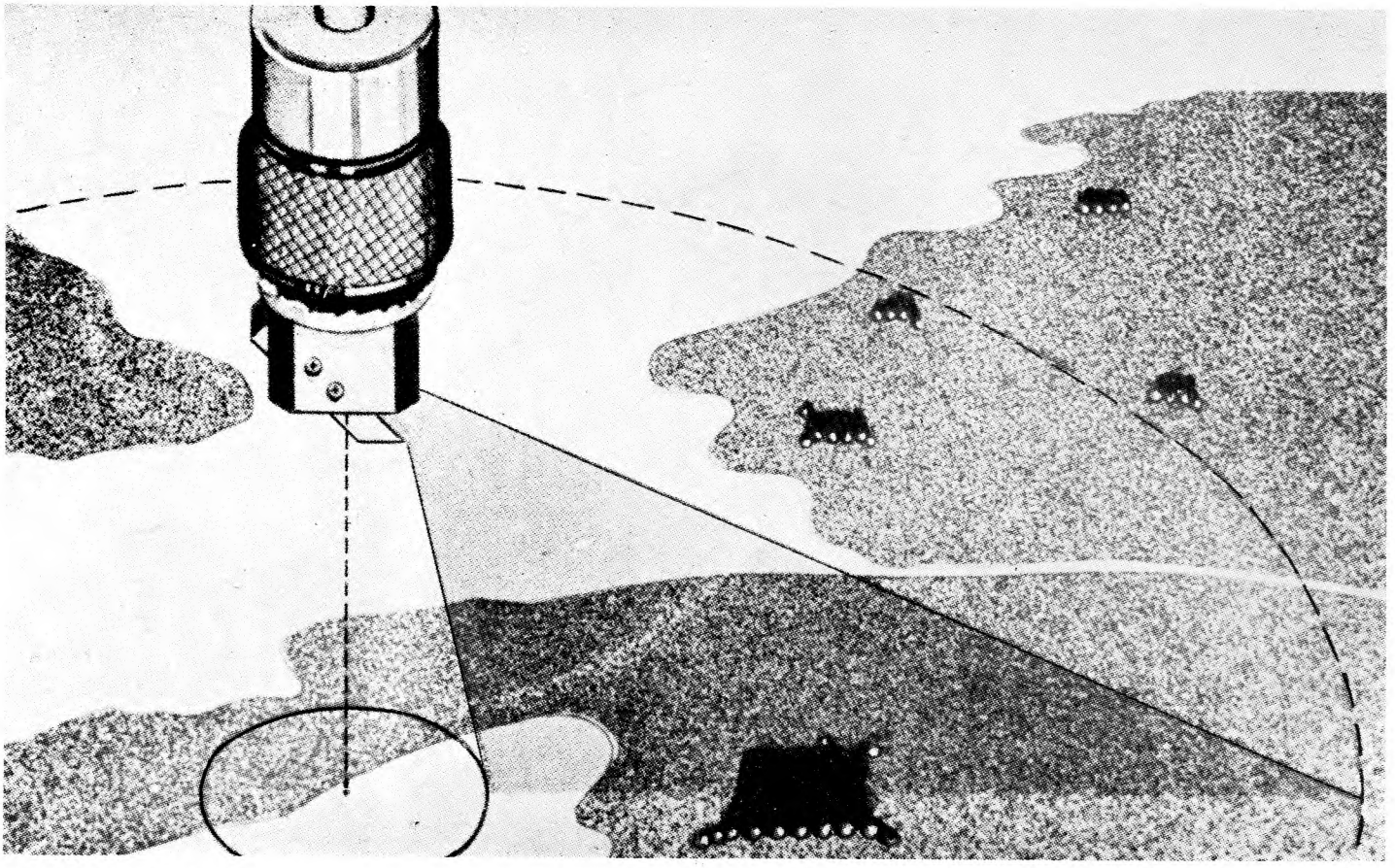
The other two approach systems currently in use are BABS (Blind Approach Beacon System) and SCS-51, the radio system recently adopted for general use by the AAF. BABS, the first approach system to go into operation, requires a radar set in the aircraft. Azimuth deviation and range information are given but there is no indication of height. With the radio system, SCS-51, equipment is carried in the aircraft but it is lighter than that used for BABS. SCS-51 relies entirely on continuous signals from a radio beam and pilot training is necessary.

Undoubtedly there are pilots who will promptly shy away from the idea of having unknown individuals help them to fly their plane, which is one way of looking at GCA. It is a fairly safe bet that a pilot coming into a strange field, flying a damaged aircraft or suffering from fatigue—conditions found often enough in combat areas—won't have that feeling.

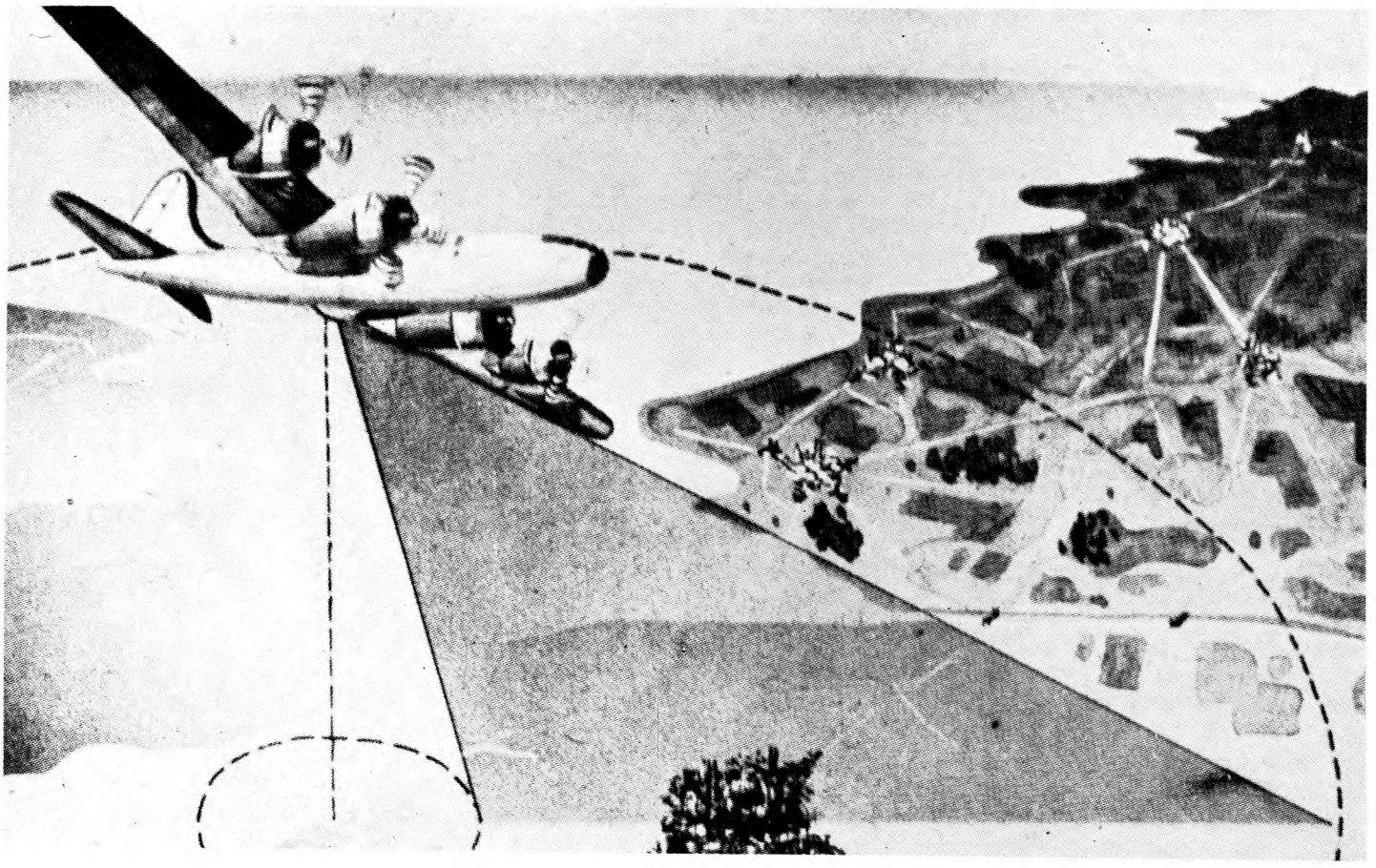
The GCA setup makes it possible for the controller to give more attention to aircraft needing it than a radio instrument landing system can. What the sound of a human voice which knows the score can mean to a combat-weary pilot is incalculable—but important.

Aside from its virtues in such special circumstances, GCA would seem to provide two major advantages over any approach system so far devised: 1) its data are not only precise and complete but are given in such a manner as to eliminate even an unwitting transmittal of incorrect information to the pilot; 2) the controller at any given moment can actually see the position of all aircraft under his control and their relation to ground and air obstacles.

On the debit side, there are the following points: 1) GCA is not air transportable, hence can't go into advance airfields; transportable equipment is very much in the developmental stage. 2) Its traffic handling capacity is limited; the nature of the system, however, allows for improvements and innovations which come only through experience, so no definite limit can be set.



Supersonic Trainer scans terrain map (above); picks up same PPI information as airborne H_2X would over area which map represents (below). In operation, Supersonic on ground is close approach to reality in air. Same radar is used, but antenna is replaced by piezoelectric crystal that "flies" submerged over terrain map, emitting supersonic pulses. These undergo electronic transition and emerge on PPI. Supersonic Trainer's big job is schooling radar team in manual operation; second is as a briefer.



Radar in replica

The Supersonic and how it works as trainer and briefer; with a follow-up report on the current status & uses of Navy's RPD

The Supersonic Trainer (AN/APQ-13-T1A), which was still pretty much in the bright idea stage when pictured in RADAR No. 4, is a going concern now. About 30 are at work at AF and Navy schools in the States; 3 are busy at the 8th and 15th AFs; elsewhere throughout the world the crates are being unpacked. Two hundred trainers for use with APQ-13, APS-15 and APQ-7 (Eagle) are in production, although it may be several months before they start leaving the factories, and the device is being set up to work with 5 additional radar systems.

What makes the Supersonic Trainer a standout is the fact that it gives an almost 100% accurate replica, on the ground, of everything that a member of a radar team gets in the air. The trainee sits at the same set, works the same receiver, the same indicator, the same bombing attachments. If he's a navigator he figures out the same problems. On the PPI scope he sees, as he "flies" the supersonic course, a constantly varied presentation that looks as it would many thousands of feet in the air. Effect of changing altitude, of azimuth motion in direction and magnitude is simulated to a "t". Noise interference, spurious range marks and ghost sweeps show up just as they do in the air. Only the r-f components (magnetron, radar antenna, r-f lines) are different. They're replaced by the supersonic system, basically a piezoelectric crystal suspended from a movable cross-carriage. It "flies" in a tank of water over a submerged terrain map, the whole synchronized to present, when electronically translated to the radar set, the same radar situation, at the same speed, as an actual flight over the same territory.

Training the airborne radar team (pilot-navigator-bombardier-radar operator) in their radar jobs is what the Supersonic Trainer was built for. It teaches them to operate the controls, to recognize what the PPI scope shows, to solve problems in the air. Now a secondary application—briefing—is getting attention, too. All that's needed to make a first-rate briefer out of the Supersonic is accurate terrain maps, and after a slow start this condition is being met. Four sets of glass maps, each representing an area 198 x 132 miles, accompany each Trainer. And the field is making more.

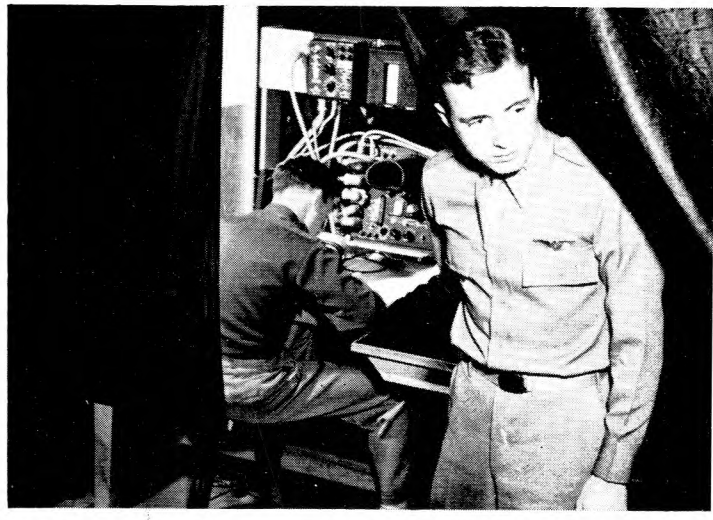
As a briefer the Supersonic gives the radar team a realistic PPI scope prediction of the whole course of the mission, does somewhat the same work as the midget-weight RPD (see page 32). In addition, it allows rehearsal of continuous flights to the target and back, something RPD can't do.

Besides the APQ-13 and APS-15 trainers, which are the same except for the radar sets themselves, the AAF has ordered fifty APQ-7 (Eagle) Trainers. The Navy wants Supersonics for APS-2 (ASG), APS-3 (ASD), APS-4 (ASH), APS-5 (ASD-1) and APS-10, as well as APS-15.

Pages 28 to 31 tell the story of the Supersonic in action, how it works, what it shows and how it trains. Included is a 20-picture scope sequence of a simulated mission on Tokyo run off for RADAR.



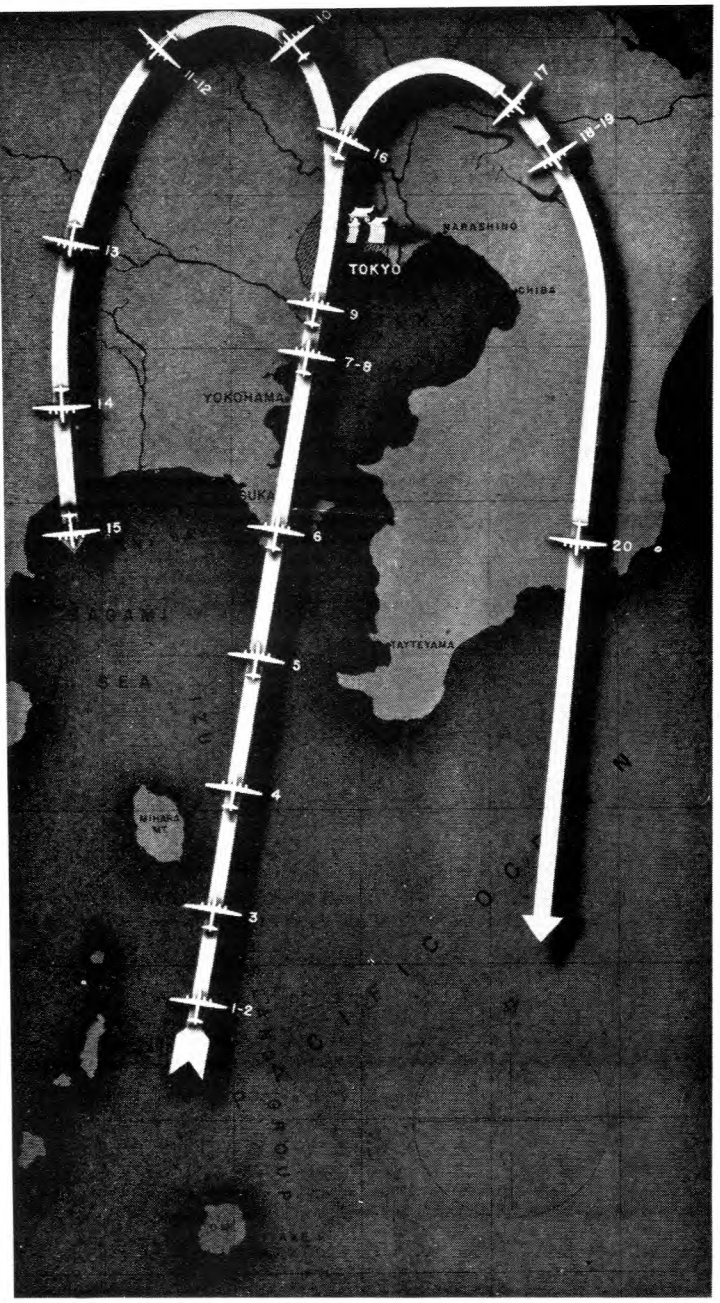
1500 lbs. go into Supersonic's double-deck, troughlike assembly housing antenna, map and water below, plotting map above



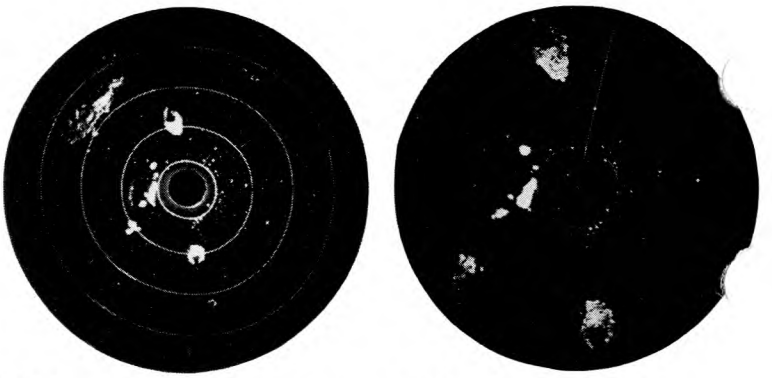
In closed tent radar operator learns what to push and turn, how to read the PPI. Blackout curtains simulate airborne conditions



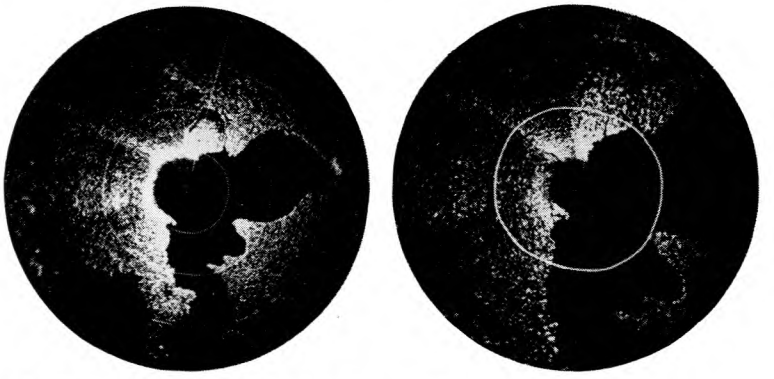
At work, trainee is all eyes as PPI gives continuously changing picture of territory scanned. Next 2 pages show mock mission



Mission to Tokyo via H_2X Supersonic Trainer was "flown" over area traced by B-29s above. Numerals mark positions at which photos of the 20 PPI simulations on these 2 pages were taken



1-2. Izu Seven Island Group shows up well on 50 and 20 mile sweeps as "flight" begins. Volcano shadows cause crab shapes

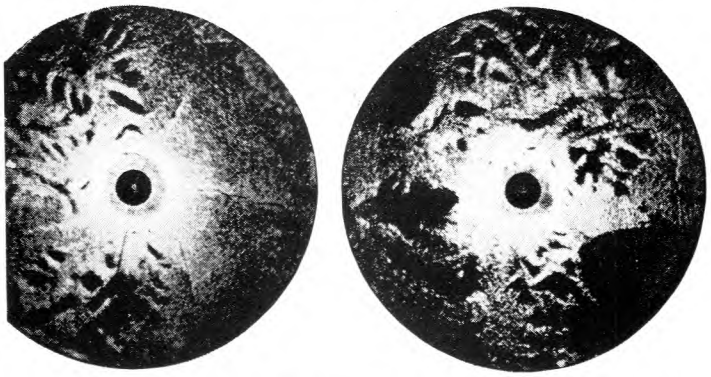


7-8. Beyond Yokohama the whole Bay is delineated on 50 and 20 mile sweeps, with populated areas along shores showing strongly

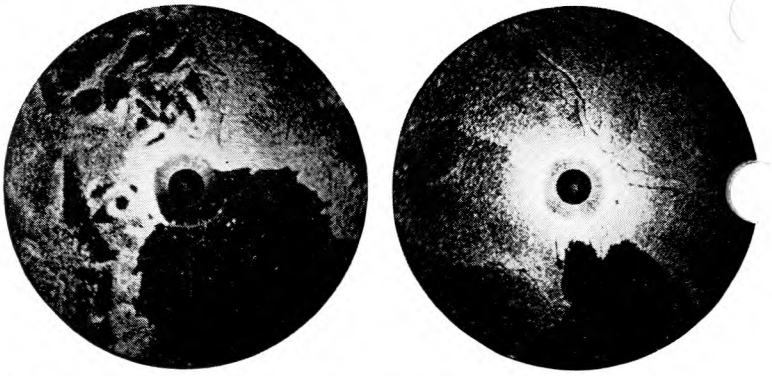
Supersonic trip to Tokyo

• *An H_2X Supersonic Trainer "flew" a simulated mission to Tokyo and back for the benefit of RADAR's readers. The 20 PPI photos strung across these pages report what it saw—i.e., what a B-29 formation flying this same course would see from 28,000 feet. After bombing the heart of Tokyo part of the formation on this hypothetical flight flew right and saw the flatlands eastward. The left section flew by the mountainous area westward, down over Sagami Bay.*

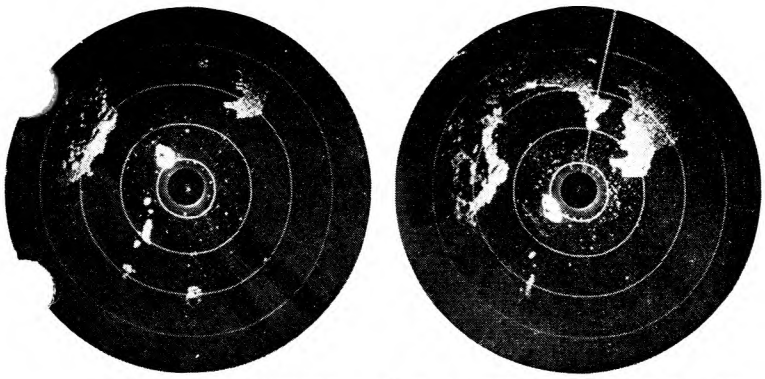
The next 2 pages tell, from start to stop, how this simulated operation was readied and flown.



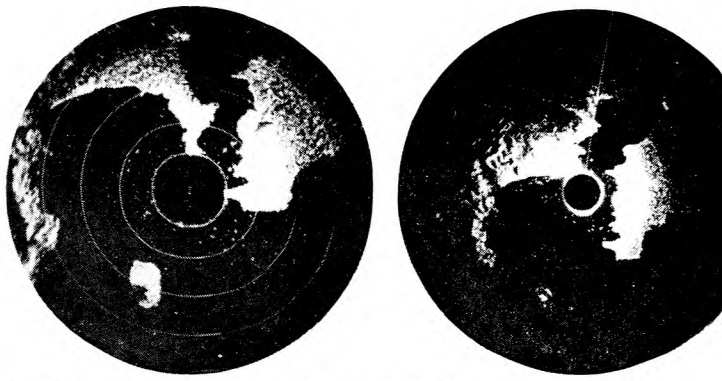
13-14. B-29s, now settling down for return journey, pass by Mt. Fuji (shadow at 9 o'clock, Photo 14). Sagami Bay begins to show



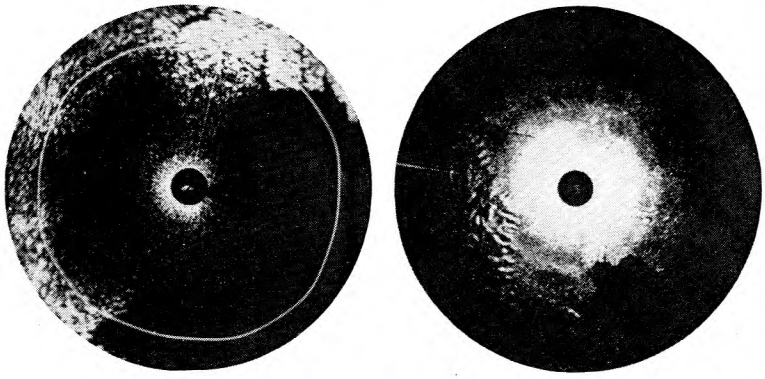
15-16. Over the Sagami Sea, toward Seven Islands and home fly the left-turn bombers. Earlier, other B-29s had headed right



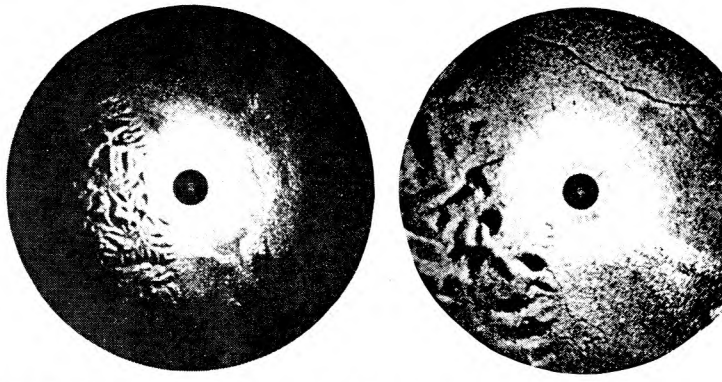
3-4. Outlines of Japanese mainland shape Sagami Sea and Uraga Channel as Oshima Island, northernmost of Group, is passed



5-6. Opposite Tayteyama and well within Uraga Channel PPI looks into Tokyo Bay. Course will take bombers right over capital



9-10. Bombs away! Center of Tokyo is target. Photo 10 was taken after squadron split. Mountains show around 8 o'clock

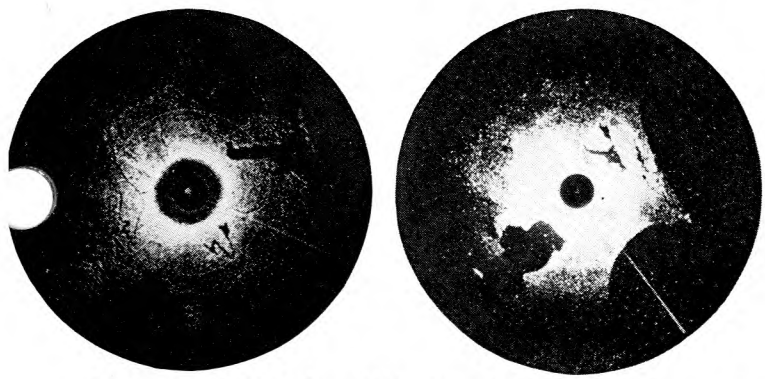


11-12. Left turn is nearly completed and peak-scarred character of west Japan emerges. Note river cutting top on 20 mile sweep

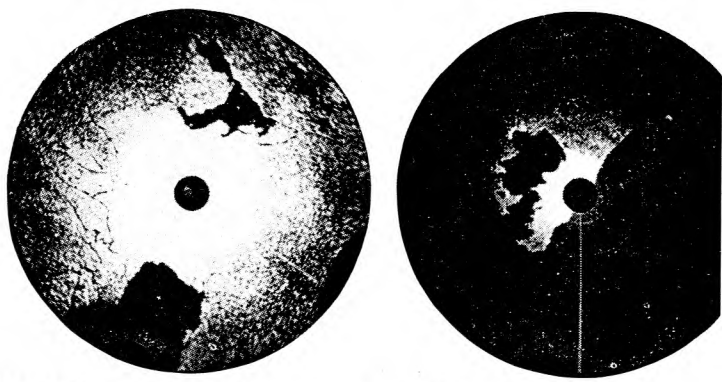
The map-making came first. What was needed was a terrain model, scale 1:200,000 (the speed ratio of supersonic vibrations to radar emanations), accurately reproducing the area of flight. A contour map was placed under plate glass 4′ X 6′ X ¼″ and necessary outlines traced onto the glass with waterfast paint. Each feature was then treated to give proper supersonic return.

Completed, the map was lowered into the shallow tank of water that forms the base of the Trainer. At an appropriate height above the map, and also immersed, was the Trainer's antenna, a piezo-electric quartz crystal that generated 15 mc. supersonic pulses of the same pulse length and recurrence rate as the actual APQ-13. When the Trainer started working the antenna scanned the map and the returning pulses went through an electrical metamorphosis to emerge on the PPI scope of the APQ-13.

As the mission started the trainee was at the radar controls (see picture, page 27). At the control board an instructor set up the flight and supervised its progress. The Supersonic antenna, suspended from the movable cross-carriage, "flew" over its underwater course, its speed figured by the time it would take a B-29 to cover the same territory. The trainee pushed buttons, twisted dials, while the trainer simulated reality with heading, wind speed, rate of turn, rate of climb, elevation, direction and magni-



17-18. Kasumija Inlet (45°), Imba Marsh (140°), curve of Kujukuri beach come in. Spots are interference from near radar



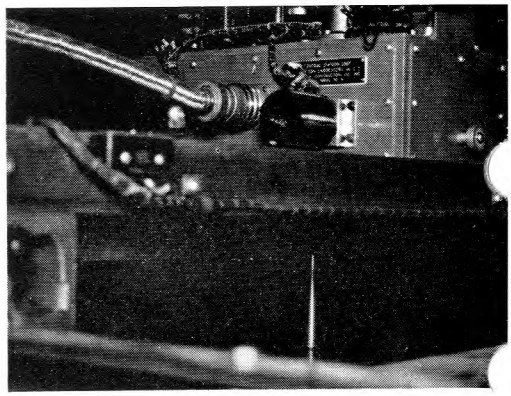
19-20. Data from preceding view are magnified on 20 mile sweep. Tokyo Bay and Uraca Channel are outlined as Pacific is reached

Trainee gets real flight feeling

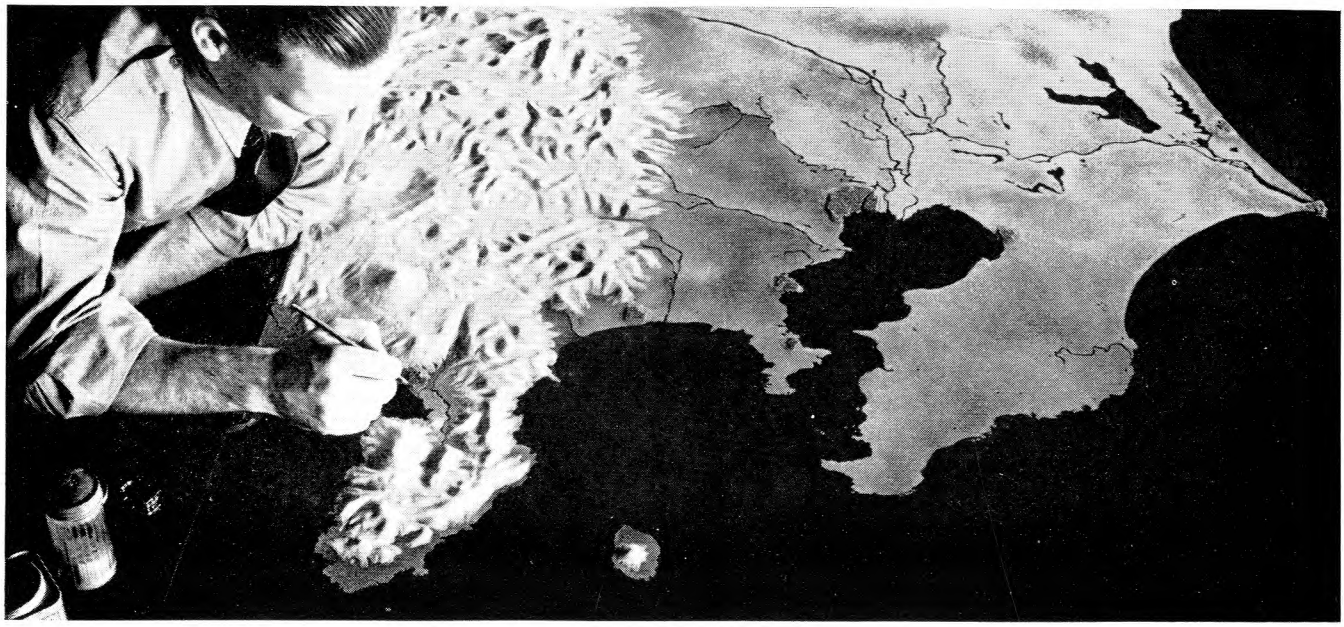
tude of wind drift—all the motions of the plane except pitch and bank (the newest Trainers will include antenna tilt).

Working the controls, it was easy for the trainee to imagine he was heading for Tokyo at an altitude of 28,000 feet. On his PPI scope he saw the terrain below, the effect of changing altitude and azimuth. He saw the effects of electronic disturbances coming from the radar itself. Meanwhile, the camera was glued to a remote PPI, recorded the shots you see on pages 28-29.

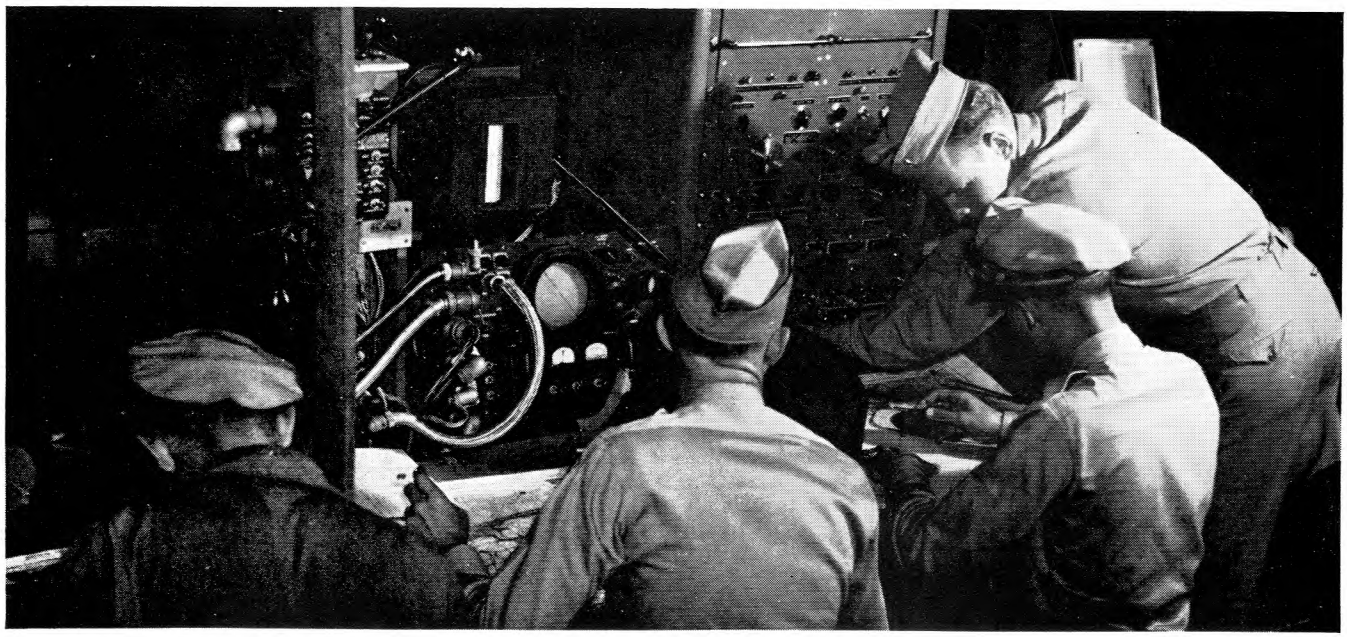
Alongside, the trainee navigator made his computations and analyses on paper. As they neared the target the bombardier went through his functions just as he would in the B-29. Occasionally an instructor studied the paper map stretched under the glass top of the trainer while, below, the crystal antenna made slow progress. On the paper map a spot of light recorded the plane's progress.



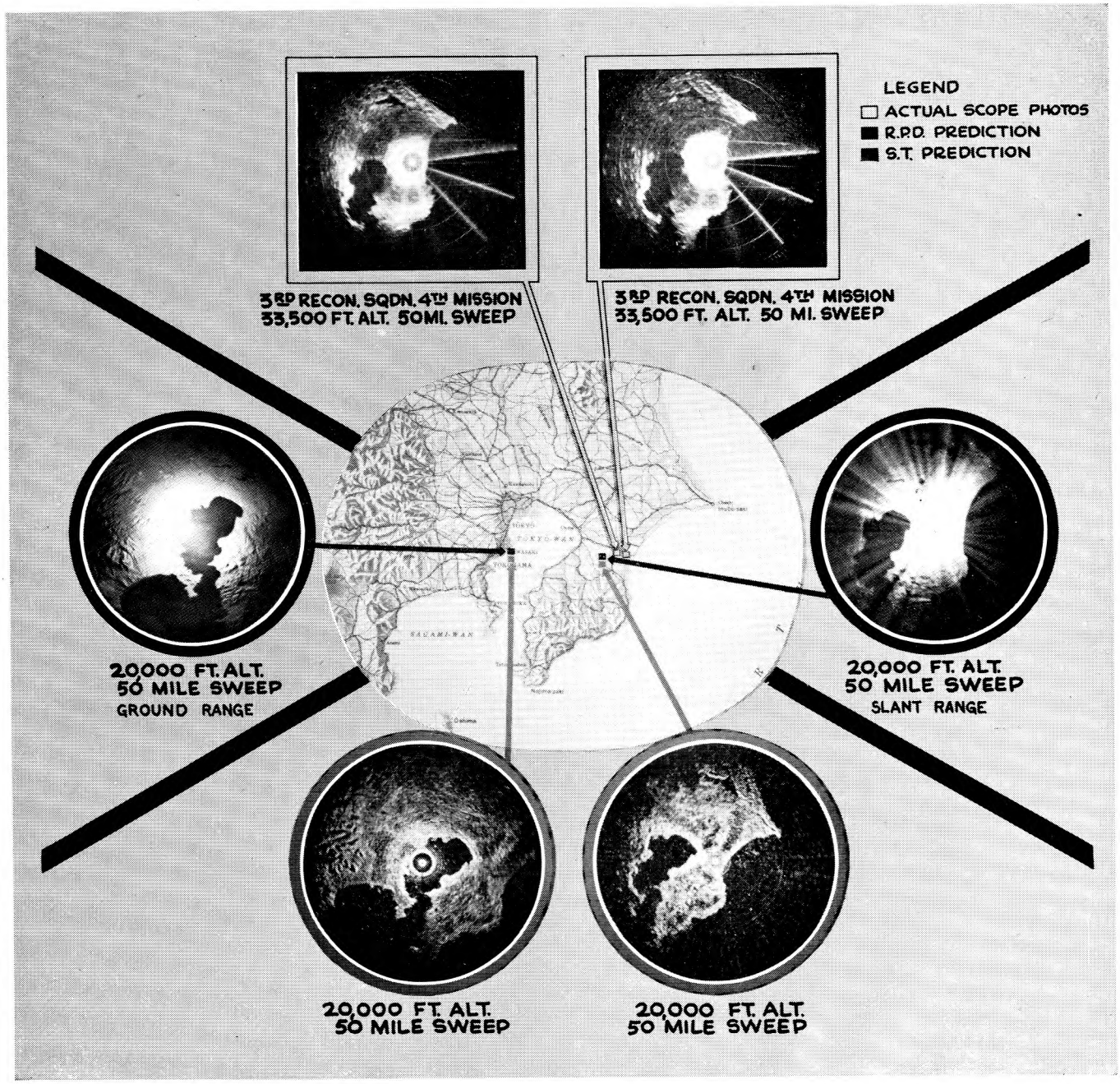
Cross-carriage mechanism keeps crystal antenna moving over terrain map at same relative speed as plane on mission



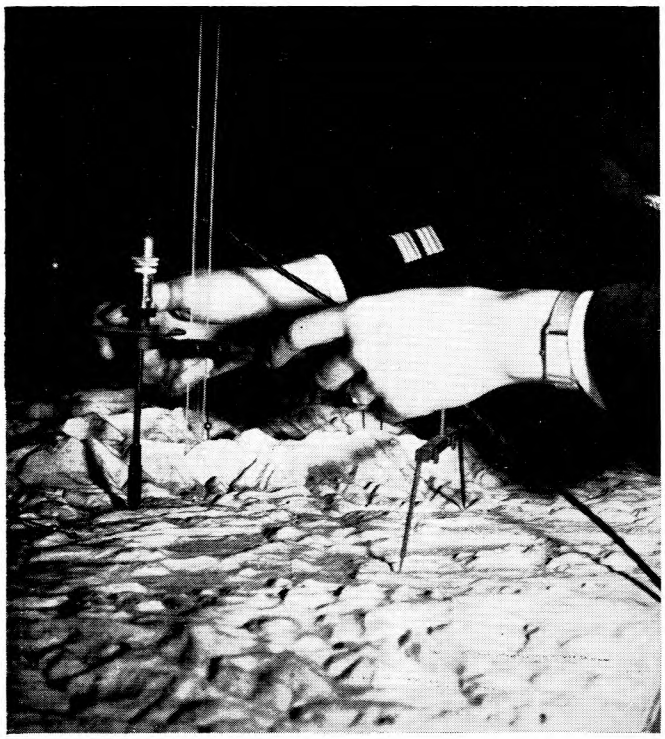
Map making, a specialized skill, is first step in operations. Sonically-speaking, smooth glass is water, sand layer is level ground, clay modeling is for hills, carborundum and beads for cities. **Below:** whole team of trainees "flies" over Germany



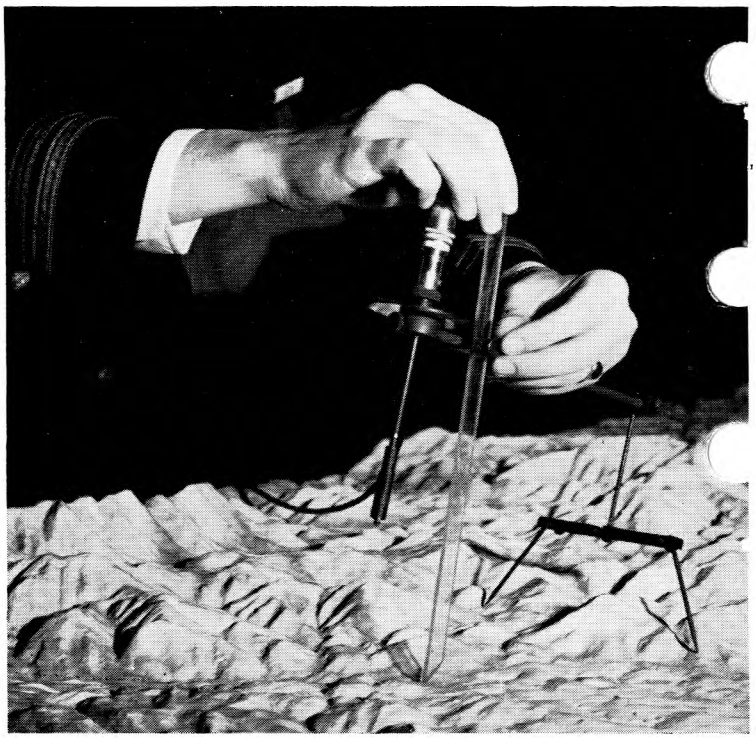
Comparison of actual scope photos of Tokyo with scope predictions by Supersonic Trainer & Radar Planning Device



How Tokyo Bay—including Tokyo, Yokohama and adjacent centers of Japanese population—compared to the eye of a recon PPI, an RPD and a Supersonic Trainer is pictured above. Real flight photos at top are products of an APQ-13 scope in a B-29, 33,500 feet over East Honshu. The 13,500-foot disparity in height between actual views and predictions (simulations were made at an estimated 20,000 feet) doesn't affect navigational recognition much, though more territory is seen at greater height. Coastlines and basic terrain features show up strong. Pyramid-shaped water return north of Tokyo on real flight photos and simulations at right is Kasumija Inlet. Mountainous character of areas west and lower east of Tokyo Bay appear on APQ-13 photos and simulations at left. A weakness of the RPD simulations, and of the Supersonic to some extent, is confused return from Tokyo-Yokohama cultural areas along western shore of Bay, which come up well in real flight versions. Cultural return will improve as PPI simulations profit by added experience in terrain model building. Spoked-appearance of right center RPD photo comes from hand operation of device needed to introduce slant range distortion (see page 33); motor-driven slant ranger now being perfected will eliminate this shortcoming.



Siting procedure, a basic use for RPD, is shown here. Spot of light starts where antenna might be, simulating antenna height. Light radiation is analogous to coverage real radar would give



Airborne prediction by RPD is same as siting except for elevation of light source to flight altitude. Height above is 20,000 ft. Planned improvement may let device show changing scene

RPD is no radar trainer, but it's apt as an air briefing-navigation aid

The Navy's Radar Planning Device is pretty well established by now. Over 500 are currently working for the AAF, Navy and Marines. 90 are in the hands of 8 Air Forces; the Marines have 250; all Naval Commands are supplied; another 350 are ready or soon will be.

Since RADAR's first report (August 1944) RPD has been seeing plenty of action and using most of its capabilities. Some of this has been ground and ship-borne, but it has been doing airborne navigation and briefing for the Saipan, Tinian, Guam and Leyte invasions, the B-29 raids on Japan. Siting, the chief ground use, hasn't had wide application yet, although in the Pacific RPD has solved at least one tough siting problem: for the MEW on Saipan (see page 36). In Europe it did siting for the Southern France operation. As we take back land areas from the Japs this use may grow.

In airborne applications, RPD isn't designed to provide the training in radar set operation which the Supersonic makes possible because RPD doesn't work with a radar set; it can't give the PPI story in motion picture style. But it is easy to build, easy to move, easy to use and the RPD organization is a well-knit, smooth-functioning outfit.

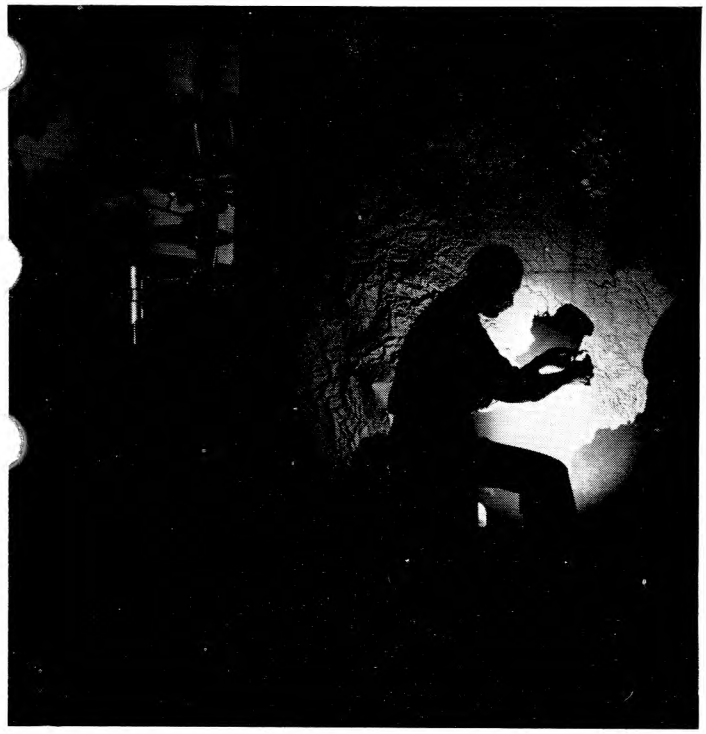
Most of RPD's value is incorporated in its PPI predictions, which have lately been made more realistic. RPD terrain models, on which accurate predictions depend, are built with exactness and skill; terrain model makers are being trained in Washington and several theaters. An RPD travelling unit (6 AAF and 1 Navy officer) coaching permanent personnel in RPD operation, tactical employment and model building is at the 20th Bomber Command, soon will move elsewhere.

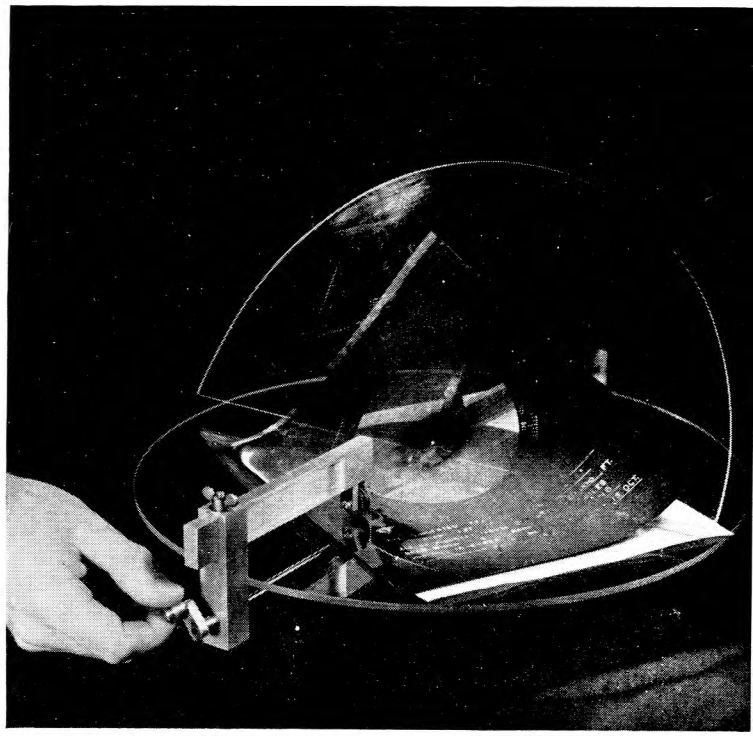
One of the latest RPD developments is a Prediction Kit made for the 21st Bomber Command. It contains 330 simulated PPI negatives forming a grid system that blankets the 21st's target areas in Japan. With it a briefing officer can quickly lay out a sequence of PPI predictions that will help guide an airborne team to its target and back. A similar project for the 20th is nearing completion.

As compared to the real thing, RPD predictions have a few shortcomings. They can't, for example, show the effect of noise; nor the effects of receiver gain control on contrast and texture of the picture. But with the recent inclusion of slant range and open and closed centers, RPD simulations come close to the real thing.

Making an RPD prediction for the air is much like doing it for the ground. For siting, the spot of light simulating the radar coverage hugs the ground; for airborne simulations, it is raised to flight height. From the desired point over the terrain model the camera takes a vertical shot, the resulting negative going through a series of photographic changes that introduce some of the radar distortions of a PPI display.

For briefing and navigation, what RPD has over the Supersonic Trainer is midget weight, accessibility, economy. Each device has its job, and, in final analysis, both will be valuable articles from now on in.





RPD doesn't use basic radar, requires vertical photographs as starting point for the PPI predictions. Negative goes through several phases before coming out as simulation of what radar sees

RPD scope simulations are being improved. Closed centers, slant range distortion, are new. Hand turned crank on present slant ranger is being replaced by motor, eliminating "spoking"

Supersonic Trainer & RPD—role of each in training-briefing*

Supersonic Trainer	Question	Radar Planning Device
Schools airborne radar teams in manual operation of actual radar equipment and in PPI interpretation. Training film forthcoming.	HOW IS IT USEFUL IN TRAINING?	Teaches airborne radar teams understanding of what they see on the PPI scope. Training film available.
Actually "flies" predicted course, producing continuous PPI scope simulations; wall displays (PPI scope simulations and comparable maps).	HOW IS IT USED IN MISSION BRIEFING?	Produces photos of PPI scope simulations of points on mission course; wall displays (PPI scope simulations and comparable maps).
Scope simulations comparing favorably with actual scope photos.	WHAT TARGET FOLDER DATA DOES IT DEVELOP?	Scope simulations comparing well with PPIs; terrain model photos for navigational charts.
Simulations are produced directly on PPI scope, which can be photographed if desired.	WHAT IS NECESSARY TO PRODUCE SIMULATIONS?	Lighted model must be photographed and negatives processed.
38 working for Army and Navy in U. S. and theaters. 200 in production, may not be available for several months. Some accurate terrain maps sent with each trainer, most theaters equipped to make others. 1 WAC map-making unit on way to theaters, others in training.	WHAT IS ITS OPERATIONAL STATUS?	500 in use by Navy, Army and Marines in U. S. and theaters, additional units available. RPD terrain model makers attached to several commands. Model makers and RPD officers being trained in U. S. and theaters.
No. Uncrated weight (device only), 1500 lbs.; crated weight, with 8 glass maps, 4200 lbs.	IS IT PORTABLE?	Yes. Uncrated weight (device only) 11 lbs.; crated weight, plus terrain models, 600 lbs.
Maintenance man needed; complete setup requires same maintenance as airborne radar.	WHAT ABOUT MAINTENANCE?	Negligible maintenance.
1 instructor; 1 maintenance man; map makers vary with work and time requirements.	WHAT OPERATING PERSONNEL IS NEEDED?	1 man to set up and operate; terrain model makers vary with work and time requirements.

** The use of the Radar Planning Device for siting operations is not discussed here; for a full report on that, see RADAR No. 4.*

14th AF radar gives ex-liner the old Whangpoo



For an ex-luxury liner that Tokyo insisted was "undamaged and still afloat," the 17,500 ton *Conte Verde* (above) looks pretty thoroughly stuck in the mud of the Whangpoo River in Shanghai. Her decks awash, this ship will be of no use to the Japs for some time to come, thanks to LAB (Low Altitude Bombing) radar and the crew (left) of the lone B-24 that flew the mission out of the former 14th AF base at Liuchow. Since then, unhappily, Liuchow and other forward bases have fallen to the Japs, much reducing the opportunity for such strikes as this. There's still business to be done on a smaller scale (see page 14). But for the B-24s, new bases in the Philippines are the big hope.

Polar diagrams

A new way to do an old job

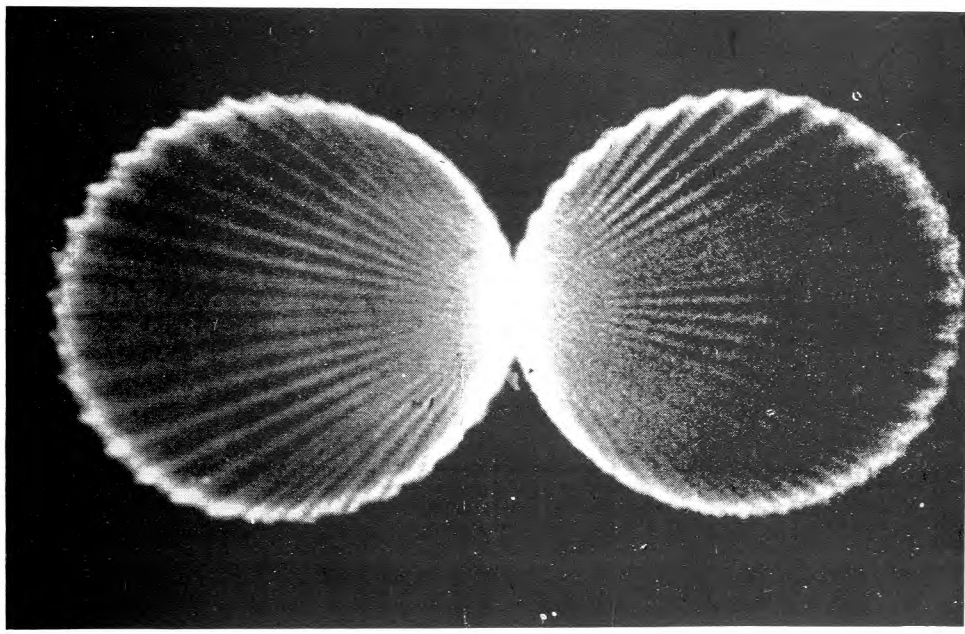
Explanation of polar diagrams, one of the salient points of basic radar instruction, presents a problem for instructors, to say nothing of the students. The standard method of working out mathematically, and then plotting on graph paper, the pattern which electromagnetic energy takes when radiated from an antenna is very much on the tedious side.

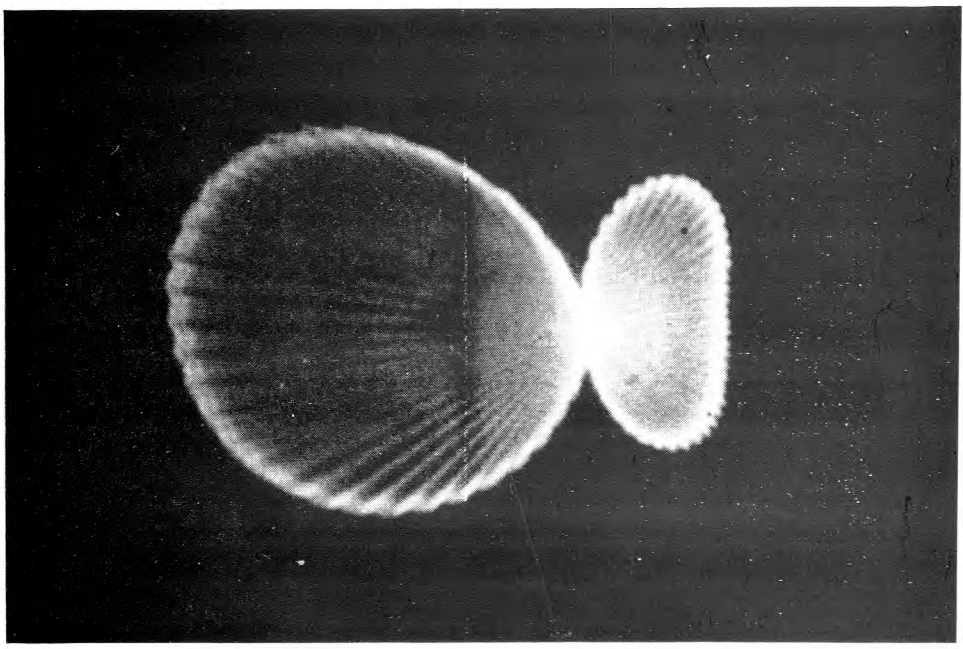
The 3 pictures at the right show the results of a simpler, clearer and more impressive method — in which basic polar diagrams for any simple antenna are shown instantaneously by visual patterns on the cathode ray screen. Flight Lieutenant R. W. Wilton of Radio School No. 5, RCAF, devised the method, which may soon be going into wider use.

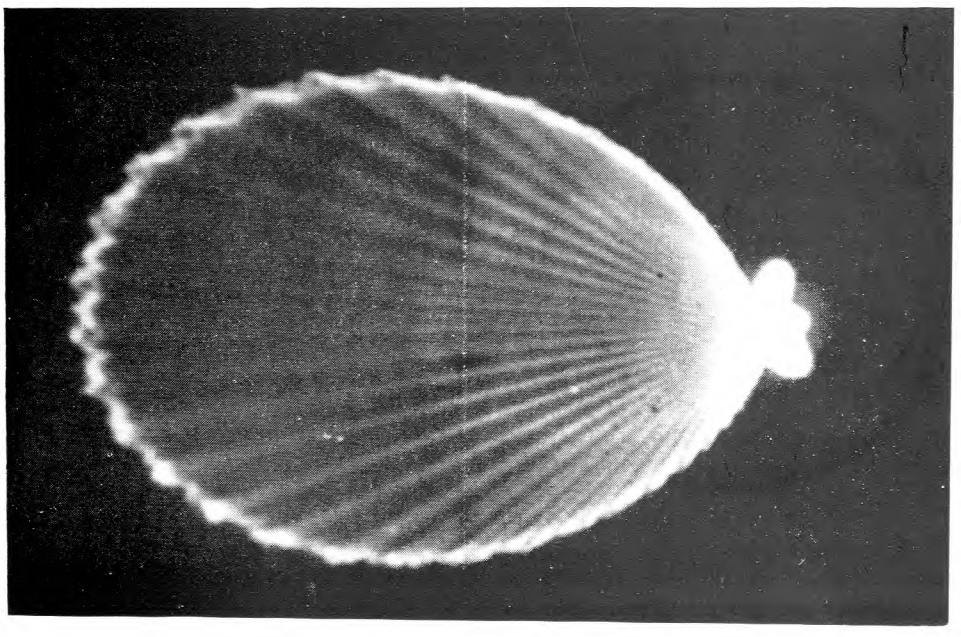
It works out like this. A transmitter is set up to operate on the frequency band of the antenna to be tested in order to excite it by the proper frequency (200 megacycles in this case), but at very low power. The transmitter is modulated by a 10 kilocycle sine wave. About 75 feet away a receiver, with a non-directional antenna, is set up and its output fed to the deflection coils of a PPI tube. The 10 Kc. modulation then appears at the receiver and forms the deflection. The coils are synchronized with the antenna under test so that the beam scans the tube once per revolution of the antenna array. As the antenna rotates, the amount of deflection on the PPI varies directly as the field strength radiated in that direction. The various changes in deflection with angular position trace out the pattern on the face of the tube. Use of a highly persistent tube enables the pattern to remain visible for some time. The 10 Kc. sine wave causes the sweep to be intensified and hence well-defined at its extremities.

With no signal, the trace on the tube is merely a spot in the center. Any signal received causes a radial deflection. Any variety of polar diagrams may be obtained by the addition and position of directors and reflectors.

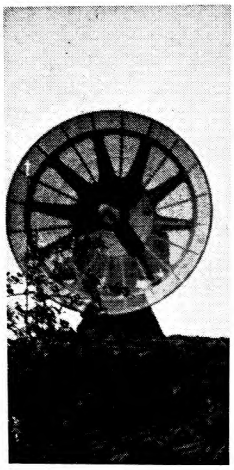
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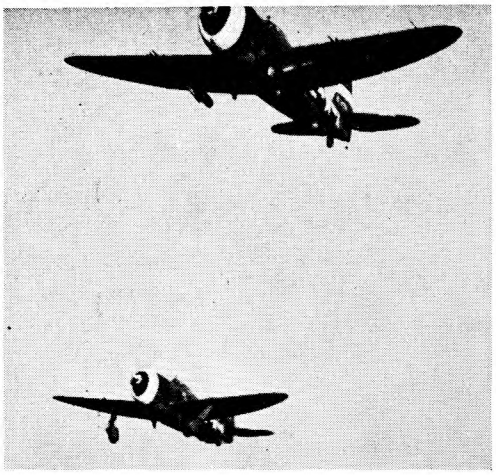






Radiation pattern at top is from straight half-wave dipole, center fed. Pattern at center is from same dipole with a reflector added but at incorrect spacing. Bottom pattern is from the same dipole with correctly spaced reflector and one director







Radar to fighter to target

An increasingly important role for ground radar on the Western Front

● *Between the rapid push of U. S. armies across France in August and the violent Nazi counteroffensive last month, there were 3 months of relatively stabilized fighting in the course of which the tactical use of U. S. air power went through some important developments. In the tactical procedures which emerged, radar—and particularly the MEW (Microwave Early Warning, AN/CPS-1) and the SCR-584—found itself playing a role of large proportions. The shape of this role was outlined in a report on close support bombing with the 584 in RADAR No. 5. On these 2 pages the outline is filled in by an on-the-spot observer of what's been going on—Dr. David Griggs of the Advisory Specialist Group, USSTAF. The report which follows is a digest of a letter from Dr. Griggs to Dr. E. L. Bowles, Special Consultant to General Arnold and one of RADAR's advisers. In reading it, two things should be borne in mind: (1) it is not an official expression but a personal comment; (2) it was written 2 months before this issue went to press. Because it is a highly competent, informed and readable account, and because its points are essentially applicable over a period far exceeding 2 months, RADAR presents this report for the special reading of all those interested in the tactical functioning of radar.*

"During the rapid advance of our Armies across France, radar played a relatively small role. The weather was good, the day-to-day movement of our forces was fantastically fast and uncoordinated, and the radar sets in general lacked sufficient mobility and organic transport to keep up with the very front lines. The air fields at which the fighter-bombers were based were distant from the battle front, communications were always poor and often lacking, targets for the fighter-bomber attack were out of range for fighter control sets even had they been at the very front. Because of the prevailing good weather and good visibility, close support aircraft were almost always able to navigate to their target or to the rendezvous with the columns for which they were providing support; hence, radar aid to navigation was not vital.

In general, the situation was that the Germans would leave behind small rear guard detachments and would try to move the bulk of their army and other equipment on roads ahead of our advance elements 50-100 miles from our front. This presented targets of opportunity but they were fleeting targets and plans for attacking them could not be laid hours in advance. They were discovered almost entirely by tactical reconnaissance aircraft and by armed recce. As you know, Tac R aircraft are unarmed P-51's and P-38's equipped for visual reconnaissance and photography. Their defense is purely speed and maneuverability deriving from their light weight. Armed recce, on the other hand, is the term applied to normal fighter-bomber aircraft bombed up and loaded with ammunition, which are dispatched to cover a specified area and to attack what they find, immediately calling in to Fighter Control Center by radio to report targets which they have discovered beyond their own power to cope with.

In only a few isolated cases, such as the Falaise pocket and motor vehicle concentration south of the Seine, was there a sufficiently stable situation to permit planning of missions more than an hour or two in advance. In the Falaise pocket the 584's were moved up into position and performed four night missions. Even here movement of the ground troops was so fast that on most of the occasions when the aircraft were vectored to a target and dove to attack, they were warned by flares from the ground that they were attacking our own troops.

The situation is now quite different. The lines are more stabilized, the opposition at the front heavier, the weather worse, communications better. Things move slowly ~~enough~~ so that planning in advance is possible and the commands and crews are more experienced in the use of radar.

In the everyday operations of the Tactical Air Commands, radar is now playing an important role. Often the fighter bombers go out only to find themselves over 3-7/10 cloud cover in the target area. If they fail to navigate to their rendezvous point or to their target in the first sweep, they frequently get lost and fail to locate their ground control unit or their pre-arranged target. But the radar control personnel is now bringing to a rather high state of perfection an opportunist operating procedure. Both MEW and 584's receive the daily field orders. They know what missions to expect and approximately when. They are now very largely concerned with plotting these individual flights as they come into the target area.

If, at the end of 5 or 10 minutes, the mission has not gone as planned, the MEW or 584 will break into the VHF channel and ask the fighters if they need help. In an increasing number of cases the fighters willingly admit their need. The MEW and/or the 584 then takes over and vectors them to the target area.

When I was at the 19th TAC the MEW had been in opera-

tion only about a week, yet it was being given a sizable fraction of the fighter-bomber missions for control. It is manned by an excellent crew—the same which performed so creditably against the buzz bombs on the south coast of England. One mission General Weyland told me about, which in his view pays for the whole effort that his command has put into radar.

On a day of very low ceiling and bad visibility, the enemy opened a fierce counterattack against the 3rd Army with a great concentration of armor. Weyland was asked by General Patton to put his airplanes into the battle, although everyone recognized the weather made it a very dangerous mission. A group of P-47's was controlled by the MEW, directed to the target area, and instructed to let down. They, with admirable courage, went down through the overcast, breaking out at about 500 feet, and came out on the "damndest tank battle they had ever seen." The Germans had not thought it possible that our fighter-bombers could operate in that weather. They were, consequently, deployed in the open, without attempt at aerial camouflage and so were sitting ducks. The fighter-bomber attack destroyed a great deal of the armor and threw the rest of it into utter confusion by the surprise of their attack. This is credited by the ground commanders with breaking up the rather large scale counterattack.

As for the 584, here's the picture of how it's now being used in the 9th TAC. At 6 o'clock in the morning every day, the 584 controllers get the field order for the day's operations. They immediately go over it and plot the coordinates of all targets for missions which lie in their control range, and they make up a tote board with the times, target coordinates, call signs, etc., of each individual mission. They then endeavor to lock on to the leader of each group or squadron which they consider most important at the time. A plot of position with identification is passed on to them from the MEW which aids them greatly in pick-up. They verify this by constant check and recheck with the VHF/DF on normal transmissions from the aircraft.

As soon as a leader has identified his target or made visual contact with the ground part he is working with, they relinquish him and lock on the next most important unit. They monitor the VHF transmissions of the aircraft and, whenever possible, the air support stations. Thus they are able to tell by plotting the track of the aircraft and by listening to his transmission whether or not he is having any trouble finding his target.

As soon as it becomes abundantly clear that he is lost or in difficulty, they break in and ask if they can be of assistance. Usually their services are required only to guide the aircraft to the target area where the pilots are able to locate themselves or their targets by breaks in the clouds. On clear days this service is seldom needed. But in the broken overcast that we have been having lately, it is frequently of vital importance. I watched two such assists and the boys described three more with tracings of the plots to illustrate just what had happened. The first two are illustrative and the third amusing.

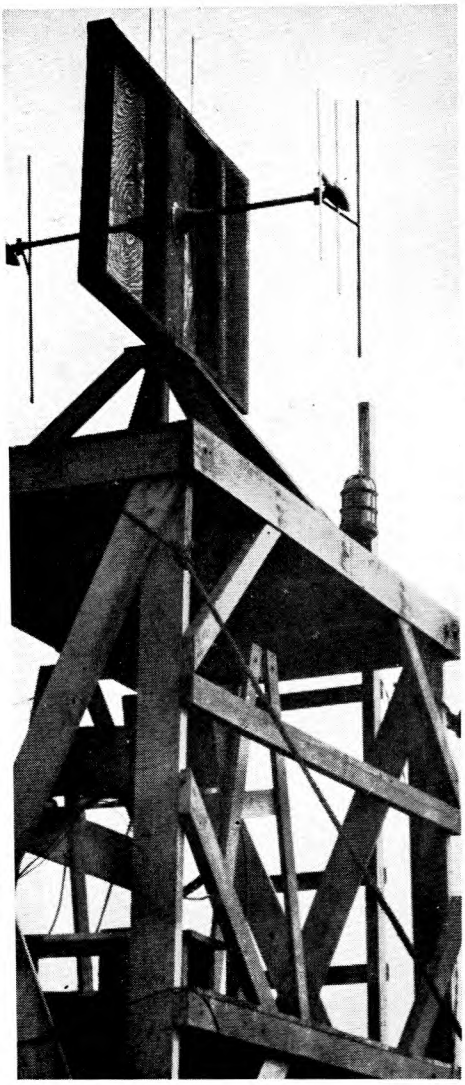
● A fighter-bomber group was lost above 5-7/10 cloud. The air support party officer in an armored column gave them a target in coordinates near a town of obscure name. The fighter leader could not locate it on his map. The 584 was monitoring the VHF and by this time had locked on to the aircraft. The 584 then called to ask if they could help, and were answered "Yes." The 584 directed them to the target area, told them to circle. They could not find the target visually nor could they see their armored column, but they asked for red smoke on the target. The task force artillery fired red smoke shells which were immediately picked up by the fighter-bombers who then were able to distinguish gun emplacements in an enemy strong point and bombed them with good effect.

● The second story is, as General Quesada puts it, a perfect example of instrumentation. Two heavy batteries were shelling one of our armored columns. They were invisible to our ground units but their location was plotted by sound ranging. The weather was bad so that when fighter support was requested, the MEW navigated the fighter-bomber squadron to the front area and turned over control to the 584. The 584 carried them to the immediate vicinity of the target and informed the leader that the target was directly under his left wing, 500 yards away. The fighter pilots could not detect any target. They were vectored back and forth over these batteries for many sweeps but they still could not pick out the batteries. Continually the 584 would inform the pilot of the exact position of the target with reference to the airplane.

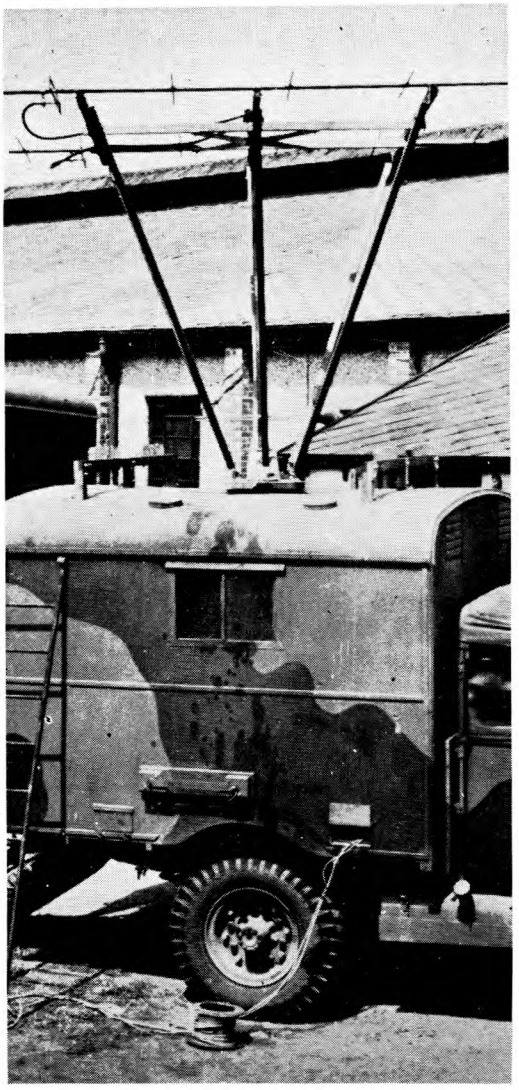
Finally the batteries opened up and pilots saw the flash of the guns. They went down immediately and bombed and strafed the points from which these flashes came. By ground report the two batteries were knocked out and the army rolled on. The fighter leader, Colonel Young, said later that the batteries were so well camouflaged that they would never have been able to pick them out without the aid of the 584. All this was done when visibility was so poor they could not even have remained in the area by visual pilotage.

● The third story is one related by an air support party officer who heard an aircraft calling for targets. Although the call sign of this aircraft was unfamiliar to him, his unit was in need of help and he requested aid from the fighter. When the affirmative answer came through, he gave the target coordinates and location with reference to a small town. The pilot could not find this town on his map and so asked for its location with reference to a larger town. Still the pilot could not find it. The air support officer then said it was 40 miles southwest of Cologne. After a few moments of silence, the pilot replied: "I can't help you, Bud, I'm in Italy."

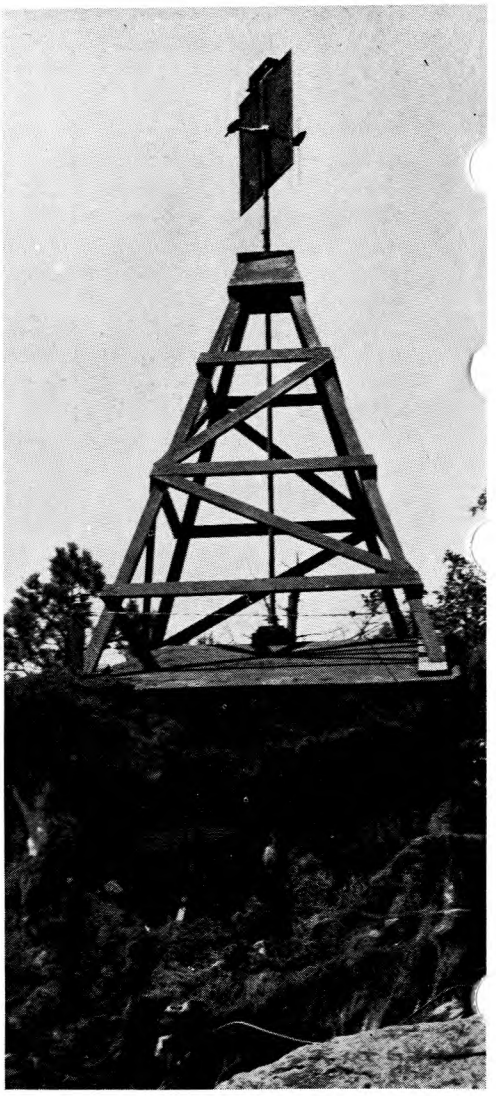
The 584's have been used on many missions to control night intruders who are vectored down roads or railroads on the chance of picking up a visual target. This, of course, accomplishes two things: First, it discourages the Germans from using the roads at night simply by the fact that an airplane is there; and secondly, if the Hun has any lights or if the moon is such that vehicles can be discerned, it permits reasonably accurate visual bombing and strafing. If the pilot is unsuccessful in locating any targets, he is vectored to a fairly large target such as a marshalling yard or a built-up road intersection, and his bombs are released blind by the 584. There is to date no evaluation of the combat accuracy of this bombing. However, the fighter pilots are as a whole enthusiastic about the accuracy and they come back with stories of having seen their bombs hit right in the middle of the road. ”



AN/GPX-1 tower installation. Extra reflector is added to regular 729 antenna



British snooper had more intricate antenna, easily collapsible on roof of truck



Grenier installation was set up on hill with unobstructed view of field's runways

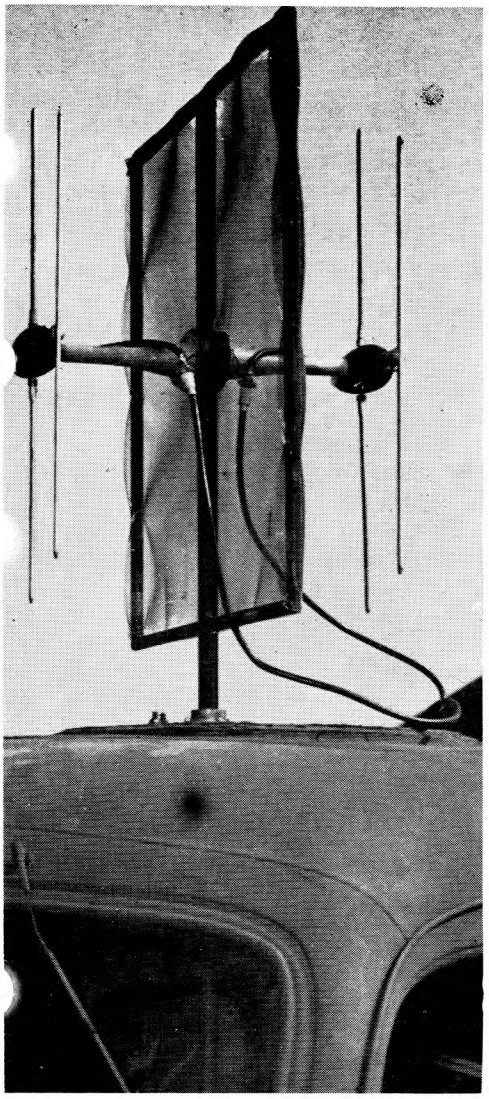
IFF: testing...testing....



Grenier Field operator keeps close check on ATC aircraft with his SCR-729 equipment since the proper functioning of IFF in aircraft going overseas is an imperative

The campaign to improve IFF operation has, among other things, pointed up a need for a sure fire way to test the SCR-695. Last month the requirement seemed to be well on the way to being met with the perfection of a new setup called AN/GPX-1. It's actually the SCR-729, airborne interrogator-responsor, adapted to a new job on the ground.

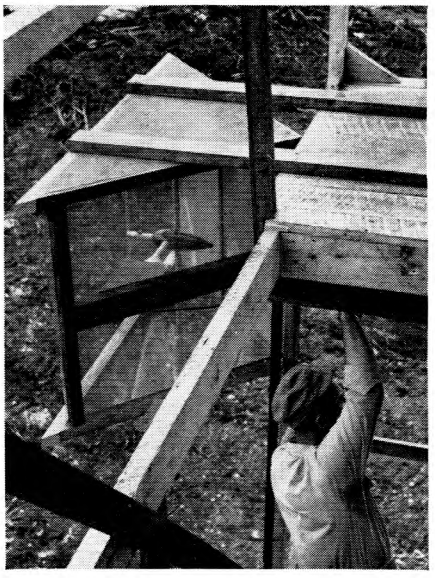
While considerable information about SCR-695 can be obtained by proper use of the IE46 test set, no test can compare with the obvious one of interrogating the airborne IFF directly and viewing its response. Standard IFF ground interrogators are quite large, require a crew to operate, and are confined to Aircraft Warning stations. But many an airstrip is located some distance from AW stations and its personnel has to depend wholly on ground checks with a test set. Such air bases need a handy equipment right in **(Continued on page 40)**



Langley Field built similar type interrogator and used it as talk-down landing aid



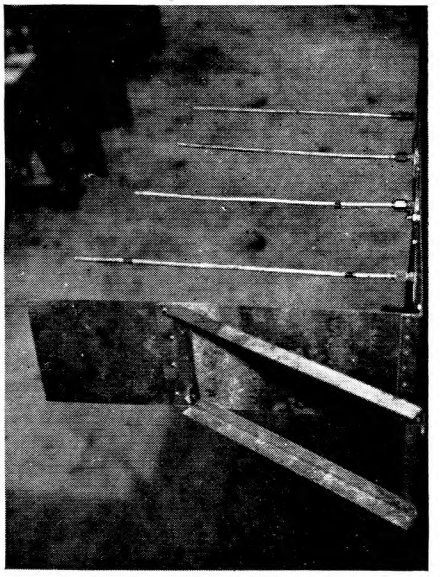
5th AF made its own snooper installation in control tower of an operational airstrip on Owi island as a part of its program to improve and extend the use of Mk111 IFF



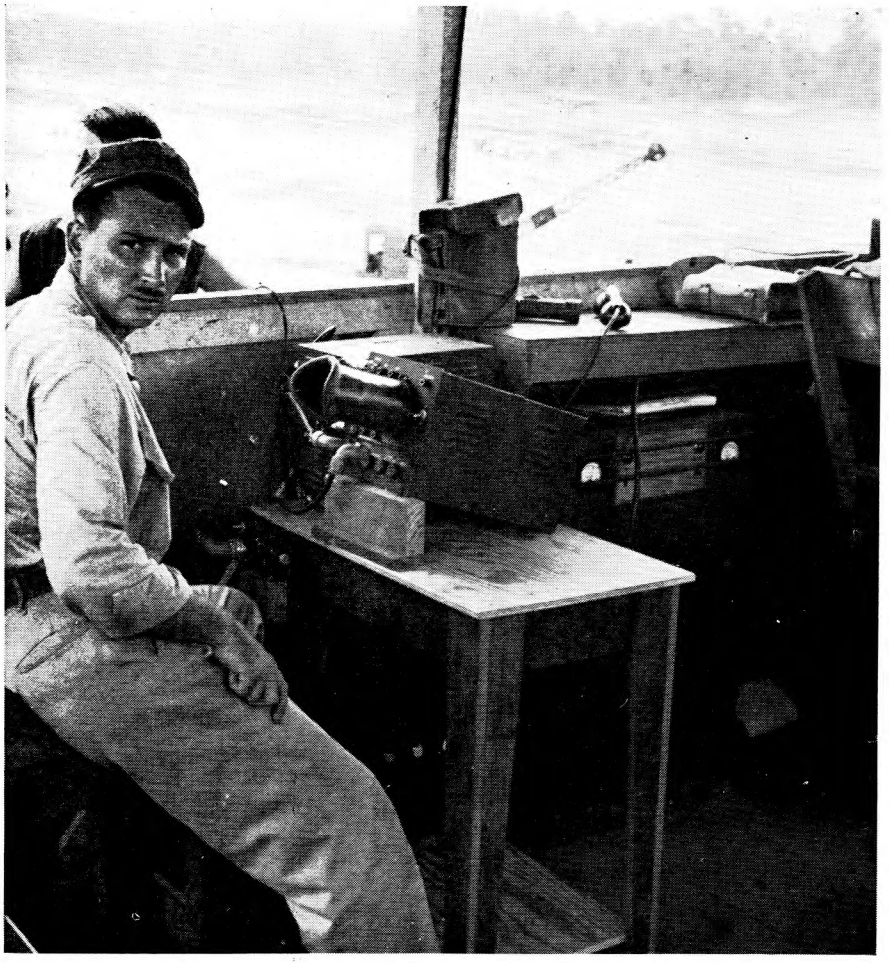
5th AF made corner reflectors with wood and mesh screen for standard 729 antennas



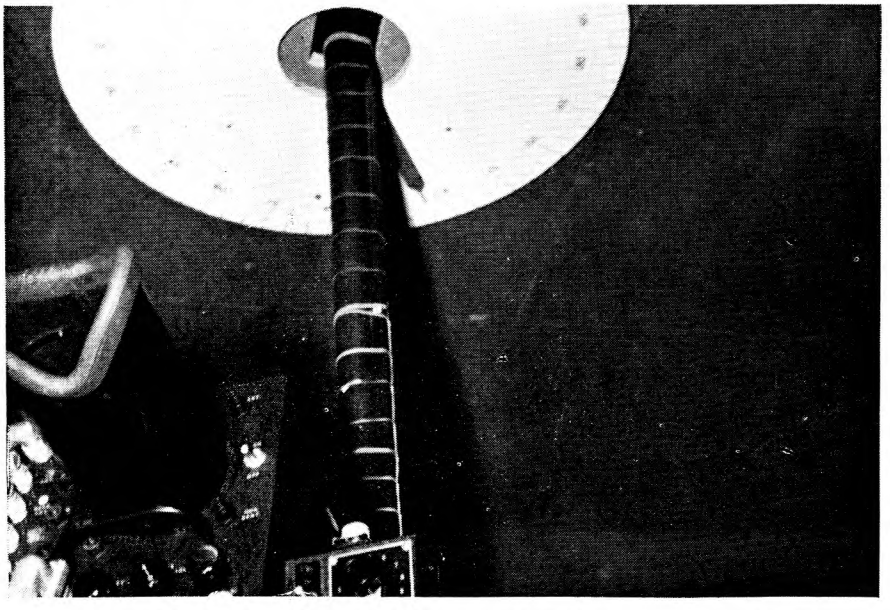
Transmitting antenna was mounted on board at front of tower for Owi installation



Receiving antenna designed by 13th AF has 2 directors, reflector and back shield



Transmitter-receiver, indicator, control box are mounted on table in 5th AF control tower. Set, tuned slightly off local beacon frequency, gets returns from planes 50 miles out. Each base resorts to whichever power supply best fits local conditions



Grenier antenna rotates without any lead-in tangle problem—operator and equipment go "merry-go-round" along with antenna support. Note the azimuth dial at top of shaft

(Continued from page 38) the tower, or capable of operation in conjunction with the tower, which can interrogate each departing and arriving aircraft. Interrogators of this type were dubbed "snoopers"* by the British, who came out with the first ones—revamped Mark II ASV (SCR-521) mounted on trucks.

In the past year there has been an epidemic of AAF snoopers—in the Mediterranean, the Pacific and various corners of the U. S. All used SCR-729 as the basic unit; main differences were in the antenna and method of mounting the equipment. Everyone reported his snooper as paying off in improved operation, everyone reported his design as the only and original.

Snooper design came in for some more attention when Radiation Laboratory undertook to make a quick installation at Grenier Field for the Air Transport Command. ATC has been strongly IFF conscious ever since a C-54 was accidentally shot down near Casablanca. Unfortunately, that hasn't been the only aircraft to suffer such a fate. There have been too many cases where Allied planes, showing no IFF due to equipment or pilot failure, were damaged or downed.

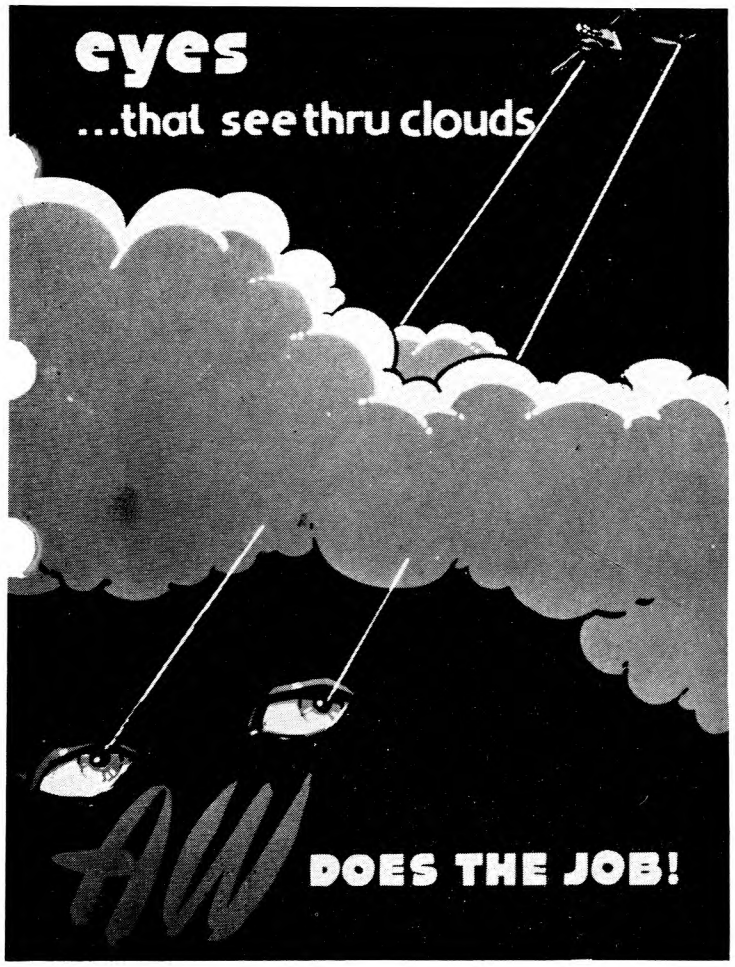
Success of the equipment at Grenier promoted interest at Aircraft Radio Laboratory, Wright Field, and out came the slide rules. ARL personnel came up with some antenna changes which made improvements in performance. And so the AN/GPX-1 was born. A kit of hardware is to be included with the equipment to permit easy assembly of the antenna to the right dimensions—also the essentials for the rotating mechanism and antenna position indicator.

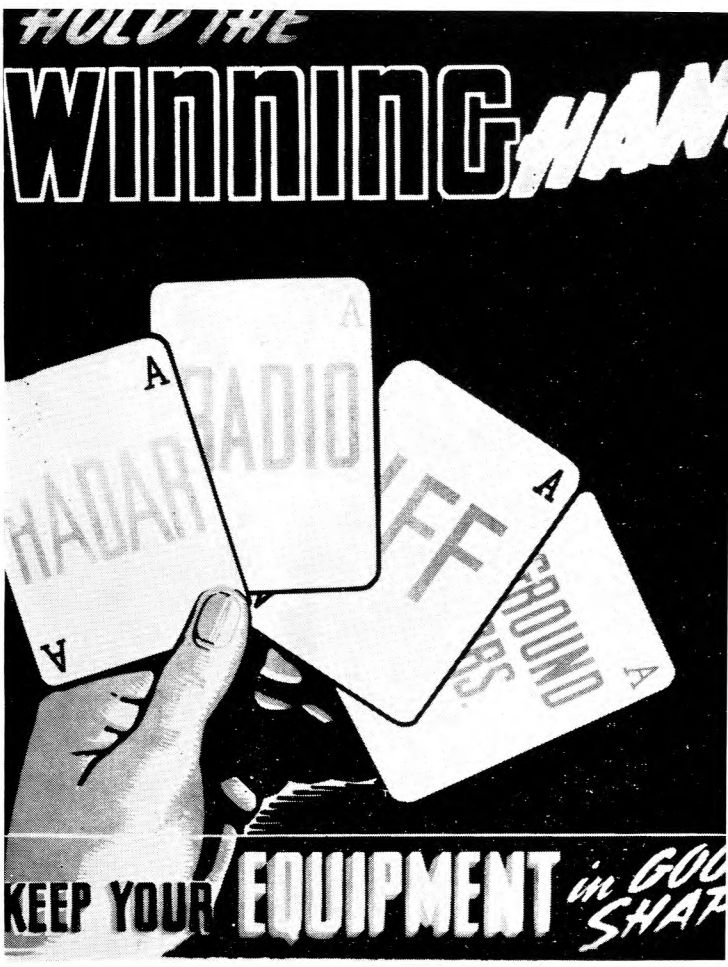
The 2nd Air Force, with the assistance of Air Technical Service Command, is already at work making GPX-1 installations at each of 32 training bases. Meantime, ATSC is prepared to start planning installations for other Continental and theater bases.

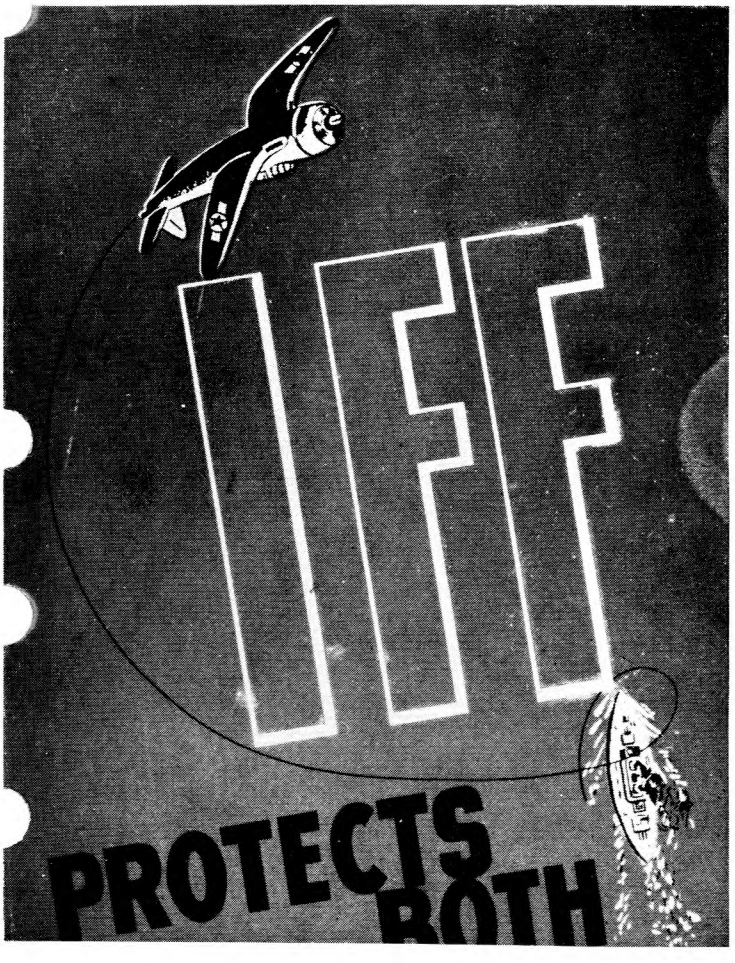
** Not to be confused with the LAB-equipped B-24s whose search tactics in the Pacific earned them the same name.*

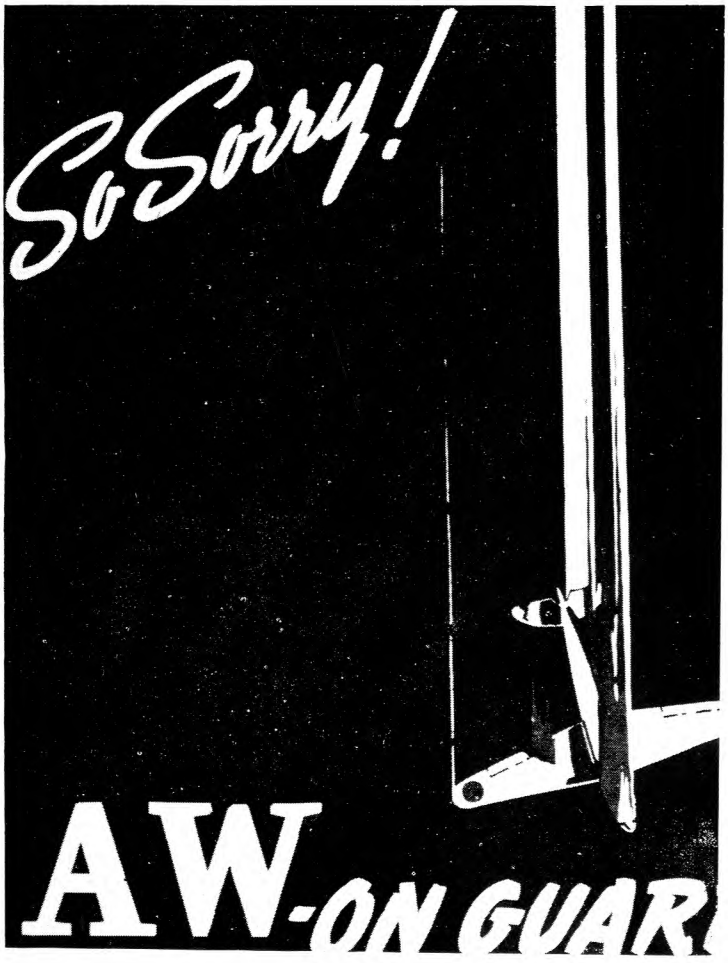
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Posters on opposite page, sent in by Aircraft Warning Unit Training Center, Drew Field, are 4 of a series worked up by the 3rd Air Force to stimulate interest in IFF and aircraft warning—favorite subjects for "theater artists."


eyes
...that see thru clouds
AW
DOES THE JOB!


HOLD THE
WINNING HAN
RADAR
RADIO
IFF
KEEP YOUR EQUIPMENT in GOO
SHAP


IFF
PROTECTS
BOTH


So Sorry!
AW-ON GUAR



SURVEY PARTY ON SAIPAN EXAMINES HILLTOP SITE FOR 66-TON MEW, PRE-SELECTED BY SITERS USING 11-POUND RPD IN FAR AWAY OAHU

The Japs got there first

In Saipan it was a question of cutting a road up-hill through tough, resisting scrub growth—to the site preselected for the big 66-ton Microwave Early Warning radar (AN/CPS-1)—before Japs came to bomb the B-29 base. With MEW operating, the 20th AF would be forewarned against raids by the best forewarner yet in business.

The Japs unfortunately got there first, and did some damage, what's more. They came in low, and there was no MEW with its powerful double-lobed low and high coverage to detect them. The SCR-270s, installed early on Saipan and old in Pacific service, couldn't quite pick up the Zekes and Bettys in time.

The MEW site was selected early by Navy's Radar Planning Device (see page 32) at the Pacific Fleet Radar Center at Oahu. A point was worked out covering the likely approaches. MEW reached the island some time before the B-29s moved in, and a reconnaissance survey showed the site to be reachable, given some hacking and cutting.

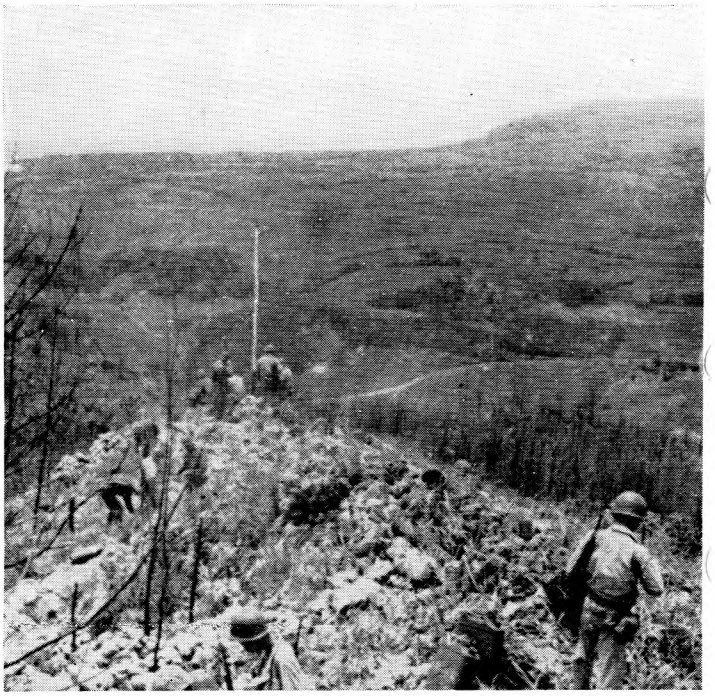
But the hacking and cutting wasn't done; one thing or another got in the way; 66 tons was a lot of tons to move; it was one of those situations, not all of which can be avoided.

And so, some time after the B-29s started work, MEW was still in crates and boxes. And MEW was still in crates and boxes when the Japs came. It's up now.

Jeep followed by Army truck breaks trail through heavy brush as reconnaissance crew makes arduous way to point picked for MEW



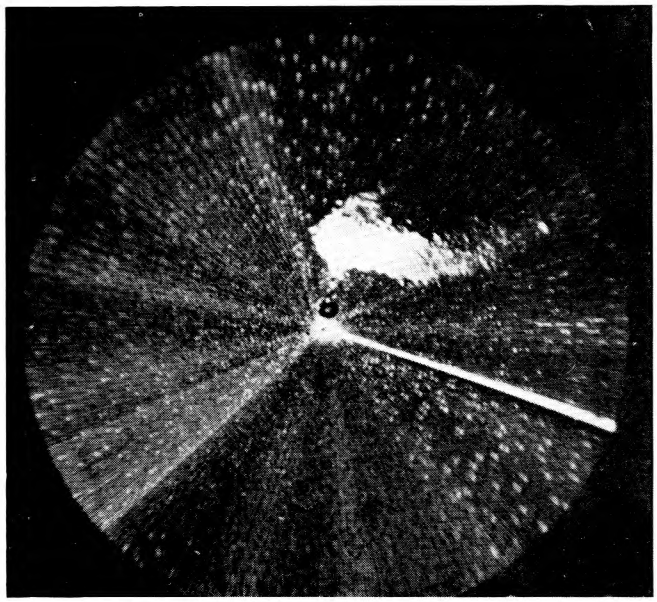
From top of hill main road is seen in valley below; the short distance in between kept MEW from being ready for Jap raiders



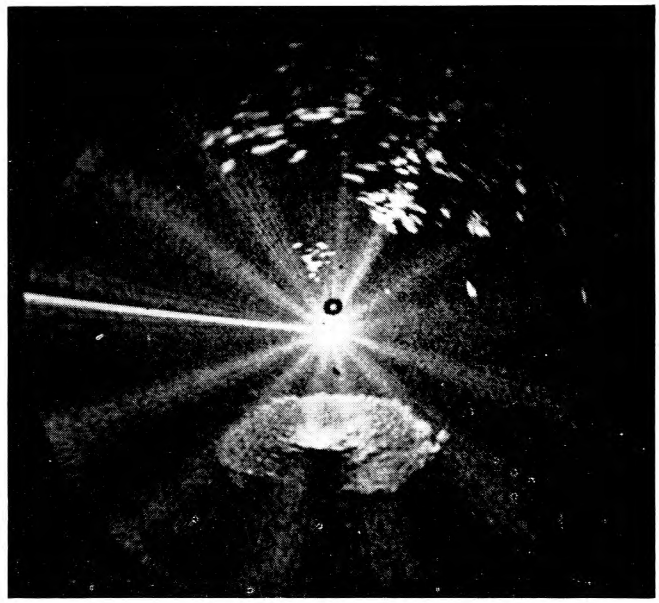
Scopes

Interference on the APQ-13—not Jap jamming—is shown below in scope pictures taken on recent mission to Yawata by 20th Bomber Command. Study of the pictures straightened out reports of operators that Japs might be jamming APQ-13. Experts who did the analyzing came to the conclusion that mutual interference, malfunction of equipment and weather disturbances were chief sources of spurious indications on the scopes of these sets in B-29s flying over Japan.

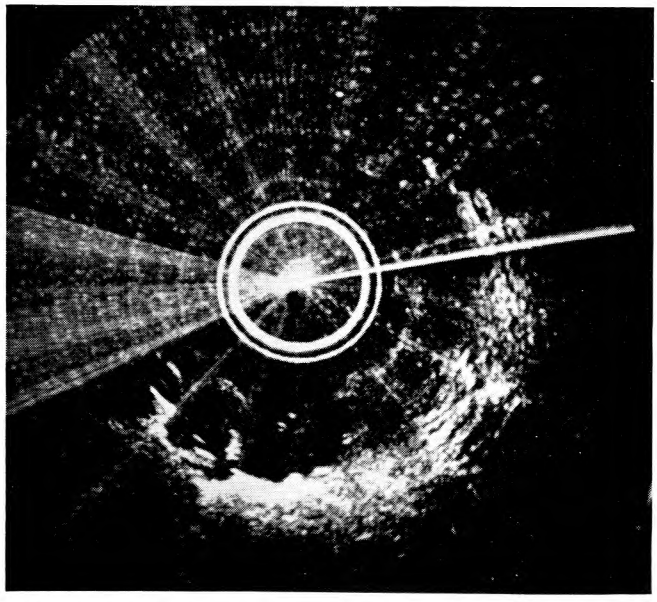
The Japs, in the opinion of U. S. technicians, have not as yet made any progress towards jamming the APQ-13. It is thought possible that some jamming—probably unintentional—may come from Jap naval gun laying equipment. But even that is speculative. Meanwhile, RADAR runs these 4 samples of interference as good lessons in the subject, worth study and comparison.



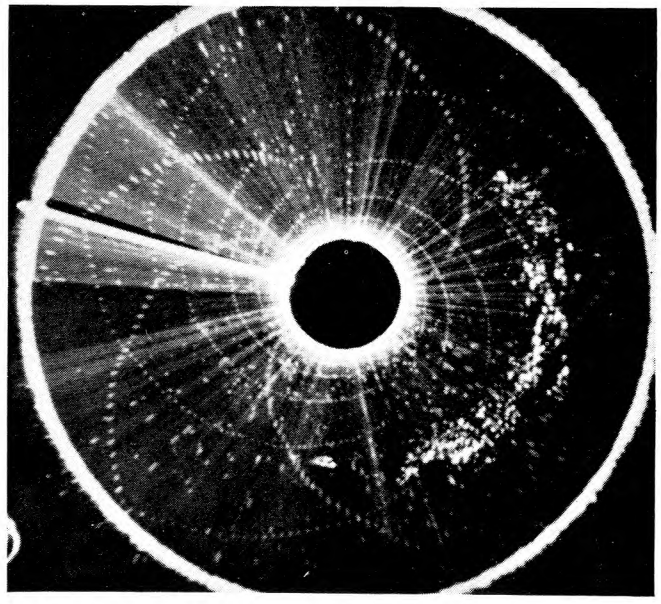
South of Saishu, interference is caused by malfunction of set and effects from other sets nearby. Bright triangle appearing from 8 to 9 o'clock is from sweep overlap during time exposure



North of Saishu, 13 bright spokes are caused by antenna's loss of speed from rubbing against its housing. Same effect comes from dirty generator brushes or from other commutator troubles

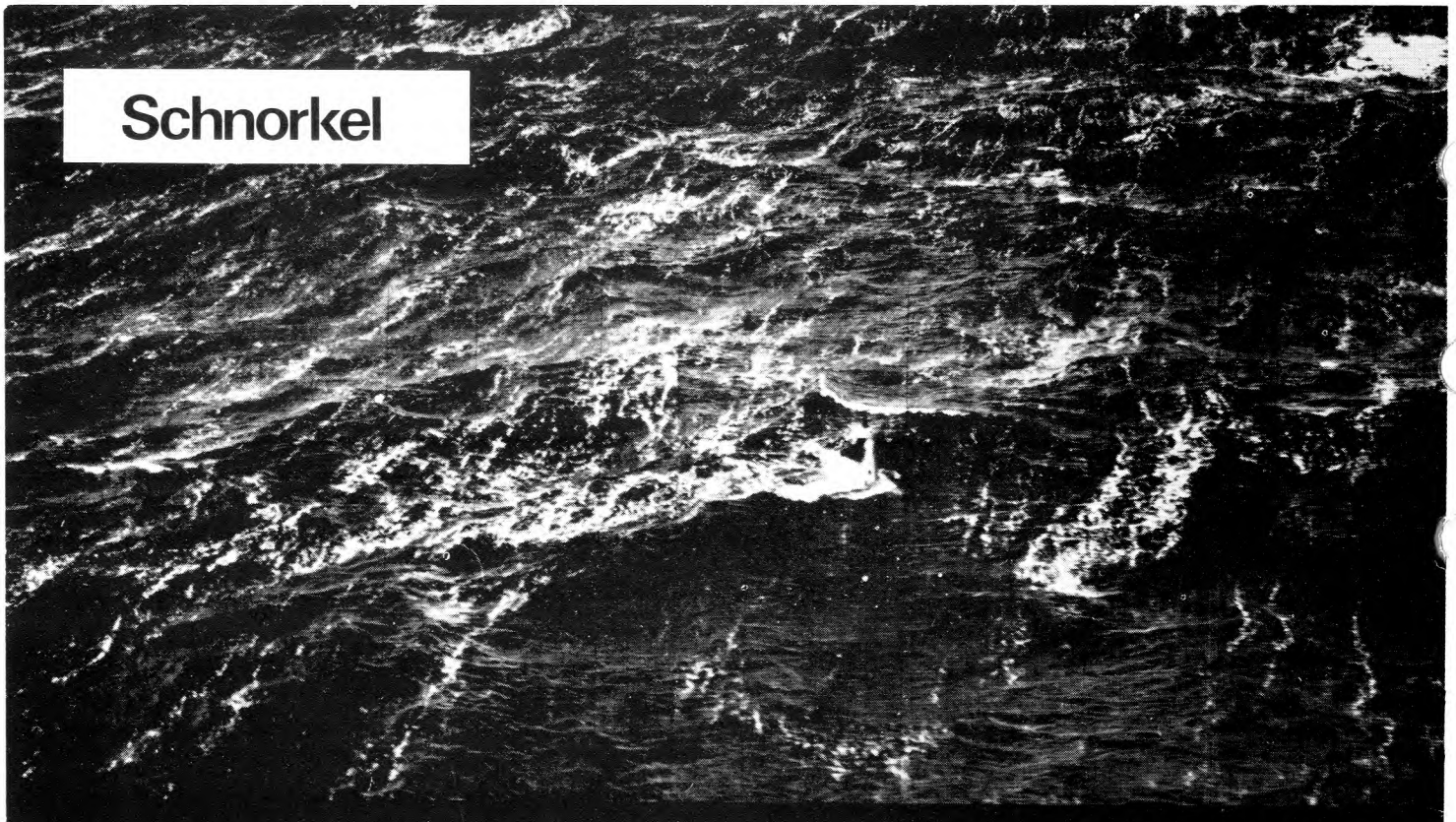


In the Yawata area, this interference came from minor electrical disturbance in the set and from the radiation of other APQ-13 equipment operating in the tight formation of B-29s

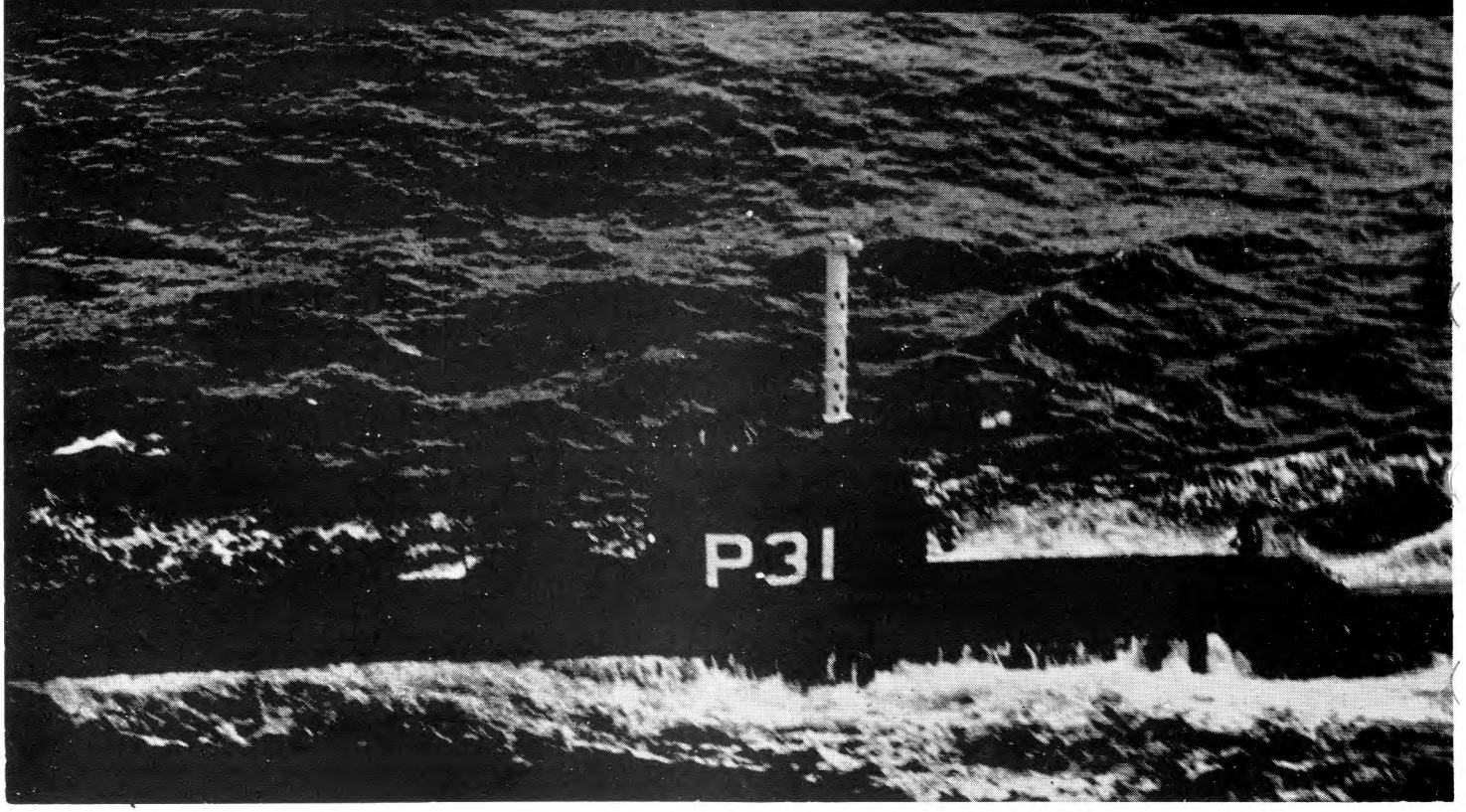


Still in Yawata area, scope shows good example of mutual interference—very definitely shown by dotted symmetrically curved patterns. Bright rim comes from minor set malfunction

Schnorkel



Any child who ever submerged himself in a swimming hole and breathed through a tube is familiar with the principle of Schnorkel, pictured here in a British mock-up. By its use the German U-boat has lately been able to reassert itself. Schnorkel, an extensible Diesel airvent, permits the U-boat to go for long periods and even to recharge its batteries without surfacing. The inevitable consequence has been a drop in sightings and hence in U-boat kills. Visually, as the photo at the top shows, the target which Schnorkel constitutes is virtually unseeable. It is obvious, too, that Schnorkel won't give anything like the echo on a radar scope that a surfaced sub gives. From diminished ranges, radar can still pick up Schnorkel, and as search crews acquire experience at identifying the tiny target at these ranges and tracking it through sea return, sightings and kills can be expected to increase. But the full answer to Schnorkel waits on the result of work now in progress—along radar and other lines—in Allied laboratories. In the see-saw battle of countermeasures which has been going on since the sub war began (see RADAR No. 5), this is the newest development.



FERRANTI Defence Systems Limited

RADAR

Issue No. 8 FEBRUARY 1945

INTRODUCTION



R.P.F. Lauder
Engineering Manager
Product Support Department

We are still immersed in the problems of navigation. In the last volume we saw that a combination of MEW and SCR 584 was a powerful means of guiding our own aircraft about the battle area, but there is an obvious and understandable desire for autonomy. The aircrew want to feel that they can find their way about without the help of colleagues on the ground.

Here we see a sudden proliferation of navigation aids which depend only on ground beacons. In principle, an aircraft in flight, knowing the range to each of two beacons on the ground, whose own co-ordinates are known, can calculate its own position by simple geometry. The principle is still in use today and world-wide systems such as Omega and Navstar depend on it.

The navigation aids we see here were limited to line of sight – about 180 miles – and the beacons were limited to about 20 interrogations simultaneously before saturation set in. There is an interesting comparison on page 23 between the four competing (or complementary) systems: Shoran, Gee, Micro-H and Oboe; the major variations were whether an on-board computer was carried, or whether the necessary computations and position were manually carried out; also as to whether the resulting information was displayed directly to the pilot, or whether he received oral instructions.

We are of course before the day when gyros and accelerometers could be made to a sufficient accuracy to allow inertial space to be defined, with accurate accelerations measured in each of the three orthogonal axes. Ferranti has made this field peculiarly its own with its FIN series of analogue and digital inertial navigation systems flying in many of the world's great combat aircraft.

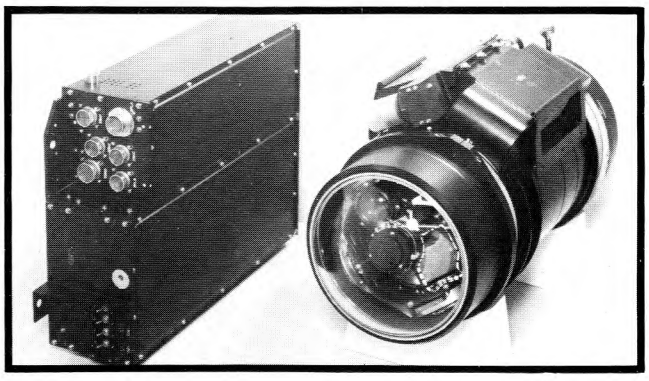
In the South Pacific, the US forces were encountering more and more Japanese radars, and many US bombers were equipped with electronic surveillance monitoring (ESM) equipment of a fairly rudimentary kind. However, it was vital to know at least the frequency, p.r.f. and pulse width of the enemy radar and, if possible, whether it had reversionary frequencies available. It was also useful to know if conical scanning was being used and, if so, what the conscan frequency was. The object of all this was, of course, to devise suitable counter measures or jamming. The US troups could be fairly certain that a broad pulse implied a search radar whereas a narrow one could be expected to be associated with weapon aiming/gun laying. It had only just been decided that the measurement of pulse width should be done at the half power points and, as the pictures on page 32 show, that determination was not always easy to make. We must remember that the circulator was probably not fitted to any of those radars and pulse shape was at the mercy of matching the complex load of antenna, duplexer directional couplers, etc., to the oscillator producing the energy.

It seems almost inconceivable to us that operators in the air could tune to one enemy radar and measure its characteristics. We have been through the situation where an enemy aircraft would be illuminating overlaps, and the pattern repeated several times for the various radars within range. To the ESM listener, he is bombarded by hundreds of overlapping pulses with different characteristics, all mixed in with CW, FMCW, AMCW and jamming. The job has now gone well beyond what the human operator can manage and automatic measures are now the norm. It is amazing what these operators managed to achieve without any information storage media other than paper and pencil and photographic film.

For the first time in this mission we find a mention of a radio controlled bomb – the Azon. There had to be no along-track errors since the controlling signal actuating the moveable rudder on the bomb itself could only correct across-track errors.

It seems to have been a weapon with a highly chequered career and was only useful against certain targets in particular terrain. The feedback to the bombardier providing the corrections was visual, enhanced by a flare on the bomb itself. Bridges have always been difficult targets and if the bomber can line himself along the length of the bridge and the across-track error removed while the bomb is in flight, we have greatly improved the performance. Today Ferranti's Laser Target Marker designating a bridge on the ground can be attacked by an aircraft carrying Ferranti's Laser Ranger and Marked Target Seeker, completely blind, with high accuracy.

Robert F Lauder



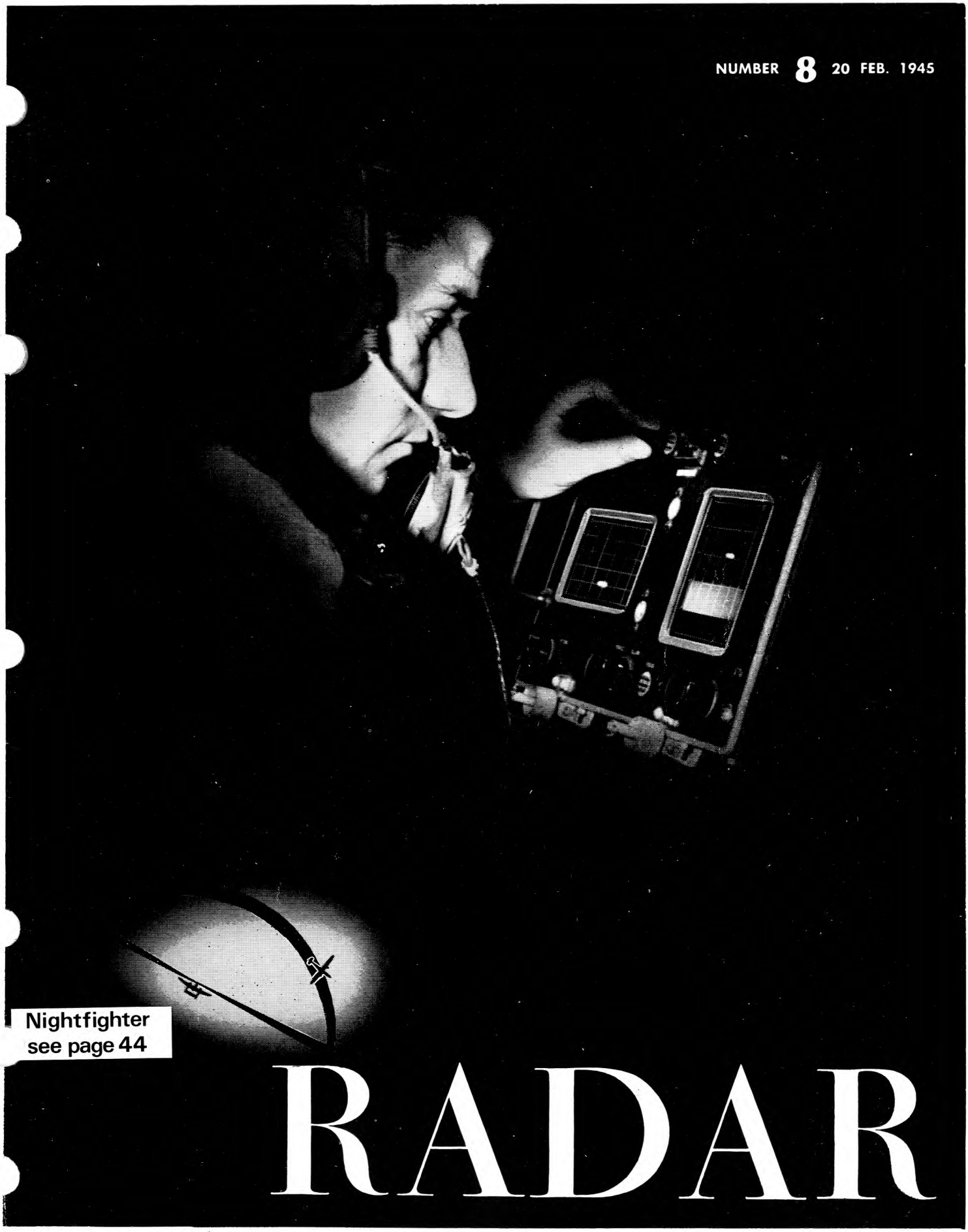
LRMTS

Ferranti's Laser Ranger and Marked Target Seeker is a highly accurate ranging system which is fitted to the Harrier, Jaguar and Tornado aircraft and can be used in conjunction with the Ferranti Laser Target Marker.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

PSD

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Nightfighter
see page 44

RADAR

RADAR

Number 8 20 February 1945

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EDITOR: Dexter Masters, Office of the Air Communications Officer.

FOREIGN EDITORS: Dr. L. J. Henderson, Advisory Specialist, Hq. U. S. Army Air Forces, MTO; Dr. L. C. Marshall, Chief, Operational Research Section, Hq. U. S. Army Forces, POA; Dr. David T. Griggs, Advisory Specialist, Hq. U. S. Strategic Air Forces, ETO.

EDITORIAL ASSOCIATES: Avis Clarke, Ruth Copland, 1st Lt. Norman R. Goldman, Dallas Johnson, Lucie Sewell, 1st Lt. Robert Wright.

CORRESPONDENTS: Sgt. John Caldwell and S/Sgt. Rob't Carlson, Advisory Specialist Group, Hq. USSTAF, APO 633, U. S. Army; John Alexander, Staff Photographer, on assignment Pacific Ocean Areas.

DRAWINGS by Presentation Branch, Office of Strategic Services.

ADVISERS: Lt. Gen. Barney M. Giles, Chief of Air Staff; Dr. E. L. Bowles, Special Consultant to Commanding General, AAF; Dr. Lee A. DuBridge, Director, and Dr. Louis Ridenour, Radiation Laboratory.

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While we're on the subject

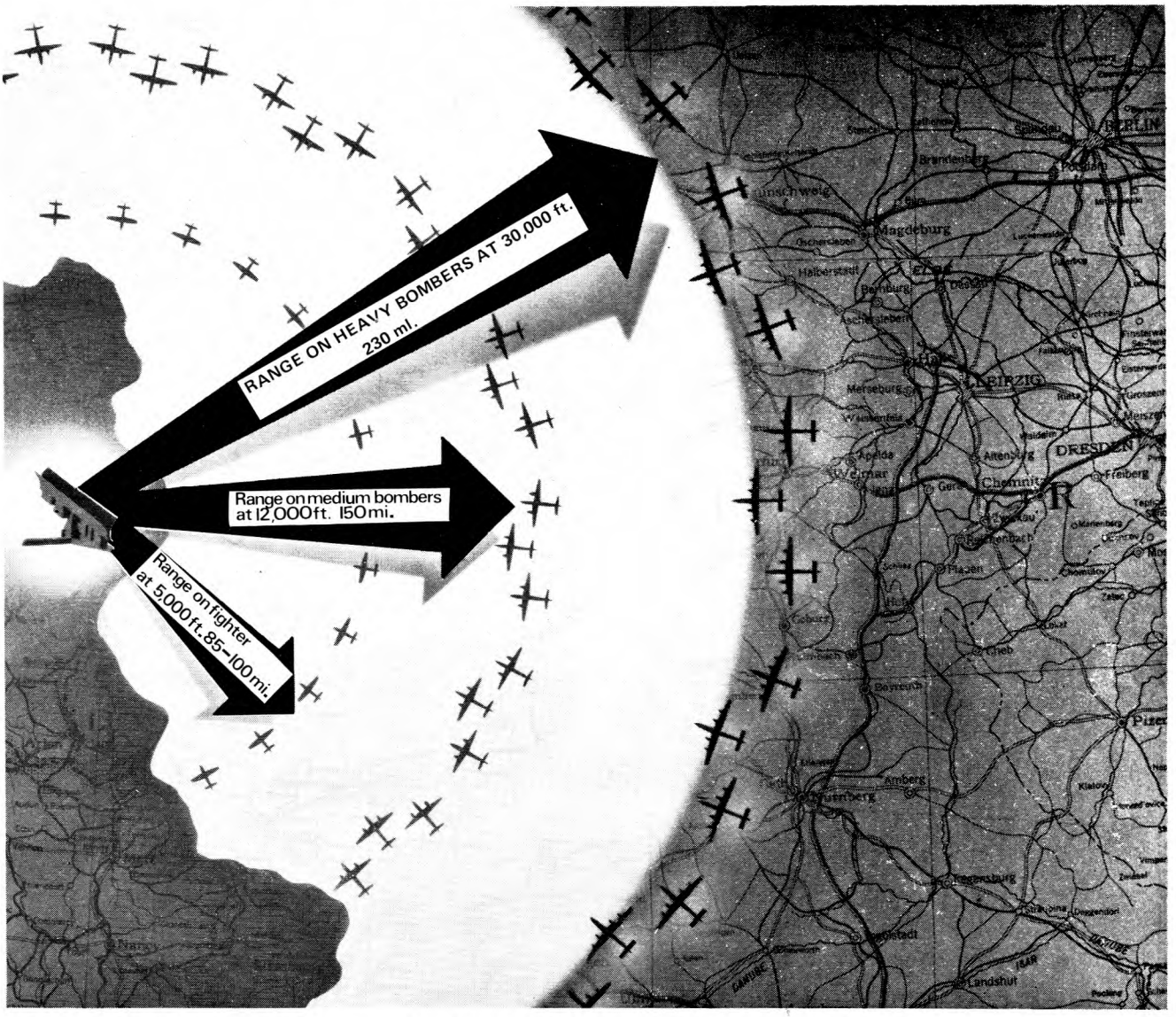
● In technical terms, it is a very curious war. It is curious in the simplest sense for the glasslike bubbles, the luminous spheres and the strange pink clouds that Allied airmen coming back from jobs over Germany have reported. No one has as yet reported any ill effects from these phenomena. Practical men have written them off as bunches of chaff glistening in the sun or as the effects of combat fatigue on the fliers. Others, perhaps no less practical, have seen in the phenomena the desperate marshalling of half-finished fruits of German research. Meantime, security officers, watching uneasily as the daily papers make hay with stories of the weird goings-on, have been holding their rubber stamps ready to slap "Top Secret" on any word of them the moment anybody can figure them out.

● Over Europe the air war is now in very large measure a radar war. It will be that way until May or thereabouts—that is, until bad weather lets up. Until then 3 out of every 4 bombs dropped, and possibly more, will be dropped wholly or in part with the aid of radar. All but a small fraction of air missions of any type will be run off with radar assisting. The situation is reversed over Japan. There bombing weather is at its best. Reliance on radar, except for navigation, is consequently much less. The big question is how dependable the reliance will be, come June and overcast. It's a fact that our bombers over Japan have had far less briefing in radar bombing than our bombers over Germany. Nor has RADAR been able to find any scope portrait of Tokyo as meaningful in bombing terms as, for instance, the one of Munich on the back cover. Does anybody know of one?

● The stand-out ground radar equipment—MEW or AN/CPS-1, whose capacities are touched on across the page and in the story on page 9—is in the odd position of being almost obsolescent and not yet in production all at once. Pre-production sets, put together out of some smart foresight a year ago, are doing triple duty in the theatres which have them. Production of the multi-ton equipments meanwhile moves slowly ahead. But V-beam radar (AN/CPS-6), which RADAR dealt with briefly in issue No. 5, is simultaneously coming along. It will do all that MEW does and more besides and will be, in short, the goddamnedest thing ever seen. Even so, MEW's obsolescence will be a highly academic point; there will be more than enough use for all the MEWs that can be turned out for a *long* time.

● The whole question of what goes on in the development, production and distribution of radar equipment is a matter of proper concern to a great many people, who may be affected very drastically by what goes on. RADAR plans a detailed examination of one piece of equipment from the time it was a gleam in its designer's eye on through to the first operational results. The equipment is Eagle or AN/APQ-7, currently being pushed through to its destiny as successor to the APS-15 of the European Air Forces, the APQ-13 of the B-29s. It will take space to cover all the involvements and RADAR has scheduled as much as may be needed—probably five successive articles.

What happened in the breakthrough



AGAIN ON THE OFFENSIVE 9TH TAC RADAR SWEEPS OVER GERMANY ON SEARCH AND CONTROL. FRONT LINE IS AS OF BEGINNING OF FEBRUARY

The map above conveys an impressive fact; one of the most impressive facts, so far as radar's war work is concerned, of the Western front situation. It shows just how extensive is the coverage over Germany of just one of the big Microwave Early Warning radars now at the front.

The area which this MEW blankets is an area in which a very high proportion of German Air Force flights are put together. The practical meaning of this is that we get about as good a picture of German air activity at its origin as the Germans have themselves. It is also an area in which supply bottlenecks and targets, both strategic and tactical, abound. And the practical meaning of this is that our heavies and our mediums and our fighters can ply effective trade with a maximum of protection and coordination. As reporters or controllers, the far-seeing MEWs at the front give us an advantage of immeasurable value.

The advantage was cut down when von Rundstedt's breakthrough buckled the December lines. The best situated of the MEWs came within an ace of being lost. And for some time, until the German pressure ran out, the big set was forced into almost purely defensive functioning. It hadn't had much practice at that since June.

The advantage of MEW for defensive and offensive work has now been fully restored. Along with a variety of associated equipment—most notably the versatile SCR-584—it is once more making total use of its capacities.

Because the German breakthrough put demands on front line ground radar which it had never before been called upon to meet, because it met the demands and because its operators learned a good deal in the process, RADAR gives over the following 5 pages to a special report on what happened, assembled by RADAR'S correspondents in the ETO.



EVEN IN RETREAT RADAR CONTROL OF TACTICAL MISSIONS WENT ON. POSITIONED BY 584, 9TH TAC PLANE BLASTS TARGET JUST BEYOND TROOPS

"Headquarters Company was rudely awakened . . . ."

"Prone to mild interest only in such news because of former positions of comparative security, Headquarters Company was rudely awakened from its complacency at 0830 hours, Saturday, 16 December, when first shell smashed into a nearby house and partly demolished it." Thus is recorded the start of Von Rundstedt's counteroffensive in the official history of the 555th Signal Aircraft Warning Battalion of the 9th TAC. The situation, as it developed, was something like this.

The Battalion had its radar units deployed in a north-south line from Aachen, Germany, through Malmedy and St. Vith to Bastogne in Belgium. This was directly in the path of the breakthrough. Beginning on the 16th with Forward Director Posts, Light Warning units and SCR-584 control stations, radar was withdrawn within the next week behind the Meuse River. The new line was roughly east-west—Aachen to Liege, Namur and Charleroi, then around the prong of the salient and back down to Dinant.

This meant that in the North, where the 9th TAC supported the 1st Army, radar search and control swung mainly from Germany and the Meuse south over the breakthrough area. At the southern rim of the salient, the 9th TAC took over search and control around Bastogne as the 3rd Army moved into that sector. Radar cover was provided throughout the breakthrough, though at times only half the usual amount of equipment was on the air. Throughout the period, one GCI station not in the direct line of attack remained on location and in operation almost continuously.

Although land lines kept workable, for the first few days of the offensive FM was the main method of communication. Control of tactical missions was a risky job because of the



LIKE LONE SOLDIER ABOVE, WHOLE CREWS PLODDED BACK FROM RADAR SITES AT HEIGHT OF BREAKTHROUGH. BUT LOSSES WERE AMAZINGLY LIGHT

difficulty of identifying the bomb line in the very fluid situation. But radar control kept flyers informed when they were over known enemy territory so they could make visual attacks.

That radar played an extremely important part in stemming the German counteroffensive is undoubtedly true. At the same time, radar facilities available were hard pressed to meet the sudden large-scale operational requirements. In the beginning it was nip and tuck. Of decisive importance were the 5 days of unexpectedly good weather a few days after the start, when many radar units were still disrupted.

Equipments dismantled and withdrawn early in the game included 2 bombing control beacon stations, the lack of which left the 9th AF medium bombers with very much reduced radar coverage. The 9th TAC MEW setup was also moved during the critical period, after guards at the gate killed a German paratroop captain who came at them with a Tommy gun. It was the recuperative powers of the radars that saved the day; 48 hours after the MEW was withdrawn it was reestablished at another site and back on the air. It controlled flights of fighter-bombers under almost unflyable conditions, and the planes were able to intercept and strafe advancing enemy tank and motor columns with good results.

Despite enemy action uncomfortably close by, including bombing, strafing and buzz bombs overhead, the MEW accounted for a record number of aircraft kills during this period. In the month of December, MEW-controlled fighter-bombers, armed reconnaissance planes, night fighters and others destroyed 161 German planes and damaged 72, with 11 probables. On just one day in December after the Germans started rolling, an MEW controller was credited with 12 Jerries destroyed, 11 damaged—all ME-109s. In short, MEW showed its merits in a purely defensive role, after concentrating almost wholly on offensive work since it was landed on Omaha Beach last June.

It was inevitable that some of the radars withdrawn during



MUD, SNOW, PARATROOPS AND STEADY GERMAN BOMBING HARASSED CREWS AS THEY STROVE TO DISMANTLE BULKY EQUIPMENT FOR WITHDRAWAL

the critical period should have become inoperative for a time. This was true of several SCR-584s moved behind the Meuse to avoid possible capture in the unchecked German advance. Behind the Meuse they were too far away to be of any use to the Allies either, since they were out of effective range. But they were back where they could do some good in relatively short order.

Two equipments—British Types 11 and 13—had to be left behind when trucks got hopelessly mired in the mud and crews retreated under small arms fire. The radar was left intact when destruction grenades proved faulty and gasoline fire ineffective. Later Army artillery pinpointed the site to destroy the equipment.

That more radar sets were not lost is a tribute, among other things, to the perseverence of crew members who, in zero weather and icy winds, wrestled with rusted nuts and bolts to dismantle the equipment and maneuver it through heavy snow onto trucks and trailers in most cases not positioned for a quick get-away. In more than one case advancing Germans arrived on the scene before the radar units were ready to go, and the 555th lost 3 men by capture. One was hit by enemy fire, some were hurt dismantling the heavy equipment. None was killed.

In the general maelstrom going on around them, the trials of the radar crews were not very big potatoes. On the other hand, close combat was pretty far from the training of most of the crews, whose daily activity up to the time of the counteroffensive had been principally technical work—with a large admixture of plain housekeeping chores. The technicians and other radar personnel proved themselves pretty well. They carried out the primary task of maintaining radar on the air as long as they could while evacuating equipment in icy cold and usually at night, with the enemy breathing down their necks.

Since the middle of January, when 9th TAC radar moved back to the German side of the Meuse River, it has been on the offensive again, just as it was every day from D-day to the beginning of the counteroffensive.



BUT CONSIDERING THEIR INEXPERIENCE AT FRONT LINE COMBAT AND THE NEED TO KEEP RADAR OPERATIVE EVEN UNDER FIRE, CREWS DID WELL

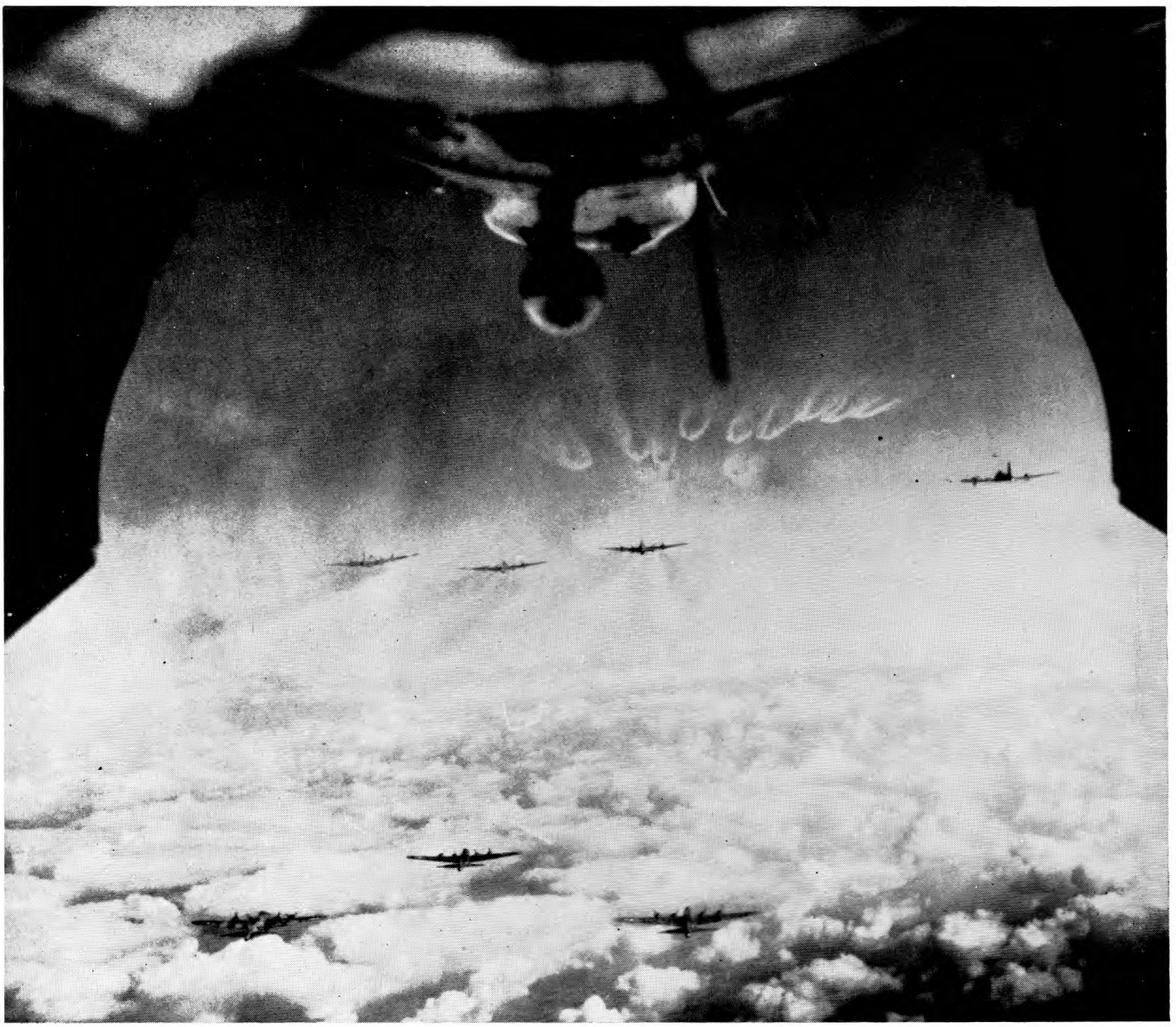
The 12th TAC was forewarned

Not until New Year's Day did the counteroffensive reach the Bitche sector, where the 12th TAC was supporting the 7th Army. German strategy apparently was to come down the ridge of Vosges mountain and seal off the road from Saverne to Saarbourg, thus hemming the Americans in. No sooner had the Germans opened with aerial bombing of Saverne and heavy artillery shelling of the front than forward radar units began to pull back. Included in the exodus were Light Warning (SCR-602), GCI (SCR-584 and SCR-527) and Early Warning (SCR-270) as well as a Forward Operations Post. Simultaneously, as the result of enemy activity in the Colmar sector, sets feeding a second forward operations setup were pulled back in the 1st French Army to the south.

Forewarned of an anticipated enemy move, all radar units had been alerted for several days and they carried out an orderly withdrawal on orders given over FM. They moved at midnight, in complete blackout and over icy roads. Although bazookas and .50 caliber guns were manned at the sites, this was precautionary rather than necessary. What probably did do good were Beaufighters equipped with Mark VIII AI, assigned to the withdrawal routes. They had orders to protect at all costs the vans carrying radar equipment.

The pull-back brought the equipment over one ridge of Vosges mountain. And within 12 hours after withdrawal one piece of equipment, the GCI 527, was in operation again; the site had been previously chosen when the 12th TAC was on the offensive in this area. Other equipment was brought back to bivouac. Reporting, early warning, GCI and other control performed by forward operations posts both north and south reverted to control centers in each area.

One reason for the smoothness of the 12th TAC's withdrawal was the forewarning; another was that personnel of the 12th TAC had been in tight places before and knew how to get out of them. They were at Sicily, Salerno and Anzio; they've made 5 seaborne landings on D-days on hostile shores.



8TH AF HEAVIES, ACCUSTOMED TO STRATEGIC MISSIONS AS ABOVE, FLEW 8800 SORTIES AGAINST TACTICAL TARGETS DURING THE BREAKTHROUGH

8th AF turns tactical

Passing up its strategic targets, the 8th AF turned tactical from 16 to 31 December. Of 9300 bomber sorties dispatched during 12 days in that period, 8800 were against targets affecting the German salient in the Ardennes sector. At the request of ground forces attempting to stem the tide of the breakthrough, Flying Forts and Liberators attacked marshalling yards and air fields, railroads and bridges, road junctions and communications centers.

Because of the urgency of the situation, missions were carried out during most of the period in weather that previously would have been considered non-operational. Planes took off with visibility as low as 200 yards, flew through freezing drizzle and frontal clouds that extended to 32,000 feet. They landed with ceilings less than 500 feet and visibility less than 1500 yards; and when there was no ceiling they went to alternate bases in the southwest of England and France.

Not only did these conditions place a premium on crew skill and courage in takeoffs and landings; they also placed a premium on skill in handling radar navigational aids and radar bombing systems. Of the tactical sorties, on approximately 5000 the bombing was done by radar—H_2X, Micro-H or Gee-H—with a variety of assists from the TAC ground radar. It is difficult to assess the hits, because of the high proportion of unobserved bombings. However, strike photos taken of observed bombings showed many very good and good results on critical targets.

Few enemy fighters were sent up against the bombers except on 2 days—the day before Christmas and the day before New Year's. On 24 December, when the 8th AF sent out its all-time record number of sorties—1880—to drop bombs on tactical targets, they were attacked by 49 fighters. On 31 December, a total of 84 fighters attacked. Although some bombers were downed and damaged by these and other enemy aircraft, most of the 55 planes lost, and the 1378 sustaining battle damage, were hit by flak.

Radar at the front

Tactical ground units prove themselves on the offensive

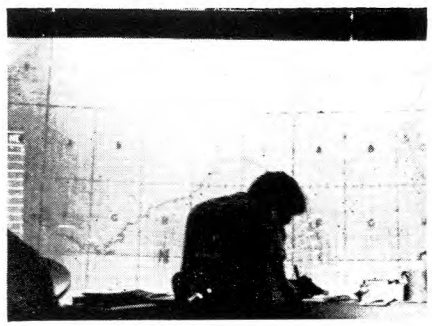
Along more than 300 miles of Western Front, 4 U. S. Armies and their British Allies are moving forward again as this is written. The Bulge is far behind and it is highly probable that the Armies will be moving even faster by the time this is read. Six months ago, when the Armies were sweeping across France, the newly-mobilized ground radar units backing them weren't moving with them so well. They are now. Scores of units, manned by a small army of their own, are right up front where they can do the most good.

The big development in ground radar in the ETO since D-day has been the switch in emphasis from reporting, filtering and the like to active participation in tactical operations. The change has been basic. It has meant an about-face from defense to offense, from fixed installations to mobility, from more or less scheduled routines to split-second decisions. The art of controlling tactical missions had to be learned.

It took combat experience to put needed functional polish on the new techniques. Von Rundstedt handed out a pretty stiff dose of it, but no one will deny the value of the lessons learned. Having withstood the pressure of recent events, tactical radar is in good shape for dealing with the battles shaping up.

U. S. Armies are now getting close and active cooperation from the Tactical Air Commands of the 9th AF and the 1st Tactical AF (Prov.). Each TAC has one or more Signal Aircraft Warning Battalions (the name no longer covers their functions) with associated Fighter Control Squadrons working into the TAC Fighter Control Centers. Thus armored units, artillery and infantry are constantly supported and frequently paced by the planes and radar of the TACs.

For an account of how the ground radar offensive system is set up, see the following pages on the operations of the 555th Signal Aircraft Warning Battalion up to—and since—the breakthrough.

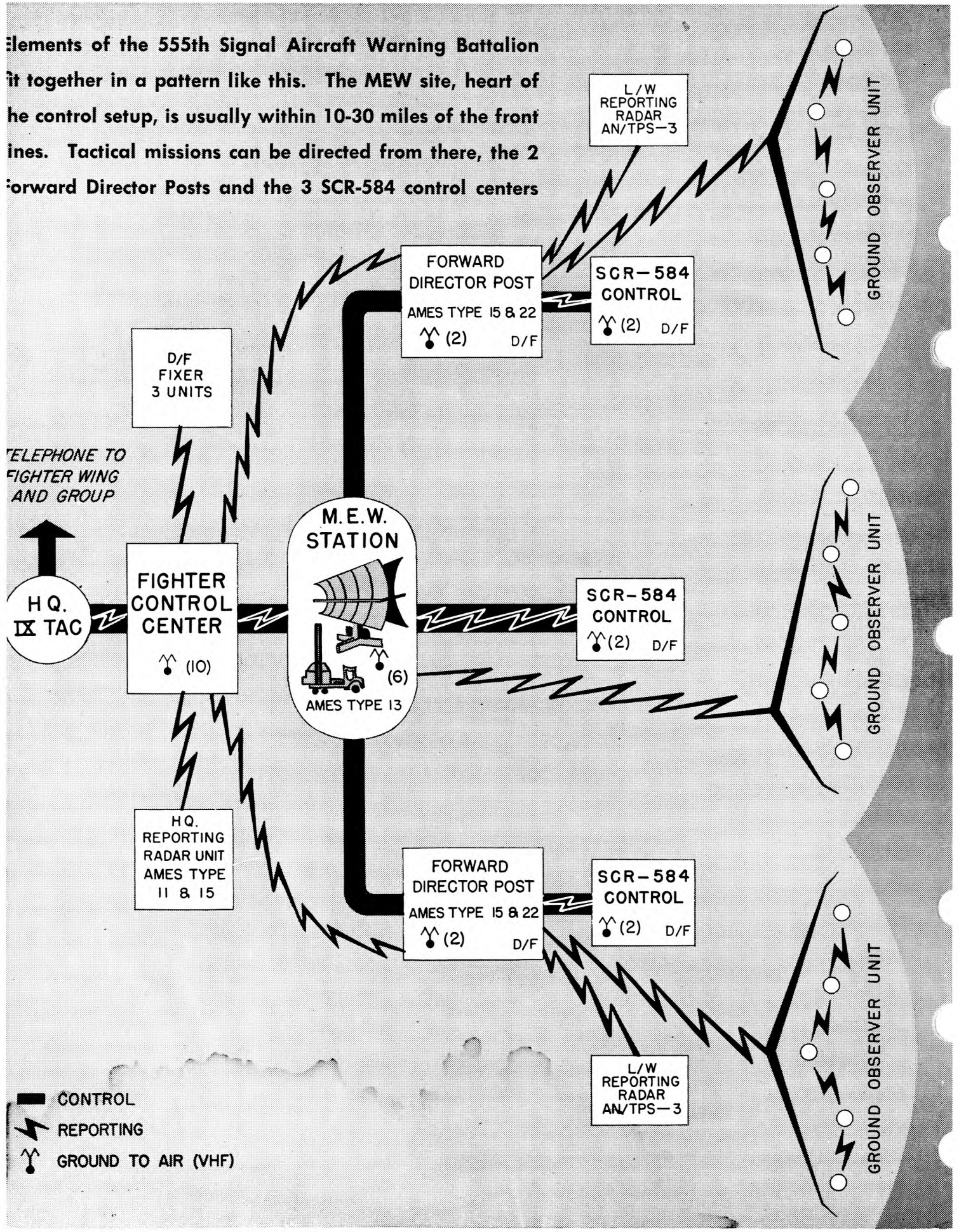


At plotting board in MEW operations hut controller studies sector air activities



SCR-584 maintains high performance in a variety of jobs. Currently its outstanding job is tactical flight control in air-ground cooperation (see text), but it continues also as leading fire control radar with AAA batteries. The dug-in, snowed-in 584 above, operating with U. S. guns at front, helped flatten the bulge as did its TAC counterparts

Elements of the 555th Signal Aircraft Warning Battalion fit together in a pattern like this. The MEW site, heart of the control setup, is usually within 10-30 miles of the front lines. Tactical missions can be directed from there, the 2 Forward Director Posts and the 3 SCR-584 control centers



9th TAC radar, both U. S. and British, is sited for front line operation

The 555th SAW Battalion of the 9th TAC is a first-rate example of the new offensive type of ground radar organization. The 9th TAC, with long combat experience, has been a proving ground for equipment and techniques. And the operational pattern evolving in it will have a definite influence on offensive radar as a whole.

As operated by the 555th, the radar control system can look after as many as 9 squadron or group formations at one time: 4 from the MEW, and one from each of the 2 Forward Director Posts and 3 SCR-584 units. Units are sited for best individual operation, also to fit into the Battalion net. Because of its great range (see page 3) and traffic capacity, the MEW gets the center spot of the sector, with 2 FDPs flanking it on either side and the 3 SCR-584 posts in front. The forward units thus form a rough equilateral triangle with the MEW. Communication between most of the units and Fighter Control Center is in triplicate (via FM, landline and CW). VHF/DF equipment provides control channels to aircraft, does the major part of plane identification.

Radar siting under combat conditions is a complex job. The fighting line naturally determines the general location of sites and that doesn't always leave much choice. Unit sites must be found which combine a good technical location with a bivouac for personnel of 30 to 400 officers and men. In some cases this problem has been neatly solved by taking over schools, hotels and other buildings, often just evacuated by the Germans. But the site and bivouac may land right in the mud, miles from nowhere.

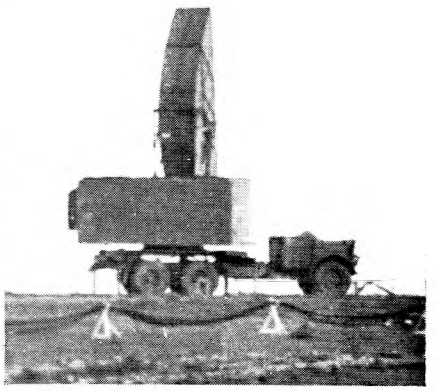
The biggest piece of baggage the Battalion has to handle is the MEW. And so far the big radar and its associated equipment have had to go on the move more than a dozen times. (One technical observer's estimate is that, on the average, the MEW antenna is good for about 10 moves.) Most of the Battalion's moves have been relatively uncomplicated, with little need for sandbags, digging in, or camouflage—thanks to air supremacy.

The Battalion did try its hand at camouflaging one location. Then it rained and a great tangle of straw and tired rope descended on MEW's rotating antenna.

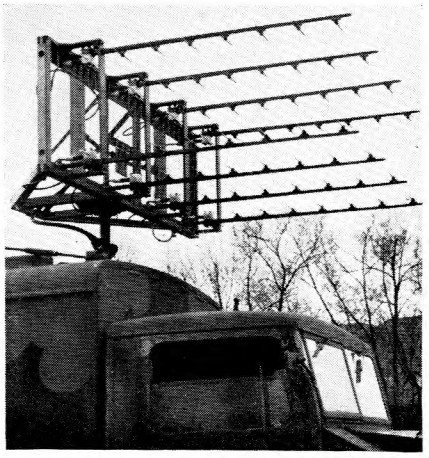
For an over-all review of the 555th's equipment, see following pages.



Type 11, left, provides radar data at Forward Director Posts. Although a medium wave radar, it has ability to evade jamming—frequency can be changed within limit of 100 mcs



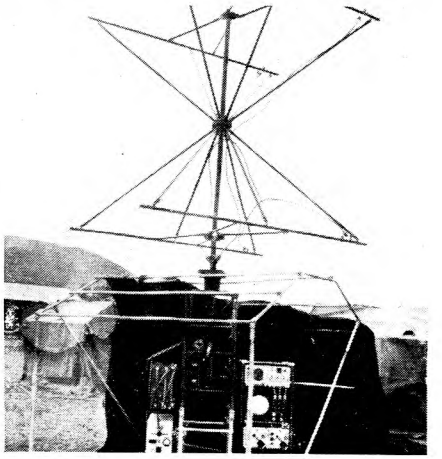
For heightfinding, the MEW employs British Type 13 partner—with good results



Type 6 Mk V, light warning radar, operates at SCR-584 posts, does other odd jobs



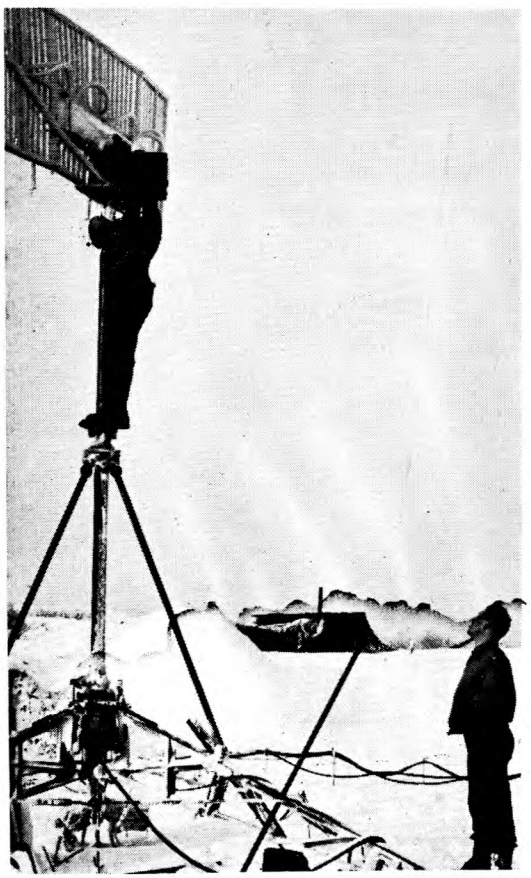
Type 15, medium wave radar, is set up at Forward Director Posts for its GCI role



Type 6 Mk III, British set similar to our 602, was mounted in U.S. truck by 555th



Fighters check in with MEW for controlled mission. IFF, not much used for control identification, is important to AA units; below, IFF at site in Luxembourg



A radar and radio net controls and reports air activity in TAC sector

The 555th SAW Battalion, like many others, operates both U. S. and British radar. Typically, its setup consists of the following:

● The MEW (AN/CPS-1A) is the No. 1 piece of ground radar, with a Jamesway hut as an operations room instead of the van formerly used. This and other recent changes have cut down mobility somewhat, but that's more than offset by gains in reporting and controlling efficiency. The Battalion has found that the most desirable site operationally for the MEW is one which is as high as possible for coverage and with natural screening low enough so that the lower beam is not unnecessarily directed into the ground. Low screening tends to increase permanent echoes close in, but the advantage gained by longer and lower coverage generally cancels out this objection. By and large, a good site 30 miles behind the lines is more efficient than a fair site 20 miles closer.

