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THE TYPE III PORTABLE PICTORIAL COMPUTER

PART II

TECHNICAL AND OPERATIONAL EVALUATION

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TECHNICAL DEVELOPMENT AND
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This is a technical information report and does not necessarily represent CAA policy in all respects

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FOREWORD

The Air Navigation Development Board (ANDB) was established by the Departments of Defense and Commerce in 1948 to carry out a unified development program aimed at meeting the stated operational requirements of the common military/civil air navigation and traffic control system. This project, sponsored and financed by the ANDB, is a part of that program. The ANDB is located within the administrative framework of the Civil Aeronautics Administration for housekeeping purposes only. Persons desiring to communicate with ANDB should address the Executive Secretary, Air Navigation Development Board, Civil Aeronautics Administration, W-9, Washington 25, D. C.

SUMMARY

This report is the second of two reports on the Type III Pictorial Computer. It describes the technical and operational evaluation of the equipment. The first report, Technical Development Report No. 172, covered the development of this airborne navigational aid.

Laboratory tests showed that the maximum average errors (the greatest error occurring in the average results of repeated tests for a given point) of the display in bearing and distance do not exceed 0.2° and 0.5 mile, respectively. Controlled flight tests, conducted as a part of the technical evaluation, revealed a maximum system error in position of 1.3 nautical miles when the display was used within 15 nautical miles of an omnibearing-distance (OBD) station.

Operational evaluation tests indicate that the equipment will provide continuous position information in all airspace within range of an OBD facility. Improved traffic-control procedures based upon greater use of lateral separation may be developed for both terminal and en route areas. Such improved procedures will permit higher rates of traffic flow than are now possible.

By displaying position information directly on a chart, the Type III unit reduces the mental workload required of the pilot for navigation. This is particularly advantageous for flight in involved terminal-area patterns. Fewer "lost"-aircraft incidents should occur for aircraft equipped with this type of pictorial display.

INTRODUCTION

To determine the feasibility of presenting omnibearing-distance information in the form of a pictorial display[1] which plots the position of an aircraft on a chart, the Air Navigation Development Board in 1950 initiated a project at this Center for the development of three types of pictorial displays When the development work was completed in 1952, a second project was established for the evaluation of these devices. The evaluation of the Type III Portable Pictorial Computer, which was developed by the Aero Electronics Company and which is the first of this series of three display units, is described herein.

By examination, it appeared that the greatest advantages of pictorial displays for air navigation would be (1) the direct pictorial presentation of position information to the pilot and (2) the continuous presentation of navigation information in all airspace.

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[1] Although the original developments and studies on this type of airborne equipment used the words "pictorial computers" in the titles and to describe the equipment, the trend in Radio Technical Committee for Aeronautics (RTCA) Special Committee SC-54 and at this Center is to replace these words with "pictorial displays," since this term describes more closely the function of the equipment.

With the direct presentation of the aircraft position on a map, the navigation workload of the pilot would be decreased greatly when compared with the use of symbolic-display systems. The pilot would not be required to mentally translate instrument readings of VOR and DME or of other aids into a visual picture of his position. The pictorial equipment would constantly indicate the actual position of the aircraft and thus would free the pilot for attention to other duties. In addition, the pictorial display would provide navigational guidance in all airspace. Present radio aids and aircraft instrumentation limit accurate navigation to certain specific courses which are radial from the ground radio facility. With pictorial equipment, no such restrictions would exist.

If a controller could use all airspace, improved air-traffic-control procedures could be developed to reduce air traffic congestion with a large reduction in aircraft delays and with resultant savings to aircraft operators. Air-traffic control could make use of additional airspace to expedite the movement of traffic by the provision of lateral separation where vertical or longitudinal separation is required with present navigational aids.

Other advantages of the OBD navigational system such as a reduction in the number of ground radio aids would also accrue. A more detailed study of the operational advantages of pictorial displays will be presented in a subsequent report. It is expected that additional information regarding the technical performance and operational usage will become available during the evaluation programs for the Types IV and V equipment. These will be described in subsequent reports.

The operational-evaluation tests for the Type III Portable Pictorial Computer were designed to determine if the foregoing operational advantages could be realized. The technical-evaluation tests were conducted to determine the performance characteristics of the equipment.

DESCRIPTION

The Type III Portable Pictorial Computer, shown in Figs. 1 and 2, is an automatic, electromechanical, airborne instrument for continuously indicating on a chart the position of an airplane with respect to an OBD station. The computer receives bearing and distance information from an omnirange receiver and from a distance-measuring-equipment (DME) interrogator, respectively. The instrument consists of two principal parts, a servoamplifier unit and a display unit connected by a flexible cable 5.5 feet in length The display unit was designed to be held on the lap of the pilot or copilot, but provisions are included for mounting it on a bulkhead or on the instrument panel. A more complete description of the Type III display, including a discussion of electrical operation and a table of weights and sizes, is provided in an earlier report.[2]

TECHNICAL EVALUATION

Laboratory Tests.

The laboratory test set, shown photographically in Fig. 3 and diagrammatically in Fig. 4, was used to determine both the bearing and the distance accuracy of the display. In the bearing determinations, the omnibearing-distance indicator (OBI) of the laboratory instrument was first set at 0° and the reading of the display was noted, the process was then repeated at increments of 10 degrees throughout 360 degrees of clockwise rotation. The tests were repeated with counterclockwise rotation in order to investigate errors caused by the approaching to a point from opposite directions. All tests were first conducted without a preliminary warm-up of the display and amplifier units and were later conducted after a 30-minute warm-up period. Results of laboratory tests for bearing accuracy showed a maximum average error of 0 2° for a given bearing in the three types of equipment tested. In individual tests, the maximum error recorded at any bearing was 0.4°. Table I gives the results of a typical test and also gives the averages obtained from a number of tests of bearing accuracy in which clockwise rotation was used Table II gives the results of similar tests in which the direction of rotation was counterclockwise. No appreciable difference in error was observed in the two

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[2]Logan E. Setzer, "The CAA Type III Portable Pictorial Computer, Part I, Development and Initial Tests," CAA Technical Development Report No. 172, October 1952.

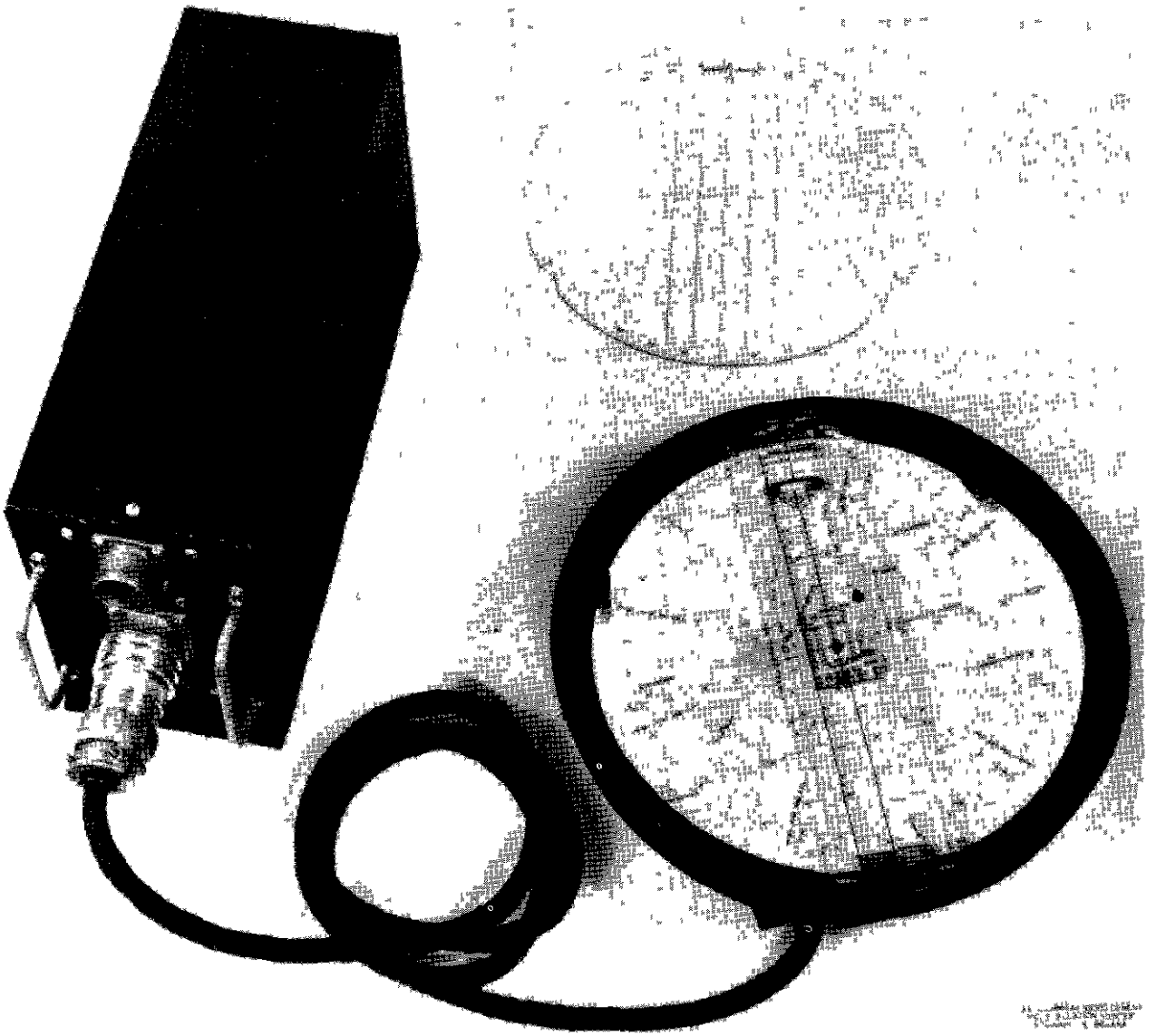

Fig. 1 Portable Pictorial Computer Type III

directions of rotation. The 30-minute warm-up period did not increase the accuracy of the equipment.

Distance accuracy was examined at 1-mile intervals on the 15- and 30-mile scales and at 5-mile intervals on the 60-mile scale. Distance information in the form of resistance values proportional to nautical miles was supplied to the display by a precision potentiometer which is part of the laboratory test set. In the first series of tests, readings were taken at successively decreasing distances; whereas repeat tests were conducted with distance increasing from check point to check point. This procedure is of value in determining the extent of error introduced by the distance-indicator linkage. In the distance accuracy tests the equipment was examined both from a cold start and after a suitable warm-up period, as described under bearing tests. A maximum average error of 0.4 mile and a maximum error for any individual test of 0.5 mile in distance indication was noted on the 60-mile scale of the displays. Maximum average errors encountered in the 15- and 30-mile scales were 0.3 and

TABLE I

BEARING ACCURACY TESTS

Bearing to Station (degrees)	Clockwise Rotation	
	Average Display Indication (degrees)	Average Error (degrees)
0	0.0	0.0
10	10.1	+0.1
20	20.1	+0 1
30	30.0	0 0
40	39.9	-0.1
50	49.9	-0.1
60	59.9	-0.1
70	70.1	+0.1
80	80.0	0 0
90	90	0.0
100	89.9	-0.1
110	109.9	-0.1
120	120.1	+0.1
130	130.2	+0.2
140	140.1	+0.1
150	150.0	0.0
160	160 0	0 0
170	160.0	0.0
180	180.1	+0.1
190	190.2	+0.2
200	200.2	+0.2
210	210.0	0.0
220	220.0	0.0
230	230.0	0.0
240	240.0	0.0
250	250.2	+0.2
260	260.1	+0.1
270	270.0	0.0
280	279 9	-0.1
290	290.0	0.0
300	300.0	0.0
310	310.1	+0.1
320	320.1	+0.1
330	330	0.0
340	340	0.0
350	350	0.0
360	0.1	+0.1

TABLE II

BEARING ACCURACY TESTS

Bearing to Station (degrees)	Counterclockwise Rotation	
	Average Display Indication (degrees)	Average Error (degrees)
0	0.1	+0 1
10	10	0 0
20	20.1	+0 1
30	29.8	-0 2
40	39.9	-0 1
50	49 8	-0 2
60	59.9	-0 1
70	70.0	0 0
80	79 9	-0 1
90	89.9	-0.1
100	99 9	-0.1
110	109.9	-0.1
120	119 9	-0.1
130	130 0	0 0
140	140 0	0 0
150	150 0	0 0
160	159.9	-0 1
170	170.0	0.0
180	180 2	+0 2
190	190.1	+0.1
200	200.2	+0.2
210	210 2	+0.2
220	220	0.0
230	230.1	+0 1
240	240.1	+0 1
250	250.1	+0 1
260	260 2	+0 2
270	270	0.0
280	280	0.0
290	290	0.0
300	300	0.0
310	310 2	+0 2
320	320.0	0.0
330	330 0	0.0
340	340 0	0.0
350	349 9	-0 1
360	360	0 0

0.4 mile, respectively. Table III shows the results of a typical test and also shows the average obtained from a series of tests of distance accuracy when the 15-mile scale was used Tables IV and V show the results of similar tests conducted on the 30- and 60-mile scales, respectively. In each test the distance was first reduced from maximum to minimum range and was then increased from minimum to maximum on a constant heading. The additional warm-up period did not improve the accuracy of distance indication.

With the exercising of care in the reading of the OBI and with the aid of a vernier attached to the display scale, accuracies within 0.1° in the interpolation of bearing information were obtained. The linearity of the distance potentiometer in the test set is within 0.1 per cent, and the vernier scale on the resistor enabled the operator to insert distances with an accuracy of 0.5 ohm or 0.1 mile. All tests were repeated a number of times so that averages could be computed.

Maximum deviations from average values showed a high degree of repeatability in all bearing accuracy tests regardless of the angular direction of approach to a point An

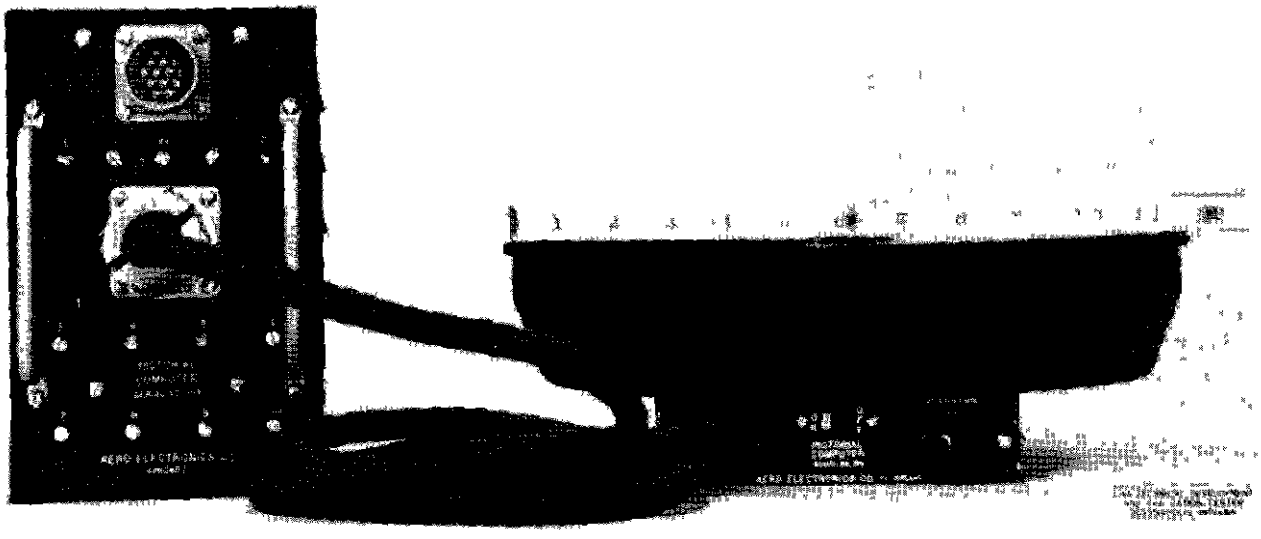

Fig. 2 Portable Pictorial Computer Type III

examination of Tables III, IV, and V indicates that a greater degree of repeatability in distance indication is obtained when a point is approached successively from one direction than when the approach is made from opposite directions along a radial.

