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ELECTRONIC DATA SYSTEM

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ABSTRACT

An Electronic Data System (EDS) is described which offers a means of increasing the speed, accuracy, and capacity of the CIC organization for handling data concerning combat targets. Relatively simple electronic techniques such as the Electronic Pencil Coordinator, (conducting-glass data takeoff) the PPI Retrace Insertion Unit, the Capacitor Store, the Velocity Derivation Unit, the Automatic Summary Plotting Board, the Height Size and Identity Store, the Conducting Glass Multiple Target Designation System, and the Coordinate Converters for $XY\text{-}R\theta$, $R\theta\text{-}XY$, and $HR_S\text{-}\phi$, have been developed and integrated into a complete CIC system. Maximum use of existing installations minimizes cost and time required for production, installation, training, and maintenance. Simplified central stores provide a flexibility of design which permits the expansion of operating features and capacity while maintaining compatibility with systems in current use, and with the most advanced data-processing systems under consideration.

PROBLEM STATUS

This is an interim report. Work is continuing.

AUTHORIZATIONS

NRL Problem Y01-04, BuShips Problem S-1680;
Project NE 020-443
NRL Problem Y01-07, BuOrd Problem Re4a-77;
Project M4A-81-2-54

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FOREWORD

This report on the development of the Electronic Data System (EDS), sets forth the history and aims of the program, and gives a brief review of the Fleet's Air Defense problem, toward the solution of which it is directed. A block diagram is presented and reviewed to define the areas of data-handling under consideration. Each of the new techniques developed at the Laboratory for application to the EDS is then described, together with the manner in which it contributes to the system. Following this, a detailing of the operational procedure covers their use in the processing of combat data. Finally, an estimate is made of the future plans for evaluation, further development, and commercial production. Separate Laboratory reports containing more technical details will be prepared on each of the equipments described under "NRL Techniques," and on further significant technical and operational advances.

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ELECTRONIC DATA SYSTEM

INTRODUCTION

Problem Background

The Electronic Data System (EDS) stemmed from the development of the Conducting-Glass Polar Coordinate Generator for Multiple Target Designation[1] which permitted a gunnery liaison officer to use a pencillike probe to contact an electrically excited conducting-glass overlay and extract polar coordinate position data from the face of a radar plan position indicator. Servos were thus controlled to position range and bearing synchros and to transmit this data to selected fire-control directors. This technique offered an increase in target-designation speed and permitted one operator to designate to four or more directors. In an effort to exploit further the inherent speed and precision with which an operator can point to a target or other mark, the Retrace Insertion Unit (RIU) and the Electronic Pencil Coordinator (EPC) were developed in 1951 and 1952, respectively. The former equipment displayed the electrical output of the latter and permitted a marker to be aligned with a radar target directly on the cathode-ray display, providing a high degree of accuracy by feedback techniques. The latter employed a plate of conducting glass, electrically excited in a rectangular-coordinate system, which resulted in equipment of relative simplicity and reliability.

During 1952 the Electronic Pencil Coordinator was coupled to a 16-target capacitor store which was based upon the development of a simple high-impedance cathode follower. At that time the predictions of speed, accuracy, and ease of manipulation were realized. Tests of the system when operated in the automatic sequential tracking mode, showed that operators with little or no training could reposition-track simulated radar targets at an average rate of 1.15 seconds each. Independent demonstrations of this equipment, and of an early version of the Automatic Summary Plotting Board[2] were presented to visiting officers representing CNO Op413. They in turn recommended that Laboratory personnel direct efforts toward coupling the conducting-glass equipment with the servo-driven summary plot, preferably in a manner which would permit more than one operator to plot on the summary plotting board the data derived from separate PPI's.

A study of methods to accomplish this disclosed that time-sharing techniques would limit the operators so employed to such an extent that little or no increase in target handling capacity or speed would be afforded by employing more than one plotter. This problem could be overcome by employing a common store into which could be inserted position data from several sources, and out of which the latest corrected data could be extracted without mutual interference or time-sharing problems. The adoption of a store supplied the basis for the facilities to be recommended.

