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EVALUATION OF HUGHES OBSTRUCTION WARNING RADAR MODEL HTR-13A

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SUMMARY

This report describes recent tests conducted by the CAA Technical Development and Evaluation Center of the Obstruction Warning Radar, Model HTR-13A, built by the Hughes Aircraft Co The equipment used in the tests was obtained on loan from Trans World Airlines, Inc., and was of the type now in use by that company

The results confirmed those concluded in Technical Development Report No 78, "Report on Comparative Tests of Existing Terrain Clearance Indicators," dated March, 1948, which covered tests conducted on an earlier model of the same equipment. The accuracy of the warning indications is adequate for the designed purpose and the warning provided will prevent collisions with mountainous terrain under the majority of conditions encountered in flight provided the aircraft climbs at a high rate when the alarm is received. However, under a small percentage of conditions, which may be encountered, the warning may not provide sufficient time for the pilot to take the necessary corrective action It is possible to predict with reasonable accuracy whether the alarm is adequate for any particular situation when the profile of the terrain, altitude of the aircraft and aircraft climb characteristics are known.

Two problems that are encountered in the use of the equipment are its average of 350 hours of life between breakdowns and the temporary assignment of the radio frequency band in which it is used.

INTRODUCTION

Aircraft collisions with mountainous terrain have presented an operational problem for which a complete solution is not readily available since both the human element and equipment aids are involved. Statistical studies of the problem have indicated that a device which would provide warning to the pilot, when he reaches a predetermined distance from an obstacle, would greatly reduce the possibilities of collision with the obstacl The operational procedure suggested for the use of such equipment, which indicates when certain predetermined distances from obstacles are approached, is to climb to a higher altitude immediately when the warning is received

Approximately four years ago, a number of flight tests were conducted on two equipments for this purpose, one of which was an early model of the Obstruction Warning Radar built by Hughes Aircraft Co These tests and the results are described in Technical Development Report No 78. Since

then, a number of these equipments, which have been improved in reliability, have been in use, the largest user being TWA.

Considerable study and flight test work have been conducted by the Hughes Aircraft Co on the use of this equipment, and the results were published under the titles "Hughes Airline Radar as Applied to the Hughes Anti-Collision System of Flying" and "Addendum to Hughes Airline Radar as Applied to the Hughes Anti-Collision System of Flying." In the majority of cases covered by the reports, the warning provided by the equipment was adequate to prevent collision. However, in several cases where sharp slopes were encountered and the aircraft was flying at altitudes far below the top of the terrain ahead, the warning was not provided in time for the pilot to avoid collision by employing the climbing procedure described.

Recently, one of the equipments now being used by TWA was obtained, through the co-operation of the Hughes Aircraft Co., to determine the operational characteristics of the equipments presently used and what improvements have been made since the original evaluational tests were conducted The following report describes the results of these tests and inspection

EQUIPMENT

The Hughes radar equipment, Model HTR-13A, is a terrain-clearance warning device which provides a warning to the pilot whenever the aircraft reaches a pre-fixed distance to an obstacle A visual warning is given by an indicating light and an audible warning is given by a bell Three warning ranges are available in the equipment tested, these may be selected by means of a range switch and are pre-set at 2,000, 1,000 and 500 feet

The equipment is a modification of the APS-13 tail-warning radar which was developed during World War II for detecting the presence of hostile aircraft within a limited range behind APS-13 equipped aircraft Its principle of operation is the same as a simple pulse-type radar which measures distance to the nearest reflecting object The equipment weighs approximately 16 pounds and requires primary power of 3.25 amperes at 28 volts dc. The equipment operates on a frequency of 423 + 1/2 Mc, a temporary assignment in this frequency band.

