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THE TDEC COURSE LINE AND PICTORIAL COMPUTER PROGRAMS

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THE TDEC COURSE LINE AND PICTORIAL COMPUTER PROGRAMS

SUMMARY

This report presents a description of five course line computers and three pictorial computers which have been tested, or are under development, at the Technical Development and Evaluation Center. The development of the pictorial computers is being sponsored by the Air Navigation Development Board. The salient features of these computers are:

The First Course Line Computer

The first experimental course line computer required operator settings of course, course offset and waypoint distance. It included servos which followed omnibearing-distance (OBD) indications and furnished indications of course deviation and distance to waypoint.

The CAA Type I Course Line Computer

Equipmentwise and operationally, this was the simplest course line computer. Operator settings are course, destination distance co-ordinate and destination azimuth co-ordinate. The installed weight, less cables, is 30 pounds. In a redesign of this equipment (the CAA Type IA Course Line Computer) the control box is contained in a standard 3-inch aircraft instrument case.

The CAA Type II Automatic Flight and Navigation Equipment

This is a control equipment which includes a storage unit and a course line computer, and combines the controls for the navigation receiver, distance measuring equipment (DME), glide path receiver and automatic pilot into a single control box. Data for course line computer courses are prepared before a flight and are stored in a punched tape. It provides for automatic flight along consecutive course line computer courses and ILS courses.

The AN/ARA-21 Course Line Computer

This computer was made by Collins Radio Co. on contract with the Air Materiel Command, Dayton, Ohio, and was used by the Airborne Instruments Laboratory, Inc., Mineola, N. Y., during their evaluation of the OBD system. It operated on the principle that a vector distance could be represented by a vector voltage.

The CAA Type VI (Collins Type 560-A) Course Line Computer

This computer operates much like the CAA Type I Computer, except that it provides additional features of courses offset from the reference course and indication of direction to the selected waypoint. The control box features veeder-type settings for the co-ordinates.

The CAA Type III Portable Pictorial Computer

This is the first of the pictorial computers. The display is a portable unit 11 1/2 inches in diameter and weighing about 9 pounds. In the display, an aircraft position marker is positioned over a chart by servos controlled by OBD signals. It requires the operator to install a chart, tune the OBD equipment and set the scale of the distance servo to agree with the scale of the chart.

The CAA Type IV, Rotatable Panel Pictorial Computer

Two versions of this computer are being built. The first version will record the airplane's position on a heat sensitive chart paper, and provide for manually rotating the chart in the computer so that progress along the desired course may be up the chart. It is intended to be mounted in the instrument panel of an airplane.

The second version will include, in addition to the features of the first, a heading indication at the aircraft position marker, and provision for course line computer function.

The CAA Type V, Panel Pictorial Computer With Heading and Automatic Chart Changing

This computer will have capacity for 700 charts on 35 mm. film. These charts will be projected on a screen. The desired chart is selected by manually controlling a motor which changes the charts. A punching in the film contains data for OBD equipment tuning and computer scale selection. The airplane position marker will be surrounded by a reticle which will indicate distance and bearing to any point on the chart, and will have an arrow which will indicate airplane heading.

INTRODUCTION

With the conception of the distance measuring and omnirange equipments, it was realized that data were available to operate a device which would provide guidance and distance information to a point remote from the radio station and that such a device would be very useful. The DME and omnirange provide an airplane with a fix with respect to the radio station, but unless the course is along a radial to or from the station, there is no direct indication as to whether a desired course is being made good, or of the distance to a desired destination or waypoint. The course line computer was conceived as a device which would provide indications on the same instruments that are used with the DME and omnirange equipments to make good a straight line-course to any point remote from the station. The pictorial computer is a display of the aircraft position over a chart.

THE FIRST COURSE LINE COMPUTER

The first of the course line computers was developed by the

Minneapolis-Honeywell Regulator Co. on contract with the TDEC. The characteristics of this computer are set forth in a previously published report.[1] It was built for experimental purposes only, and fabricated of components immediately available without any consideration for weight or size. The computer, shown in Fig. 1, weighed about 75 pounds. Technically, it was very rudimentary. The data set up in the computer consisted of the bearing of the course, the perpendicular distance from the course to the omnirange station and the distance along the track from the foot of the perpendicular to the desired waypoint. This computer was extensively flight tested and the results of these tests are shown in the simplified map presentation of Fig. 2.

CAA TYPE I COURSE LINE COMPUTER

This computer, shown in Fig. 3, was designed and built at the TDEC. The setting in of the data on this computer was simplified in that, instead of setting in the perpenducilar distance from the course to the station and the waypoint distance, the polar co-ordinates of the destination with respect to the omnirange station were set into the Type I Computer. A functional schematic diagram and the geometry of the computer paths for this computer are shown in Figs. 4 and 5. This computer was installed in an airplane at TDEC in August 1948 and is still operable. The control box of this computer was approximately five inches in diameter and weighed about seven pounds. In a redesign (CAA Type IA, Fig. 6) the control box is contained in a standard 3-inch instrument case. When the Type IA computer is in operation, two control boxes will be mounted on the pilot's panel so that co-ordinates may be set into control box No. 1 while using box No. 2, and control is transferred from box No. 1 to box No. 2 when a waypoint set in box No. 1 is reached.[2]

CAA TYPE II AUTOMATIC FLIGHT AND NAVIGATION EQUIPMENT

This equipment was designed by TDEC engineers and is now in the process of construction. Fig. 7 is a photographic view of the computing unit. The equipment (shown by block diagram, Fig. 8) combines the outputs of the navigation receiver, glide path receiver, DME and gyrosyn compass. It performs the functions of the automatic approach control equipment and the course line computer, together with a punched tape data storage function for setting up predetermined courses and tuning the radio equipment. In addition, the control box provides controls for a modified C-1 autopilot. There are four indicators provided for the operator. These are the course deviation

[1]Francis J. Gross and Hugh A. Kay, "Initial Flight Tests and Theory of an Experimental Parallel Course Computer," Technical Development Report No. 83.

[2]Chester B. Watts, Jr. and Logan E. Setzer, "CAA Type I Course Line Computer." (This report to be published in the near future.)

indicator, DME distance to OBD station, omnibearing indicator and waypoint distance indicator. The control box provides a master power switch and engage button, a course number selector, a pitch control for the autopilot and the required alarm devices. The operator is given a chart of the courses which are set up in the storage unit, showing roughly the position of the courses and their assigned course numbers. In operation, the operator sets into the control box the number corresponding to the first course it is desired to fly. The airplane is flown manually until it is within range of the omnirange distance station which furnishes data for the first course. The engage button is operated. If the airplane is at a great distance from the first course, it will turn and fly approximately perpendicular to the course until it comes near to it (the crosspointer showing less than full-scale deviation). At that time the airplane will turn and bracket the course and fly along the course to the first waypoint. When the first waypoint is reached, the computer automatically advances to the next course in the sequence and the airplane proceeds along the new course. This is continued until the flight is terminated either in a holding pattern or in an automatic approach to the runway. The holding patterns are formed by having two parallel courses laid out quite close together. At the completion of the second course, the storage tape, instead of advancing to the next sequence number, moves backwards to the last course so that the airplane flies the last two courses alternately in a holding pattern. All data for the operation of this computer, except the selection of the initial course number and the operation of the pitch control knob, are calculated before the storage tape is prepared. Punchings in the storage tape contain the following information for each course:

1. Course number.
2. DME tuning data.
3. Navigation receiver tuning data.
4. Computer setting data, consisting of:
    a. Course.
    b. Waypoint azimuth co-ordinate.
    c. Waypoint distance co-ordinate.
5. Kind of course:
    a. Course line computer course.
    b. Automatic approach on localizer and glide path.
    c. Magnetic course for the autopilot without reference to the radio equipment.
6. Whether the course is the second course in a holding pattern.
7. In the case of automatic approaches:
    a. Glide path receiver tuning data.
    b. Type of ILS localizer (phase comparison or tone).

Also, the storage unit has capacity for information to use in automatically selecting charts in the CAA Type V Panel Pictorial Computer With Automatic Chart Changing.

THE COLLINS COURSE LINE COMPUTERS

The Collins Radio Co. of Cedar Rapids, Iowa, has built two models of course line computers. Their first model, shown in Fig. 9, the AN/ARA-21(XA-1) Automatic Electrical Computer, was built on contract with Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio. It was designed on the principle that each vector component of the navigation triangle can be represented by a vector voltage. That is, the destination distance co-ordinate consists of a direction and distance. A voltage is generated in the AN/ARA-21 computer, the phase of which represents the direction component, and the amplitude of the voltage represents the distance component of the destination distance co-ordinate. This voltage is added vectorially to a voltage which represents the omniDME vector, and the resultant is fed to a resolver which gives the course deviation and waypoint distance components. This computer was extensively tested by Airborne Instruments Laboratory, Inc. during their evaluation of the OBD system.[3] Tests on this computer also were conducted at TDEC. Much difficulty was experienced in the maintenance of this computer, and the design was abandoned in favor of one more like the Type I Computer.

The CAA Type VI (Collins Type 560A-1) Course Line Computer, Fig. 10, was built on contract with TDEC. Its operation is about the same as the Type I. See Figs. 11, 12 and 13. However, it provides for offset courses which are parallel with the basic course but displaced either to the right or to the left of the basic course by units of 5 miles from 0 to 30 miles. Also, it provides an indication of the direction to the waypoint in addition to the distance and deviation from the selected course. The arrangement of the control box is a considerable improvement over the Type I computer. The distance-to-waypoint indicator is a counter-type indicator and includes a flag alarm which indicates malfunctioning of the computer power supply and failure of the servos to reduce the input signals to a small value.

SUMMARY OF FEATURES OF A CHART DISPLAY BASED ON OBD INFORMATION

In preparing specifications for the three pictorial computers, consideration was given to the results of tests of pictorial and symbolic VOR displays conducted at the University of Illinois.[4] Also the matter was discussed with personnel of the Aero Medical Laboratory, Wright-Patterson AFB and Special Devices Center, Department of the Navy, Port Washington, L.I., N. Y. As a result, a list of features that could be incorporated in pictorial computers was prepared, and the specifications were written so as to

[3]Final Report on evaluation of Omni-Bearing-Distance System of Air Navigation; Report No. 540-2, October 1950, Airborne Instruments Laboratory, Inc., Mineola, L. I., N. Y.

[4]Roscoe, Smith, Johnson, Dittman and Williams, "Comparative Evaluation of Pictorial and Symbolic VOR Navigation Displays in 1-CA-1 Link Trainer," CAA, Division of Research, Report No. 92, Washington, D. C.

include as many of the most desirable features as was possible. A list of these features, identifying the computer in which they are incorporated follows:

1. Orientation of Chart.
   1.1 North up - Types III and V.
   1.2 Manually rotatable, course up - Type IV.
   1.3 Servoed heading up.
2. Mounting.
   2.1 Portable - Type III.
   2.2 Panel mounted - Types IV and V.
   2.3 Pedestal mounted - Type IV (possibly).
3. Heading Display.
   3.1 At airplane position - Types IV and V.
   3.2 At periphery of chart.
   3.3 Omitted - Types III and IV.
4. Airplane Position Indicator.
   4.1 Must be non-directional in character unless heading is displayed - Types III and IV.
   4.2 With distance circles and magnetic direction radials - Type V.
   4.3 With small compass rose and heading arrow - Types IV and V.
5. Relative Motion.
   5.1 Chart fixed and centered on omnirange DME station - Types III, IV and V.
   5.2 Airplane in center of display, chart servoed.
   5.3 OBD station in center, chart servoed to maintain heading up.
   5.4 Others.
6. Method of Recording Track.
   6.1 Facsimile paper for charts.
   6.2 Heat sensitive paper for charts - Type IV.
   6.3 Marking of position by operator - Types III and V.
   6.4 Ink records of track.
7. Preparation of Charts.
   7.1 Individual charts cut from sectional aeronautical charts and manually inserted in computer - Types III and IV.
   7.2 Charts printed on a long roll and cranked into position.
   7.3 Charts photographed on film and projected on a screen.
      7.3.1 Individual charts for each scale of each area, manually inserted.
      7.3.2 One large film moved each time a new omnirange station is selected.
      7.3.3 One large film servoed about airplane in center of display.
      7.3.4 Same as 7.3.1, except charts on a roll and roll electrically operated to find desired chart - Type V.
      7.3.5 Same as 7.3.1, except charts automatically selected from call letters set up on three dials - Type V may be modified to include this feature.

8. Automatic Tuning of Radio Equipment.
   8.1 Frequency information must be included on chart so as to convert from call letters to frequency - Type V.
9. Use: To be evaluated.
   9.1 As navigation instrument - Types III, IV and V.
   9.2 As flight instrument.
10. Size of Display. Ten-inch diameter was about the maximum for experimental units.
11. Course Line Computer - Type IV.

