RADAR MAPPING OF THE CHICAGO-NEW YORK AIRWAY

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SUMMARY

This report describes a radar flight from Chicago to New York during which time several hundred pictures of the radar indicator were taken with a Fairchild Type 05-A radar camera A number of representative radar prints are included together with explanatory remarks and a discussion of the possibilities and limitations of navigation by radar The equipment used was an AN/APS-10 3 cm airborne search radar installed in NX-300, a B-25J airplane

INTRODUCTION

The type of camera used in these tests was originally developed for the armed forces to photograph various types of airborne radar displays, and has been used by them successfully for several years not only for recording performance of equipment, but also for showing pilots and navigators exactly how specific routes and objectives would look on their radar screens Unusually clear photographs are obtained due to the special design of this unit which incorporates a color separation filter which allows only the very short persistence (blue) image to reach the photographic emulsion, completely eliminating the long persistence (yellow) image which is required by the observer This permits simultaneous viewing and recording without any noticeable loss of intensity either for the camera or the observer, and, at the same time the blurring noticeable in photographs taken with an ordinary camera which is due to the persistent image, is eliminated

The camera is entirely automatic, the shutter being operated and the film advanced at each sweep of the radar antenna, or by simply setting a switch on the control box, a picture may be taken every other scan, three consecutive scans out of twelve, or five out of sixty Along one edge of each 35 mm frame, there is a recording of a watch with sweep second hand, a data card on which any information may be written with a pencil, a counter which numbers each frame (a duplicate counter is visible to the operator) and six lights which can be used to indicate range setting or any other type of 'on-off' type of information desired

The magazine holds 100 feet of 35 mm film sufficient for approximately 1,600 pictures It can be attached or detached in an instant without tools so that an extra loaded magazine may be quickly substituted for one in which the film has been used up, with little or no loss of continuity of the pictures The magazine is so designed that no loops are required in the film, and it can be loaded easily and quickly by anyone without special skill or instruction

The APS-10 is an X-band lightweight airborne search radar Production of the APS-10 was just getting underway at the end of the war and consequently it was never used extensively by the armed forces Since the cessation of hostilities, much experimental work has been done with the APS-10 by both military and civil organizations[1] It has shown itself to be a very versatile equipment, and is being used at the present time by the Air Force for weather surveillance, while at the same time its value to serve additional functions is being closely investigated by others

The complete APS-10 system consists of the following major units

- Antenna, with 18-in parabolic reflector
- Synchronizer, containing operating controls
- Transmitter-receiver, contained in a single unit
- Rectifier power unit
- Indicator

Total weight of the equipment is approximately 140 lb

The radar transmits a 0 8 μ sec, 4 to 8 kw peak power pulse, at the rate of 405 pulses per second A continuously variable range scale is provided from 4 to 25 miles

[1] Richard C Borden, "Air Navigation by Radar in Southeastern Alaska" Technical Development Report No 65

with the particular range indicated by the number of two mile range markers appearing on the oscilloscope A 50 mile range is also available with ten mile markers In addition the radar may be used in connection with ground beacons The range capabilities are such that strong signals, such as those returned from cities and mountains, can be detected at the maximum range of 50 miles The antenna beam width is about 5 1/2° in the horizontal plane while a broad cosecant squared pattern is used in the vertical plane

In order to take advantage of the automatic photographing feature of the Fairchild camera, it was necessary to install a micro-switch on the antenna mounting to operate the camera control mechanism when actuated by rotation of the antenna. The control mechanism was adjusted so that the time of exposure would be equal to that of a single antenna revolution, approximately two seconds Mounting of the camera on the APS-10 indicator was accomplished by modifying slightly an adapter which is used with another type of radar

Due to the fact that the shock mounts on the APS-10 indicator are not designed to support the additional weight of a camera, a temporary installation was accomplished by suspending the entire assembly of camera and indicator by means of shock cord in the rear compartment of the B-25 It was located in such a position that an operator sitting in the rear seat next to the waist window could view the scope comfortably, and additional shock cord ties were used to restrict the movement of the unit in all directions

