AIRBORNE PHOTOGRAMMETRIC RADIO EQUIPMENT*

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ABSTRACT

The early history of radar is presented along with an explanation of how a radar set collects the basic information for presentation on the cathode ray tube. The superior characteristics of a radar photograph over a conventional photograph are explained. Photographs of a research model of a photogrammetric radar set recently delivered to Wright Air Development Center are shown with a brief explanation of the various functions and controls.

INTRODUCED

THE ability to obtain photographs of terrain from an aircraft in flight, unimpaired by night, fog, smoke, clouds and ordinary obstacles has challenged photogrammetrists ever since the first aerial photograph was obtained. Radar photography makes this possible. These radar photographs contain sufficient information, presented in such a manner that it is possible to use them in the construction of small-scale maps and charts.

Radar is an addition to the photogrammetric equipment which affords new facilities for the construction of maps and charts. It enables a certain class of objects to be seen at distances far beyond those at which they could be distinguished by the eye or a camera. It is unimpaired by any normal atmospheric condition. The measurement of direction and distance to these objects is made in a simple and natural manner.

EARLY HISTORY

The fact that radio waves have optical properties identical with those associated with ordinary visible light was established in 1886 by Heinrich Hertz, the German physicist and pioneer in electronics. He showed among other things that radio waves were reflected from solid objects. This phenomenon was not used until 1925 when this principle, with pulse ranging, was used to measure the height of the ionosphere. The step from the technique to the notion of using it for detection of aircraft and ships was not a great one. By 1931, planes at a distance of 50 miles had been spotted by radio reflection under favorable circumstances. This was the crossing of the frontier from observed phenomena into practical use and the real inception of what we now call radar.

Between 1931 and 1939 an extensive research and development program was carried out. U. S. production manufacture of radar was begun in the fall of 1939 with six (6) sets ordered by the Navy for shipboard use. These sets were detection and ranging devices and were used for fire control. The first successful flight test of a modern airborne radar set was made in the spring of 1941.

A tremendous amount of work was carried out during World War II by the research and engineering staffs of many military installations and industrial concerns. This enormous investment of money, skill and productive facilities in radar paid the allies handsome dividends.

The usesof radar in a peaceful world were just beginning to be worked out in 1946. Radar charting is only one of the many benefits devised from the skills developed and funds expended during World War II.

HOW RADAR WORKS

Radar operates by sending our radio waves from a transmitter of such power that measurable amounts of electro-magnetic energy will be reflected from the objects to be seen. This reflected energy is picked up by a receiver, usually located at the same site as the transmitter, and presented in a suitable manner. The transmitter may send out signals generated in a variety of ways but pulse radar has re-

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ceived the most attention and has developed much farther than any of the other possible methods.

In pulse radar, the transmitter is modulated in such a way that it sends out very intense, very brief pulses of electro-magnetic energy at intervals spaced rather far apart in terms of the duration of each pulse. During the waiting time of the transmitter between pulses, the receiver is active. Echoes are received from the nearest objects soon after the transmission of the pulse, from objects farther away at a slightly later time and so on. When sufficient time has elapsed to allow for the reception of the echoes from the most distant object of interest, the transmitter is keyed again to send out another very short pulse and the cycle repeats. This cycle is repeated many times a second.

Since the radio waves used in radar are propagated with the speed of light, the delay between the transmission of a pulse and the reception of the echo from an object is a measurement of time. Since the velocity of light is high, the intervals of time that must be measured in radar are very short. If it is desired to measure range to a precision of five (5) yards, which is necessary in some applications of radar, the time intervals must be measured with a precision of better than one-thirtieth (1/30) of a micro second. Modern electronic timing and display techniques have been developed to such a point that this can readily be done. The measurement of range by means of radar is thus a straightforward problem of time measurement.