● Heightfinding for the MEW is done by British Type 13 radar. Because of the importance of fast and accurate "angels" (height data) in controlling, use of a second Type 13 and location of its display in the MEW ops room is a possibility.

● At each of the Forward Director Posts a combination of 2 or 3 British radars is used—usually either Types 11 and 15, or Types 15 and 22. Type 15, a mobile medium wave set, is somewhat cumbersome but effective except for low coverage. It's probably the most popular British equipment with U. S. crews. Type 11 is a medium wave radar with narrower beam, lower coverage and greater mobility but no heightfinding capabilities. With the 11-15 combination, a Type 13 is added, when available, to do a real job on heightfinding. Type 22 is actually a combination of 13 and 11. All the sets have good operational records once the crews really get the hang of them.

● The 555th operates 3 Bombing Posts, each equipped with 2 modified SCR-584s. All the 584s now have 180° plotting tables. They will gradually get the new super x-y plotting board, recent tests of which have been extremely favorable. This board has a 360° plot and an expanded scale as well as the normal one.

● Light Warning radar is used for gap filling, for leap-frogging in long movements and for search assistance to the 584 control posts. Two types of LW sets are used, the British Type 6 Mk III and the AN/TPS-3. Sometimes the Battalion uses Type 6 Mk V, essentially the same as Mk III, but higher frequency and with a more efficient antenna array.

Two pre-production models of the TPS-3 have given good performances as gap fillers for the Battalion radar net, especially in hilly terrain where relative absence of permanent echoes in TPS-3 display is advantageous. The pre-production sets haven't been quite rugged enough to take the beating that radar gets in the field, but that was to be expected. Production models are going in and being mounted in very neat truck installations. TPS-3 is expected to take over the entire LW job for the Battalion.

● The search and reporting net is completed by Ground Observer Posts, which send plots on aircraft observed visually and by sound (no radar). They are organized in 3 groups with one GOP serving as a control station for each group. Observer posts, located as close to the front line as possible, perform an indispensable role in reporting and identifying aircraft, particularly low flying planes in areas where radar coverage is cut off or made difficult by PEs.

All this Battalion radar equipment takes up more than 50 vehicles, trucks and trailers. Almost as much again is needed for the extensive communications net which must be established to make the radar effective.

The communications net

As radar equipment gets better and radar operations multiply, the pressure on communications gets hotter. The FM net which covers the entire Battalion is doing a notable job as first line of communications. For the most vital and crowded traffic, FM (SCR-610 and the higher powered AN/TRC-1) is paralleled by landline and CW channels.

For ground-to-air communication, the MEW has 6 VHF channels and each of

the FDPs and 584 posts has 2. VHF communication is handled by the SCR-573 transmitter, SCR-574 receiver and the 4-channel SCR-624 transmitter and receiver. The standard SCR-522 is in the aircraft. In addition, the Battalion operates 11 VHF-DF fixers, 4 with the MEW, 2 with each FDP and one with each 584.

Reporting and controlling operations go on simultaneously 24 hours a day, with completely separate communication channels reserved for each function. Principal reporting problem at present is to make the information on the Fighter Control Center filter board as complete and accurate as the information at the radars. The big MEW has a clearer picture of air activity in the sector than it's possible to get at the FCC filter board. So there has been much talk of making duplicate MEW scope display available at the FCC, or moving FCC to the MEW.

At present, the MEW operations board and the FDP filter boards plot tracks from their own scopes, from any LW sets around, and from the GOPs. Plots are made as complete as possible—grid coordinates, number of aircraft, height, direction—and passed on to the FCC.

Identification

Initial problem at all units is to locate and identify aircraft to be controlled. Originally identification was handled by the FCC but lately the bulk of this work has been turned over to the MEW since the controllers there, through their radio contacts with pilots, have better identification facilities. When there is much air activity, it means a lot of highly skilled PPI analysis by the controllers. Use of IFF for identification, although it is showing signs of being put into fuller operation, remains fairly limited.

However, field orders for the day make it possible to identify most of our own planes, especially large bomber and fighter formations. VHF communication and VHF-DF fixing does the rest of the identification job. Each control unit has DF equipment at the site and, while the controller talks to pilots by VHF, the DF team gets a bearing. MEW and FDP controllers then use the bearing as the azimuth to observe on the PPI; the 584 controller uses the bearing to direct the 584 beam to find and lock on the target. Final proof of identity comes when the scope signal and plotting table "bug" of the 584 move to correspond with vectors given to the pilots by the controller.



Before the snow there was mud. The 555th is an old hand at working in both. Underneath bleak camouflage is a Forward Director Post. Each FDP is in effect a combination early warning, filter, and control center capable of carrying out GCI operations on its own. Generators for radar equipment (below) are dug in for protection



TAC radar runs all kinds of missions

Arming P-38, P-47 and P-51 aircraft with rockets, cannons and bombs in addition to their .50 caliber machine guns, the Tactical AFs seek out Germans on the ground if they can't find them in the air. Fighter bombers now fly level bombing missions, dive bombing and strafing sorties, and delayed bombing attacks against all kinds of targets—pill boxes, tanks, artillery installations, transportation, personnel, or anything else which can be harassed or destroyed.

The most simple and effective missions performed by the 584s of the 555th Battalion are in aid to air support parties. These parties of control and communications personnel, detached to the ground forces by the 9th TAC, travel with the forward units of a division. When an enemy strong point is encountered, the party officer requests a flight of aircraft to assist in overcoming that point. The crew at the 584 vectors the fighters or fighter bombers to the target, which is then marked with colored smoke shells by the artillery. When the flight leader sees the smoke, he positions his flight and attacks.

In general, air support parties request the following types of missions:

1. Planned mission—flown subsequent to the day of request.
2. Request mission—flown on the schedule of current day's operations.
3. Immediate request mission.
4. Tactical reconnaissance mission.
5. Photo reconnaissance mission.
6. Artillery reconnaissance.

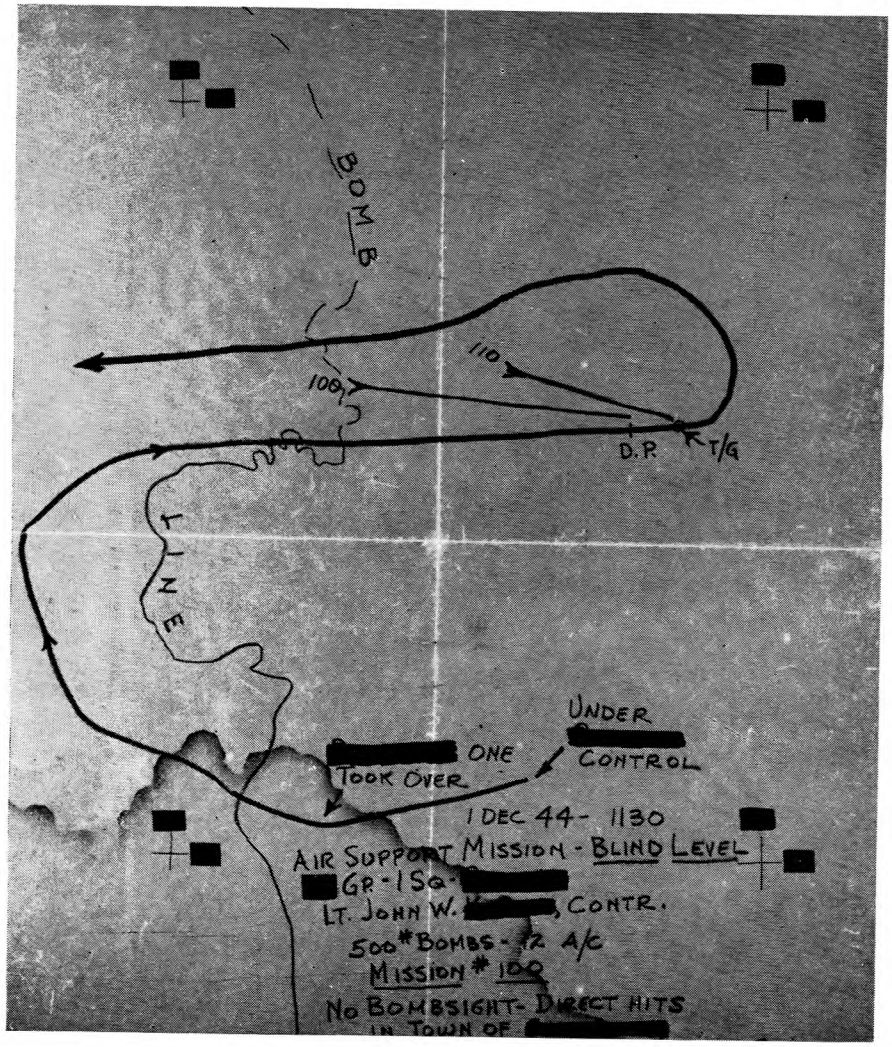
Basis of 9th TAC radar-controlled operations is the daily field order, transmitted by teletype to the MEW and by courier to FDPs and 584 posts. Planned and request missions may be allocated by field order specifically to any one of the Battalion's units. If not specifically assigned, such missions all go to the MEW to be run off either by the MEW or reassigned.

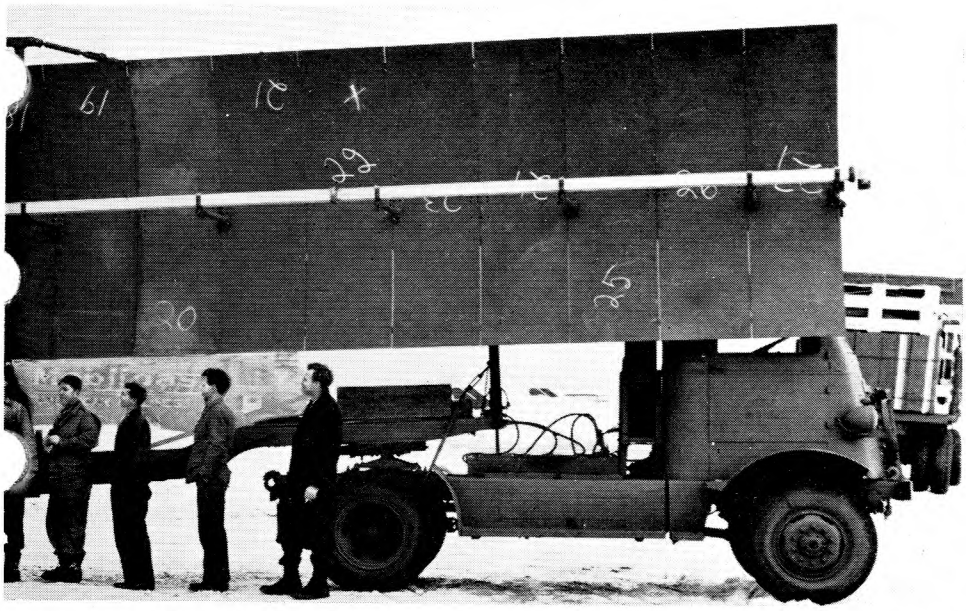
Assignment of the mission to a particular FDP or 584 depends on the location of the target in the TAC sector, on the nature of the mission and on the amount of business to be handled at the same time. From its location at the center of the TAC sector, the MEW can designate control for unspecified mis-



New mammoth MEW antenna, only one of its kind to date, is now undergoing test. The 50 ft. dish (twice original size) will cut down mobility some but performance will

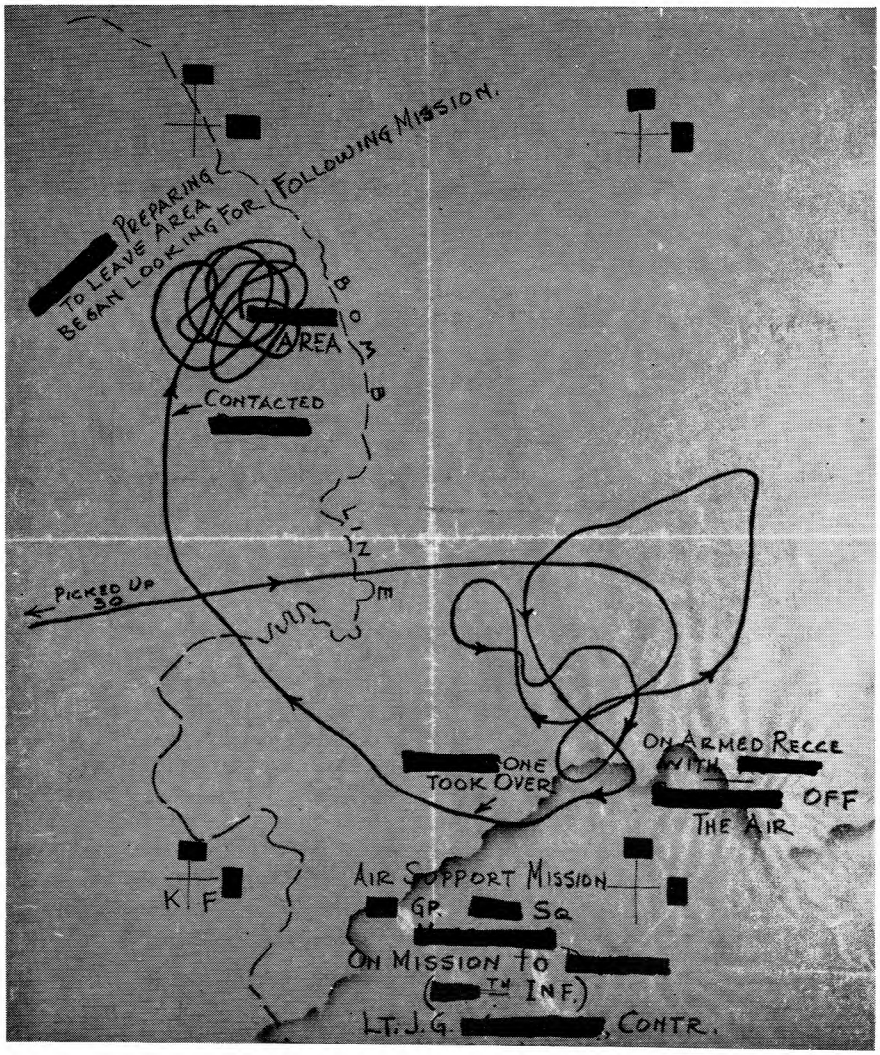
The 2 plots below are exact copies of charts taken off plotting table of an SCR-584 with the 555th Battalion at the front. For security purposes, code and place names were deleted. Course of plane was plotted automatically by the plotting table; other data was written in by the 584 controller at time of mission. Plot at left was a





be upped considerably. A range increase of about 40% is expected. No modifications have to be engineered into set and installation of dish requires little time off air

controlled mission throughout, with 584 controller vectoring flight to target and giving bomb release information. At right, lead plane was tracked throughout but not controlled, except for run between armed recce mission and second target area. Contrast between 2 plots gives idea of time, gas and effort saved by radar control



sions by the most logical unit, or keep the control itself.

Once a mission is under control and the target established, the controller gives the necessary vectors and angels, maintains a constant lookout for enemy aircraft. On a 584-controlled mission, this protection is given by the controller either at the MEW or the FDP associated with that particular 584.

On completion of an SCR-584 mission, the planes are usually released to the MEW or FDP for homing vectors since the 180° coverage of the 584 plotting table covers the combat area, not home base.

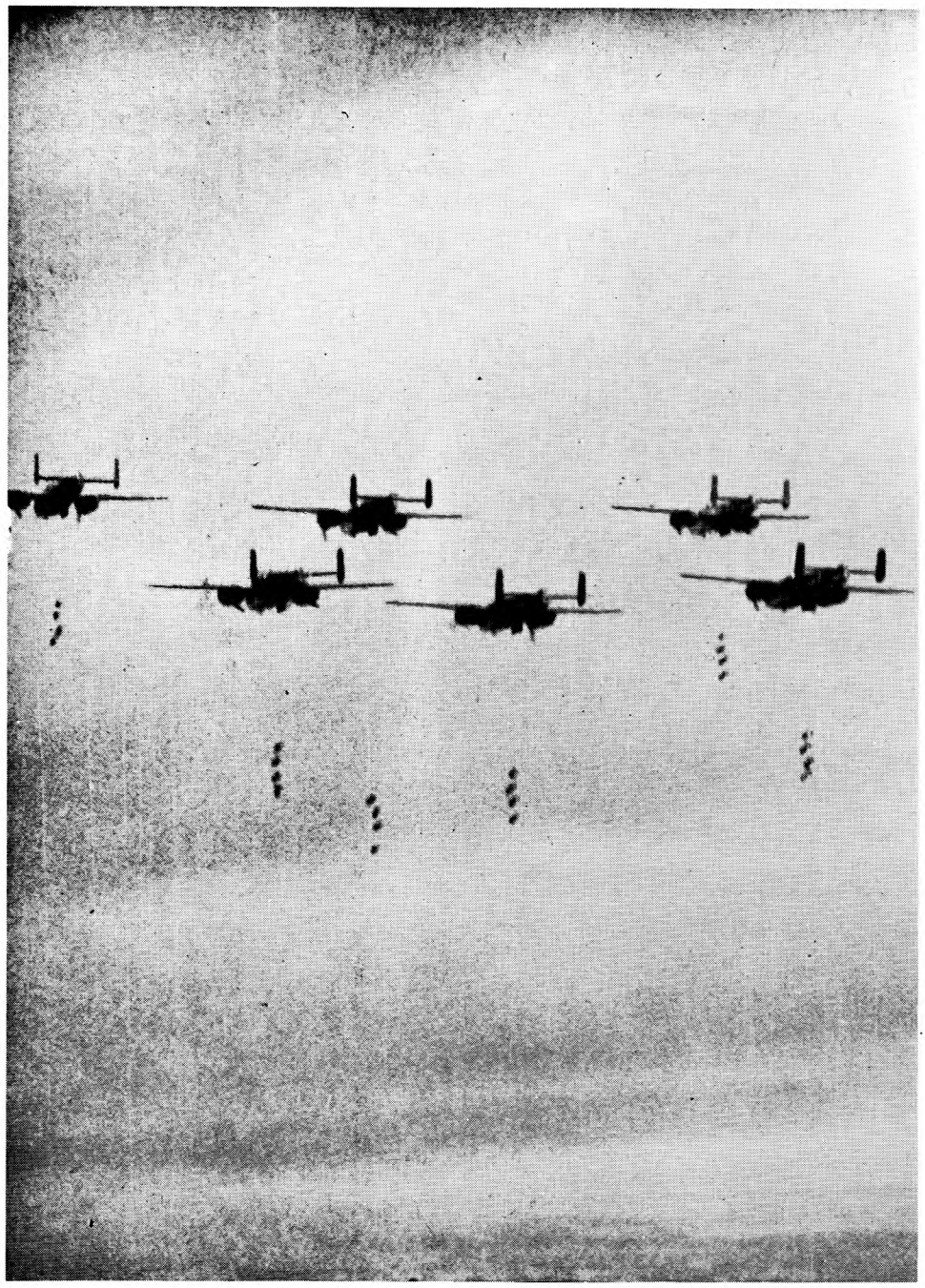
During periods when no controlled missions are scheduled, the TAC air sector is kept under surveillance by all radar control units. Many missions of opportunity are picked up through alertness in watching the scopes and constant monitoring of the VHF.

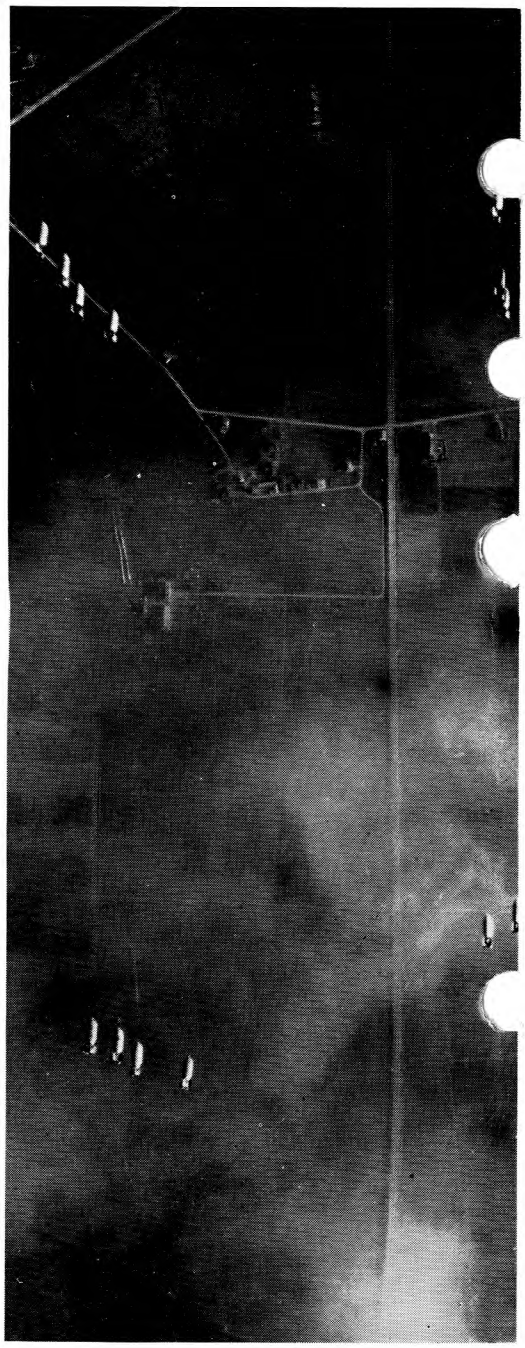
Not long ago, a flight of fighter bombers called in to one of the 584s to say they were going to jettison their bombs; fast closing weather had made it impossible to locate the targets. The 584 controller put them right on a vector to make a bombing attack on a rail line.

Both in planned missions and emergency control pickups, the value of radar control is multiplied by intelligent cooperation of pilots. Experience in flying controlled missions increases confidence in control vectors and in warnings against enemy planes and flak areas. At the 555th Battalion, flying personnel are encouraged to visit radar sites and observe control operations at the source. So the fliers get a glimpse of the problems and headaches of the controller, and at the same time a chance to correct any impressions that radar is more miraculous than it actually is.

When the Battalion first tried its hand at offense, the misapprehensions were in the other direction—with little but theory for guidance, there was a tendency to underestimate the full capabilities of ground radar as an offensive weapon.

In many instances during the first months in France, tactical radar wasn't used as often as or in all the ways it might have been. But it survived its growing pains. A recent AAF Letter tells how well: "It has now been proven that radar is essential to offensive air operations and is an inseparable element of the Tactical Air Force." The 555th SAW Battalion helped to make it so.





B-25s OF THE 12TH AF EXECUTE A NEAT RADIO-CONTROLLED BOMB DROP AT A SHORAN-DETERMINED RELEASE POINT OVER NORTHERN ITALY

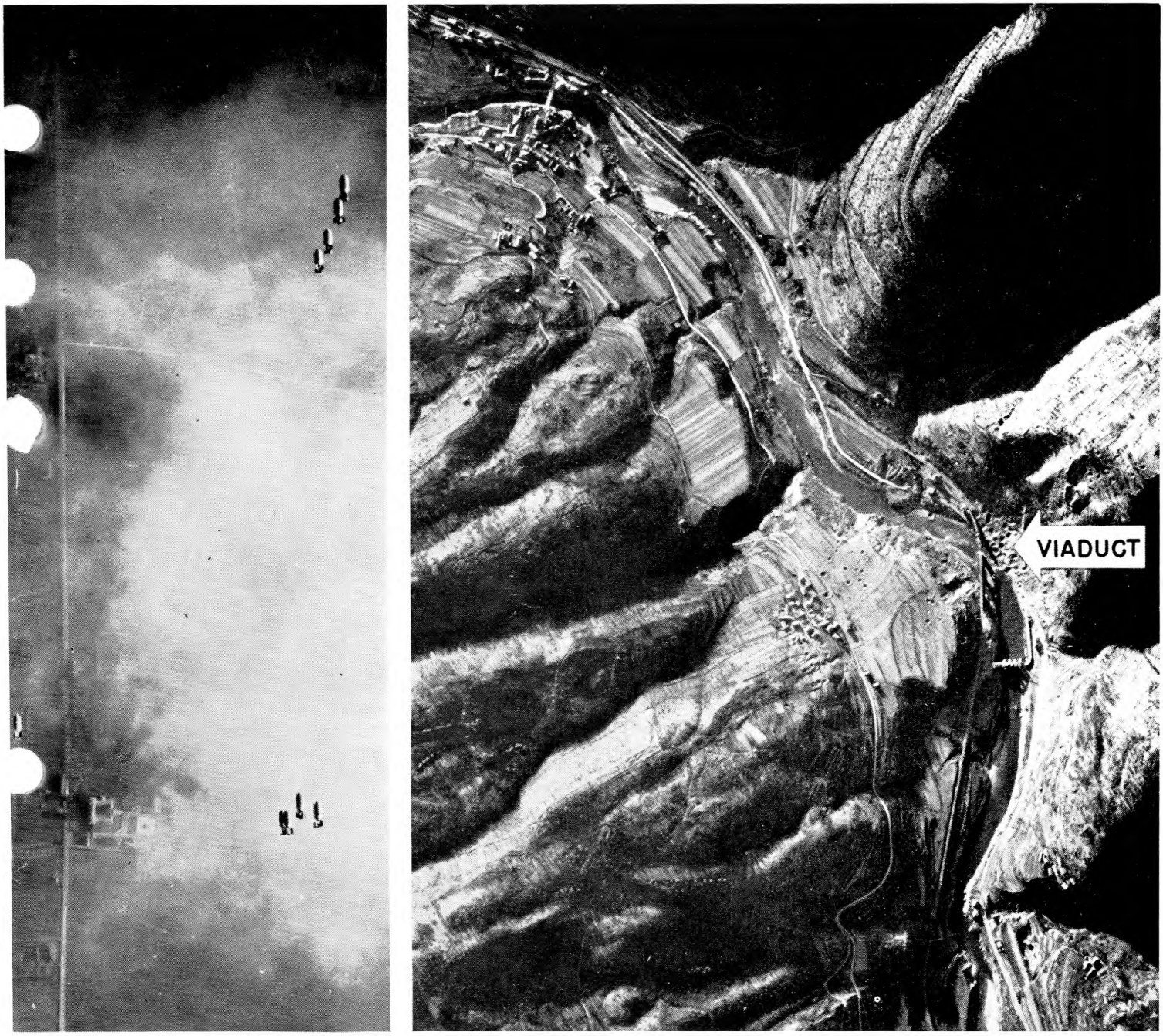
Shoran: 5 year old newcomer

For navigational and bombing accuracy, this radar system looks like the best yet

Untouched after 6 visual bombing attacks, the main span of the Canale D'Izonzo railway viaduct on the important Piedicolle rail line in Northern Italy was cut December 31st. The success was scored on one of the very first combat trials of Shoran,* and it wasn't just luck, either. Two Shoran missions earlier in December scored hits on other rail bridges and subsequent missions have resulted in hits on supply and ammo dumps. Within the first month of operations 6 bridges crumpled in 8 attacks by Shoran-led B-25s of one 12th AF Bomb Group. That's *real* precision bombing and it has won long deserved recognition for the method.

* Shoran is derived from "Short Range Air Navigation". The ground unit is AN/CPN-2; the airborne, AN/APN-3.

Though Shoran has been to war for less than 3 months, it has been out of the laboratories and ready for war for more than 3 years; it was worked out more than 5 years ago. In the time intervening it has been groomed to a perfection which makes the equipment about the most reliable system extant. That's one of the reasons why Shoran is good—why it could score direct hits on initial



CLEANLY SLICED BY THE SHORAN BOMBERS IS THIS RAIL VIADUCT. NOTE BREAK IN SHADOW INDICATING WHERE BOMBS KNOCKED OUT SPAN

combat trials—why it is the only radar system so far demonstrated to be capable of 12 mil bombing. Shoran is, in fact, almost matching bomb for bomb the best records chalked up by visual methods.

Along with reliability, Shoran has the additional advantage of being easy to operate and to maintain. The Shoran introduction in the MTO has met with amazing success, yet few, if any, of the crew members had ever seen a radar set 2 weeks before.

Naturally the "Shoran Air Force" (the 310th Bomb Group) hasn't rung the bell on every mission—there have been busts. It's a fact, however, that hurried training and lack of experience accounted for most of them, with only 2 equipment failures reported.

The Tactical Air Forces have needed what Shoran has for some time, and their need could hardly be greater than now. The effectiveness of medium bombers in both the ETO and the MTO has been greatly reduced by bad flying weather—even the birds have been walking. The subsequent lack of air coordination has hindered ability to cope with such circumstances as, for instance, the Belgian bulge.

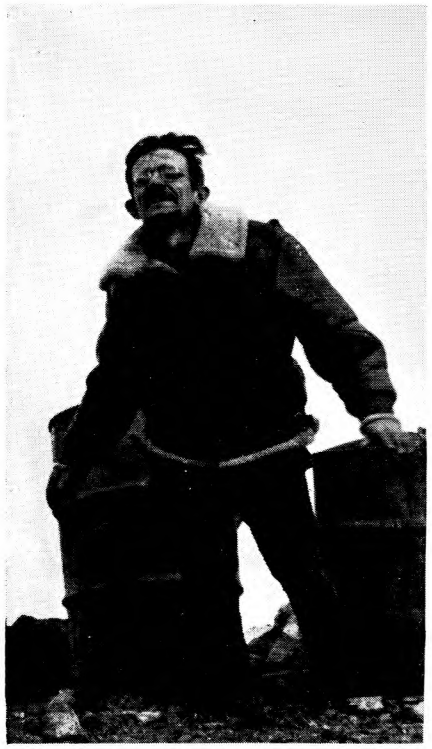
On the basis of the MAAF combat trials, the Tactical Air Forces are counting on Shoran to keep medium bombers off the ground and on the enemy in all weather. It rates top priority.

The one 12th AF Group already equipped and operating will soon be supplemented by others. In the ETO the 9th AF will get 44 airborne and 10 ground sets this month, most of which will be used to get the planes of the "weather logged" 1st TACAF (Provisional) off the ground.

For a description of the Shoran system and how it works, turn the page.



Shoran ground station atop Corsica mountain was anchored to truck to keep it from becoming airborne in high winds. Antenna mast, usually 50 ft., was cut down to 10. Airborne Shoran antennae are just like these on ground minus the V-shaped reflectors



Displacement angle of man above, at Corsican site, is fair measure of gales there



Crash landing resulted when this hut at Corsica station took off on 70-mile wind

Shoran is, first of all, a simple system

Shoran is a radar system in which an airborne interrogator receives replies from 2 ground responder beacons of known location.

Precision navigation within line-of-sight range can be performed by ranging on these two stations. A plane can locate itself in space to within 50 feet—and this accuracy does not vary with distance from the beacons.

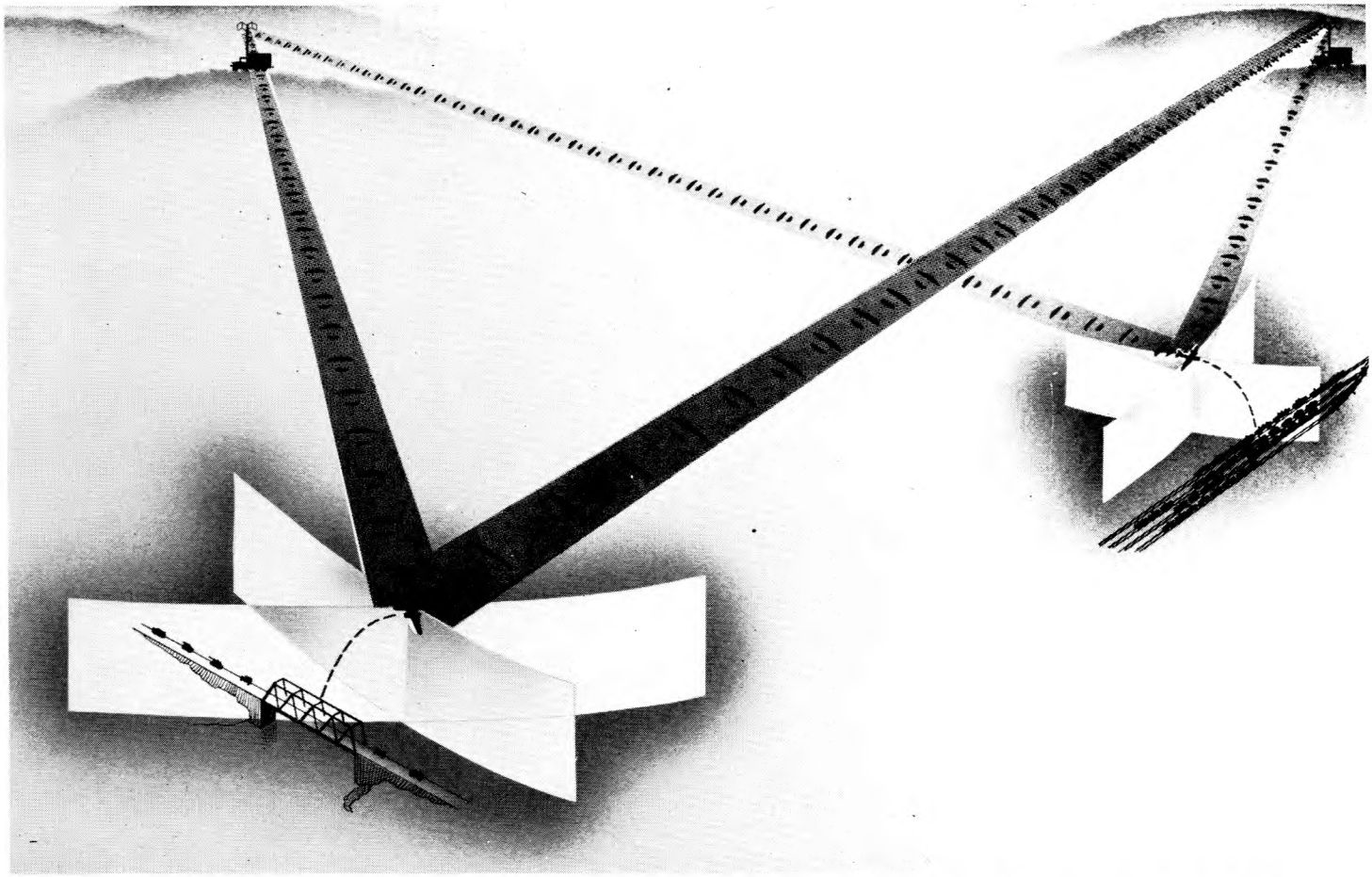
Bombing through overcast is accomplished by flying the plane along a circular track with reference to one ground station so that it passes through the true release point at a predetermined range from the other station.

Herein lies one secret of Shoran's accuracy—radar is used only for range measurements, at which it excels, and not for azimuth measurements, at which it is notably less good as a rule. This advantage is supplemented by complete airborne control of the plane's flight, which further sharpens aim and adds flexilibity to the system. Several targets can thus be attacked simultaneously by as many as 20 planes.

Airborne control is made practical by the use of a calibrated, variable timing device. On the circular trace of a 3″ J scope 3 pips appear—2 from the ground stations, which may be positioned along the trace by mileage dials, plus a stationary marker pip at the top of the scope. If the dials were set at zero miles the 2 beacon pips would coincide with the marker, one on either side of the trace. In this case all 3 would be aligned with the transmitter pip, which is blacked out. Normally, however, the beacon pips are at a distance from the marker representing plane-to-beacon ranges. By rotating the mileage dials until the received pips are aligned with the marker, these ranges can be read from the dials.

To get range information from both ground stations simultaneously the airborne radar transmits pulses on alternating frequencies, one for each beacon.

A simple navigational fix can be obtained with this setup in a matter of seconds. The operator merely rotates the 2 mileage dials on the timing unit panel until both pips coincide with the marker pip. At that moment he reads the dials and gets a Shoran fix from which he can plot his position on the map. Since dial



Shoran principle is shown above. Release point is at intersection of 2 imaginary arcs centered on beacons. Since activating unit is airborne there can be as many intersecting points as planes, up to 20 at once. Planes can fly along either arc

calibrations can be read directly to the nearest 1/100th of a mile (52 ft.) and estimated to 1/1000 (5 ft.), the plane can be located accurately in space at ranges up to 180 miles at 12,000 feet.

Passive elements in the Shoran system are the ground stations. They perform a simple give-and-take function. Upon receiving a Shoran pulse from a plane, they amplify it, shift its frequency and send it back. To render this service the station uses a receiver-transmitter combination with accompanying power supply and a directional antenna some 50 ft. high. The manpower problem is simple; 2 men with no exceptional skill can set up a station and put it on the air in a matter of hours. Usually, "high on a windy hill" is the best location.

So much for the basic Shoran system, which is a precision navigational instrument capable of moderately accurate bombing. It becomes a precision bombing device with the addition of an airborne computer unit. The use of this unit imposes directional limitations not required for navigation. Specifically, sites and targets must be chosen so that the angle between ground stations as viewed from the plane is less than 150° and more than 30°. But that's a small price to pay for the accuracy introduced by the unit.

The bombing computer uses Shoran data just as the Norden bombsight uses optical data. It is coupled into the mileage dials in such a way that the transition from optical to Shoran bombing is very simple. The bombardier still twists rate and displacement knobs and the pilot still reads his PDI (Pilot's Direction Indicator)—but it's an improved PDI. The displacement needle is supplemented by another which indicates rate of displacement. When both needles are centered the plane is on the desired track. This double indication greatly simplifies the pilot's job; his speed of approach to the track is known and he doesn't have to cross and recross the course before settling on the final run.

Flight procedure with the computer is a plain knob-turning routine. Anyone with normal reflexes can handle it, and after very little training.

One beacon, known as the "drift" sta-



Shoran salesman, from Hq. AAF, Capt. F. B. Gunter, helped to take it to 12th AF

tion, provides a circular path through the bomb release point. The other, called a "rate" station, determines the true point on this path for bombs away.

Predetermined Shoran coordinates for this intersection are set into the computer and the plane is navigated, via Shoran or any other means, to within ¼ mile of the desired track. The PDI takes over from here and, when less than 10 miles from release, the bombardier arms the computer, puts the PDI on low scale and forgets about the drift station. Drift data is transmitted to the PDI by the computer so the pilot can maintain his circular course.

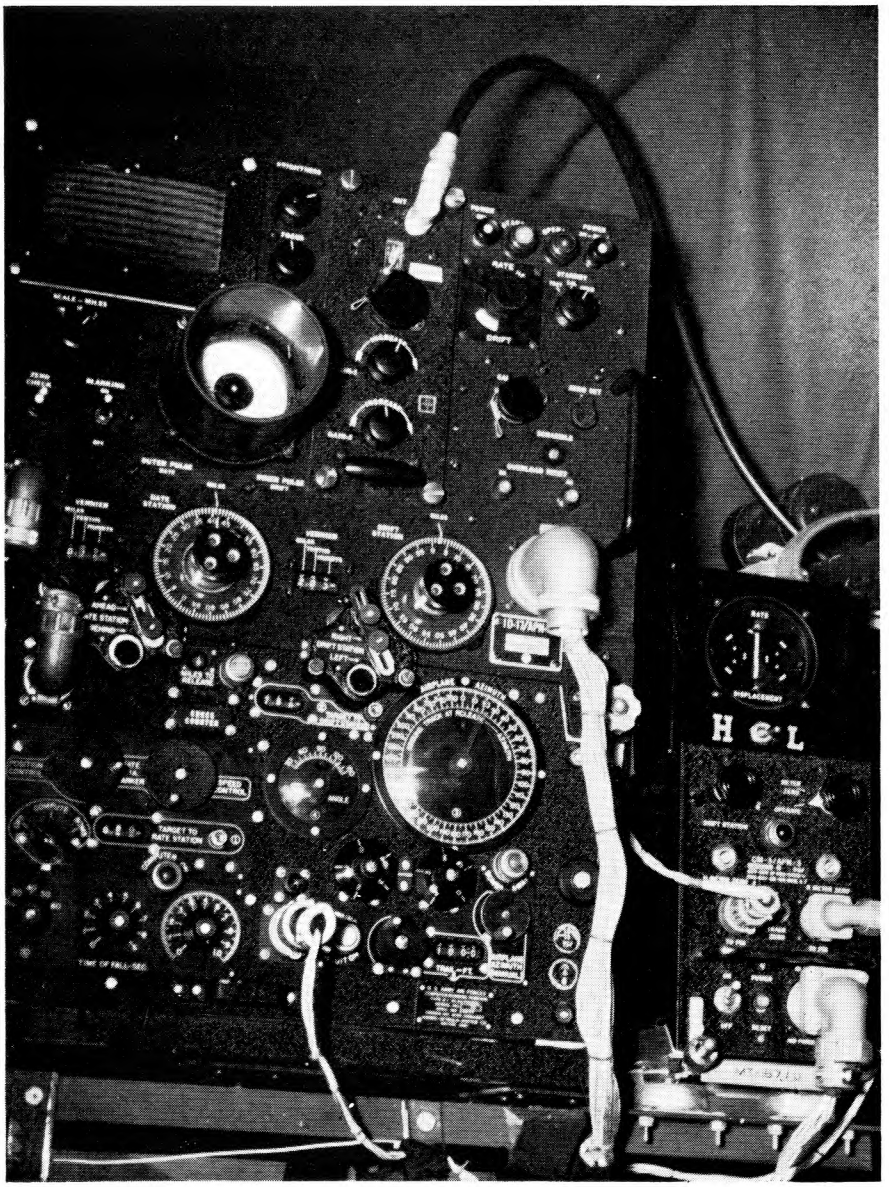
At 2 miles from release the bombardier sets in the plane's heading on the azimuth scale. From this setting the computer automatically makes corrections for drift and cross trail and transmits them to the PDI and rate station dial setting. From here on until bombs are automatically released the bombardier merely keeps the rate and marker pips aligned. The final run may be as short as 30 seconds.

In addition to performing all these functions the computer includes a "miles-to-release" dial, which provides continuous indication of the plane-to-target distance and shows how much time there is for evasive action.

A final perfecting touch can be added to Shoran drops by using Radio Bomb Release. The initial Shoran group had considerable success with such releases using "Crawfish"—a modified Azon (guided missile) transmitter in the Shoran plane, Azon receivers in the rest.

You could have perfect equipment, seasoned operators and everything else, but you couldn't hit a thing with Shoran unless someone had first determined the Shoran coordinates for the bomb release point—and determined them well. The coordinates are the keys to precise Shoran bombing. Bridges, supply dumps and other targets must be located to within 10 yards and located by Shoran distances. There is a difference—caused by the earth's curvature, altitude of antenna and plane, and radio propagation phenomena—which can amount to ¼ mile in some cases.

Actually, the job is not as tremendous as it sounds. All computations for a mission can be made in about 2 hours and the whole process becomes pretty routine to anyone mathematically inclined. But it's the boys with the unromantic slide rules who are as responsible for Shoran's success as anyone.



Airborne Shoran equipment as installed in blacked-out nose of B-25 looks like this. Comparator is lower right with PDI, duplicate of pilot's, just above. Indicator unit is at upper left and computer lower left. Note drift and rate station mileage dials and azimuth indicator. Best bombing results to date have been obtained with a combat box of 6 B-25s dropping on a single Shoran-equipped plane but larger boxes can be flown

Shoran sold itself once it got going

Two life rafts bearing a human skeleton and 13 identification bracelets washed ashore on a beach in South America about 2 years ago—only trace of an army plane and its 23 passengers lost at sea 3 months before. One of the bracelets had belonged to Lt. Col. R. Reid Brunner, Shoran project officer from Hq. AAF.

Shoran has been the unfortunate victim of circumstances since its beginning 5½ years ago. It was following the first Shoran trials during the summer of 1942 that the fateful trip to England was made. At that time the equipment had dropped bombs with an error on the order of 25 to 30 mils, but the project had been canceled because of claims being made for other equipments. Lt. Col. Brunner went to England with several other Shoran backers to investigate these claims. They wanted to compare

Shoran, prove its superiority, sell it to British and American AFs.

They did, but on their way back to the U. S. Lt. Col. Brunner and the AAF and RAF Shoran advocates with him lost their lives. Unforunately, though several others knew Shoran's value, the men who died were the ones in position to set the intricate procurement machinery in motion. Shoran had to be resaddled and resold and the job took 2 years.

Shoran is blowing bridges today because some of the individuals who knew its merits had faith enough in it to keep the project alive.

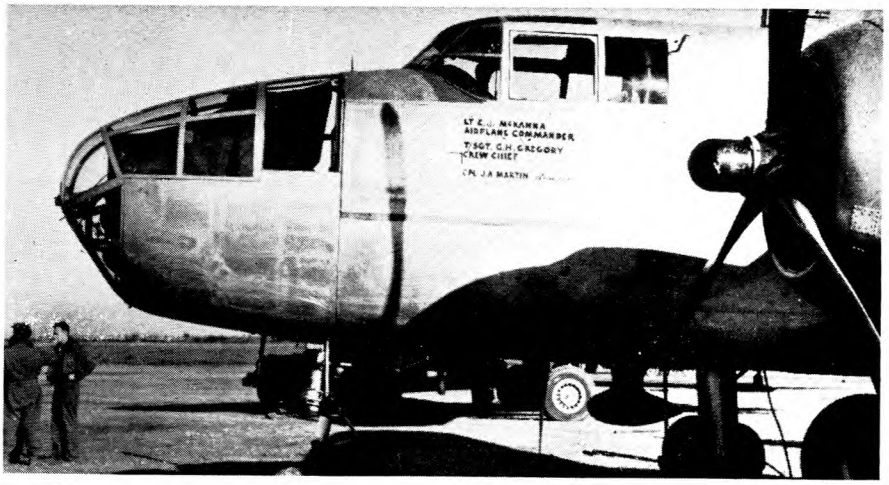
For the current success, credit goes to those who coached Shoran's MTO initiation 3 months ago: Engineer E. I. Anderson and Associates E. M. Hinsdale and W. R. Alexander, who designed the equipment; Maj. R. L. Dickson, Armament Laboratories, who had the idea for the computer; Capt. F. B. Gunter, AAF project officer.

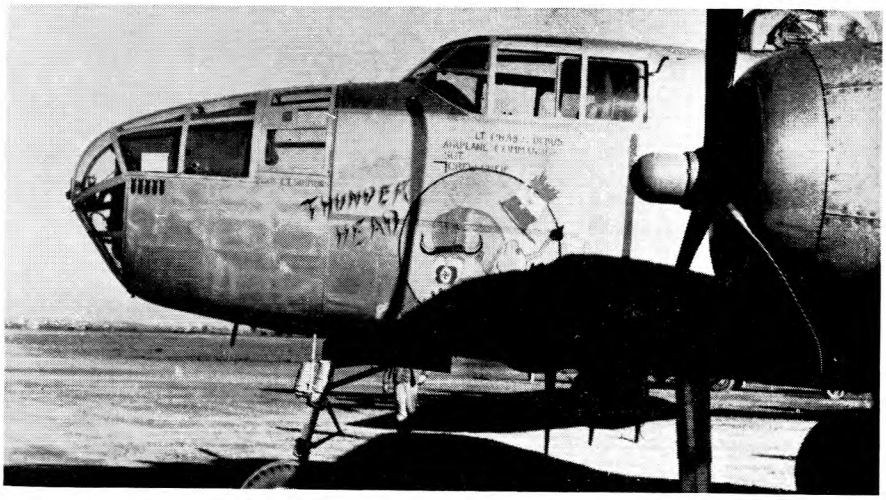
Capt. R. J. Winn and Lt. E. C. Ladd, with a special Shoran-equipped B-17 and a crew from Air Transport Command, flew the initial training flights. They used the small Island d'Africa in the Tyrrhenian Sea, 200 ft. in diameter, for a practice target.

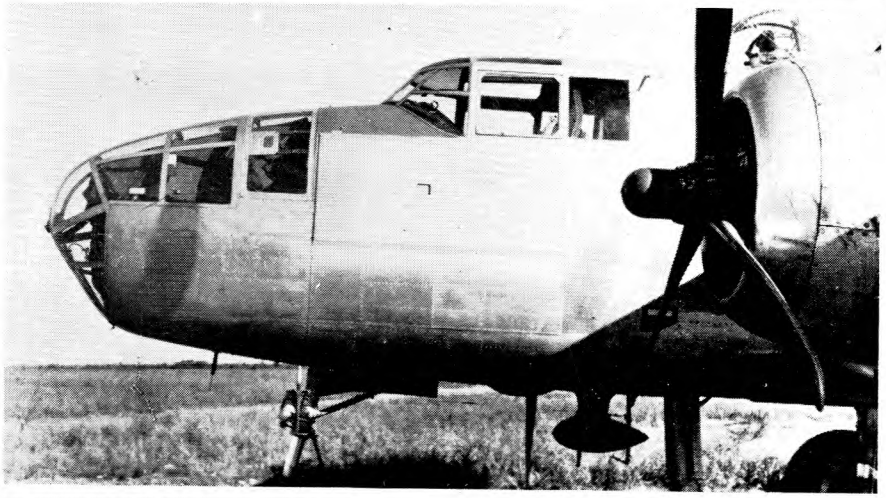
All of these men, among others, sold Shoran. But Shoran sold itself once the pilots and bombardiers got the feel of it and ripped up a few bridges.

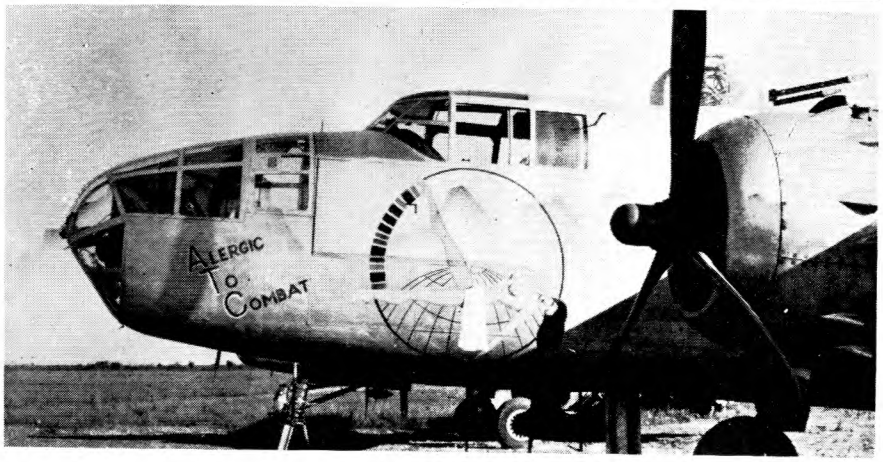
Getting the system organized was the toughest problem. Most of the possible ground station locations were either atop inaccessible mountains or in enemy territory. An unexpected situation arose in siting one beacon station: Corsica was found to be out of place. There was an error of 60 yards latitude and 180 yards longitude in the map location, enough to throw Shoran's computations way off. With the expert help of British Army surveyors Corsica was relocated.

But as soon as the stations were up. bridges went down. The good word spread to other fronts and now instructors trained by the original crews are starting Shoran programs in France. Shoran has gone to war—late, but better late than never.







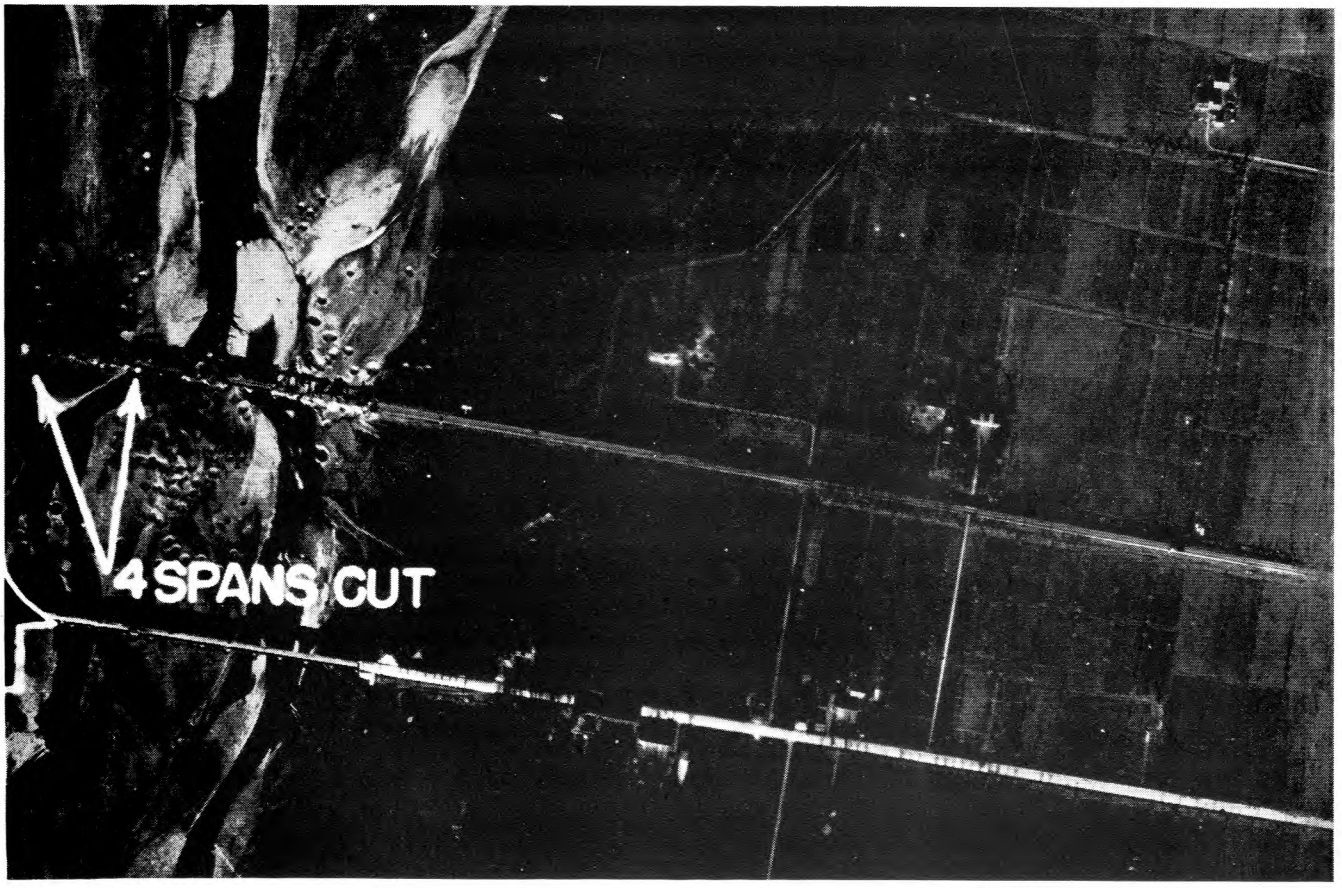


"Shoran Air Force" *began with 4 B-25s of 310th Bomb Group (right). Units have since been forwarded to equip 4 aircraft in 2 other B-25 groups of 12th AF. 9th AF should have 44 air and 10 ground units soon, and RAF, 12 air and 4 ground*



Direct hits (above) are scored on Parma West bridge in North Italy by one combat box of Shoran-led B-25s. This damage was done on Shoran's second combat mission by 310th Bomb Group in December. Mission was flown in good visibility to allow photos

Recon photo taken later (below) gives proof that 4 spans of bridge were cut—absence of shadow shows where. Although the bridge had been previously damaged, shadows reveal where makeshift repairs had made it passable prior to this Shoran attack



How Shoran compares with other beacon bombing methods

Contemporaries of Shoran in the so-called beacon bombing field are Gee-H, Micro-H and Oboe Mk II. RADAR reviews them comparatively in the 10-point table on this page.

Characteristics which tend to be shared by each method have been omitted; for instance, their tactical application. Each system was built for bombing through overcast and all can be used for navigation, air-ground cooperation, mapping, etc. Range and coverage are essentially the same for all—line of sight from ground stations, or about 200 miles at 25,000 ft. Also, the methods are alike in that they each require about 2 hours of pre-flight computation before a mission.

On the other hand, accuracy indications have been omitted, not because accuracy is the same for each, but for lack of an adequate basis of comparison. There are too many variables. Generally speaking, their accuracy is somewhere between direct H_2X bombing at its best and visual, although Shoran has been demonstrated to be equal to or better than visual in some cases.

These systems do not pose as substitutes for H_2X, which remains unchallenged for long range radar bombing against strategic targets. Beacon bombing has a field of its own—short range precision bombing of tactical targets, such as supply dumps and command posts, which cannot be resolved on a PPI scope. And this type of bombing is becoming more and more important with the shrinkage of German territory.

	SHORAN	GEE-H	MICRO-H	OBOE MK II
Method of tracking	Dual beacon system. 2 normal beacons on ground with ranging interrogator and computer in plane.	Dual beacon system. 2 beacons on ground. Ranging interrogator in plane. No computer.	Dual beacon system. 2 normal beacons on ground. Ranging with airborne H_2X; data can be fed to bombsight. Mk I has delay attachment on ground; Mk II. in plane.	Dual interrogation of transponder in plane. Ranging interrogators on ground. Plane tracked in range and ground speed from ground.
Flight control	Automatic tie in to PDI showing rate and displacement.	Oral directions to pilot.	Oral directions to pilot or manual AFCE tie in.	Aural indications to pilot (tone signals).
Presentation	3" J scope with 1, 10, 100 mile sweeps. Pip matching. Circular trace.	Normal Gee "A" scope. Double trace and strobes.	Normal beacon presentation on PPI scope divided into 2 sectors.	Tracking from ground stations; no presentation in plane.
Airborne equipment	Comparator, computer, indicator, receiver and transmitter, 335 lbs.	Interrogator-responsor and indicator, 200 lbs.	AN/APS-15, 500 lbs. Delay attachment, 10 lbs.	Receiver, filter and special interphone boxes, 300 lbs.
Ground equipment	2 beacon stations which operate unattended.	2 transmitting stations for bombing, 3 for navigation; operate unattended.	2 AN/CPN-6 beacons; very little attendance required.	2 ranging interrogators and control center; skilled ground crew needed.
Planes used	Medium bombers.	Mediums and heavies.	Heavy bombers.	Medium bombers.
Saturation point	20 interrogating planes per pair of ground stations, attacking up to 20 targets.	5 interrogating planes per pair ground stations attacking 5 targets. Any number for Gee navigation.	50 interrogating planes per pair of ground stations, attacking up to 50 targets with Mk II, limited number with Mk I.	1 plane every 15 min. against 1 target.
Airborne operator	Bombardier.	Navigator or radar operator.	Radar operator.	Pilot and co-pilot.
Training for operator	2 weeks for bombardier and pilot.	2 or 3 flights for navigator or operator familiar with Gee.	4 flights for regular radar operator.	10 hrs. in link trainer for pilot.
Operational status	First used by 12th AF Dec. 1944. 12th AF can equip 4 planes each in 3 groups. 44 air and 9 ground sets in 9th AF	First 8th AF mission a year ago. Effectively used on D-day and against buzz bomb sites.	First combat mission for Mk I Nov. 1944 by 8th AF. 5 beacons on Continent, 4 in England. Mk II operational soon.	First U. S. mission Jan. 1944 by 8th AF. Now in 9th AF (44 sets of Mk II).



Visar units are all located at bombardier's position. Synchronous range tracking tie-in comes from cylindrical box on front of sight. Altitude knob is visible above eyepiece. Remote scope seen to left of bombardier's seat may be mounted above bombsight

Nosmo? Visar?

Much-discussed offspring of the H2X synchronous bombing procedure (see RADAR No. 7) are Nosmo * and Visar, two comparable schemes for further sharpening APS-15 bombing accuracy. Both are products of the search for ways to provide continuous radar-bombsight synchronization and to eliminate the cumbersome interphone or signal light tie-in. Visar was doped out by the 15th AF to prove that such worthy aims were within reach. Nosmo is the product of parallel developments in U. S. laboratories. They are two almost equally desirable ways of doing the same things.

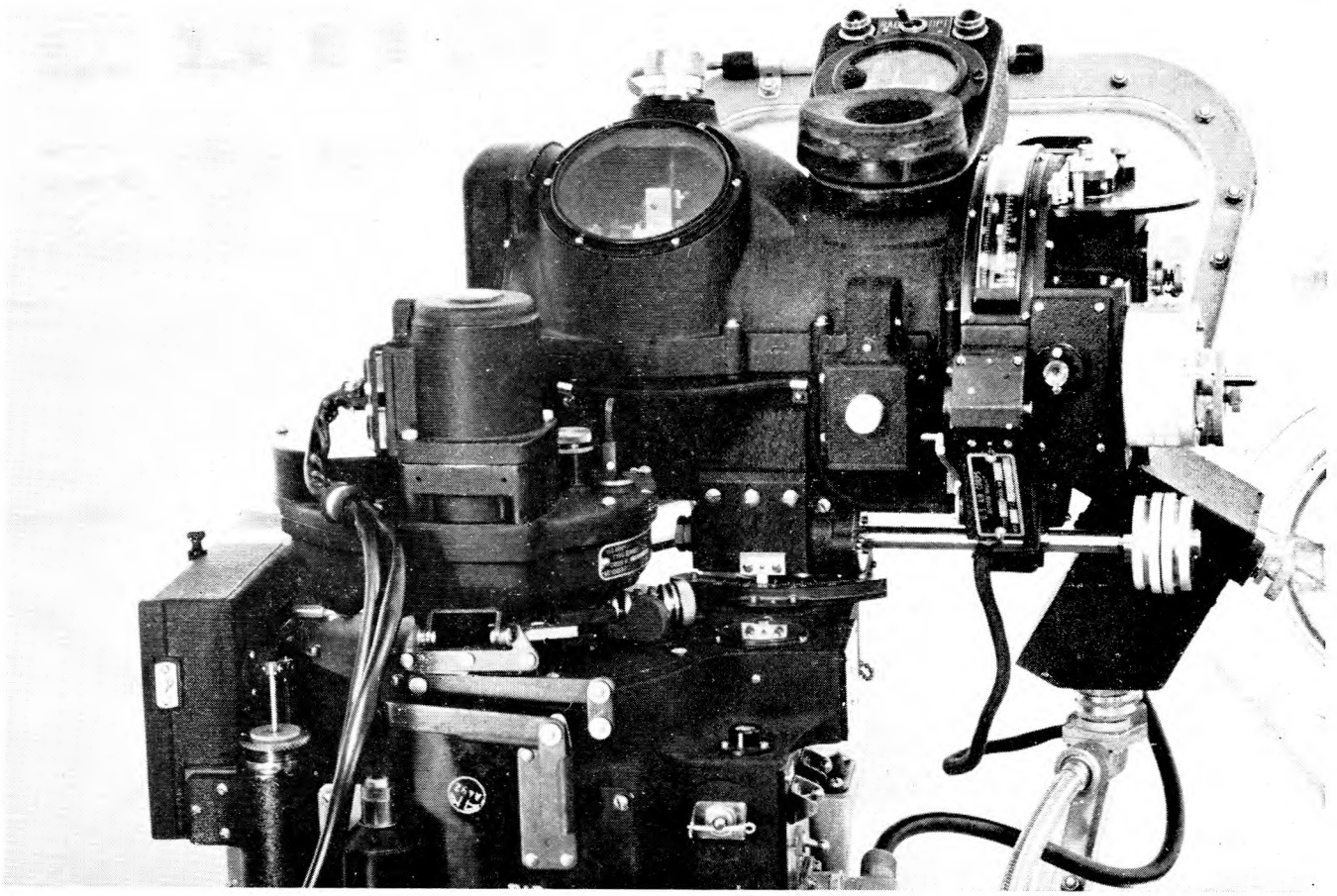
Nosmo provides for continuous tracking of the target with an auxiliary Norden rate head at the radar position to drive the range circle potentiometer. The operator works out the bombing problem by adjusting rate head controls to keep circle and target in coincidence. His solution is transmitted instantaneously to the bombardier, who synchronizes his sight by turning sighting angle and rate knobs to keep the needle on an adjustment meter zeroed.

Equally important is Nosmo's "Doppler Drift" attachment, resulting from the accidental discovery of a very useful radar phenomenon. The phenomenon is that amplitude modulation of ground return results whenever the spinner antenna is positioned off the ground track. That's drift data served on a platter and Nosmo makes first use of it. Drift readings can be made in 20 sec., accurate to ½° and without alteration of course. An electronic gap in the range circle indicates the plane's ground track.

Visar differs from Nosmo thus: 1) The bombardier, with a remote scope, has all bombing responsibility. The radar operator merely keeps the set in adjustment. 2) Synchronous tracking is tied into the bombardier's sight, with control exactly the same as that for the Norden range hair. The Norden rate knob controls rate at which the range circle diminishes. 3) Drift is killed with the aid of an electronic "target line," put on the scope so that the drift knob controls its position. As with visual procedure the knob is turned until relative motion between target line and image ceases. 4) Plane is flown through the bombsight on PDI or AFCE.

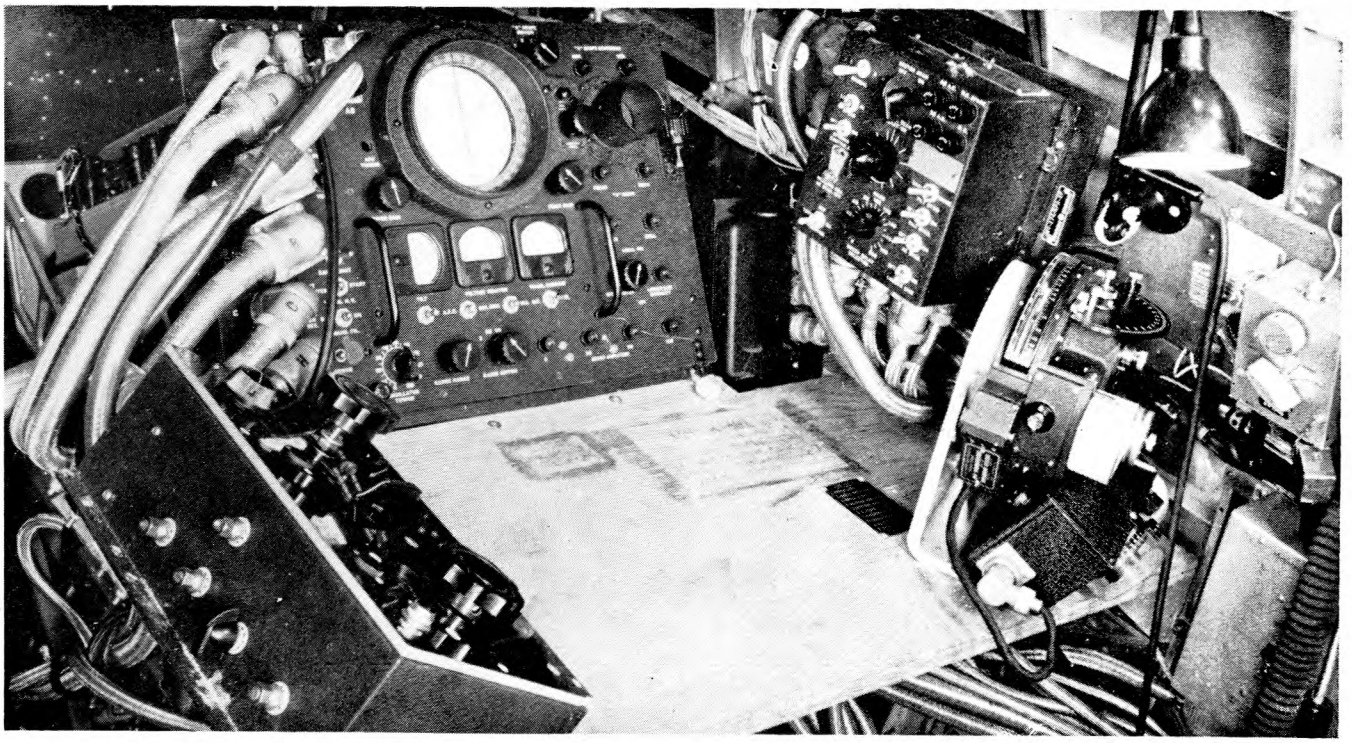
The theaters have made it clear that whether it be Visar or Nosmo they want 4 things pronto. Listed in order of priority, they are: 1) continuous synchronized radar tracking; 2) Pulse Doppler drift determination; 3) the target line system; 4) remote scope for the bombardier. Since Nosmo is engineered for production and satisfies the first 2 requirements, it will probably be accepted immediately and Visar features incorporated as soon as possible.

* A version called "Nosmeagle" has been designed for use with AN/APQ-7 (Eagle).

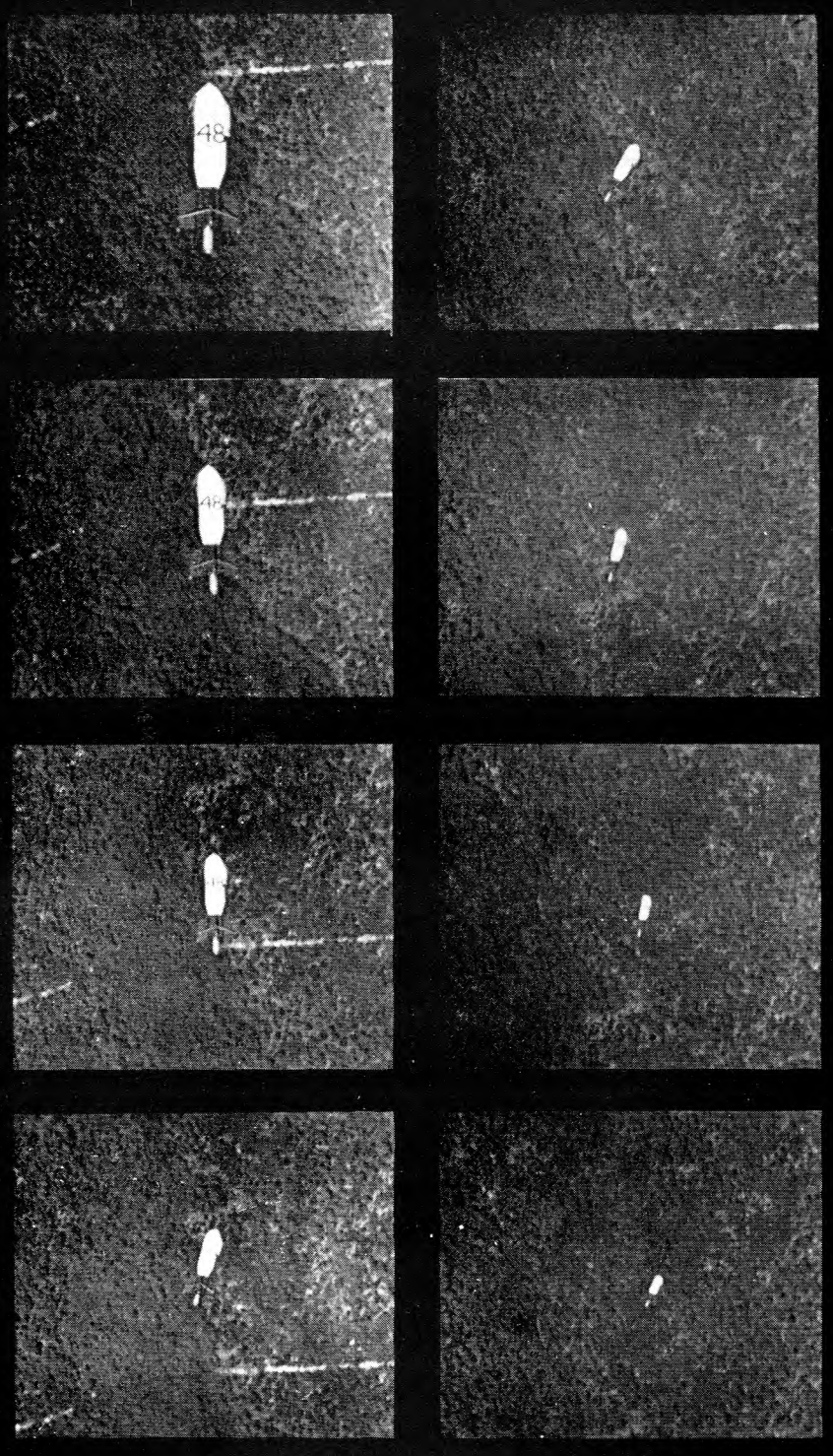


Nosmo attachments to Norden bombsight (above) are a center zero meter just above eyepiece and box shown just below rate head

Radar position with Nosmo (below) includes an auxiliary Norden rate head at right and a Doppler Drift control box to the left



Azon bomb reacts to radio control

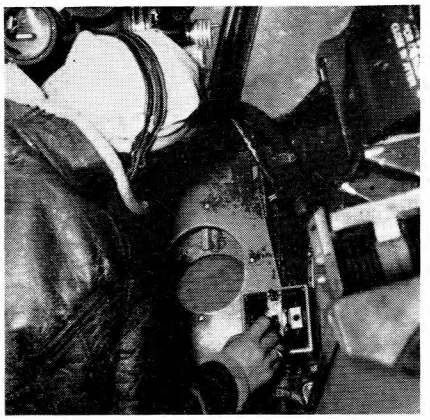


The 8 photos above show control test of an early Azon model. Shots were taken one-half second apart. Control was first applied just as 3rd picture was taken. One second later tail rudder reached maximum deflection

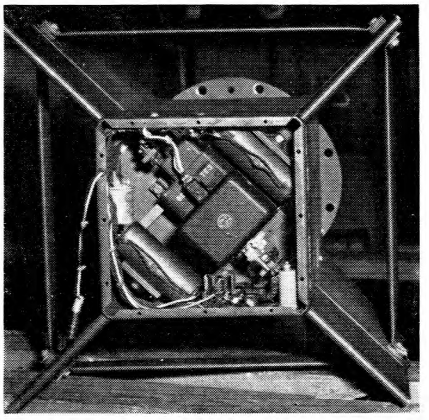
Azon does a

Azon has had an in-again, out-again career. At this writing it's in, as the result of some impressive recent trials in Burma. Azon is a high angle bomb with radio control for azimuth—officially called VB-1 (Vertical Bomb) and designed primarily for precision line target bombing. Simplest of the "guided missiles," it incorporates a standard 1000 lb. M-65 bomb with gyro, radio control unit, storage battery, motor and solenoids contained in a special tail assembly. A flare, attached to the tail, makes it possible to follow the bomb's flight visually. Left-right control signals come from a transmitter in the plane.

After a year or more of tests and modifications, Azon went operational on a crash basis in April 1944. Six trained crews went to Italy and 10 crews, originally trained for CBI, were diverted with their aircraft to the U.K. Results were



Bombardier at Fort Dix, Special Weapons Training Establishment, controls Azon as he watches it through special aperture



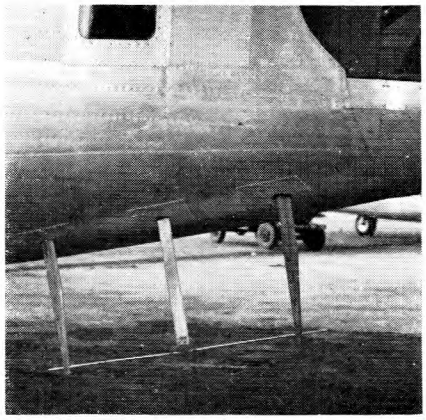
Compact tail assembly houses receiver and rudder-control units which respond to left-right signals transmitted from plane

iob in Burma

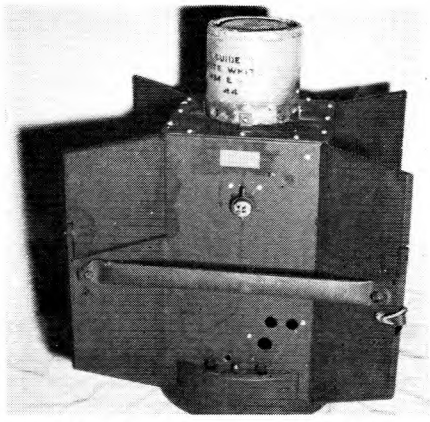
fairly good. But, for one reason and another, interest in Azon didn't jell.

A couple of months ago the quiescent Azon program came to life again. In the India-Burma Sector, a few B-24s manned by a combination of both trained and untrained personnel knocked out 14 bridges completely in 7 missions. Moreover, they scored 2 probables and one unconfirmed. These bridges weren't just test targets; they were key points of communication on the Japanese supply line.

How widely Azon will be used is speculative. It's a special purpose weapon, the effectiveness of which is conditioned by tactical requirements, type of target, terrain and combat conditions; by and large, the Pacific War seems to set up conditions most suited to Azon. Since Azon is capable of results against appropriate targets, more should be heard of it in that quarter.



Antenna, as used on B-24 with transmitter which supplies control energy for Azon, is a center-fed dipole with two supports

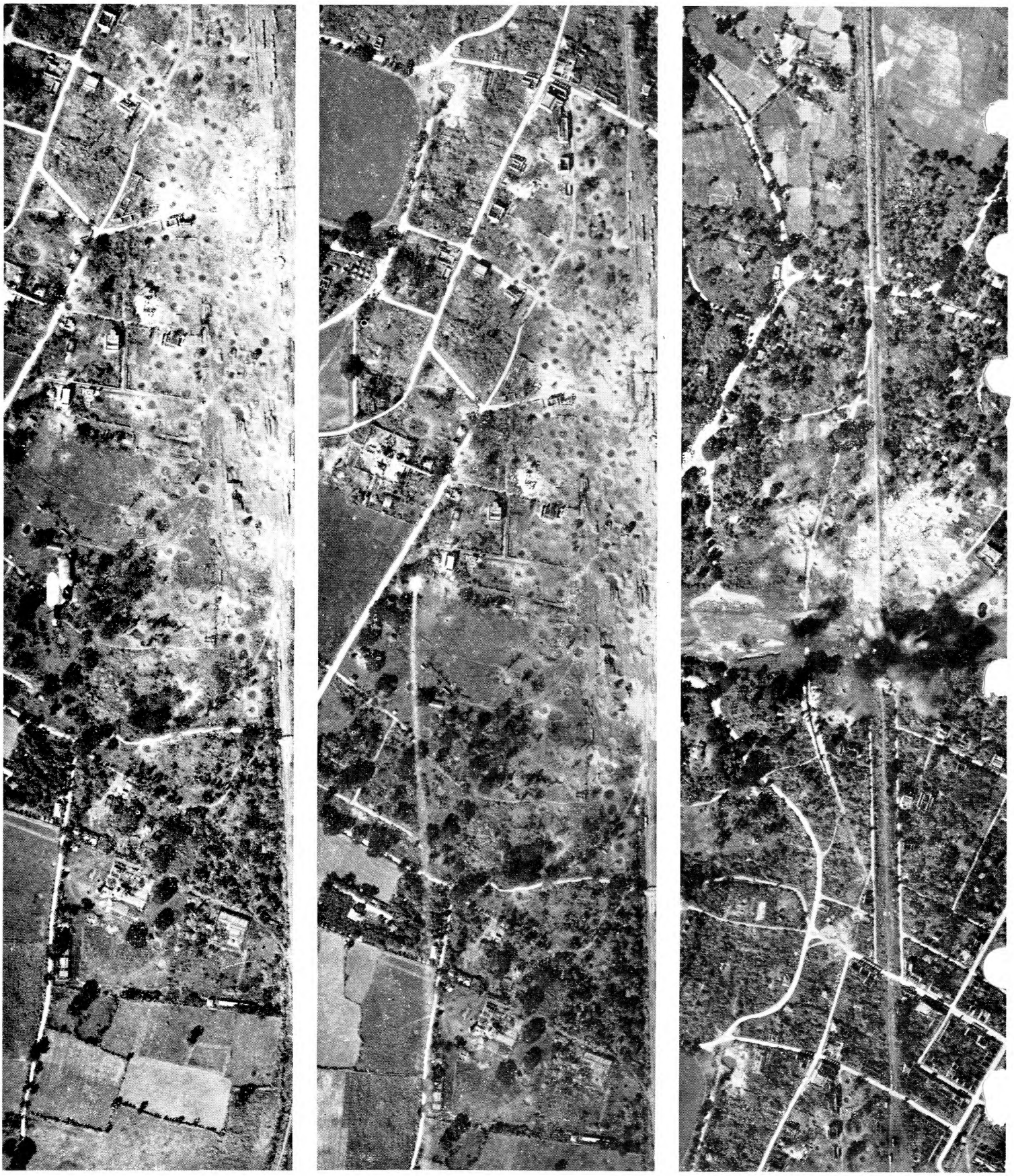


Tail strut (receiving antenna) is designed to receive signals from above, making control almost immune to ground jamming



On early Burma mission the railway bridge above was polished off. Enemy flak was accurate but out of the 9 Azons dropped, 6 made direct hits near center of the bridge. Below, the Taungup Bridge comes to an end under impact of 4 Azons—3 other bridges on this much-bombed supply line were destroyed during the same mission





Successful Azon attack on Pyinmana Bridge is shown in 3 photographs above. Both marshalling yards and bridge had been heavily bombed for some time but the bridge remained in use by the Japs. Azon bombs have just been released at left and the flare path of one of the bombs with control being applied is shown at center. Direct hits (right) knocked one of the spans into river

The Jap radar net

The 20th Bomber Command has been checking up on it

Getting a line on Jap radar coverage, location, frequency and applications was a prime concern of the 20th Bomber Command when it set out on its first B-29 mission in midyear 1944. It needed to know as much as the Allies in the ETO knew about Germany's Freyas and Wurzburgs. At the time it was pretty blind, although its RCM observers had intercepted some Jap Army portable air warning when they flew over the Hump shortly before the big job started.

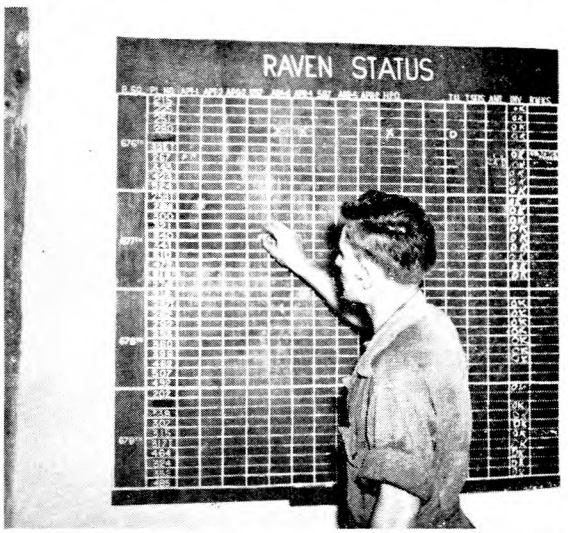
The 20th BC didn't stay blind long. A program back in the States had trained RCM observers for ferret roles aboard B-29 strike aircraft. All they had to do was take an APR-4 search receiver and an APA-11 pulse analyzer and move in. A few planes were equipped with APA-24 D/F antennas. As the B-29s headed for the target the idea was to catalog the enemy frequency spectrum and pinpoint



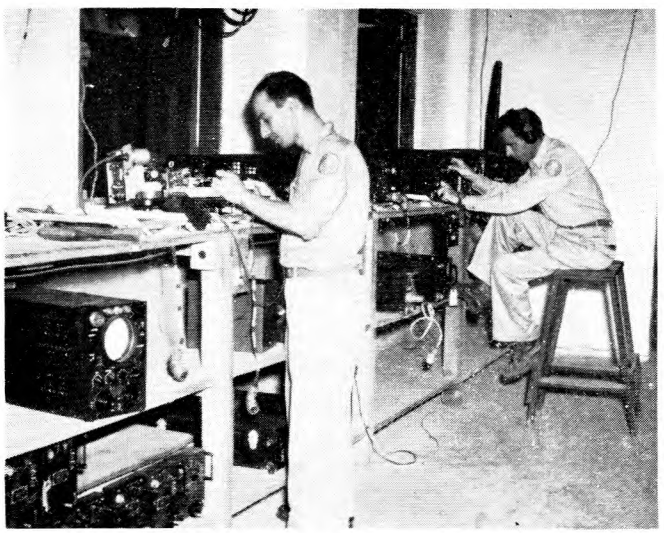
RCM-equipped B-29 of the 20th Bomber Command prepares for a routine search mission against Jap radar in CBI theater



RCM section of one 20th Bomber Command group poses in front of the radar and RCM shack—a typical native structure. "Raven" is the code name applied to all radar and radio countermeasures



Status board makes for efficient functioning of RCM section. Maintenance of Raven equipment is routine responsibility but research and development are vital extra-curricular activities



Maintenance bench in RCM laboratory of 20th Bomber Command group. Each group has combined radar and RCM shack providing accommodations for offices, storage, laboratories, power



Potential jam for Jap gun-laying radar is stored here in more than 100 transmitters, checked, cleaned and calibrated. Moisture-proof wrappings protect sets from the damp or dust of India

the radars. This didn't allow freelancing, but it permitted a big bomber to do double duty over actual mission routes.

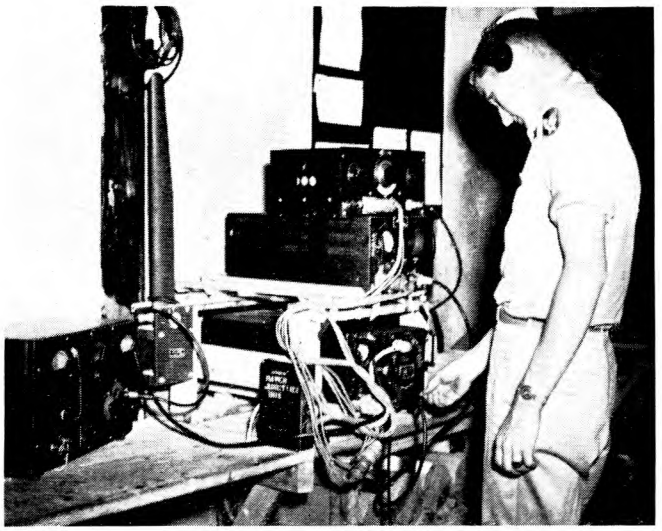
During the last half of 1944 the Jap early warning net across North China and Japan was plotted bit by bit. It took a long time due to the infrequency of missions, which were scheduled only 2 or 3 times monthly for a while as a result of supply problems.

Going into 1945, the Jap Islands revealed only what had been found on other Pacific Islands earlier. There was nothing that looked like German radar, no confirmed intercepts above 220 mcs. Reports of AI radar, searchlight and flak control aroused suspicions but so far the 20th BC hasn't substantiated them. The enemy's radar seemed of such low usefulness that the jamming transmitters were bench checked and laid away in waterproof storage. They're there at this writing. But they may be coming out soon. Recent indications are that more and better Jap radar may be on the way.

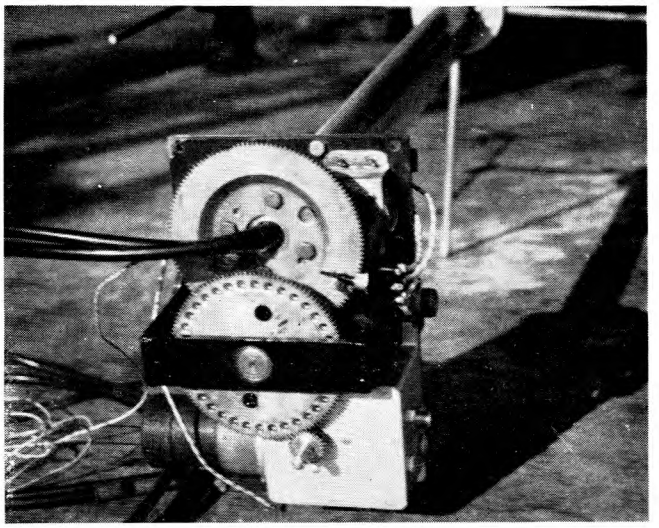
An additional element in the picture was the enterprising 14th AF's "Interim Ferret," a converted B-24 that in one solid month of freelancing did a lot of investigating that the B-29s couldn't. Aboard were 2 RCM observers borrowed from the 20th BC. Late in 1944 a new ferret reached the 14th AF and has been carrying on since. Additional B-24 ferrets are being assigned to other AFs now.

Today nearly every 20th BC combat mission includes a number of RCM equipped aircraft, with one RCM observer on each. Most of the 9 missions flown during January, 1945, had 6 or 7, and all started out with at least one.

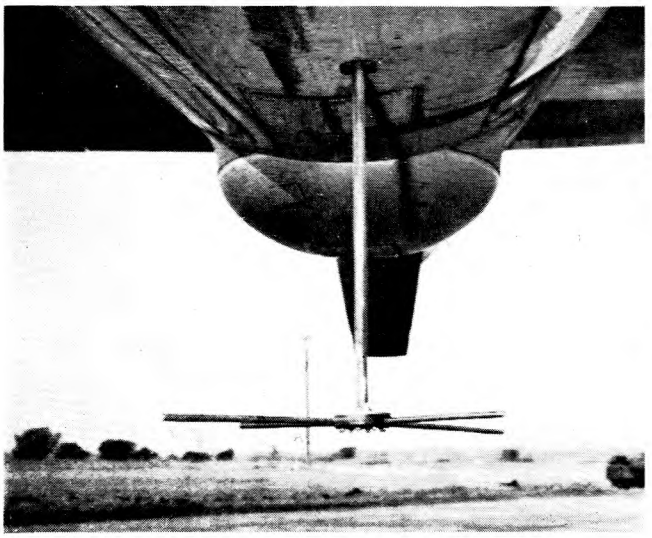
RCM activity in the 21st BC follows the same pattern, probably not quite as well established because not as old. With the B-29s handling the highways and the roving B-24s the byways, the combination looks profitable.



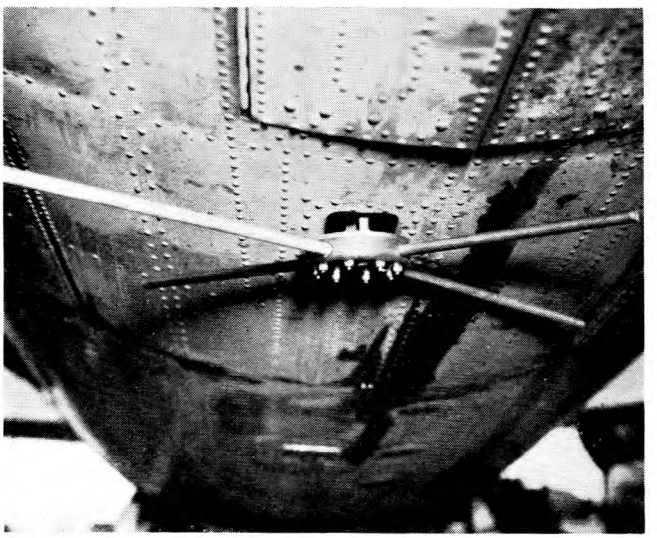
Search equipment in mockup of B-29 Raven position is tuned up before mission. This RCM equipment is installed 8 ft. aft of the bomb bay on the port side and in a pressurized compartment



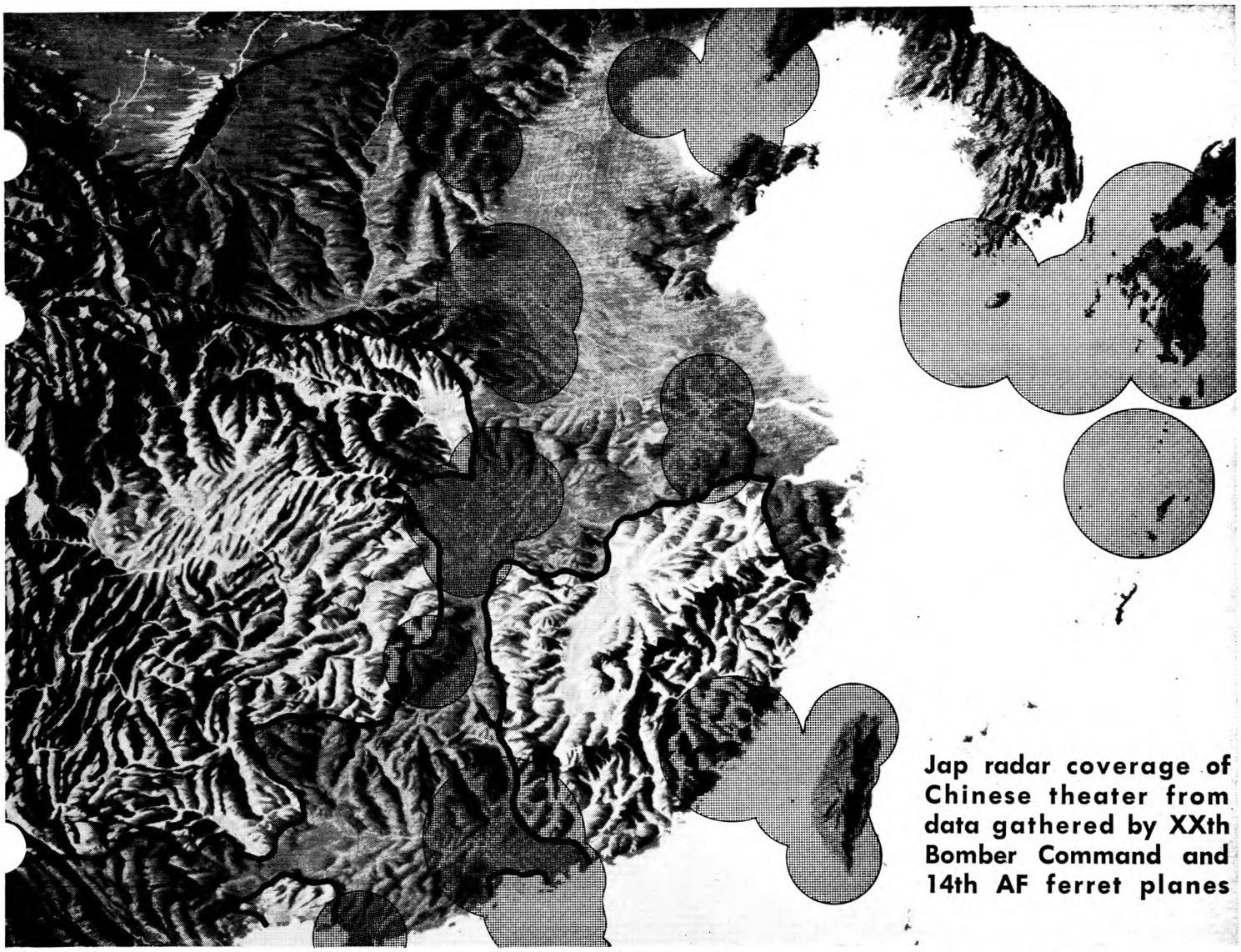
Electrical drive for retracting underslung APA-24 D/F antenna was designed by RCM observer and made up in the field. Interference from wings made top-mount of antenna unsatisfactory



Fully extended position of the APA-24 antenna in new location under fuselage. B-29 has 7 antenna locations to accommodate various Raven equipments chosen to fill the 4 racks provided

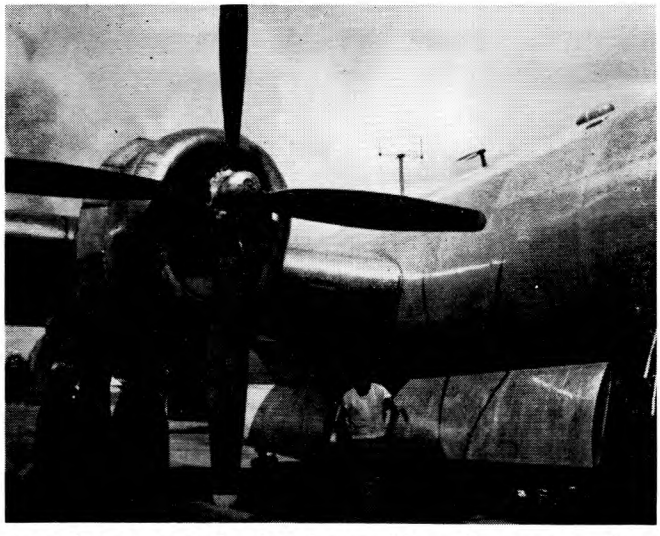


Fully retracted position requires elimination of vertical dipoles —few vertically polarized signals are received in that theater. The AN/APA-17 rotating antenna is latest D/F development

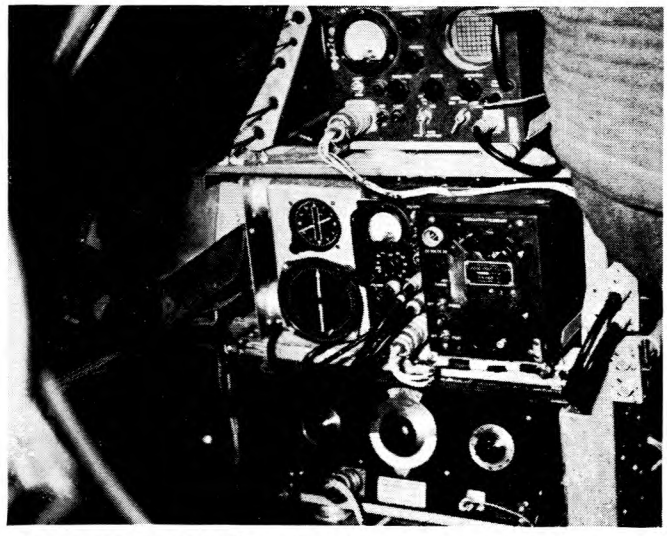


Jap radar coverage of Chinese theater from data gathered by XXth Bomber Command and 14th AF ferret planes

Initial phase of the growing RCM campaign against Jap radar is represented in this coverage map. Effectiveness of future large scale jamming and deception depends upon the reliability of these early investigations. B-29s searched those areas beyond reach of 14th AF B-24 ferrets. Note how coverage pattern, dated 8 Nov. 1944, conforms to the outline of enemy lines



Superfortress search aircraft viewed from No. 3 engine. Most Jap radar these planes have uncovered to date is early-warning. Signals are under careful study for gun-laying characteristics



Raven station in B-29 equipped for search. Top to bottom are APA-6 pulse analyzer, APR-4 receiver and H-P audio oscillator. Flux-gate compass and D/F antenna indicator to left of receiver

20th BC investigations of Jap radar point need for standardized searching

Jap radar is the latest subject to pose for scope photographers of the 20th Bomber Command. Resulting pictures aren't so artistic as those from the PPIs but they are no less revealing.

A Jap pulse can tell an RCM observer plenty about a radar—frequency, pulse width, PRF, type and use. By photographing the pulse as received observers avoid hurried, inaccurate interpretations—they can take it home for study.

Several make-shift attachments for pulse photography have been tried in the 20th BC, with varying degrees of success. The best pictures, sampled on this page, were taken with a C-3 camera (4.5 lens and 8-10 sec. exposure) mounted in the open end of a dust cover encasing an extra CRT. The extra scope was attached in parallel with the one on the APA-6X pulse analyzer and controlled from its panel. Thus, pictures could be taken without hindering operation of the equipment.

The pictures shown serve to illustrate a problem which has grown out of expanding activities in the Pacific—the problem of standardizing search procedure.

There are a lot more people seeing and hearing Jap radar than ever before and, if what they see and hear is to mean anything, criteria for interpretation must be devised. Several observers may investigate the same radar, yet one might see it as a search set and another as gun laying, with any number of figures for pulse width and PRF. The effectiveness of future large-scale jamming depends upon absolute identification. Which means there must be a standard basis for determining frequencies, pulse widths and PRF.

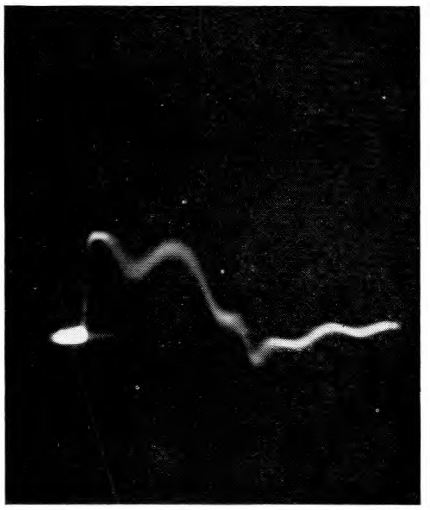
Within the 20th Bomber Command certain standardizations have already been initiated. Frequency standards are set by running calibration curves on all equipment with the best frequency meter available. An officer visits all bases every 6 weeks so that these curves can be run on test equipment and receivers. It has also been decided that pulse widths should be measured at half power point with the gain of APA-6X adjusted to make the pulse about 1″ high.

Because Jap pulses often have unpredictably bad shapes (note picture below) some believe that 2 readings of pulse width would be advisable—one on the time base and another at the half power point.

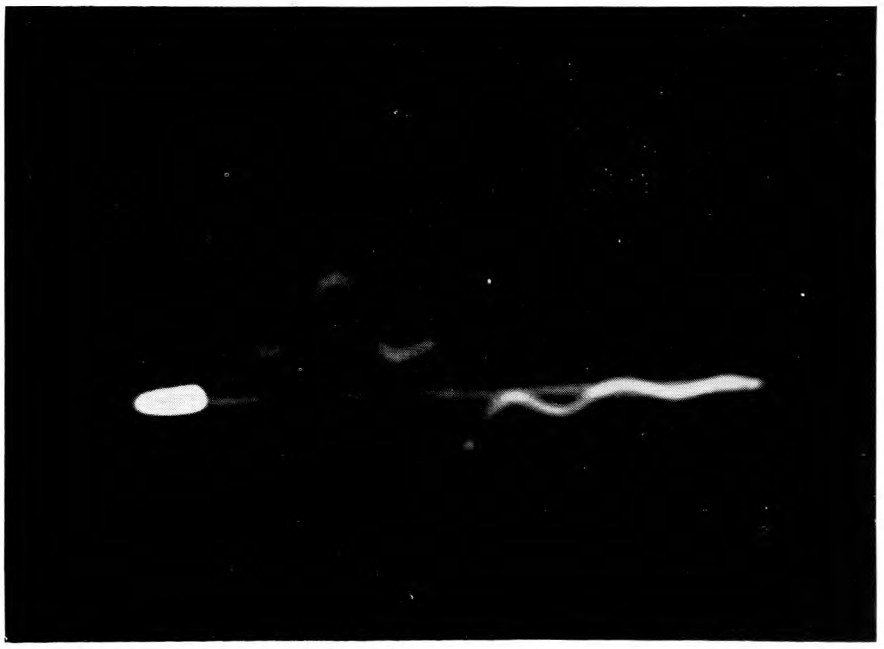
Other Commands with ideas on search standardization are urged to pass on what they have for use in future issues.



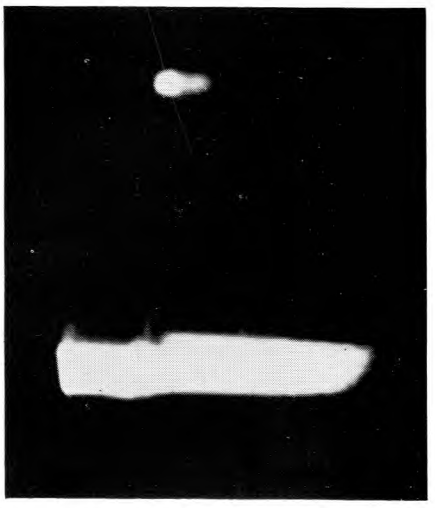
Square pulse from Jap radar at its best: correctly adjusted 75 mc. Mk-Chi search



Typical pulse indicates very poor adjustment of Mk I Mod II 200 mc. search radar



Interpretation problem is presented by this Jap pulse. Measured at half power point it's narrow enough for gun laying but on the time base it's large enough to be search



Scope picture when audio frequency input to analyzer is locked with a received PRF

B-24 bomber out looking for ships does 3-in-1 job on Jap radar instead



Homing on Sibago Island signal, B-24 crew saw lighthouse first, then hut, then antenna. Low level runs were made for photos, for estimating altitude, and later for strafing

Formally and officially, destruction of Jap radar installations in the Southwest Pacific is a 3-step process involving: 1) rough location of the radar by a ferret plane; 2) pinpoint location by photo reconnaissance; 3) destruction by a special strike mission. This is a little story about a firm-minded B-24 of the 13th AF which accomplished all 3 steps in one flight, after setting out to do another job entirely.

The assigned job was to search the Mindanao Sea for enemy shipping. For this the B-24 was equipped with LAB radar, but even that efficient instrument can't hit ships where there aren't any. And there weren't any.

But the B-24 also carried some RCM equipment (search receiver, pulse analyzer, etc.) and a couple of RCM observers. And while the bombing radar was scanning empty seas, the search receiver picked up some radar signals and the analyzer showed they were Jap. Thereupon the B-24 became a ferret. First of its self-imposed assignments was to try to pinpoint a Jap radar reported to be on Basilan Island, not far away.

Nothing was seen or heard of the Basilan Island radar, but just before search was given up, a signal was heard which led northeast of Basilan directly to Sibago Island. As the plane homed on it, the signal went off the air.

From 4000 feet the only discernible objects on Sibago were a lighthouse and a nearby hut on a small hill. Low level inspection revealed a radar antenna projecting from the roof of the hut. No AA or machinegun fire was encountered, so several low level runs were made for photographs. On the last run the height of the hill was estimated by flying level with its crest and reading off altitude from the radar altimeter.

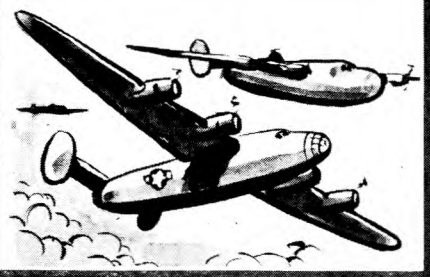
The B-24's bombs had no-delay firing, so the plane shot back up to unload. It was on again, off again for the Jap radar as the Nips thought the B-24 was headed home, then found it headed into a bomb run. In 3 Norden-sighted runs, four 500-pounders were dropped. But the height of the hill had been miscalculated; the bombs fell short. A fourth fixed-angle run was made to drop the remaining bomb, but that one missed, too. Then followed a series of low level strafing runs. Numerous tracers were seen to enter both targets.

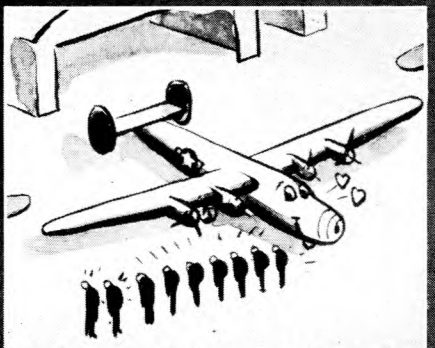
Holding back the rest of its ammunition for possible fighter encounters on the way home, the ferreting, photographing, striking B-24 then set off. On this page are 2 of the pictures it got.



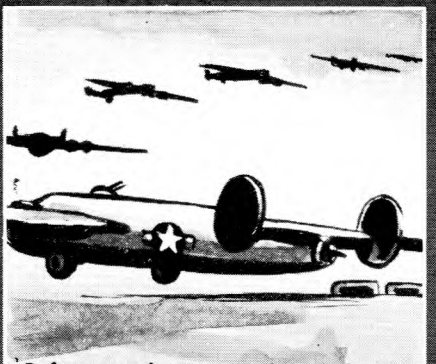
Low level runs revealed details of antenna structure projecting from the thatched roof of the hut; it was a signal from this antenna, identified as being from a Jap Mk 1 Model 3 radar (an early warning set), that led the B-24 directly over Sibago

Six months with the 489th Bomb Group

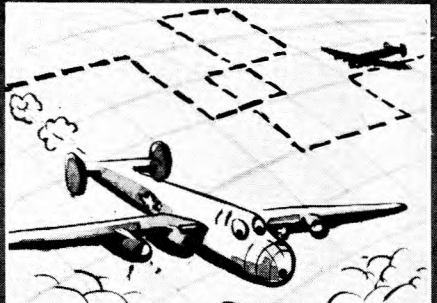




Fresh from U. S., crews and Liberators were activated last May in England

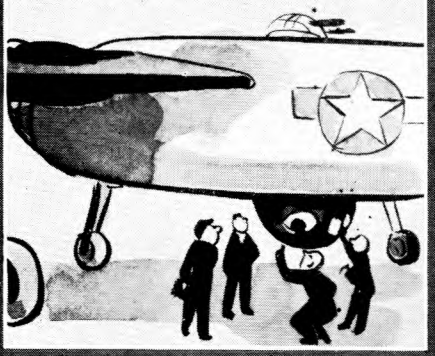


Before month was out they took off for Germany on their first bomb raid

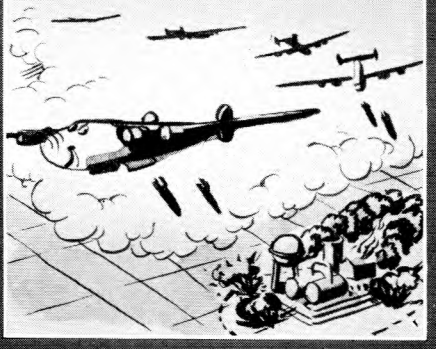


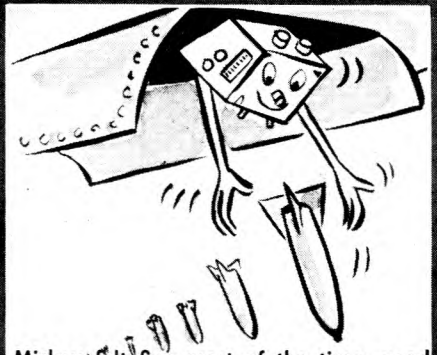
At start Group had only 8 unfamiliar Gee sets to find way to unfamiliar targets

H X equipped planes from the Pathfinder Force came into the Group in July

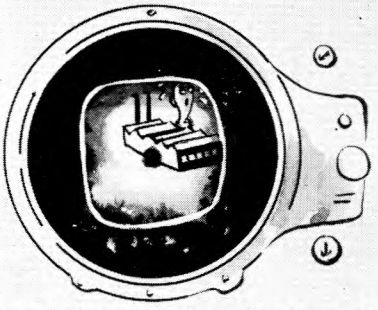


H.X highpoint was Schalau refinery raid; many bombs hit target, none strayed far

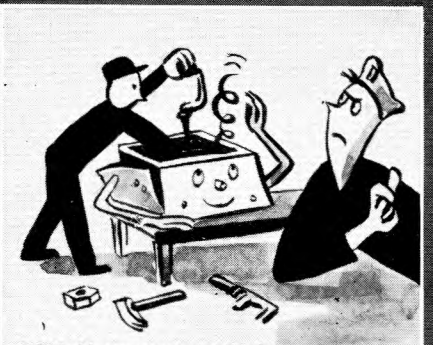




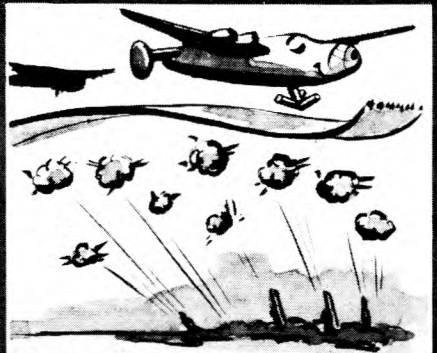
Mickey felt fine most of the time; good maintenance kept it steadily operational



Group prided its ability to bomb on echo from definite target area within a city



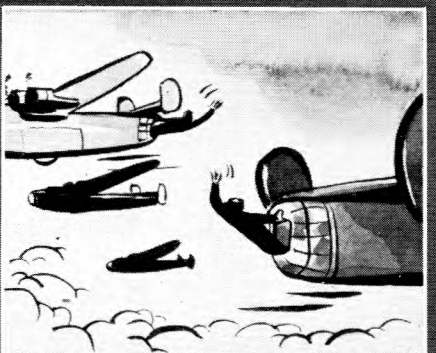
RCM Lieutenant crossed his fingers as Carpet was readied for its first run



But once the bugs were out of the new jammer, not one plane was lost to flak

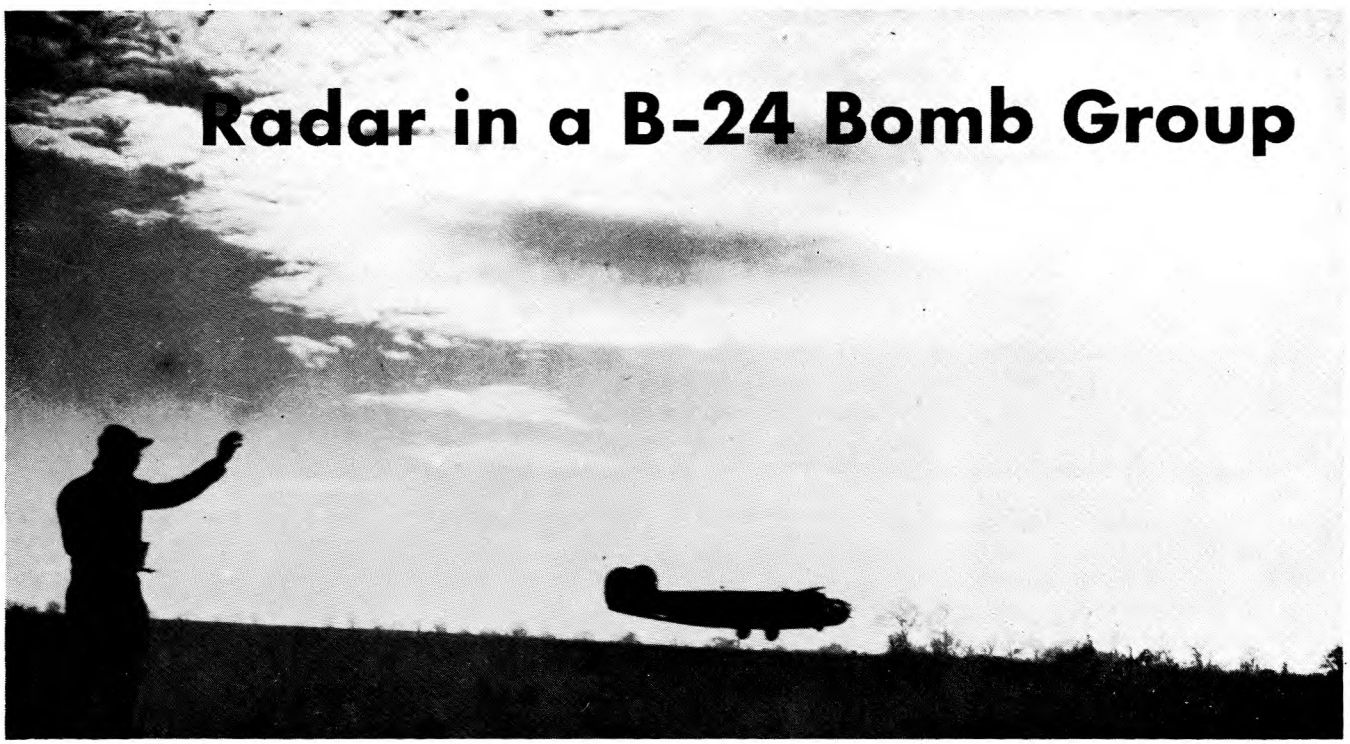


Libs' last raid was over Metz, November 10, blasting way for advancing 3rd Army



Six months and 98 missions after coming to the ETO, the group headed for home

Radar in a B-24 Bomb Group



With 98 ETO missions under its belt, the 489th Bomb Group has moved on to new jobs. Its 6-month career with the 8th AF is here reviewed, with special reference to its use of radar

The story of the 489th Bombardment Group in the European theater begins on a day early last May in Suffolk, England, when the Group's ground and air crews and 52 Liberators, fresh from the U. S., came together for the first time. Under Col. E. W. Napier, they were assigned to heavy bombardment duty with the 2nd Division of Lt. Gen. Jimmy Doolittle's 8th Air Force.

Before the month was out they had lifted their first bomb loads from Suffolk fields, carried them across the North sea, and dumped them on air hangars in Oldenberg, Germany. Before 6 months had passed, and their tour of duty was over, they had completed 98 such assignments. Canals, bridges, marshalling yards, chemical works, oil refineries, armament plants, tank factories, submarine pens, V-bomb sites and coastal defenses on D-day were targets for their bombs.

In the beginning, the Group used but little radar; only 8 Gee sets rode along on that first mission to Oldenberg. But despite shortages, the radar section gradually received equipment, and with it crewmen to specialize in its operation. By 10 November, when 36 of the Group's Liberators thundered away with the 20th Combat Wing to blast Metz fortresses in the path of Lt. Gen. Patton's 3rd Army, the planes were H_2X-led, RCM-protected, and each navigator had a Gee set to pinpoint his way across France. It was the Groups of the 2nd Division to which Gen. Patton was referring when he said: "The yellowtail B-24s did a superb job . . . materially aided the 3rd Army's advance."

That was the 489th's last mission over Europe. Back from Metz, the props had scarcely stopped turning when the crews heard they were leaving the ETO for new business. Had they stayed on, they were in line to get Gee-H equipment for their bombing.

As it stands—and pending activities yet to come in new assignments—the radar story of the Group is a story of Gee, H_2X and countermeasures in the form of Carpet. The equipment line-up is pretty characteristic; for its success in using what it had, the 489th would seem to deserve some special credit.

Only lead aircraft of the 489th had Gee when Lt. John T. Watson opened shop for the radar section in May. By August the mechanics had installed a set in every plane. With the push into France, and the subsequent death of many Jerry jamming stations, the Gee fixes were able to take the navigators farther and farther toward German targets.

On one of these missions, Lt. Bob Johnson was getting such good reception that he extended his lattice lines an inch beyond the printed borders. "I knew the fixes wouldn't be as accurate with the interpolated lattice lines," he said, "but it was 10/10th below and my fixes hit the course right on the button."

When the Pathfinder Squadron joined the Group in July, the Radar Section was ready for them with a PFF maintenance crew, headed by Lt. Donald J. Swett. Although testing was conducted with only one accurate volt-ohmeter the first month, Lt. Swett, his crew chief S/Sgt. Lloyd DeVaney and the PFF mechanics turned in a very pretty first-month maintenance record; the Mickey aircraft were 92% operational through each of the month's missions. Average for the entire 8th AF would probably run

about 85% operational over the target.

With the arrival of more test equipment, the PFF mechanics were able to get even better results. At the time the Group was called home, Mickey ships had run up a total of 52 consecutive operational sorties without an equipment failure.

Excellent maintenance led to better than average results. Mickey operators of the 489th were among the first successfully to use the radar echo of a definite target area in a city for a Mean Point of Impact. Less and less did they have to unload with the center of the city as the briefed MPI.

In August the PFF planes led the 2nd Division to an oil refinery at Schalau, near Hamburg, and laid most of their bombs within 2000 feet of the target. Another refinery was almost completely destroyed when the Group carried the ball for the 20th Combat Wing in a PFF attack on synthetic oil plants at Gelsenkirchen, in the north of the Ruhr. Just before the invasion of Marseilles, the 489th flew from England to join the 15th AF up from the Mediterranean; they bombed Lyon-Bron with a PFF lead.

At Trier on August 26, Mickey picked up the target at 50 miles; drift was killed from that point. As the Group closed in, it looked like an H_2X job and the bombardier got his readings from the Mickey operator, clutched in and set up the bombsight as usual. Then clouds pulled away for about 30 seconds over the target: the bombardier dropped visually, slanting the demo's right in the barrel.

Two weeks before the 489th went off, its Mickey was given a good test on 2 missions flown the same day. Two squadrons pinpointed the Mittelland canal through 10/10th clouds and another squadron made an H_2X attack on a synthetic oil plant in the Ruhr. With the canal, the airmen were aiming for a hairline 3¼ miles long that was being used as an east-west waterway linking the Ruhr steel cities with the Baltic.

While the Group was Mickey-led from July on, it wasn't until early October that it was supplied with RCM protection against enemy fire control radar. Tunable Carpet, the spot jamming answer to Jerry's ack-ack, was the last electronics equipment to go into use for the 489th.

The Colonel who quipped, "So this is the stuff that brings up Jerry's fighters?" when Carpet was being installed in lead Liberators of the 489th, got a knuckle-rapping answer from the report of the Group's losses after Carpet became operational. Once the bugs were out of the jammers, not a plane was brought down either by flak or by Jerry's fighters. It was a no-loss month right through until the group broke up in November.

The theory that the enemy will automatically put up his fighters if and when his AA control is nullified didn't hold for the 489th. Perhaps Jerry was loath to use his planes and gas when he couldn't be sure whether he would find a bombing mission or a wild goose decoy on the other side of the Carpet. Or it may have been that he didn't have fighters to spare; in October-November he was having a bad time.

At any rate, the 8 Carpet sets installed in the 489th are conceded to have paid their way handsomely. The crew members who maintained and operated them get an extra hand for that; for, although it is possible that some of them may have seen some Carpet equipment before, tunable Carpet for spot jamming was new to them. Mechanics and operators alike had to feel their way through unfamiliar intricacies, experiment and explore to find out what the equipment would do.

Before the 489th's first Carpet mission, RCM officer Lt. Bernard T. Lenahan crossed his fingers and hoped that the



U. S. airmen learn Gee in the field

The 489th was not the only Bombardment Group that started out with Gee as its sole radar equipment. Gee was, in fact, item No. 1 for most bombers operating in the ETO. The Americans borrowed it from the British in December '42; by the time the 489th finished its tour of operations in November '44 the 8th AF was 80% Gee supplied.

Used first as a blind bombing system back early in 1942, Gee was jammed out of this business. It has held firm as a basic navigational aid. One of the real veterans of radar, it has stood up while many another device has been retired under the pressure and speedup of war. Gee does all its work in Europe and the Mediterranean. Its U. S. derivative—the more recently developed and longer-range Loran—carries the load partly over Europe and wholly in other parts of the world.

Since widescale installations of both equipments have taken place with most navigators and maintenance men already in the theaters, training has been carried on to a large extent right in the field. That's what's happening in the picture above, which shows David Davidson of Radiation Laboratory (upper left) teaching Loran to U. S. airmen in a French hut.

Many a U. S. airman has learned his Gee and Loran under just such circumstances as these.

luck of the Irish would stand them all in good stead. As it turned out it was more practical to depend on S/Sgt. Dominic Buononno, Sgt. Bernie Strauss and the rest of the maintenance men.

There were modifications to make in the new equipment and rough spots to iron out; there were loose wires to be soldered and tubes to be replaced. Before each flight there were tests to make sure the jammers were actually putting out. And every night when the 8 Liberators came back to base the mechanics probed the Carpet sets for all possible causes of malfunction. Operators were checked out on the idiosyncrasies of each installation until they could coax all the hash from the equipment that it could give. Power output curves were plotted for each transmitter, and characteristics for certain frequencies noted, so that operators would know where the strength and weakness of their equipment might lie.

For the operators, the simplest part of the job was learning how to locate Jerry's radar by the signals on the "Blinker" receiver, and to dish out jam on the proper frequency. It was harder to distinguish on the earphones between the high pitch of the small Gun Laying Wurzburg (3750 cycles per second), on which the jamming was concentrated, and the low pitch of the giant GCI Wurzburg (1875 cycles per second).

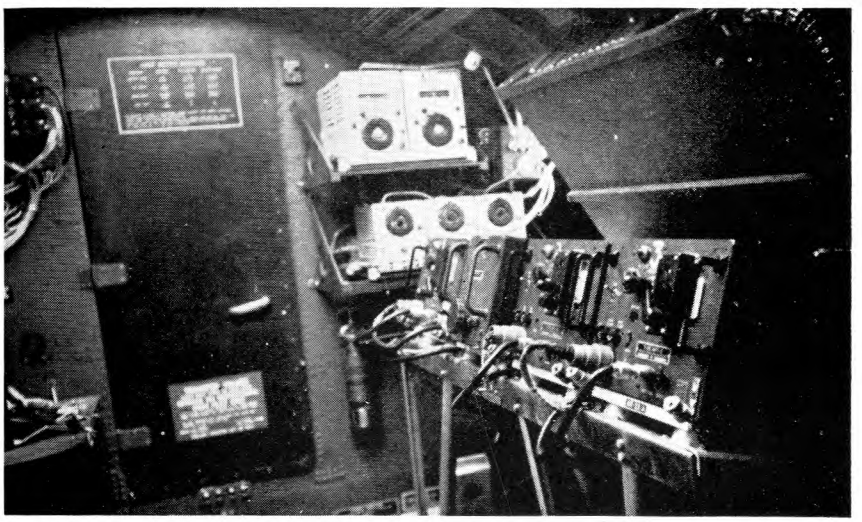
Once the tricks were learned, it was a matter of playing hide-and-seek with Jerry—winner take all. And as the enemy came to know more about Carpet the game got rougher. Jammed on one frequency, Jerry would shift 2 or 3 megacycles to another. Or he would turn his signals off to make believe he was all through. Or he would try to camouflage his GL Wurzburg by putting it near the frequency of his GCI Wurzburg.

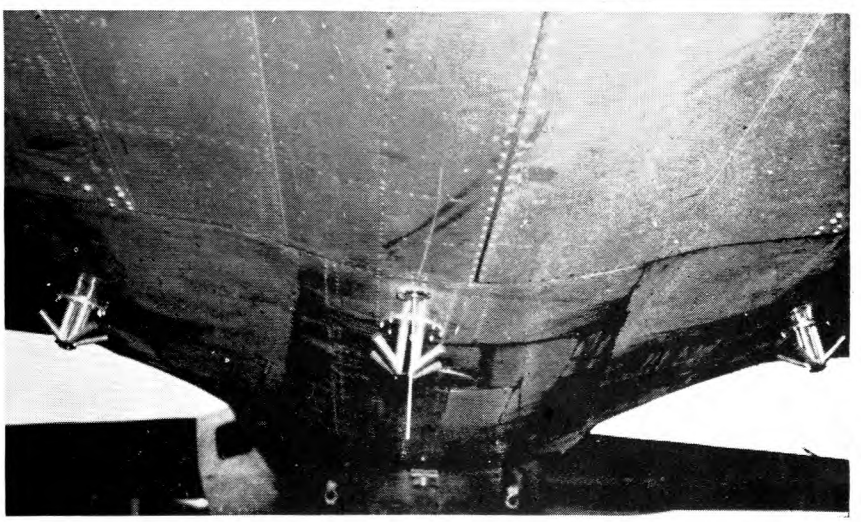
A lot of the tricks that kept RCM operators in the 489th constantly resetting their transmitters have become less useful to the Germans as the 8th Air Force has pushed forward its program of equipping all Divisions for both barrange and spot jamming (see page 39). But that doesn't affect the 489th now. It learned plenty and now it's getting ready to use its knowledge elsewhere.

Currently in this country, crew members are taking refresher courses, boning up on new radar methods, getting ready for their assignment. The story of the 489th is opening on Chapter 2.

Jamming show goes on in all theaters





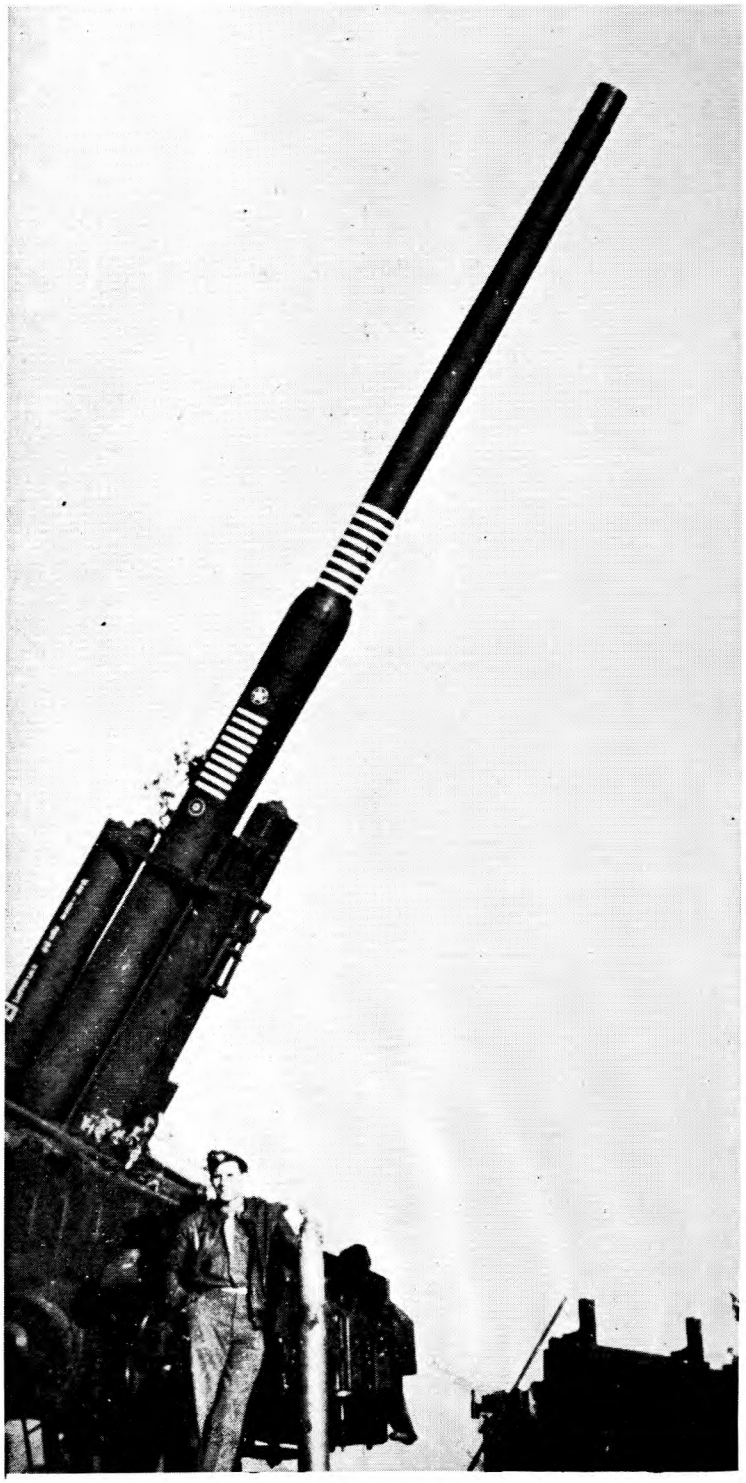


At Radar City Music Hall in Gioia, Italy, Lt. G. L. Elmergreen (above) and others of the 1044th Signal Company trained RCM operators, designed and installed spot jamming setups like one shown center in B-17 (fishhook transmitting antennas at bottom). For more on RCM in ETO and MTO, see next pages

RCM: tailored to fit

Jerry's fire control and U.S. countermeasures are both getting better as the war tightens up





WHITE RINGS SHOW KILLS MADE BY THIS RADAR-AIMED GUN AT PLOESTI

As every airman over Germany knows, Jerry has gone all out for gunlaying—gunlaying radar and heavier AA batteries—and it's a powerful combination. Installations which used to have 4 guns now have as many as 32, largely made up from guns moved in from outlying regions to be concentrated on choice targets in the heart of the Reich. In other words, the flak is thick and tough.

Allied countermeasures are tailored to suit. They are tailored out of a variety of equipment and techniques and out of the total product of RCM experience on the part of all U.S. Air Forces active over Europe. A lot of this experience was gathered the hard way over Ploesti last summer. The first section in this roundup of RCM activities and German radar developments deals with the Ploesti RCM campaign, some lessons of which are now being well applied in other areas.

From May to August 1944 there were very few days—perhaps 4 or 5—when the 15th AF did not go bombing. And one of their regular targets—Ploesti—put up a solid wall of fire every time. Flak from Ploesti guns was even worse than that from Europe's No. 1 target, Berlin, because of the tight area in which the oil refineries were located. On several raids at least 245 heavy AA guns were identified. As many as 25 batteries of heavy guns (8 guns to a battery) would regularly be brought to bear hard on one Bomb Group at a time.

Primary flak control in every case was radar. There was always one radar set for every battery, sometimes 2. After the capitulation of Ploesti an RCM delegation from the 15th AF visited the refineries' defenses, talked to some of the Rumanians who had been manning the Wurzburgs. Fire control, they found, came from the tried and true combination of Small Wurzburg GL sets helped out operationally by the Giant Wurzburg-Freya GCI setup (see RADAR No. 6). When the 15th's jamming interfered, gunlaying was accomplished by acoustical or optical means. In clear weather optical range finders were useful, but never as efficient as the Wurzburgs.

The intense RCM war on this A-1 installation was preceded by a lot of background work on the part of the 15th's countermeasures experts. Days were spent log checking, flying ferret missions to pinpoint German radar installations and note their operating frequencies, making maps of all target areas to show gunlaying and AA installations. The 1044th Sig. Co. set up a school at Cioga, where all incoming officers and men were trained in the ways of Chaff, Carpet and Wurzburg.

Against Ploesti's flak power, there were 4 Bomb Groups in

4 Wings of the 15th AF equipped for barrage jamming; and every Group was equipped to dispense Chaff. The RCM group in the 15th knew that enemy gun crews were instructed to pick out the first formations over the target and keep at them as long as possible. And RCM men couldn't do anything about that. But they could do something about the leading Groups, which had no previously laid Chaff trail to protect them. At that time the Carpet wasn't thick enough to provide the answer nor had spot jamming been worked out sufficiently to take care of the ever-spreading German frequencies which pre-set barrage jamming could not cover. More spot jamming, the best solution, would take some time (it didn't come along, in fact, until mid-August).

So the RCM people developed the Chaff Bomb. They used an M-26 flare case, which they packed with old style CHA-3, or CHA-3-(3). A mechanically timed M-111 flare fuze was used to detonate cordite, which was put in so that detonation pulled out the Chaff without "birdsnests." Chaff bombs were dropped from P-38s which preceded the leading groups from the Initial Point of the run to the target.

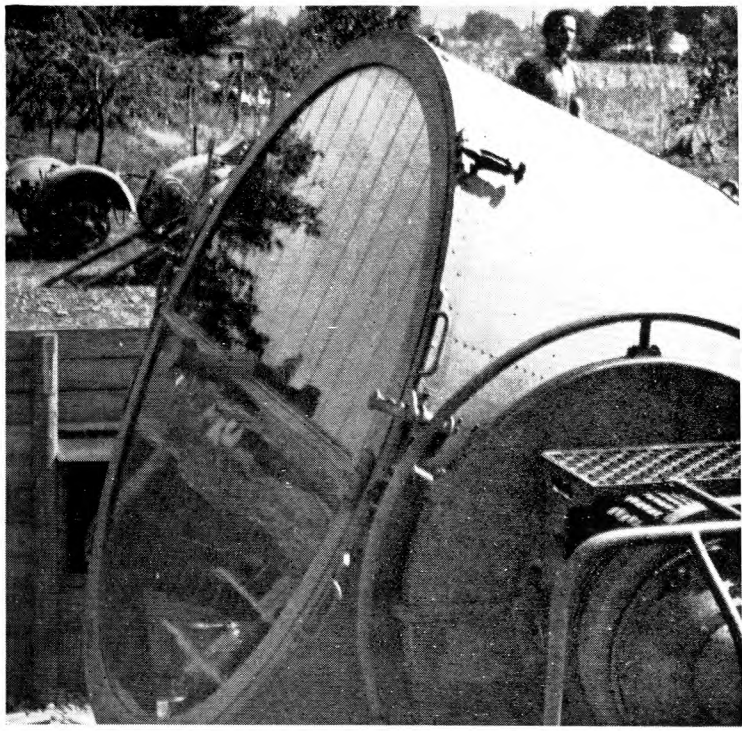
Bombs were fuzed to expel at 25,000 ft. and 23,000 ft., from an altitude of 30,000 ft. Dropped in pairs at 8000 ft. intervals, they spread concentrations of Chaff along the path of the run so that a Group would always be within 4000 ft. of a concentration. This vertical screening was not as complete as the horizontal screening of Chaff trails, but it seemed to cause confusion on Wurzburg scopes.

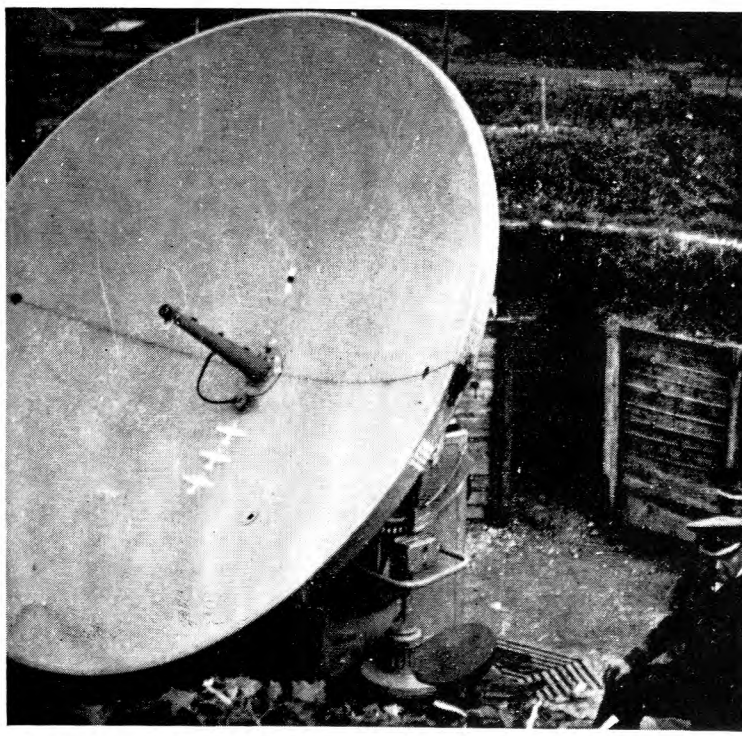
During the 7 August raid on the Blechhammer Oil Refineries, fifteen P-38s, going in 3 minutes ahead of the bombers, dropped 30 pairs of Chaff bombs in 2 parallel columns 1½ miles apart. The leading Group (no Carpet) received no losses, one plane was severely damaged and 3 others slightly damaged by flak. The 484th Bomb Group (no Carpet) one minute later suffered 16 slightly damaged. Blechhammer had 135 heavy AA guns and 11 GL radars in action that day, according to photo interpretations.

Although this and other missions showed that protection from Chaff bombs justified their use, and that protected groups suffered about a third fewer flak losses than others, it was still true that a combination of Chaff and Carpet was needed to reduce flak losses significantly. The real need for more Carpets was brought home to the group visiting Ploesti when a Rumanian officer said that his Wurzburg, operating at 562 mc. in the center of the barrage band, was completely jammed at all GL control distances by many Carpet missions. The German system of interlocking fire, however, obviously makes it desirable to jam *all* their GL radars. And that, of course, has been the objective of the greatly increased shipments of Carpet jammers to the ETO and the MTO in recent months.

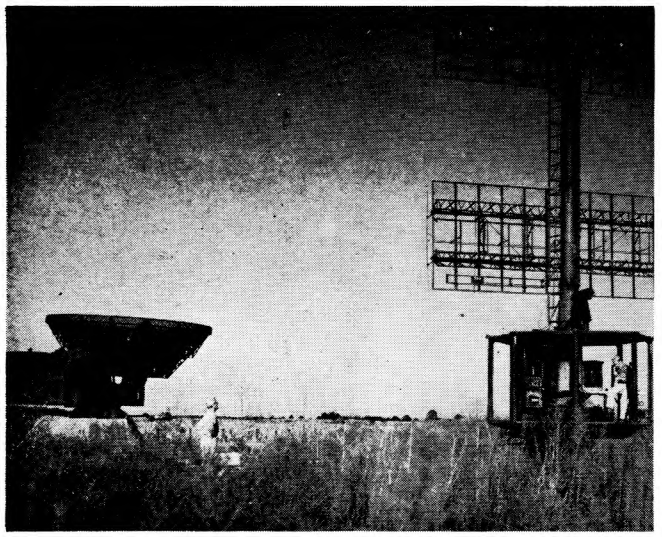
Knowing their Wurzburgs are going to be jammed, the Germans are spreading frequencies ever more widely; mounting low frequency radar at Wurzburg sites to take over when the higher frequency stuff is jammed; trying out anti-jamming circuits (see cut, page 41). And they are developing a new computer which enables one radar to control a large number of AA batteries simultaneously. Against all this the 8th AF is doing plenty, some of it detailed below.

Close to 7,000,000 units of Chaff are tossed out by the 8th AF in a month, and the greatly expanded Carpet program, which began in the fall when Carpet jammers began to arrive in quantity, is now in full swing. Now all 8th AF Bomb Groups operate barrage jammers on every mission—some using Carpet I, but most now using Carpet III, a higher powered jammer more effective at crippling Wurzburgs operating in a narrow frequency band. Spot jammers are in use in all Groups in the 2nd Division, and in most Groups of the 1st and 3rd Divisions—and there is more coming. Jerry's





TOP: WURZBURG-CONTROLLED 200 CM LIGHT. BOTTOM: THE WURZBURG



STANDARD GERMAN GCI RADAR TEAM IS STILL GIANT WURZBURG, FREYA

reaction to all this jamming is to hunt for new frequencies, or, more often, simply to shut up shop and wait until it blows over.

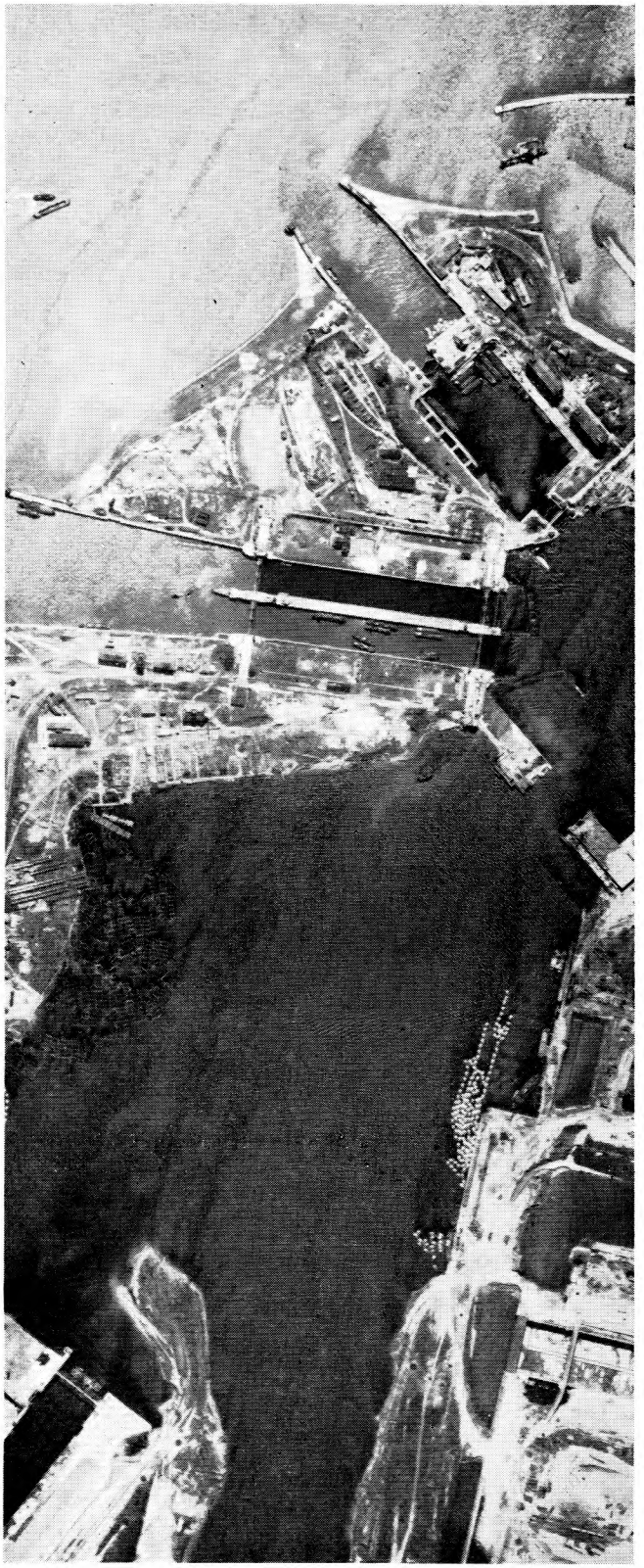
One of Chaff's knottiest problems, as in the 15th AF, has been to protect the leading groups in a bomber formation—the ones that go out front and drop for the others. The 8th AF experimented to some extent with 100-pound Chaff bombs carried by P-51's, and has lately been trying out other methods.

One practice, worked out by the RCM officer of the 1st Division of the 8th AF, is to load a P-51 with two 108-gallon battle gas tanks—one for gas, and one split in half and loaded with Chaff—suspended below each wing. This has proved successful in the 8th AF, which doesn't have as long trips to their targets as does the 15th. When there are no P-51's to send out, they've tried slitting the ends of Chaff cartons, stuffing the cartons into the bomb bay and opening up the doors at the right time. Meantime, automatic dispensers, which saved wear and tear for the 15th AF, are being introduced into the 8th AF.

Beyond Chaff and Carpet, RCM offers other ways of fighting the flak. An early operational use of AN/APA-17 showed a crew from the 94th Bomb Group one way. The APA-17 is an airborne DF equipment for horizontally or vertically polarized signals, which displays on a CRT indicator the direction of a radar signal tuned in on the associated AN/APR-4 search receiver. The crew, flying a B-17 equipped with this, deviated from the Mickey navigator's course and got lost. The radar operator, watching the antenna pattern painted on the APA-17 tube, suddenly predicted flak batteries ahead. They ran right into them.

Crossing the coast on the plane's next mission, the pilot asked the radar operator to hunt for flak areas. So he hunted through the Small Wurzburg band, and found a strong signal at 1 o'clock. The pilot immediately altered his course to the left, and 5 minutes later the flak came up to the right. This time it was low, and over 300 yards away.

A skillful operator knows how to combat the fact that APA-17 does not give range. It is possible to decrease receiver sensitivity so that only stations dangerously close will be received, and still to warn the pilot in time to duck the flak.



Decoy docks in Wilhelmshaven harbor are sheet metal corner reflectors about 12 ft. square, designed to divert H_2X bombers from real objectives. Each of the corner reflectors is mounted on a boat-like float. These and similar installations at Kiel are the only known use of such tactics—the ruse was unsuccessful

The stepped-up RCM war has been accompanied by an intensified anti-jamming training program for radio and radar operators in the U.K. Officers of the Technical Liaison Division, OCSigO, have been directing the proceedings, which started late in the fall. Courses were planned to increase operators' ability to receive through all kinds of interference and jamming likely to be encountered under combat conditions. The necessary equipment, including motion picture projectors, sound reproducers, code practice equipment, etc., was then packed in a sort of ambulance which has since been going all over the U.K. putting on A-J shows.

From them, operators have gotten a personal knowledge of battle area conditions through films, sound recordings, and demonstrations of the latest enemy jamming. During November alone the troupe played before more than 2000 operators, covered 2 Armored and 3 Infantry Divisions, and established several unit schools.

Germany has been pulling back a lot of big guns and a lot of gunlaying radar before advancing Allied armies. But not all. RCM investigators, going in to pick up Jerry's radar pieces, have found no startingly new techniques or tricks, but one new German radar set, a GCI radar known as Jagdschloss (see cut). Herewith a brief report on that.

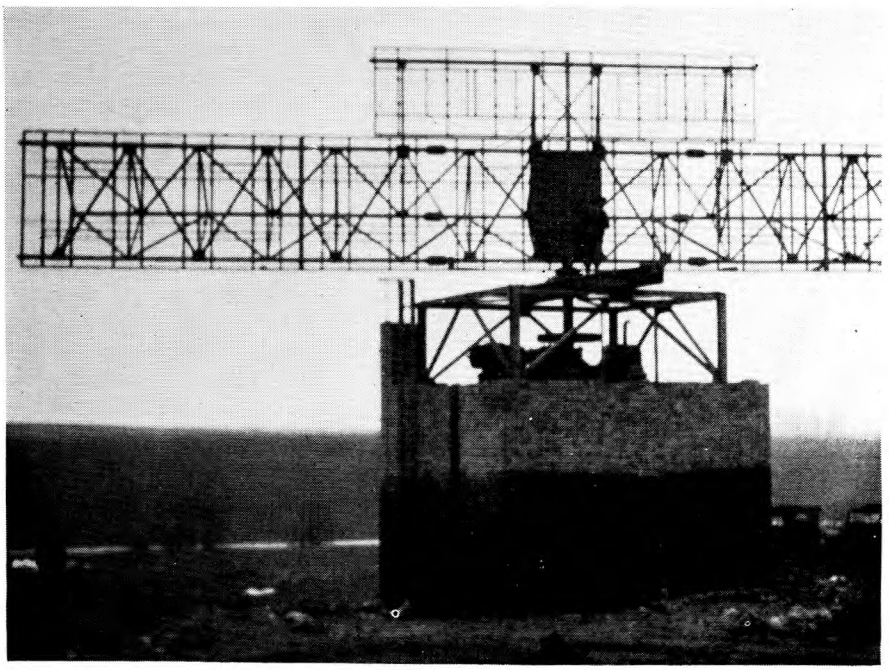
In November 1944 an RCM delegation paid a call on what was left of a hastily abandoned and incomplete German radar installation at Aisemont, in Belgium. They had seen pictures of this set, and had dubbed it an "Extended Freya" for want of a closer look and a better name. It proved to be Jagdschloss—an equipment designed for GCI work and the only new German radar set to make an appearance in recent months. This was the equipment which, according to P/W reports, made use of the first German-made PPI scope.

During the summer various sources had made it clear that Jagdschloss existed, but it remained for photo-reconnaissance to fill in the picture. Seven or eight installations have been identified by photographs since the first picture was made by the British, who sent a plane on a spectacular flight over the site at Tybjaerg, on the Island of Zeeland, to obtain the first detailed oblique shot.

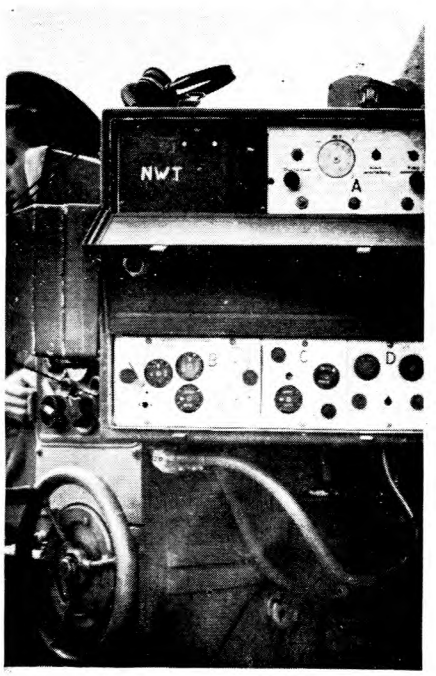
Putting the pieces together, we know that the Germans were busy completing the Jagdschloss stations during the summer and fall. It is unlikely that the chain of stations—about 80 miles apart—is completed yet, but if and when it gets into full operation it will probably cover most of Germany.

In some cases, as at Darmstadt (near Gernsheim) and at Weissenfels (southwest of Leipzig), a Chimney has been erected for heightfinding. RCM groups, studying Jagdschloss's capabilities, estimate that its reliable range is about 60 miles. The large (80′ x 10′), continuously rotating aerial sends out a narrow beam, which helps against increasingly successful Allied jamming. The small upper array is for IFF.

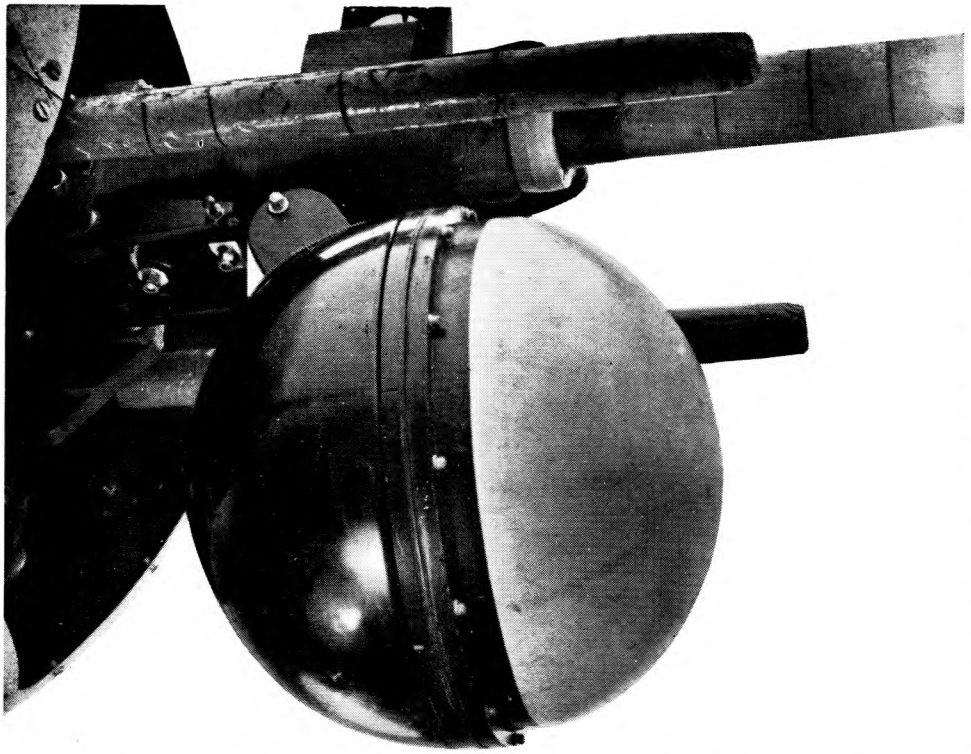
No aerials, power supply or other radar gear had been installed at Aisemont before the Germans were forced to get out, nor could evidence of any be found there. Details of the antenna framework, however, were helpful in confirming siting and antenna studies. A technical team visiting a GCI site at Mars La Tour a few days after the trip to Aisemont, found an old-type Giant Wurzburg-Freya station left in the process of being jazzed up with a Jagdschloss-Chimney combination. There was plenty of radar: two Giant Wurzburgs, a Limber Freya, a pole Freya, a Box Girder Chimney, and the Jagdschloss—the last two incomplete. Local French, who had been working on the site, told visitors that the installation, started last August, was to be complete by the first of 1945.