Flag-alarm circuits were tested for response with 3° of bearing error and one-half mile of distance error by blocking the indicator-bridge assembly and by introducing errors of the

TABLE III

DISTANCE ACCURACY TESTS, SCALE 1 250,000, 15 MILES

Distance (nm)	Decreasing Distances		Increasing Distances	
	Average Display Indication (nm)	Error (nm)	Average Display Indication (nm)	Error (nm)
0	0.15	+0.15	0.1	-0.1
1	1.15	0.15	0.75	0.2
2	2.15	0.15	1.8	0.2
3	3.2	0.2	2.8	0.2
4	4.2	0.2	3.8	0.2
5	5.3	0.3	4.9	0.1
6	6.3	0.3	5.9	0.1
7	7.2	0.2	6.9	0.1
8	8.1	0.1	7.8	0.2
9	9.1	0.1	8.8	0.2
10	10.1	0.1	9.8	0.2
11	11.1	0.1	10.9	0.1
12	12.2	0.2	11.8	0.2
13	13.2	0.2	12.8	0.2
14	14.2	0.2	13.8	0.2
15	15.2	0.2	14.8	0.2
Average Error		+0.18		-0.17

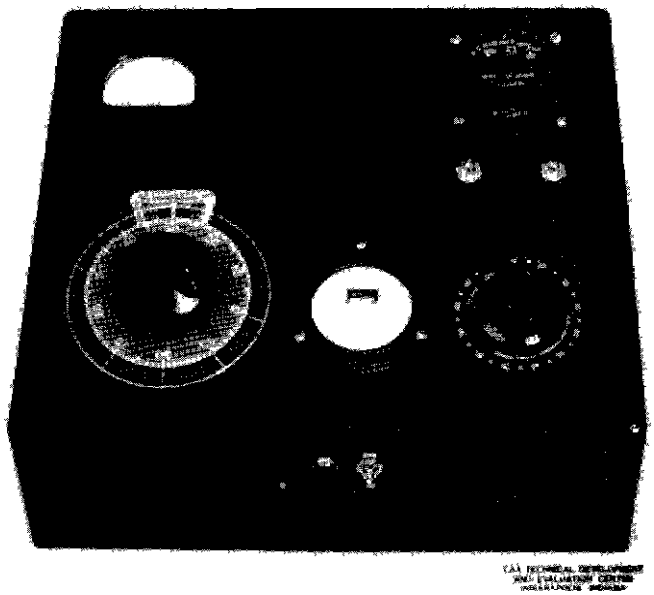

Fig. 3 Laboratory Test Set Used in Evaluation Tests

specified magnitude. Under these conditions, the mechanism operated properly Further tests showed that the circuits can be adjusted to alarm on any errors greater than 0.75° and 0.25 mile. However, it was extremely difficult to adjust the flag circuits to operate on any exact value of bearing and distance error. In addition, the flag system is not fail-safe because loss of emission in the servoamplifier tubes does not produce an alarm even though the bearing and distance functions of the display unit become inoperative.

When the range-limit control was adjusted to cut out at 15.5 miles on the 15-mile scale of the display, the point of operation for each range was noted. The results of this test are recorded in Table VI.

The temperature rise caused by heating of the components of the display unit was measured under two conditions. In the first test, the display was mounted on its storage rack in such a position that air could circulate freely around the case, and in the second test, a location was selected in which the flow of air was partially restricted. The temperature rise in the display unit was 30° F in one hour of operation when air circulated freely around the case. When the air flow was partially restricted, the temperature rose 51.3° F in one hour and 79.3° F in six hours of operation.

Damping of the position indicator was found to be variable from an oscillatory to an overdamped condition.

Silk-covered flax and thin metal-cable dial cords, as well as 10-pound-test silk fishing line, were examined to determine which type would provide optimum performance in the distance-indicator drive mechanism. The silk-covered flax dial cord did not stretch but showed excessive wear after 75 full-scale operations. The thin metal-cable dial cord was not sufficiently flexible for this operation, breakage occurring after as few as 10 full-scale operations. The 10-pound-test silk fishing line lasts indefinitely with normal operation but stretches badly when the movement of the indicator assembly is impeded, as when a pencil is used to record the aircraft track made good. The equipment demonstrated a high degree of reliability during the tests and required only the replacement of two potentiometers and one vacuum tube in more than 100 hours of rigorous use. The string drive on the distance-indicating assembly broke on several occasions, but this was due chiefly to misuse.

A special problem was set up to compare the relative accuracies of the Type III Pictorial Computer and of the Type VI Course-Line Computer. A square path defined by 35 preselected points about an OBD station was chosen as a representative problem presenting equal complexity of solution to each equipment. OBD data for each point and values of waypoint bearing and distance for each course were measured from a chart accurately scaled to 1 250,000. The information thus obtained was supplied to the equipment through the laboratory test set. The position indicated by the two types of equipment for each of the 35 points was recorded, and

TABLE IV

DISTANCE ACCURACY TESTS, SCALE 1 500,000, 30 MILES

Distance (nm)	Decreasing Distances: Average Display Indication (nm)	Decreasing Distances: Error (nm)	Increasing Distances: Average Display Indication (nm)	Increasing Distances: Error (nm)
0	0.2	+0.2	- 0.2	-0.2
1	1.2	0.2	0.8	0.2
2	2.2	0.2	1.9	0.1
3	3.2	0.2	2.9	0.1
4	4.3	0.3	3.9	0.1
5	5.3	0.3	4.9	0.1
6	6.4	0.4	5.9	0.1
7	7.4	0.4	6.9	0.1
8	8.2	0.2	7.9	0.1
9	9.3	0.3	8.9	0.1
10	10.4	0.4	9.9	0.1
11	11.4	0.4	10.9	0.1
12	12.4	0.4	11.8	0.2
13	13.4	0.4	12.9	0.1
14	14.4	0.4	13.9	0.1
15	15.3	0.3	14.9	0.1
16	16.2	0.2	15.8	0.2
17	17.2	0 2	16.9	0.1
18	18.1	0.1	17.9	0.1
19	19.2	0.2	18.7	0.3
20	20.2	0.2	19.8	0.2
21	21.1	0.1	20.8	0.2
22	22.2	0.2	21.9	0.1
23	23.2	0.2	22.9	0.1
24	24.2	0.2	23.9	0.1
25	25.2	0.2	24.8	0.2
26	26.1	0.1	25.9	0.1
27	27.1	0.2	26.8	0.2
28	28.2	0.2	27.8	0.2
29	29.2	0.2	28.7	0.3
30	30.2	0.2	29.7	0.3
Average Error		+0.23		-0.13

lines were drawn through the points to show continuous tracks. The results of these tests are shown in Fig. 5. A comparison of the tracks made good with the proposed flight path shows a maximum error of 0.3 mile in the Type III Pictorial Computer and of 1.0 mile in the Type VI Course-Line Computer.

Flight Tests.

To obtain additional technical information a pattern was flown three times clockwise and three times counterclockwise in a Douglas DC-3 airplane while pictorial display, omnirange, and DME indications were recorded over each of 30 ground check points. These recordings were then compared with measurements of bearing and distance to these points obtained from a specially prepared chart scaled to 1 125,000. Measured bearing and distance to the station, omnibearing and distance-indicator readings, and display indications for each check point are shown in Table VII. Maximum average bearing and distance errors over a point were 1.6° and 0.3 mile, respectively. Figure 6 shows the proposed flight path and the average indications of the OBD instruments and of the pictorial display.

Table VIII shows the magnitude of errors found in the various types of equipment during a typical flight. Maximum errors in bearing and distance in this case were 5.0° and 0.4 mile,

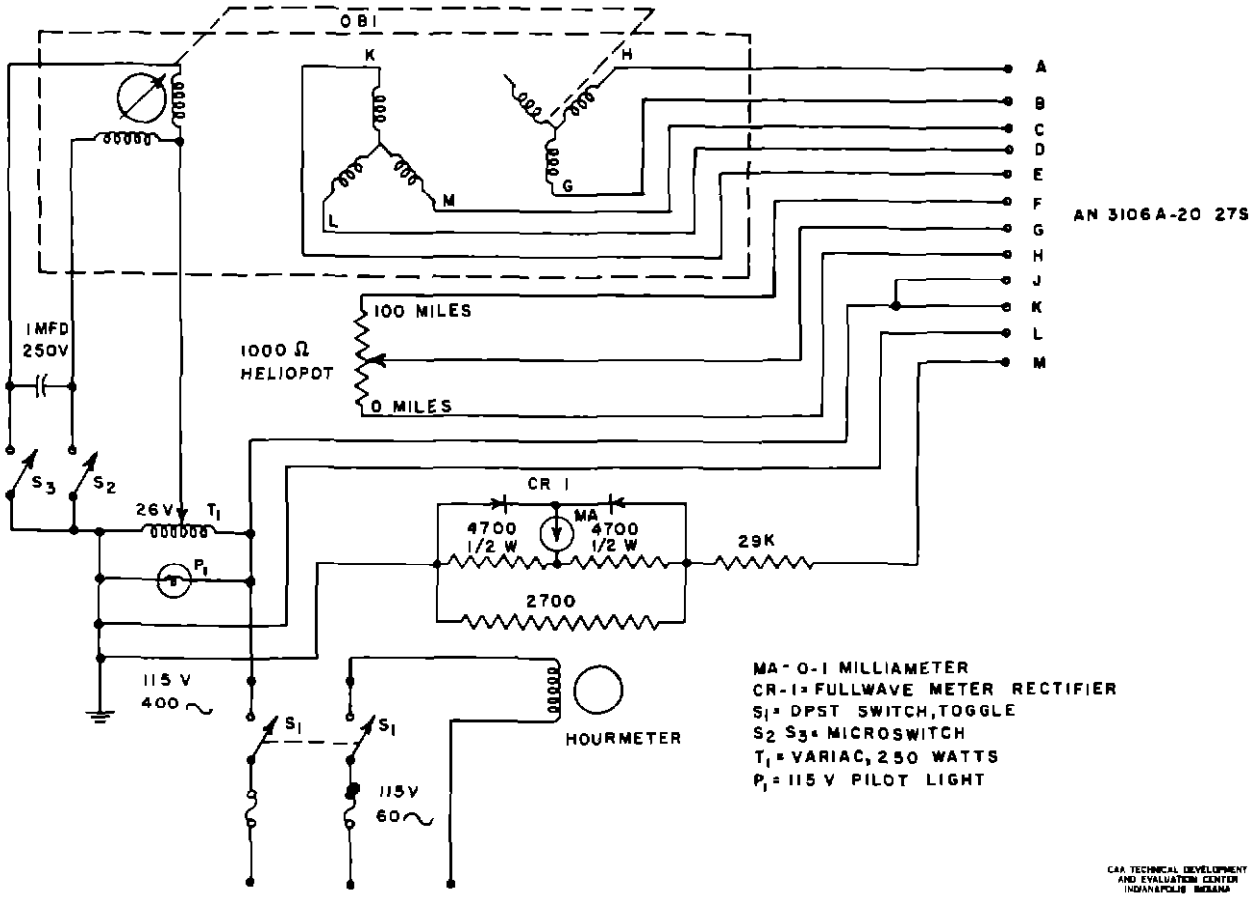

Fig. 4 Schematic Diagram of Laboratory Test Set for Type III Pictorial Computer

respectively. Figure 7 shows the proposed flight path and the indications of the OBD instruments and of the pictorial display

The pictorial display appears less accurate in actual flight than in the laboratory, where variables of bearing and distance may be inserted with much precision. Differences in equipment indications and in OBD-instrument readings in flight may be accounted for by the following uncontrollable factors. Frequent oscillations of the OBI followed by similar oscillations introduced into the display make it difficult if not impossible to obtain accurate readings of bearing at any given instant. Occasional small but rapid changes in distance were noted on the remote-distance indicator and were recorded as errors before the pictorial display could complete correction. Despite these apparently large errors, an examination of Figs. 6 and 7 shows that the maximum displacement of the pictorial-display indications from the proposed check points did not exceed 1.3 mile.

OPERATIONAL EVALUATION

To obtain data on the navigational and traffic-control characteristics of the Type III Pictorial Computer, a number of flight tests were conducted in a Douglas DC-3 airplane. These limited flight tests were directed primarily at qualitative measurements. A large number of pictorial displays and of aircraft types would have been required to obtain accurate quantitative data relating to system performance. All tests were made using the Indianapolis VOR/DME facility. The pilot used the Type III Pictorial Computer for all navigation information except as noted. Pilots were briefed before each flight as to the desired tracks to be

TABLE V

DISTANCE ACCURACY TESTS, SCALE 1 1,000,000, 60 MILES

Distance (nm)	Decreasing Distances		Increasing Distances	
	Average Display Indication (nm)	Error (nm)	Average Display Indication (nm)	Error (nm)
0	0.1	+0.1	- 0.2	-0.2
5	5.3	0.3	4.8	-0.2
10	10.4	0.4	10.1	+0.1
15	15.4	0.4	15.0	0.0
20	20.3	0.3	19.9	-0 1
25	25.4	0.4	25.0	0 0
30	30.3	0.3	29.9	-0.1
35	35.2	0.2	34 8	-0 2
40	40.2	0.2	39.7	-0.3
45	45.1	0.1	44.6	-0.4
50	50.0	0.0	49.7	-0.3
55	55.3	0.3	54.8	-0.2
60	60.3	0.3	59.8	-0.2
Average Error		+0.25		-0.17

TABLE VI

RANGE-LIMIT OPERATION

Display Range Scale (nm)	Cut-Out Distance (nm)	Cut-In Distance (nm)
15	15.5	15.1
30	32.5	32.0
60	64.25	63.0

flown. In most cases, the desired flight paths were also drawn on the charts used in the pictorial display. The track and the position of the aircraft, as they were indicated by the pictorial display, were recorded by inserting the point of a pencil in the hole in the slide assembly.

Although the Type III Pictorial Computer was originally designed to be carried on the lap of the pilot, previous flight tests had indicated that this arrangement was undesirable from the standpoint of weight, of heat generated, and of interference with necessary operation of aircraft controls. Therefore, in these tests the computer was supported between the seats of the pilot and of the copilot.

To provide a rough measurement of the accuracy of the pictorial-display indications, the track over the ground was recorded by a visual observer standing behind the pilot. Accurate detailed charts showing all county roads and terrain features of the Indianapolis area were used for this purpose by the visual observer. It was estimated that these observations were accurate to within 0.25 mile.

It should be noted that errors in the indications from the pictorial display are the resultant of all errors in the elements used in the system. These elements include the ground very-high-frequency omnirange (VOR) and DME stations, the aircraft VOR and DME receivers, the aircraft OBI and DME indicators, and the pictorial equipment itself.

TABLE VII

FLIGHT TESTS OF TYPE III COMPUTER

Check-Point Number	Measured Values		Average Pictorial-Display Indication		Average OBD-Instrument Indication		Pictorial-Display Error*	
	Bearing to Station (degrees)	Distance to Station (nm)	Bearing to Station (degrees)	Distance to Station (nm)	Bearing to Station (degrees)	Distance to Station (nm)	Bearing (degrees)	Distance (nm)
1	288.5	4.9	286.0	4.1	285.25	4.0	+0.75	+0.1
2	293	2.4	298.6	2.3	298	2.3	+0.6	0.0
3	329	0.5	338.8	0.9	339.5	0.8	+0.7	+0.1
4	92	1.6	87.0	2.2	88.3	2.1	-1.3	+0.1
5	97.5	2.6	93.5	2 9	93.1	2.8	+0.4	+0.1
6	100	4.3	97.3	4.2	97.5	4.2	-0.2	0 0
7	101	5.1	97.5	5.3	97 3	5.1	+0.2	+0.2
8	101.5	6.5	98	6.8	98.8	6.6	-0 8	+0.2
9	102	7.8	100.2	8 4	101.0	8.4	-0.2	0.0
10	102	9.2	100.4	9.2	102.0	9.3	-1.6	-0.1
11	110	9.5	105.6	9.6	107.0	9.6	-1.4	0 0
12	119	10.25	116.1	10.1	115.3	10.4	+0.8	-0.3
13	122	10.5	122.5	10.9	121.5	10.9	+1.0	0.0
14	127.5	11.5	126.6	11.5	127.1	11.7	-0.5	-0.2
15	133	12.5	131.4	12.3	132.4	12.5	-1.0	-0.2
16	138	13.5	136.0	13.6	136.2	13.8	-0.2	-0.2
17	144	12.3	143.5	12.4	142.3	12.4	+1.2	0.0
18	154	11.2	151.5	11.2	151 8	11.2	-0.8	0.0
19	163.5	10.5	161.5	10.5	159.5	10.7	+1.0	-0.2
20	171	10.2	169.5	10.2	171.0	10.2	-1.5	0 0
21	185.5	10.2	181.4	10.3	181.2	10.1	+0.2	+0.2
22	196	10.5	190.6	10.5	190.6	10.7	0 0	-0.2
23	206	11.5	202.3	11.2	201.1	11.4	+1.2	-0.2
24	212	10.6	208.0	10.4	209.5	10.6	-0.5	-0 2
25	218	9.7	214.8	9.8	216.0	9.8	-1.2	0.0
26	229	9	226.6	8.9	225.6	9.0	+1.0	-0.1
27	239.5	8.5	238.3	8.6	238.1	8.6	+0.2	0.0
28	248	8.4	247	8.5	246.5	8.4	+0.5	+0.1
29	257	8.5	256.1	8.6	255.0	8.5	+1.1	+0.1
30	261	8.5	260.6	8.7	260.0	8.6	+0.6	+0.1

*Bearing error is the difference, in degrees, between OBI and pictorial-display indications, distance error is the difference, in miles, between DME-repeater and pictorial-display indications.

Description of the Operational Flight Tests.

Flight Test No. 1 was made to check the use of the equipment for navigation along present-day airways. The aircraft was flown along an assigned departure track of 360° from the Indianapolis airport to the north edge of Green Airway 4, thence, well to right of the course along Green Airway 4 to Terre Haute (the pilot was requested to fly along the right edge of the airway), in a holding pattern on the east course of the Terre Haute low-frequency (LF) radio range, and back to Indianapolis via Green Airway 4. A normal transition procedure from the Clayton fan marker to the holding pattern at the instrument-landing-system (ILS) outer marker was followed by flight in the ILS holding pattern. The pilot was instructed to leave the marker inbound at a specific time to simulate timed-approach procedures. A low approach to Runway 4 was then made and was followed by a simulated missed approach and by circling for a landing on Runway 31.