It is also desirable to be able to measure the direction in which a target lies as viewed from the radar station. In principle, this can be done on the basis of triangulation, using range information on the same target from two (2) or more separate radar locations. This method permits a high degree of accuracy and is used in Shoran applications. It is desirable from the standpoint of simplicity and flexibility to measure direction as well as range from a single radar station. Measurement of directions was made possible by the development of radar techniques on wave lengths short enough to permit the use of highly directional antennas to more or less shape a beam of radiation. When the pulses are sent out on such a beam, echoes will be received only from targets that lie in the direction the beam is pointing. If the antenna is swept or scanned around the horizon, the strong echoes will be received from targets when the beam is directly towards the target and no echoes will be received from targets from the other directions. The bearing of a target can be determined by noting the bearing of the antenna when the target gives the strongest signal. This can be done in numerous ways but the same basic principal applies to all methods.

Indicators

The device which presents radar data in useable form is called the indicator. It is usually a cathode ray tube but may be a pen and ink recorder, flashing light, moving coil meters, a loud speaker or mileage indicators. The PPI, plan position indicator, is a cathode ray tube which presents range and angular disposition of targets at all azimuths and is the type most commonly used for radar charting. The direction of each echo signal from the center of the tube shows the direction of the target from the radar set, and its distance from the center is proportional to the target range. The cathode ray tube permits interpretation of electrical phenomena in terms of a picture painted on a phosphorescent screen similiar in appearance to a television screen. Recording cameras are so mounted as to photograph the face of the cathode ray tube. The resultant photography is used for charting purposes.

Camera

The camera presently used to photograph the cathode ray tube is especially designed for the purpose. Since the normal operating speed of the antenna is about twenty-four (24) scans per minute, the camera must remain open for one complete photograph. The camera system is so designed that the rotation of the antenna will open the shutter at the start of a scan and close the shutter upon completion of the scan. The camera is entirely automatic and can be set to record every scan, or any sequence of scans desired.

Various types of cameras have been used for recording the image on the cathode ray tube. The simplest form was a Kodak 35 mm. camera mounted on the end of the tube and by use of the bulb exposure feature of the camera, manually expose the film for one complete scan.

Characteristics of Radar Photography

The superiority of radar photography to ordinary vision lies in the greater distance at which objects can be seen and its ability to work regardless of light conditions or state of the atmosphere. One feature of a radar photo that is far superior to an aerial photograph is that all scale distances on the photo are correct within the limits of the radar sets. All the area covered by the photograph is presented in a plan view regardless of the distance reached by the radar set. It is also very easy to change the scale of the presentation. This is done by setting up the proper delay in the circuits, and is accomplished in flight simply by turning a knob for the desired range. The presentation is always the same size on the same tube and is recorded with the same equipment. The scale does change with a variation of altitude as with visual photography.

The USAF has recently accepted delivery of an experimental photogrammetric radar set that incorporates the latest state of the art developments. The desired characteristics of accuracy, both in range and azimuth, resolution, precision recording, size and weight have been engineered in this model. The absolute values desired have not been determined and provisions have been made to adjust these values under flight conditions to obtain comparative data. This radar set has three (3) major packages, composed of the recorder and control units, the transmitter and receiver unit, and the antenna.

The recorder and control unit (Figure 1) required many changes from the conventional airborne radar sets. The camera is a modified K-24 aerial camera that photographs a direct image of a flat-faced radar scope at a 1 to 1 scale. Recordings of the auxiliary data are presented on the same frame. The numerous controls shown on the panel provide selection of range, terrain and recording camera controls, altitude settings, range mark selection, focus control and an eye piece to monitor the radar display. Calibration marks are provided on the controls to assist in duplicating any favorable set of conditions.

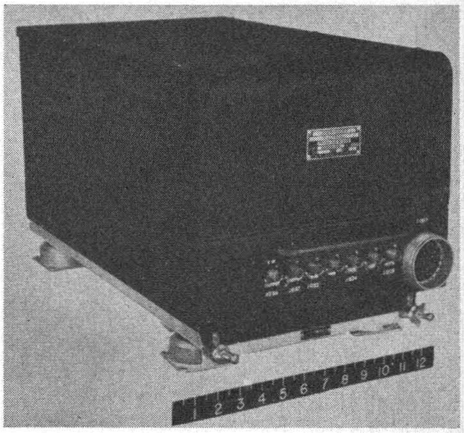


FIG. 2. Synchronizer.