TEST FLIGHT AND RESULTS

Airplane NX-300 departed from Indianapolis at 1 23 p m , December 17, 1946, and proceeded north toward Chicago It had been agreed that for best results all radar controls should be pre-set at optimum levels and then left untouched during the complete photographic run The portion of the flight between Indianapolis and Chicago presented an excellent opportunity to determine the most desirable settings for these controls A radar range scale of 14 miles was selected since, when used with proper antenna tilt, this seemed to be the maximum range setting at which even coverage could be obtained from zero to the outermost range circle A greater range scale would have resulted in less quality of coverage as well as loss of small detail on the indicator Shorter ranges would have narrowed the width of the area mapped The 28 mile width afforded by using a 14 mile range scale appears adequate for most navigational purposes Prior to arriving over Chicago, this setting, plus proper adjustment of the various radar controls affecting oscilloscope display (focus, brilliance, bias centering, video gain, etc), had been accomplished

It was further decided that the aircraft should remain at constant altitude throughout the flight to prevent the necessity of adjusting the antenna tilt for changes in altitude, The altitude selected was 5,000 feet For guidance in interpretation of photographs the following is a brief outline of the test conditions

Indicated air speed	220-230 mph
Ground speed	305 mph (approximate)
Scanning rate	35 rpm
Picture rate	3 out of 12 scans 20 6 sec per group 1 75 miles per group (approximate) 0 15 mile per scan (approximate)
Weather	Clear, some haze

It is felt that examination of representative photographs taken during the flight will best illustrate the possibilities and limitations of employing radar as a means of navigational guidance

Figs 2 through 7 are examples of flight over terrain ideally adapted to radar navigation The correlation between these photographs and the map of Fig 1 will illustrate the ease with which location by radar can be accomplished in such a distinctive area Fig 1 is a tracing made from United States Coast and Geodetic Survey sectional aeronautical chart U-8 (Cleveland) and the scale is approximately the same as that depicted in the radar photographs Progress of the aircraft along the course indicated is self-evident in this series of photographs and illustrations

Figs 8 through 13 show an entirely different type of terrain, over which radar navigation can be accomplished only by highly trained radar observers already possessing radar familiarity with the area These pictures also show good examples of ridge presentations

CONCLUSIONS

The problem of radar navigation, as evidenced by comparing the two cases illustrated in Figs 2 to 7 and 8 to 13, respectively, is either easy or difficult depending on the nature of the terrain over which the aircraft is flying In either case it is felt that successful radar guidance could be accomplished, but in the latter case this type of navigation is considered impractical in areas where more easily interpreted navigational facilities are available The possibility of making a mistake over such generally similar geography cannot be overlooked In order to determine location with any certainty several different targets must be cross checked, whereas in the case of the flight over the Sandusky region, a glance should be sufficient to verify the position of the aircraft It is further believed that attempts to navigate by radar over uncertain territory should not be attempted without the aid of previously prepared radar maps, preferably from actual radar photographs It must be remembered that the characteristics of the radar with which the original mapping pictures are taken must coincide with those of the radar with which radar navigation, using these maps, is attempted Any discrepancies between characteristics or operating conditions (frequency band, sensitivity, antenna pattern, range scale, etc), will complicate the problem considerably

It is believed that, in general, radar photography should be carried out with the sensitivity of the radar turned well down This practice will make it easier to pick out distinctive targets from general ground clutter, and in addition will allow a tolerance for radar equipments which may not be at peak performance

Adoption of radar solely as a navigational aid on the basis of its search function alone appears unfeasible for scheduled flying, but if airborne radar equipments can be developed to perform satisfactorily other functions not now being served or being served at present by several separate facilities, its ability to furnish self-contained emergency navigational information would be an additional factor in favor of its adoption

