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Preliminary Study of Aircraft Radar Target Size

FOR LIMITED DISTRIBUTION

by

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FEDERAL AVIATION AGENCY

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PRELIMINARY STUDY OF AIRCRAFT RADAR TARGET SIZE

SUMMARY

This report describes a preliminary study made at the Technical Development Center of the Civil Aeronautics Administration at Indianapolis, Indiana, to determine the relative radar target size of three types of aircraft; namely, a Twin Beechcraft C-18S, a Douglas DC-3, and a Convair 340. The measurements were made using a modified FPS-8 radar system operating at 1,300 megacycles. Data were recorded photographically with the antenna held stationary. The final results were obtained by averaging the data collected during individual measurements. Further investigations are in process, and a final, more accurate report is planned at a later date.

INTRODUCTION

The CAA has many short- and long-range, surveillance-type radars in operation and will continue to install more in the future. Each radar is flight-checked at the time of commissioning and at frequent intervals thereafter to assure that adequate performance is being obtained. These flight checks normally are made using a Twin Beechcraft C-18S aircraft, however, with the increase in number of radar installations and the approaching obsolescense of the Twin Beechcraft for this application, it will not be practicable to continue this practice. In order that other types of aircraft may be used interchangeably, it was necessary to obtain a target size conversion factor for each aircraft. Also, since the target size on L-band and S-band radars differs for a given aircraft, it was necessary to perform tests using both types of radars.

Most of the known previous efforts to determine radar target sizes of different aircraft types have dealt with absolute values rather than relative signal strength measurements. Some work has been based on calculations and other work on measurements using aircraft models.[1] The results of these absolute measurements have been so inconsistent, both in the methods of obtaining the data and in the results, that the work has been of little value to the CAA.

Previous work has indicated that the nature of an aircraft radar target is very complex. Variations caused by multiple propagation paths have a great effect on the strength of the return signal. Aircraft attitude also has a profound effect on the return signal. In tests which were performed by the MIT Radiation Laboratory, it was found that for 1/3° change in aspect angle, the return power could change as much as 15 decibels (db)[2] These combined effects result in a rapidly fluctuating return which is very difficult to analyze.

[1]Donald E. Kerr, "Radar Targets and Echoes," Propagation of Short Radio Waves, Radiation Laboratory Series, Vol 13, p. 470.

[2]Louis N Ridenour, "Properties of Radar Targets," Radar System Engineering, Radiation Series, Vol 1, p. 76.

METHOD USED FOR MEASUREMENTS

To obtain an accurate value of relative target size, it appeared that a large number of data samples should be recorded while the aircraft were being flown through the same airspace. The average target size for each aircraft then could be compared It was felt necessary to have all aircraft types flying at the same time, to avoid errors being introduced by changes in propagation and other test conditions During a given set of measurements, the antenna was fixed at one azimuth. It was feasible to use for this azimuth a short segment of highway so situated that the extended centerlines of the highway segment would pass through the radar site. The test aircraft could fly along this highway, and thus remain in the fixed beam of the radar antenna Since the aircraft's altitude was held constant when flying over the segment, the same volume of airspace could be used over and over The length of the test paths was 1.6 nautical miles (nm) and the midpoints were 20 nm from the radar site Three different azimuths, namely, 89°, 248°, and 359°, were used Flights were made at altitudes of 3,000 feet and 3,500 feet mean sea level (MSL). The vertical lobe structure of the antenna radiation pattern was calculated,[3] and these altitudes were selected so that the volume of airspace used for the test was near the maximum of the second lobe of the antenna radiation pattern. The aircraft were flown over the test range in both directions; that is, inbound and outbound Aircraft broadside measurements were recorded when the aircraft were flown through the fixed antenna beam at a range of 20 nm.

Target returns were displayed on a delayed sweep of an oscilloscope which presented only the test range As the aircraft passed through the test range, a time exposure photograph of the oscilloscope presentation was made. The horizontal grid lines of the oscilloscope were calibrated, using a standard microwave test set, thereby permitting the recorded target amplitudes to be determined. This pulse was introduced to monitor the radar system sensitivity continually. This fixed calibration pulse is shown in each of the photographs A sample of test data is shown in Figs. 1 to 7, inclusive.

To analyze the photographs, seven vertical grid lines were drawn at equal intervals over the test range on each photograph. Photographs were analyzed for each of 20 inbound and 20 outbound flights of each aircraft Some data were not usable; however, there were approximately 120 samples taken for each inbound and each outbound aircraft.