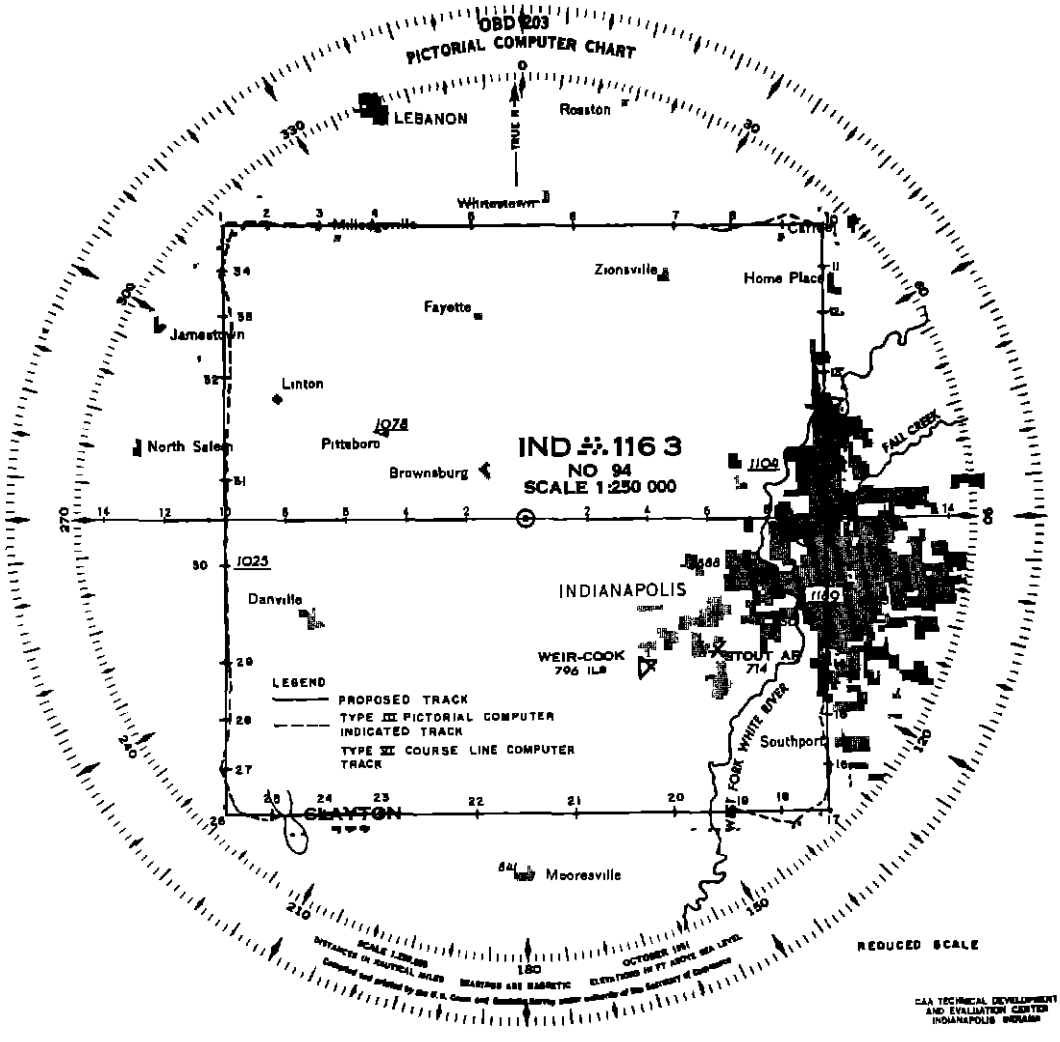

Fig. 5 Accuracy Tests, Type III and Type VI Computers

Figure 8 illustrates the terminal-area portion of this flight, and Fig. 9 the en route portion. The edges of the airway, the holding pattern at Terre Haute, the return course from Terre Haute, the ILS course, and the normal holding pattern southwest of the ILS outer marker were drawn on the chart to assist the pilot. However, no specific departure track was indicated. No difficulty was experienced by the pilot in flying along the desired tracks. The computer provided all navigation information required for flight along present-day airways without use of the LF radio ranges.

Flight Test No. 2 was made to check the use of the computer as a navigational aid in flying direct off-airway courses to airports not served by navigational aids. It was planned to fly from the Indianapolis LF range direct to Kisters Airport at Bloomington, Indiana, from there direct to Columbus, Indiana, Airport, then direct to Atterbury Air Force Base; and finally direct to Stout Field at Indianapolis. Figure 10 illustrates the first leg of this flight. Because of a DME failure shortly after reaching Bloomington, no records were obtained beyond that point.

Flight Test No. 3 was made to check again the use of the computer for direct-course navigation to various airports. In addition, two low approaches were made to a small private airport located about 1 1/2 miles from the Indianapolis OBD station. These close-in

TABLE VIII

FLIGHT TESTS OF TYPE III COMPUTER

Check-Point Number	Measured Values		Typical Pictorial-Display Indication		Typical OBD-Instrument Indication		Pictorial-Display Error*	
	Bearing to Station (degrees)	Distance to Station (nm)	Bearing to Station (degrees)	Distance to Station (nm)	Bearing to Station (degrees)	Distance to Station (nm)	Bearing (degrees)	Distance (nm)
1	285.5	4.9						
2	293	2.4	300	2.8	301	2.6	-1.0	+0.2
3	329	0.5	344	1.0	345	0.8	-1.0	+0 2
4	92	1.6	94	1.6	93	1.9	+1.0	-0.3
5	97.5	2.6	100	5.0	95	3.0	+5.0	0.0
6	100	4.3	103	4.2	107	4.2	-4.0	0.0
7	101	5.1	104	5.3	107	5.2	-3 0	+0.1
8	101.5	6.5	104	6.7	105	6.6	-2.0	+0.1
9	102	7.8	105	8.2	108	8.2	-3.0	0.0
10	102	9.2	105	9.4	106	9.5	-1.0	-0.1
11	110	9.5	114	9.7	117	9.7	-4.0	0.0
12	119	10.25	125	10.2	123	10.2	+2.0	0.0
13	122	10.5	129	10.5	130	10.8	-1.0	-0.3
14	127.5	11.5	132	11.3	133	11.2	-1.0	+0.1
15	133	12.5	136	12.5	138	12.5	-2.0	0.0
16	138	13.5	140	13.7	141	13.8	+1.0	-0.1
17	144	12.3	150	12.6	151	12.5	+1.0	+0.1
18	154	11.2	160	11.4	160	11.2	0.0	+0.2
19	163.5	10.5	166	10.7	165	10.8	+1.0	-0.1
20	171	10.2	173	10.4	175	10.2	-2.0	+0.2
21	185.5	10.2	184	10.3	185	10 2	-1.0	+0.1
22	196	10.5	193	10.5	195	10.8	-2.0	-0.3
23	206	11.5	205	11.3	205	11.6	0.0	-0.3
24	212	10.6	210	10.6	210	10.4	0.0	-0.2
25	218	9.7	218	10.0	220	9.9	-2.0	-0 1
26	229	9.0	229	9.4	230	9.0	-1.0	+0.4
27	239.5	8.5	240	9.0	241	8.7	-1.0	-0.3
28	248	8.4	249	8.8	250	8.5	-1.0	-0.3
29	257	8.5	256	8.8	255	8.6	+1.0	-0.2
30	261	8.5	261	8.8	260	8.8	+1.0	0.0

*Bearing error is the difference, in degrees, between OBI and pictorial-display indications, distance error is the difference, in miles, between DME-repeater and pictorial-display indications.

approaches were designed to simulate operation at an airport with the OBD facility located on, or immediately adjacent to, the airport. Figure 11 illustrates the first approach to this airport from a close-in pattern, and Fig. 12 illustrates the second approach plus a portion of the en route operation to Lafayette and from Kokomo to Stout Field. On the low approach to Stout Field on return, the pilot aligned the plane with Runway 22 and flew visually over it. The pictorial display indicated that the aircraft was about one mile behind the actual position and was approximately 1500 feet southeast of the actual track over the ground.

Figure 13 indicates the en route portions of this flight. When the aircraft approached Lafayette, the bridge assembly of the computer began to bind in the outer-shell housing with the result that erroneous position information was presented to the pilot. The record of the visual track indicates the efforts of the pilot to obtain correct course indications from the equipment. Binding of the bridge assembly resulted from the method of supporting the computer by resting the outside shell on the arm rests of the pilot's and copilot's seats. To prevent a recurrence of this difficulty, a small tray was fabricated to support the computer on subsequent runs. In the vicinity of Kokomo when a turn was made to return to Stout Field,

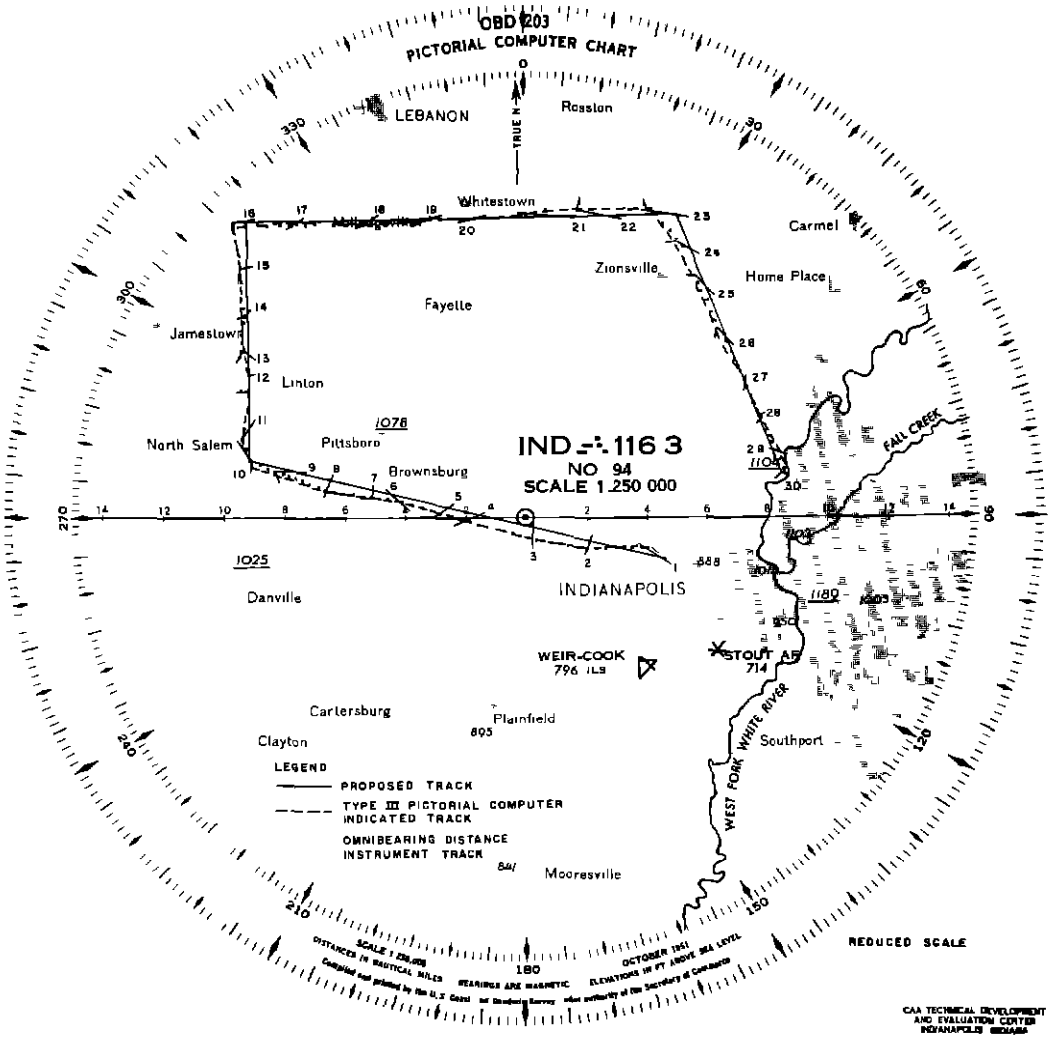

Fig. 6 Average Results of Technical Flight Tests

the DME began hunting. The altitude of the aircraft at the time was 4500 feet. The aircraft was climbed to 5000 feet to determine if a higher altitude would give better reception, but normal DME indications were not received for several minutes. An oscillating trace was recorded on the pictorial-display chart during this period.

Flight Test No. 4 was made to check the use of the Type III Pictorial Computer as a navigational aid for terminal-area work. Departure tracks on nonradial courses, low approaches, and instrument-flight-rule (IFR) holding patterns assigned without reference to ground radio aids were flown.

Figure 14 illustrates flight along a departure track of 360° followed by a low approach to Runway 15 at Stout Field. On this approach, the aircraft was visually flown over the runway. The pictorial display indicated that the aircraft was approximately one mile behind the actual position and approximately one-half mile northeast of Runway 15. Figure 15 illustrates flight along a departure track of 015° followed by a low approach to Runway 22 at Stout Field. On the approach, the alignment of the pictorial display with the runway-extension line was excellent, however, the equipment indicated that the aircraft was approximately one mile from the runway when the approach end of the runway was reached. Figure 15 also illustrates a long straight-in approach to the Brownsburg airstrip from the south. The distance indications

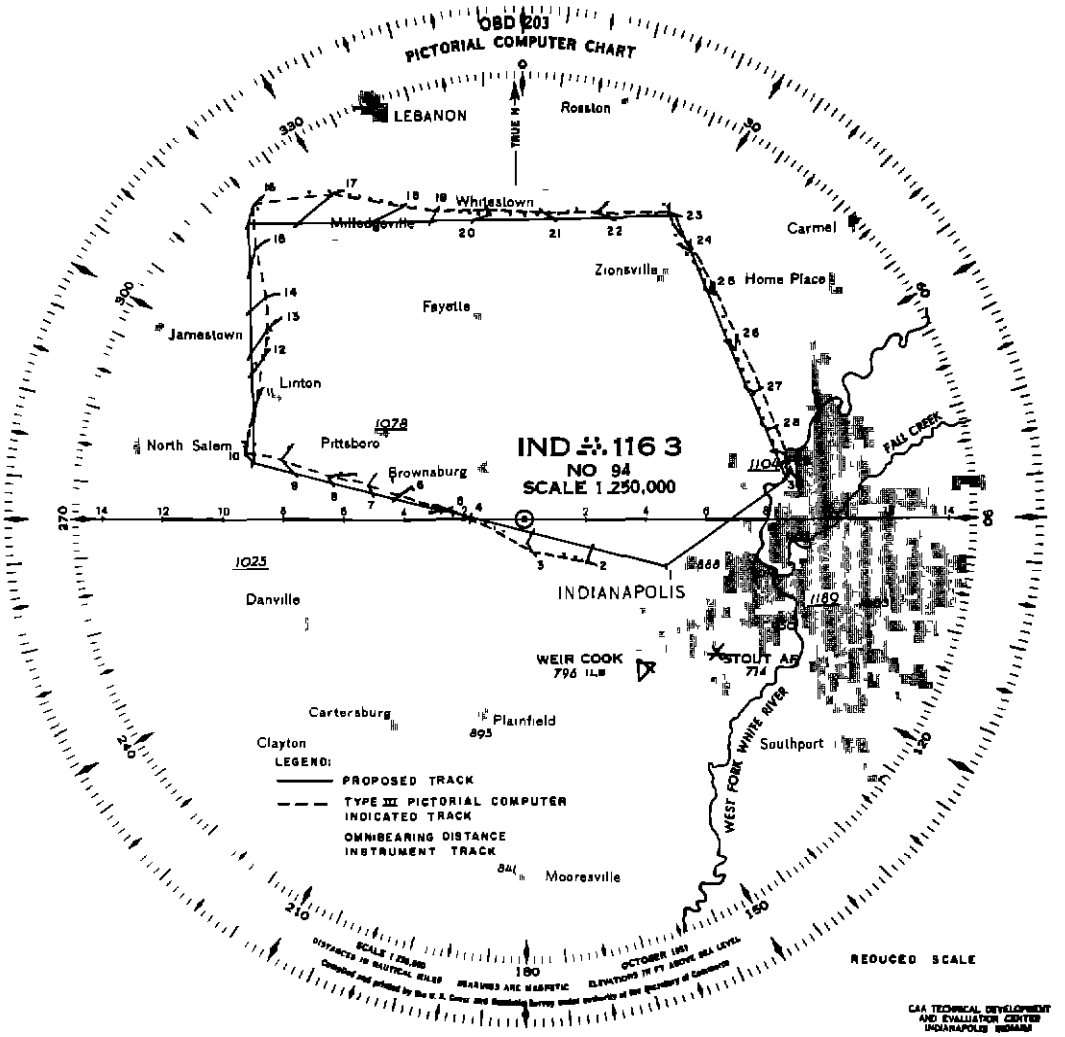

Fig. 7 Results of a Typical Technical Flight Test

from the end of the runway were good, but the aircraft was one-half mile east of the airport when the pictorial display indicated that the aircraft was passing along the east edge of the field. Figure 16 illustrates a straight-in approach to the Brownsburg airstrip from the north. The aircraft actually passed directly over the airstrip with the pictorial display indicating that the flight was still approaching one mile from the airport. Figure 16 also illustrates flight in a holding pattern west of Plainfield to demonstrate the utility of the pictorial display in the terminal area for assigning holding instructions in any unused airspace without regard to normal radio fixes. This holding pattern was followed by a low approach to Runway 4 at Indianapolis.