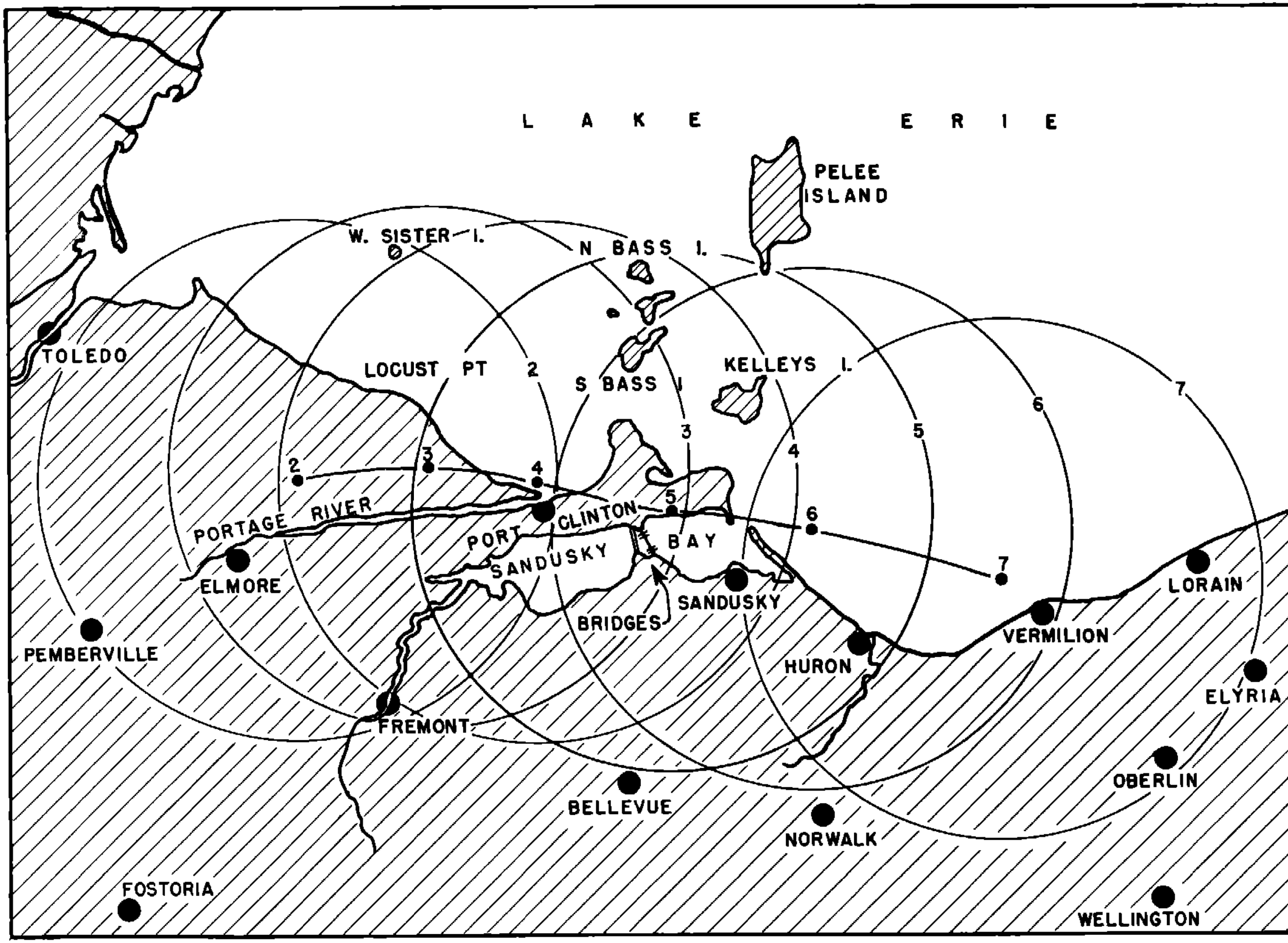

Fig 1 Map of Sandusky, Ohio Area

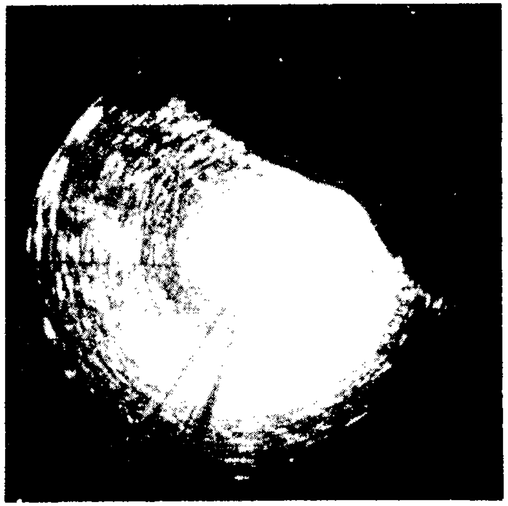

Fig. 2

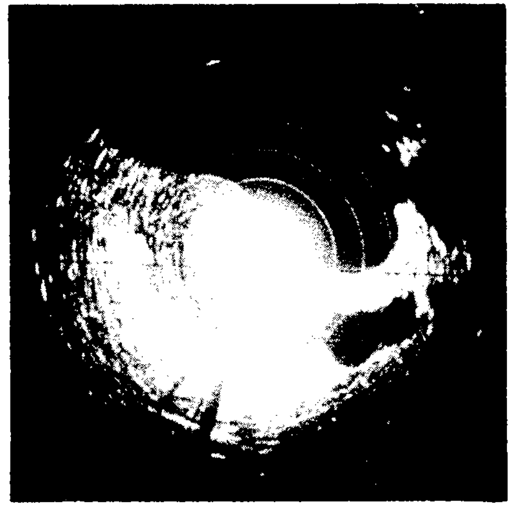

Fig. 3

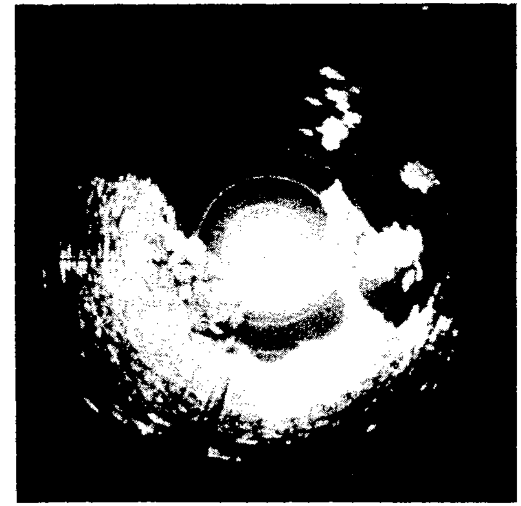

Fig. 4

AIRCRAFT HEADING ⟶

Fig. 5

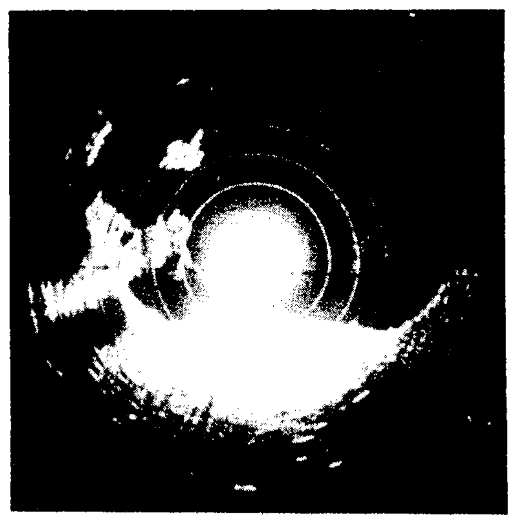

Fig. 6

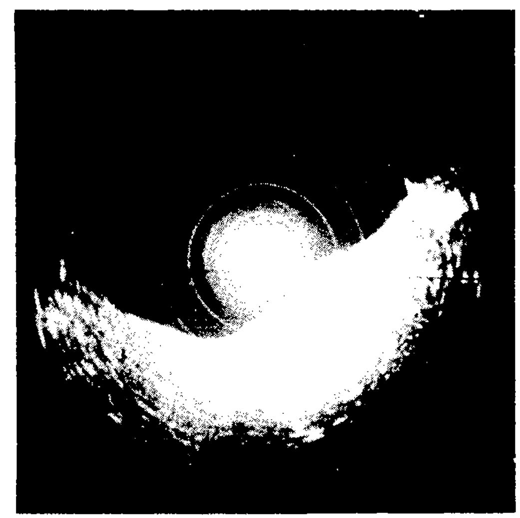

Fig. 7

Enroute Radar Photographs

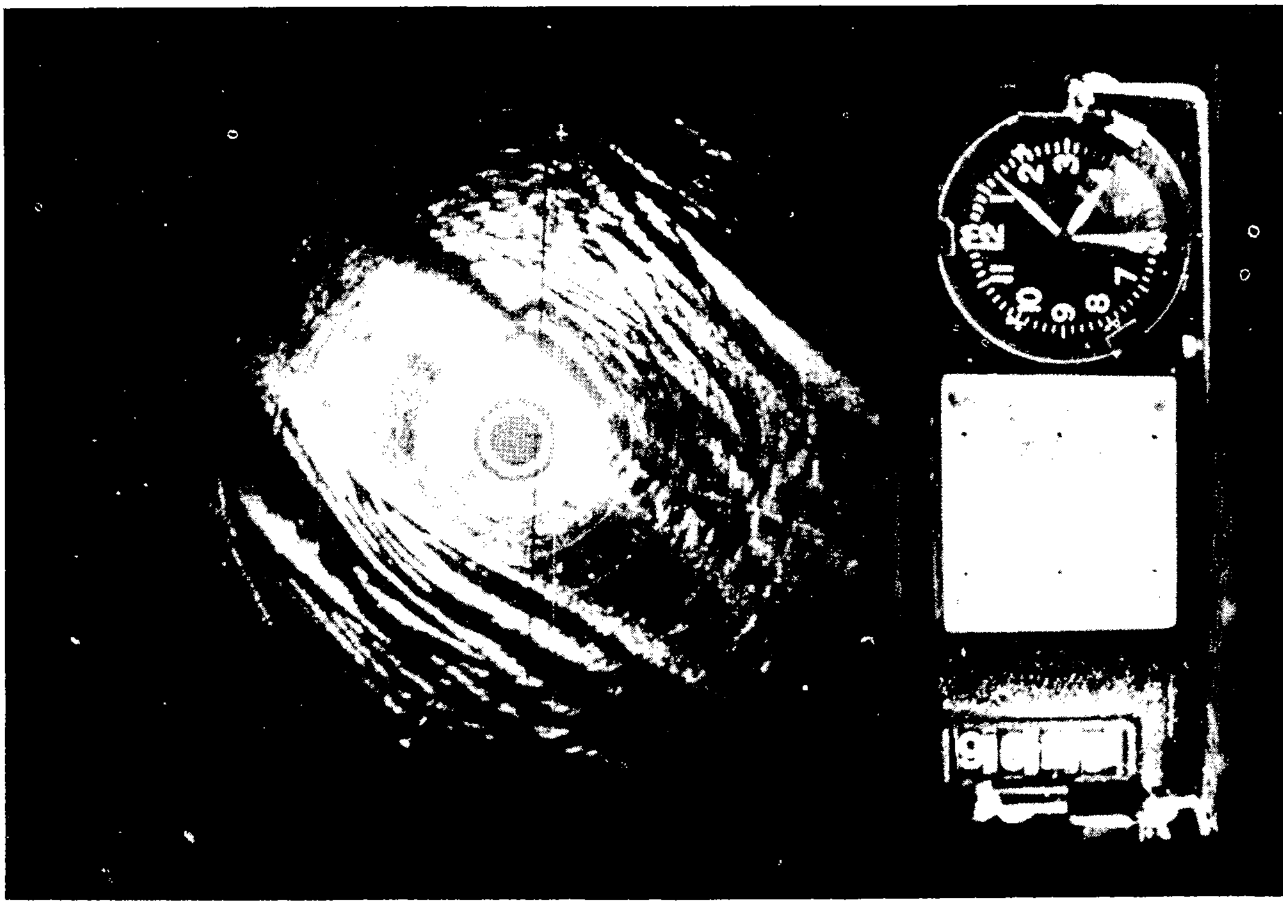

Fig. 8.

Zero degrees relative bearing is at the top of each picture in this series. Reference to Fig. 14, a partial tracing of the U. S. C. & G. S. sectional aeronautical chart U-9 (New York), indicates by means of encircled figures, the approximate location of the aircraft at this time, and at the time of the five succeeding pictures.