RESULTS

The results with reference to the Twin Beechcraft show that the Douglas DC-3 return signal was 0 4 db stronger inbound, 1.1 db weaker outbound, and 2.4 db stronger broadside The Convair 340 return signal was 2.1 db stronger inbound, 4.2 db weaker outbound, and 6 4 db stronger broadside.

[3]J Francis Reintjes and Godfrey T Coate, "Reflection From a Conducting Plane," Principles of Radar, Third Edition, pp 961-964.

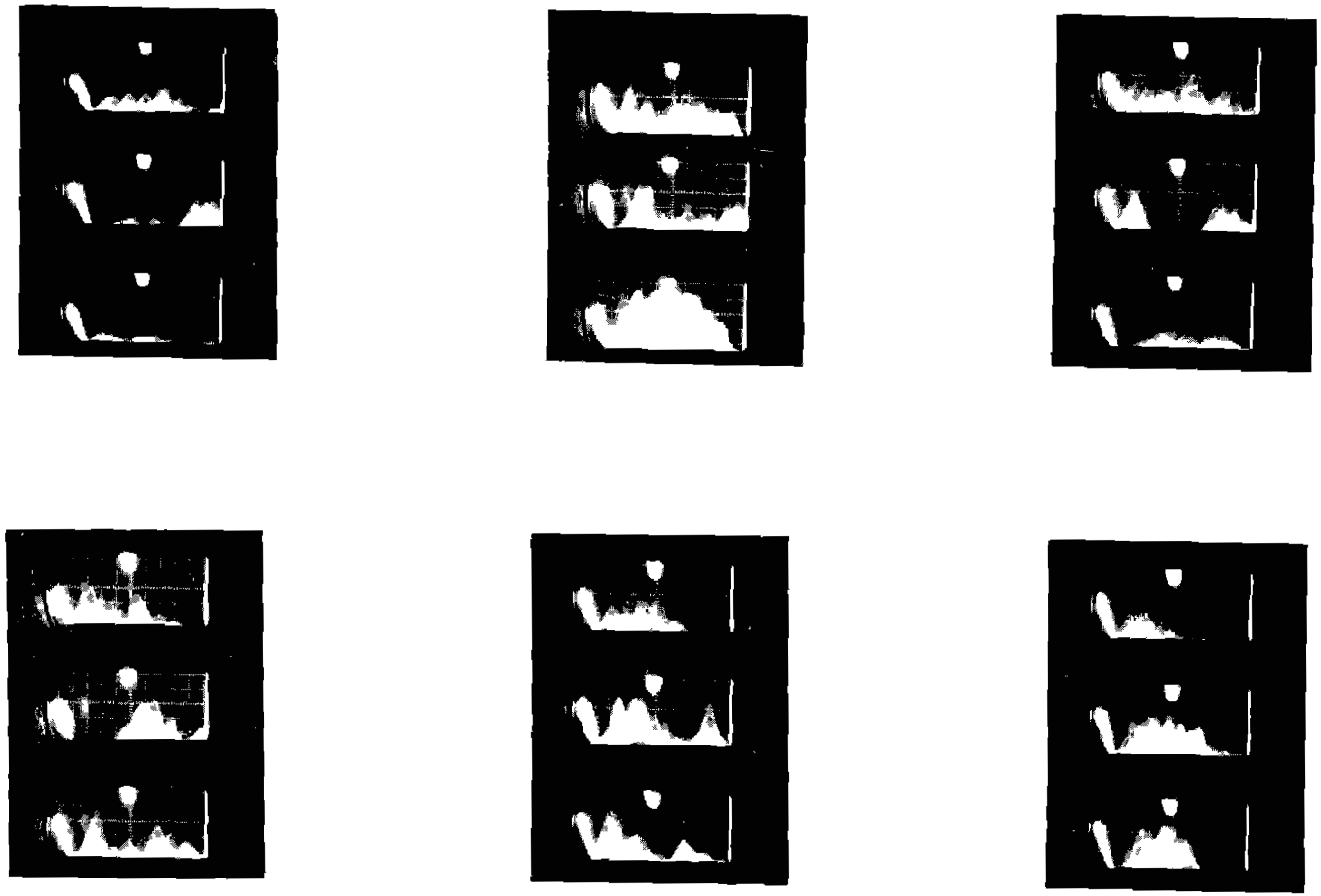
These results can be interpreted in terms of detectable range since it is known that the maximum detectable range varies as the fourth root of the target area which, in this case, is proportional to received power. From this, it can be stated that the Douglas DC-3 can be detected at 102 per cent of Twin Beechcraft range inbound, and at 94 per cent of Twin Beechcraft range outbound. The Convair 340 can be detected at 113 per cent of Twin Beechcraft range inbound, and 79 per cent of Twin Beechcraft range outbound.