Jagdschloss antenna, 80 by 10 ft. and continuously rotating, sends out a narrow beam that's hard to jam. Small upper array is IFF. 7 or 8 of these newest GCI radars have been identified in reconnaissance photos and are believed to use the Panorama Gerat, first German PPI. The set has a wide frequency band and estimated range of 60 miles. Antenna consists of wideband dipoles 1 meter long. IFF unit is vertically polarized



AJ panel on Small Wurzburg. "NWT" is for Nurnberg (propeller modulation device), Wurzlaus (moving target discriminator), Tannus (wavefront discriminator). All of these anti-jam devices cut range



Bulbous APG-15 antenna housing, here attached to B-24 tail turret, will soon appear on B-29s. Weight of tail protection radar is 125 lbs. It does conical scanning

Aid to the turret gunner

Two fire control radars, long time coming, get first tests

A bomber has 2 jobs: (1) to drop its load smack on the target and return; (2) to protect itself. The 2 are linked, but—with respect to radar—the first takes priority. In poor visibility, non-radar aerial gunnery isn't as handicapped as non-radar bombing and navigation. Which explains in part why, within radar's earlier crash programs, bombing and navigational radar came in ahead of airborne fire control.

The situation is changing now. With the priority items in hand and aerial gunnery increasingly important as the enemy strives to counter mounting Allied air blows, fire control is rushing into use. Giving it impetus is the fact that the turret gunner's assignment, what with faster planes and more gadgets, has been getting harder to handle. He needs radar to help cope with it, whatever the visibility.

AN/APG-5 (Airborne Range Only) and AN/APG-15 (Airborne Gun Sighting) are the initial systems scheduled for large-scale use. They come on the scene with the unmanageable qualities that vexed their early development mainly erased. The LHTR (Lighthouse Tube Transmitter-Receiver) makes compact, featherweight, automatic range finders possible; other components are trimmed down; the airborne precision problem is licked. So are most of the bugs.

APG-5, a 90 lb. range finder for flexible turret guns, hasn't reached the installation stage yet, although quantity production is proceeding and all new B-17 and B-24 upper and lower turrets are soon to be engineered with Class A parts. Currently, it's undergoing test. The tests don't imply lack of confidence in the radar, but are designed to find a sight that advantageously uses the accurate range information. Production installation will begin if and when the current AAF Board tests joining APG-5 to the new K-15 gyro sight prove satisfactory.

Combat tests are meanwhile in progress in the 15th AF with a small number of B-17s fitted in the U. S. and flown across in December. An equal number of B-24s will be similarly tested by the 15th. AAF Board trials of APG-5 with the K-3 sight, made some months back, resulted in 7.1% hits with radar ranging vs. 4.4% for manual ranging. If present expectations are fulfilled, the K-15 sight will better the ratio. Another test, conducted by the National Defense Research Committee in 1944, determined that a turret gunner's target tracking ability increased 4 times when he was freed, by radar, of the job of estimating range.

The gunner's operation of APG-5 is elementary. He throws a couple of switches inside the turret and optically tracks in azimuth and elevation. Meanwhile, accurate range data between 200 and 1800 yards on the enemy aircraft automatically feeds into the lead computing sight.

As with Falcon, ARO manual variation of APG-5 (see RADAR No. 7), the target must be seen visually since the broad-beamed, non-scanning antenna is fixed on the axis of the line of sight of the guns. When the gunner has his sight trained on a target the ranging unit locks and holds until it's released or the contact is lost.

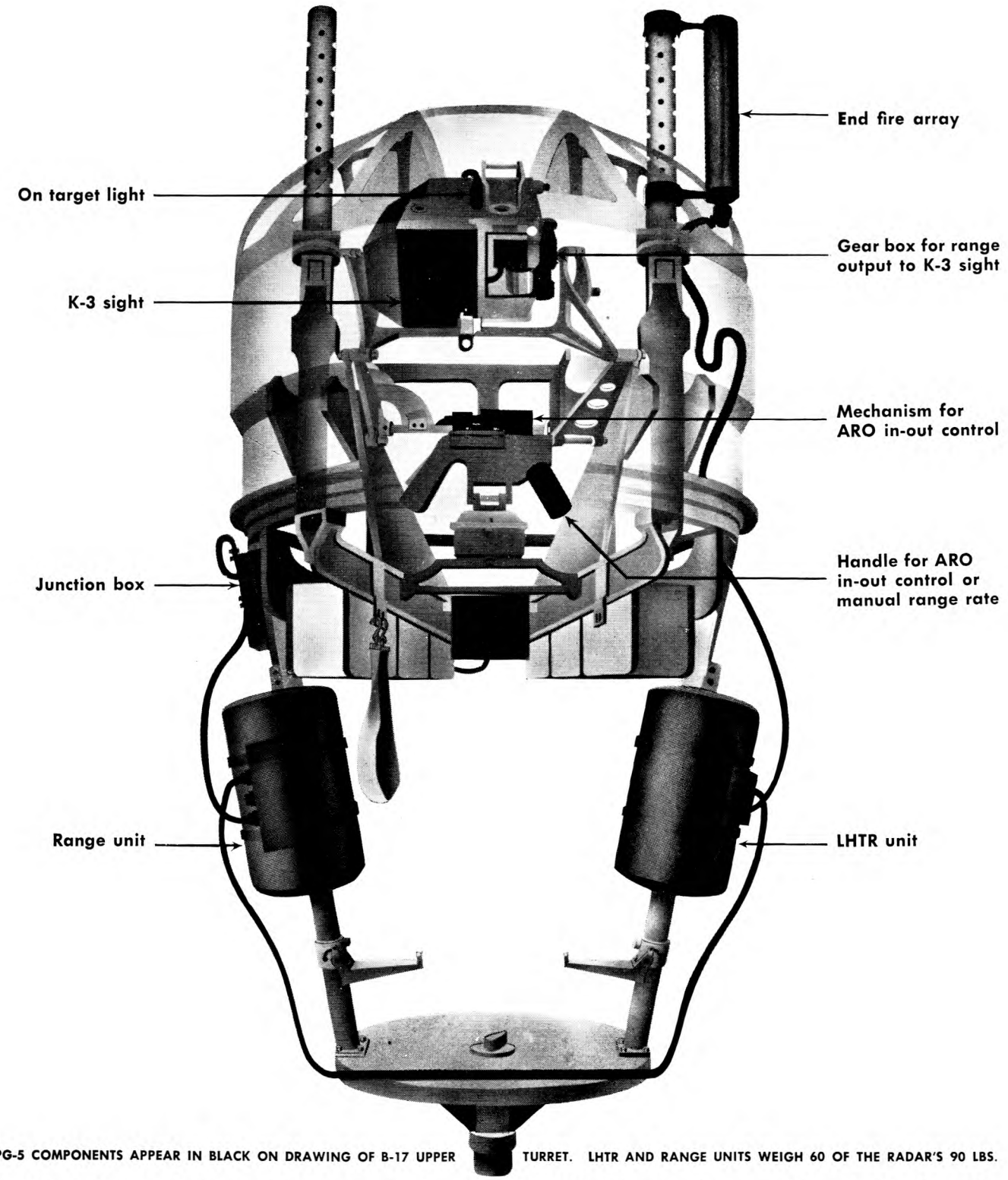
The future of APG-15, combination ARO and AGS radar for bomber tail turrets, is on a firmer footing. Several thousand sets are in production and will be installed in all new B-29s, along with AN/APX-15, a new identification teammate.

In a recent report the AAF Board recommended installation of APG-15 in all B-29s for nighttime operations. The Board has not yet officially reported daytime tests, although preliminary results have shown 300-400% increase in hits. Six B-29s of the 20th Bomber Command fitted with APG-15 recently started operational tests and some day and night missions have been reported. In these the equipment performance was good but the enemy failed to appear.

B-24 tail turrets are now being engineered with Class A parts for APG-15. Production installations are scheduled to begin as soon as AAF Board results warrant. Plans are being readied to fit APG-15 into B-32 tail turrets, but similar tail protection for B-17s is stymied by space limitations.

APG-15 performs an APG-5 function by day or in good visibility, but positions guns for pointblank fire by night or in bad visibility.

During conditions of good visibility the gunner tracks the target through his sight normally, not bothering about range. The radar takes care of that. But at night the computer is out and 30° conical scanning gives accurate angular data on a "G" scope. The gunner has a spot indication that tells him whether he's aiming at the target. As

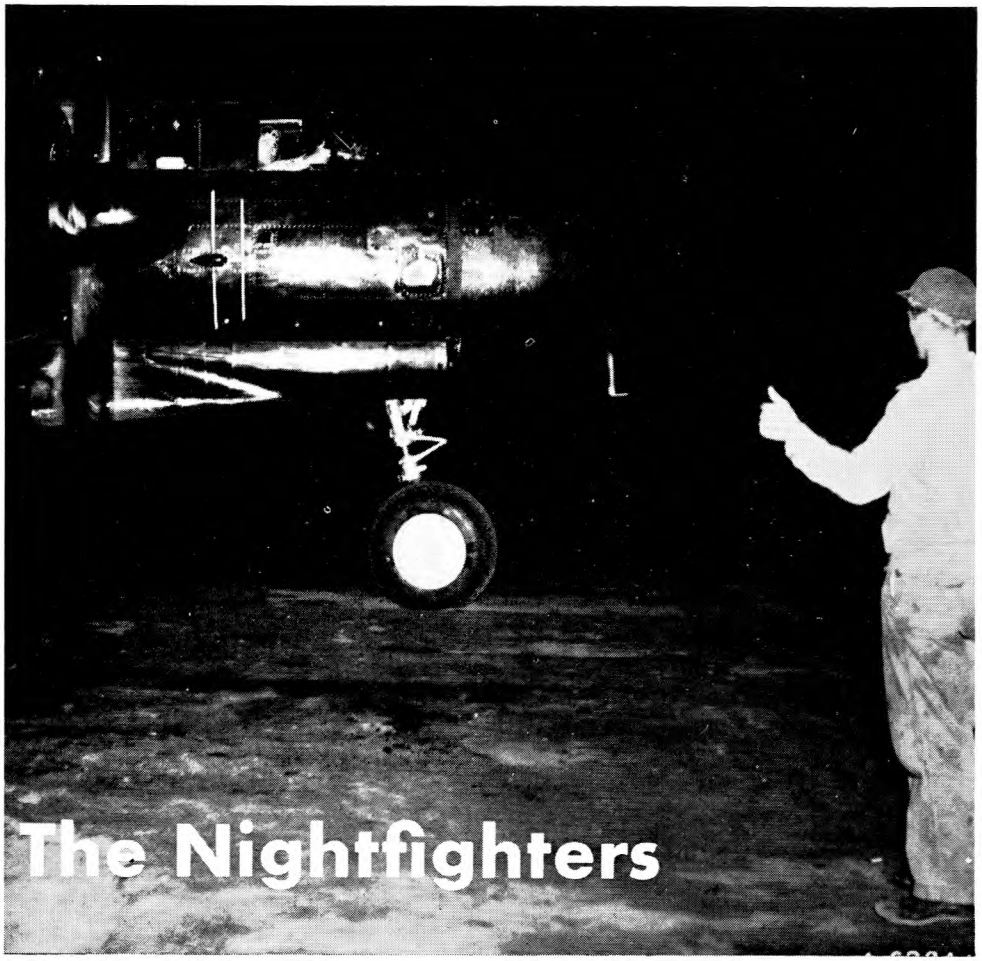


APG-5 COMPONENTS APPEAR IN BLACK ON DRAWING OF B-17 UPPER TURRET. LHTR AND RANGE UNITS WEIGH 60 OF THE RADAR'S 90 LBS.

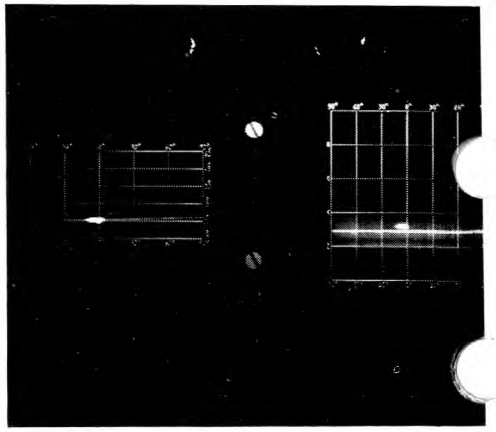
the distance lessens the spot widens (grows wings) until at firing range it completely fills the "goalposts" in the radar scope.

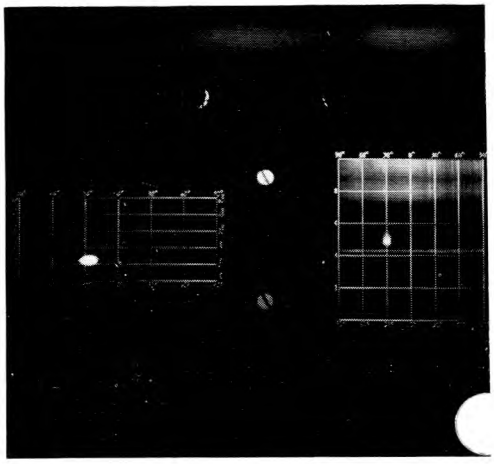
When scientists began thinking about airborne fire control they had in mind a system that would do everything APG-5 and APG-15 do but, additionally, would align the radar axis with the target irrespective of the plane's axis. For offensive night fighter and defensive bomber aid, something of this sort would carry airborne fire control to its next logical stage of development. No such system is in production as yet. When one is forthcoming it probably will be fully automatic and of lightweight X-band design, searching and tracking in azimuth, range and elevation, locking on the target and furnishing data to a computer.

Appraising the potentialities of the whole airborne fire control program, it is obvious that much depends on the reception the equipment gets from air crews in the theaters, who are introduced to it one day and fly it the next. Right now it's getting just such a baptism.



The Nightfighters





Contact on 720's "B" scope (right, above) at 17,000 ft., 5° port on 10 mi. range. Below, 3 mi. range reads 7,000 ft., 25° port. "C" scope shows quarry 5° above

With improved equipment & techniques nightfighter squadrons are mushrooming. Their trade

Nightfighting, which used to be a pretty specialized art—and almost exclusively an RAF one—is branching out in lots of ways. It's worldwide now. It's multipurposed, and getting more so. Equipment going into nightfighter units is better; squadrons are mushrooming.

The enemy has nightfighters, too. The GAF has had them for a long time, and evidence is accumulating that the Japs are learning the trade. Compared to the Allies, they're both handicapped by lack of quantity and quality.

Allied nightfighting, 1945 version, links specially-designed fighters, serviceable microwave AI and identification-homing radar, long range ground control (though intruder missions outside control limits are on the increase), dependable ground-to-air communications and well-trained crews. Notwithstanding, the business has a full quota of headaches. Some, for example the speed and climb limitations of the P-61, No. 1 AAF nightfighter, are being met by improved engines. Other troubles, like window jamming, are now getting special attention during radar operator schooling. At both ends of the deal, crews and GCI controllers require involved and coordinated training.*

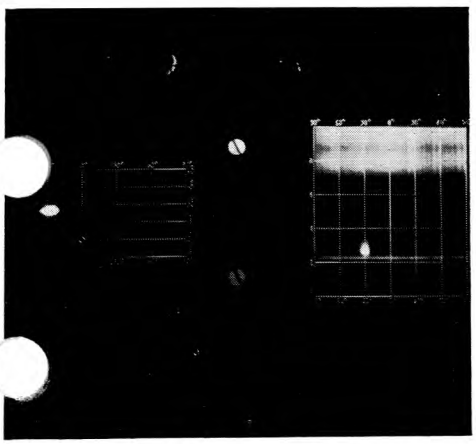
The AI set itself (SCR-720, now standard for AAF and RAF) doesn't do as much as the present state of radar development allows. It detects, but, lacking sufficient directional accuracy, doesn't allow reliable unseen fire. At the moment that deficiency doesn't mean much, for IFF identification uncertainties in most theaters mean the pilot has to fly up close for a visual anyway. But these conditions are bound to change and when they do blind firing AI radar will probably come into use.

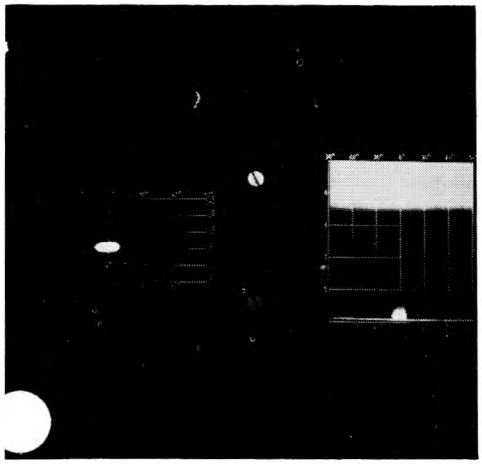
Once a strictly defensive art, nightfighting lately has gone on an offensive rampage in the ETO. Freelancing over Germany, Mosquitos and Black Widows ambush Junkers, Heinkels and Focke-Wulfs coming home to roost, empty their guns on truck convoys, trains and encampments.

In the Far East, whether from Navy carriers, Marine or AAF land bases, the job still is largely defensive. That may change as the tactical situation changes. All told, nightfighters the world over are a mere handful alongside their daytime brethren. But their effect isn't. Even when kills don't result, their threat serves to keep the enemy unnerved and sometimes grounded after dark.

The RAF, with some 25 squadrons in the ETO, plus more elsewhere, is tops in nightfighting. RAF crews, at it a long time, know all the tricks and make the best of their equipment. In 1944 their kills exceeded 500, compared to which the AAF total was a mere fraction. But AAF units, originally integrated with the British, are developing

* Nightfighting training will be reviewed in an early issue of RADAR.





Bogey now 4,000 ft., 30° port, 25° above. Altitude increase results as target takes evasive action. Below, close to the kill. Bandit dead ahead at 800 ft., 15° above



is now worldwide—and more and more it's on the offensive

on their own in the ETO, and in the Jap zones AAF, Navy and Marine units are building up for heavy work ahead. The AAF now has close to 20 squadrons in 7 air forces.* The Marines began on a small scale late in 1943. The Navy came in soon after and, between them, they have made around 60 kills.

SCR-720, since 1944 the standard Air Forces AI, is a 500 lb. S-band radar scanning 180° in azimuth and, with an RAF modification, allowing +50° to −20° in antenna tilt. Its reliable range under test conditions is 7 miles, although by and large contact is at 4 miles or less. The first operational AI, the British 1940 Mk III, had a maximum 2-mile range with bad fading part of the way. Mk IV raised the maximum to 4 miles and eliminated the fading. Mk V gave 5 miles. Mk VII centimeter AI, though it didn't increase range, removed the height-above-ground range limitation that had bothered long wave sets. Mk VIII, standard AI radar during 1943, boosted range to 6½ miles.

The Navy-Marine X-band AN/APS-6 —which follows the earlier AIA model— weighs 290 lbs. and gives 30% to 50% less range than its AAF contemporary. It provides a form of fire control but late reports indicate that Navy pilots still prefer visual firing.

Several ground radars supply the GCI function. In the ETO and MTO, for the AAF, it's usually the potent MEW (AN/CPS-1) coupled with a British height finder, or the venerable SCR-527. The RAF sticks mostly to British Type 25, which embraces one to 3 basic radars. In the Far East the need for compact, air-transportable equipment sometimes results in hybrids like the SCR-636 (SCR-527 receiver and SCR-602 transmitter) which has earned its salt with the 14th AF.

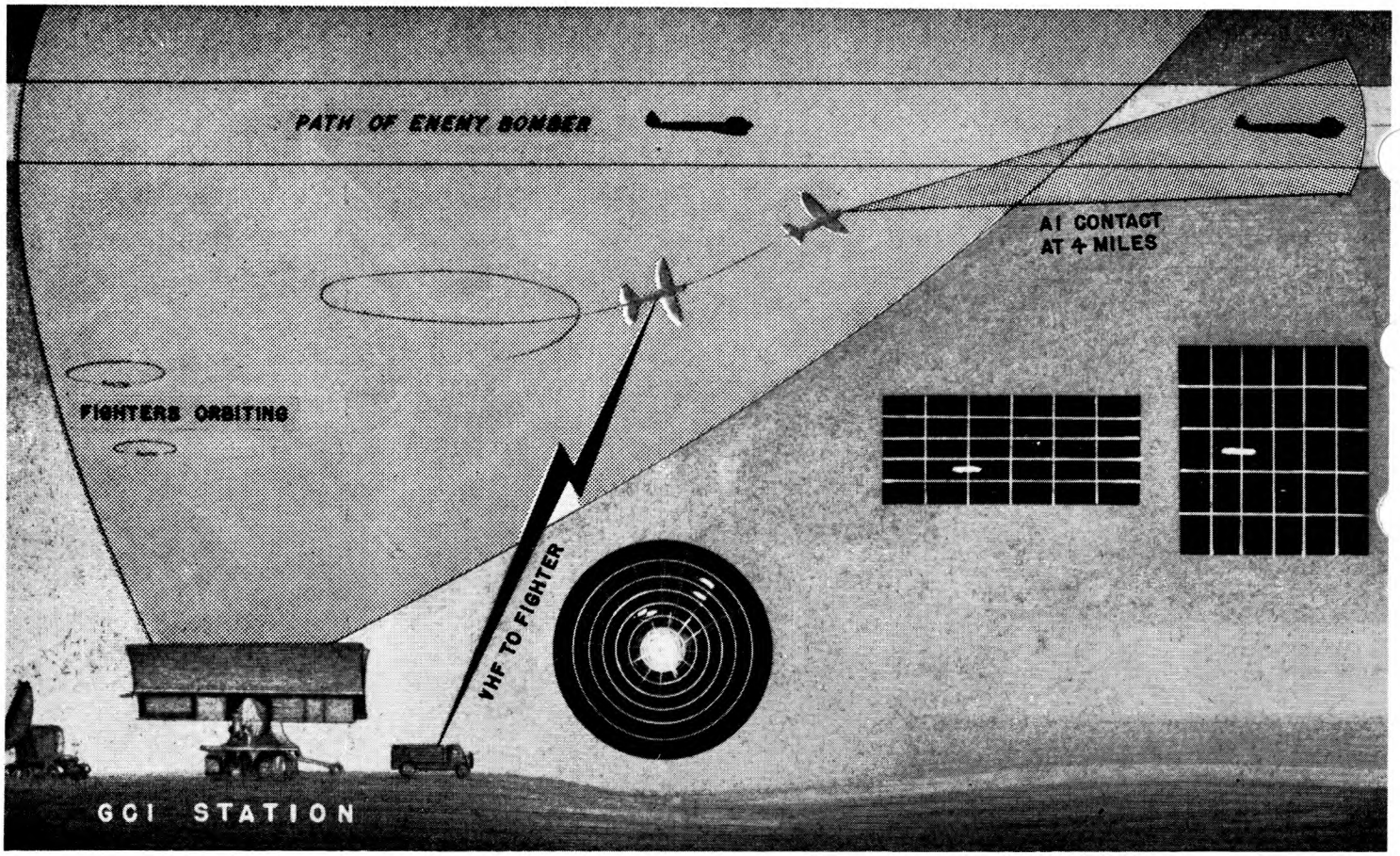
Components of the art are discussed on the next 5 pages.

*5th, 7th, 9th, 10th, 12th, 13th, 14th.

75 RAF contacts: findings

Right now the best nightfighting combination, in terms of results, is probably an experienced RAF pilot-radar operator team flying a Mosquito fighter equipped with Mk X (modified SCR-720). The following analysis is based on 75 contacts made by just such ETO teams during the fall of 1944:

1.	Number of contacts	75
2.	Number definitely destroyed	48
3.	Number probably destroyed or damaged	13
4.	Avg. AI contact range above 5000 ft.	4 mi.
5.	Avg. AI contact range below 5000 ft.	2½ mi.
6.	Avg. visual contact range	525 yd.
7.	Avg. visual identification range	250 yd.
8.	Avg. range at which fire opened	180 yd.
9.	Number times evasive action reported	32
10.	Number aircraft destroyed or probables despite evasive action	24



"TRADE" TO "JOY" TO "KILL", HERE IS THE PICTORIAL ACCOUNT OF A NIGHTFIGHTER CHASE. AFTER THE AI CONTACT THE FIGHTER IS ON ITS OWN.

On the ground and in the air, nightfighting calls for close teamwork

In nightfighting parlance, there's currently plenty of "trade" (enemy suspects) but not so much "joy" (enemy identification). That's different than the 1941 era, when anything that moved over England at night was fair game.

Today Allied air forces dominate the skies over the Western Front and beyond; 9 out of 10 bogeys turn out to be friendlies . . . which makes the snowballing score in kills quite impressive. The meagerness of Nazi night action was emphasized during the big German offensive in the last days of 1944. Beaufighters, equipped with Mk VIII and directed by SCR-527s, were under orders to protect the night withdrawal routes at all costs. They found little to do. Later, when the situation was reversed, Allied fighters had a field day intruding into Nazi withdrawal columns.

The bogey caught in the GCI coverage is up against a hard-to-beat combination. Unless he's too fast or has tail warning, or both, he finds that the pinpointing GCI plus the efficient AI generally outmatches him. And even with his advantages, when he has them, he's frequently caught.

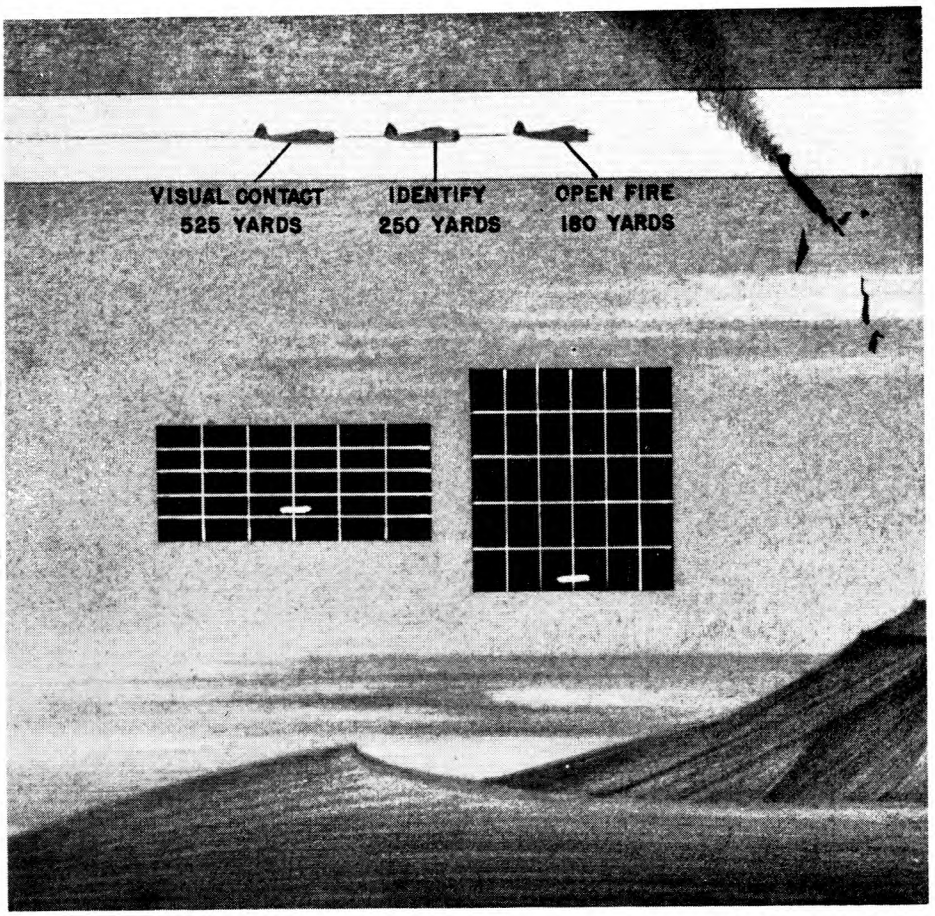
One substantial reason for increased intruder action, which often carries outside GCI range, is the feeling in many quarters that bringing down bandits in forward areas, before they can do any damage, should be a nightfighter's main mission in life. If they break through let the AA batteries take over, while the fighters stand clear. That's a direct parallel to the work against the buzzbombs, when fighters chased the bombs up to a certain point, after which the AA guns got busy.

In the Pacific, especially, night fighters and AA have learned to work very closely together. Jap bombers, chivvied by night fighters up to the target area, are then blasted by 90 mm fire controlled by SCR-584 or SCR-545. If the bandits leave the target area, the nightfighters again take over. Sometimes, for variety, dayfighters in conjunction with searchlights insert themselves into this chain of destruction.

The 2-man nightfighter teams—pilot and radar operator—used on all except F6F carrier-based aircraft, are an interdependent unit. They train together, live together and work together like members of a basketball team. They work against an alerted enemy who's always wary of an interception.

The radar operator tunes in fast when the controller gives him "Punch" (meaning it's about time for a contact); as soon as the contact is made he replies with "Judy" (meaning he's taking over the interception). From that point to the visual contact the RO directs the pilot while the GCI controller stands clear.

Five years of combat have taught RAF nightfighters that it's best to let the RO handle all the radar, although the pilot has his own scope. They reason that the pilot has plenty to do without reading the scope; besides, looking



DISTANCES ARE RAF AVERAGES. PPI SPOTS SCENE FOR CONTROLLER; OPERATOR USES AI SCOPES

at the lighted scope has a detrimental effect on his ability to see in the outside darkness.

Despite this, Navy nightfighter pilots in F6Fs, who have no alternative, have learned to fly by the scope even at extremely low altitude, never looking outside until they arrive at almost point-blank range. Perhaps the extremely good night visibility often found in the Pacific makes the switch from scope to sky somewhat less hard for the eyes to handle.

Both ends of the occupation—ground and air—involve the skills of daytime interception, plus a lot more. There are schools for nightfighter teams overseas and in the U.S. There's a separate school for controllers.

The airborne team takes what it's taught into the air, and then gets another heavy dose of learning there. It faces tail warning devices, evasive action, enemy fire. The pilot has to watch his fuel supply like a hawk; it's easily overlooked during a chase. He has to make positive identification. He has to get home and land by night, often from outside the range of his homing SCR-729 or other effective communications. The RO is responsible for holding the AI contact, leading the pilot to the visual, reading through any window jamming. He's got to know the radar business and read his scopes trigger-quick.

Along with everything else, a low altitude chase over rugged terrain—not uncommon as the bogey takes evasive action—is particularly hazardous. Protection here is the absolute altimeter AN/APN-1.

Since nightfighters have become offensive weapons, their home bases often are forward airfields lately taken from the enemy and partly repaired. That means takeoff and landing conditions which, added to the night hazards, aren't pleasant to contemplate. Carrier-based F6Fs, which sometimes stray a long way from home, have to locate their floating bases in the darkness or else. Taking one consideration with another, the night fighter's job is not an easy one.

The ideal in nightfighting would be control by ground radar everywhere. In practice, this is becoming increasingly impossible, for the best of the radars for GCI can't follow a fighter beyond 100 miles, and intruders are constantly poking their noses into alien nooks and crannies.

At present the best GCI comes from the MEW, which gives the AAF Black Widow squadrons under its control in the ETO an advantage over the Mosquitos and Beaufighters directed by British Type 25. The advantage, however, is more than neutralized by the RAF's very extensive ground and air experience.

The MEW gives range—lots of it—and bearing. In the ETO it is augmented by British Type 13 for heightfinding; in the MTO and the Pacific SCR-615 helps out. MEW's traffic-handling ability is prodigious. Supplied with VHF channels for ground-to-air communications—the number is elastic—one MEW can handle a number of GCI jobs with the dexterity of a professional juggler.

For the RAF, type 25 may be any or a combination of the following:

(1) Type 15 (low frequency) with PPI for range and bearing and an "A" scope for height. In the absence of jamming it's an especially easy set to handle and needs no supplementation.

(2) Type 11 (medium frequency) for range and bearing and Type 13 (high frequency) for height.

(3) Type 14 (high frequency) for range and bearing and Types 13 or 15 for height.

When all of these setups are employed in Type 25, two combinations do interception and the third reporting. Some unit is working every hour around the clock while one or both of the others are down for maintenance.

In many parts of the world, the old SCR-527, not quite up to its newer competitors, still holds forth. It does GCI alone but is handicapped over rugged terrain. SCR-636, a hybrid, is appreciated in some CBI locales—despite its shortsightedness—merely because its light weight allows it to be there at all. SCR-584 has also been known to help in nightfighting GCI in more than one advance theater.

On patrol, a nightfighter is nearly always under the watchful eye of the GCI controller. Like a police car touring its beat, it hurries to the scene of action at the controller's bidding, then goes back for another spell of patrolling pending another alarm.

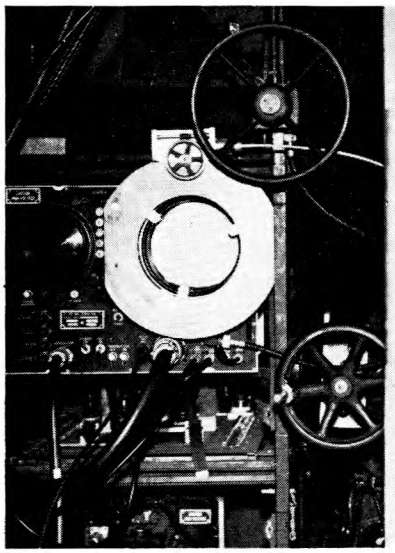
For a detailed report of what happens on a nightfighter's beat, see page 50.

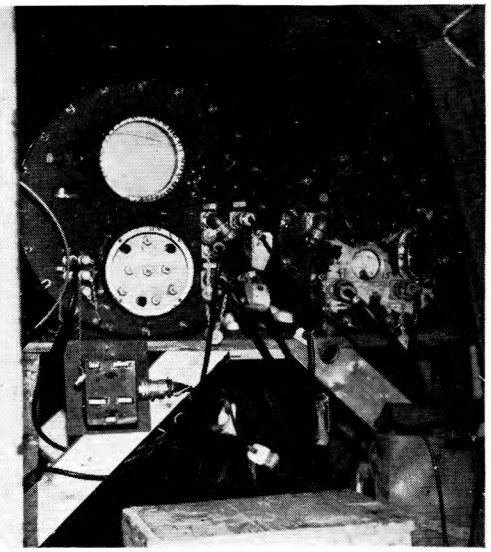
GCI in Pacific areas poses special problems; one answer is given here

A light, portable, battle-scarred search set that has kept an eye peeled for enemy raiders in defense of many a Pacific beachhead is AN/TPS-1. The TPS-10 (Li'l Abner) is a highly regarded X-band newcomer—the first 40 are just off the line—that gets its nickname for its virtues in mountainous terrain. Put together to make the small-scale GCI setup shown below, they loom as a promising answer to some of the troubles that plague Pacific and Far East commands in their search for light, accurate equipment that will work anywhere.

For GCI, the combination is capable of about 40-45 miles, good enough for minimum defensive interception. It can be set up in less than an hour, and combining the 2 equipments presents no complications.

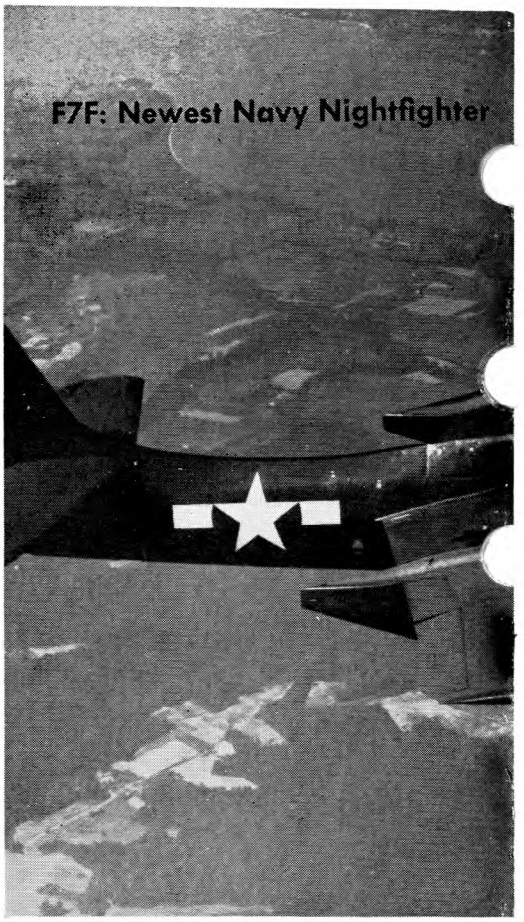
These winning qualities may not weigh so well in other parts of the world; other GCI equipment is better over leveller ETO sectors, where light weight, portability and narrow beam vision aren't the most vital values. In GCI, as in every other radar application, no gear will fit all feet.







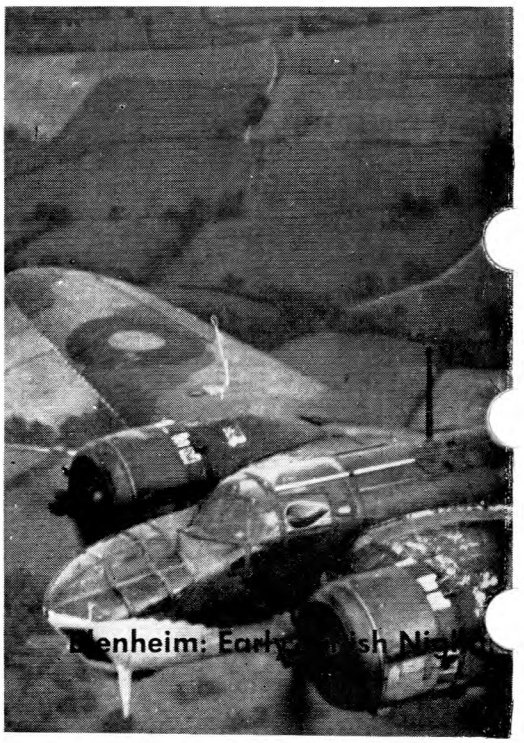
TPS-1 and TPS-10 are easily teamed. At top, TPS-10's control wheel, between scopes, can be used by either operator. "Azicator" on PPI gives sets same bearing when needed



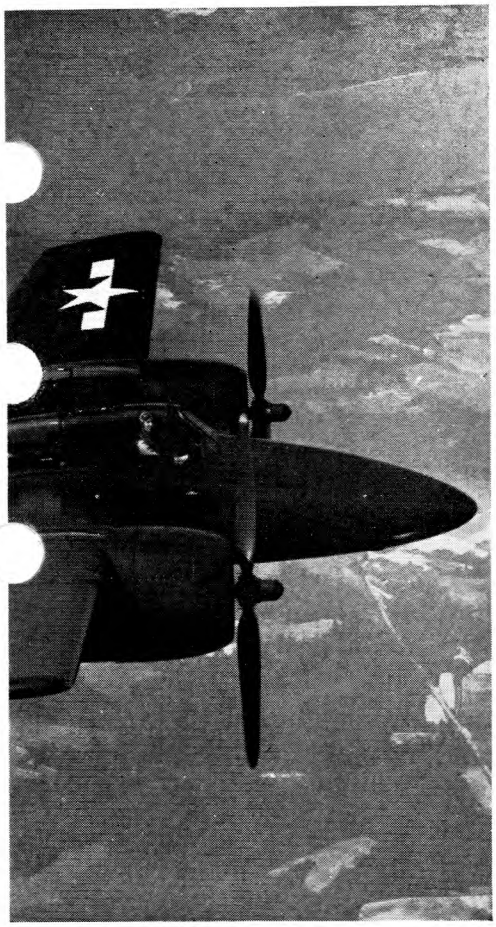
F7F: Newest Navy Nightfighter

AI: chronology

The history of nightfighting AI, which in 1941 had much to do with the successful defense of England, is mostly British. First combat equipment was Mk III (Mks I and II never became operational) in 6 squadrons of converted Blenheims (*see cut*). They made few kills. Beaufight-



Blenheim: Early British Night





Mosquito: Best British Nightfighter

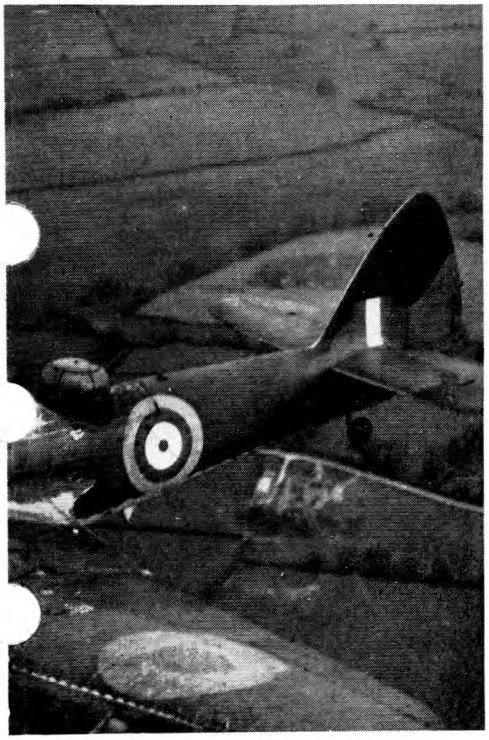
ers, built for night work and teamed with Mk IV in 1941, did much better. Beaufighter squadrons, once 2, grew to 19.

England saw the first U. S. centimeter AI in 1941, a bulky laboratory prototype of SCR-520, parent of 720. The RAF was impressed, but not with the packaging.

Mk VI, fully automatic version of Mk V for single-seater fighters, had a brief career in Defiants and Hurricanes. Mk VII, operational in Beaufighters in 1942 (*see cut*), marked the changeover to microwave AI. In production it became Mk VIII, the standard 1943 equipment.

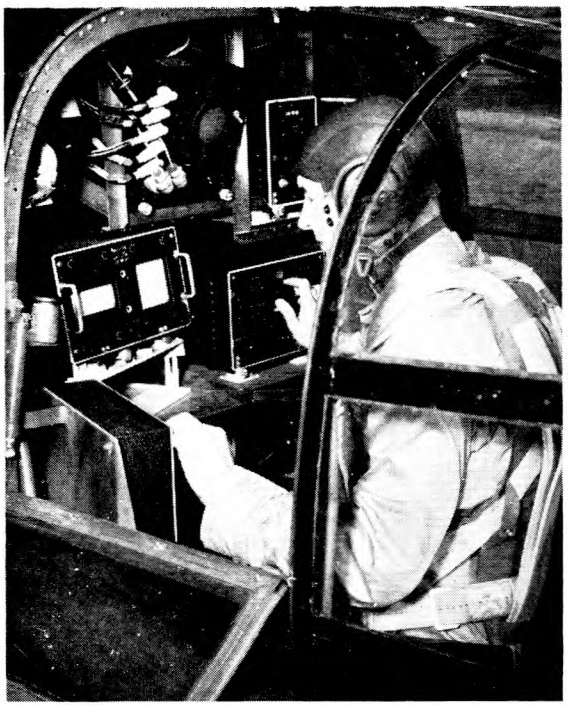
The first nightfighter Mosquito, using Mk V, saw action in 1941. A standby still, it has been fitted through the years with a succession of AIs. Today Mk X, a modified SCR-720, is its teammate (*see cut*). SCR-720 has been standard for both British and U. S. since early 1944.

The Navy and the Marines began their nightfighting late in 1943, now are neck-deep in it. Both use X-band AN/APS-6, an abbreviated AI equipment, with carrier-based F6Fs and twin-engined F7Fs.

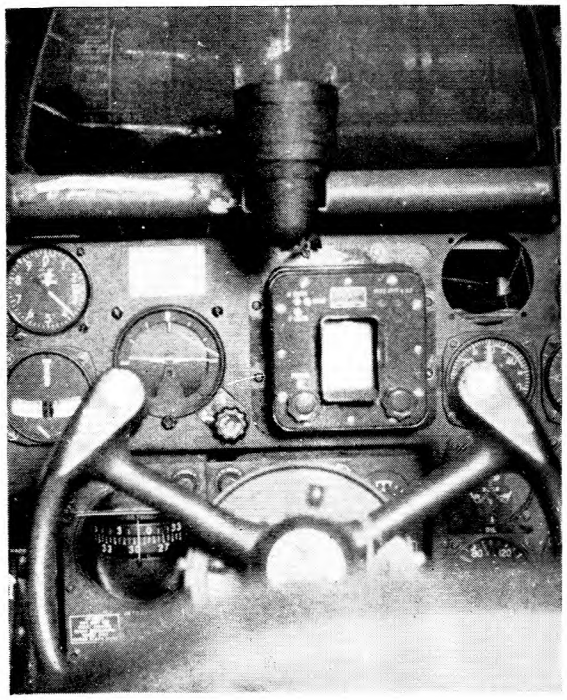




Beaufighter: at it since 1941



RO, in rear cubicle of Black Widow, usually tries for contact on signal from controller. He directs pilot from AI to visual recognition via intercom. Here he works 720 while watching "B" and "C" scopes



Pilot's night vision may be affected by alternately watching remote scope and probing darkness. Most RAF vets won't use it, many AAF pilots do. Navy F6F pilots have no choice; they operate singlehanded

"Punch" and "Judy"

A nightfighter at work, based on reports of an actual ETO interception

At 2015 the Tomcat was airborne. 1st Lt. Bill Rainey flew it and F/O Walter Jablonski, behind, operated the radar. Its twin radial engines sang evenly as they swept through the evening. The Tomcat was a P-61 nightfighter; its radar was SCR-720.

The MEW controller took the Tomcat east on 080 vector. "Trade," he said. But after 11 minutes of hot pursuit the tip turned out to be a friendly. Business was slow for awhile, so the Tomcat settled down to humdrum patrolling. On other nights it intruded into the Saar, ground strafing, maybe tracking an HE-111 or a JU-87 home. This night it was sticking to the GCI pattern.

At 2203 the MEW reported trade eastward and the vectoring started again. The idea was to bring the Tomcat close behind the bogey, cinch the contact. But the unknown was in a hurry. Reluctantly, the controller let him go Reichward, called off the chase. Some of those babies could really travel.

"Looks like a dull night," remarked Jablonski after some more patrolling. He spoke too soon. The controller was back again, calling them northward. "Bogey near Russell", he observed, matter of fact. If the suspect maintained altitude the Tomcat would have to drop 4000 feet to come in dead astern. Jablonski flashed his weapon, but he was too early. The controller, at his PPI, kept feeding dope to Rainey unhurriedly. He was an old hand. "Punch," he said finally. It was time for the RO to make the contact.

"Judy!" yelled Jablonski. He had taken over the interception. A split-second later his heart sank as the fleeting indication vanished from the "B" scope. Then it came back, 4½ miles at 2 o'clock. The Tomcat closed in fast, with Jablonski calling instructions over the intercom. "Throttle back," he shouted, "you're doing two to his one." The pilot came back hard.

At 1500 feet he had his visual. It was dead ahead, one o'clock. Then the bogey started evasive action, turning hard to port and diving. "Tail warning," thought Rainey. He followed down to 1700 feet. Then the bomber turned hard to port, climbed, and Rainey followed, closing in as the bogey levelled. Now the pilot used his night glasses, eager for the identification. It was a Stuka, no mistaking that. He moved up a bit and opened fire. The Stuka dived to port, jettisoning a fat bomb on the way.

A moment after the first burst the wing roots caught fire and the undercarriage dropped off and drifted lazily through space. The bandit turned on its back and went into a crooked spin and then, in another moment, it crashed.

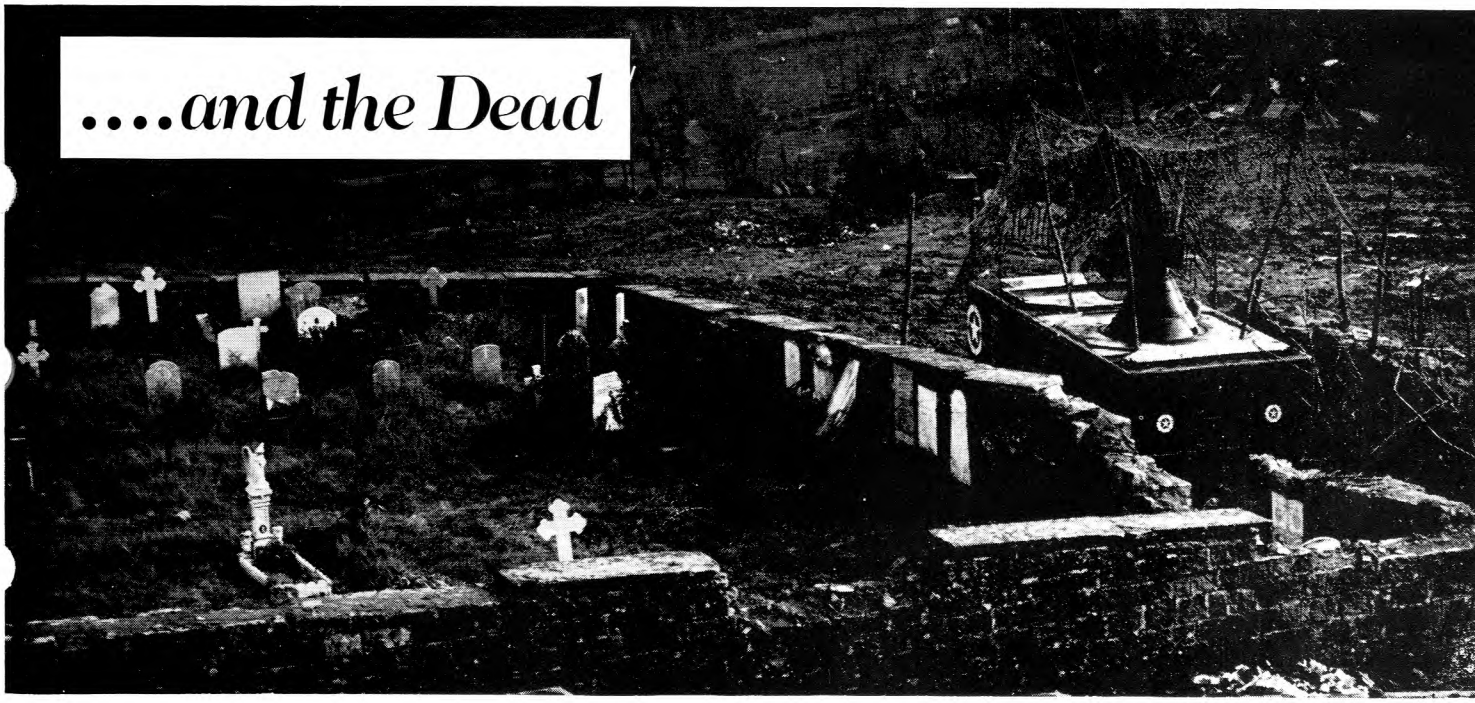
How to be a Nightfighter

As a trade, nightfighting demands very special training. It emphasizes a high order of coordination between pilot, radar operator and controller. How this team trains will be discussed in a forthcoming issue of RADAR.



The Quick

In an abandoned farmhouse near the Italian front Pfc. Calvin O. Belcher plots data from an SCR-584 set up by the protecting wall of a quiet cemetery nearby. Pfc. Stanley Kielian phones on the findings. Data in this case are presumably for early warning, into which the 584 is usually tied. Fire control information is passed on to gun units automatically through the M-9 director



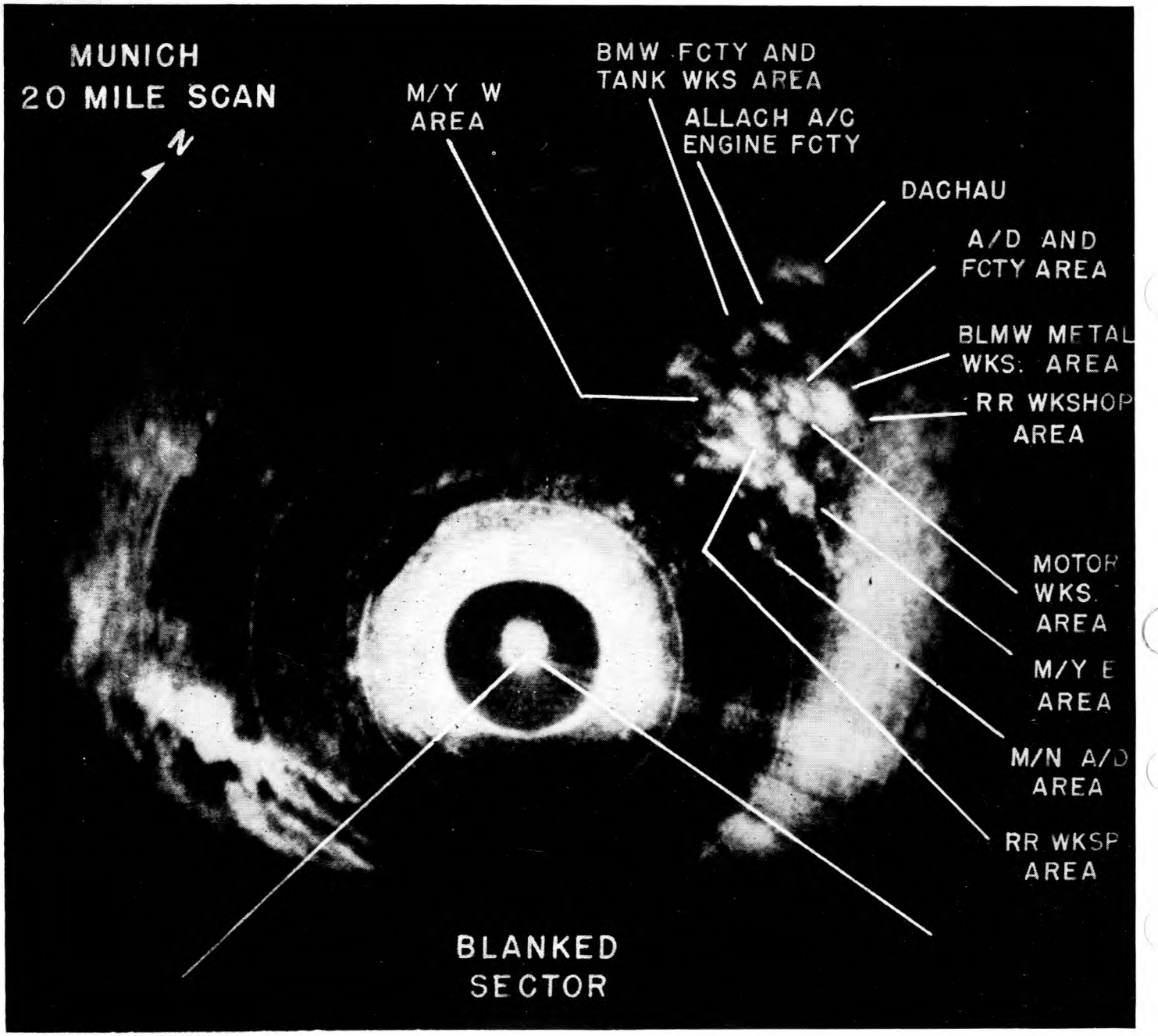
....and the Dead

PORTRAIT OF A DOOMED CITY

Munich, the womb of the Nazis, after 5 years of war seems slated to become the fortress city of their final stand. To Munich and the mountain-protected area around it, Nazis are fleeing as Berlin goes down under Soviet pressure and U. S.-British bombs. Here is the city as laid out on the scope of a 15th AF radar, and as marked out for bombing by the 15th's skillful intelligence officers. Munich has felt the impact of radar bombing many times already from U. S. airforces. The number of times Munich has yet to feel that impact may be, pretty accurately, one measure of the days remaining to the war in Europe.



The PPI photo below, made from a modified P-38 on reconnaissance, is an A-1 entry in radar's target information file. Good check points (e.g., Lake Wurm), city contours and specific sections are all clear. Nose installation of APS-15 causes blanked area



FERRANTI Defence Systems Limited

RADAR

Issue No. 9 APRIL 1945

INTRODUCTION



R.P.F. Lauder
Engineering Manager
Product Support Department

After 1942 the American airforce gave much less priority to night fighting than did the RAF. However night fighting was used and exposed the problems of both men and equipment in this most difficult of the warlike arts.

The earliest British Airborne Intercept (AI) radar was the ASV Mk.II and its American counterpart – SCR 540. These both suffered from the limitations of the operating frequency around 200 MHz. Two pairs of receiving antennae were provided, one giving overlapping polar plots which gave error signals in azimuth. The second set gave error voltages in elevation. The receiver was rapidly switched between these dipoles, and two displays showed the amplitude and sense of the angular errors in azimuth and elevation, and each gave range.

Although the overlapping lobes gave quite accurate angle indications off the boresight, the primary problem was that each lobe was so wide at the low frequency used and the lower elevation dipole produced such large signals from the ground beneath the plane, that targets could not be seen at a forward range greater than the altitude at which the aircraft was flying.

This was such a serious operational limitation that there was great pressure to develop a microwave version which would fit into the aircraft nose and provide a sufficiently narrow beam to avoid contact with the ground in level flight.

The SCR 720 reported on in this volume was the result of this pressure. It operated at a wavelength of 9.1 cm and provided a 10° beam from its 29 inch parabolic antenna. This was sufficiently narrow to see co-altitude targets at much greater range than the interceptor's own altitude. The paraboloid was continuously scanned in azimuth and slowly tilted in elevation. The resulting helical scan covered 25° in elevation.

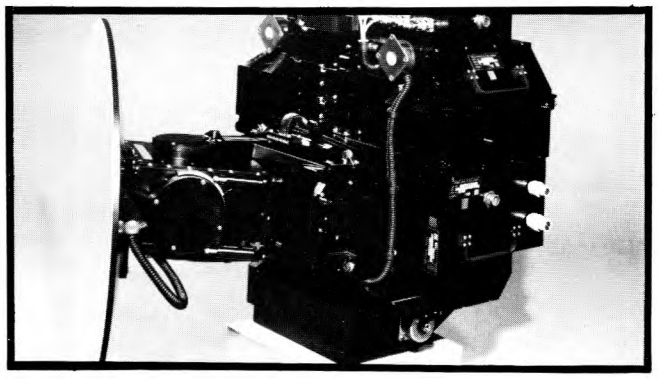
Two types of display were provided. The Radar operator had a B-scope giving targets in range-azimuth. He had a moveable marker under control of his hand wheel which extracted the video signals from a range interval centred on the marker and fed them to a C-scope. This mitigated the poor signal-to-noise characteristics of the C-scope and it was repeated for the benefit of the pilot. The pilot also had a range meter operated by the radar operator which allowed him to gauge the progress of his interception.

We must realise that this radar never locked to the target and was always in scan. However a tracking AI radar called SCR 702 was developed. It was basically a lightweight version of the SCR 584 and was manufactured in small quantities but never used in the war even though it had been highly regarded by the aircrew who used it.

In the business of determining wind speed and direction at various heights, meteorological balloons were – and still are – used. It did not take long to realise that radar was the electrical equivalent of the optical theodolite, provided that the balloon could be enhanced in the electrical sense to make it a good radar target. Considerable ingenuity was used to interrupt the CW signal transmitted by the balloon by a barometric switch or switches set for various heights.

The old SCR 268 mentioned in this volume was first demonstrated to the US Secretary of War in May 1937 and operated at 205 MHz. An array of 4 x 4 dipoles and reflectors gave a beamwidth of about 29" in both azimuth and elevation. The return echoes were received in separate dipole stacks. The azimuth receiver was six dipoles wide by four high, while elevation had two dipoles wide by six high. Again overlapping polar diagrams were used to make accurate angular determination. This was achieved by having two separate feeds to the antenna stacks arranged to change the phase of the dipoles. By switching rapidly between the feeds, the overlapping lobe pattern was realised.

The whole arrangement rotated in azimuth about a central pedestal and carried 3 operators with it, a range operator and an azimuth, and an elevation controller. The range operator had a range hand wheel to track the target and this movement was fed to a so-called "height convertor". This was an analogue computer containing a three dimensional cam to make the trigonometrical calculations needed to establish height.



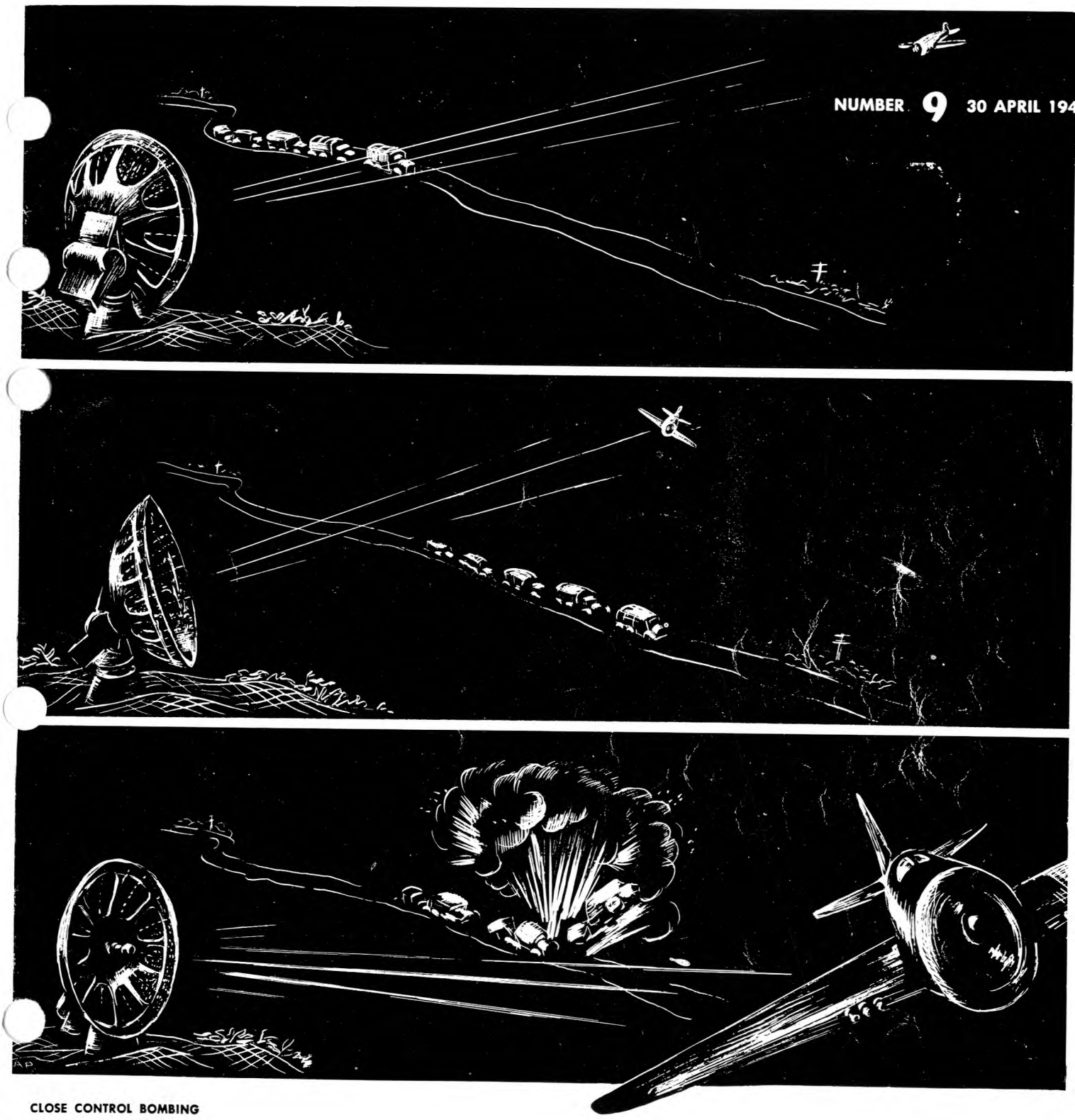
BLUE VIXEN

Blue Vixen is one of the latest Ferranti multimode pulse doppler radars being developed for the mid-term update for the Sea Harrier, but also with application to the AV8B aircraft and other Harrier derivatives.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

PSD

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RADAR

RADAR

Number 9 30 April 1945

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EDITOR: Dexter Masters, Office of the Air Communications Officer.

CONTRIBUTING EDITORS: Dr. David T. Griggs, Hq. USSTAF (Paris); Dr. L. J. Henderson, Hq. USAAF (Caserta); Dr. L. C. Marshall, Hq. USAFPOA (Oahu); Col. P. C. Sandretto, Hq. AAFPOA (Guam).

EDITORIAL ASSOCIATES: Avis Clarke, Ruth Copland, 1st Lt. Norman R. Goldman, Dallas Johnson, Lucie Sewell, 1st Lt. Robert Wright.

CORRESPONDENTS: Sgt. John Caldwell, S/Sgt. Rob't Carlson, John Garfield, Hq. USSTAF (Paris); J. Alexander, Hq. AAFPOA (Guam).

DRAWINGS by Presentation Branch, Office of Strategic Services.

ADVISERS: Lt. Gen. Barney M. Giles, Chief of Air Staff; Dr. E. L. Bowles, Special Consultant to Commanding General, AAF; Dr. Lee A. DuBridge, Director, and Dr. Louis Ridenour, Radiation Laboratory.

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While we're on the subject

● Much to the relief of many radar operators who thought they were slipping, several reports have come in recently to explain those moving echoes sometimes seen on a scope when there is apparently no moving target to get an echo from. The answer is, in a word, birds. At a site near Foggia, Italy, a flight of ducks was picked up by a 584 one day and automatically tracked across the airfield. Early next morning, so it is reported, an enterprising T/Sgt. was caught mounting a shotgun to the antenna parabola.

● A few long-awaited production units of Ground Control of Approach equipment (AN/MPN-1) are now set up and working in the ETO. By the beginning of this month, 3 of the sets had made well over 100 indoctrination approaches, over a dozen emergency assists. Like the one at Iwo (see page 4), these already are paying off on the cost and effort it took to get them out. One of the emergency cases called for bringing down two P-61s returning through soup from a mission. The pilot of the first, when asked at what altitude he broke through the overcast, replied: "I didn't—I just felt a strong bump and I was on the runway". When the second plane was brought in visibility was so bad that the pilot couldn't see from one runway light to the next. He had just 10 gallons of gas left.

● With strategic bombing ended in the ETO—as announced by General Carl Spaatz on 16 April—the heavies are making a quick transition. It's chiefly a transition in modus operandi, probably won't affect equipment. Besides, the B-17 and B-24 aircrews have gone tactical before. They did it on D-Day when they bombed the Normandy beaches, mostly with H_2X, destroying 190 Nazi coastal radars in the process. They repeated on other invasions. During the Germans' December breakthrough the 8th AF threw 8,000 bomber sorties against railroads, bridges, road junctions, air fields and other focal points in the Ardennes sector . . . 5,000 with H_2X, Micro-H or Gee-H. They were also supported by TAC ground radar (MEW and SCR-584) —as presumably, they will now be more than ever.

● *Correction* is hereby made of some statements relative to beacon bombing in RADAR No. 8, page 23. The saturation point of Gee-H is 80 to 100 interrogating planes per pair of ground stations—not 5. Although the Gee navigational system uses 3 ground stations, as stated, navigational facilities are also provided by the 2 Gee-H stations used for bombing. Reference to ground stations operating "unattended" was meant to convey only the idea that no ground control of aircraft is exercised. The saturation point of Oboe Mk II is one plane every 10 minutes—not 15—against one target per pair of ground stations.

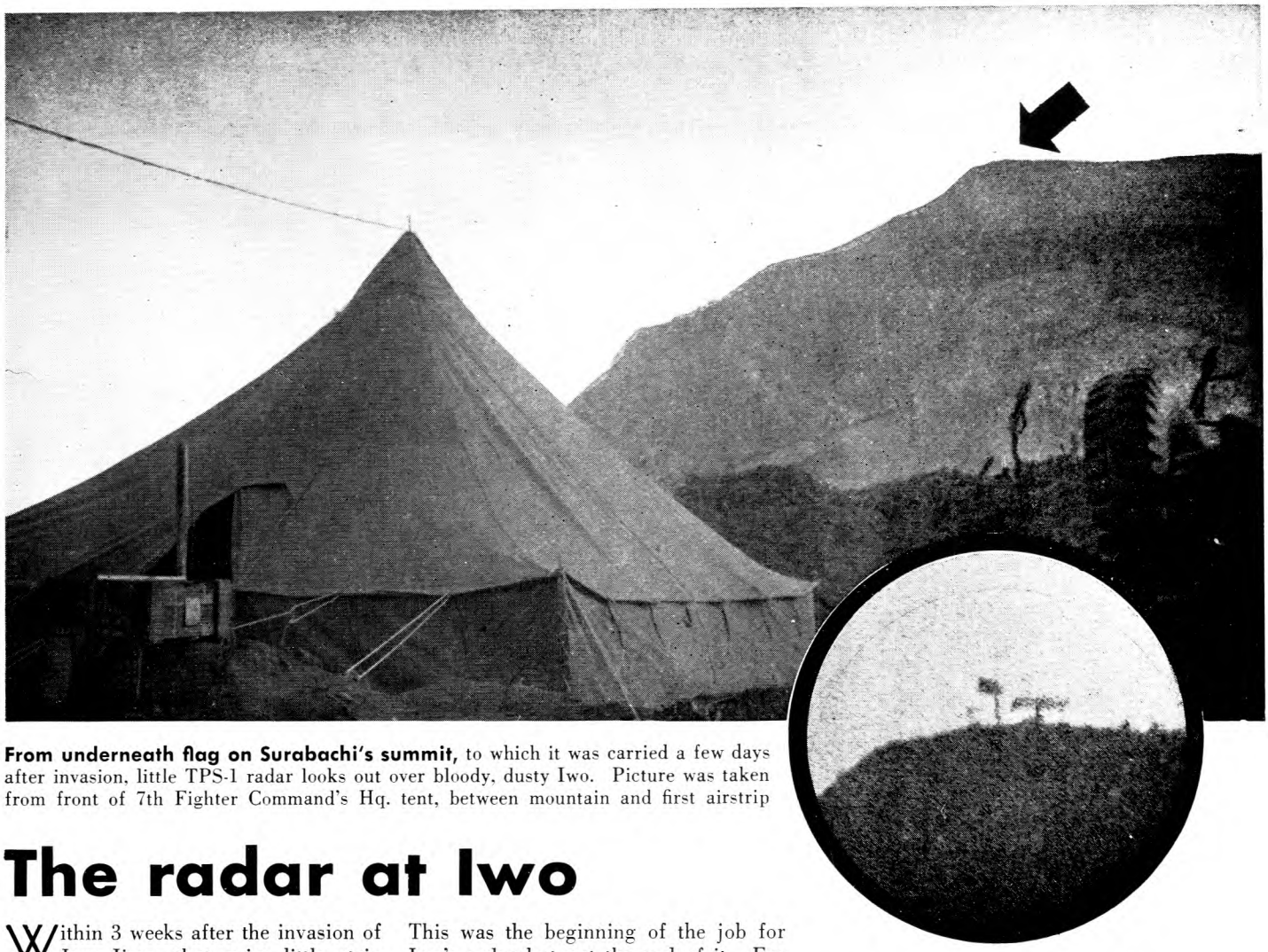
● *Apology* is hereby made to the 1st TACAF (Provisional) which is not a part of the 9th Air Force as seemed to be implied in RADAR No. 8, page 17. It is, of course, a separate and distinct AF, supporting the 6th Army Group.

● The following was noted in General Order No. 31 from the office of the CG, Hqs. USSTAF in Europe:

"Awards of the Bronze Star Medal for meritorious service in connection with military operations from 8 Sept. 1944 to 17 Jan. 1945.

S/Sgt. Robert B. Carlson ASN 16100247
Sgt. John H. Caldwell ASN 32867743"

Sgts. Carlson and Caldwell have been RADAR correspondents in the ETO since the summer of 1944. In the process of keeping tabs on radar developments and radar operations right where they're happening, Correspondents Carlson and Caldwell have moved around Europe a good deal. They're well known to AAF personnel from generals to ground crews. Congratulations.



From underneath flag on Surabachi's summit, to which it was carried a few days after invasion, little TPS-1 radar looks out over bloody, dusty Iwo. Picture was taken from front of 7th Fighter Command's Hq. tent, between mountain and first airstrip

The radar at Iwo

Within 3 weeks after the invasion of Iwo Jima, that grim little strip had been turned into the most heavily equipped radar site in the world. By that time the Japs were compressed into less than one of the island's 9 square miles. In the remaining 8, U. S. forces had brought ashore enough radar to provide coverage of one kind or another at the rate of roughly 2 radars per square mile. It is doubtful that all this was strictly necessary, but the Iwo campaign was neither built nor fought on a minimum basis. There was too much to be gained from possession.

The critical importance of Iwo's location midway on the B-29 bombing highway from Saipan to Tokyo set the problem which only radar could solve. The problem was that, for the first time in the long march through the Pacific islands, Iwo gave us a base around which Jap bases within reach could not be effectively knocked out or neutralized. That couldn't be worked at Iwo without putting the quash on Japan itself, only 700 miles to the north.

And so the defenses of Iwo had to be worked out to cover the possibility of regular attacks—at any time and in force. This was the beginning of the job for Iwo's radar but not the end of it. For Iwo was to be a fighter base, with the emphasis on nightfighters, and it had to start work at once. Headquarters of the 7th Fighter Command were established at Iwo even before we had the first of the airstrips. At the Fighter Command's insistence GCI (Ground Control of Interception) and GCA (Ground Control of Approach) radar came ashore as early as the rest, 3 or 4 days after invasion.

The big truck and trailer assembly containing the complex GCA equipment, complete with power and air conditioning units, was never meant for waddling across a shell-pitted beachhead in the middle of battle. Somehow this one managed. Despite reports filtering back to Oahu that it was damaged, as half of those who readied it back there expected, it got through unscathed. What was expected of it, it was shortly thereafter ready to provide for Iwo's dense air traffic: the security of safe and accurate landings in total blackout.

One other radar made its Pacific battlefront debut at Iwo: the TPS-10 or Li'l Abner, heightfinding companion to the SCR-527 in GCI work. Iwo has several 527s, all of which arrived on D-day.

By the time all early deliveries were in, Iwo's radar resources came to this:

AN/TPS-1s for low angle coverage (one of these was knocked out).

SC-3s (Navy) for search.

SCR-527s for GCI and search.

TPS-10 for GCI heightfinding.

SCR-584s for AA fire control.

AN/MPN-1 for GCA.

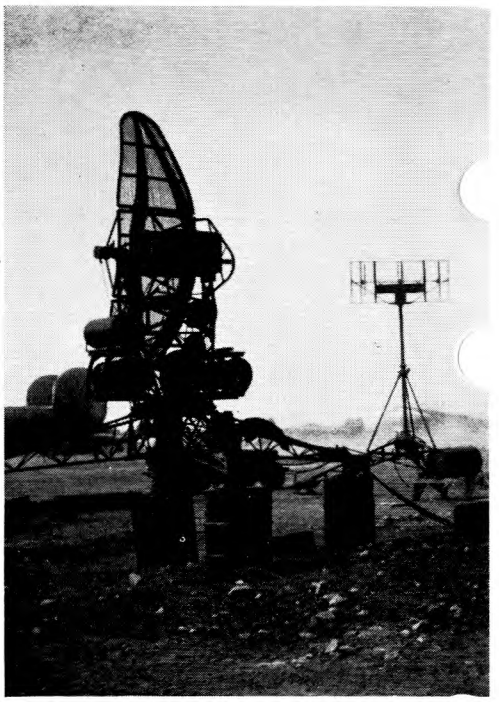
And then, on D plus 19, a load of SCR-270s for early warning was piled ashore. And meantime the bull-dozers scraped across Mt. Surabachi, preparing for the biggest radar of them all—the AN/CPS-1 (MEW). And offshore, in Navy ships, were still more radars. Plainly the Japs were going to have a hell of a time getting through all that.

With the MEW fully operative, Iwo's radar setup can be tightened up and some of the excess moved on. As the base settles down, the 568th Signal Aircraft Warning Battalion can have a more efficient Control Center; for the first month it functioned in a reconverted VHF van. But it functioned. For more on Iwo's radar, see next page.

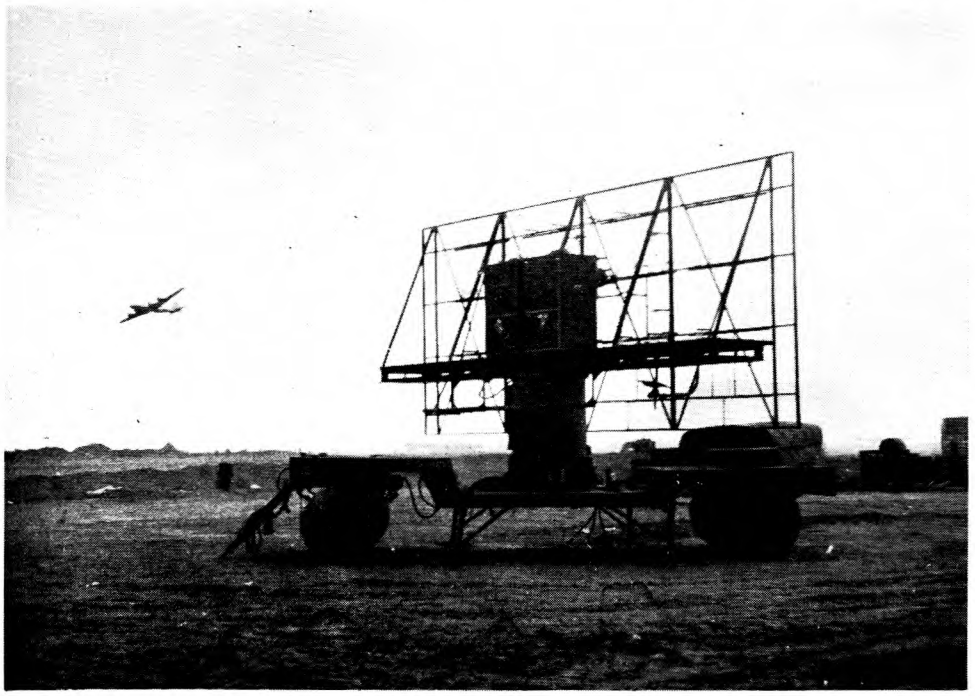
Iwo's radar: big pieces, little pieces, airborne, ground.



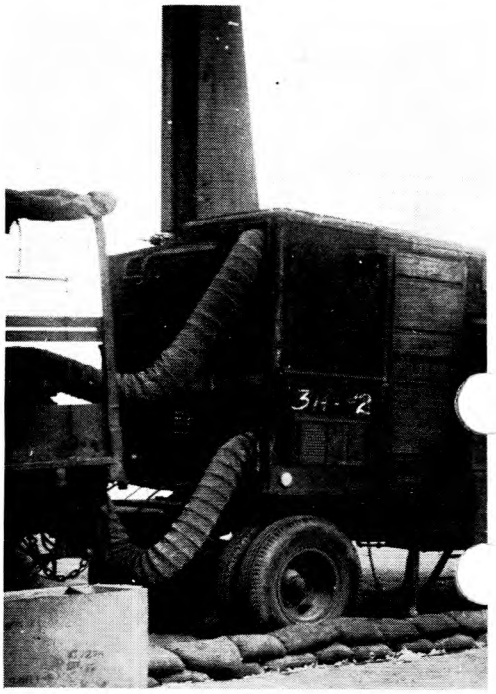
From Headquarters tent dug in behind pile of volcanic ash half mile from south airstrip, 7th Fighter Command directed its flocks of fighters pending permanent construction. Radar-nosed P-61 nightfighters did everything but nightfighting for first month as no Jap raids materialized. Then one came over, was routed before it could hit



Li'l Abner got to Iwo by way of Saipan, where it was given a 2-day trial and breaks in packing were repaired. In operation at Iwo power unit proved inadequate and had to



Iwo's middle is flat enough for critical siting requirements of SCR-527. Several came all the way from Oahu set up to operate in transit on LST decks and calibrated with LSTs full, empty and in between to meet all contingencies. Idea was OK, but with all the other radar on hand, no one got around to using it. After landing, 527s started work

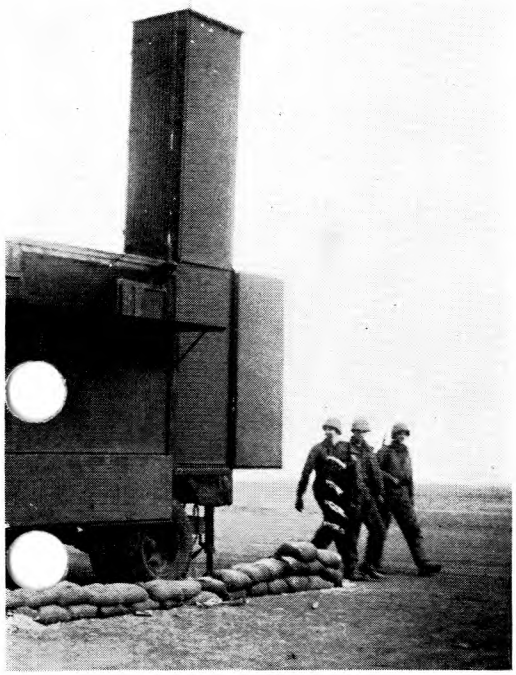


Complex GCA surprised everyone by getting ashore safely on D plus 3. Run by crews of Army Airways Communications System, the big equipment has been used to train

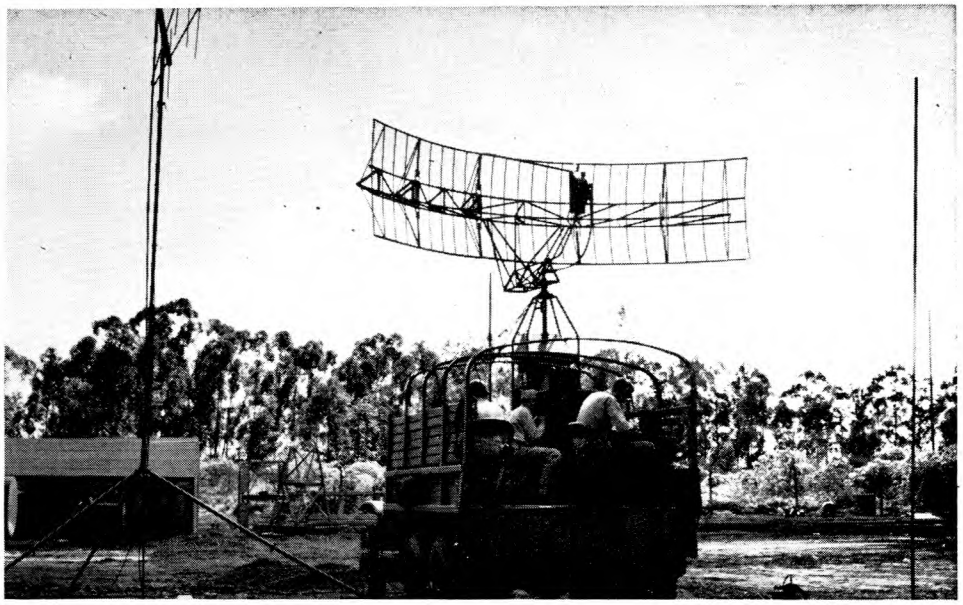
Here's a part of it



be built up. But performance has been tops. Lacking much GCI work to do as height-finding partner of SCR-527, it soon became one of island's most reliable search sets



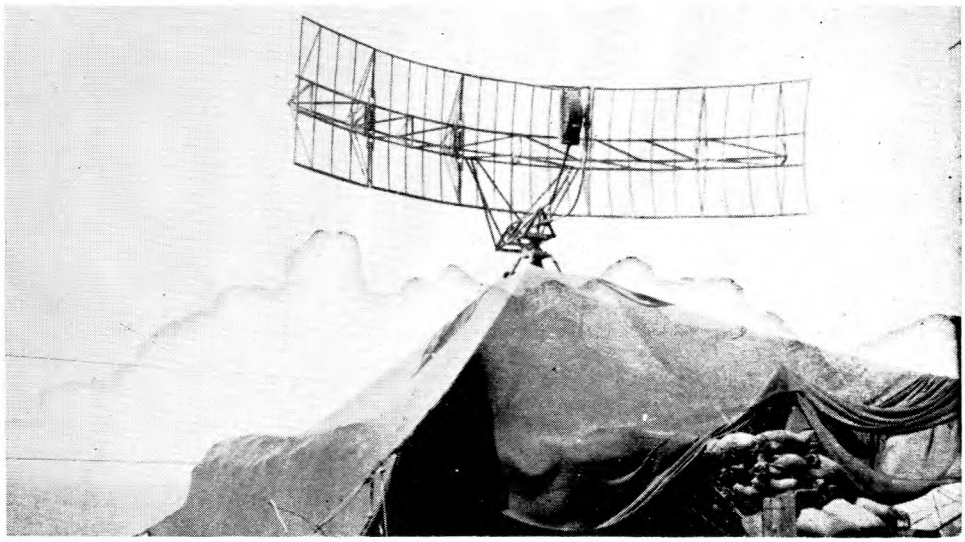
fighter pilots in blind landings. But early this month it paid its cost on a lost B-29, bringing the bomber in through a 100 ft. ceiling. Iwoans expect it to save many more



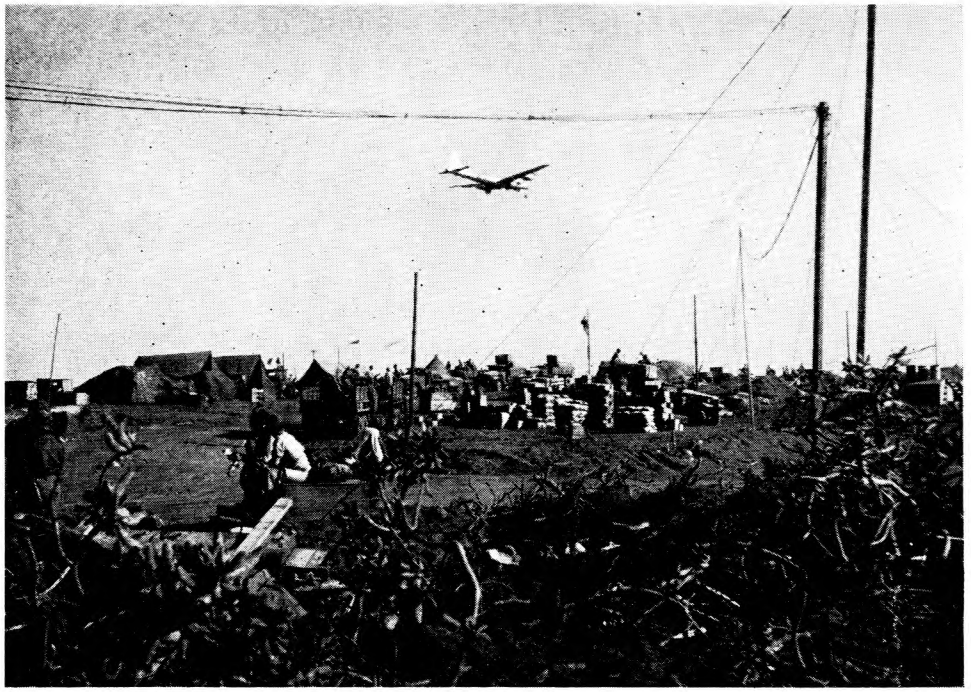
At Oahu TPS-1 was truck-mounted during training of crews who later took the light-weight sets into Iwo. Although this particular mounting wasn't used at Iwo, it was worked out specially for mobility under beachhead conditions, may be used later on



Across invasion beach, where Marines landed, all equipment has since come in. The TPS-1s were among first radars ashore. One went up Surabachi; one was hit; this one, when picture below was taken (D plus 20), stood guard north of airstrip, south of Japs



Iwo: B-29s and Piper Cubs . . . shell-pitted ash and dump heaps



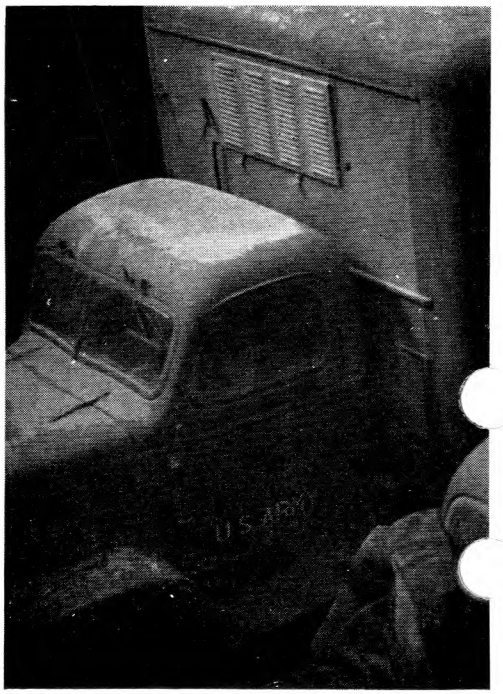
More than 30 B-29s, of which this is one, came in over Iwo's grimy, jam-packed landscape for forced landings on Iwo's inadequate airstrip during first 3 weeks. Some were suspected of forcing a landing so crews could have a look around. But many—short of gas or banged up—would have been lost in days before we had the island



Control tower, as inadequate as the airstrip, was up to its ears in fighters, bombers, transports until things got organized. So tight was the traffic that radar installations,

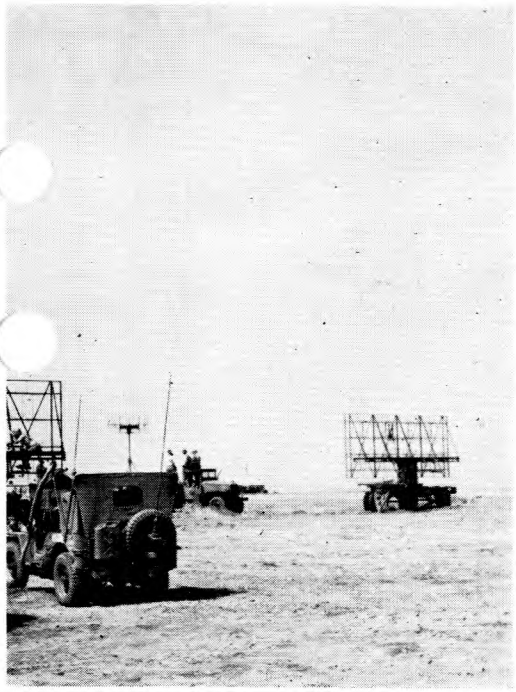


In the plane dump Jap casualties piled up fast. Meantime, in another dump, the Joint Intelligence Committee, POA, gathered up for analysis all the Jap radar, communications equipment, etc., it could get hold of. The Japs had quite a bit of radar on Iwo but preliminary study disclosed nothing startlingly new. Final report isn't in yet



Damage to U. S. radar, in view of the amount of it and the time it went ashore, was unexpectedly small. A couple of sets were knocked out, but this SCR-527 power

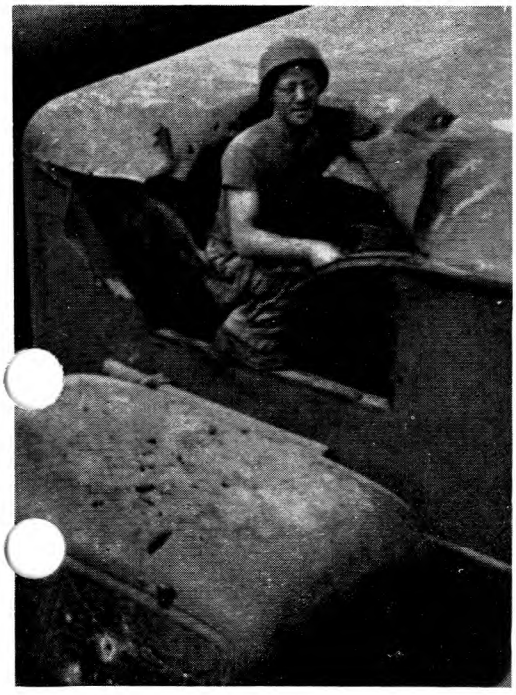
. . . and meantime, at Saipan, the start of another invasion



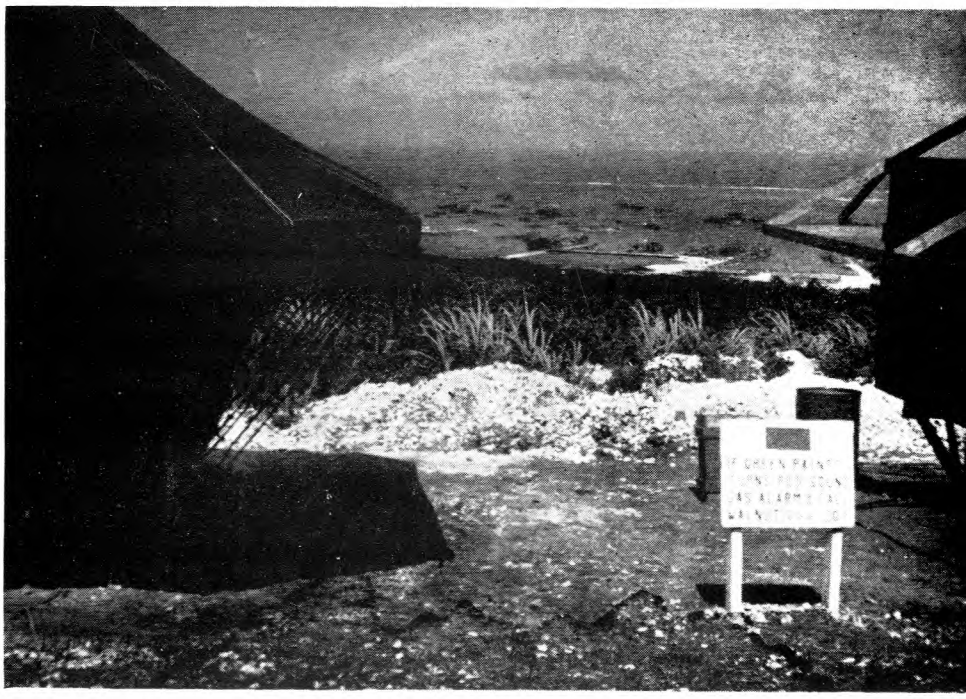
mostly near the strip, were upset. Corner reflectors to mark runway for GCA were obscured. Planes practically constituted permanent echoes for some of the radar sets



Terminal tent at end of airstrip bore island's only marker. In front of it, the day RADAR's correspondent took off, a Jap prisoner sat looking at what he could see: B-29s, B-24s, B-25s, C-47s, P-61s, P-47s, P-51s, Hellcats, bulldozers, jeeps, vans, trucks, 4 radars, several hundred Marines. Then he looked at the sign. Then he sighed



van, which looks as though it might have been, wasn't. A Jap mortar shell punctured it, hit into a lot of rations that had been stuffed into the spaces, didn't harm the works



Back at Saipan, base for B-29s whose bombing trips over Japan made Iwo's capture necessary, warships and transports were gathered for next operation long before cleanup of Iwo was over. RADAR will report in early issues on radar as used in the Ryukyu invasion, and on post-invasion radar developments both at Ryukyu and at Iwo



LT. GEN. HOYT C. VANDENBERG, CG, 9TH AF, oversees fast frontline cooperation between U. S. Armies and his 3 TACs. Similar work is accomplished by 1st TACAF.

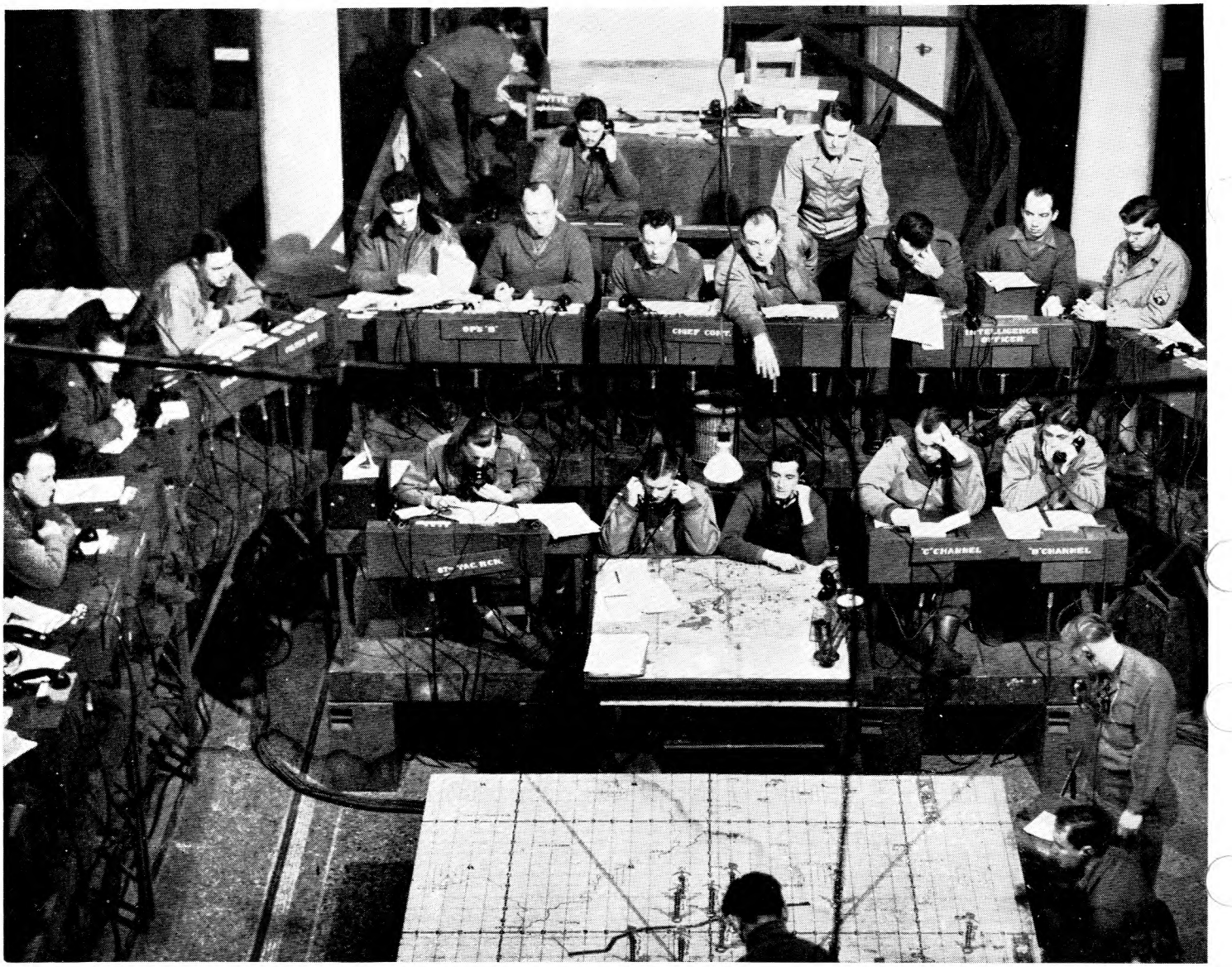


MAJ. GEN. O. P. WEYLAND, CG, XIX TAC



BRIG. GEN. R. E. NUGENT, CG, XXIX TAC

Fighter Control Center to MEW (or FDP) to SCR-584 is flow of action for typical close control mission in ETO. Controllers, plotters, intelligence officers here shown in FCC at





MAJ. GEN. E. R. QUESADA, CG, IX TAC

Command Post of IX TAC are cataloging and assigning flights for MEW and 584 control

Close control bombing

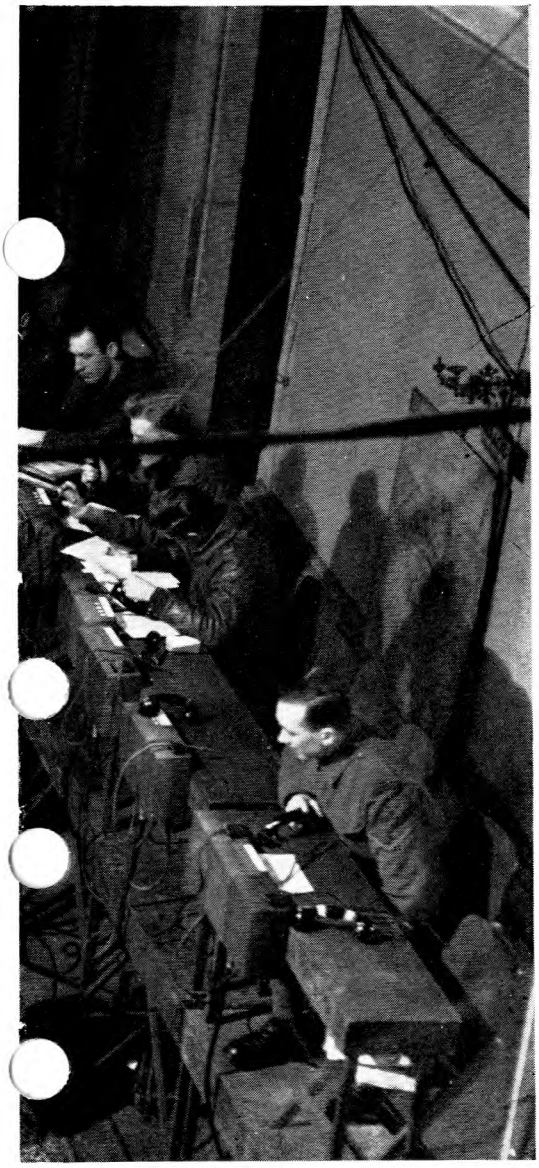
by Maj. Gen. E. R. Quesada

COMMANDING GENERAL, IX TAC

In the ETO, the emphasis on air operations which for most of the war belonged to the Strategic heavies has shifted to the Tactical Air Forces. The trend became increasingly apparent as the distance separating the Allies east and west diminished, as ground operations grew decisive. Then, on 16 April, General Carl Spaatz of USSTAF made it official by announcing the transfer of the B-17s and B-24s to tactical operations.

This is a field which the big bombers have plowed a couple of times before (see page 2). But the old hands are the fighter-bombers of the 5 Tactical Air Commands of the 9th AF and the 1st TACAF (Prov.), which have things pretty well in hand after the intense operations of past months. Increasingly, during those months, tactical operations have been emphasizing close control operations utilizing the talents of SCR-584 and its giant overseer, the MEW. To clarify just what close control means in the now all-inclusive tactical bombing picture, Maj. Gen. E. R. Quesada has written the following article for RADAR on the employment of SCR-584.

On the record so far built up by all the TACs, opinion of close control operations is generally favorable, often enthusiastic. But the record is far from complete, mainly because photographic assessments of bombing under SCR-584 control are largely lacking. Some strike photos have shown poor results; others, and many visual estimates, have been highly encouraging. That much effective close control work has been done, whatever its proportion to the total, is apparent from Gen. Quesada's article.



Of the many radar devices that the IX Tactical Air Command is currently using, none attracts more respect and attention than the SCR-584. To us the versatility of this equipment has become the key support for a large part of our operations. That it has had considerable influence on the conduct of our operations goes without saying, but I'd like to emphasize it anyway.

It is in the close control of aircraft that we have found the SCR-584 most useful. In this article for RADAR it is my intention to tell about some of the close control uses to which we have put this electronic device.

Necessity, which need not be described here, has on occasion caused our airdromes to be located as much as 75 miles behind the front lines, putting them as much as 300 miles from some of the tactical targets in which we were interested. Under these circumstances we frequently found ourselves with operational weather at our bases—in eastern Belgium and western Germany—and with non-operational weather in the target area—beyond the Rhine. The Strategic Air Forces have solved the same problem as it affects them by the application of various airborne equipments. We with the fighter-bombers could hardly hope to employ similar methods. But SCR-584 gives us a means of operating with an acceptable degree of accuracy from above the overcast.

Specifically, the SCR-584 has permitted us to utilize our full force on many occasions when operations would otherwise have been impossible . . . for example, when we have had a 1,000-foot ceiling with visibility of one mile at the base, and similar or worse conditions at the target area. Flak, as a general rule, precludes any possibility of operating with these weather limitations. However, a take-off and assembly on top can be accomplished with ease. Then, through the combined use of our MEW and SCR-584's, it is easy to direct our aircraft on a well-defined track to a selected target.

Inasmuch as the SCR-584 can control the aircraft down a given track with great precision, the only requirement remaining is the determination of the bomb-release point. We get that through the use of a Norden bombsight mounted in the radar van and tied to the plotting table.

Horizontal bombing above the overcast is now accepted as a normal operating procedure. Our daily Operations Order includes targets for this type of attack, and each SCR-584, of which we have six, is therefore able without further notice to control aircraft to appropriate targets as necessary. Naturally, when weather permits, visual operations are conducted, in which case the SCR-584 becomes a contributing and not a controlling factor. But there have been times—many of them—when a day of "full scale operations" has been possible solely through the use of this equipment. The application of SCR-584 to horizontal

Close control with SCR-584—who does what

Each SCR-584 is set up so that it can either assist in a close control mission or run a complete mission on its own. Main duties of 584 personnel can be broken down briefly as follows:

CONTROLLER determines sectors to be searched, VHF channels to be monitored. He locks in the plotting table, then gives instructions to the aircraft by VHF. For level bombing, he operates the Norden bombsight located in the van and synchronized with the plotting table.

RADAR MECHANIC turns on radar and checks plotting board. As chief trouble shooter, he makes all emergency repairs.

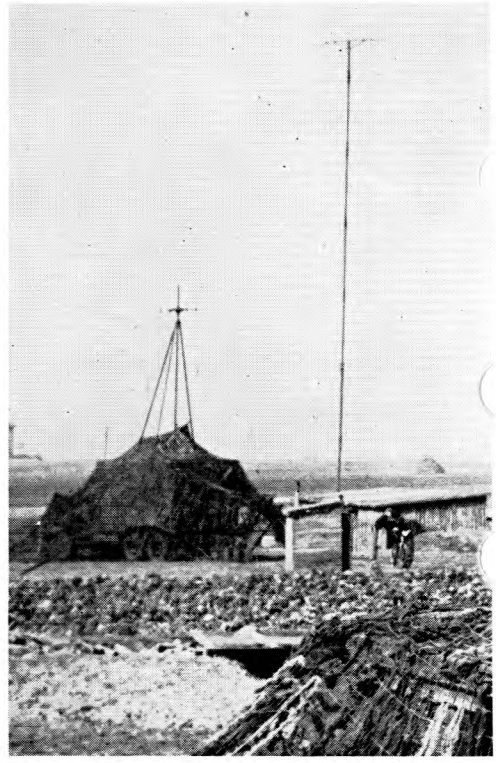
CREW CHIEF enforces SOP, supervises operations, acts as controller's assistant.

PPI OPERATOR controls antenna movement. Receiving plots from the FDP, he locates the search sector. As a mission starts he gets D/F bearings to aid in picking up the aircraft. When he has it, he gives distance to range operator and when range operator gives the "on target" signal, he locks on.

RANGE OPERATOR helps to pick up flight by searching on the 32,000 yard scope. He is responsible for holding the signal after the target has been locked on.

PLOTTER receives all D/F plots, records them for the controller and passes all necessary ones on to the PPI operator. He also plots the tracks of aircraft and operates the communications switchboard.

IFF OPERATOR puts the RC-184 on the air, searches slowly in azimuth until he gets correct reply from the flight to be controlled, then tracks signal manually in both range and azimuth to get position data for PPI operator.



bombing from above the overcast is No. 1 on our list of uses for this equipment.

But the uses are not confined to what was heretofore non-operational weather. As we all know, photographic weather requires nearly perfect conditions of visibility—something in which the ETO is grossly deficient. But we can get from SCR-584 the necessary control of very high flying photographic aircraft making mosaics for daily front line coverage. This equipment will guide a single aircraft along a well-defined flight line; and it enables planes to fly widely separated parallel strips accurately. Today SCR-584 control is Standing Operating Procedure in obtaining front line coverage and other mosaics within fifty miles of the front line.

Flight lines which are determined by our reconnaissance group, whether for a mosaic or a strip map, are given to one of our SCR-584s, which will in turn plot them on the control map in the van. The controller has little or no difficulty getting the aircraft to follow these lines, and that is a great relief to the pilot. Under our procedure, the pilot is responsible only for flying at a constant altitude and in a level position. The controller does the rest. Anyone who has attempted to make a mosaic from high altitude will have no difficulty appreciating the SCR-584's contribution here.

The control of night photographic aircraft has also been tried with considerable success, permitting us to direct them over specified roads and highways. It is most difficult for a pilot to navigate at night within the required accuracy of pinpoint photography in a blacked-out area. With SCR-584, the crew is told when to take the picture and acceptable accuracy is achieved. Greater use of this procedure is envisioned.

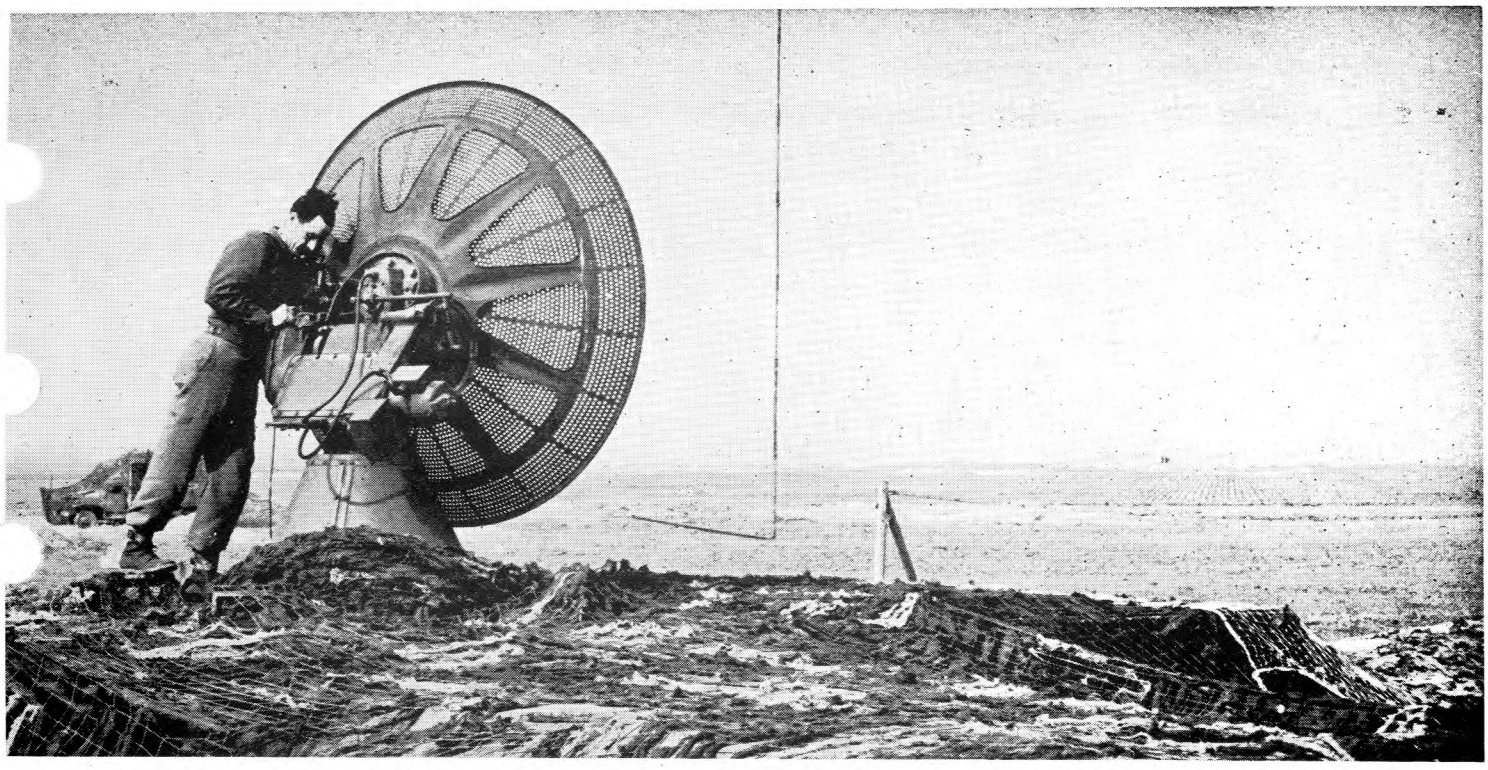
Recently, our night fighters found themselves nearly out of a job because Jerry was putting up so little for us to go after during the hours of darkness. These conditions were unbearable to the night fighter boys. Again the SCR-584 reared its useful head and provided us with the control necessary to place them over specified, pinpoint targets, where they could look for a slight sign of life to begin intrusion activities.

These same night fighter boys now carry bombs on their A-20s and P-61s, and, through the medium of the close control provided by the SCR-584, are able to release them with a reasonable degree of accuracy on pre-selected targets. There are many occasions when our night fighters are thus able to operate, while, at the same time, weather over the German bases precludes any enemy operations. For our night fighters to take off for defensive missions under these conditions would be silly. Their bombing is far from it, and particularly when the bombs are fuzed with varying degrees of delayed action, as they usually are. We find that Jerry becomes very annoyed by our night bombing of this sort in the tactical area.

A very profitable use of SCR-584 has developed in the direction of squadrons to specified small villages in which targets are located. Such villages often harbor ammunition dumps, a headquarters or some other tactical target. As the countryside of western Germany is strewn with small villages, each of which looks much like another, errors of navigation can easily result in the wrong target being attacked. But squadron leaders have implicit confidence in the radar equipment's ability to lead them to these difficult-to-spot targets.

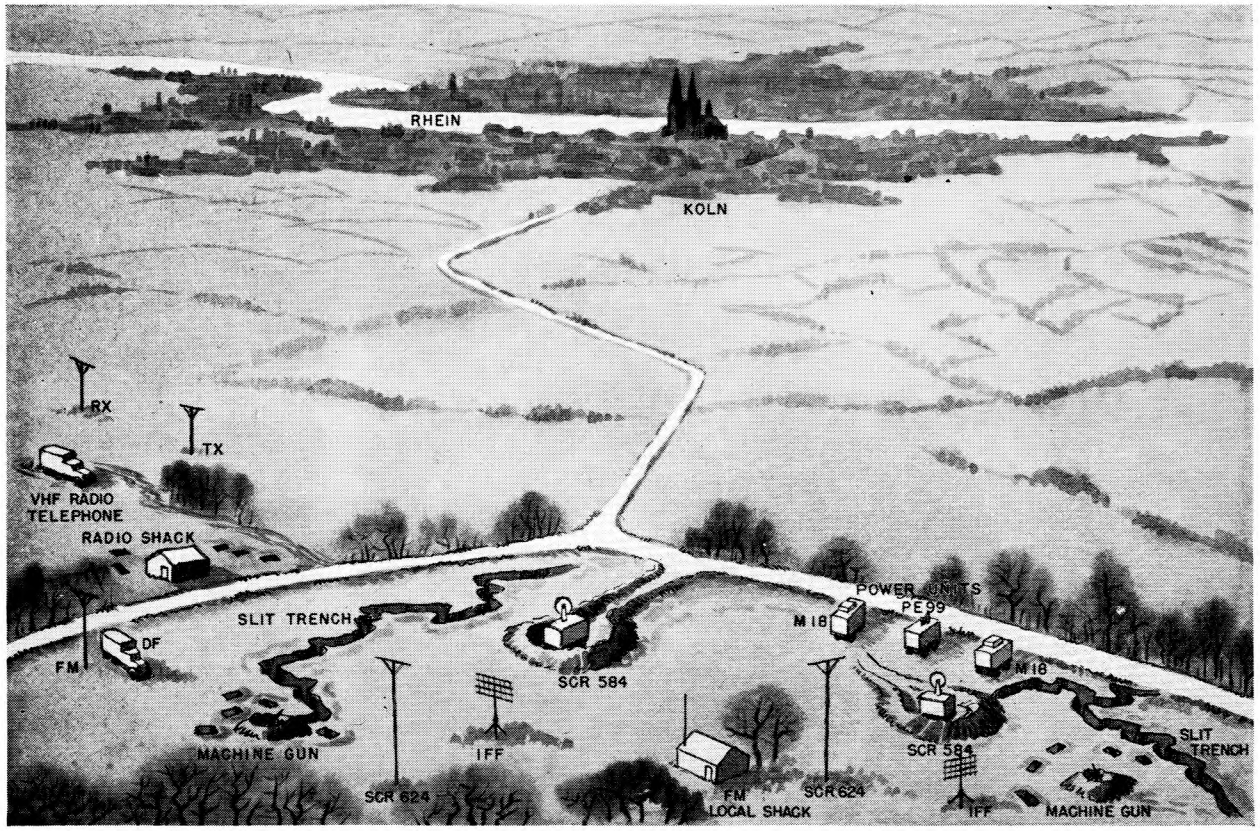
A very useful, though unique, application of SCR-584 occurred one day when the artillery of a particular Corps was unable to silence a heavy German gun position which was inflicting great damage to one of our military installations. The only key to the location of this gun position was obtained through a sound and flash battery. Four-place coordinates were telephoned to the SCR-584 closest to the target, along with other related information. At the same time our Fighter Control Center directed an airborne squadron—which, incidentally, had been briefed for another target—to contact the SCR-584. The radar then vectored the squadron to the target.

On the first three passes over the target the squadron leader couldn't get a visual. On the fourth pass, in spite of the fact that the gun was heavily camouflaged and not firing at the time, a visual was obtained. A successful attack followed.



Outside Cologne 2nd Lt. C. C. Bagley, whose platoon put first close control SCR-584 in action at St. Lo, orients antenna. Inside 584 van, Gen. Quesada and Lt. Col. Wm. S. Cowart, Jr., CO of IX TAC's 1000-man 555th Signal AW Bn., watch at plotting table as 1st Lt. J. W. Kotun controls P-47 flight. Said Gen. Quesada: "I want you men to know how important your work is in saving lives with close control bombing." Col. Cowart formerly headed 482d Bomb Group, pioneer of 8th AF H_2X (see page 41)





At Cologne site, the IX TAC's Charley Dog pair of SCR-584s were thus set up in ex-German heavy gun emplacements. They were so far ahead of their parent MEW that FM communication couldn't bridge the distance. Messages were relayed via passing planes. The 584s are controlled by MEW but each handles own missions—36 in one 48 hour period

It is easy to see that the control allowed the squadron commander to confine his search to the exact place in which the target was located, thereby vastly increasing his chances of getting a visual on this well camouflaged target. The whole job was accomplished in approximately twenty minutes.

In terms of a continuing operation SCR-584's work during the period of the German breakthrough was outstanding. During this unhappy period of "The Bulge" we were at a great disadvantage. All of eastern Belgium and western Germany was covered by a blanket of snow and navigation was most difficult.

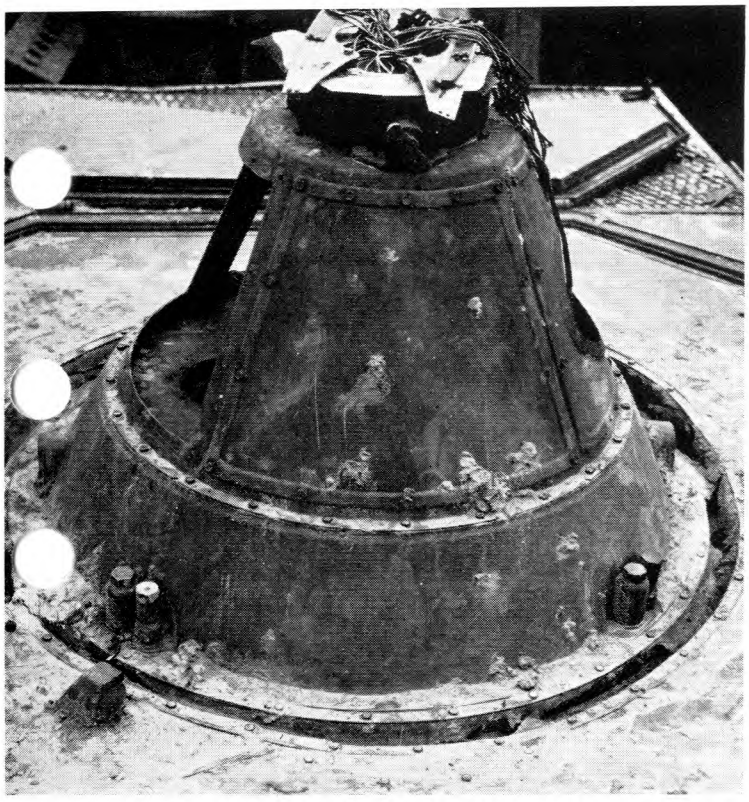
"The Bulge" contained no well-defined geographic features. It was a narrow segment protruding deep into our own lines and the whole thing could be flown across in less than ten minutes. Our roads were "chockablock" with movements and so were those roads just recently acquired by the Germans. We couldn't distinguish our vehicles from theirs because every last one of them was snow covered.

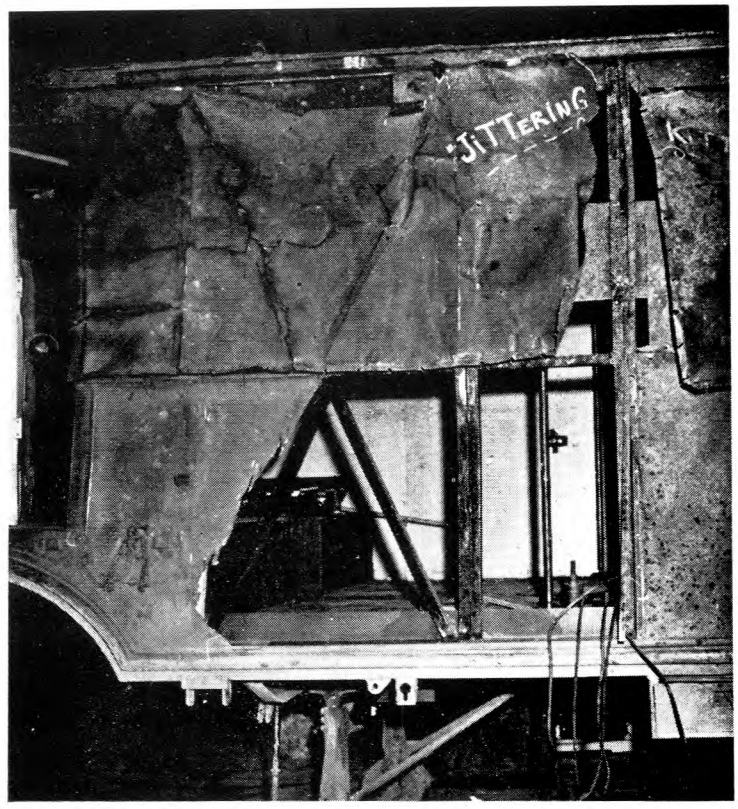
Our SCR-584s were quickly moved to meet this situation and pressed into very active and valuable service. It was our hope to track each flight directed into The Bulge. On most occasions our pilots were able to tell German transport from ours only by instructions received from the SCR-584 controlling them. The controllers were able to tell the pilots that the transport below was German or American, solely and entirely because of their ability to tell where the aircraft were. Plane crews were instructed to contact the control facilities prior to launching attacks and in this way we were singularly fortunate in not attacking our own forces.

Generally speaking, during good weather and in daylight hours we keep the SCR-584s tracking units of our own operating close to the front lines. And not infrequently we have been able to keep them from attacking friendly ground forces, sometimes just in time.

Our ability to provide this type of control to our aircraft—i.e., position with respect to ground forces—should be a source of great satisfaction to those who, working in scientific fields, were instrumental in the development of SCR-584. The number of American lives saved by our ability to stop attacks on our own columns and installations cannot be measured; nor can we measure the number of Germans killed because our fighter-bomber boys can be informed *with assurance* that other columns are enemy. All of our boys have a horror of beating up our own troops. The elimination of doubt permits them to exercise their aggressive spirit to the full.

For all the reasons touched on here, we who are responsible for the conduct of operations are greatly appreciative of this equipment, and of the efforts that made it available for our use. We recommend its consideration by others.





WHAT V-1 BUZZ BOMB DID TO ANTI-AIRCRAFT SCR-584 WHEN IT LANDED 20 FEET AWAY. THIS IS ONE OF 5 DAMAGED BY V-1 ON CONTINENT

One for V-1

The SCR-584 pictured on this page was part of the 50th AAA Brigade's defense around Antwerp. It fell victim to its own special antagonist, a V-1 buzz bomb. One set was being exchanged for another when the bomb landed between the two, decapitating this one.

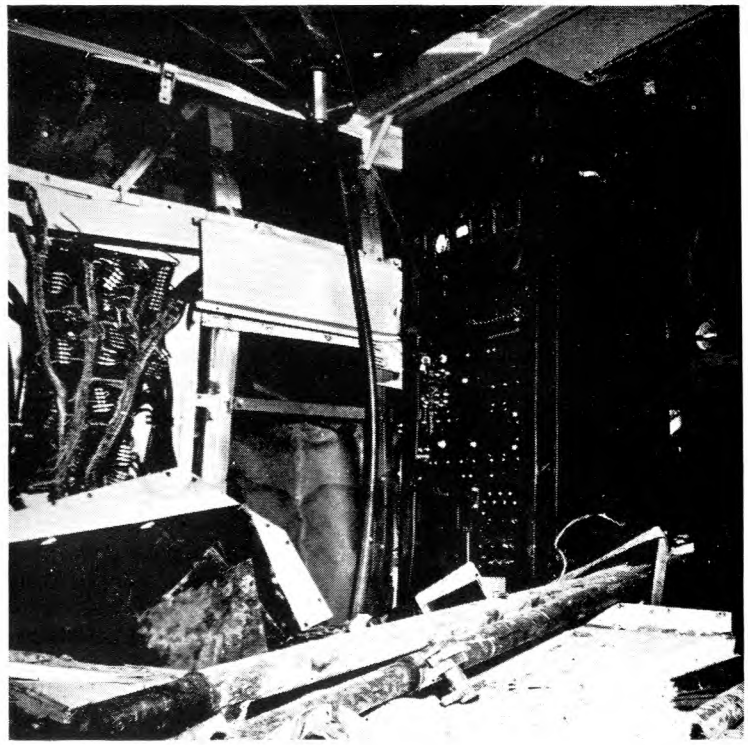
The incident is neither commonplace nor unique. This happens just often enough to show that ground radar, like any other combat area material, is vulnerable to war. Five SCR-584s have been hit by buzz bombs on the Continent. The record is better in England where, despite some close calls, not a single SCR-584 has been damaged.

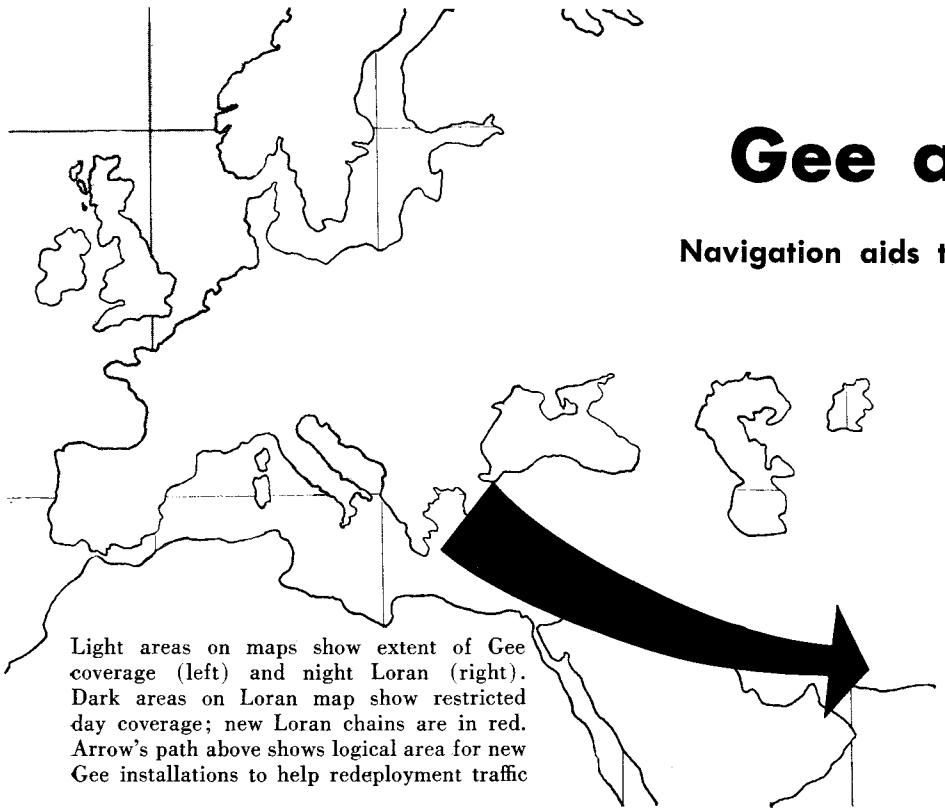
Installations are generally dug in as soon as they reach an operational location. This one, being readied for replacement, was not.

Actually, the price thus far in SCR-584 casualties is small for the multiple services the set renders. And of these its proficiency against the buzz bombs—tracking them, calculating launching sites, controlling AA fire and vectoring fighters—has been by no means least.

DESPITE STURDY VANS, BLAST MADE SHAMBLES OF INTERIOR COMPONENTS. CREW WAS AT MESS WHEN BOMB FELL. LONE OCCUPANT WAS STUNNED







Light areas on maps show extent of Gee coverage (left) and night Loran (right). Dark areas on Loran map show restricted day coverage; new Loran chains are in red. Arrow's path above shows logical area for new Gee installations to help redeployment traffic

Gee and Loran

Navigation aids to redeployment

RAF and AAF will use both to reach Pacific combat zones. Once they're there, Loran will play dominant role

"When hostilities cease in Europe, the War Department intends to marshal against the Japanese every soldier and every item of equipment that can be used effectively to speed our final victory."

Secretary Stimson's statement, made a few weeks ago, takes full measure of redeployment. Details on how planes and ships will make the transfer are still top secret. But, in driblets, some of the movement has already started. And it's no secret that before the job is done it will be one of the most tremendous and complex shifts of men and material ever attempted.

That navigation will be a No. 1 problem is obvious. That Gee and Loran, the navigational aids developed successively by the British and Americans, are slated for top transport roles, is becoming apparent.

It looks now as if Gee will take the overland route from the ETO to the CBI. Gee chains already operating in the United Kingdom, France and the Mediterranean, provide preliminary coverage for the route to India and more Gee may be installed further on. RAF heavies, scheduled to be prime users of the route to the east, are almost 100% equipped with airborne receivers.

Loran coverage stretches west across the Atlantic, North America and the broad reaches of the Pacific. There is only one gap—western U. S. to Hawaii —and that is being closed now. In redeployment this route will be used chiefly by the U. S. Navy and the AAF. A substantial number of naval vessels are already equipped with receivers, and nearly 100,000 airborne sets either have been produced or are on order. Of these 9% are for the Navy, 53% for the AAF and the rest for the U. K.

Once in the Far East, British and Americans alike will use Loran. At present it is the only kind of coverage available there, and with good reason. The Pacific Theater has the wide open spaces, and one of Loran's virtues is its long range—particularly over water. It takes pinpoint navigation to pick out an island target that is little more than a speck in an expanse of ocean—and return to an island base that may be even smaller.

The fact that navigation by Loran can make it possible for B-29s to carry less gasoline and more bombs on their missions from Guam, Saipan and Tinian to Japan, indicates an extra importance of Loran to Pacific warfare. This particular potentiality was noted in a cable sent by the 21st Bomber Command to 20th AAF headquarters last Christmas Day. "We anticipate an increase of bomb load," read the message. "Recent installation of Loran improves reliability of return navigation and warrants reductions in gas reserve."

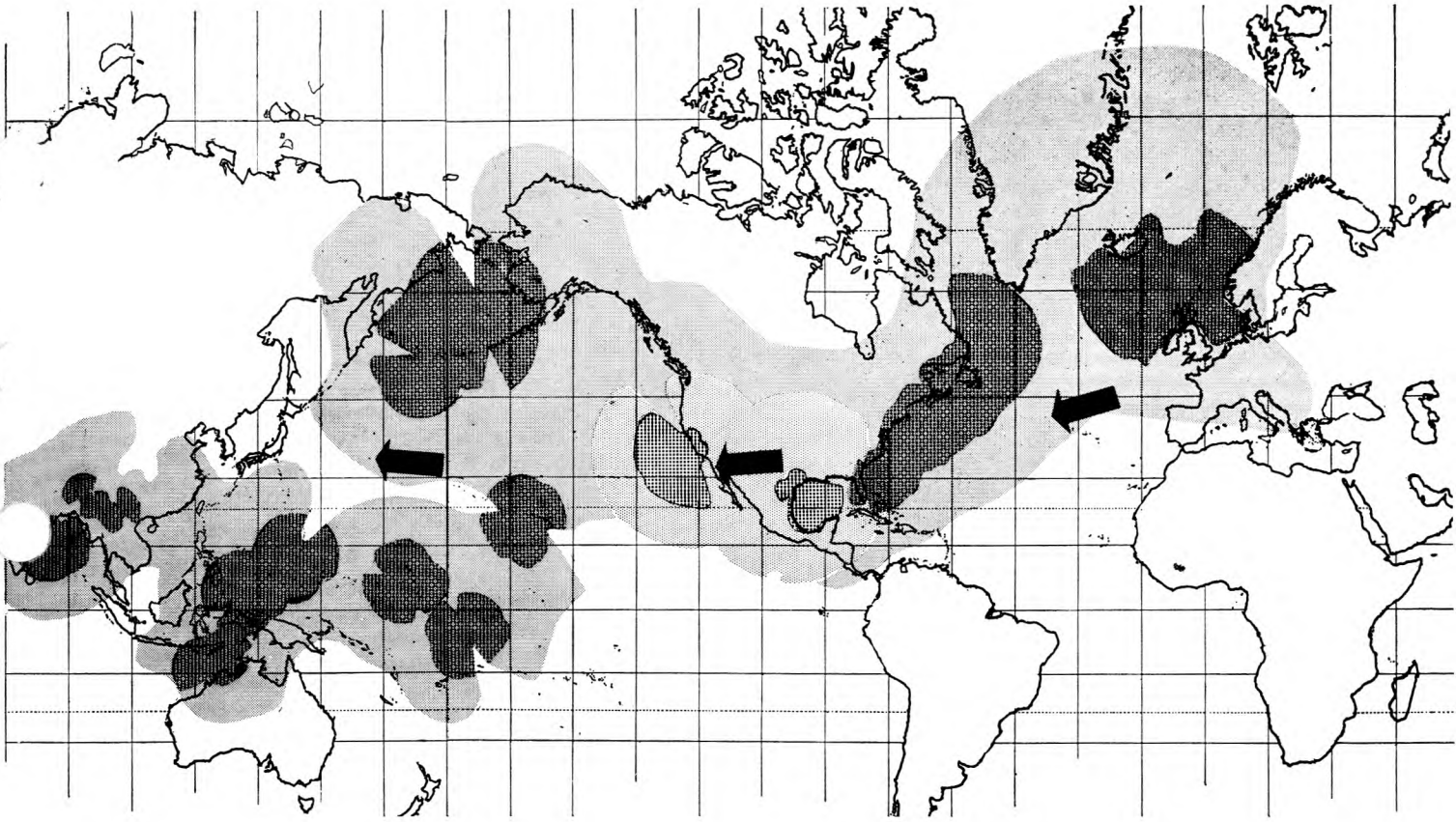
In the CBI, where Loran also has exclusive coverage, it has been found to have unexpectedly good range in mountainous territory. Transmitters installed in the Himalayas, to guide traffic across the Hump, have helped to safeguard air transport between India and China. Additional Loran chains are now being readied for shipment to the Central Pacific and the CBI to provide coverage for the advance upon Japan.

From the beginning both Gee and Loran have been essentially Allied Systems. Although Gee was developed and manufactured by the British, and the ground installations are operated by the RAF, airborne Gee has become an integral part of the AAF in Europe.

Loran was developed in the U. S. and used first by the U. S. Navy. Now there are ground stations operated by the U. S. Coast Guard, the Royal Canadian Navy, the British Admiralty and more recently the AAF and the RAF. Ships and planes of Britain and her Dominions, as well as the U. S., use the coverage.

In the European Theater many planes carry both Gee and Loran. This is particularly true of the RAF Bomber Command, approximately 800 of whose planes have dual installations. Loran is used chiefly for nighttime navigation on deep penetration into enemy territory beyond Gee coverage—although latterly it's been used also for blind bombing to some extent. RAF Coastal Command also uses both systems, the choice depending on the mission. Although the AAF generally sticks to Gee in its daytime sorties over Europe, the 8th AF has some squadrons that carry both Gee and Loran.

In contrast to Gee, which was first used for blind bombing, Loran was developed primarily as a navigation aid—and more often than not has been used in connection with transport. Early in-



stallations were on naval vessels assigned to escort freighters across the North Atlantic and there's been a great deal of this work ever since. In its airborne role, Loran is firmly established in AAF's Air Transport Command, and in the Naval Air Transport Service. It is also being used in commercial airliners flying under Government contract.

Of all the radars, it would seem that Loran is most likely to have a steady job in the postwar world. That this is expected is indicated by a recent decision handed down by the Joint Chiefs of Staff to the effect that after the war Loran will be released to commercial carriers of all the United Nations.

Loran's big advantage—as its name implies—is that it is Long Range Navigation. With only 4 times as many transmitters as Gee, its coverage is 20 times as great. It already covers more than a quarter of the earth's surface. Physicists who are working to extend its range like to joke about the time when with a transmitter at each pole and 4 around the middle, Loran will cover the world!

But there's no joke about pulse navigation being essentially international. It neither stops short nor changes gauge when it comes to a national boundary. It's just as good on one side of a border as it is on the other. It's equipment for "one world."

Gee and Loran: How they work, wherein they differ

THERE is some argument whether Gee and Loran are radar at all. While they employ the familiar pulse radiation and scope presentation, they differ from conventional radar in that they do not use reflected radiation or echoes.

A pair of ground based transmitters—a master and slave—operating some distance from each other, send out synchronized waves of radio energy. The master pulses first; the slave follows at a fixed time interval. These pulses reach planes and ships within range, and are there displayed on a scope.

Difference in time of arrival between master and slave pulses is measured in microseconds. And this difference in time bears a direct relation to the difference in distance traveled by the 2 pulses. Thus, the navigator can find his line of position—a hyperbolic curve drawn through all points whose distances from the 2 transmitters are proportionate—on a specially prepared chart.

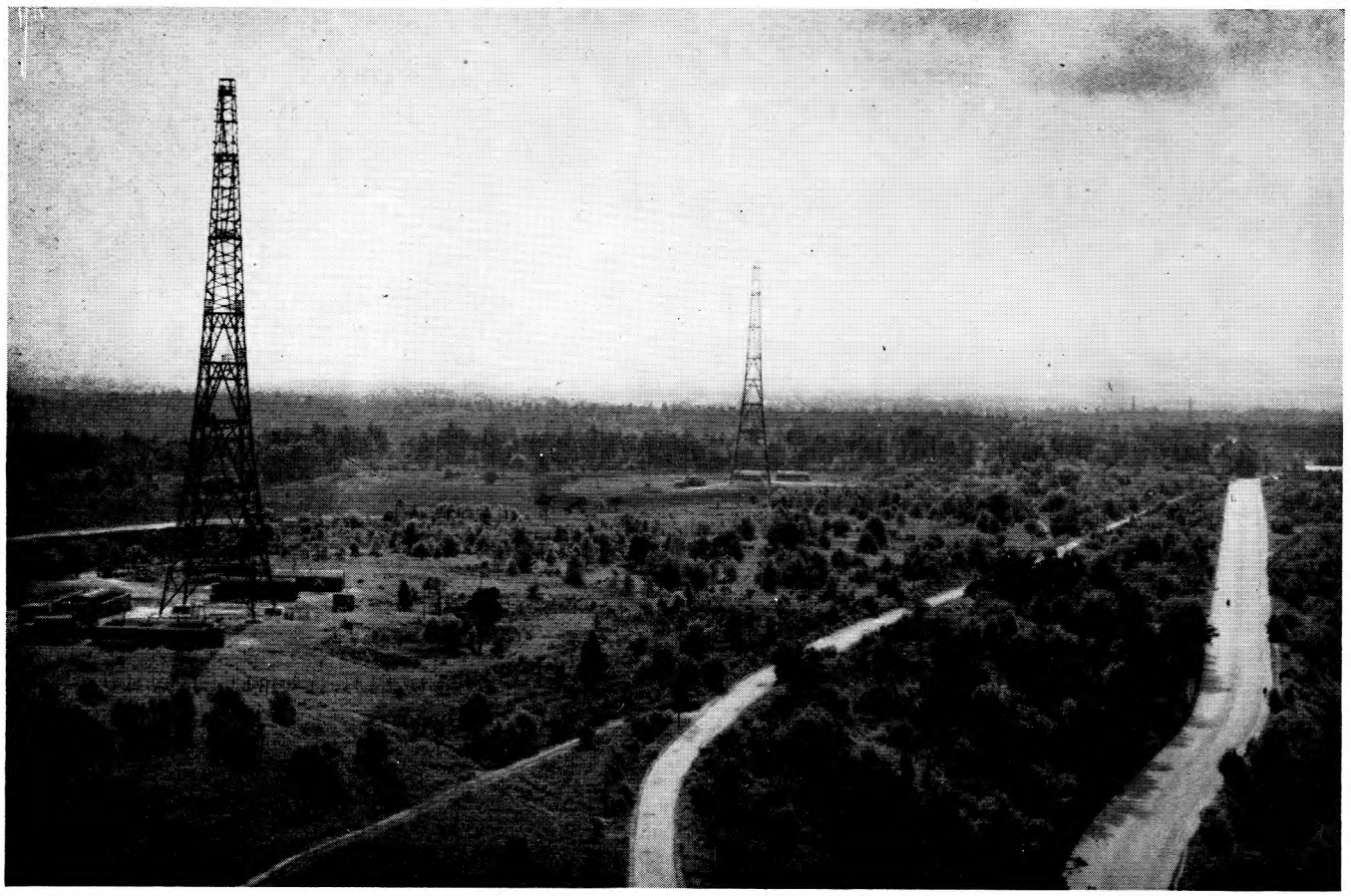
To get his exact position on this hyperbola, in other words to get a fix, the navigator must take a reading from a second pair of transmitters whose hyperbolas cross those of the first. He identifies the second pair by the presence of a ghost or "ident" pulse on Gee, and a difference in pulse repetition rate in Loran.

Usually 3 transmitters are used to form 2 pairs, the master working with each of 2 slaves (a third slave station is sometimes used to fill in gaps). Gee transmitters are about 70 nautical miles apart, Loran several hundred miles.

The essential difference between Gee and Loran is the radio frequency used, the latter operating on a much lower frequency that enables it to extend its night range by using skywaves as well as ground waves. While high frequency Gee waves go right through the ionosphere—electrified layers of atmosphere which contract at night to form a reflecting surface for low frequency signals—Loran waves are reflected downward and can be used by navigators to obtain readings.

Thus while Gee direct waves have a night and day range of 300-400 miles (depending on the height of the aircraft) and Loran ground waves have a day range of 500-700 miles, at night Loran sky waves extend coverage to 1400 miles. Often Gee and Loran are used together since Gee is somewhat more accurate at shorter range and Loran can take up where Gee falls off.

Another difference in the two systems is in the method of taking fixes. In Gee, pulses from both pairs of transmitters appear on the scope at the same time and readings are made simultaneously. It takes just a minute to get a fix. In Loran, only one set of readings can be taken at a time. In addition, sky waves are hard to handle. It takes 2-3 minutes as a rule—occasionally less—to get a Loran fix.



MULTIPLE ANTENNAS AT THIS FIXED GEE GROUND STATION IN THE U. K. MAKE IT POSSIBLE TO SWITCH FREQUENCIES TO THWART ENEMY JAMMING

Gee still does a job after all this time

What is most surprising about Gee is that it's still in use after so long a time. In the field of radar, where equipments are outmoded almost as fast as women's hats, this is a record. Development of Gee goes back to 1936. However, it wasn't until about a year after the war started that it was tested operationally, both for navigation and as a blind bombing aid.

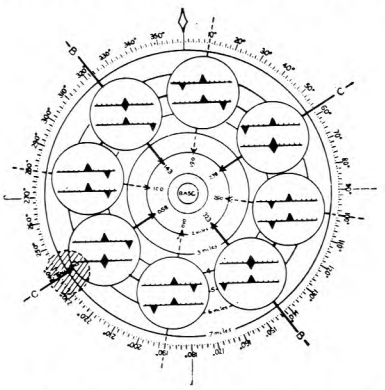
Used operationally for the first time on a mass raid of 211 RAF heavy bombers over Essen, its accuracy was considered sensational. Following this success, operations were expanded as rapidly as possible, climaxing in the then unprecedented RAF 1000 bomber attack on Cologne on May 30, 1942.

Gee made it possible to achieve "concentration in time" on large night bombing missions, thus increasing the devastation of a given weight of bombs. At the same time losses were reduced, since enemy defenses were saturated.

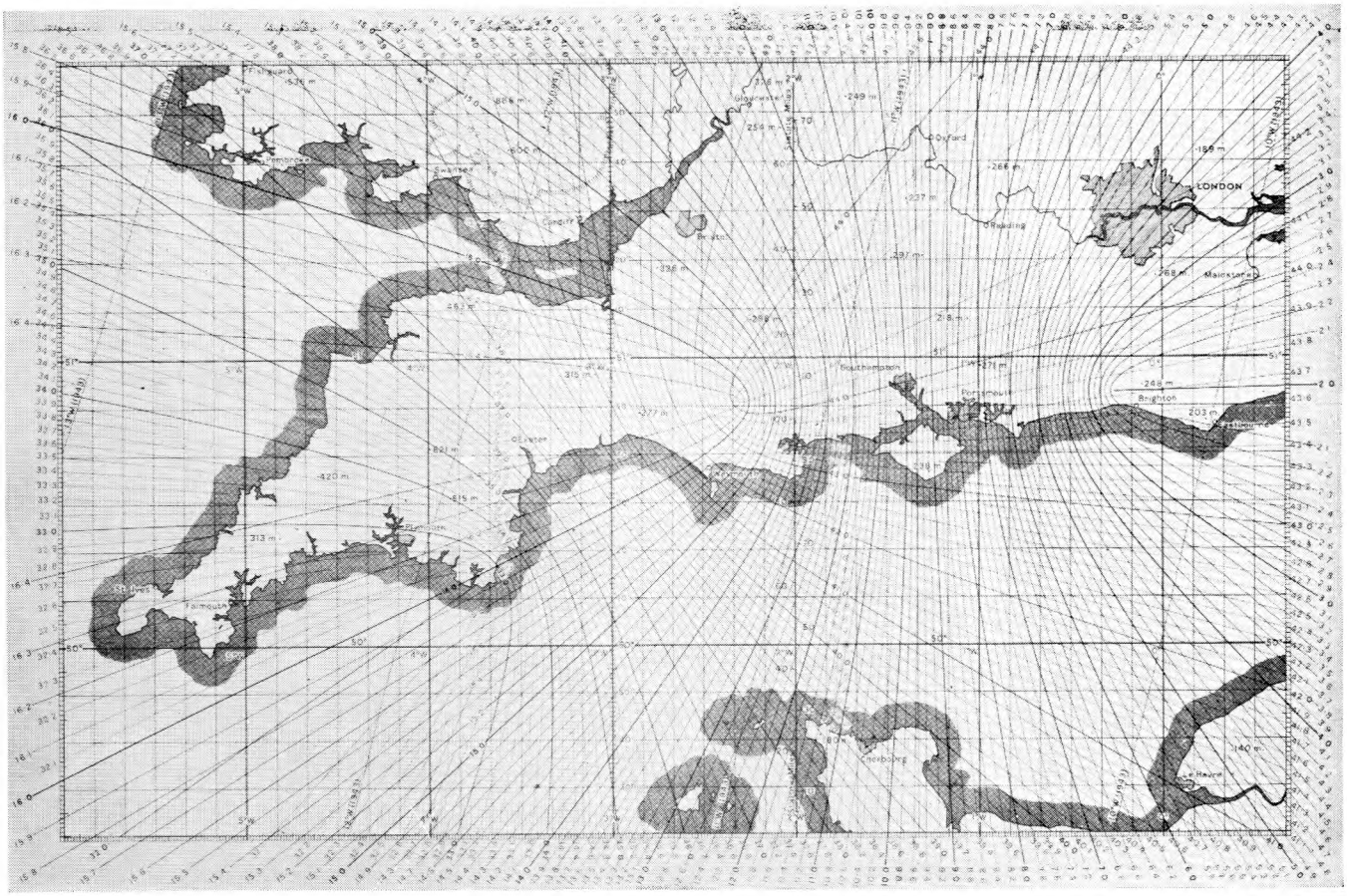
The ease and accuracy of homing with Gee was, in addition, a blessing to weary and keyed-up bombing crews. It is safe to say that the assembly and return of such large night formations would have been impossible without Gee.

The British anticipated that the Germans would be on to Gee within a few months. One Gee-equipped plane was lost over Germany during trials and more were lost once operations started. Jerry finally started jamming 5 months after Gee's introduction, and although anti-jamming circuits were introduced it soon was impossible to get fixes over deep enemy territory. With the development of other blind bombing techniques the Gee system assumed its present status as basic navigational aid. Its value over Allied territory, over ocean and Channel, and within limited ranges over enemy territory, has not been impaired.

German jamming efforts have continued and this has resulted in the establishment of several bands of frequencies, which can be changed from day to day or even during the course of a mission. A complete new band of frequencies was used on D-day. Jerry has also attempted to fly Gee courses with captured equipment. To prevent this, the phase between master and slave pulses is now changed occasionally. Allied fliers carry a correction key.



Gee homing card like this is used to bring plane into base when course permits. Gee navigators carry cards for home bases



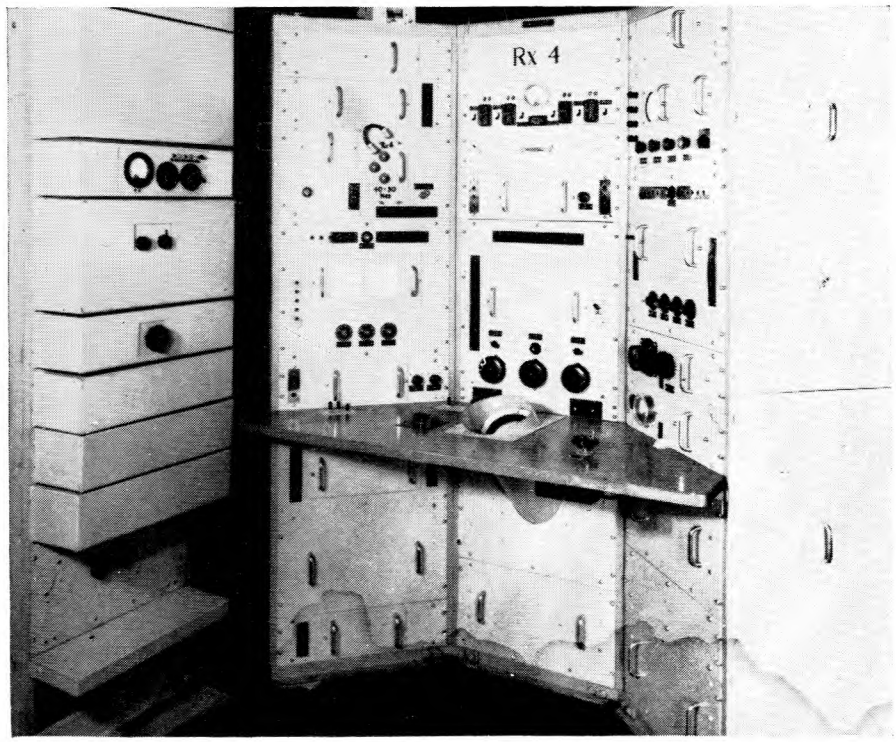
EACH CURVED LINE ON THIS GEE CHART HAS A NUMBER; WITH 2 SUCH NUMBERS OBTAINED FROM SCOPE READINGS, A POSITION CAN BE FOUND

When the AAF entered the ETO heavy bomber arena in 1942, it soon became apparent to liaison officers that Gee was a natural for them. It would help solve at least 2 of the problems that plagued incoming American pilots and navigators: the lack of distinctive landmarks in the U. K.—and the weather.

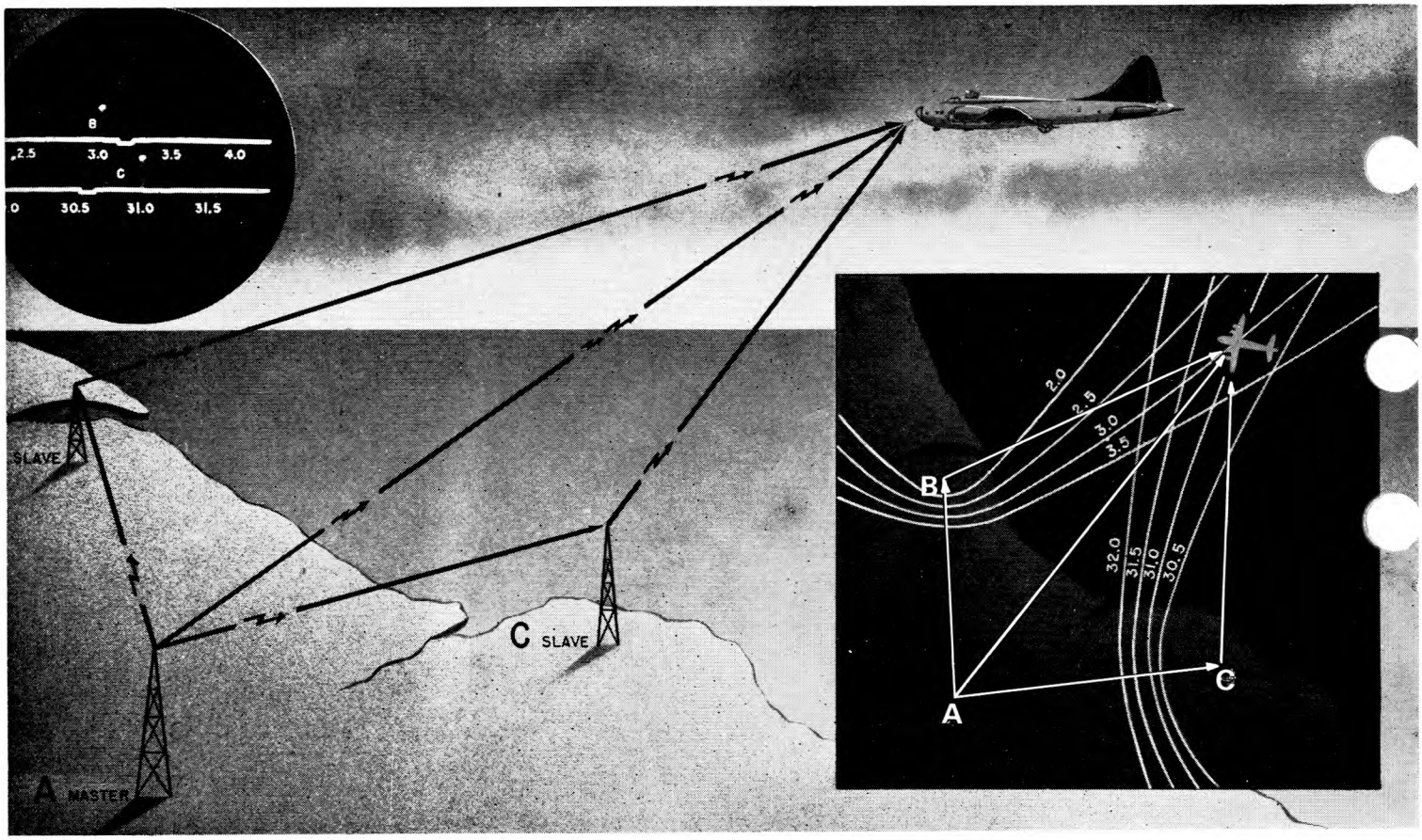
The AAF began experimenting with a dozen installations of Gee Mark I late in 1942, and began serious work when Gee Mark II was made available to them in March, 1943. One of the major problems was the procurement of airborne sets, provided by British factories already rushed to fill RAF requirements. By August there were 250 installations in the 8th AF.