This photograph was taken about one mile northwest of McClure, Pa. At this time the aircraft had just passed over the ridge four miles back and is approaching another, now only two and one-half miles ahead. Ridges are characterized by a sharp discontinuity of the radar return followed by an area of comparative darkness (shadow). The fact that radar signals can be seen beyond both ridges indicates that the altitude of the aircraft is sufficient to clear them.

This photograph illustrates how the Fairchild 05-A radar camera records the time and number of each picture, thus considerably simplifying identification of each negative.

The range circles on the APS-10 indicator represent a range of two nautical miles each, while the sectional chart is scaled in statute miles. The ranges referred to in this report are nautical miles.

Fig. 9.

Fig. 10.

Reference to Fig. 14 will identify this photograph as having been taken at about 40° 40' north, 77° 11' west. The distinct bright targets at 170° and 150° relative, are quite possibly echoes received from the small towns of Paintersville and Mifflin, respectively. Note the narrow ring of complete darkness around the broad circle at the center. The width of this dark ring is a measure of the evaluation of the aircraft above the ground, or absolute altitude. By examining the photograph, an estimated altitude of 1,000 feet is obtained. Reference to the preceding photograph, where estimated absolute altitude is about 3,500 feet, indicates that the aircraft is now passing over the oncoming ridge of Fig. 8. Even an untrained operator could hardly fail to notice the diminishing altitude circle, thus receiving a warning of approaching high terrain.

The aircraft is now 11 miles southwest of Selinsgrove, Pa., which is indicated by the relatively bright spot at 320° relative. Throughout this sequence of pictures the course of NX-300 was approximately due east. It can be observed that the altitude circle has now expanded to about 3,500 feet again, the ridge of the preceding picture having been safely traversed. Between 330° and 355° at eight and ten miles, a section of the Susquehanna River may be seen. In actual practice, a better definition of the river could be obtained by using less radar receiver gain. The hook shaped dark area between 280° and 305° is a small ridge just off the tip of the larger ridge which shadows the lower left-hand portion of the scope. This unusual ridge formation can easily be identified on the sectional chart.