It also is of interest to note that the Twin Beechcraft return signal is 3 1 db stronger (120 per cent range) outbound than inbound, the Douglas DC-3 return signal is 1 9 db stronger (112 per cent range) outbound than inbound, and the Convair 340 return signal is 2.5 db stronger (116 per cent range) inbound than outbound. It should be noted that the interpretation of photographic data of this type is very difficult and time-consuming Inaccuracies in analyzing the photographs can readily be responsible for as much as 0.5 db Improved methods of data collection and analysis should be made prior to any further testing.

CONCLUSIONS

It is concluded that the Douglas DC-3 and Twin Beechcraft C-18S airplanes present approximately the same average target areas, whereas the Convair 340 airplane presents a larger average target inbound, and a smaller average target outbound. Peak and null return signals for all aircraft targets differ widely from the averages shown.

While better methods of recording and analyzing data in future tests are required, the results of these tests nevertheless are interesting and should be useful in connection with the flight-testing of L-band radars until refinements can be made.



ALTITUDE 3000 MSL

AZIMUTH 248°

INBOUND

TOP DC-3

MID BEECH

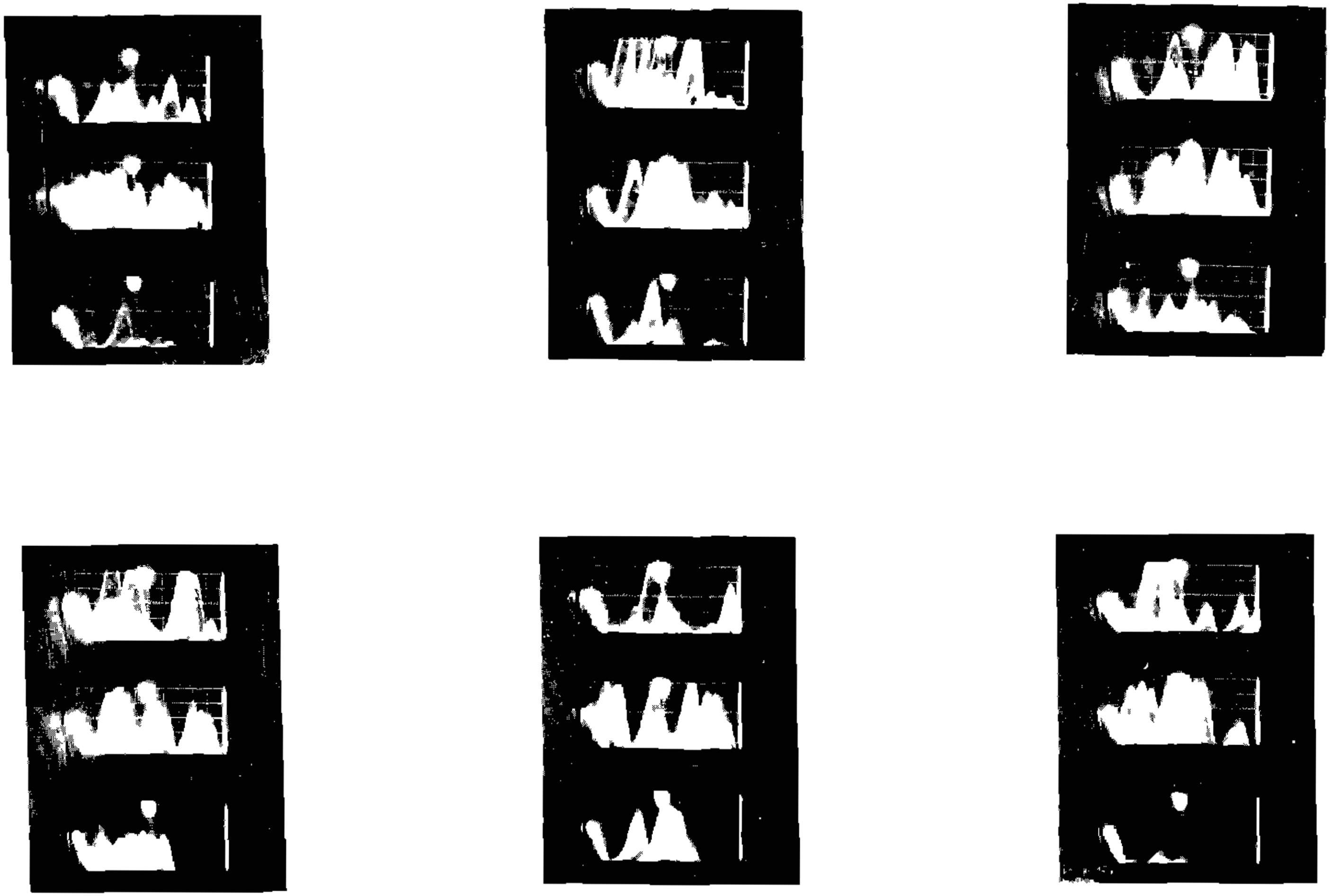
LOW CONVAIR

7
10
12 5
14
17

CALIBRATION CHART
(- DBM)

JULY 16

FIG. 1 PHOTOGRAPHS OF OSCILLOSCOPE DISPLAYING RADAR RETURNS VERSUS RANGE



ALTITUDE 3000 MSL

AZIMUTH 248°

OUTBOUND

TOP DC-3

MID BEECH

LOW CONVAIR

7

10

12.5

14

17

JULY 16

CALIBRATION CHART

(-DBM)