As soon as the pictorial computer program was well under way, the Coast and Geodetic Survey was requested to prepare eight special sample charts (four scales each for the Indianapolis and Terre Haute omnirange sites) for use in the pictorial computers. The scales to be used are 1:250,000 (approximately 4 statute miles per inch), 1:500,000 (approximately 8 statute miles per inch), 1:1,000,000 (approximately 16 statute miles per inch) and 1:2,000,000 (approximately 32 statute miles per inch). Two of the charts have been completed and are shown in Figs. 18 and 19. These are Indianapolis (scale of 1:500,000) and Terre Haute (scale of 1:1,000,000).

Some features considered in compiling these charts were:

1. Sites to be used for the sample charts
2. Scale
3. Topographic features
4. Cultural features
5. Radio facilities
6. Airway facilities
7. Plotting aids

CAA TYPE III PORTABLE PICTORIAL COMPUTER

General

This computer is being manufactured by Aero Electronics Co., Chicago, Ill., on contract with TDEC. The development is sponsored by the Air Navigation Development Board. It is shown in Figs. 14 and 15.

The Portable Pictorial Computer is an automatic, electro-mechanical airborne instrument for continuously indicating on a chart the position of an airplane, its distance and bearing from an OBD station. The computer receives all the necessary data from the OBD station via an omnirange receiver and a DME.

The instrument consists of two principal units: The display unit and the amplifier unit. The size and weight of the display unit have been kept to a minimum in order that it may be held in the pilot's lap, or mounted on the instrument panel or the bulkhead of the airplane.

Display Unit

The display unit consists of a fixed circular chart holder, the airplane position marker assembly and a servo-drive mechanism. The chart holder accommodates special aeronautical charts of 10-inch diameter. The location of the OBD station appears at the exact center of these charts. The airplane position-marker assembly consists of a scale which slides in a guide extending diametrically across the chart holder and can rotate on its surface. A small hole at one end of this scale marks the location of the airplane. An ordinary lead pencil can be inserted into this hole to mark the position of the airplane at any time, or to trace the airplane's course. Graduations extending from the center of this hole along the scale indicate the distance from the airplane to the center of the chart, i.e., to the OBD station. The bearing to the ground station is indicated by a 360-degree azimuth scale engraved on the chart holder and by hairlines at the two ends of the rotatable guide.

Amplifier Unit

The amplifier unit contains two servo amplifiers with their power supplies, a flag alarm system for causing the flag of the course deviation indicator (a component of the navigation receiver) to come into view in the event of failure of the equipment and an automatic cut-out system for stopping the airplane position marker. The flag alarm system warns the pilot whenever failure of the 110-volt, 400-cps supply, the 28-volt, dc-power supply or the B+ voltage in amplifiers occurs; or if the error of omniservo system exceeds ±3 degrees, or the error of the DME servo exceeds ±2 miles. The automatic cut-out system stops the airplane position marker whenever the airplane flies beyond the range of the chart; and automatically resumes plotting when the aircraft comes back within range.

Controls

The Portable Pictorial Computer is completely automatic and has only two controls: The on-off switch and the map-scale selector. The latter must be set to correspond to the scale of the chart at the time the chart is selected.

Operation

Navigation of an airplane equipped with a Portable Pictorial Computer is similar to ordinary navigation using landmarks, except that it is no longer necessary to manually track the flight path on the map. In the event that the airplane flies off the chart, the next OBD station along the flight path must be tuned in and a new chart put in the display unit. This is accomplished simply by swinging the airplane position-marker assembly to one side, removing the old chart, putting in a new chart and replacing the marker assembly. The map-scale switch also should be checked to see that its setting corresponds to the scale of the new chart. Should the airplane fly beyond the reliable distance range of the OBD station concerned, or should the computer error become excessive for any reason, a flag of the course deviation indicator will immediately warn the observer that computer indication is not correct. Thus, there is little chance that the pilot will follow an incorrect path.

Accuracy

The range accuracy is ±0.4 nautical mile on all scales except the 1:2,000,000 scale. The bearing accuracy is ±1/2 degree or 1/32 inch, whichever is the greater.

Size and Weight

The display unit weighs 8 3/4 pounds. Its over-all dimensions are 11 1/2 inches in diameter and 3 3/4 inches high. The amplifier unit is built in a standard S-2 case and weighs, approximately, 12 pounds. It is to be mounted in the airplane communications rack.

CAA TYPE IV ROTATABLE PANEL PICTORIAL COMPUTER

General

The CAA Type IV Rotatable Panel Pictorial Computer is being designed and manufactured by Sperry Gyroscope Co., Great Neck, L. I., N. Y. on contract with the TDEC. The development is sponsored by the Air Navigation Development Board. This instrument is also designed to facilitate flying on the OBD radio navigation system. It combines a recording map indicator with a course line computer.

Five experimental units of the computer are being produced for flight test and evaluation. Three of the five units are "combined" models which include heading indication and course computation with the map indicator. The other two units consist only of the recording map indicator.

Indications

With the Pictorial Computer the position and track of an airplane can be observed on a map of the terrain surrounding an OBD station. During flight, the recording map indicator, shown in Fig. 16, continuously plots the ground track of the airplane on the map. The position of the recording stylus on the map corresponds to the aircraft position over the terrain. Thus, the position of the airplane can be seen in relation to the OBD station and the landmarks which normally would be seen on the terrain during clear weather. The track scribed on the map serves as a memory by recording the maneuvers of the airplane.

In the combined versions of the Pictorial Computer, a small steel arrow mounted on the stylus indicates the heading of the airplane relative to the track and the desired course. This indication of relative heading aids in orienting the airplane, compensates for wind effects, brackets a designated course or flight path and executes other maneuvers on the map.

The course computer included in the combined model of the instrument calculates (1) the airplane's deviation (distance off-course) to the right or left of any selected course set on the map, and (2) the distance to go along the course to the selected destination. Right-left deviation and distance-to-go are displayed on suitable meters or indicators on the instrument panel in the cockpit. The right-left deviation signal calculated by the computer also can be used to operate an automatic pilot through a suitable coupler circuit. When coupled to the right-left deviation signal from the computer, the autopilot will fly the airplane automatically along the selected course set into the computer.

Description

The CAA Type IV Rotatable Panel Pictorial Computer requires a rectangular space 15 1/4 inches wide by 12 inches high. It is expected to weigh approximately 15 pounds and extend not more than 9 inches behind the face of the panel.

A circular opening on the face of the computer contains a map ten inches in diameter. The center of the map represents the location of the OBD navigation station. Distance and bearing information from the OBD station actuate a driving mechanism which moves the track writing stylus across the map in synchronism with the motion of the airplane over the terrain.

The transparent plastic arm which carries the stylus is pivoted on a shaft which is mounted off the map and behind the panel. This arrangement permits the arm to move off the map and out of sight so that it will not interfere with the insertion and removal of maps.

The map table is covered by a hinged plastic window. When the window is opened to change maps, an interlock switch causes the stylus and arm to move off the map automatically.

Recording Maps

Maps used with the indicator are specially prepared. Maps are printed on heat-sensitive recording paper, cut to the exact circular size and mounted on metal backing discs. The discs are notched so that they will index automatically with corresponding points on the map table when they are inserted in the indicator. Changing maps requires only a few seconds.

Tracks are recorded permanently on the map by a simple dry process. The stylus consists of a fine wire which is always in contact with the surface of the map. When the wire is heated by an electric current, the point of the stylus instantly develops an intense hot spot on the white surface of the map. As the stylus moves over the map, the spot generates a permanent black line which represents the ground track of the airplane. Printing of tracks by the stylus can be stopped at any instant by turning off the current which heats the stylus point.

A knob on the indicator panel changes the indicator scale to correspond with the map scale, and must be set when maps are changed. Other controls on the panel around the map table are a switch for turning the instrument on or off, and a dimmer control for adjusting the illumination of the map. Additional controls are provided on the combined models of the computer for setting in data to operate the course computer.

Course Computer

Bearing and distance data received from the OBD station and heading data received from a gyrosyn compass are amplified in electronic servo units to drive the map indicator mechanism. This mechanism consists of a gear train and the elements of the course computer. The electronic servo units serve only to amplify the input data. All course computation is done by electro-mechanical means. Addition, subtraction and multiplication functions are done mechanically. Trigonometric functions are handled by means of small electrical resolver units.

In addition to operating on the data received continuously during flight from the OBD station, the computer depends upon initial data set in by the pilot to define his course and destination. This data consists of the magnetic direction of the course, the omnibearing of the destination and the distance of the destination from the OBD station. Knobs and dials for setting in this data are located on the panel around the map table. The knob for setting in course direction rotates the map table until the course runs vertically from the bottom to the top of the map. Course direction is indicated on an azimuth ring around the periphery of the map table. Distance and bearing of the destination are set in on dials located on the panel. A switch is provided for operating the instrument either as a simple map indicator or as a combined indicator and computer.

Alarm Indicator

A small opening on the panel contains a flag alarm indicator similar to the flag alarm on the standard flight-path deviation indicator. When the computer is operating and the necessary input data are being received properly, the alarm flag is not visible through the window. If a failure occurs, the alarm flag becomes visible and reads OFF. At the same time, the stylus stops recording its trace, although the tracking arm may still continue to move. The alarm circuit prevents the stylus from recording incorrect data on the map. The flag will appear when (1) a large error signal is present at the input of any servo amplifier, (2) the VOR receiver is inoperative or its signal is below normal, (3) when the DME stops tracking, or fails or begins to search for the range pulse and (4) failure of the various power supplies which would affect the accuracy of the information given by the computer.

Map Indicator Operation

Using the simple version of the Pictorial Computer, which consists only of the recording map indicator, requires no advance preparation other than having the necessary maps aboard the airplane. To use the map indicator, the desired OBD station is tuned in, the appropriate map is inserted on the map table and the scale selector is switched to the scale of the map. When the plastic window is closed, the tracking arm moves over the map and positions the stylus at the point where the airplane is presently located over the terrain. When the tracking switch is turned on, the stylus begins recording the track of the airplane on the map.

The stylus moves over the map wherever the airplane flies. To fly an airway marked on the map, the airplane is flown so that the stylus intercepts the airway and then turns so as to plot a track along the airway. The next map must be inserted on the table when the stylus approaches the edge of the first map. To change maps, the window is opened and the tracking arm swings out of the way automatically. The old chart is lifted off, the new one is laid on, the window is closed and the new OBD station is tuned in. The stylus takes up its tracking on the new map at a point which corresponds to where it left off on the old map.

With small scale charts, such as planning charts of 16 miles/inch scale, map changes occur relatively infrequently in the average civil airplane. Flying at 160 mph, the maximum straight-line flying time between map changes on a planning chart in the indicator is 60 minutes. At 240 mph, the time is approximately 40 minutes. Maximum straight-line flying time occurs when the course runs through the center of the map. Most straight-line courses along civil airways will go through or near the center of the map because installation sites of the OBD stations are planned to be on or as near as convenient to the center of the airways.

Tracking rate of the stylus is so slow that its motion is barely perceptible. Tracking rate depends upon the speed of the airplane and the scale of the chart. Only when flying at high speeds and using large-scale charts does the stylus have any appreciable motion. On an approach chart, 300 mph ground speed moves the stylus at a rate of 48 seconds per inch or about 2/100 inch per second. On a section chart the rate is one-half of this and half again on a planning chart. A ground speed of 180 mph on an approach chart moves the stylus one inch in 80 seconds or little more than 1/100 inch per second. At the same speed on a section chart it takes 2 2/3 minutes for the stylus to move one inch.

Section charts (8 miles/inch scale) are used in the indicator when more detail of the terrain is desired. Because their scale is twice as large as the planning charts, the pilot will have to change them twice as often. (At 160 mph, the maximum straight-line flying time is approximately 30 minutes.)

Instrument approach procedures can be worked with the Pictorial Computer by using approach charts (4 miles/inch) in the indicator. When the airplane nears the airport, it may be lined up for entering final approach by flying the stylus in relation to the approach paths marked on the map.

Course Line Computer Operation

Operating the course line computer in the combined version of the Pictorial Computer requires some advance preparation. To operate the course line computer, the direction of the course and the OBD co-ordinates (VOR bearing and DME distance) of the destination must be known. These data can be obtained by measurement on the map. If desired, the course may be drawn directly on the map. Although this is not required for the operation of the computer, having the line on the map provides an additional means for checking the data calculated by the computer. It permits a comparison reading of the deviation indicator with the deviation of the stylus from the course drawn on the map. For planned flights, courses can be drawn and the data measured prior to take-off.

To operate the computer, the chart is inserted in the same manner as described previously. Next, the map is rotated so that the course is vertical and the destination is at the top end of the course line. This is done by turning the course knob on the panel until the azimuth scale around the periphery of the map table indicates the magnetic direction of the course. Last, the OBD co-ordinates, bearing and distance to destination, are set in. This is done by setting two dials on the panel to the bearing and distance numbers.