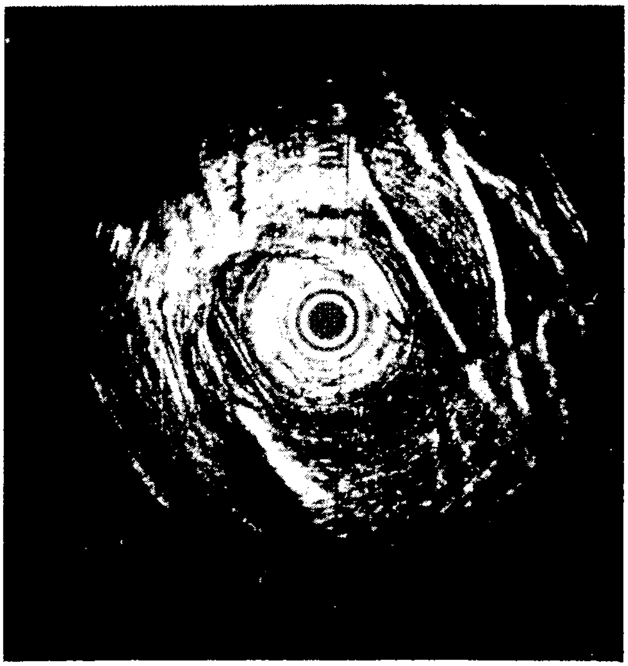

Fig. 11.

This picture was taken just prior to crossing the Susquehanna. By examining the river closely, two fairly large islands can be seen in its center, together with some smaller ones north of them. This identifies the point of crossing as Port Trevorton. The radar return from Selinsgrove is now largely masked by other heavy ground return but can still be seen at eight miles bearing 270° relative. The fairly distinct group of echoes 285° near the end of the scope are originating from the neighborhood of Sunbury, Pa. The hook shaped ridge can still be seen but is now falling behind. The V shaped ridge to the right may be readily identified on the chart, the break in the closest leg representing the point at which the river passes through it, positively identifying the town of Liverpool, Pa.

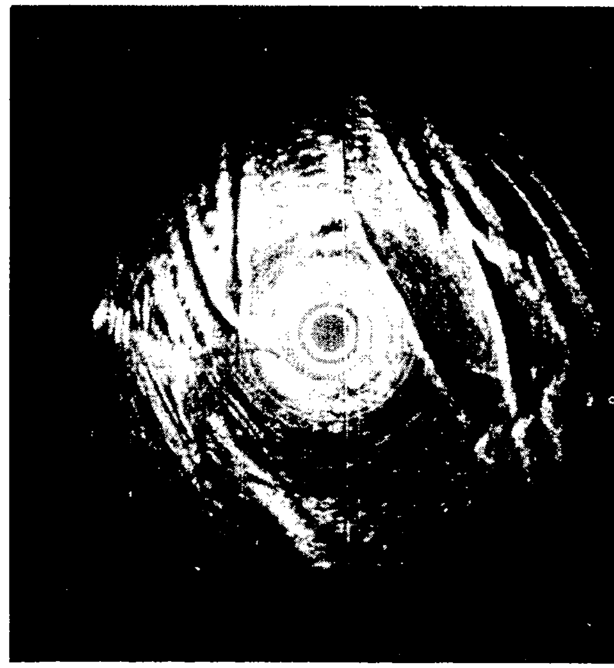

Fig. 12.

The flight has just crossed the Susquehanna and is still progressing eastward. The V shaped ridge discussed previously is still visible and the path of the river through the base of the V is indicated by a discontinuity in each leg. Sunbury is now at 270° relative, or due north, while Selinsgrove can be detected only with difficulty at nine miles bearing 240° relative. This is a good example of the variation of a radar signal from a given target when viewed at different angles. It will be noticed that the river also appears differently when viewed from the opposite side. This is probably due to a difference in steepness and height of the opposite banks. In some cases, narrow rivers with steep banks appear as bright lines on a radar indicator, exactly the opposite of the normal indication. Note another distinctive V shaped ridge appearing to the left of the flight path with an additional ridge in the center of the V.

Fig. 13.