FIG. 2 PHOTOGRAPHS OF OSCILLOSCOPE DISPLAYING RADAR RETURNS VERSUS R 'NGE

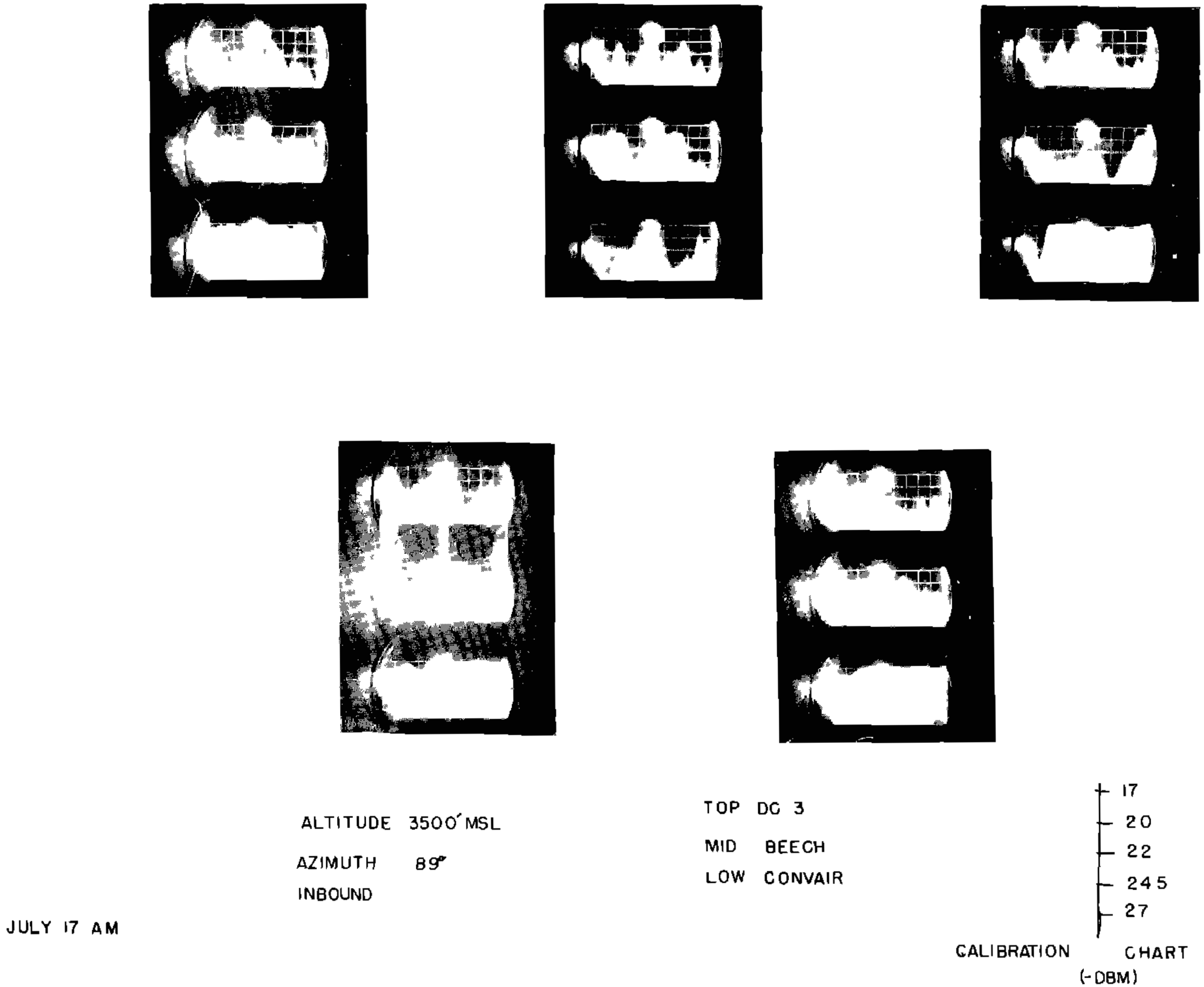
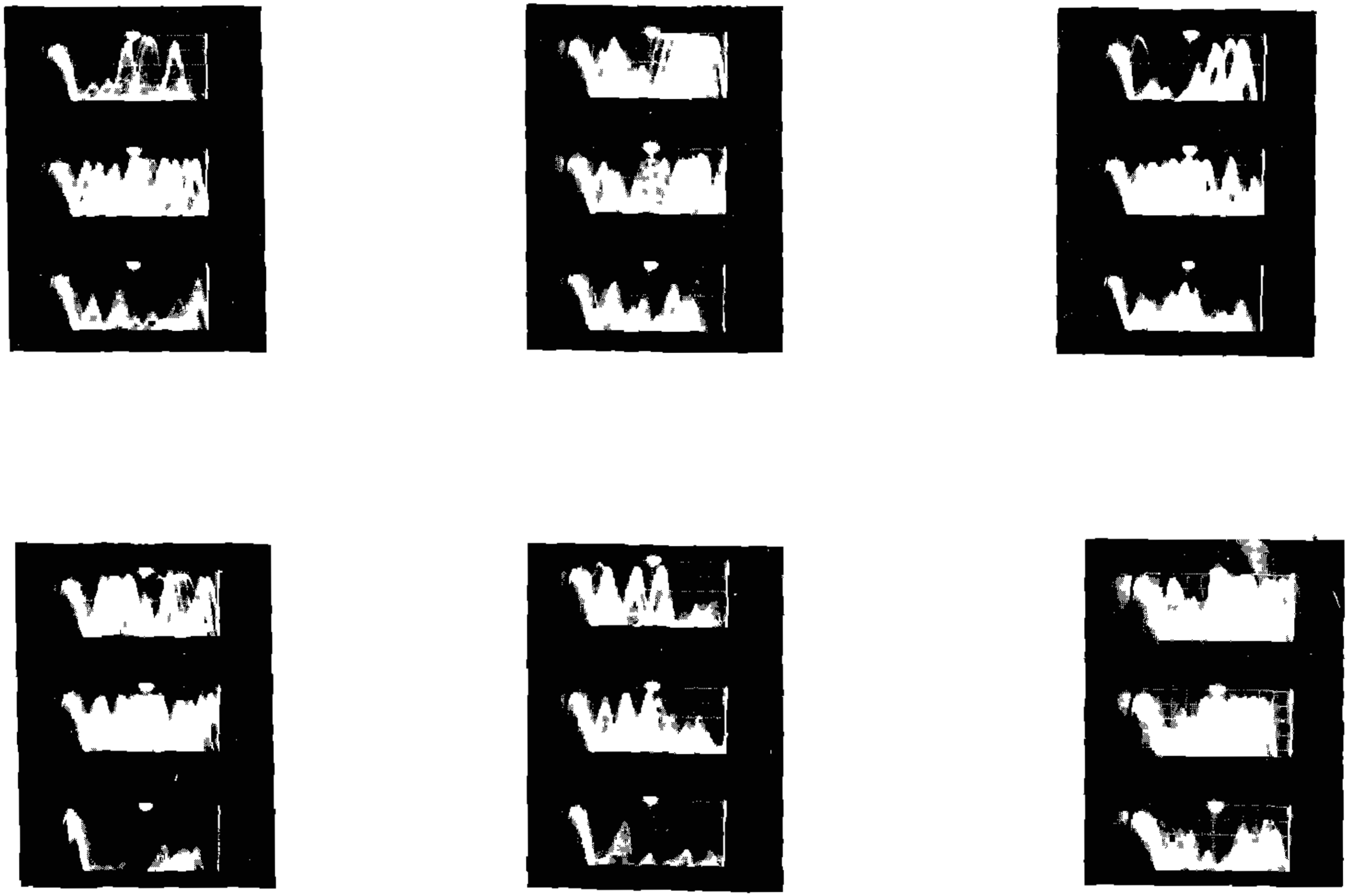