The only reference lines available to the pilot on Flight Test No. 4 were runway-extension lines to permit easier alignment of the pictorial display on low approaches. Much oscillation of the aircraft-position indicator was recorded on this flight. It was noted that the OBI also was oscillating ± 4° at times. The reason for the large jumps in the pictorial-computer track on the approaches to Brownsburg is not known, however, part of this may have been the result of drag introduced by inserting a pencil point through the hole in the plastic slide mechanism to record the track made good by the pictorial display. This drag of the recording pencil probably accounts for some of the lag in the equipment on low approaches.

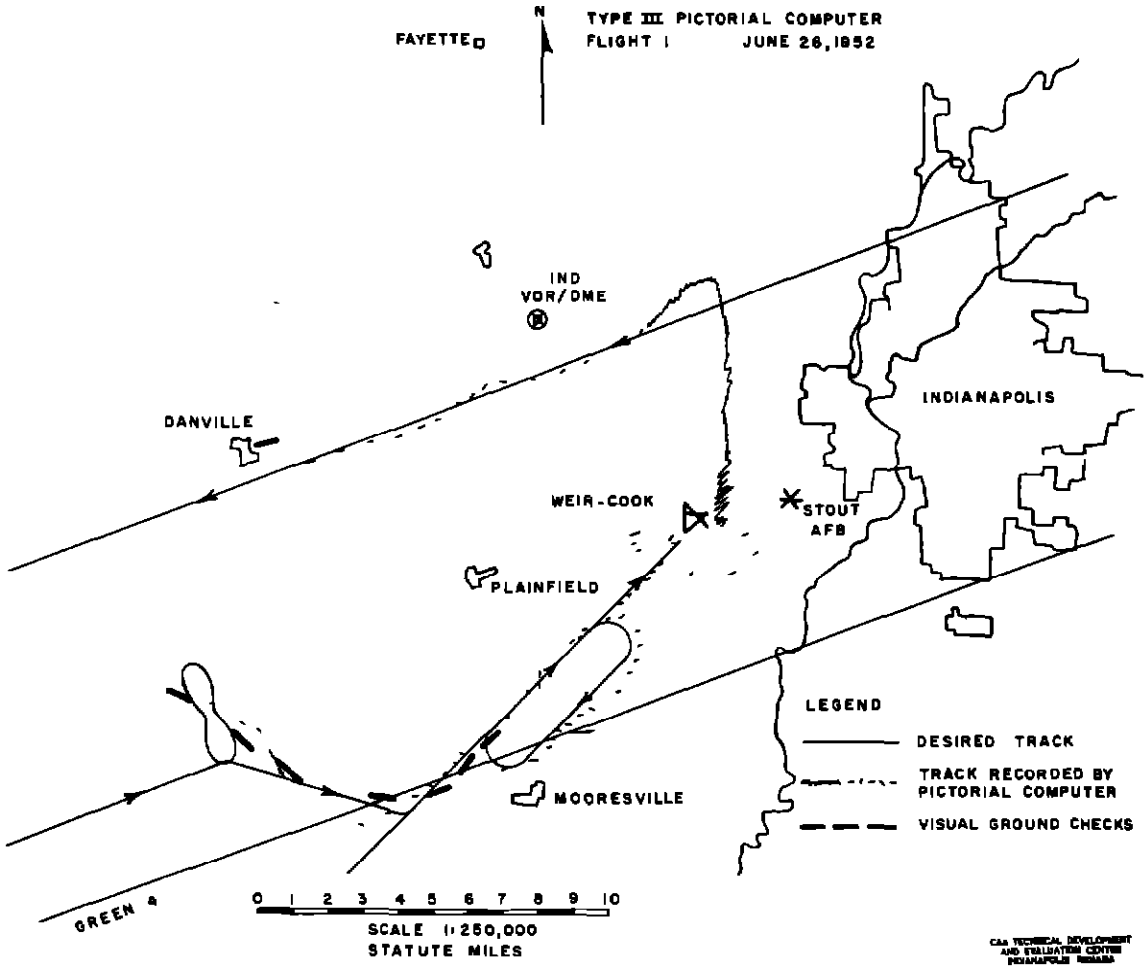

Fig. 8 Operational Flight Test No. 1, Terminal Area

Flight Test No. 5 was set up to evaluate the use of the Type III Pictorial Computer for navigation along parallel tracks en route. The flight commenced at the Indianapolis airport, proceeded along the north edge of Green Airway 4 to the Greencastle fan marker, and used the pictorial equipment for all navigation information. Eastbound from the Greencastle fan marker to New Castle, Indiana, the pilot navigated by listening to the low-frequency radio-range courses to illustrate separation between those aircraft equipped with and those aircraft not equipped with pictorial displays. The track for this portion of the flight was also recorded on the Type III Pictorial Computer. From New Castle to Indianapolis, the pilot flew along the north edge of Green Airway 4, again using the pictorial display as the primary source of navigation information. Approaching Indianapolis, the pilot proceeded to a track parallel to and four miles north of the north edge of Green Airway 4. When abeam Greencastle fan marker, the pilot proceeded eastbound on another track parallel to and eight miles north of the north edge of Green Airway 4.

Figure 17 illustrates the results of this test and demonstrates the possibilities of using lateral separation en route on multiple-track airways. Multiple-track operation to provide lateral separation for the climb to cruising altitude and for the descent from cruising altitude is one of the greatest needs of air traffic control today. Present-day use of many different types of aircraft with varying speed and performance characteristics has accentuated this phase of the air-traffic-control problem.

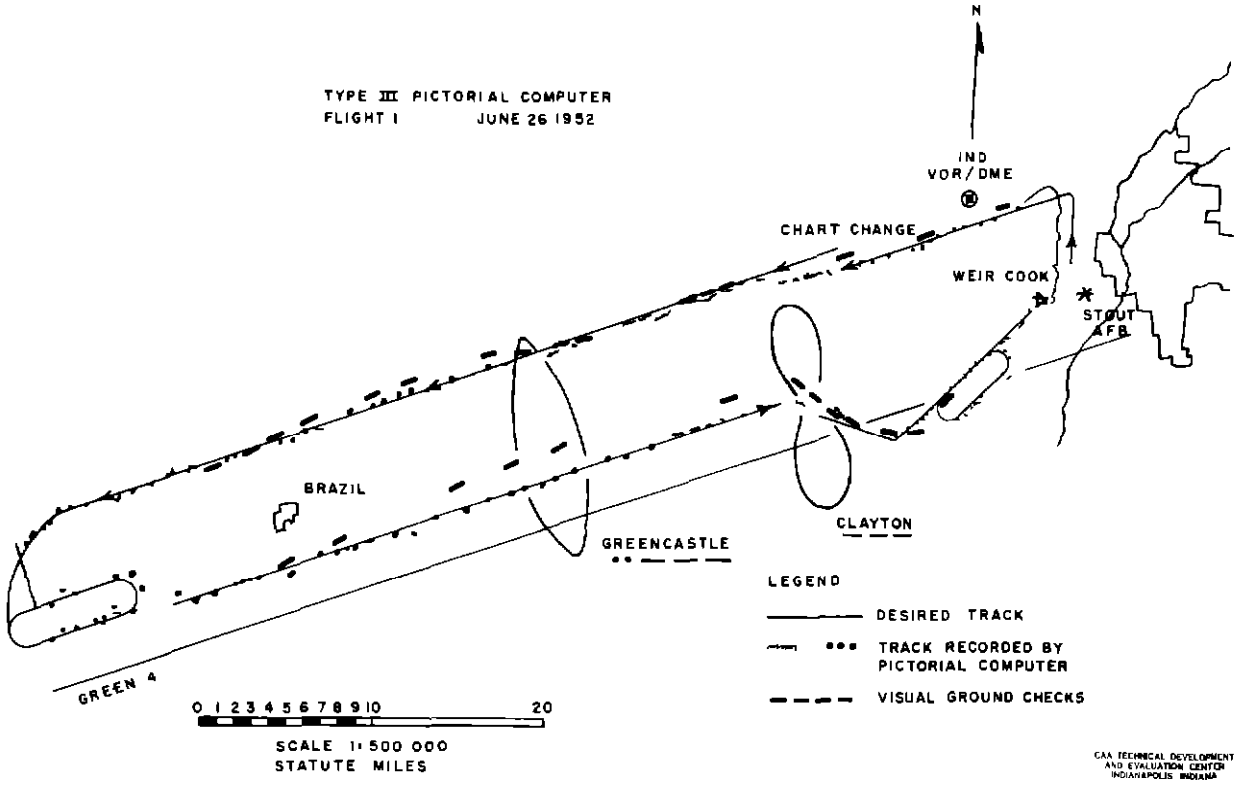

Fig. 9 Operational Flight Test No 1, En Route Area

Flight Test No. 6 was made to check again the use of the pictorial display for terminal-area navigation. A series of departure tracks, of approaches, and of holding patterns were flown. Figure 18 illustrates the use of departure tracks having angular divergence from a preselected point in space. Comparison of tracks separated by 15°, 30°, and 45° may be made. Figure 19 illustrates the use of parallel departure tracks with ten miles of separation after initial separation had been established by tracks separated 90°. The flexibility of possible air-traffic-control procedures and the use of all available airspace is again demonstrated with navigation no longer confined to radial courses to or from ground radio facilities.

Figures 20, 21, and 22 illustrate low approaches to the Indianapolis Weir Cook Municipal airport and to Stout Field. During these approaches, the maximum lateral deviation, indicated by the pictorial display, from runway alignment was 1000 feet. The aircraft-position indicator lagged behind the actual position of the aircraft up to 3/4 mile on these approaches. It appeared that the display would permit instrument letdowns to any runway down to present circling weather minima. Use of the equipment for straight-in letdowns to the airport will permit pilots to achieve ground contact at an earlier time and will thus reduce delays inherent in present procedures in which the pilot must fly along preset radio courses before beginning letdown.

Figure 23 illustrates the use of the pictorial display for navigation in adjacent holding patterns Holding patterns A and B are separated four miles end to end, and patterns B and C are separated four miles between sides These patterns illustrate the advantages of pictorial displays for assignment of specific flight paths and for possible reduction of the buffer space required around holding patterns The holding of several aircraft at the same altitude in adjacent patterns would be particularly advantageous under certain weather conditions, for example, in the avoidance of icing or of thunderstorm activity The ability to hold several aircraft at the same altitude level would also permit air traffic controllers to use the altitude levels which are freed for other traffic, including departing and en route flights

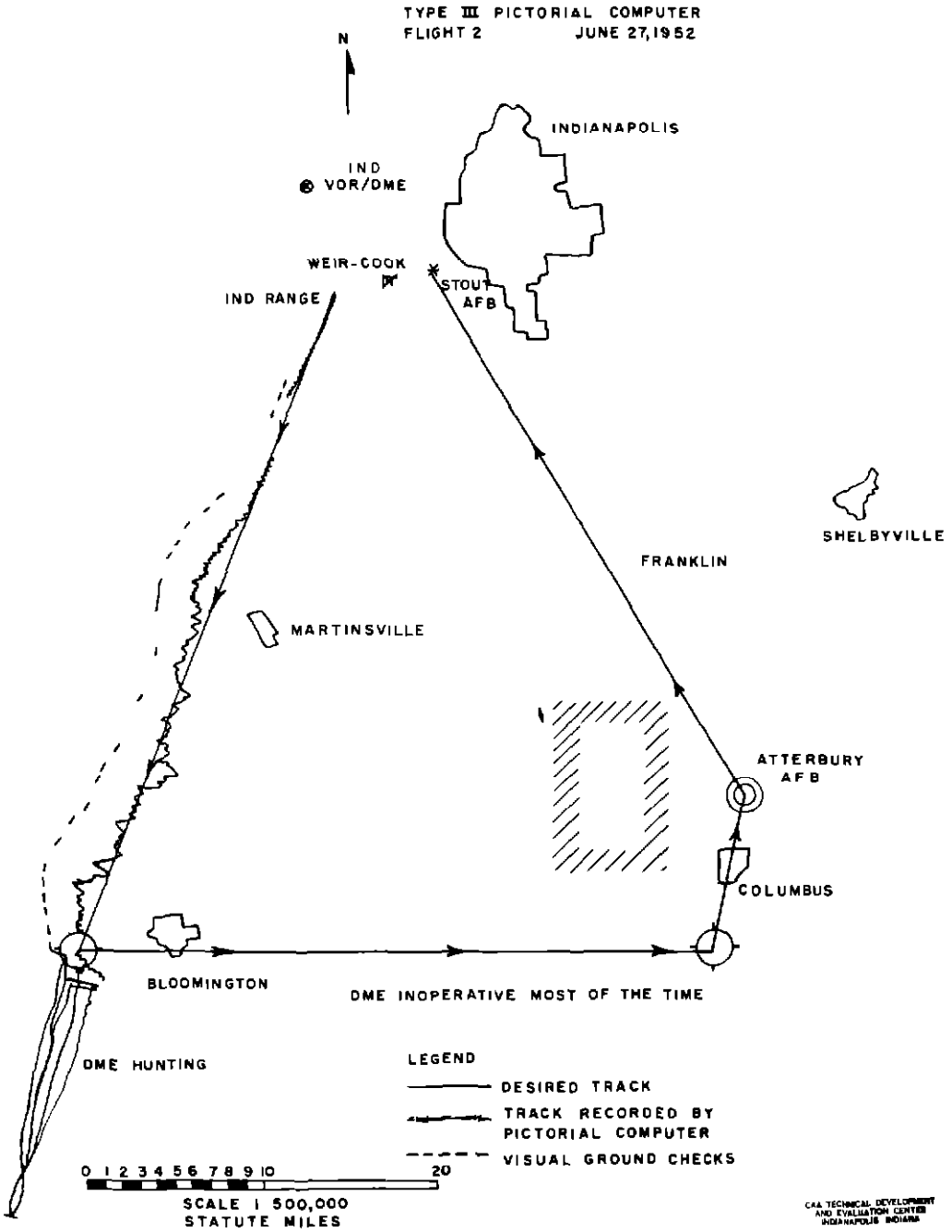

Fig. 10 Operational Flight Test No. 2

It was decided to repeat the first three flight tests because greater inaccuracies were noted in the computer on these flights than on subsequent flight tests. Some of these apparent errors were due to chart inaccuracies. Discrepancies between the pictorial-display charts and the accurate-detail charts used for visual plotting were noted when the composite illustrations were made by use of a Saltzman projector. Some errors were possibly due to

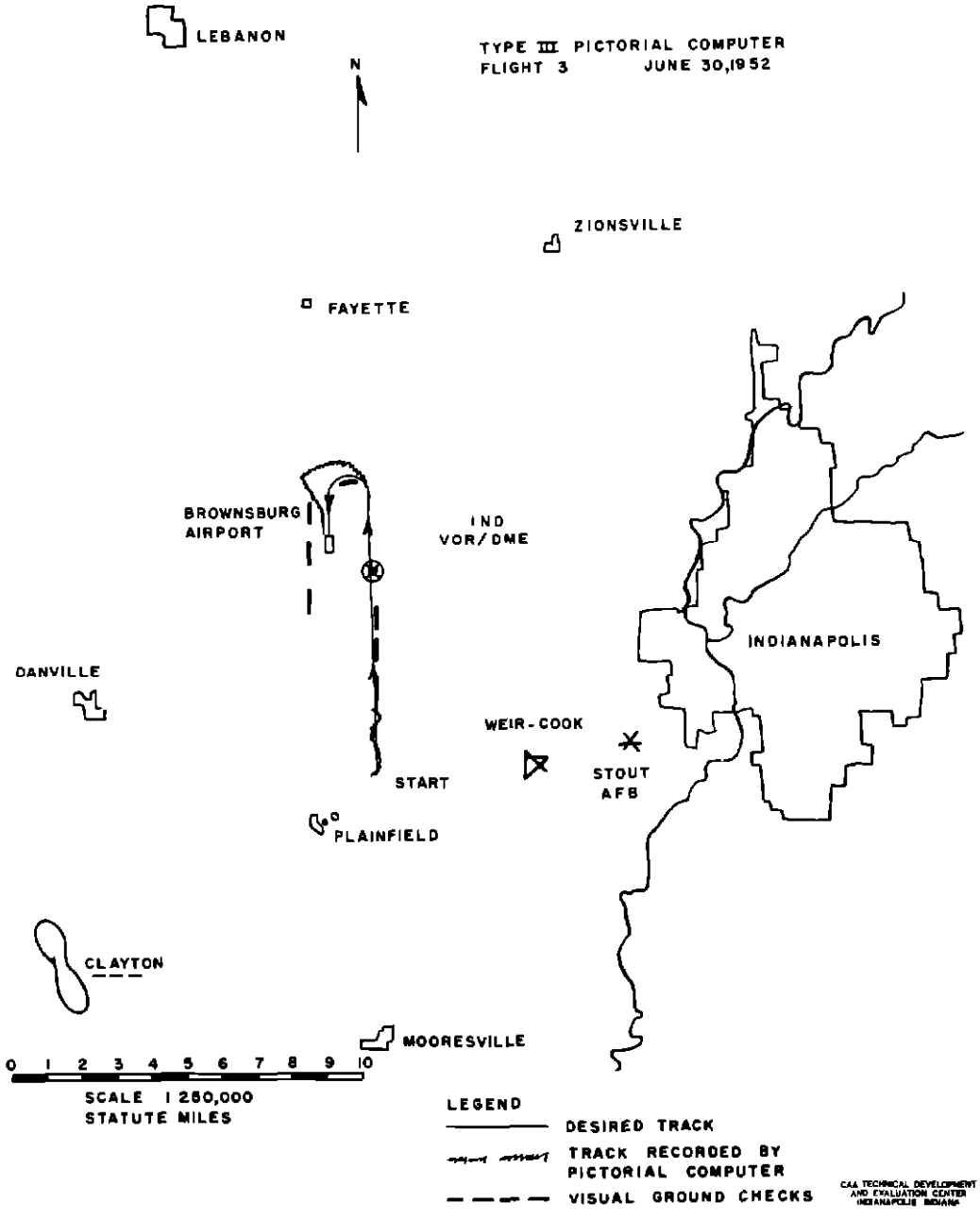

Fig. 11 Operational Flight Test No. 3, Approach No. 1

faulty DME operation, and some of the errors were due to the calibration method used. For the first four runs, the computer had been calibrated on the bench with one DME unit (Type DIA). For the flights, the DME unit already installed in the aircraft was used. For the last two runs, the same DME unit was used both for calibration and for flight tests and resulted in much better correlation between pictorial-display indications and the observed track over the ground. The difference between individual DME units is apparently due to the slight differences in output-potentiometer resistance at the zero-mile point. Standardization of these output-resistance levels is essential for operational use to permit rapid change or replacement of DME or of pictorial-display units without the necessity of recalibration.