The map indicator continues to function exactly as it does in the simple version of the instrument. Added to this is indication of heading on the stylus and the course data provided by the computer. Left-right deviation from the course is presented by the vertical needle of a course deviation indicator and the distance-to-go to the waypoint is displayed on a dial provided on the instrument panel for this purpose.

The left-right deviation indication on the course deviation indicator provides better precision in flying the selected course on smaller scale charts. Full-scale deviation on the meter represents a distance of four nautical miles off-course. Equivalent deviations of the stylus from the course drawn on the map are 1.15, 0.58, 0.29 and 0.14 inches on the standard charts.

Left-right deviation signal also can be switched into an automatic pilot so that the airplane can fly the selected course automatically.

The distance-to-go indication gives the pilot a direct means for estimating his ground speed and time of arrival (ETA). Distance-to-go data also will be useful in checking the progress of the flight for traffic control purposes.

Heading indication provided by the small arrow on the stylus makes flying by the stylus easier. Since the selected course runs from the bottom to the top of the map, the heading arrow provides direct left-right sensing with respect to the course. Deviation of the arrow from the course also is a measure of the rate at which the airplane is approaching the course. Heading of the airplane relative to a course or track must be known in order to line up on that course or track directly. The heading indication speeds lining up with a course on small-scale charts where motion of the stylus is very slow.

Computer Accuracy

Maximum allowable errors specified for the indications and outputs of the Pictorial Computer are:

Map Indicator	
Distance	±0.4 mile
Bearing	±0.5 degree
Heading	±7.0 degrees
Course Computer	
Course deviation	±0.7 mile
Distance-to-go	±1.7 miles

These are the accuracies with which the Pictorial Computer will reproduce the navigation data supplied to it in the airplane. They do not include any of the errors contained in the navigation data supplied to the instrument. To date these accuracies have been exceeded in laboratory tests of components of the instrument. Accuracy of the finished instrument will not be known specifically until a completed unit becomes available for testing.

CAA TYPE V PANEL PICTORIAL COMPUTER WITH HEADING, AUTOMATIC CHART SELECTION AND AUTOMATIC RECEIVER TUNING

General

This computer is being designed and manufactured by Arma Corp., Brooklyn, N.Y., on contract with TDEC. The development is sponsored by the Air Navigation Development Board. It is designed to display visually and continuously aircraft heading and position over the ground with respect to a preselected known point. The display unit shown in Fig. 17, is designed to be mounted on the instrument panel or elsewhere in the cockpit of an aircraft, and to be clearly visible to both pilot and co-pilot under all operating conditions. The charts against which position and heading are shown in the display unit are self-contained and are quickly selected by means of a slewing control on the front of the unit.

The equipment consists of two principal units: The display unit; and the amplifier unit, containing all relays, amplifiers, special power sources and amplifiers. The amplifier unit is intended to be mounted in the radio rack of an aircraft and is of a standard outline size.

The Display

Aircraft heading and position are shown against a chart of the area. The chart is part of a 35 mm. film roll in the display unit and is projected at 10 power magnification onto a 10-inch diameter, see through type screen. At the center is an OBD station, which is the fixed geographical point from which the panel pictorial computer and associated equipment calculate range and bearing for position indication. Aircraft position is indicated on the chart as the center of a reticle of concentric range circles and radial bearing lines. Aircraft heading is indicated on the chart by a series of arrows passing through the aircraft position. Heading may be read to one degree against compass roses superimposed on several range circles. Any point on the chart may be headed for simply by turning the aircraft until the heading indicator points toward and falls over the chosen spot. Then, except for the crab angle necessary to compensate for wind set and drift, the aircraft will, in due course, pass over the required point. Setting up the crab angle is simple, since it is necessary only to swing the aircraft into the wind in increments until the required point on the chart is held at a constant bearing. Bearing lines are conveniently spaced so that small changes in bearing are detected quickly.

Range circles and bearing lines are provided to a maximum range of 160 miles on the largest scale chart, thus permitting aircraft position to be off the projected chart, but with distances and headings to all points on the chart clearly indicated.

Automatic Chart Selector

Storage facilities in the display unit allow for a film roll containing up to 700 charts. The total number of OBD stations presently commissioned is about 300, so that the designed chart capacity allows for charts at 2 and sometimes 3 scales for each station, with a remainder of about 100 to be used for small-scale airport approach charts. Charts are situated on the film in alphabetical order using the call letters of the OBD station at the chart center. Where charts of the same central area but different scales are furnished, the order is from the largest to the smallest scale.

A chart selector motor, when energized, drives the film roll at one of three speeds; viz., a slewing speed at 12 or more charts per second, an intermediate speed of about 4 charts per second, and a slow speed of about 1.5 charts per second, slow enough to read the OBD station call letters directly from the chart image. While slewing, a coarse-drum dial indicator on the face of the display unit shows progress through the alphabet and serves as warning to the operator to slow down for the desired chart.

Automatic Receiver Tuning

Associated with each chart in the film roll, is a series of 12 on-off code locations. Nine of these locations are used to identify the particular frequency combination of the OBD station transmitters and transponders situated at the center of each chart. Three are used to set the scale of the instrumentation automatically to correspond with the scale of the chart. The coded locations consist either of holes or no holes in the film roll. Pawls or fingers interrogate each coded location as soon as a chart has been selected. The pawls actuate a relay network in the amplifier unit, which in turn controls automatically and remotely the autopositioner tuning mechanisms in both the navigation receiver (bearing) and DME (range); such that, after a particular chart has been selected at the display unit, inputs to the Panel Pictorial Computer are returned automatically to the new OBD station.

Inputs to the Equipment

Instrumentation of the Panel Pictorial Computer is accomplished with three servos; range, bearing and heading. All are of conventional design and operate on 400-cps signal inputs. Range is obtained from the shaft orientation of a potentiometer in the DME, which calculates the distance (up to 100 nautical miles) to the OBD stations to which it is tuned. Bearing is obtained as a single speed, 400-cps synchro signal from the omnibearing indicator, a unit of the navigation receiver which calculates bearing to the OBD station to which the receiver is tuned. Magnetic heading is received as a 400-cps single speed synchro signal from the gyrosyn compass.

Controls

The Panel Pictorial Computer is completely automatic except for the selection of charts and for certain initial adjustments. After power is turned on at the power switch, the desired chart is selected by first pulling out on the slewing handle to enable the chart changing mechanism; and then turning it to the right or left, depending upon the alphabetical listing of the chart desired. The greater the amount of turn, the greater the slewing speed. The slewing may be stopped completely even though enabled with the handle near dead center. An alphabetical coarse-drum dial is provided to indicate the portion of the alphabet passing the projector system at any time, and may be used when slewing to determine when to slow the rate of film transfer.

When the correct chart is in the projector system, the image brightness may be adjusted by a knob. This permits operation under widely varying conditions, from sunlight to darkness.

Projector lamps to be used in the panel pictorial computer are expected to have a minimum life of 100 operating hours, with an average life of at least 150 hours. A spare lamp is provided for in the display unit and, when the lamp in use burns out, the spare may be brought into position in the optical system at once by pulling on a flexible cable at the front of the unit. The short length of flexible cable is left dangling as a remainder to replace lamps at the next ground facility.

Flag Alarm

A flag alarm is provided to indicate failure in the computer, in the inputs to the computer, or to indicate that the distance to the OBD station is beyond range and signals received are below the usable threshold strength.

Size and Weight

The display unit is about 13 by 7 1/2 by 16 inches, except for blisters on the front to accommodate the 10-inch round screen, and other blisters at the rear to accommodate the chart changing motor and the lamp house of the projector system and its blower. The unit is mounted to the instrument panel in the cockpit of an aircraft, and weighs about 16 pounds. Dimensions and weight do not include shockmounts.

The amplifier unit is packaged within the outline of a standard S-2 case and weighs about 21 pounds, including shockmounts. It is to be mounted in the communications rack of the aircraft.

Accuracy

The range accuracy is ±0.4 mile on all scales. The bearing accuracy is ±1/2 degree or ±1/32 inch, whichever is the greater. Heading indicator accuracy is ±1 degree.

Charts

Special new charts will be furnished for Panel Pictorial Computer use. They will be designed for all types of flying where visual ground contact is not maintained. Chart legends will be clearly visible from a distance of 40 inches, about the distance of the instrument panel from the pilot's eyes. Charts will be prepared in tones of a single color and will contrast with the black position and heading indicators of the Pictorial Computer.

Special Features

Special features inherent in the design of the Panel Pictorial Computer include the following:

1. Operation is completely automatic except for controlling the chart slewing handle.
2. Associated electronic equipments which furnish Pictorial Computer inputs are automatically tuned. There is no time lost in setting up new frequencies after selecting a new chart.
3. Range and bearing of all points on the chart with respect to the aircraft are given. This holds even when the aircraft is off the chart, in navigating toward and over a specified point on the chart.
4. The computer furnishes continuous orientation of the aircraft with respect to the ground. This is valuable in flying where visual ground contact is not maintained, such as in medium- and high-speed aircraft.