FIG. 3 PHOTOGRAPHS OF OSCILLOSCOPE DISPLAYING RADAR RETURNS VERSUS RANGE



OUTBOUND

JULY 17 PM

ALTITUDE 3500

AZIMUTH 359°

TOP DC 3

MID BEECH

LOW CONVAIR

21

26

28

30

32.5

CALIBRATION CHART

(- DBM)

FIG. 4 PHOTOGRAPHS OF OSCILLOSCOPE DISPLAYING RADAR RETURNS VERSUS RANGE

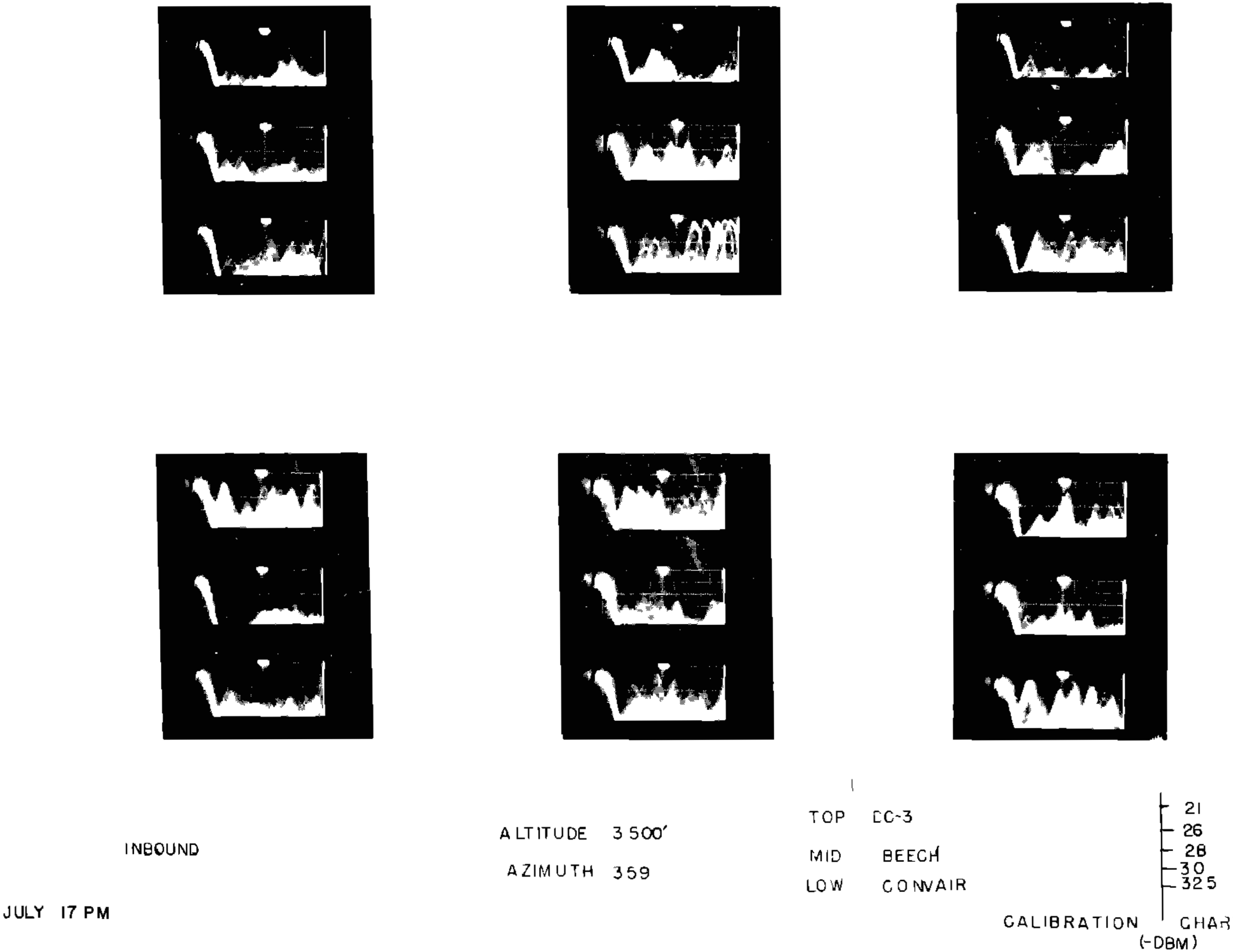
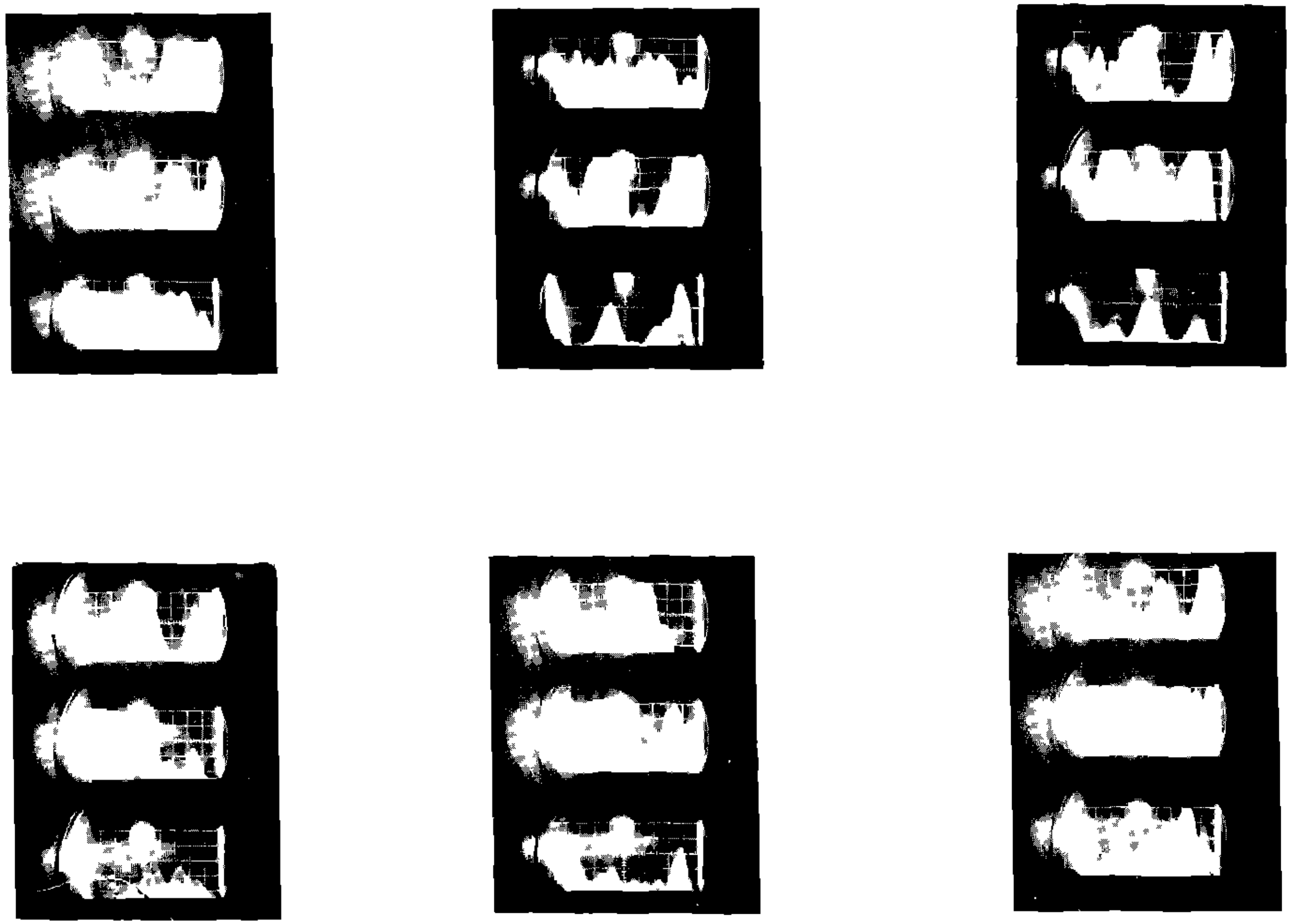