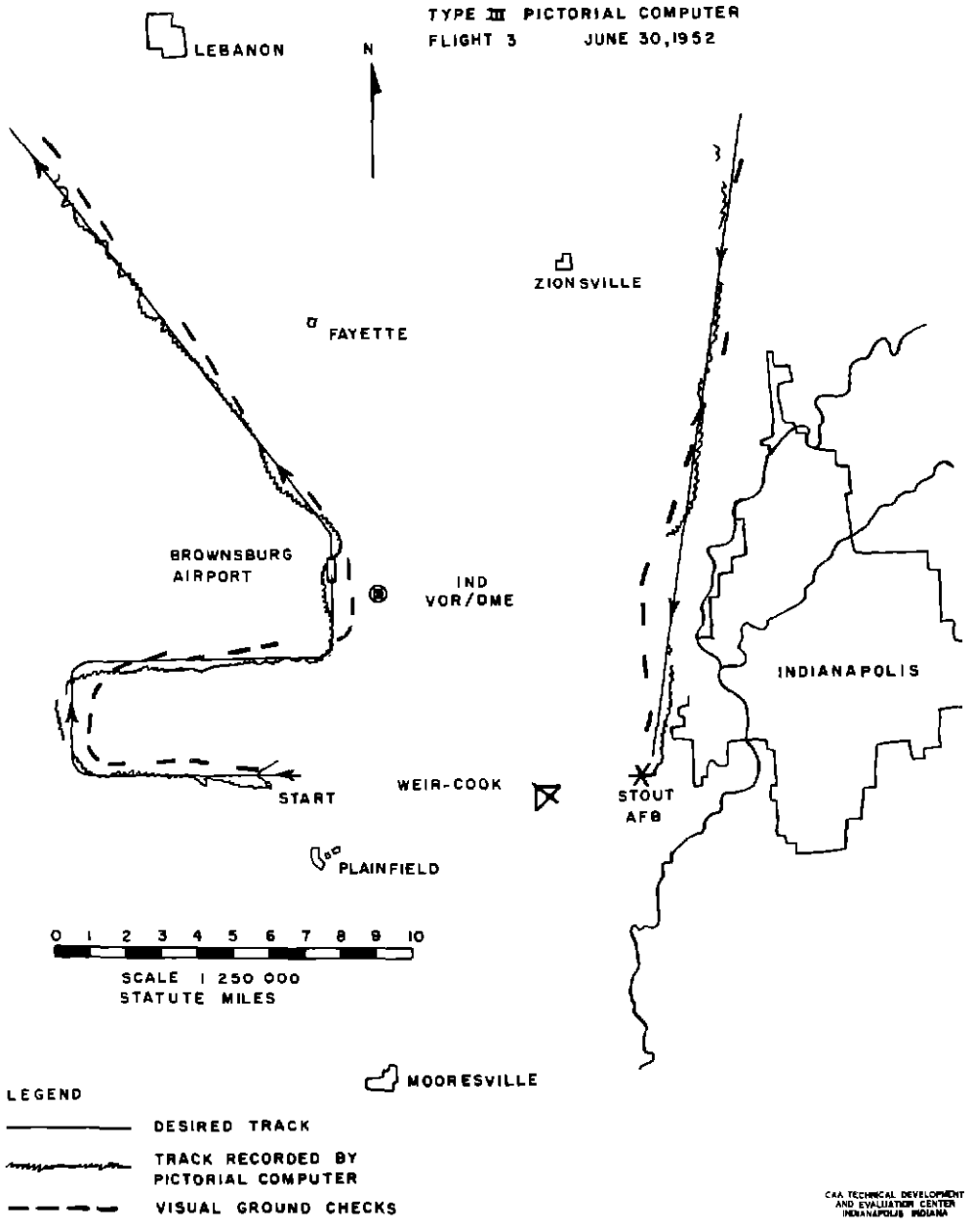

Fig. 12 Operational Flight Test No. 3, Approach No. 2

Flight Test No. 7 was a rerun of Flight Test No. 1. Figures 24 and 25 indicate close agreement between the visually observed tracks and the track recorded by the pictorial display.

Flight Test No. 8 was set up to repeat Flight Tests Nos. 2 and 3. Figure 26 illustrates the en route portion of this flight to the off-airway airports at Bloomington, Columbus, and Atterbury. Much better course accuracy was indicated on this flight. Bad scalloping was noted in the vicinity of Atterbury Air Force Base and on the course to Lafayette. This scalloping was also observed on the OBI feeding the pictorial display. Figure 27 illustrates the terminal-area patterns. The approach to Stout Field from the southeast was made to 200 feet above the ground. Alignment with the runway was excellent until about two miles out, when the aircraft

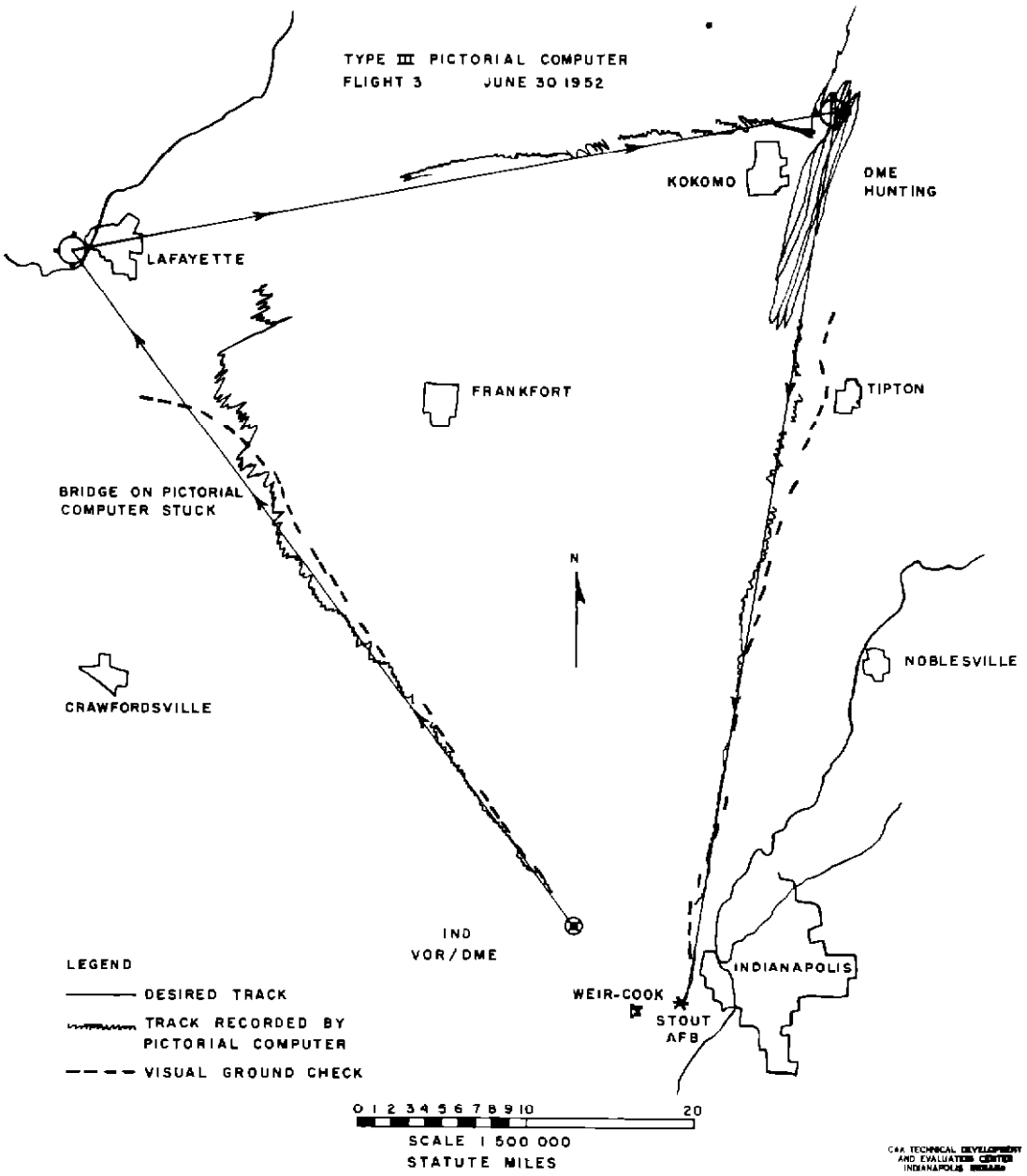

Fig. 13 Operational Flight Test No. 3, En Route

was 800 feet above ground. Below this level, the pictorial display indicated wide deviations to the left, apparently due to inadequate VOR signals.

General Observations Made During the Operational Tests.

In all of the operational test flights, the pilots experienced no difficulty in using the Type III Pictorial Computer as the primary source of navigational information or in flying along the desired courses when these were preplotted on the pictorial display.

All of the pilots participating in these tests commented that the mounting of the Type III Computer on a swinging arm or on the instrument panel would be preferable to carrying it

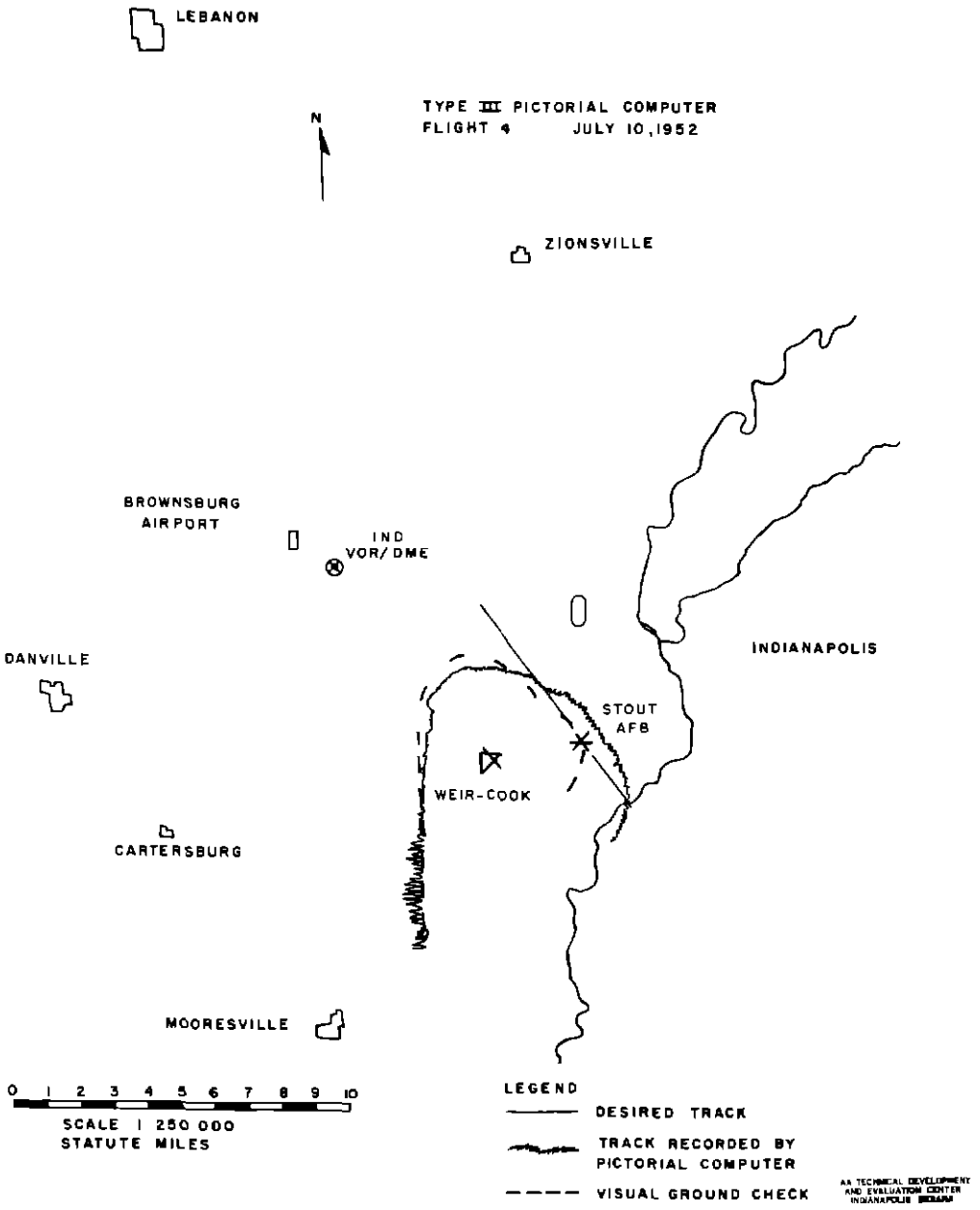

Fig. 14 Operational Flight Test No. 4, Departure No. 1, Low Approach No. 1

either on the lap or between the seats of the pilot and the copilot. The latter type of mounting required the pilot to look to his side and downward and thus to take his attention away from the instrument panel. This interference was particularly undesirable during the flying of involved patterns which require the frequent observation of the pictorial display in order to stay on the desired track.

Chart-changing in the computer requires from 30 seconds to one minute. The charts must be accurately cut to fit. On one run, a chart was torn in attempts to insert the notches under the clips. Inaccuracies were also discovered on the pictorial-display charts. For

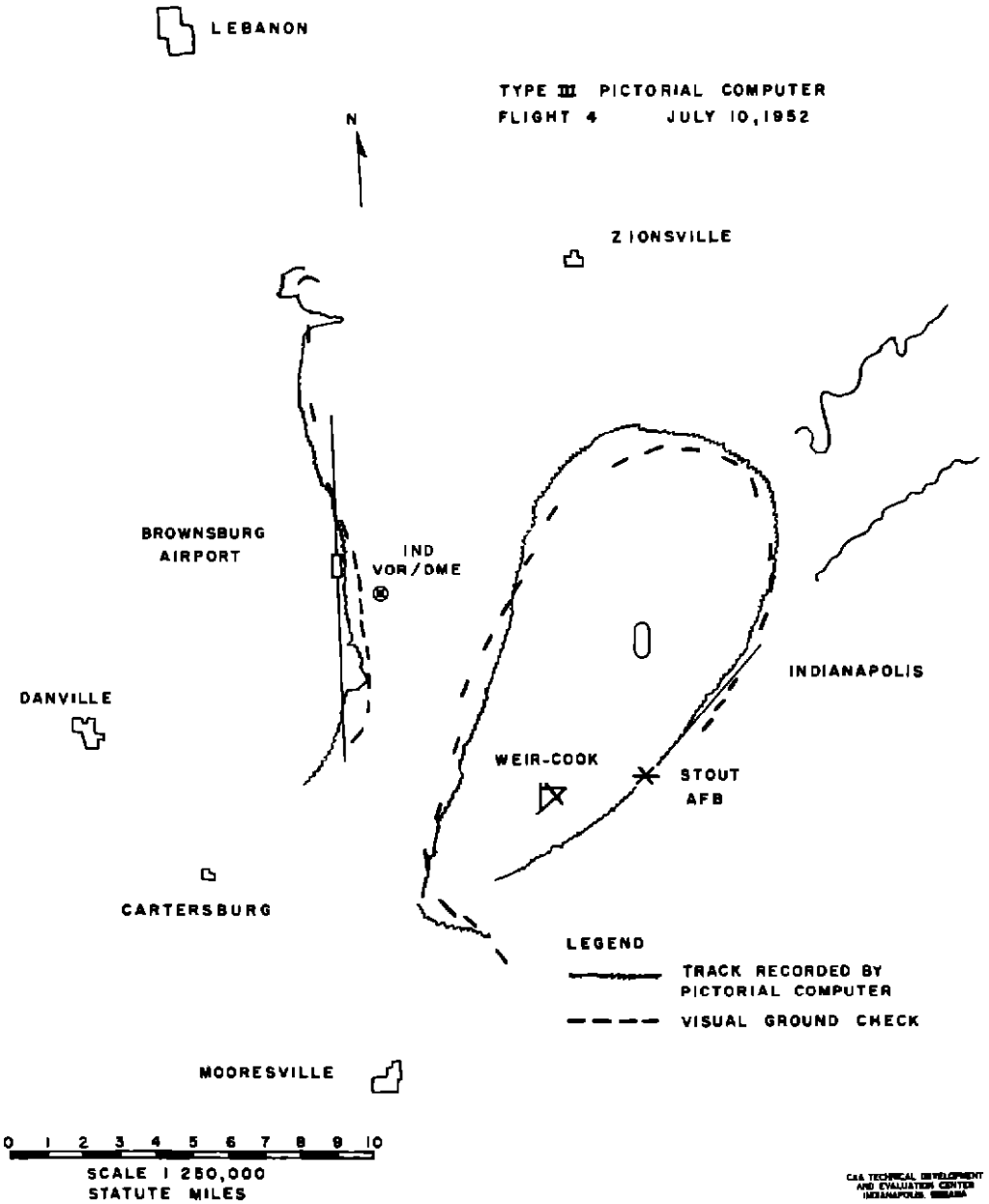

Fig. 15 Operational Flight Test No. 4, Departure No. 2, Low Approach Nos. 2 and 3

example on the 1 1,000,000 chart, Kisters Airport at Bloomington is apparently displaced two miles to the northwest compared to its position on the accurate-detail charts (A3928) prepared by the Coast and Geodetic Survey.

