effectiveness.

Thermal-Radio System Takes Shape

Operation of the entire system was to take place in the following manner: Detection of the target was first to be made by the radio equipment. Data transmitters would then transmit electrically the azimuth, angular elevation, and range of the target to the indicator panel at the thermal locator. Here an operator would match pointers by variation of the azimuth and elevation controls, thus pointing the thermal locator at the target. As soon as a thermal pickup was made, control would be transferred to the thermal operator, who would continue tracking the target. When the radio data indicated that the target was within range, the searchlight would be thrown on. On illumination of the target, control of the thermal locator would be transferred to the telescope operator, who would continue to track the airplane visually, thus keeping the searchlight beam on the plane.

If no thermal pickup was made, the target would be tracked by radio until it came within range, when the searchlight would be thrown on. If the target was illuminated, control would pass immediately to the telescope operator, and visual tracking would proceed as before.

As a result of the intensive research, the service-test system began to take final form. At this stage of development, the

equipment comprised a radio detector and locator system, and a combination thermal and control-station unit.

The radio elements of this system, Radio Set SCR-268-T1, were mounted on three trailers. One of the trailers contained the transmitting equipment, another carried the azimuth receiving equipment, and the third mounted the elevation and range-determining equipment. Suitable cables interconnected the three trailers.

During October 1938 the modifications were completed on the thermal locator and the entire radio-thermal system was tested. The characteristics of the system were investigated, trackers were trained, and by November the entire detector-locator equipment was virtually complete and ready for service test.

First Service Test--A Combination Radio-Thermal System

After a demonstration test before two members of the Coast Artillery Board at Fort Hancock, Radio Set SCR-268-T1 and the thermal locator were moved to Fort Monroe, Virginia, by a Coast Artillery Detachment for service-testing. A few difficulties were encountered while moving the radio equipment, because of the great size of the antennas and of the long period of time required to dismantle and reassemble the equipment. These were not considered too much of a handicap, however, since it was assumed that the size of the antennas could be reduced satisfactorily. ~~and that ordinarily there would be comparatively few occasions when it would be necessary to move this type of equipment.~~

The performance of the radio set during the test for the most part was highly satisfactory. It did not meet fully the military characteristics set up for it, but it proved to be a long step forward from the sound locator, which was the only other type of detector in use at the time. It detected approaching aircraft under all conditions of visibility, pointed the gun control to insure visual pickup beyond eye range, tracked targets obscured by clouds, and spotted for antiaircraft fire against obscured targets.

Although there still remained certain things to be said in favor of the sound locator, such as its smaller size, lower cost, and need for fewer and less skilled personnel, these favorable points were believed to be minor considerations in view of the results desired.

The military characteristics set up for the set were:

"(1) Detect the presence of aircraft in a sector of approximately 120° in azimuth, elevation 0 to 90°. This sector represents the zone which the device must be able to cover by rapid sweeping in azimuth and elevation; the apparatus to be actuated by the heat radiation or radio waves set up by the airplane.

"(2) Register, or indicate, in proper units of measure the position of the located airplane with respect to the detector or some other designated reference point; this indication of data to be continuous so that the aircraft while in motion may be followed by a searchlight or observing instrument laid on such data."

The first of the two was fully served by the equipment, as the radio unit alone detected aircraft to a maximum altitude of 32,400 feet and a maximum range of 50,000 yards. However, the tests did not show completely satisfactory results regarding the second characteristic.

Neither the azimuth nor the elevation data was accurate enough to allow the searchlight to be laid on the target, at once, without searching.

The azimuth receptor was the least successful, showing an absolute average error of 70.9 mils. There was no reason to believe that this receptor was affected in any way by either the elevation or the slant range, though the location of the equipment, with a variety of ground obstructions in the vicinity, may have had some effect. Also a percentage of error probably was due to some inaccuracy on the part of the reader, as well as from the effort necessary to traverse and elevate the antenna arrays.

The elevation receptor was not completely satisfactory. Since the average absolute error was 45.4 mils, there was obvious need for improvement. It was felt that both azimuth and elevation receptors could be modified with comparative ease to achieve a much higher degree of accuracy.

The slant range finder also was erratic at all ranges, having an average error of 672 yards.

However, the set immediately furnished data after it began to operate, it was so designed that it could be operated by the average skilled enlisted personnel, and its power requirements were such that it could be installed in the average antiaircraft defense system of an area.