FIG. 5 PHOTOGRAPHS OF OSCILLOSCOPE DISPLAYING RADAR RETURNS VERSUS RANGE



ALTITUDE 3500 MSL

AZIMUTH 89°

OUTBOUND

TOP DC-3

MID BEECH

LOW CONVAIR

17

20

22

24 5

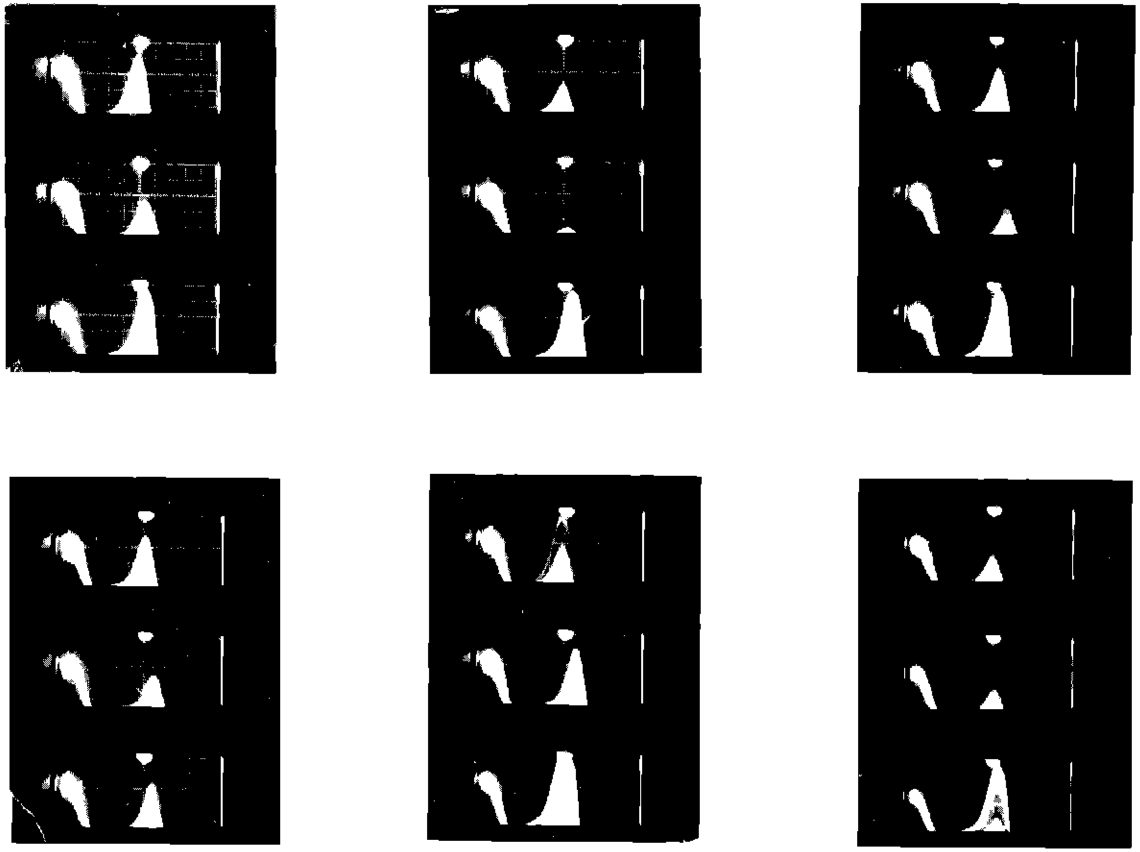
27

JULY 17 AM

CALIBRATION CHART

(-DBM)

FIG. 6 PHOTOGRAPHS OF OSCILLOSCOPE DISPLAYING RADAR RETURNS VERSUS RANGE



ALTITUDE 3500' MSL

AZIMUTH 359°

BROADSIDE

TOP DC-3
MID BEECH
LOW CONVAIR

8
13
16
18
21

CALIBRATION CHART
(-DBM)

JULY 17 PM

FIG. 7 PHOTOGRAPHS OF OSCILLOSCOPE DISPLAYING RADAR RETURNS VERSUS RANGE