Additional study of the data to be shown on pictorial-display charts will be required. Where accurate navigation along specific tracks is required, it appears that these tracks should be shown on the chart to assist the pilot. Information on fan markers, other VHF ranges, and such factors is not considered essential on pictorial-display charts. Such information tends to clutter up the chart and to reduce readability of desired information. The

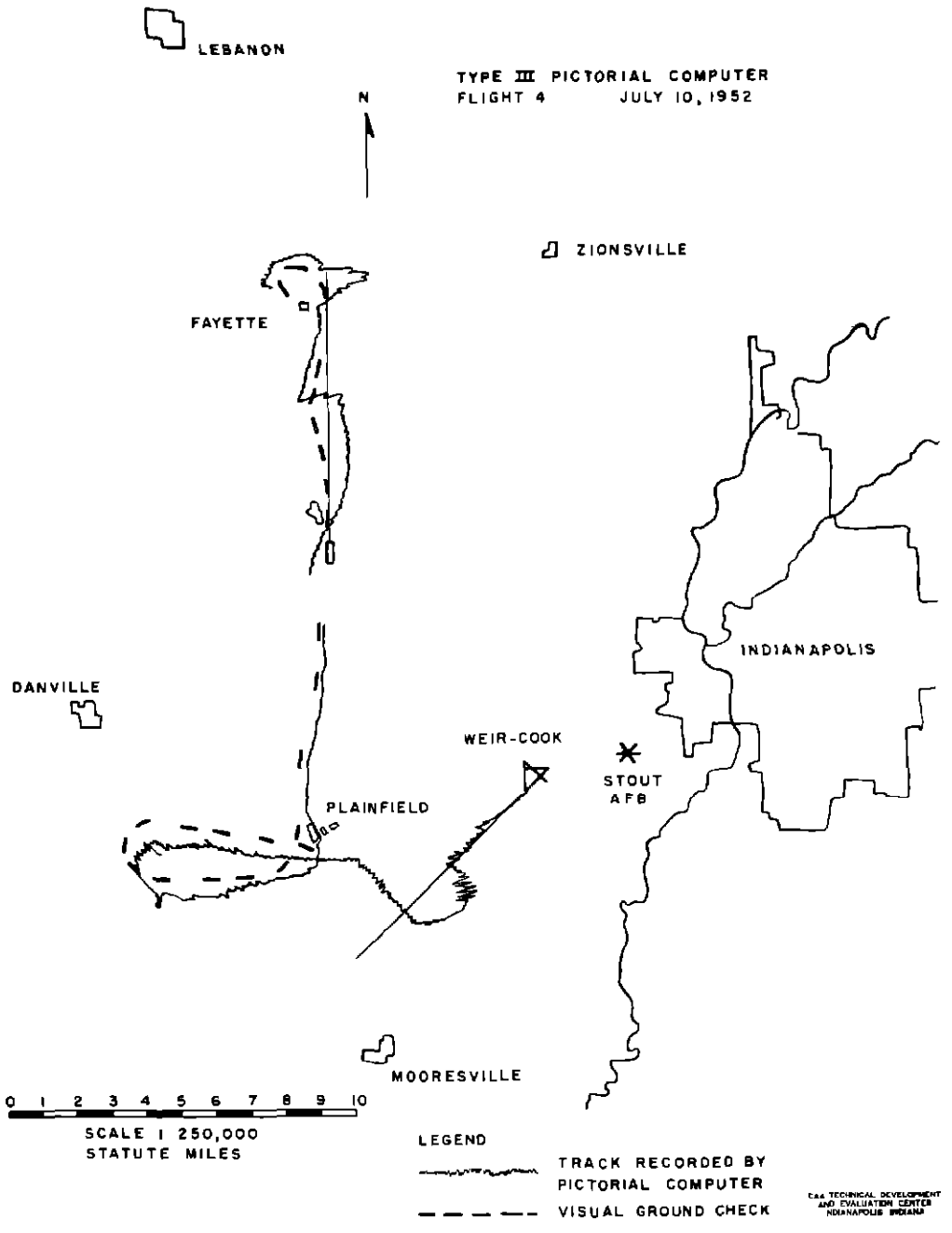

Fig. 16 Operational Flight Test No. 4, Low Approaches Nos. 4 and 5 and Holding Pattern

indication of topographical features should also be held to a minimum. Information on elevation of terrain would be essential in mountainous areas.

Charts should be color-coded or otherwise marked as to scale, with the scale-selector knob on the computer brought out to the top of the unit and similarly coded. The present location of the chart-selector knob is inconvenient for operation, and the knob setting cannot be checked readily for proper scale selection.

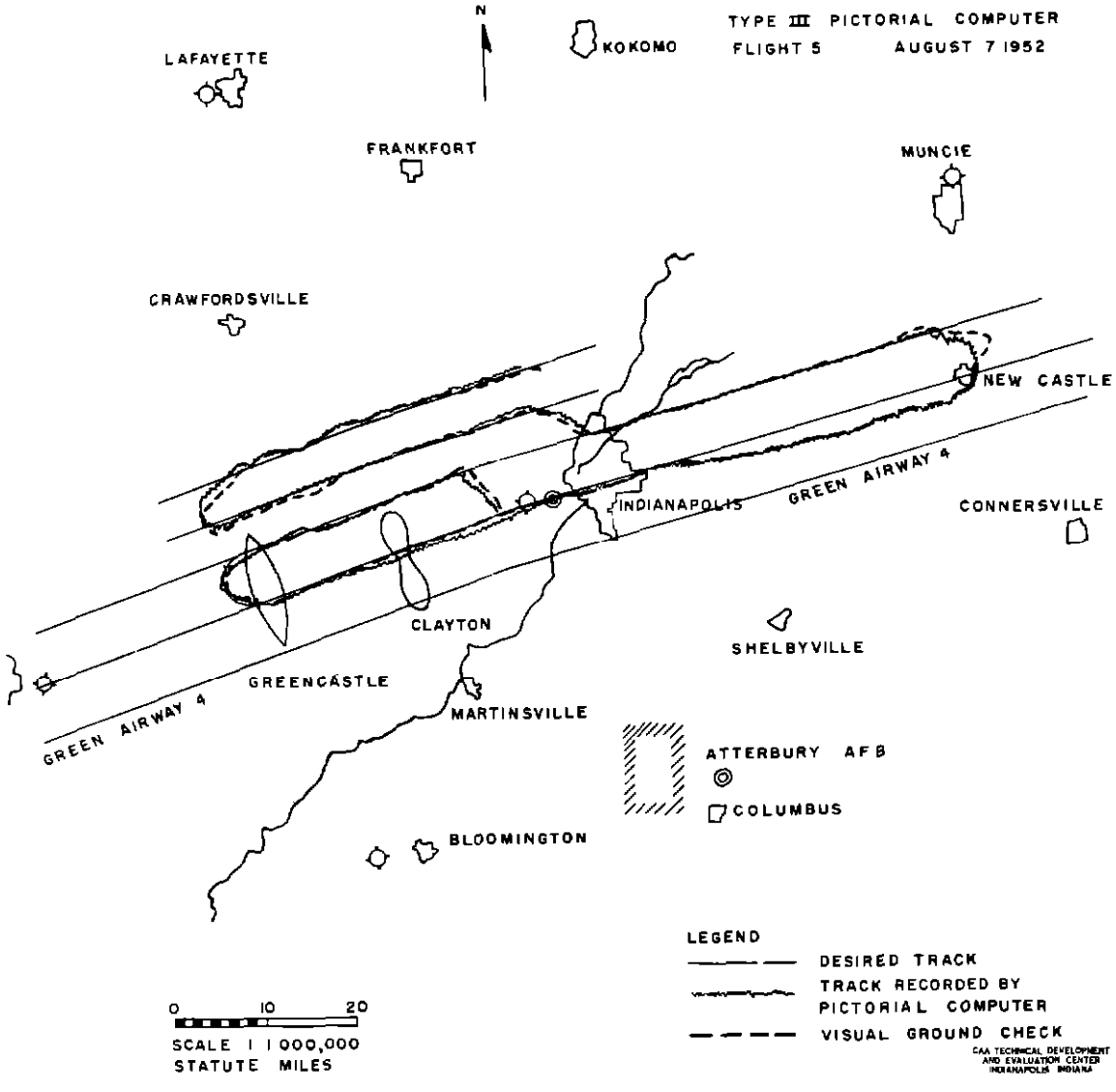

Fig. 17 Operational Flight Test No. 5, Parallel Tracks En Route Airway

The bridge assembly obscured the charts on the computer very much. It is believed that this assembly could be reduced in size and that all mileage marks could be eliminated on the plastic slider. Concentric mileage circles in very light printing could be added to the charts to provide the pilot with indications of mileage from the station.

CONCLUSIONS

On the basis of evaluation tests, it is concluded that the Type III Pictorial Computer used with OBD-system facilities

1. Furnishes navigation information to the pilot by continuously indicating the position of the aircraft directly on a chart.
2. Reduces the mental workload of the pilot when he is flying complex patterns, as compared to the workload incurred with the use of navigation data presented by conventional symbolic instrumentation.

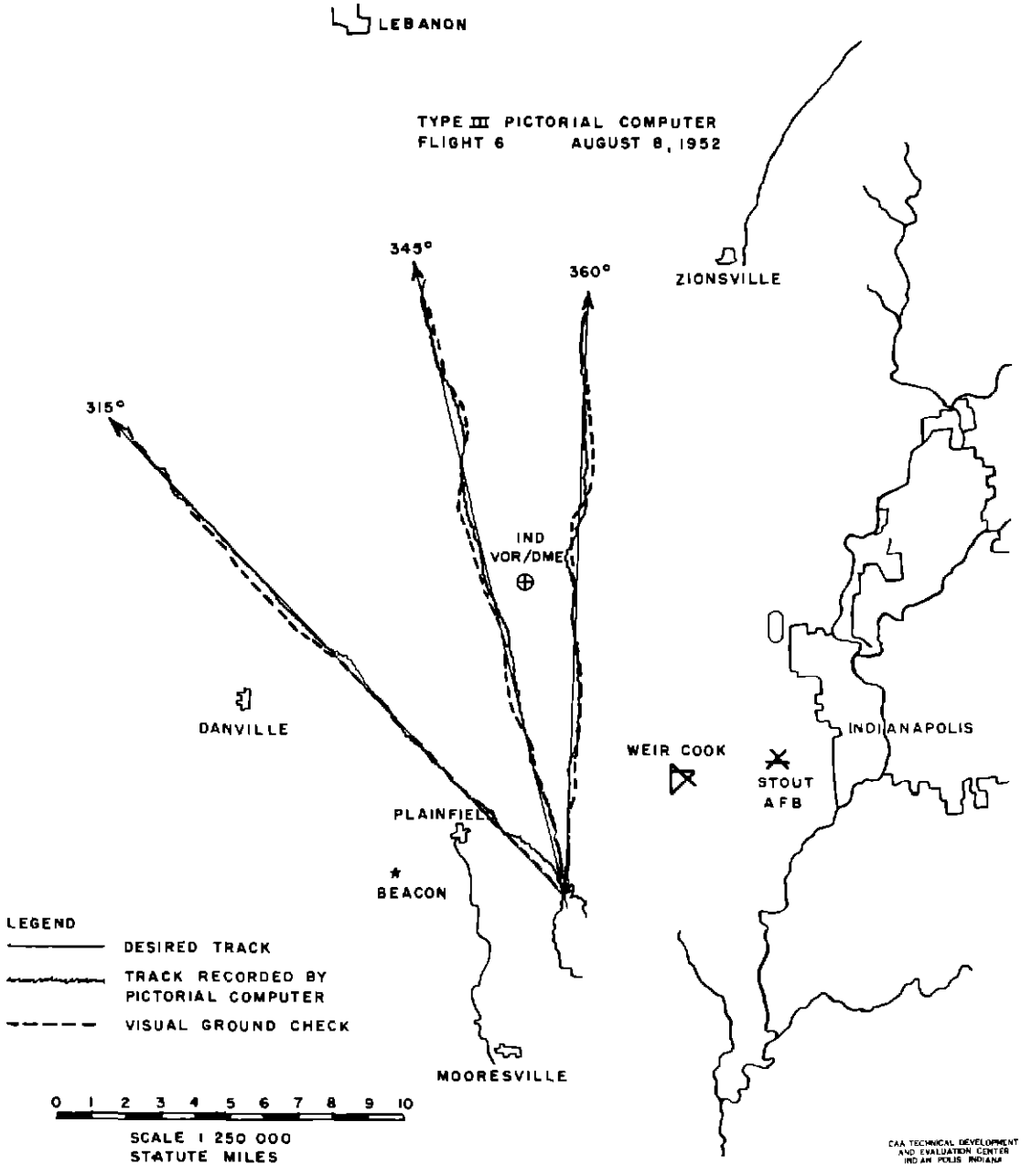

Fig. 18 Operational Flight Test No. 6, Angular Departure Tracks

3. Permits flight along any desired course without confining flight paths to radial courses from ground radio aids.

4. Permits navigation in all available airspace with a minimum number of ground radio aids to navigation.

5. Permits navigation to the general vicinity of any airport within radio coverage of OBD facilities with the inherent altitude-line-of-sight limitation of all VHF aids. Accuracy of navigation decreases with distance from the OBD facility.

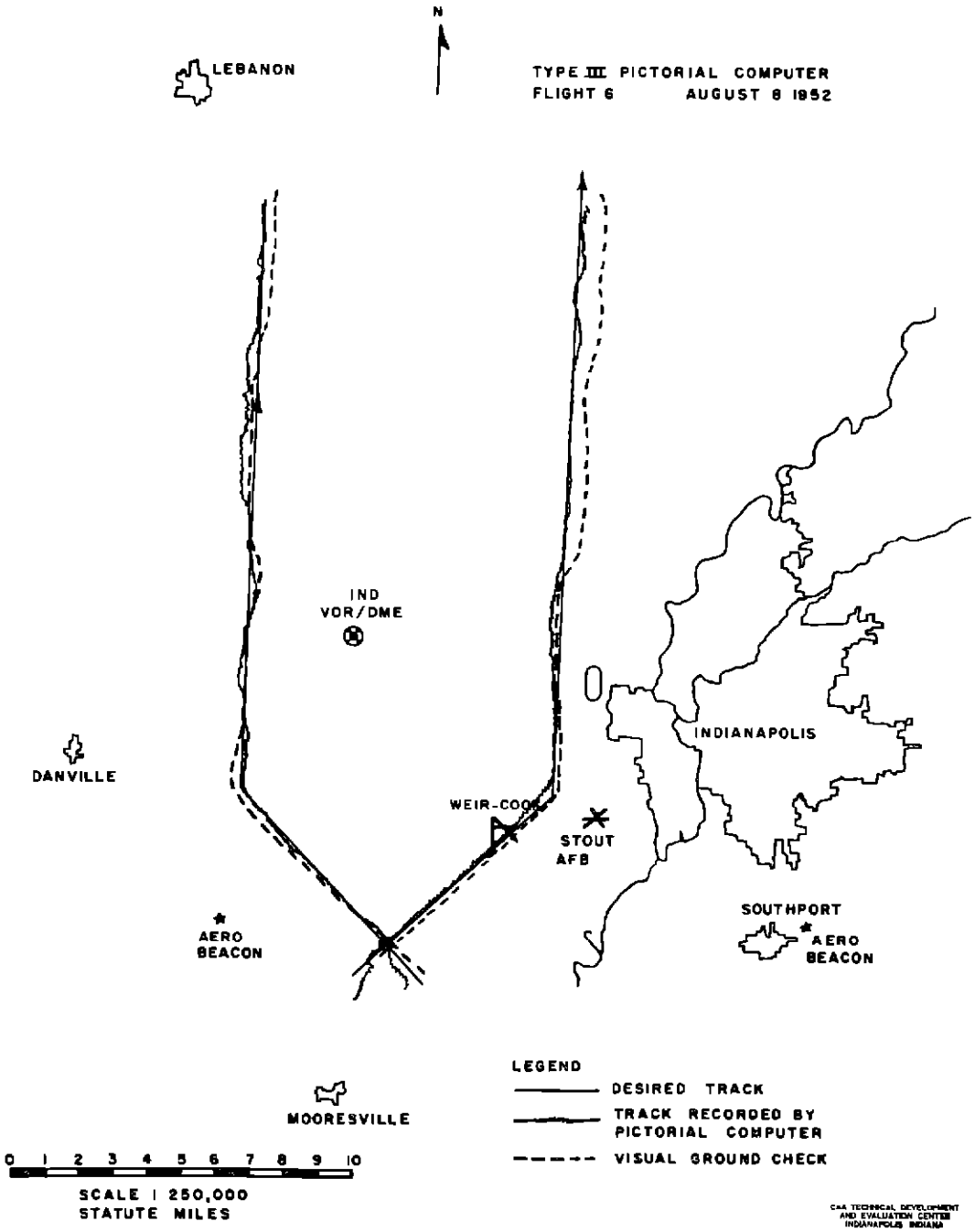

Fig. 19 Operational Flight Test No. 6, Parallel Departure Tracks

Concerning equipment characteristics, the following conclusions may be drawn.