A DC-3 type aircraft, N 182, was used during the tests on the equipment, and the installation was made with the aid of Mr Norman Hall of the Hughes Aircraft Co , who made the loan arrangements with TWA and delivered the equipment to this Center on September 12, 1951 Upon completion of the installation, flight checks were conducted, with Mr Hall collaborating, to assure that the equipment was performing in a normal manner The equipment used was Model HTR-13A, Serial No 365. Figs. 1, 2 and 3 show the equipment as installed in the aircraft. Fig. 1 is a view of the transmitter-

receiver unit Fig. 2 shows the antenna installation and Fig. 3 shows the warning lights in the cockpit

An inspection of the equipment showed that it is essentially the same as that used in the original tests, with the exception of several circuit modifications, designed to improve its over-all life and reliability. These are described in detail in Technical Bulletins Nos 2 and 3, dated April 8, 1948, and April 20, 1949, respectively, on the HTR-13( ) equipment, issued by the Electronics Department of the Hughes Aircraft Co. The major modifications made were in the modulator circuits and a change in the type of modulator tube used. It is estimated by TWA that these modifications increased the average reliable operating time between maintenance periods from 150 to 350 hours It appears that the modifications did not change the over-all performance characteristics appreciably.

TEST RESULTS

Since the equipment appeared to have the same major performance characteristics as the original equipment tested, the tests were conducted primarily to determine changes in the performance characteristics and to obtain data on tests not included in the earlier program.

Tests were made over Lake Michigan, west of Benton Harbor, Mich , to check the accuracy of the equipment. The results are shown in Table I. With wings level, the rate of descent was approximately 200 feet per minute and the rate of ascent was approximately 400 feet per minute. Rates of ascents and descents for the various wing banks were from 200 to 300 feet per minute Errors were calculated assuming that the altimeter readings were correct. Negative errors indicate that the alarm was given at altitudes less than the correct altitude. The altitude of Lake Michigan, as determined from Sectional Aeronautical Chart U-7 for the Chicago Area, is 581 feet.

From the data in Table I, it is noted that alarms are given at slightly lower altitudes when the aircraft is ascending than when it is descending. This difference is caused by lag in altimeter indications, since lag in the obstruction warning equipment would cause alarms to occur at lower altitudes when the aircraft is descending. During the tests, it was noted that altitude changes of 20 to 40 feet were required after the alarm first occurred until the alarm was continuous Similar altitude changes were required for transition from alarm to no-alarm indications. During the transition period, the warning light flashed on and off and the warning bell sounded several times.

Several passes were made over the east bank of the lake, south of Benton Harbor. The top of the bank is approximately 80 feet above the water. Satisfactory alarms for the 2,000-, 1,000- and 500-foot ranges were given as the aircraft passed over the bank at altitudes of 2,620, 1,580 and 1,120 feet.

TABLE I

Accuracy Tests

Warning Light Observed Feet (Above Ground)	Aircraft Wing Bank (Degrees)	Error - Feet Aircraft Ascending	Aircraft Descending
2,000	0	0	+20
2,000	30 Left	-20	-10
2,000	30 Right	-20	-10
2,000	45 Left	-30	-30
2,000	45 Right	-40	-30
2,000	60 Left	-60	-50
2,000	60 Right	-60	-50
1,000	0	-40	-30
1,000	30 Left	-50	-30
1,000	30 Right	-50	-30
1,000	45 Left	-60	-55
1,000	45 Right	-60	-50
1,000	60 Left	-70	-60
1,000	60 Right	-70	-60
500	0	+10	+20
500	30 Left	-10	+10
500	30 Right	0	+10
500	45 Left	-10	-20
500	45 Right	-10	-10

A flight was then made to the Smoky Mountain Area to observe operation of the equipment when flying over mountainous terrain Five passes were made over Mt. LeConte, 35° 39' North Latitude and 83° 26' West Longitude, approximately 35 miles southeast of Knoxville, Tenn. The heading of the aircraft was approximately 190 degrees. The aircraft paths and profiles of Mt. LeConte are shown in Figs. 4, 5 and 6. Passes were started from initial altitudes of 3,700, 4,500, 5,500 and 6,000 feet above sea level. The profiles shown are not identical since it was necessary to use slightly different headings for some passes in order to avoid clouds near the summit. The profiles were plotted from a U. S Geological Survey map of the Great Smoky Mountains National Park Altimeter, air-speed, rate-of-climb indications and time were recorded during the passes.