A difficulty met by all three operators was that of keeping on the proper target. No doubt this was due to a considerable extent to the long distances between them. Also the tremendous effort necessary to traverse and elevate the reception antenna arrays and the lack of mechanical means for smooth, easy tracking made for considerable error. Lack of a slip ring complicated matters, for the cable serving the control station unit had to be unwound for all-round traverse, and the transmitter antenna speed was too slow. But here again modifications were suggested that seemed to offer the solution for improved functioning.

On the other hand, the performance of the transmitter, the control station unit, and the searchlight was very satisfactory, and the performance of the set itself offered few difficulties. Only two hours were lost in trouble-shooting throughout the entire two-week period of testing, and remarkably little attention was necessary from Laboratory technicians.

Thermal Unit Limited in Usefulness

The thermal locator could be tested only at night when it was clear and cold. Under such favorable conditions it functioned well up to 8,000 yards, but being affected by climatic conditions and of little value in the daytime, its usefulness was decidedly limited. Also the comparatively short range of effectiveness was a distinct drawback. In spite of its limited usefulness, however, and the fact that it increased the cost of the equipment by approximately 50%, it

was considered unwise to dispense with it until the azimuth accuracy of the radio equipment could be greatly improved.

During the firing tests it was discovered that little trouble need be anticipated from shock to the equipment. No damage was done by the bursting shrapnel used for preliminary tests before firing the guns. Nor did the firing of the guns themselves do any damage. Some inconvenience resulted from shock from the gunfire, which influenced an overload switch in the pulse-projector equipment. This could easily be remedied by the installation of a relay switch. The entire set, both radio equipment and thermal locator, showed itself to be rugged and serviceable-standing up under field service and withstanding the shock of gunfire as well.

Radio Equipment Highly Successful

It was felt by those who were testing the apparatus that, with a few modifications, the radio set as it was would serve a great need--and that its possibilities for future development were tremendous. Among the modifications suggested were: substituting a wooden antenna frame for the steel antenna frame on the azimuth receptor used in the test; supplying more suitable traversing and elevating mechanism to insure easy and smooth tracking; installing slip rings for unrestricted all-round traverse; doubling the traversing speed on the pulse-projector antenna; using another hookup on the pulse-projector traversing motor so that voltage fluctuations would not affect the oscilloscope pictures; installing some means of intercommunication between the three operators

for more positive identification of the target; adding fine horizontal lines at quarter-inch intervals to aid in qualizing the pulse-echo images on the oscilloscope; adding relay switches in insure operation without interruption during gunfire; providing means for continuously directing either searchlight or antiaircraft gunfire.

Improvements that were suggested for immediate attention in the development program were: first, increased direction-finding accuracy in azimuth as well as in elevation below 275 miles; second, increased accuracy of the slant range finder; third, reduction in the size of the antenna; fourth, reduction in the number of components; fifth, reduction in the time required for installation in an operating position; sixth, eventual production of a radio-detection device which would provide accurate azimuth, accurate angular height, and accurate slant range for use as basic firing data for antiaircraft guns.

So far as "jamming" was concerned, the apparatus was not considered immune, since all radio receivers are subject to jamming. However, it was believed at that time that successful jamming of this equipment could be made a very difficult problem.

The two greatest advantages of the radio equipment over sound locators were the marked increase in the range covered and the much greater accuracy achieved. Also, the equipment was not dependent on noise output from the target to insure efficient operation, it was unaffected by loud noise and wind, and it had a wider tactical application.

All in all, this first short-range service-test radio equipment for aircraft detecting and tracking was highly successful, the forerunner of long-range development, and showed rather conclusively that radio equipment was a real answer to an urgent need for a long-range detector. It also pointed out the direction for future development in gaining more far-reaching and accurate data.

V. INTENSIVE DEVELOPMENT PROGRAM STARTS IN 1939

Early in 1939 the report on this service test of Radio Set SCR-268-T1 was received from the Coast Artillery Board. The Board felt that the results of the test were very satisfactory and that great improvement in azimuth accuracy and a radical reduction in the size of the antennas might reasonably be expected. It recommended that the equipment be standardized as a development type and suggested the procurement of a limited number of the sets for extensive tests. Believing that an energetic development program was warranted, the Board further recommended that the equipment should be given a high priority as well as a liberal allotment of funds for continued development work.

After carefully studying the report, the Laboratories forwarded their comments and recommendations to the Chief Signal Officer. Since no funds were immediately available for procurement, the Laboratories undertook the job of developing a unit which would correct the defects that had showed up on the service test of the 110 mc Radio Set SCR-268-T1.