1. Much difficulty was encountered in preparing the charts and in inserting them in the display unit to avoid the introduction of errors caused by displacement of the OBD station from the center of the instrument.
2. The position-indicating bridge obscures a large amount of chart detail.

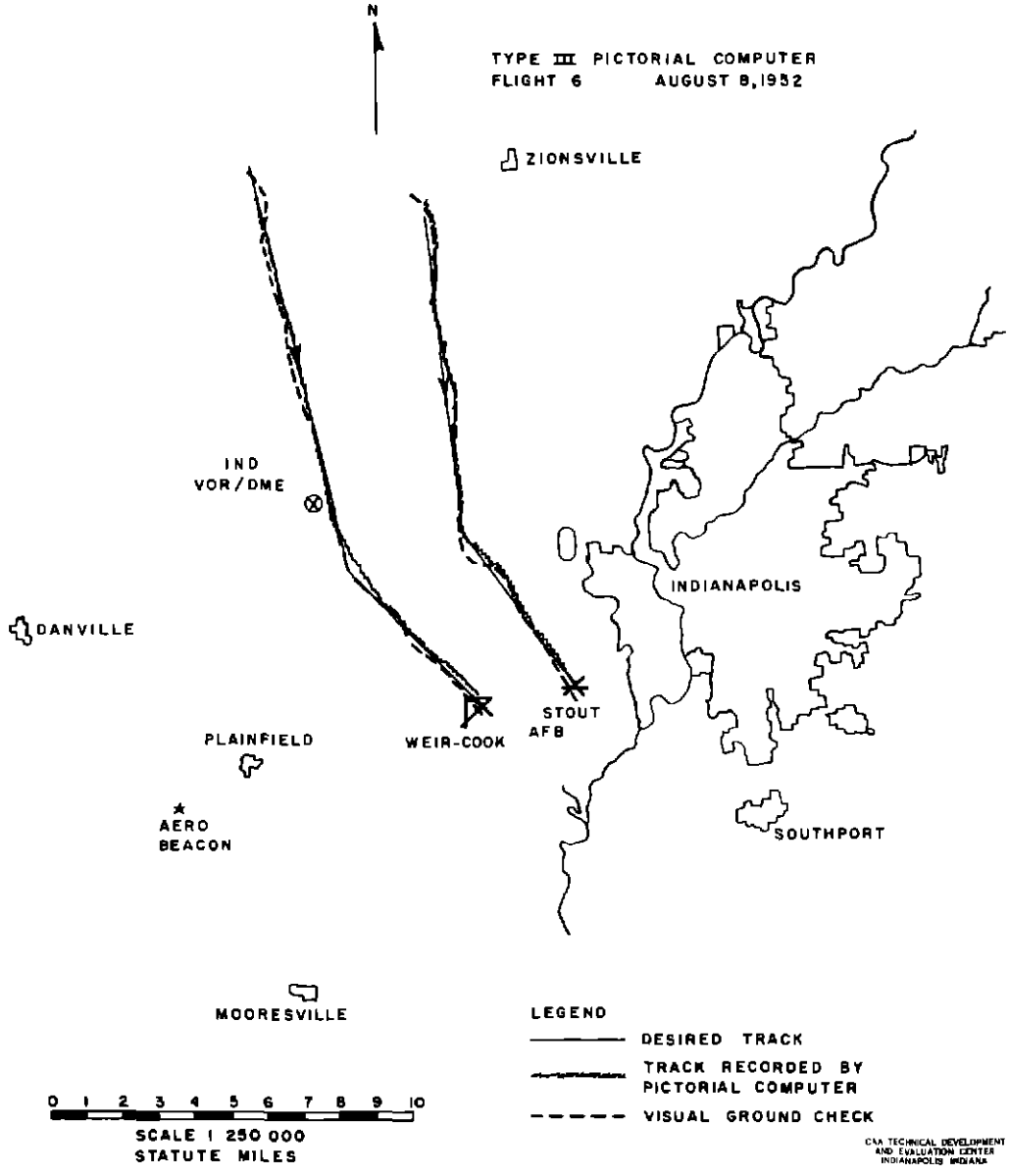

Fig. 20 Operational Flight Test No. 6, Low Approaches No. 1 and No. 2

3. It is not practical to consider the equipment as a lap-held device because the display unit generates excessive heat and restricts the movement of aircraft controls.

4. Heading information is desirable.

5. The tendency of the position-indicating slider to separate from the rest of the bridge assembly complicates chart-changing.

6. Although usable in its present form, the size and weight of the display could be appreciably reduced without the sacrifice of operating quality or of chart size.

7. Some device which assures the proper selection of a chart to match the chosen range scale is imperative.

8. Charts scaled to 1 500,000 are not necessary because the most expanded scale, 1 250,000, is required for terminal-area operation and the 1 1,000,000 scale suffices for

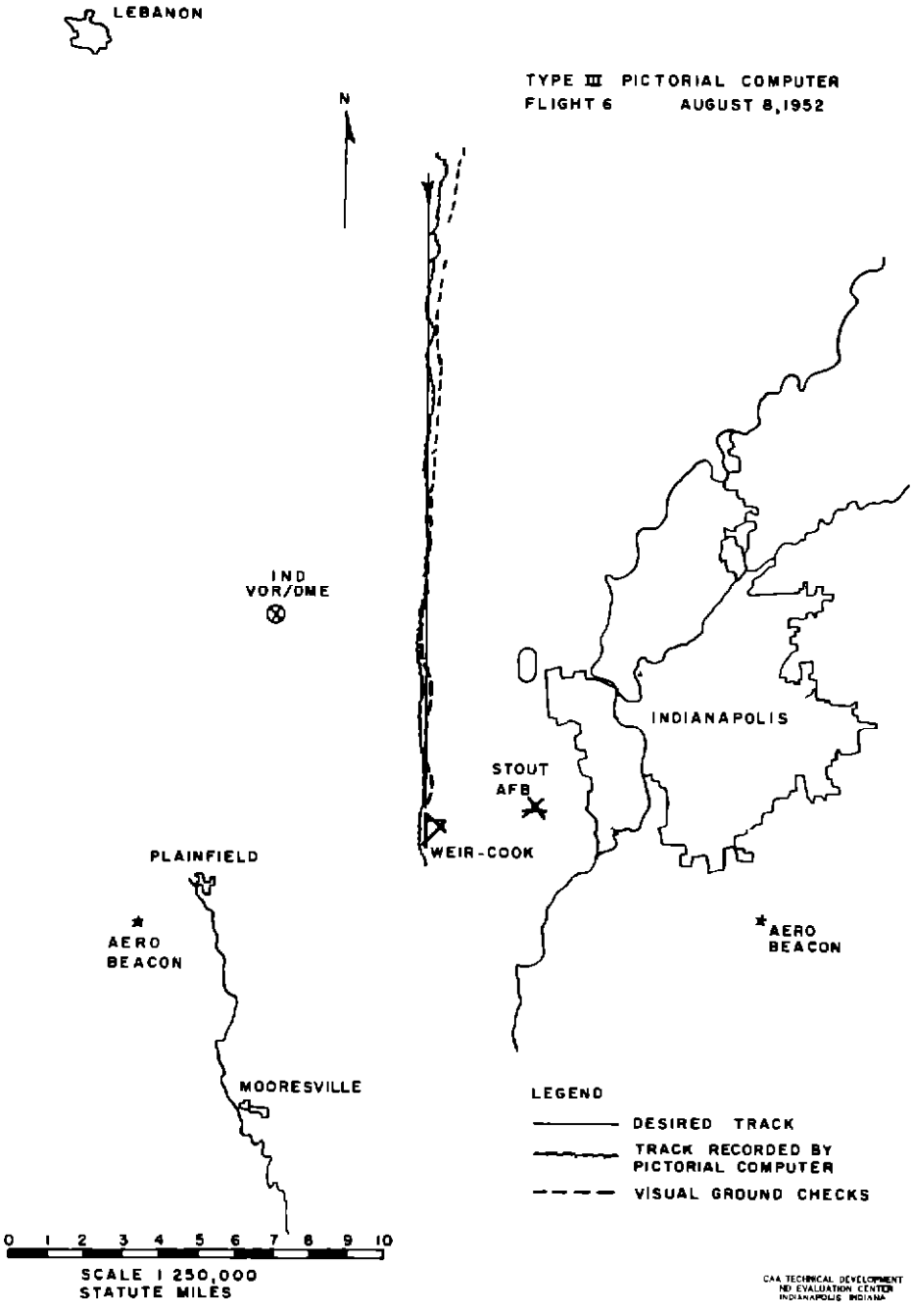

Fig. 21 Operational Flight Test No. 6, Low Approach No. 3

present en route navigation problems. However, in designing for modern high-speed aircraft applications, a range scale greater than a 60-mile radius may be desirable under some conditions.

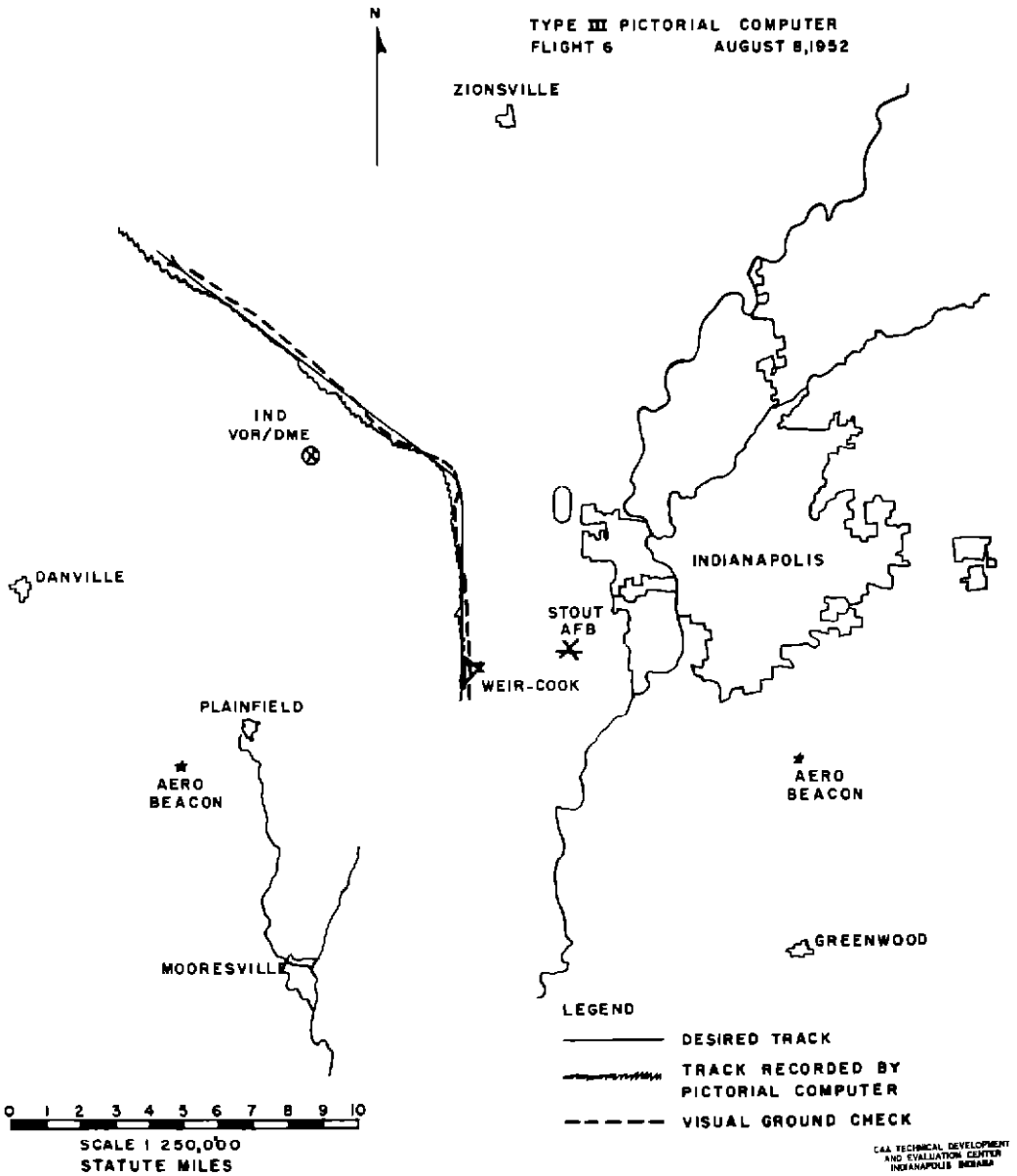

Fig. 22 Operational Flight Test No. 6, Low Approach No. 4

RECOMMENDATIONS

On the basis of tests conducted in this evaluation, it is recommended that

1. The scale-selector switch be mounted on the front of the display unit where the range in miles can be plainly seen.
2. The charts be printed with a large number 15, 30, or 60 to correspond to markings on the scale-selector switch, instead of using the present chart-identification system of 1 250,000, 1 500,000, 1 1,000,000.
3. The chart guides and the leaf clamps be replaced by two-position spring-loaded clamps to improve the ease and accuracy of chart orientation.

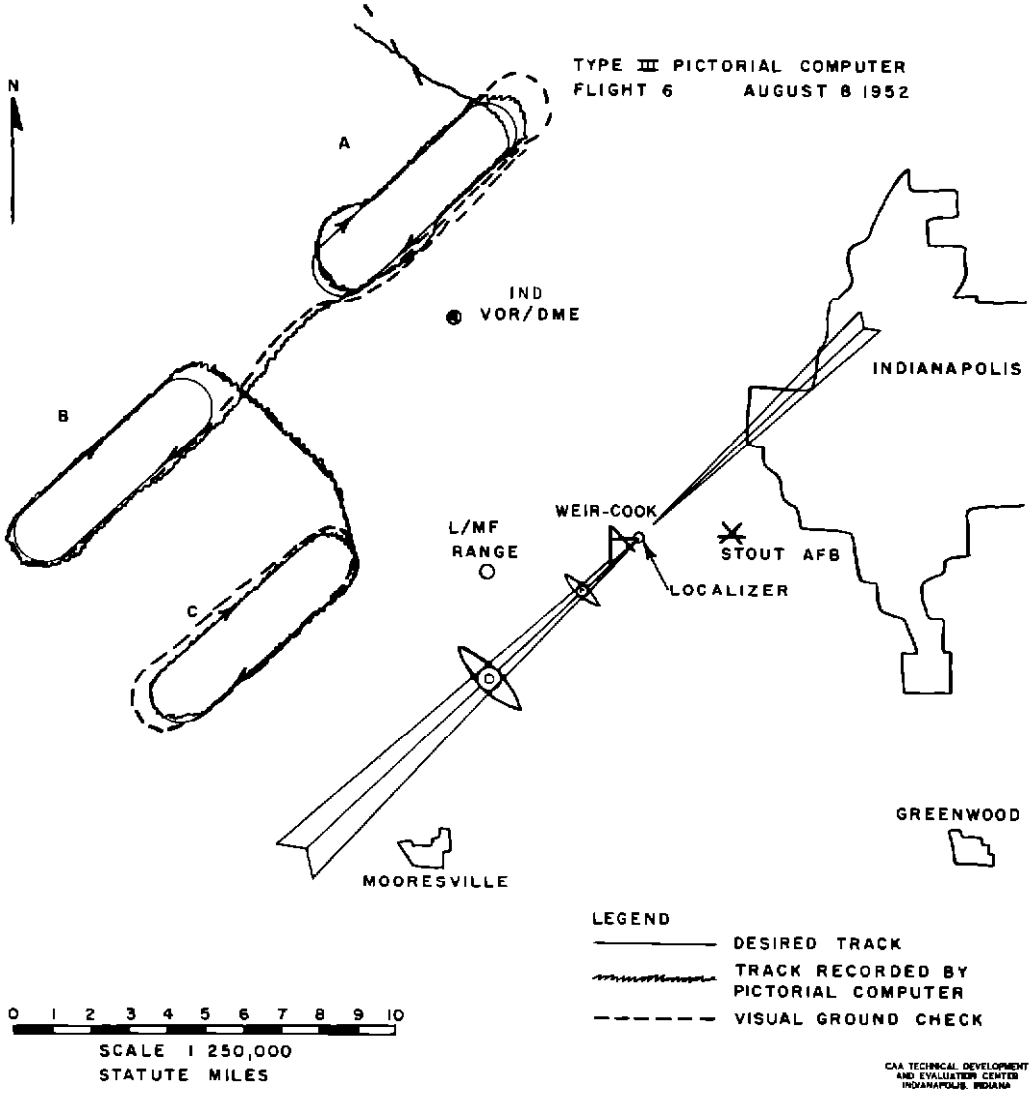

Fig. 23 Operational Flight Test No. 6, Adjacent Holding Patterns

4. The face of the display unit be equipped with a retractable pin-point projection at the OBD station to further facilitate accurate chart insertion.