Another growing pain was the installation of cabling and mounts. Since most of the ships were already in service, it was rare that installation crews could get more than 24 hours for a job and the lack of standardized B-17 and B-24 layouts often meant fast improvising—which hard-working mechanics provided.

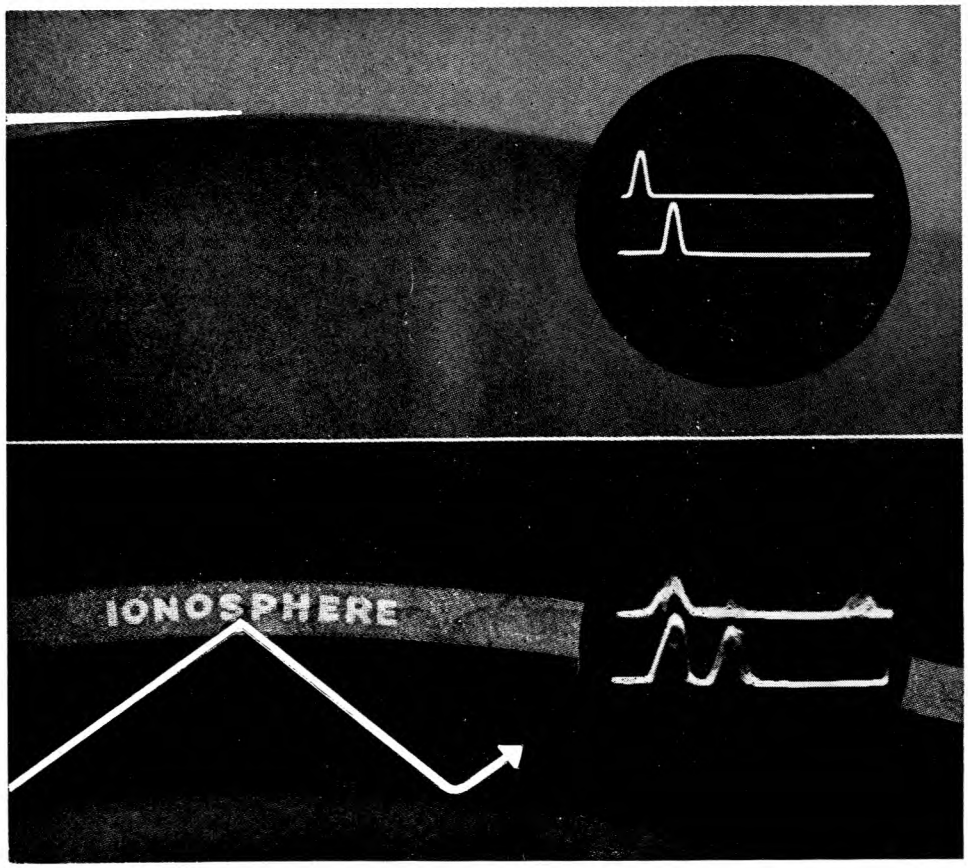
But once receivers were installed, mechanics had little trouble with Gee.



Critical part of Gee operation, locking slave pulse to master pulse, is done by slave receiver (above) which picks up master pulse and uses it to trigger slave transmitter



Same basic principle underlies both Gee (above) and Loran. Master transmitter (A) sends out timed pulses. These trigger slave transmitters (B) and (C) which in turn emit pulses of their own. Pulses from all 3 stations reach receiver-indicator in aircraft. In Gee they appear on scope simultaneously (see round inset). Navigator takes reading by measuring time difference in arrival of pulses, and from this is able to locate appropriate lines of position—or hyperbolas—on special map (as in square inset). Loran (below) gets greater range by using skywaves as well as ground waves at night; ionosphere forms reflecting surface





Pilot, navigator and gunner study Gee map before taking off on ETO mission



Same pilot and navigator are in group spending off hours taking Loran course

The majority of faults are tube failures. Even at the beginning, 9th AF records showed an average of 18 operational hours per fault. At present the average is better than 200 hours per fault.

By the time the AAF borrowed Gee from the RAF, the British were also able to provide instructors, course material and practice equipment. But even with this help, Gee training in the AAF turned out to be pretty much a hit or miss proposition.

The big difficulty was that most of the training had to be done overseas. With few exceptions, U. S. navigators had never heard of Gee until they got to the ETO. And they were scattered all over the United Kingdom by the time the AAF was ready to start instruction.

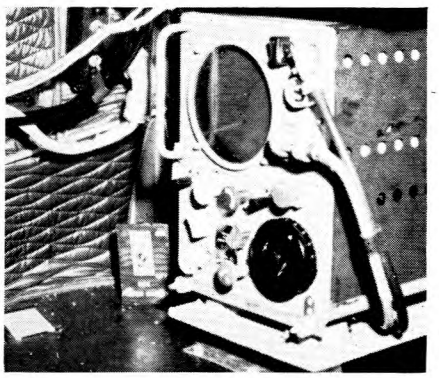
There was also a tendency among the fledgling navigators to resist additional instruction; they were fed up with courses and wanted action. It took some bad weather flying experiences over Europe to make them receptive.

Eventually most of the operators learned Gee by working out on trainers at Combat Crew Replacement Centers and with operational groups. Or they learned on the wing—without benefit of ground training. Gee training is more routinized now. Courses are given in the U. S., and overseas there is instruction for replacements as well as weekly refreshers.

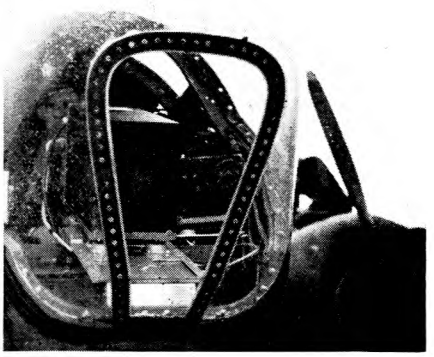
At present most U. S. navigators in the ETO know Gee. 80% of the 8th AF is flying with it; the 9th and the 12th have equipments; and the 15th—with access to Gee coverage only since July—has installations in 25% of its planes.

Since shortly after D-day, there have been Gee chains on the Continent. Several of these are mobile and have gone forward with the front. Beginning right with D-day, Gee has played an important role in all operations of the 9th Troop Carrier Command of the 1st Allied Airborne Army. In Normandy the devious courses of ships and gliders, and the location of exact dropping and landing zones for airborne troops were brilliantly executed—in all of which Gee played a highly useful part.

A few months later, when the 9th TCC was preparing for the invasion of Southern France, Gee coverage was requested for that area. Three mobile RAF transmitters were broken down in England and shipped by air together with crews.



Gee indicator sits on navigator's table. With receiver, airborne weight is 80 lbs.



Loran installation in nose of this A-20 helps photo recon crew find its objectives

Gee and Loran complement each other

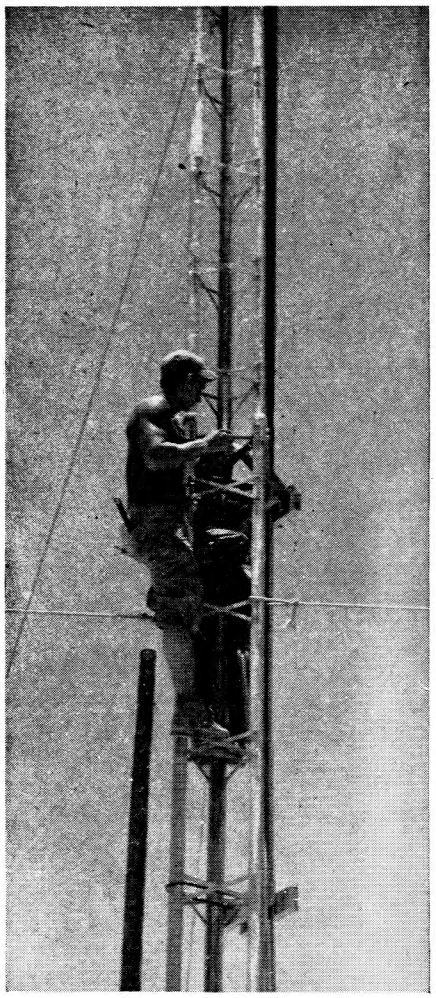
	GEE	LORAN
FREQUENCY	20-85 megacycles	About 2 megacycles
BASELINE	About 70 miles	200-500 miles, over water 60-80 miles, over land
HOW PULSE TRAVELS	Direct wave only	Ground or sky wave
RANGE TO AIRCRAFT	Over land or water: 300-400 miles Light Transportable, less	Over water (day): 500-700 miles Over land (day): 175-350 miles Over land & water (night): 1400 miles Air Transportable, less
ACCURACY AT BASELINE	± 300 feet	± 500 feet
ACCURACY FURTHER OUT	Many factors cause variations. Average error is not more than 1% of distance from plane to chain	Many factors cause variations. Average error is ¼ to 1% distance from plane to chain
READING ACCURACY	Very high (± ⅔ microseconds)	Moderate (± 1 to 2 microseconds)
PAIRS IN CHAIN	2 or 3 pairs	2 to 8 pairs
CHAIN IDENTIFICATION	Radio frequency and "ident" or "ghost" blink	Radio frequency and pulse recurrence rate
FIX MADE BY	2 readings taken *simultaneously* and used to locate lines of position on chart. "Fix" is where lines cross	2 readings taken *successively* and used to locate lines of position on chart. Discrepancy in time of readings is made up by advancing one line

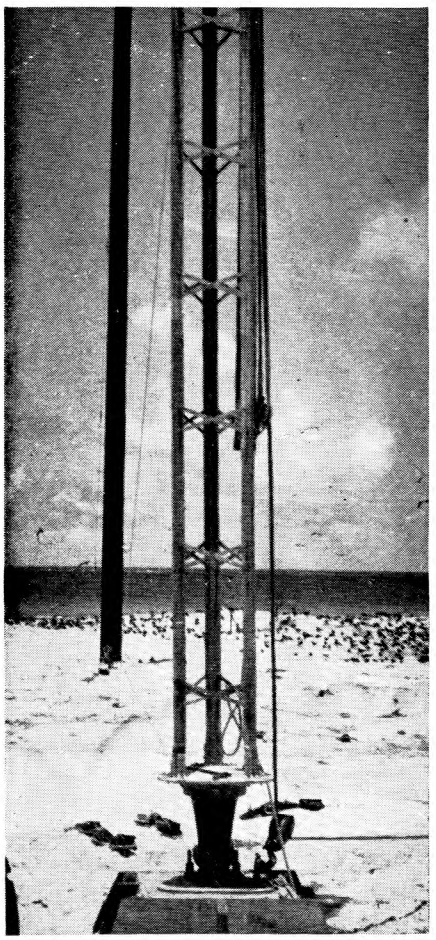
All distances are given in nautical miles

Since the sites all turned out to be on mountain peaks, equipment had to be hauled by mule and manpower up paths to an altitude of 3000 to 4000 feet. While this struggle went on, charts were computed at MAAF Headquarters.

Tests proved successful, but just at zero hour one slave station "packed up." Though limited to one set of position lines covering the invasion coast, Gee was still used by many of the Troop Carrier fleet.

As unit commanders were sold on Gee, airborne installations multiplied. By the time the 9th TCC carried out their drop behind enemy lines in the Nijmegan-Arnhem sector of Holland (see RADAR No. 6) Gee was an integral part of troop carrier operation. Later on, at the time of the German breakthrough, Gee was used in the resupplying of Bastogne. Most recently it played an important part guiding planes and gliders to destinations across the Rhine.





Loran covers a quarter of the world

Loran was barely out of Radiation Laboratory, and being tested operationally by the Navy, when the Joint Chiefs of Staff recognized its tactical potentialities and took over. Priorities were established early in the game; Loran went where it was needed most.

It was needed most—in 1942-43—to get convoys from North America to Russia and the U.K. The route across the North Atlantic was beset by 2 evils—bad weather and U-boats. Loran helped defeat both.

Civilian engineers from Radiation Laboratory made the first installations with the assistance of the U. S. Coast Guard and the Canadian Navy. The Greenland, Labrador and Newfoundland installations were tough, especially the one at Narsak, Greenland.

Finally established, this master station with its slave in Labrador set the record for the longest ground wave synchronization ever achieved; the baseline is 600 miles. It is operated by the Coast Guard, which has since established and run all Naval Loran stations—35 in all. Coverage over the North Atlantic was completed by the British Admiralty with a chain from the Faroes to Iceland and the Hebrides.

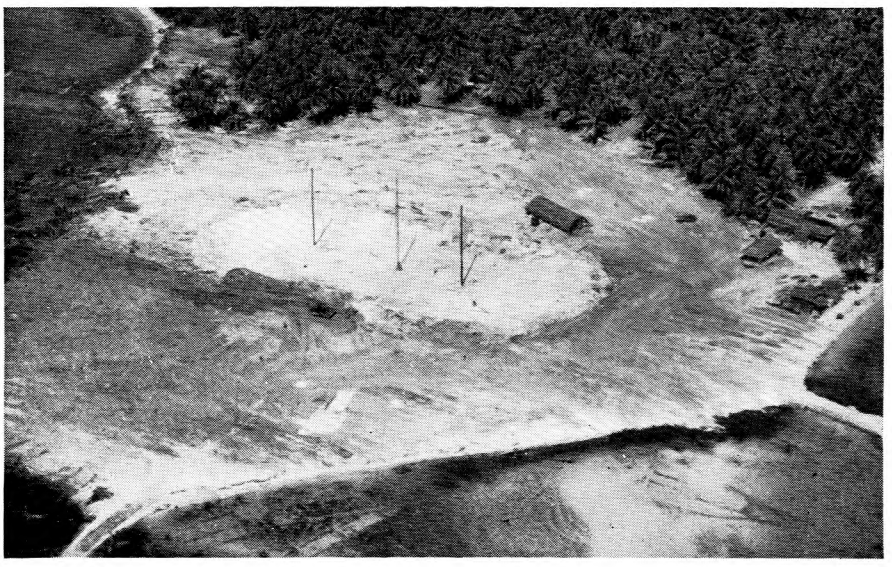
Just as fast as the chains became operative, they were used by Naval vessels taking convoys of freighters across the Atlantic. Like most successful radar equipment, Loran can claim credit for selling itself. Working in the most adverse weather, the system brought through more than one big convoy that might otherwise have run aground.

When Loran went airborne, in 1943, the first sets were installed in coastal patrol planes assigned to search North Atlantic sea lanes for German subs and surface craft, still taking a heavy toll of convoys. Nearly 80% of these early sets went to British and Dominion Coastal Commands.

Loran is ideal for sea search, since a plane can be assigned a particular area on a Loran chart, and can execute perfect coverage simply by patroling up and down lines of position. Loran search technique, adopted for airsea rescue, has been instrumental in saving the lives of many downed Allied airmen.

When France was liberated, and major German Naval activity shifted to Norwegian waters, the RAF met the need for additional Loran coverage by the installation of a special slave transmitter on the Shetland Islands, locked to the master station of the Admiralty chain on the Faroes.

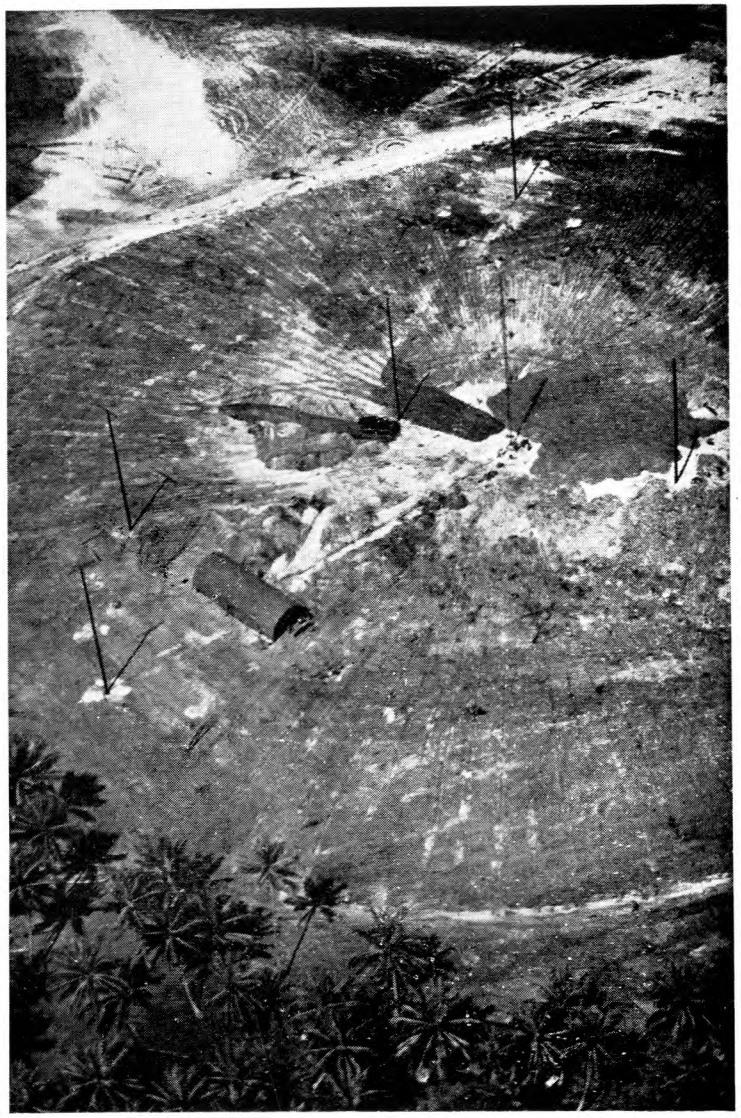
Earliest Loran installations in the Pacific were made to give navigation aid through the bad weather areas surrounding the Aleutians. As the war pushed further into the Pacific, and the need for long range navigation increased, the Army and Navy planned Loran



Uprooted palms ring land side of area cleared for Loran station on Pacific island. Quonset hut for use as main transmitter building and towering antenna assembly are here in place. Left, antenna going up. Photos on this and next pages from Coast Guard.



Crew members install radiating ground wiring at base of antenna to increase useful power and thus build up the range



Within a few days ground wiring has been completed. Compare with picture at bottom of page 20, taken a week earlier



Completed station, silhouetted by a Pacific Island sunset, is now operating. A red light burns at the top of the main transmitting antenna, in the foreground. On either side are auxiliary transmitting antennas, for use in emergencies. At the left of the equipment hut is the remote receiving antenna, which picks up signals from other stations in the chain and helps keep pulses synchronized



Through Quonset's ribs, camera catches construction crew working in storm on one of newest Loran installations—in Newfoundland, to extend North Atlantic coverage

chains for Hawaii, the Phoenix, Caroline, Marshall and Admiralty Islands—and Australia. With the exception of the latter, all of these were installed by the Coast Guard.

On the northwest coast of Australia, the AAF put in its first Loran chain. The job was handled by the Army Airways Communications System, and since then the AACS has established more than a dozen stations.

At about the same time, the AAF's Office of the Air Communications Officer set out to discover how much range Loran would give over land. Up to this time it had been regarded primarily as an over-water navigational aid. The ACO's interest was in coverage through the Himalayas. Since Loran coverage over mountains was involved, test stations were set up in Bakersfield and Lemon Cove at the foot of the Sierra Nevadas in California.

For a month a lone B-17 conducted Loran tests, using this chain. And on the basis of the tests, which showed that a range of 180 to 200 miles was obtainable, the AAF decided to install its Traffic Guidance system over the Hump. Once in India, Loran had to sell itself again. It wasn't until the India chain was installed and proving effective that the 14th AF agreed to relinquish enough of its tight cargo space to get the second set of transmitters over the Hump for installation on the other side, in China. Both chains are now active, and are getting, in fact, nearly twice the daylight coverage obtained in the original California tests.

The TG Loran system was designed for areas through which a large amount of air traffic must pass. It consists of 2 pairs of stations—one at each end of the congested air route, and so arranged that the lines of position of one pair are roughly parallel to those of the other. The navigator is assigned to a particular line of position which he follows to the half-way mark, where he switches to an over-lapping line from the other pair. Where frequent storms force the pilot to detour from the assigned line of position, as in the Himalayas, a third station is added to the original pair so he can get a fix.

At the same time the Hump system was installed, other Loran chains were being established. One triplet, established by the AAF, provides coverage for the Bay of Bengal. Two pairs, operated by the RAF, give coverage over the ETO. There, for the first time, Loran has been used for blind bombing; the RAF Bomber Command uses it for night nuisance raids.

In addition, Air Transportable transmitters have been developed for flying into advanced bases to supply coverage in combat areas.

Loran training

Several of the newest Loran chains are specified for training purposes. In the U. S. the Coast Guard has recently installed a chain along the Southeastern coast; the AAF is establishing chains along the Gulf of Mexico and in California; still another will be sited in the Midwest.

Up to now most U. S. navigators have learned Loran on ground receivers and with simulated pulses. And since simulated pulses are all ground waves, most navigators have never seen a sky wave until they get into the theaters. As a result, they have a tendency to mismatch ground and sky waves. One operator was under the impression that he could get a fix by matching the 2 tallest pulses!

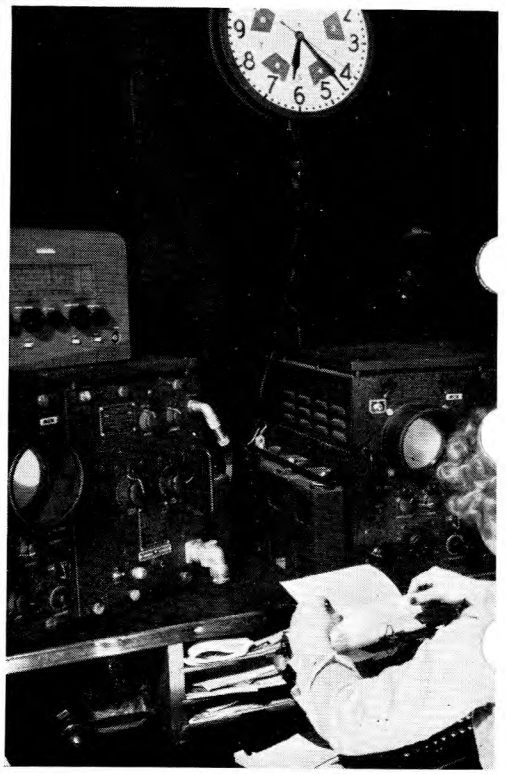
With the new U. S. chains, Loran will be taught in the air as well as on the ground. AAF navigators will have to take 25 acceptable fixes under actual flying conditions before they can leave the country.

More and better training will help to eliminate another common error of navigators—miscounting pips (missing 1 pip can make a difference of from 10 to 100 miles). Help along this line will also come from the new AN/APN-9 Loran receiver, which has a simplified counting system. AN/APN-9 will not replace AN/APN-4, will only be used in new installations.

A third lack in many navigators—insufficient information about coverage areas—can be made up partly by better training, partly by better briefing. With the completion of the California chain, linking the U. S. to Loran coverage in the Pacific, briefing will begin at home.

In the beginning, Loran training suffered from that congenital radar disease

Loran monitoring station, one of 12 run by the U. S. Coast Guard, is staffed by Spars, who keep 24-hour check on scopes



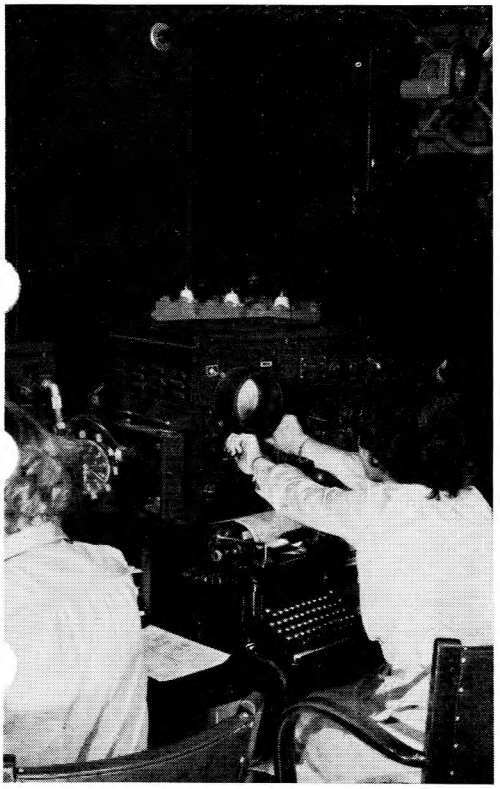
—equipment going into the theaters before it goes into training. Since Loran didn't come to Training Command, Training Command sent instructor teams to Loran in the theaters. For almost a year, these teams have been teaching Loran to crews in the Central and South west Pacific, the CBI, and even the ETO. In addition, in the 8th and 9th AFs and Troop Carrier Command in the ETO, there has been some Loran training in preparation for the time when these units will move to the Pacific.

Loran maintenance

There has been less difficulty training maintenance men, for the reason that mechanics don't need sky waves to learn how to test equipment. They use simulated pulses for testing in any case. Once they are in the field, they have other troubles, however. Chief trouble arises from the supply situation, which is still critical; few Squadrons have either spare parts or testing equipment.

At the other end of the system, malfunctioning transmitters can send air and sea craft in the wrong direction just as surely as sign posts pointing the wrong way can misdirect automobiles. And unless Loran charts are prepared correctly, they can be as misleading—and much more fatal—than bad road maps.

Monitors keep tabs on steadiness of signal, shape of pulse, accuracy of timing, thus insure accuracy at navigator's end.



From the beginning, Loran experts have insisted that a careful watch be kept on the transmitting operation. Usually this means that scopesmen keep a 24-hour check on the pulses, not only at the ground station but at a separate monitoring station located from 20 to 250 miles away. The importance of this was demonstrated by the Admiralty chain. Pulses from these stations were undependable, but it wasn't until a separate monitor was put in that service was improved.

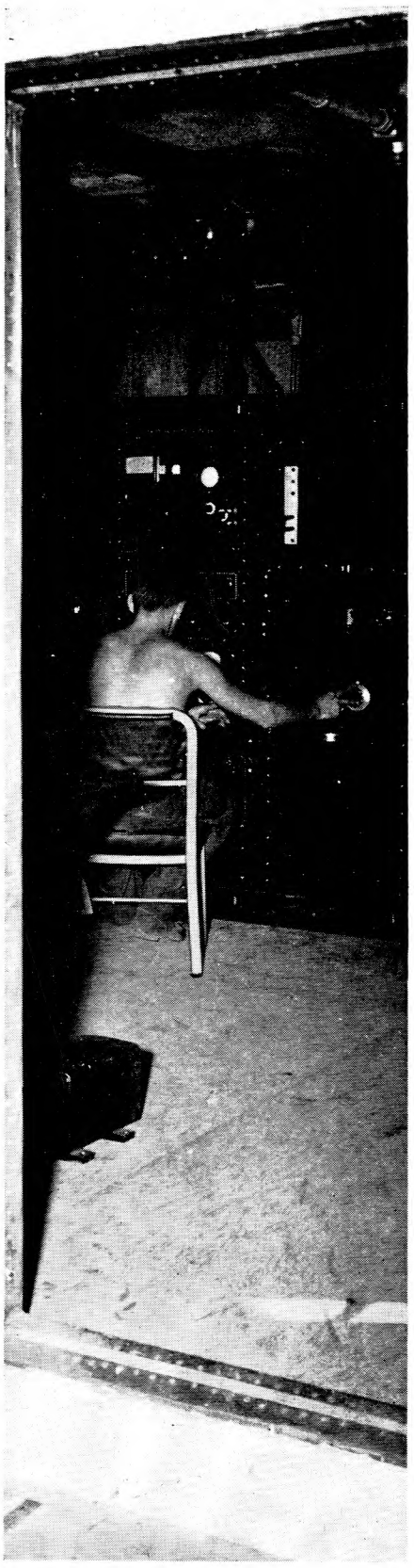
The monitors check steadiness of the signal, shape of the pulse and accuracy of timing. If anything goes wrong they let the ground station know—unless the ground station indicates awareness of its fault by "blinking its blip," which is also a warning to navigators.

In the realm of chart making, there's probably no better operator than the U. S. Navy. Its Hydrographic Office has been charting world waters for more than a century; it is understandable that when Loran came along it should have taken on the job of charting the air. Its output at present runs to 125,000 charts a month. Four out of five go to the Pacific.

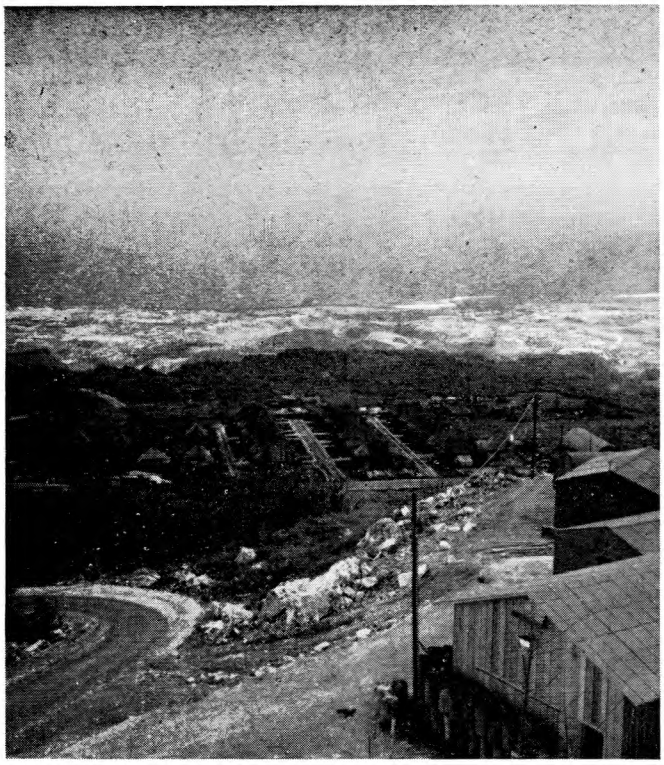
The Aeronautical Chart Service of the AAF provides some of the charts for the Southwest Pacific, and practically all charts for the CBI. There are also Loran charting teams that make provisional charts giving coverage for newly installed Air Transportable Loran systems as well as Coast Guard mobile chains. The Air Ministry and the Admiralty supply charts for their North Atlantic chains and the ETO.

With everything in order—ground and airborne equipment and charts—Loran will be accurate within half a mile in favorable locations under good conditions; errors may exceed 5 or 10 miles under poor conditions in unfavorable locations. Although interference due to static is sometimes bothersome, it is always possible to obtain a line of position by waiting a few minutes. So far enemy jamming has not constituted much of a problem.

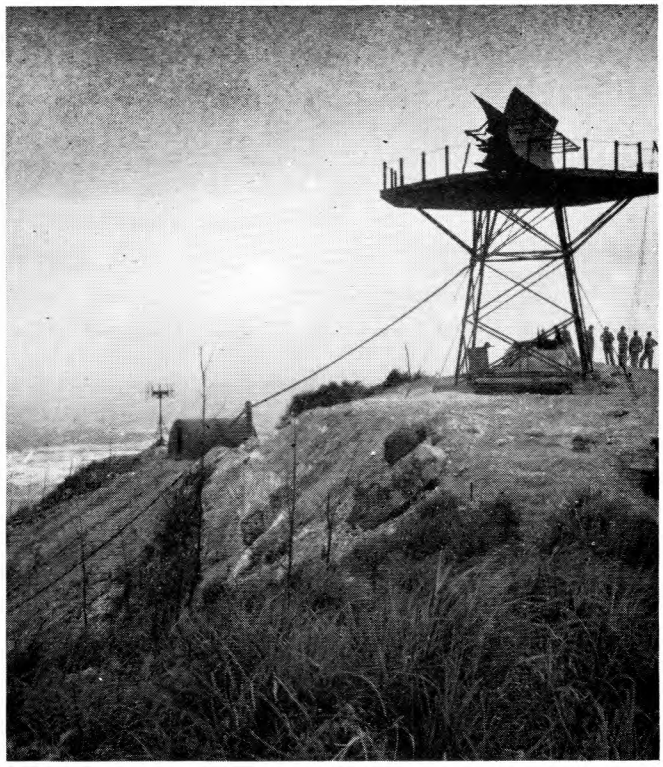
Navigators who use Loran as a sole reliance run the risk of forgetting the ordinary techniques of their trade. And then, when a tube conks out, or a resistor burns up, or power sources fail—or they get into areas where there is no Loran coverage—they're out of luck. Like the rest of the navigation aids, Loran was intended to be just that—an aid. As such, it's proved to be a good one.



In screened rooms like this one the world around Loran operators keep up the flow of pulses that brings planes and ships home



MEW's Saipan site is now approached by good roads. Plotting and scope rooms are in shack at lower right, just below the summit



MEW on Mt. Tapotchau as it is now. While rushed-in TPS-3 stood guard on low angle coverage, summit was levelled off

Stop-gap on Saipan

How TPS-3, sent up for a quick fill-in, got a steady job

One of the first radars to go ashore on Iwo was AN/TPS-1. Shortly after D-day, a TPS-1 sat beside the famous flag on Mount Surabachi (see picture, page 3), and a couple of others stood guard down below.

The men who spotted the little sets on Iwo in the middle of the fighting had practice for the job. They had done the same thing at Guam, and again at Saipan, except that the equipment they set up there had been the older SCR-602s. They had stayed with the 602s until heavier, permanent installations started functioning and then, as plans for more invasion began to shape up, they moved back to Oahu to train on the new lightweight TPS sets.

This reconversion training was one of the first assignments taken on by the New Equipment Introductory Detachment (NEID). Operating out of the Signal Corps Ground Signal Agency, NEID started out under the name of Field Instructors Detachment a year ago. About that time, a whole crop of new ground equipments was about to go into the field. As had often been the case, theater personnel just weren't familiar enough with the equipment to put it into immediate operation. But you could get around this if you could send qualified people into combat areas before the equipment arrived or as soon as possible thereafter. And so the Detachment was born.

Selected personnel was sent to learn the new equipments from stem to stern at factories and laboratories. Teams of officers and enlisted men (many of the teams were one-man affairs at the start) went into theaters of operations on temporary duty orders. They set up schools or prepared courses in existing schools on operation, maintenance and tactical uses of the equipment; met theater requests for assistance in special tests or emergency missions; gave general assistance on any radar or communications problems. By late 1944, the organization was in full swing.



Operators work at double line of MEW scopes. At first, sea clutter was very bad and made equipment almost useless at low angles. Recent modifications have fixed this



In pre-MEW days, the TPS-3 had to be hand-carried piece by piece up jagged, coral-studded cliffs to summit of Mt. Tapotchau



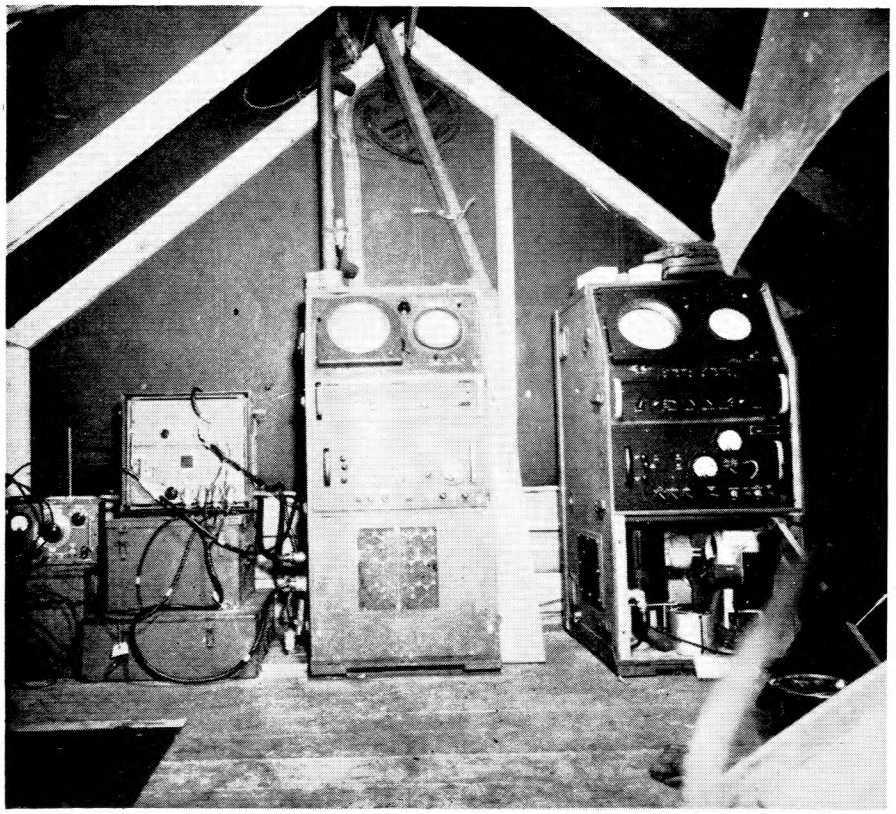
Right on summit TPS-3 was installed. Indicator units and spare parts were kept in abandoned Jap machine gun cave, lower right

BURNING B-29s ON THE SAIPAN AIRSTRIP PRESENTED A GRIM SIGHT AFTER JAPS SNEAKED IN AND HAD A FIELD-DAY WITH INCENDIARIES





TPS-3 at its Marpi Point site is set up on a 20-foot wooden tower so that radiation will not be lost in the tree line. Tents on ground house personnel and supplies



Operating room is in tent on top of the tower. TPS-3 console is at center; spare components are in console at right; IFF, spares, and test equipment are at left

On November 26, 1944, a conference was held at Hq. AAFPOA to discuss the lack of low angle radar coverage on Saipan. It is true that the MEW was there, and had been for some time, but it was still sitting in its weather-beaten packing cases (see RADAR No. 7). All in all, there were several gaps in Saipan's defense setup and the Japs were making the most of them. So far as radar was concerned in this situation, a set was needed which could supply adequate low angle coverage at a minimum cost of installation time.

Two days later personnel and equipment were assembled for the flight to Saipan—a platoon of SCR-588 personnel, 2 officers, one NEID representative, AN/TPS-3 radar, power units and IFF.

From the beginning, the Saipan mission was no cinch. For one thing, the group ran into a lot of sales resistance—scepticism about the equipment and its ability to do the job as well as a certain reluctance to accept outside help. However, early in the morning of 2 Dec., the first TPS-3 was hauled up to the summit of Mount Tapotchau the hard way. It took about 3 days to get it in operation. After it had been on the air half an hour, orders came to move so blasting could begin for the MEW.

While the TPS-3 was being dismantled, a new site on Marpi Point at the northern tip of the island was picked. The move was made on 6 Dec. and that evening the TPS-3 went on the air again. Operators and maintenance men themselves had to serve as guards against stray Japs. Early next morning, 7 December, several bogies were detected and reported. The flash "red' wasn't given until half an hour later and Japs got in to drop incendiaries on Isley Field. But next day a Naval Construction Battalion crew was sent down to build a wooden tower for the radar and a group of Marines was detailed as guard.

Shortly thereafter, calibration flights were run and odd bugs were ironed out. Classes were held almost daily in the course of normal operation. During this period, Saipan-based aircraft ran surprise flights on the TPS-3, any time, day or night, to see how well radar and crew would stand up. They didn't miss.

The TPS-3 did an excellent emergency job and so did NEID. More than that, even after the MEW was installed on the mountain, it was decided to keep the little set on Marpi Point as a permanent installation. It's still there.



Radar middleman

Col. Dolan knew what microwave could do and proved it

If Col. William C. Dolan ever gave radar a serious thought before February 1942 nobody knew it. Yet by February 1945, when he was lost flying the second of the new APQ-7 installations to the ETO, he had helped to ready a whole string of microwave airborne radars for combat. He came in with the first U. S. microwave ASV and went out with high-resolution Eagle. In between he left his stamp on all of these: 517A, 517C, 717A, 717B, LAB and APS-15.

Col. Dolan was a sort of radar middleman, bridging the gap between production and theater use. He flight-tested the equipment, developed tactics and techniques for getting the most out of it and trained crews to use it.

Most people who knew sandy-haired, fiery Bid Dolan wondered what kept him glued to U. S. chores when battles were being fought elsewhere. He did it for radar. But he was forever scouting ways and means of battle-testing the equipment himself, and occasionally, as in the anti-sub campaign, he succeeded.

Chance threw him face to face with microwave radar. What he saw made him fall for it. On the basis of background a hundred thousand other men would have seemed likelier apostles. He was no operational analyst. He was far from being a scientist. And he was short on formal education. But he was a good instrument pilot—one of the best—with a keen instinct for the tools that upped an aircraft's fighting value. To Col. Dolan airborne radar held the same significance as a machine gun or a compass. He expounded on that steadily.

With respect to radar, he was the crash product of a crash period. The Army needed some instrument pilots to test the first microwave ASVs, fresh from the Laboratory, against the U-boats which in 1942 were sinking 16,000 tons of shipping daily. Col. (then Lt. Col.) Dolan was rooted loose from his B-26 squadron command under secret orders and shortly found himself at Cambridge, Mass., looking at his first radar installation. He did plenty of looking during February and March 1942 while being initiated into the new art. He ran ASV tests against friendly subs off New London, detecting and homing. Once he homed too well, for when he brought his unarmed plane in close over the target he found a U-boat and tender shooting at him. "I sure got the hell away from there," he said.

By the time the 1st Sea-Search Attack Group was activated on 17 June 1942 with Col. Dolan in charge, he had already led radar hunts from Boston, New York and Key West (later from Trinidad, too) and was building up a reputation as an anti-sub tactician. The "killer" techniques he developed went a long way toward defeating the U-boat, although the credit goes jointly to the RAF, Antisub Command and others. Day in, day out, Col. Dolan's group worked at testing and improving radar and associated devices.

When U-boat warfare shifted to the other side of the Atlantic, there was plenty of activity on radar bombing to take its place. Col. Dolan trained and equipped the Wright, Scott and Hopson Projects, which brought LAB to the 13th, 5th and 14th AFs, delegating some of his best sub-fighters as the nucleus.

After the Sea-Search Group was inactivated in April 1944, Col. Dolan, by now Deputy Base Commander at Langley, gave birth to a 4-day radar indoctrination course for AAF officers from Generals to Lieutenants, and pitched in on the instruction. After his transfer to the 8th AF in August 1944, the school moved to Orlando.

In the ETO he dug in on the knotty problems of high altitude radar bombing. He felt handicapped because he hadn't flown combat over Germany, so he wrangled and wheedled until permission was forthcoming. By unofficial count he had 16 missions.

He had followed APQ-7 during his days at Langley and early in 1945 he flew to Florida to hurry the installations. He was taking one back when he ran into storms over Newfoundland and disappeared.

Today Bid Dolan's interest in radar is commonplace. But a few years back it was truly unique. That makes him one of radar's operational pioneers; his students are at work the world over.

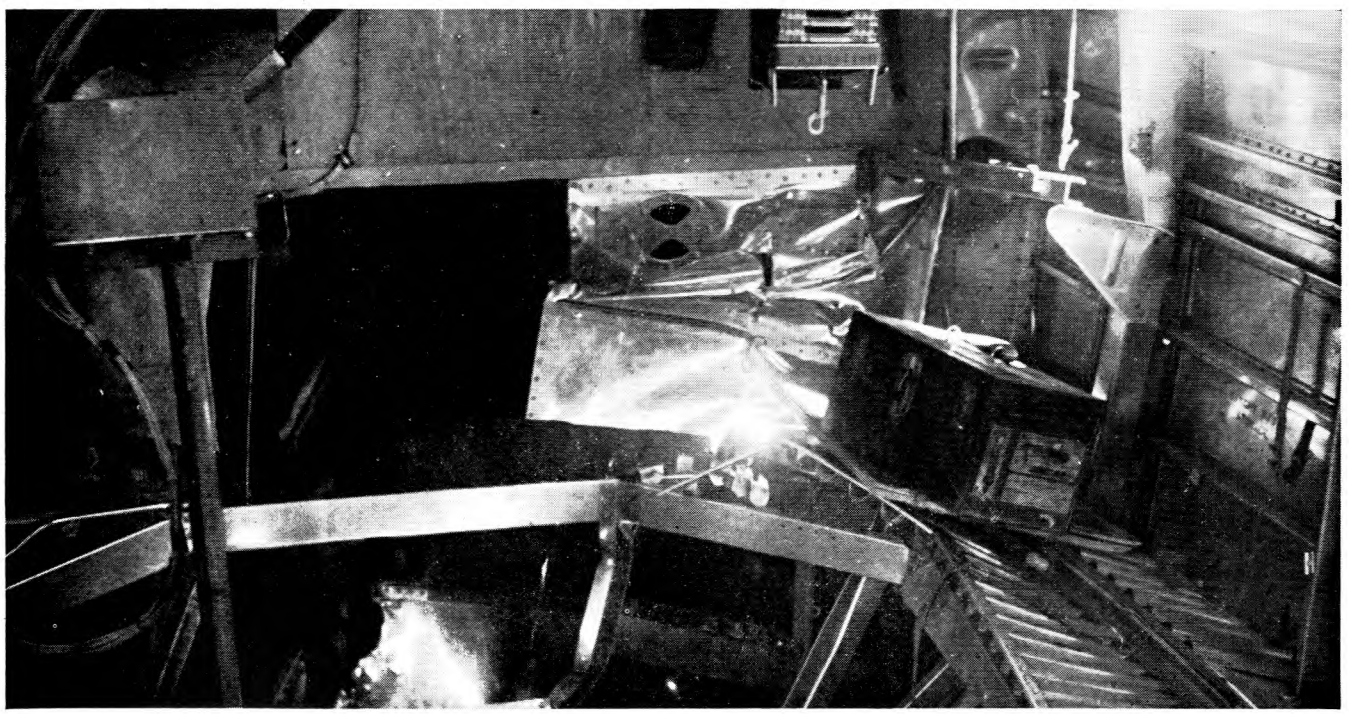
Fallen ferret

The unhappy B-24 Ferret below, newly arrived on Guam only a few days before this picture was taken, blew a tire just before becoming airborne on a test flight. Swerving off the runway, the plane crashed into an embankment with results shown below. Strangely and fortunately, no lives were lost—there wasn't even a serious injury to anyone aboard.

The crashed Ferret was one of 4, representing the latest thing in radar search equipment, delivered to the XXI Bomber Command's 3rd Photo Recon Unit. RCM gear, previously crowded into half of the B-24 rear bomb bay, occupies the entire rear bay in the new Ferrets. An early issue will report on the fitting of these planes by the Fairfield ATSC.



RCM compartment in rear bomb bay of crashed Ferret (below) held latest equipment for locating and analyzing enemy radar. All countermeasures equipment was salvaged except one APR-4 search receiver and 2 antennas, APA-24 and APA-17. Four remaining Ferrets and replacement due in June are destined to pinpoint Japanese home radar in preparation for the final Allied assault

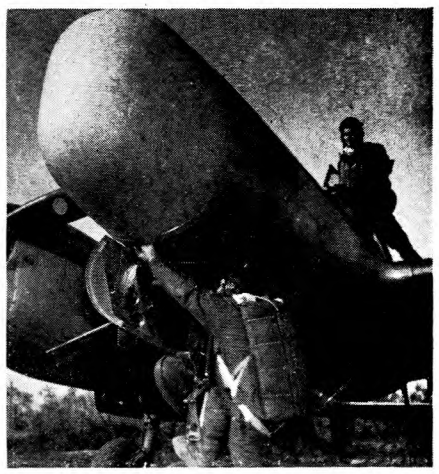




A lot of gas goes into radar-equipped P-38 which has to lug 2 extra 250 gallon tanks



Flight plan is checked carefully by pilot and Mickey operator just prior to take-off



Mickey operator literally crawls into the APS-15, components of which surround him

Lightning borne H_2X

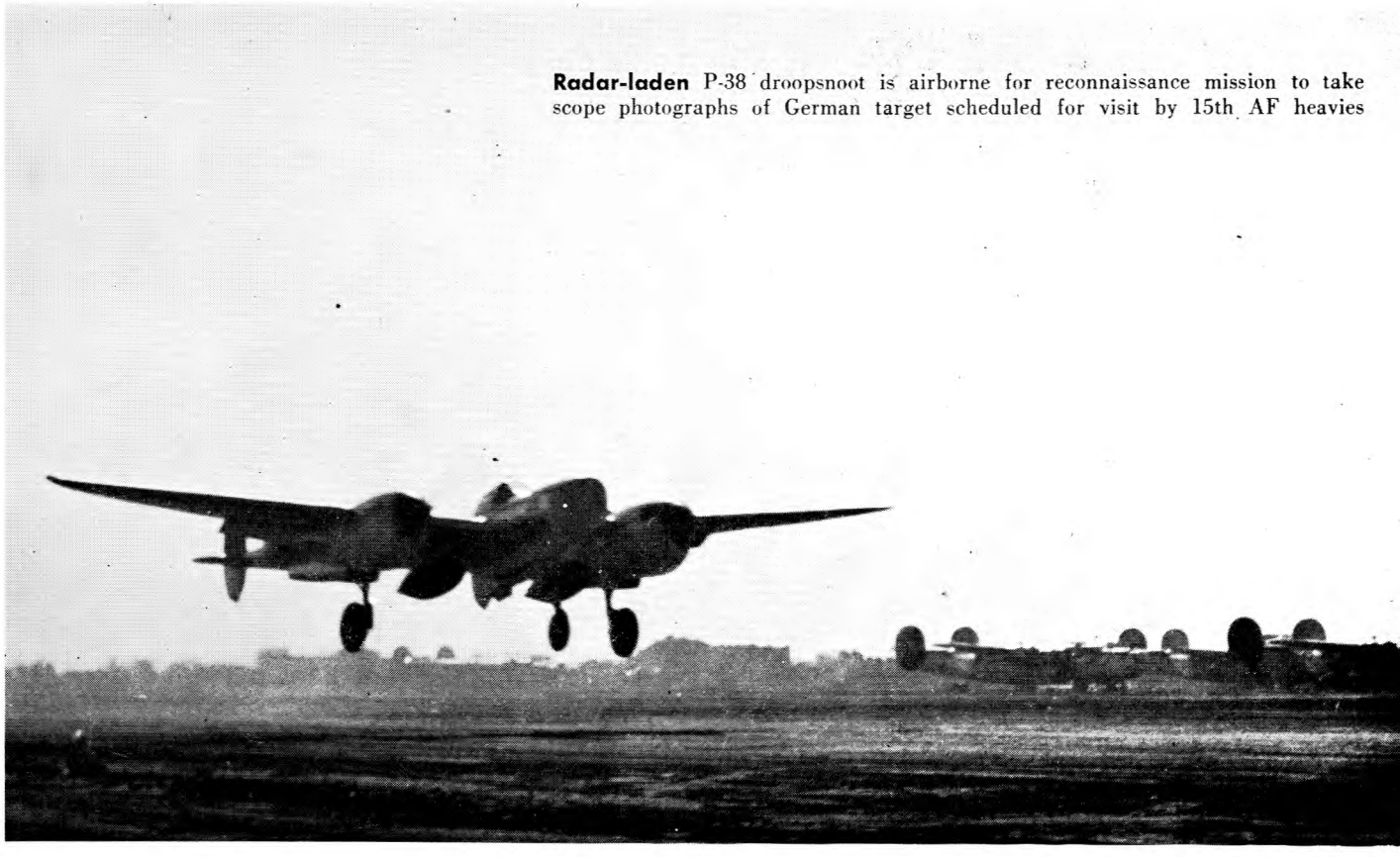
Droopsnoot P-38s are paying off as radar scouts

The malleable snoot of the P-38 was originally dropped to accommodate a bombardier. More recently it was reworked to play host to H_2X radar. It's a fair question whether the plane was modified to include AN/APS-15 or the APS-15 modified to include wings and engines. Whichever it was, these face-lifted Lightnings are being put to good use by our European Air Forces for radar reconnaissance.

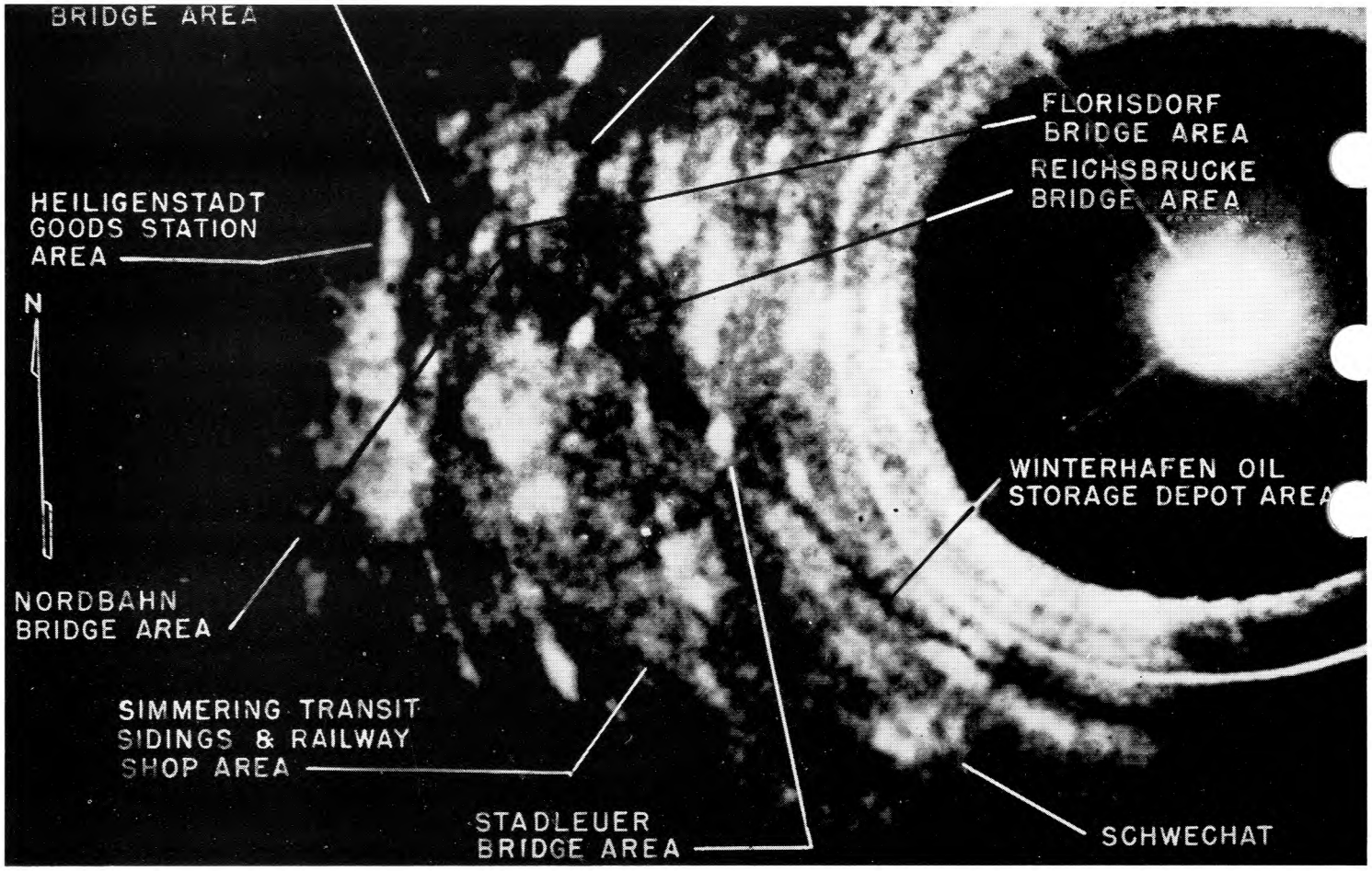
In the 15th AF, resulting scope pictures are transforming target information files into enviable galleries of "scopographic" art. City portraiture is a specialty: see Munich in RADAR No. 8, Vienna on page 30 of this issue.

There are several advantages to fighter reconnaissance, as opposed to bomber, which may account for this improved photography. One of the most important is that the primary objective of ship and crew is to take scope photographs. The operator can bend his entire effort to that end. Moreover, the use of a P-38, with its high ceiling and great speed, assures a minimum of risk from flak and enemy interception. With the employment of 2 extra 250 gallon tanks the droopsnoots can cover all targets within operational range of 15th AF bombers.

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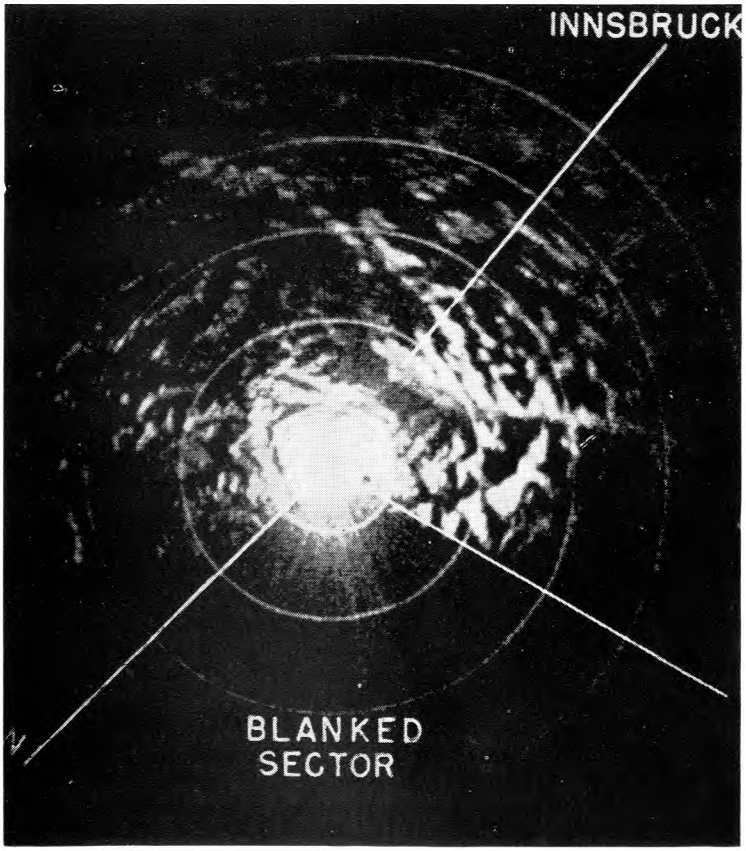


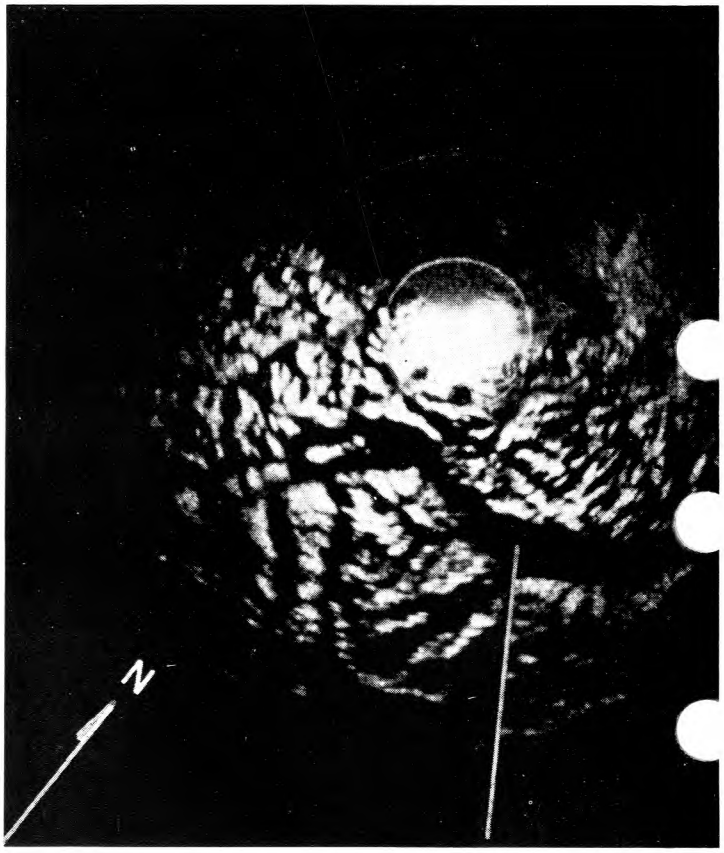
Radar-laden P-38 droopsnoot is airborne for reconnaissance mission to take scope photographs of German target scheduled for visit by 15th AF heavies



Vienna was a juicy target for 15th Air Force heavy bombers until the Soviets knocked it out of the war this month. This scope photo of Vienna, taken in an AN/APS-15 equipped P-38, was valuable in identifying specific target signals within the built-up area

Approach angle is a vital factor in radar navigation as illustrated in scope photos below. Innsbruck, Austria, is visible when approached from the south (left). From the north (right) the valley in which Innsbruck lies can be seen—but not the city



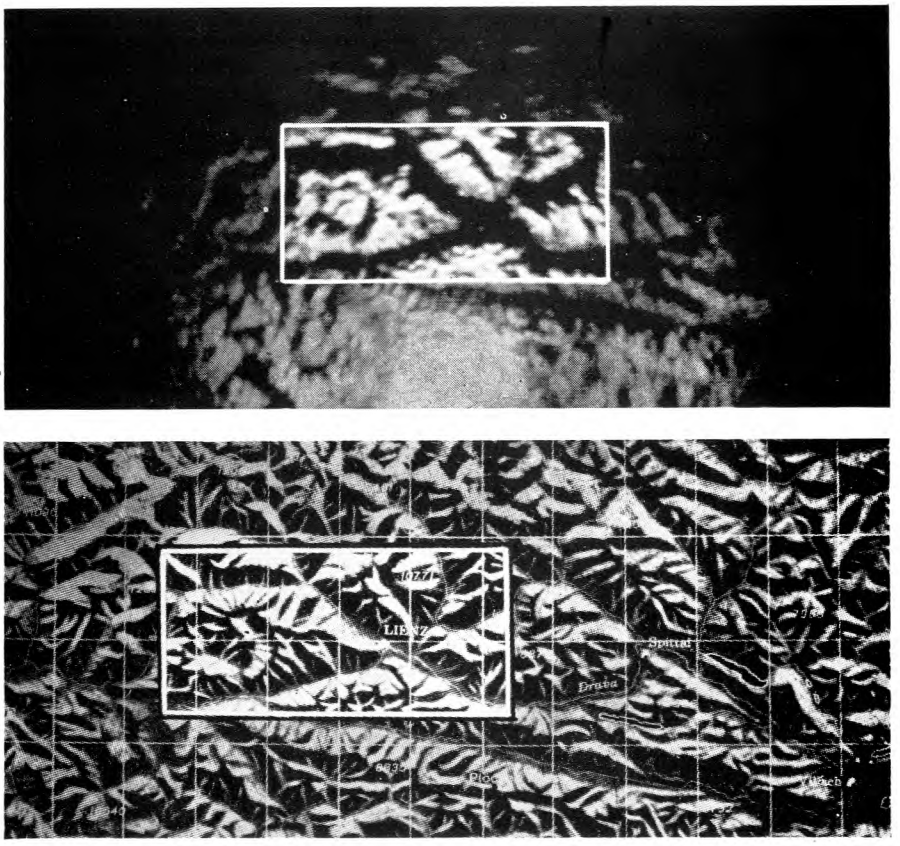


Replacing the pointed P-38 nose is a blunt radome, housing the spinner assembly for APS-15. The receiver-indicator is directly behind the spinner and below it is an entrance hatch for the radar operator. Inverters, transmitter-converter unit and junction boxes are just behind the operator's seat. Hung at the operator's right side is the control unit, with the PRI (remote scope) near his left shoulder. Two large windows afford adequate view to either side of the plane.

Scope photos are taken from the remote scope which is mounted in an upright position with separate brilliance and focus controls. A modified K-24 camera, with f6.8 lens of 3″ focal length, is attached. For picture taking the set is run at slow speed scan.

The APS-15 operates in a droopsnoot just about the same as it does in a bomber. However, PPI resolution covers only 250° of azimuth because pulses from the snoot-mounted reflector are broken up by the plane itself when the spinner is pointing rearward. Attempts to provide azimuth stabilization with the flux gate compass failed because the transmitter could not be installed where the magnetic field of engines and plane didn't interfere. However, stabilization has been achieved lately with the magnesyn compass and one plane is now so equipped.

The 3 original P-38s of this type were assigned to the 15th Photographic Reconnaissance Squadron, 5th Photo Group, and veteran navigators were obtained to operate the Mickey sets and take pictures. For more on droopsnoots turn the page.



Navigation over mountainous terrain can be easy with scope pictures and relief maps like those above. Photos are plotted rapidly by 15th AF scope interpreters (below)



A P-38 recon mission brings back a lot of information

A P-38 radar reconnaissance mission provides scope photos for the routes to and from a target as well as for a series of target runs, made from the cardinal points of the compass and from logical axes of attack. A complete coverage of the target, on the 20-mile range, is thus obtained. Resulting pictures illustrate how a signal varies when the target is viewed from different angles, and are helpful in planning approach patterns. Also, while these runs are being made the target is rolled out to about 6 miles, giving maximum size to the return. Against large cities this procedure has been of great value in identifying industrial areas, marshalling yards, refineries, and other specific sections of the city.

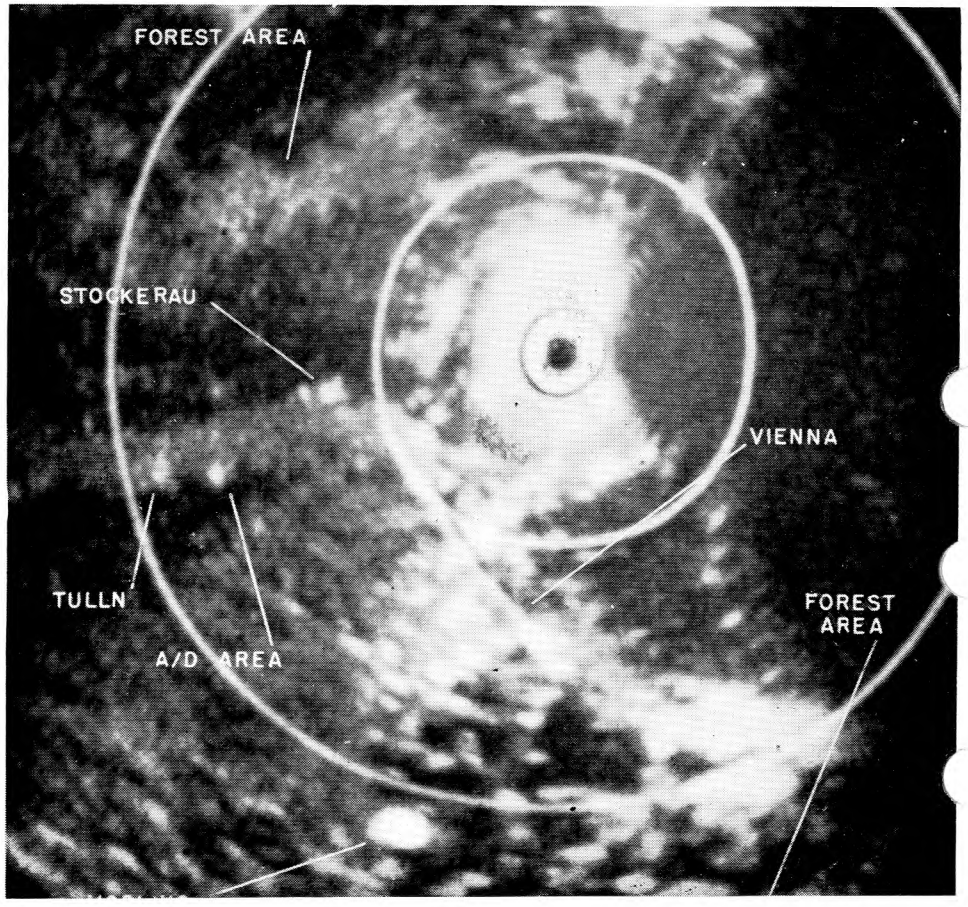
Navigation to and from the target is done via radar, just as it would be done by the Pathfinder operator on a bombing mission. The same signals are used for check points as the Pathfinder operator would use so that photos, taken on the 50-mile scan, make excellent orientation pictures.

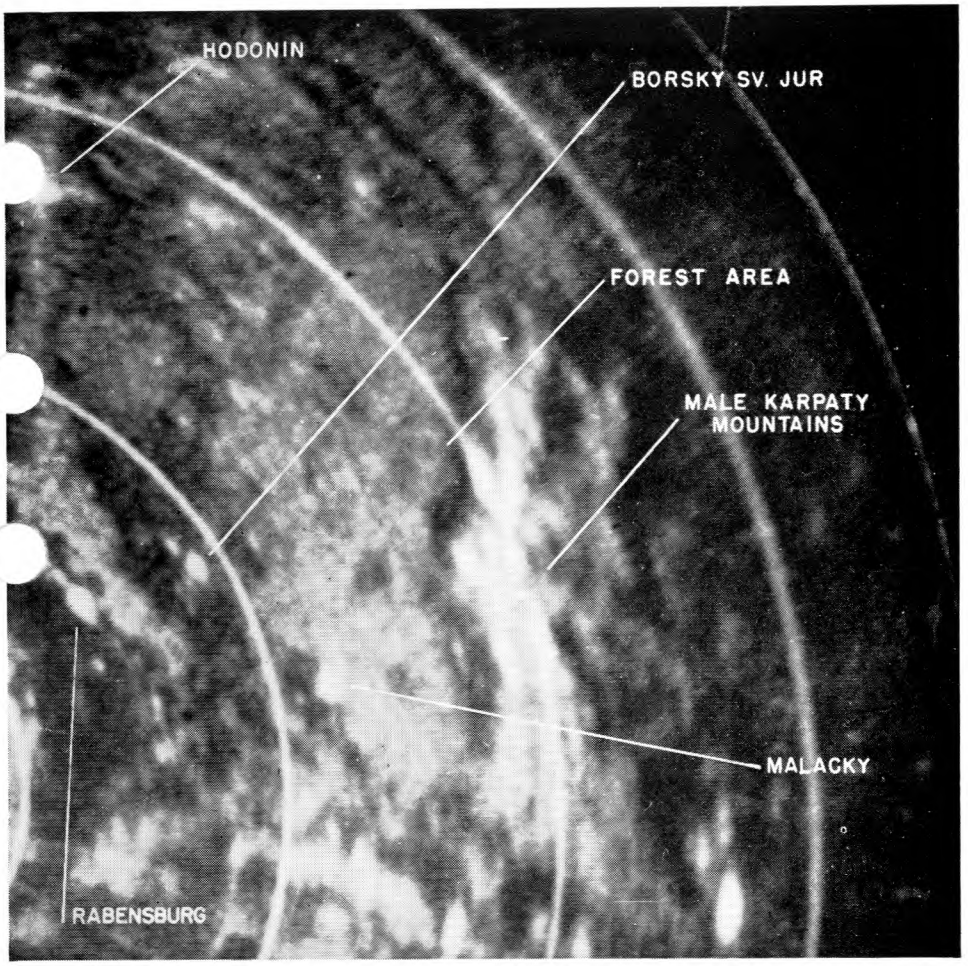
Immediately upon the completion of a mission the film is processed and a set of prints forwarded to the Air Force interpretation section. With the aid of notes made by the operator as to headings and general target areas, the interpreters plot each photo on their maps and make a thorough analysis. The best pictures are then reproduced in the form of contact prints, lithographed layouts, and numbered as supplements to the Pathfinder Operators Target Information File. The material is also used by Plans personnel in making decisions as to the suitability of targets for Pathfinder bombing.

P-38 scope reconnaissance has given interpreters some exceptionally fine pictures to work with. As a result, they have been able to uncover more and more of the vital intelligence presented, though often unrecognized, on the PPI screen. At first, scope interpretation was limited to plotting towns, lakes and large rivers. Then, as the stock of photos grew and interpreters became more adept, it was possible to identify factory areas, marshalling yards, etc.

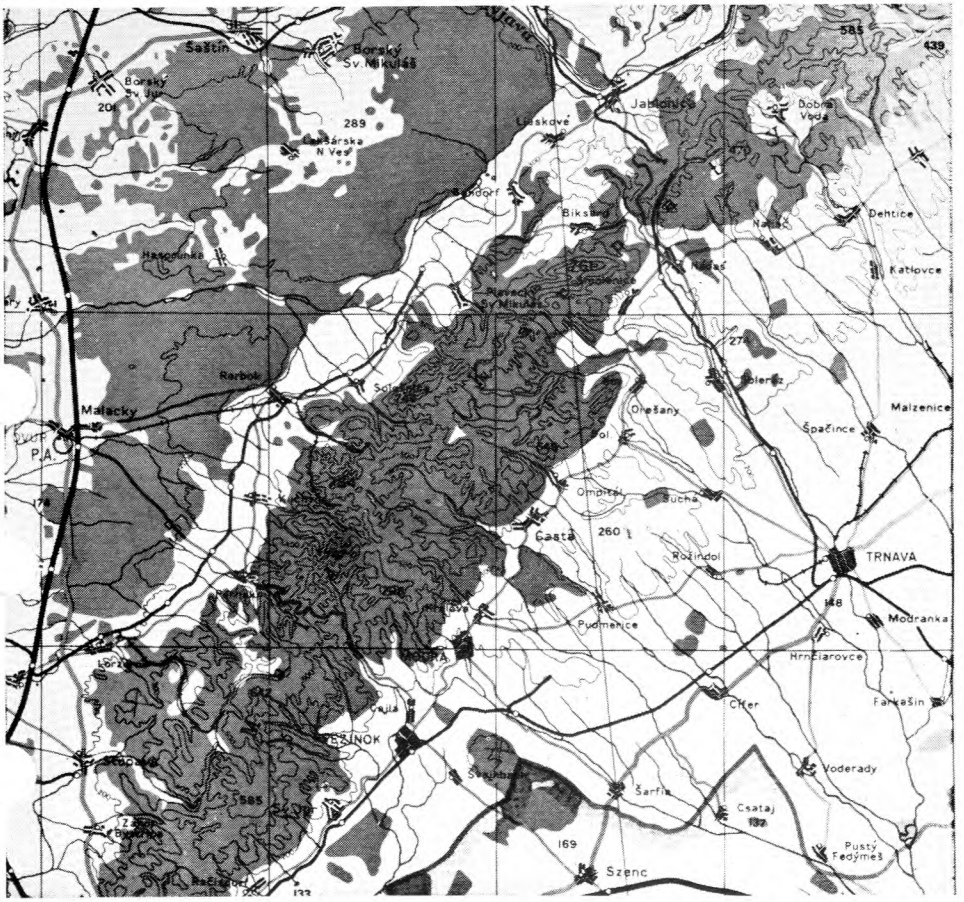


Forest areas around Vienna are resolved on APS-15 scope in droopsnoot P-38 (50 mile range). Such returns are good enough to be used as check points in H_2X navigation





Male Karpaty mountains and adjacent wooded areas show up well but rail lines and roads do not—in fact, they give a negative return when compared with forest signals



Droopsnoot photos show wooded areas give positive return

Recently 15th AF interpreters have added another "row of letters" to radar's vision. One day, a series of photos they were examining showed a large river giving an unexpected positive return in some places while elsewhere it gave the usual negative return. One explanation was that the river banks were covered with snow. Yet a river could be frozen over and snow covered and still give a negative return. When the "positive-negative" river was compared with an accurate map, it was found that the positive return was obtained *only* when the river banks were wooded. There was no sign of a signal where there were no trees.

This explanation was contradictory to the original idea that wooded areas would give little or no return. So interpreters looked for wooded areas elsewhere, away from rivers. And sure enough, on a flat land area a forest was seen to give a positive signal, weak, but clearly identifiable as a return nevertheless.

Interpreters are still a bit hazy as to why, although some plausible explanations have been advanced. It may be a seasonal phenomenon, caused by rain or snow on the trees. A wet wooded area would seem to be a better reflector than barren land. The type of tree, too, could affect the strength of the return—pine needles would tend to disperse energy while flat leaves would be more likely to reflect it.

It is probable that these forest returns have always been present, needing only experienced operators to bring them out. On the other hand, it is possible for forest returns to be missed entirely by the operator, although they are recorded by the camera.

In any case, as pictures and maps on this page show, the advantage of being able to identify forest patterns in complex target areas can be without any doubt a solid one.

In recognition of the growing importance and improving techniques of scope photography, an early issue of RADAR will present a detailed survey of the subject, including a portfolio of noteworthy scope photographs.



ARMORERS-GUNNERS OF 7TH AF NIGHTFIGHTER SQUADRON IN THE MARIANAS FEED 20 MM. SHELLS INTO P-61 BEFORE START OF MISSION

The Nightfighters: II

Success hinges on teamwork and training

More so than with U. S. air forces, in the RAF nightfighting is a prestige service. The distinction stems from the crucial nights in 1941 when a handful of Blenheims and Beaufighters, newly fitted with AI radar, helped to stave off invasion.

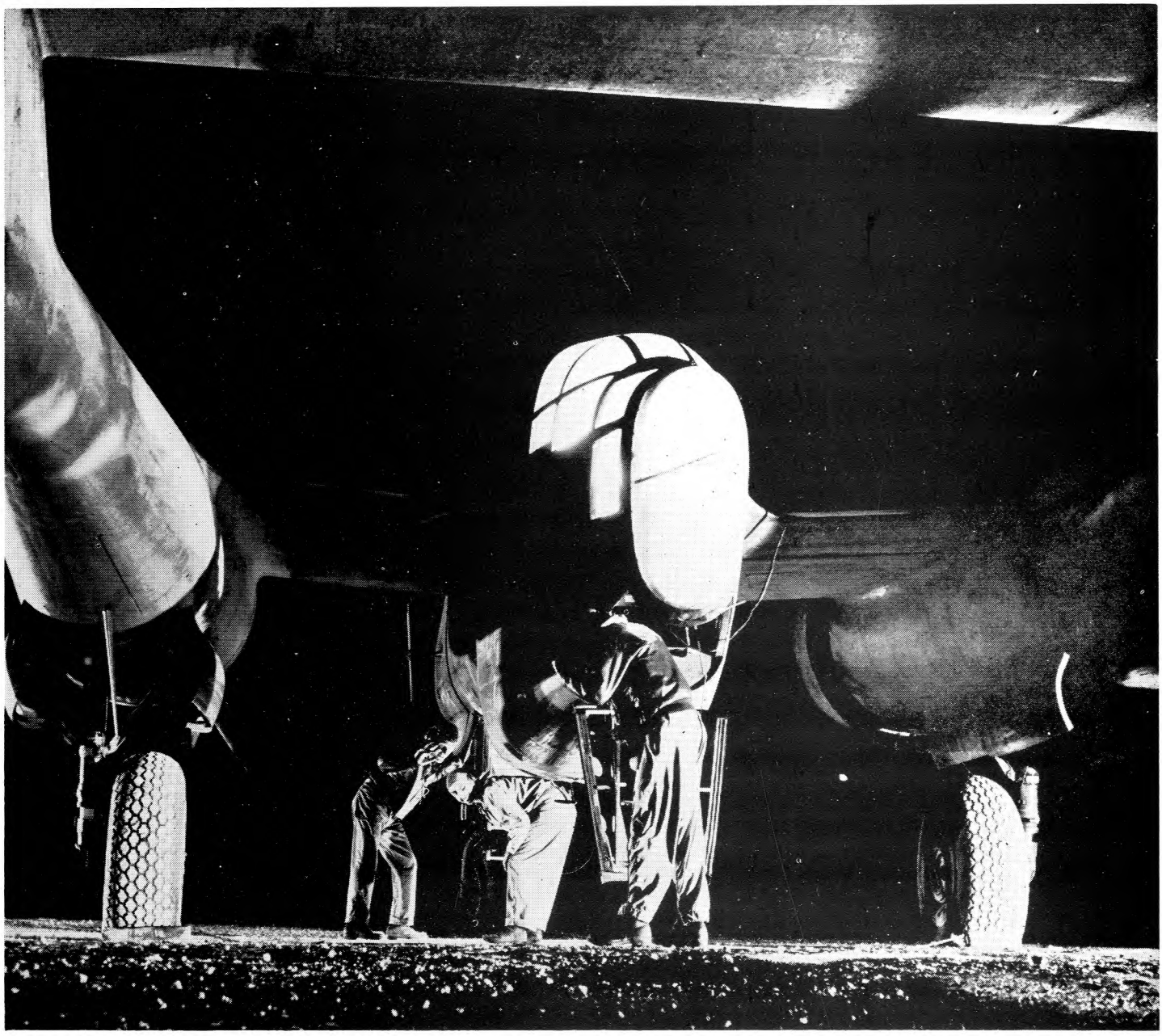
Nowadays, the distinction is more than past glory. Only the select make the grade as members of an RAF nightfighter team and not all of these stay to enjoy the status. The RAF radar observer who loses one contact on his Mk X (SCR-720B) radar is in disfavor. Three and he's out.

The responsibility is shared by his pilot through tight orbits, sudden peel-offs, throttling back and any other maneuvers that the quarry may try.

By and large, nightfighter training—whether AAF, RAF, Marine or Navy—follows the same pattern. The length of training doesn't vary much. And U. S. establishments rate with the best.

Originally considered an "old man's job" because of the need for steadiness and sound judgment, nightfighting today is no different from day fighting with respect to crew age. One of the vital aims of training is to infuse the same qualities of steadiness and judgment into youngsters, and to weed out those that don't respond. Otherwise, the hazards stack up too heavily. Although nightfighters infrequently go down in combat they often succumb to their own mistakes. A veteran put it this way: "Day fighters are killed in combat. Night fighters kill themselves."

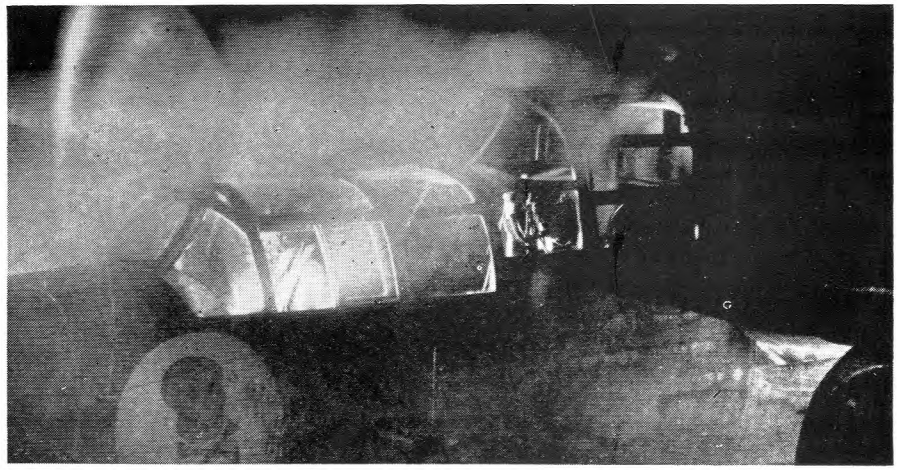
Teamwork and training fuse early in nightfighting and one means little without the other. In the P-61 and Mosquito, the leading AAF and RAF nightfighters, the aircrews are basically the



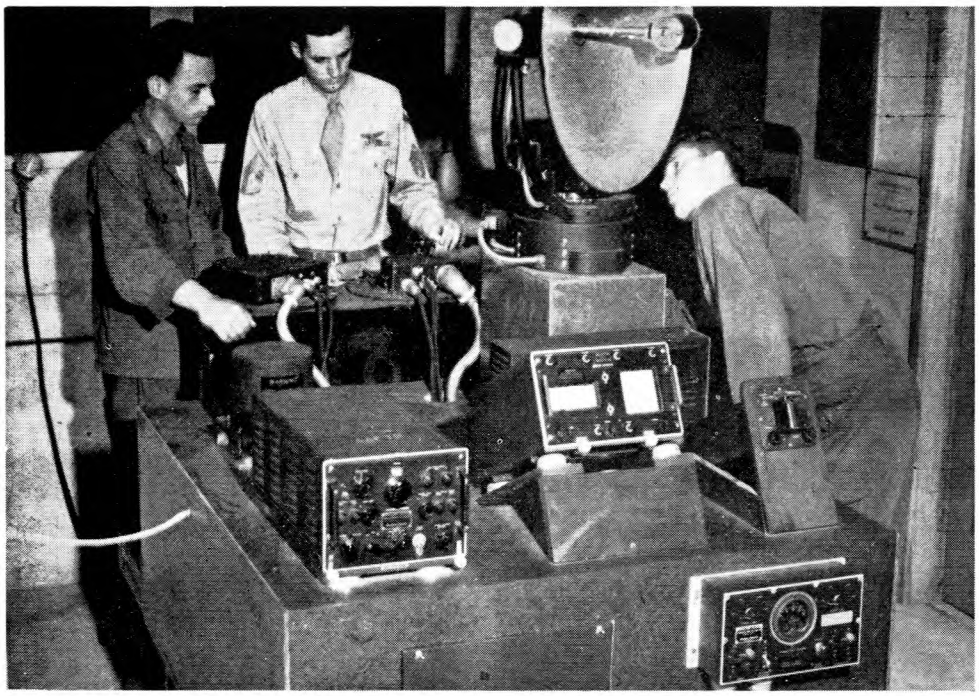
TRAINED AND CONFIDENT, TEAMMATES WAVE CHEERFULLY AS RO CLIMBS INTO REAR CUBICLE. THIS CREW HAS 3 KILLS, 1 PROBABLE

pilot and the RO. The Navy's carrier-based F6F is a one-man aircraft. This resolves the teaming problem but puts an extra heavy load on the pilot-observers' shoulders. So far they've borne up well, and their number soon will increase with the expanding Navy program. The Marines, who went into nightfighting before the Navy, use both F6Fs and F7Fs, the latter a 2-engine, 2-man plane scheduled for widespread Navy work (see RADAR No. 8).

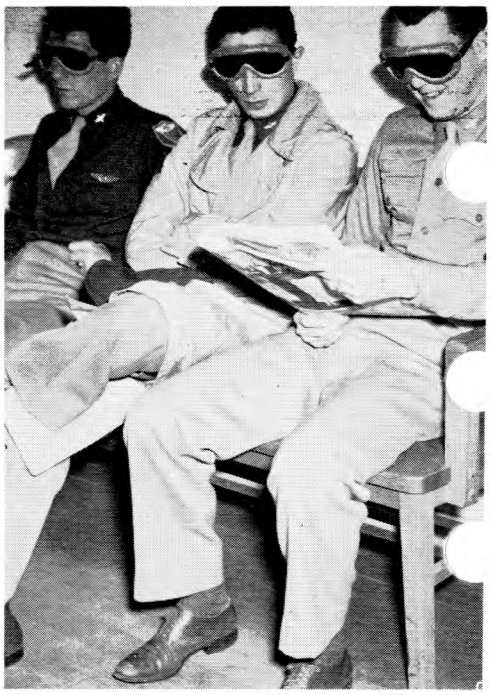
Nightfighting is inherently instrument flying, with a full kit of radar aboard. So the training prepares the team for blind flying, and as the curriculum moves on the proportion of night to day exercises becomes increasingly heavier.



Before takeoff, with props churning, pilot testfires his four .50 cal. machine guns



Trainee ROs give SCR-720 mockup get-acquainted glance as 9 week primary course begins. Setup shown here is used in training tuneup, calibration and trouble shooting



Aircrews wear red goggles before entering dark room for night vision training

How a nightfighter team becomes one

For the radar observer and the aerial gunner, AAF nightfighter training starts in Florida. The pilot begins his chores in Texas. After a few months they all get together in California to be welded into a team. What actually takes place as the training progresses is told here in a step-by-step account of the training of a fictitious aircrew.

Before coming to Boca Raton, Florida, for radar observer training, Don Marshall had been an aviation cadet. He had washed out after 70 hours because of an unforunate habit of landing his prop before the rest of his plane. But Don had a knack for electronics and, since his air time exceeded 50 hours, the minimum requirement for RO training, he was picked.

Boca wasn't the first stop. He was shipped to Tyndall Field for a 6-week schooling in aerial flexible gunnery, an essential for the man who has to handle the backward-looking .50 cal. machine guns on a P-61. At Boca he found himself immersed in a study of radar, including fundamentals, AI equipment, IFF, SCR-729, radar altimeter, interception techniques, navigation, air-to-air interception in a TB-26.

Nine weeks later, on graduation, he had put in 324 hours in training and had acquired some useful proficiencies. One of these was the ability to complete any type of AI interception with the target taking gentle evasive action and peel-offs. Another was navigation by radar, beacon and dead reckoning. He also had a good working knowledge of radar and could operate and perform 1st echelon maintenance on SCR-720 and supplementary nightfighting radar; he could send and receive Morse Code at the rate of 8 words per minute and blinker code half as fast.

To the west, somewhere in Texas, 2nd Lt. Hillis Wright was sweating out 10 weeks of transition pilot training in preparation for the real thing at Hammer Field. He had recently won his wings and was chafing for action, but the call for nightfighter pilots, preferably good instrument men, had brought him into the program. His transition work consisted mostly of learning the ins and outs of twin-engine aircraft, in the form of a B-25, after his cadet days in a single-engined AT6. By the time he was ready to move on he had chalked up 100 hours more of flying time, half in night and instrument work, and 136 hours in ground school.

Student RO Don Marshall and Pilot Hillis Wright almost bumped into each other on arrival at Hammer Field. But one didn't know the other existed until the first month was nearly over. Wright was neck deep in more transition, this time in a P-61, while Marshall soaked up more ground school knowledge. They met one night during a boxing match at the gym. Marshall, smaller but faster, scored an unintentional knockout and later spent considerable

ROs are taught use of standard E-6B computer (mockup on wall) to estimate wind by radar during dead reckoning navigation. Crews get intensive navigation schooling





SCR-720 Link Trainer room combines interception components. Left, instructor at interception table; far corner, RO's compartment; right, plane with pilot's scope

time apologizing. Within a week the two were inseparable and it was only natural that they should decide to join forces when it came time to team up at the start of the second month.

They were lucky, for "marriage" is one of the most crucial steps in night-fighting. To operate effectively, the pilot and radar observer must have confidence in each other and coordinate almost instinctively. They must live, eat and fly together. In a word, they must "click." Their lives and usefulness depend on it.

During their second month the new-found teammates developed a healthy respect for one another. Most of their work was in combination. This was the basic phase of team training. Thirty-five hours were devoted to night flying, 22 hours to day flying and about 40 periods (each 40 minutes) to ground school lectures. The bulk of the flying hours went to AI interception and night navigation. Instrument flying, air to ground gunnery, GCI flying and AI link trainer work came in for attention. The ground lectures stressed combat intelligence and operations, aircraft recognition, interception technique and night vision.

The next month completed the syllabus. During the first week Sgt. Gil Block, who had been trained as a remote control turret mechanic-gunner at Tyndall Field, joined the team and shortly thereafter began going along on midnight intruder practices across the San Joaquin Valley, over the High Sierras and past Death Valley. They used infra red film for bullets.

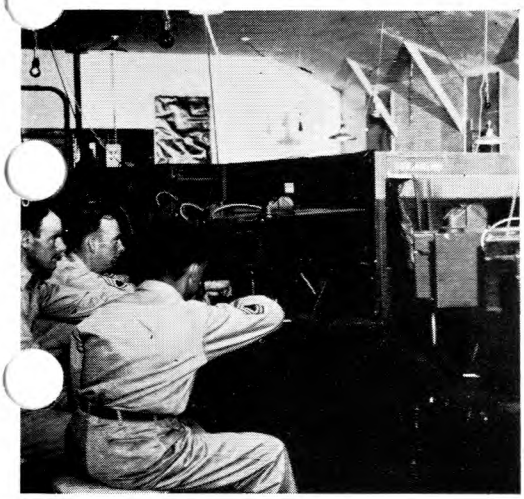
This was the testing month; the instructors had to be convinced that the team knew its stuff. Of 54 hours of flying, 38 were at night. In addition, there were 49 periods of classroom study. Some of the teams failed to make the grade and were held back for further training, but Lt. Wright's crew went sailing through with only one scare. That was when Marshall's low level intruder navigation had them all lost for a shaky 10 minutes.

By graduation day the RO had demonstrated his proficiency on both low and high level intruder navigation and on SCR-720 checkout tests. Wright had handily passed air-to-air gunnery and instrument tests. The team had proved itself able to follow and intercept a target despite any type of evasive action encountered in combat, to perform a patrol, strafing or bombing mission, to return home without landing light. It also showed that it was able to work with the GCI controller, who had himself received a 12-week schooling at Hammer Field.

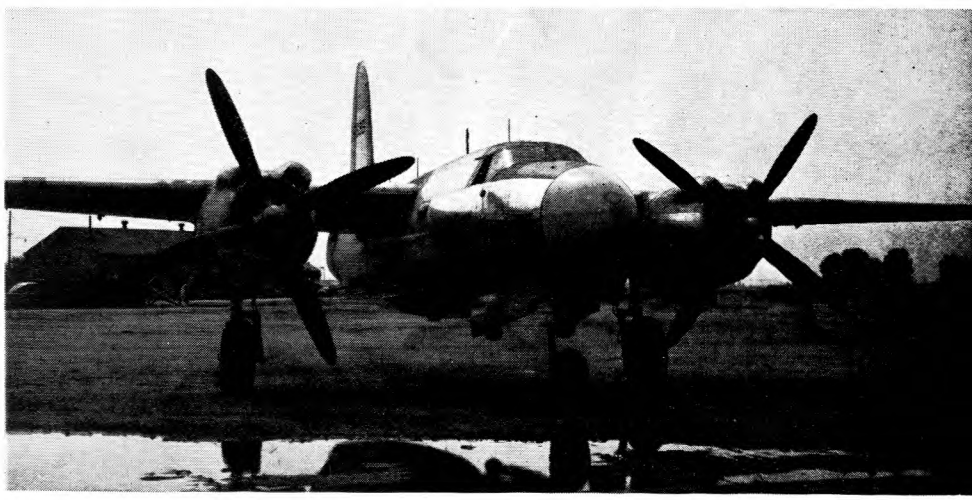
The next few weeks were spent in reassignment to a combat squadron, for Hammer was turning out nothing but replacement crews. While they waited for word to pack, the crew practiced as often as Lt. Wright could get a plane. They had been learning so many things that they were afraid some of their knowledge would slip away before they reached their squadron.

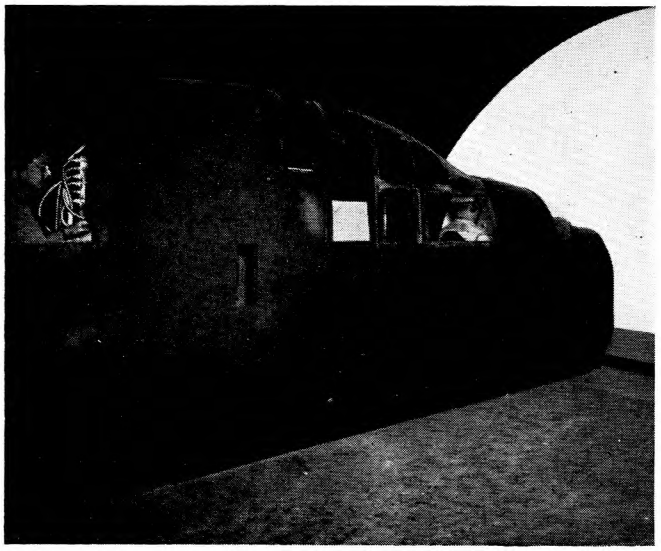
The first post was on an island off the Asiatic mainland. The squadron had seen more than 6 months of action and there was plenty of work, but for the new team it would all be training for another month or two. They had a shiny P-61, named the Merry Widow, equipped with SCR-720 and all the trimmings. Their job was to convince the

Aircraft identification trainer flashes enemy and friendly planes across screen

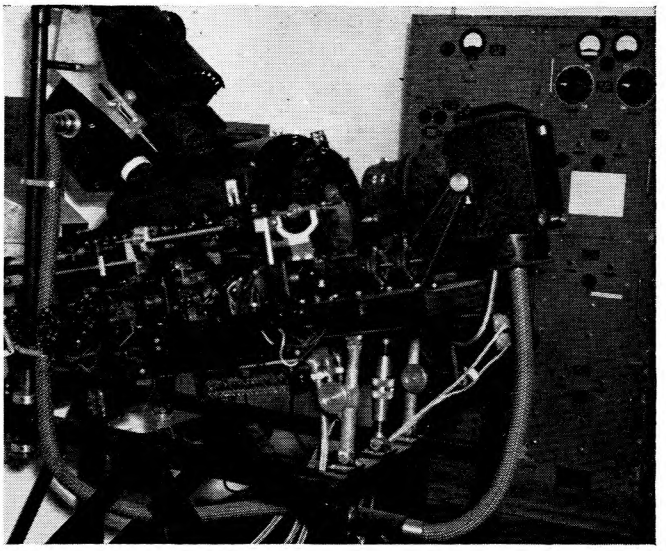


TB-26 is workhorse nightfighter sky trainer. Spherical nose holds SCR-720 spinner. Instructor and 5 student ROs sit on bench in cabin watching airborne presentation





Stripped-down YP-61 fuselage is business end of Type 19 Trainer which sets up and executes AI problems at Hammer Field. RO operates 720. Finally pilot will see visual target on cyclorama



Complex projection apparatus helps put target silhouette on cyclorama exactly at right instant, makes target react instantaneously to any movement of pilot's or instructor's controls

CO that they knew what to do with it.

AI and GCI missions, high and low level navigation, instrument flying, air-to-air and air-to-ground gunnery filled their nights and days, with 3 hours of night flying to every one during daylight. The older crews, who were still learning things themselves, provided plenty of operational tips. Disaster almost overtook the Merry Widow before it tasted combat; early one morning, landing in a driving rain, it slid off the runway and came to rest on its nose. But under the eager hands of the ground crews the big nightfighter was pounded into shape and one afternoon—some 50 days after they joined the squadron—the CO said it: "Get ready. You're flying tonight."

How to stay in the nightfighting game

The operational problems that vex nightfighting novices recently underwent Navy analysis. The findings were significant and the Navy hopes to minimize the shortcomings now that it knows what they are. The following isn't complete, but it points out some of the things that should be stressed in any nightfighter training.

Trust your instruments. Under emergency conditions many a man whose life depends on his instruments unconsciously deserts them.

Trust your fighter director officer (GCI controller). He's on the team.

Maintain strict night vision discipline. A white light, even the flash of a cigarette lighter in the dark cockpit, will destroy night vision for 30 minutes.

Check radio and radar equipment personally. A few minutes of pre-mission testing may make all the difference later.

Know every instrument blindfolded. This is a training requisite, but crash-knowledge acquired during the course is forgotten without constant practice.

Be expert at aircraft identification. Tragedies have occurred and legitimate targets lost because of faulty recognition.

. . . so they bailed out and walked home

What can happen during a nightfighter mission, and frequently does, came to light in this verbal report by an AAF air crew in Italy.

At 2200 hours on 1 March, 1945 a bogey was detected at 25,000 feet and Capt. Englert, pilot, and Lt. Dickie, radar observer, were scrambled from a forward field to attempt the intercept. Their plane was a Mosquito; their AI was Mk X (SCR-720B). Halfway up, the starboard engine lost power and gave out. Continuing on one engine the interceptor made AI contact at 22,000 feet. But now the reduced speed hurt and the chase continued all the way to the northern Italian border and into Germany, the fleeing target sewing window along the way. Through everything Lt. Dickie held the contact. When the E/A began a descent, apparently to land at its home field, Capt. Englert closed, identified the quarry as a night recon JU-188 and made the kill.

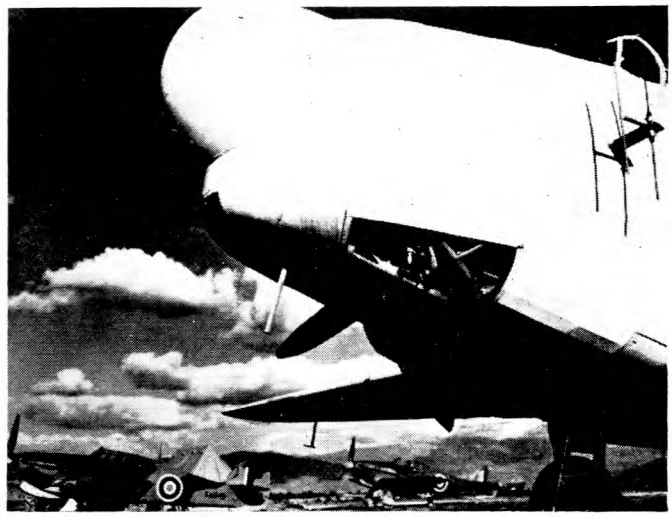
During the long pursuit the team had lost its way. But coastline returns on the SCR-720 gave enough information for a homeward course. On the way back several things happened almost simultaneously. The starboard landing wheel unlocked and wouldn't retract, the flaps wouldn't stay put and the instruments went out. The Mosquito became as bucky as a rodeo stallion but by dint of teamwork at the controls the pilot and RO managed to hold the course.

Over their field ground fog was bad. They circled around, trying to think up ways to get their battered vehicle down, when the port engine caught fire. They bailed out and walked home.

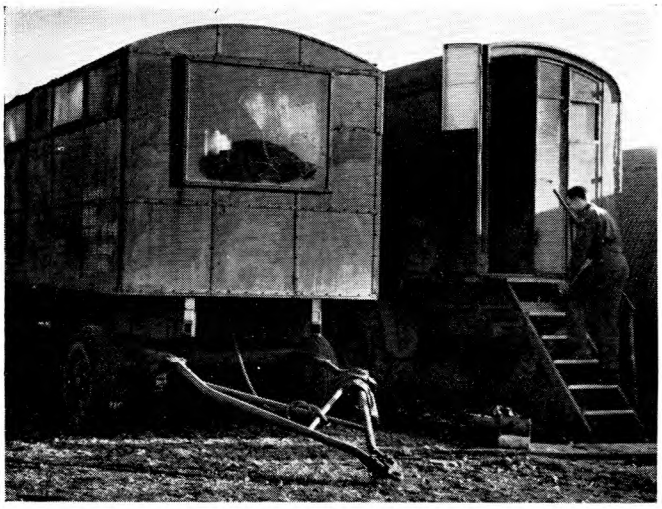
Training in the theater

In 5 years of nightfighting a dozen or more RAF and AAF AI models have come and gone. Each requires new radar observer skills, new crew coordination and, accordingly, new training. The necessity goes double for the current set, SCR-720B (British Mk X), which is substantially changed and the hardest to operate. Late in 1944 and early in 1945, MAAF teams based in Italy made the transition from Mk VIII—and novices among them brushed up on theater techniques—via the Mk X Conversion Flight.

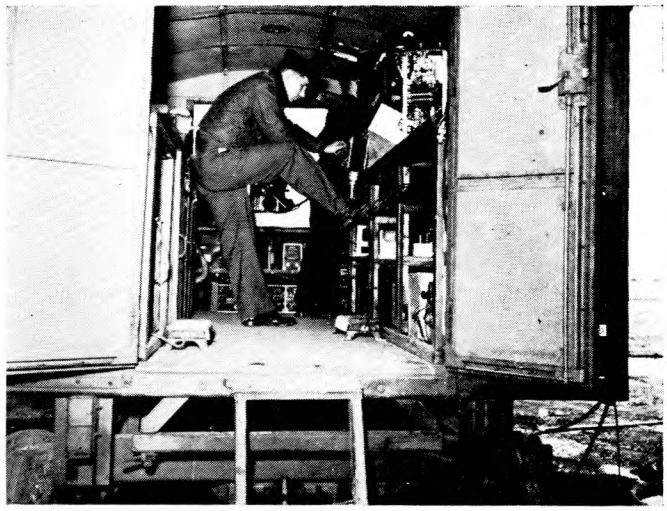
The Flight is an all-RAF outfit, assembled in England, composed of nightfighter veterans. The 25-hour syllabus, all meat and muscle, centers around the RO although the pilot gets in on the air exercises, too. The course includes airborne practice, synthetic trainer work, lectures and films. Here are pictured some highlights.



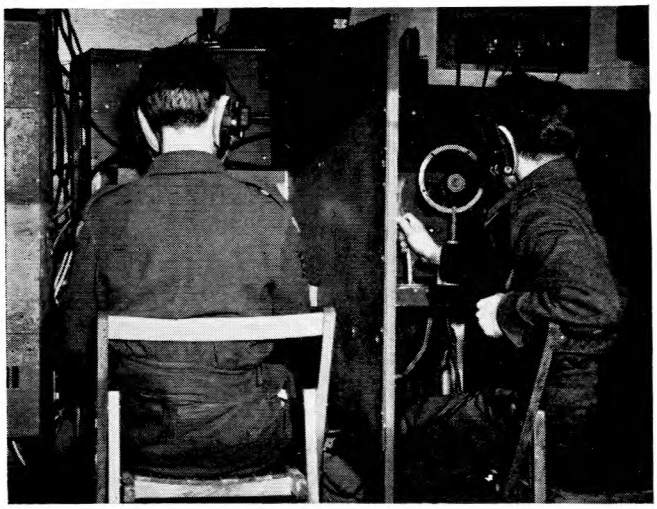
1 Nose radome and SCR-729 antenna identify white Wellington, called Wimpey, as Mk X Conversion Flight flying classroom



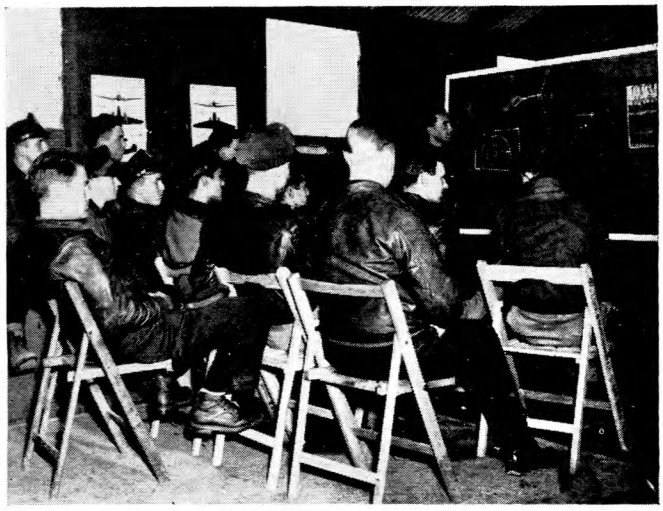
2 Radar workshop, left, and Mk X ground trainer operate side by side in nightfighter training. AAF, RAF share quarters



3 RO gets feel of SCR-720 controls in radar workshop. New AI is harder to master than MK VIII, but RO vets catch on fast



4 Nightfighter pilot, right, sits alongside target pilot as simulated trainer mission unfolds. Van houses the synthetic setup



5 Trainees of 2 MAAF squadrons soak up knowledge during interception tactics talk. Among ROs are some fresh from home



6 Ground school over for day, trainees head for Wimpey and a whack at the AI knobs and gadgets while chasing sky target



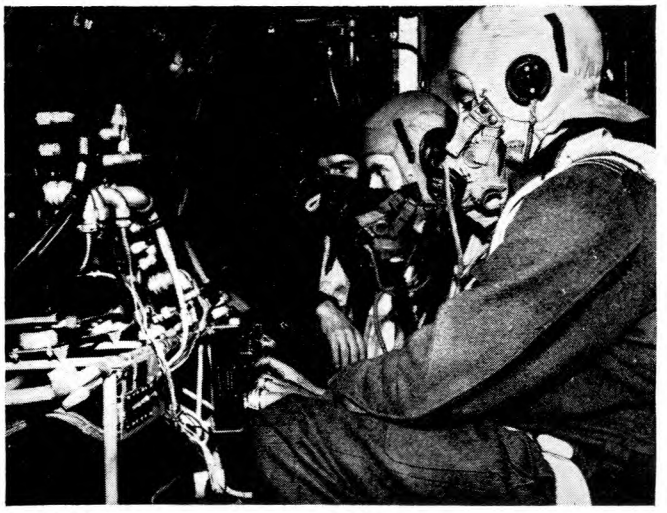
7 Before test flight students crouch around instructor for briefing. Only ace RAF night fighters are picked to teach



8 Today's target is Hurricane flown by nightfighter pilot. He learns what receiving end is like, gives ROs stiff workout



9 ROs and equipment are loaded into Wimpey. Mission starts. Training interceptions like these are hub of 25 hr. course



10 All eyes on B and C scopes. Four students and instructor are capacity load for Wimpey classroom. They handle AI



11 Flight over, training staff examines students' progress reports. Right, Squadron Leader H. Quittenden, unit chief

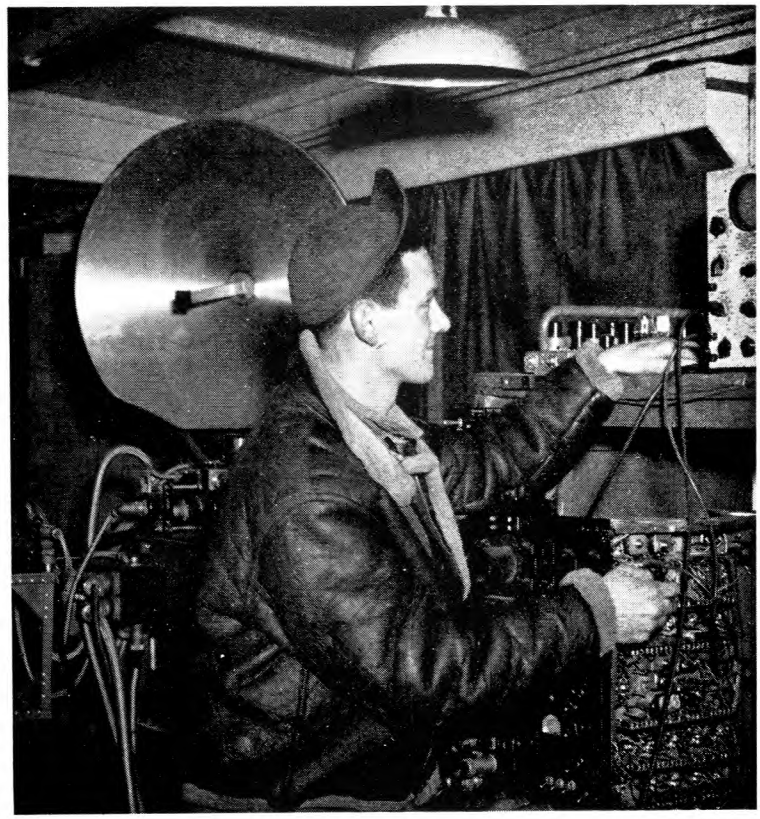
H_2X field school

With strategic bombing over in the ETO, the 482d Bomb Group's techniques may be a guide to improved results against Japan

Leading the field of H_2X education is the 482d Bomb Group of the 8th Air Force—an outfit steeped in radar tradition. This is the Group that won a name for itself by conducting all of the 8th's Pathfinder operations from the introduction of H_2X late in 1943 to March 1944. By then equipment was arriving in quantity and H_2X was dispersed to other groups. Thereupon, the training job was dumped on the 482d.

Since that time the Group has been turning out an average of more than 75 Mickey graduates per month. By now some 25,000 hours of training flights have been flown.

It is a good year's record, and as this issue goes to press it looks like the record book is closed—at least for the present setup. Because strategic bombing, in which the Group's students did their postgraduate work, has been written off as accomplished in the ETO (see page 9). It will continue full force against Japan, however, and for Japanese targets new training programs will have to be organized. To that end the educational system developed by the 482d Group can well serve as one good guide. For the record to come, RADAR here briefly reviews the Group's techniques.



Trouble shooting is part of 482d Bomb Group curriculum. Shops maintain 3 squadrons of Mickey ships and do developmental work. The 482d also handles radar reconnaissance assignments for the 8th AF. Crew below prepares for a recon mission over Germany

To minimize possible failures, candidate requirements for Mickey operator training are kept high. All men chosen are veteran combat D-R navigators or bombardiers picked by group commanders—volunteers being encouraged.

The 90 students who begin a course of instruction with the 482d at its Alconbury base are divided into flights and paired off so that 2 students work together throughout the 4 weeks of instruction. It's a rough 10 hour per day schedule from the beginning week of ground study. These first days are devoted to introducing the overall H_2X system—from the set itself, AN/APS-15, to radar maps, scope photographs and supersonic trainers. Also, during the first 15 days, navigators are refreshed in and bombardiers introduced to D-R navigational techniques.

Flight training, which constitutes the main part of the course, begins with the second week. The 2 students fly every day for a total of 16 flights and approximately 65 hours over 10 different routes. During each flight one student of a pair serves as Mickey operator, one as D-R navigator.

Although most of the last 3 weeks are spent in the air, students spend 2 hours of each day working out problems on one of the Group's 4 supersonic trainers. Since these trainers are fitted with the Norden sight, the practice serves to smooth out the synchronizing procedure. Throughout the course special emphasis is placed on briefing, intelligence, theater navigation, target study and scope interpretation. A close check is kept on student progress. On the ground, through examinations—in the air, through simulated bomb runs.

At the conclusion of his training the student is either checked out for operations, given additional flights, re-enrolled or washed. An average of 12 to 15% of the students fail to





H$_2$X isn't this good—but it's getting better. Above inspiration for Mickey students was created by Sgt. John "Trader" Horn

check out, not a bad percentage considering the course.

Credit for development of this training program is shared by the entire Group. That includes the Group Navigators Section, which now conducts the school; the Radar Shop, which has pioneered in H_2X technical developments and in devising training aids; the Squadrons and combat crews, who flew the first Pathfinder missions and have flown all the hours of training without accident; the Group Intelligence Section, which was instrumental in the developments of scope photography and radar maps; and the Group Operations and Headquarters Staff, which integrated them all into one unit.

Of all the sections the Radar Shop is probably most versatile and unique, functioning as a mechanics' school and a research-maintenance laboratory simultaneously. In the latter capacity it has been responsible for many of the modifications necessary to make the APS-15 combat worthy.

The 4 weeks of schooling a Mickey operator gets from the 482d is really only the beginning of his radar education—there is no end. But the beginning, as worked out at Alconbury, goes a long way toward shaping the end. The program in England is being duplicated now by schools set up in the States which are scheduled eventually to take over the entire training job. To date, because of the shortage of skilled Mickey operators, all schools have been operating full blast.



Operational check is made on Mickey equipment in B-17 by 482d instructor before his student takes over for a training flight



H$_2$X problems in navigation and synchronous bombing are worked out on supersonic trainers, one of which is being checked here



D-R navigation problem which was worked on by Mickey student is gone over by instructor. Gee indicator shows in background

Just how accurate is H_2X bombing?

Oxford experiment showed up serious errors; but they can be, and are being, remedied

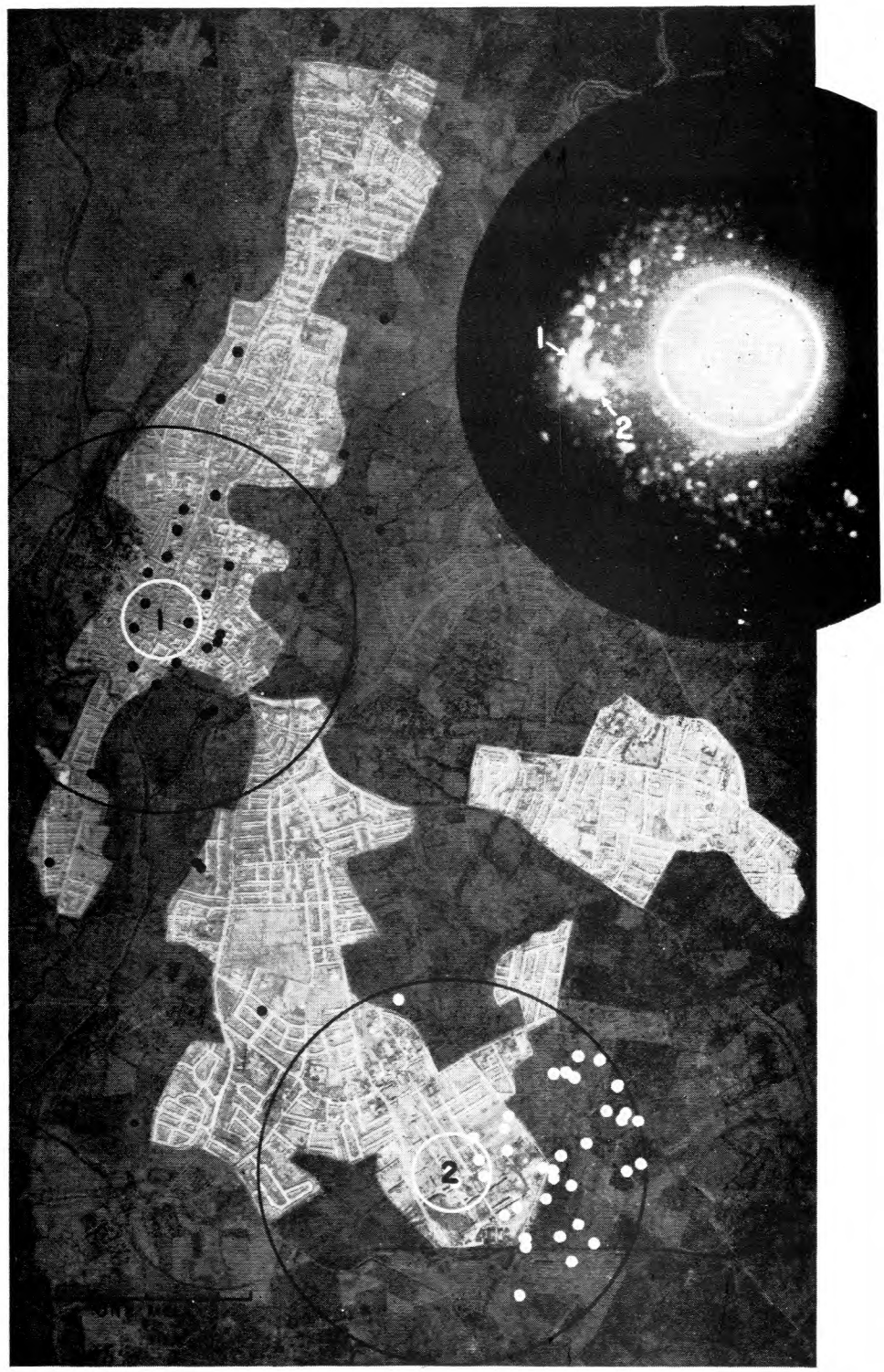
More than 300 heavy bomber sorties were launched against England's famed university city of Oxford. No people were killed—no fires started—no buildings destroyed—no bombs dropped. This was a new kind of bombing—constructive rather than destructive. It took place a few months ago and the results, duly calculated, throw some revealing light on the peculiarities and capacities of H_2X bombing with the AN/APS-15 equipment.

The sorties were flown by 2 B-17s of the 8th AF in what was the first comprehensive operational test of H_2X bombing accuracy ever made. Results provided some of the best answers yet to the question, "How good is H_2X?", to say nothing of valuable information gained on how to make it better.

Organized by the Operational Analysis Section of the 8th AF, the Oxford Experiment was conducted with 2 main objectives in mind. First, to isolate the causes of error in H_2X bombing which are independent of combat conditions; and second, to determine the capabilities of the system under controlled conditions, thus providing a realistic standard of performance to strive for in combat.

Oxford was chosen as a target because it happened to be located near the British 60 Group Calibration Section, a unit equipped with a specially-modified gunlaying radar (British equivalent of our SCR-584*) which could track and score the missions in any weather. Such equipment was essential since England's cloudy weather ruled out the practicability of camera scoring. Measurements of range and deflection errors by radar were within 115 yards of their true value—a negligible amount in comparison with the bombing errors, and smaller than the usual error in camera scoring. (Methods of scoring with SCR-584 will be reported in an early issue.)

Two targets were selected. The first was a street intersection in the center of



Strike pattern against Target No. 1 (black)—combined plot of Crew A from 18,000'—shows wide dispersion of strikes when aiming point is spot in center of city. Similar plot of Crew C against Target No. 2 (white) shows more concentrated pattern against an isolated industrial complex. Since heading was 230°, plot illustrates tendency for strikes to be short. Scope photo (insert) on 20 mile scan shows Oxford at 11 miles

* Based on the Oxford demonstrations, all 3 Bombardment Divisions of the 8th AF are setting up SCR-584 practice courses.

the city, and the second a large manufacturing plant at the outskirts. Each plane, with a veteran crew from the 94th Bomb Group, was set up to fly 40 missions against each target from 2 different altitudes—18,000 ft. and 25,000 ft. Of the 320 missions thus scheduled, 310 were used for the final tabulations.

Those tabulations represent a pretty thorough analysis of the H_2X bombing program. Here are some specific conclusions that were drawn.

• ***The Type of Target*** decidedly conditions results which can be expected from H_2X bombing. Against target No. 1, which was merely a point near the center of the city, average circular error was 5630 ft. and 82% of all strikes fell within built-up areas of the city. Against target No. 2, a compact industrial plant on the outskirts, average circular error was 3350 ft. and 54% of the strikes fell within built-up areas. The pattern was more concentrated than against target No. 1 and 34% of the strikes fell on the plant itself.

• ***Systematic Errors*** of serious proportions were revealed; notably, the persistent tendency for hits to be short in range or to have deflection bias either to left or right, varying from day to day. Deflection bias was probably caused by failure to center the sweep on the scope. If the sweep is .076 inches off center, it means an error of a mile on the ground. The mistake can largely be avoided by always centering the sweep on the 20 mile range, since that scan is used for bombing.

• ***Faulty Synchronization*** of bombsight and radar accounted for another systematic error. In setting rate into the sight with 4 or 5 checks the average error was about 10 mph. Furthermore, there was a consistent tendency to sight short amounting to an average of .37 mile. Short sighting is probably caused by a combination of factors. Improper calibration of the bomb circle, along with the habitual tendency to make the circle too wide, would invariably produce serious shorts. In addition to this, when a bright blip approaches the circle there is a certain amount of light diffusion or "bloom" across the fluorescent surface, which gives the impression that the two are in contact before they actually are. To eliminate these synchronizing errors it has been suggested that preliminary checks be made on a substitute aiming point about 5 miles from the target.

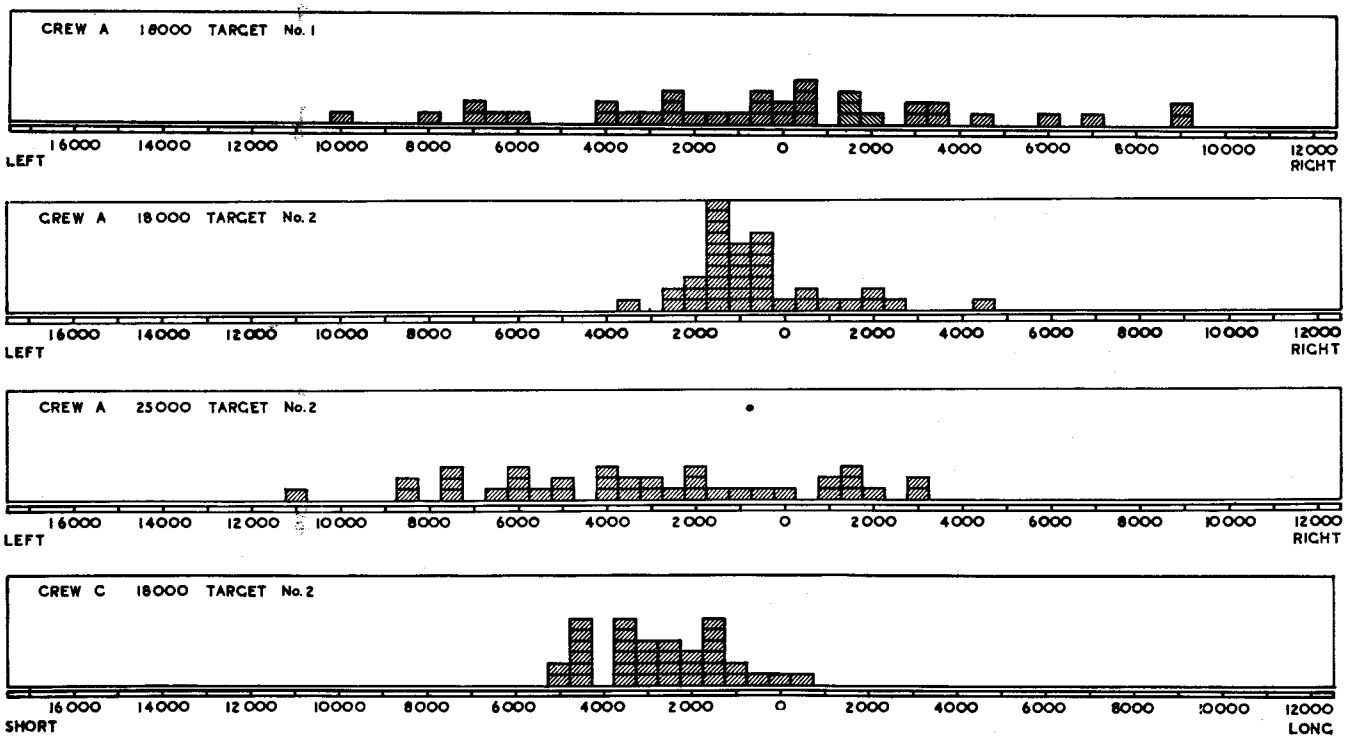
• ***Elimination of Errors*** described above would have led to 4 times as many strikes within 1000 ft. of the aiming point, 3 times as many within 2000 ft.

• ***Altitude*** did not appear to have any effect on accuracy against target No. 1 but against No. 2—the isolated industrial plant—accuracy was 1.5 times as good at 18,000 ft. as at 25,000 ft.

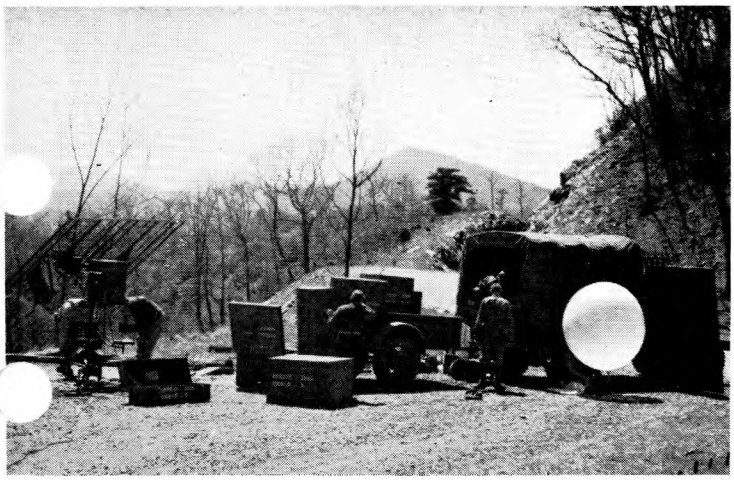
• ***Ground Speed*** was found to have little effect on range errors. However, there was some indication that deflection errors increase with ground speed. Wind direction made no difference.

• ***Combat Accuracy*** cannot be expected to match the results of the Experiment, which didn't take into account equipment failures, fatigue, enemy opposition, navigational errors, unfamiliarity with targets, etc.

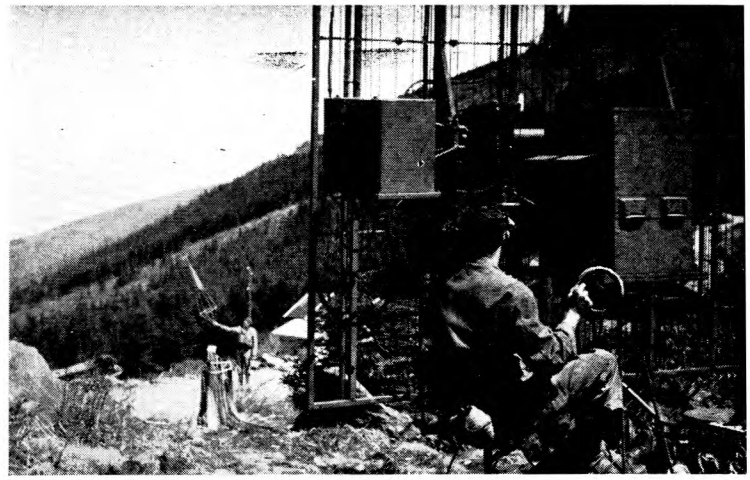
In view of the Oxford results it is evident that H_2X is no bombing instrument of the "pickle barrel" variety. No one ever rated it as such, but the feeling had been prevalent that H_2X was better than these tests showed. The great importance of the Experiment was that it helped to identify correctible errors; much of what was learned has already been incorporated into H_2X procedures.



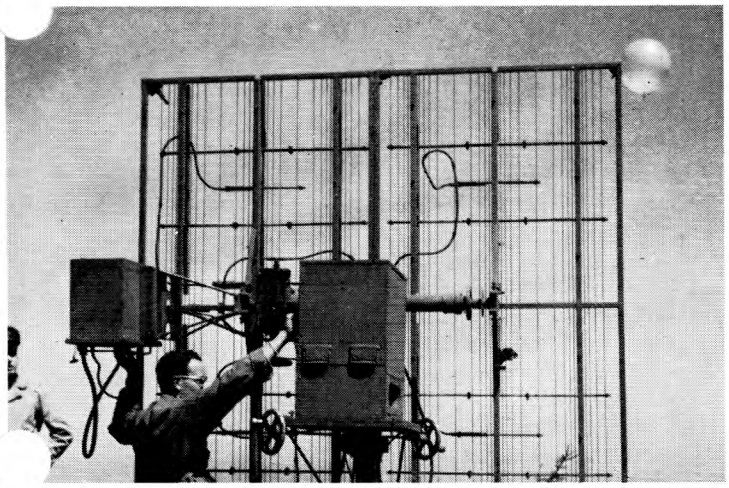
Histograms show frequency with which each error occurred in 285 radar-scored runs of the Oxford Experiment. Examples above are indicative of overall findings. Strike patterns were more concentrated against isolated factory area (second) than against city center (top); accuracy decreased with altitude against factory target (third); and strikes were consistently short (bottom)



One of first SCR-658s is set up for preliminary test. Truck and one-ton trailer carry all necessary supplies for operation



Operator positions 658 antenna on target before transmitter is released. Transmitter is suspended several feet below balloon



Operator tunes receiver to get good signal from transmitter. RDF gets accurate wind data up to 45,000 to 50,000 ft. consistently



Operator follows balloon and radio transmitter. Shortly after these service tests were run, SCR-658 production was started

Wind and storms

What the AAF Weather Service is doing with radar and RDF to improve meteorological data the world around

No radar has ever been designed exclusively for weather purposes. On the other hand, most radar sets *can* provide weather data of some kind.

For the past 2 years almost every equipment with any weather possibilities has been tried out by the AAF Weather Service. As a result, an assortment of radars plus one Radio Direction Finding (RDF) set have all been adapted to the business of storm detection and/or wind analysis. Using them, the Weather Service is getting better meteorological data than has ever been known.

Some means of improving traditional methods of wind analysis had to be found. Confined to visual sightings with theodolite and pilot balloon, the standard method was completely dependent on good visibility and became useless during periods of overcast when data were most needed.

Efforts to get better results were given further impetus the latter part of 1943 when the artillery—AA, seacoast and field—asked for AAF forecasts to supplement their own upper wind observations.

That same year the radar method was put into field operation and a year later the RDF method emerged from the experimental stage. Both methods call for external attachments to conventional balloons. One is a corner reflector whose position can be detected by radar; the other is a CW transmitter whose direction is determined by RDF and whose altitude is measured by momentary interruptions of the CW signal. Observations taken by either method are called "rawins".

Today, radar and RDF between them have just about all the wind problems licked.

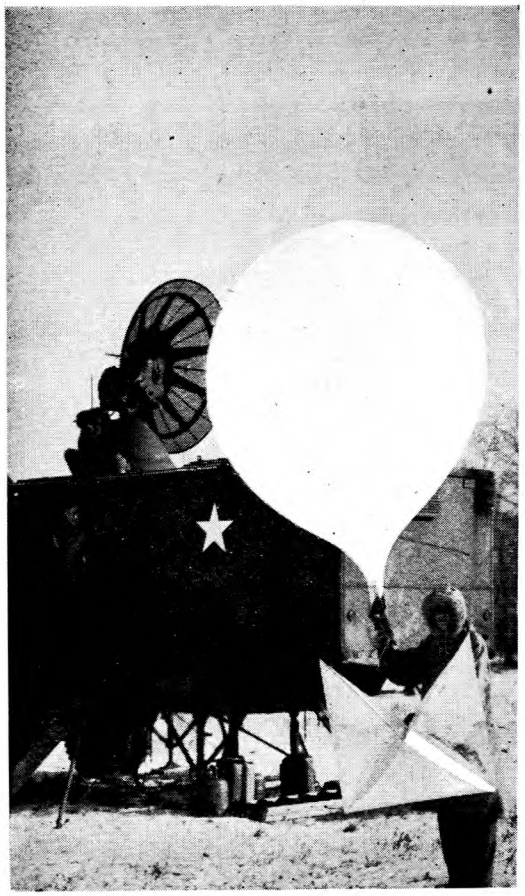
The RDF set used for rawins is the SCR-658. Nearly any radar set designed for gun-laying or for directing searchlight batteries can be used. Radar, of course, supplies that important element range, in addition to azimuth and elevation angles. Three radars are currently used in the field for wind analysis—SCR-584, SCR-545 and, in small number, the old SCR-268. But in the present program the 584 and the 658 handle the major part of the rawin job.

RDF for rawins: SCR-658

SCR-658 is directly suited to the needs of the weather service. It is highly mobile, requires only 2 trained men for operation and maintenance and can be operated in any kind of weather. Units now in use are preproduction, but sev-



SCR-584 rawin crew prepares for balloon run. When release signal is given, man at telescope directs 584 operator on target



eral are doing combat jobs in China and elsewhere nonetheless. The finished 658 is just getting off the end of the production line about now.

The 658 determines azimuth and elevation angles of a high frequency continuous wave transmitter attached to a free 350-gram balloon. The antenna moves in both the horizontal and vertical plane, so that the operator can track the balloon, and receives the constant radio signal sent out by the transmitter. Azimuth and elevation angles are recorded every minute. In the circuit of the transmitter there is a baroswitch which periodically interrupts the CW transmissions at pre-set barometric pressures. This supplies necessary data for computing heights, using known pressure-altitude relationships. In the case of winds for artillery fire, the wind speed and direction at specified altitudes are determined by trigonometric solution and then are translated into ballistic winds.

Because of its great mobility and possible use under all weather conditions, RDF equipment will probably come into wider use. There are 3 drawbacks: 1) since it's not used for gun-laying or aircraft warning, it is not distributed in the quantity that radar is; 2) RDF-trained personnel must be assigned with the set; 3) the 658 doesn't equal radar performance, particularly at low elevation angles. Compared to radar, the 658 is considerably cheaper and easier to maintain. However, radar will continue to do a big part of the job.

Radar for rawins: SCR-584

Since radar equipment suitable for wind observations is already widely distributed in all theaters, separate installations don't always have to be made for weather purposes. In many instances, a weather observer makes arrangements to get his observations on sets belonging to other outfits, scheduling observations for those times when the equipment is not in use. This arrangement has worked out fairly well in ETO, but the vast Pacific theater presents more of a problem. The Weather Service has tackled the situation by utilizing all available sets already in the theater, procuring as many of its own radars as possible and training personnel to go with some of them.

The ubiquitous 584 does double duty, both for wind determination and for storm detection. With a pepped-up J-scope, the 584 will track a corner reflector consistently beyond 60,000 yards slant range and has a high degree of accuracy down to 5° elevation.

Rawin procedure with the 584 goes roughly as follows:

1. One man inflates the balloon (either 350 or 100 gram) and attaches the corner reflector at the hydrogen shelter while two others tune and adjust the 584 and check communications.

2. When the ready signal is given, the antenna is directed toward the balloon release point while an observer takes his position at gunsight on the roof of the 584 van.

3. The observer watches the balloon release through the gunsight and directs the radar operator onto the target, then goes to assist the operator in the van.

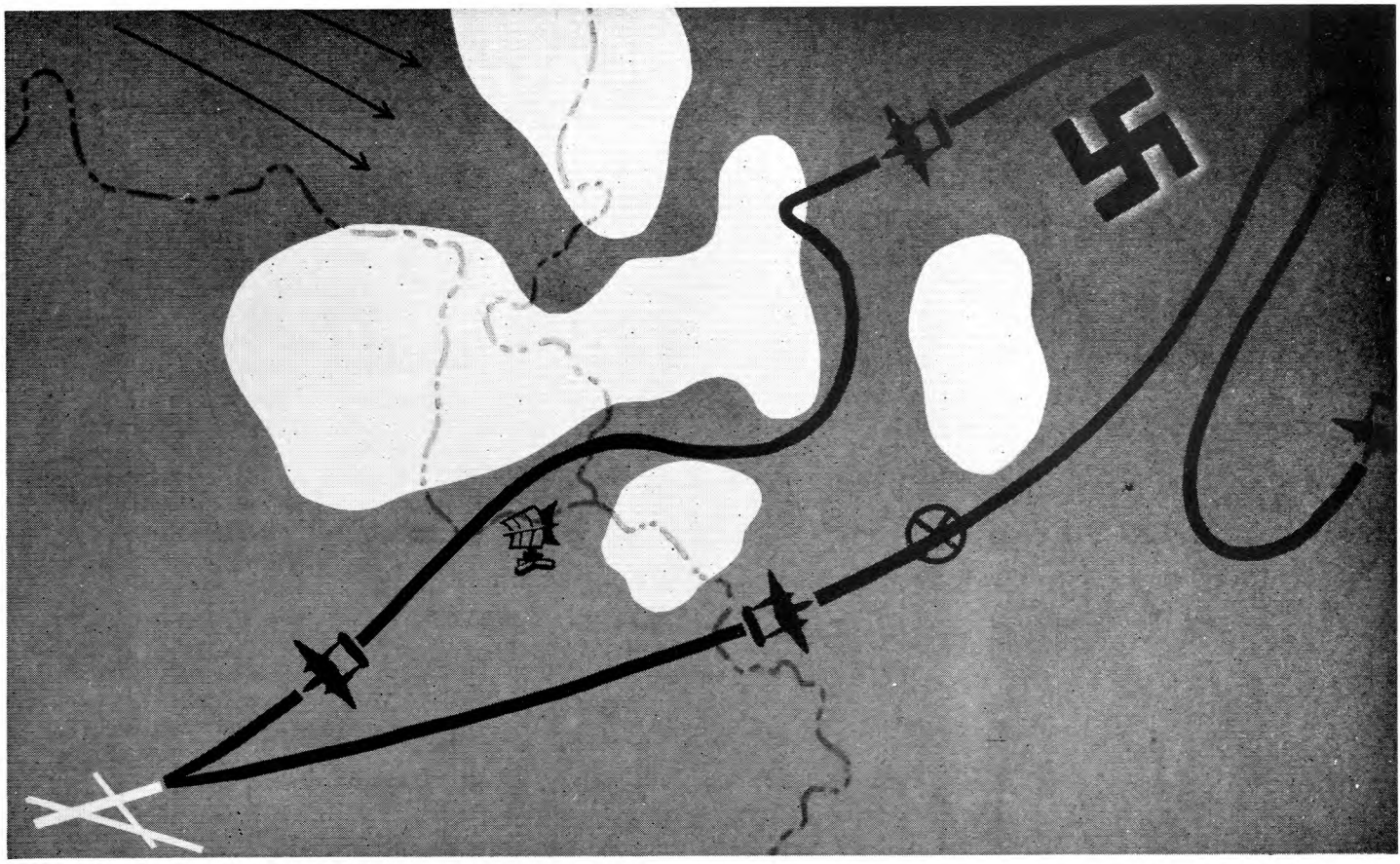
4. The first man takes his position at the plotting board (a standard ML 122 board). He records the data and computes winds. The operator tracks in range and reads range every minute from the J-scope. At the same time elevation and azimuth dials are read every minute by the third man.

5. At the completion of the run, the rawin message is transmitted over teletype to all stations on the weather circuit.

The Weather Service frequently uses artillery-owned 545s in the field for wind determination, and the artillery, of course, takes constant readings on ballistic winds as part of its own operations. The range of the 545 is a bit less than that of the 584 but it has good accuracy and the same good low angle coverage.

An old-timer, SCR-268, was the mainstay of the first real rawin station which was established at Meeks Field, Iceland, in October 1943. The 268 is by no means tops in balloon tracking but it is still used when no other sets are available both for training and for theater operation. A long wave radar with manual tracking, it can see a balloon out to about 30,000 yards slant range.

Until such time as RDF stations are sufficiently dense, radar will continue to supply vital wind data. More than thirty 584s have been allocated to the Weather Service. A good many of these are in the POA now and 4 are on their way to CBI. At the moment there is a program shaping up to install a network of the remaining 584s for wind analysis in the continental U. S. Rawin operation will be their primary and full-time function. Storm detection comes second as serious disturbances occur only a few months out of the year in many areas.

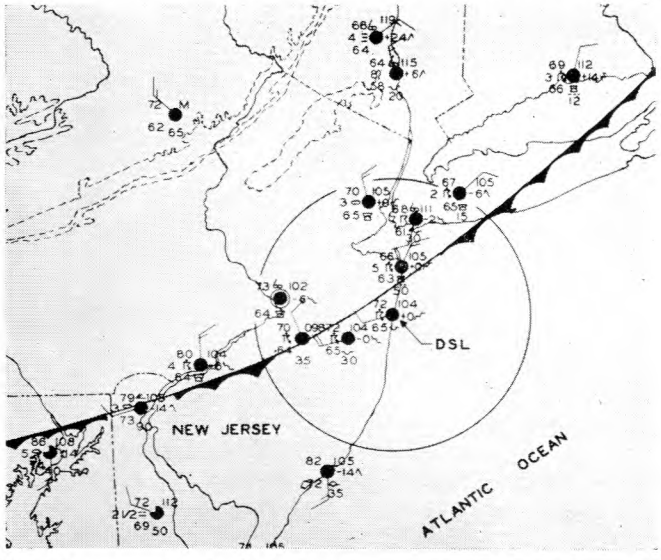


MEW of IX TAC tracked flight of P-38s to target, then on into Germany to look for targets of opportunity. On the return trip planes ran into thunderstorms, gas supply got low. As shown, MEW vectored flight around danger areas by shortest route to base

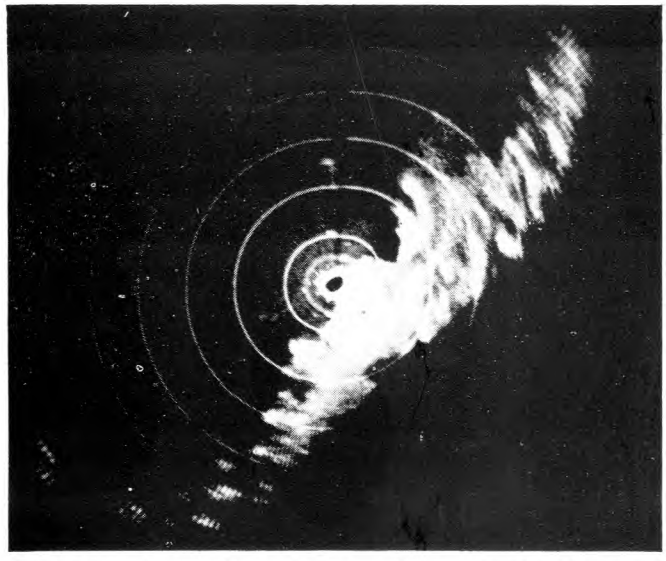
Storm detection is growing job for radar

The Weather Service hasn't yet become wholly accustomed to radar's somewhat sudden invasion of the traditional weather reporting field. When it was found that microwave radar gave both practical and precise meteorological information, time-honored methods received a bit of a jolt. Progress in the new field was slow at first because the meteorologist had few proven theories to go on. (Even now there is a crying need for further fundamental research in the interpretation of storm echoes.) Also, as in the case of early rawin experiments, the Service lacked equipment of its own.

One important tactical application of radar storm detection is the guidance of aircraft around thunderstorms and rain areas. The ideal situation, of course, would be to have suitable radars at all airfields with PPI scopes available to all personnel controlling aircraft. Precipitation areas, often quick to develop and



Weather map for the Spring Lake area, shown above, gives position of cold front 15 minutes before 584 scope photo was taken



584 scope shows echoes of heavy rain associated with intense thunderstorms occurring at a sharp cold front near Spring Lake

SCR-584 Records Storm's Progress



Above photographs of a 584 PPI were taken at Spring Lake over a period of one hour and 40 minutes. Echoes were caused by a group of air mass thunderstorms which converged upon the station while dissipating along the way. Aircraft echo is clearly visible in many of the photographs

move, may easily filter through a weather network without being observed visually. A radar network, on the other hand, can give a running picture of serious disturbances and maximum use can be made of the data, given direct communication between radar observers and aircraft in the vicinity. Nothing like such a setup exists, but tests will be conducted to evaluate such procedure in the not too distant future.

In general, microwave radar detects concentrations of large water drops falling through the atmosphere as precipitation or suspended by strong vertical currents. There are several ground radar equipments, S-band, which pick up weather targets well, and it is possible that X-band airborne radars will find their way into use on the ground. The ability of existing ground radars to do storm detection varies in accordance with the purpose for which the set was designed. The MEW, for instance, has excellent range and coverage but, because of the width of the beam in the vertical plane, it's almost impossible to determine accurately the vertical limits of the echoes.

Despite that, the MEW has done a notable job of storm detecting and aircraft vectoring on several occasions. The sets in the ETO, particularly the Tactical Air Command MEWs, have guided many an aircraft around dangerous storms. And in the Pacific, the Saipan MEW has been doing a fair share of the same.

Both SCR-584 and SCR-615 are well suited to storm detection. Less used and less suitable are the SCR-582 and SCR-682, but they do a good gap-filling job when other sets aren't available. The 584 is limited in range for detecting disturbances, but what it can do it does well. When a storm area is picked up, its vertical extent can be determined by elevating the beam above the cloud echo, then lowering it and checking the angle of elevation at which the echo reappears on the scope. As the 584 is included in the rawin program, it will be used in greater numbers for storm detection than any of the other ground radars.

The application of airborne search sets to ground weather use is in the process of being proven. A small number of SCR-717s have been adapted for ground use on a more or less experimental basis. But there is no plan to procure them in any quantity. It might be that one of the newer airborne search equipments—APQ-13 or APS-15—could

do the job better. In the air, APQ-13 will pick up a healthy storm out to 90-100 miles. It would take some careful testing to find out what it could do on the ground, and the job would seem to be worth doing. About half a dozen of the APQ-13 equipments will be given a preliminary trial within a couple of months at air fields in the B-29 training area—special attention to storm detection service has been requested for 2nd and 3rd AF bases during the summer season when violent thunderstorms are frequent. This network of installations will not only serve to fill an emergency but will also be an experiment to evaluate the practicability of the APQ-13 used on the ground for storm detection.

Storm warning in Panama

Since September 1943, microwave radars of the Aircraft Warning Service in Panama have been used for reporting storm areas, along with their primary work of reporting aircraft in the vicinity of the Canal Zone.

Rapid development and dissipation of small but severe thunderstorms make the weather forecaster's lot an unhappy one in the tropics. Often he must provide a weather forecast for a local flight route based solely upon weather reports made at the terminal air fields. These fields may report CAVU conditions, while 20 to 30 miles away a thunderstorm rages with severe turbulence and zero ceilings. Radar weather reports are the answer to some of the forecaster's prayers. They are combined with the standard weather observation sequence reports and AAF forecasters in the region say that the result constitutes about the most valuable meteorological observations available.

The reports submitted by the Radar Weather Section of the 6th Weather Squadron in Panama have provided the basis for the accepted codes and procedures now in force for all storm detection work.

To make the reports, several weather observers—specially trained in Panama for the work—have been placed on detached service at Army Aircraft Warning outposts.

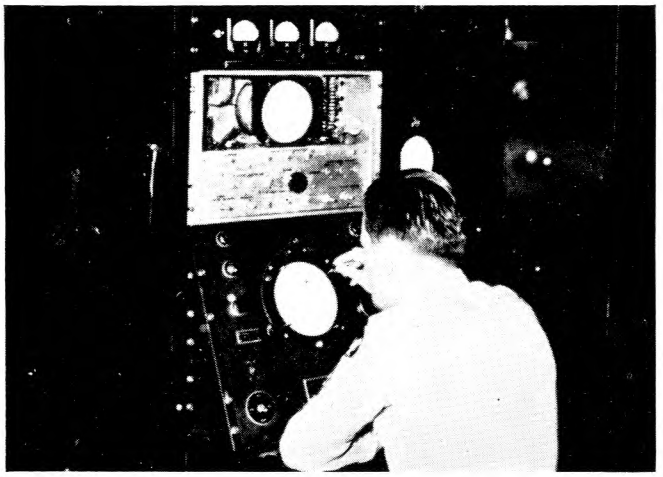
In addition to the aircraft warning sets such as the SCR-582 and SCR-615, the Caribbean area acquired an SCR-717 modified for use on the ground as of last month. No conclusive word on its performance is available as yet.

The picture series on page 50 shows how radar storm information gets from scopes to pilot.