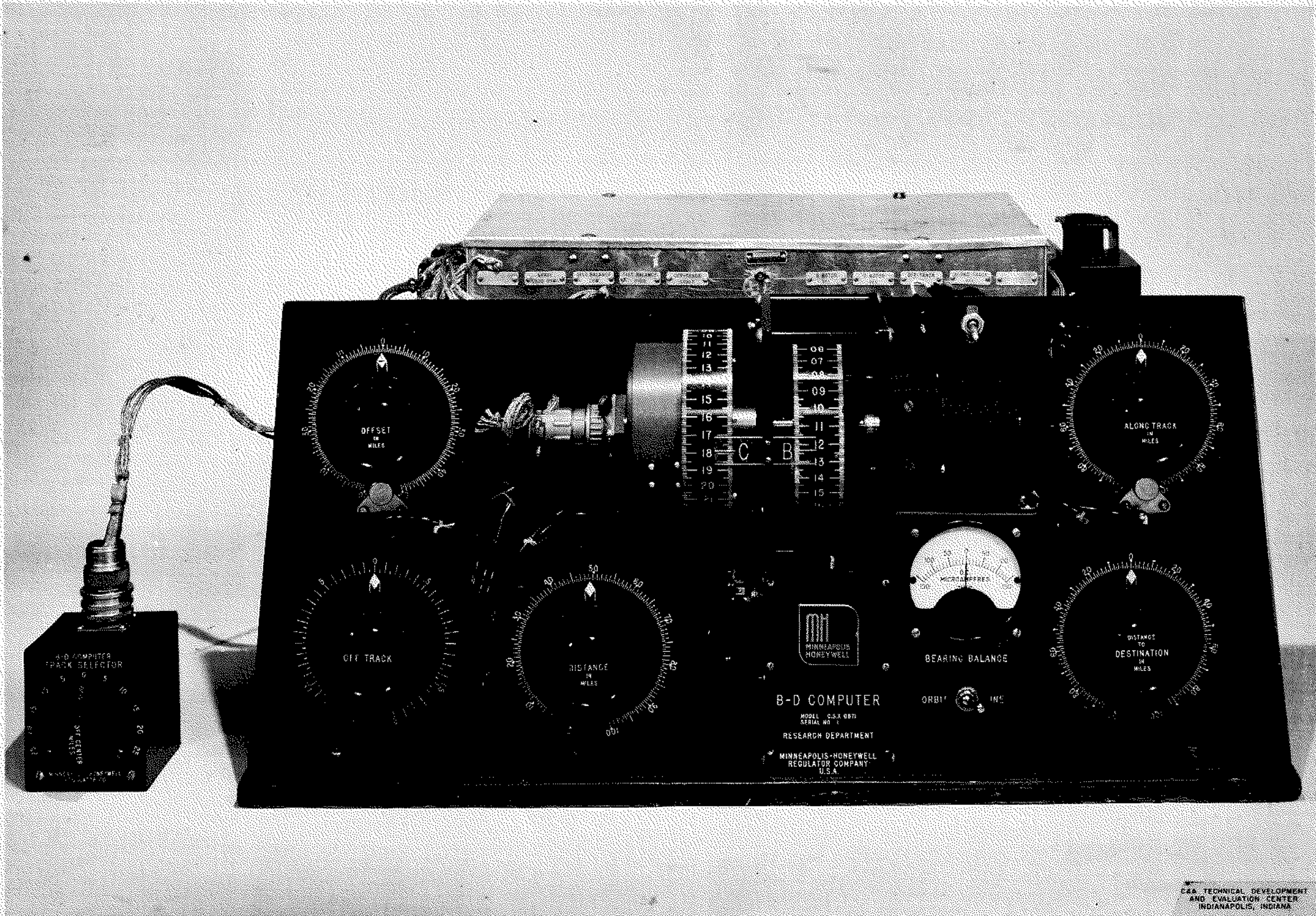

FIG. 1 THE FIRST PARALLEL COURSE COMPUTER

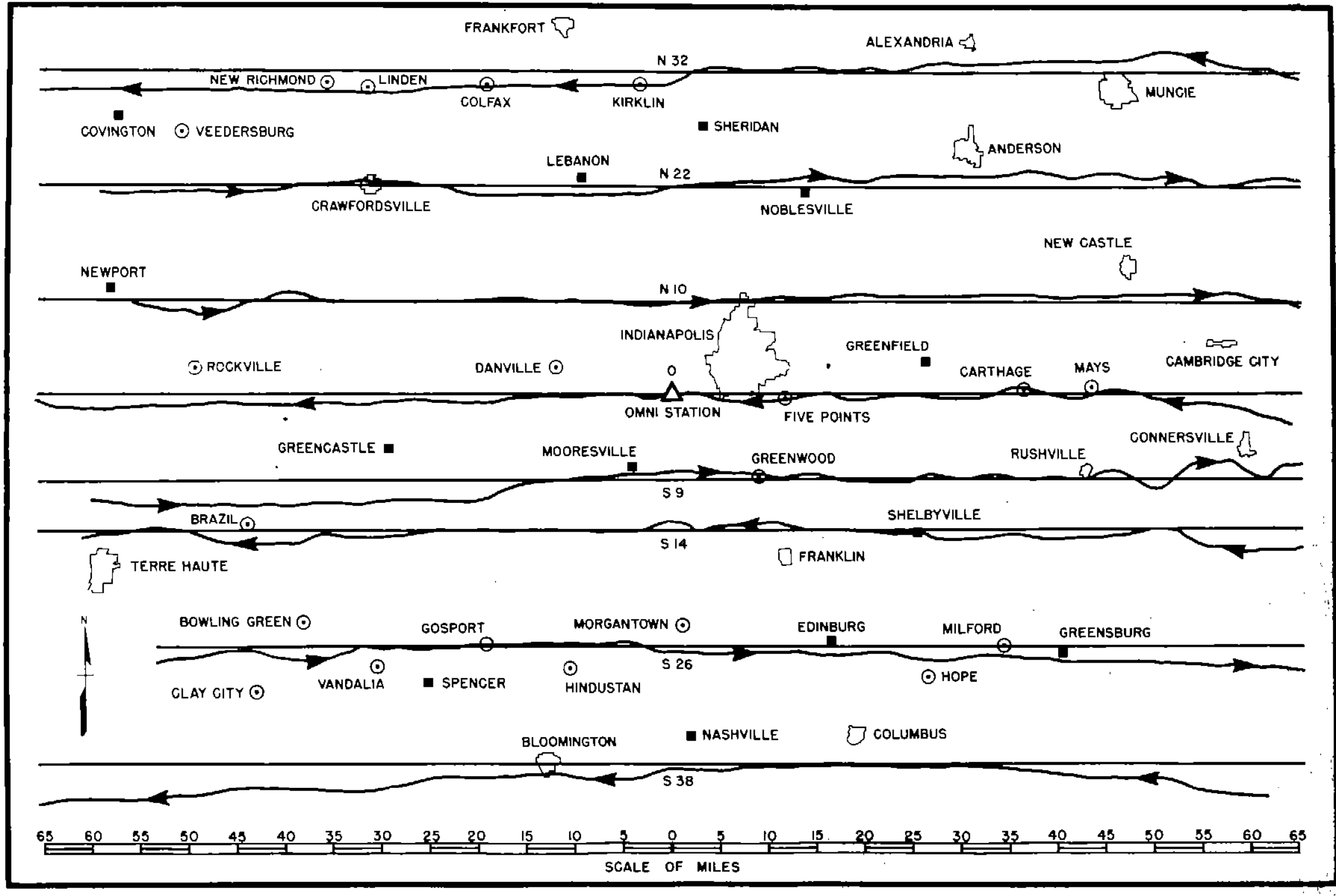

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FIG. 2 MAP OF TEST DATA OF THE FIRST PARALLEL COURSE COMPUTER

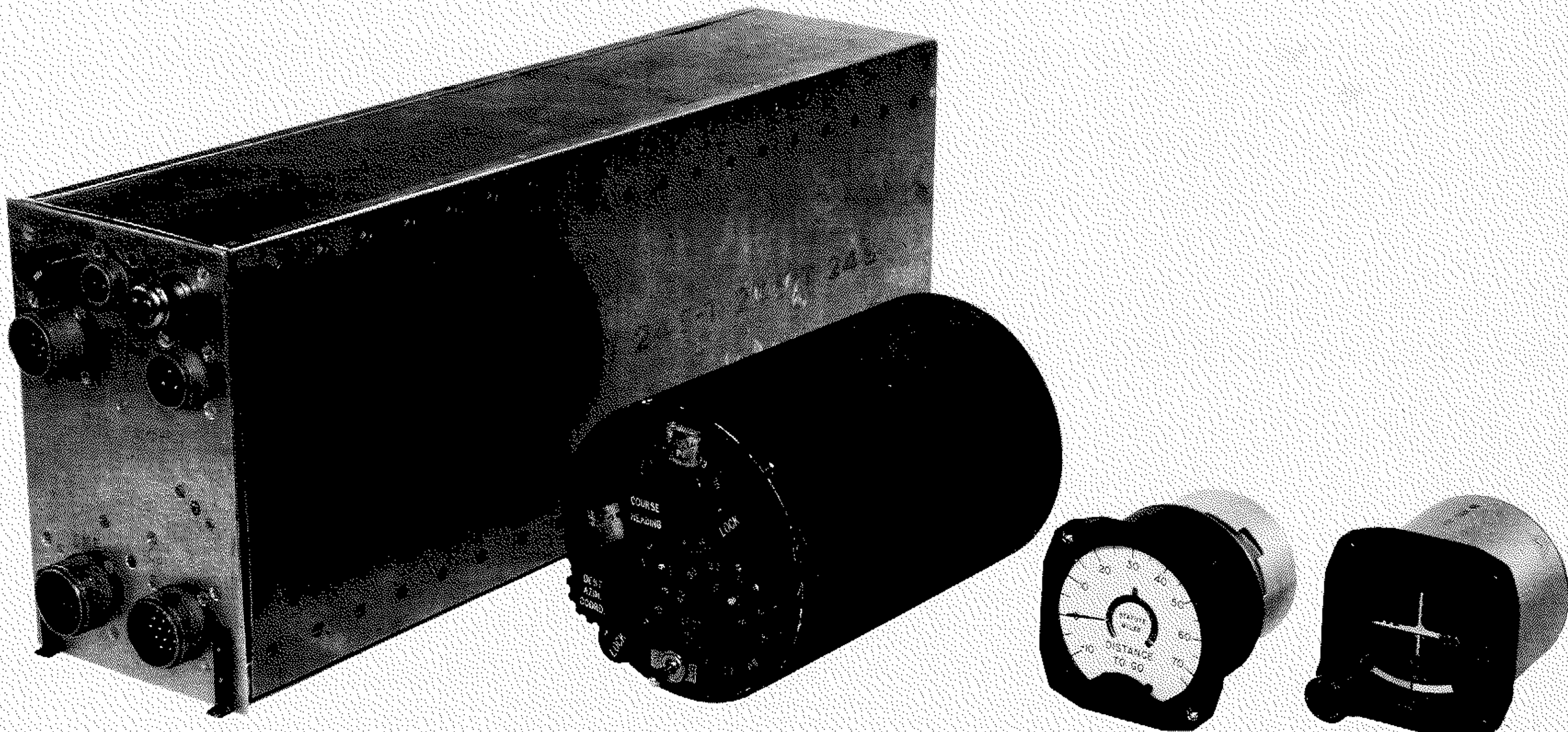

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FIG. 3 CAA TYPE I COURSE LINE COMPUTER

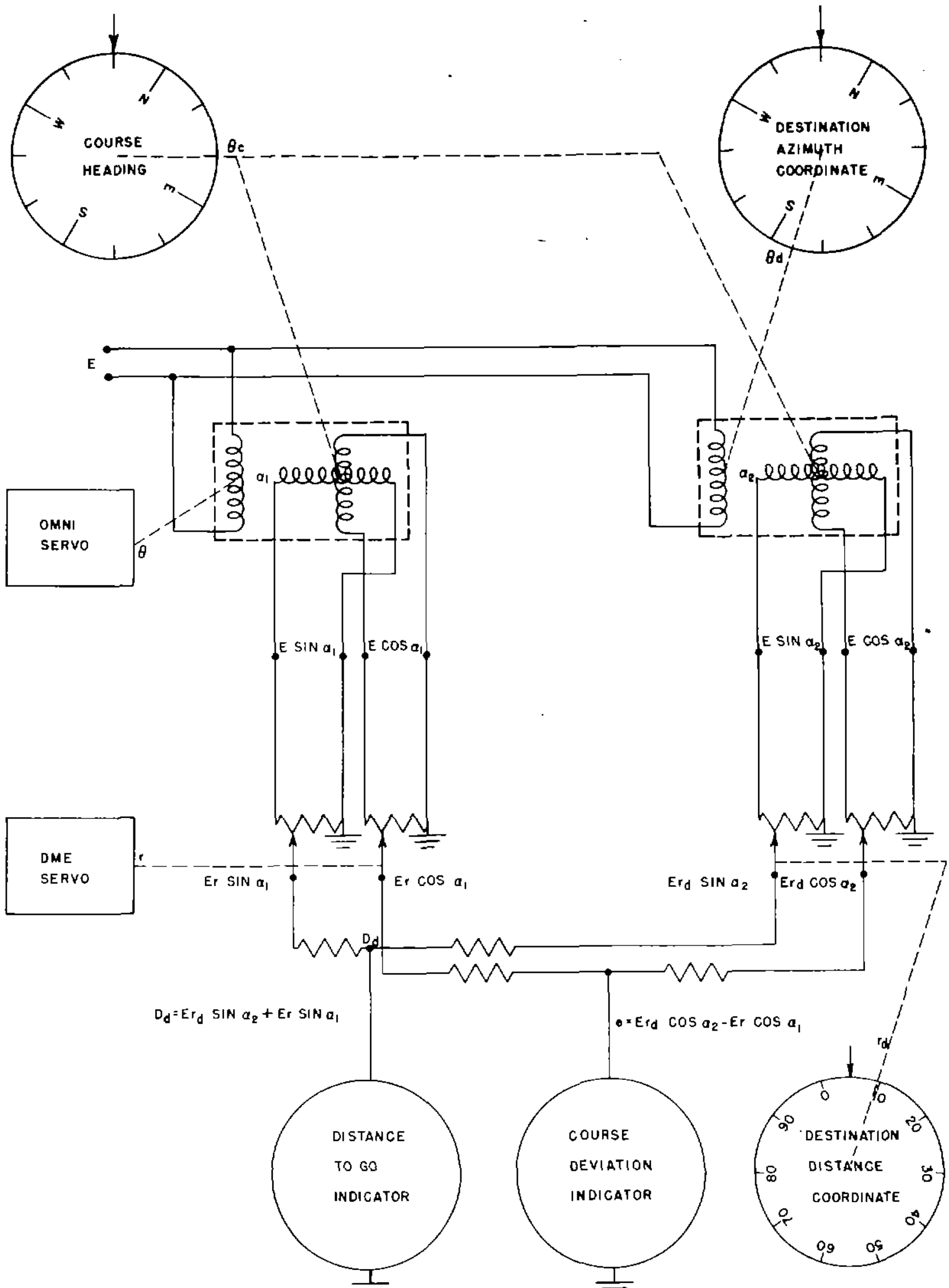

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FIG. 4 FUNCTIONAL SCHEMATIC DIAGRAM OF CAA TYPE I COURSE LINE COMPUTER