The single ridge within the V shaped one on closer approach has taken the shape of an additional V. The general ground clutter to the left of scope is not nearly as intense as that to the right. This effect is caused by banking of the aircraft to the right. It serves to illustrate that reduction of gain would render distinctive ground targets more readily discernible, since thinning of radar energy directed to the left, due to the antenna pointing upward during a right bank, has the same effect as reduction of gain. It will be observed that Selinsgrove is showing very clearly at ten miles bearing 230°, while only the nearest echo from Sunbury (245° at 13 miles) is still on the scope. Comparison of the ridges to the right with the sectional chart will identify each of them. The small town of Gratz can be seen four miles to the right of the flight path while the bright spot at seven miles bearing 80° is undoubtedly originating in the vicinity of Lykens. The points at which each of these pictures were taken were not logged during the flight, but each was pinpointed without difficulty by reference to the sectional chart.

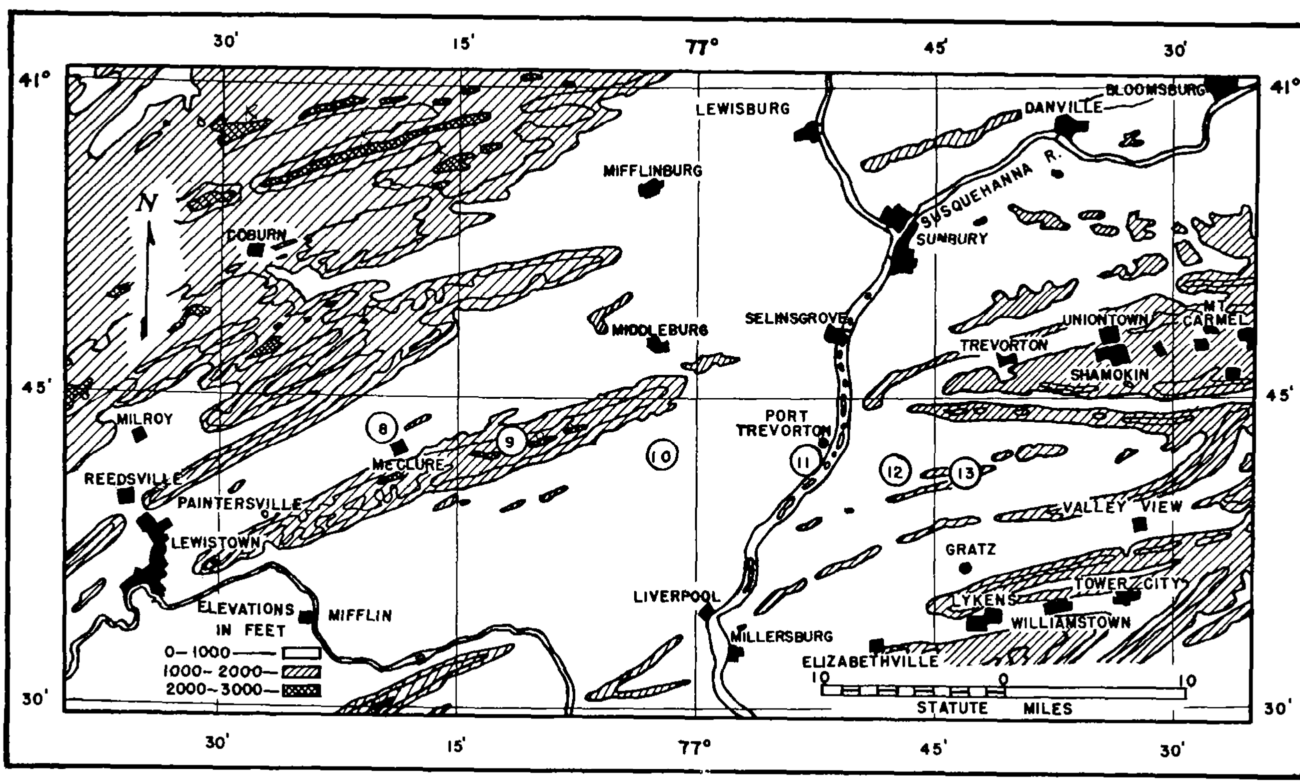

Fig. 14 Map of Sunbury, Pa. Area