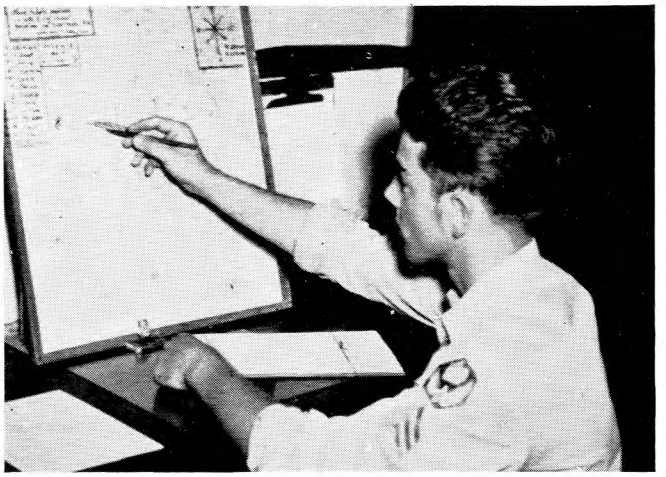


Radome of SCR-582 sits high on a tower to guard the Panama Canal against enemy activity and to help protect our own aircraft against fast-moving tropical storms

Tropical storms are thus detected, plotted, reported to pilot:



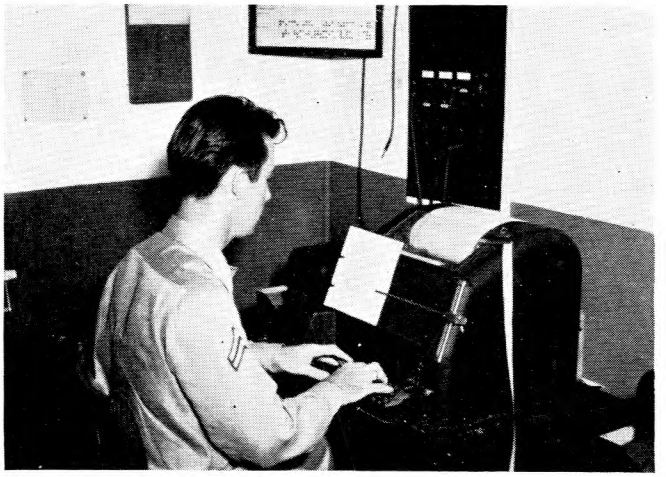
Radar operator at console of Panama SCR-582 adjusts gain to search for storms. This is done 3 minutes out of every hour



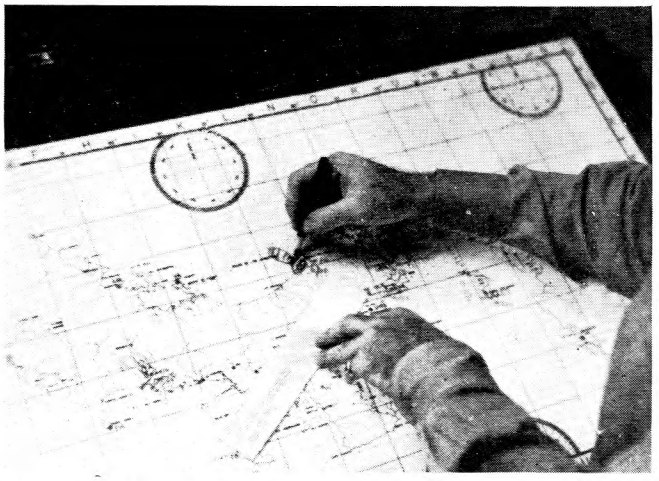
With radar data on range, intensity, direction of storms, observer changes polar coordinates to rectangular grid coordinates



Weather station receives hourly reports from all radar stations. Reports are plotted with a china pencil on a weather chart



At collection point, teletype operator assembles reports from different stations and cuts tape for automatic transmissions

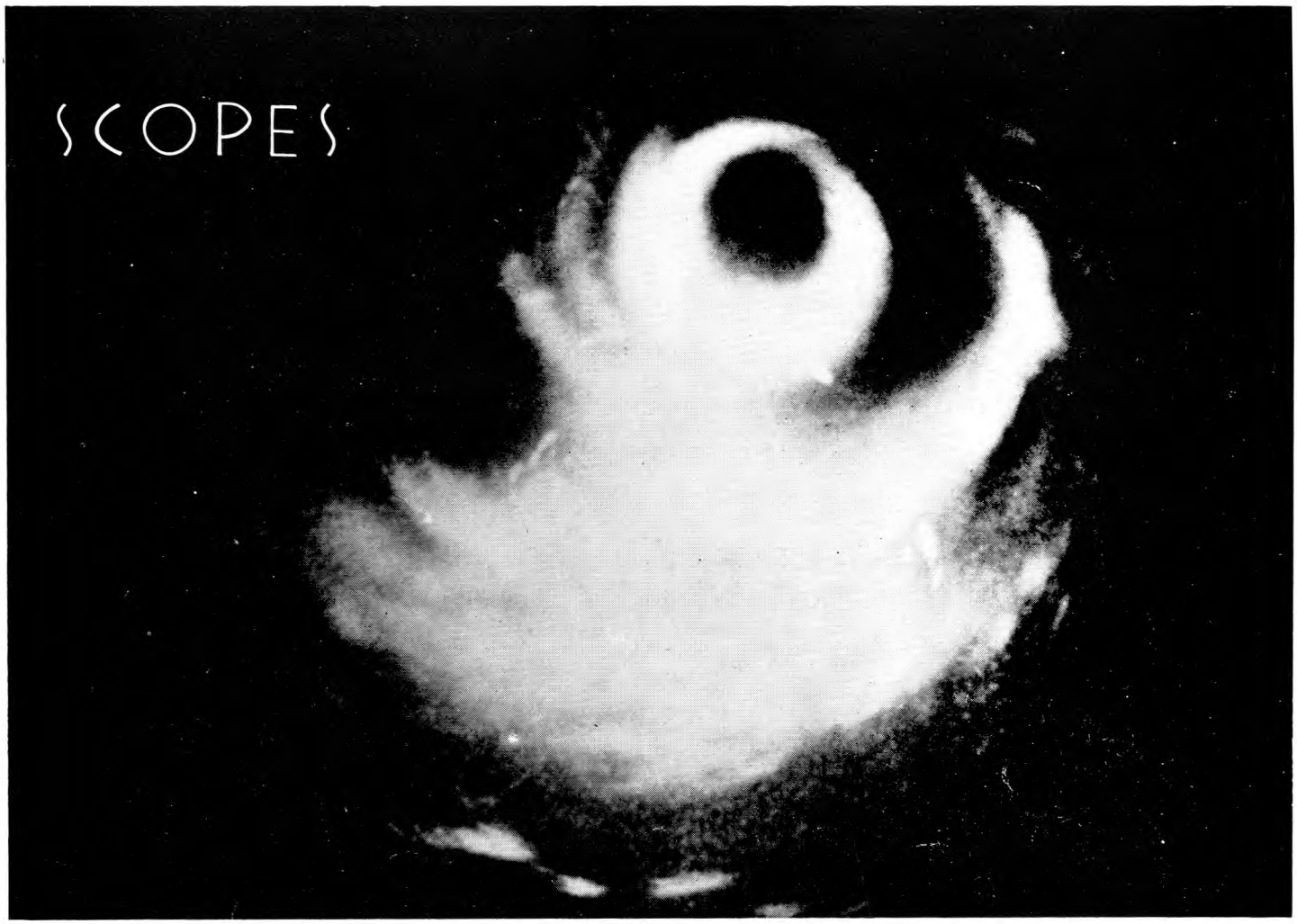


Observer plots the reports for forecaster's reference. Different colors of ellipses indicate characteristics of storms

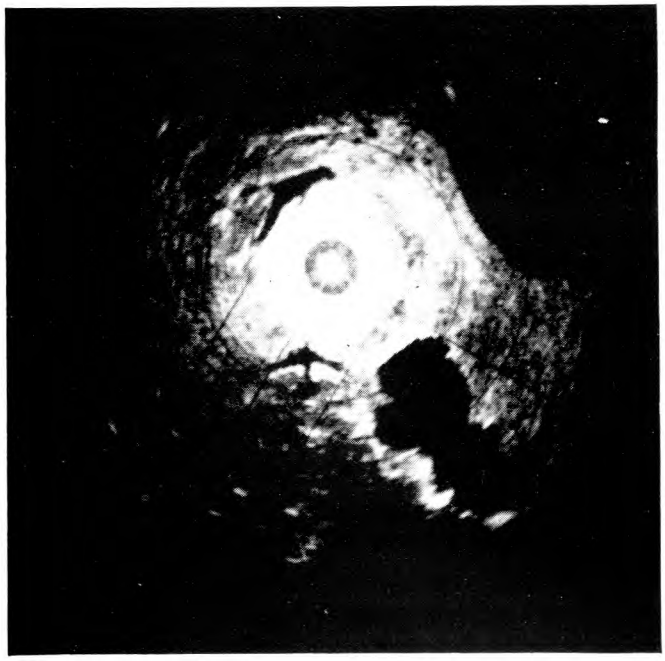


Forecaster, in clearing pilot, gives him precise information on areas covered by storms and how they may best be avoided

SCOPES



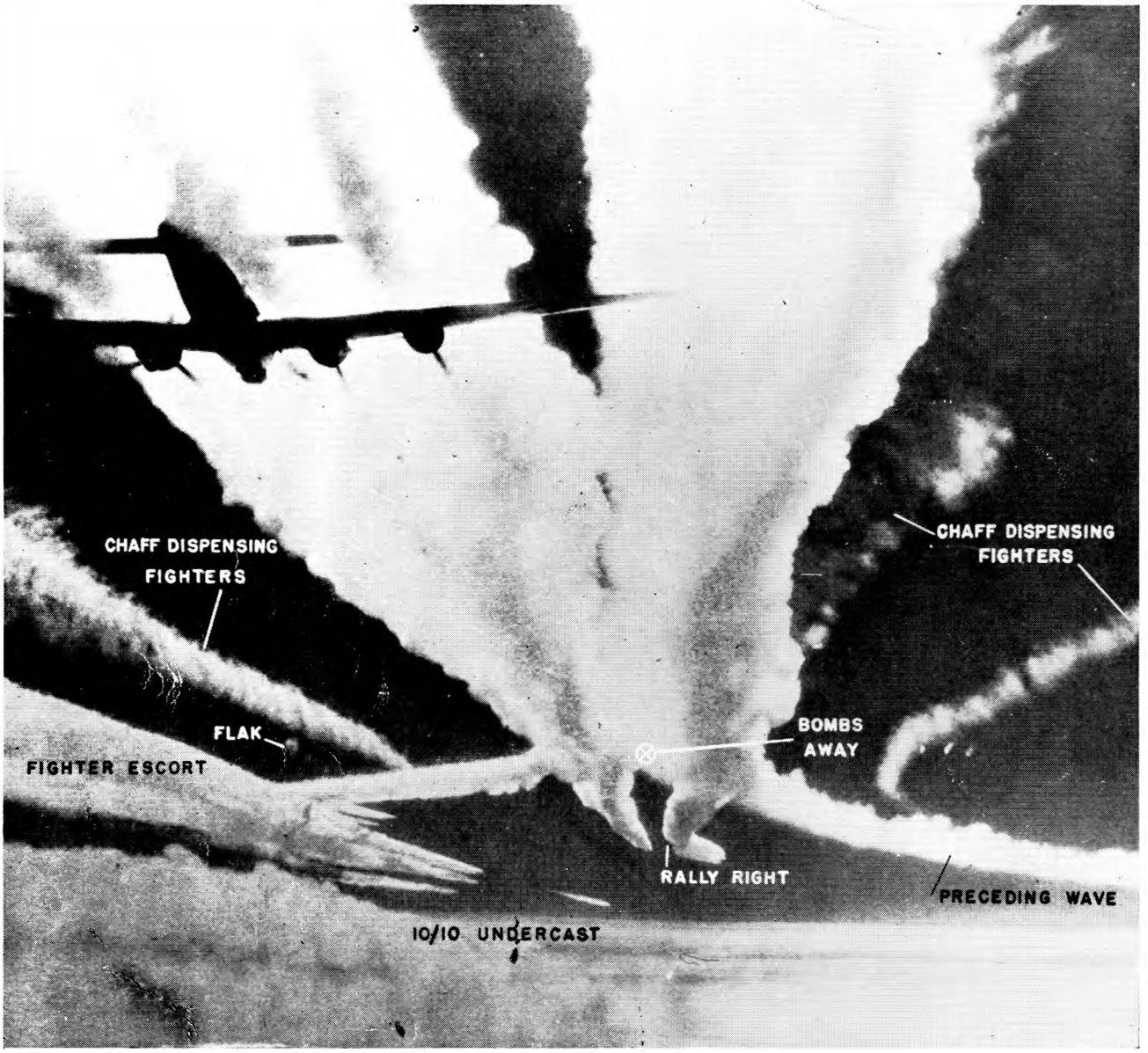
This scope shot of a typhoon was taken on a Navy SM radar when units of a U. S. Naval Force operating off the Philippines on December 18, 1944, encountered a "small, violent, young typhoon that had not fully developed and was moving in a west-northwesterly direction at an accelerated speed." At time of photo, seas were 40 feet plus. Eye of the typhoon is clearly visible



Scope tricks over Tokyo Bay. This one shows radar shadow of a B-29 which stamped out its silhouette in the ground returns received by APQ-13 of another B-29 several hundred feet above



Map-scope montage of the Tokyo Bay area is tried out as briefing aid by 21st BC's scope artists. At best, technique is an orienting help, at worst a confusion. One above is fair sample



PATHFINDER BOMBING TEAM IN ACTION

Condensation trails in this unusual photograph trace the pattern of a complete Pathfinder bomb run made over Germany by the 15th Air Force. The impression given by the picture is very much like the effect of watching a well coordinated football team run through a play in slow motion. On this bombing team, though, it is a backfield of bomb-laden B-17s that carries the ball, with fighter interference blocking out interceptors and dumping chaff to break up the enemy's defense. Now, with most of Germany's strategic targets overrun, patterns like this will be traced more and more frequently in Japanese skies. Furthermore, it is this highly effective teamwork, characteristic of Allied tactics in general and so important in H_2X bombing, which spells doom for Japan as it did for Germany.

FERRANTI Defence Systems Limited

RADAR

Issue No. 10 JUNE 1945



R.P.F. Lauder
Engineering Manager
Product Support Department

INTRODUCTION

The one problem in air-to-ground mapping is that fine discrimination requires a very narrow beam. In the middle of 1945, RF generators working beyond 10 GHz were not available and working at longer wavelengths implied very large antennae. Both the US and the UK designers and operators were convinced that the key to accurate bombing lay in a high discrimination radar map.

This volume gives the first part of the story of the development of the Eagle mapper. Since high frequency magnetrons did not exist, the solution lay with the antenna. Dr. Alvarez of the Radiation Laboratory in Cambridge, Mass., meditated on the problem with Dr. Bowen of the UK. It took some time to realise that a pencil beam was neither required nor desirable, and for ground mapping purposes a cosecant squared vertical plot with a narrow beam was what was needed.

A slotted array was first considered but later gave way to dipoles mounted on the waveguide. Every alternate dipole of the 250 along the 16 foot length of the array was reversed in phase. This provided the necessary fan beam, and quite simple shaped flaps either side of the horizontally polarised dipoles provided an approximation to the cosecant squared beam in elevation, with 0.4° to 0.5° width in azimuth.

However, to provide a radar map, the beam had to be scanned on either side of the boresight covering at least 60° total angle. It was bad enough accommodating a 16 foot long antenna with 250 dipoles on it without having to make it rotate as well. The solution clearly lay in electronic scanning but how was this to be accomplished? It was already known that the direction of the beam from such a phased array was proportional to the root of one minus one over a^2 where 'a' was the width of the waveguide. If the width could be altered the beam would swing from the boresight. In this antenna, with the dipole spacing used, the beam was normal to the array when 'a' was equal to 1.2". If this could be reduced to 0.66", the beam would swing 30° to one side. But how was it to be made to swing 30° to the other side?

Dr. Alvarez was a self-confessed non-expert on antenna design, and this was probably the reason for the successful outcome of the development. He was not hidebound by convention! The obvious theoretical solution was to squeeze the waveguide to approximately half its width, and then feed it from the other end. Dr. Alvarez did not concern himself with the practical difficulties of actually doing this in hardware. Fortunately other enthusiasts worked out how it was to be done and conceived the ingenious idea of using two 'L' shaped sections with choke joints to maintain the energy in the guide. One rode upon the other with roller bearings to maintain the width. The switching to either end every 2/3 second was realised with a simple vane rotating 90° in a junction of four waveguides as shown on page 33.

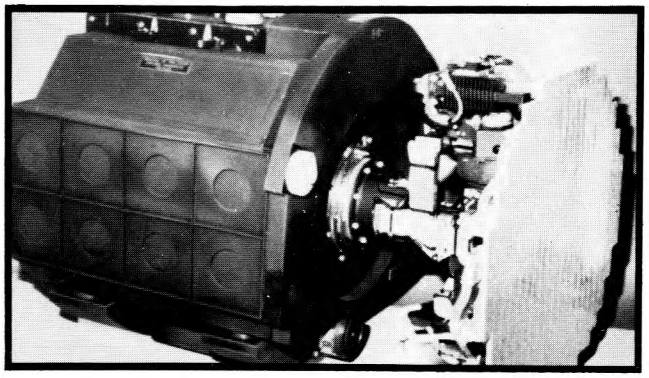
The energy from the transmitter was brought through fixed dimension waveguide to one whose width was constantly varying between 0.66" and 1.2". The so-called "jog transition" was used where a small step 0.1" deep and 0.4" long in the fixed part of the variable waveguide created a reasonable match over the roughly two to one variation in the antenna's guide width.

This antenna design must rate as one of the most ingenious and complex mechanical and electrical inventions of 1942, and it is a great tribute to the many engineers who created it in hardware that it was made to work with such success.

For any ground based radar such as MEW one of the big problems is the fact that ground clutter from large objects such as hills, and terrain within the beam in general, compete (successfully) with the much smaller signals from moving targets. From the beginnings of radar it was the dream to remove the stationary objects from the display leaving only the much more interesting moving ones.

The problem facing these early designers was to find a method of reception which responded differently to fixed and moving targets and then to take advantage of the difference by selecting only the moving ones. All MTI systems rely on the doppler effect and the modification kit to the MEW added a reference oscillator which was phase locked to the transmitter giving the receiver a CW reference signal. Each sweep was stored in a supersonic delay line and then subtracted from the succeeding one. The results are shown on page 56 and were taken on a ground radar at Bedford Mass., at 10.7 cm and a p.r.f. of 300.





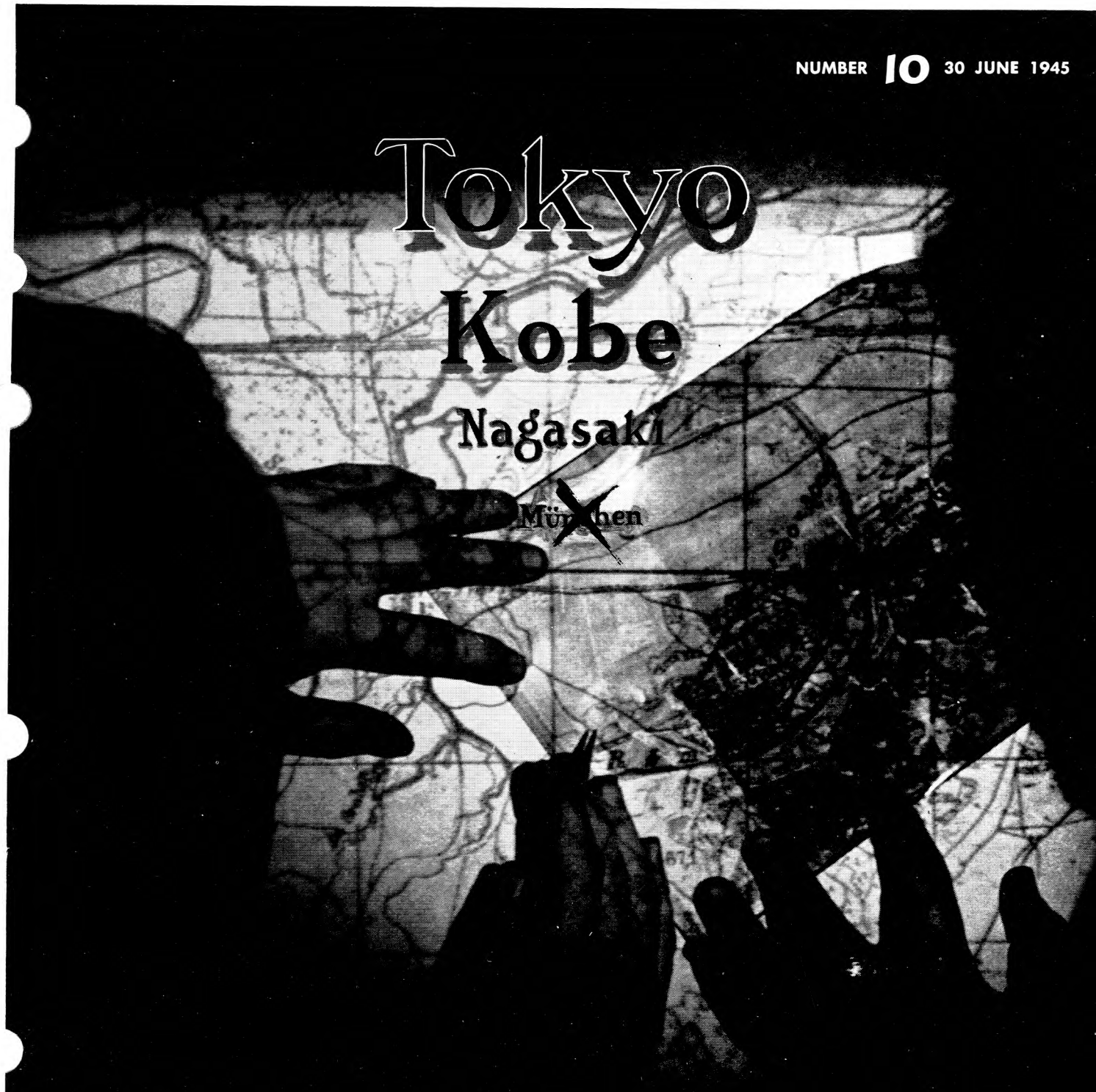
RED FOX

Red Fox is Ferranti's repackaged version of the successful Blue Fox radar used in the Sea Harrier FSR Mk. I where it acquitted itself successfully in the Falklands Crisis. Using LRUs of proven reliability, Red Fox is ideally suited for fitting to new or existing airframes.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

PSD

NUMBER 10 30 JUNE 1945



PINPOINTING A SHORAN TARGET

See page 47

RADAR

RADAR

Number 10 30 June 1945

SECRET

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EDITOR: Dexter Masters, Office of the Air Communications Officer.

CONTRIBUTING EDITORS: Dr. Dale Corson, Glenn Fowler, Dr. L. J. Henderson, Dr. L. C. Marshall (Oahu), Col. P. C. Sandretto (Guam).

EDITORIAL ASSOCIATES: Avis Clarke, Ruth Copland, Lt. Norman R. Goldman, Lucie Sewell, Lt. Henry Sharp, Lt. Robert Wright.

CORRESPONDENTS: J. Alexander (Guam), Lt. John Caldwell, Lt. Robert Carlson, Roger Powell (India-Burma), Talbot Waterman (Manila).

ADVISERS: Dr. Edward L. Bowles, Special Consultant to Commanding General, AAF; Dr. Lee A. DuBridge, Director, and Dr. Louis Ridenour, Radiation Laboratory, Massachusetts Institute of Technology.

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While we're on the subject

With this issue RADAR raises its classification, heretofore Confidential, one notch.

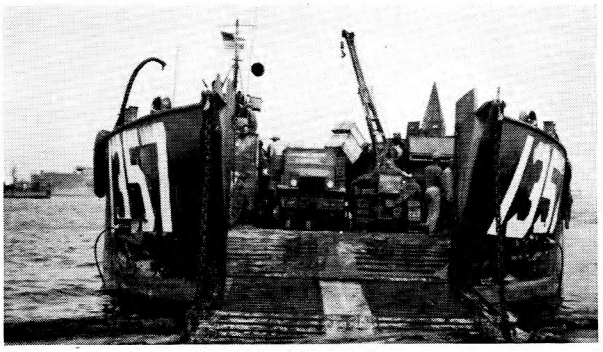
There is nothing in the security regulations which says that an individual who can make valid use of this issue can't see it, have it, hold it and read it. Whoever has been getting RADAR can continue to get it and the only new ingredient is the requirement to observe the rules for handling Secret material.

The Secret classification is not necessarily permanent. It is, in fact, frankly experimental. The experiment is to determine whether the extra material we can now carry warrants whatever extra effort there may be in handling a Secret publication. The answer to this will have to come from RADAR'S readers.

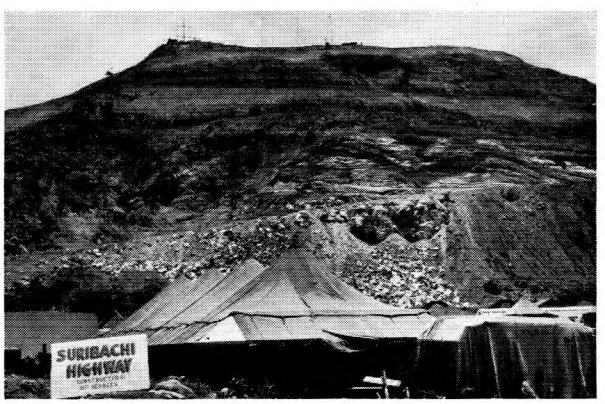
The aim of this publication is to reach the people who need or can use it with the kind of information they need or can use. If the Secret material in this issue doesn't add appreciably to RADAR'S usefulness, then the experiment is a bust and you should tell us so. If the Secret classification makes RADAR too hot to handle, sets up too many difficulties in getting it around, then ditto.

But you'll have to let us know.

The MEW lands at Iwo



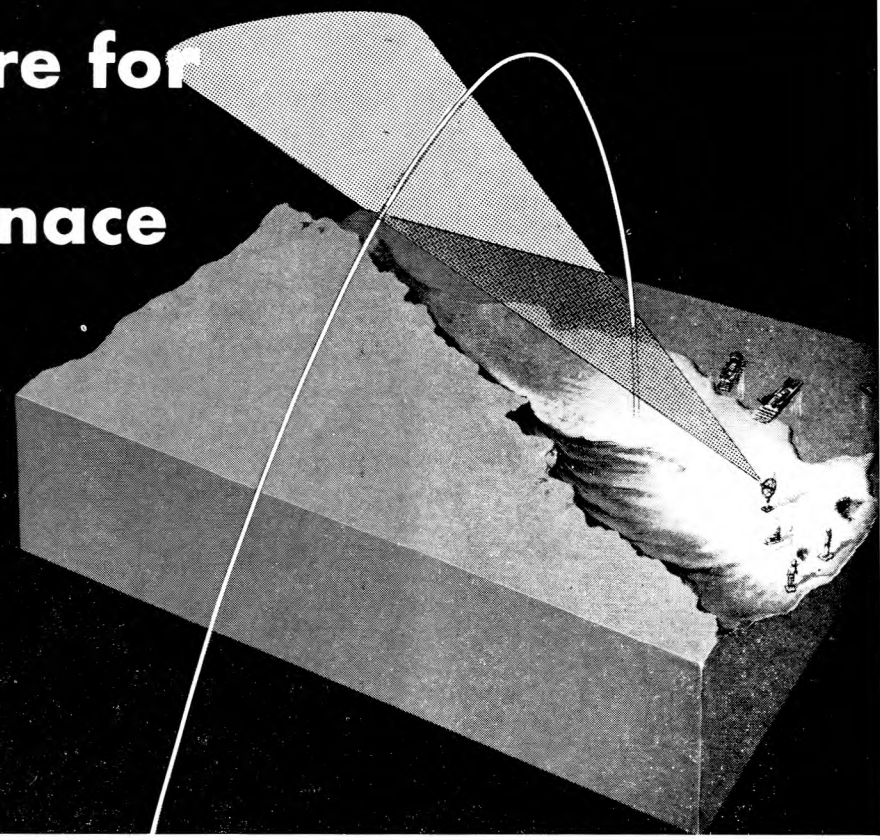
MEW and 615B are landed on Iwo's Brown beach by LSM. Their 846 boxes weighing 380 tons occupied 1½ decks of Victory ship, unloaded in storm middle of May.



On Suribachi's rim SCR-270 and VHF antennas can be seen. MEW is being sited where 270 stands, replacing it and other radars. Installation will cover most of rim shown

Countermeasure for the mortar menace

Radar starts new job of spotting sites by tracking mortar shells



Typical setup (above) shows radar (TPQ-3) being used to get 2 points on mortar shell trajectory, first step in location of mortar. Radar methods will be used against all types of Jap mortars—from light "knee mortar" and type below on up to 320mm weapon



"Fifty percent or more of all casualties in the various theaters are the result of mortar fire."—Surgeon General's ASF Survey.

"Use of radar to locate enemy mortars is a device which, even in its infancy, is saving many American lives. Perfected, it can save many more . . . ."—General Brehon Somervell.

Mortar location by radar got its start in the field and out of grim necessity. The enemy, both German and Jap, knew only too well how to make the most of this weapon; it has been one of the most widely used weapons of the war and one of the most effective.

Most of the early experimentation with radar against the mortar was carried on right at the battle front, starting with Anzio in the spring of 1944, when Allied forces were trying desperately to deal with withering enemy fire. With the feeling that anything was worth trying, they attempted to locate enemy gun batteries with radar. And while experimenting against artillery shells, they discovered that it was possible to get signals from mortar shells and to plot those signals.

The equipment being used was, of all things, one of the oldest of radars—a British LW, prototype of our SCR-602-T6. Allied Army personnel, incredulous at their find, went to work in earnest on their discovery. Almost concurrently, British forces in Normandy started using their GL IIIs similarly, based on experiments in the U.K.

By the fall of 1944, it was officially recognized that radar could and should be used to plot the trajectory of a mortar shell in order to find the location of the weapon. Plans were made to modify existing sets to do the job better and to design equipment specifically for a mortar detection role.

Both equipment and techniques are still experimental. But enough has been done in past months to make it clear that radar has found a new job of major importance. For more on the subject, see following pages.





Mortars are easily concealed and moved but this German 81mm mortar and firer didn't move fast enough. At Iwo (right) Jap mortars took high toll of men and equipment

Mortars are deceptive things

The appearance of a mortar is deceptive—it is deadly, accurate and its fire power is all out of proportion to its size. Light, small, easy to handle, it is an easy weapon to move and conceal, and its characteristic high trajectory means that shells can be lobbed over hills or other obstructions which would rule out other field weapons. Because a mortar is so easily defiladed, direct location of it by either visual or radar means is usually impossible.

The next best thing is to determine its location indirectly by plotting the trajectory of the projectile. The trajectory can be observed with any radar set having the necessary power and resolution to pick up a target as small as a mortar shell. Depending on the type of radar and the plotting facilities, the parabolic path of the shell can be determined either by plotting one or more points on the curve or by continuous tracking and, in both cases, computing the mortar's location by backward extrapolation.

The two most successful sets to date for this work are the SCR-584 and the AN/TPS-3 (TPQ-3). Other candidates are the AN/TPQ-2, a newcomer, and AN/APS-3.

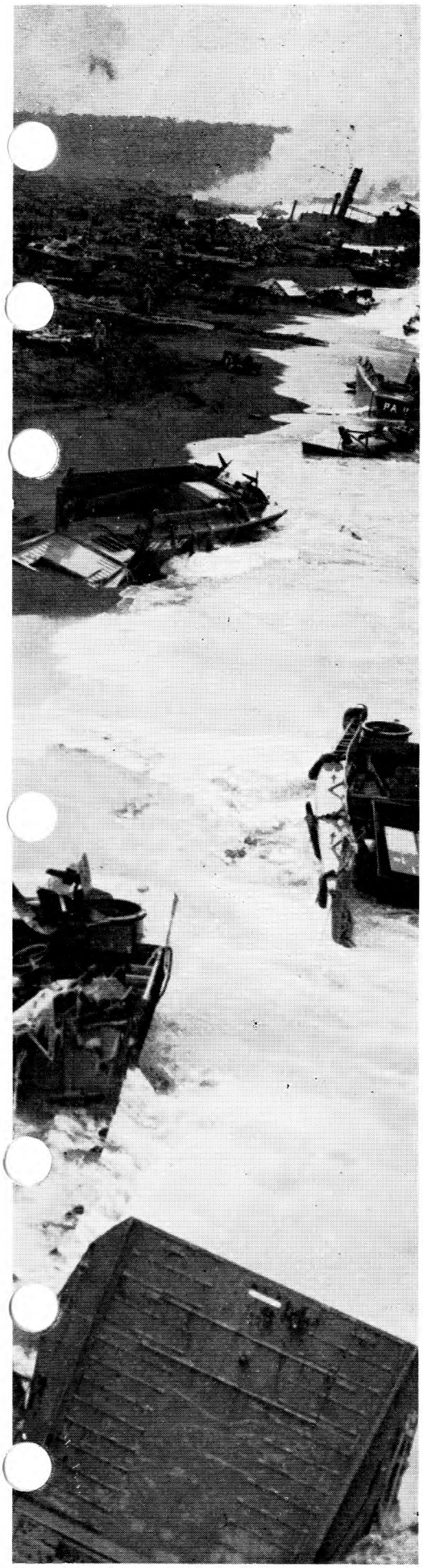
The SCR-584

SCR-584, with modifications, is the only U. S. equipment which has been actually used in combat for mortar detection, although modified APS-3s were sent to France for experimental tests under combat conditions. A handful of available 584s were tried out in the ETO, but the tactical situation became so fluid shortly after their arrival that the program never did get into full swing.

When tried in Italy, the 584 was considered moderately successful. There were numerous drawbacks, one being that a very small group of men with a big job on their hands had to start the trials from scratch with practically no equipment. Secondly, Italian terrain is inclined to be unpleasantly mountainous and it's no mean trick to move a 584 around and site it properly under such conditions. Allied Army personnel, however, stuck to their guns; by dint of hard work and improvisation, they helped to prove that mortar location is possible.

The modifications necessary to convert a basic anti-aircraft SCR-584 to mortar work are:

1. The N^2 gate, which was first developed in late 1943 primarily as an anti-jamming measure (see RADAR No. 5). In 1944 it became almost a standard modification, particularly for those sets used in buzz bomb defense. Generally speaking, it's a big help in tracking small targets through cluttered areas.



2. A 584 sector-scan kit, which was developed specifically for buzz bomb work. It is particularly adaptable to mortar location since the general area to be searched is known beforehand.

3. Provision for a 10,000 yard range on the PPI.

Several plotting methods with variations have been tried with the 584. Current approved method is graphical plotting by hand. The assigned sector is searched until a mortar projectile is detected, then the equipment is thrown into automatic tracking. Three 5-second readings on slant range, azimuth and elevation dials are taken after locking on. These data provide discrete points on the trajectory which are projected to the ground. The line of fire is then drawn. The height of each point is computed, the trajectory drawn and extrapolated backward, freehand in most cases. The position of the mortar is the intersection of the extrapolated trajectory and ground mortar level—the latter checked closely against maps and aerial photos.

The TPQ-3

Lightweight L-band AN/TPS-3 has become, rather surprisingly, first choice for an interim mortar locater until something better comes along. It's surprising, because the TPS-3 is not a microwave set and a mortar projectile is a very small target. Although there is quite a gap between the TPS-3 and the 584 in general performance as radar equipments, they become comparable as mortar location sets.

AN/TPS-3, with the following principal modifications for its mortar role, becomes the AN/TPQ-3:

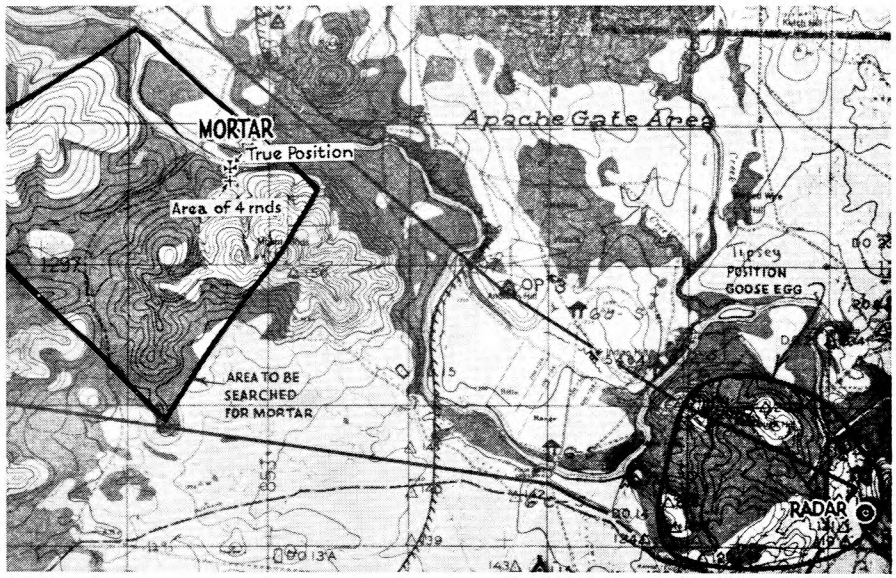
1. Change in polarization from horizontal to vertical.

2. Separation of radar from antenna by about 100 feet so that consoles may be dug in and protected.

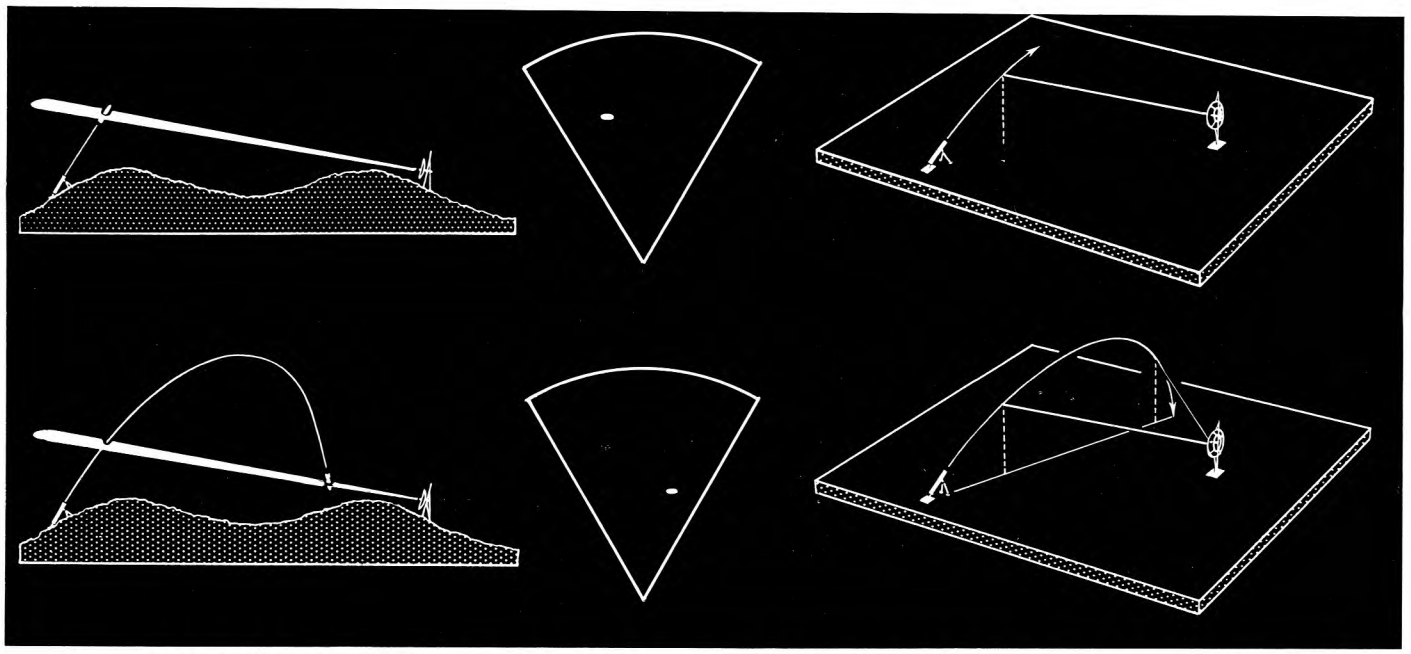
3. Installation of a range and azimuth marker unit; off-center PPI; sector-scan switch.

4. Change of maximum range to 10,000 yards. Knowing the approximate direction from which the mortar fire is coming, the operator scans a sector of about 60° until a shell signal first appears, then continues the scan over a narrower sector centered on the shell echo. The range-azimuth marker, which is merely a movable spot of light on the PPI, is centered directly on the first point (ascent), then on the last point observed (descent). Range and azimuth to each point are recorded. The parabolic path of the shell originating at the mortar and passing through these two points is then determined by a special slide rule.

The TPQ-3 has two big advantages over the 584. It weighs a great deal less, which means a lot in mortar work, and, being L-band, it is much less susceptible to rain echoes. Heavy rain will almost blanket a 584 scope when



Mortar location test at Fort Sill approximated battle conditions as closely as possible. TPQ-3 could be sited anywhere within circled area. Based on radar data, counterfire was directed at mortar site 5300 yards away, scoring near miss just below the site



Trajectory of shell fired within sector searched by TPQ-3 passes through beam (left); location of 2 points is determined from PPI (center). For determining mortar site, range and azimuth of points are plotted on map and line drawn representing enemy line of fire (right). Length of line, height of points, time between points establish parabola extending back toward mortar

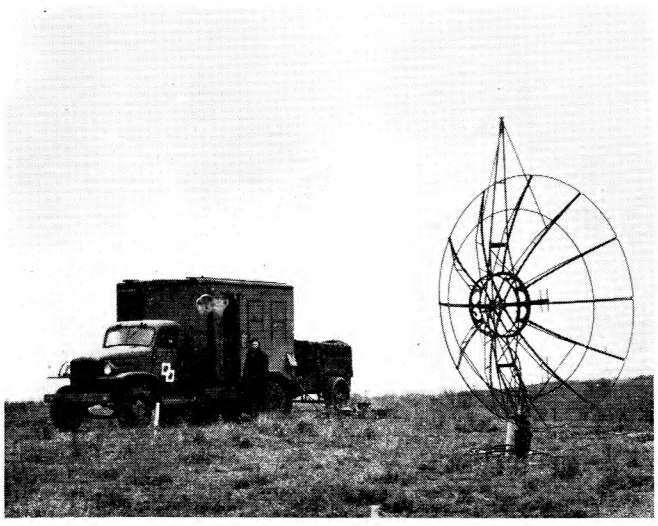
the set is used to track small targets at short ranges. The 584, on the other hand, has the edge on accuracy. In comparative tests, its errors of location are about one-half those of the TPQ-3. The 584's lack of mobility in mountainous terrain is offset by a certain flexibility when it comes to siting—that's the advantage of a narrow beam. TPQ-3 can go more places but it has to be sited carefully in order to avoid a lot of headaches with ground clutter.

TPQ-3 training is going on currently at Fort Sill and Fort Monmouth. Mortar location teams are made up mostly of ex-AAA radar personnel. These men get basic training, then maintenance and operation courses, and end up with four weeks training as a team. Within a few months, several teams will go to theaters to launch a program designed to fill one of the most acute needs of this war.

The APS-3

The APS-3 is a Navy airborne search set which weighs only 250 lbs. without the power supply. Some range and accuracy have to be sacrificed with a set like this in order to get its mobility and simplicity—and it would seem a good idea to have such an equipment only as a supplement to heavier, more accurate radars. Modified APS-3, mounted in a vehicle, is strictly a front-line proposition for counter mortar use rather than mortar location.

The APS-3 will detect a mortar shell at ranges of about 4000 to 5000 yards. Plotting procedure is simple, slightly on the rough side, but effective. Range and azimuth of two signals from an enemy mortar shell are plotted directly from the B-scope to a chart but the location of the enemy mortar itself is not computed. Because the signals from our own mortar shells can be seen on the same scope, counterfire can be directed with some degree of accuracy through points of pickup of the enemy shell. Counterfire by this method re-



TPQ-3 antenna is set up for test. Cabling is long enough to allow separation of antenna from rest of equipment. This gives flexibility of siting since crew can operate from dug-in position



Operating crew in 584 van track mortar shells during tests at Field Artillery School at Fort Sill. A modified SCR-584 can be returned to its AA function when desired by throwing a switch

quires the use of a weapon whose trajectory is comparable to that of the enemy mortar.

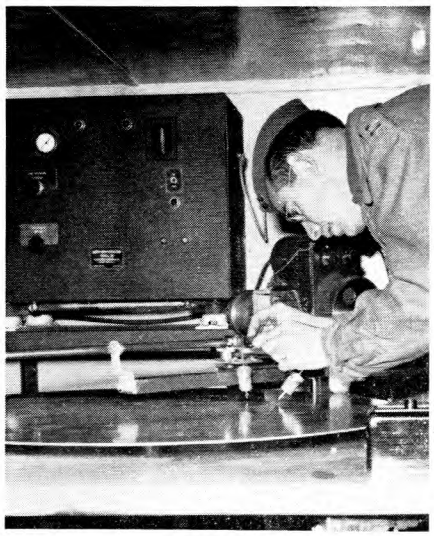
Whether APS-3 will be used in its present form, which is not considered rugged enough to stand up under field use, remains a speculation.

The TPQ-2

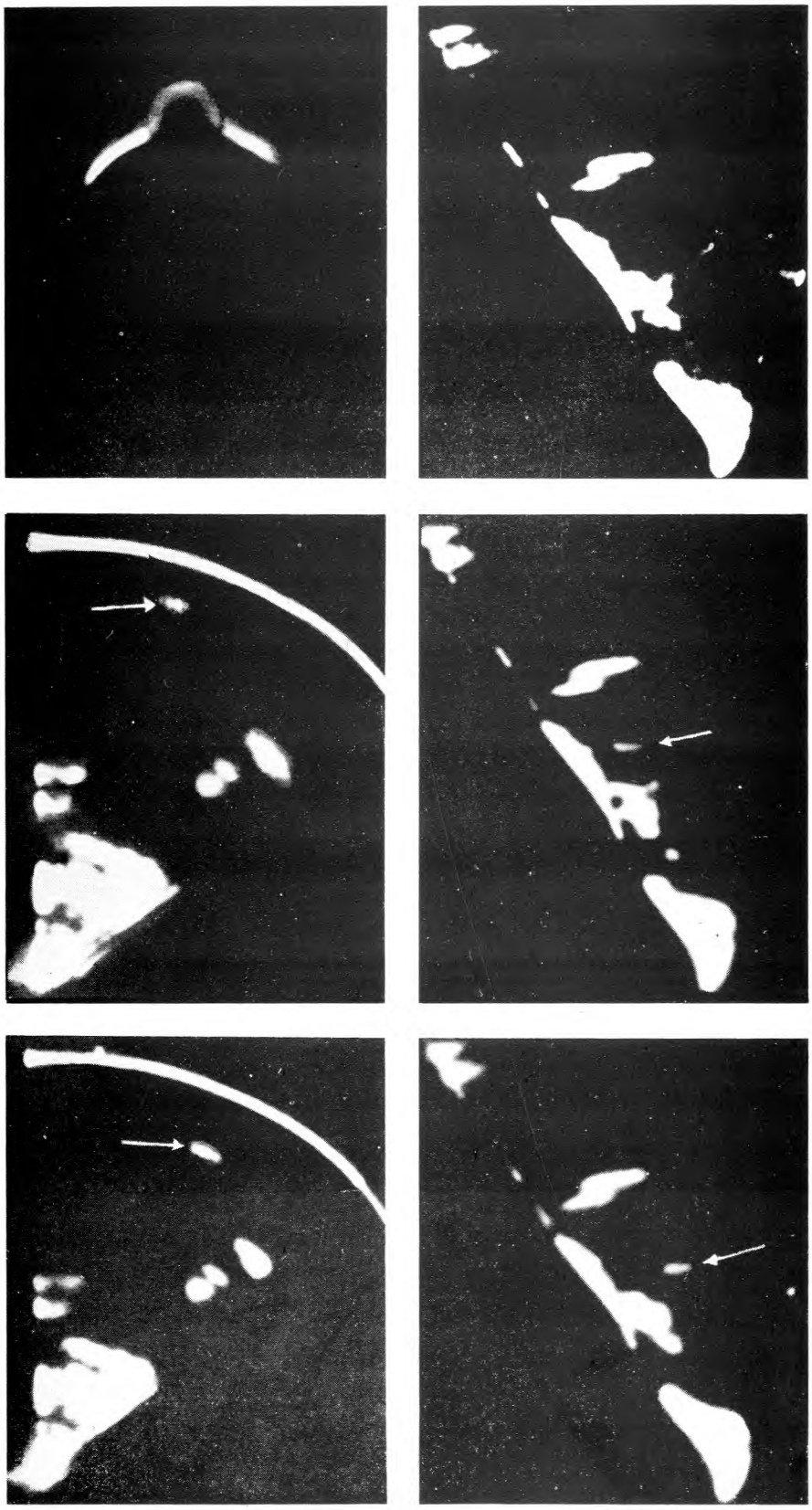
In contrast to the APS-3 is the more complex K-band equipment, AN/-TPQ-2, designed by Camp Evans Signal Corps Laboratory for mortar location. It's hard to say just how much the TPQ-2 will do, since the set is still under development and test. Also K-band performance hasn't completely emerged from the land of unknowns.

Instead of a parabolic reflector, the TPQ-2 has a lens radiator (based on the Fresnel lens theory) and two folded scanners. The antenna system provides two narrow pencil beams, each 1° wide and separated by 2° in elevation in the vertical plane. This means that two points on a trajectory can be located accurately without using tracking methods. The lower beam can be directed close to the ground surface with minimum interference from ground clutter. A mortar shell, therefore, can be detected quite close to its point of origin.

Two signals appear on an expanded B-scope as a shell passes through the two beams and exact positions are shown on the scope with electrical range and azimuth markers. An automatic computer performs linear extrapolation through the two observed points to mor-



Plotter used with 584 in Italy had map on turntable. Two pencils mounted on table drew range and elevation against azimuth

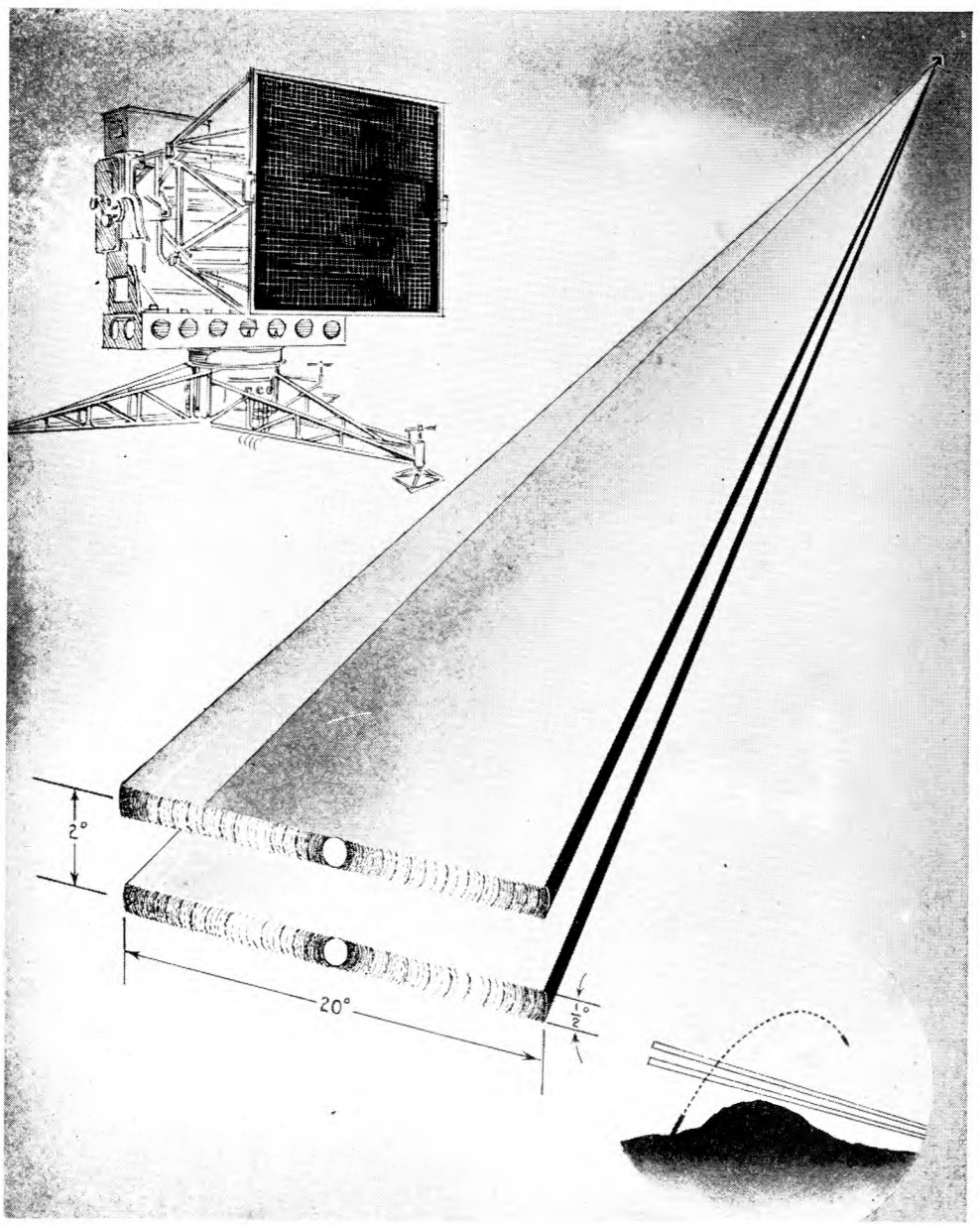


Echo of mortar shell is visible in gate of 584 J-scope (top); shell going up (center) and down (bottom) shows on PPI sector

TPQ-3 PPI shows ground clutter only (top); signal as shell goes up (center) and down (bottom) through radar beam



British LW/AW at front near San Sepulcro with Allied Army crew was one of the first radars used for mortar location in 1944. Sketch (below) shows antenna and double beam of newest equipment for mortar work, the AN/TPQ-2, which is just about ready for tests. Because of set's sharp beam, ground clutter can be effectively eliminated as a rule



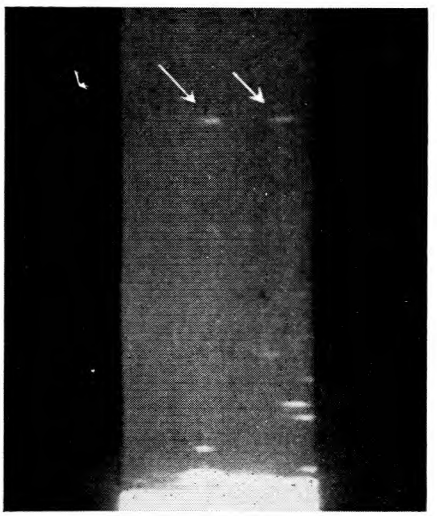
tar level; no manual plotting is needed.

TPQ-2 gives excellent definition, but unfortunately that excellence is limited badly by rain. Even if it should prove to be a fair weather set, however, TPQ-2's accuracy should more than offset the shortcoming.

With work proceeding at a high priority, the first 40 TPQ-2 equipments plus teams should be ready to go into combat areas within the next few months.

With present location methods and equipment, an enemy mortar position can be neutralized. But there are several prerequisites—well chosen sites, experienced operators, and, of course, a knowledge of mortar employment. Under some field conditions it is difficult to obtain a site that will give optimum radar performance, but even under unfavorable conditions, it should be possible to direct counterfire close enough to a position to make it untenable.

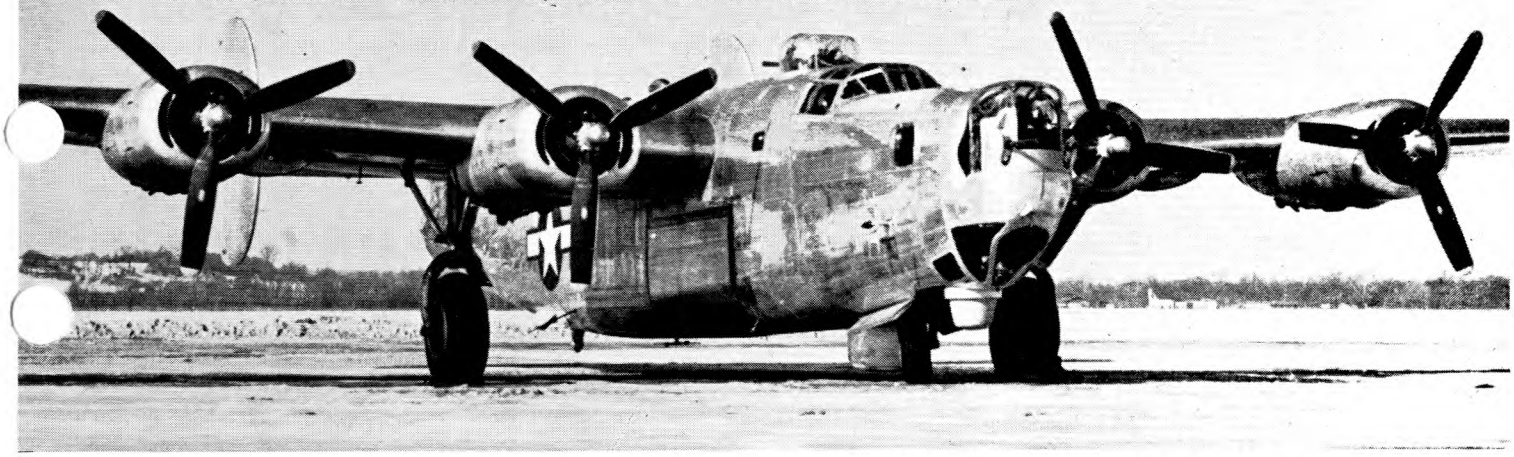
No conclusive performance figures on any of the radars are available since none of them has been fully tested under combat conditions. The AN/TPQ-2 is expected to give the highest degree of accuracy, although limited by weather and range (5000 to 6000 yards in comparatively good weather). SCR-584 and AN/TPQ-3, both of them interim equipments, have greater range capabilities. Under extremely favorable test conditions, accuracies as high as 10 to 15 yards have been obtained with these two sets; at the present time, general operational accuracy couldn't be expected to better an average of about 75 yards.



Pips show on B-scope as 60mm shell cuts TPQ-2's 2 beams. Echo trace sequence indicates whether shell is going up or down

The search for Jap radar

New Ferrets, dressed for the kill, move out to cover home islands



THE B-24J ABOVE, HERE READY FOR ITS FIRST FLIGHT AFTER BECOMING A FERRET, IS ONE OF 5 PUT OUT IN RECORD TIME BY FAIRFIELD ATSO

Getting information as to the nature and deployment of radar in the Japanese home islands has been, to date, pretty much a B-29 affair—largely because of the big distances involved. With search receivers and pulse analyzers, Jap radar signals are checked by RCM observers on routine B-29 missions.

This kind of searching by strike aircraft has been going on in both the XX Bomber Command from China bases and in the XXI BC from the Marianas. It has been and it still is a necessary procedure, but it was never intended to provide the complete coverage necessary for overall planning. Particularly it doesn't now with offensive planning focused more and more on the home islands. And that is why when the distances narrowed to Liberator range, the XXI BC obtained on a crash basis specially-equipped B-24 Ferrets.

To provide these planes, Headquarters AAF established a requirement for 5 Ferrets of a new design to include all that is new in RCM equipment. To meet Theater requests, all of the planes had to be delivered in 35 days. The job was not only done, but done with 2 days to spare, in the laboratories of the ATSC.

Briefly, the Pacific RCM situation at present shapes up about like this. Some XX and XXI BC Superforts are carrying search equipment with provision for jammers as the need arises. Increasingly, FEAF strike aircraft are being equipped with search receivers and jammers. Ferrets, of both old and new types, have the following distribution: 4 with the XXI BC; 2 with the 5th AF; 2 with the 14th AF; and one theater-made job with the 13th AF. B-25's have recently joined the hunt as "radar busters." One each in the 5th and 13th AF's are equipped with search receivers. They seek, bomb and strafe in one operation.

The 13th AF has come up with something new in RCM—a "radar intercept station." Essentially, it is a Ferret based in a foxhole to intercept any transmissions from attacking Jap planes.



Navigator uses SCR-717C indicator, Loran and SCR-718 altimeter for precision navigation to pinpoint Jap radars



Ferreter at left usually looks for signals up to 300mc.—operator at right, covering higher frequencies, picks up some of radars



Radar operator handles SCR-717C controls and works closely with navigator and Ferreters using a special interphone system

The makings of a ferret

Except for a profusion of antennas scattered over its fuselage, the new B-24J Ferret looks about like any other Liberator. Internally, you wouldn't recognize the place. The bomb racks have been ripped out and in their stead are the things that make a Ferret—search receivers, analyzers, navigational devices, recorders and other appropriate gadgets for getting the most out of any Jap radar signals that might be picked up.

This conversion from bomber to Ferret wasn't done on a production line. It wasn't even done according to routine engineering processes because the job was complicated by a lack of blueprints, T/O and experimental models. To remove the bomb racks and substitute a room, without weakening the structure of the plane, presents some pretty knotty engineering problems, especially when that room occupies the entire aft bomb bay. They had to be solved on the spot with construction machinists taking verbal orders from engineers and working from rough sketches. Each installation was literally handmade. For these reasons, the 141 individuals in 14 ATSC and FATSC organizations, who worked night and day to finish the Ferrets on schedule, would seem to deserve a big hand.

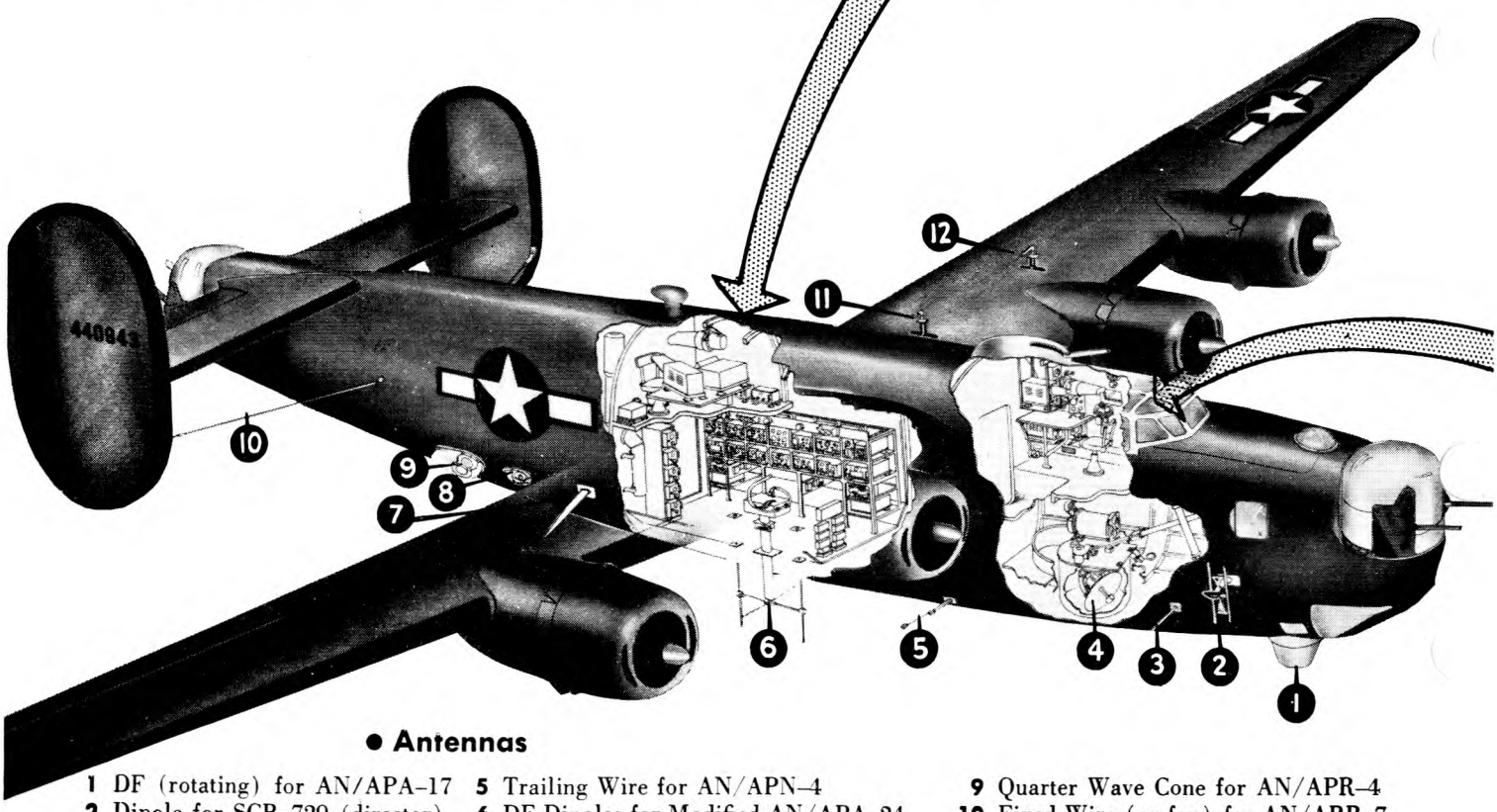
The RCM room was enlarged from half to all of the aft bay to accommodate a greater amount of equipment, as well as to provide some degree of comfort for the 2 Ferreters who may often spend up to 19 hours at a stretch in the 8½′ by 5½′ compartment. They can work in comparative luxury now with such features as soothing dull green walls, reostat control of lights, posture type chairs, gasoline heaters, eye level dials, electrically heated suits, electric heater and fan. The room itself is constructed of aircraft plywood, insulated with quilted felt aircraft cloth and floored with rubber matting that has a heavy felt base.

The equipment, which is racked along the left wall, includes every thing new in RCM gear. In fact, many of the sets included are the first production models and, in the case of a retractable direction finding antenna, pre-production.

To allow close cooperation between navigator, radar operator and Ferreters, a special interphone system was devised which eliminates interference from pilot-to-crew conversation. Special jack boxes in the radar, RCM and navigator positions provide facilities for operating either the normal or special interphone or for switching to any combination of receivers.

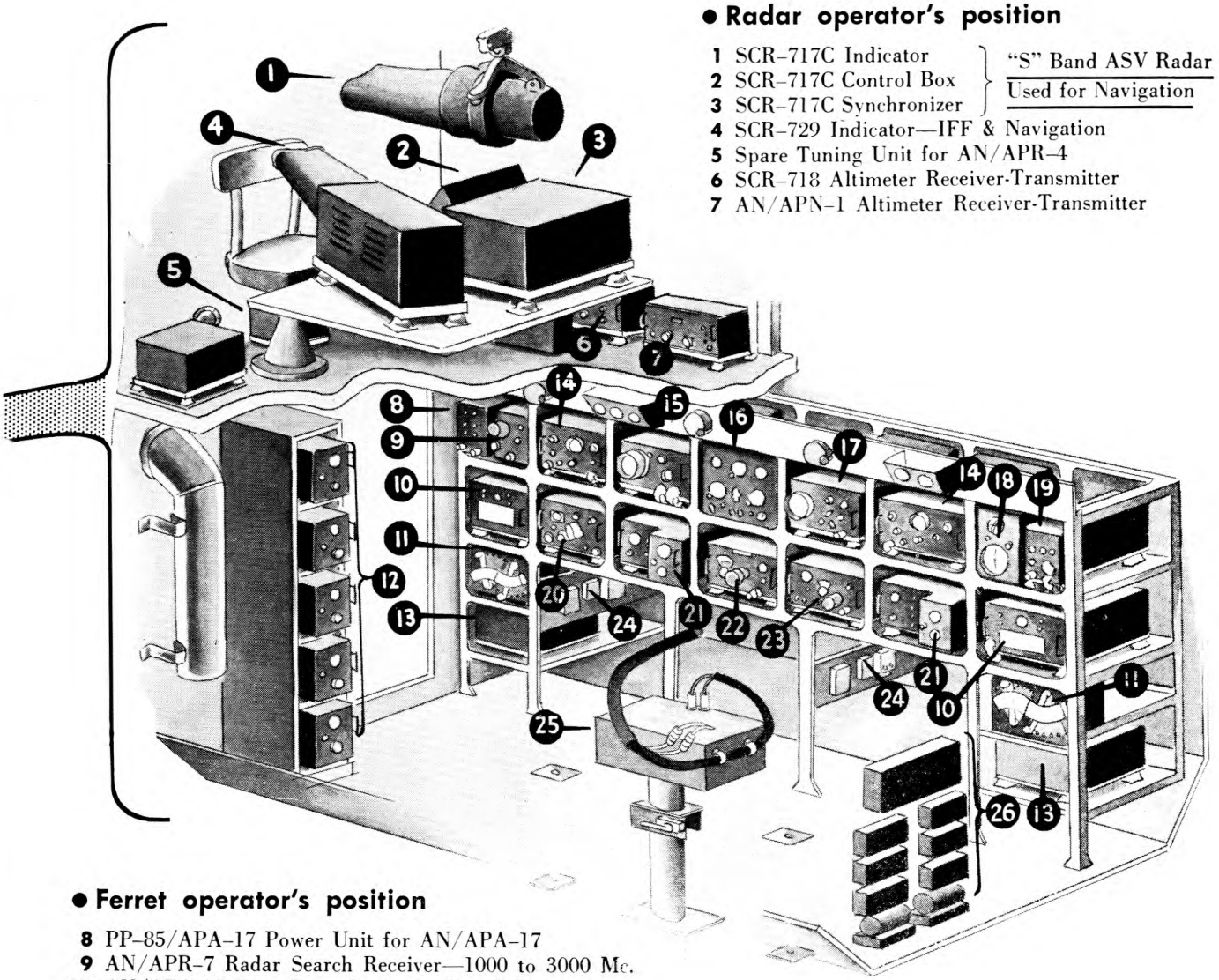
Four of the new Ferrets were delivered to the XXI BC's 3rd Photo Recon Unit on Guam, which already had an old-style B-24 Ferret. The other one went to the RCM Reconnaissance Training Center, March Field, California. Of these only three are left. One of the Guam planes crashed when taking off for a test flight (but with no loss of life). The March Field Ferret recently disappeared on a routine training flight over San Francisco.

More of the new-style B-24 Ferrets are now under construction in U. S. modification centers and plans are being considered for B-32 Ferrets if those aircraft become available.



• Antennas

1 DF (rotating) for AN/APA–17
2 Dipole for SCR–729 (director)
3 Spike for SCR–729 (reflector)
4 Spinner for SCR–717C
5 Trailing Wire for AN/APN–4
6 DF Dipoles for Modified AN/APA–24
7 Stub for AN/APR–4 & –5 & AN/APR–5
8 Quarter Wave Cone for AN/APR–5 & –7
9 Quarter Wave Cone for AN/APR–4
10 Fixed Wire (or fan) for AN/ARR–7
11 Altimeter Dipole for SCR–718
12 Altimeter Dipole for AN/APN–1



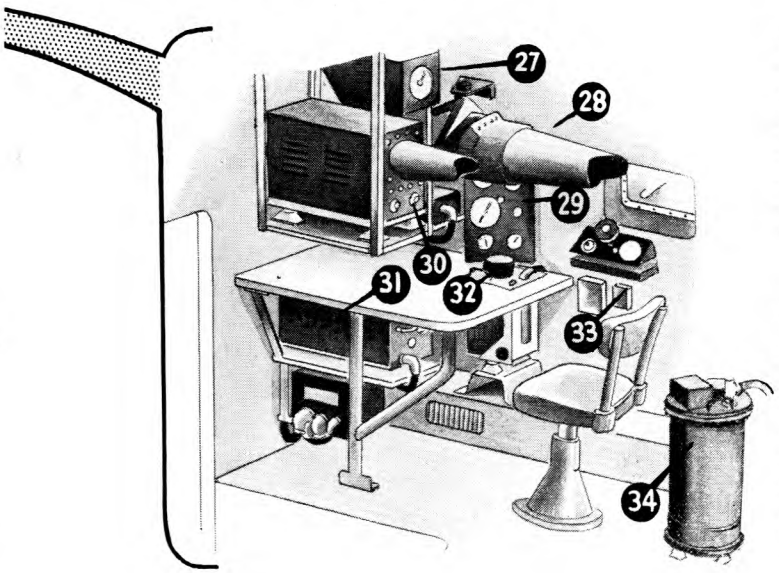
• Radar operator's position

1 SCR–717C Indicator
2 SCR–717C Control Box
3 SCR–717C Synchronizer
} "S" Band ASV Radar Used for Navigation

4 SCR–729 Indicator—IFF & Navigation
5 Spare Tuning Unit for AN/APR–4
6 SCR–718 Altimeter Receiver-Transmitter
7 AN/APN–1 Altimeter Receiver-Transmitter

• Ferret operator's position

8 PP–85/APA–17 Power Unit for AN/APA–17
9 AN/APR–7 Radar Search Receiver—1000 to 3000 Mc.
10 AN/APA–23 Tape Recorder (u/w Search Receivers)
11 Antenna Switching Assembly SA–23/AR
12 Spare Tuning Units for AN/APR–4
13 AN/ANQ–1 Wire Recorder (Audio)
14 AN/APA–11 Radar Pulse Analyzer

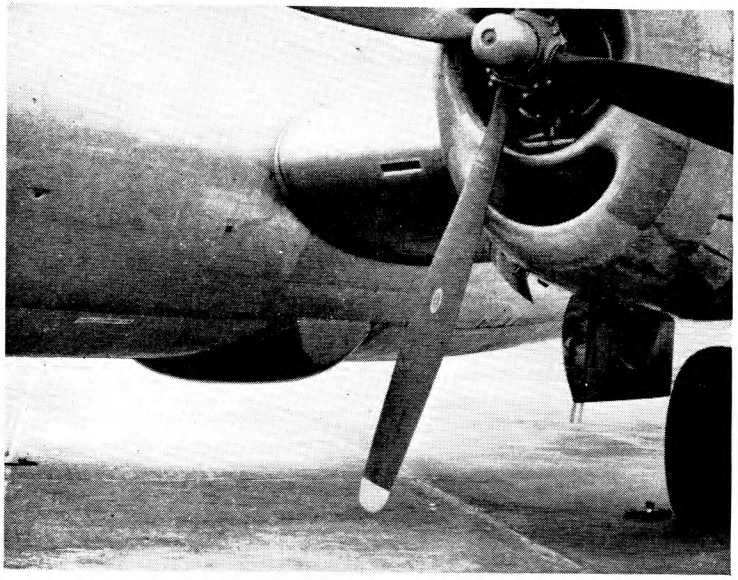


15 AN/APA–17 Indicator—Radar DF 25 to 1000 Mc.
16 Instrument & Switch Panel
17 AN/APA–10 Panoramic Adaptor
18 AN/APA–24 (Mod.) Indicator Radar DF
19 PP–32/AR Power Unit (u/w Search Receiver)
20 AN/APR–5 Radar Search Receiver 1000 to 6000 Mc.
21 AN/APR–4 Radar Search Receiver 400 to 4000 Mc.
22 AN/ARR–7 Radio Search Receiver 550 Kc to 28 Mc.
23 AN/ARR–5 Radio Search Receiver 28 to 143 Mc.
24 Interphone Jack Boxes
25 AN/APA–24 (Mod.) DF Radar 85 to 450 Mc.
26 Special Interphone Amplifiers

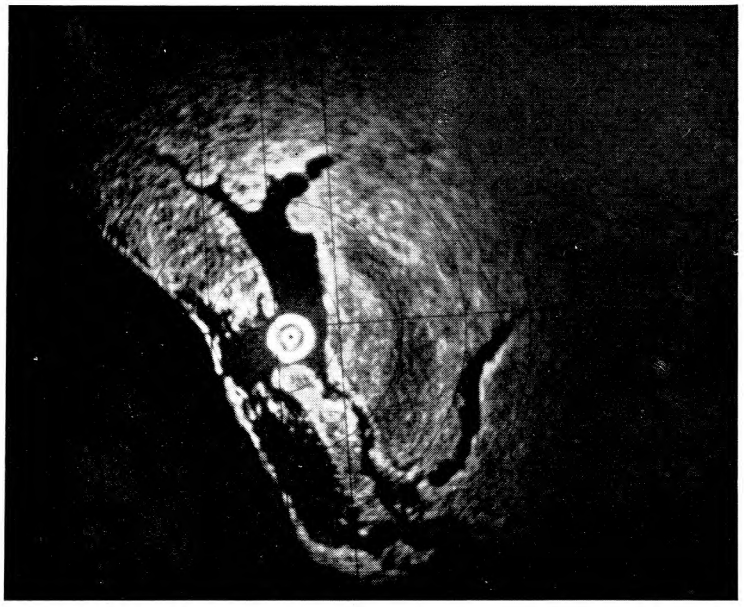
• Navigator's position

27 Fluxgate Compass Indicator
28 SCR–717C Indicator
29 Instrument Panel
30 AN/APN–4 Indicator
31 AN/APN–4 Receiver
} Precision Navigation

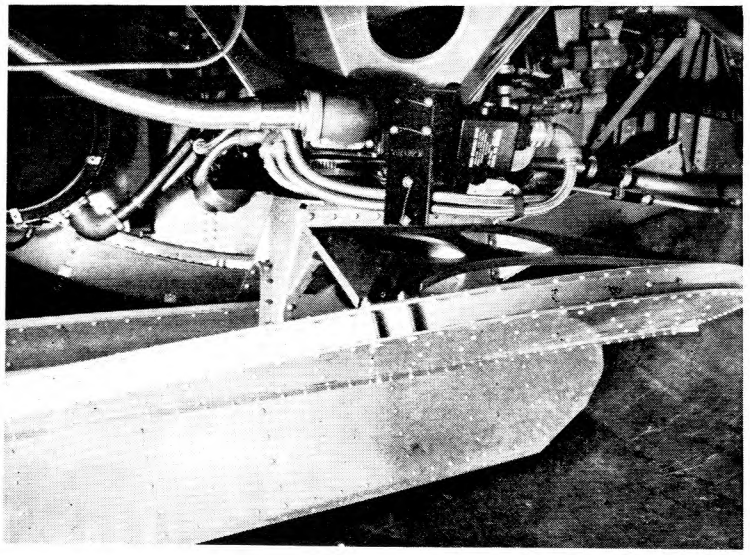
32 SCR–718 Altimeter Indicator
33 Interphone Jack Boxes
34 SCR–717C Radio Frequency Unit



60" dish antenna for APQ-13 makes only slight blister on belly of B-29. Radome is 70" by 68" and protrudes only 10" below keel line of aircraft, causes less drag than radome for 30" dish



Resolution is greatly improved by 1.3° beam width of this wide antenna. Photo above was taken over Ft. Meyer, Fla. Antenna construction is shown below—pillbox radiator is in foreground



Radar-computer

Computer	Radar	Availability*	Aircraft
APA—46 (Nosmo Mod I)	APS–15, 15A	Currently in operation	B–17
NOSMEAGLE	+APQ–7 = APQ–7A	Now available	B–29
APQ–5 (LAB)	SCR–717	Obsolete	B–24
APQ–5B	APS–15, 15A APQ–13	Currently in operation	B–24 B–32
APQ–5C (Noslab)	APS–15, 15A APQ–13	August	B– B–
APA–5	APS–15, 15A	Used by British and Navy.	B–24
MX/344 (APQ–13 Mod II)	+APQ–13 = APQ–23	July	B–29
APA–44 (GPI)	+APS–22 = APQ–34 +APS–23 = APQ–24 +APQ–7 = APQ–16 +APQ–13 = APQ–26	Early 1946	B–40s B–29

* With modifications computers could be attached to any basic radar—these are planned combinations. Availability is accurate only as of June '45.

Because Pacific bombing at present is predominently long range, most bombing through overcast must be conducted with the least accurate of existing radar systems—that is, with high altitude airborne radar unaided by ground equipment.

And that is unfortunate because, while radar control and beacon bombing at the close of European operations was almost on a par with visual, the accuracy figure for H_2X was not so good. It was so low, in fact, that although H_2X was responsible for heavy damage to German industry, in one 4-month period near the end of the war, the 8th AF was able to put only .2% of its bombs within 1000 feet of the aiming point and 5.6% within one mile, through 10/10 overcast.

Compared with the record that Shoran-equipped mediums chalked up in the final stages of the European war (see page 47) that's not very sharp bombing. Nor does it compare with the 300 to 400 yd. accuracy that fighter-bombers were often getting under MEW and SCR-584 control.

But that was in Europe with mediums and fighters. Now, with heavies and very heavies in the Pacific, its H_2X or nothing, at least for awhile. Therefore, considerable effort is being expended to overcome its shortcomings—the greatest of which involves target identification. The 60" dish for APQ-13 and high resolution Eagle are big steps forward, but the most significant developments have been with computers. In addition to providing a more accurate solution to the bombing problem, the latest models have offset facilities which greatly simplify target identification. The chart above shows the computer picture. The story that follows fits it into Pacific planning.

combinations for Pacific bombing

Characteristics

Bombing problem solved at radar position with aid of auxiliary Norden rate head—With modification kit, can be installed in bombardier's position (as such, it's APA-47). Rate indications to bombardier via PDI type meter—Course determination by pulse doppler—Continuous range tracking—PPI presentation—Electronic azimuth marker—Range offset possible—Altitude range 5,000 to 40,000 ft.

Nosmo without pulse doppler—Cannot be installed in bombardier's position—Eagle 60° indication—Altitude range 5,000 to 40,000 ft.

Bombing problem solved at bombardier's position—B-scope presentation—Drift and course controls common with Norden, range control not—Slant Range tracking—Altitude range 0 to 2,000 ft.

Bombing problem solved at bombardier's position—B-scope presentation—Drift and course control common with Norden, range control not—Synchronous tracking in slant range up to 2,000 ft. altitude—H plus B impact predicting with bombing tables up to 30,000 ft.

Bombing problem solved at bombardier's position—B-scope presentation—Norden tie-in for high altitude tracking—Range offset—Maximum tracking range limited by 70° sighting angle of Norden—Up to 2,000 ft. altitude, computer operates same as APQ-5B—Computing done through Norden tie-in above 2,000 ft. and up to 40,000 ft.—All course and rate control knobs common with Norden.

Bombing problem solved at bombardier's position—Synchronous electronic computer—Memory point tracking which yields average horizontal range rate with single knob range rate control—Ground range tracking—B-scope presentation—Altitude range 0 to 40,000 ft.

Bombing problem solved at radar position—PPI presentation with synchronous electronic range and azimuth cross hairs—Range and azimuth offset within 10 miles from any azimuth—Rate and position tie-in with Norden via meters to assist visual bombing—Automatic scope expansion—Double grip range and drift knobs like Norden—Altitude range 3,000 to 50,000 ft.

Bombing problem solved at radar position—PPI presentation with synchronous electronic range and azimuth cross hairs—Range and azimuth offset within 10 miles from any azimuth—Wind automatically computed by tracking any target—Automatic dead reckoning via dials which record ground position—Special PDI and time-to-go meter for pilot—Memory point tracking which yields average horizontal range rate with single range rate control—Maneuvering to 25° bank—Autopilot tie-in—Automatic sweep expansion—sector scan centered on cross hairs—Altitude range 0 to 50,000 ft.—off-center PPI on bomb run with APS-22 and 23—Rate and position tie-in with Norden via meters to assist visual bombing.

Operational simplicity is the key to accurate radar bombing—both tactical and strategic. That realization can be chalked up as one of the most significant contributions to radar bombing to come out of the ETO. Significant, because it stimulated the development of computers to provide the simplicity and because the radar-computer marriage is about to put BTO on a paying basis in the Pacific.

Like all radar equipment, individual computers are short-lived. Often, before one model can get into operation, a new and better one is in production to replace it. The chart above shows the family of computers for airborne radar as it now exists, but already research is underway to improve APA-44, most advanced of the computers listed.

Because the status of these radar and computer combinations is so very fluid, it is impossible to present any plan for their employment which would be valid for more than a month or so, at most. But some indications can be given.

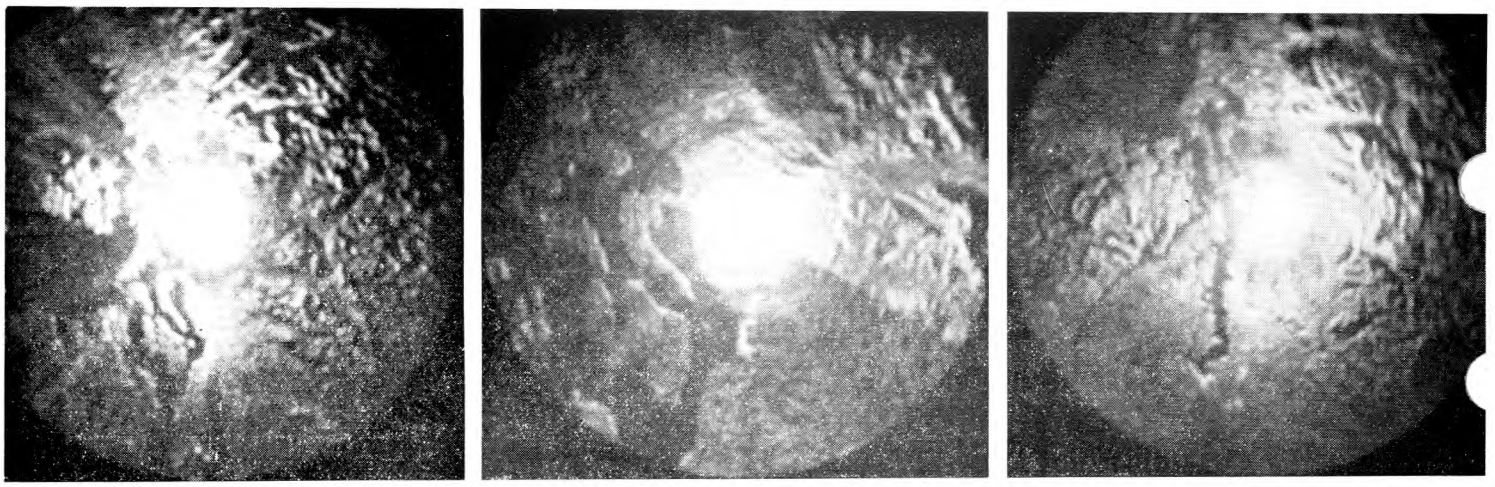
Liberators will continue to carry APS-15 in the following percentages: 25% in SWPA, POA and IB; 0% in China; 50% in the North Pacific. APQ-5B or C will do the computing for S-15, replacing the now obsolete APQ-5 and SCR-717 combination. The Navy and British are replacing the Q-5 series with APA-5 (see page 16). Those B-17s which are radar equipped will have APS-15 and APA-46.

The Superforts carrying APQ-13 will be fitted with the new 60″ dish antenna and MX/344 computer as soon as possible. Installations of the 60″ dish are scheduled to start in November; the MX/344 computer should be ready for action this summer. If possible, it will be installed retroactively in theater aircraft and will be the standard computer for APQ-13. B-29s of the 315th and 316th wings will hit Japan with the Eagle-Nosmeagle combination. Nosmeagle probably to be replaced at some future date by APA-44. The one group of B-32s going out will have APQ-13 and APQ-5B or C.

Standard equipment for Jet bombardment aircraft will be APQ-24—a combination of APS-23 (an X-band version of K-band APS-22) and the APA-44 computer. At present, acceptance of K-band equipment is limited in view of its limited range (see back cover).

These are the radars and computers for the strategic war in the Pacific. Among tactical radars, the outstanding example of what a good computer can do for accuracy is Shoran, the only beacon bombing radar now being considered for Pacific action (see page 47). Although Shoran shares the disadvantages of terrain limitations with its predecessors, Gee-H, Micro-H and Oboe, it surpasses them in accuracy and reliability—largely because it is easy to operate. A good computer and a straightforward presentation make it that way. On the basis of its record in Europe Shoran is going to war in the Pacific aboard heavies and very heavies as well as mediums. 25% of all B-24s, B-17s, B-32s and B-29s going out are to have group A parts, for the time when Shoran can be used.

However, for the present it is apparent that APQ-13 with MX/344 and the 60″ dish will probably be seeing the most of Japan. This system, APQ-23, is discussed on following pages.



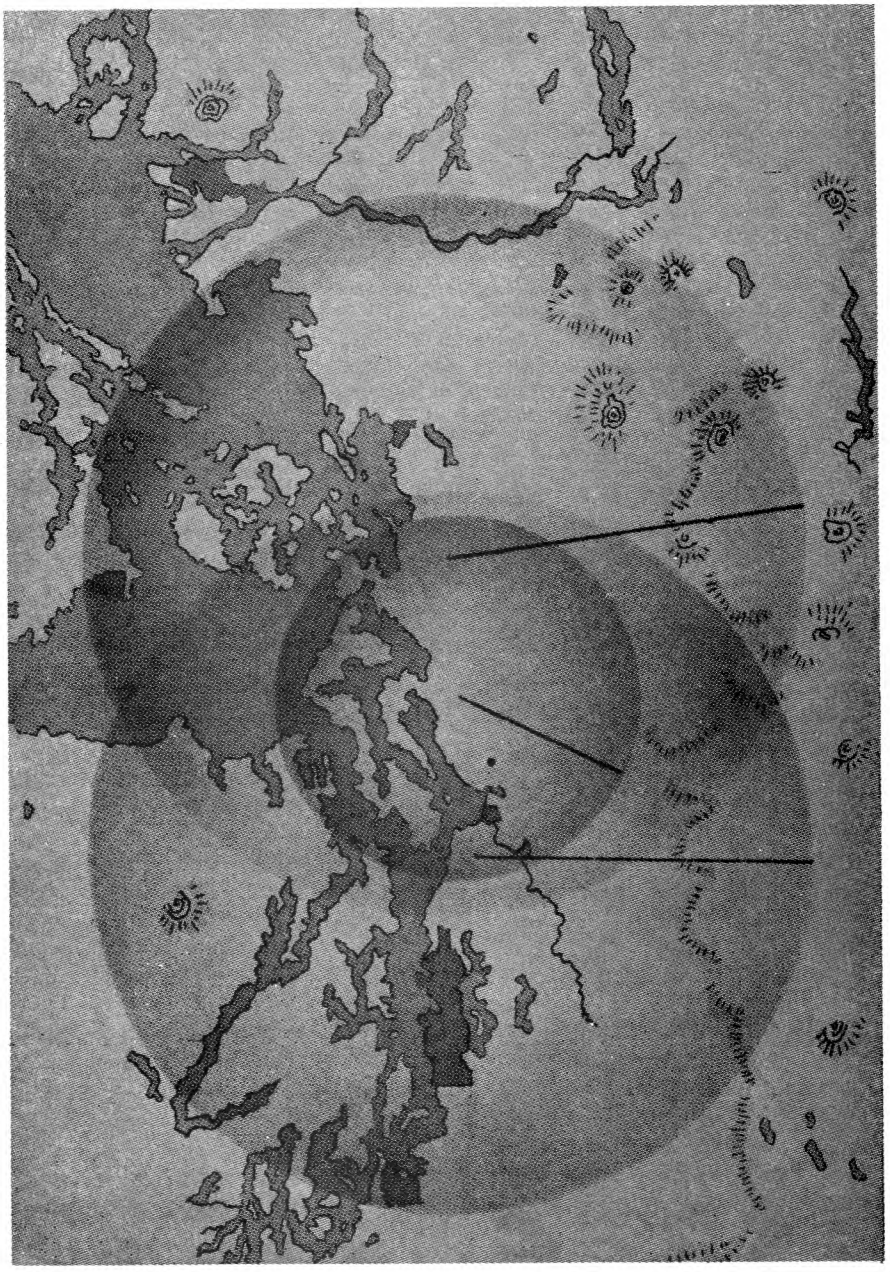
Seattle area reproduced by APQ-13 with 60″ dish at 30,000 ft. Sweeps are, left to right (top to bottom on map), 50, 20 and 50 mile. Photos show uniform ground coverage, absence of dark rings and interference fringes, and very satisfactory resolution

The APQ-23 system

The MX/344 computer (APQ-13 Mod II) will be the first equipment to see action which provides for automatic offset bombing. If it could do nothing else, this feature alone would justify its use because it goes a long way toward eliminating target *mis*-identification. With offset facilities if the target gives a poor return, the operator doesn't have to track it to bomb it. Instead, he tracks a well-defined aiming point near by, while the computer accounts for range and azimuth offset and directs the aircraft to the release point automatically.

But APQ-23 does more than offset bombing. The computer makes of the Q-13 a self-contained bombsight and strengthens its navigational abilities as well. In a nutshell, the 707 lb. equipment is worth its weight because it provides north-stabilized land mapping to 50 miles and shows large cities at 100; beacon recognition and measurement to 300 yds. at 200 miles; ground speed and drift measurement directly on dials; synchronous electronic indices giving presentation similar to a bombsight's; automatically centered sector scan; plus automatic scope expansion, control of aircraft and offset release.

These features should add a lot, but soon the Q-13 will have all this and better resolution, too. A 60″ dish antenna has been developed which narrows the Q-13 beam width to 1.3° as compared to 3° with a 30″ dish. With the combination of a $\csc^2$ elevation pattern, a chopped dish, and smart streamlining, the new radome causes less drag than the smaller antenna. The antenna protrudes only 6″ below the keel line—with radome, 10″.



It all adds up to better bombing

A navigational fix can be taken instantaneously with APQ-23. The range and azimuth crosshairs are simply placed to intersect any radar check point within 15 miles of the aircraft. This done, the azimuth and ground range can be read directly. Also, slant range, between 15 and 200 miles can be read to within 300 yards.

On any point in the area ahead of the plane and within 15 miles, a synchronous fix can be taken which will record ground speed and drift on dials. By taking two fixes on a check point at known times or by taking fixes on two different known points, ground speed and track can be determined beyond 15 miles. Then, the wind vector and finally ground speed and drift for any heading can be projected or taken. All of this does not mean that any normal method of obtaining this information cannot be used.

To facilitate beacon navigation, provision is made for a delayed sweep, whereby an expanded picture, being any multiple of 10 miles in length with sweep timed to start at any range out to 200 miles, can be displayed. In this way beacons and terrain features may be examined on an expanded range scale.

The bombing problem is set up after arriving at the target area. With APQ-23 the operator's job is largely a matter of reading dials and setting information into them. The computer does the rest.

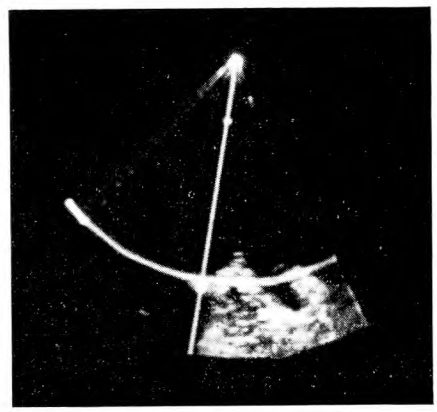
For offset bombing the bearing of the target from the aiming point (within 0.1°) and the distance between the two points (within 0.01 miles) are set into the proper dials. Altitude, which is measured as range to the ground, is read on a dial between 2,000 and 35,000 ft. With the altitude figure determined standard bombing tables are used to find trail and time of fall for the kind of bomb used. Trail to the nearest mil, along with time of fall to the nearest .01 second, are then set into their respective dials.

With the computer dials thus adjusted, the electronic crosshairs are set to track the AP at a maximum range of 15 miles. The crosshairs are controlled with double grip knobs like those for the Norden sight. Automatic scope expansion keeps their intersection at a constant distance from the center of the display. In this way the tracking controls move the target to match the index, keeping it away from the center where a crowding together of signals increases the possibility of error.

The plane is controlled on the bomb run through a C-1 autopilot, or it may be flown by the pilot from a PDI and distance-to-go-to-release meter.

As a final adjustment, the ground speed and drift, after being determined from the heading and wind vector, are set into the dials to the nearest 1 mi/hr and ¼°, respectively. The resulting track will be a straight line to the target displaced by crosstrail. It may be interrupted by the pilot for a short time with little cost. Since the electronic index is synchronous it remains on the AP with few adjustments.

When the point is reached at which the AP is no longer in the area ahead of the plane, no new information can be set into the computer as it does not track points to the rear. This is indicated to the operator when the tracking marks disappear and a warning light flashes on.



Synchronous crosshairs provided by APQ-23 are shown tracking a point of land

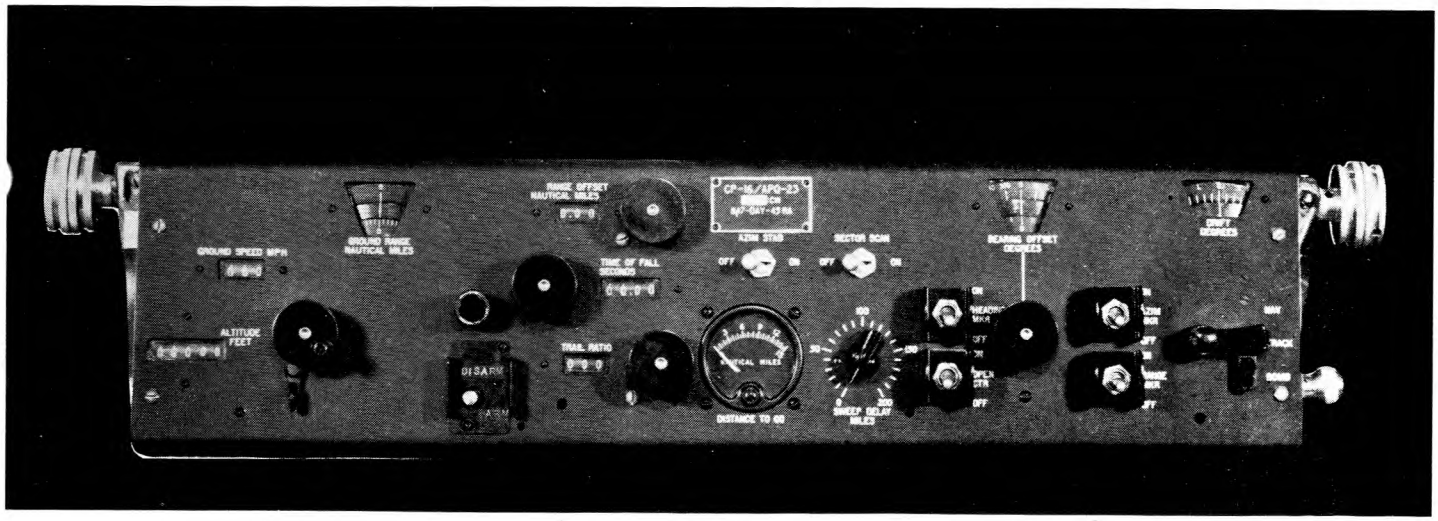
From here to release, which is automatic, the plane must be flown on the information now in the computer. There is a "trigger" (labeled "arming switch") like that on the bomb sight which protects the automatic release.

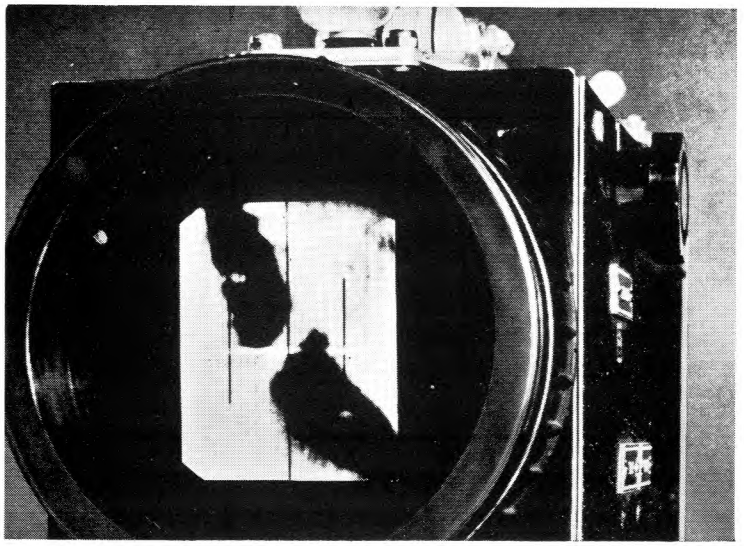
Meanwhile, just in case visual methods can be used, the bombardier sets his sighting angle and refines his ground speed by setting the horizontal needle of a zero-reading meter to remain on a center mark, just as if the needle were the crosshairs of his sight and the center mark of the scale the target. He decides whether the drop will be by radar or optics and throws a switch accordingly.

For direct bombing the procedure is the same as for offset except that tracking is done on the target.

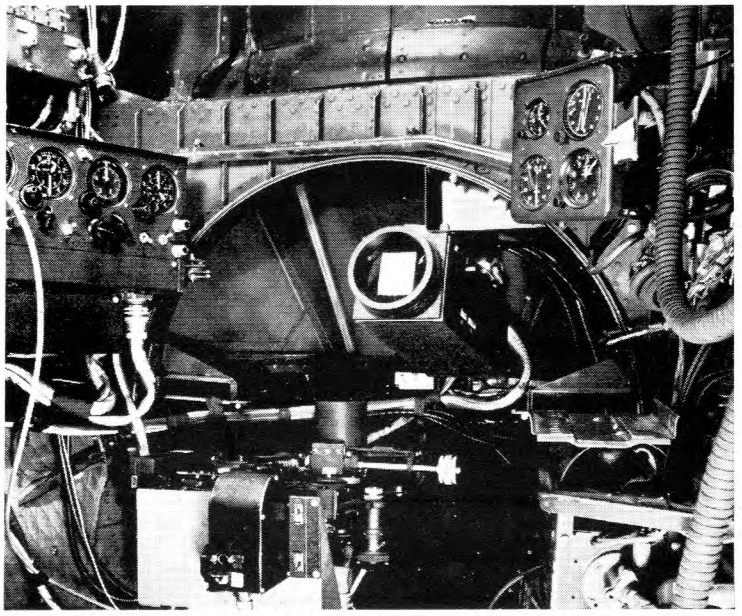
Current figures show that 6000 of the basic APQ-13 radars have been furnished to the services and current delivery is at the rate of 600 per month. Six MX/344 computer kits were delivered in April and 40 in May, with production building up to 750 per month by December 1945.

MX/344 computer attached to APQ-13 replaces phasing unit, azimuth control box, torque amplifier and CP-7 computer. Double grip knobs on right are drift and turn—those on left are range displacement, ground speed. Box is 26" x 16⅛" x 10⅝"

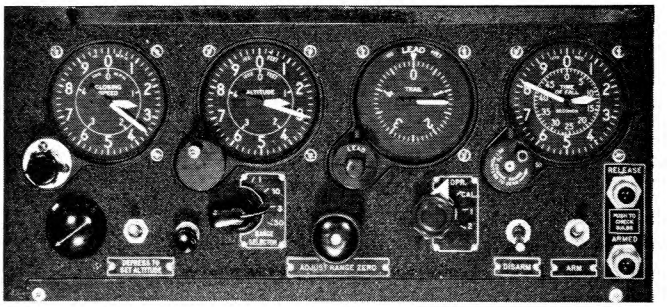




George Washington Bridge on the B-scope crosshairs of an APA-5. Picture was taken 3 miles from bomb release point at 10,000 ft. Two boats on river would make excellent targets



APA-5 components as installed in B-24. Control box is upper left, B-scope is in center, tracking knobs are those below scope and on black box in lower foreground. Total weight is 130 lbs.



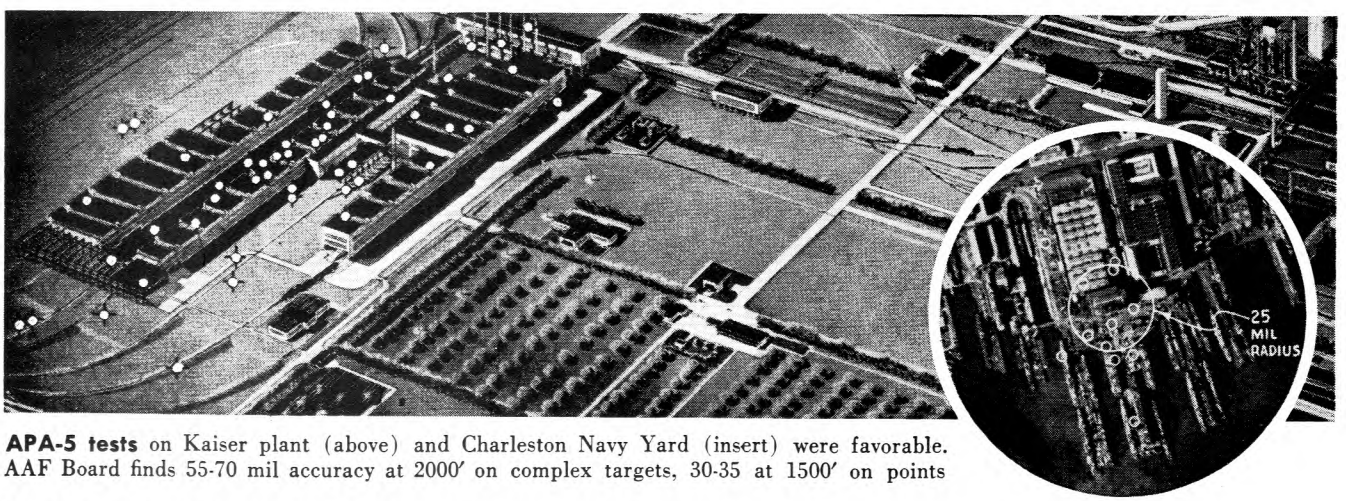
APA-5 control box solves tracking and release triangles electrically and presents information on easily read aircraft dials

. . . . and the versatile APA-5

The APA-5 computer, subject of current and extensive testing by the AAF, introduces some new techniques to radar bombing. From results already in, it is evident that those techniques are not without considerable merit. In fact, the Navy and British have already placed substantial orders for APA-5 on the basis of its accuracy, simplicity and versatility.

One of the features which makes the equipment exceptional on these counts is its ability to solve tracking and release triangles electrically, converting altitude and slant range to ground range. Other significant virtues are, briefly, tracking from a B-scope using the Norden turn and drift controls; single knob range tracking; use of the Norden bombing tables; sector scan of adjustable amplitude centered about the line of sight; increased azimuth sensitivity by use of an azimuth error voltage generator; improved slow sweep. Although the present model provides no automatic offset, a means of doing that is being developed. The APA-5 was designed as a completely synchronous computer to permit bombing at all altitudes with X-band radar.

So far as the AAF is concerned, it goes along with general views on APA-5 merits. On the other hand, it has expended considerable time and effort in development and training on equipments with other sizeable advantages of their own—namely, APQ-5C and MX/344 (see page 12). The testing program will determine whether the advantages of APA-5 are sufficient to warrant acceptance in view of commitments.



APA-5 tests on Kaiser plant (above) and Charleston Navy Yard (insert) were favorable. AAF Board finds 55-70 mil accuracy at 2000′ on complex targets, 30-35 at 1500′ on points

More hits, more runs, less errors

How B-29s operate at new lower levels against Jap targets

When high-flying B-29 crews of the 21st Bomber Command dropped from 25-30,000 feet to 15-20,000 feet for daylight precision bombing and to 5-10,000 feet for nighttime incendiary bombing last March, some crews were apprehensive. The setup looked too good for Jap AA gunners.

This turned out to be a misapprehension. As altitudes decreased, so did losses. The flak thrown up against the big planes was not heavy enough to bring many of them down, and most of those that were hit were able to limp back—at least as far as Iwo. By comparison, the higher altitudes had of themselves produced a larger proportion of losses. The long climbs, the high winds, the marginal supplies of gasoline had taken an operational toll.

The lowering of altitude for precision bombing was done for one main reason: to increase the amount of damage to enemy pinpoint targets. Neither visual nor radar methods were good enough at 25-30,000 feet. Coming down to 15-20,000, bombardiers were able to get more bombs within the pattern, make fewer gross errors. It was easier to identify the target since there were fewer cloud layers, easier to bomb accurately with reduced wind intensity. There were more bombs to put on the target since less gas had to be carried.

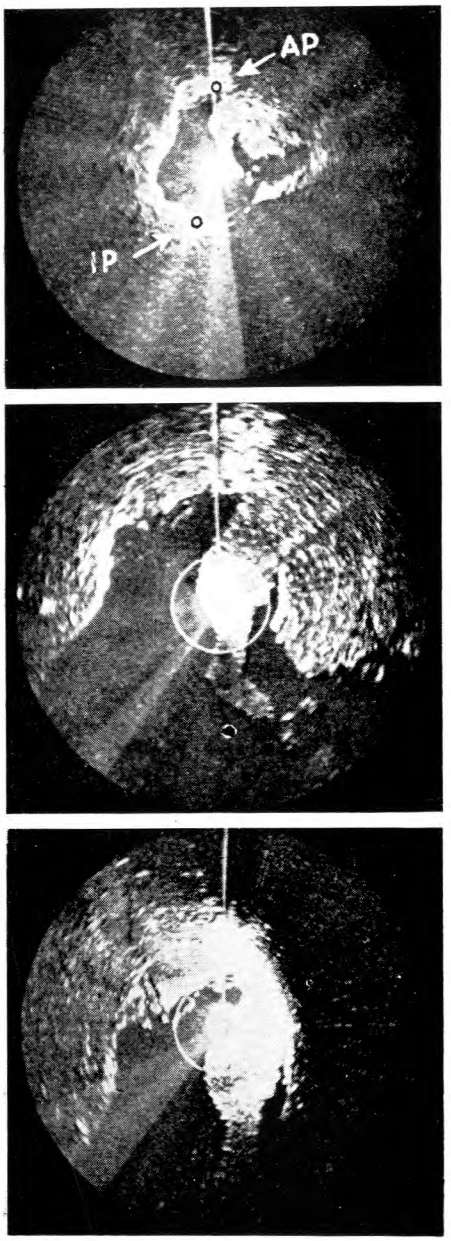
The co-introduction of nighttime incendiary raids at 5-10,000 feet constituted a major change in policy. The purpose was to break the backs of Jap cities, to get at dispersed Jap industry. A few daytime incendiary raids have also been run. All of this has resulted in a big increase in our air activity.

B-29 radar (APQ-13) has been used extensively on both the high level precision raids and the low level incendiary raids. The Radar Operations Officer helps to select all targets and plan the operations. Standard procedures are regularly used for briefing crews to navigate and bomb by radar.

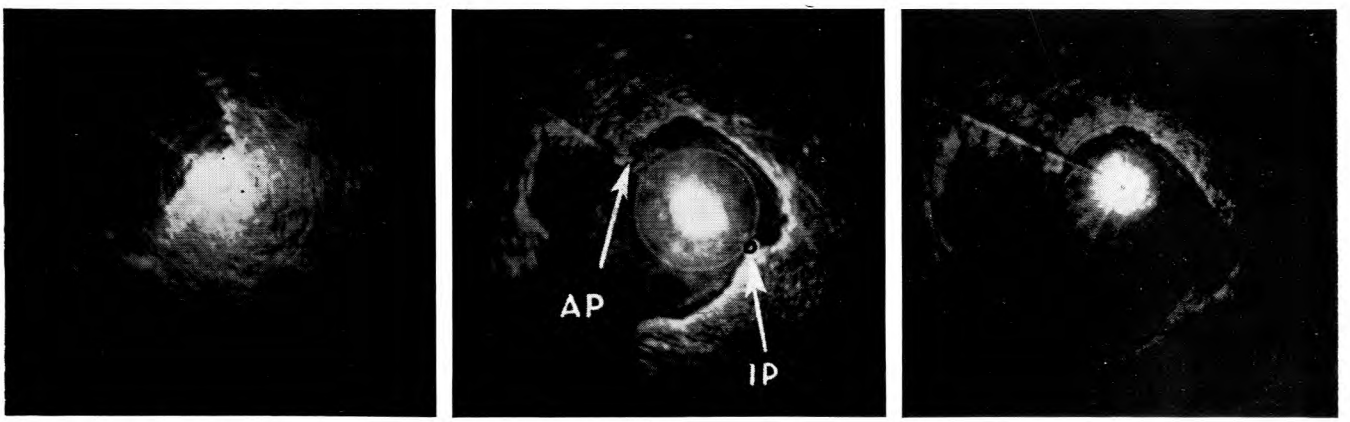
Primary targets for daylight precision raids are not always identifiable by radar. When that happens there's a secondary target for radar. For example, Musashimo plant in the northwest suburbs of Tokyo might be the visual target, and the entire dock section of the city the radar target. When the primary target is completely socked in planes go on to the secondary target.

On nighttime raids lead planes drop large incendiary bombs to mark the targets. They start their bomb runs by radar, but if they can actually see the target they make the releases visually. Usual procedure with radar is to use an offset aiming point with either a timed run or a back slant range release. Synchronous bombing has not been done at the altitudes flown. Thermal turbulence makes the back slant range method the preferable one.

Since formation flying is not attempted at night, each plane in the mission is on its own. Following planes practically never use radar for bombing. They don't have to. By the time they get there the fires set earlier have lit the cities up bright as day.



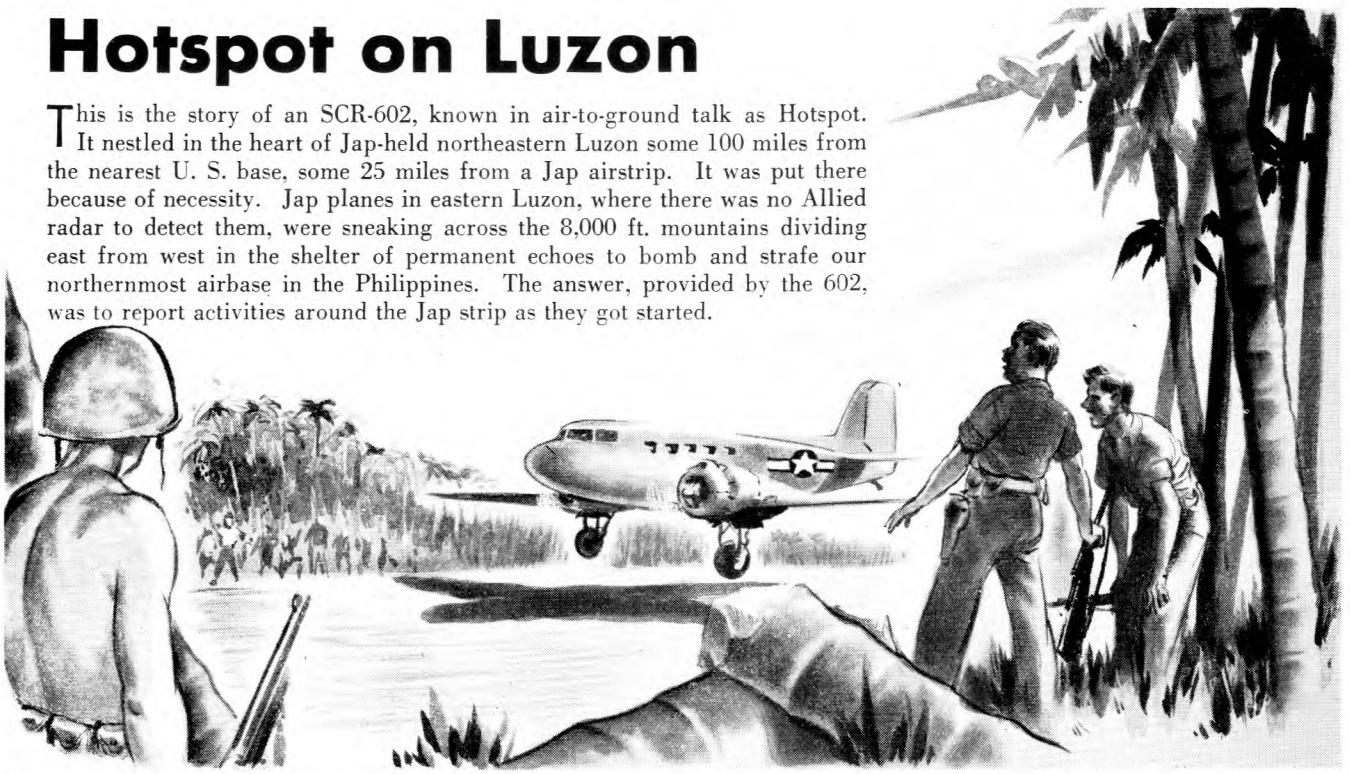
B-29s had no trouble finding Nagoya; Ise Bay and bootlike Cape Tomikai are easy to identify. 50 and 20-mi. sweeps



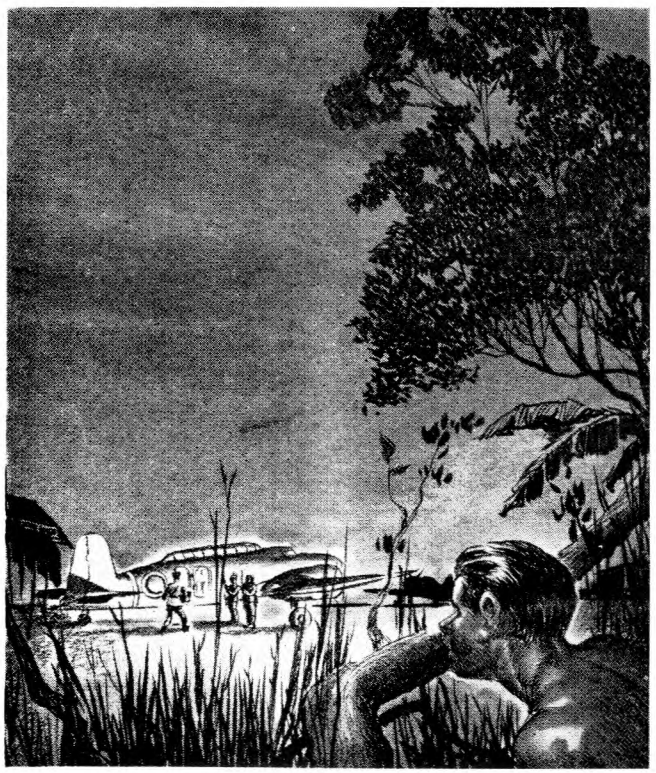
Approaching Tokyo from southeast, planes of 504th Bombardment Group took these scope photos at 5-6,000 feet using 20-mile sweep length, on early low level nighttime raid. Group Radar Operations Officer, Lt. Richard B. Wolf, sent in the pictures

Hotspot on Luzon

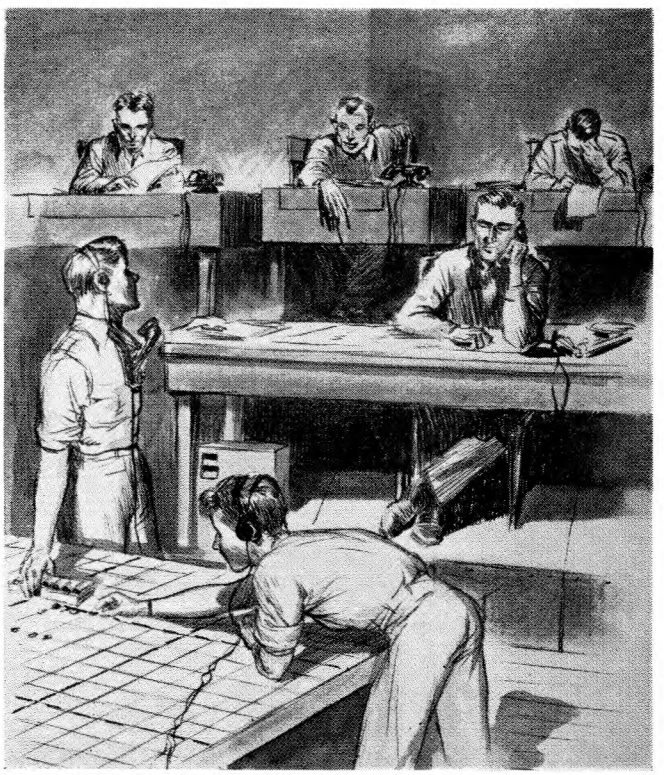
This is the story of an SCR-602, known in air-to-ground talk as Hotspot. It nestled in the heart of Jap-held northeastern Luzon some 100 miles from the nearest U. S. base, some 25 miles from a Jap airstrip. It was put there because of necessity. Jap planes in eastern Luzon, where there was no Allied radar to detect them, were sneaking across the 8,000 ft. mountains dividing east from west in the shelter of permanent echoes to bomb and strafe our northernmost airbase in the Philippines. The answer, provided by the 602, was to report activities around the Jap strip as they got started.



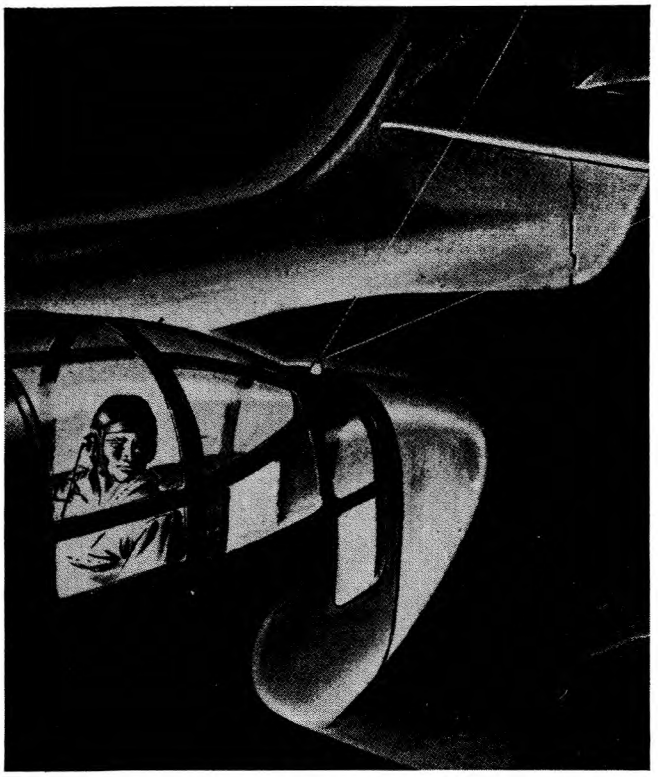
1 Guerillas—2,000 of them—made it possible. They hewed a 2500 ft. airstrip out of the wilderness. Ten C-47s flew in. Out came the 602, 33 enlisted men and 3 officers, jeeps, food, carbines. In short order the 602 was set up and working. Among other things, it made a puzzling observation. From the Jap strip, where all should have been quiet at night, came twilight echoes



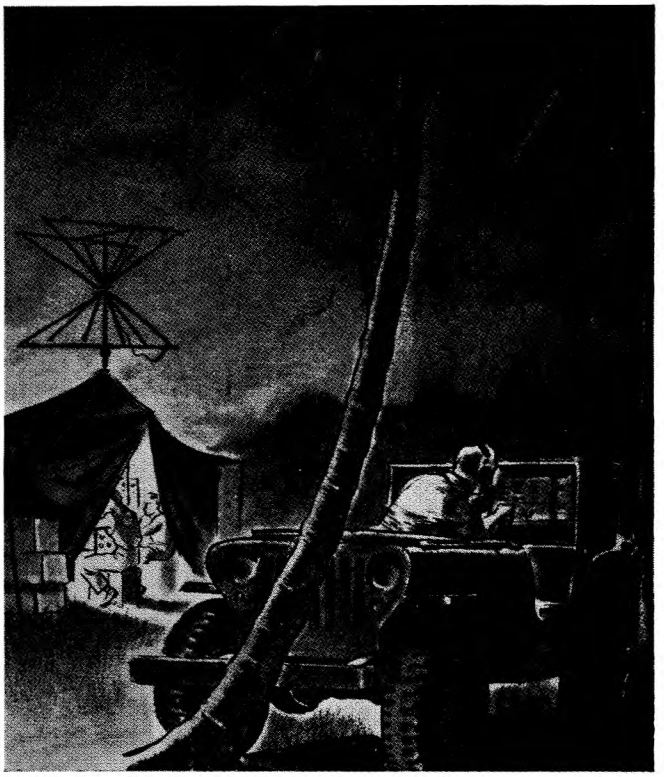
2 Guerilla scouts investigated. What they found were courier transports, loaded with enemy military dignitaries. One landed about dusk each night, gassed up, was on its way again



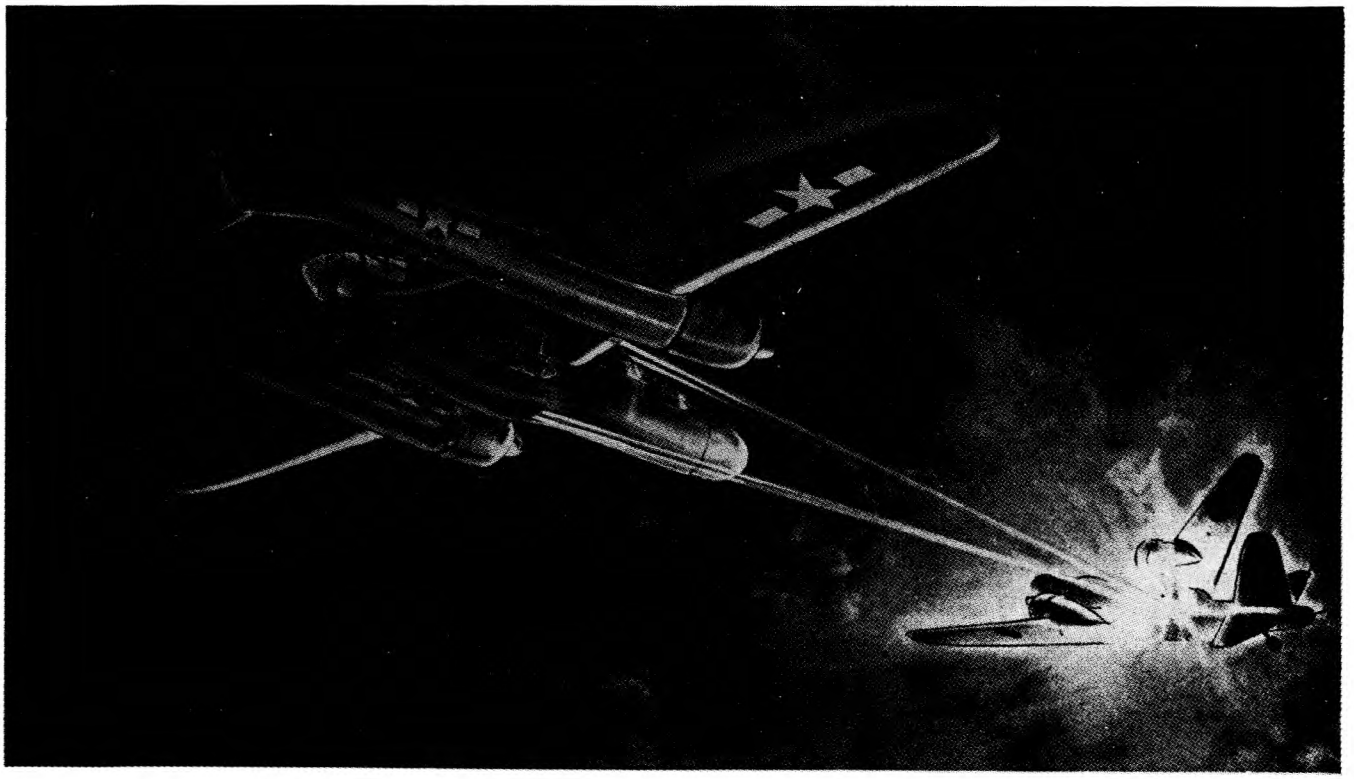
3 These data went to the Fighter Control Center at Laoag which handled operations aimed at Formosa, the China Seas, East Luzon; then to Lingayen Air Field 150 miles from Hotspot



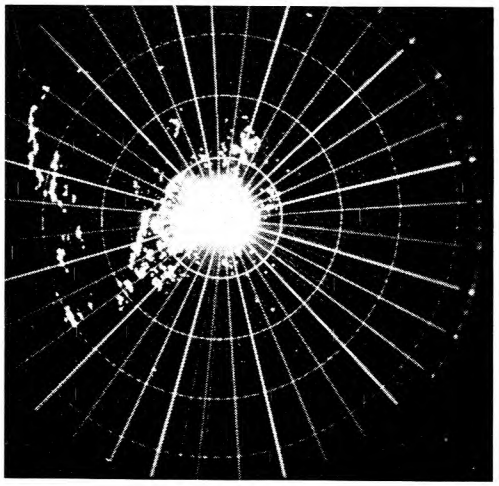
4 From Lingayen 2 Black Widows had been going out each afternoon—500 lb. bombs under their wings—to patrol. Now there was specific work. The P-61s orbited close to the 602

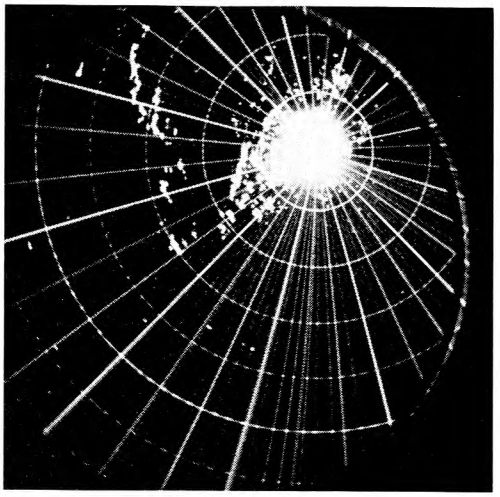


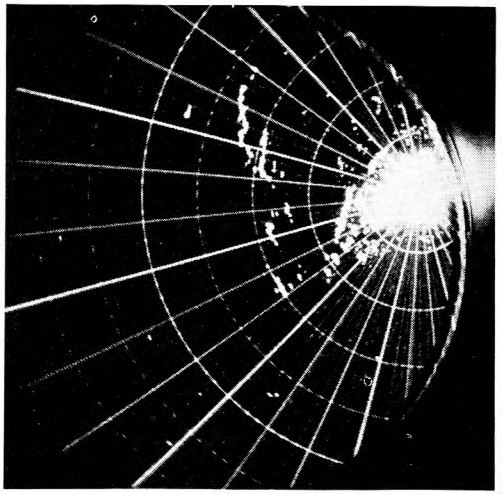
5 On the ground, the 602 controller kept one eye on the nightfighters, the other peeled for the courier plane. He saw one come in. When it was outward bound he began vectoring

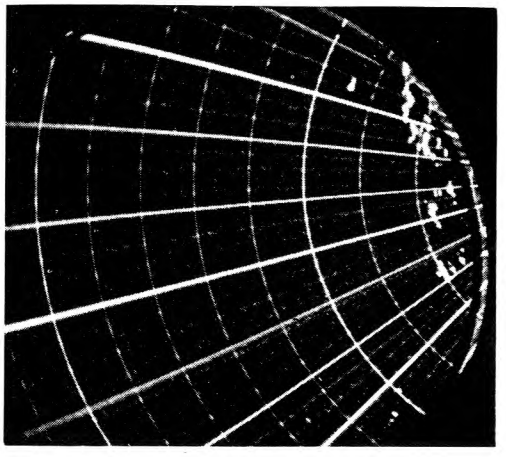


6 He brought the nightfighters within a few miles of the quarry. One made the AI contact and started in close for identification. But now the transport began a series of violent evasions. The AI radar held the contact. The P-61 opened fire. After a few bursts the transport flamed and spun down. At last reports 3 Jap courier planes—unwarned—had succumbed this way









Off-center PPI

It's the answer to a controller's prayer

Among all the new devices worked into MEW during the past year (see page 55), the off-center PPI tube has had one of the biggest shares in making an already successful radar more so. This tube's big advantage lies in its ability to maintain a map-presentation of proper scale and orientation while magnifying it so that any part of the radar coverage is spread over the entire tube face—consequently, most of the B-scope's advantages without B-scope distortion. As a result the off-center PPI is now standard for MEW, and will be for other control equipments, such as V-beam. It will even be incorporated in some of the newer airborne radars, on the books for next year.

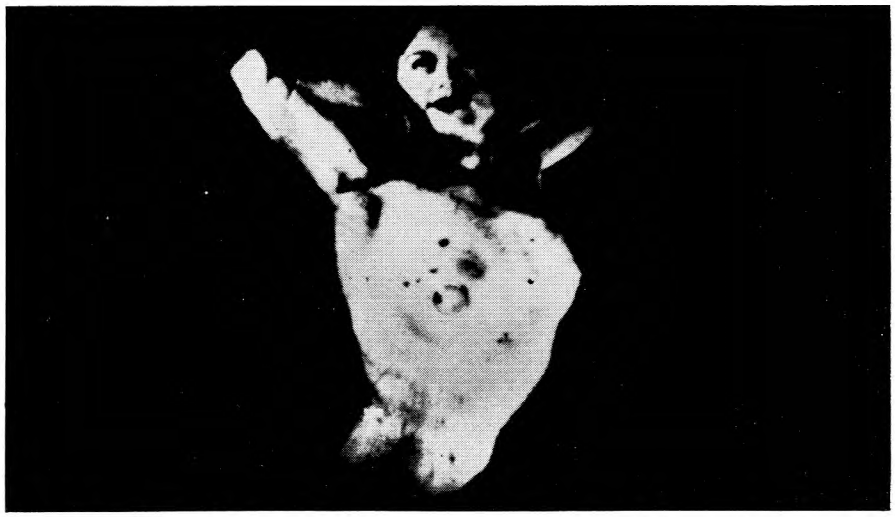
The idea of off-centering was worked out, in fact, in connection with plans for some airborne equipment. That was a couple of years ago. But it was not until the MEW became operational just before D-day that it was tried out. It went into actual although limited use over the following months.

An MEW controller may move the center of PPI rotation to any point of the compass, and displace the center by as much as three radii. This is made possible by an additional coil, concentric with and adjacent to the deflection coil. The angular position is set manually by a simple gear drive; a potentiometer on the front panel controls the extent of off-centering by varying the current passing through the coils.

Off-center PPIs are used practically exclusively for controlling—only rarely for plotting or reporting, although they do pretty well there, too. The controller generally sets up his tube by adjusting the center of rotation so that the important part of a mission will be covered. He marks bomblines, targets and such on the tube face with a chinagraph pencil, and marks the center position so that if he shifts his coverage temporarily, he can return to the prepared set-up.

The practice of marking the tube face has its disadvantages—marks must be changed if the controller shifts to a new sector. Also, azimuth and range numbering must be changed if the center is moved.

The remedy for this seems to be forthcoming, too, in the form of an electronic bombline marker. Essentially a television technique, this is a device for putting bomblines, airfields, flak areas, fiddle points (briefed reference points), grid squares, etc., directly onto the tube face with or without range and bearing marks. Data are correct on all tubes, regardless of coverage shift. This latest wrinkle in MEW-control has just gotten started. When entirely worked out, it ought to be pretty useful.



For electronic marking, map of target area is scanned by lightbeam under phototube, result fed into PPI via video circuits. Triumph above was obtained by scanning girl's picture, presenting it on scope fitted into suggestive permanent echoes. **Left:** off-center sequence of MEW 50-mi. sweep shows how planes can be enlarged and followed



At 19th TAC, an MEW Controller marks a target on face of his off-center PPI. The large illuminated map at his elbow was an innovation introduced to 19th TAC by its Chief Controller, Capt. C. E. "Shorty" Long. All necessary detail is marked on map, including range and bearing from MEW. Map gives much more information than could be put on tube face with china pencil. helps Controller supplement pilot's visual navigation. Newest way to accomplish this and more is electronic marker (see p. 20)



AN/MPG-1 is used with 155mm and 90mm batteries as a rule. This firing system, when combined with recently standardized M-8 data computer, is most accurate yet



SUPPLIED WITH MPG-1 FIRE CONTROL DATA, 4-GUN

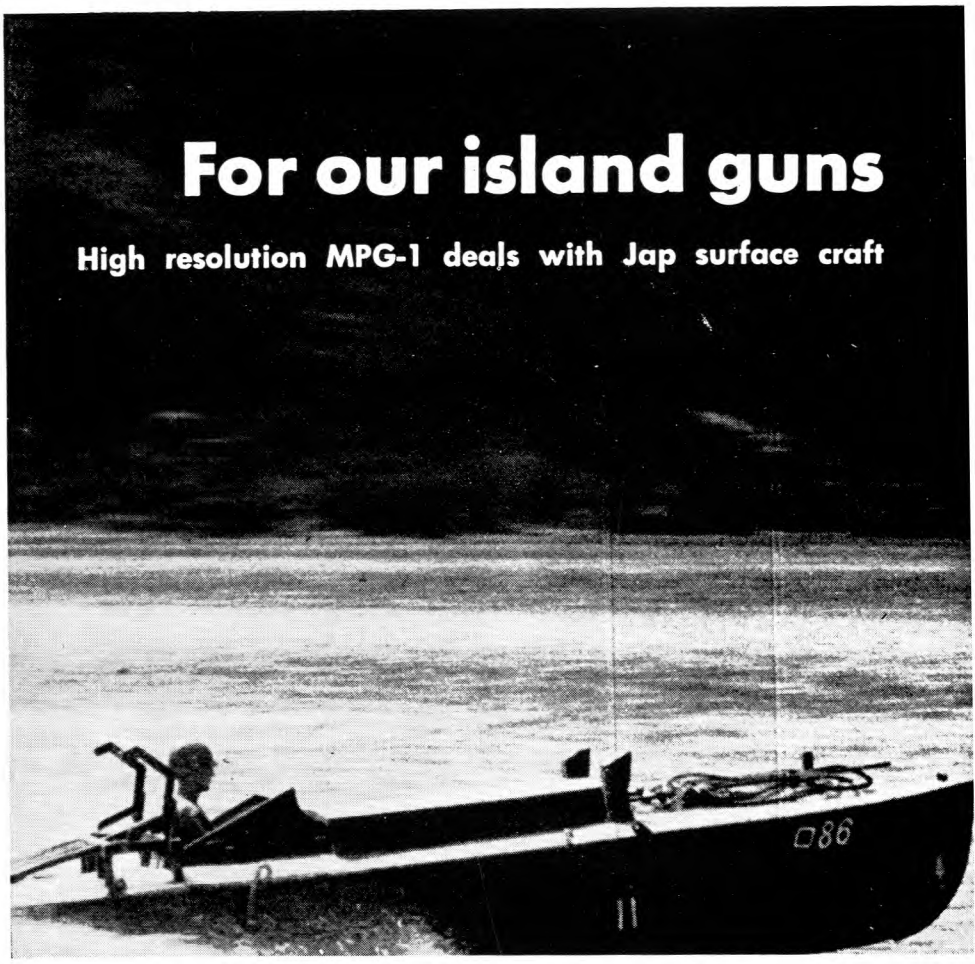
At Iwo, already laden with radar of all kinds and descriptions (see RADAR No. 9), a bright and shiny new fire control radar went into operation last month with Iwo's coastal artillery. And if Iwo was a well-protected little spot before, which it was, it's a lot better protected now with its AN/MPG-1. Belated in its arrival, this newcomer among operational radar—Iwo's installation is the first in a combat area—has proved itself so thoroughly in an extra-heavy schedule of tests that its Coast Artillery operators think they have one of the best pieces of equipment to date.

They got it the long way around, but that was because MPG-1 was a victim of circumstance. At the beginning of the war there was a high priority on coastal defense, but at that time neither the Coast Artillery Corps nor anyone else had any microwave radar ready for use. The Navy was the first to use gunlaying radar with heavy caliber guns against water targets. They had their FD radar, longwave ship-borne equipment. And



For our island guns

High resolution MPG-1 deals with Jap surface craft



155MM SEACOAST ARTILLERY BATTERIES LIKE ONE ABOVE CAN PICK OFF TARGETS SUCH AS JAP SUICIDE CRAFT. CAPTURED ONE IS SHOWN HERE

the Coast Artillery, badly in need of something, got some of the Navy sets, converted them for ground operation, dressed them up with some modifications such as doubling the effective range. The result was the SCR-296.

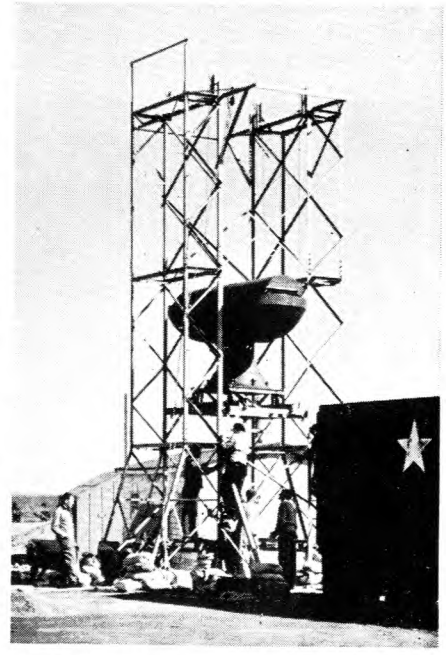
Even as this equipment was being installed at Panama, Oahu and on U. S. coasts, laboratory work got under way on the MPG-1, designed to comply with military characteristics set up by the Coast Artillery. But before the work really got going, the priority dwindled as we took the offensive and home coastal defense tapered off in urgency. So the development of MPG-1 dragged on and the Coast Artillery got used to the 296.

This was a very weighty piece of equipment and left a lot to be desired in the way of discrimination, according to present standards. Basically, it was, and still is, a good set, and in 1942 it looked particularly good. Its biggest drawback was its inability to spot shell splashes and its lack of a PPI for search.

There are no such drawbacks to the MPG-1. If it developed slowly, it developed well. When the first experimental model concluded its service test, along with several special tests, the Board gave an enthusiastic endorsement. Shortly thereafter MPG-1 went back where it came from—Radiation Laboratory—for reconditioning and shipment to Hawaii.

By this time high priority had returned to coastal defense, specifically the coastal defense of the island outposts we were taking over in the Pacific. These had to be guarded and immediate threats were growing up in the form of Jap suicide water craft and aircraft.

It is just such threats as the former that the MPG-1, now installed at Iwo, is designed to meet. Before the equipment was sent to Iwo, it went through an extra set of tests at Oahu which combined demonstration and training. As of the end of May, the set had not had occasion to strike any blows for freedom at its forward site but it's there in good working order with trained men to operate it.



Hoisting of ton-weight AN/MPG-1 antenna can be done within 15-20 minutes



Azimuth operator at left of console and range operator at right track target on B-scope. Remote B-scope for spotting shell splashes is set up at other end of the van

Rapid scanning, sharp beam are two ingredients of MPG-1's high accuracy

The MPG-1 equipment, when it's completely packaged, weighs about 11 tons—which makes it about two tons heavier than the more familiar SCR-584.

The main unit is a trailer, very similar in appearance to the 584 trailer. In transport, this contains all the basic radar components, plus the antenna, plus the antenna tower. The trailer is completely waterproofed and can be floated to shore in an emergency—a handy attribute in the Pacific. Spare parts, tools, test equipment and spare power plant are carried separately along with the rest of the gun battery equipment.

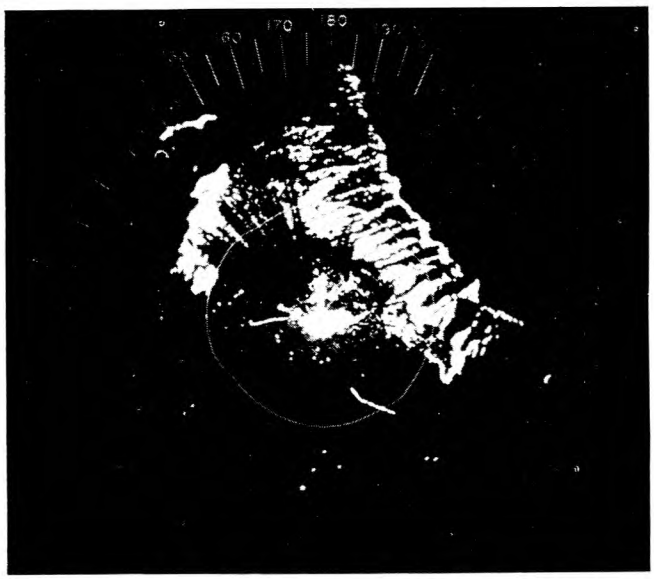
Electrically speaking, MPG-1 is a standard X-band search set incorporating the latest circuit refinements. Its unique feature is the Schwarzschild antenna (supported on a 584-like pedestal atop a tower) which produces a beam extremely narrow in azimuth and with low side lobes. Combined with a .25 microsecond pulse, these characteristics make for angular and range discrimination not found in any other gun-laying radar now operational.

Design of the Schwarzschild antenna is based upon an optical mirror theory. On the surface, the operation is fairly straightforward—radio frequency energy is fed into a folded piece of waveguide from a horn which scans in the horizontal plane. The folded waveguide produces a plane wave .6 degrees wide, swept through an angle of 10 degrees in azimuth. The sweep occurs 16 times per second. For normal search, the scanning horn is stopped and the entire antenna is rotated.

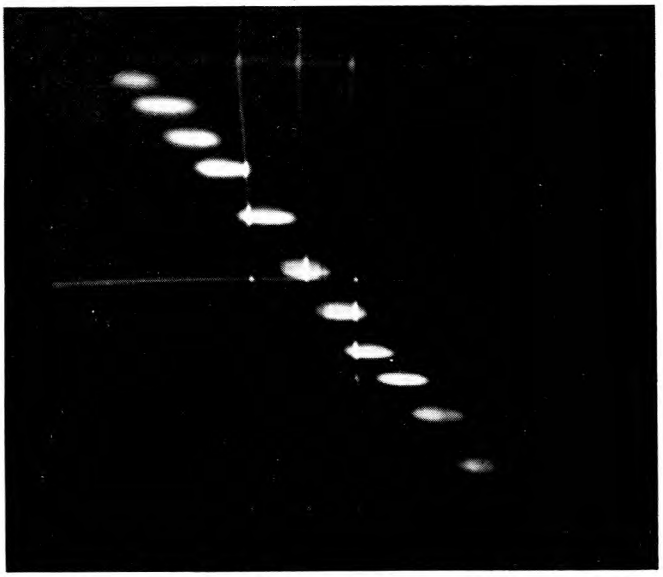
MPG-1 presentation makes the most of its narrow azimuth beam. For search there is a 7″ PPI, with north at 180° instead of 0° in conformance with CAC practice, and with 2 scales—80,000 yards for routine search and 30,000 yards for business. Either sector scan or continuous rotation is available to the operator.

The 7″ B-scope should please the most critical of B-scope connoisseurs. A good operator can usually determine the heading of even small ships at ranges less than 10,000 yards, and sometimes distinguish between bow and stern. The B-scope shows an expanded version of a small portion of the PPI, covering an area 2000 yards deep and 10 degrees wide with the center at any desired point. A second B-scope (remote) is set up in the van purely for spotting the shell splashes of the radar-guided guns, thus to provide correction data for the gunners. This is where discrimination counts (see cut, page 25).

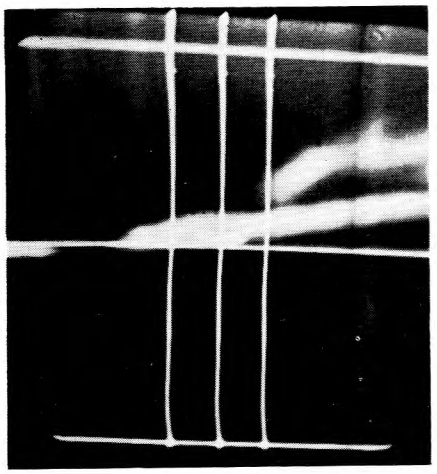
Aided tracking controls in both azi-



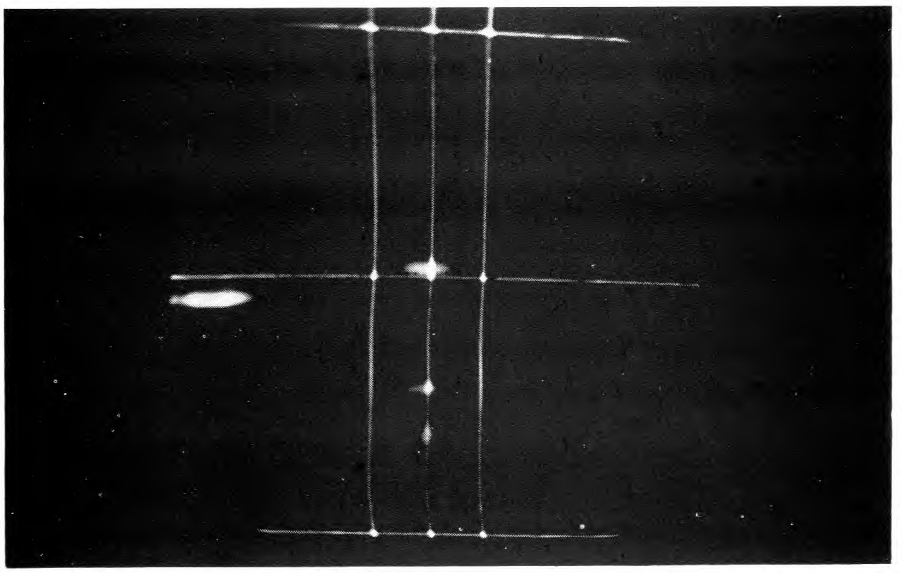
Koolau range on Oahu shows up clearly on PPI. Range marker set at 15,000 yards intersects a formation of 23 LCIs



Signals from 11 of 23 LCIs are picked up on B-scope. Average separation between craft is 150 yards in range, .6° in azimuth



Even with gain turned up, signal at center is visible through X-band window



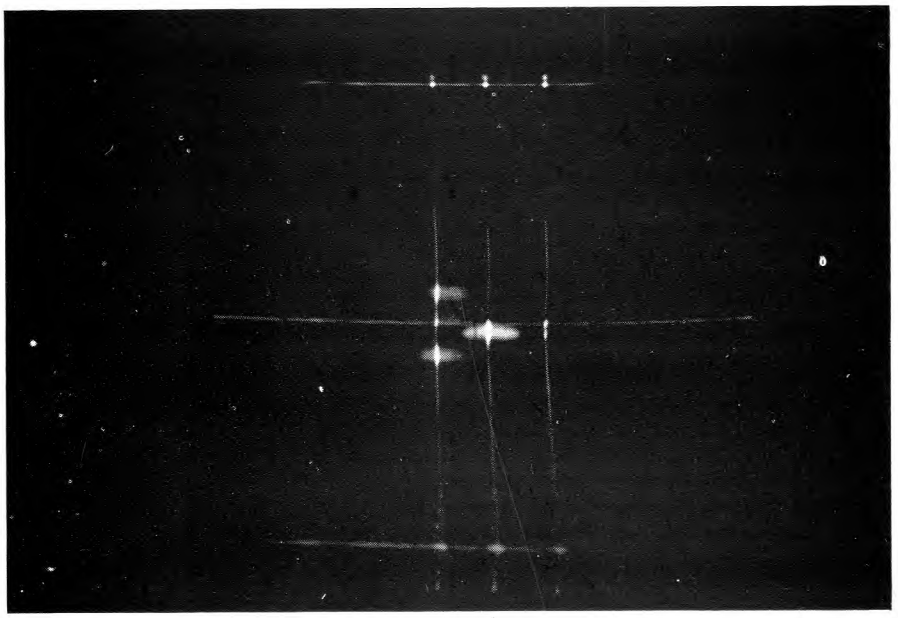
B-scope picks up signals of destroyer mine sweeper at left towing radar reflector target (echo at center) at range of 24,350 yards; splash echoes are from two 16-inch shells

muth and range complete the picture. Once the target is picked up on the B-scope, only minor adjustments of the handwheels are required to keep the target on the crosshairs. Tracking is smooth and accurate enough to allow continuous computing and gun pointing—a new concept in Coast Artillery practice. This feature is not normally necessary when tracking slow-moving water targets but it becomes of paramount importance in the case of fast torpedo boats.

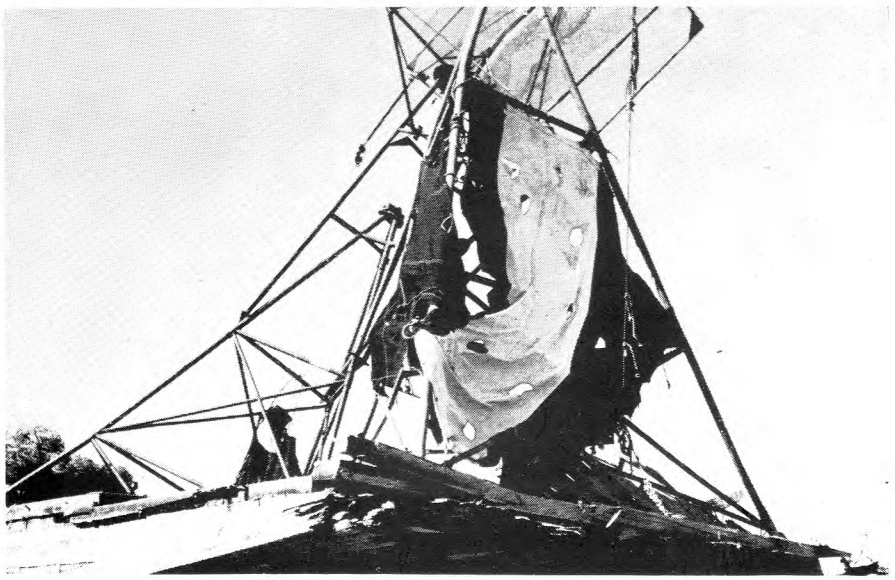
The shell-spotting feature is an artilleryman's dream come true and it is this as much as anything that makes the system the hot item that it is. The spotter has a pair of crosshairs which can be moved rapidly to the center of impact of a group of splashes. The deviation of the center of impact can then be read from a pair of dials and immediately entered into the computer as a "spot." This moves the center of impact right on top of the target — with obvious results.

Operation of the equipment requires no highly specialized skill on the part of the operators. When a likely target is selected on the PPI it is followed until it comes within 28,000 yards. The range operator then cranks an adjustable range marker so that it passes through the signal from the desired target, and calls the azimuth to the azimuth operator who turns his handwheel to that reading. A switch is flipped, the target appears on the B-scope and the operators adjust their handwheels until the target stands still on the crosshairs.

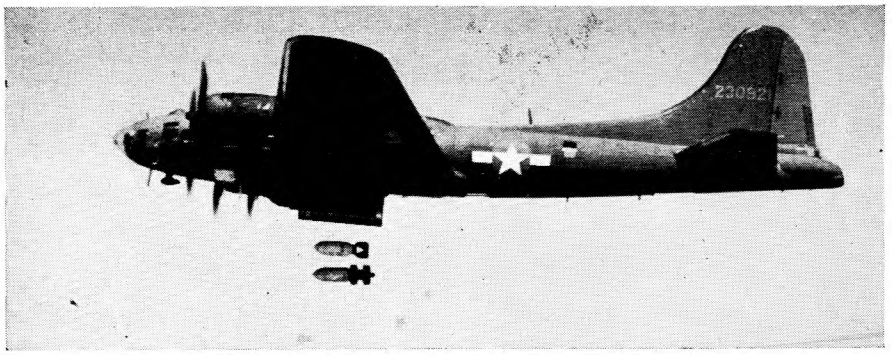
Then it's all over but the shooting.



Signals of splashes from 155mm shells show that guns are almost on target (center). Below, Navy type radar target on shore after being hit by 12-inch inert projectiles

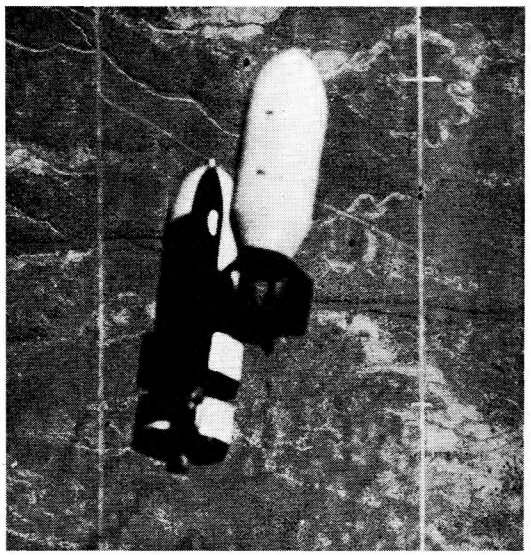


Razon: tests



Razon and standard 1000 lb. bomb are released from bomb bay in test drop. B-17 will carry a maximum of 4 Razons which are mounted in normal manner—only additional attachments necessary are electrical connections to keep the radio receivers warmed up

While Azon is overcoming its early bad reputation and making a good name for itself in the India-Burma theater (see RADAR No. 8), Razon (VB-3) is undergoing extensive tests prior to its operational debut. Razon is similar to Azon but it goes one step farther—it is controllable in range as well as azimuth. A missile with azimuth control only is primarily a line target proposition but, with range control added, it becomes a good bet for real precision bombing.



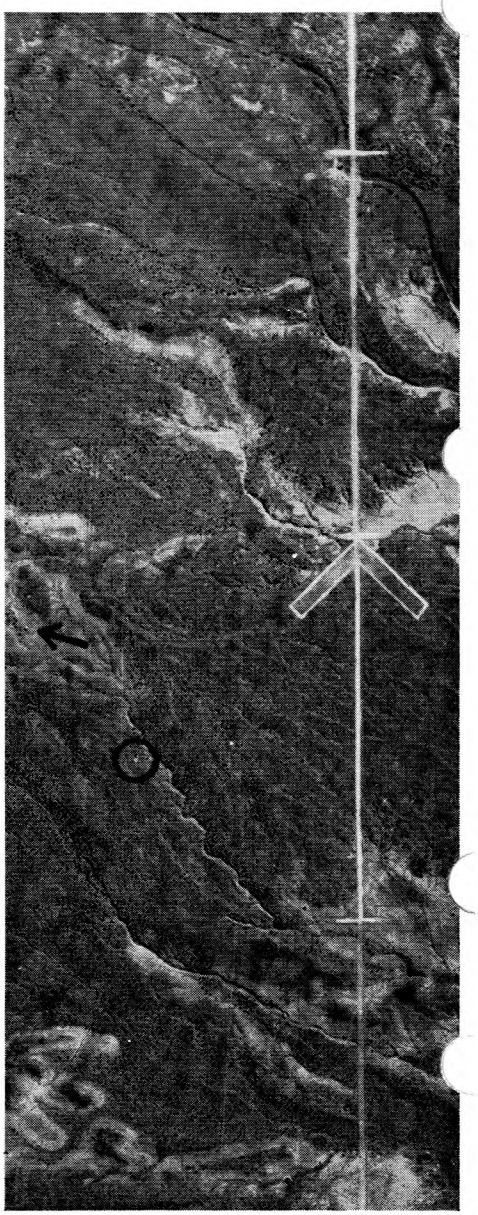
Amount of evasive action that can be taken after Razon release is not yet known. AAF Board tests will help determine that



Flare on tail of Razon (left) ignites after few seconds of fall. Good visibility is necessary in order to follow its descent



Razon yaws as it receives some right control. Pitch, due to range control, is not apparent in these plan view photographs



Standard dummy bomb is barely visible at left. Razon is still responding to right azimuth control as it moves toward target

reveal a promising tool

Preliminary tests at the Special Weapons Test Unit at Wendover, Utah, have shown that Razon is a promising tool.

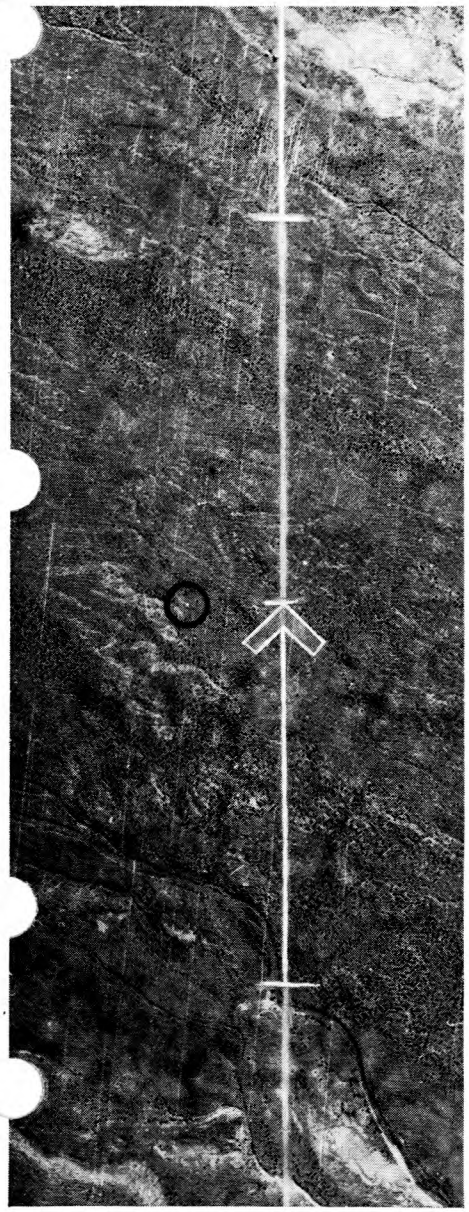
A 1000 lb. high angle bomb, Razon is controlled by means of a radio link between it and the aircraft—a receiver (AN/CRW-7) in the tail assembly of the bomb and a transmitter (RC-186) in the aircraft. A second shroud on the tail, called a lift shroud, makes for greater control and stability.