Radio Equipment Given Full Attention

During the early months of 1939 Radio Set SCR-268-T1 was entirely

reconstructed to make Radio Set SCR-268-T2. It was decided that this new set should be a 205 megacycle set with three antennas, one transmitting antenna and two receiving antennas.

Work on the thermal locator was discontinued, since it had proved of such limited value in its service test. All attention was directed toward obtaining greater accuracy, longer range, and more co-ordinated results from the promising radio equipment. Industry cooperated fully with the Laboratories in the development of components for use on the radio equipment.

Various transmitters were designed and tested with the various types of tube available, resulting in a service-test transmitter using 8 double-ended Eimac 100 TL tubes. This particular tube had been developed specifically for the Signal Corps, whose engineers were largely responsible for its design. Experiments with television tubes in the receiver proved unsuccessful because of the tubes' long recovery period, but single intermediate frequency was tried successfully. A receiver employing double input was constructed and proved very successful when tested. After minor changes found necessary to minimize the effects of regeneration in order to secure a steadier output picture in the oscilloscope, this receiver was made a part of the service-test model of Radio Set SCR-268-T2.

A new antenna was constructed for this set, incorporating a director system to narrow the antenna pattern in the vertical plane.

This system showed so slight a gain in signal strength that it was not used in the final service-test model.

Several modifications were made in receiving antennas already developed. The presence of lobes on both the elevation and the azimuth antenna patterns accounted for their erratic behavior, and modifications were made to reduce the lobes. The data-transmission systems of both receiving antennas likewise were modified to provide for the transmission of data to the Mark IV antiaircraft director. On both receiving antennas a mechanical angular displacement was introduced between the two halves of each to replace the electrical displacement previously used to secure double tracking. The data-transmitting system of the elevation receiving antenna also was modified to adapt it for use with the Mark VI searchlight controller, and the gearing of the thermal-locator chassis modified accordingly to permit use of the optical system of this unit for accuracy measuring purposes in connection with the radio-detector system.

Two antenna mounts were the original models of K-28 and were ordered to handle the azimuth and elevation parts of 3-mount 205 mc job. When the first model arrived, steps were immediately taken to make a single mount 205 mc job. These efforts culminated successfully in April 1939. All necessary parts were delivered, less the required antennas, frames, beams, and without antenna metal work.

Although all the modifications planned had not been finished, a complete service-test model of Radio Set SCR-268-T2, using an experimental transmitter and antenna, was turned over to the Coast Artillery Detachment in May 1939 for field tests. These tests showed that the system had great accuracy, but difficulty was experienced in tracking

because of the existence of false tracking points. The antennas were adjusted to minimize these false indications, and work was continued on other improvements and modifications for greater ease in operation, improved accuracy, and more far-reaching data.

Long-Range Unit Constructed

Late in 1938 directives from Washington had indicated that work on a device for the detection of aircraft at long range for purposes of aircraft warning service be given an active development status on the development program, rather than a research and study classification. A service-test long-range unit was requested as early in 1939 as practicable.

A development contract with the Westinghouse Electric and Manufacturing Company for high power tubes netted results for the long-range development program in January 1939 with the delivery of tubes capable of giving 100 kw per pair at 100 mc.

Another development contract was signed for procuring a mobile antenna support which would be suitable for use with a mobile long-range detection station.

Work on this antenna support progressed during the early months of the year, along with progress in the development of other components. The major advance necessary in the construction of the unit was the development of a technique to permit a sensitive receiver to operate on the same antenna with a 100 kw transmitter without the

receiver's being damaged, yet to have the receiver in a sensitive condition during the periods when the transmitter was inoperative. This was finally achieved by the careful selection of receiver time constants to insure rapid recovery time and by using a transmitting tube an an input r-f tube of the receiver, with a spark gap across the receiver's input. Various other expedients, such as the use of a mechanical shorting device, were tried but abandoned -- not because they seemed impracticable but because the pressure placed on finishing the project forced the adoption of the first method that secured reasonably satisfactory results.

Various models of other components were constructed and tested before it was felt that they were sufficiently satisfactory for installation in the service-test unit. Because of the need for haste, a reasonable degree of good performance was all that could be demanded for inclusion in the service-test set. Of the several transmitters tested, that employing two 3007 tubes was found to give a greater power output. This transmitter, with a previously tested single-input superheterodyne receiver, was install d on an experimental antenna, a horizontally polarized arry 4 dipoles wide and 9 dipoles high.

This antenna had a similar reflector parasitically excited and was constructed to rotate in azimuth and be adjustable in elevation when in an operating position, and also to collapse for transportation purposes. The method of feeding this antenna was changed from feeding