The transmitter-receiver unit is a basic radar component and extreme care has been used in its construction. The synchronizer or timing device is the heart of the radar system. (Figure 2). Accuracy and reliability has been stressed in this unit. The accuracy of the range, or scale of the display, is directly a function of the unit.

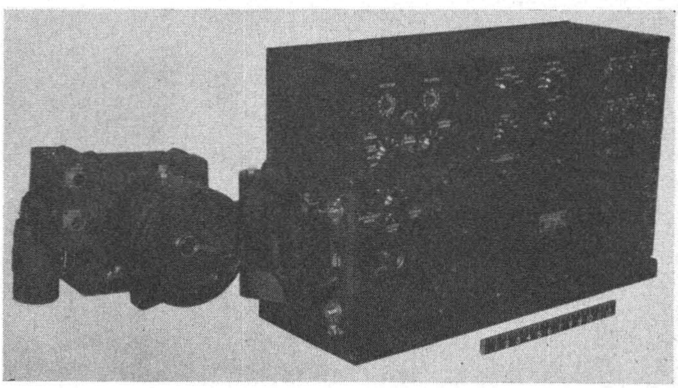


FIG. 1. Indicator-recorder.

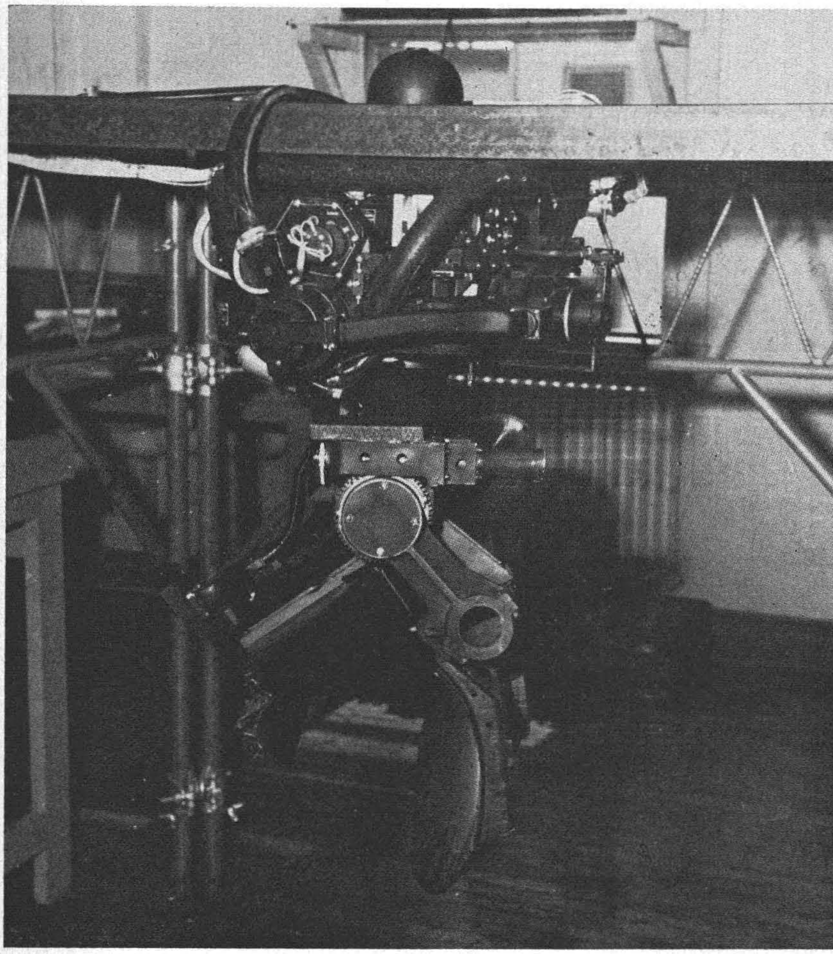


Fig. 3. Antenna.