The aircraft cleared the peak satisfactorily in each case. Generally, the rate of climb assumed after the alarm was approximately 1,500 feet per minute for the first mile and approximately 1,000 feet per minute for

each succeeding mile until the alarm ceased. Level flight was resumed after the alarm ceased. In a few cases the alarm was off momentarily and there was insufficient time to resume level flight. On the pass starting at the altitude of 3,700 feet, Fig 1, the pilot followed the procedure of continuing the climb for approximately 500 feet after the alarm ceased in order to obtain safer clearances

A study of various profiles of Mt. LeConte indicates that the Hughes obstruction warning equipment provides warning that is adequate to prevent collision, provided that the aircraft is capable of climbing at least 750 feet for the first mile and 500 feet for each succeeding mile. Examination of mountainous profiles west of Salt Lake City, Utah, parallel to the northwest leg of the Fairfield radio range and within four miles of the center of the airway, shows that rates of ascent up to 1,300 feet per mile for distances of approximately 1 1/2 miles would be required for clearance if the aircraft was 2,000 feet below the summit when the alarm is given For a ground speed of 120 mph, the required rate of climb is 2,600 feet per minute and for a ground speed of 180 mph the required rate of climb is 3,900 feet per minute. No allowance is made for possible downdrafts in the above calculations For the above conditions, the warning is not adequate to prevent collisions

The operation of the equipment during take-off and landing was observed at several airports Due to the varying altitude of terrain surrounding airports, it was not possible to check the accuracy of the alarms; however, it was noted that the operation of the 500-foot alarm was unreliable when the aircraft was less than 100 feet above ground. In several cases, the alarm ceased when the aircraft was 90 feet above the runway, and was on and off several times as the aircraft descended to the runway.

No maintenance or adjustment was required during the tests, which consumed a total operating time of approximately 12 hours

CONCLUSIONS

From the above tests and from information contained in previous reports prepared by the Hughes Aircraft Co and this Center, it is concluded that

1. Except for erratic operation of the 500-foot warning indications when the aircraft is less than 100 feet above ground, the accuracy of the warning indications is adequate. It is understood that the design tolerances used by Hughes Aircraft Co. are ±100 feet for the 2,000- and 1,000-foot ranges and +50 feet for the 500-foot range It is believed that the only time that erratic operation below 100 feet could be objectionable is during runway approaches.

2. The warning provided by the equipment is adequate to prevent collision with mountainous terrain under the majority of conditions provided that the aircraft climbs at a high rate when the warning is received. In a few cases the alarm would not be adequate to prevent collision. The warnings are adequate if the aircraft is not too far below the peak at the time of the alarm. The slope and height of some ridges and peaks near or on airways are such that the rate of climb of many aircraft is insufficient to avoid collision if the aircraft altitude is 1,000 feet or more below that of the peak when the alarm is given. It is possible to predict, with reasonable accuracy whether the alarm is adequate for any particular situation when the profile of the terrain, initial aircraft altitude and aircraft climb characteristics are known Such predictions do not allow for downdrafts sometimes encountered in mountainous areas and which may cause aircraft to lose altitude when approaching a peak.

3. The indications are not fail-safe The indications for no-alarm condition and most types of equipment failures are identical. The pilot or co-pilot must press a "check" switch button to determine whether the equipment is operative When the "check" switch button is pressed, the warning light selected is illuminated if the equipment is in operating condition. The check operation does not provide any indication of the condition of the antenna or its transmission line.