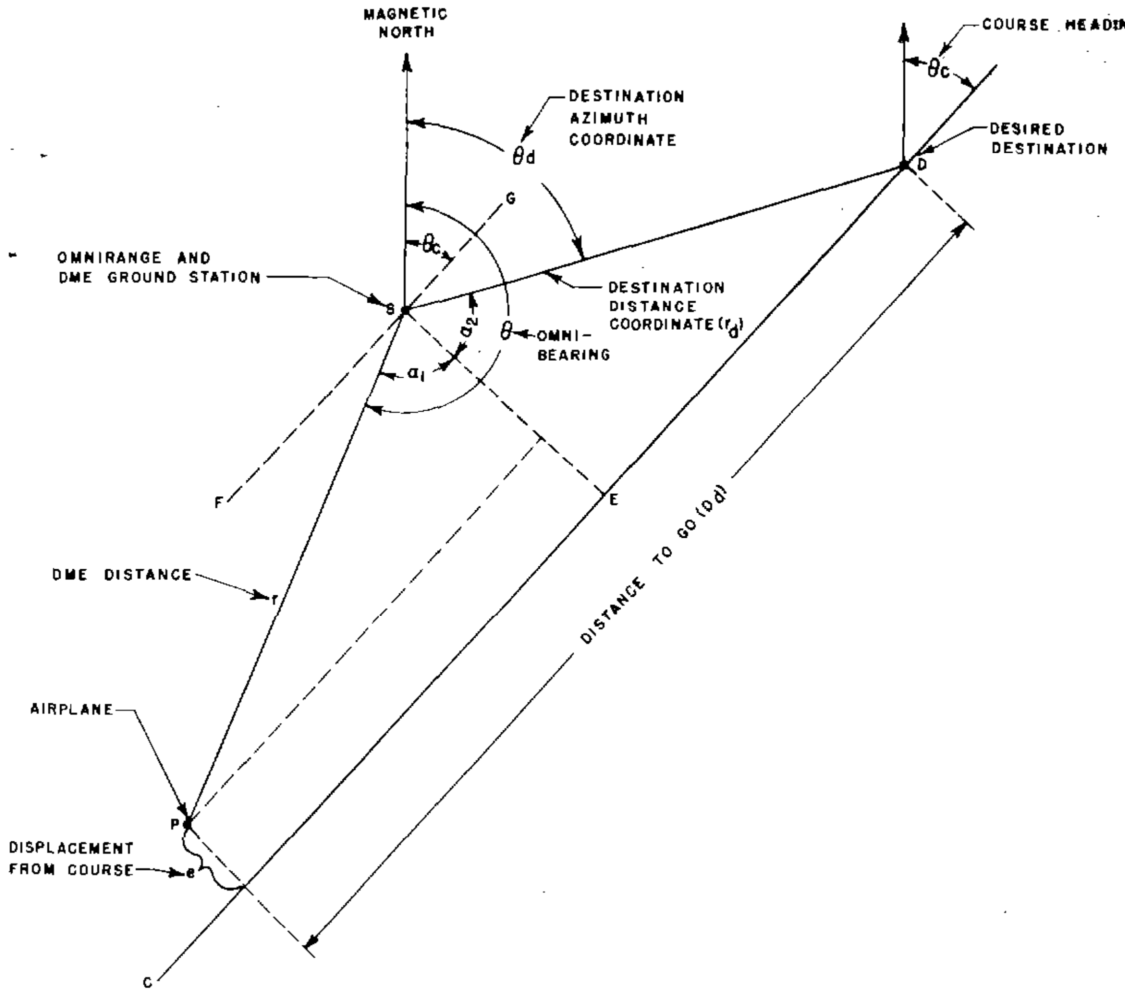

FIG. 5 GEOMETRY OF A COMPUTED PATH USING CAA TYPE I COMPUTER

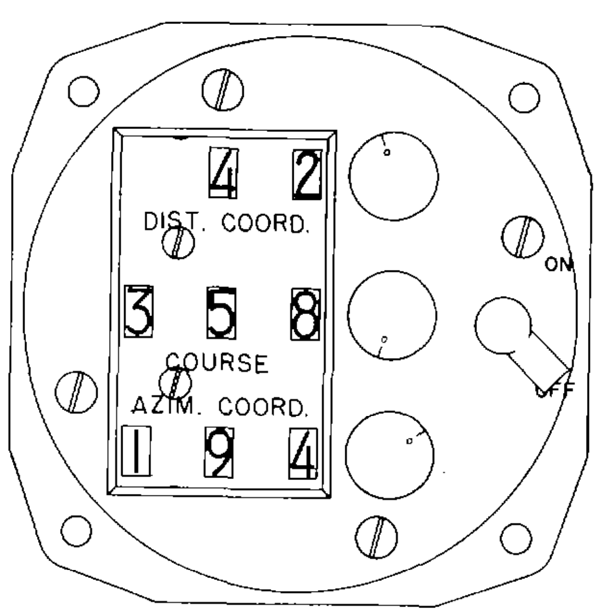

FIG. 6 CAA TYPE IA COMPUTER

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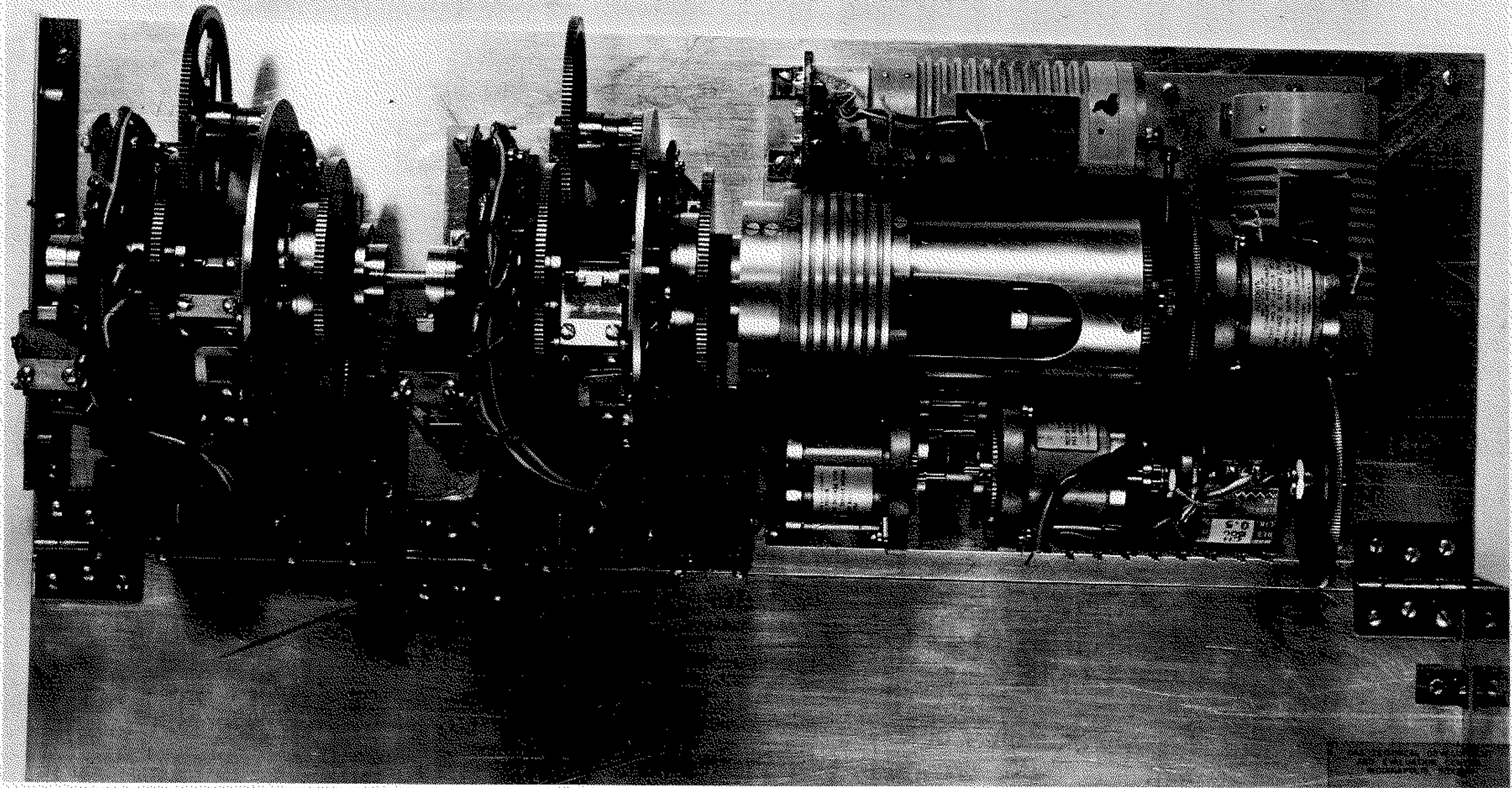

FIG. 7 COMPUTING UNIT, CAA TYPE II AUTOMATIC FLIGHT AND NAVIGATION EQUIPMENT, TOP VIEW

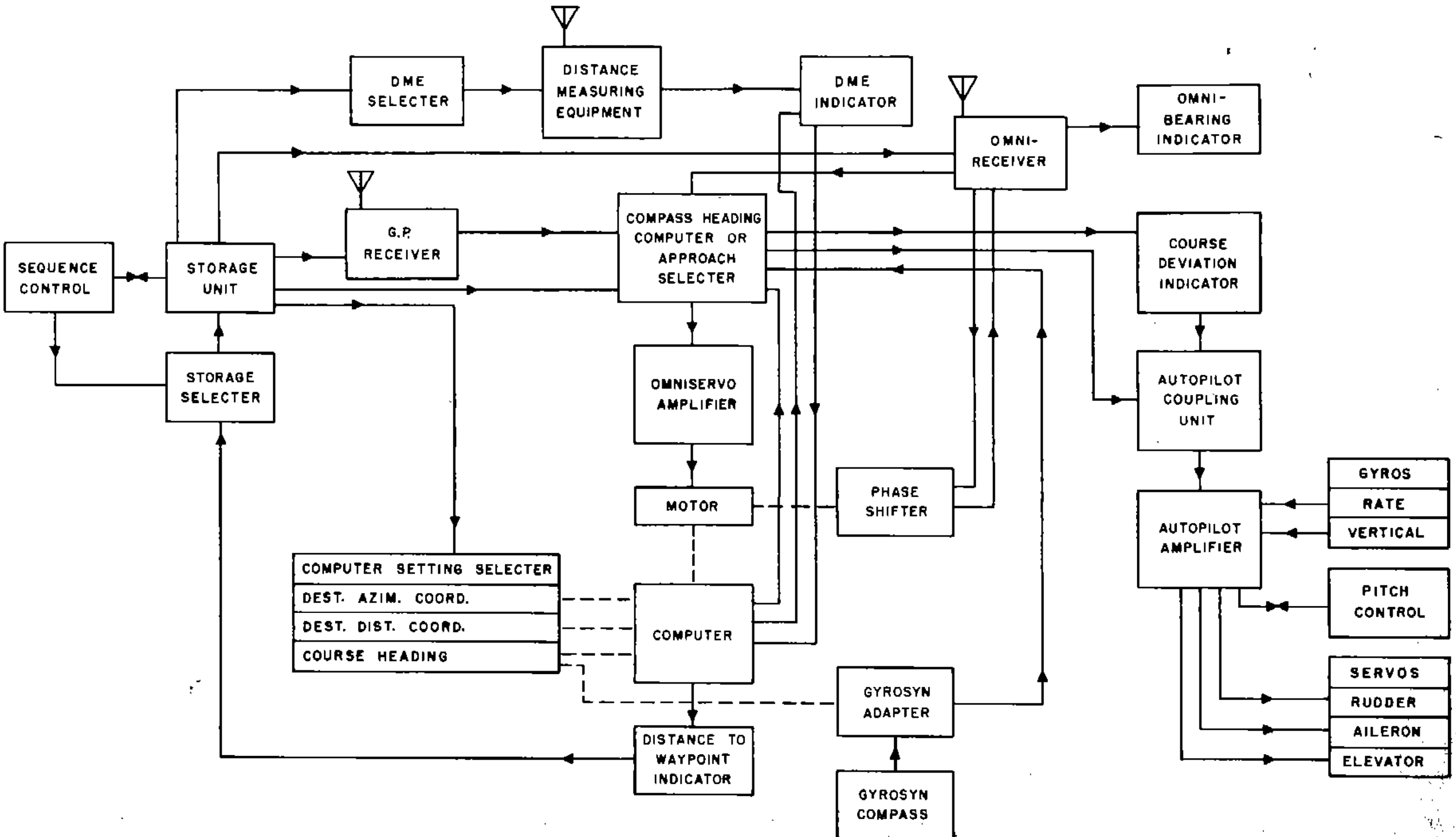

FIG. [illegible] BLOCK DIAGRAM OF CAA TYPE II AUTOMATIC FLIGHT [illegible] AV[illegible]TION [illegible]