Present tests at Wendover are about over and from there Razon will go to the AAF Board at Orlando for its official workout. Operation and maintenance differ so little from that for Azon, that personnel already Azon-trained in the theater and in the U. S. can take over Razon with a minimum of extra training.

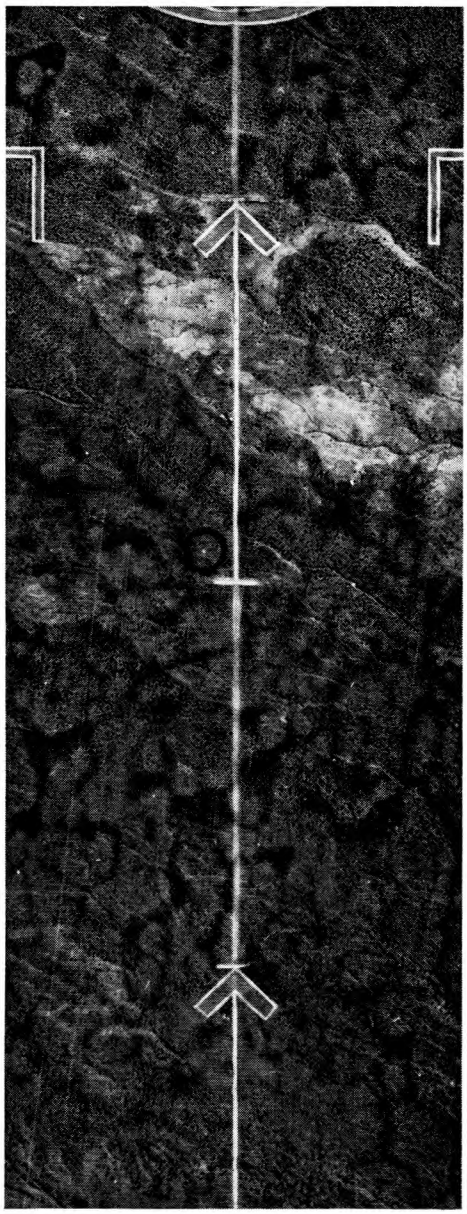
Next month the first lot of production units will be delivered. There's a lot of difference between tests and combat use but, if all goes well, Razon should be hitting some real targets within 90 days.



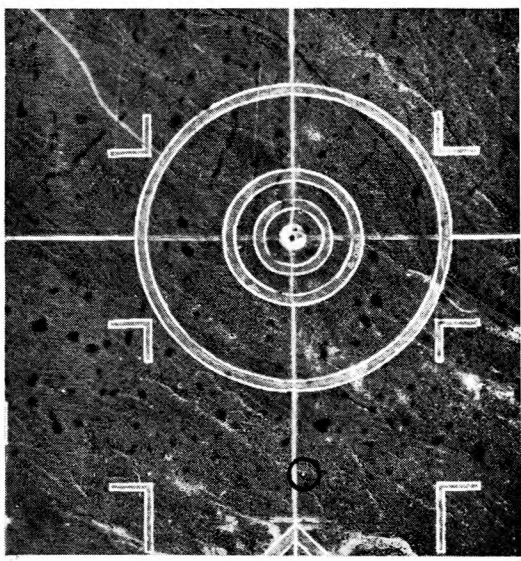
Bombardier controls Razon while watching missile through Norden bombsight with an attachment to allow wider vision



Razon nears center line of target approach. Other bomb which was falling toward the left can no longer be seen



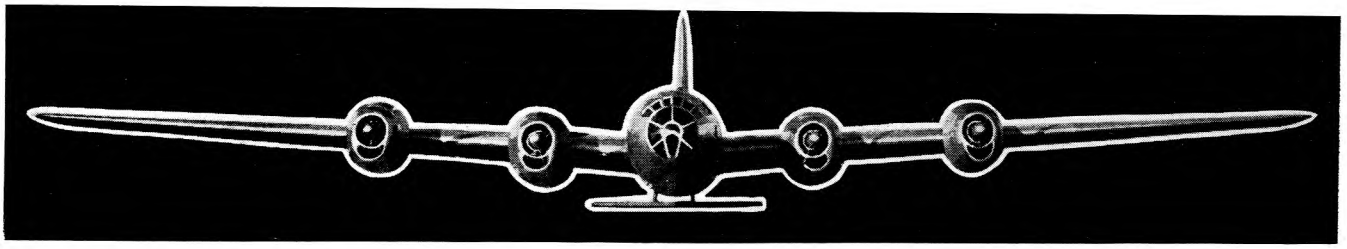
Main target area becomes visible. Razon drop from 15,000 feet requires about 30 seconds additional time over the target



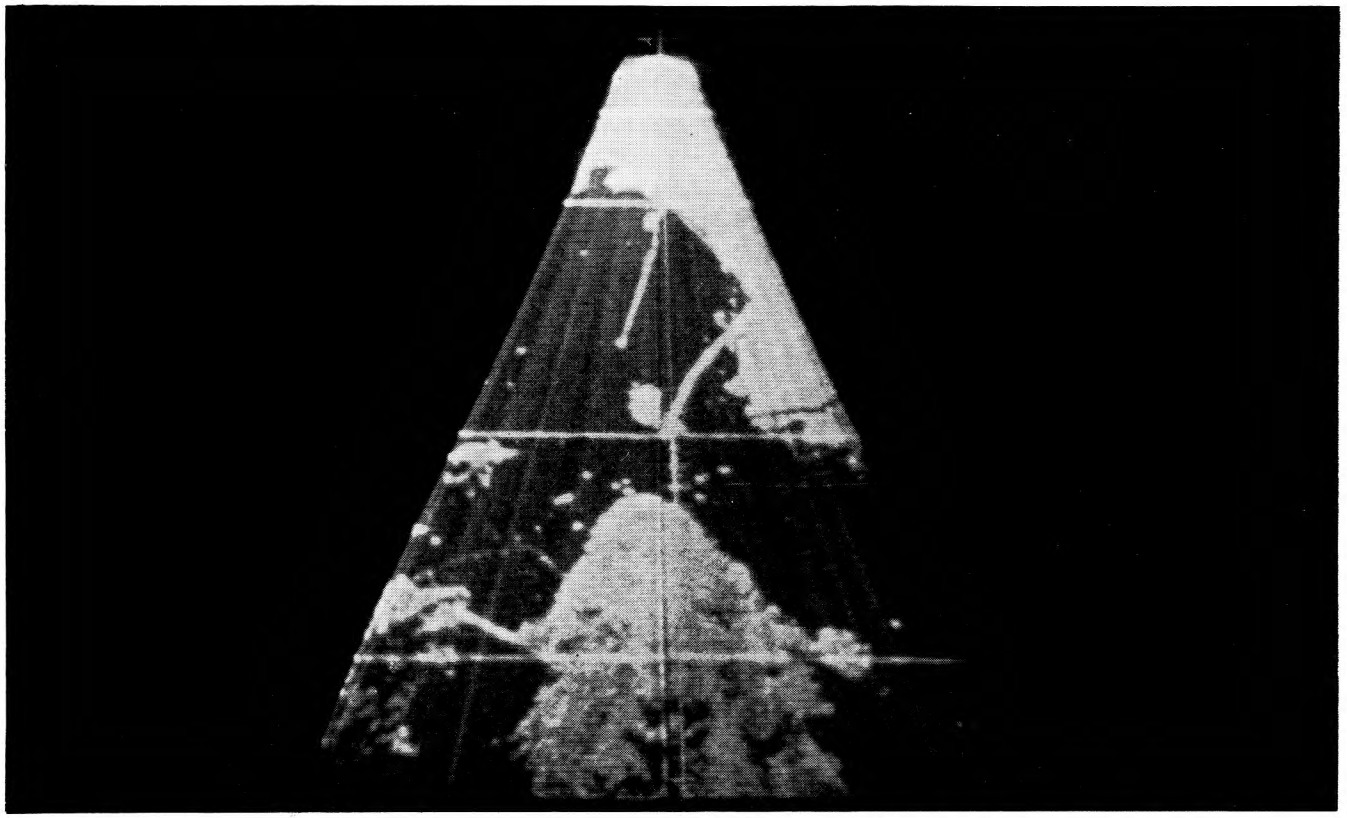
Too much right control was given missile, which is now being given left control to bring it back in line with target center



Razon is guided to center of the target and hits the bull's-eye. Explosion is small since the test bombs were sand-filled only



The Eagle story: how it all began



EAGLE SCANS SAN FRANCISCO AND BAY AREA. BRIDGE PIERS NEAR CENTER OF AN/APQ-7 SCOPE SHOW DETAIL OBTAINABLE FROM 10,000 FT.

With the story of Eagle (AN/APQ-7)* which begins on the next page, RADAR tracks a radar set through research, development, production, installation, training and all the subsidiary roads that lead into battle. Few military men get the chance to make the study themselves. So RADAR, believing that an appreciation of how any radar system is developed leads to a better understanding of all radar, undertakes it.

This happens to be the Eagle story, but any equipment—including some scheduled for wider use—might have been substituted. Essentially, every radar goes through the same routine, varying one from the other only in details.

But every radar has its special significances. Eagle's are these. The revolutionary antenna idea that sired it almost simultaneously resulted in development of the MEW and GCA. So urgent was the original requirement that hundreds of sets were in production before the first was combat tested. ETO employment was nipped short of operations. But 2 wings of the 20th AF, Eagle-equipped, are swinging into action.

Eagle has been a long time coming, and in the interim the emphasis on resolution that loomed biggest to its creators has blended into other considerations—in particular, the realization that no BTO system is better than its computer (see page 12). Such shifts in emphasis are part of the record of many radars and serve to underline one of the points these articles illuminate: namely, that development and engineering of a piece of radar is a complex, time-and-energy consuming job, so much so that the conditions and standards prevailing when the job starts have usually changed by the time it's done. In this respect Eagle has not suffered so much as some.

In the process of bringing a piece of radar to birth the work of many men is drawn upon. This was assuredly true in the case of Eagle, to which scores of Radiation Laboratory staff members and technicians contributed in the introductory phases, and engineering, manufacturing and military personnel later on. The work of all of them is reflected in what follows. But this series is concerned more with product than producers; and, incidentally, more with the compacted sequence of events than with exactness of date.

Chapter by chapter the series will cover: (1) birth, research and early development; (2) flight tests, engineering and production; (3) AAF installation, training and operations.

* High resolution radar for high altitude, precision blind bombing.

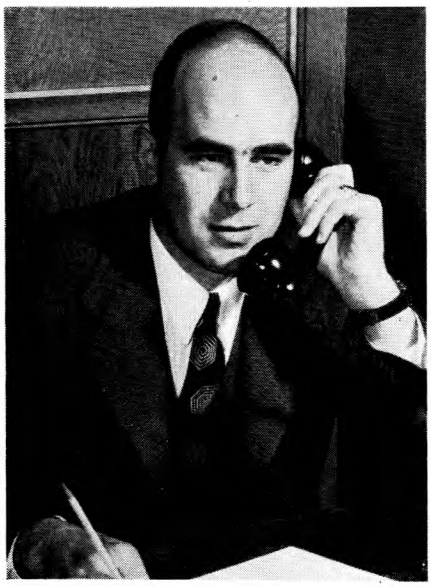
About the time a handful of British fighters were beating back German bombers with new AI radar in 1941, physicists at the new OSRD-sponsored Radiation Laboratory in Cambridge, Mass., were busy exploring the possibilities of microwave radar as a means of bombing through overcast. The days of great bombing raids over Germany then seemed pretty remote. But Army Air Forces had already expressed their deep interest in a high altitude blind bombing set "that would put a bomb in a pickle barrel from 30,000 feet."

Among the scientists working on the problem was eminent, good-natured Dr. Luis Alvarez, a Californian who generated ideas and had what it took to see them through. He knew that the high resolution needed for identifying and bombing land targets was to be found in high frequencies and an oversized antenna structure. And since he couldn't hope to achieve what he wanted through high frequency alone, he started in on the big antenna. Such a structure wasn't easy to harness to a plane; the subject called for some new thinking. At the time H_2X was yet to come.

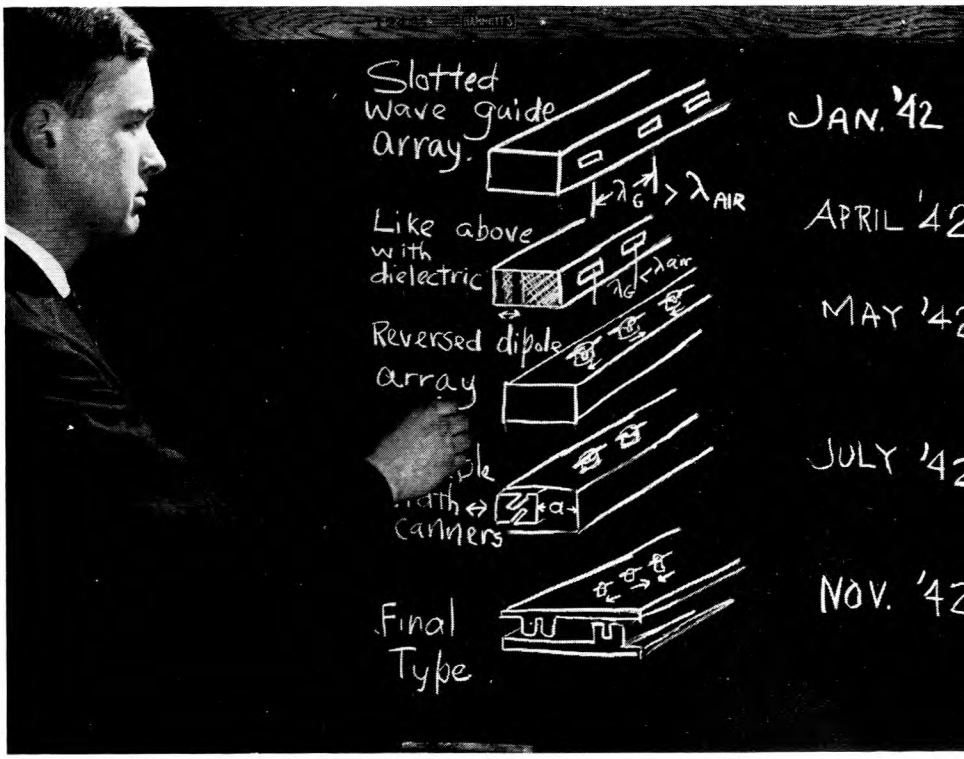
One afternoon in the fall of 1941, Alvarez was in hot conversation with Dr. E. G. (Taffy) Bowen, a British scientist now in Australia. The men who had been thinking of an antenna for blind bombing all had been seeking something that would give accurate range, azimuth and elevation. This requirement seemed to demand a narrow



Men who helped make Eagle: Dr. Luis Alvarez, who sparkplugged the project into being, saw his linear dipole array harnessed also to MEW and GCA. Antenna specialist Dr. Randal Robertson, at blackboard (below), is another of many men who contributed

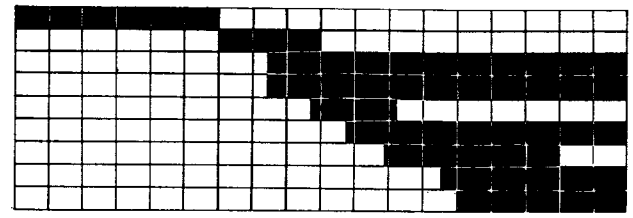


Project engineer Dr. E. A. Luebke keeps Eagle work moving. He started in 1942



Phase 1: research and early development

STAGES OF WORK IN THE EARLY PERIOD ARE SHOWN WITH TIME REQUIRED FOR EACH



EACH DIVISION IN THE BLOCK ABOVE REPRESENTS APPROXIMATELY ONE MONTH'S WORK

beam vertically as well as horizontally, thus complicating the antenna concept.

When Bowen and Alvarez parted, Alvarez had the idea that the beam need not be narrow in the vertical direction. In fact, what seemed desirable for an "overland" bombing radar was an antenna that would send out a sheet of radiation narrow in azimuth, wide vertically.

Alvarez knew that a beam of this shape could be obtained from an antenna structure which had a large horizontal dimension and a small vertical dimension. That meant that if a way could be found to scan electrically instead of on a rotating principle, as all the scanning antennas then known did, he could do business with an elongated array mounted inside the leading edge of the wing.

That night he mulled this over and made his first notebook entries. In the next few days he worked out the block diagrams, basing everything on X-band radiation and a phased linear antenna device. What he recorded during those hours was the concept from which 3 radar systems evolved. The others were MEW and GCA.

Describing the work of those hours to RADAR, Dr. Alvarez said: "I drew up a linear array type of antenna that I thought might work. There were changes, as we learned, which had to be made, but at least the radiation properties were identical to those of the present system, and the basic ideas were there. It was proposed to put two such antennas in the leading edges of the wings. I realized that the beam would deform into a cone as it was scanned, and then it was a simple exercise in geometry to get the hyperbolic form of the beam on the ground and the hyperbolic nature of the sweeps on the PPI tube.

"I liked the idea of stabilizing the pattern of the scope against roll, yaw and motion of the plane in a straight line, and so sketched block diagrams of how this might be done electronically. It was interesting that pitch had no effect in view of the symmetry of the conical beam. The reason for making the antenna so long was that I thought, and still do, that resolution is the most important feature of a bombing set."

Dr. Alvarez buttonholed everyone in sight during the next few weeks and quizzed them on building the sort of antenna he had sketched. But the idea was so new that the best he could get were some haphazard guesses. Alvarez did not consider himself any antenna expert. As a matter of fact, his ignorance of practical construction details kept him following lines of thinking so unorthodox that they shocked the specialists.

The antenna was the key to the whole system. And for several months Alvarez spent all the time he could borrow or steal trying to figure a way to make the linear array throw out a single narrow beam. He built his earliest waveguide with slots about one wavelength apart, but it wouldn't give out the hoped-for strength of radiation. There was good reason why it wouldn't, as the antenna experts soon found out. Dr. Alvarez had cut the holes parallel to the lines of current flow—no way to get a strong beam.

This hitch was soon taken out by turning the slots around and the "leaky pipe" antenna really started radiating. But when the first patterns were measured, 3 beams showed up instead of one.

Early in the Spring of 1942 Dr. Randall Robertson began to work with Dr. Alvarez on the antenna problem, spending most of his time trying to eliminate the extra lobes and exploring various scanning methods. Many hours and days of diagnosis set the trouble as a case of the wavelength in the waveguide having a greater value than the wavelength in air, whereas the reverse was necessary if the extra lobes were to be erased. Nobody knew the solution, everybody had an idea, and anything went.

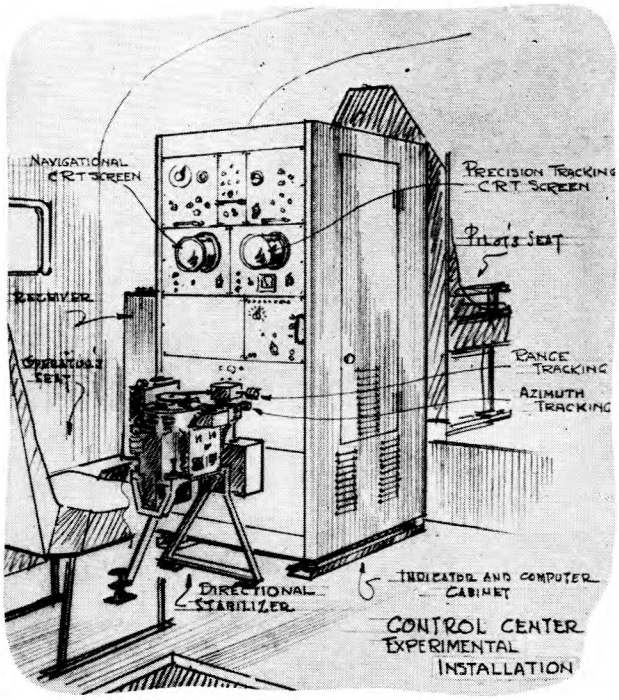
For a while stuffing dielectric, in the form of polystyrene, into the guide looked good. That reduced the wavelength within the guide enough to cut off the surplus lobes. But at the same time it complicated the job of varying the angle of the beam in flight. The waveguide had to open and close partially; the polystyrene interfered with this and, furthermore, introduced absorption. Following this setback, a lot of mechanical devices for altering the grating spacings were suggested. None worked.

In May Dr. Alvarez, who had a habit of popping in and out of his MEW, GCA, beacon and other interests, came to the rescue. He had been trying to work out an antenna for MEW and not getting as far as he hoped because of extra lobe worries. The idea of dipole radiators instead of slots looked good. So Alvarez did some mental juggling and came up with the idea of using twice as many dipoles as had at first seemed necessary, reversing them alternately so that they radiated in phase even though they were spaced electrically 180 degrees apart.

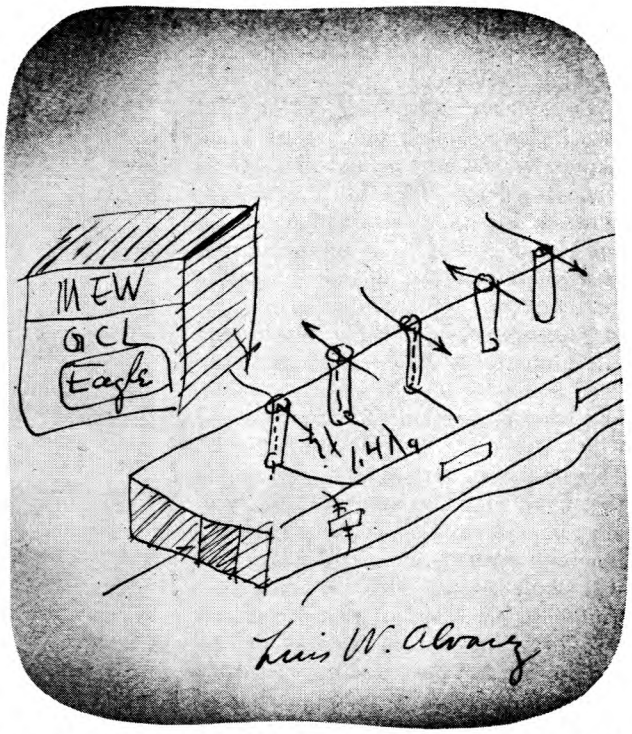
That killed the MEW's extra lobes and it did the same for Eagle, resulting in the one narrow beam necessary for high resolution. At the same time a variable width waveguide was developed which permitted the RF energy to flow along the length of the antenna smoothly. Operating mechanically, the waveguide squashed the RF to size between its aluminum jaws and caused the antenna to "scan" electrically (see cut, page 33).

Now, midway in 1942, with the promise of a workable antenna, Eagle required more laboratory manpower. Dr. E. A. Luebke, who had been pioneering with X-band ASV, was enlisted as project engineer.

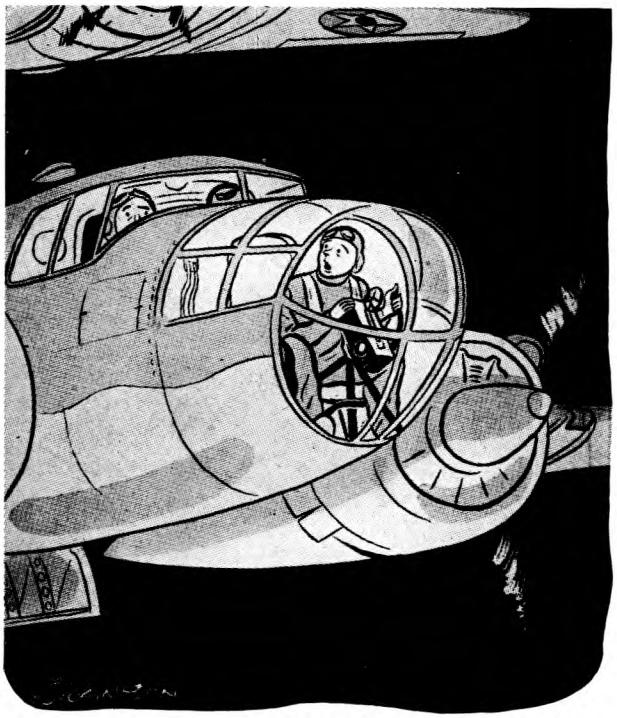
Work began almost immediately on a 3-foot scanning array. The result was a crude and inaccurate model, the first prototype of the present Eagle antenna. When it was done and put into operation a year or so after Alvarez' initial inspiration, the ability to scan electrically was clearly demonstrated by observing signals on an A scope. At this point things really began rolling. Other Laboratory staff members and technicians dug in on the antenna unit and the indi-



Deluxe system was one of the hopeful expectations for Eagle during first 2 years. Setups like this were pruned later on

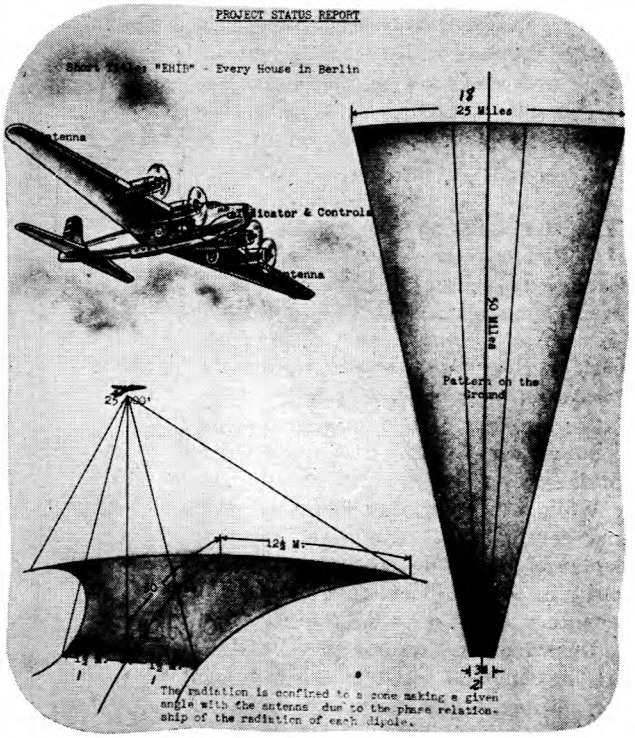


Early Alvarez sketch touched on the ingredients that went into licking the antenna problem and the 3 radar sets that profited



"Was that address 106 Leipzigerstrasse, or 107?"

Collier's cartoon, on door of Eagle project room since 1942, served as trademark for the scientists who did the research



This early sketch was interesting but inaccurate. Leading edge antennas show initial thinking; ground pattern shapes were wrong

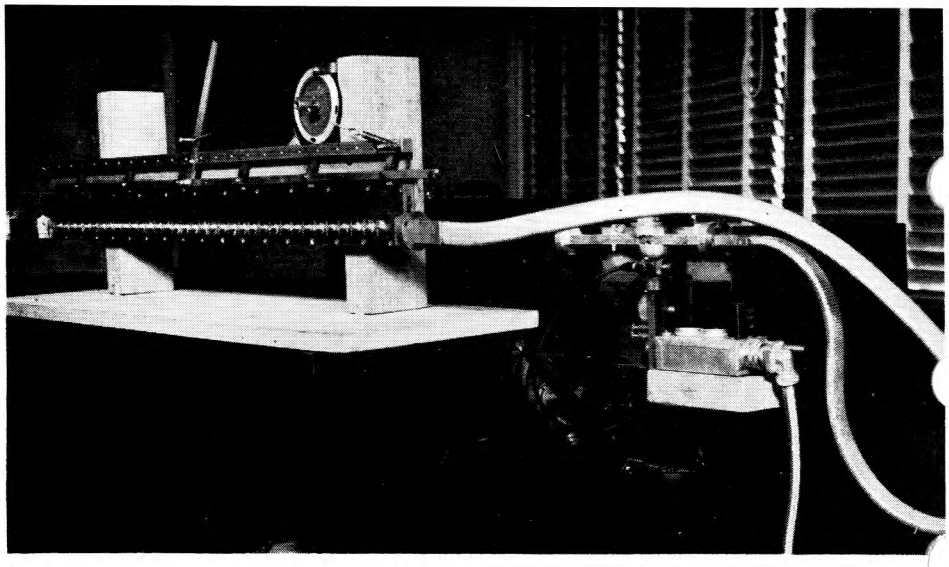
cator. And a search began for a satisfactory computer. The common goal was production of a deluxe bombing system that could take full advantage of the high resolution.

The indicator was under development as a bulky, complex unit housed in an impressive cabinet behind the pilot's seat. It offered one CRT presentation, gyro stabilized, for navigation; a second, which provided an amplified view of a small area, for bombing. At the same time, the computer group was trying to line up something that would make fullest use of the resolution. They tried to modify the Norden bombsight, had other models built to order, worked with BTL's "Universal Bombsight." They followed the general philosophy that Eagle could be harnessed to any of a number of mechanical and electrical bombing computers, ultimately tying in with the elaborate 1000 lb. UBS. The grandiose plans of this period were revised, late in 1943, in favor of lighter-weight, simplified components that could be produced faster. UBS lost much of its attractiveness a year ago, partly on account of its weight, but it did at least exert influence on some of the computers which will now be used with Eagle (see page 12).

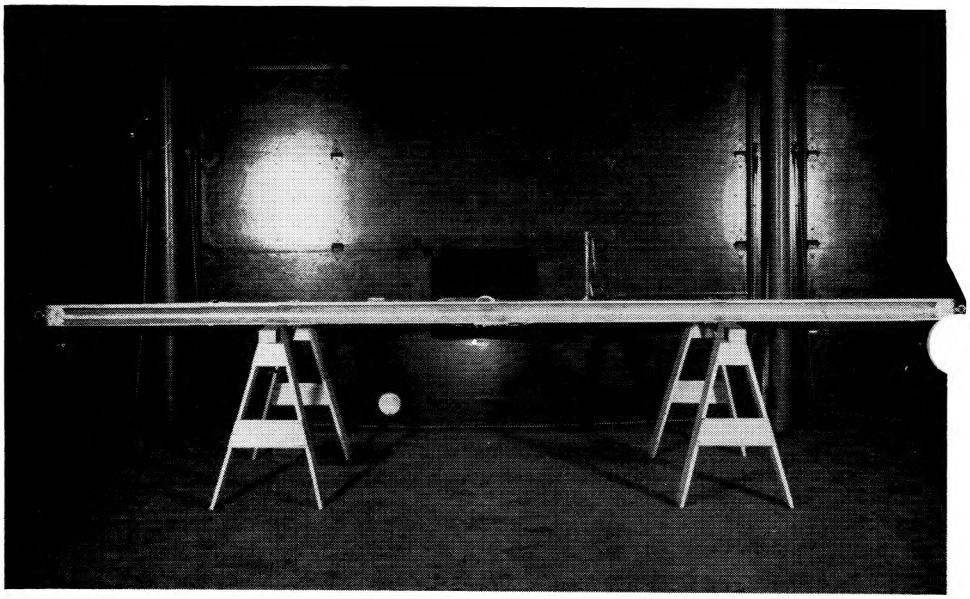
Antenna work was going on all the time. A 6-foot scanner followed the 3-footer. When it was finished late in 1942 it showed bad RF losses, its dimensions were odd, and its waveguide was stuffed with dielectric. But none of these conditions was chronic and before long the model was whipped into shape.

The first Eagle system operation with a PPI and the latest antenna, from Radiation Laboratory's Building 24 Roof overlooking the Charles River, was quite an occasion. Dr. Henry Guerlac, Laboratory Historian, was startled by the resolution when he went up to the Roof. "It's wonderful," he enthused. "I could count the cars crossing the Cottage Farm Bridge."

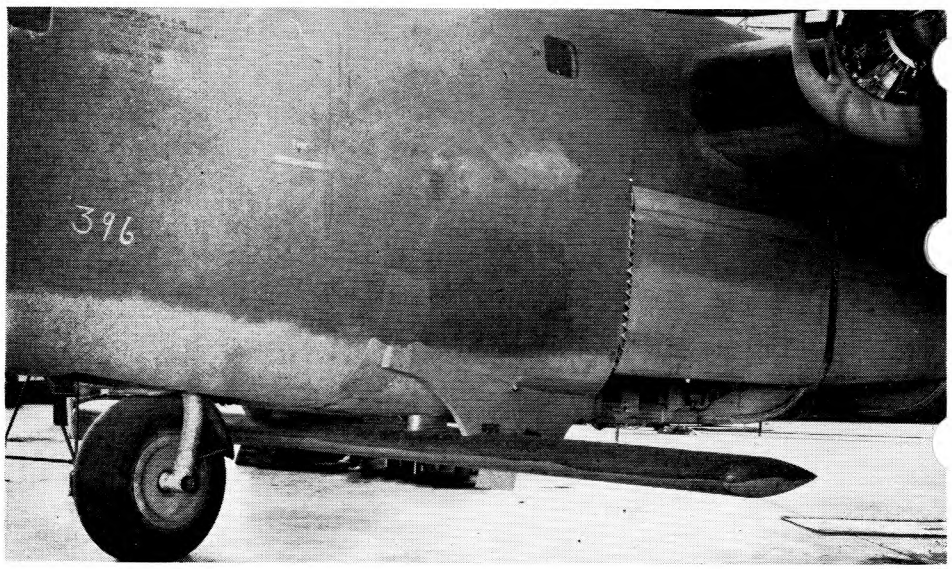
While tests progressed so did research and development. An 8-foot antenna, containing 108 dipoles, was finished early in 1943. The original idea of mounting antennas on the leading edges of the wings was dropped after Dr. Robertson proposed a separate vane to house the antenna, to be mounted parallel to the wings on the underside of the fuselage. He argued that the dihedral angle and sweepback of the wings complicated

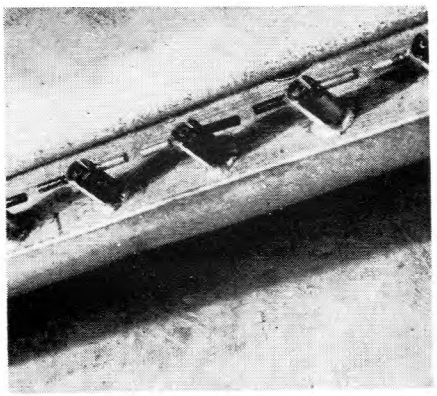


First of electrical scanning linear dipole array antennas was this 3 footer installed on the Roof at Radiation Laboratory. Inaccurate and clumsy, it still proved that beam angle, or scan, could be varied by mechanically changing the width of the waveguide

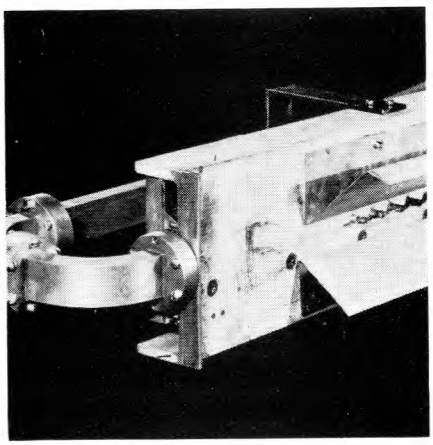


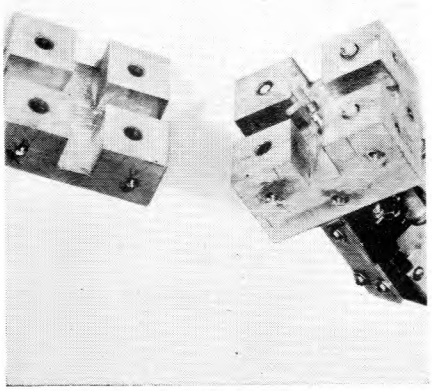
The 16 foot, 250 dipole antenna shown above, first to be installed in an aircraft, followed 3, 6 and 8 foot models. **Below,** first Eagle vane, a plywood product housing 16 foot antenna. Hung on Wright Field B-24, it was flown to Cambridge in spring of 1943



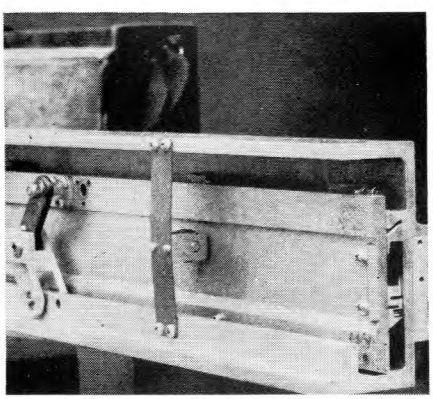


Closeups of the 16 foot antenna: dipoles, above, were radical modification of British S-band version. Below, reflectors hood dipoles. RF feed curves around from rear





Flipper in center of disassembled switch feeds RF energy into alternate ends of scanner. Below, waveguide rear wall moves up and down. Chokes are seen in opening



the indicating circuits, and that "flapping" of the wings might interfere with operation.

A maze of other details, large and small, had to be handled. Some of these, such as contractual arrangements, legal matters, location of manufacturers to handle phases of the work and liaison between these companies and the Laboratory, fell to the lot of J. W. Eggers, the Transition Office representative, acting as a sort of project business manager.

The development of a suitable dipole caused sleepless nights. The search continued until Dr. Robertson, after studying a British S-band dipole, came up with some modifications which filled the bill.

Another headache was the vitally important RF switch, which had to feed RF alternately from the left and right ends of the guide at the rate of 3 switches every 2 seconds. If the RF were fed from only one end the scan would be limited to 30 degrees. The 2-end technique provided 60 degrees. Space was limited and the contemplated switch had to be small. After considerable experimentation a new type was worked out which answered all requirements (see cut, col. 1).

The 60 degree scan was only a fraction of the 360 degrees that all-around-looking scanners offered, but it was felt that the higher angular resolution more than compensated for the shortcoming.

For a long time the Army had been looking on with keen interest. Officers viewing the Roof tests now reported real progress. Late in 1942 the Armament Laboratory at Wright Field had decided to give Eagle project status and to furnish an airplane for experimental flights. B-17s, B-24s and B-29s were being considered for production installations.

During the early 1943 months Dr. J. H. Buck and a few others buzzed around planning for the installation of the experimental system in a Wright Field B-24. A 16-foot scanner was now in the making—limited to that length only because no bigger planer for machining it could be found. It had a beam width of about 0.4° and, in Roof tests, it worked fine. Its length was studded with 252 dipoles, later trimmed to 250 in deference to a manufacturer who preferred to work in round numbers. A vane was designed by Professors J. S. Newell and O. C. Koppen of M.I.T., then built of plywood by F. H. Haggerty Co. of Cohasset, famous maker of racing shells.

In early May antenna and vane were installed in the B-24 and flown to Cambridge by Col. Stuart P. Wright, then AAF Liaison Officer at the Laboratory who reported that the wing didn't materially affect speed or flight characteristics. At the same time the Douglas Aircraft Co. at Los Angeles was working on a contract to design, build and install a vane for flight tests and to assist in a general study of the aerodynamic, deicing and pressurization problems.

Meantime, the Air Forces' need for a precision blind bombing equipment was becoming more urgent. The early introduction of a manufacturer was essential. Materiel Command, AAF, recommended close collaboration between Radiation Laboratory and Bell Telephone Laboratories. And this partnership brought in Western Electric Co. as manufacturer while BTL itself handled the engineering.

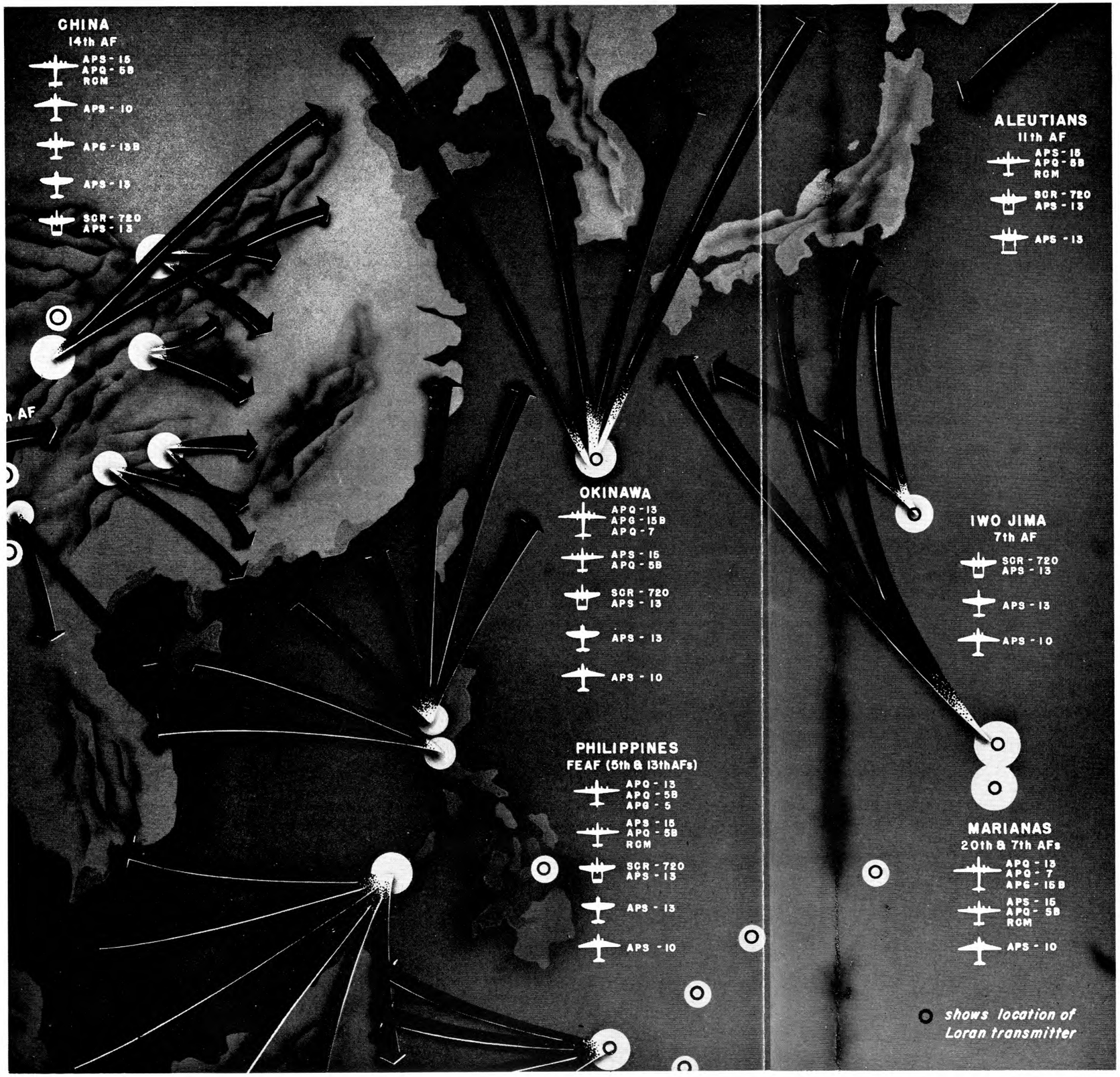
In May of that year a series of meetings started with AAF, BTL and Radiation Laboratory people in attendance to formalize a cooperative Eagle program. The same month Western Electric received an Army contract to produce 5 development models. In July, B-24 flight tests of Eagle were made at Westover Field, Massachusetts.

•

(This is the first of three articles on the development of the Eagle radar.)

E.H.I.B. Into Eagle

Through most of the months covered by research, Eagle had been called E.H.I.B., which stood for "Every House in Berlin" and showed in a highly unofficial way what Radiation Laboratory members thought of Eagle's precision possibilities. One day Dr. Lee DuBridge, Director of the Laboratory, found it necessary to change the name; the reason was self defense. At a conference a solemn visitor inquired what E.H.I.B. meant. Dr. DuBridge, hesitating to tell him, thought fast and came out with "Electrical High-altitude Indicating Bombsight." The solemn gentleman eyed him suspiciously and DuBridge determined to concoct a simpler, less bombastic title forthwith. So came Eagle.



Radar in the Pacific

What the AAF is doing where, and what the pattern is

The Pacific war, which not many months ago was principally confined to the southern areas, is closing in on Japan. But the combat area is still big and broad, with enough distance to tax the limits of our heaviest bombers. The main prongs of attack pierce the Japanese homeland and occupied China, with the industrial regions of Manchuria and Korea also threatened.

The biggest job at the moment is to seize and secure air bases near enough to the targets to permit our full weight of air power to be used. At this writing the chief takeoff points are Saipan, Guam and Tinian for B-29s, Clark Field near Manila for B-24 and B-25 forays against the China coast and Formosa, Iwo Jima for fighter sweeps and escorts into Japan, and Okinawa for a variety of chores, some not yet under way.

Strategic bombing ranks first of the jobs on hand. Anti-shipping, which used to be a vital item, has tapered off considerably due to the scarcity of targets. As a result, the 14th AF and elements of FEAF operating around Borneo have shifted their B-24 LAB work in large measure from anti-shipping to land bombing. A large part of Jap shipping plies between Korea, North China and the Japanese islands, carrying the manufactures of Manchuria to the homeland.

With radar for navigation and position finding, B-29 and B-24 mining of Shimonoseki Straits, the Inland Sea, Nagoya, Hong-Kong, Chichi Jima, Singapore and other strategic spots has turned out to be eminently profitable in the blockade of the Japanese empire and the fleet. The miners generally work under cover of darkness, dropping their loads from an altitude of several thousand feet by parachute. Fighters are proving increasingly useful as the home islands loom bigger and P-61 squadrons are spotted here and there to help neutralize sneak raids.

What has been learned in the ETO will, in many particulars, prove useful (see pages 12, 40 and 47).

Ground radar in the Pacific, China and IB follows the same pattern in most places. Each area has its complement of SCR-270s, 271s, 527s, 602s, TPSs and 527s. 584s for AA have gone into some places and are due for plenty of close control employment as Allied forces are established on Japan's doorstep. MEWs, soon to be equipped with MTI (Moving Target Indicator for electronically removing permanent echoes), are in at Saipan and Iwo. One is being sited at Okinawa and more are going elsewhere. Beaver-tail-beamed TPS-10 (Li'l Abner) is gaining renown for its target-finding and height-finding virtues in hilly places. Light weight invasion radar, notably the 5,000 lb. Australian-built LW/AWs, has made history all the way up from New Guinea. At Okinawa, 602s went in with the assault troops and a 270 and some 602s provided advance aircraft warning from Keramma Retto on D minus 6. AN/MPN-1 (GCA) has thoroughly justified its existence at Iwo (see page 38) and elsewhere.

By areas, these are the significant air operations unfolding in the Pacific and China now (see map).

Aleutians: weather and shipping searches over North Pacific, and offensive strikes against Kurile bases.

China: sea and river sweeps. Fighter sweeps along coast. Bombing and strafing of enemy airfields. Support of ground troops. Transportation over the Hump.

Philippines: China Sea sweeps. Shipping strikes along China Coast. Land attacks on Formosa, Shanghai, Hongkong, Canton and other strongholds. From southern Philippines, bombing of oil and other installations in Borneo and French Indo China.

Morotai: Macassar Strait, Flores Sea and Banda Sea strikes.

Noemfoor (Dutch New Guinea): anti-shipping and oil strikes.

Marianas: bombing of industrial targets, airfields, etc. from Honshu to Kyushu. B-29 mining of harbors and straits.

Iwo Jima: fighter support of B-29s. Strikes on airfields in parts of Japan.

Okinawa: fighter sweeps against Kyushu and in support of Allied action.

The Suicides

Right now the suicide attacks of the Kamikaze Corps rate biggest of the headaches in the Pacific. They're largely a Navy headache, but land installations aren't immune. The AAF soon may be in the thick of the fight. For one thing, the Baka suicide rocket plane, now launched from bombers, may be ground launched like the Nazi V-1 and V-2. A sort of suicide raid against Yontan Airfield on Okinawa is another example of what the AAF can expect. Six bombers carrying about 15 men each tried to land and demolish installations. One did heavy damage.

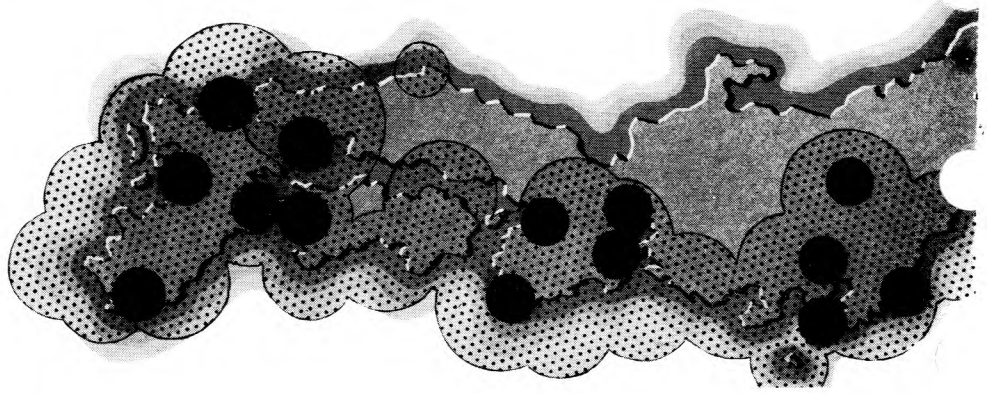
Since October 1944 the Kamikaze has been destroying itself for all it is worth, and not without results. In five months suicide planes hit about 150 naval and cargo vessels, sinking a score. The tempo has increased since.

Naval defense against the Kamikaze depends initially on the ability of the CAP (Combat Air Patrol), working with shipborne CIC, and finally on AA fire, controlled to a great extent by the cumbersome Mk. 37 director in combination with Mk. 4 or the more effective Mk. 12 fire control radar. Both are limited in tracking low flying planes. Sometimes these systems are supplemented by new, light weight, maneuverable deck combinations.

Against this defense the enemy is showing an appreciation of radar tactics. He briefs his suicide contingents accordingly. The pilots hug close to homeward bound friendlies, thus consolidating blips; separate into multiple targets to overload the sets; change altitude to confuse heightfinding; sneak under and over effective radar coverage; take advantage of ground clutter.

The Navy, meanwhile, is trying to minimize the null areas and improve discrimination. It's doing this by deck-mounting AI radars like AN/APS-6 and SCR-720 for vertical close-in coverage. Long range requirements contemplate use of AEW (Airborne Early Warning) and introduction of SX radar, which gives a more complete pattern than SK. Anti-clutter devices are being rushed. But most of this takes time. In the meanwhile more carrier planes are being delegated to CAP. There is considerable feeling in the Navy and in the AAF for joint fighter control.

Early warning radar blankets large areas of Jap Homeland and is reported around west coast of late. Fire control is growing fast in both quantity and accuracy.



Japanese radar, weak at start, is picking up

From a flat-footed start, Japanese radar has been coming along fairly well. Since Mk I, Model I, a crude handmade AW, was captured at Guadalcanal in 1942 more than 50 distinct types of equipment—ground based, airborne and shipborne—have been taken or otherwise cataloged. Some 850 ground sets, doubtless including some duplications, were reported in operation as of 1 May 1945.

Of the estimated 850 a chain of about 100, operating between 60 and 200 mcs., gives early warning to Japan's southern coast and island approaches. This is the area of intense coverage, although similar nets are not lacking in China and Southeast Asia and the Kuriles. Jap radars dot the overrun and outrun sectors, many inoperative or on their last legs, as in the Philippines.

In a general sense, Jap radar lags several years behind Allied equipment in effectiveness. Their AA fire control, for instance, first noted operationally in late 1944, appears to be no better than what we had in 1940-41. But quantity is mushrooming, the quality is bound to improve (reports at press time bear that out) and about 70 fire controls have been detected on the home islands. Soon after the beginning of the B-29 attacks on Japan an A-1 priority was slapped on the Jap radar industry and hasn't come off since.

Allied equipment has had a substantial influence on what the Japs turn out. One set is unmistakably modeled after the British GL Mk II (giving range, azimuth and approximate height) captured at Singapore in early 1942. Another resembles our SCR-268 (for searchlight control), taken in the Philippines about the same time. Features of the efficient German Wurzburg are seen in one shipborne system.

Not everything has been borrowed. Japan has competent scientists, some of whom have been working on radar a long time, and much of their current activity is concentrated on radar. Jap experiments with the magnetron and microwave radar date back several years. One 50 kw Army set compares to SCR-270. A Navy fire control is 10 cm, although its 2 kw power output limits use.

Airborne radar has been slow. So far only ASV equipment is known to be operational. But AI experimental models have been designed and probably have been built. No blind bombing setups are yet evident.

The enemy probably is working hardest on fire control improvement, AI and fighter control radar. For fighter control one of his biggest deficiencies is lack of an adequate height finder. The Japs are perfectly cognizant of the tactical values of radar, but still lack the equipment and the organization to do a great deal about it. In the countermeasures field they use a great deal of window—mostly cut to 200 mc length for use against Navy SK and SG radars. Some of their efforts have stopped us for a time, although by and large our trained radar operators are able to read through. Jap use of electronic jamming has been limited.



Jap radar—ground, airborne and shipborne—breaks down into 56 models, currently thought to exist. Many of these are in their experimental and developmental stages, others may have been dropped. Radar has an A-1 priority in Japan and the picture is expanding fast. The equipments listed below are the most important of the crop. All of these have been captured or are well documented.

Ground Warning

MK I, MODEL I: 100 mc—PRF, 1000—pulse width, 20. Crude fixed AW. Several captured, first at Guadalcanal.

MK I, MODEL I, MODIFICATION I: 100 mc—PRF, 1000—pulse width, 15. Fixed AW with improved TX and antenna. Observed in Netherlands Indies, Philippines, Formosa.

MK I, MODEL II: 200 mc—PRF, 1000—pulse width, 5-10. Mobile AW. Disadvantage of poor low angle coverage and high minimum ranges. Found in 1944; tested at Naval Research Laboratory.

MK I, MODEL III: 150 mc—PRF, 500—pulse width, 10. Portable AW. Crude, light construction, mounted on tower or tent. Captured at Morotai and Philippines in late 1944.

MK 230 (formerly Mk B): 100 mc—PRF, 750—pulse width, 30-50. Mobile AW for field use. Jap adaptation of SCR-270. Captured or destroyed in Philippines and Formosa.

MK 229 (EXPERIMENTAL): 68-80 mc—PRF, 500 or 1000 interchangeably—pulse width, 10-30. Fixed land based early warning in areas controlled by Jap army. Sometimes found as auxiliary to Mk 230.

Ground Based Fire Control

MK IV, MODEL I: 200 mc—PRF, 2000 or 4500 interchangeably—pulse width, 3. Portable fixed gunlaying and searchlight. Captured at Peleliu. Jap adaptation of SCR-268. Not effective for fire control.

MK IV, MODEL III: 200 mc—PRF, 1550 to 2500—pulse width, 2-8. Gunlaying and searchlight. Jap adaptation of British SLC. May also be used aboard ships. Captured in Philippines; tested at NRL.

MK TA, MODEL III: 75 mc—PRF, 2000—pulse width, 2-10. Gunlaying. Used extensively. Based on British Mk II GL. Found near gun positions giving data for 6 AA guns.

MK TA, MODEL IV: 200 mc—PRF, 1000—pulse width, 1-2. Mobile searchlight or gunlaying. Captured in Philippines in 1945. Improved model of earlier TAs.

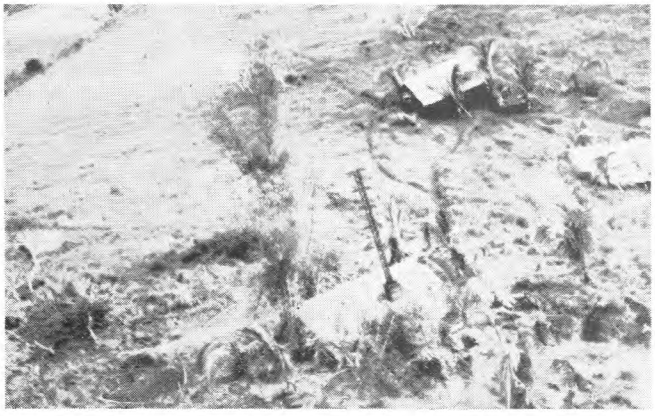
Airborne

TAKI MK I AND MK III: 200 mc—PRF, 1000—pulse width, 5-7. ASV search radar. Found in Leyte in 1944 on crashed plane. Mk I is used for heavy bombers, Mk III for mediums.

MK VI, MODEL IV, TYPE III: 150 mc—PRF, 1000—pulse width, 5-8. ASV search radar. Similar to British ASV Mk II. Several captured in Kates and Bettys. Tested at NRL and Oahu. Neither this nor Taki models are used extensively.









Two Jap radars in Philippines get blasted by B-25 radar busters. Top left, Mk 230 with Mk 229 auxiliary near bottom of picture, before attack. Top right, Mk 230 down and out Lower left, before radar buster started firing. Mk I, Model 3 radar gave AW around Pata Island. Lower right, still up but useless. Over 50 Jap radars in Philippines have been silenced



Bringing in a Superfort

What GCA can do; how it brought in its first B-29

While Marines were still carving out Iwo's beachhead, cumbersome GCA (below) was put ashore. Scarcely was the flag planted on Mt. Suribachi than TPS-1 (above) was installed beside it with IFF on other side. Now on the same site is a big MEW (CPS-1). These and other Iwo radars have one job in common: to maintain a support base for B-29s

Ground Control of Approach went to work early at Iwo Jima—so early, in fact, that the crew of the first faltering B-29 directed down out of bad weather for a safe landing had never even heard of the equipment. The air crew trusted blindly because the GCA crew (of the Army Airways Communications System) seemed to know what it was doing. The story of that landing, first of several to take place on Iwo, is told dramatically in the following report:

0710 Tower called GCA just after shutdown from night alert with nightfighters and advised that several dreamboats were approaching the island for emergency landings. Walnut Field was closed and ceiling and visibility were bad at Maple—Would GCA stand by? GCA stated it would fire up and stand by although it hadn't been officially authorized to work anything but P-61s. The weather was such that four B-29s were able to land visually after several tries. However, the weather was steadily closing in.

0830 Agate Base was heard to receive a call from Pluto 41, a B-29 lost about 70 miles north, and give it headings to bring it over the field.

0857 Pluto 41 was observed on the PPI scope approaching the field and while approaching he was being maneuvered about the area under control of Agate Base.

0900 GCA attempted to get official clearance from 7th Fighter Command but could not locate Major Alford.

0920 Major Alford called and authorized GCA to offer assistance to Pluto 41. Tower was contacted and informed we were operational. Pluto 41 advised tower it would work with GCA, but tower advised waiting to see if weather improved. GCA stood by.

0938 GCA asked that B-29 pilot be sent to trailer to act as adviser since that type of aircraft had not been worked before.

0950 Lt. Col. Daughtery, B-29 pilot based on Iwo, and Major Alford arrived at GCA trailer. Major Alford acted as pilot observer on the succeeding runs. He contacted the aircraft and advised pilot that we would give him information that would enable him to land safely.

1010 GCA traffic director called aircraft on channel Queen giving first heading and altitude we wished him to fly. GCA crew had never worked a B-29 before and had not worked a bomber since November 1944. Controlling is difficult until controller is familiar with manner in which aircraft responds to corrections. In addition, there was a strong cross wind and severe turbulence, particularly in vicinity of Suribachi. In meantime, effective ceiling had come down to about 100 feet and visibility to less than a mile. Under these conditions controller was unable to keep aircraft properly lined up during first three runs. As dreamboat was turned onto final approach the fourth time the pilot called in: "Either get me down or shoot me down, there isn't enough gas for another try."

1055 As dreamboat approached end of runway it broke through 100-foot ceiling just 75 feet to left of centerline of runway. It was flying a corrective heading that enabled the controller to turn it so as to be lined up at touchdown.

GCA earned the undying gratitude of pilots and crew that night. Navigation equipment difficulties had driven them far off their route, and they couldn't have made it on to Saipan. Turbulence was so bad that the pilot was flying the rudder and the co-pilot the elevators; it was not surprising that GCA had difficulty lining them up.

Since Pluto 41 came to Iwo, all B-29s leaving Saipan, Tinian and Guam have been briefed on the equipment. Among other things they are reminded that GCA is not full proof against the weather. With ceiling zero or near zero, landings are not advised.

One reason is that when an aircraft under GCA control gets right down on top of the landing strip, observers can't follow it because of ground clutter on the scopes.* And at Iwo, where the field is small and congestion great, planes have been lost for this reason; pilots there have to be able to see where they're going (or be seen) all the way to a stop.



* The addition of Moving Target Indicator (see page 55) to future models of GCA will take out clutter.

POSTSCRIPT ON

EUROPE



On the next 28 pages • A final assembly of reports on the doings of radar in the ETO, to round out the picture presented in RADAR through the past months • Some observations on radar achievements and problems by General Carl Spaatz, Lt. Gen. Ira Eaker, Lt. Gen. John Cannon and others • A review of Shoran's hot record during the war's closing days, with some precautions concerning its use in the Pacific • How the MEW is benefiting from the heavy and varied use it got in Europe • Where we stood with Schnorchel at the end of the war • What happened on Hill 880 • A note on the score chalked up by the GCAs • and other reports

RADAR
AND THE
WAR IN EUROPE

★

An evaluation of the record by some of those who helped to compile it; a series of comments and reports prepared at RADAR's request especially for this issue.

AN INTRODUCTORY STATEMENT
BY DR. EDWARD L. BOWLES

Expert Consultant to the Secretary of War and Special Consultant to the Commanding General, Army Air Forces

Nowhere in the Army has the application of radar been of more significance than in the Air Forces. From an inauspicious beginning with the status largely of a warning device, it has now grown to be a versatile instrument whose boundaries of application, particularly in offensive terms, are expanding at a prodigious rate.

All too often a development such as radar is held back for lack of understanding by those responsible for its ultimate use. In this respect radar has been fortunate. Indelibly written into the early record, in which basic conservatism had to be overcome and vision and courage were needed, is the name of Secretary Stimson. He saw the great implications of radar and he opened the way for its assimilation. Except for his foresight in the early, precarious period and his continued forceful interest, the achievements touched on here in all likelihood would not have been realized.

Through the support of Secretary Lovett and the progressive leadership of General Arnold, centimeter-radar bombing was introduced into the Air Forces. The success of this introduction was assured by General Eaker, who offered the Eighth Air Force as the all-important H^2X combat laboratory. By the ultimate organizational set-up, with General Spaatz commanding USSTAF, General Twining the Fifteenth, and General Doolittle the Eighth, full exploitation of strategic bombing by radar was made possible.

In General Spaatz, radar in all its applications to air operations found an understanding and progressive backer with rare ability to visualize its possibilities. It was General Spaatz whose broadmindedness opened the way to capitalize on the scientific resources so essential in letting us get the most out of these new instrumentalities.

In tactical air operations, radar was again fortunate. Today the achievement of this branch of operations in the defeat of Germany is known to all of us. On the part of all the tactical air leaders, the acceptance of radar control techniques and the eagerness to give them a try contributed in no small measure to the overwhelming power of our air arm.

Meanwhile, under General Williams of the IX Troop Carrier Command, it was possible literally to start from scratch and completely equip his force for the operations that were later so successfully carried out—operations which would have met with great difficulty, if not failure, had it not been for the radar navigational techniques brilliantly conceived and applied by his command. Conspicuous again was the eagerness of this command for all manner of support, including that of the engineers and scientists who largely had been responsible for the development of the gear.

Beyond the Air Forces you find such immeasurable factors as the steady support of General Bradley and his appreciation of the vital importance of precise control in the operation of tactical air. It is unlikely that, without these things, we could have achieved the efficient combination of talents that led us, for example, to such outstanding control techniques as those involving the MEW and the SCR-584. Typical of General Bradley's interest and incisiveness was a remark of his shortly before D-day: shortly after D-day, he said, his headquarters and General Quesada's would be 50 yards apart, and why not add in the experimentalists with their radar control equipment so that he, General Quesada and the scientists could practice directly on the enemy? What more could one ask in terms of the ultimate objective?

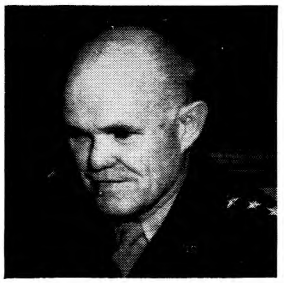
This wholesome attitude, coupled with the day-in, day-out support of General Marshall, General McNarney and others, made it possible here at home effectively to integrate scientific effort, industrial potential and military leadership and know-how. A strong element in the early appreciation of the problem was General McClelland, and his continuous effort has done much toward achieving the integration. The whole blending of efforts portends even greater stature for radar in the Pacific campaigns, but that is another story, yet to be told.



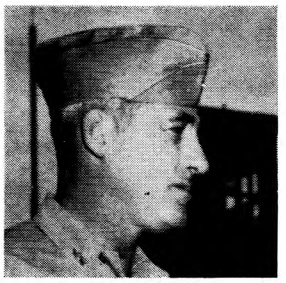
ENERAL CARL A. SPAATZ



LIEUT. GEN. IRA C. EAKER



LIEUT. GEN. J. K. CANNON



MAJ. GEN. N. F. TWINING



DR. L. A. DUBRIDGE



"In most instances . . . the techniques we have developed can be used with telling effect against the Japanese."

★

BY LIEUT. GEN. IRA C. EAKER

Deputy Commander, Army Air Forces

As we turn our main effort toward the war in the Pacific, all of us in the Army Air Forces must resolve to make the fullest use of the lessons we have learned in the European war. While strategic and tactical problems will differ somewhat from those encountered in the war against Germany, in many instances the new weapons we now have and the techniques we have developed can be used with telling effect against the Japanese.

Offensive radar is one of the most vital of these new developments. We must strive to the utmost to extend our present very elementary knowledge of the operational possibilities of radar as a weapon. Our experience in Europe has demonstrated that, employed imaginatively and aggressively, the radar available today can be used with telling effect to increase the striking power and efficiency of our air effort.

I urge all commanders and operations staffs to explore fully the potentialities of both airborne and ground radar in offensive operations. This requires more than a passive interest or a few inconclusive experiments. It calls for systematic planning, and intensive, continuous effort on the part of both operations and technical personnel. We must always remember that while our radar experts can install and maintain the equipment, it is up to those charged with the responsibility for planning, training and operations to exploit this weapon and develop the tactics and techniques which will achieve maximum results.

BY GENERAL CARL A. SPAATZ

Commanding General, USSTAF in Europe

There are at least three things of fundamental importance to be said concerning the role of radar in the European war.

One is that, so far as the work of the air forces was concerned, the job could hardly have been done without the various radar devices with which we were provided.

The second is that, even so, it was sometimes necessary to classify our employment of radar with the walking dog, which commanded respect not because it walked so well but because it walked at all. Our radar bombing wasn't all first rate.

The third is that the effectiveness of radar is measured, on the record, in direct proportion to the understanding brought to bear on its applications and limitations by staff commands and operators alike.

In the early days of radar in the air forces there were decided extremes of opinion concerning its effectiveness, and not much basic core of understanding. There was much more of the latter at the end, and the bombing was best where the understanding was greatest. There was no reason why this should not be so, and it is not for its originality that I stress the point. But radar bombing techniques are still new techniques, undergoing changes and refinements almost daily. The job of understanding them is a very large job.

It is a job almost without end because, where understanding leaves off, imagination takes over. With a great many of the individuals who helped make radar in the European strategic and tactical air forces the highly successful instrument it was, this quality became a driving force. It was largely responsible for the fact that, by the time war ended in Europe, radar had been perfected to the point where practically all of our operations were dependent on it.

Radar devices and techniques can accomplish even more from now on in the Pacific than they did in Europe. More and more of radar's tremendous potentialities are coming up for realization as new equipment and new procedures come forth to solve old problems. But all of them put new and continuing demands on operational know-how—and on the imagination which gets the most out of that know-how.

★

BY LIEUT. GEN. JOHN K. CANNON

Air Commander-in-Chief, MAAF; formerly Commanding General, Mediterranean Allied Tactical Air Force and Twelfth Air Force

The early campaigns in North Africa, Tunisia, Sicily, and Italy showed that our defensive radar left much to be desired. By the time the present network of new and improved



COL. G. K. GEERLINGS



BRIG. GEN. T. C. DARCY



BRIG. GEN. A. W. MARRINER



BRIG. GEN. T. J. MANNING



DR. JOHN G. TRUMP

ground radar became operational, German air effectiveness had been reduced to such a low level that we never had an opportunity to test fully our defensive capabilities. We turned, consequently, to the use of our ground equipment for offensive tactical operations, and achieved some measure of success, particularly in night level bombing by our A-20's and A-26's under SCR-584 control. The creditable effort put forth by the first unit of this kind in our theater demonstrated to us as well as to others what was still in doubt at the time, namely, the operational value of level bombing with this technique, within the range limitations of the equipment.

I believe the exceptional results obtained by the Fifteenth Air Force with H_2X, at best an interim blind bombing device because of its inability to approach visual precision, are well known by now. There is, of course, no question of the necessity of some kind of long range blind bombing device, since without it a strategic air force would often be helpless at critical times. The effort being placed on development of higher precision strategic bombing radar is unquestionably justified.

The Twelfth Air Force was foremost in sponsoring Shoran and putting it into operational use for the first time anywhere. I am thoroughly convinced that this is the best tactical blind bombing system yet developed. The limitations of the equipment must, of course, always be borne in mind, especially that of line-of-sight range, and also the necessity for accurate mapping or Shoran surveys. On the other hand, the simplicity of operation, the very small inherent instrumental error, and the complete elimination of the target identification problem are extremely strong recommendations for the use of Shoran in tactical operations.

Largely because of lack of specialized laboratory facilities and personnel, there was never any question in this theater of our engaging in a large number of experimental radar projects or operational trials. Perhaps partly because of this, the smaller number of programs which we did carry out were for the most part successful, and paid dividends operationally.

★

BY MAJ. GEN. NATHAN F. TWINING

Commanding General, Fifteenth Air Force

From March 1944 until our final mission against the Salzburg Marshalling Yards on May Day of this year, H_2X in the Fifteenth Air Force grew steadily in effectiveness. In my opinion, successful and sustained strategic bombardment is impossible without it.

In evaluating the effectiveness of radar heavy bombardment, however, some standard must be used. The force required to destroy a given target under blind conditions is about 25 times as great, and under partially visual conditions about 10 times as great, as when visual bombing can be done. H_2X bombing of pinpoint objectives is thus certainly wasteful. However, the effectiveness of radar bombing increases greatly with the size of the target, and on a large industrial complex when damage is desired over the entire area, the advantage of visual over radar bombing is not so disproportionate.

We have proved that a given objective can be destroyed by blind bombing methods alone, if a force is applied in keeping with the accuracy capabilities of the equipment. It must be emphasized that standing down an air force which is capable of sustained operations is frequently a more wasteful process than operating that air force with the reduced efficiency which can be expected under non-visual conditions.

Our major sources of error have been, first, target identification, and second, inaccurate bombing of the assigned aiming point. Both of these problems deserve more attention. Very little improvement in the identification of the aiming point can be expected until equipment with greater definition becomes available.

Pinpoint targets which can be seen on the scope will continue to be bombed ineffectively until a more accurate computer system and better means of killing drift are developed. The recent modifications of H_2X equipment, providing a fully synchronous tie-in with the Norden bombsight and an improved method of killing drift, have already given promising results in combat. The Fifteenth Air Force was a pioneer in the early development of both these improvements and it is my hope that our experience and the lessons we have learned will help to shorten the time needed to crush our one remaining enemy.

★

BY BRIG. GEN. THOMAS C. DARCY

Director of Operations and Intelligence, MAAF; former Commanding General, XXII TAC

All too frequently have we in the combat zones heard of the rapid strides which are being made in the development of new radar devices back in the States. Those gadgets may have tremendous *potential* value, but as far as killing Jerries and Japs *today* and *tonight*, they are absolutely worthless. Operationally, we can only judge by the results at hand.

Our dealings with new radar equipment in the XXII TAC have been pretty much limited to the modified SCR-584 and the MEW—except, of course, for the standard aircraft warning devices which constitute the keystone of any normal air defense system. When this new equipment first arrived, it appeared to us that both the assigned military personnel and accompanying civilian technicians were somewhat overly concerned with the purely technical aspects of the machinery. We did not feel that the equipment was being employed to do its job, but rather constituted a field laboratory for further experimentation. In short, the equipment was in the Theater

"Operationally we can only judge by results . . . ."



for altogether too long a period before it became an integral part of the war effort.

Eventually, however, both the 584 and MEW were moved into the battle area and, from that point onward, began to pay dividends in a constantly increasing degree. The 584 in particular, from its position high in the Appenines, permitted innumerable night attacks which might otherwise have been listed as abortive sorties. Air crew enthusiasm, a feature essential to the success of any new Air Force weapon, was on the increase.

The war in Italy ended before the maximum advantages were derived from both the 584 and the MEW. In the Po Valley campaign, we were just beginning to realize the true value of this fine equipment. It did a splendid job but I believe it could have done a much better job had it been oriented earlier with respect to the operational picture.

As for recommendations for future development and operations, I would put it this way: (1) develop the technical side of the equipment back in the States where proper facilities are readily available; (2) once the equipment arrives in the combat theater, waste no time whatever in getting it into active service; and (3) keep a steady flow of reports going back to the development laboratories covering current employment so that future models may be modified to incorporate the most desirable features for future use.

As for the personnel associated with the equipment, they must think objectively. They must measure their success in terms of targets destroyed.

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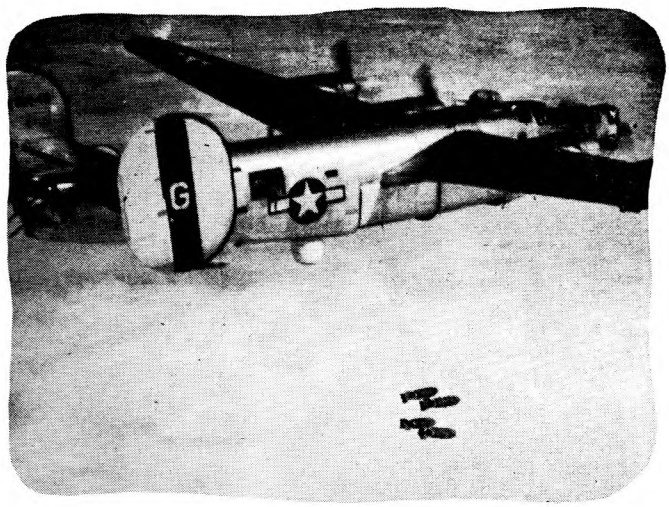
BY COLONEL GERALD K. GEERLINGS

Director, Radar Bombing Operations, Eighth Air Force

There were five main Army cooperation missions in the ETO—two visual and three with solid overcast. The first was D-day in Normandy; overcast was solid. No bombs were dropped on friendly troops. The barrage caused the enemy to abandon gun emplacements on commanding positions along the coasts, and later to testify to the effects of the bombing on their morale. The second and third missions (Saint Lo and Caen) were both visual missions and, unfortunately, on both occasions bombs fell on friendly troops. The fourth and fifth missions (Metz and Duren-Eschweiler) were with solid overcast conditions and no bombs fell on friendly troops. Congratulatory messages were received from the ground forces after all three of the solid overcast radar bombing missions.

The Battle of the Bulge (December 1944) has been discussed by von Rundstedt since his capture, and according to the General, air power so interrupted his lines of communications that he was first stopped and later forced to retreat. This confirms what was shown on a series of impressive photographs taken after the skies cleared following 18 continuous days of radar bombing. Some of the small communication centers were villages no larger than the size of the airborne formations, yet the bombs dropped through solid overcast blanketed the targets.

To get some idea of what radar accomplished in Eighth Air Force bombing, suppose the war had been fought without it. Airborne task forces would have been mauled by flak before reaching the IP. Cloudless skies from take-off to



"Before the introduction of radar, the number of missions during the winter months averaged four to five per month. During the winter of 1944-45, operations averaged at least 25 missions per month."

inland targets were unheard of. Flak-free corridors became fewer and fewer, more and more constricted. No DR navigator could be expected safely to guide a formation over a series of dog-leg courses flying above broken or solid clouds between landfall and IP, and none ever pretended it could be done. Navigators became admittedly dependent on H_2X—e.g., about February 1945, on returning from a mission, a formation chose to "divert" and spend the night at a base in northern France *just because the H_2X set was not functioning.*

Before the introduction of radar, the number of missions during the winter months averaged four to five per month. During the winter of 1944-45, operations averaged at least 25 missions per month. Bomb damage assessment or "K" reports offer conclusive proof of the effectiveness of radar bombing during the winter months of 1944-45.

Industrial installations like Meschede, which is in the southeast corner of the Ruhr, were practically obliterated by single missions. In fact, targets at the Ruhr were hit time and again by radar, yet because of extensive smoke screens, Huls was the only target ever hit visually in the vast Ruhr area.

A fair percentage of missions took off when poor or nil visibility was predicted over the target, yet due to sudden weather changes long visual bomb runs actually materialized. Before the use of radar no mission would even have been contemplated unless good visibility was assured.

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BY DR. LEE A. DUBRIDGE

Director, Radiation Laboratory

One needs to travel only for a day or two in ruined Germany to witness the crucial role which Allied air power played in the war. Every important industrial city in Germany is in complete ruins. Effective railroad facilities are non-existent. Long lines of destroyed railroad cars and road convoys testify to the complete disruption of military transportation. All Air Force commanders agree in stating that the effectiveness of the Allied air power would have been



"Actually, without radar the troop-carrier phase of this operation would have been a complete failure."

far less without the extensive and effective use of radar which was made available.

The most spectacular radar activities were those connected with the tactical air commands. They were spectacular partly because of their success and partly because the most important tactics were based on new equipment just out of the laboratory or developed on the spot. In a certain sense the tactical air commands became huge combat radar laboratories. New equipment of promise was promptly put into action, and the techniques for using it most effectively were developed as the war progressed. The conversion of the MEW from an early warning set to a radar used for complete control of offensive air operations is one of the greatest stories of the war. The development was possible only because of the collaboration between a keen and aggressive group of air force officers and a group of expert scientists with laboratory facilities in the theater, who knew thoroughly the new equipment and its possibilities and who could assist in making modifications and attachments and in working out effective methods for employment.

In Germany, as nearly as can be judged, practically none of the top flight physicists in universities and research institutes was drawn into a national radar program. Apparently the high command did not have the vision to carry on the mobilization of such scientists, nor did the scientists themselves band together to volunteer their services to their country. Also, the German radar engineers made a bad guess at the beginning of the war on the possibilities of microwave radar. The first revelation to them of the possibilities of microwaves came when some of the early British H_2S equipments were shot down near Rotterdam in early 1943. Some attempts to develop similar techniques were evidently begun then, but the pressing problem of the air defense of Germany did not allow appreciable research effort to be concentrated on the microwave problem.

Finally, it appeared that there was no sound concept of the offensive use of radar in Germany. No adequate radar bombing equipments were ever put in use, which was natural without microwave techniques. Also there was apparently no development in radar aids for a tactical air force.

A number of German scientists and engineers are now willing to admit that the lack of an active scientific radar research and development organization and the lack of a close tie between scientists, engineers and the military organizations constituted a crucial defect in German military power and was therefore a critical element in the Allied victory.

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BY BRIG. GEN. TIMOTHY J. MANNING

Commanding General, 51st Troop Carrier Wing, 12th Air Force

During the course of approximately three years of combat operation, the chief concern of the 51st Troop Carrier Wing has been to get the men and supplies through to their destination and get the aircraft and crew safely home. Radar has served both these aims well. It has developed from a skeptically regarded gadget to the most important navigational aid we have. Many missions, which otherwise would have aborted because of overcast or ground fog at target, were tried and successfully completed through the use of radar.

In supplying Partisans in northern Italy and the Balkans at night, radar enabled our pilots to skirt dangerous thunderheads, to make landfalls over unseen coastlines and to locate a pinpoint drop zone within enemy territory. During entire missions, the basic radar equipment (SCR-717-C) provided navigational information including continuous drift correction and on-course check points. Entire groups and squadrons have relied on the perfect functioning of the radar as a pathfinder to establish the position of the drop zone.

The large-scale use of the 717 and Rebecca-Eureka enabled our formations to drop paratroopers in the invasion of southern France, through an overcast that obscured the ground, with an accuracy that was better than that of any previous large-scale drop. Actually, without radar the troop carrier phase of this operation would have been a complete failure.

Never again will our aircraft fly over enemy or friendly vessels, unknowingly, nor find themselves betrayed by a sudden and intense wind shift, as occurred in the invasion of Sicily. The mental strain of long periods of instrument flight has, for the most part, been relieved.

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BY BRIG. GEN. ALFRED W. MARRINER

Deputy Air Signals Officer in Chief, MAAF; Communications Officer, AAF/MTO

Airborne radar equipment contributed immeasurably to the success of the air campaign in this theater. It has been used as a navigational aid, as interception equipment for night-fighters, in several less spectacular roles and, of course, for blind bombing.

The major difficulties we have experienced can all be classed as "personnel"; insufficient supply of personnel, inadequate training, the lag of Tables of Organization behind actual operations, and the difficulty of rotating technical personnel to the United States for training on new types of equipment. Personnel have, of necessity, been assigned to units entirely different from their actual duties and frequently

deserving personnel could not be promoted. Our heavy bombers have on occasion been grounded due to the lack of trained radar operators.

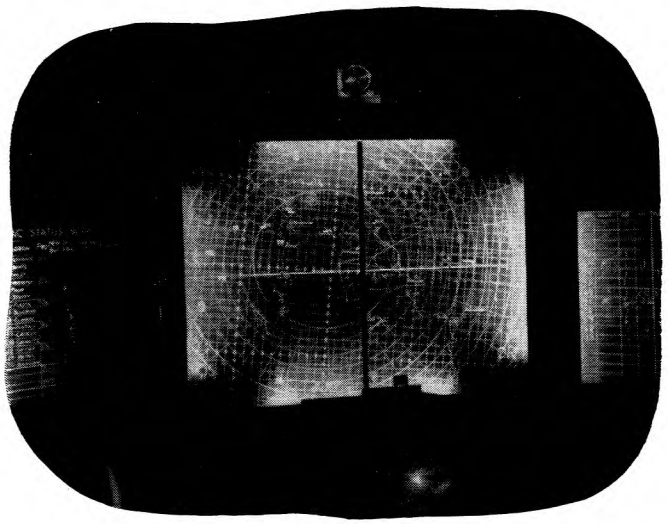
I believe the major lesson learned is the necessity of providing adequate personnel authorization, together with adequately trained personnel to exploit to the fullest the capabilities of the radar equipment.

In a theater which has any system of roads and highways, ground radar equipment must be mobile. Fixed radars, such as the SCR-588-B and SCR-627, are soon left far behind the battle. Even the light weight TPS series requires vehicle mounting. The cost—a $3500 truck to carry a $33,000 radar—is relatively slight. The advantages, in addition to the obvious ease and rapidity of movement, are greater protection for equipment and—of greater importance—suitable conditions for operators, who must perform a tedious, sedentary task for long hours in all weather conditions, and who must work at peak efficiency if equipment potentialities are to be realized.

The entire fighter control organization was found to be too large, unwieldy, and topheavy administratively for tactical operations. The organizational pyramid, consisting of the Fighter Wing, the Signal Aircraft Warning Battalions with their companies and platoons and the Fighter Control Squadron with its teams, became so cumbersome that there was always a tendency in the tactical air command operations staff to leave the whole structure to its own devices. This tendency, as much as any other single factor, explains the tardy appreciation of ground radar as an offensive weapon.

It was found necessary to decentralize many of the functions of the information center. Forward director posts, each having one or more radars plus a VHF fixer system and the necessary VHF ground-to-air communications, took over most of the close-cooperation missions. Communication difficulties forced the initial change and continued to have a bearing, but the smaller, less complex posts soon proved more efficient in sorting out the essential portions of the air picture.

Downgrading the security classification of essential radar information did much to facilitate our tasks in that it permitted awareness of radar's importance, capabilities and problems to permeate all echelons.



"Perhaps the outstanding operational development was the employment of the MEW by the tactical air commands for the accurate navigation control of all types of fighter, photo-reconnaissance, night-fighter and intruder operations."

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BY DR. JOHN G. TRUMP

Director, British Branch Radiation Laboratory

By the end of the war with Germany, radar navigation and bombing aids had become established as an indispensable factor in Army Air Force operations. H_2X bombing by the heavies, Oboe II bombing by the mediums, and MEW- and SCR-584-controlled fighter sweeps contributed in a determining way to the continuous offensive air action against industrial, tactical and front-line targets. The adoption of Gee-H and Micro-H bombing increased the flexibility of the heavy bombers and enabled them to cooperate in ground-force offensives.

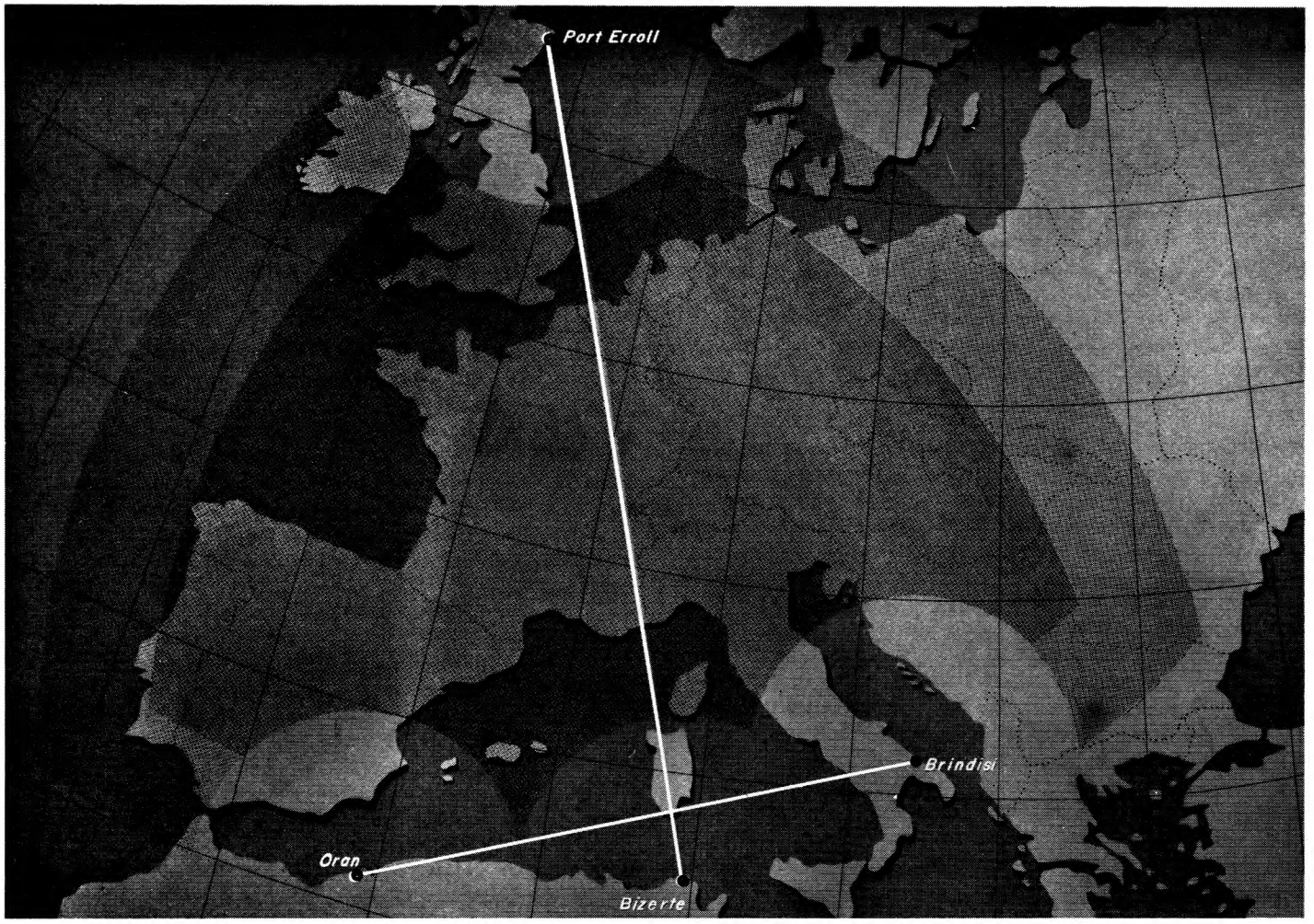
Perhaps the outstanding operational development was the employment of the MEW by the tactical air commands for the accurate navigation control of all types of fighter, photo-reconnaissance, night fighter and intruder operations. A late-comer—but still in time to demonstrate against the enemy its unusual bombing accuracy and relative ease of operation—was Shoran.

In the final phase, microwave air-borne beacons under MEW control were given combat trial by Eighth Air Force fighter groups and with SCR-584 control by the Ninth Air Force. Many other radar devices were essential in the operational plan, notably Gee for general navigation, SCR-720 for night-fighters, SCR-717 and Rebecca-Eureka for troop-carrier operations, SS Loran mainly by the RAF for deep penetration raids into Germany, Altimeters and Tail-Warning.

These radar systems, vastly superior to the products of the enemy, were conceived, developed and produced in the span of a few years through the cooperative effort of the services, science and industry, and were made effective with great rapidity in a distant theater in the face of many difficulties.

The problems which confront a command in the theater in assimilating a new radar aid cannot easily be overestimated. In addition to the often-present supply inadequacies of basic equipment, spare parts and instruction manuals, there is the necessity of training theater personnel, maintaining optimum equipment performance under often highly unfavorable physical conditions, developing suitable methods of analyzing operational results, working out and improving the standard operational procedures. Theater training based on operating experience is probably the single factor which can contribute the greatest dividends in improving the operational effectiveness of a given equipment.

At the conclusion of hostilities, no command was satisfied that its radar aids had been brought to full realization of their operational possibilities. Bombing accuracies were still low; many of the potentialities of radar for landing aircraft, for controlling night operations, were still almost untouched. This situation, however, was generally realized and appreciated. It required more time and energy than was available. Nevertheless the European war had served as a tremendous laboratory for developing and exploiting the operational aspects of radar in large-scale, all-weather air operations.

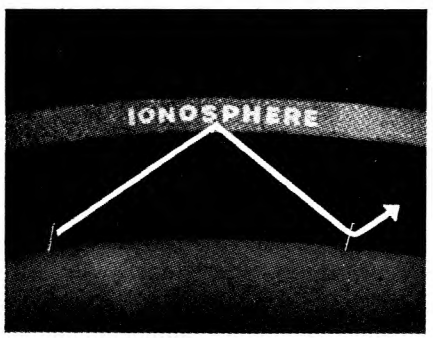


SS Loran in Europe consists of 2 pairs of Loran transmitters synchronizing by skywave over baselines more than 1000 miles long. Coverage extends out 1400 miles for planes at lower altitudes (dark areas): 1600 miles for planes at 20,000 feet (light)

SS LORAN

IT'S TOPS FOR ACCURACY

Before the ETO war ended, SS (Skywave Synchronized) Loran had proved itself not only the most accurate long range navigation system in the business, but an effective instrument for certain types of blind bombing missions. SS Loran was first used for navigation last Fall. Commencing early in February, Mosquitoes of the RAF 8th Bomb Group, the Pathfinder Force, used it almost every night on nuisance raids against Berlin. In average bombing accuracy it was about equal to H_2X.



All radiations travel by skywave in SS Loran. Thus, since the ionosphere contracts to form a reflecting surface only at night, SS works only from an hour or so before dusk to an hour or so after dawn

SS Loran differs from Standard Loran (see RADAR No. 9) in that radiations travel from master to slave transmitter, *as well as* from transmitters to receivers, by skyways all the way. Thus pairs of transmitters can be separated by great distances. Another result is extreme accuracy—errors no greater than a mile anywhere in the main coverage pattern.

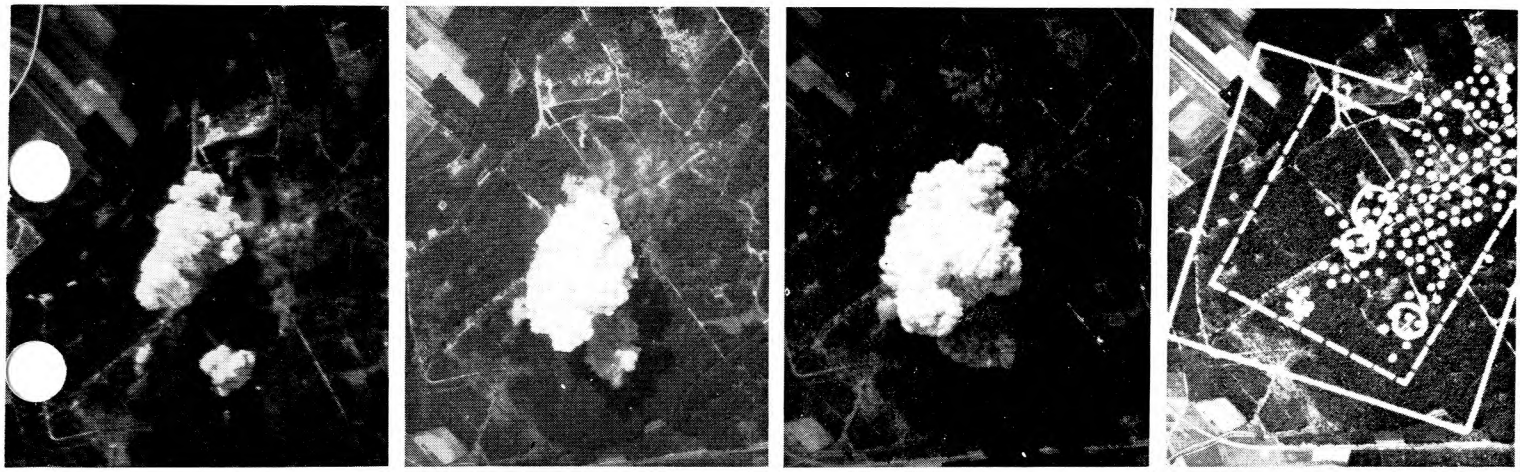
The end of the war in Europe didn't mean the end of SS Loran there. Actually, the AAF is making more use of the coverage now than before, when it used Loran only for weather and photo reconnaissance, and for experimental bombing. Prime war user was the RAF.

Since VE-day, the big project has been training for the Pacific. The need was great, since most U. S. operators handled nothing but the British Gee in their ETO and MTO careers. Once in the Pacific they will have no choice; Loran—of one kind or another—is all that's available.

It makes no difference to the operators whether the Loran is SS or Standard, since they get their fixes the same way. But they have to learn to identify and match the skywave signals—which have a habit of splitting and fading—particularly in view of possible Jap jamming. There has been none as yet, but Loran was jammed somewhat by the Germans.

Whether or not the European SS Loran system will remain in use when training programs stop is not known. It depends on whether the occupational forces decide to use Gee or Loran or both. Adjacent to Europe there are two Loran chains that *will* continue to function: the North Atlantic chain (Standard), and a new Eastern Atlantic chain (SS). These will be used for trans-Atlantic operations and weather flights.

Meanwhile experts are testing a still newer Loran—Low Frequency—and investigating the German system, Sonne.



SMOKE PLUMES, TERMED "AMMO-CUMULUS," RISE FROM DUMP AFTER SHORAN RAID. BOMB FALL AREA IN SOLID LINE—TARGET AREA IN DOTTED

SHORAN'S RECORD IN EUROPE

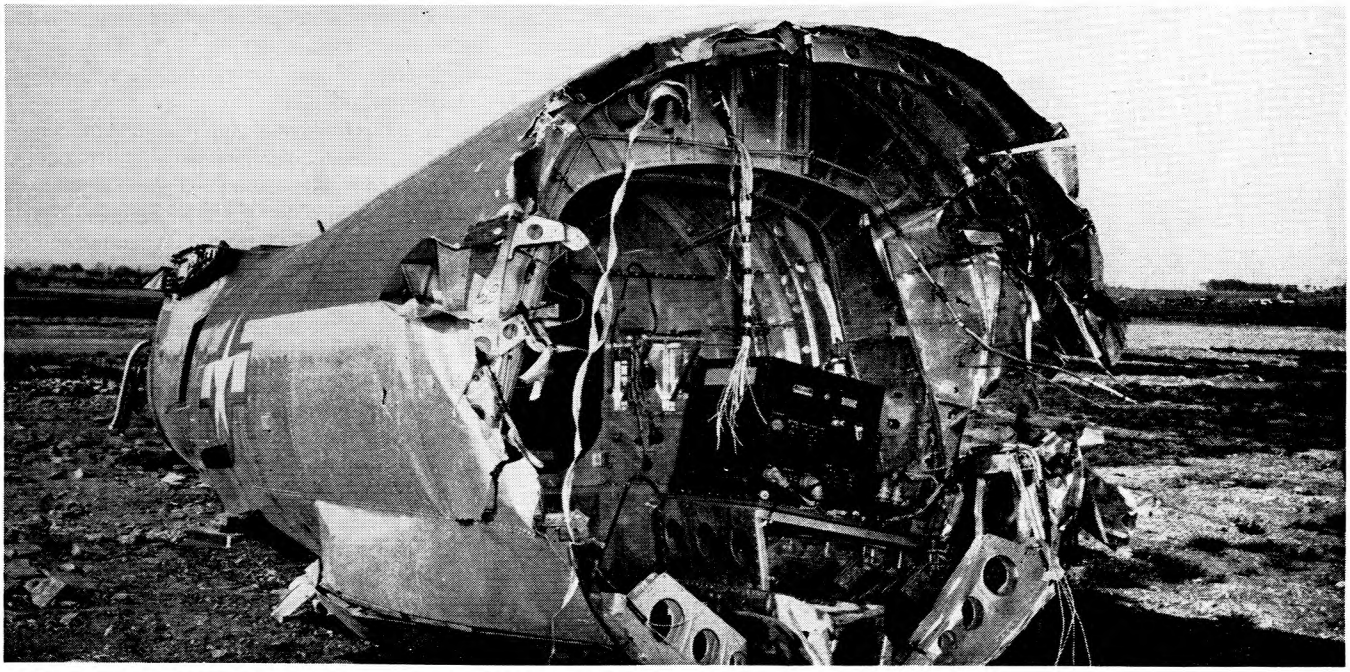
IT MAY BE DUPLICATED IN ASIA—GIVEN TIME

After a slow start, Shoran has skyrocketed into popularity. Its five-month record in Europe has won many friends and influenced many people. As a result, it is being viewed by some not only as a very sharp bombing device, but as the tactical radar to end all radars—the perfect system. In view of this, Shoran's abilities are being diverted into many channels—night photo recon, mapping, position indication for dropping paratroops and supplies, air-ground cooperation and even strategic bombing. That Shoran can do many things and do them well was proved in Europe. But the proof must be accepted in the light of several big "ifs."

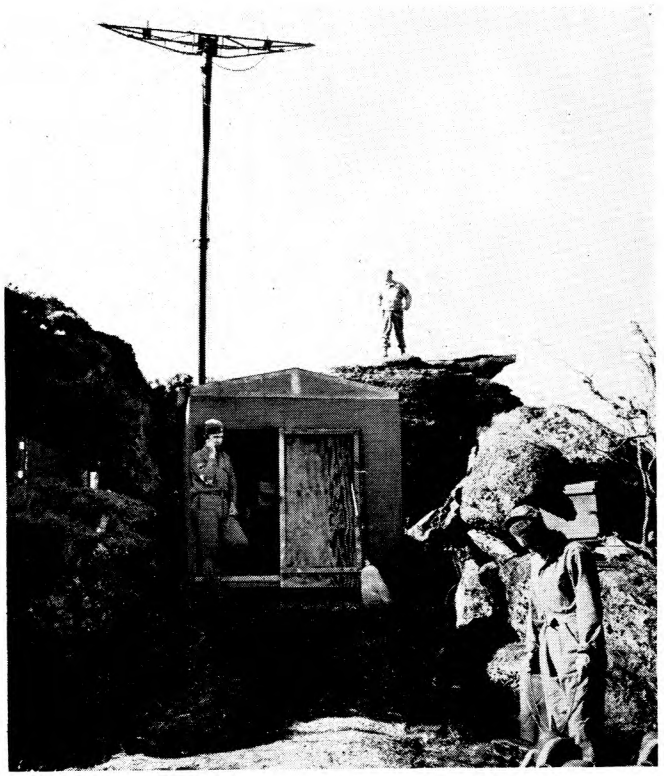
Shoran is worthy of all that has been said for it *if* the range from ground stations to target is not greater than 250 miles, *if* ground stations can be sited so that terrain features will not block signals, *if* accurate trigonometric data are available for the computations and *if* the computations are carefully and accurately made.

Europe provided all this, or the means to it—the Pacific, at present, doesn't. However, extensive attempts are being made to fit Shoran for that theater. There has been talk of installing ground stations in everything from sampans to P-38s, of making ground stations expendable for dropping in parachutes, of installing relay mechanisms for extending the range, etc. None of these things is more than a vague hope at present because the Shoran system involves extremely critical measurements. The distance from ground station to target must be known exactly; a slight error at the station multiplies considerably at the target.

Therefore, it is with a note of caution that RADAR presents the following report on Shoran in Europe. It has worked well there from the start. It will work well in the Pacific only when the tactical situation has changed to its favor.



Cut-away view shows Shoran transmitter installed in aft bomb bay of 17th Bomb Group B-26 Marauder, which is being junked after a crash landing. Timing unit and computer are installed in radio compartment. Complete airborne equipment weighs 290 lbs



One Shoran ground station was sited atop Mt. Schneeberg in Vosges mountains for 42nd Wing. As site was once used for German radar, tree tops had been conveniently trimmed



Siting calculations are checked on ornate bench mark. With accurate marks like this siting was often easy in Europe—could be done without survey engineers. It will be difficult in Asia

Shoran kept 'em flying

Shoran came to the veteran 42nd Bomb Wing of the 1st Tactical Air Force on VE-day minus 90. In three months, without benefit of any prior experience with any radar, the Wing put not only Shoran but Gee into operation. Thus equipped, the 1st TACAF was able to get back into full activity at a time when bad weather had cut its bombing opportunities to a minimum. Ensuing results added up to one of the outsanding radar achievements of the war.

The 42nd Bomb Wing's visual record, established in campaigns through Africa, Sicily and Italy, is one of the best and the outfit itself was always notably aggressive. It had been scheduled, in fact, to conduct the initial Shoran combat trials in Italy, an assignment taken over by the 57th Wing of the 12th AF (see page 52 and RADAR No. 8) when the 42nd moved up to join the 1st TACAF. After the move the 42nd ran headlong into the famed weather problem of the ETO; and there was nothing its aggressiveness could do about that without radar. The situation was bad because ground forces of the 6th Army Group, with which the 1st TACAF was cooperating, were facing frequent German counterattacks at the time.

Then came Shoran. In the first 35 days of operation there were as many Shoran missions flown as visual and results were very nearly parallel.

For an outfit with no previous radar experience and not even one radar mechanic, this was pretty hot. To get the program started, key operational and maintenance personnel had visited the 57th Wing of the 12th AF, where Shoran was just getting its baptism. These men formed a nucleus for the 42nd Wing's installation and training schedules and had them ready to function when equipment arrived late in January.

Ground stations for training were sited by 3 February and the 1st practice bomb was dropped on the 7th. It missed the target by a mile and a half, causing palpitations. However after an error due to misinterpretation of the computing formula was discovered and corrected in air, a direct hit was scored with the second bomb.

From this beginning an intensive training program developed. Briefly, the minimum requirements to turn out a pilot-bombardier team were as follows: 8 hours ground school, 3 observer rides, 3 flights of PDI and drift arc practice, 75 practice bombs, 4 navigational missions and a check ride. All of which took about 3 weeks.

While the first Shoran crews were being trained the Wing was also busy installing the airborne equipment in operational ships, assembling crews, siting ground station transmitters, developing speed and accuracy in Shoran computing and smoothing out the infinite number of details which crop up in the course of establishing a new bombing system.

It was recognized that for some time there would not be enough Shoran ships to lead flights of six or nine planes, as originally planned. Instead, they would have to lead as many as 36. So, with only two ships equipped, the 320th Bomb Group flew the initial combat missions on 10 and 11 March, in weather which prevented photo assessment. The same two ships served for the 17th Bomb Group's debut on the 13th, in which 65% of the bombs dropped on target.

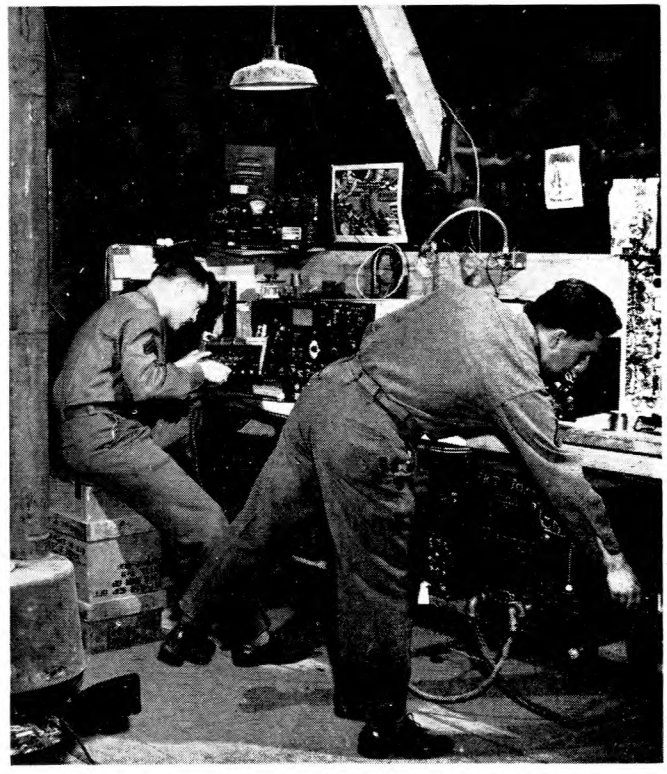
Shoran really began to pay off in an attack coordinated with the 7th Army's final smash against German resistance



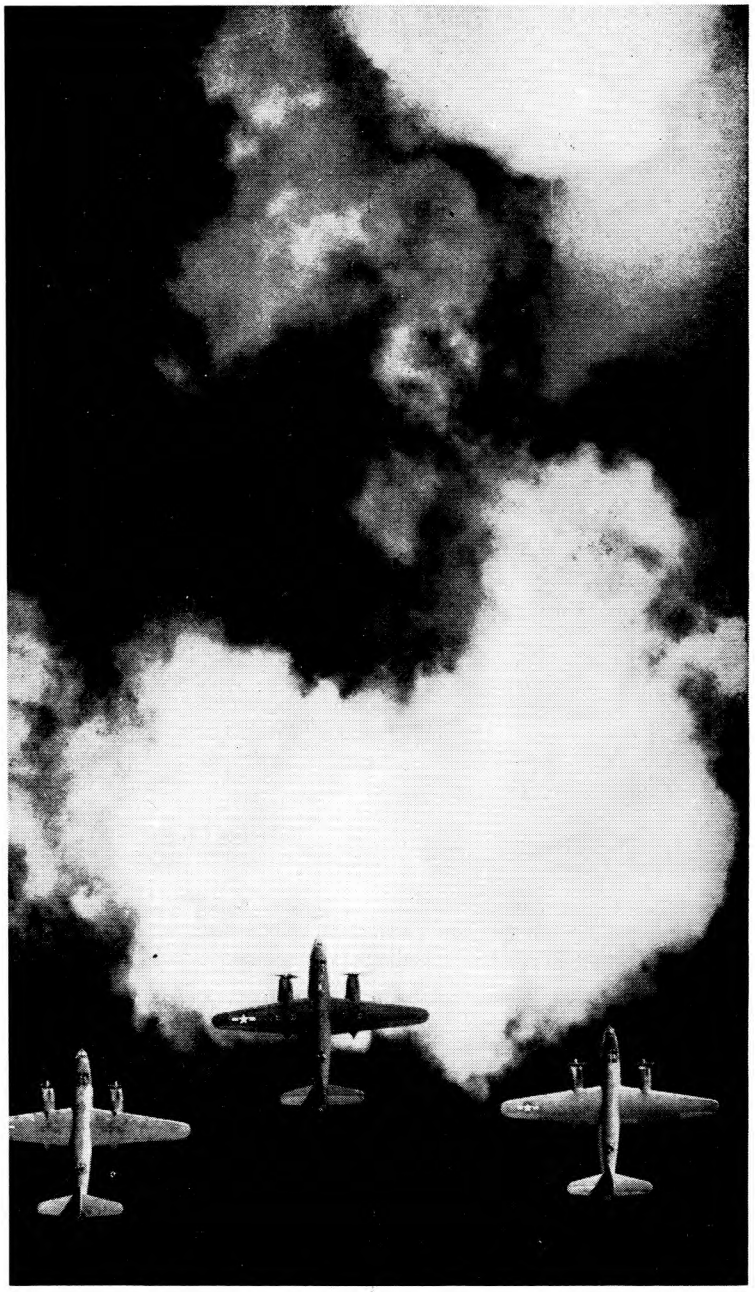
Shoran pilots and bombardiers of 17th Bomb Group check data sheets and charts in relatively simple pre-briefing session. Computations for data sheets were made in less than two hours by computing section (see front cover). In 42nd Bomb Wing the decision to use Shoran was based on nature of target, target location with reference to ground stations and weather predictions



Crewmembers of lead ship in 320th Bomb Group make final check on Shoran data before mission. Pilot and bombardier are key men, crew must be alert—all are keen to out-bomb Norden



Radar mechanics of 17th Bomb Group check airborne equipment on test bench. Wing maintenance record has been good although mechanics started from scratch with Shoran program



B-26 Marauders carried Shoran for 42nd Wing. To make most of equipment, as many as 36 ships released on Shoran lead

west of the Rhine. Targets, in the Zweibrucken area of the Siegfried line, were just areas marked on recon photographs. A headache to pick out visually from the air even under CAVU conditions, for Shoran the targets were the same as any other set of map coordinates.

The 320th Bomb Group sent two missions against them on 15 March, placing 79.75% and 99.20% of their bombs in the target areas. On the 16th, after scoring an inexplicable zero on its first mission, the 17th Bomb Group turned in a percentage accuracy score of 56.50 and 63.50 in two other tries. On the same day, the 320th sent four more missions over the area putting 55.60%, 77.13%, 64.50% and 74.00% in the assigned areas.

With scores like these, Shoran missions in the 42nd Wing rapidly increased to a point where the system ranked with Norden visual bombing in quantity as well as quality. Just how closely the systems compared can be seen in percentage



Shoran bombardier talks pilot onto drift arc of Shoran course and down bomb run. Pilot also gets PDI information on the run

figures for 42 visual and 42 Shoran missions, run in the 35 days following Shoran's debut. Bombing accuracy for Shoran was 51.19%, including two missions with zero bombs in the target area; for visual, 59.73%, including one zero mission.

In making these direct comparisons full weight must be given to differences in the two systems. Formation size wasn't the same and each had its special kinds of targets and conditions. Shoran was often used on a mission when visibility was good, if the target was such that the visual bombardier couldn't recognize it soon enough to make a precision run. Incidentally, when a mission started on Shoran, it finished on Shoran even though visual methods could be used—there is no provision for Norden synchronization.

Once airborne and assembled, navigation to the IP was done by the Gee navigator and Shoran bombardier in the lead ship. The Shoran bombardier took over for the run at the IP (see RADAR No. 8) while the Gee navigator continued to take fixes. These were used to check against gross Shoran error or malfunction and to provide a rough assessment.

Technical failures with Shoran airborne and ground equipment were fewer than originally anticipated. In airborne units, the biggest headache was PDI adjustment. Partly because of this, pilot to bombardier "talk" was emphasized, not only during the approach to the drift arc but right down the bomb run. A good team could even anticipate the PDI rate needle in smoothing out the course flown.

For a report on the 42nd Bomb Wing's final and most successful Shoran operation in the ETO, see next page.

"Oleron"—made-to-order



"Bat" is the code name for Shoran in the 57th Bomb Wing

A mile off the western coast of France, opposite the Gironde river estuary, lay the Ile d'Oleron. Although the tide of battle had swept far beyond this island by April 1945, some 2000 by-passed Germans still held possession. With strong fixed artillery positions and defensive fortifications they were largely responsible for keeping water traffic from the port of Bordeaux.

By April, demands of the main offensive against the Reich had been largely satisfied and French ground armies were free to concentrate on the Ile d'Oleron pocket. To take the island they needed accurate tactical bombing. But the targets were mine fields, gun positions and troop concentrations, situated in wooded areas or along the coast where definite visual aiming points were not easily found. In addition, long-range weather forecasts promised overcast skies.

Here was a tactical situation made-to-order for Shoran. Fortunately, Shoran-equipped Marauders of the 42nd Bomb Wing were on hand to take advantage of it.

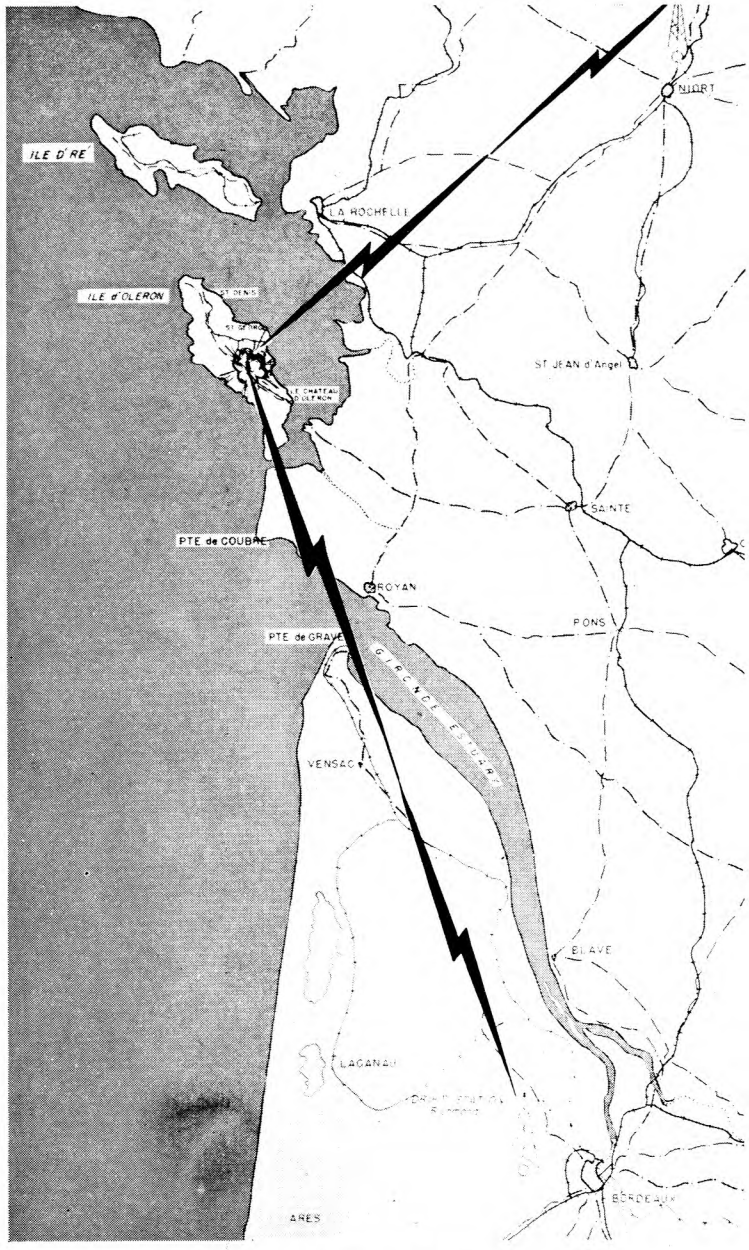
The 17th and 320th Bomb Groups, on the last day of April and first day of May, sent 20 missions against the Ile d'Oleron in cooperation with French ground forces, which were able to take the island in two days as a result of the air action. In the words of the 42nd's Commanding General, the liberation would have been "impossible without Shoran."

Operation "Oleron" really began on 24 April when 2 officers were sent to select the ground station sites. At the outset, it was found that all existing trigonometric data within the area was based on a 100-year-old survey which was totally inadequate for Shoran accuracy requirements. But for a fortunate encounter with the U. S. 1st Field Artillery Observation Battalion, this might have ruled Shoran out. The Battalion had a captured German survey of the area with corrected maps, and it was these that were used.

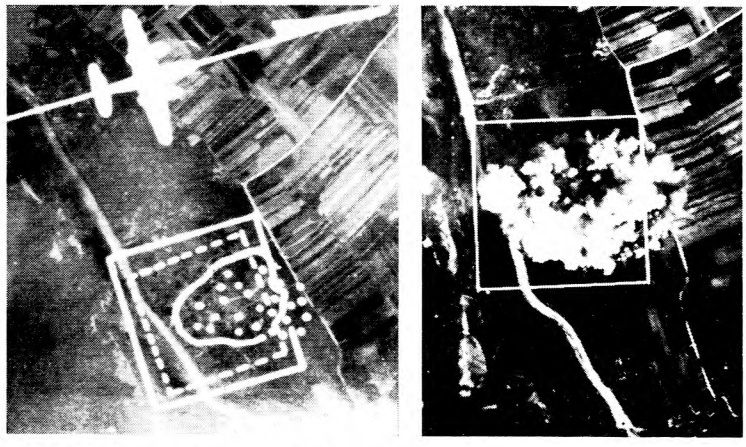
With this problem solved, thanks to the Germans, the ground stations had to be moved from the training center at Istres, near Marseilles. They were installed (see map) and ready to operate the morning of the 27th, after being flown several hundred miles through hazardous weather.

Three days later the liberation of Ile d'Oleron began. Preceding ground action, the 42nd Wing launched 16 medium bomber missions in weather which prohibited photographic scoring and kept two Groups of French mediums from bombing visually. French ground forces reported that the Shoran bombing was highly precise and, as a result of it, the troop concentration area was taken with negligible resistance. By evening 1,500 German prisoners had been taken and the ground forces had possession of more than half the island. The next day four more missions were flown. The German commander surrendered his remaining forces at 1845 hours.

The missions involved in operation "Oleron" were the last flown by the 42nd Bomb Wing in the ETO, winding up two years of aerial combat. It was a fitting climax.



Ground stations for operation "Oleron" were flown from training sites and relocated as shown on basis of a German survey

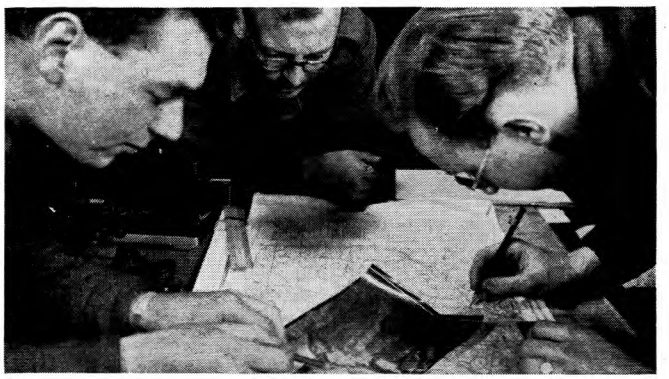


La Perroche gun positions defending coast of island were thus neutralized by 17 Shoran-led Marauders of the 17th Bomb Group



Italian targets in the mountains and on the plains felt sting of Shoran-aimed bombs during final push. In general, Italian weather permitted more visual attacks than weather over Europe





Shoran computing problems were solved in 57th by British personnel detached from 13 Field Survey Company, R. E.

The Shoran score in Italy

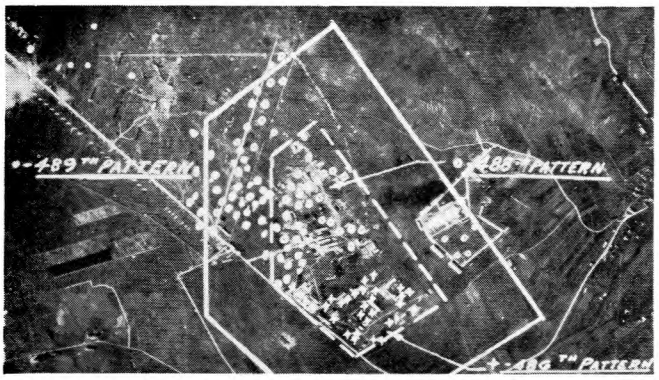
In Italy, Shoran was well beyond the honeymoon stage when fighting ceased. Sponsored by the 57th Bomb Wing of the 12th AF and flown by the 310th, 321st and 340th Bomb Groups, Shoran was very nearly matching the best visual scores. The beauty of Shoran was that it matched those scores when bombing targets which, under the circumstances, could not be attacked successfully, if at all, by visual methods.

A striking demonstration of what Shoran can do for tactical bombing was given during the final cleanup in Italy. Battle area targets were attacked between 9 and 18 April using both Shoran and visual methods. Here are the results:

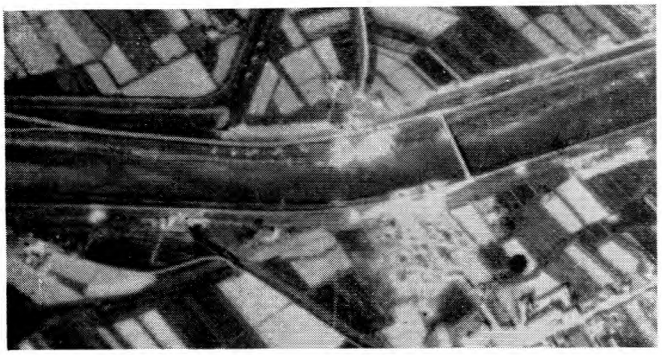
	SHORAN		VISUAL	
Sorties	No.	%	No.	%
Airborne	443		1097	
Effective	378	85.3	866	80.8
Failures				
Weather	8	1.8	41	3.7
Dust, haze, smoke	0	0.0	41	3.7
Personnel	32	7.2	59	5.4
Enemy opposition	3	0.7	18	1.6
A/C equip.	0	0.0	27	2.5
Shoran equip.	22	5.0	–	–
Other	0	0.0	25	2.3
Average % of bombs within 600′ of or within T. A.	80.1%		72.1%	

Although Shoran outscored visual methods in this particular instance, the overall reliability and accuracy of Shoran is somewhat less—a result of gross errors caused by equipment and personnel failure. In all three Shoran groups, 63.3% of the sorties were successful between 12 and 14 April—that is, bombs were in the target area. However, the veteran 310th Bomb Group, having eliminated many gross errors, scored successes on 80.4% of their missions. Including all errors, the CPE came to about 632 ft. By eliminating gross errors the CPE would be reduced to 414 feet.

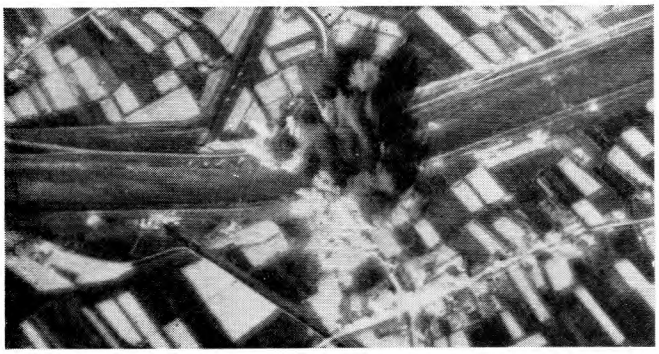
By way of comparison, 85% of the visual missions during April were successful, with a CPE between 500 and 600 ft. If the war had continued, it is reasonable to assume that 70% of the Shoran missions would have been successful.



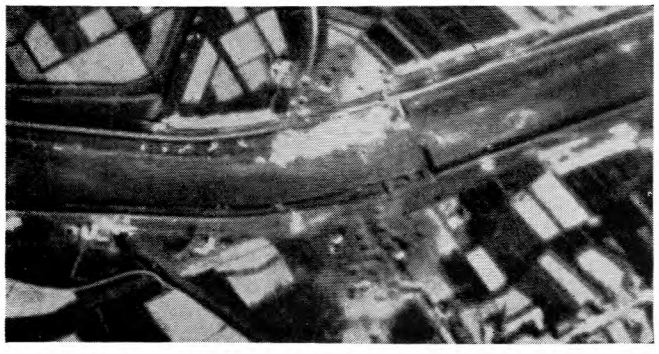
Spilembergo Powder Plant as hit by Shoran bombers of the 340th Group. Plane at right has just made run on this target



Before attack by Shoran bombers of the 57th Bomb Wing temporary bridge is intact—original span was destroyed before



During attack smoke plumes rise from direct hits on the bridge. It is one of many destroyed by Shoran in 5 months of operation



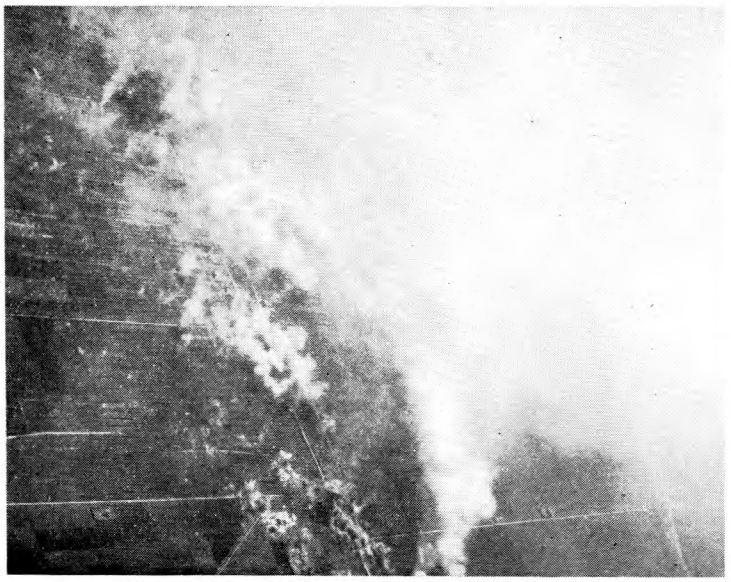
After attack recon photo shows bridge is cut. Shoran results aren't always this clearly defined—especially in battle areas



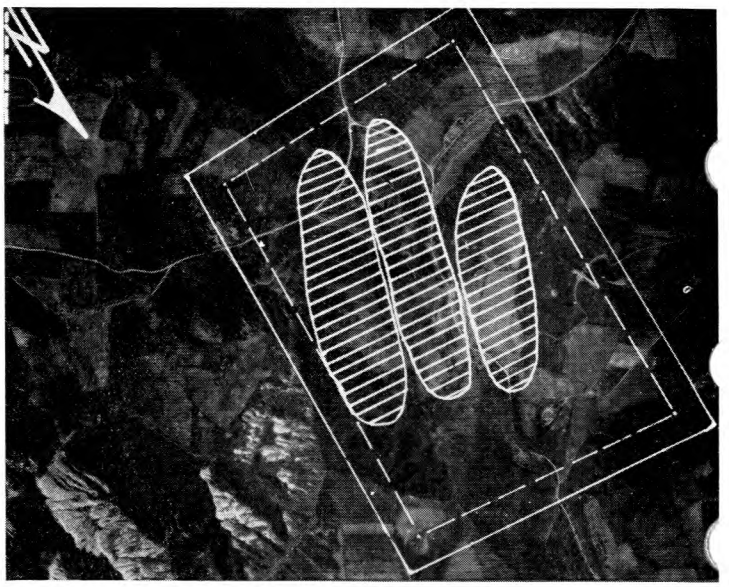
B-25 Mitchells carried Shoran for 57th Bomb Wing in Italy. This one just fired Spilembergo Powder Plant—see plot above



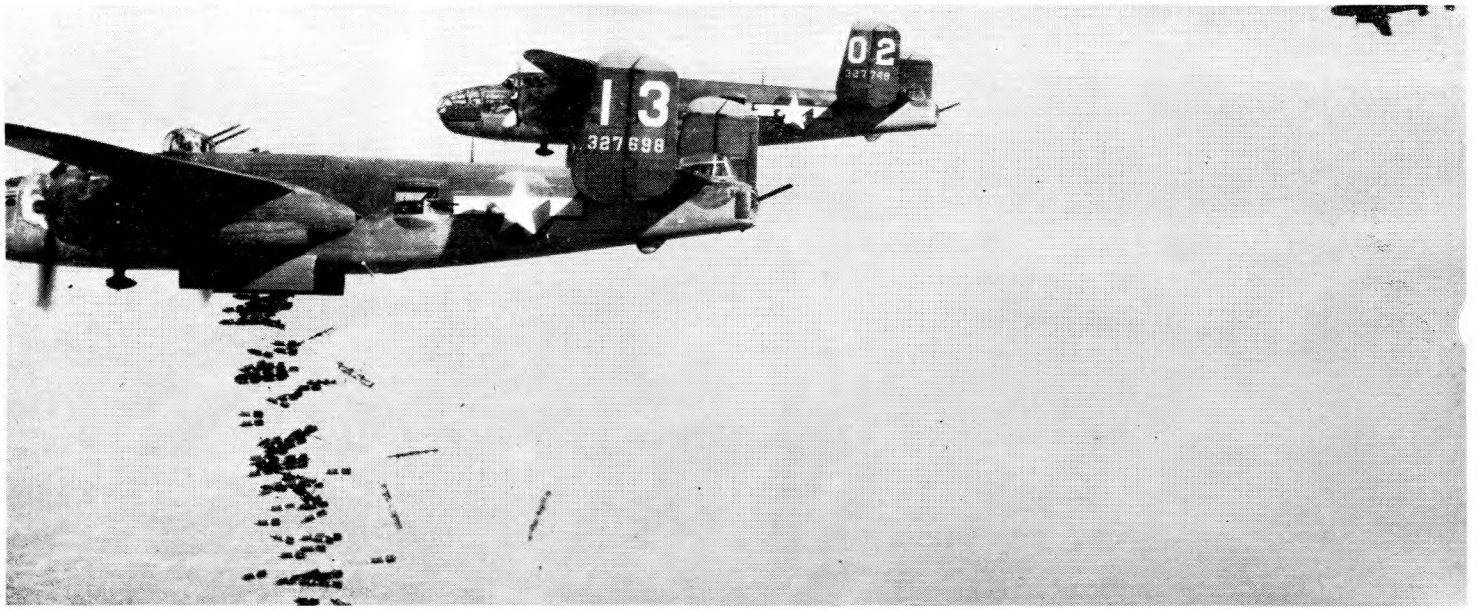
Ferry pier still smokes after a Shoran attack. Ferry was put into operation after previous bombing had destroyed the bridge



Battle smoke and haze limit effectiveness of visual bombing in attacks on battle areas—Shoran allows maximum air cooperation



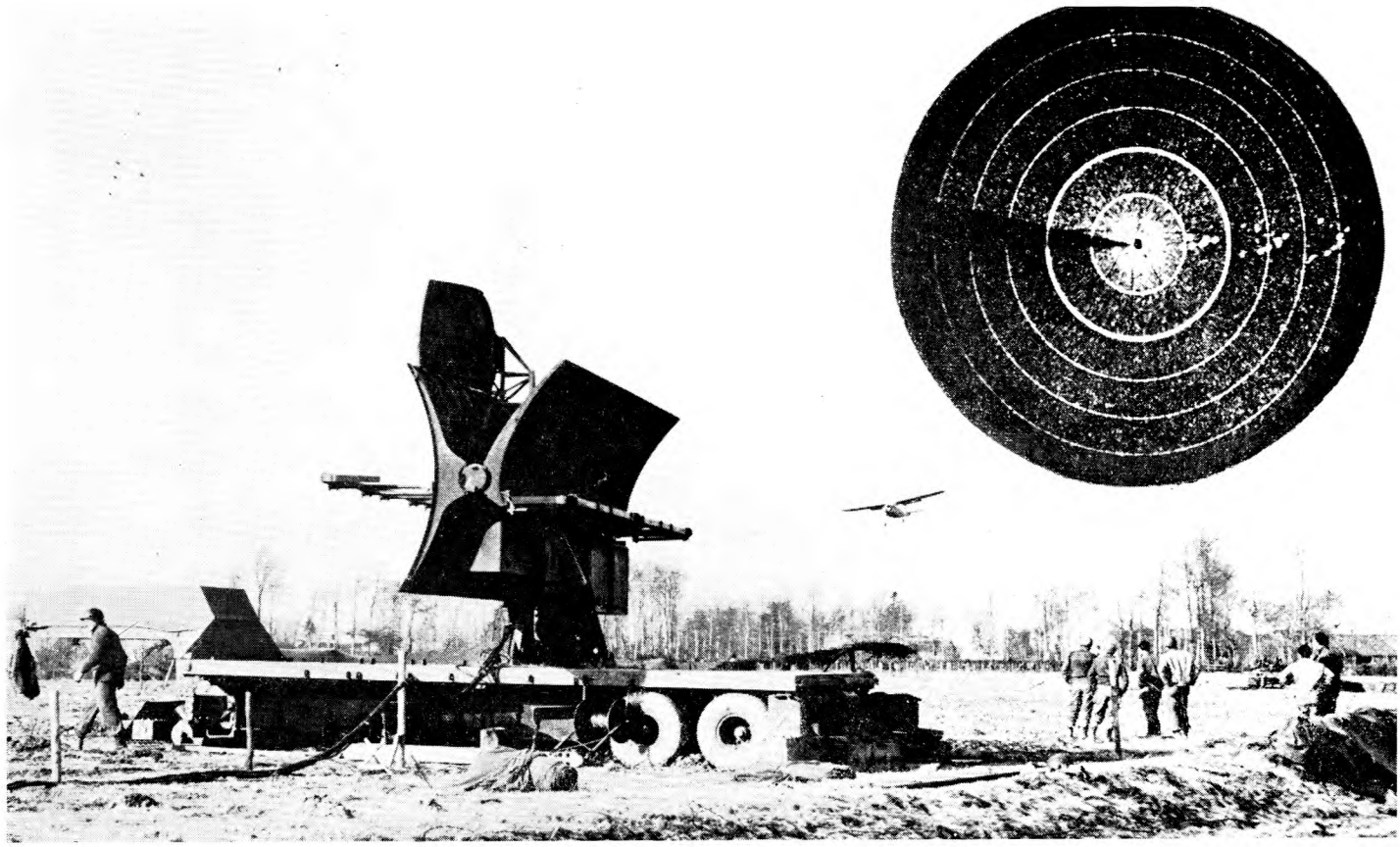
Target identification is difficult in terrain like this. With Shoran a perfect pattern was laid in target area (broken line)



Fragmentation attacks by Shoran-led Mitchells of the 310th Group hit troop concentrations. Photo frames target area

Average Shoran mission in 57th Wing had 3 boxes of 6 aircraft, each box dropping singly. Errors were mostly in rate





Rosebud receiving antenna atop 8th AF MEW helps identify and control long range fighter sweeps over Germany. On scope 2-1 code of airborne S-band beacon shows at 11 o'clock and 127 miles. Beacon range is read from code pip nearest scope center

Kits for the MEW

New modifications will boost its control power

Already one of radar's most versatile products, the MEW still seems to find room for improvement. Now it is getting set for its Pacific debut as a control radar, with a whole variety of new modification kits. Some of these kits have had operational theater trials; some just look good enough in trials at home to warrant being sent to war when finishing touches are added.

The emergence of all the kits is the result of the varied and extensive ETO activities of the preproduction MEWs (AN/CPS-1A). The production MEWs (AN/CPS-1), which are just coming off the line now, will get the benefits of all that experience in the form of new provisions for airborne beacons, MTI circuits, and all that goes into transforming an early warning radar into an up-to-date control center.

Airborne beacons

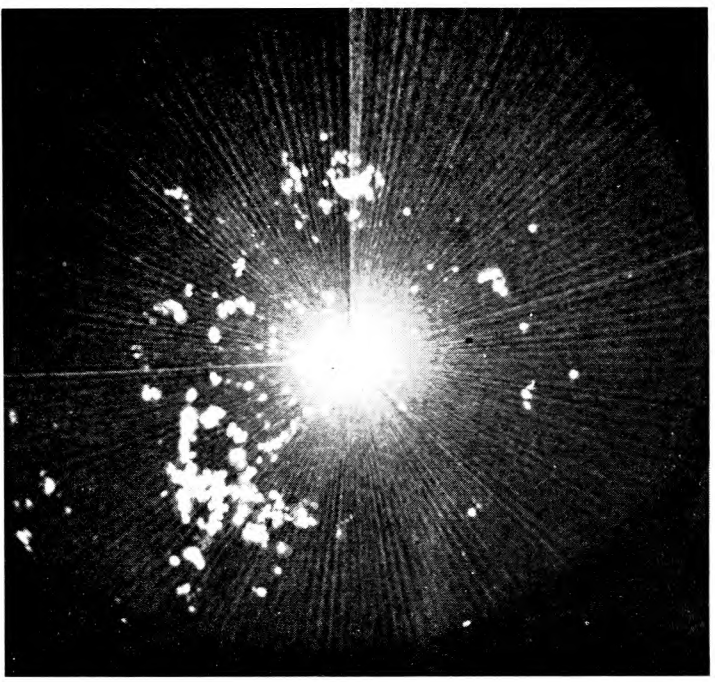
The operational proving ground for airborne microwave beacons (Rosebud) was mainly with the fighters operating with the 8th AF MEW. With only a very limited number of beacons, the installations were limited to six fighter groups. On 8th AF escort and strafing missions, however, one beacon was sufficient for the control of one group, or section of a split group—50 or 25 planes. And with beacons, control does not have to be close. A range of 90 miles at 25,000 feet on a fighter becomes 200 miles after the beacon is installed.

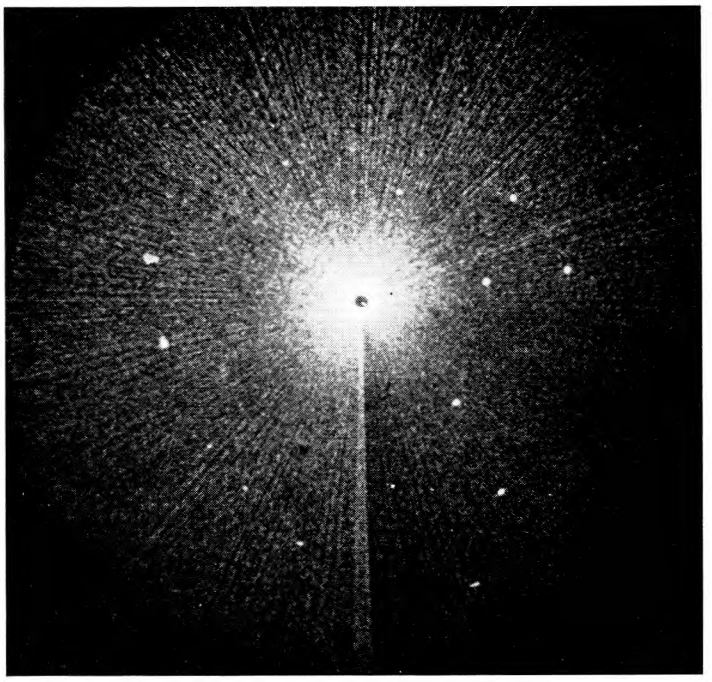
The positive identification beacons provide is an especial aid to MEW, whose job has been complicated frequently by the large number of aircraft in an area at one time. And the mechanics of identification are simplified by the use of the beacon's coder unit, supplied with all but the very early models. This unit causes a series of several pulses, or groups of pips, to be displayed on the MEW PPI at the same azimuth but separated in range. Seven codes can be selected by an adjustment on the beacon box in the aircraft.

An airborne beacon is essentially a small transponder radar set. A beacon receiver picks up and amplifies pulse signals from the transponder; the receiver output triggers the beacon modulator, which in turn keys the transmitter, causing it to send out short pulses. Since airborne beacons receive and transmit vertically polarized signals only, the beacons operate with MEW's lower beam only. In order not to interfere with the set itself, and to make it possible for MEW to see a number of beacon-equipped aircraft simultaneously, all beacons in an air force reply on the same transmitting frequency, outside the MEW band. Besides the straight MEW PPI display, the controller can switch to beacon presentation only, and so see Rosebud codes without ground clutter; or he can select a mixed display.

Because the beacon must operate on a different frequency from MEW itself, the MEW modification kit is necessary. It includes the beacon receiving system—the antenna, with its 8′ x 4′ dish, and associated receiving circuits.

Several forms of S-band beacons were tried out in the ETO. Among them was an airborne version of the AN/UPN-2 (BUPS), known as the AN/APN-29, or





MTI on an experimental MEW, 40-mile range. On one antenna rotation, normal PPI was photographed; on next, MTI-PPI. Thirteen aircraft lost in confusing clutter on first presentation are easily visible on second. Operator switches on MTI as desired

Rosebups. This was generally considered unsatisfactory because of its size and weight, and neither it nor another runner-up, the AN/APN-21, will be used in quantity. The latter was used to some extent in close control, but proved to be more complicated and less flexible than the AN/APN-19—Rosebud—the beacon which will be used with SCR-584s and MEWs in Pacific operations.

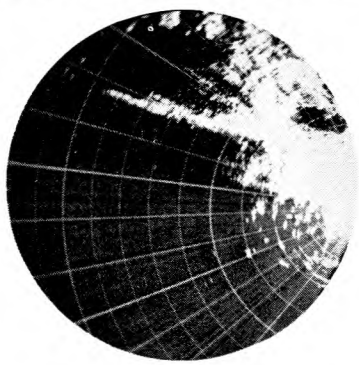
Moving Target Indicator

Clutter — both ground and sea — cramps MEW's style as much as anything could. From the Po Valley where the 12th AF now and then lost planes in clutter caused by anomalous propagation conditions, to Saipan, where sea clutter has been extremely annoying, people have been dreaming up ways to wipe it out. There are a number of circuits, of the sensitivity time control or fast time constant type, which do the trick. One such circuit was worked out on Saipan and incorporated in the MEW there. Designed by Lt. Roy James of the 735th SAW, it is an STC-type circuit, which has enabled the MEW to follow planes through 35 miles where they would be normally lost in sea return, right into the edge of the island. There plane signals once more become lost.

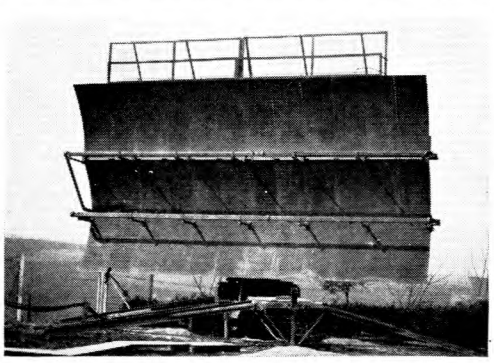
The real solution to the whole problem seems to lie in MTI (Moving Target Indicator). Now wrapped up into kit form, this equipment provides the means to wipe all permanent echoes off the PPI.

MTI's complicated circuitry makes use of the simple fact that aircraft echoes move and ground echoes do not. The first set of signals returning from a transmitted pulse are delayed until the second set arrives; then the first set is subtracted electronically from the second. The signals which do not move—the ground echoes—are cancelled out, leaving the signal from the aircraft, which shows on the scope as usual.

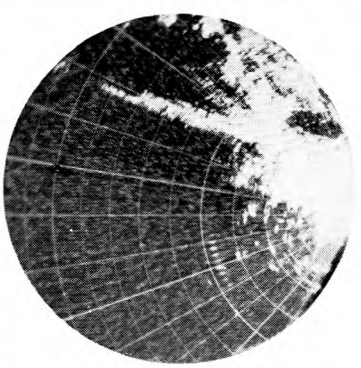
The MTI kit is quite an extensive affair. Its inclusion requires that MEW's rotary gap modulator be replaced by a hydrogen thyratron, which can be trig-



At 55 and 57 mi., 267°, 2 planes show on 12th AF MEW scope



The Canary array is eight elements wide, vertically polarized and with a reflector screen



Planes at 45-46 mi.; one shows characteristic wide G-band echo

gered sufficiently accurately to permit the held-over signals to be released for subtraction coincident with the set of signals just arriving. Besides room on the mount for the new oscillator, modulator, MTI receiver and necessary power supplies, more MTI goes on a small workbench in the maintenance room. With all this, however, goes a 5 db gain in overall operating efficiency —partly from the new modulators, which drive transmitters of both beams with a 2 microsecond instead of 1 microsecond pulse, and partly from new low-noise input circuits in the receiver.

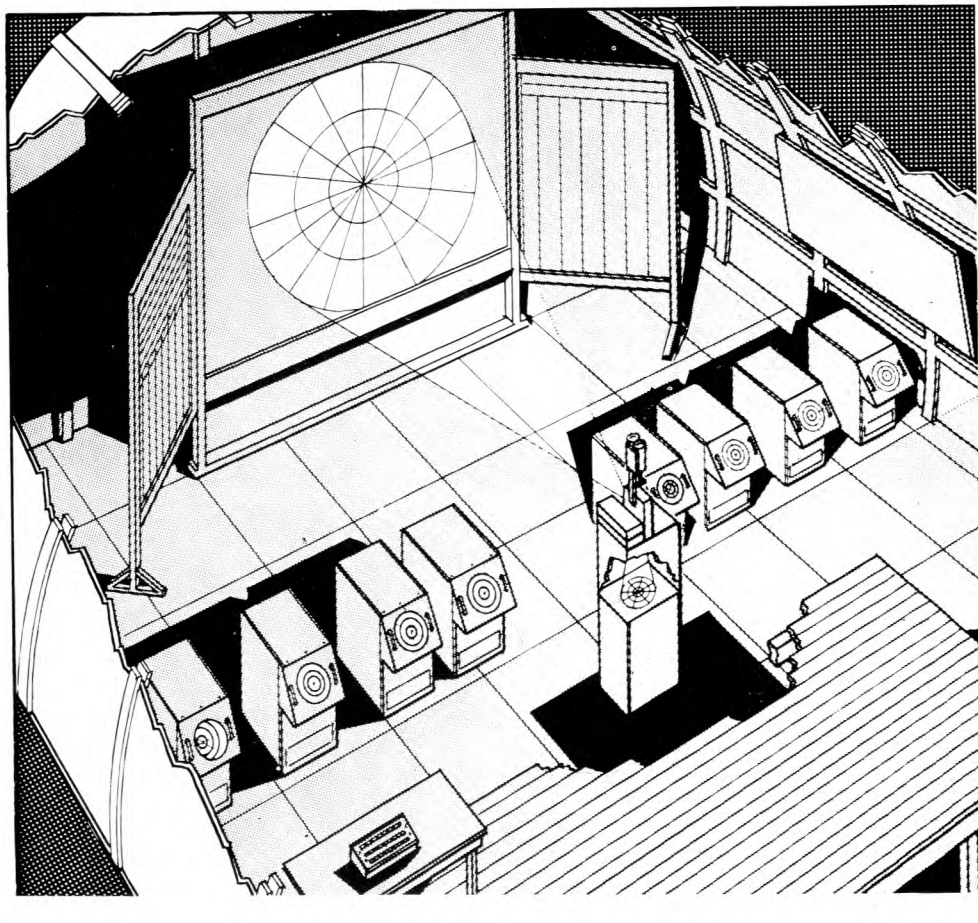
Canary

Another possible MEW modification, not standard, not planned at present for kit form, but most effective in the 12th AF where it was developed and put to work, is Canary. The addition of this G-band IFF facility helped to make the 12th AF MEW a complete tactical unit. The finished product, which went into operation early last winter, proved to be an ideal field installation: it made use of the only equipment available in quantity which gives satisfactory identification on MEW scopes—the SCR-695 responder, which is installed in many nightfighters. The interrogator was put together out of salvaged components of an SCR-602-T6 and parts of half a dozen other sets. Video information from the interrogator could be displayed on the PPI when the controller desired.

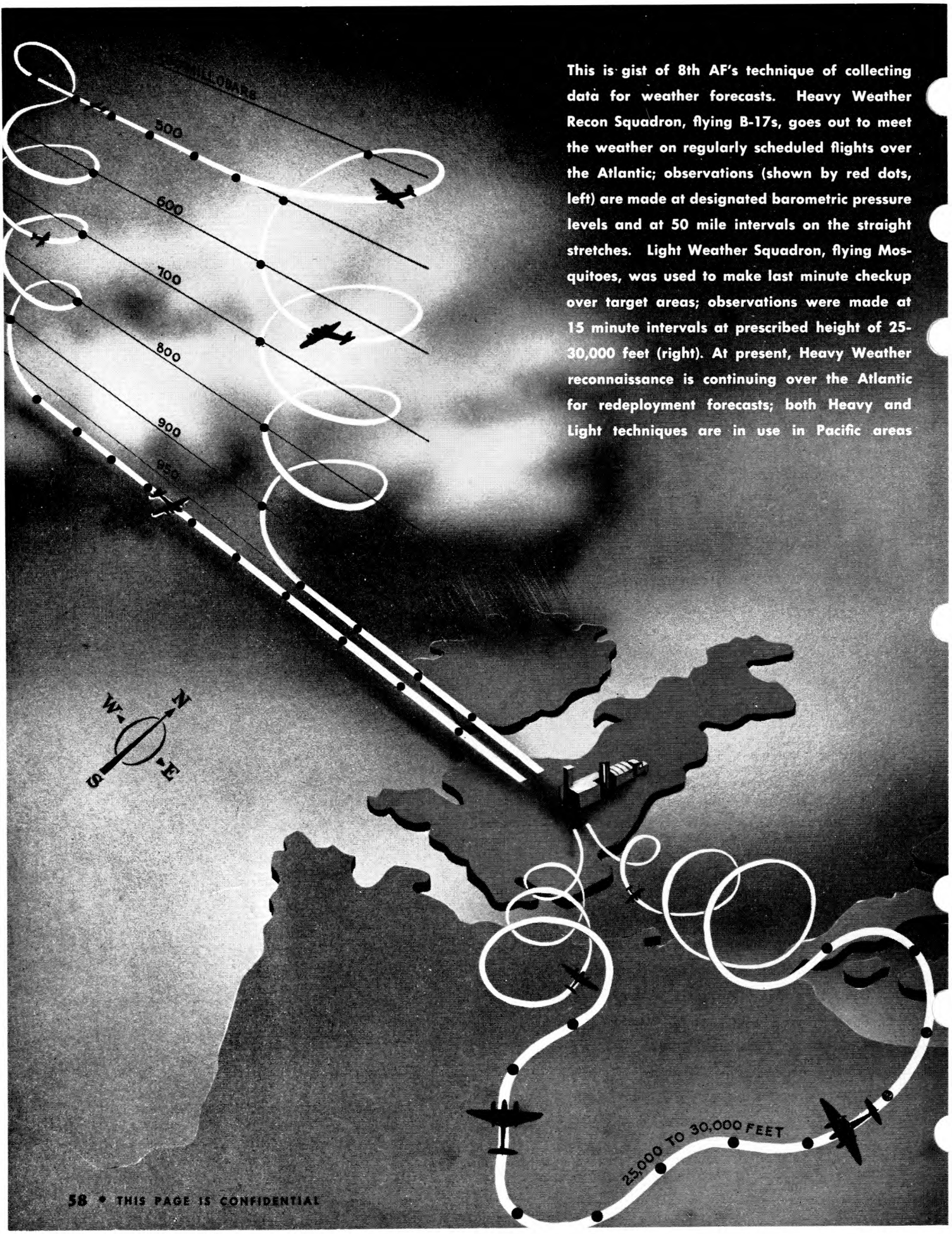
Photo projection

Photographic Projection PPI (P^4I) fills a long-standing requirement for presenting a scope picture to a large number of people. The P^4I equipment is mounted vertically over the PPI console, automatically photographs one PPI rotation, processes the film, projects the negative on an 8-foot screen—all in approximately ten seconds. The equipment, excluding the PPI chassis, weighs under 200 pounds, and uses standard photographic supplies. The use of P^4I means that fewer plotters are needed, since plots appear automatically at the right coordinate point on the display and need only to be marked. Accuracy in general should be better than that achieved by scope-reader/plotter teams, and weak echoes ordinarily lost are reproduced at constant intensity during a projection cycle. Further trials are to be carried out before theater shipment.





All necessary components for well-appointed operations room, such as vertical plotting board worked out in ETO, come with AN/CPA-7 kit. P^4I goes step further in streamlining control center. Diagram below shows it mounted on PPI chassis, set up for operation in Jamesway hut. Its series of exposures become permanent radar record



This is gist of 8th AF's technique of collecting data for weather forecasts. Heavy Weather Recon Squadron, flying B-17s, goes out to meet the weather on regularly scheduled flights over the Atlantic; observations (shown by red dots, left) are made at designated barometric pressure levels and at 50 mile intervals on the straight stretches. Light Weather Squadron, flying Mosquitoes, was used to make last minute checkup over target areas; observations were made at 15 minute intervals at prescribed height of 25-30,000 feet (right). At present, Heavy Weather reconnaissance is continuing over the Atlantic for redeployment forecasts; both Heavy and Light techniques are in use in Pacific areas



BEFORE STARTING OUT, B-17 RECON CREWS ARE BRIEFED ON ALL AVAILABLE SYNOPTIC WEATHER DATA THAT MIGHT AFFECT THEIR OBSERVATIONS

WEATHER RECON

HOW AIRBORNE OBSERVERS GET WEATHER DATA TO BRIEF CREWS

No one from the ETO will believe it, but for a good part of the year the weather around Japan is as bad as, or worse than, the weather over Germany. It goes in for tricks of its own, but at core it sets up the same problem—how to navigate and bomb through never-ending layer upon layer of overcast. Radar's uses in getting the bombs through are the spectacular part of radar-at-war. Increasingly, its uses in the unspectacular job of weather reconnaissance are helping the whole air war.

Airborne weather reconnaissance involving radar for navigation and height-finding was developed by the British. It has been carried out in the U.K. by both the RAF and the AAF, which shared the work and pooled their information. Allied weather squadrons in the Pacific are now using similar techniques and, in addition, have added airborne radar for storm detection.*

But for its effectiveness in servicing an entire theater of war and for the interest it holds for Pacific operators, the ETO system deserves a writeup before it becomes history. As a matter of fact, part of it—Light Weather reconnaisance over bombing targets—is already history. Heavy Weather reconnaissance out over the Atlantic continues, and will be used for redeployment.

ETO flying weather is so consistently foul that there sometimes seemed to be no point in attempting to forecast it at all. Actually, of course, up-to-the-minute forecasting was needed to obtain most effective operation of the mammoth Allied air fleet, and to prevent the weather from becoming the enemy's most potent air defense.

Today's weather in the ETO is yesterday's weather from the Atlantic Ocean, which makes the eastern Atlantic the logical laboratory for meteorological checks. In peacetime it was easy enough to obtain such information from ships; in wartime ships maintain radio silence.