4. Two of the problems confronting a tentative purchaser of an equipment of this type are, the present average service life between repairs of less than 500 hours and the temporary assignment of the frequency band on which the equipment operates. Since the equipment was originally designed for a military application, during the recent war, a redesigned model easily could provide the desired reliability if the present life characteristics are not satisfactory. However, a more permanent frequency assignment is required to avoid interference with other radio and radar transmissions and to avoid obsolescence of equipment. An assignment to a higher frequency band would prove to be less satisfactory because of the increased probability of encountering false alarms from clouds and areas of precipitation

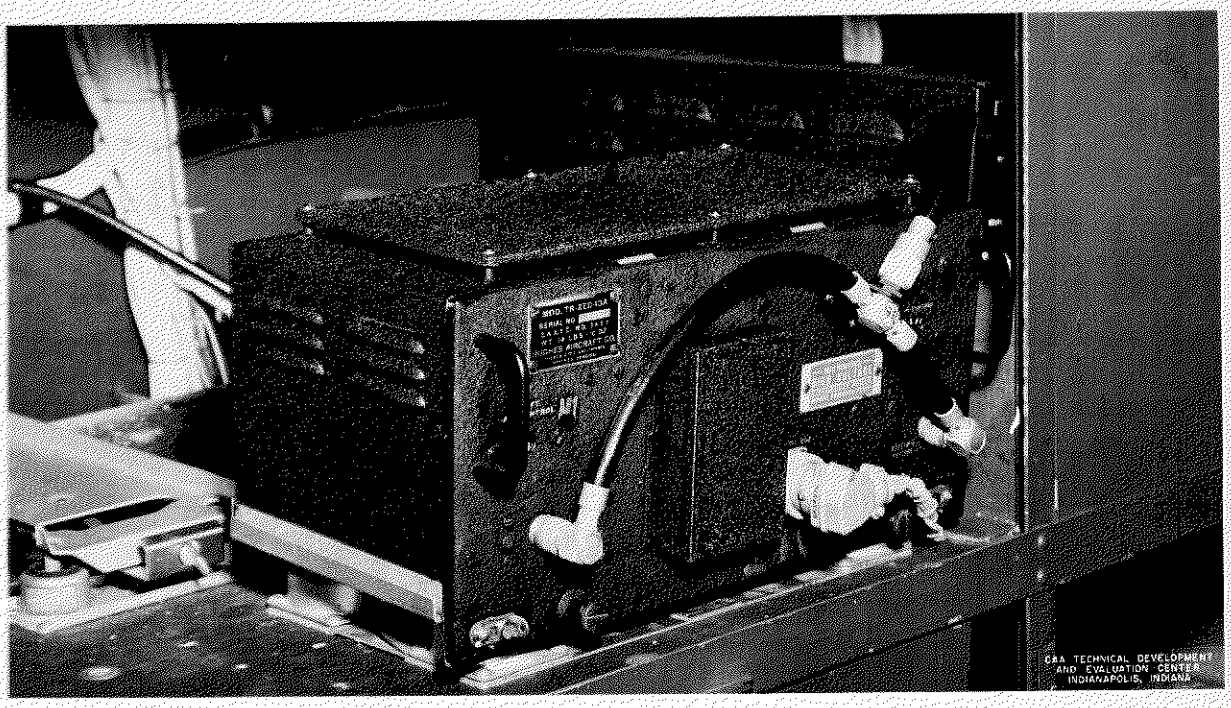

FIG. 1 HUGHES MODEL HTR-13A TRANSMITTER-RECEIVER UNIT

FIG. 2 HUGHES OBSTRUCTION WARNING EQUIPMENT ANTENNA, INSTALLED

FIG. 3 WARNING LIGHT ASSEMBLY FOR HUGHES OBSTRUCTION WARNING EQUIPMENT

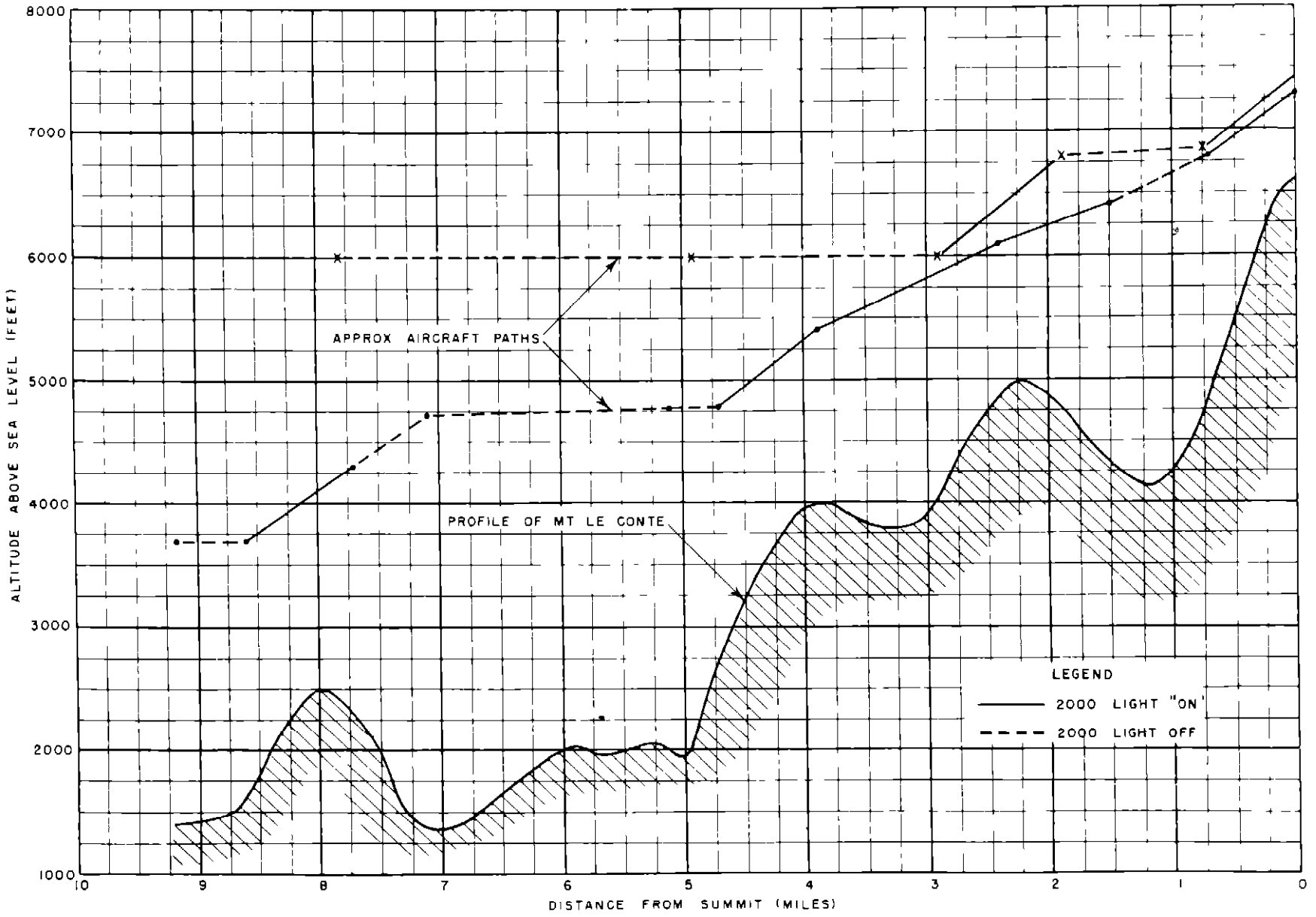

FIG 4 ASCENT OF MT LE CONTE FROM INITIAL ALTITUDES OF 3700 AND 6000 FEET USING AIRCRAFT NC 182 EQUIPPED WITH HUGHES AIRCRAFT CO OBSTRUCTION WARNING RADAR