The antenna and related mountings are a necessary portion of the system. (Figure 3). In order to obtain a complete photograph, the antenna must rotate 360 degrees and project below the aircraft. The reflector, or dish, has been accurately constructed in order to generate a beam of known characteristics. The rotation mechanism has been platform stabilized and is accurately tied to the indicator.

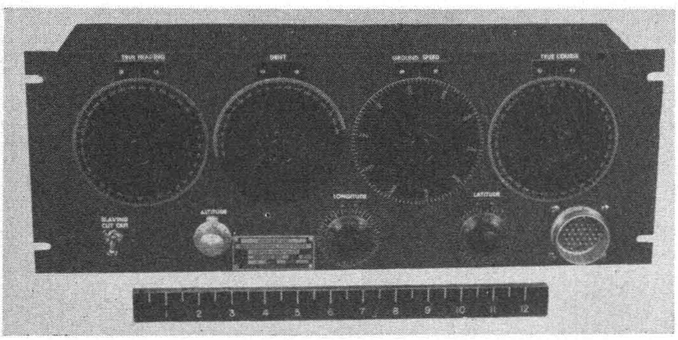
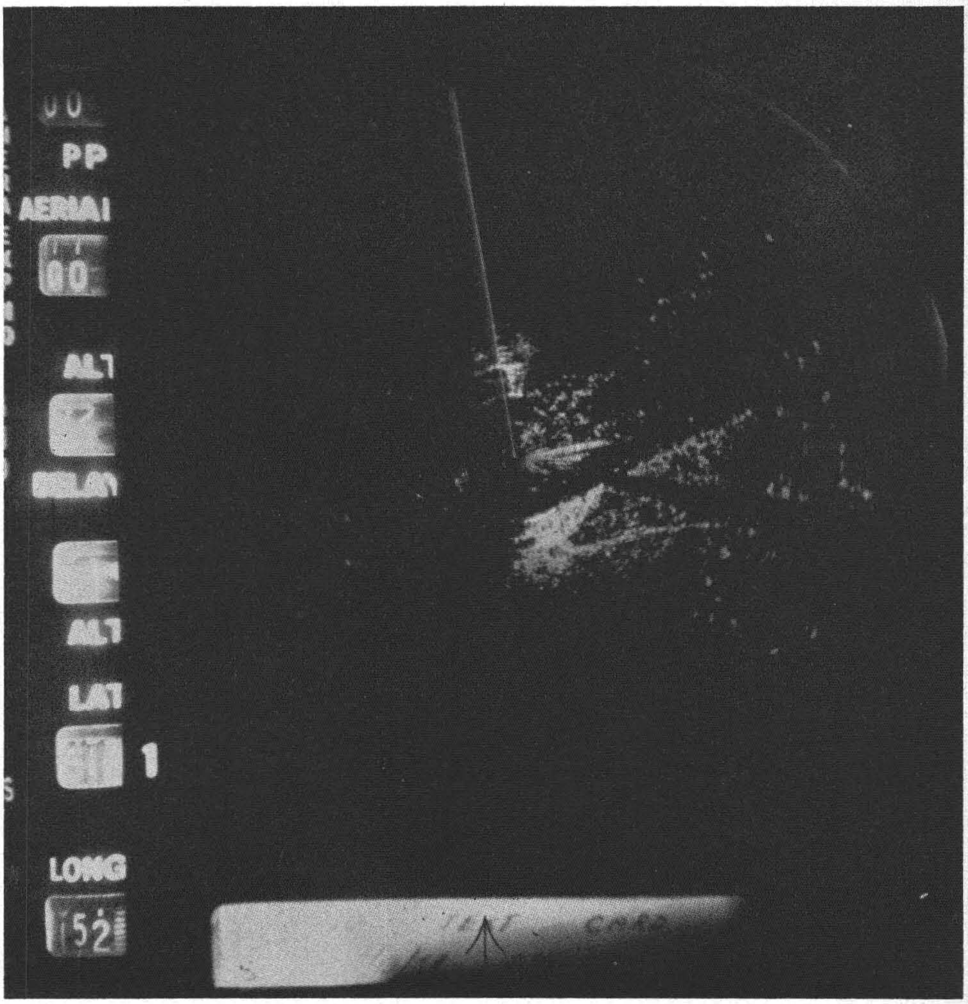


FIG. 4. Simulator.