FIG. 9 COLLINS AN/ARA-21 COURSE LINE COMPUTER

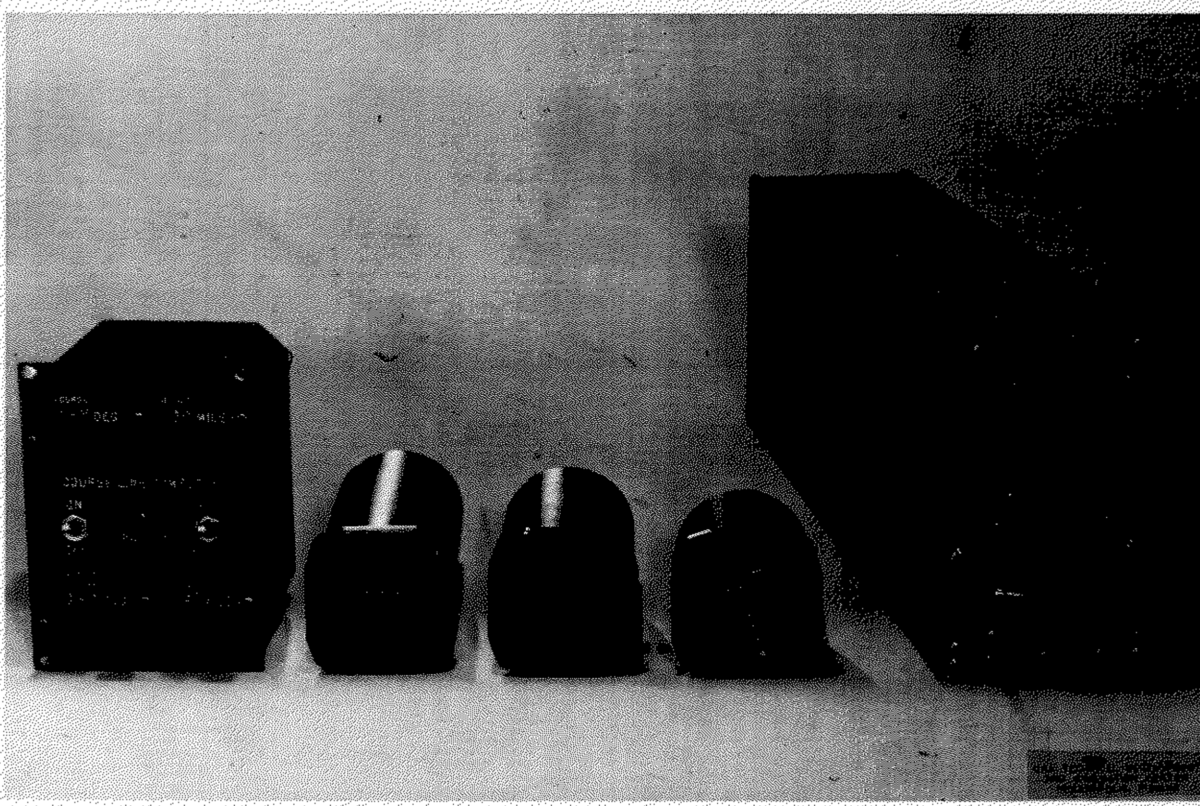

FIG. 10 COLLINS TYPE 560A-1, CAA TYPE VI COURSE LINE COMPUTER

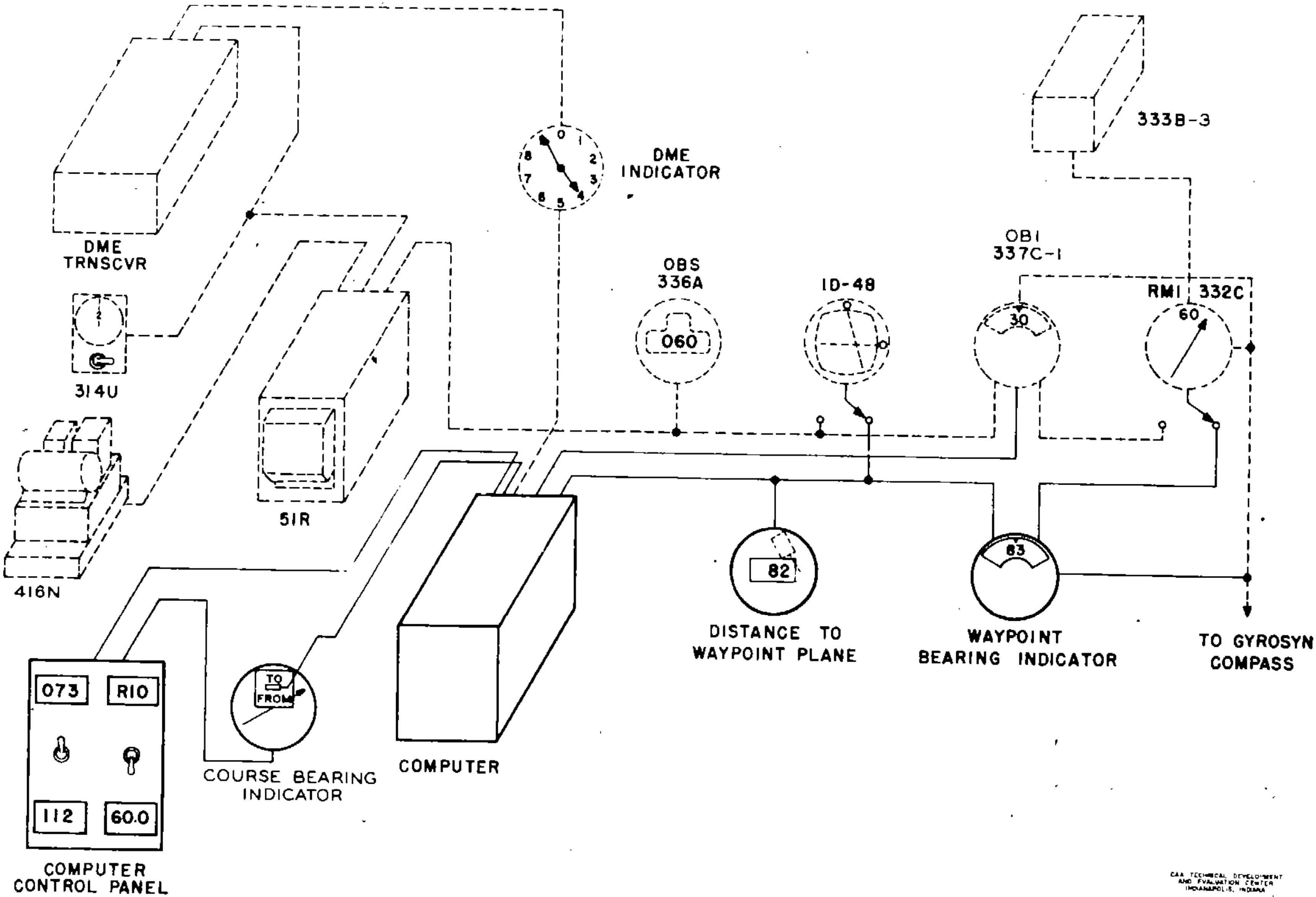

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FIG. 11 CABLING DIAGRAM, COLLINS TYPE 560A-1, CAA TYPE VI COURSE LINE COMPUTER