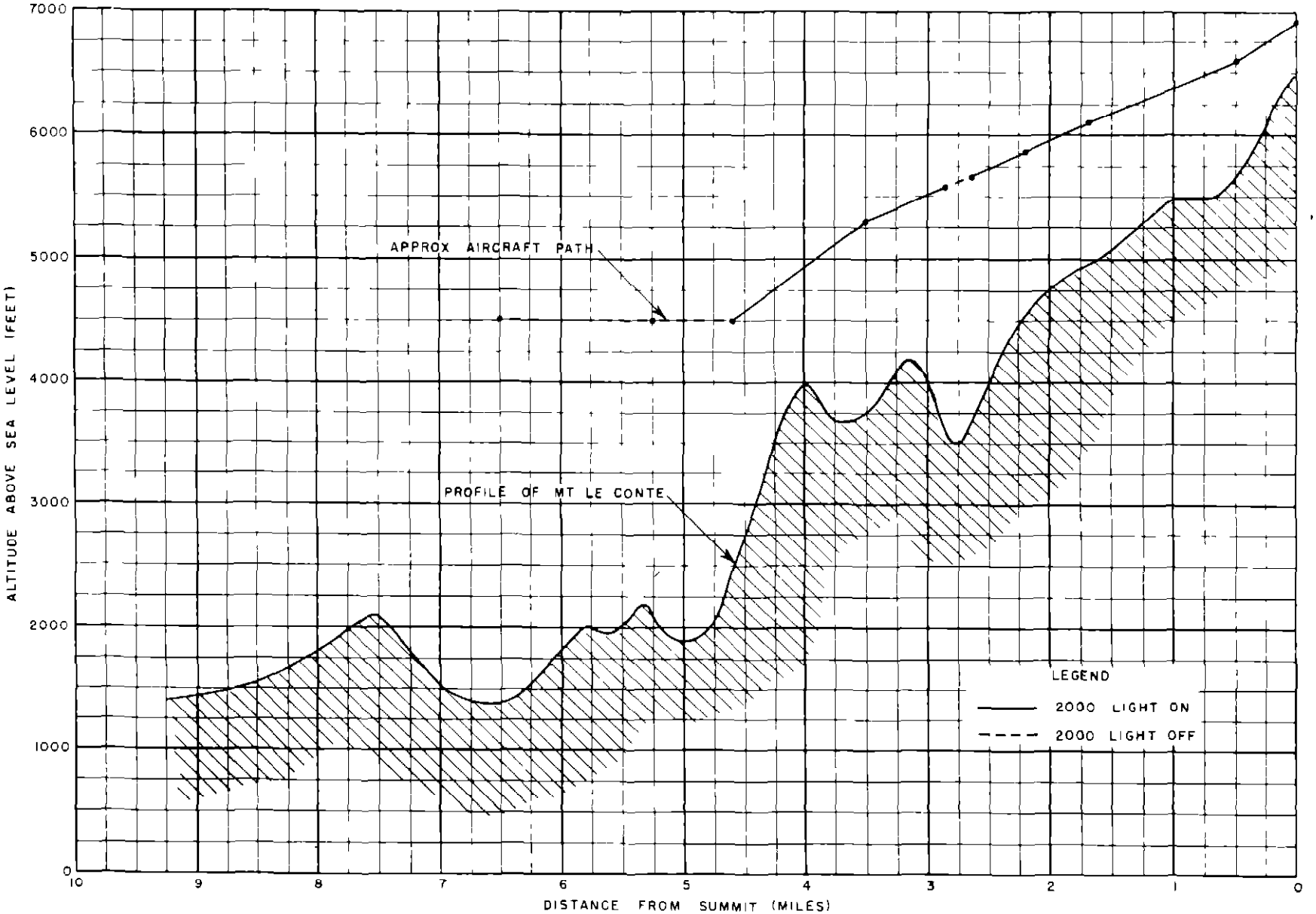

FIG 5 ASCENT OF MT LE CONTE FROM INITIAL ALTITUDE OF 4500 FEET USING AIRCRAFT NC 182 EQUIPPED WITH HUGHES AIRCRAFT CO OBSTRUCTION WARNING RADAR