With England a natural base for weather reconnaissance operations, all that was needed was to substitute planes for ships, and to develop appropriate airborne techniques. Once this was done detailed reports were secured regularly at 50 mile intervals on a pattern of lines radiating out from England.

Chief user of weather information gleaned from the system, the 8th AF did a large share of the work. Its reconnaissance was concentrated in the 25th Bomb Group under the direction of the 325th Photo Recon Wing. One squadron, the 652nd, carried out patrols over the Atlantic and will continue to for awhile; another, the 653rd, has been responsible for last minute checkups over the North Sea and Europe.

The 652nd is called the Heavy Weather Squadron because of its complement of 18 Flying Forts. The ships are stripped of some standard B-17 armament and equipped with weather recording instruments, extra gas tanks and radar in the form of Gee, Loran, AN/APN-1 (low altitude absolute altimeter) and SCR-718 (high altitude absolute altimeter). The 653rd, known as the Light Weather Squadron, used Mosquitoes carrying Gee and Loran. For more on both, see next page.

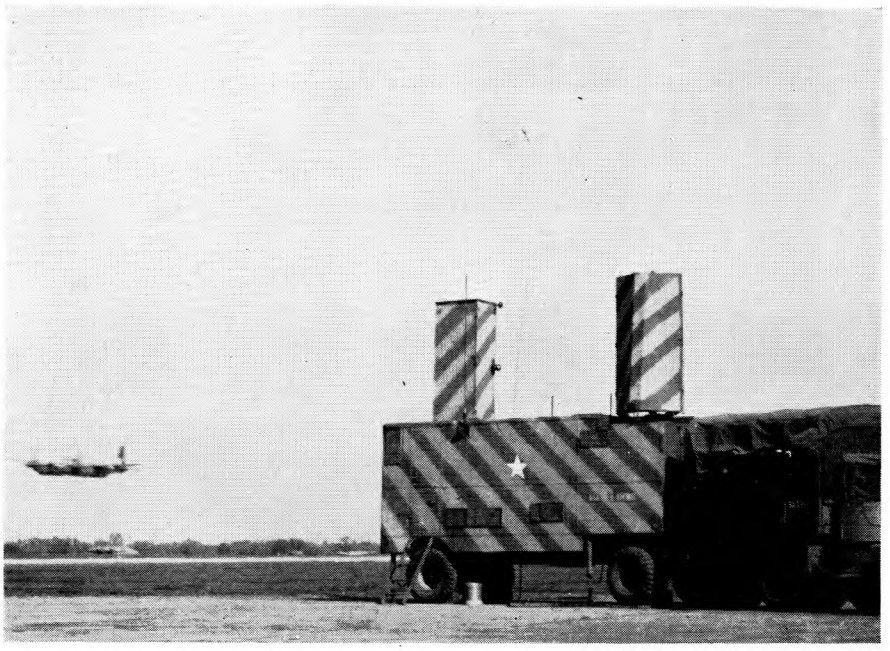
* For reports on use of radar (ground and airborne) in other weather jobs, see RADARS No. 6 and No. 9.

Two kinds of flights four kinds of radar

Heavy Weather Squadrons in the ETO fly 2 regular Atlantic recon routes, "Allah" and "Sharon," one comprising 1000 nautical miles and the other 1500 nautical miles of overwater flight. Two flights are made daily on each route to provide day and night observations. Measurements are made of barometric pressure, temperature, humidity, wind velocity and direction, visibility, cloud conditions and icing conditions. Observations are radioed in code to the U.K.

Accurate navigation of the long ocean routes is essential to the usefulness of the weather data, in order to obtain meteorological information which will benefit subsequent air force operation. This places a premium on the precision fixes obtainable with Gee and Loran; both must be carried in order to get coverage over the entire route and the approach and homing course.

Gee is also used to make wind observations. It is not quite so accurate as direct determination of wind drift from visual observation of a flare, but there is plenty of weather in which flares cannot be used. Successive Gee fixes can be correlated with plane speed and heading to give a wind vector.



Although the ETO war is over, this Mark III GCA at 8th AF weather base in U.K. will continue to maneuver landings for weather recon A/C operating in low visibility

Low altitude radar altimeters are a must for Heavy Weather stints. With best visibility it is difficult to estimate altitude over water, particularly when the plane is making its descent from 25-30,000 feet to sea level. Before installation of the AN/APN-1, one heavy recon ship was lost to unknown causes—last reported making its descent on a routine flight.

The APN-1, used with the barometric pressure altimeter, makes it possible to



Intelligence Officer (left) gets last minute weather report from navigator and pilot of Light Weather Mosquito just back from taking observations over target areas in ETO. Reports like these go to brief bomber crews; no more in ETO but still in Pacific

calculate exactly what the sea level atmospheric pressure is, from measurements at 150 or 250 feet. The high altitude radar altimeter, SCR-718, does the same job at higher levels. Last of the radar equipment to be installed, it gives exact data on the altitude of millibar levels from 950 up to 400 millibars, providing an accurate picture of the density of the air column, which is important in current meteorological methods.

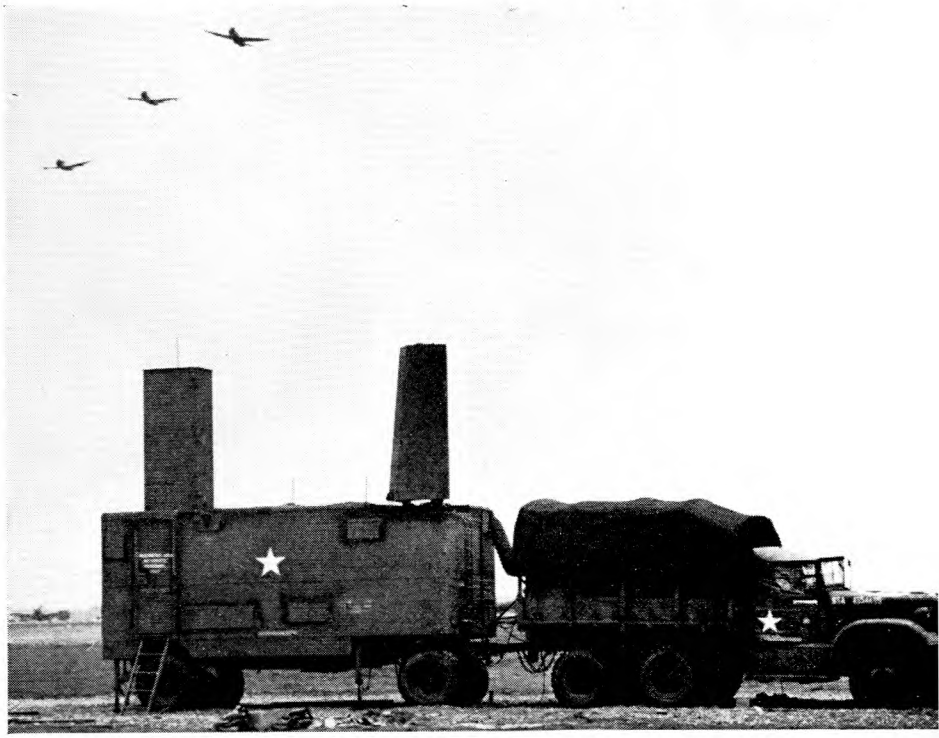
Since Light Weather Squadrons were on call for last minute meteorological scouting sorties in advance of heavy bomber missions, they operated sporadically. Usually they made their observations within 12-18 hours before a mission was scheduled to hit German-held territory.

Normally several planes were sent out for fast flights over the North Sea and the area of the main and alternate targets. Some took off in the late afternoon in order to return in time for a "night before" forecast. Others left in time to get back just before the last-minute briefing of the bomb crews.

On Light Weather sorties, observations were made every 15 minutes and whenever pertinent weather changes occurred. The survey included target conditions such as type and amount of cloud, heights of bases and tops, cloud boundaries and visibility. Along the mission route, observations were made on the height and persistency of contrails, clouds, turbulence, icing and precipitation. The planes investigated frontal cloud through which the bombers might have to climb, and cloud layers between which the bombers might have to assemble.

In all of this, Gee and Loran played straight, conventional roles. Purely and simply, they were navigation aids—although navigation was no simple task on such missions. Weather recon missions operate on the margin of weather that is at all flyable. For the same reason, landings were a critical factor in the operation. Moreover, landings had to be made at the home base; landings at alternate bases were unsatisfactory because of consequent delays in getting the weather data to bombing crews. The 25th Group base was therefore selected for one of the first ETO installations of the radar blind landing system, Mark III GCA. It was just getting into operation when the disintegration of Germany put an end to bombing missions.

GCA's record in ETO was brief but good



Installed near Verdun, France, last January, this GCA set was the first to be used in Europe. Altogether 8 sets became operational with fighter and bomber groups before V-E day. They handled approximately 417 successful aircraft approaches

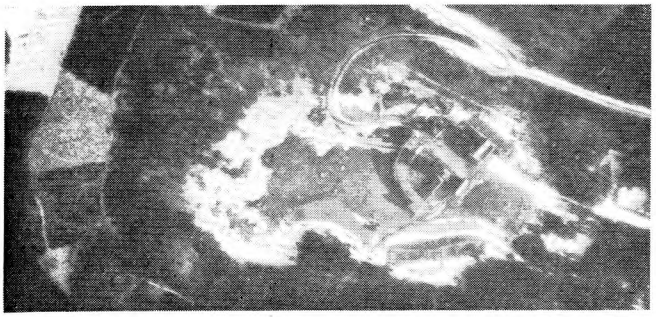


GCA crews such as this one directed the planes down. Many approaches were absolute emergencies in which crews would have had to bail out without GCA; some were under zero zero conditions and pilots couldn't see the runway even after landing

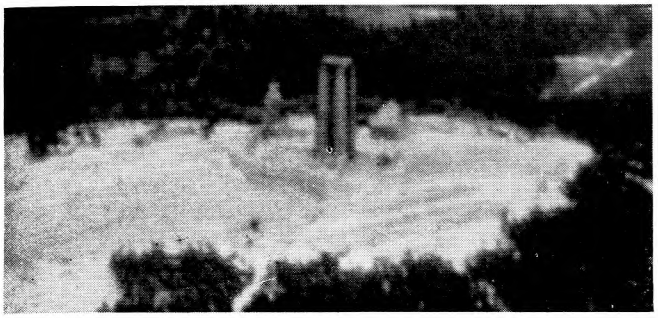
HILL 880

ALLIES TURN IT INTO "RADAR HILL" IN ONE OF ETO'S FINAL ACTIONS





Gee jamming station on Hill 880 as photographed (above and below) by 9th AF Photo Recon Group prior to Allied bombing



All that was left after the 1000-pounders fell is shown below. Thereafter Hill 880 was no more; Allies made it into Radar Hill



Bad Homburg once lured the burghers of Frankfurt and Mainz to picnic outings in the summer, to winter sports when snow fell. In the snows of last winter the hill was put to other uses; the Jerries set up a jamming station there to disrupt GEE navigators of the USAAF and RAF. What happened to the jammer, and what happened on the hill when Allied forces moved in, put a neat cap on the closing days of the radar war on the Western Front.

When action started on Bad Homburg, it was known militarily as Hill 880. Before action ended, Hill 880 was known for miles around as "Radar Hill" and with good reason.

Attention was first directed to the hill shortly after some extremely effective and annoying interference in the operation of Gee navigation began on 7 January 1945. The interference was in the form of unlocked pulses which moved across the time base of the Gee receiver, greatly hindering the ability of the operator to obtain accurate fixes. It was causing considerable trouble to all planes using continental Gee chains.

The interference was soon established to be of enemy origin. When it grew so bad as to reduce effectively the success of operations by units relying entirely upon Gee—among them the 155th Night Photographic Squadron of the 9th AF—the decision was made at Air Staff SHAEF to take offensive action.

So a smooth little team play was called to do the job. The RAF 72nd Wing, which operated the Gee ground stations, was able to obtain a three station fix on the source of the interference. After checking and rechecking, the 72nd Wing stated:

". . . it appears that the enemy jammer is probably on the high ground near Frankfurt, and the most likely location is Bad Homburg, an 880 meter peak N. W. of Frankfurt."

The next step was undertaken by the 10th Photo Reconnaissance Group of the 9th AF, which obtained vertical and oblique aerial photographs (see opposite page) showing a large tower and other buildings on the crest of Hill 880.

Copies of the photographs, along with an order to destroy the target, were passed on to XIX Tactical Air Command on 26 February. But things were happening in quantity those days and the mission couldn't be scheduled until 3 March. The RAF 72nd Wing was notified of the attack. They were observing the interference on their Gee scopes as it came off.

The attack was made by twelve P-47 Thunderbolts, each carrying two 1000-pound bombs. Reported the leader:

"Fifteen direct hits. Target ⅔ destroyed. Column of smoke and flame 1000 feet high from building north of tower, strafed after attack."

The 72nd Wing reported the interference ceased abruptly at the time of the attack. And it didn't start up again. Aerial assessment photographs showed the tower badly smashed.

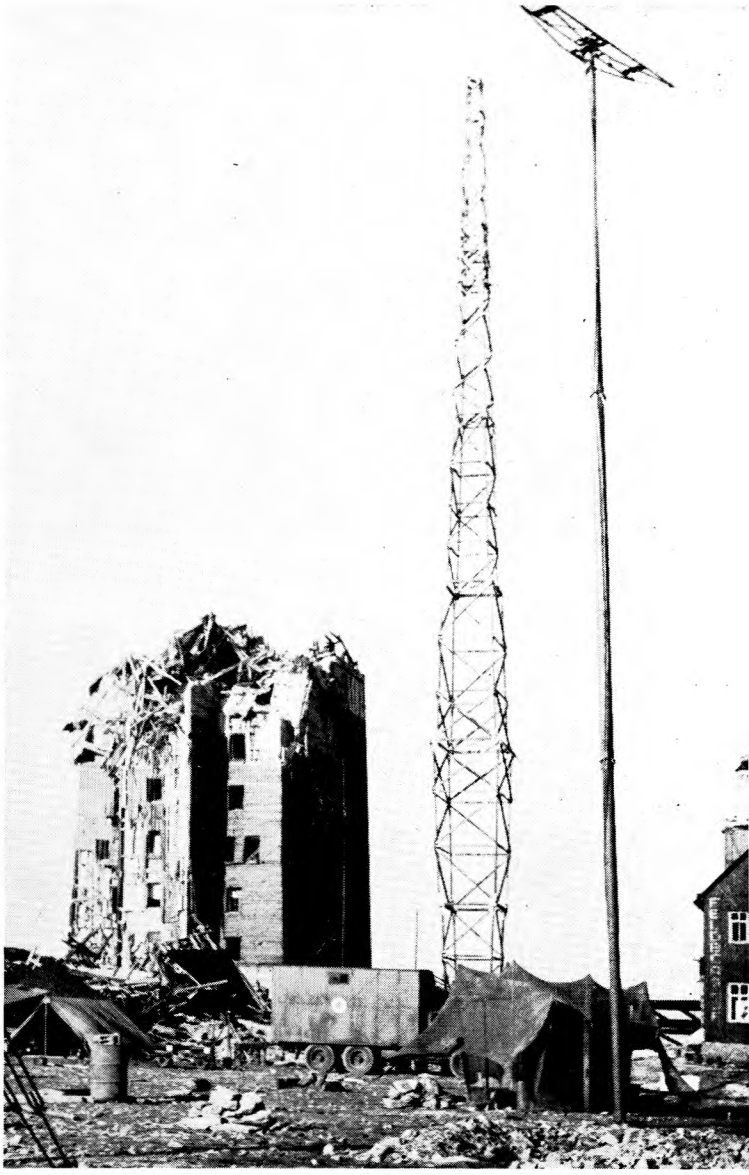
Shortly after the attack Frankfurt and surrounding territory were captured by the U. S. 3rd Army, and detailed examination was made of Hill 880. Most of the installation was blown to bits, particularly the units in the top of the tower, which sustained direct hits. As a result, the 9th AF began referring to the P-47 as an "anti-jamming device."

While this was going on, and quite independent of it, the siting officers of a number of U. S. and British radar outfits had become aware of Hill 880. They had their eyes on it as a likely location for Allied radar long before the ground forces reached the Rhine. Its location just east of the Rhine, plus its height, made it ideal for radar beacons.

And so, one day a few weeks after Jerry's Gee jammers had been knocked out, an RAF crew came to Hill 880 and on its top started putting up a Gee transmitter. This was highly fitting. More to the point, it considerably extended the coverage of continental chain Gee fixes over Germany.

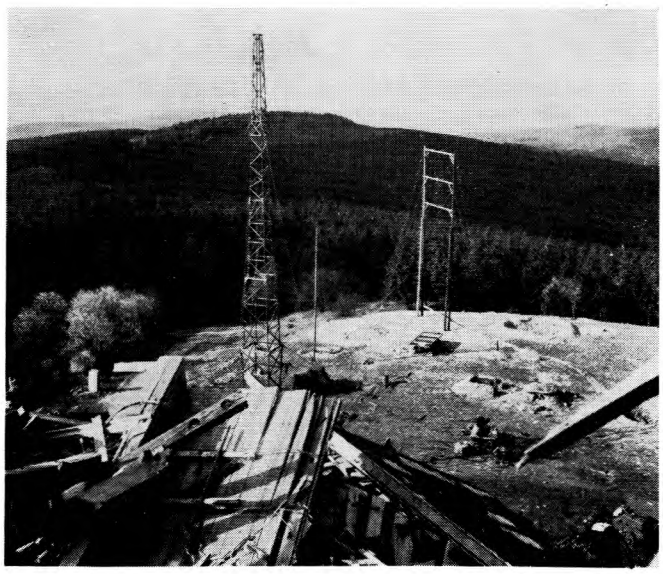
Then ground transmitters for the Oboe blind bombing system were brought in, to serve U. S. and British medium bombers. Then came Shoran beacons, to service the navigation and blind bombing operations of 1st TAF's medium bombers in the veteran 42nd Bomb Wing (see page 47).

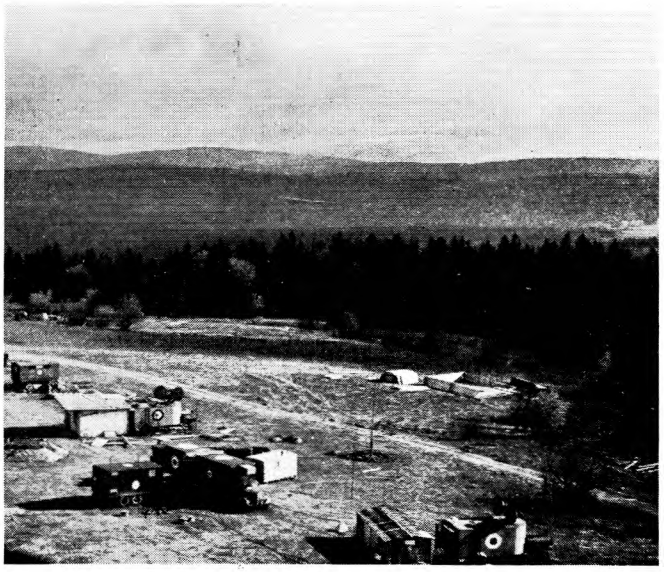
Each of the radar installations was complete with radio transmitter and receiving stations. There was also a 9th Air Force FM relay station. And in spite of the bewildering welter of antennas, only relatively minor mutual interference was reported. With all the equipment working, with the leading navigation aid and the hottest bombing aid there, Hill 880 was a little monument to Allied radar as war ended.



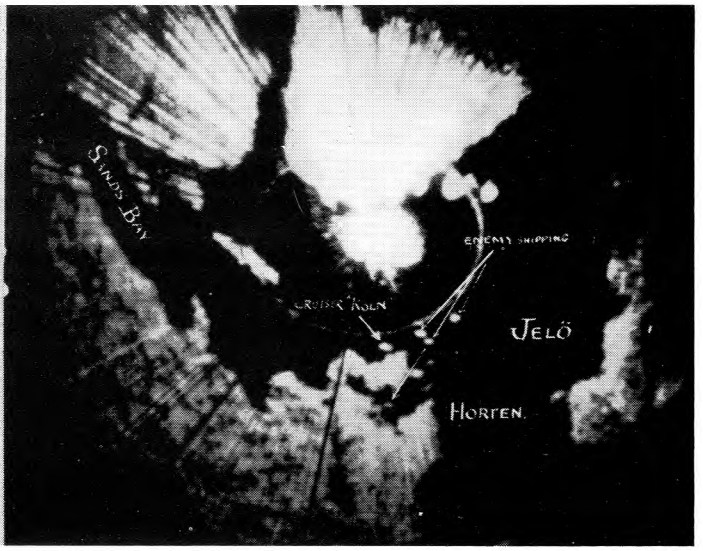
Beside shattered German jammer and research station Allies put up Gee and Shoran antennas (above), moved in truck-mounted reflectors of Oboe's transmitter layout (below), set up radio links

100-foot mast for Gee transmitter stands near bird cage antenna strung on 2 wooden poles and left behind by the Germans. Allied radar people who examined it weren't sure what it was for









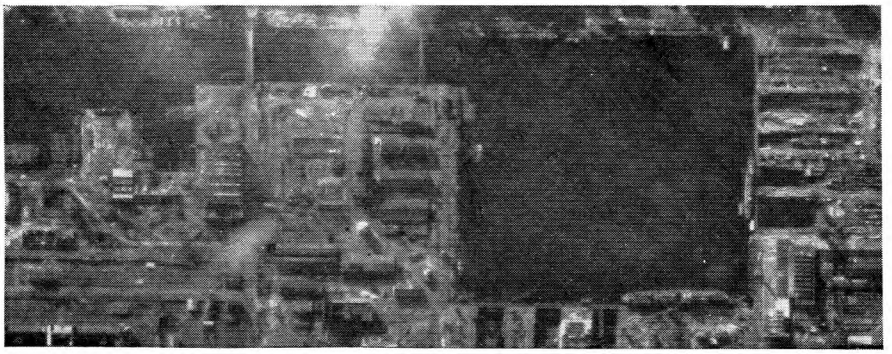
GERMAN CRUISER KOLN WAS IN NORWEGIAN WATERS LAST DECEMBER WHEN RAF BOMBERS TOOK ABOVE H_2S PHOTO IN NIGHT ATTACK

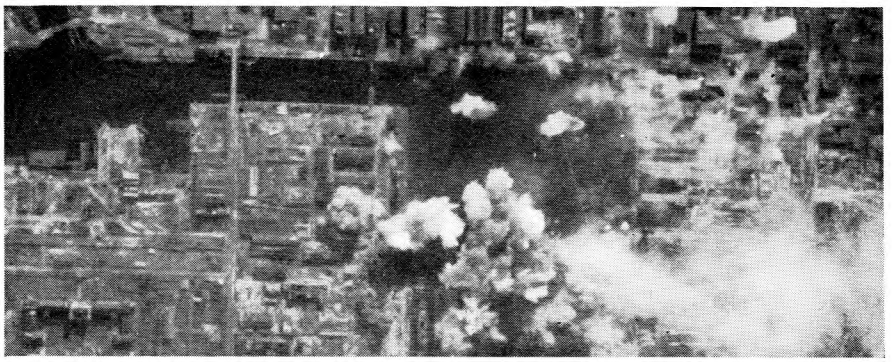
KOLN KILL

Among German targets that Allied air power hit again and again was shipping. Methods used were effective enough so that, toward the end of the war, enemy naval craft had almost disappeared from the scene. It was a lucky day for the bombing crews assigned on a regular mission over Wilhelmshaven at the end of March, when they looked through a hole in the clouds and saw the Koln, a cruiser carrying 6-inch guns.

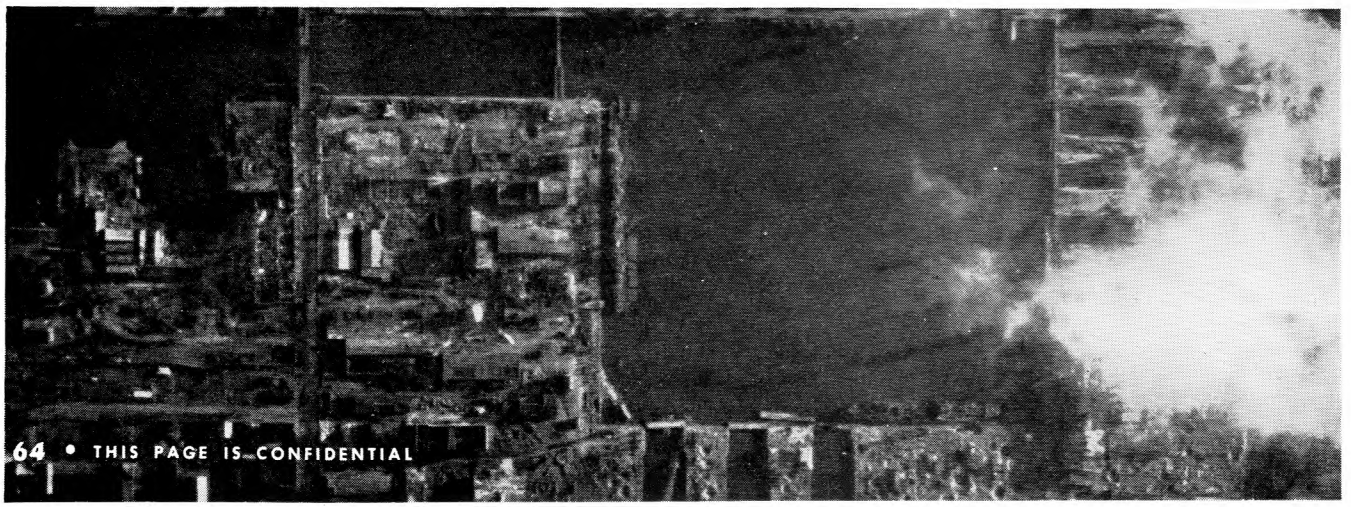
What it was doing there (it had been operating in Norwegian waters) nobody knew. What they cared about was hitting it, and hit it they did. It was an H_2X-visual attack through 6-9/10th cloud cover. This combination was not unusual for Wilhelmshaven, where intense and accurate antiaircraft fire made overcast missions desirable, and where the sharp appearance of the harbor on the H_2X scope made the city more readily identifiable than most.

The attack was carried out by 358 B-24s from the 8th AF's 2nd Air Division. They dropped 239 tons of GP.





Three months later when 8th AF attacked Wilhelmshaven, the Koln was sighted again (above, at harbor's left). This time she was bombed (center) and damaged (below)





RADOME MOUNTED ON NAVY TBM HOUSES BIG DISH ANTENNA OF AN/APS-15 DESIGNED TO INCREASE DETECTION OF SCHNORCHEL IN ROUGH SEAS

SCHNORCHEL WORKED

When Admiral Doenitz called in the German submarines last month, he halted operation of what was conceded to be the enemy's most effective countermeasure to search radar. This was Schnorchel, the "breather" that enabled U-boats to stay under water while recharging batteries. That Schnorchel may reappear in the Pacific on the subs of the Imperial Japanese fleet is a continuing possibility, although right now US Navy experts discount its use there.

It is no wonder that radar found it difficult to locate Schnorchel. In operation it showed up only as a vertical pipe 16 inches in diameter, extending 2-3 feet above water with a float and radar intercept receiving antenna (ineffective against long wave) mounted on top. As compared to a surfaced U-boat, which is about 250 feet long and rises 5 to 20 feet above water, this was a pretty small target. What's more, using Schnorchel, U-boats could stay under water as long as crews could stand the discomfort.

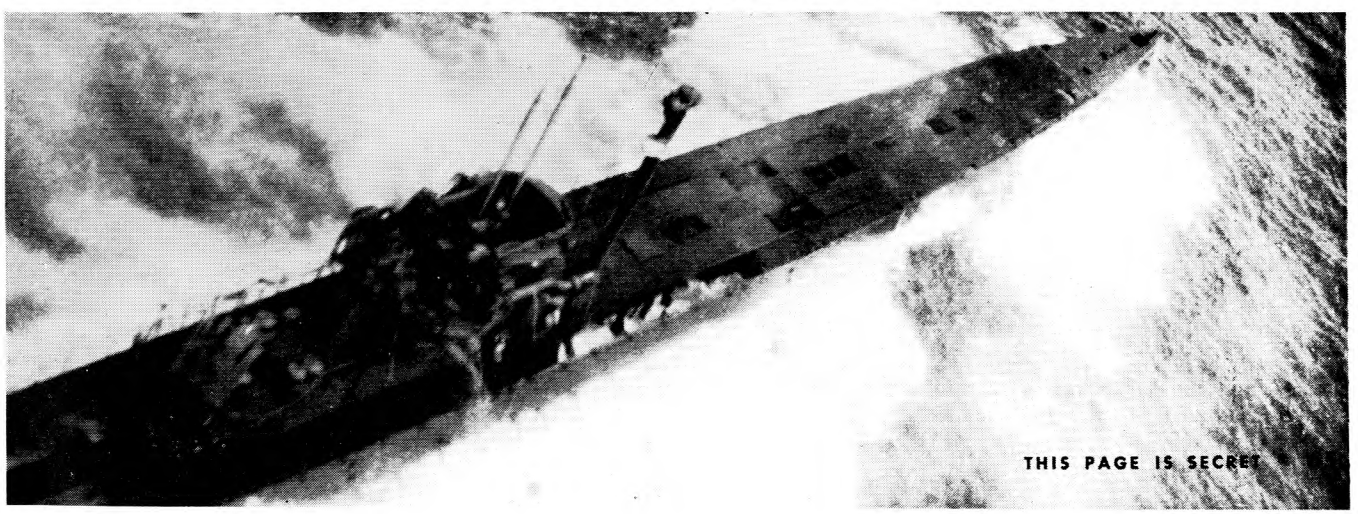
While a Schnorcheling sub had less speed and mobility than a surfaced sub, it was able to proceed at 4 to 6 knots, about twice the cruising speed of a totally submerged sub. And although it was in a poorer position to detect the approach of an enemy, it dictated new tactics that compensated for these losses —at least in the beginning. There was more hide and less seek; subs played safe by remaining underwater and operating where shipping was heavy.

As a measure permitting operation in shore waters from which the U-boats had been driven early in the war, the system worked. Such inshore operations became strategically necessary after the landings in Normandy. And as more and more German subs got Schnorchel through the summer and fall of 1944, Allied air patrols made fewer kills and there was a rise in Allied shipping losses. Whereas in June the RAF Coastal Command operating around the UK sighted a sub for every 311 hours of flying, by August this figure was 859 hours and by January, about 1000 hours. The number of patrolling U-boats was apparently about the same.

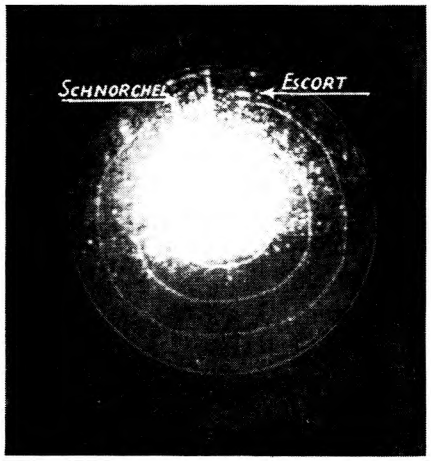
Through the last half of the year, as the number of U-boat sightings by aircraft fell off, the *proportion* of Schnorchel sightings increased—from 19% of total sightings (52) in July to 68% of the total (20) in January. Of the 60 Schnorchel sightings in this period, 48 were visual and 12 were by radar (previously—in 1943—the ratio of radar to visual approached 50 per cent). Visual sightings predominated for 2 very good reasons. One was exhaust "smoke" and the other wake, both dead give-aways for visual detection but not for radar.

Schnorchel alone was so small that in order to get it on the radar scope at all, aircraft had to be operating at comparatively close range (average

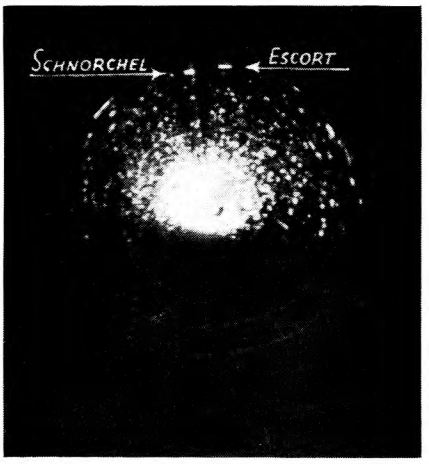
FULLY SURFACED U-BOAT, HERE BEING STRAFED BY ALLIED PLANE, SHOWS UNDERWATER AIR VENT, SCHNORCHEL, PROTRUDING AT RIGHT CENTER



THIS PAGE IS SECRET



Schnorchel cannot be distinguished from sea clutter on this APS-15 scope



FTC (Fast Time Constant) anti-sea-clutter circuit makes the blip easier to see

sighting was 5-6 miles, about one-third that for a surfaced sub). Even the fact that it was on the scope did not necessarily mean that it would be seen. At such short range, unless the sea was very calm, sea return was apt to blot out a Schnorchel blip up to 3 or 4 miles. And if the operator did see the blip it was possible that it would disappear in the run over the target or as the Schnorchel pitched and rolled. The rougher the sea, the more likely all this was to be true.

In the beginning, air search for Schnorchel over rough seas was an academic question, since Schnorchel itself was not used in rough seas. But toward the end of the war, U-boats were Schnorcheling in most kinds of sea.

Even before camouflage, Schnorchel was extremely effective as a counter measure to radar. But the Germans gilded the lily. They coated the Schnorchel with a rubber-like or plastic substance to reduce further its reflecting qualities. This ridged covering weakened the echo response and the effect was heightened by careful shaping. Against the right wave length (S-band and just possibly X-band) it may have cut down the range as much as 50%.

If the war had lasted longer, radar might have begun to reassert itself against the U-boat. In the laboratory ways and means were being found to spot Schnorchel. More suitable equipment was being developed, and new search techniques recommended. More important, operators were getting training and experience in recognizing small bobbing targets and following them.

Tests conducted by the Navy's Anti-Submarine Development Squadron, Atlantic Fleet, against a mock-up Schnorchel demonstrated that X-band radar gave greater range and got more contacts than S-band. Out of the trials also came recommended altitudes for search, and probabilities of detection depending on the state of the sea. Results, expressed in round numbers by Operations Research Group of CominCh, were:

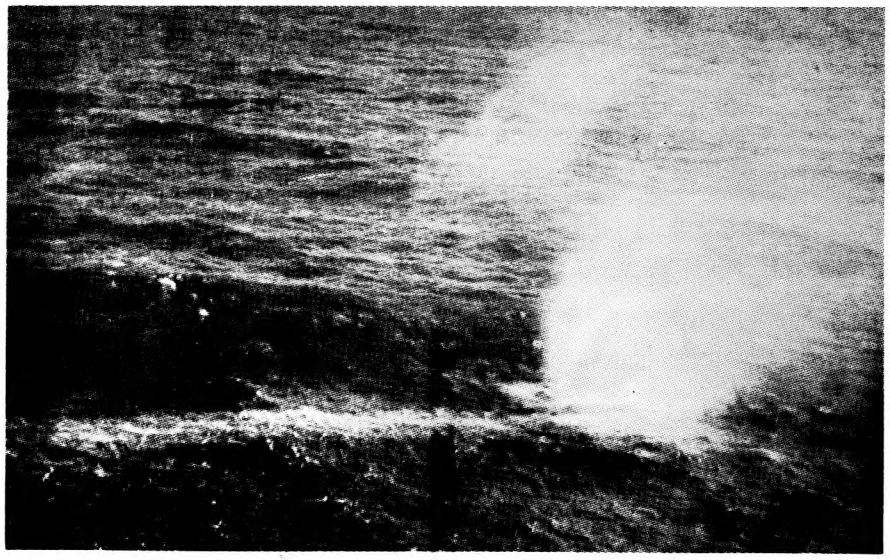
	SEA STATE		
	Smooth	Slight	Moderate
APS-2 (S-band)			
Height (ft)	500-1000	300-600	200-500
Range (mi)	5	4½	4
Prob. Detect.	90%	75%	60%
APS-15 (X-band)			
Height (ft)	500-1000	300-600	200-400
Range (mi)	10	9	8
Prob. Detect.	100%	75%	60%

The development of a short pulse width AN/APS-15 fitted with an oversize dish (8 feet wide) to provide higher resolution was being completed just about the time Doenitz called in his submarines. Some of these sets, installed on TBM Navy carrier-based planes, are ready in case the Japs do use Schnorchel.

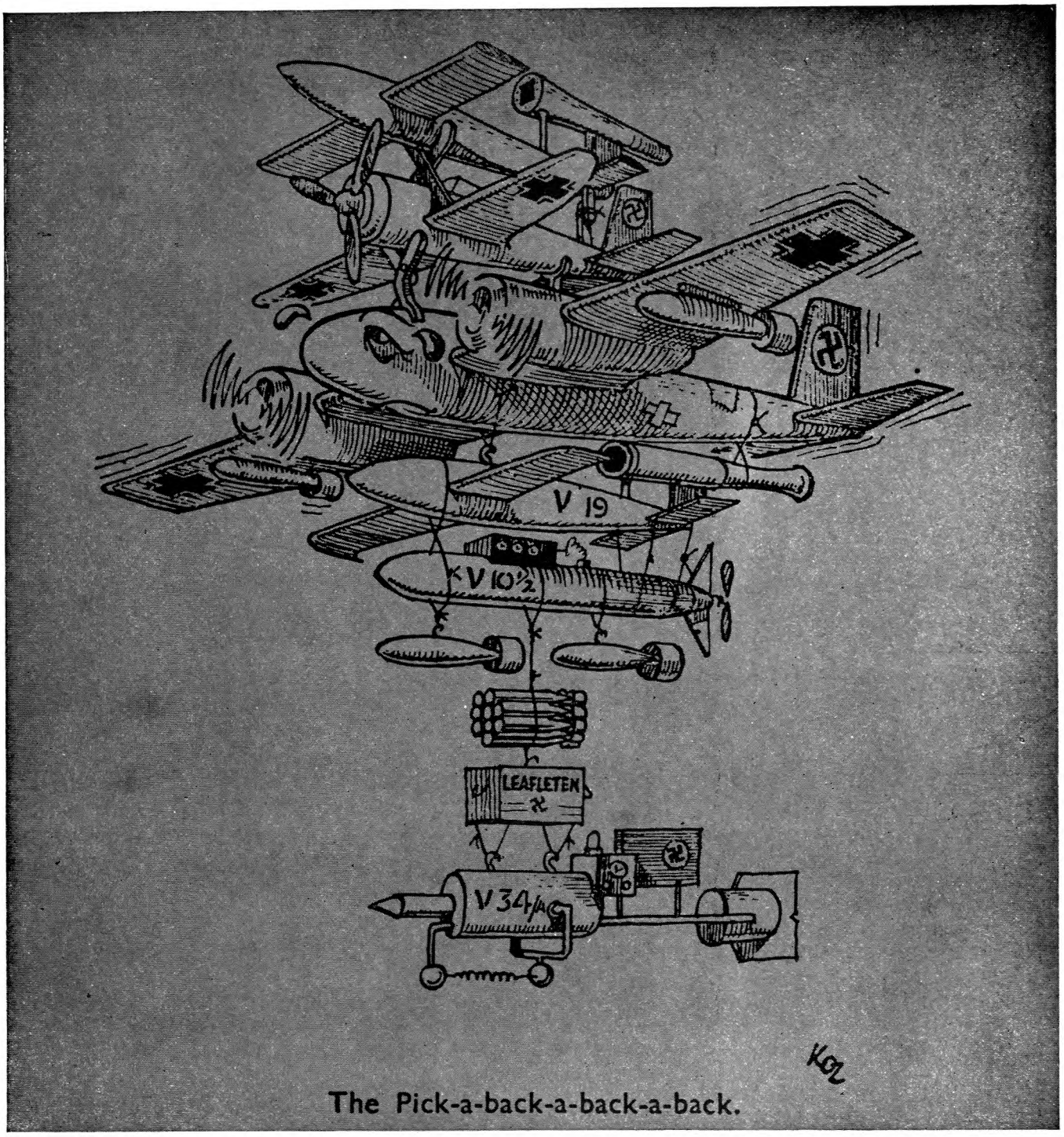
Experiments were also conducted with special anti-sea-clutter filters. Fast Time Constant circuits were developed to allow the stronger signal from Schnorchel to stand out recognizably from the fluctuating wave signals. Before the ETO war ended, anti-sea-clutter kits were being assembled for spot installation.

Actual search experience using sea return eliminators, as well as higher resolution radars, has been limited. Some RAF operators assigned to AN/APS-15 said they preferred S-band. Others using sea return eliminators for the first time reported that the eliminators scattered the sea return and actually made it look like Schnorchel signals. The extent to which these early reactions came from natural resistance to new and more complicated equipment, from lack of training and experience, is not known.

In any event, airborne radar countermeasures against Schnorchel had little operational value before VE-day. Just as soon as it was discovered that U-boats were concentrating their activities in smaller areas, surface craft went to work. Using sonar devices and sightings by both air and shipborne radar, and covering 30 square miles an hour, they knocked out an average of a submarine a day the last month of the war.



Steam and spray above the water, resulting from hot exhaust released below surface, gave visual evidence of the presence of Schnorcheling subs; but radar couldn't see it



The Pick-a-back-a-back-a-back.

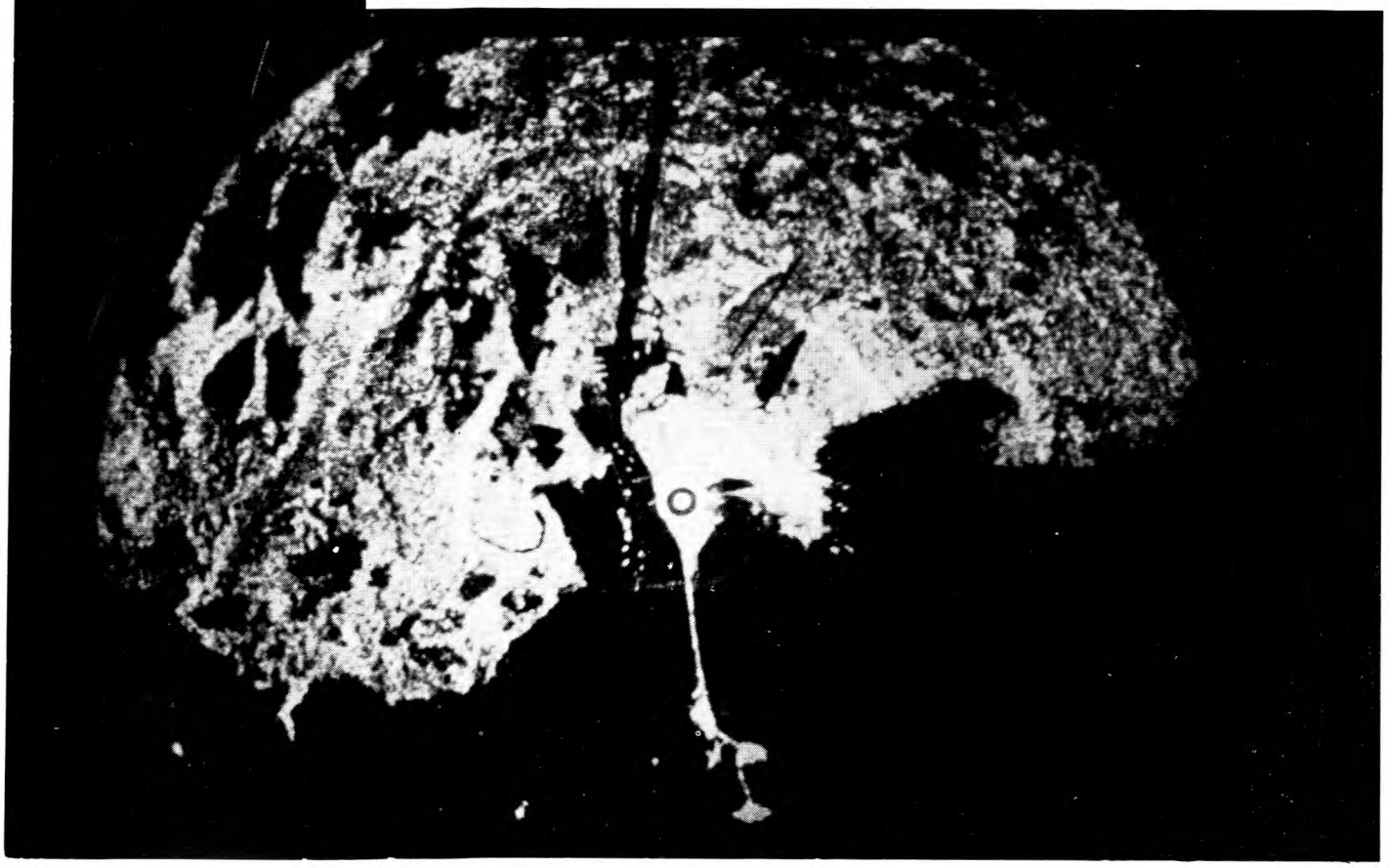
Led by a Pathfinder force of pressurized Piper Cubs, the 711th AF (Very Light) knocked out Bad Erewhon, Germany, in the final raid of the ETO war. An armored division of technical consultants, forcing entry into the unique bastion (built entirely above ground for deception purposes), found that Bad Erewhon housed the long-sought experimental center in which the Germans were readying their newest secret weapon. RADAR correspondents attached to the Division managed to get a blueprint of the new weapon past the Divisional Security Officer by holding it upside down. It appears above, right side up and in a high state of suspension.

It is not known whether the Germans had been able to get in production on actual models of the new weapon. Said one of the technical consultants: "It is a very complex device and therefore would have proved an extremely effective addition to the enemy's repertoire of the matériel." Pending detailed examination, technicians would say no more than that the design reflects an ingenious application of U. S. principles of aerodynamics, particularly as found in the mounting of radar antenna structures on U. S. planes.



K-BAND

With K-band, radar about reaches its present operational limits. At this frequency, the price paid begins to outweigh results—K-band resolution is the best yet but attendant limitations are great. Ranges of 50 miles are obtained only when weather is good and water vapor content low—a healthy rain and K-band is done for. As a general purpose equipment. K-band radar just doesn't pay off. As a specialized addition to existing sets, it might have exensive possibilities. Taken on a laboratory model from 1500 feet, these photographs show the Panama Canal—busy waterway for redistribution traffic. Above is Atlantic entrance; below, the Pacific.



FERRANTI Defence Systems Limited

RADAR

Issue No. 11 SEPTEMBER 1945

INTRODUCTION



R.P.F. Lauder
Engineering Manager
Product Support Department

The war is over, the peace treaty has been signed and the editorial staff of this volume know that it is the last issue. But there is no sense of deja vu, no backward glance, because new and exciting things are still going on in radar science, and they want to pass on this "hot" information to the troops.

Until now, it has always taken two radars to measure azimuth, elevation of the target (i.e. height) and range. The great ingenuity of the AN/CPS-6 with its V-beam is that it reduces the measurement of elevation to two measurements of azimuth. As the V-beam, with one of its beams vertical and the other at 45°, sweeps through a target aircraft, the horizontal distance between the beams is equal to the vertical height of the target to the ground by the very simple geometry of the system. Height is extracted as the range times a function of the delta angle of rotation between the two beams of the V. To avoid the difficulty of targets at very low elevation merging into the two beams at the base of the V, a fixed 10° separation is inserted so that theoretically a target at zero elevation can be observed. The two sails of the antenna are 25 feet by 10 feet. The vertical antenna is fed by three transmitters feeding a horn and a series of dipoles. The 45° antenna is fed by only two transmitters because its purpose is only to measure height leaving the more powerful vertical beam to measure range.

In the introduction to Vol.10 we were promised three articles on the Eagle radar. However, the editors were not to know that the war was to end and that they would only produce one more volume. As a result, this volume has a comprehensive description of the fabrication, assembly, polar diagram and environmental test of the Eagle antenna. Regrettably we are given no pictures of the polar plot because it would have been very interesting to see what the side lobe level was like in the azimuthal plane. However we get a good idea from the picture at the bottom left hand corner of page 38, particularly when compared with the best which the APQ-13 could do in the same location on the bottom right hand picture of the same page. The plus and minus 30° seems to be slightly asymmetrical. There are also signs of slight banding on the radar map. This may have been slight spoking due to interference from some other on board equipment, but the match with the real map is so good that the angular movement of the beam with the variable width guide must have been very exact.

In the early volumes of this series it was considered almost magical that a radar map was produced at all. Yet now, a mere 17 months later. the niceties of scope distortion are being criticised. It is now realised that the same land feature will be differently displayed by the radar by approaching it in two directions at right angles to each other. The low frequency transmitters in use are fed to antennae which cannot be made large enough in terms of wavelengths, to achieve an azimuthal beamwidth capable of fine resolution – the Eagle antenna apart. This means that range resolution is still superior to azimuth, leading to the feature mentioned above.

None of the airborne radars described in this series was roll stabilised. This meant that the radar, and more importantly, the antenna rolled with the radar. In ground mapping terms, this meant that, during roll, the point on the ground directly beneath the aircraft, which was the centre of the map, swung out many hundreds of yards during aircraft roll. This produced quite large map distortion with quite modest angles of roll. This was not particularly important for navigation to the target but was of first order importance in the blind bombing run. Fortunately the bomb aiming equipment in use at the time required the bomber to steady into his final run with wings level.

Ferranti's airborne radars have always been roll stabilised to cope with fully aerobatic flight. In the connection between transmitter and antenna, two rotating joints are inevitable for the azimuth and elevation movement of the antenna. Roll stabilisation would imply a third joint. In high power systems, the number of joints in the high RF power path should always be minimised since they represent a weak link in the waveguide path. Ferranti has always mounted the transmitter on the roll shaft so that the third joint is eliminated.

Ferranti salutes these men who brought the excitement and challenge of the radar art so vividly alive in these historic pages.

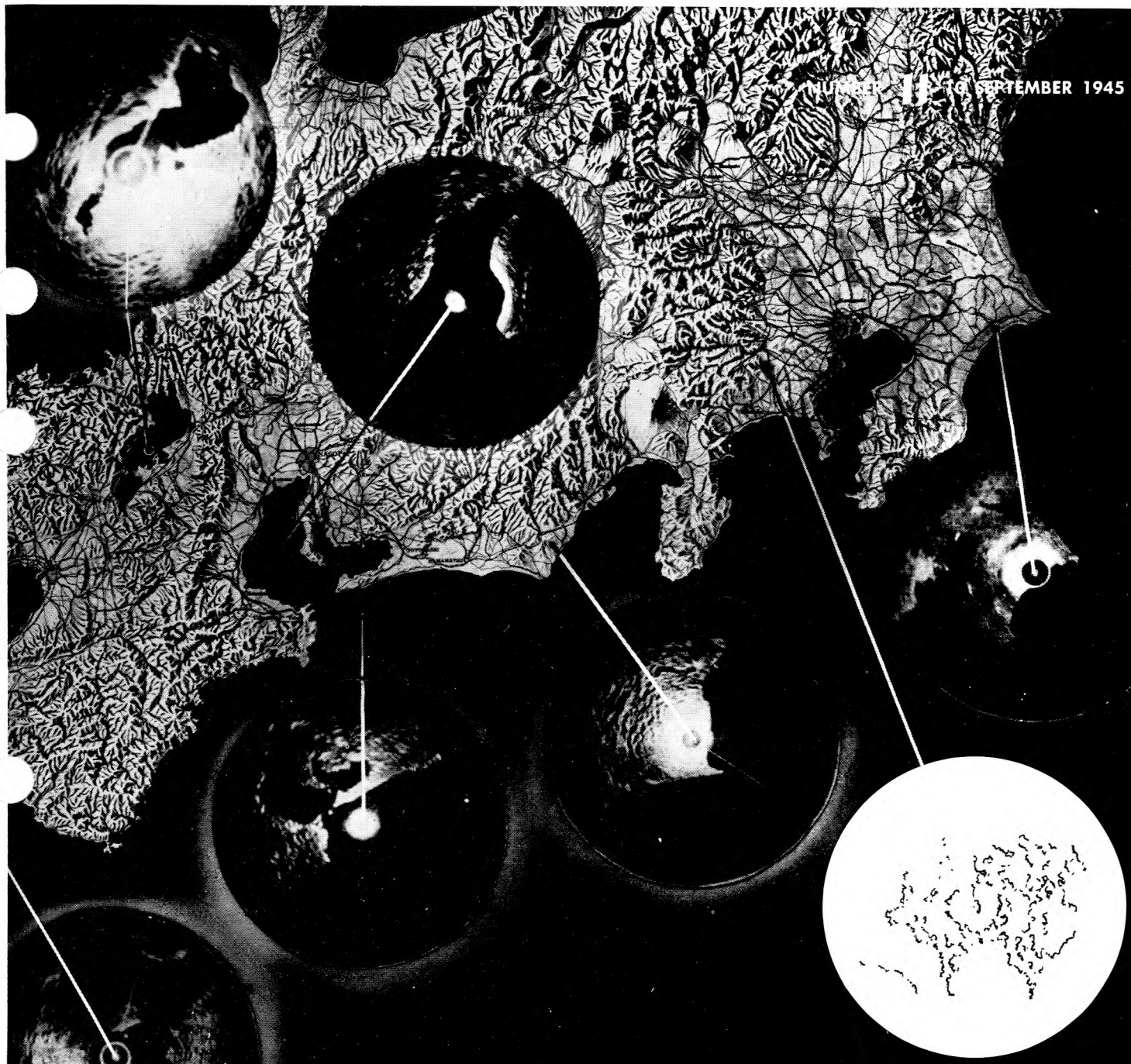


COMED

Ferranti's Combined Map and Electronic Display provides the pilot of the fast low-level aircraft with a moving map of the terrain beneath, superimposed with a variety of electonic cues, or matched radar map.

Product Support Department
South Gyle Industrial Estate
Edinburgh EH12 9EA
Tel. 031–337 2442 Telex 727896

NUMBER 1 TO SEPTEMBER 1945



RADAR

RADAR

Number 11 10 September 1945

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EDITOR: Dexter Masters, Office of the Air Communications Officer.

CONTRIBUTING EDITORS: Dr. Dale Corson, Glenn Fowler, Dr. L. J. Henderson, Dr. L. C. Marshall (Oahu), Col. P. C. Sandretto (Guam).

EDITORIAL ASSOCIATES: Avis Clarke, Ruth Copland, Lt. Norman R. Goldman, Lucie Sewell, Lt. Henry Sharp, Lt. Robert Wright.

CORRESPONDENTS: J. Alexander (Guam), Lt. John Caldwell, Lt. Robert Carlson; Roger Powell (India-Burma), Talbot Waterman (Manila).

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ADVISERS: Dr. Edward L. Bowles, Special Consultant to Commanding General, AAF; Dr. Lee A. DuBridge, Director, and Dr. Louis Ridenour, Radiation Laboratory, Massachusetts Institute of Technology.

Printed with the approval of the Director of the Bureau of the Budget

RADAR closes shop

With this issue RADAR, its job done, closes shop. Its mission, as stated at the start by Maj. Gen. H. M. McClelland, who directed its activities, was "to improve the tactical and operational use of radar equipment among Air Force personnel, thus to increase the AAF's fighting effectiveness."

This mission was carried out for 17 months, until it was completed with the war's end. It started early in 1944 while a flock of radar systems—chiefly airborne, just coming into their own—were being rushed from laboratories and factories into combat. Out in the theaters there was plenty of radar educating to do. Many men were skeptics and some were being newly introduced to the meaning of the word "radar." Others wanted to know what was being readied, what to request in line with specific needs and how to use what was requested. So RADAR, filling a unique and urgent role in the AAF, had its hands full.

At the beginning it concentrated on the basic educational need. It told for the first time what was going on in the secrecy of the laboratories. It explained what AAF radar was designed to do and, when results were available, how well it was doing it. Later it kept the field abreast of new systems and developments. MEW, GCA, Shoran, Loran, Eagle, enemy radar, countermeasures and many other subjects occupied its pages. And it spoke a language that everyone from commanding generals to maintenance men understood.

RADAR sent its reporters and photographers into many places where radar information could be located. Civilian scientists in U. S. laboratories and world-wide theaters lent a hand. Its offices in the Pentagon became a port of call for radar personnel in from the field and a clearing house for reports of radar at work.

Though RADAR stuck to its AAF chores, it proved useful to other services. The British, who in 1940 had pooled their radar knowledge with ours, requested and received a big allotment. Navy requests accounted for some 25% of the press-run. The Marines, RCAF, RAAF all got a supply.

Coming in cold, RADAR's editor and staff profited by help and inspiration from many channels. To all who have helped RADAR along the way, to its readers who by their interest in its pages have helped it realize its mission, our thanks and well wishes.

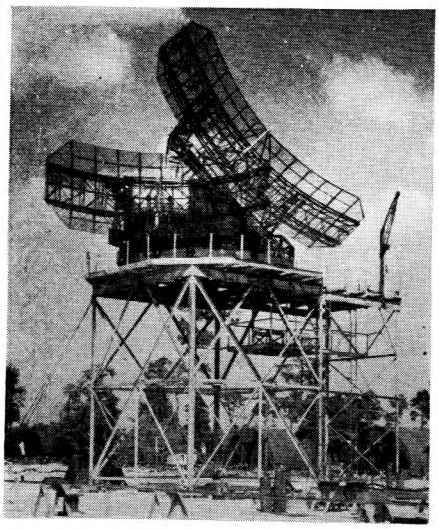
While we're on the subject

● Radar is taken so much for granted today that the wide-spread skepticism and all too common misapprehensions of a scant two years ago are almost completely forgotten. Here are some quotes from Intelligence interviews with U. S. officers and EMs in 1943, who obviously felt that radar wasn't here to stay:

"In recent weeks", stated a Lt. Col., "the German Army has developed a rocket bomb which has rendered our famed Radar completely worthless. This bomb is released from a plane and after a period of approximately ten seconds is exploded. This explosion fills the air with long streamers made of foil and metal. The streamers are about 24" in length and ¾" wide. As these float earthward the air is blanketed with them setting up a magnetic field which attracts the radar

CONTINUED ON PAGE 50

Carousel control: V-beam



AN/CPS-6 antenna sails, cab and mount are set up for operation on 25-ft. tower

It's ready, waiting for a peacetime job

Fanciest and newest of the fancy new radars is V-beam. Built to adapt itself to anything from early warning to the more sophisticated forms of ground control, at the war's end it had just reached the ready-to-go stage. Now it's waiting to be cast in one of radar's peacetime roles—traffic control—probably in the general area of the Japanese Islands, possibly in the U. S.

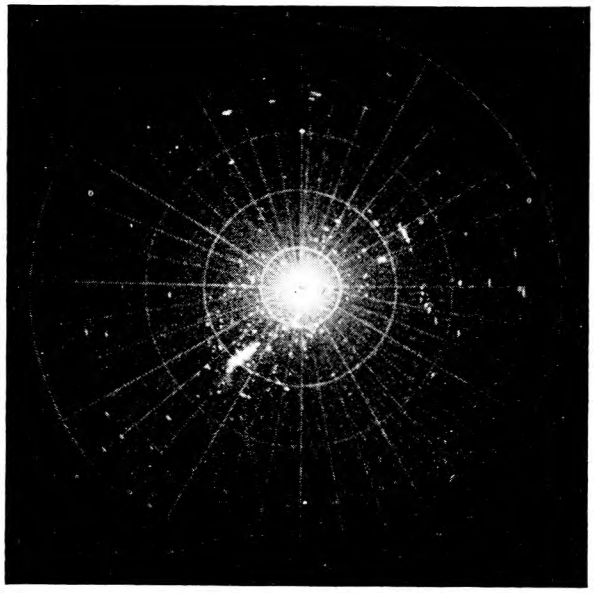
Besides the dismembered V-beams, waiting in crates for a trip to the POE, there are two installations set up for training. At Camp Pinedale, the Air Warning Training Unit Center in Fresno, the 427th and 429th Fighter Control Squadrons, which were to take the first two sets to war, are just putting the finishing touches on an operational technique learned first at Orlando.

The AN/CPS-6 keeps most of the best features of other control centers, and incorporates a new one. It is equipped to act as its own heightfinder. To accomplish all this, two cut paraboloid antennas ride around on the V-beam's merry-go-round mount. Together they carve out the remarkable coverage pattern shown above. The horizontal sail forms the energy fed into it into three vertical beams, extremely narrow in azimuth, which make up what is equivalent to a single vertical fan-shaped sheet of energy extending up as high as 35,000 feet and out to nearly 170 miles. This is the beam which gives range and azimuth data.

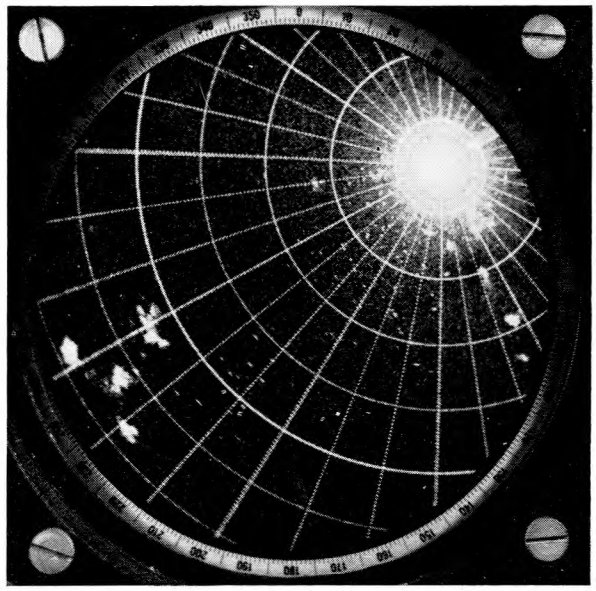
Signals from these three lobes are mixed in the video, and thus fed into the battery of PPIs and B-scopes. When the vertical mixed video is presented, the set can see a group of B-17s flying at 25,000 feet out to just about 170 miles. For early warning, the lower vertical beam only can be switched on —making the B-17s visible to about 195 miles.

The slant sail's two beams form another sheet of energy, narrow in azimuth, and tipped at 45° to the vertical sheet. This beam can pick up a P-51 at 70 miles, and at more than 25,000 feet.

These two main beams together make up the "V" part of V-beam. The first step in heightfinding is to measure the angle of rotation through which the merry-go-round sweeps the beams between the interception of the target first by the vertical and then by the slant



V-beam PPI presents air activity. Large signal at 220°, 15-25 miles is forest fire. Signal shape tells wind direction



In sector enlarged by off-centering PPI controller vectors flight around signals (230-260°) of storm center

beam. Low targets make small rotation angles; high ones, larger angles. The distance of the target from the radar also affects this delay angle. Actually the two beams do not form an exact V at the set. A 10° lag has been inserted to facilitate measurement of the very small angles caused by low-flying aircraft.

V-beam's scope system is designed to make the most of the type of graphic angular presentation described above. The height indicator, a modified B-scope, is set up adjacent to a PPI, from which target areas are selected, and range and azimuth called out to the height tube operator. When the height indicator is oriented to a selected target, it presents a 10° sector of the PPI. Information on the tube comes just from the vertical beam until the slant beam is switched on.

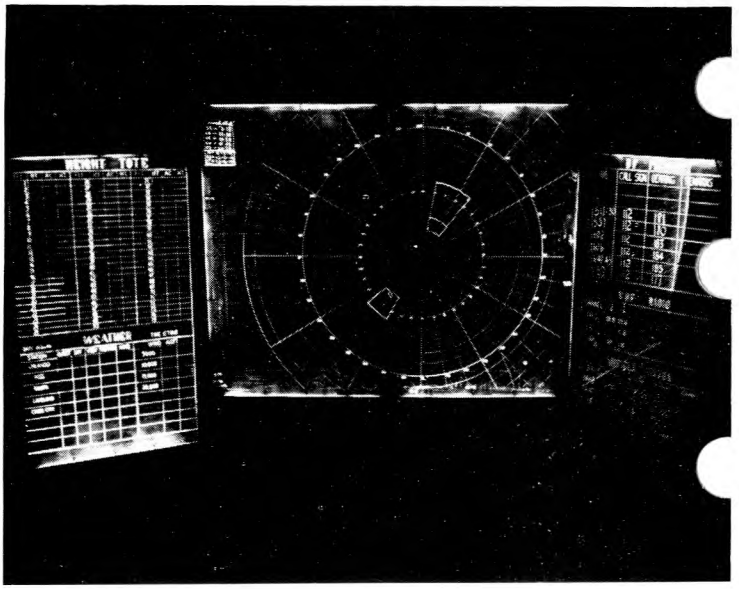
With both beams feeding information to the height tube, two signals show up for each target, one above the other. A movable scale is placed across the tube face, with constant height and index lines calibrated to solve the trigonometry involved in measuring the rotation angle and range information. When the lower signal is bisected by a height line, the upper signal will also be bisected; from the separation between signals the operator determines the target's height.

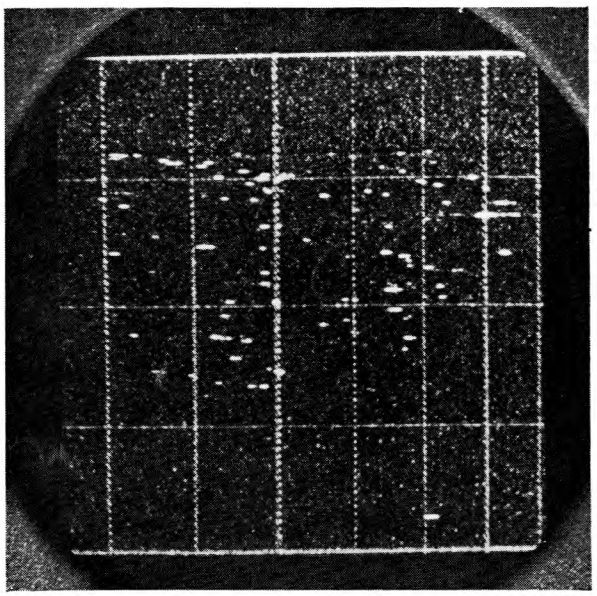
Although its heightfinding feature is V-beam's main claim to fame, it should prove to be an excellent all-round control center. It benefits—so far as operational layout and technique go—from MEW's long experience, but MEW still has an edge on it in some respects. The MEW is all set for MTI (moving target indication) and V-beam is not. Engineering MTI into the five beams of AN/CPS-6 is a long-range project. Also, V-beam may be transportable, but it's far from mobile. In its present state it could never get around the way the MEW does. For all that goes into a V-beam installation, see the diagram of a station layout on the following page.

Controllers and height tube operators sit forward in control shelter; liaison officers for AA, air-sea rescue, etc., rear

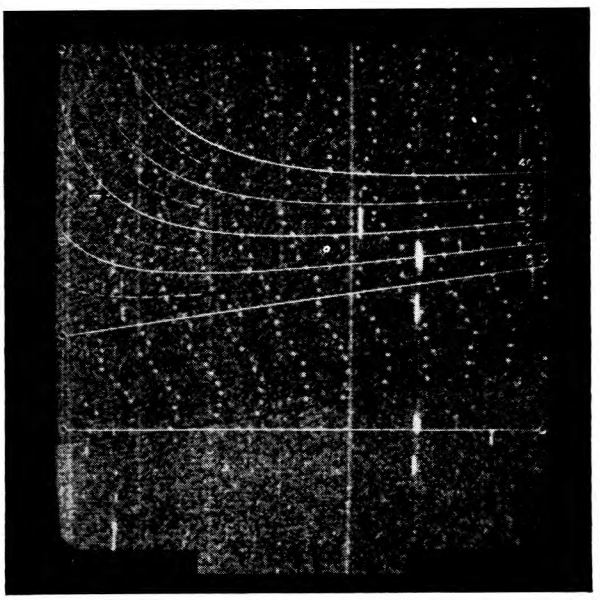


Beside vertical plotting board others show data on altitude, IFF response, number of a/c in flight; weather, field status, VHF

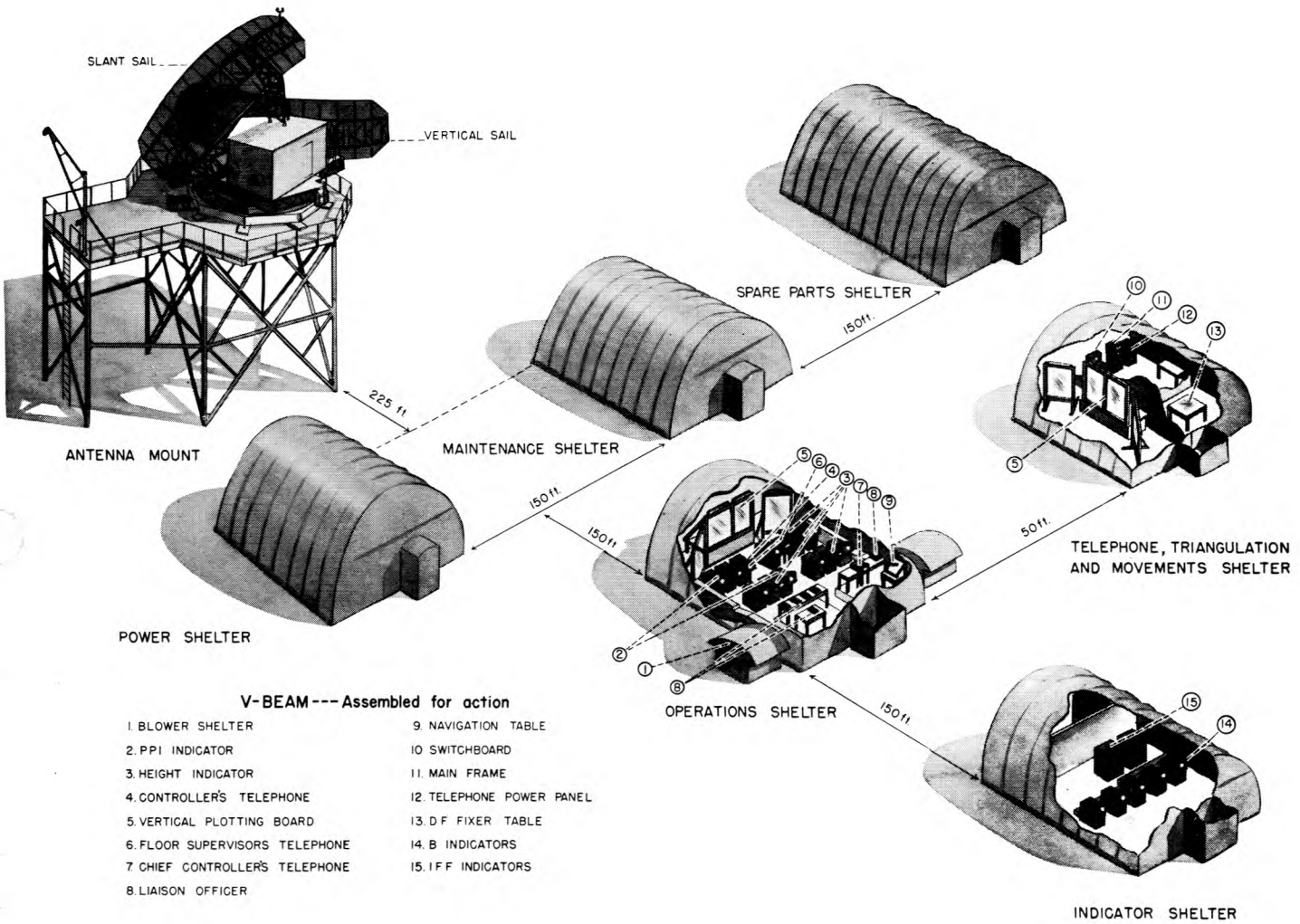




B-scopes are for reporting, can be set to cover special sector. Scope here has 10-mi. range, 10° azimuth marks

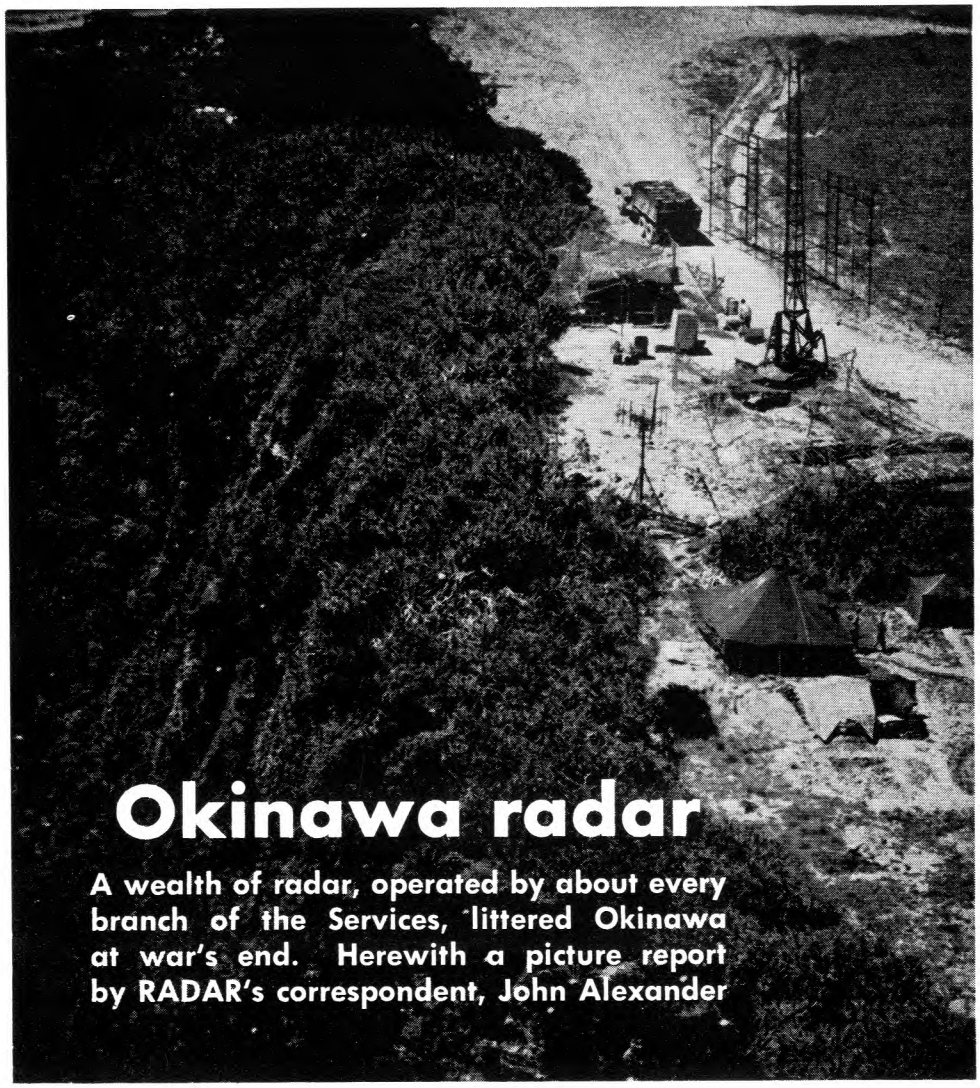


Height scope set for 10-80 mi. shows pair of a/c at 60 mi., 8000′; lower echoes from vertical, upper from slant beam



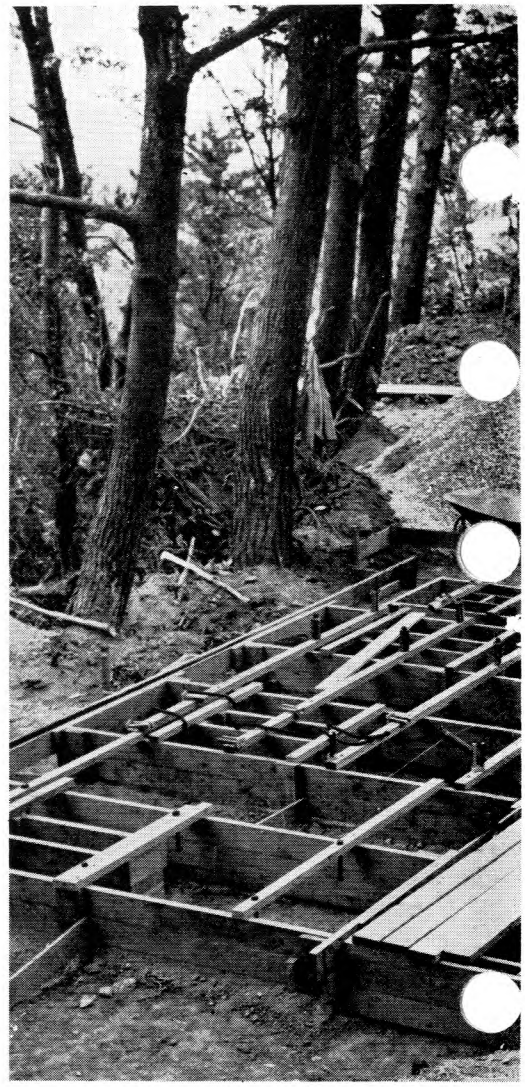
V-BEAM --- Assembled for action

1. BLOWER SHELTER
2. PPI INDICATOR
3. HEIGHT INDICATOR
4. CONTROLLER'S TELEPHONE
5. VERTICAL PLOTTING BOARD
6. FLOOR SUPERVISORS TELEPHONE
7. CHIEF CONTROLLER'S TELEPHONE
8. LIAISON OFFICER
9. NAVIGATION TABLE
10. SWITCHBOARD
11. MAIN FRAME
12. TELEPHONE POWER PANEL
13. D F FIXER TABLE
14. B INDICATORS
15. I F F INDICATORS

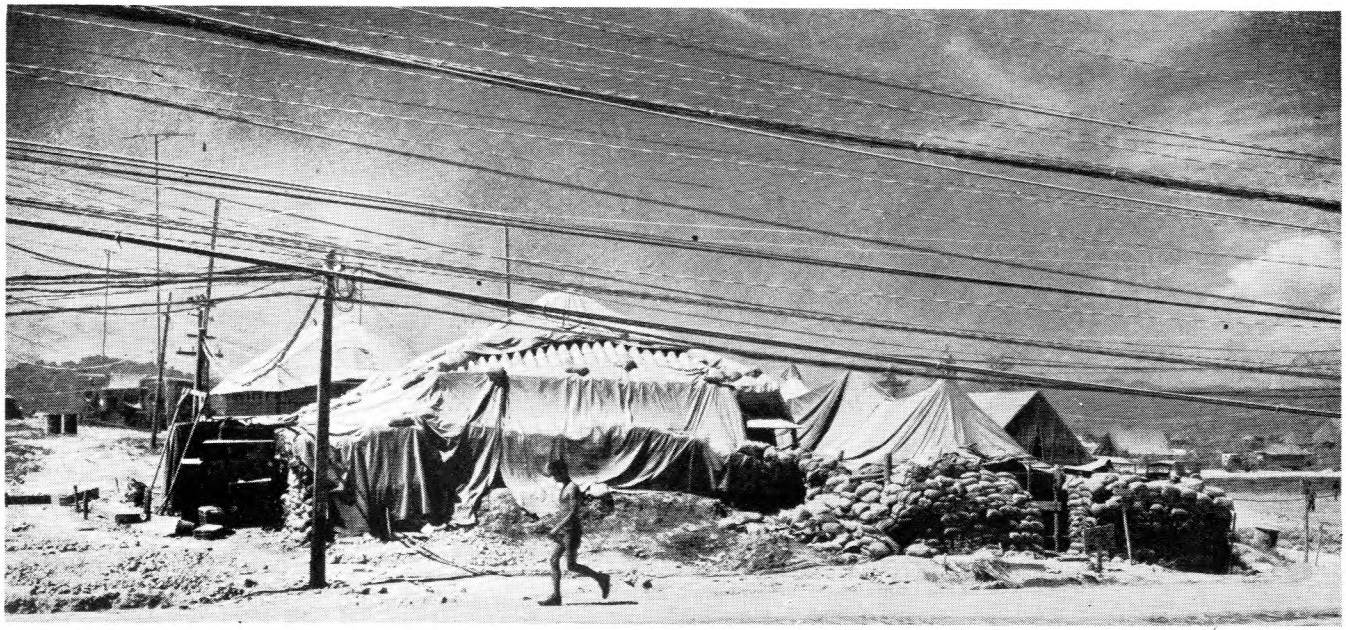


Okinawa radar

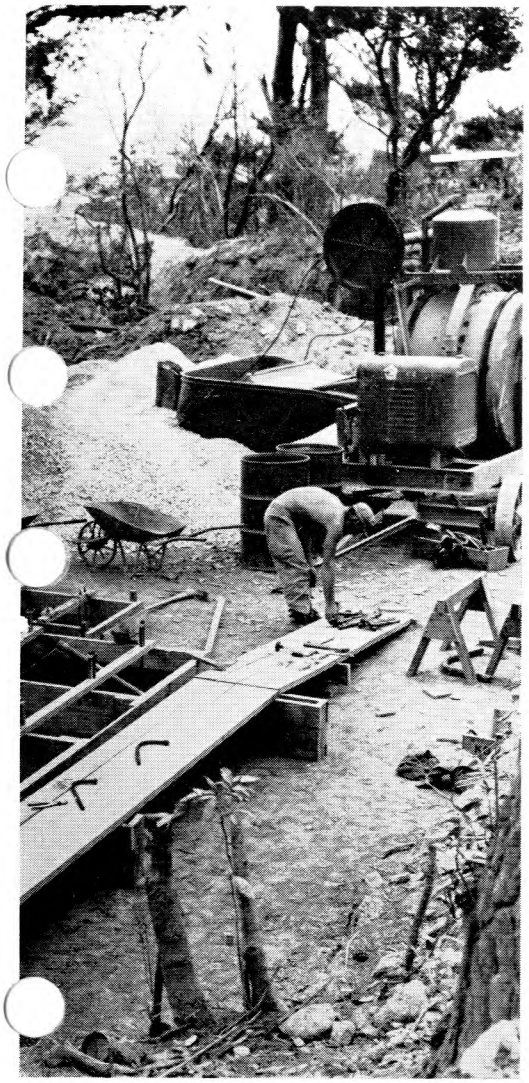
A wealth of radar, operated by about every branch of the Services, littered Okinawa at war's end. Herewith a picture report by RADAR's correspondent, John Alexander



SCR-270DA sat on edge of sheer 200 foot drop to sea (above). Preparations were being made at war's end for MEW (center), biggest of big three to guard northern tip of island. On top of Mt. Yontan engineers were building concrete base (center)

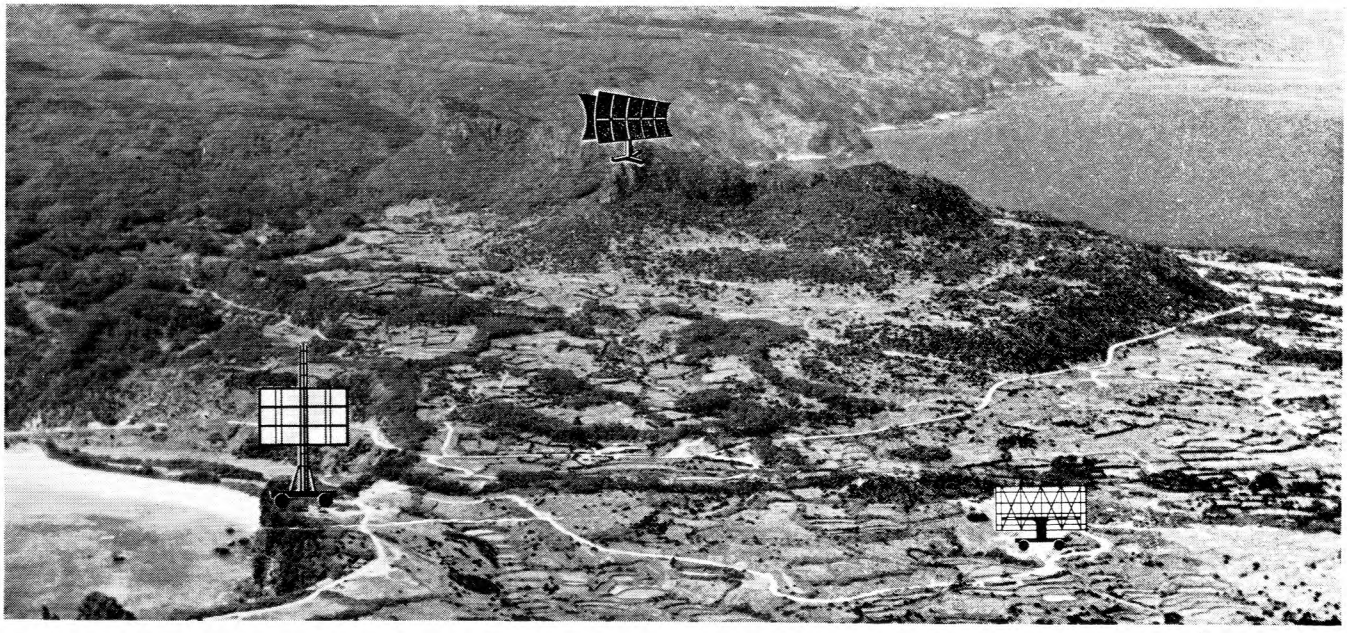


Main ADCC, located southwest of Yontan Field, was set up in old Japanese house. Sandbagged entrance at right was to office of Fighter Control Director of Tactical Air Force which operated in conjunction with ADCC. Galaxy of wires was for telephones





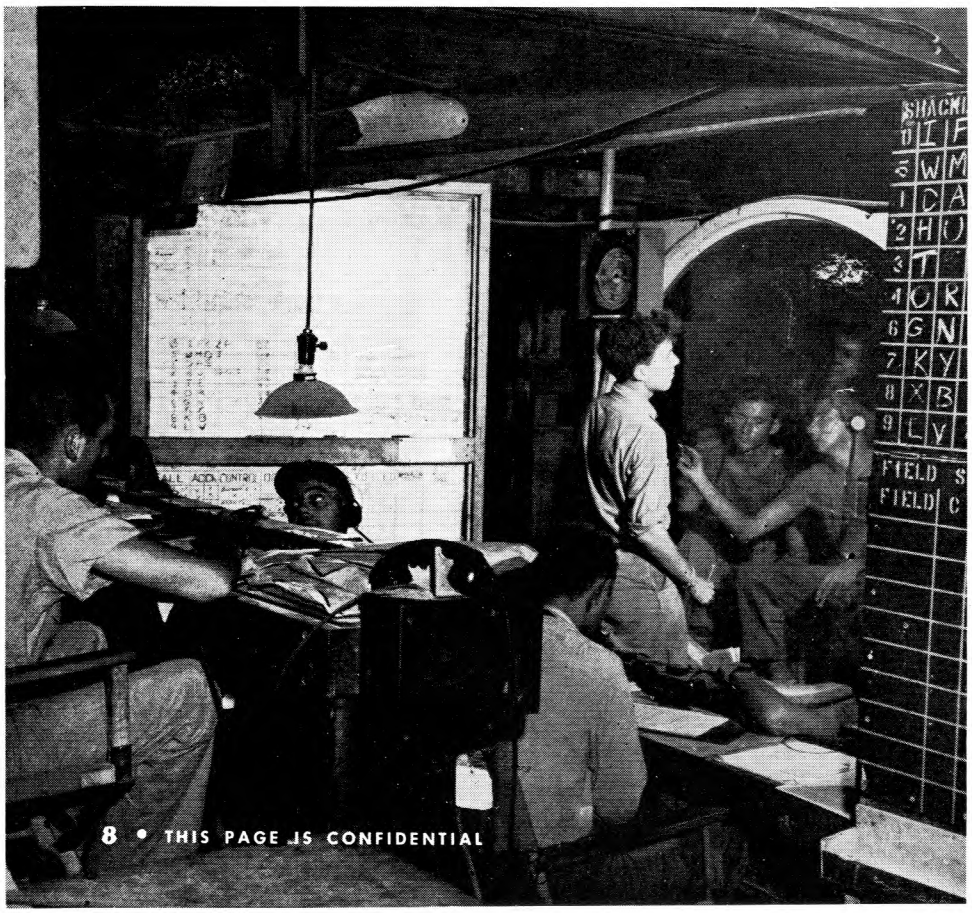
SCR-527 (right) worked with 270 to give as much coverage as possible until MEW site was completed. Path up through palms in back led to TPS-1B on top of knoll. SCR-584 (not shown) served AA batteries which protected warning setup in this area

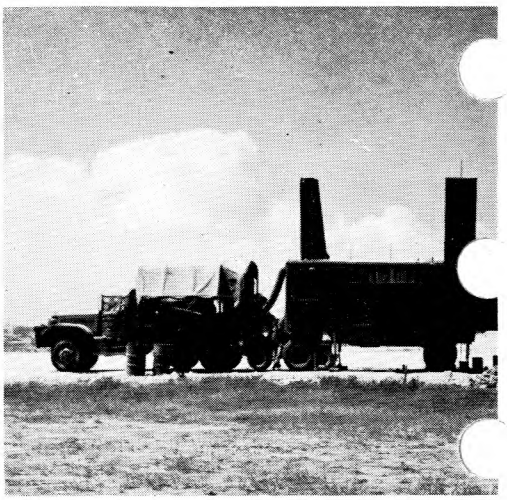


North end of Okinawa looked like this from 200 yards offshore. Locations of the 527 and 270 shown at top of page are marked by symbols. MEW was to operate from top of center mountain peak. Li'l Abner was to be there also as MEW's heightfinder



Operating positions in main ADCC were: 1st row—VHF, intercept fighter director, radar telling; 2nd row—AAA liaison, fighter director watch officer, VHF position; back row—air/sea rescue people and one Army bomber liaison officer. Below, men behind vertical plotting board made plots, man in front drew course of aircraft

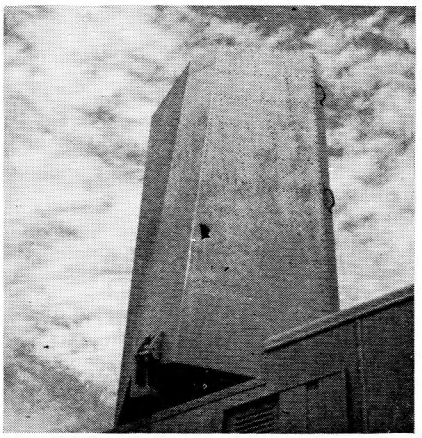




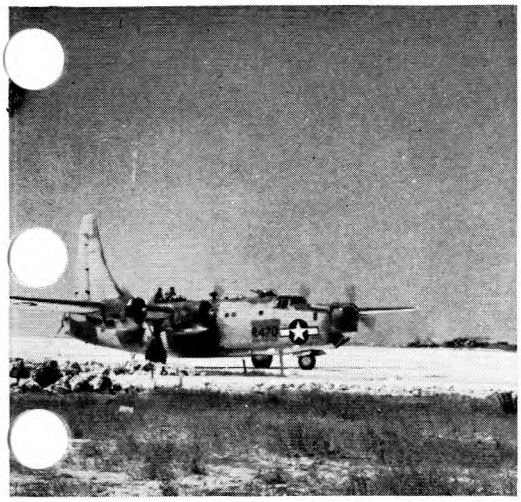
Hard-working GCA looked after planes coming into Yontan Field. Equipment had a hardstand on other side of runway as



These Marine pilots made up the oldest nightfighter squadron in POA; they had 30 night kills for the Okinawa campaign.



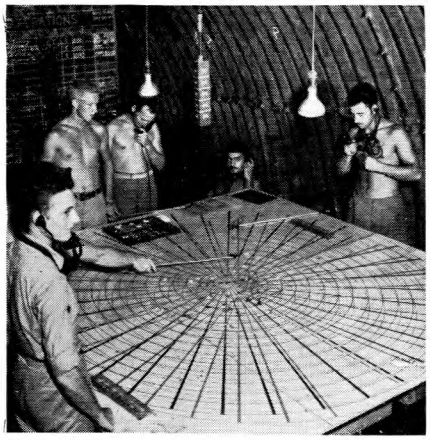
GCA was only casualty when F4U crashed on takeoff and rockets exploded. Shrapnel ripped through van over crew



well. PB4Y2 on strip was one of the Navy patrol bombers based at Yontan. GCA sets in Pacific were staffed by AACS crews



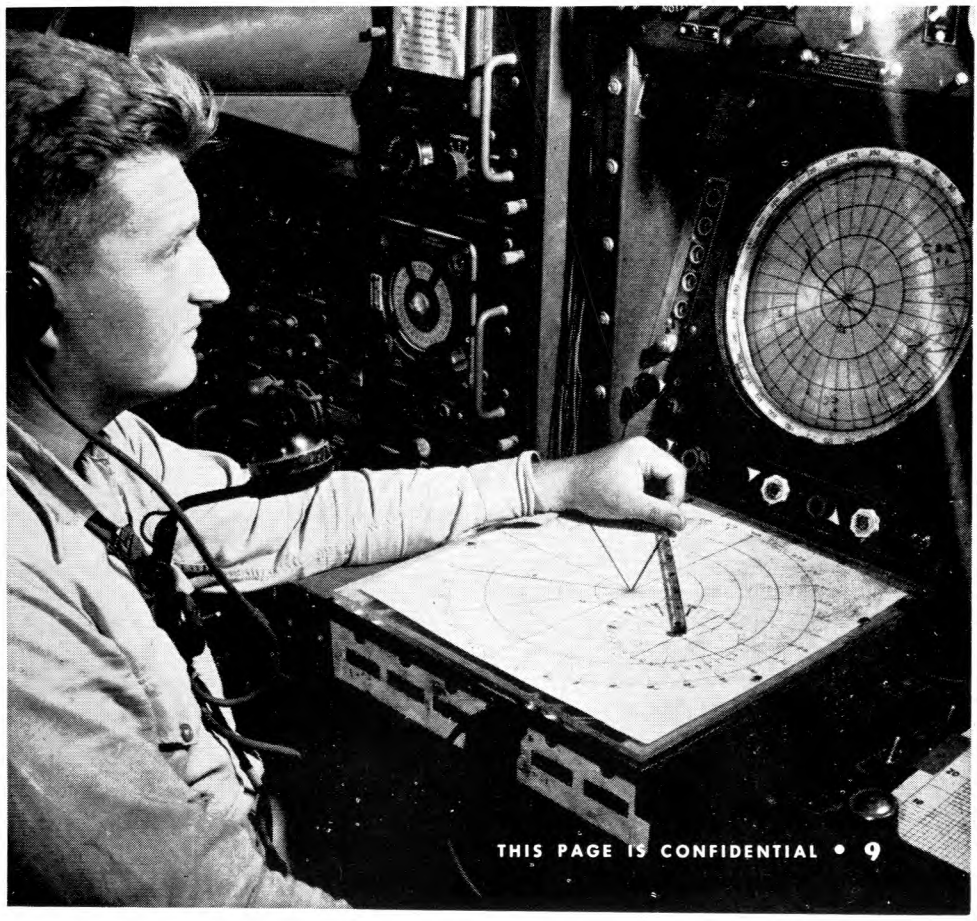
At time of picture, they had just been replaced and were on way home. Nightfighter shown was squadron's high scoring plane

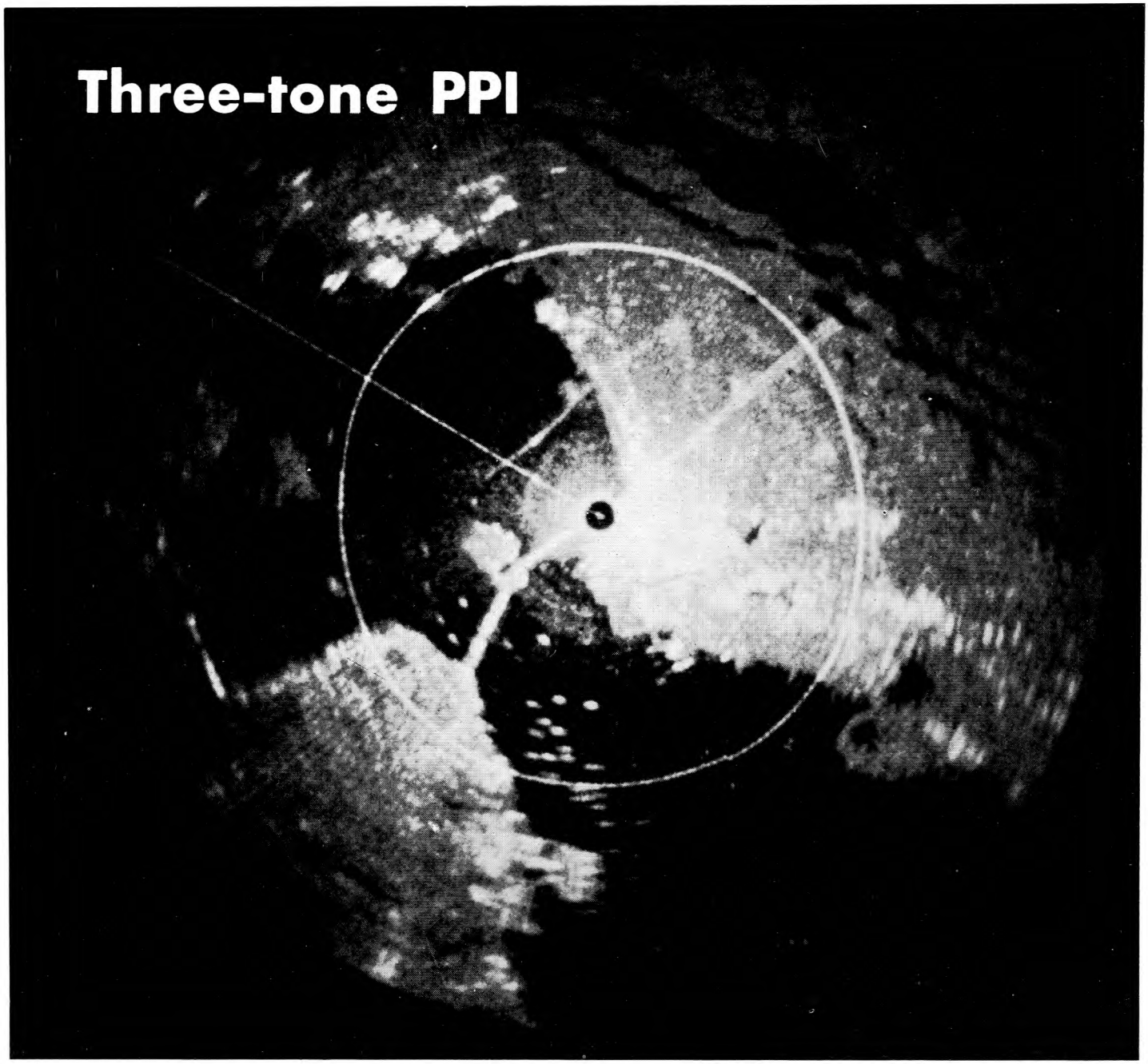


Control center of Marine AW Squadron One received reports from TPS-1s, 527s, 270s and a 602 on neighboring islands



Chief controller eyes record of 19 night, 10 day kills by this Marine SCR-527 on Ie Shima. This radar came ashore on Red beach on April 21; it made as many as three kills in one night. Below, scope of Marine 527 at Aguni Shima had map of set's effective range drawn on face. Special small plotting table was crew's own innovation





A THREE-TONE SCOPE PORTRAIT OF SAN FRANCISCO AREA POINTS UP INDUSTRIAL COMPLEXES—KAISER YARDS SHOW UP NEAR TOP OF PHOTO

New circuits give H_2X scopes new life

In the interests of better bombing, the basic H_2X system received several shots in the arm during its 20 months of combat operation. These stimulating doses were administered in the form of computers, such as Nosmo and MX/-344; antennas, such as the 60″ dish (see RADAR No. 10); and circuit modifications, such as those which have now produced a three-tone PPI.

With this development, objects which would usually give strong signals are made to show up especially bright on the scope, with general land painting dimmer and water areas black. The effect is achieved by superimposing the PPI picture normally obtained with low receiver gain on top of one obtained with high gain. The increased discrimination between strong and weak signals thus gained is obvious from the pictures shown here. Since individual target areas within a city stand out clearly from ordinary land return, target identification within complex areas is simplified. And target identification is one thing that can stand simplification.

Three different methods were devised for putting three-tone circuits in APS-15 and APQ-13. Although each method approaches the problem differently, the picture on the scope in every case is about the same.

The simplest way of getting three tones is by providing circuits to switch IF and video gain up and down alternately on

alternate sweeps. In this way, one time the sweep has a low gain IF and a high gain video, the next time a high gain IF and low video. Because, as a modification kit, this arrangement would have been easy to install in the field, it would probably have been the technique most widely used.

Another method requires two receivers —one kept at normal gain and the other at low gain. The output of the preamplifier is fed into each receiver, their outputs are then joined and fed into the PPI. The receiver at normal gain gives maximum range and maximum land painting while the one at low gain picks up only the strong signals. Since strong signals come through both receivers and weak signals only through the one with normal gain, three-tone painting results.

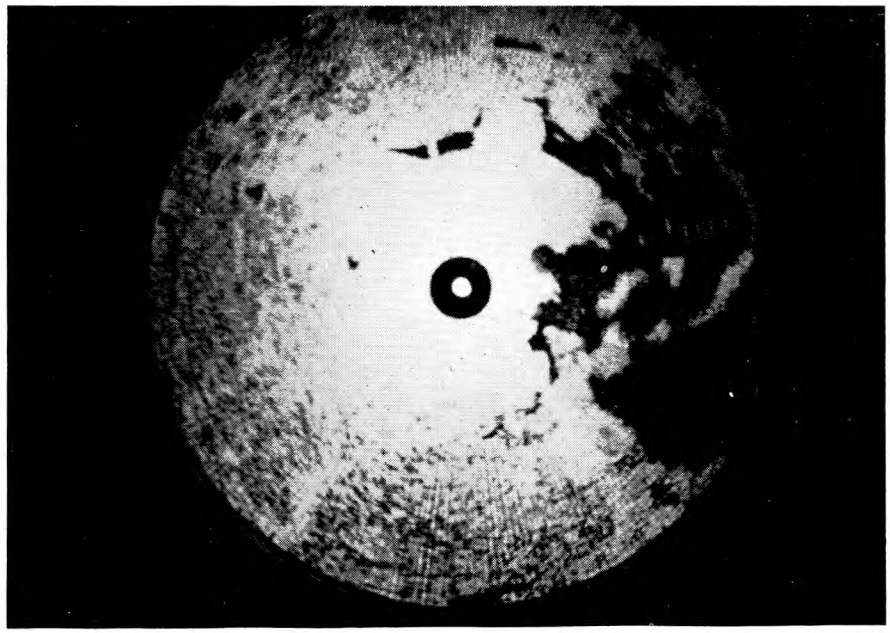
With APQ-13 a double-limiter method is especially good. It produces the desired effect by limiting weak signals at one level and strong signals at another.

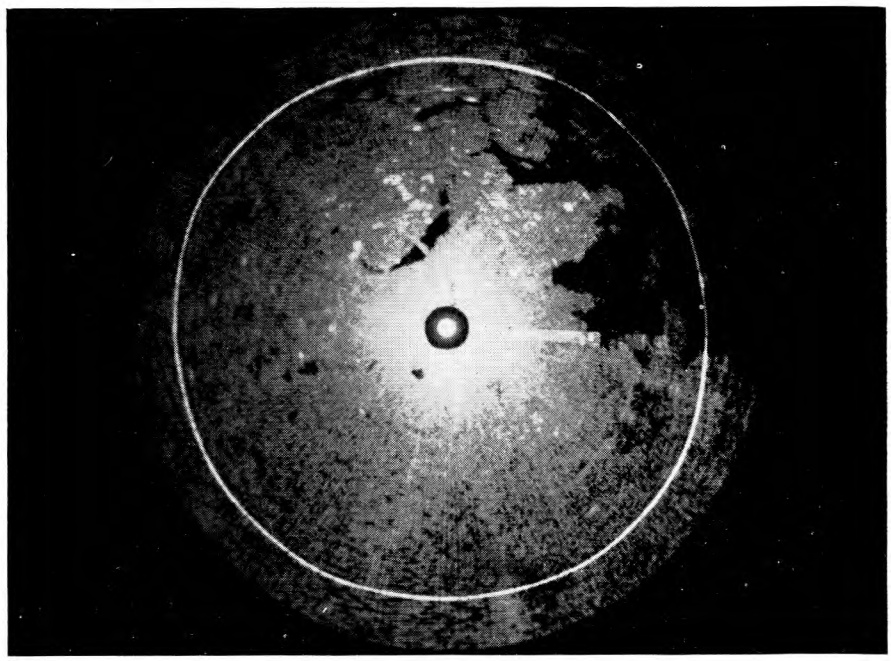
Fortunately, this added discrimination can be obtained, in each method, without burdening the operator with added duties. Although the circuits add another knob, they actually simplify the operator's job since he doesn't have to ride the IF gain. Furthermore, three-tone circuits can be switched in and out as desired.

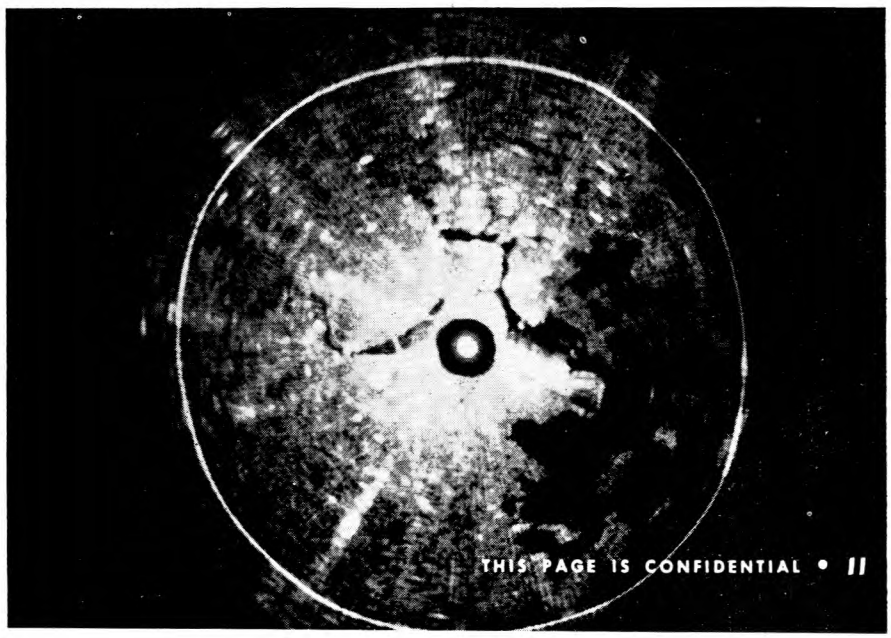
Three-tone PPI isn't a cure-all for interpretation or approach problems. Bright signals will tend to fade or change shape when viewed from different aspects just as they do on low gain with the normal PPI. Errors from this can be minimized with adequate scope photo coverage of target areas. The most desirable approaches can then be determined and operators briefed to know what signals to expect.

On the basis of favorable test results, three-tone PPI, in one form or another, was about ready for active duty when the war ended. Tokyo had been resolved in three tones to test the idea in combat and the 20th Air Force had requested 200 kits for APQ-13. Similar circuits were being considered to give Eagle the added discrimination.

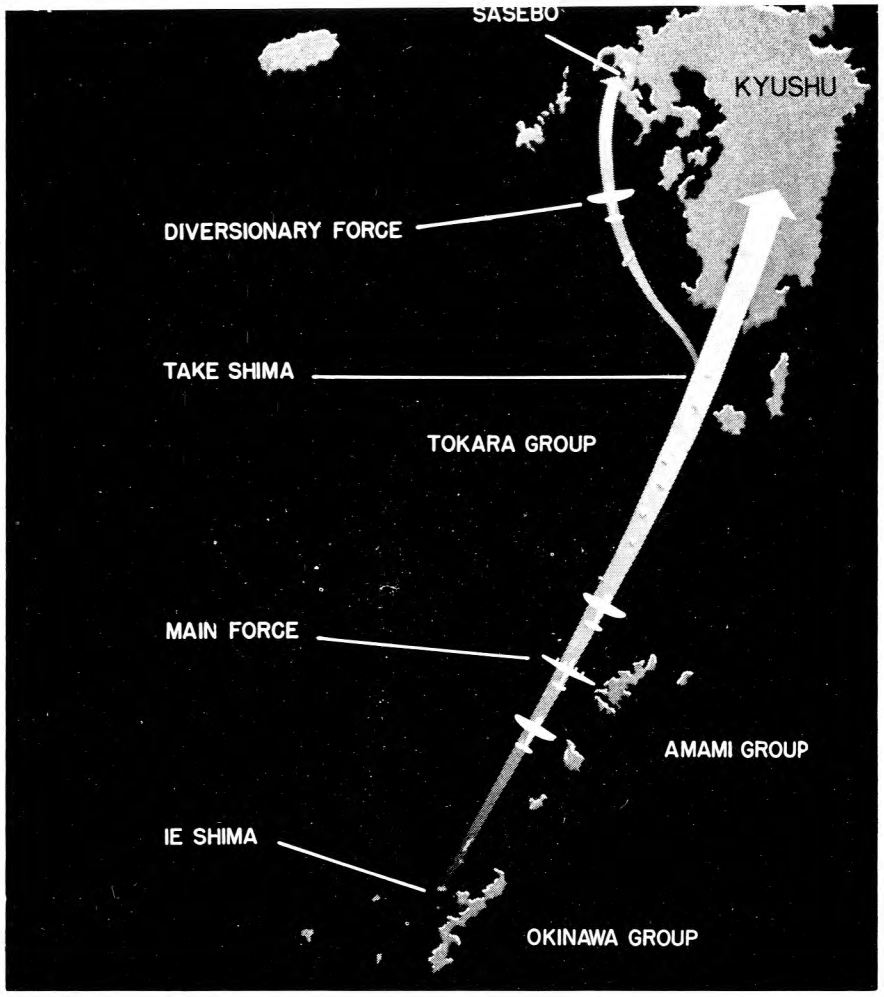
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Boston Harbor as resolved on normal PPI (top), three-tone at high gain (center) and three-tone at low gain (bottom). All photographs were taken at about 4000 ft. altitude and the range marks are 5 miles. Built-up area is easily distinguishable



RCM strategy used in Marine photo mission resembles football maneuver. Diversionary P-47s skirt end while B-24s hit center. 180 lbs. rope, 400 lbs. window were expended

RCM over Kyushu

It helped lift veil from enemy's fire control radar

It looked like a routine job as it came to the desk of the Operations Officer of Tactical Air Force, 10th Army, on Okinawa. TAFTen was to support two photo-recon Liberators of Navy VD-1 in photographing southern Kyushu.

Kyushu was, to some degree, old stuff to TAFTen, whose principal job was to give air support to the Okinawa operation. Some P-47s of the 318th Army Fighter Group of the 7th AF already had been sent there on heckler missions.

But, as it turned out, this job was a little different.

Enemy strength was not completely known to TAFTen Intelligence. It was estimated that the Japanese could send up approximately 500 fighters from widely scattered fields, among them Kogashima, Tojimbara, Chiran, Byu. Kanoya, Sadohara and Omura. But a study of Japanese interception against aircraft of such commands as the 20th AF revealed no set pattern of procedure.

The problem of Japanese anti-aircraft marksmanship was an even greater guess. The Japanese were known to have some gun-laying radars in the 75 and 200 mc bands, but how accurate they were had not been fully established. If the Japanese wanted a good target for continuously-pointed, radar-controlled fire, the Liberators of VD-1 would provide it. A photography plane must fly a straight and level course minute after minute when it seems like hour after hour to pilot and crew.

For a month prior to receiving the assignment, Operations had given Marine RCM Unit #1, in the Communications Section of TAFTen, a fairly free hand in finding out what the radar picture was, particularly up and down the Nansei Shoto chain.

Results from each of a score of flights were the same: plenty of early warning radars, very little fire control. Ack-ack was received on several occasions but apparently was not radar-controlled.

From TAFTen's doubts of their evaluation of fire control was born a double-barreled plan. First, send eight P-47s in a diversionary raid against Sasebo naval base in northwestern Kyushu to strew a path of rope (CHR-2) and thereby draw Japanese fighters away from the area to be photographed. Second, send Navy RCM personnel, with a wide variety of tuned window, in each of two B-24s guarded by four other P-47s of the 7th AF. Additionally, 24 P-47s were to attack any fighters encountered in Kyushu as a sort of free-lance protecting force. One of the B-24s was hastily equipped with search and analysis equipment so that on-the-spot-evaluation of Japanese fire control —if any—could be made and the proper countermeasure applied. Window cut for 150, 200, and 300 megacycles was carried in each plane. It was up to the RCM co-ordinator to determine for both crews, by observing frequency, pulsing rate and pulse width of received signals, just when and how each type should be used. Each Liberator also carried 24 packages of rope which would have a frequency coverage from 75 to 300 mc.

It was originally intended that two P-47s should be equipped with automatic rope dispensers, each loaded with 120 rope targets. However, because of the necessity of carrying wing gas tanks, it was decided to divide up the 240 units of rope among all eight P-47s assigned to make the diversionary attack. Pilots would then discharge them manually.

RCM personnel was busy during the last months of the war keeping tabs on Jap radar over the home islands. Fire control radar in particular needed watching; returning B-29 crews reported that it was improving. On Okinawa a Marine officer, Captain Arvid F. Jouppi, veteran of 25 RCM missions, wrote this report of RCM over Kyushu.

Take Island, approximately 20 miles south of Kyushu, was designated the coordinating point. Diversionary fighter pilots were instructed to leave immediately upon arrival on a course of 325° magnetic. At the end of ten minutes they were to make a five mile orbit, dropping a rope target each ten seconds. The fighters were to make two additional orbits while proceeding toward Sasebo.

The Liberators and their escort planes were to form an initial five mile orbit and discharge their ropes along with window of appropriate category. This was intended to hide from the Japanese the number of planes remaining over Take or, to be optimistic, to deceive them into believing that the Take element was the tail end of a long raid against Sasebo. The Liberators were to hold their orbit for 15 minutes and then go in for their photographs, hoping that all available fighters had gone out to intercept the head of the spurious air armada apparently heading for Sasebo.

At 0700 on 7 June the photo-mission planes rendezvoused above little Ie Shima and headed out toward Kyushu. Even before the flight left Ie Shima the search receiver showed that Japanese radars, probably from Okini Erabu, were tracking. That was to be expected.

The formation skimmed at 20,000 feet above the Nansei Shoto chain, passing as if from hand-to-hand from the beam of one Japanese radar into the beam of another. It would be possible to navigate to the target simply by keeping tabs on Japanese radars.

When passing over Takara Gunto, Jap radars at 73, 86, and 79 megacycles took their turn at tracking. By this time the enemy must have known the exact composition of the flight. The hope now was to deceive the enemy as to direction of the attack.

Take Shima was reached just two hours after leaving Ie Shima. True to briefing, eight P-47s left immediately on a course of 325°. They sowed their first rope between Shima-Koshiki-Jima and the south tip of Kyushu. The main flight continued to orbit around Take. Radars which had previously been bearing on the main flight were noted to rotate away, presumably to investigate the deceptive trail left by the P-47s.

Just 17 minutes after arriving at Take, the time was ripe. The Liberators moved out under their cover of fighters. Four PBY's, serving for air-sea rescue, remained to orbit in the Take area, now completely infested with window and rope. The Liberators passed over the coastline into Kyushu. The ack-ack would begin bursting now or never.

Not altogether in keeping with ideal photographing conditions was the 5/10ths cloud cover over most of the southern area. But from the RCM point of view this was the test. It would take radar-controlled ack-ack to reach the Liberators.

For three minutes there were nothing but early warning signals (a 157 megacycle signal had meanwhile come on, making four radars, all rotating). Then from somewhere came ack-ack, with still no fire control radar. However, in keeping with a pre-arranged plan, 28 inch window, for 200 megacycle radars, was dropped each five seconds. The fire, probably 75 millimeter, was way off, with some bursts being 200 yards from the aircraft. The entire band from 40 megacycles to 3400 megacycles was hastily searched. No signals. However, the 28-inch window was dropped for a period of 20 minutes. The photographing continued on schedule and there was no more ack-ack. One of the Liberators continued to sow 28-inch window sporadically. Both planes sowed 37-inch window (for 150 mc), at 10-second intervals. This was to confuse any Jap fighters which might remain in the Kyushu area, and also to keep the search radars confused as to the true number of planes over Kyushu.

Then some ack-ack showed up again. The first burst was about 50 yards to starboard of the RCM plane. It came within a minute after a 240 mc radar went on, indicating that it took about 40 seconds for the radar to pass data to a gun battery, allowing 20 seconds for the shell to climb to 20,000 feet. While this happened the window boys were busy. Within 20 seconds after the squeaky 2200 PRF signal came in, 28-inch window was floating down—two sleeves every three seconds. Both B-24s were tossing it out.



"The tail turret gunner reported he saw 40 foot puffs . . . about a half mile back"

Other bursts aft were seen by the tail turret gunner and by a cameraman. The tail turret gunner reported he saw 40-foot puffs above the clouds about a half mile back. After seven minutes of operation the 204 megacycle radar gave up. If there was any more ack-ack it was too far away to be observed.

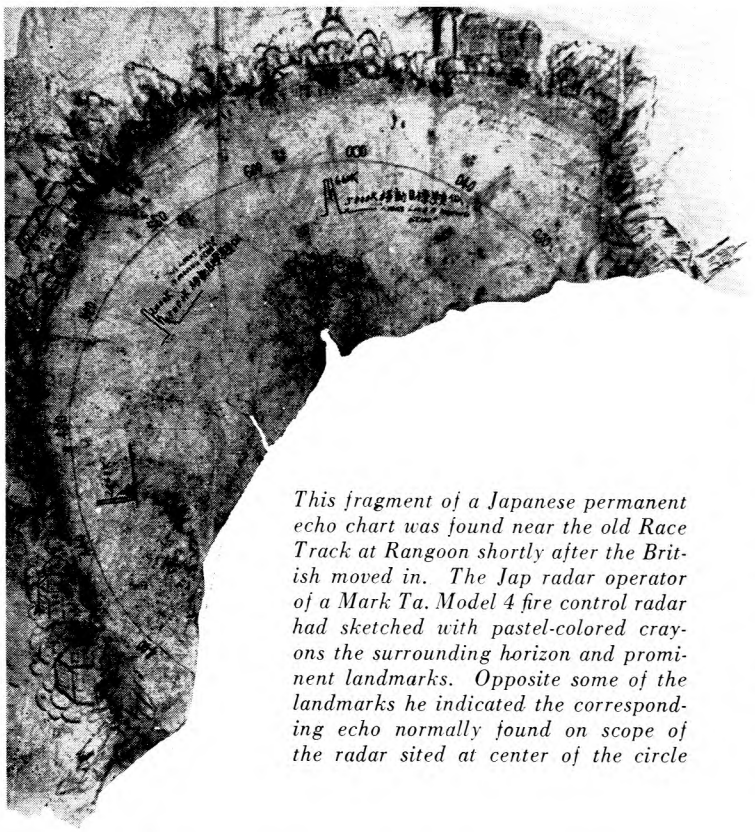
The anti-aircraft artillery had been beat. But what about all those aircraft from enemy airfields? When the story was told to intelligence officers that evening, the information was encouraging from the fact that it was largely negative. Not one plane was found over the area to be photographed.

The eight P-47s which went on the diversionary raid were not satisfied to go home once they had scattered their deception. They had orders not to tangle with any planes which might rise for the deception, so they headed for central Kyushu, found no aircraft to fight on the western half and proceeded to the eastern sector. There, near the Japs' proud Miyakonojo airfield, 12 Zeke fighters rose to meet them. The P-47s got credit for two kills.

The four-fighter escort for the Liberators went out ahead and spotted nine Jap aircraft north of Kago Shima Wan. Either because the Kyushu area must have looked like a mass of planes as the result of window, or for reasons of their own, the Japanese did not fight.

The 24 opportunist fighters saw 15 Zekes near Sasebo, (the diversionary flight was designed to feint a raid there). These 7th AF fighters tangled and brought down two Japanese. But two P-47s were hit and had to head back for Okinawa.

That evening TAFTen intelligence relayed varying stories to operations officers. Some fighter pilots couldn't see any sense to carrying rolls of shiny metalfoil instead of going out to blast the enemy. But the B-24 pilots, who had accomplished their photo mission, were in agreement that the window had helped ward off Japanese AA fire.



This fragment of a Japanese permanent echo chart was found near the old Race Track at Rangoon shortly after the British moved in. The Jap radar operator of a Mark Ta. Model 4 fire control radar had sketched with pastel-colored crayons the surrounding horizon and prominent landmarks. Opposite some of the landmarks he indicated the corresponding echo normally found on scope of the radar sited at center of the circle

AW adventure

Most of IBT's radar ration was ground gear which went to hill and valleys for air defense

India-Burma, at least a good part of it, is fit for neither man nor radar. Living conditions are pretty bad by any standards and, as for operating conditions for radar, they're just plain lousy. Even so, through three years radar was operated at almost inaccessible sites in "impenetrable" Burma, with head-hunters for neighbors and one of the world's most extreme climates to put up with.

The part of airborne radar was small. The India-Burma theater was so close to the bottom of the equipment priority list that very few IB aircraft boasted a radome. Rebecca-Eureka, the only type of airborne equipment used to any extent, aided Troop Carrier and the Combat Cargo Task Force in their unique and unprecedented operations. Loran stations went into the Assam area in the fall of 1944—the first of a large system recently completed.

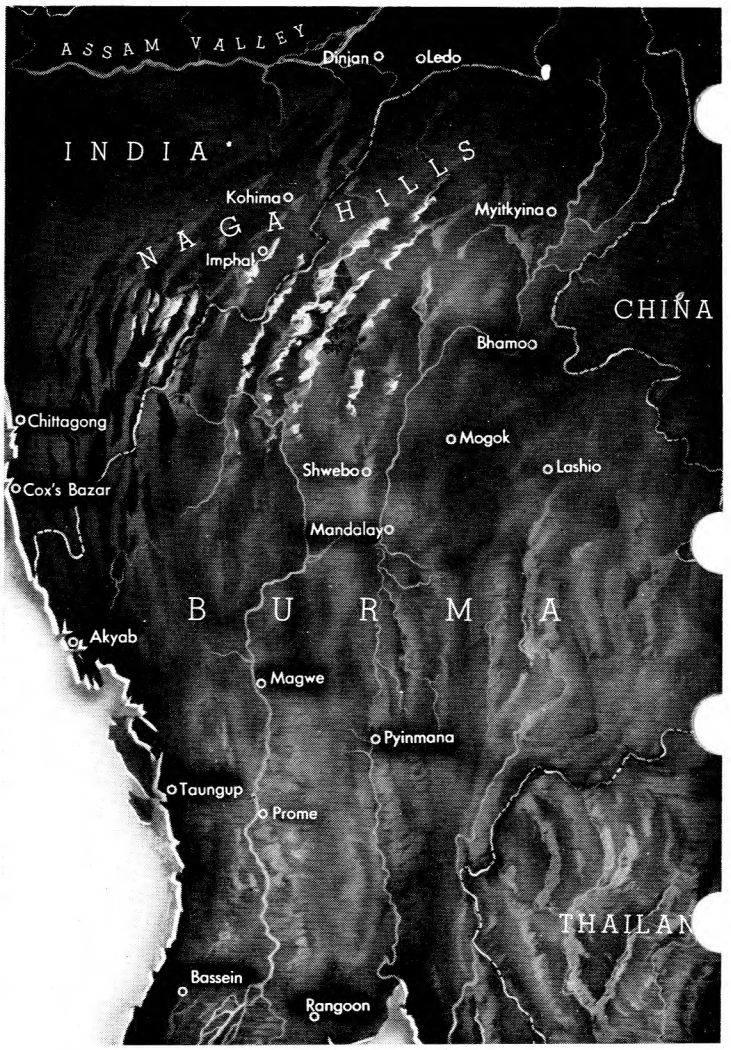
The war in this theater, particularly the radar end of it, was always one of supply, whatever other turns it took. In the early days when sets were precious, one whole equipment would often be relieved of most of its parts in order to keep other sets in operation. But the endless fight for equipment and spare parts was only the beginning—IB got the short end of the stick on weather, terrain and the native situation. There were also Japs.

Radar's assignment in India-Burma was aircraft warning, and it was one of the toughest assignments ever handed out. Operations were defensive and they started and ended as such.

It all began in July 1942, when the 679th Signal Aircraft Warning Company (Special) arrived in Karachi, India. A radar company of four reporting platoons, one plotting platoon and a headquarters section, it was accompanied by four antiquated SCR-516s. The radars were in poor shape, suffering from salt air, wind and an intense curiosity for classified equipment on the part of men who had handled them. The 679th's mission was to defend the Karachi area, a primary Army port of debarkation at the time. Impending danger of air raids came, not from the Japanese, but from the Germans who were advancing far too rapidly in Africa. Fortunately, the two 516s set up at Karachi weren't called upon to do much defending—the sets were old, the men inexperienced and the performance level correspondingly low.

By this time, General Stilwell had pulled his forces out of Burma with the Japs close behind him and almost treading on his tail. The Japanese had invaded from Siam, striking both north and south and making both British and U. S. positions untenable. However, the AAF had fighter and ferry command bases established in Upper Assam. These bases had to be protected against air raids. And so upper Assam became the first priority area for the one AW company in India. Captain Guy C. Underhill of the 51st Fighter Control Squadron and Captain John G. Haury of the 679th SAW Company left Karachi for New Delhi to discuss the warning problem with the commanding general of the 10th Air Force, then went on to upper Assam to look things over.

What they saw wasn't good. This was the terrain over which AW *had* to be furnished and all they could see was a





Ledo Road, engineering miracle in road building, runs southeast from Ledo through a good part of Naga Hills. Supply to hill stations and advance posts soon improved



Operator of TPS-1 near Bhamo looks for plane which will drop parts and mail

line of mountains 150 miles long and ranging from 6,000 to 10,000 feet high—the Naga Hills. And this was in the days when radar sets had wide beams that made a specialty of ground clutter. The two officers didn't have to look twice to see the absolute futility of trying to operate 516s or 270s there. Moreover, there was the little problem of transporting anything like a 270 over the terrain. AW by ground observer teams only was suggested. The area commander, out of an unshakeable conviction that radar warning, good or bad, would help the grave tactical situation, insisted that radars be brought in.

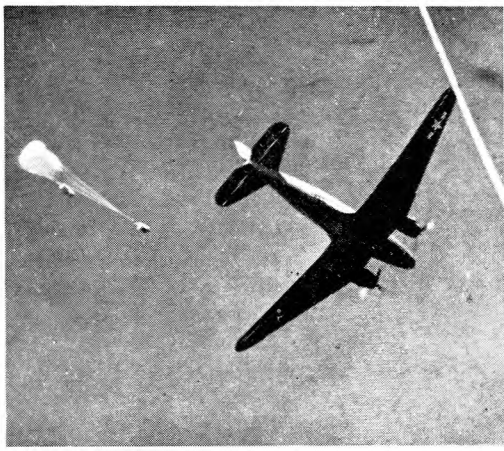
Even if radar could be made to work in such terrain, there wasn't enough of it to do the job. So it was decided to try to form a warning net by filling in the gaps with ground observer posts. The 51st Control Squadron supplied half a dozen radio-equipped GO teams which were to furnish as much warning as possible until two 516s came along.

The 51st squadron started deployment of its GO posts, and two reporting platoons of the 679th began the heartbreaking and backbreaking task of building two 25-mile jeep roads into the mountains without any engineering assistance. One 516 and even the engine and generator were broken down into the smallest possible components, which were then taken by jeep to the end of the road. From that point they had to be hand carried over the last three miles of steep jungle trail, as many as 100 men being required to haul some of the heavier pieces. After several days the radar was in perfect working order—and the scope was completely covered with the finest of permanent echoes. Several test flights were run on the 516 but the planes couldn't be detected. The uphappy outcome of that experiment resulted in the other 516 project being abandoned.

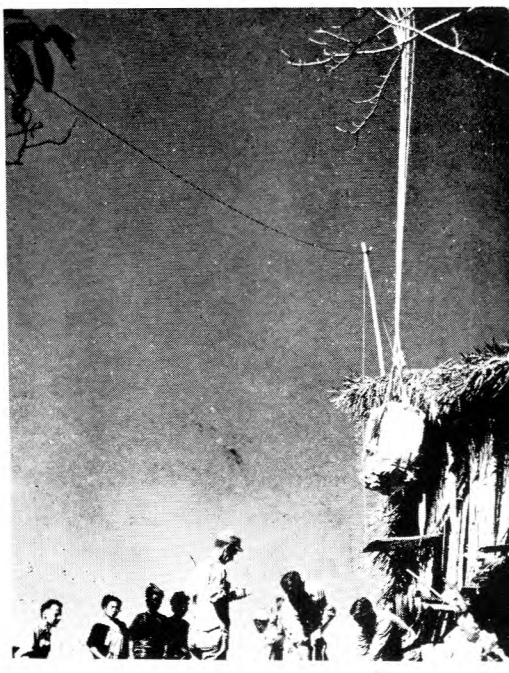
Meanwhile, the AW situation couldn't exactly be termed satisfactory. So a conference was called at 10th AF Hq, New Delhi. Talking it over produced the decision to reorganize the 679th into a Ground Observer Company — 24 GO teams of ten men each, four net control teams and a company headquarters.

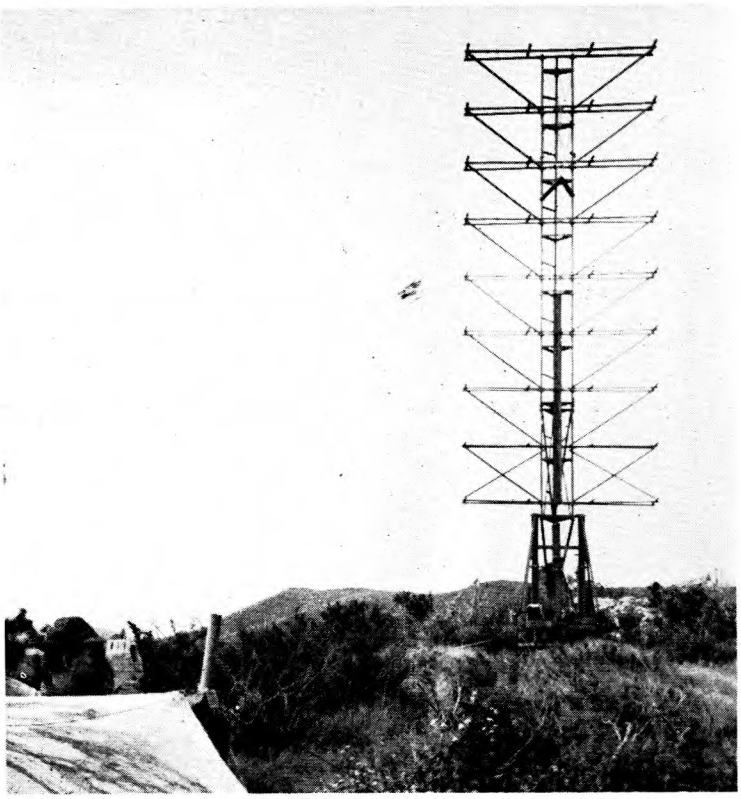
By this time the 675th Signal Aircraft Warning Company had arrived in India. It took over the four SCR-270s that were already in India and set up a four-radar aircraft warning net in East Bengal, operating as secondary to the existing British Aircraft Warning System. The 675th operated in this location for a year without any major upsets.

By June 1943, the converted 679th, now completely trained, deployed 12 of its GO posts. Four months later all 24 posts were deployed in the hills. They were spread over an area 300 miles long and 150 miles wide and all the stations were in inaccessible locations requiring a 3 to 15 day jungle walk from the nearest road. The fact that any of our troops at all went into that territory was a source of great amazement to British officials. The hills were full of head-

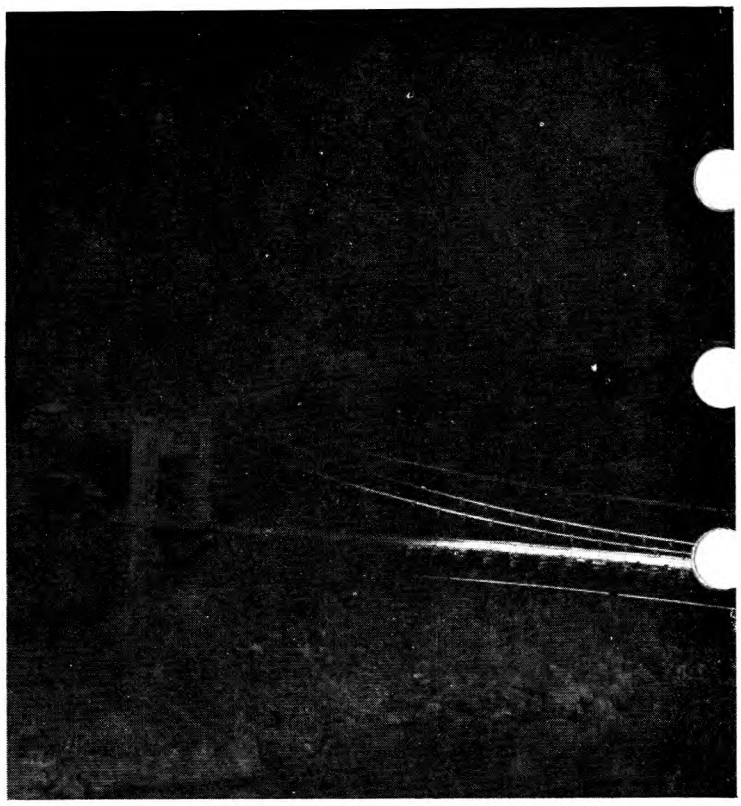


C-47 releases its cargo. Below, a GO team takes stock of a successful air drop





Only a few of the 270s saw action. Transportation and siting were difficult and lack of spare parts was a chronic disorder

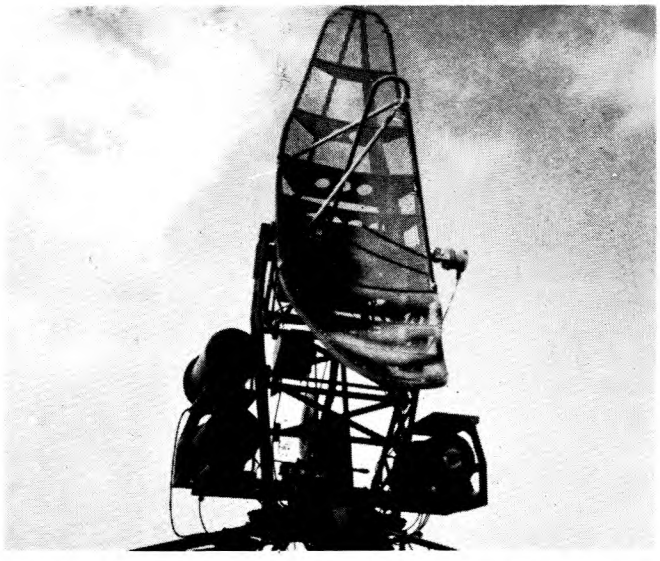


Worst headache was that of supply which lasted throughout entire campaign. Slowly but surely big transports started to roll

hunting and supposedly hostile Naga tribes and the terrain was practically impossible to travel over in the dry season and certainly so during the monsoon.

The American teams had to meet the native situation if they hoped to maintain their hill stations and remain healthy. They did it through an old American custom—they made friends with the Nagas. The men found that salt, cloth and trinkets went a long way and as long as they didn't interfere with the well-established Naga custom of removing heads, all went well as a rule.

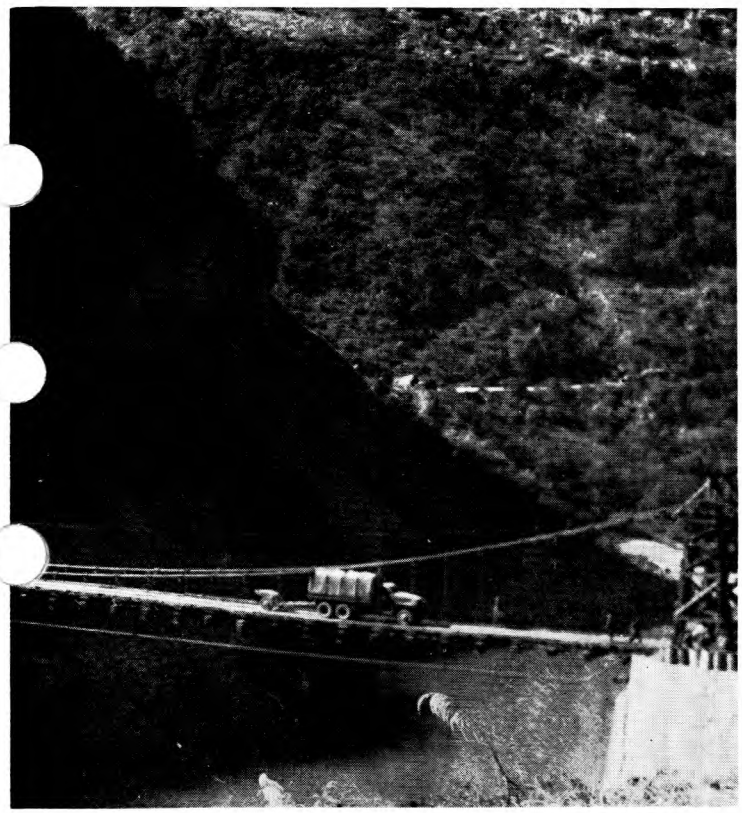
There was the odd tense moment, of course. Lieut. William Atwell on one reconnaissance trip in search of a new ground observer site hit some territory inhabited by unfriendly tribes and later found that he was the first white man to get there in 60 years. The lieutenant went on his way unmolested, however, and considered himself a successful business man when he bought the new site from a Naga chieftain for 15 rupees. But on the return trip, Atwell was suddenly confronted with a large party of Naga warriors who were quite obviously on the mad side. It turned out that the lieutenant had bought the Brooklyn



Li'l Abner could have made a big difference to AW in the hills but fireworks were about over when the single set was uncrated



Plotters of the Fighter Control Center at Bhamo followed 10th AF planes as they helped push Japs south through central Burma





down snaking curves through the mountains with precious equipment and supplies, supplementing the parachute freight service

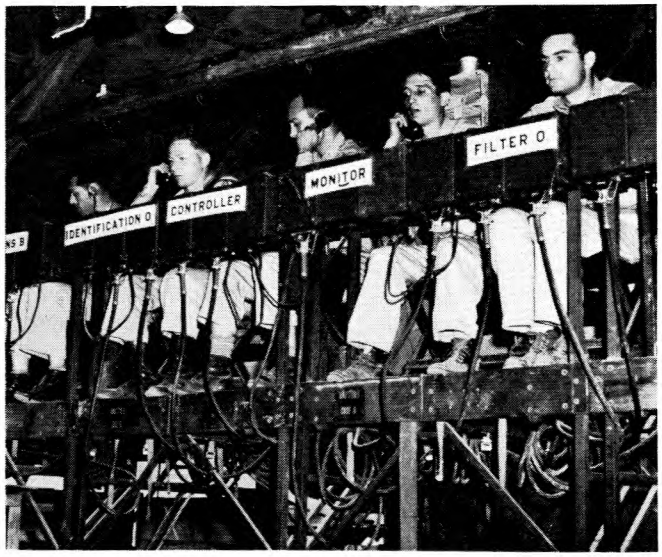
This 602-T6 on night duty at "Broadway", was taken in by air. A few days later it was no more—an enemy bomb hit it squarely

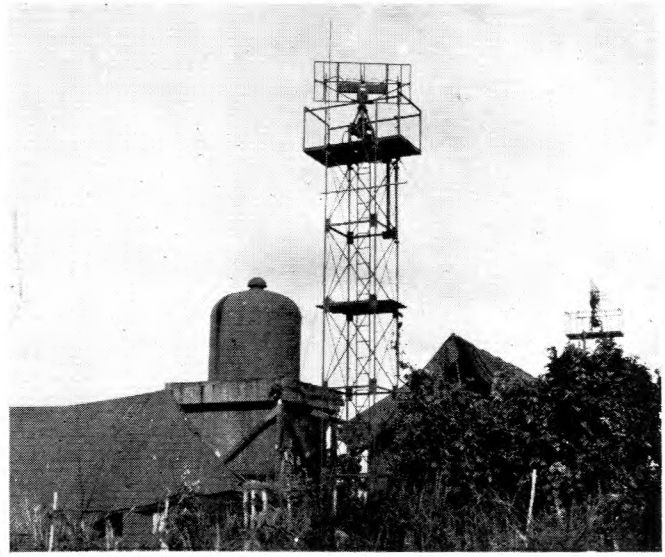
Bridge—Naga style. The chieftain who had pocketed the rupees didn't own the land but the one who looked ready for trouble did. Peace was restored when the site was repurchased.

Because of the terrain, all AW stations in the hills were supplied by air drops. Even radio equipment was dropped with surprisingly few breakages.

July 1943 was an eventful month in AW history—four 602-T6s plus operating personnel showed up in Dinjan, Assam. In the hope that a 602 would do better than the 516, one equipment was sent up into the hills for test. Lt. Donald O. Hartburg set out on a siting trip that took him some 200 miles over rugged mountain trails at the height of the monsoons. When the radar finally got into operation, the answer was still the same—all permanent echoes, no aircraft signals. Even the die-hards had to admit the obvious—early warning was just not possible in mountainous terrain with the existing radar. So the 602s were put in the Assam Valley to track hostile aircraft within the valley after being alerted by the GO stations.

The India-Burma campaign sagged considerably on both sides for eight





Bhamo FCC looked about the same inside as most centers in any theater. 10th AF had similar setups at Kanjikoh and Myitkyina

Getting the big 615 and its associated IFF into Myitkyina was a real chore. Storm watching was one of greatest contributions



A ground observer keeps watch from the tower of his homemade post in Naga hills



Capt. Haury (now Lt. Col.) poses with a young Naga warrior outside native village

months. Then in early 1944 the Allies got their wind back. They started into action with almost the whole of Burma to be won back but they had something to fight with this time. British and Americans opened up with a 3-way attack which began a series of the most colorful and unorthodox campaigns of this war or any war. With transports, troop carriers, L-5s or anything that would fly working overtime, they air-dropped just about everything from sulpha pills to small armies.

Two more SAW companies arrived from the U. S. and the 675th Company moved out from East Bengal and into the fray. As the ground forces advanced, SCR-602 stations were sited in the valleys and GO posts were placed on the hilltops to fill gaps in coverage.

One of the 679th's teams with a 602 radar took part in General Wingate's airborne invasion of central Burma. The radar and crew went into the air strip at "Broadway" with Col. Philip ("Flip") Cochran's 1st Air Commando Force. The set operated for five days, in spite of a bad case of PE's, detecting enemy flights in time to alert the area. But on the fifth day, the enemy won out —one Jap dive bomber managed to place an incendiary bomb directly on top of the 602. The crew, fortunately, was luckier than the radar and stayed on at Broadway to set up the 602's successor, a British Type VI.

As Allied forces advanced, the Japs made a drive in the Kohima sector in the northwest. It was the ground observers at their Naga Hill posts who first reported enemy activity (see page 19). Although enemy columns were converging on two of the posts, the observers continued their AW work.

By May 1944, General Stilwell's forces started to close in on Myitkyina and again a 602 was flown into the air strip while the Japs still had it under fire (see RADAR No. 7).

Finally by December 1944, the equipment situation really began to look up with 12 AN/TPS-1s, 12 AN/TPS-2s and 12 SCR-602-As—enough additional radar to equip properly the SAW people, who had been reorganized into two battalions, and even some overflow, which went to the 14th Air Force in China. The 602s, although essentially short term equipments, did a tireless job. Two of them operated continuously in India-Burma for 18 months.

An SCR-615 had also arrived in the theater but for several months bits and parts of it could be found anywhere between Calcutta and Myitkyina—it took 18 sorties to air-lift the radar. (The 615 didn't get on the air properly until February, 1945; at war's end it was still in top working order in Myitkyina.)

Allied forces had pushed south past Myitkyina to Bhamo by December. The 559th SAW Battalion and the 96th Fighter Control Squadron moved down to set up a mobile fighter control center in a rice paddy about 8 miles from Bhamo before the town actually fell. The first few days were spent dodging enemy shells and killing off odd Japs who infiltrated into that area. Nevertheless, communications facilities were installed and a TPS-1 put on the air so that, shortly after the town fell, Bhamo had a fullfledged FCC.

Early 1945 saw a lot of air activity on the part of the Allies, the Jap air force having diminished considerably. A few 10th Air Force planes carrying Azon took out bridges right and left in the Lashio and Taungup areas and tied up the Rangoon rail line, cutting off Jap supplies and communications and allowing the British to speed up their advance in that sector. The single nightfighter squadron, 720-equipped, drummed up a little business, but nothing spectacular. The 10th Weather Squadron with their APQ-13 equipped B-25s worked overtime, however. Mandalay fell in April and it was only a matter of weeks before the British, aided by American Troop Carrier and Combat Cargo aircraft, recaptured the final objective—Rangoon.

At war's end, several sets were still being maintained in north Burma as protection for the Ledo Road area and the airstrips at Myitkyina and Bhamo. Although the probability of enemy attack was low, there were a few Jap airfields in Indo-China which were within range. One set may stay on in Burma for some time—the SCR-615 at Myitkyina. Technically the 615 still had tactical responsibilities some time after the fall of Rangoon but in actual fact the equipment functioned almost solely as a storm detector. Mounted on a tower, with its dish inverted and barrel stave section removed, the 615 turned into a first rate weather set for the constant flow of air traffic passing over Burma. Weather data were supplied also by the 10th Weather Squadron with its B-25s newly equipped with APQ-13, and by Q-13s operated on the ground.

FRA NR2 021800 O JAN INFO JUST RECEIVED ENEMY NOW ON THREE SIDE OF US ABOUT ONE DAYS

Ground observer—Burma style



(HAURY FROM CRANMER) Party Nagas went seven miles from here. Wiped out village of two hundred and fifty. Passed through with thirty heads. Have photos verifying this. We are located between these villages. Would like some hand grenades, may need them.

(HAURY FROM TEAM CHIEF) On the twenty-seventh of December a party of twelve Assam riflemen escorting one American soldier and equipment stopped at Nengw village to camp overnight and went to buy rice for coolies. The King of the village drew muzzle loading shotgun. Riflemen captured King, put him in chains and brought him back to station. Natives of village had knives out and going to attack party. Thirteen rounds fired to turn them. No casualties. Holding four shotguns and King at station. Advise.

•

(SIVIK FROM HAURY) Peter Four Zero crashed near Lapyep GA 15 JIG 38. Pilot bailed out. Planes circling area now. Make preparations for patrol to rescue pilot and await instructions. Notify HQ any information immediately.

(HAURY FROM TEAM CHIEF) Medic and Abdoo with SCR 284 left with Gurkhas at 8 AM, will stand by at regular hours after we set up radio until 9 PM.

(HAURY FROM TEAM CHIEF) Pilot reported safe at Lapyep GA confirmation and more details later.

Party being held up in jungle near destination due to native trouble. Coolies feeling unwilling to proceed for fear of Japs. Situation difficult.

(ABDOO FROM LABONTE) This afternoon the second, a flight of four planes will come out and circle the spot where pilot bailed out then the planes will look for your camp. Display triangle panel. Planes will buzz your camp to impress natives. Offer one hundred rupees or cloth, salt, for information. Advise me if you are close to spot circles by planes.

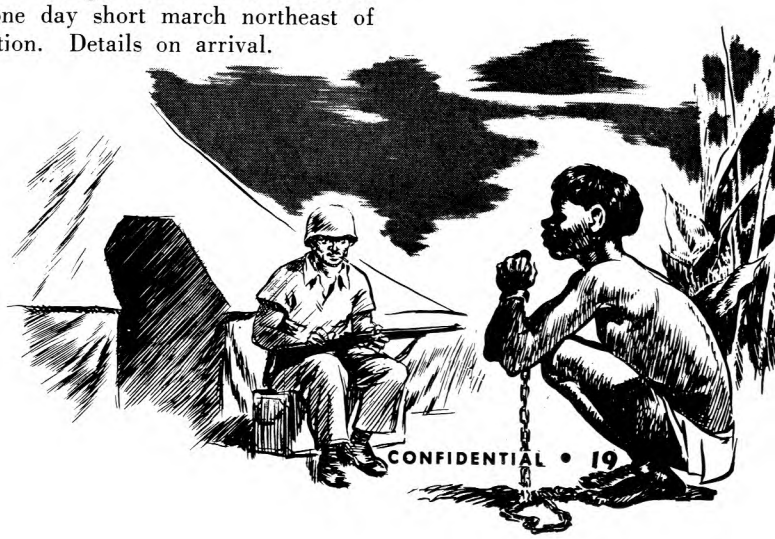
(LABONTE FROM ABDOO) Planes buzzed village and we offered reward but natives still claim no information. Planes about seven air miles southeast of our camp.

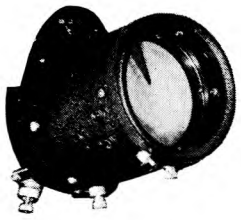
Info just received enemy now on three sides of us about one day's march. We must move our location at once. Natives are scared. Some villages already deserted.

We have been dodging Japs for three days in dense jungle which is reason for not contacting you. We are now in safe area one day short march northeast of Makwaring. Everyone OK except for exhaustion. Details on arrival.









Pulse Doppler

It would have opened way for our planes to attack moving ground targets from the air at night; herewith its theory, what it does, and its application to Firefly and Butterfly

One of the most commonly noticed phenomena of physics is the change in pitch of a train whistle as it approaches, then recedes in the distance. Physics books call it the "Doppler Effect."

Applied to radar techniques, this same phenomenon has served to open a number of locked doors. For the Germans it provided a means of distinguishing between the false echoes of Chaff and true aircraft echoes. For us, had the war continued, it would have supplied the means to attack moving ground targets from the air at night. Already it had made possible the elimination of permanent echoes from ground radars and, for drift determination, had provided the most accurate method yet devised.

Drift Determination

The Pulse Doppler philosophy, as it applies to drift determination, and as used with Nosmo equipment, works out like this:

Radar waves, since they behave in much the same manner as sound waves, change frequency (pitch) when the wave source is going toward or away from an observer—the numbers of waves received per second is increased or decreased respectively. The magnitude of the change is directly proportional to the velocity of the source with respect to the observer.

Putting the radar in a moving plane complicates things. The plane becomes not only a moving source but also a moving observer because radar waves make a round trip, thus multiplying the change in frequency by two. The velocity of the source, in the direction of the observer, now becomes the component of the plane's ground speed in the direction of the reflecting surface—being maximum along the plane's ground track. Thus, because the plane is catching up with signals sent ahead of it, there is an increase in frequency; it is going away from signals sent behind it and there is a decrease; and with signals sent directly to the side there is no change in frequency.

Therefore, since the radar beam has a finite width and the pulse a finite length, the signal received from the ground at a given range will be composed of echoes returned from a collection of point reflectors—each having a different velocity with respect to the plane and, therefore, each having a slightly different frequency from that transmitted.

When this type of signal is fed into a non-linear detector in the radar receiver, its output will contain frequency components equal to the differences between each and every input component. These are known as beat frequencies. If they are less than 20 cycles per second the output signal of the radar set for that block of signals will vary up and down at this rate and the modulation will be discernable by the human eye. If the beat frequencies are greater than 20 cps the modulation is seen as a blur.

Beat frequencies are at a minimum, so that modulation can be detected, when the antenna is positioned along the ground track. This is because frequencies returned from points at the edges of the radar beam will be about the same as those returned from the center. In other words, with the antenna positioned on the ground track all points illuminated by the radar beam are moving with about the same velocity with respect to the plane. As the antenna swings off the ground track all points within the beam will have increasingly different velocities and therefore, different frequencies—the differences increasing to a maximum at right angles to the track.

Knowing this, it is a simple matter to determine drift. The antenna is "searchlighted" slowly until the position is reached where ground clutter blur, as seen on the PPI or A scope, breaks up into individual signals having a minimum of flutter. At this point the antenna is pointing along the ground track and the angle between it and the plane's heading is the drift angle.

While drift can be taken in this manner with any basic H_2X set, the addition of Nosmo (APA-46) equipment refines the process considerably. For instance, with a servo control on the spinner motor and a servo amplifier, the radar antenna can be smoothly and accurately positioned by turning the drift angle dial. Also, the PPI is fitted with a special filter containing a blue wedge to eliminate the persistence of the tube in the region where doppler measurements are being made. Once the ground track is determined the drift angle can be read directly on a dial. An electronic azimuth mark also appears on the scope, displaced from the plane's heading (lubber line) by an amount equal to the drift angle.

Getting drift with Pulse Doppler is quick and it can be done over land without using reference points or turning the aircraft, thus shortening the time required to put the plane on a collision course with the target. Unfortunately, the null is not sufficiently clear-cut for measurement over water.

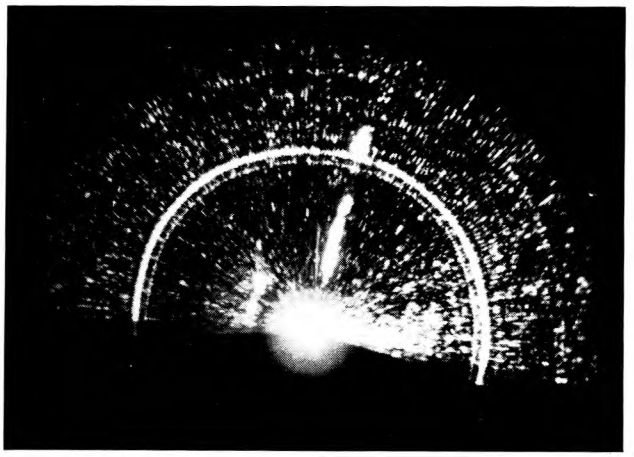
Moving target identification

In serving the war from start to finish radar made the complete shift from defense to offense and in the process was put to use in almost every tactical situation which developed—with one notable exception. Radar in our night fighter-intruder planes was unable to spot trains, tank columns, truck convoys and other moving targets.

While it is true that the radar to provide this useful feature was far from battle readiness on V-J day, some encouraging experiments were under way. The most promising development was Firefly, a scheme making use of the Pulse Doppler phenomenon to detect moving vehicles. A second method,



Firefly picks out moving autos on Worcester Turnpike and approaches to Boston. This is 5 mile sweep at 3,000 feet



Moving train is clearly resolved on Firefly scope as mercury delay line cancels out signals from the stationary targets

Butterfly, although less desirable because of certain limitations, would have been available sooner.

Both were experimental and definitely to be classed as "things to come."

The basic Doppler theory is always the same, whether used for determining drift or, as with Firefly, for identifying moving targets. In every case, echoes received from objects on the ground are shifted slightly in frequency because of the motion of the plane. Firefly goes a step farther and takes advantage of the fact that echoes from moving vehicles will be shifted in frequency even more than echoes from fixed objects. With X-band equipment the Doppler shift in frequency is 28 cps for a radial velocity of one mph.

If there is a target moving at, say, 10 mph in the line of sight of the aircraft, there will be a shift in frequency of about 280 cps. As a result, a small modulation shows at 280 cps.