5. The display unit be attached to a scissor-link extensible bracket-and-swivel device, so that the unit will be readily accessible for use or can be easily pushed out of the way when not required in order to provide a better solution to the mounting problem.

6. The miniaturization of components be considered in future developments in order to effect a reduction in size and weight.

7. The flag-alarm circuit be studied for possible redesign to incorporate fail-safe operation and additional ease of adjustment.

8. The position-indicating slider and the remainder of the bridge assembly have tongue-and-groove construction to prevent separation of the two units when the charts are changed.

9. The position-indicating slider be redesigned for easier reading to eliminate present detail and to substitute cross hairs in order to show aircraft position.

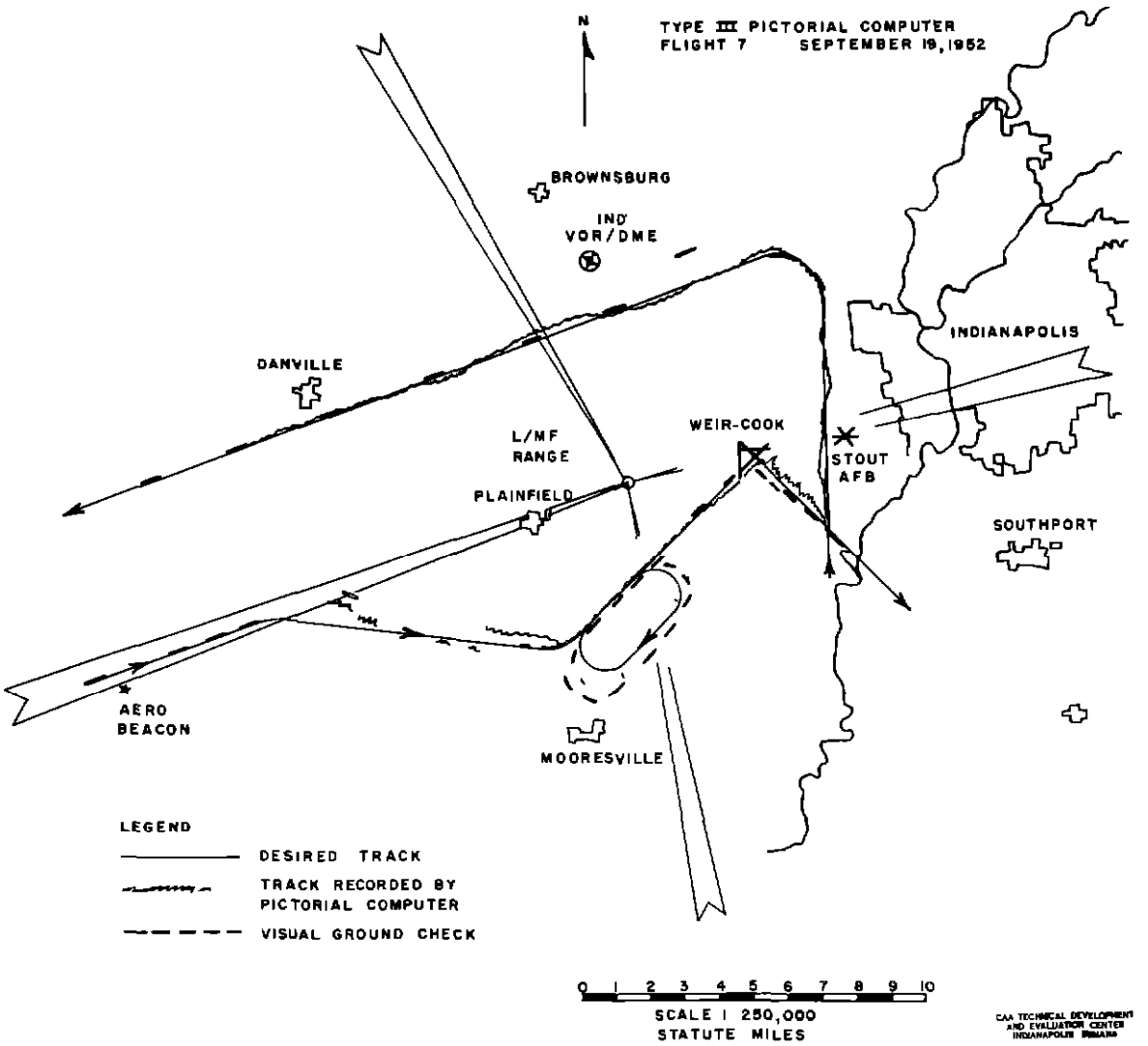

Fig. 24 Operational Flight Test No. 7, Terminal Area

10. Consideration be given to the operation of the display bearing indicator directly from the navigation receiver instead of through the OBI. The mechanical ranging circuits could also be moved from the DME interrogator to the display to obtain direct drive of the distance indicator. These modifications should improve the accuracy and should reduce the over-all weight and complexity of the OBD-computer system.

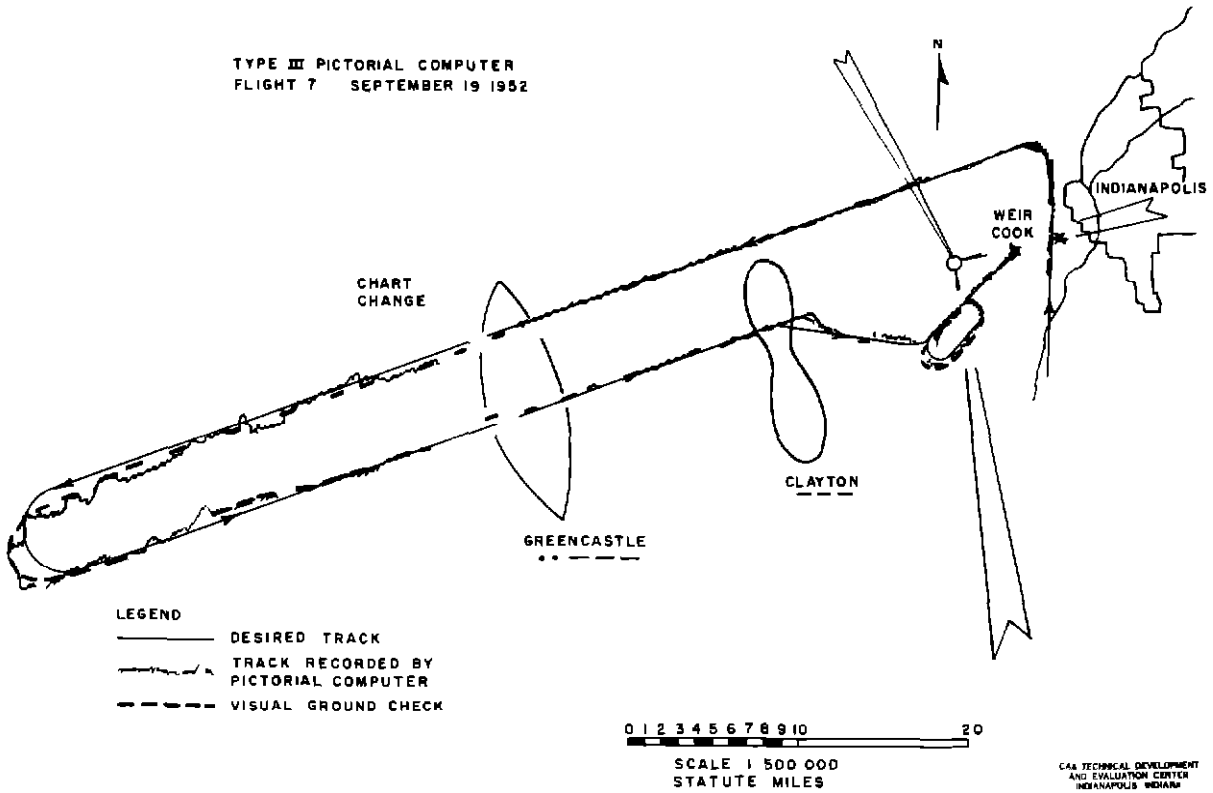

Fig. 25 Operational Flight Test No. 7, En Route Area

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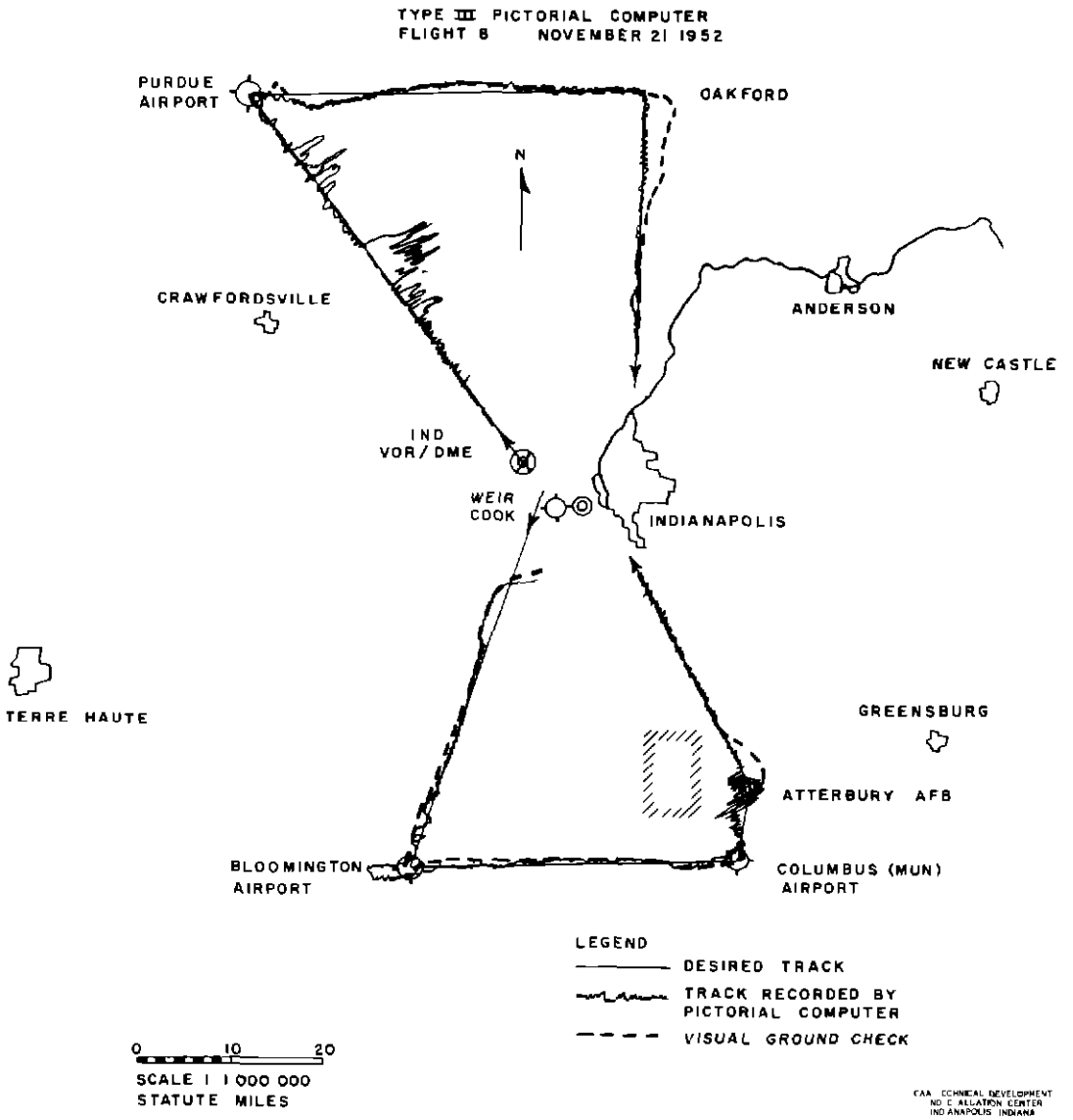

Fig. 26 Operational Flight Test No. 8, En Route Area

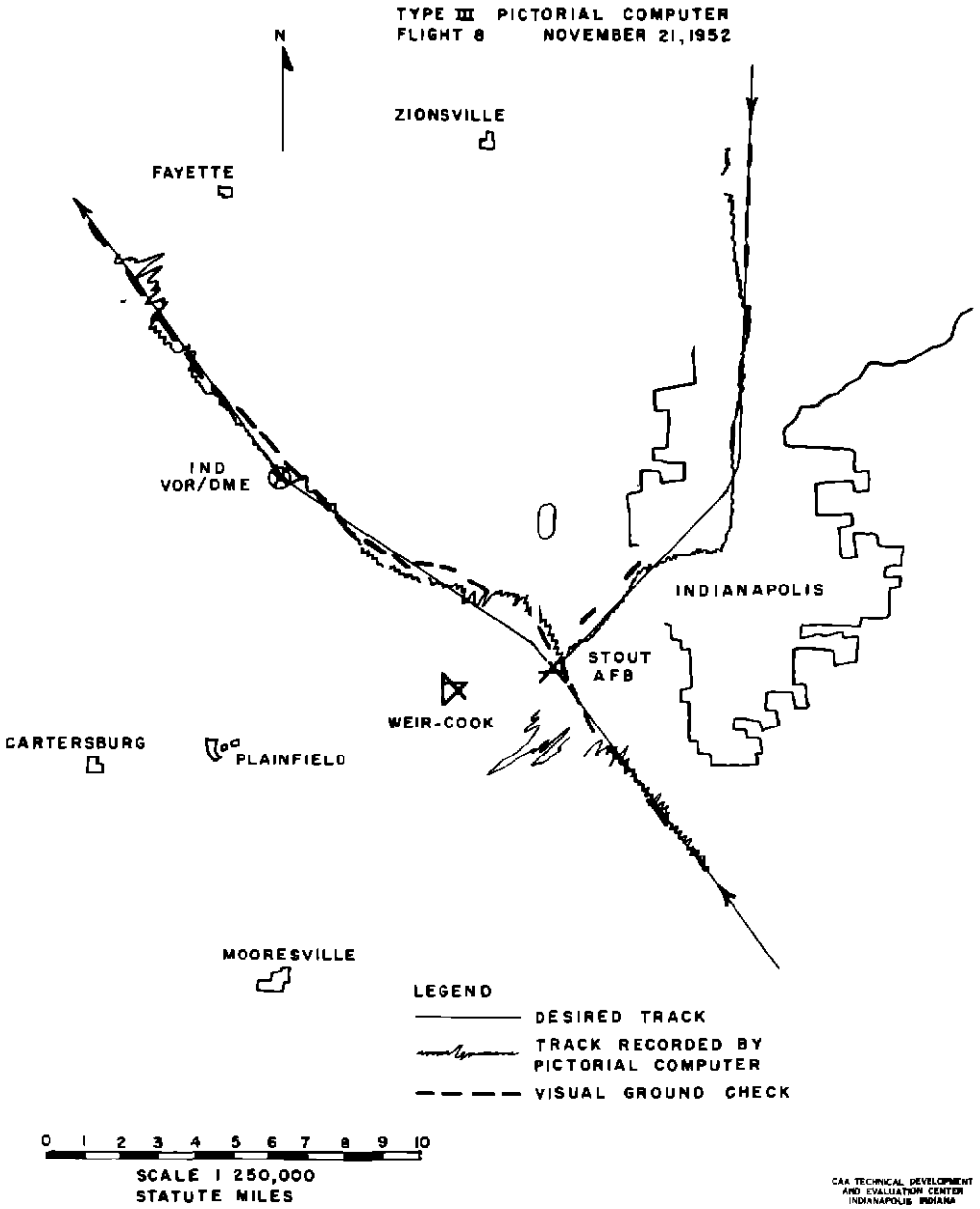

Fig. 27 Operational Flight Test No. 8, Terminal Area

GPO 809185-1