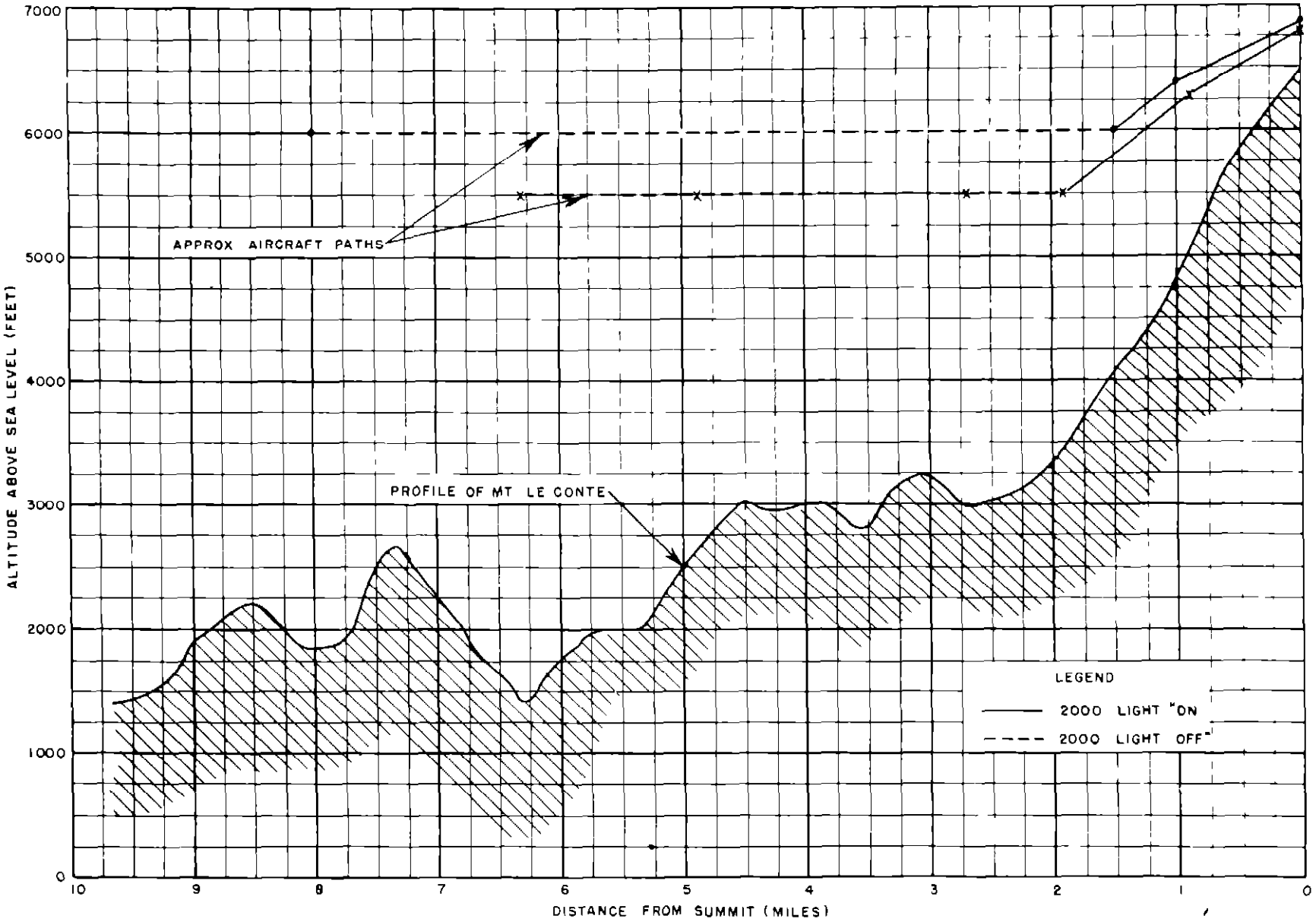

FIG 6 ASCENT OF MT LE CONTE FROM INITIAL ALTITUDES OF 5500 AND 6000 FEET USING AIRCRAFT NC 182 EQUIPPED WITH HUGHES AIRCRAFT CO OBSTRUCTION WARNING RADAR