Echoes showing this modulation can be picked out by sending the radar video signals down a mercury delay line which stores them for the interval between pulses. In this manner it is possible to take the string of echoes from the next pulse and compare them in amplitude with the echoes stored on the delay line. As a result, all echoes which are relatively unchanged pulse-to-pulse will cancel out and only those that differ in amplitude will remain. Only echoes from moving targets will be displayed on the scope—as shown in the photos on these two pages.

Although these are the first pictures ever taken of a Firefly scope and are products of early experiments, they reveal Firefly to be a tool which could make armed reconnaissance at night profitable. Combined with a bombing computer, such as APA-5 or APQ-5B or C, around-the-clock attacks could be conducted against moving trains and columns of vehicles.

But Firefly was pretty much a laboratory baby, about 4 months behind Butterfly, which would have been ready in December.

Butterfly differs from Firefly principally in the means used to detect the modulation which occurs when a moving target is viewed through ground clutter. With Butterfly, the resulting beat frequency is detected through an audio device rather than by the delay line and cancellation method.

Counterbalanced against Butterfly's one big advantage, simplicity of design, there are some important limitations incurred through use of audio detection.

In the first place, the video signal must be gated so that only those signals from a sector 400 or 500 yds. wide and 2 to 3 miles ahead of the aircraft are received. Otherwise, what happens at one value of range will be inextricably mixed with what happens at all other ranges. Furthermore, audio detection can be done only in the narrow forward or aft sector, to utilize the fact that flutter is at a minimum along the ground track.

This means that the antenna cannot be used for scanning with Butterfly, nor can the radar be used for navigation. Because of this, ground control must be provided, either by SCR-584 or some other means.

With the antenna directed along the ground track and the tilt adjusted to bring signals in the gate, there will be normally a rushing and sputtering background noise in the headphones. These various components of background noise haven't the slightest musical quality, whereas signals produced by moving targets do. And these musical tones, which indicate the presence of a moving target, are clearly recognizable even when the noise level is moderately high. By transmitting this audio output to the controlling ground radar via VHF, a Butterfly plane can provide reconnaissance information on moving vehicles.

However, with this system, the speed of the moving vehicle also becomes a limiting factor. The noise background is concentrated in the low frequencies and is reduced by a high pass filter cutting off sharply below about 90 cps. The minimum detectable velocity, therefore, is about 3 mph, since the X-band conversion factor is 28 cps per mph. Also, if the target moves relative to the ground at such a speed that it traverses a whole number of half wave lengths in each pulse repetition interval, it will not modulate the echo and the vehicle will remain undetected. The velocity corresponding to Butterfly's present PRF is 57 mph. Consequently, velocities between 54 and 60 mph cannot be detected.

The Butterfly system has been flight tested at Eglin Field. Ensuing verdict was that, under control of SCR-584 and plotting board, Butterfly was able to detect moving vehicles in such a way as to be tactically useful. A Butterfly system, consisting of components of APS-15A and an additional control box, was being prototyped at war's end.



From Mt. Suribachi's summit, protected by sand-filled drums, an AN/TPS-10 swept Iwo's skies for its first partner there, an SCR-270. At war's end an MEW was set up here

The Li'l Abners

They were the

The lone Li'l Abner (AN/TPS-10) which landed on Iwo on D plus 5 ended up the fight with lots of company there and elsewhere. At the north end of the Island that first Abner remained on the alert—doing short range search and heightfinding with an SCR-527. Another Abner continued heightfinding for the MEW atop Suribachi right up to the finish—double insurance against any last-minute ideas the Japs might have dreamed up. Before the Japanese surrender more Abners went to work for the Okinawa MEW, where they will be very busy helping with traffic control until the Japanese occupation is completed. Two were set up for training in the Philippines, and a set arrived at Oahu, specially mounted on a stable base. The Navy had plans for that one, for shipboard use.

Although the TPS-10 was designed primarily for search in mountainous country, that's not all it can do. Its heightfinding abilities made it a star performer in GCI teams. And in its MTO proving ground it showed that it was tops for front-line coverage when the depleted GAF started to concentrate all its energy on harassing front-line troops.

Iwo's two Abners never did get much of a whack at the Japs. From the first of May through the middle of July, there were in all about ten raids, usually made up of two or three planes which were soon discouraged by our radar-directed AA and fighters.

The largest raid came on the night of 21 May when seven Japanese planes tried to sneak in low. The Surbachi Abner first picked up a bogey at 355° and 57 miles, 15,000 ft. As the planes came in Abner picked up each one, followed their flights, and reported to the Filter Center. The Abners were usually instructed by the Center to keep hunting for low-flying bogeys. In this raid one Abner watched the Jap planes drop from 15,000 to 6000 ft. The other Abner, the one with the SCR-527, picked the raid up first at 40 miles and 6000 ft., and followed it in. Several planes dropped window, then went into a dive to 300 ft. The SCR-270, which was then operating on the peak of Suribachi, had window trouble, but the two TPS-10s weren't confused.

The Li'l Abners, like their famous namesake, are rugged. At Iwo they gave a fine performance, and a continuous one. They saw P-51s out to at least 35 miles, P-61s to 45, and a bomber the size of a B-24 to 55. Although the greatest cause of damage to either of the Iwo sets was in shipping, both sets moved around a lot and stood the strain pretty well. The first set to go out was moved three times, because of a stop-over en route for trial operation atop Mt. Tapotchau, at Saipan. The Suribachi Abner was operated first down below, then moved to the summit; it came down again while the MEW was being set up, and then went back up.

Until it went to work for the MEW, the Abner on Suribachi operated with



The 568th SAW camped below summit near Jamesway storeroom for their MEW-615 equipment damaged en route, while "ducks" put more radar on Brown and White beaches

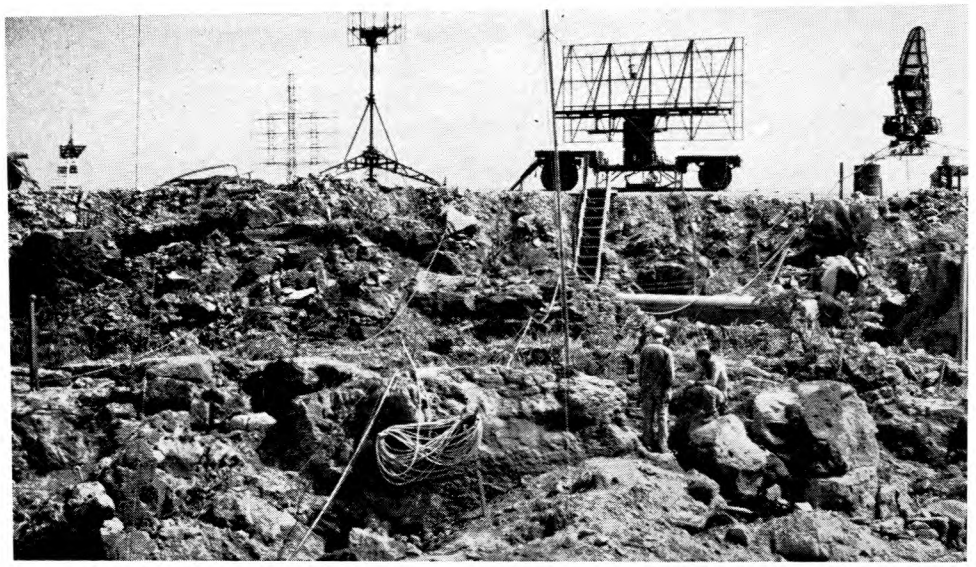
best friends a GCI ever had

an SCR-270. The Abner indicator was located in a tent, reported to the SCR-270 plotting board and Filter Center by telephone. Now there's an Abner indicator right beside the MEW PPI. The other set operates in much the same fashion with an SCR-527. In a GCI set-up which was described as one of the best in the Pacific, the Abner operator reported azimuth, range and height on all targets while the plotter reported directly into the Filter room. There the Abner indicator was installed in the 527 van opposite the 527 PPI, so that the controller could look at either scope. Bogeys of special interest were investigated on request from the Filter Room. In general, for GCI the Abner operator stayed on the bogey to provide an accurate track in case of evasive action while he read height directly from the scope to the controller.

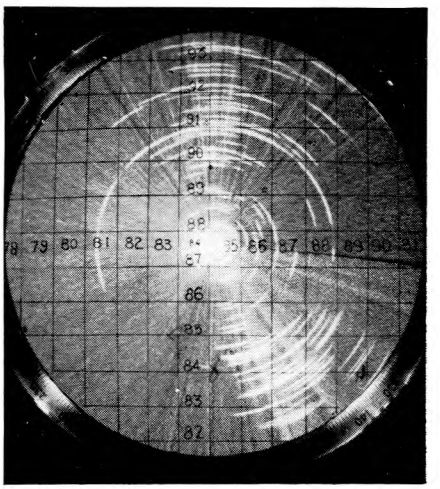
The beam shaped by Abner's 10′ x 3′ antenna is 2° in azimuth, and 0.7° in elevation. It can be made to rotate through 360° at a rate of 1/3 rpm, or scan through a sector, or track a target. While the antenna rotates it nods up and down through a 25° sector—from −2° to +23°. When the operator tracks he uses a handwheel—continuous azimuth searching stops, but the antenna still covers the 25° elevation sector. Slant range and height information are presented on a 7″ RHI scope (for Range Height Indicator) from which the data can be read directly. Ground clutter appears along the lower limit of the sweep, with aircraft and cloud echoes appearing above. The operator reads height by bisecting the center of the signal with the height line, drawn on a plastic strip mounted on the tube face. There are six vertical range markers, spaced ten miles apart to help read off range. On the RHI panel a dial, driven by the scanner turning mechanism, gives azimuth. The fact that the RHI gives slant range proves to be relatively unimportant, since the altitude of most targets is limited, and the vertical angle, therefore, small.

A plotting board has been supplied with each set, but the Suribachi Abner's board was a special one—while operating with the 270, the set used a servo-driven board located in the Operations tent. A plotting arm, calibrated to facilitate reading range in miles, was servo-driven to indicate the antenna's bearing. Whenever Abner was called upon to do general search and reporting duty away from the main search radar this board was a great help. When the Abner was used solely for height-finding, and its scope located in a main operations room with a central plotting board, the servo-driven Abner board wasn't so necessary. But it speeds up the set's traffic handling capacity. With the board it is not necessary to stop the antenna on each target while searching in order to read off bearing.

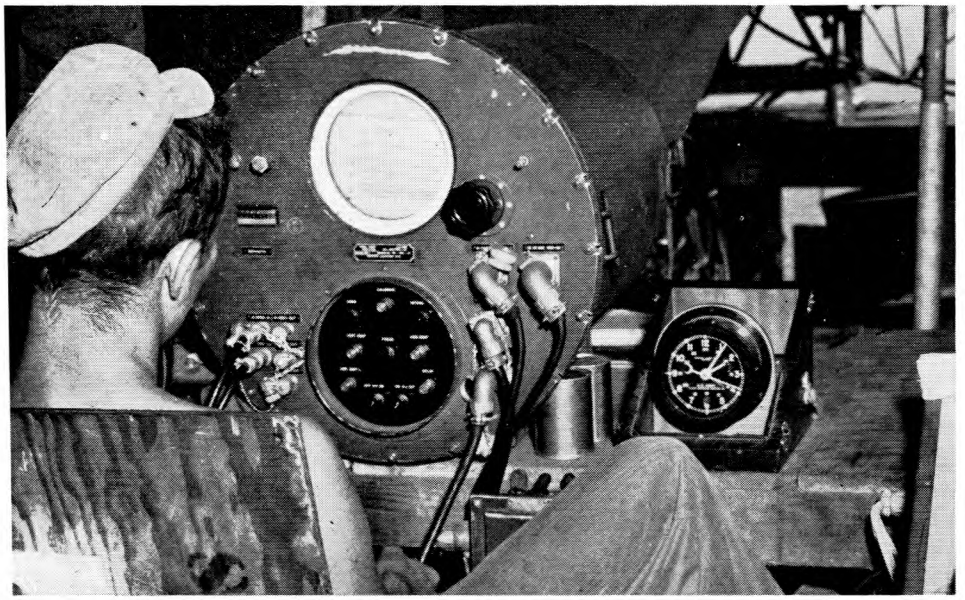
There are other ways of boosting the number of plots the TPS-10 can handle. Using parts from an old 270 antenna



At Island's north end, Abner operated in real radar jungle consisting of two SCR-527's, SCR-270DA, IFF. In Surabachi operations tent (below) RHI-man monitored scope. Height markings on tube were made by crew, replace wrecked mechanical calibrator



Skyfull of B-29s streaming back from Japan, over Iwo, down toward Marianas base shows on 527 PPI at Iwo's north end

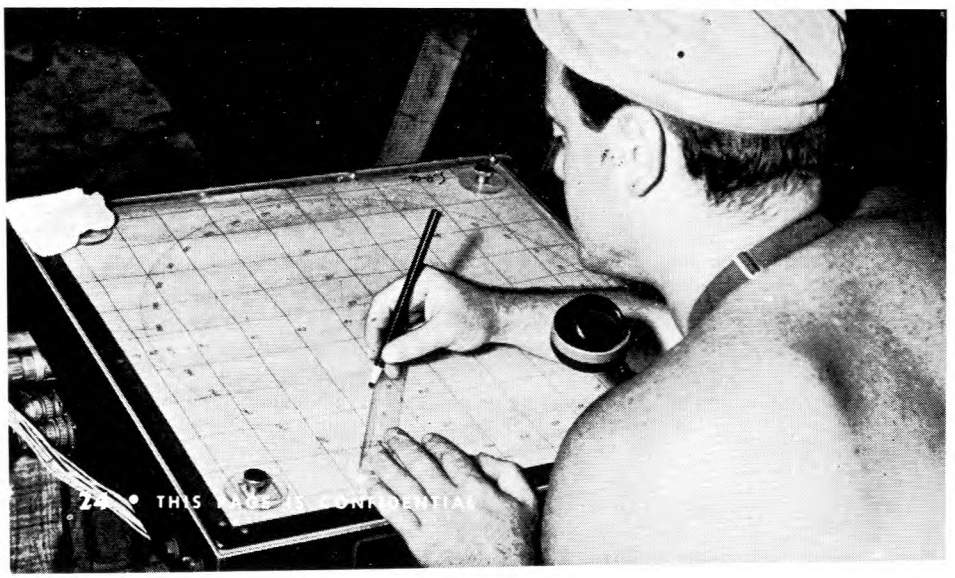


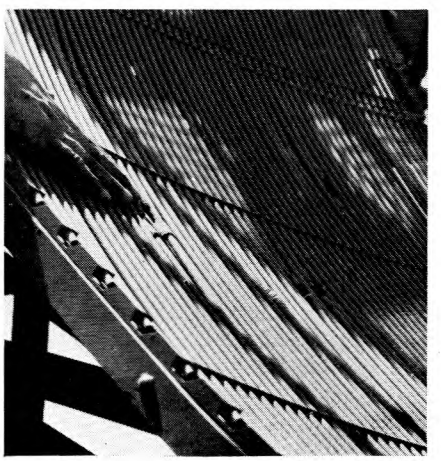
New height calibrations (above) were made by having plane flown at known altitudes, putting data right on scope as overlay. Process was lengthy, but meant highly accurate information for the plotter (below) who worked special servo-driven board

drive, the 7th Fighter Command built and installed a new servo drive for the MEW Abner which increased its slewing rate to about 4 rpm and positioned the antenna just as accurately as the mechanical handwheel formerly used.

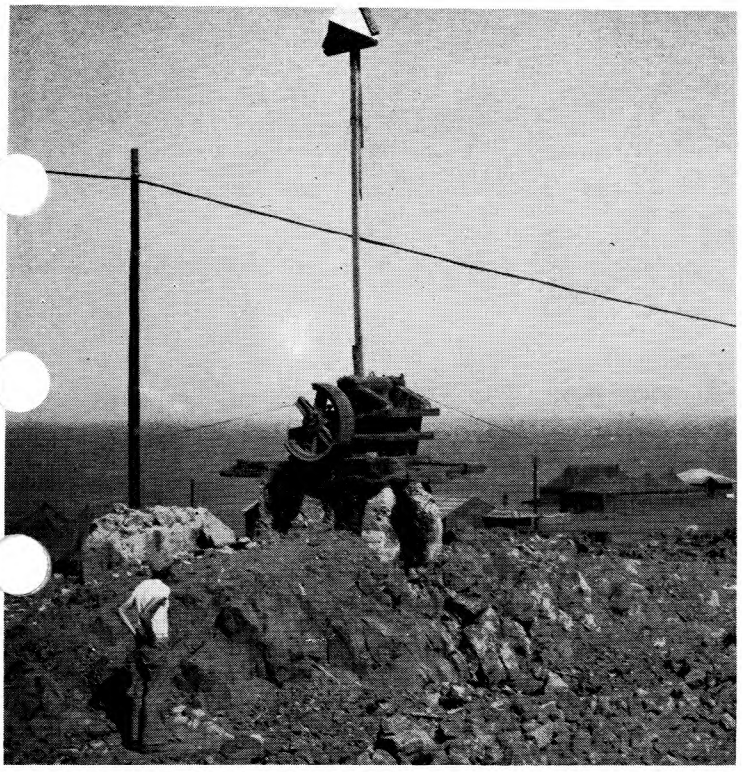
For Abner, with its very narrow azimuth beam, to be a thoroughly efficient member of a GCI team, aid is necessary in positioning its antenna with respect to a target selected on the main search PPI. The "azicator" is just such an aid. It is a servo-driven cursor, mounted on the search PPI to follow the Abner azimuth position continuously. The 7th Fighter Command constructed an azicator, too,—mostly from SC-3 parts —for the 12″ MEW PPI.

Li'l Abner's capabilities would have been well suited to life in the Burma hills. For its use there, see page 14.

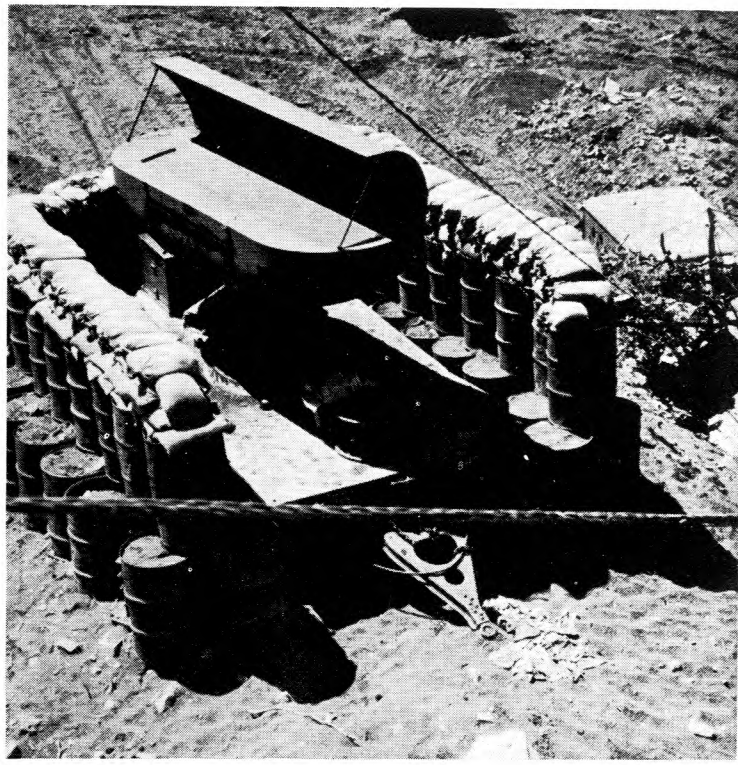




Li'l Abner's dish grillwork still bears scars from shrapnel and mortar fire of its D plus 5 landing. Frame was also hit



Iwo lacked points for calibration so crew watched scope while corner was carried around on pole, placed on Jap rock-crusher



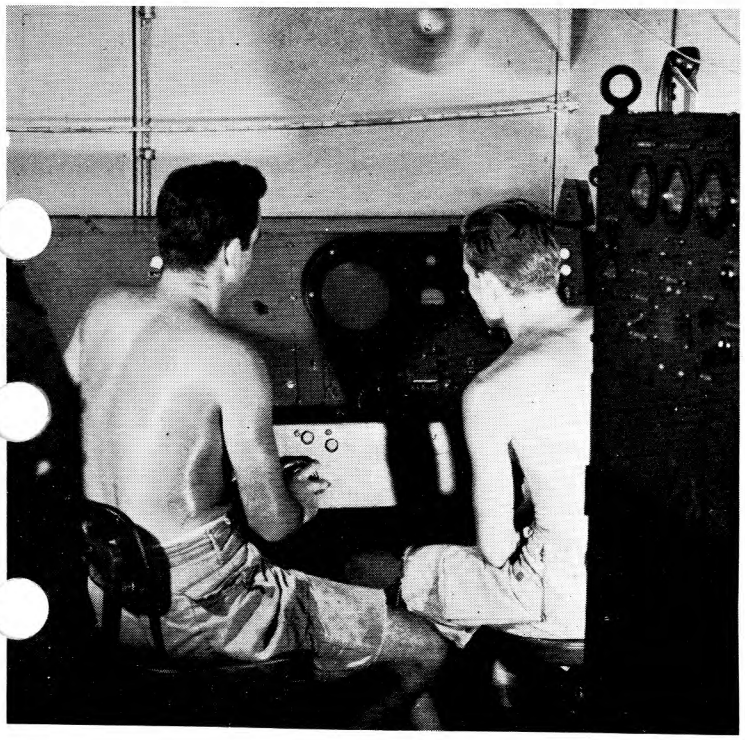
MPG antenna sat on trailer beside dug-in operations van. 176th CA diggers found Jap cave (under boards), used it for cool room

Iwo's guns: readied, MPG-aimed, unfired

The 176th CA Battalion had top radar control for its 155-mm guns after the AN/MPG-1 lumbered up to its site on Iwo's north shore on 25 April 1945. The tactical situation, however, didn't call for the MPG's use then, nor did it up to the war's close. The enemy surface craft which the MPG was built to get were, in this area at least, non-existent.

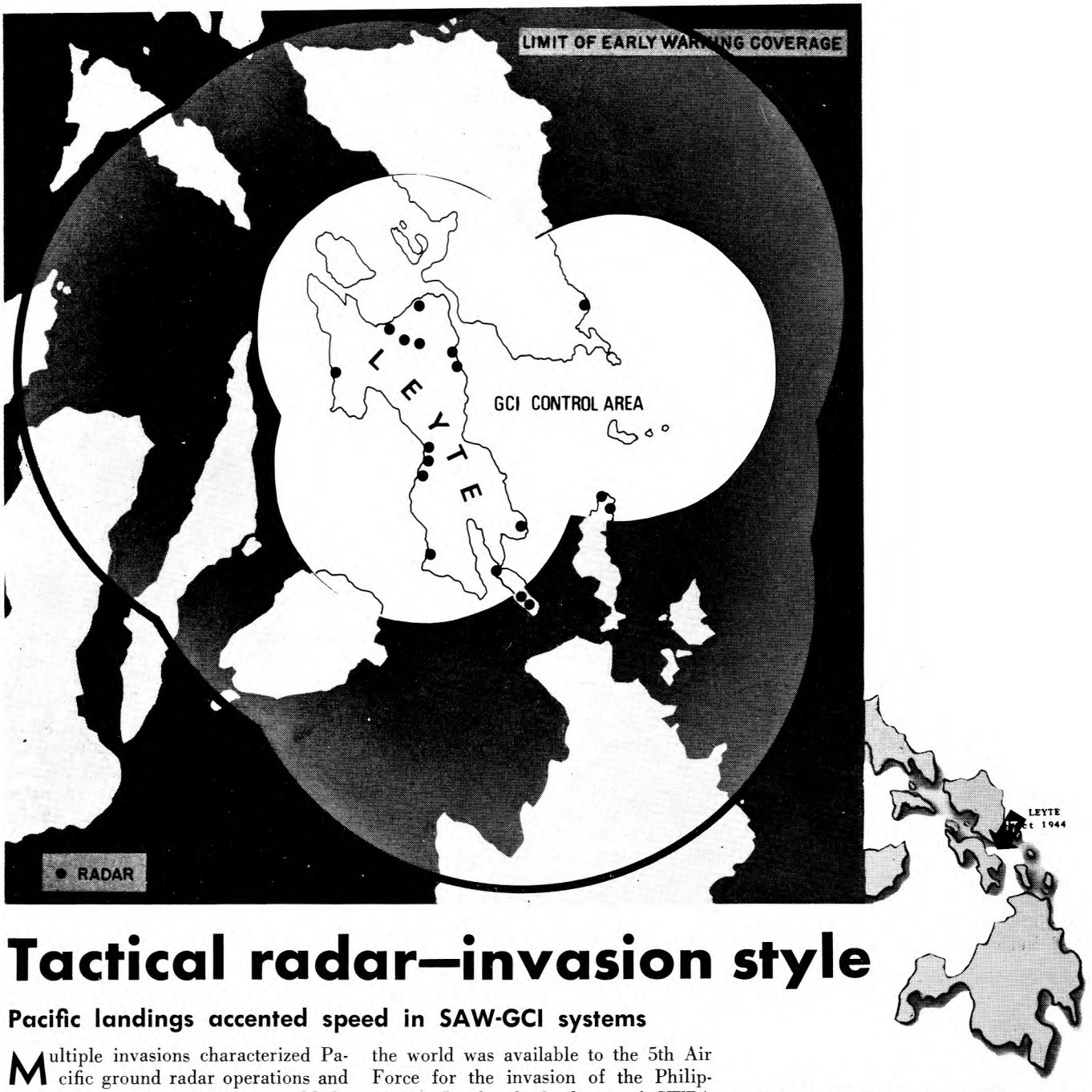
From its location—100 yards to the rear of the battery—the MPG looked out over a slice of ocean from 0° North to 200°. And in that sector it could see surface craft out to 80,000 yards—28,000 for fire control. Since the set was so near the guns, the spotting scope could be located right in the plotting room; there was no need to send data from van to plot. Every other night the crew ran off a radar drill. Meanwhile they plotted the courses of friendly ships, and stood their watch along with the rest in Iwo's solid system of defense.

For MPG drill B-scope operator in van set up buoy signal, tuned and detuned set to give spotting operators 3-second look at target



In plotting tent during radar drill, spotting scope operators practiced centering on signal from buoy 1800 yards off-shore





Tactical radar—invasion style

Pacific landings accented speed in SAW-GCI systems

Multiple invasions characterized Pacific ground radar operations and emphasis was on immediate establishment of tight air warning nets and efficient GCI. These requirements developed a tactical radar system quite different from that of the ETO (see RADAR No. 8) where rapid movement over large ground areas was the rule and relative absence of enemy air attack subordinated GCI to close control bombing and intruder work.

On this and the following pages RADAR presents highlights of tactical radar operations in the SWPA and Central Pacific with special attention to the climactic invasions of Leyte Island and Okinawa.

One of the largest radar armies in the world was available to the 5th Air Force for the invasion of the Philippines. In the final phases of SWPA operations, the 5th Fighter Command had two operating Wings, 85th and 86th, each with one lightweight and one heavy Signal Aircraft Warning Battalion, and two additional SAW Battalions in reserve. In addition, the AW strength of the Command was reinforced by another SAW Battalion detached from XXIV Army Corps for the Philippine landings, making a total of more than 15,000 seasoned AW troops.

This was a far cry from the picture at the beginning of SWPA operations in 1942 when the AW system of the 5th AF comprised a handful of men, limited to a few units of heavy mobile radar, SCR-270, SCR-268 and SCR-516 (a modification of SCR-268 used for search with moderate success).

In the very first SWPA campaign under jungle war conditions, it became immediately apparent that some type of LW radar was absolutely indispensable. Transportation of the heavy units was sometimes impossible, and at best often created dangerous delays. It was many times necessary to operate from mediocre or poor sites.

The first lightweight radar available to U. S. forces in the SWPA was the Australian-built LW/AW, a 5000 lb. unit which was flown over the New Guinea "Hump" to Buna on 5 Decem-

ber 1942. The LW/AW was rushed into production in Australia after Pearl Harbor; until then there was *no* AW equipment in existence down under. It gave good results with the SAW units and was particularly distinguished by excellent tropicalization.

The first American LW, the SCR-602-T6, gave poor results. It wasn't until the arrival of the SCR-602A that full development of LW radar for assault and rapid deployment could be realized. Ultimately 18 SCR-602As were provided in each "lightweight" SAW Battalion. A few units of AN/TPS-2 were tried out by these Battalions but were only partially satisfactory in limited uses. Besides the radar equipped teams, the lightweight Battalions each had one company of Ground Observer teams.

Field efficiency was achieved by concentrating larger radar units in the "heavy" or "mobile" SAW Battalions. Such Battalions had three companies; each company had three SCR-270 teams (also equipped with LW/AWs for emergency operation); two platoons with SCR-527s; and one or two platoons with SCR-615 or Navy SP1M for height-finding.

Invasion and tactical radar technique was learned fast in the SWPA as the forces under Gen. MacArthur developed the program of accelerated island hopping towards Japan. One of the first necessities discovered was the need for air warning during the assault phases of both airborne and amphibious landings. Such landings as those at Cape Gloucester, Finschafen, Hollandia, and Biak also stimulated new ideas about the mobility of heavy radar.

The two Wings of 5th Fighter Command leapfrogged each other up the New Guinea coast and through the islands. In most invasion operations, the radar commitment included one light radar company, one mobile company, and a Fighter Control Squadron or detachment.

Invasion field orders called for the radar assault echelon to land at H-hour plus 4 with SCR-602s and plotting and fighter control personnel. Heavy mobile units, both 270s and 527s, were often landed as early as D plus 3. By D plus 10, the AW and GCI net was expected to furnish an air-tight aircraft warning system and be ready to deploy supporting radar units as the tactical situation required.

Leyte—perhaps the best example of operational radar technique in the SWPA—went close enough to plan to illustrate the nature of radar invasion routine, and there were enough obstacles and setbacks to dramatize the difficulties of carrying out a routine in combat.

The 85th Fighter Wing drew the initial Leyte landing. In the assault wave, it had Company "C" of the 583rd SAW Bn., which had made the Hollandia landing. The mobile Company was "C" of the 565th, which had established the first American FCC at Buna in December 1942. In addition, the 85th Wing was given operational control of AW units from the XXIV Corps from the Central Pacific. A total of 23 radar units were committed to the operations.

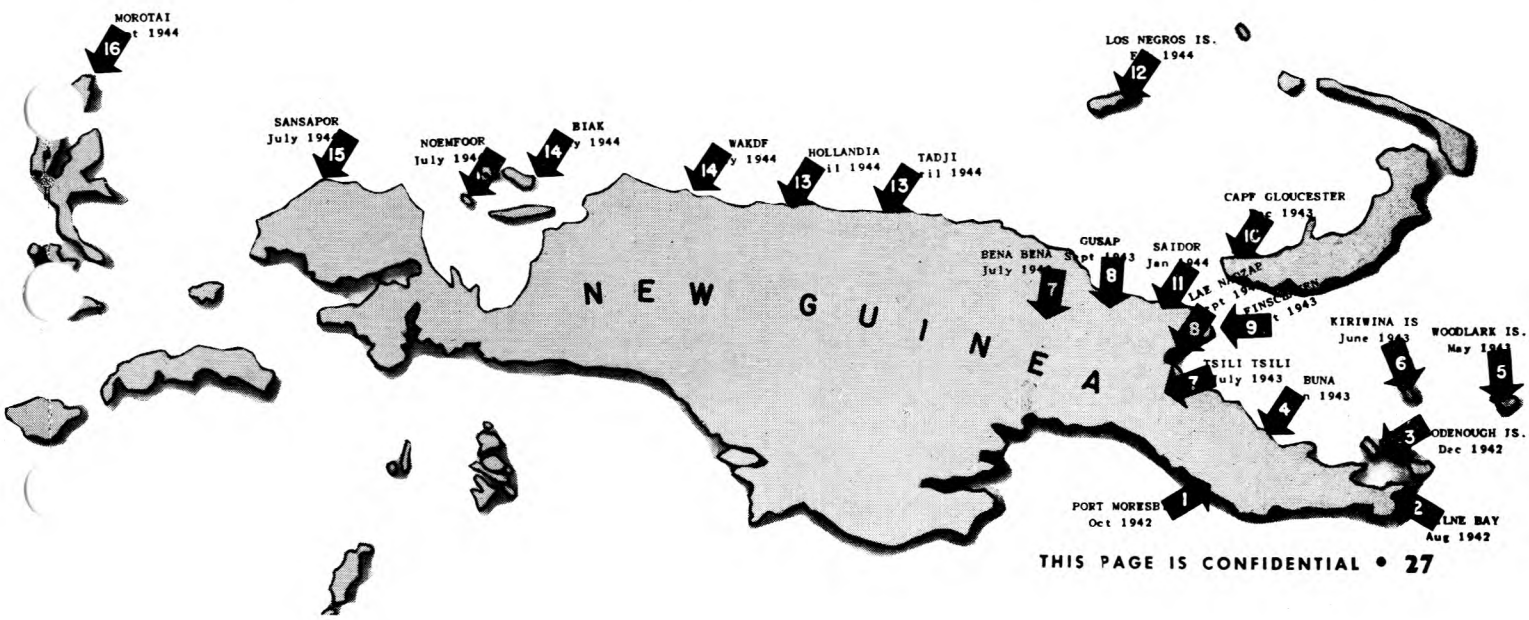
Well in advance of D-Day, a detachment of GOs and volunteers from LW units, equipped with TPS-2s, were dispatched by submarine to Negros Island. By 10 October all assault units were loaded and waiting in Hollandia Harbor. On 14 October other GO teams left Finschafen to land with the Rangers on strategic islands in the Leyte Gulf. On 15 October the largest convoy ever assembled in the Southwest Pacific sailed for the Philippines.

At 0930 on 30 October the first wave of infantry went ashore at Tacloban, Palo and Dulag. At 1130 radar plotting and fighter control personnel hit the beach and by 1530 all AW personnel were ashore and equipment was being unloaded. The landing was a complete surprise at Tacloban and Palo and the beachhead was secured to three miles inland by evening. In the assault phase, night ground infiltration was heavy but the worst obstacle was gumbo mud which made movement of any kind of equipment a nightmare.

Lightly equipped plotting and fighter control units had the least trouble; they soon had an AW net in operation with reports from GO posts, Filipino guerilla stations, and information from the Navy.

Deploying radar units was another matter. The priority air strip was at Tacloban but all equipment had been landed at Palo, 8 miles south. The strip was under control on D plus 1 and by pushing, hauling and bulldozing, one SCR-602 was in place by nightfall. On D plus 2 by 1600 hours the set was sited, dried out and operating. At 1640 it picked up its first hostile target—28 miles out in Ormoc Bay.

By D plus 2 a second 602 went into operation at Palo. On D plus 3 the first 527 came ashore at Palo and the FCC was in operation at Tacloban with an air warning net which was considered adequate protection for the beachhead.

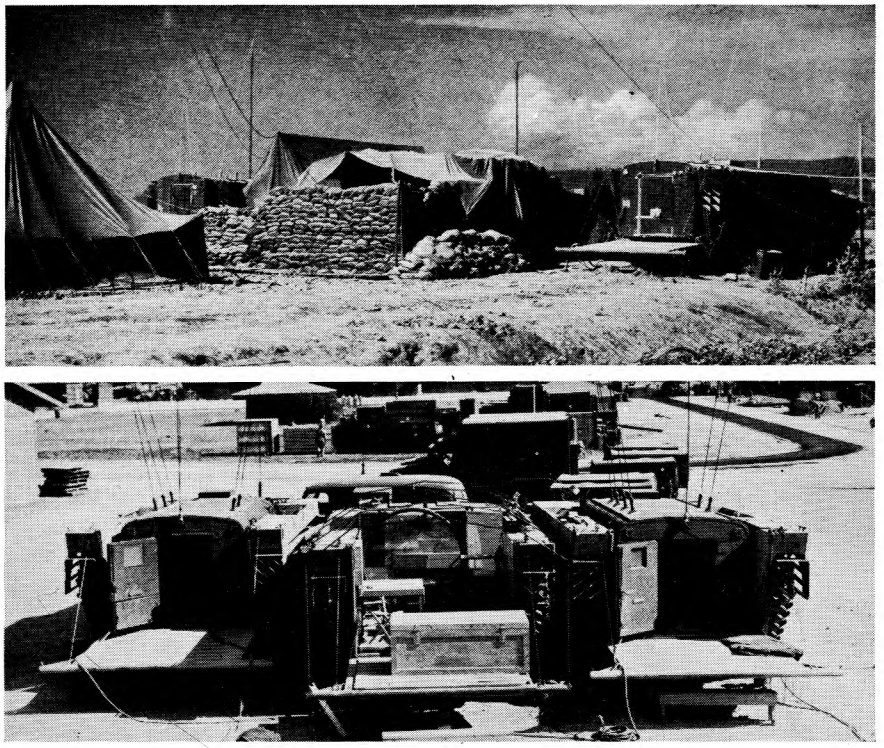


With this accomplished, the Wing AW detachment concentrated on deployment of units to meet the tactical situation. Coverage to the west was extended by siting a 602 at Baybay as soon as it was reached by an infantry spearhead. Early warning to the north was advanced by landing a 602 at Babatngon on the northern tip of Leyte. Radar coverage over Leyte Gulf was delayed by naval engagements which held up plans for a 602 on Desolation Point on Dinigat Island, but this unit was landed by D plus 10 in the face of a rising typhoon. Also by D plus 10 a second 527 was put into operation at Dulag in order to extend the GCI net in anticipation of enemy air reaction.

The enemy tried every trick in the book during the Leyte campaign. The intensity of air attack is indicated by the score of 467 enemy plane kills credited to 5th Fighter Command, including 11 downed by night fighters under GCI control. Besides constant infiltration, the Japs employed airborne paratroopers and saboteurs, once completely surrounding the Hq. of Air Force, Fighter and Bomber Commands.

The complete, continuous and alert AW and GCI system must be credited with a major assist to the final victory in the battle of Leyte, which came to a crashing climax on 7 December when the 77th Division was pulled out of central Leyte and loaded on transports to make an amphibious landing at Ormoc.

A week later, Allied forces hit Mindoro, and the power of SWPA was headed north to Lingayen and Luzon, almost overnight transforming Leyte to a rear area.



Last word in assault radar was this Air Defense Control Center mounted in LVTs. At top: ADCC at Okinawa where it landed at H-plus-½ hour, was on the air one-half hour later with two radar units reporting. Below, at Oahu, before moving out: plotting and control room in center LVT, duplicate communications units on each side

Marine radar record was tops at Okinawa

The invasion of Okinawa Rhetto revealed the assault radar system of Marine Air Group 43 at the peak of its development — aggressively employing the radar know-how perfected in previous operations with Tactical Air Force, 10th Army, in the long drive through the Jap island strongholds of the Central Pacific.

The radar Marines unveiled their new assault Air Defense Control Center at Okinawa. The ADCC came ashore in its LVTs at H-hour plus 30 minutes and rolled to its site at Point Bolo near Yontan Field. One half hour after arrival, the new Air Defense Control Center was on the air with two stations reporting.

These stations were early warning radar units which landed on islands near Okinawa, Zamami and Nagannu Shima, several days before the initial assault on the main island. Until a better claim comes along, this should stand as the war's speed record in establishing a radar aircraft warning and fighter control net.

MAG 43 carried the responsibility for radar coverage, including AW and GCI, for the entire Ryukyus operation pending the installation of an AAFPOA microwave net which was planned for the islands with two MEWs, six AN/CPS-5s, four SCR-615Bs, and six AN/TPS-10s.

The weight of this responsibility may be measured by the intense Japanese reaction to the Okinawa thrust. Between 1 April and 8 July, the Marine Aircraft Warning net and Air Defense Control Center handled early warning and GCI for a total of 622 enemy plane kills by TAFTen, 60 of them by night fighters. In addition to kills, the radar net was a vital aid to air and ground defenses in harrying all enemy planes and preventing accurate bomb runs.

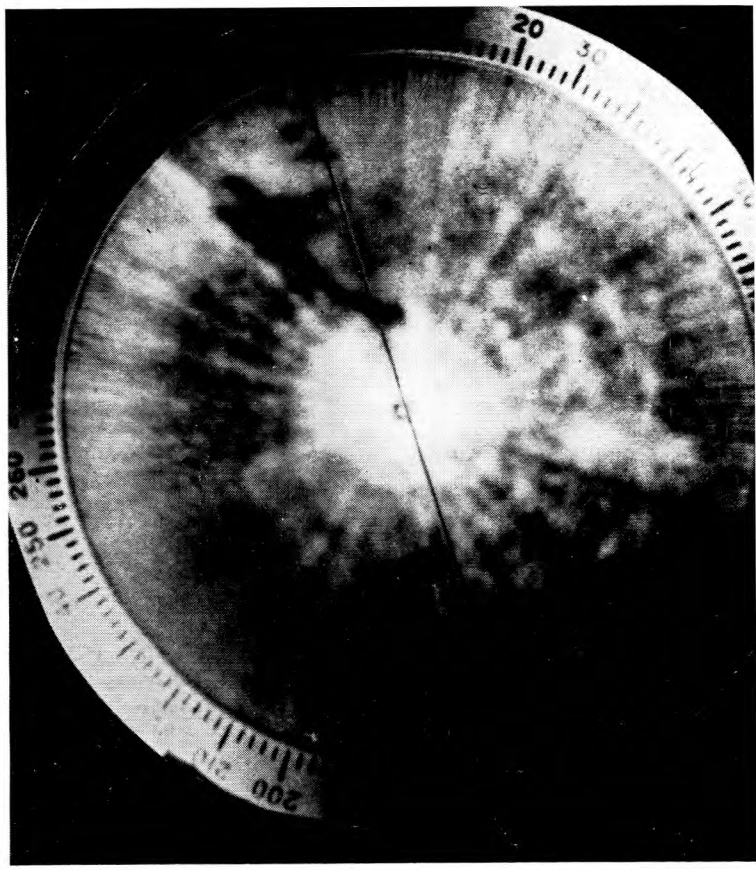
For the Okinawa and Ryukyus air warning system, MAG 43 had five Marine Aircraft Warning Squadrons, 1, 6, 7, 8, and 11, and the Army's 727th SAW Company, which was rushed from Leyte to operate six TPS-1s to round out the Marine radar complement of SCR-270s, SCR-527s, SCR-602s and SP1Ms.

In the Ryukyus net, each MAW Squadron operated a sub-area ADCC to filter information from its own radar units to the ADCC regional control on Okinawa. A Combat Air Patrol was kept aloft at all times by each of the sub-area ADCCs.

AW Squadron 1, the oldest Marine radar squadron in the Pacific, from its ADCC on Ie Shima was responsible for coverage for 200 miles to the west, northwest, north and northeast. Four islands were included in the deployment of its radar units.

In its first thirty-six days of operations, the Squadron plotted a total of more than two hundred enemy raids, and the CAPS under Squadron GCI scored a total of 149 enemy aircraft destroyed or damaged.





Signal fuzziness, caused by pulse length and beam width, can be predicted. In photo at left black area was put in to show return expected from Lake Worth. Points along shore were extended 800 ft. parallel to track for range smear, 2000 ft. perpendicular to track to account for azimuth smear. Scope photograph above shows actual return

Scope distortion

It was one of radar's toughest operational hazards

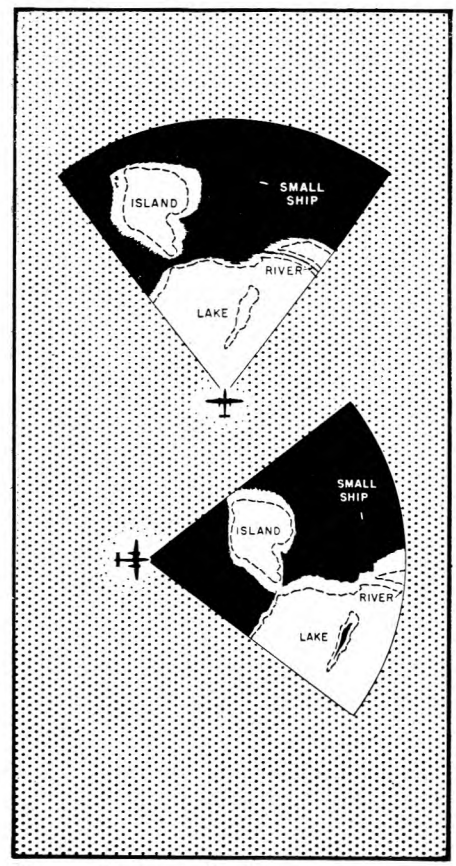
Radar operators were having trouble with scope interpretation on the first H_2X missions in November 1943 over Germany—they were still having trouble when radar dropped its last bomb of the war over Japan. The interpretation difficulty stemmed from the fact that radar, mechanically and electrically, simply cannot paint a precise picture on the scope. A certain amount of distortion is unavoidable.

In a broad sense the term distortion has come to define all limitations to the usefulness of the scope image. Those limitations can be classified as fuzziness, a lack of detail in the radar image and true distortion, which exists when scope signals have incorrect relative positions.

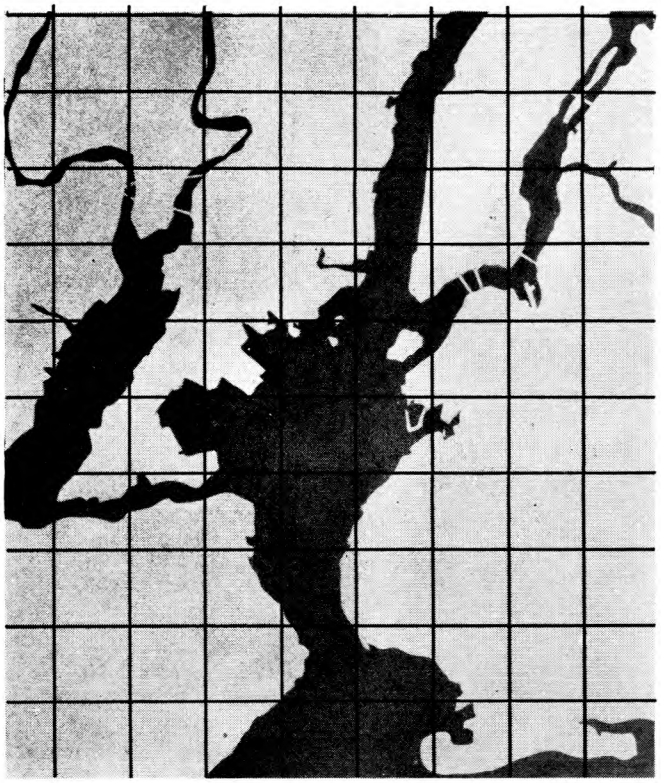
Fuzziness, or smearing, is largely caused by the combined effects of pulse length and beam width. All radar pulses have finite length—in the case of microwave radars about one microsecond. Since objects on the ground will reflect energy and brighten the scope for this length of time those objects will appear to be extended in range by about 500 ft.

To make matters worse, this range smearing is combined with azimuth fuzziness caused by beam width. Although microwave beams are often sharp, even the 3° beam of APQ-13 and APS-15 produces a certain amount of smearing. As the radar antenna revolves a target will be illuminated for 3° of the revolution. The resulting PPI signal will therefore subtend a 3° angle.

True distortion (signals appearing out of place) is largely the product of slant range measurement. For instance, a scope with a 10 mile sweep at an altitude of 5 miles would receive its first



Scope picture will change as approach angle of aircraft changes because range resolution is better than azimuth resolution. Diagrams show effect of this change

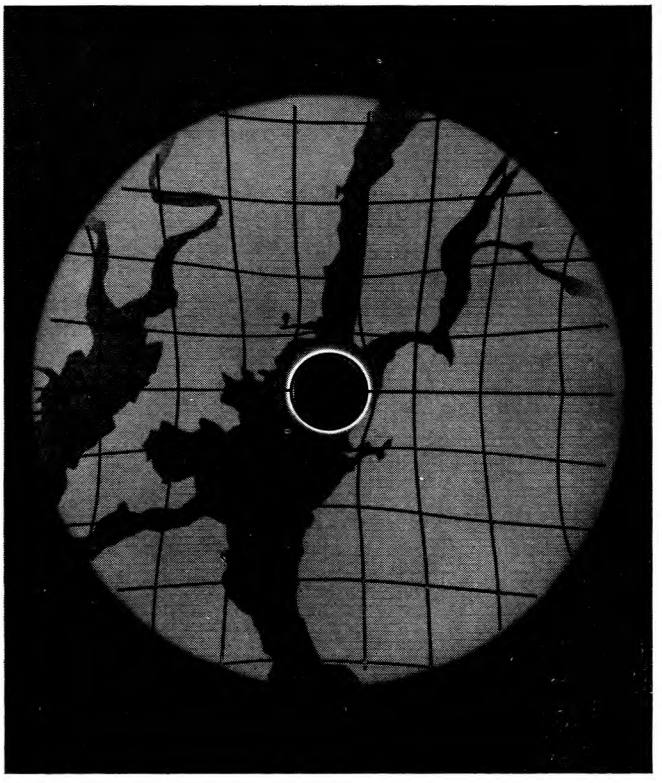


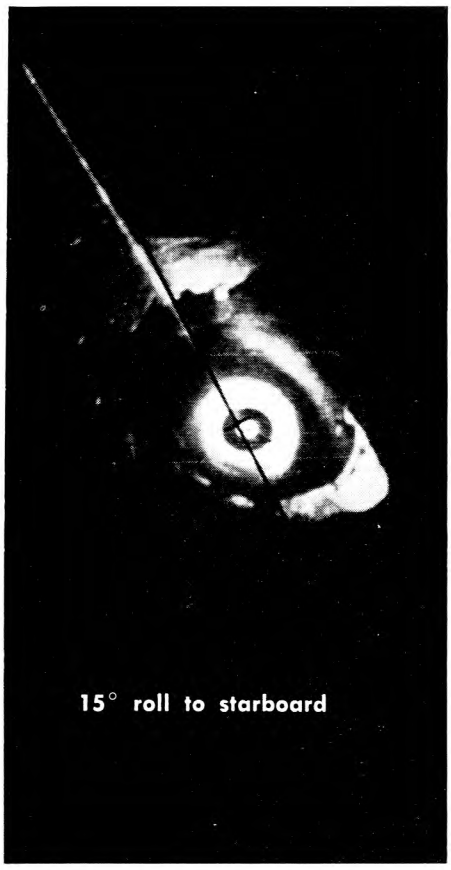
Altitude distortion caused by slant range measurement can be corrected with sweep delay. Map of New York Harbor (above) is squeezed into outer half of PPI (below) if no delay is used at altitude of 4.1 miles with 9 mile sweep length. Center of map is represented by circumference of dark circle. Drawings assume no sweep distortion. Spacing between grids is about 2 miles

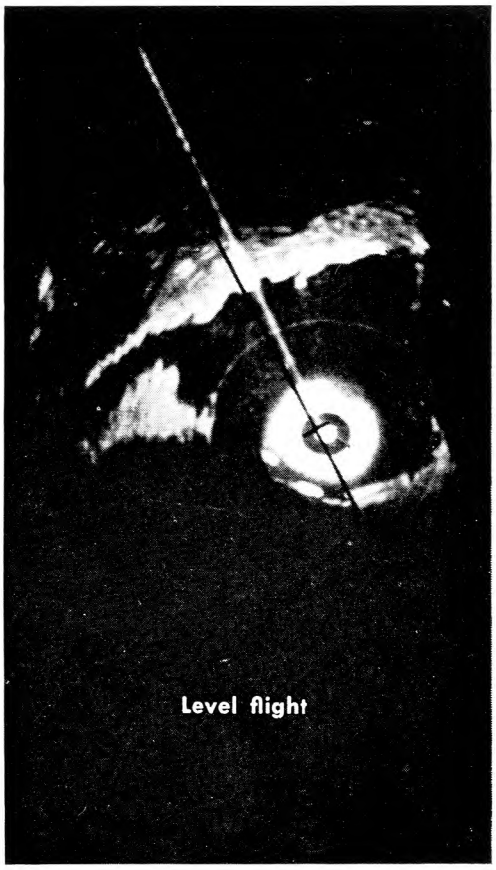


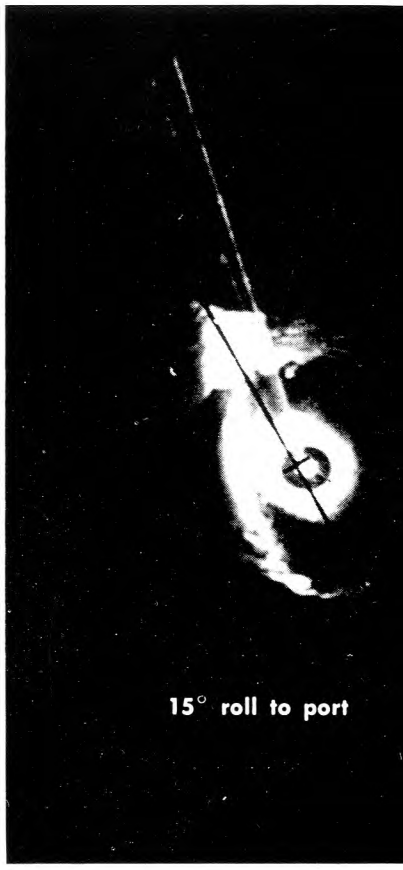
Sweep delay equal to altitude (above) places first ground echo at start of sweep. All signals within 10 miles slant range are covered by 6 mile sweep because of delay. Distortion now present is opposite from that when no delay is used. Dotted lines show boundaries minus scope fuzziness. Map suffers minimum distortion with a sweep delay equal to about 4/5 altitude (below)





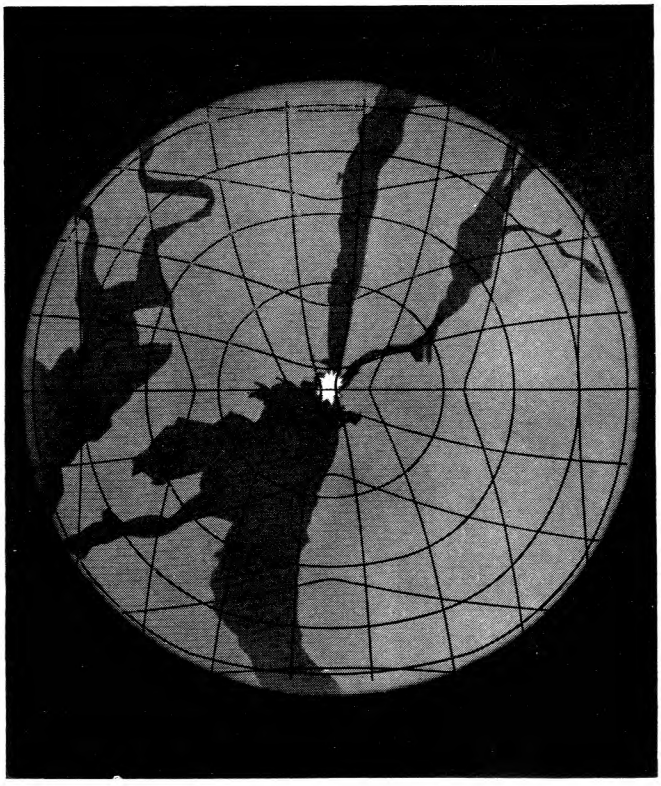


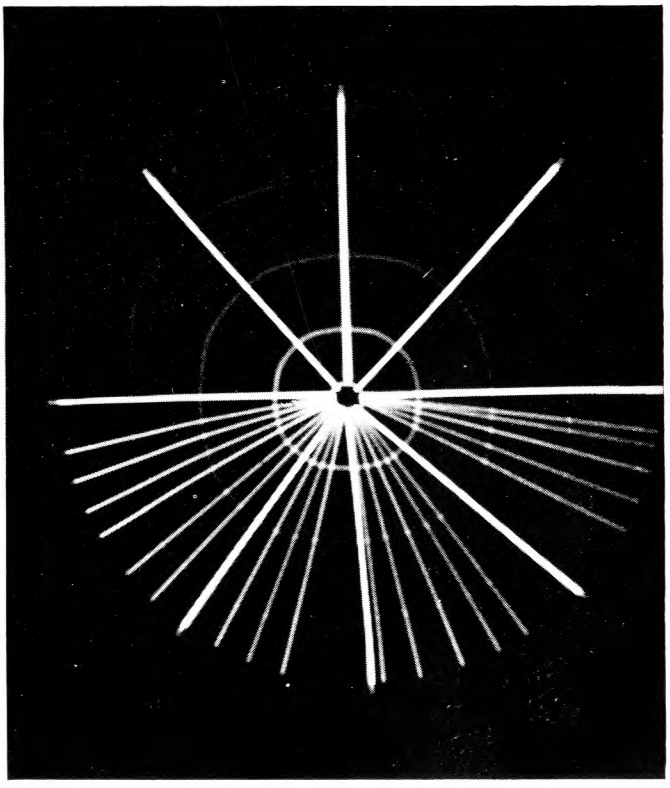




Sweep rate which isn't constant causes uneven spacing of range circles and distorts map toward center (below). Sweep unbalance from overloaded deflection yoke causes trace to be curved instead of straight for certain azimuth positions. In photo below bright traces are straight, others are slightly curved. Resulting range circles resemble squares with rounded corners

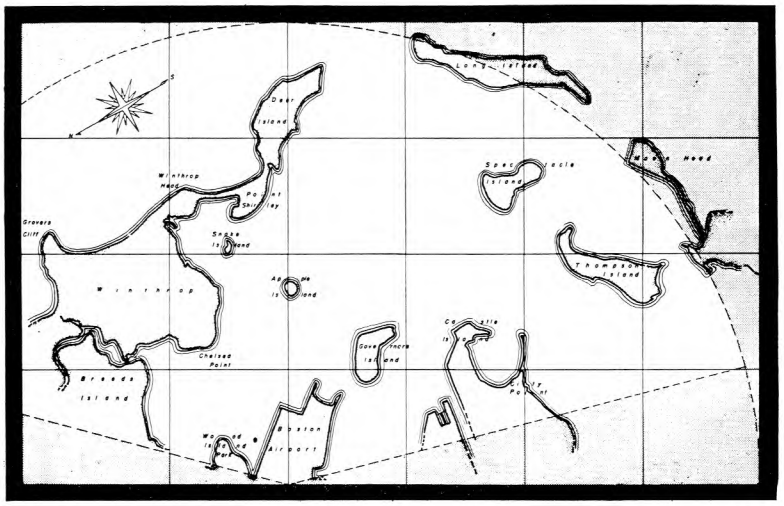
Non-level flight causing unequal distribution of illumination is shown above in pictures of Nantucket Sound. Whole picture is displaced if plane is not level. With one wing 3° down at 4 mi. altitude, a condition hard to detect, center of PPI is point displaced from that directly below plane by 416 yds. Resulting bad azimuth readings could throw H_2X bombers off target

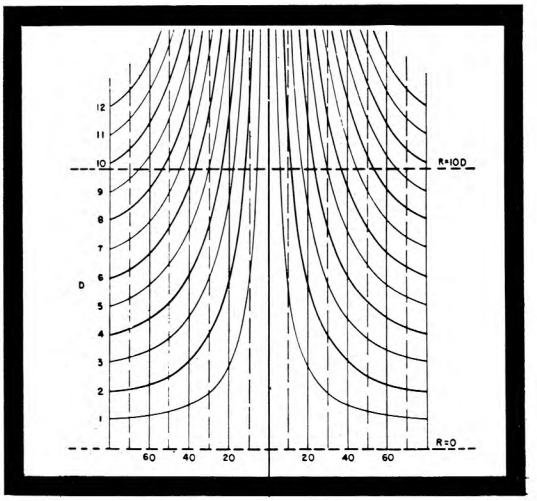




ground signals at a range of 5 miles. Thus, the point on the ground directly beneath the plane would be represented by a circle half way out from the center of the scope. Furthermore, an object which is 10 miles from the plane by slant range measurement is only 8.7 miles from the point on the ground directly below the plane. Objects on the ground included in a circle 8.7 miles in radius and centered on the point directly below the plane are squeezed into the outer half of the PPI. This means that 8.7 miles of ground range are displayed in a sweep length corresponding to 5 miles of slant range. The resulting picture is considerably distorted, especially near its center. Fortunately, this distortion can be minimized by incorporating a sweep delay equal to about $\frac{4}{5}$ the altitude, as illustrated on page 30. Another way of avoiding it is to provide the set with a non-linear (ground range) sweep, as is done with APQ-7.

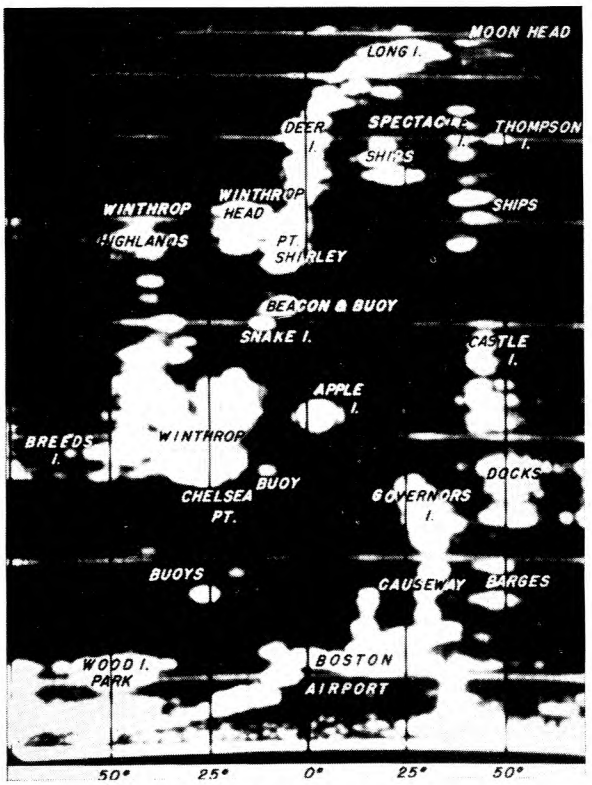
Distortion can also be caused by irregular CRT sweep rate, sweep unbalance and non-level flight. For whatever cause and in whatever form it was found, distortion presented one of radar's chronic challenges to wartime operators. In peace, since precision bombing is not a peacetime operation, distortion will not handicap radar to any great extent.

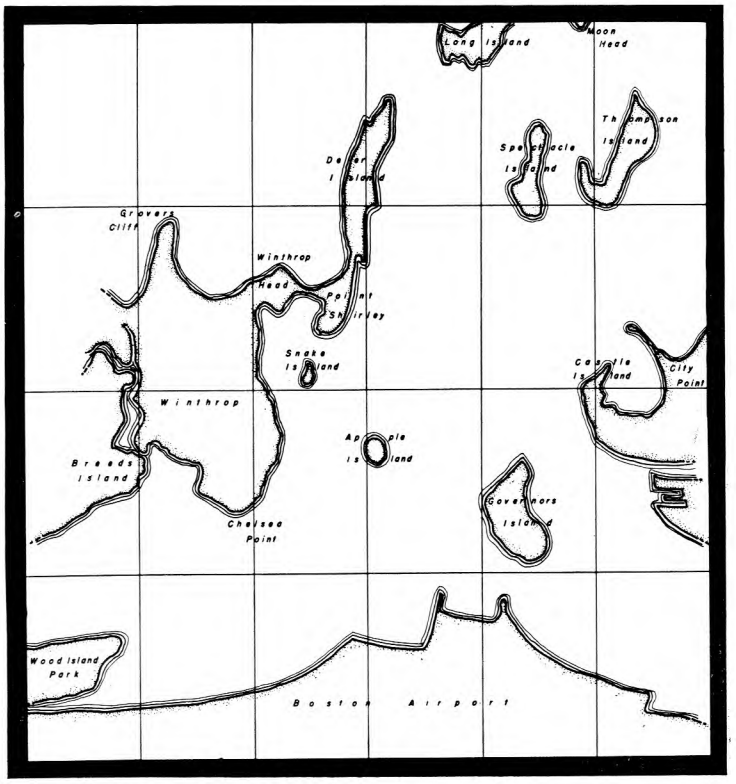




B scope distortion is more pronounced than PPI because range and azimuth are presented in rectangular coordinates—a fan shaped sector of earth's surface (above) is transformed into rectangle as shown in scope and map below. B scope pictures of area differ with every approach. Without specially designed overlay, distortion limits navigational use of B scopes to homing

Course indicator overlay (above) enables operator to fly straight course in any direction relative to signal received. Curved "paracourse" lines represent straight lines parallel to track and are separated by 1/10 distance measured by range reference lines R=O and R=10D. To fly course 10 mi. left of beacon operator tracks signal down corresponding line right of center





Briefing for land ferrets

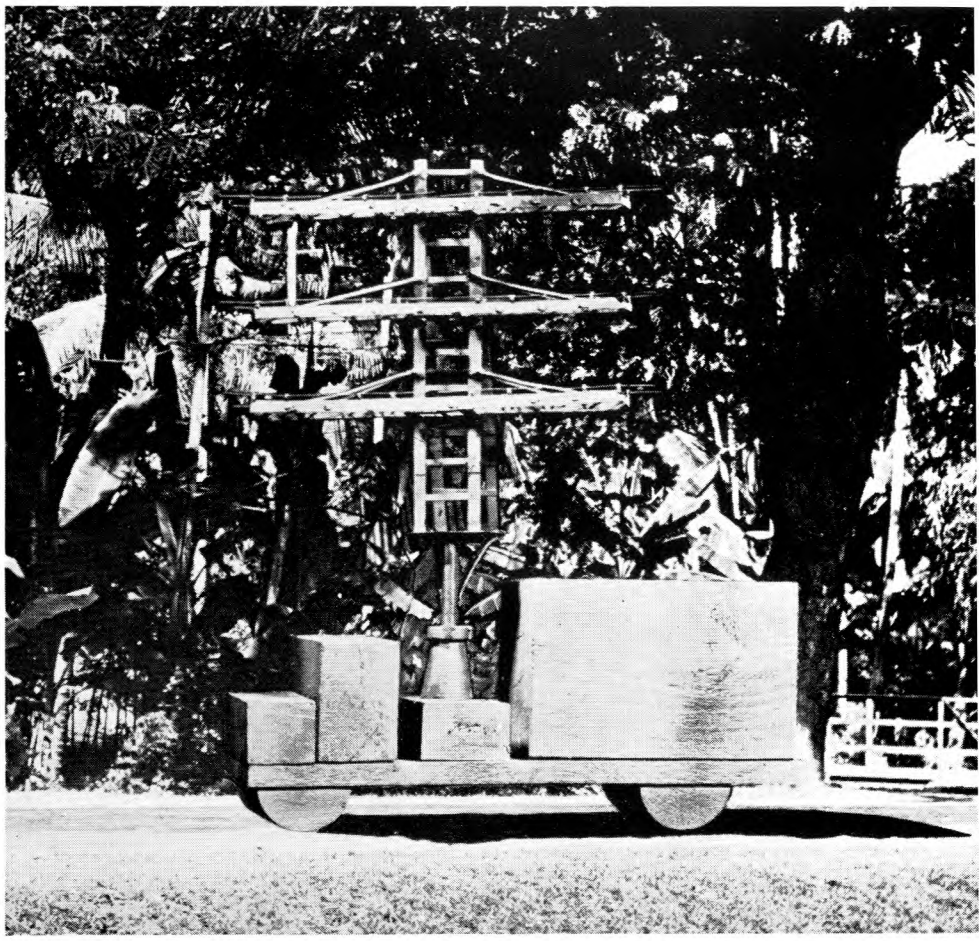
The fall of Rangoon formed a non-spectacular climax for the arduous Burma campaign (see page 14). At the same time, it provided an opening gambit for the final liberation of Malaya and Sumatra. One of the main goals of this next campaign would have been the recapture of Singapore. But the enemy had good radar coverage from Rangoon down through the peninsula to Singapore which gave them fair warning of Allied movements in and around the Andaman Sea and the strategic Malacca Straits. The South East Asia Command had to neutralize the Jap radar screen before any move was made in that direction.

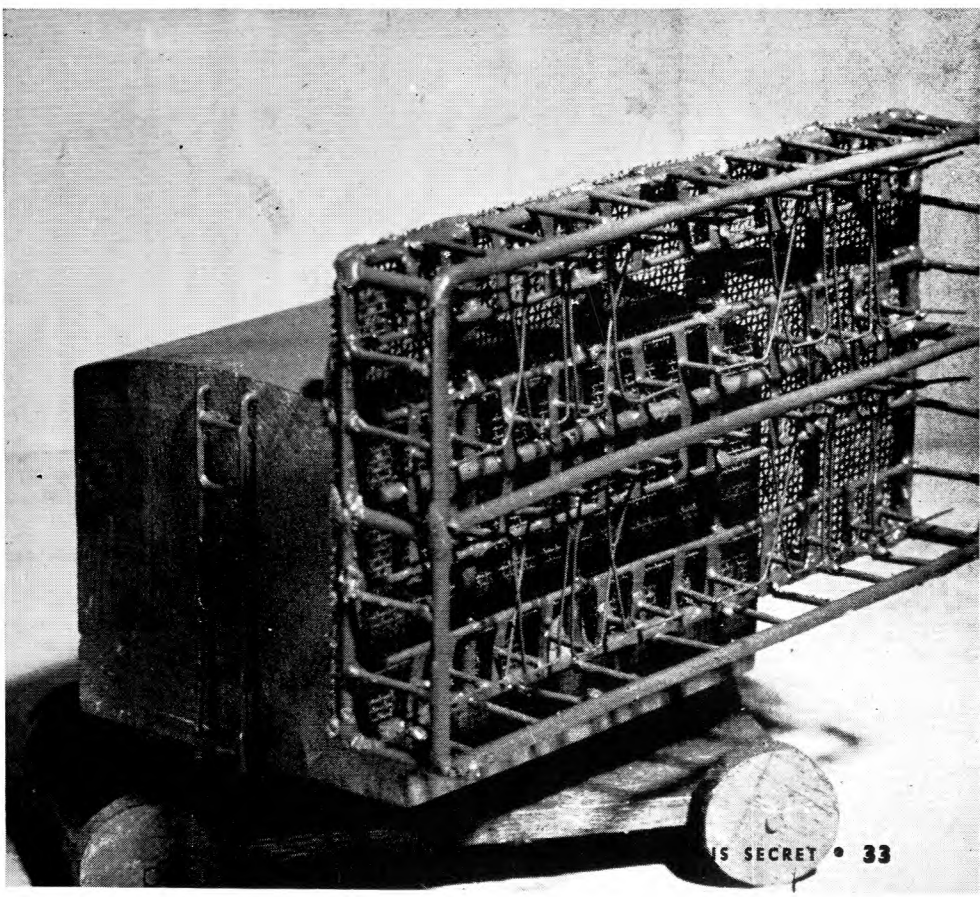
The 20th Bomber Command had gathered a wealth of radar interceptions. But when they moved from Calcutta, SEAC was left with little or no facilities for getting data on enemy radar.

Natives, trained as military observers, had long been a major source of general information on Jap defenses. There was no reason why they couldn't work as ground ferrets. So enemy radar installations were placed among the top priority targets to be investigated. There was only one drawback—these natives had little if any knowledge of radar and would have to be given some sort of special radar recognition briefing.

So SEAC went into the model-making business. Using information from 20th BC intercepts and technical data from the Pacific, small scale models of Jap radar likely to be encountered were constructed. Soldiers and natives worked together to build copies about one-twenty-fourth the size of the real thing. The miniatures were then placed against different backgrounds to show observers how the equipment would blend with vegetation. Attention was drawn to details of the antenna—the most eye-catching part of a set, particularly when rotating—so that observers wouldn't confuse radar with communication equipment.

This briefing met with immediate success. Many observers had seen the equipments but, hampered by language difficulties and lack of technical knowledge, hadn't realized their significance. Assisted by the models, these natives made up in part for South East Asia's dearth of long range ferret aircraft.

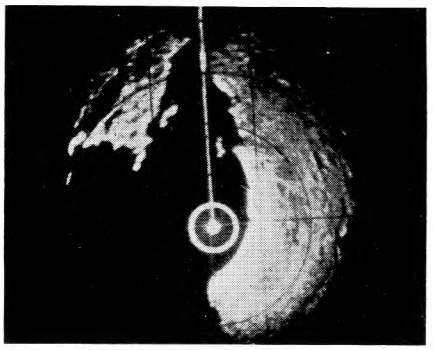


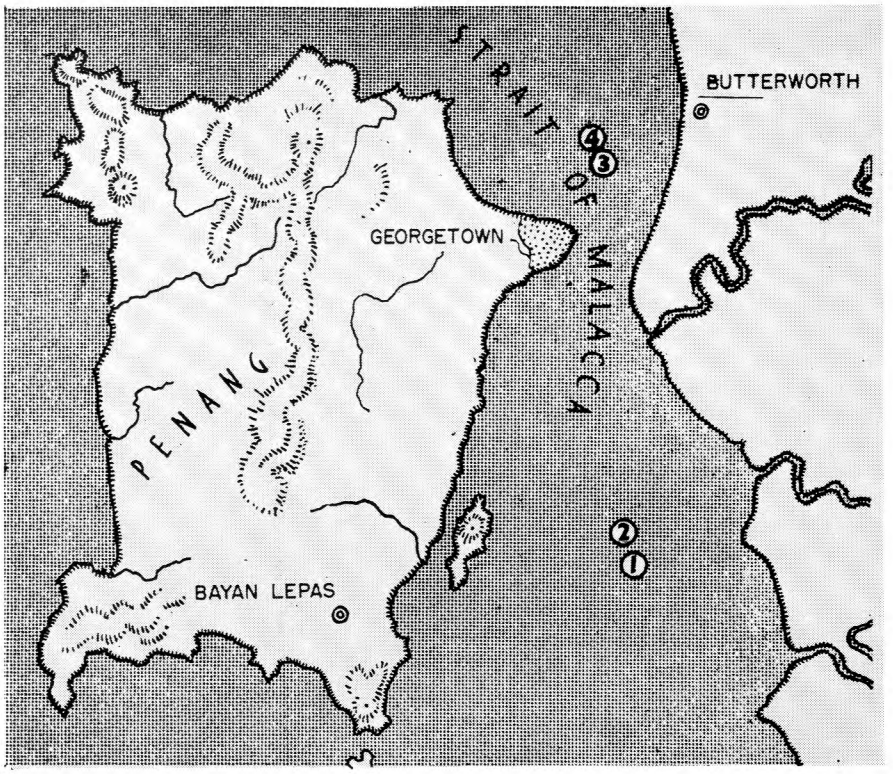


Miniature of Japanese 200 mc Model B radar (above) is placed against typical background. Mark I Model II 200 mc set (below) looks like child's toy. Many small features are omitted in building models but details such as ladders often aid recognition

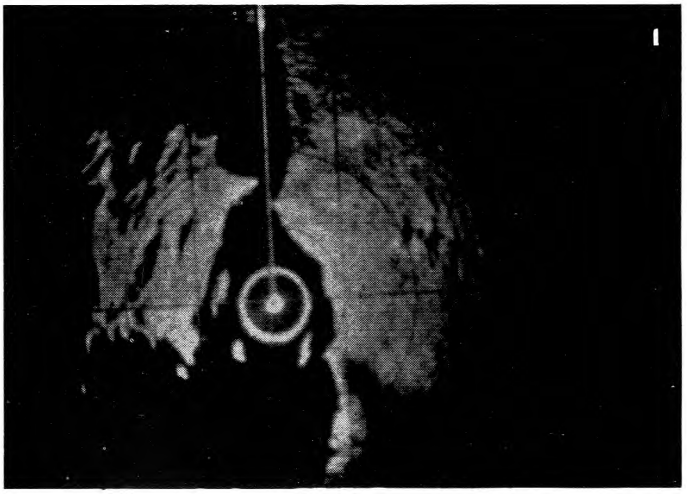


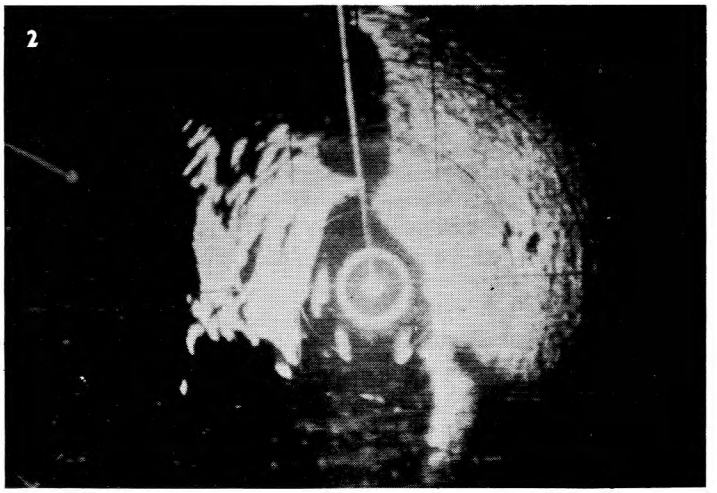
On way to mine harbor B-29s move up Peninsula. Numbered photos show last lap

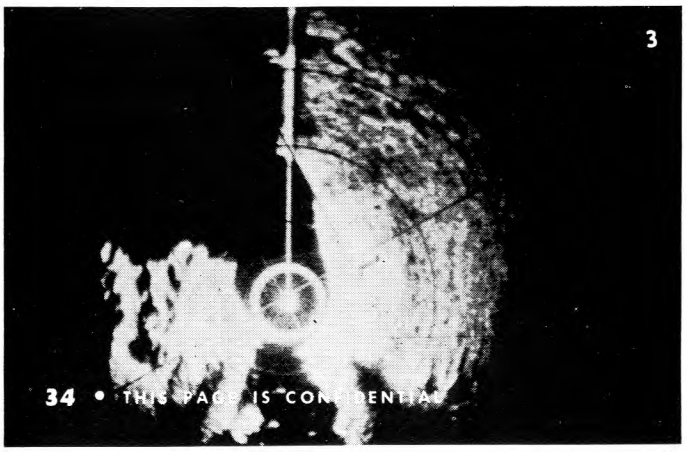


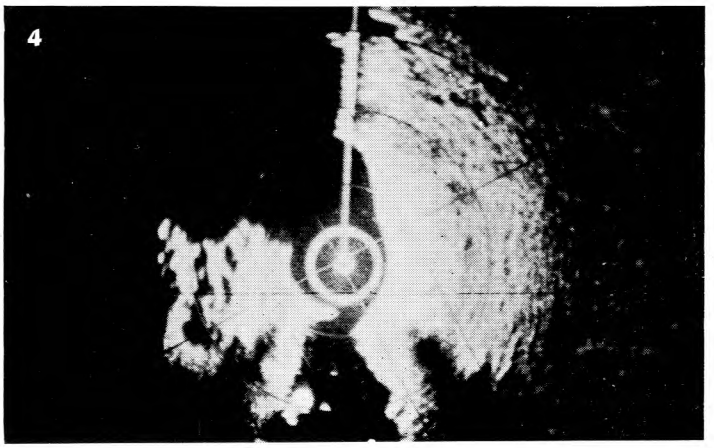


Mining aircraft get ready to release their loads between west coast of mainland and Penang Island. This is what shows on 20 mile sweep at 11,000 feet. Numbered circles in the map above correspond to scope photos below. Complete Georgetown Harbor area is delineated in scopes 1 and 2. Drops are made at 3 and 4, as mouth of channel nears. Aerial mining was done at night









The B-29 blockade

Aerial mining on grand scale bottled up Jap shipping

What remained of Japan's depleted merchant marine and Navy as the war ended moved cautiously in home waters. Frequently it didn't move at all. Every few days B-29s of the 20th AF roared over Japanese harbors and channels in another aerial mining mission, dropping hundreds of magnetic and acoustic mines, each weighing 1000 or 2000 pounds. And now that it's all over we're sweeping them up—out of the way of our own occupation shipping. APQ-13 scope photos taken when the mines were released are helping locate them now.

Aerial mining was a job that the 313th and 315th Bombardment Wings did around Japan and, to a limited degree, that the Navy's Okinawa-based Fair Wing I did against Korea. The result was a substantial blockade of a nation which relied on waterborne transportation 75% of the time. As the Japs capitulated mining was at a peak.

The 313th performed 35 such missions between mid-April and mid-July 1945. During that time it mined 25 places in Japanese and Korean waters, generally using about 30 planes but occasionally going above 90. Sometimes the mines were laid visually, sometimes by radar. Whatever the method, radar was SOP in two ways every mission.

Standard B-29 equipment—APQ-13, Loran, a radar scope camera and other odds and ends of radar aids in a Superfort—comprised the lot of mine laying radar. APQ-13 worked all the way. On the way to the target it was joined by Loran in rendering navigational aid. One 16-plane mission to the Shimonoseki Straits, for example, took a total of 216 radar fixes and 206 Loran fixes (average maximum range of the latter was 1200 miles). Close in, APQ-13 was especially useful, not only because mining missions almost always were at night but because the water into which the mines dropped was generally close to land. The land-sea boundaries, showing up distinctly on the PPI in most cases, served effectively as predetermined IPs, offset APs and check-points.

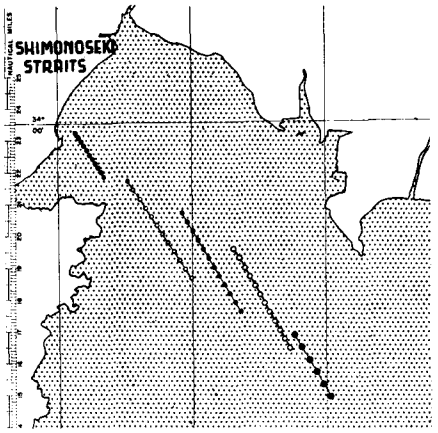
Over the target, usually a section of water located some seconds away from a predetermined IP on a designated course, many a bombardier preparing to mine visually found last-minute undercast. So he dropped by radar.

Following the initial release, other mines were dropped about 10 to 20 seconds apart. In the meantime the radar scope camera took at least three PPI pictures. The 313th took one 10 miles before reaching the radar aiming point, a second five miles further and a third at the point of first mine release. Sometimes subsequent releases were snapped, too. In all cases heading line, range marks and track lines were on.

Back at the base, Intelligence reviewed the scope photos as evidence of success or failure. Here is the critique of a minelaying action against Kure Harbor in April: "Radar analysis of the results of Mining Mission No. 3 show that two-thirds of the aircraft dropped as briefed. The resulting pattern was as planned and should produce the desired result, i.e., to restrict movement of naval vessels in the harbor area surrounding the Kure Navy Yard. One mine was observed to explode on impact, caused either by a parachute failure or a slight failure in predicted wind. This was a small percentage considering the land-locked nature of the target and the altitude of attack, 25,000 ft."

Most mines were dropped at altitudes from 6000 to 8000 feet, thereby minimizing wind drift. High altitude releases, as on the Kure mission, were infrequent. Not many months ago "splashing" mines from 200 to 300 ft. was common among B-24 AAF and RAF minelayers, and RAAF Catalinas went down even lower.

The first aircraft mine was laid in April 1940, by the RAF. Since then British aircraft have flown over 20,000 minelaying sorties. Together with the Royal Navy, RAF minelaying was credited with sinking or damaging 100 enemy ships during the Normandy landings. LAB Liberators of the 14th AF were early in the aerial minelaying business, starting in the late fall of 1943 with two sorties on Haipong, then branching out to block off the Yangtze. The frequent mining of Hong Kong is credited with seriously hampering the Japanese in their northward push into China. In March 1944 carrier-based aircraft mined-in enemy units at Palau; bombers later came over and sank 32 ships. B-29s started minelaying in August 1944 when eight planes closed up the river channels leading to the important oil installations at Palembang. Singapore soon was being menaced, too.



This is one of mining patterns laid down by B-29s at Shimonoseki Straits. Dots spot 1000 and 2000 lb. mines per scope data. Circles mean non-radar data

As the war ended the favorite target was the Shimonoseki Straits, which separates Japan's arterial waterway, the Inland Sea, from the Asiatic mainland. By bottling up Shimonoseki—as the 313th did 23 times in three months—we forced Japan to sweep the Straits again and again or to reroute its feeble tonnage around the southern tip of Kyushu or the northern end of Honshu, where it was subject to submarine and aircraft attacks. Photo recon and other intelligence showed the enemy resorting to suicide tactics in order to clear out acoustic mines, and one on-the-spot camera caught a minesweeper blowing up. Admiral Nimitz paid a compliment to the mining effectiveness of the 20th AF with a cable stating that the planning, operational and technical execution of aircraft mining on a scale never before attained brought big results.

Mining of the Kure-Hiroshima area in March and April prevented a major portion of the Japanese Fleet from moving against our landing forces at Okinawa. About the same time the Battleship *Yamato*, later detected by submarine and sunk with the aid of radar, was prevented from joining other units of the Imperial Fleet by similar blockades. But weighing heaviest in the value of the mining campaign was the near-severance of Japan's lifeline to Manchuria and Korea, and the blocking of supplies to her armies outside Japan.

THE EAGLE STRIKES

It paid off at the war's end



This and 58 other Eagle-vaned B-29s of 315th Wing participated in blow against Maruzen Refinery. Damage shown was 95%

In the last several weeks of the war Eagle (AN/APQ-7), after undergoing 3½ years of research, development, production and crew training, finally saw some action. It had lost out in the ETO, where the 8th and 15th AFs were only readying it when hostilities ended. The action came in the Pacific, where Eagle was getting into stride against Jap oil refineries when the war ended.

Combat Mission #1 was flown 26 June against the Utsube River Oil Refinery near Ise Bay. The attacking force was the 315th Bombardment Wing of the 20th AF, first single-purpose unit in the Theater. The purpose was bombing by Eagle. Results of Mission 1 were hard to estimate because elements of the 313th Wing had hit the same target a few days before. Intelligence figured that 539,330 sq. ft. of roof surface, or 30%, was destroyed or damaged in the two attacks, and the 315th claimed two-thirds on the basis of photographic evidence.

The next two missions sent parts of two groups (less than 60 aircraft at a time) against other refineries with nothing more than fair results. Mission 4 was a repeat strike against the Maruzen Oil Refinery at Shimotsu on the night of 6-7 July, with 59 planes participating. This time the 315th did itself proud, practically obliterating the target and earning this commendation from





EIGHT EAGLE-EQUIPPED B-29S AND COMBAT CREWS AT GUAM AIRFIELD AWAIT TAKEOFF FOR ONE OF LAST MISSIONS AGAINST JAP REFINERIES

Maj. Gen. Curtis LeMay, CG of what was then the XXI Bomber Command:

"With a half wing effort you achieved 95% destruction, definitely establishing the ability of your crews with the APQ-7 to hit and destroy precision targets, operating in difficulty at night. This performance is the most successful radar bombing of this command to date."

Other missions followed in an effort to halt the flow of Jap fuel but results were not yet in as this issue went to press. The Maruzen Refinery success might have been beginner's luck—as in the case of APS-15 some 20 months earlier (on its first assignment, against Wilhelmshaven, APS-15 had worked way over its head). Or it might have been the product of growing crew experience, better briefing and better procedure for solving wind drift.

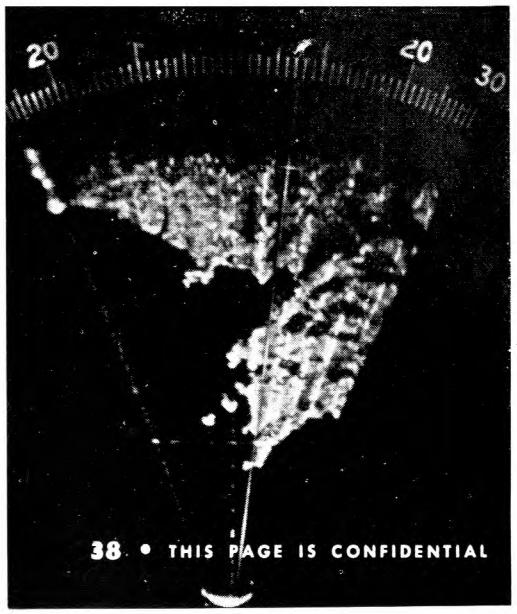
Readying Eagle took many months, men

Eagle was nearly two years old when, in the summer of 1943, it was ready for its airborne tests. It was still at least 75% antenna, for into the original linear dipole array idea had been poured most of the labor and talents of a whole corps of scientists. But now the antenna was fairly well under control and increased effort was going into other components and phases of the system, notably the indicator and computer.

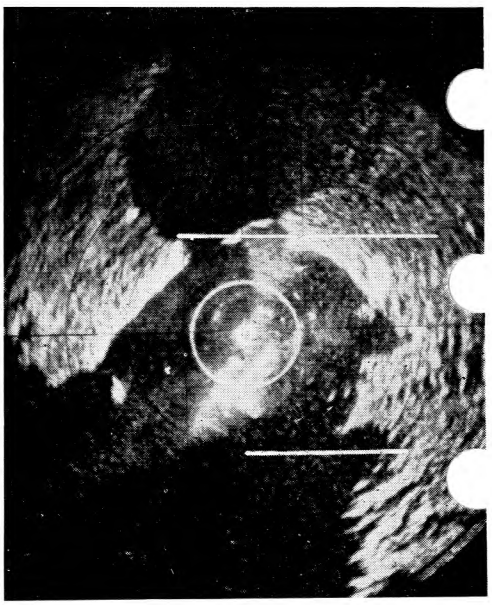
On 16 June 1943, Liberator No. 42-40344, assigned to Radiation Laboratory by the Armament Laboratory at Wright Field, took off from Westover Field on the first of 133 proving and performance flights that it was to make during the next 11 months. The 16-foot Eagle antenna, housed in a handmade plywood vane, was suspended below the fuselage. Inside the plane was an electrostatic tube indicator that was causing some trouble even before it was flight-tested, a makeshift computer, odds and ends of other components and a lot of complicated circuitry.

The Westover Field tests, which continued until No. 42-40344 flew south to Boca Raton Field in October, resulted in many revisions and adjustments. The electrostratic tube fell short of expectations and was replaced by a magnetic tube system. The circuitry was painstakingly corrected. The antenna, which everybody was watching anxiously, generally held up well.

HOW SHIMOTSU STRIKE AREA COMPARED ON SCOPES OF APQ-7 (LEFT) AND APQ-13 (RIGHT) IS SHOWN BY REFERENCE TO MAP IN CENTER





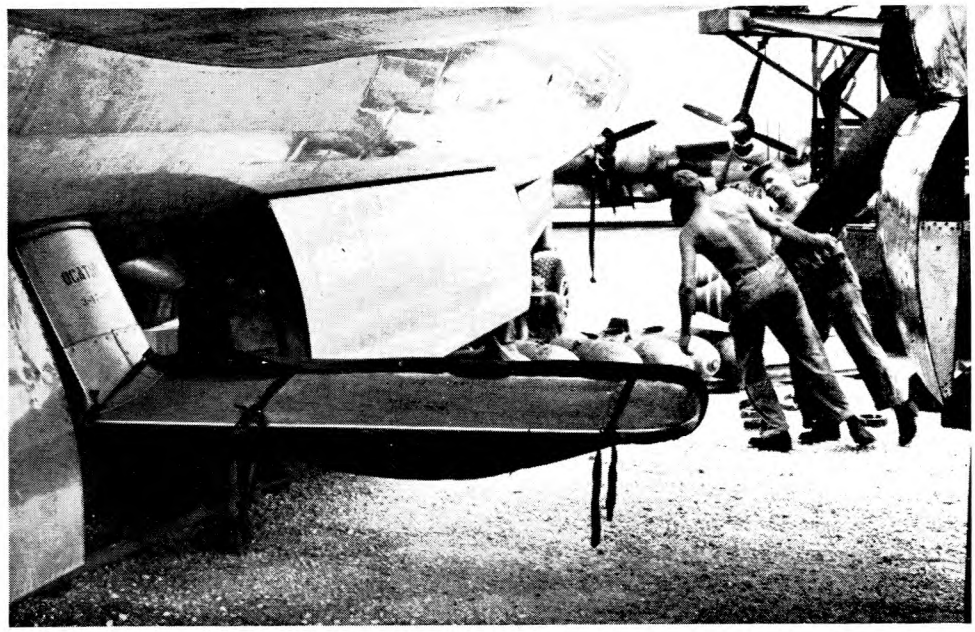


Amid the incessant findings and fixings the tests were encouraging and spurred on Eagle's growing number of supporters. Because of its high resolution, they felt, it would replace H_2X, itself not yet in operation. As the best, it deserved every worthwhile idea that could be added, and during the summer many were. Most of the additions were on paper, but some went right into the test setup.

The indicator, on paper, was perfected to present a picture fully stabilized in roll, yaw and range on two scopes—one much as the Eagle scope now is, the other a sort of B-type presentation showing an expanded sector two miles square. The U.B.S. (Universal Bombsight) computer, a deluxe, bulky Bell Telephone Laboratories idea that figured in preliminary planning, was expected to allow excellent maneuverability during the bombing run.

About the time No. 42-40344 was taking to the air on its proving flights, discussions were beginning on production plans. BTL was picked for final development and production design because of its extended work on U.B.S. and other computers. The formative program was under the collective direction of Dr. Lee DuBridge, Director of Radiation Laboratory; Col. George F. Metcalf, in charge of radar at the Aircraft Radio Laboratory (then under the Signal Corps, now under the AAF); and Dr. Donald A. Quarles, Director of Transmission Development at BTL. In June a group of three Bell engineers, headed by Larry Morrison, who was soon to become Eagle project engineer, went to Radiation Laboratory to make an appraisal of the system. At the same time Ray J. Nordlund, an ARL veteran, and Capt. Robert J. Doran, who recently had returned from overseas, were appointed to serve as ARL project engineer and project officer, respectively. They put their heads together and wrote preliminary specifications, based on a rough model and ideas submitted by RL, which guided BTL later on. The three men who had studied the situation for BTL in June issued a favorable report. The next month, 10 engineers were on the job.

In short order, BTL's engineers were completely charmed by Eagle's promise and were joining RL's scientists in contributing ideas to perfect it. Unfortunately, these also added to the system's complexity and bulk.



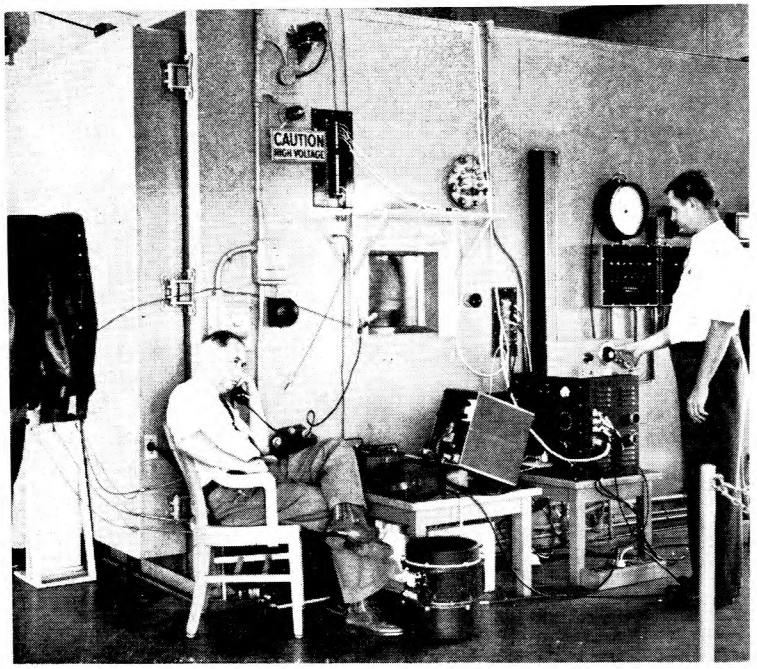
Cloth weather protector for Eagle's vane will be stripped off soon after propeller is wound and oil starts flowing. Then the plane will be off for Shimotsu

Then, in August and September a new feeling arose. H_2X was almost ready for the 8th AF. But maintenance and lack of resolution were disturbing laboratory people in the U. S. as they rushed last-minute tests at Grenier Field, N. H. Particularly, high resolution, which H_2X lacked, at least in comparison with Eagle, seemed to be required. At Army headquarters and in the research centers the subject was discussed. The answer seemed clear: simplify Eagle to a point where it could be handled in the field, and get it out in a hurry. So ended the dream of a deluxe bombing set with all the trimmings.

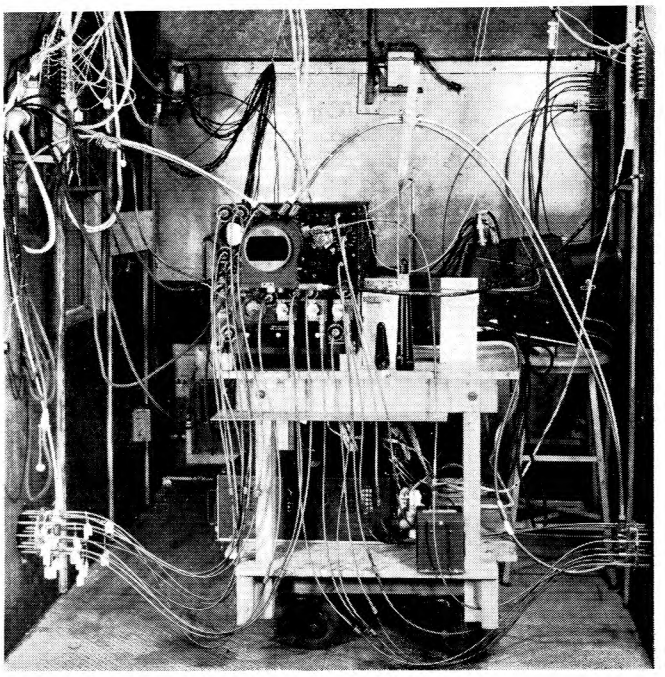
On 22 October 1943 a joint meeting of RL, BTL and Army officials stressed "the immediate need for a high-resolution radar system of blind bombing" and approved RL's new 4-point program for Eagle: (1) simplify operation and maintenance, (2) make the equipment relatively lightweight, (3) include approximate ground range sweep corrections, which had been tested all summer and found useful, (4) develop impact predicting bombing procedure that already had been fashioned for H_2X. The equipment was called Eagle Mk. I and BTL was asked to make, for AAF training uses, 40 preproduction systems to be ready by August 1944. Western Electric Co., selected as manufacturer, was to start production in July 1944. At a three-day conference at Cambridge rep-

This pile of engineering drawings represented Eagle's status a year before it saw action. They were used by BTL in the vital transition from research to production





Operational durability of Eagle prototype model was checked by BTL and Army engineers from pressure chamber readings



Within chamber indicators underwent hard 3-week temperature, humidity, altitude tests. Leads permitted control from outside

resentatives of RL, BTL, ARL and Armament Laboratory established final Army specifications.

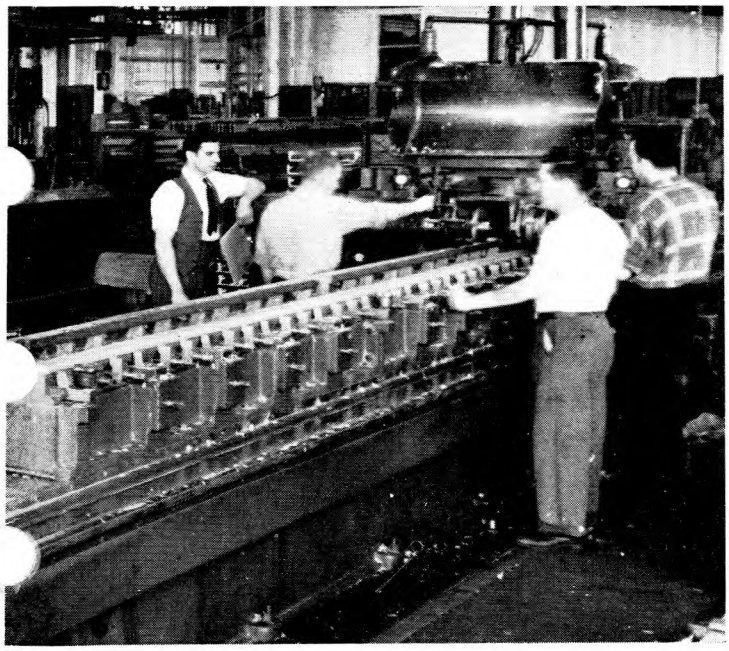
Simplification of Eagle didn't mean overhauling the antenna but it changed almost everything else. The deluxe indicator-computer ideas were out, together with the weighty cabinets, special scopes, roll and yaw stabilization and, of course, a lot of the fancy circuitry.

In the fall of 1943 Eagle activity was branching out in several directions. The center of gravity had shifted from the Laboratory at Cambridge to BTL's engineering rooms in New York with ARL at Wright Field calling the moves. A steering committee under the chairmanship of John E. Keto, Chief Engineer of ARL's Radar Laboratory, had been formed to coordinate the engineering phases of the organizations working on the project. At RL plenty of work still was going on, mainly on the antenna pattern. Douglas Aircraft on the west coast was finishing a vane that could serve for production. Western Electric engineers were soaking up Eagle knowledge in anticipation of production headaches, and, in a nationwide hunt, were trying to uncover a subcontractor capable of milling the 16-foot Eagle antenna.

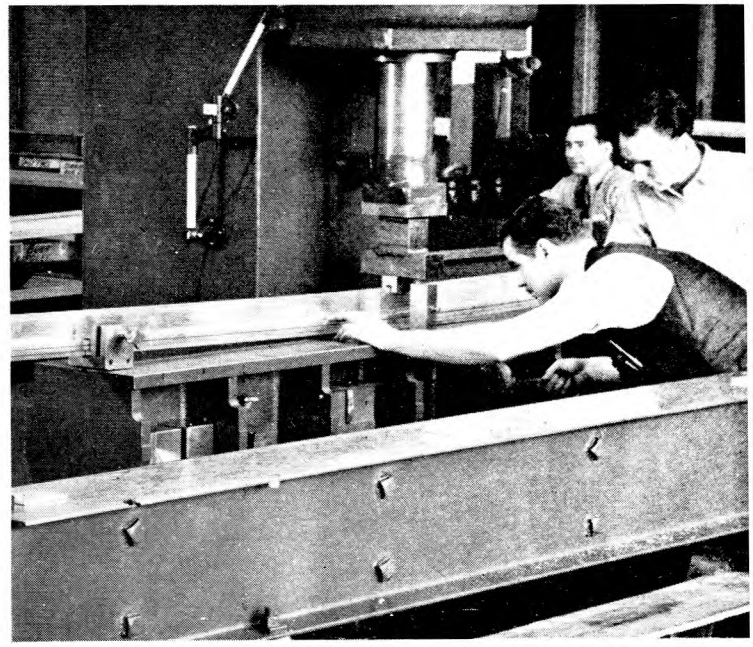
At BTL and ARL the engineers, building three prototype models for test purposes plus the 40 preproduction sets promised by late summer, struggled with a mess of problems. BTL engineering had started on the premise that all that was needed was a redesign of RL components to fit them to production. Now fundamental improvements of circuits and mechanical elements came to light. The Army requested changes. Such things were done as designing a diecast dipole for large-scale manufacture and devising a machine method to cut the probes (which extended into the waveguide and energized the dipoles) to proper length after the dipoles were in place. The rf switch had a habit of performing annoyingly at high altitude. That was rebuilt. The antenna timing apparatus was giving some trouble and a new electro-magnetic relay was built. A navigator's indicator, a test oscilloscope and a small, simple bombing computer all were built. Units were redesigned for aircraft installation. These and many more complications kept the men handling the transition from re-

Manufacturing the Eagle antenna required facilities of several firms and factories. Assembly of mechanical parts, including dipoles, flaps, movable plates, waveguide units, occupied this corner of Detroit plant. At Brooklyn same work was done





Movable plates to fit inside antenna waveguide were milled at Ex-Cell-O plant. Western Electric engineers helped full-time



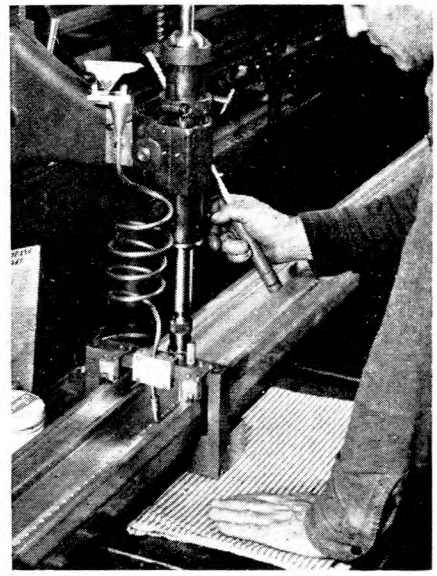
"E" sections, antenna backbone, were straightened by hydraulic process. Amount of pressure applied required seasoned judgment

search to production really hopping.

After interviewing 50 possibilities for the antenna machining job, Western Electric early in 1944 selected Ex-Cell-O, a Detroit machine tool manufacturer with a 16′ planer. Ex-Cell-O furnished units for preproduction and production.

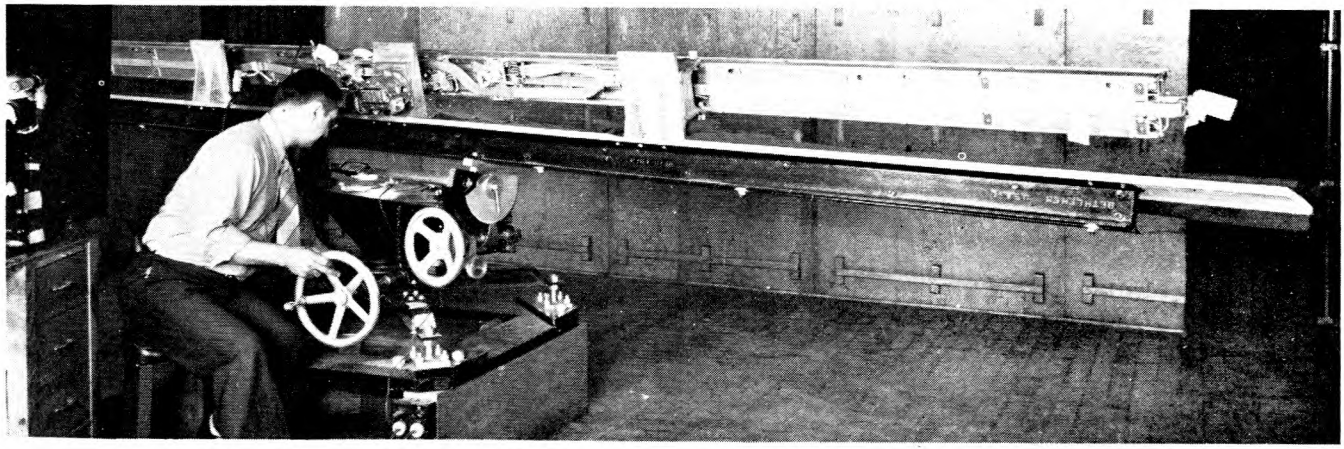
While No. 42-40344 was at Boca Raton working for Radiation Laboratory, a second B-24, No. 73111, was used as a model by ARL in accomplishing a preliminary mock-up which later was adopted for general use. In May 1944 one of the three prototype models fresh from BTL's Model Shop was installed in No. 73111 at LaGuardia Field. Some shakedown flights were made and then the Liberator went traveling. First it went to Washington, D. C. to show Army officials what Eagle looked like, then to Fort Campbell, Ky., to check its resolution against tanks and artillery concentrations. The Kentucky results weren't good enough to recommend Eagle for this sort of work and No. 73111 proceeded to Boca Raton to go through its bombing paces. Trouble followed. No. 73111 was ordered to an Ogden, Utah depot for overhauling. A month was lost. Then, on the first bombing test after its return to Boca Raton, the nose wheel collapsed on the take-off. A tragedy was averted when 73111 slid 500 yards on Eagle's vane.

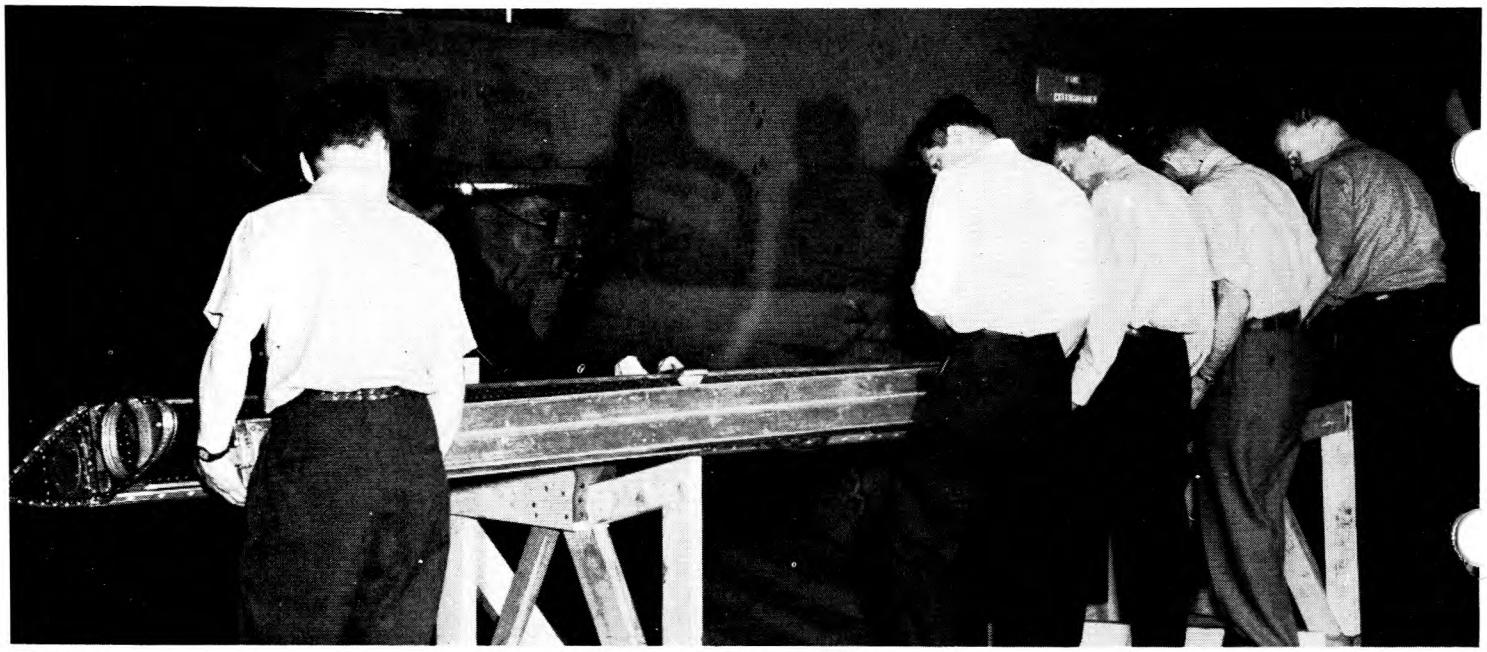
A second prototype, about the same time, was getting a going-over in the atmospheric chamber at BTL's Whippany, N. J. laboratory. Service requirements for altitude, humidity and hot and cold temperature were simulated here.



Holes for dipoles—250 per antenna—were sized by forcing ball-bearings thru

Antenna pattern check was made by examining pulses returned from target ½ mile away. This was only one of antenna tests made at Detroit, New York, Wright Field





EAGLE PROTOTYPE ANTENNA WAS LIFTED INTO VANE AT LAGUARDIA FIELD BEFORE BEING FASTENED TO FUSELAGE OF B-24 NO. 73111

Manufacturing started from scratch

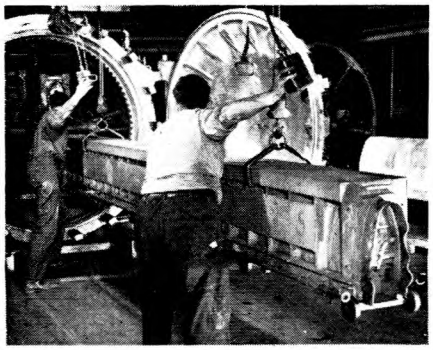
In the Spring Western Electric, gearing itself for manufacture, moved into top speed. On 1 May it began its hunt for a suitable factory to house the project. Ten days later the Lane Bryant Building on 42nd St. in New York was leased and its numerous tenants, ranging from liquor distributors to manufacturers of ladies' underwear, were cajoled, argued and negotiated into vacating. The building, old and dilapidated, needed major overhauling before the work could begin. The plumbing and heating systems were knocked out and replaced, lavoratories installed, roof water tanks enlarged, firewalls built. A laboratory was constructed on the roof for antenna tests. In the cleaning-up process over 800 loads of debris were removed.

While building renovations were in progress, manufacturing equipment was being installed. The equipment came from many sources and often only after some ingenious ferreting. Western Electric was told, for example, that generators to supply current for operating tools and testing current would be unavailable for 26 weeks. The emergency was met by locating some reconditioned units that had been used in obsolete submarines and borrowing others from Western Electric plants. Sources of supply had to be earmarked and subcontractors signed up, all the way from St. Louis in the west to Georgia in the south and New Hampshire in the east. When production got going, 1813 separate items were converging at the 42nd St. plant from scores upon scores of subcontractors and supply houses.

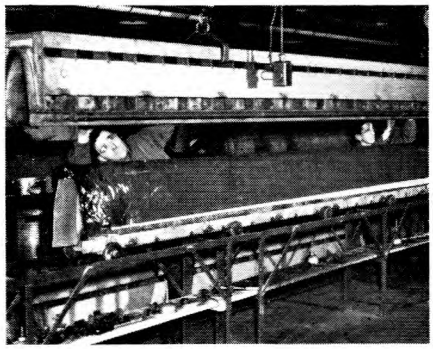
Eagle production on the indicator and computer units was a case of a commercial contractor starting from scratch. The nucleus working organization mostly came from other Western Electric units. The personnel department had its hands full interviewing, checking, hiring and training electrical and mechanical project engineers, testers, wire equipment inspectors and the hundreds of girls necessary to "man" the assembly lines. The training division was a full-fledged organization itself, schooling top technical employees in advance radar theory and principles of Eagle's operation. New operating personnel all attended special classes under full-time instructors covering periods up to four weeks. In July 1944, when production was just getting under way, 42nd St. plant personnel totalled 475. By January 1945 the figure was 1537. Bell Telephone Laboratories, at the height of its engineering work, had 204 engineers, draftsmen, mechanics, wiremen, testers, component handlers and others busy. And elsewhere throughout the U. S. other hundreds were helping build the system.

A fast-moving production line technique had been devised at the 42nd St. plant. The roller-skate chain turned at right angles frequently to make use of floor space; each girl worked with a maneuverable cradle into which the framework on which she was working fitted. A finger's pressure would turn the cradle in any direction.

From the start Eagle production proceeded well. The first five preproduction systems rolled off the BTL line in July 1944. By August 33 more were



Vane's plastic leading edge in embryo. This mould was about to go into furnace



After 30 minute baking skin was taken from mould. Two skins were put together

ready and in September the last of the 50 preproduction sets was done.

Western Electric production came along as follows: On 28 September two systems were ready. In October 40 more were finished, tested, accepted by the Signal Corps, packed and shipped. By the end of November 142 systems were off the line and production proceeded two months ahead of schedule.

At Ex-Cell-O's plant in Detroit, where the antenna was being machined, production had started earlier. The first antennas were finished in July and by November, when indicator-computer production was booming in New York, the output was four daily. One out of every 10 was boxed and shipped to the 42nd St. plant where, in the testing penthouse, ARL engineers assured themselves that the job was satisfactory. Late in 1944 the American Machine and Foundry Co. of Brooklyn joined in on the antenna work.

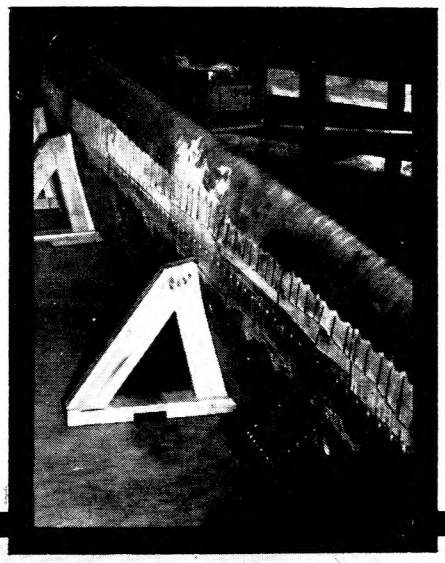
Tested and boxed, the 42nd St. output rolled southward and westward to AAF depots and then to modification centers, while the antennas, leaving Detroit and Brooklyn, took a separate route to meet up at the same points. B-17 production went to the Douglas Aircraft plant at Oklahoma City. If the components were for B-29's, they went to the AAF modification center in the same city. B-24 production traveled to the Consolidated-Vultee Modification Center at Tucson. As the war ended the systems were going into B-29's almost exclusively and installation work had shifted to Georgia and Alabama.

Flight testing continued for a long time, with ARL's No. 73111 proving an able workhorse. Late in 1944 its test bombardiers were doing better than 30 mil bombing against point targets at 35,000 feet, far superior to the results that RL's No. 42-344 had achieved some nine months earlier.

Out in the theaters Eagle was eagerly awaited. And on 2 October 1944, exactly one year after the first H_2X set reached the 8th AF, the first Eagle was in the hands of the same people. It was in a B-17 that had left Langley Field, Va., the day before, destined for the 482nd Bomb Group. Appropriately, its name was "Too Little, Too Late," for it never went into action although it made many a trial flight. A second set started over in a B-24 piloted by Col. William C. Dolan, who was pushing for higher-resolution bombing equipment in the 8th AF. He was lost over Newfoundland. During the 1945 spring some 30 B-17's and B-24's were rushed to the 8th, many of them being used in a crash training course for radar operators. The 15th AF was just getting some Eagle planes when the war ended in Europe.

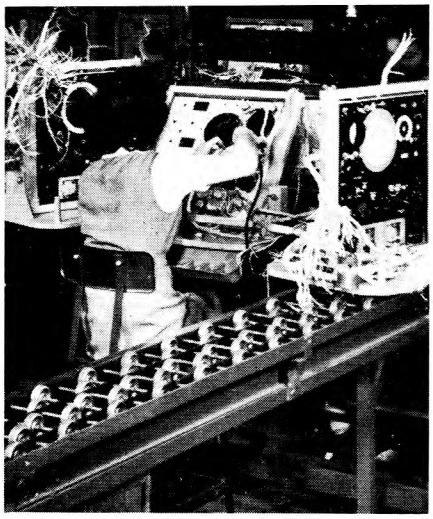
The Eagle scene thereafter shifted to the Pacific. There, in late summer, as the Japs surrendered, the 315th Bombardment Wing of the 21st Bomber Command was beginning to provide a combat return for all the work that had gone into the system. In a month of solid action Eagle helped appreciably to level Japan's oil refineries and, by a hair's breadth, was saved from the sad fate of having been nearly four years in preparation and never having fought at all.

This second of two articles concludes RADAR's report on the Eagle story.

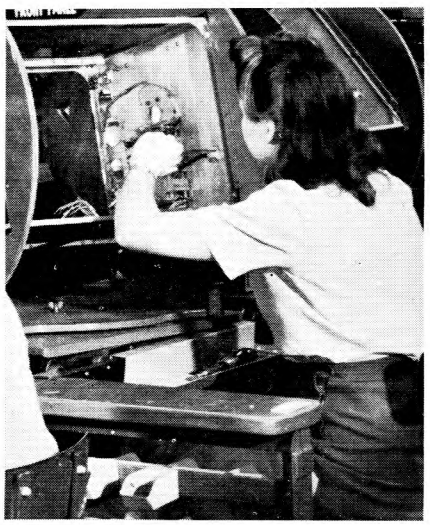




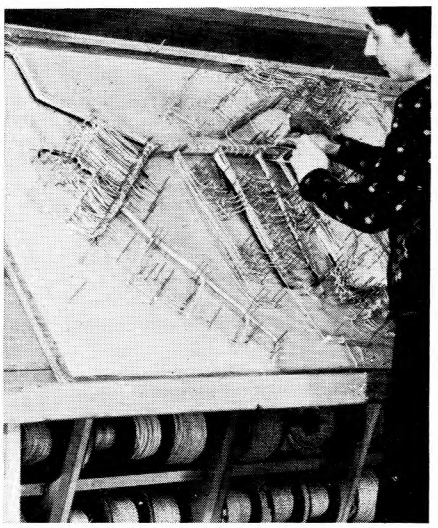
Liberator No. 73111 took a belly-flop and skidded 500 yards on its vane during Florida bombing test. Friction wore vane dime-thin on bottom (see inset) but plane was saved. In ETO, one wave-hopping Eagle bomber was saved when vane acted as a pontoon



Steps in Eagle assembly line process at Western Electric. A panel is soldered



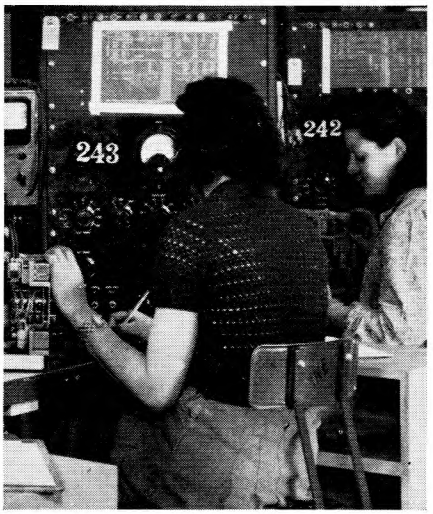
Panel is fitted to main assembly. Each girl is given 30 minutes to finish operation



Looking like complex road system, main cable of indicator is fashioned and sewed



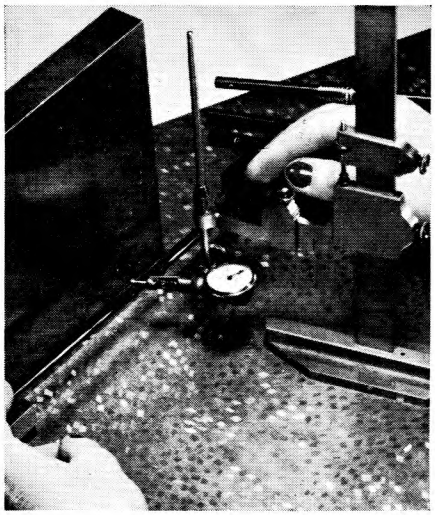
Cathode ray tube and scope assembly are adjusted into position in indicator cabinet



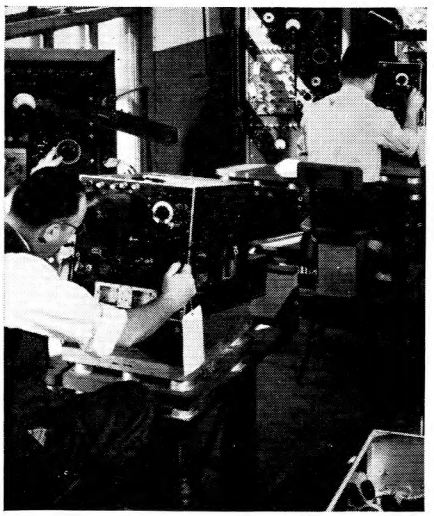
Computer testers shown here were trained by manufacturer for checking assignment



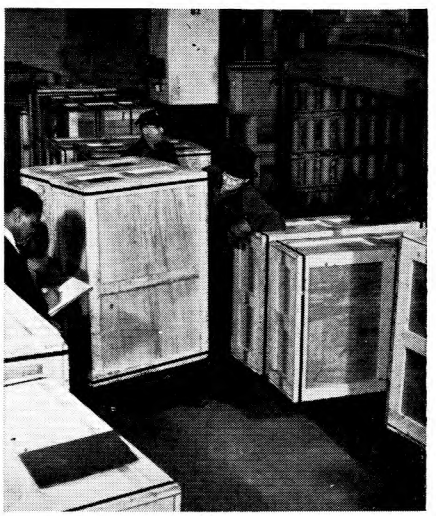
Shunt gears received from subcontractor are micrometer checked for production use



Operator tests concentricity of shaft to be used in computer to a tolerance of 0.002



After final indicator unit tests Army makes inspections. At work here are top testers



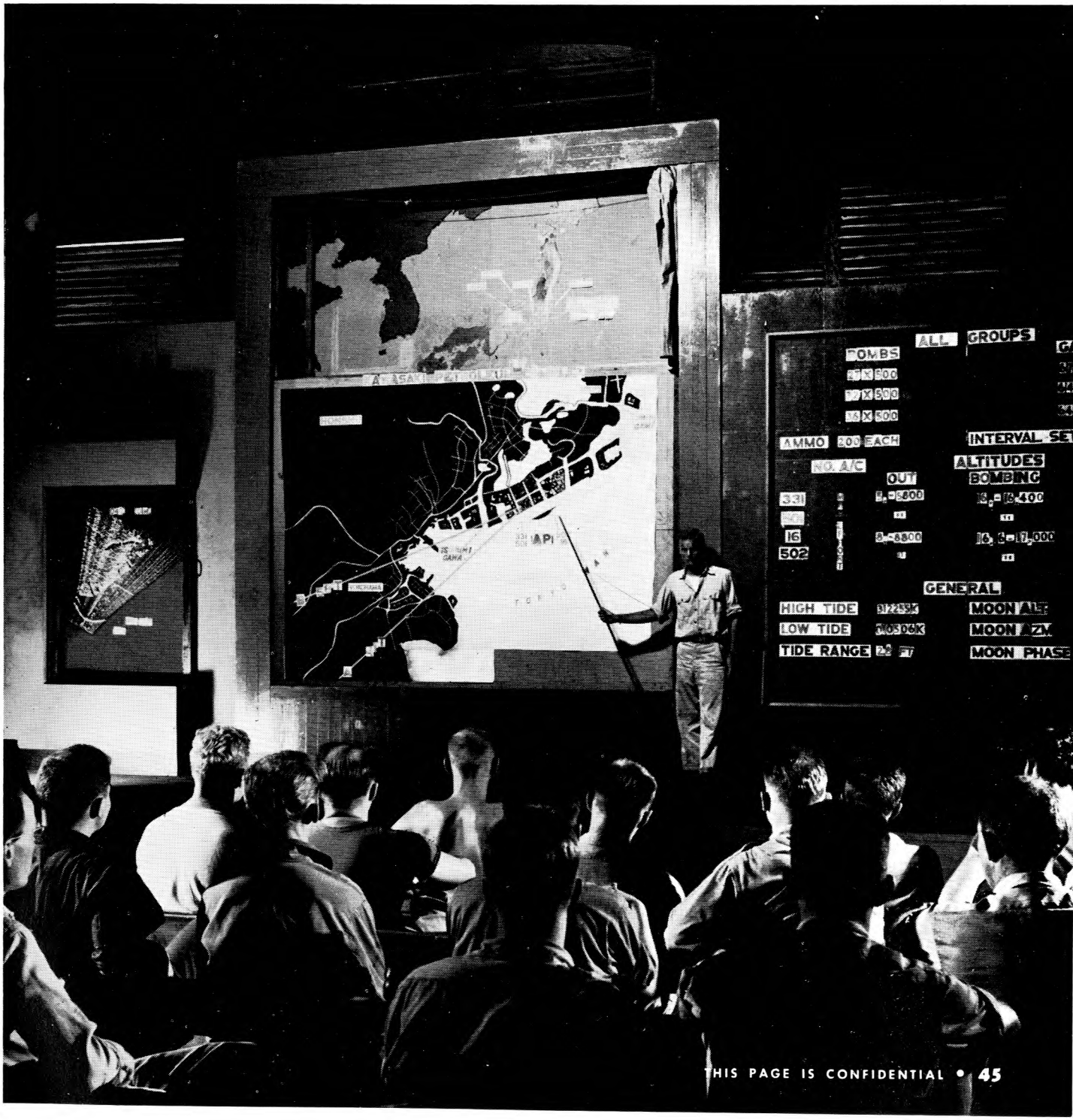
Checked and double-checked, Eagle components are crated and freighted to depots

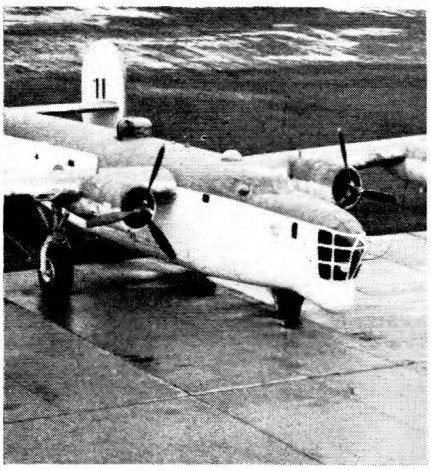
Eagle crews brief for Kawasaki mission

What these men of the 315th Bombardment Wing, being briefed at headquarters for a run against Kawasaki, saw and learned here was typical of the cramming that went on before every Eagle mission. To the left, in the radar panel, the pilots, navigators, bombardiers and radar operators saw the Kawasaki area on the 10 mile scale. The large target area chart in the center is one of several presentations—including the weather chart, the landfall-to-lands-end chart, the taxi and takeoff plan, the flak and fighter panels—that slid into view as the one in front was pushed out of sight. Above is the main route chart and to the right the operations panel with its variety of data.

This picture shows only one of the four radar panels employed in the briefing. Besides the 10 mile sweep the crews saw landfall scope shots, the IP, 30 mile sweep of the target area.

The Kawasaki strike was different from most, being two-pronged to enable the 315th Wing to hit at two separate targets in the same sector. Earlier the 315th had partially destroyed two targets in the area and was out to finish the job. Two axes of attack and two aiming points are shown on the target chart; flight paths nearly meet.





First droopsnoot, Dumbo I. flew ASV to England in '42. Radar had to be placed to keep plane modifications at minimum



Mickey began as aeronightmare, but performance convinced Army B-17 and B-24 lower turrets could come out for domes

Design vs Drag

Radar's dome is getting polished off

Radar demonstrated that it could be as valuable an offensive weapon as a bomb load. It took its wartime place as an integral part of an aircraft which had to be a complete tactical unit—one that was expected to communicate, navigate, search, identify, bomb and shoot. That being the case, the problem of designing a permanent home for the radar became an increasingly important one.

The situation was somewhat different when microwave radar took to the air for the first time. That was in 1941, and radar was in no position to ask favors from airplane designers. Those early installations made radarmen think the day would never come when planes would roll off the line all ready to receive a black box. Meanwhile aircraft designers shuddered while B-25s fishtailed over large round turrets, and wondered just how long the physicists were going to be allowed to get away with cluttering up aircraft which had been painstakingly designed to go further, faster.

Then the Air Communications Officer, realizing that aircraft and radar could no longer be designed separately, started the ball rolling on a nationwide tour of aircraft plants; laid the ground work for a meeting where NDRC, the Services and the aircraft industry could talk it over. After the Army-Navy-sponsored Symposium held at M.I.T.'s Radiation Laboratory a year ago, aircraft designers and radar designers got to know each other better, and radar housing took an aerodynamic turn for the better.

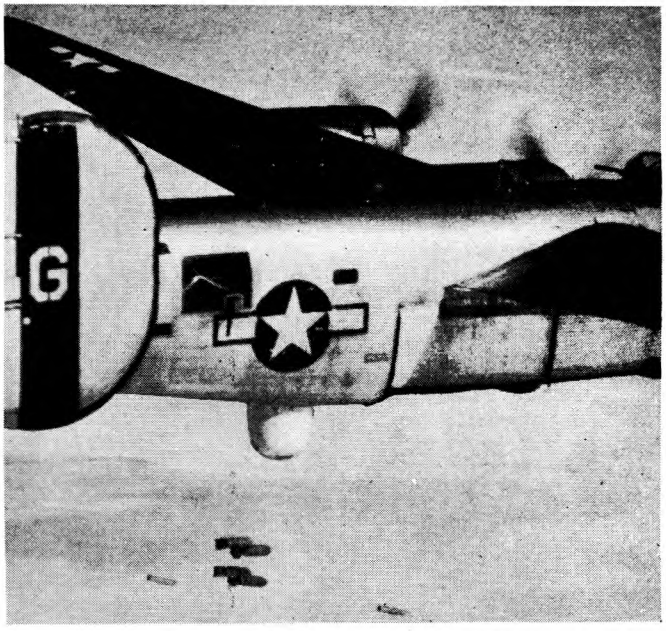
All in all, a radome is a complicated affair. It has to be designed to withstand large air and inertia loads, to protect the electronic apparatus inside from the weather. Along with its structural and aerodynamic requirements, it must be electrically satisfactory. The material from which it is moulded is chosen to permit unhampered radiation; it must not absorb or deflect the energy beam; the radome wall thickness must be a function of the radiation wavelength. Also, the placing of the radome must be a compromise between keeping the radome within the streamlining of the plane and obtaining full radar vision.

With the work on radome shape has gone research and development of radome materials. Radar researchers first used plexiglas (methyl methacrylate) in radome construction. They found that plexiglas had good electrical prop-

CHART BELOW SHOWS HOW MORE THAN THREE YEARS OF STEADY STREAMLINING HAS HELPED TO REDUCE APPROXIMATE SPEED LOSS IN MILES PER

RADAR	RADOME SIZE	AIRCRAFT				
Preproduction H2X	Round; 42" deep, 32" diam.	HB				
AN/APS-15	Round; 33" deep, 35 1/2" diam.	HB				
AN/APQ-13	Round; 24" deep, 35 1/2" diam.	HB, VHB				
AN/APQ-7	Streamlined vane, 16' long	HB, VHB				
AN/APQ-13 (60" dish)	Streamlined; 8" deep, 70" long, 68" wide	VHB				
AN/APQ-13	Streamlined; 24" deep, major axis 61", minor axis 36"	HB, VHB				
AN/APS-10	Streamlined; 27" deep, major axis 55", minor axis 22"	C				
AN/APQ-34	Streamlined; 11 1/2" deep, 46" wide, 73" long	HB, VHB		10	9	8





Veteran TCC radar, SCR-717, shown here in C-46, used same old high-drag cylindrical radome as H_2X (right). Crews found that drag from latter could be cut from 9 to 4 mph by flying radome half retracted. Original Mickey dome depth of 42″ was shortened to 33″, finally to 24″ where drag was about 6 mph. At war's end APQ-13s in B-17s and B-29s had begun to get streamlined radomes

erties, but was subject to cold flow at high temperatures. Also, its strength-to-weight ratio is poor, and it cannot be ribbed successfully without affecting its radar transmission performance.

Impregnated plywood was given a try, but soon discarded because the binder disintegrated after long exposure to air and salt water (as on submarine patrol), causing excessive moisture absorption by the wood. Polyfiber was first used for AN/APS-15 in B-17s and B-24s. It has good electrical properties, but it is not strong enough.

The round radomes for APQ-13 installations in B-29s were made of cyclicized synthetic rubber. Like polyfiber, its electrical properties are good, but it is attacked by aromatic fuels, and its impact strength drops off at low temperatures. Most recent and most satisfactory radome material has been a sandwich construction consisting of thin skins of fiberglas and a light cellular synthetic rubber core. All AAF streamlined domes in production are so made.

Several general trends in radar development made the aerodynamicist's lot a bit easier toward the finish. A year or two ago those who thought very much about streamlining radomes were few in number. Domes had always been cylindrical, designed on the assumption that the axis of scanner rotation had to be the center of a circle—so the radiation would pass through the dome at a normal angle. When researchmen found out more about radome materials which are transparent for angles of incidence other than normal, streamlining looked more possible.

With a streamlined radome it was no longer necessary to follow the original plan of using radar only on the bomb run, flying with the radome retracted to reduce speed loss on the trips to and from a target area. Streamlined domes offered new material possibilities; round domes must necessarily be built stronger because of higher airloads. Some aircraft, such as the low-slung B-24, do not have sufficient ground clearance to carry a streamlined radome, although the Navy found a spot for a streamlined dome behind the B-24 nose wheel. For other plane types, the streamlined radome turned out to be just what the doctor ordered.

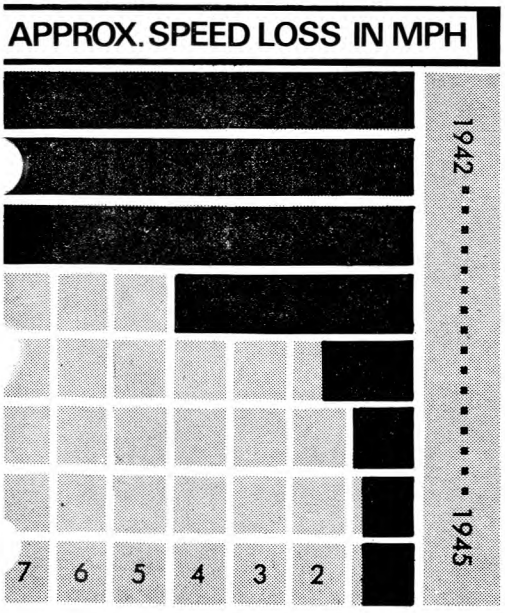
Of course, radome shape has been largely dependent on antenna design also. The drive toward higher resolution has meant wider scanners; wide, shallow scanners mean shallow radomes. The steadily increasing use of the cosecant squared-type antenna pattern, with RF energy fed into the dish and radiated in such a manner that the entire scanner assembly does not have to be external to the surface of the aircraft, also has meant shallower radomes.

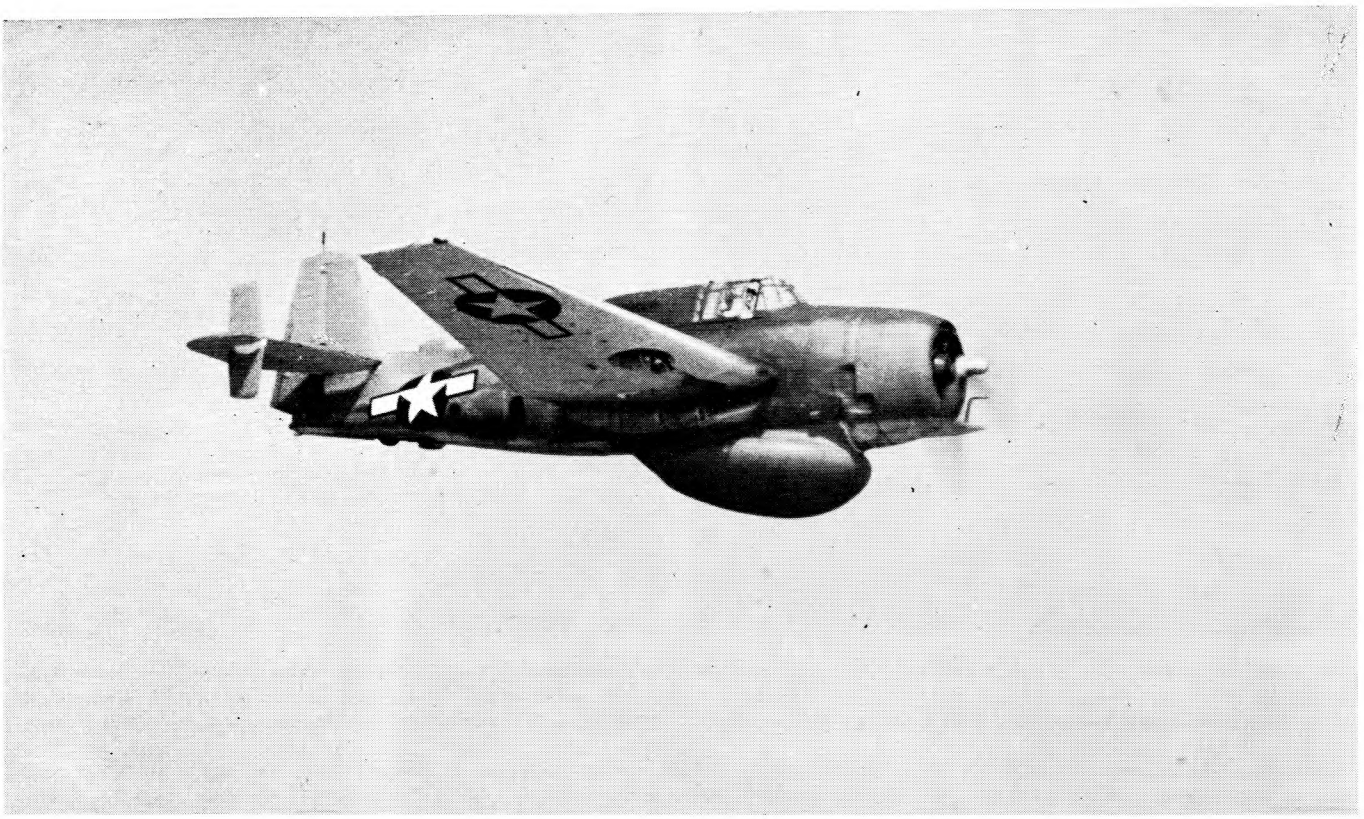
Always a complicating factor, the stabilization mechanism added a complexity here, too. Of the various ways to keep a scanner steady on an unsteady airplane, only line-of-sight stabilization (which makes use of gyro) requires no extra radome room and finally was considered to be the only fashionable method. Roll and platform stabilization, on the other hand, require deep domes to take care of scanner tilt.

In the decade from 1934-44, the speed of both bombers and fighters increased at the rate of about twenty miles per hour per year. And with this spectacular rise went a speed penalty for equipment drag which increased tenfold, with the range penalty increase not far behind.

Better radome design had begun to make up for some of that loss as war ended. The newer installations were good evidence that constant design work and testing at Wright Field, re-design of radar, and the efforts of the aircraft in-

HOUR CAUSED BY DRAG OF BULKY RADOMES





Most spectacular of new radar sets is this Navy installation, still in experimental stage at the war's close. The bulbous radome hits a new high in size: it's 8.5′ wide, 13′ long, 3.5′ deep. With the aid of two extra stabilizers and some good dome design, little TBM handles well in spite of its load, has cruising speed cut only 5 mph by radome and associated beaconry

dustry in radar's behalf were beginning to have some effect. Determining the exact effect of a radome on plane performance was always a shaky matter at best. Pilot's estimates on radome drag ranged all over the lot. Some even insisted that the damn thing handles better with the radar than without it.

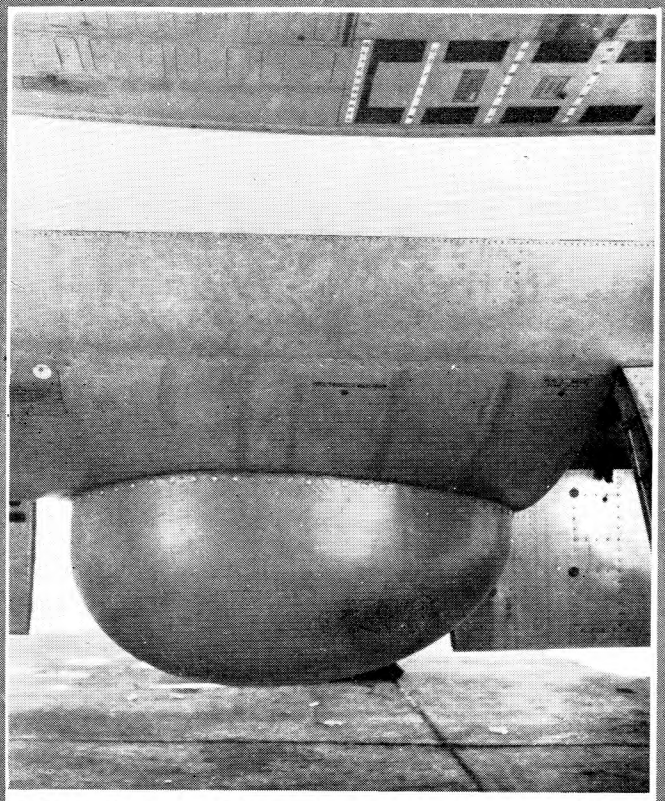
Radar ended up the war with plans made for housing which really befitted the best new aircraft design. With the new medium jet bomber series putting in an appearance complete with a wholly internal radar installation, in nose space designed and reserved for radar, things, aerodynamically speaking, were looking up. The foundations of radar's post war house have, so to speak, been laid.



AN/APS-10, lightweight radar for navigation, was planned for C-46 and C-82 TCC operations, also for P-61 weather reconnaissance work. Here is its streamlined dome, installed on C-46



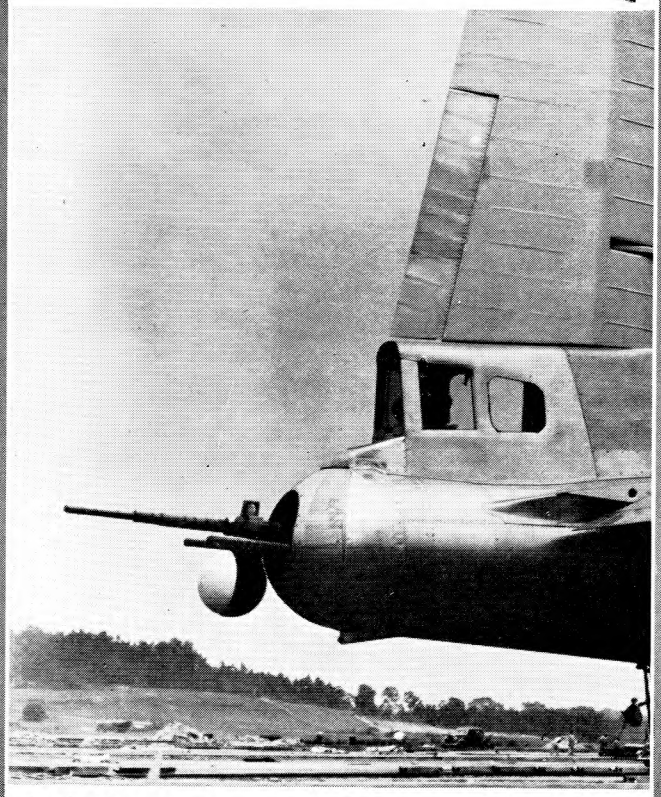
In one of their first radar jobs, aircraft industry decided to put Eagle antenna in 16′ streamlined auxiliary vane which could be attached to existing bombardment planes by special struts



Streamlined bathtub was latest housing for APQ-13s. Resulting speed loss was one-sixth of that caused by old radome



Fast fighters feel effect of smallest of radar antennas—the Rosebud "peanuts". Drag on P-51 in level flight was 1 mph



AN/APG radars caused practically no aerodynamic headaches. At B-29's tail the effect of APG-15 was negligible



Falcon antenna fits into plane's shape, but Vulture (APG-13b, Overland Falcon) with suspended bomb, dragged on B-25s

While we're on the subject

CONTINUED FROM INSIDE FRONT COVER

wave. However, the wave cannot penetrate this field, and is bounced back to the Radar Machine, causing a great jumble of noise. This noise resembles that which is heard when there are perhaps 40 planes overhead, and confuses our ack-ack batteries greatly. Our searchlights also become worthless, because they are radar-controlled. This bomb is the best weapon I have seen and so far we have developed nothing to counteract it."

The report went on to say that most Army technicians had concluded that radar had proved unsatisfactory and its future use to "a very large extent limited."

The following conclusion was the outcome of an interview with three radar technicians in 1943:

"Long experience in the operation, use and repair of radar sets has revealed to these soldiers that radar is practicable only under certain conditions; even the newest radar models, they say, have failed to overcome weaknesses caused by topographical obstructions."

"Radar operators generally have little difficulty with finding the azimuth but elevation is almost always incorrect, according to these men. They believe that it is pure coincidence when correct elevation is obtained and that in such instances the range is rarely maintained for any length of time. In contradistinction, they say, the azimuth is seldom more than 25 mils off the target."

● Allied RCM not only jammed enemy radar but jammed their scientists. In an effort to salvage their huge investment in ground radar equipment which our countermeasures were rendering ineffective, the Germans diverted an extraordinary amount of their best scientific effort to anti-jamming research and development. This diversion of effort, resulting from our RCM program, seriously delayed the development and introduction of more advanced radar equipment.

● Telecommunications Research Establishment in England has published a document (JEIA 1017) which accords radar trainers high praise for the huge savings of materials they have effected. From the beginning of the war until last December, the document estimates, more than 2000 of these trainers have been used by the services of Great Britain. Use of the various types of trainers up to that time was equivalent to the employment of a force of 4000 planes flying two million hours with a petrol consumption of 250 million gallons. Since 1940 the report goes on, 50,000 operators, controllers and air crew personnel have been given instruction on trainers. It is estimated that the availability of radar training devices has resulted in a monetary saving to Britain of 56 million pounds.

● A secret Jap report found on Iwo Jima indicated that the Japanese were fairly well up on their radar absorptive materials. The following are excerpts from the report: "Research is progressing on methods of concealing the location of targets through the absorption of radar waves. It is anticipated that a time will come when aircraft and ships will be covered with radar wave absorbing materials.

In addition to the technique of eliminating the reflected wave by absorption, another technique is being studied whereby either the reflected wave is cancelled by the transmission of another wave from the target, or calculations of position are rendered inaccurate by the transmission of an impulse stronger than the reflected wave."

● Postwar ground radar may add SEW (Smuggler Early Warning) to the radar alphabet. The Department of Justice and the Bureau of Internal Revenue are considering search radar as a countermeasure for smuggling. It seems that a new high in smuggling by air is expected, particularly over the Mexican border.

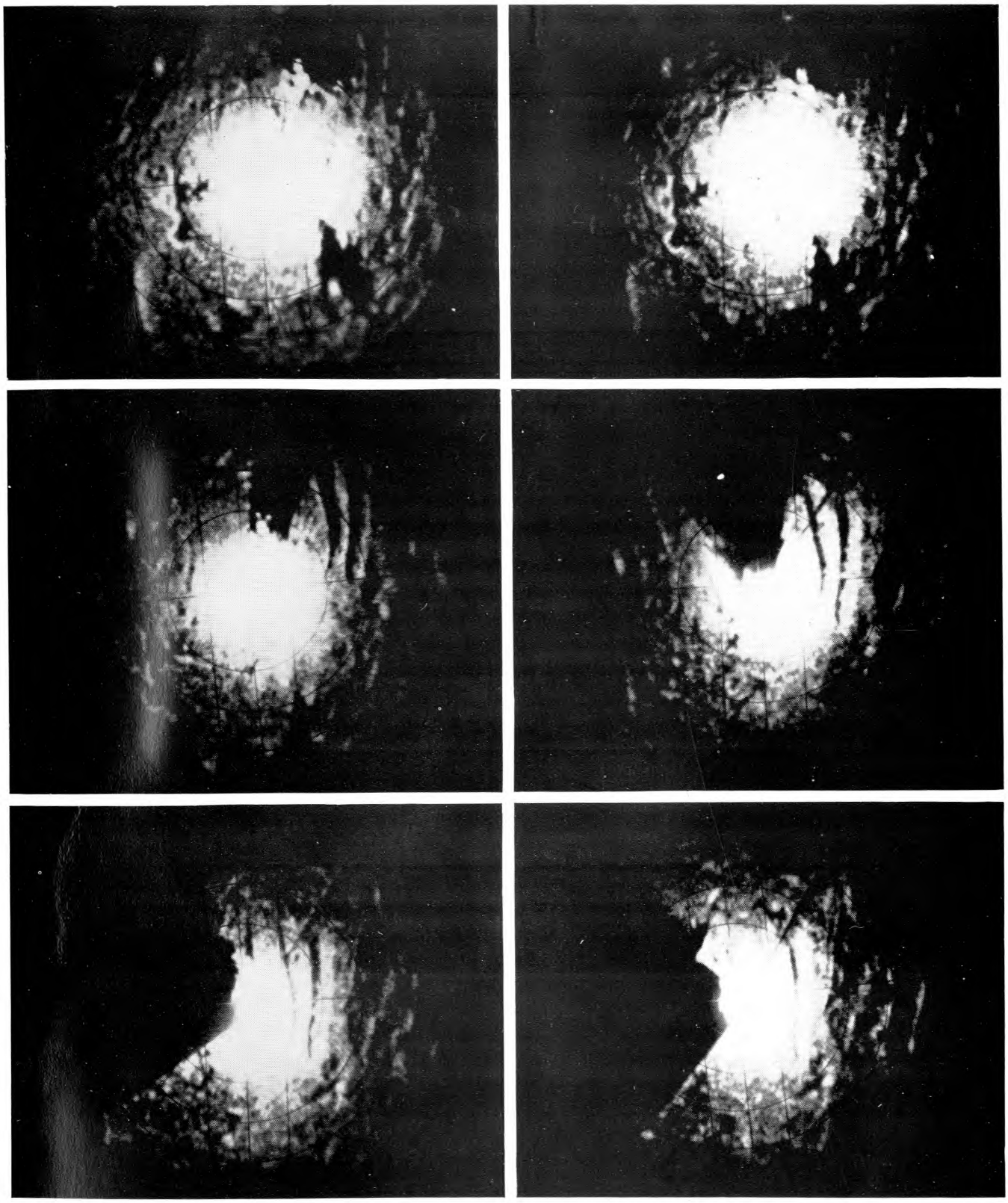
● Possibility that the Japs were using metallized clouds or powder instead of the conventional window to clutter up Allied radars was raised following an experience a task force had off Iwo Jima. The pips caused by the new material faded quickly and gave the impression that it had been dropped in clumps. The report stated the following: "On the whole, the material was much more effective than conventional window and radar operators required a few seconds longer to check each target to be sure of their plots. On the PPI of shipborne radars, the blanked area was very thinly streaked and much less dense than normally, and pips on the A scope were some what more sharply defined than with 200 mc window."

● The British Air Ministry sent an investigating party to Schleswig on 20 May 1945 to conduct a post-mortem on the GAF night fighter system. What they found, among other things, was that the enemy's intelligence was remarkably good. German confidence in the completeness of his intelligence was such that they had completed the scenario of a film illustrating the planning and execution of an RAF night bombing attack, to the last detail. They'd even made every effort to select German actors who resembled the British commanders and staff members mentioned.

According to Luftwaffe reports on radars sited in Denmark, Allied window played havoc with the German radar coverage. Loss in reliability due to window was put at an average somewhere between 30 and 50 percent—the highest was around 80 per cent. Electronic jamming claimed an even higher toll.

● Details of a new Japanese window bomb which explodes and pours out its window after a 35 or 40-second delay recently were revealed by the Allies. Tape projected from the nose of the bomb, and when this was pulled it ignited a 35 or 40-second delay fuze which in turn set off the explosive charge used to expel the window from the tail of the bomb. The window was a continuous metal strip backed by good-quality paper. Unlike the newspaper-backed window on which the metal is sprayed and therefore flakes off readily, the new type of window could be bent without breaking the continuity of the metal.

● Just before the Germans surrendered, one of their foremost scientists was developing an improved anti-radar material for Schnorkel—a very wide-band wave-absorbent material to cover the spectrum from 2 to 280 cm. The professor applied for a patent but was told he would have to wait until Germany won the war.



Scopes

A big black shadow is the effect produced on the PPI when an aircraft's altitude is lower than a nearby mountain. This effect is seen in these six photos, taken at 30 second intervals. The shadow blanks out more and more of scope as the aircraft approaches the mountain.

This mountain on Ceylon, rising to 2514 feet, is viewed on the 10-mile sweep beginning at range of 6 miles with the aircraft at 2000 feet. Training photos like these warned India-Burma navigators that shadow meant danger, not radar malfunction. Such shadows are caused by reflection of radar's energy from mountain. Airmen saw similar shadows from the Alps.