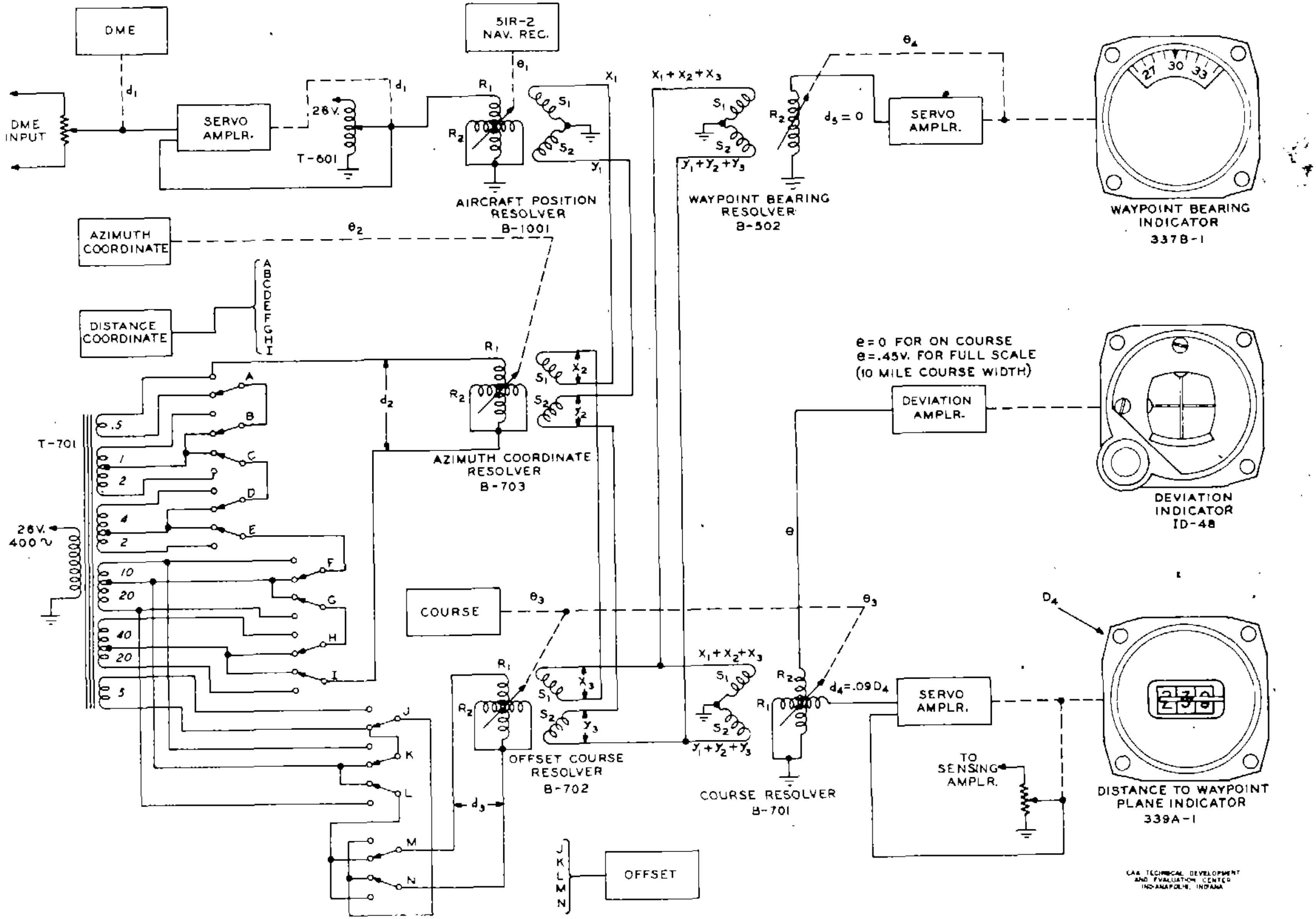

FIG. 12 FUNCTIONAL WIRING DIAGRAM, COLLINS TYPE 560A-1, CAA TYPE VI COURSE LINE COMPUTER

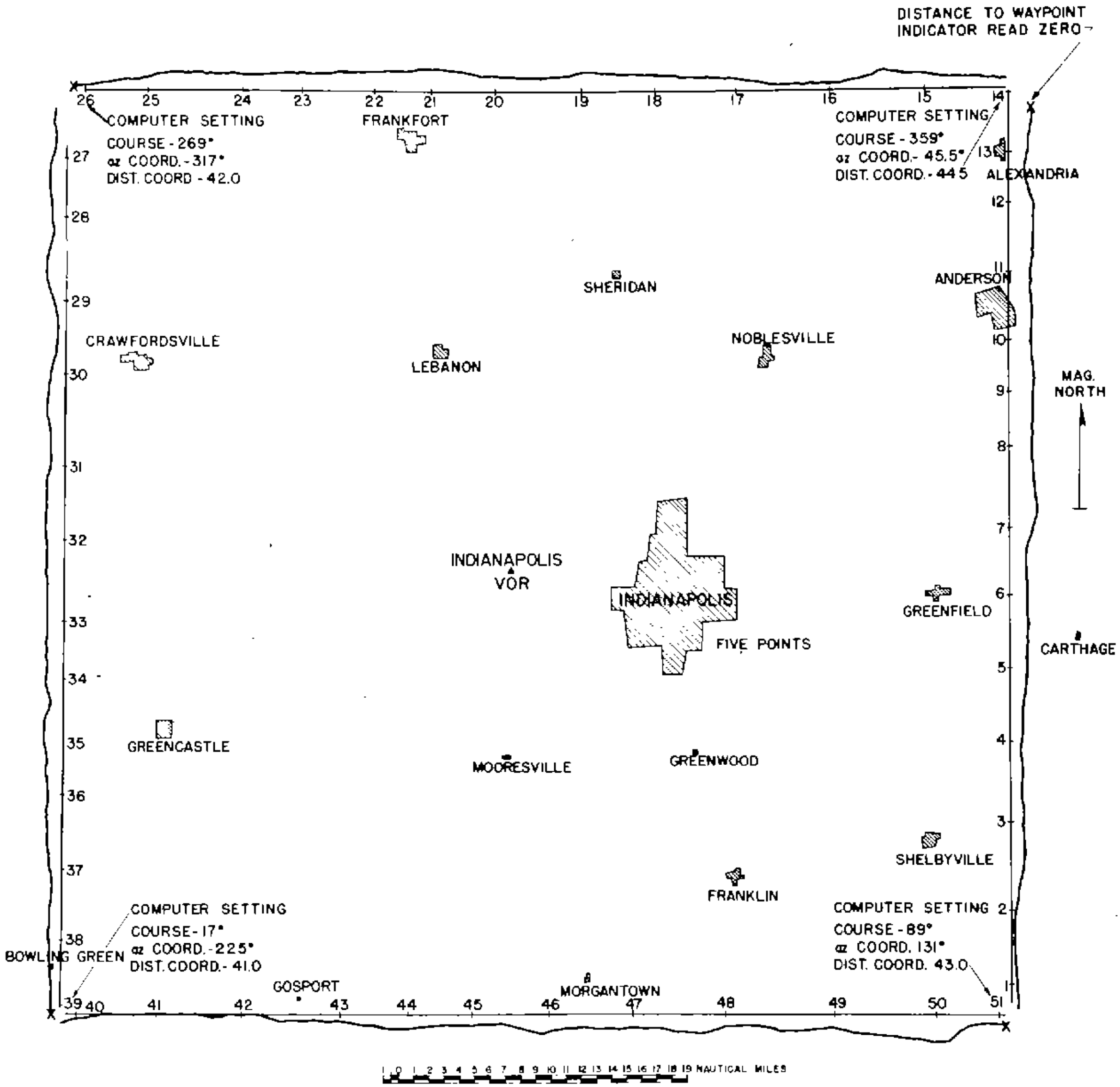

FIG. 13 COLLINS TYPE 560A-1, CAA TYPE VI COURSE LINE COMPUTER TEST DATA

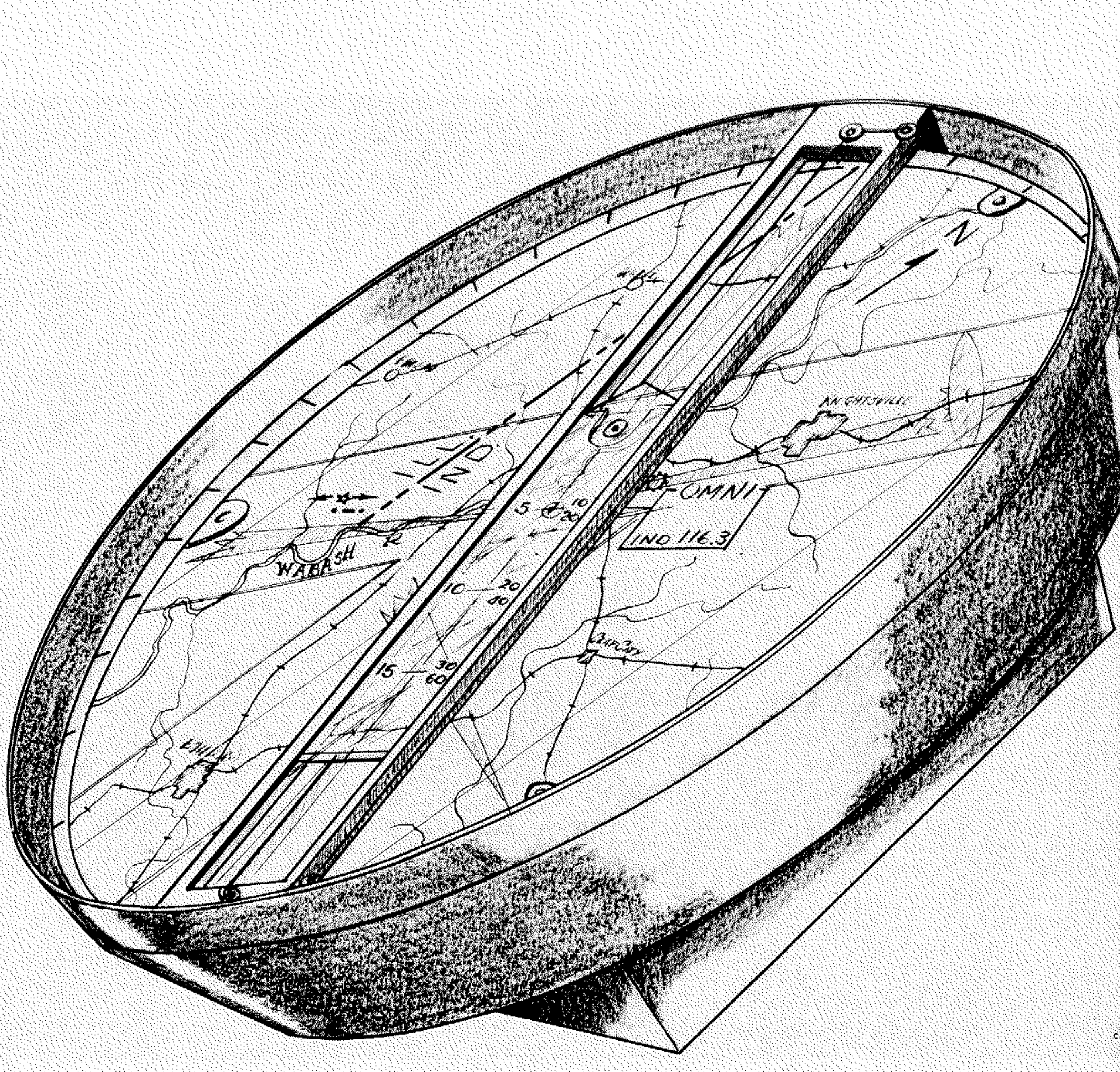

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FIG. 14 PORTABLE PICTORIAL COMPUTER, CAA TYPE III
MANUFACTURER: AERO ELECTRONICS CO.

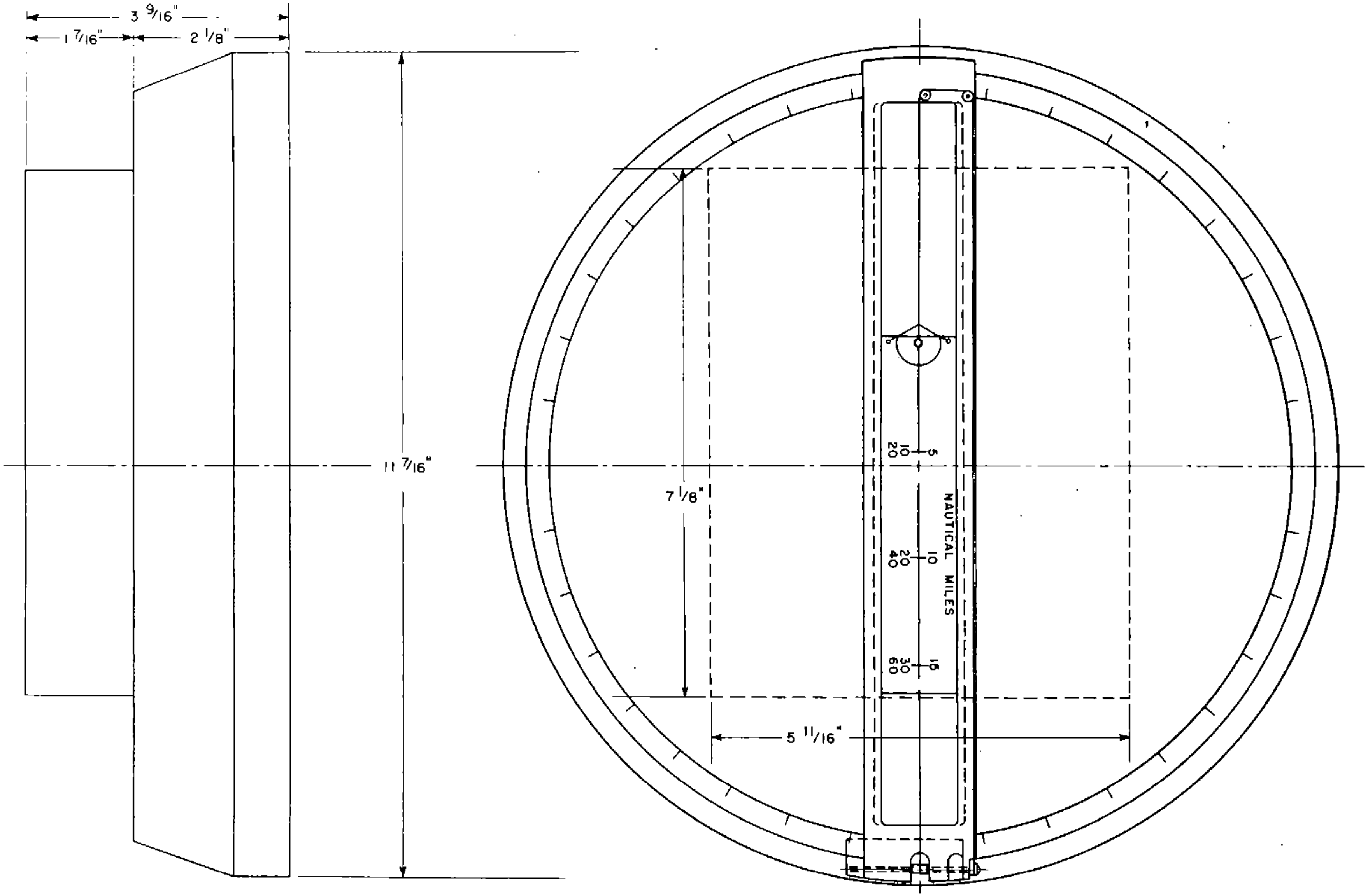

FIG. 15 PORTABLE PICTORIAL COMPUTER, CAA TYPE III

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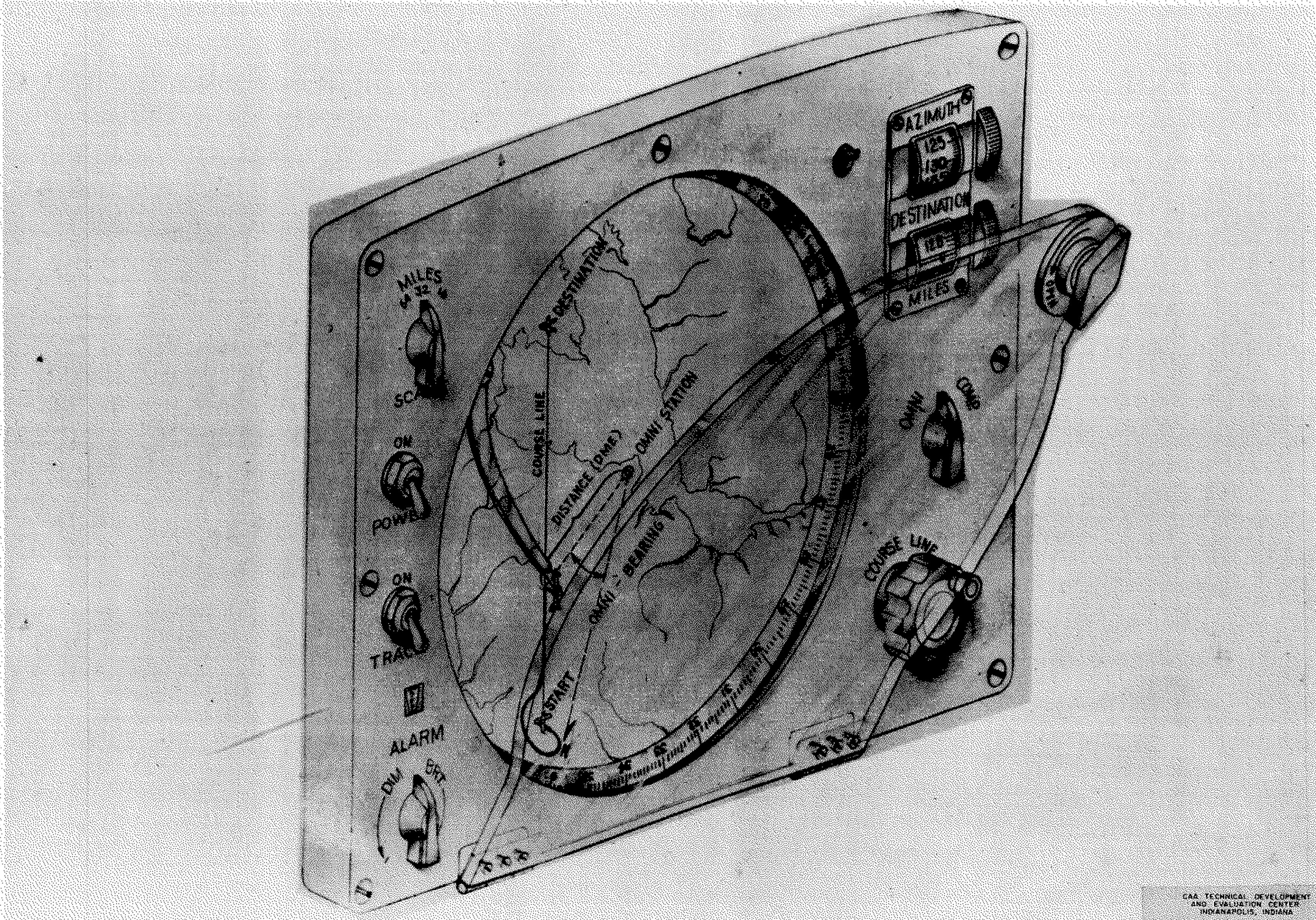

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FIG. 16 ROTATABLE PANEL PICTORIAL COMPUTER, CAA TYPE IV
MANUFACTURER: SPERRY GYROSCOPE CO.