RADAR PHOTO—APQ 45 (XA—3)

FIG. 5. Radar photograph.

Any error in this system results in an error in azimuth or loss of resolution in the photograph.

Figure 4 shows a simulator that has been added to the system to present positional information on the recording. It also supplies input signals to the radar set for stabilization of heading reference, and image motion compensation. This item can be replaced by any of several automatic navigation systems that will supply the same type of information.

The photograph—Figure 5 and obtained on a bench test—is the output of this equipment. The circles are the range markers which are used to determine scale. The bright line is the heading reference. The auxiliary recordings are shown on the left. The top number is the exposure number of the recording camera, the next is the exposure number of the terrain camera. Altitude delay, which indicates whether ground range or slant range is being employed, appears in the next box. This is important information that is used for control extension. The next box is altitude of the aircraft. Lat. and Long. is the position of the aircraft, which in this particular system is provided by the simulator shown in Figure 4. The figure 1 represents the value of each range marker shown. Range marks showing 1, 5, or 10 nautical miles may be displayed on the scope.

Conclusions

Radar photography has provided the photogrammetric engineer with a new tool for the preparation of maps and charts. The present art, from the standpoint of refinements of equipment or methods of compilation, has not progressed to the extent that any definite conclusions can be drawn. Radar photography has decided advantages and disadvantages as compared to visual photography. The electronic engineers have a big problem in improving the radar equipment and the photogrammetric engineers must devise ways and means of using this photography for the compilation of charts of a known accuracy.

It is not expected that charts made by electronic means will replace conventional methods in the near future. Radar photographs do have a place in a charting program and as the knowledge obtained by working with this type of equipment increases, more applications will be found for their use.

GALILEO-SANTONI STEREOCARTOGRAPH MODEL IV*

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Abstract

This paper will cover the characteristics of the Stereocartograph Model IV, plotting instrument, with regard to its adaptability to different focal lengths, camera lens characteristics, diapositive sizes and ratios of enlargement and reductions. Comments will also be included relative to its accuracies and economical adaptability for compilation purposes, its bridging possibilities, its personnel requirements and training required for operation.

There will also be remarks in the paper speculating on the increased use of first-order instruments as indicated by the present mapping trends toward larger scale, smaller contour interval work.

For the past several years we have had a great interest in large scale, small contour interval mapping and could see the future in this type of project. However, we were skeptical of the economic feasibility of a commercial organization using a first-order instrument for anything other than full-time extension work. We realized that this type of instrument would be highly advantageous for purposes of extension of control, but we were doubtful if the cost of the instrument could be justified on this one factor.

After considerable thought and investigation, we reached the conclusion that any instrument in this price range would have to be extremely versatile to meet the varied and rapidly changing demands of the clients of a commercial company, and that it would have to operate economically for compilation as well as extension. After investigating the first-order instruments manufactured, we decided that the Stereocartograph Model IV would best meet our needs for versatility, and that it had several features that could be used to great advantage in what we believe to be the future mapping trend.

The Abrams Aerial Survey Corporation obtained one of these instruments and it was put in operation in our Lansing plant on the first of March, 1954. After a year's operation on a three-shift basis, we are convinced that the choice was a good one, as the instrument has been completely satisfactory from both an economical and operational standpoint.

There follows some of the characteristics of this instrument that particularly influenced our decision to obtain the Galileo-Santoni Stereocartograph Model IV:

First, the Galileo-Santoni instruments

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