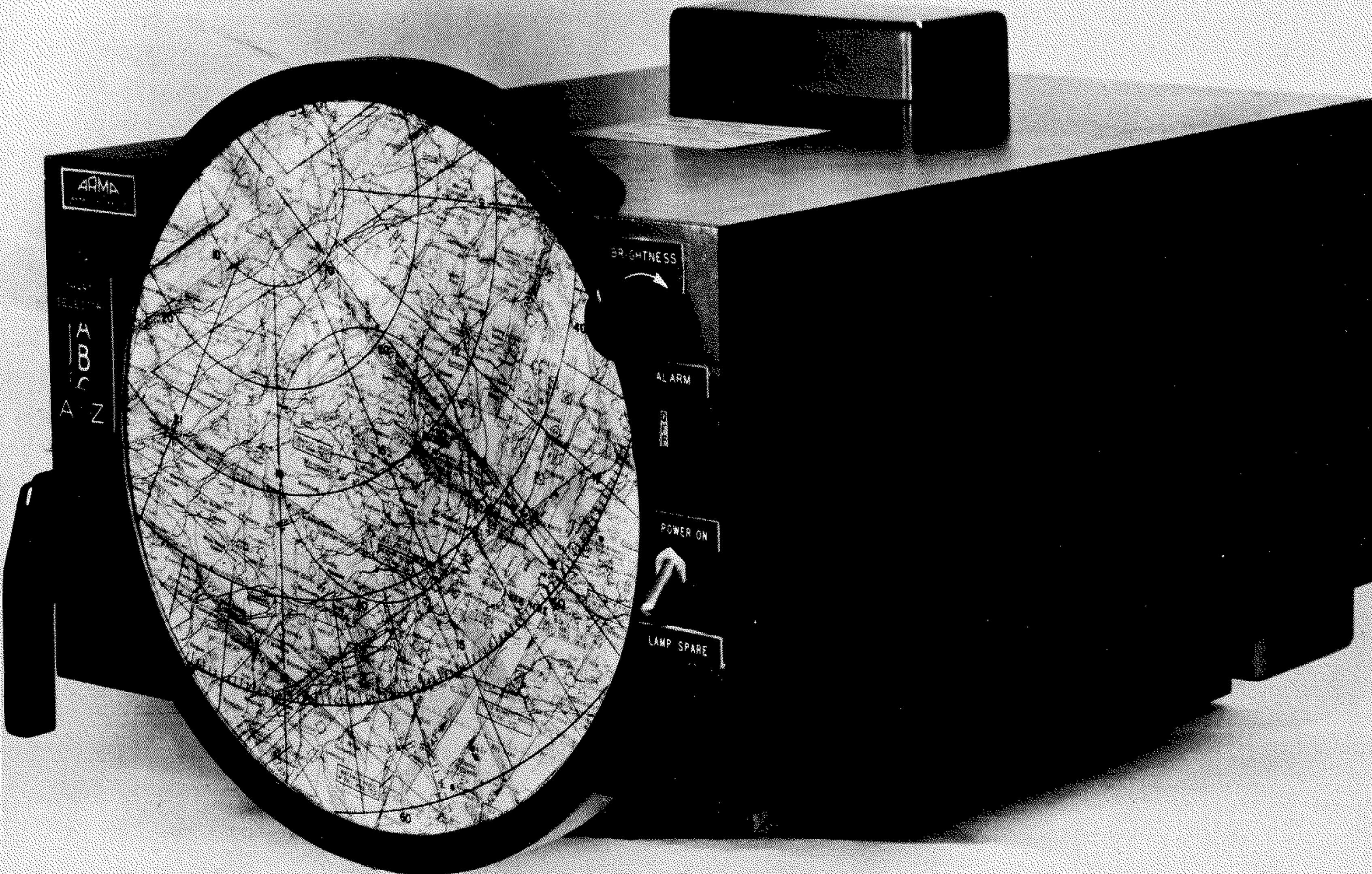
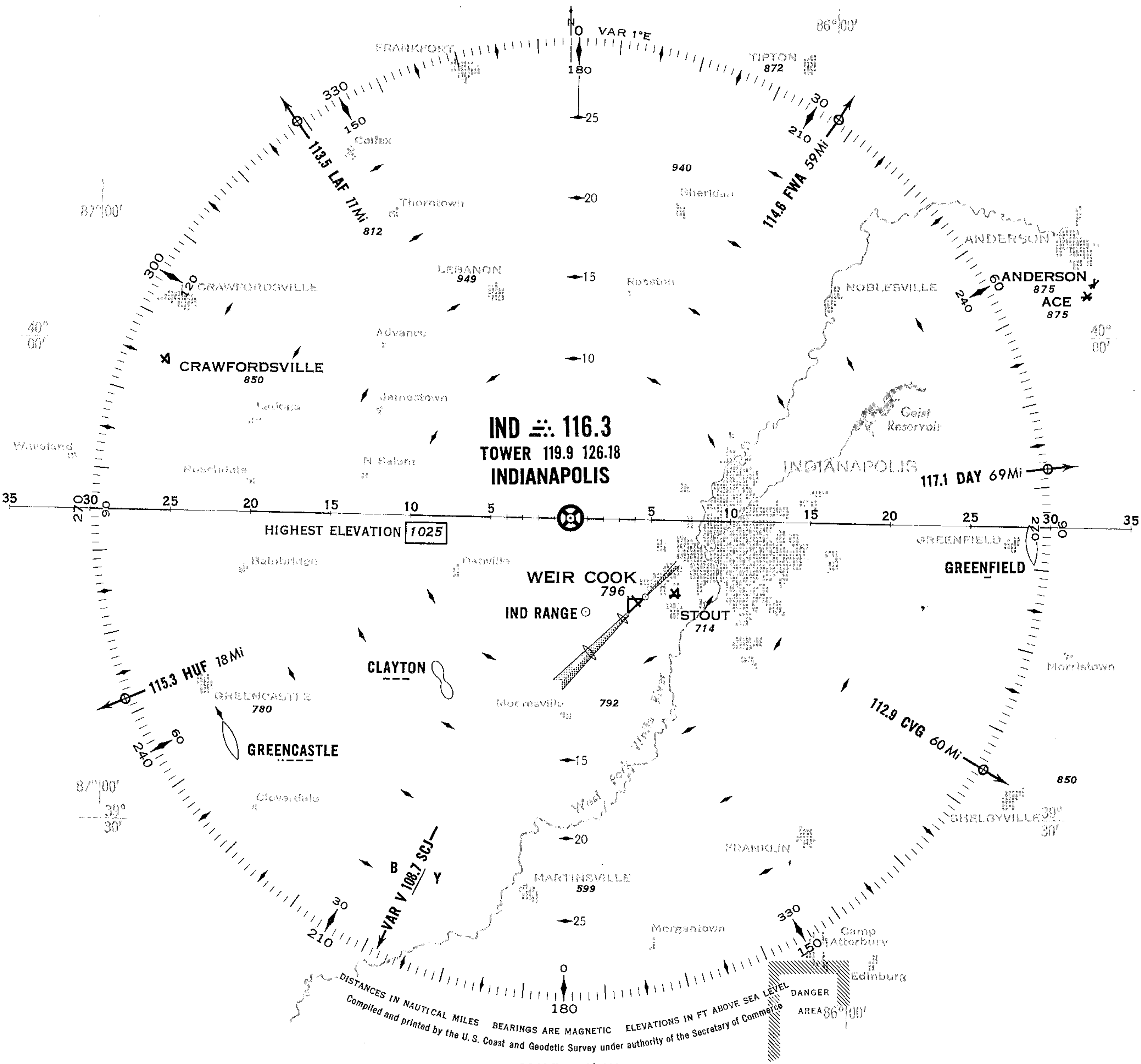


FIG. 17 PANEL PICTORIAL COMPUTER, CAA TYPE V
MANUFACTURER: ARMA CORP., BROOKLYN, N. Y.

OBDS-203-XB

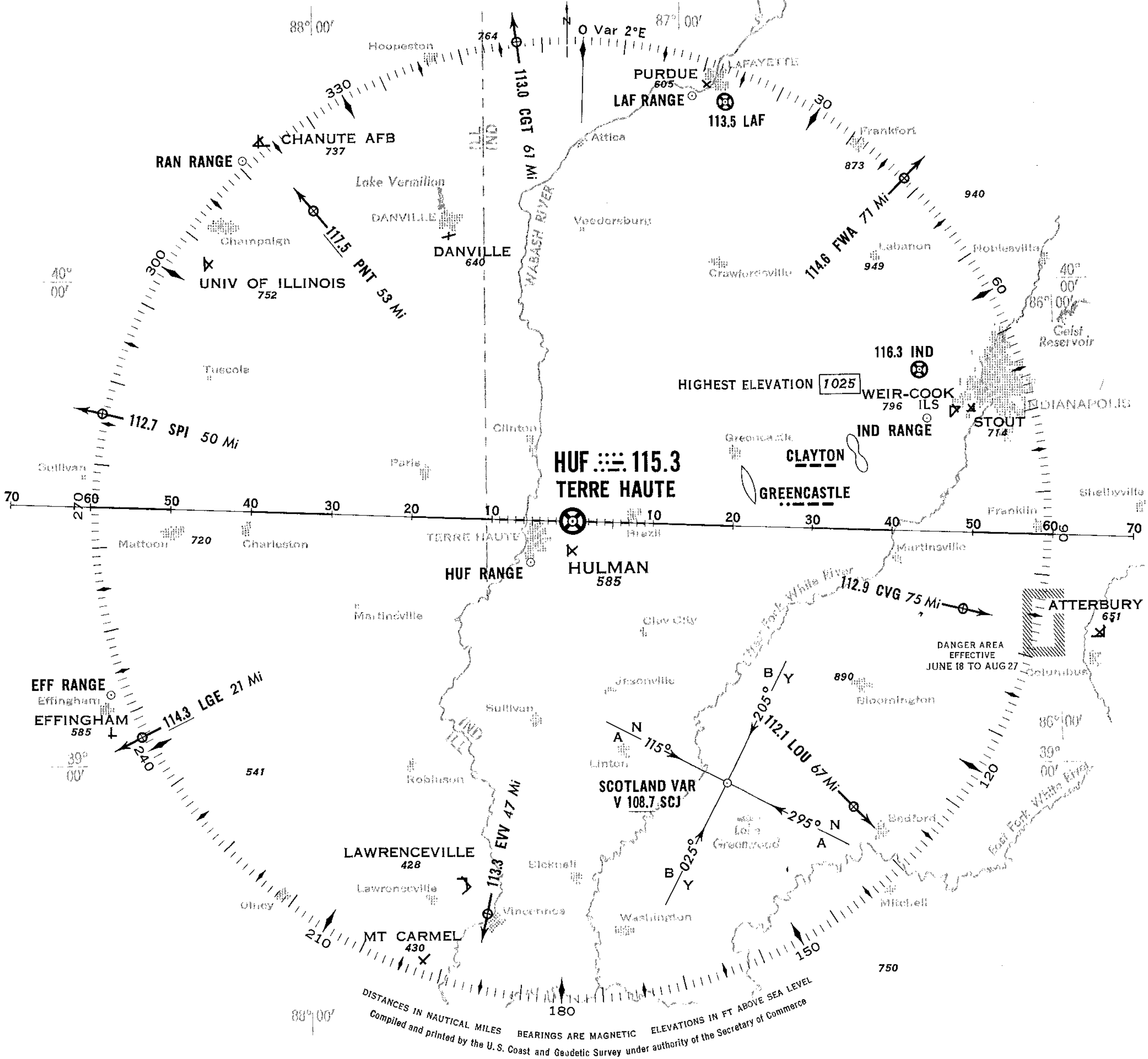
PICTORIAL COMPUTER CHART
O.B.D.S. (EXPERIMENTAL)



SCALE 1:500,000
20 NOV 1950

OBDS-608-XC

PICTORIAL COMPUTER CHART
O.B.D.S. (EXPERIMENTAL)



DISTANCES IN NAUTICAL MILES   BEARINGS ARE MAGNETIC   ELEVATIONS IN FT ABOVE SEA LEVEL

Compiled and printed by the U. S. Coast and Geodetic Survey under authority of the Secretary of Commerce

SCALE 1:1,000,000

30 NOV 1950