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[1] To Chief, ONR from Director, NRL Ltr. 3950-242/51, dtd. 10-4-51

[2] Winston, G. C., "An Accuracy Evaluation of the NRL Interim Aircraft Intercept Control System," NRL Report 4351, Confidential, August 1954

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Application to Air Defense

At the same time, the study was extended to cover the operational employment of the proposed equipment to the air-defense problems of the fleet, and in particular, of the fast carrier task force. It became evident that the air-intercept phase of any future engagements will require that surveillance be extended considerably to cope with aircraft travelling from two to five times the speeds employed in World War II, and with even faster guided missiles. Both the increased area to be surveyed and the probability that attacks of the future will be in considerably larger numbers, will place a greater load upon the detection and tracking organization. The higher target speeds will leave less time to handle the data and place greater reliance upon accuracy. This is heightened by the single-pass, head-on attack methods now employed by AI fighters. "Data" as here described are now extended to mean in addition to plan position, the target height, identity, and size, as well as other pertinent "status" information.

Further study showed that urgency also existed in the necessity of improving the coordination between the AI and the gunnery phases of air defense to obtain the maximum effectiveness of both without unnecessarily endangering friendly craft. This problem promises to be even more critical with the advent of guided missiles. Present target designation systems (excepting experimental models) are limited to the transmission of data in two coordinates (R_S and θ), and OpDevFor tests[3] have disclosed serious delays in transferring this information from the search radar to the precision, automatic-tracking, fire-control radar. These delays permit the targets of today and of the future to move out of the field of view of the f-c radar before designation has been completed.

Problems of coordination between units of a task force which is dispersed to limit damage in an atomic attack, of the extension of radar surveillance over greater ranges, and of low-angle coverage by pickets, require that air defense data be exchanged with sufficient speed and quantity to meet these problems. In some respects, these dispersed units will be required to coordinate their efforts as closely as though the task force were one large ship.

This brief review of the general air defense problem has been treated in much greater detail elsewhere, but has been cited to show the scope of considerations which has been included in the study to effect the development of equipment having more than immediate utility.

Operational Standards Adopted

Stringent standards were established to guide the development of suitable components. Consistent with the size of the craft, the organization available, the equipment required, and the tasks assigned, the system should be planned for a maximum target capacity, and should be capable of expansion if required. Numbers of operating personnel should be kept to a minimum. Under standby conditions, a reduced staff should permit satisfactory operation even during sudden emergencies. The minimization of operators would be of limited value if the complication of added electronics would result in a corresponding or even greater increase in maintenance personnel. Technicians require lengthy training and will always be in relatively short supply. It has been estimated that one ETM is required for each 200 to 300 vacuum tubes in use.

[3] OpDevFor final report on "Evaluation of the Features of CA-134 (USS DES MOINES) Class Cruiser," Project Op/S 165/S 65-7

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Where practicable, existing installations should be employed or modified to extend their usefulness. A relatively simple device known as the Retrace Insertion Unit (RIU) has been developed and can be employed with any of the Navy's fixed-coil radar repeaters (such as the VK, VK-2, VK-3, VK-4, VK-5, VN, SPA-8, SPA-9, and SPA-8A), which total over 4000 installed or in production. The use of the RIU permits the modernization of these indicators with a minimum of time and expense, extending their usefulness without affecting the original utility, and preventing the obsolesence of equipments representing a large investment in money and time.

The addition of electronic devices to facilitate the stated objectives, should be held to minimums of size, weight, power requirements, and complexity. Disruptions of CIC layouts necessitating shipyard overhaul should be avoided; where feasible, units designed to be installed by shipboard personnel would prevent tying up the entire ship and would result in savings in time and expense.

Due attention must be devoted to the possibility of failure or damage to components during critical engagements. Two simultaneous approaches to this problem seem prudent. First, more rapid servicing of equipment can be promoted by providing convenient performance test points, through use of telltale failure indicators, and by employing plug-in circuit packages which permit rapid replacement, allowing a defective unit to be repaired at a more convenient time and place. Second, the failure of a circuit, unit, or an entire equipment should not prevent the use of the basic device (such as a radar indicator, if still in service) in the same manner as employed in CIC practice today.

Any devices, equipments, components, or techniques should be adaptable to all classes of service. Although these problems are being studied primarily in the light of surface-ship CIC requirements from the smallest picket to the largest command ship, the specialized requirements of the submarine and airborne CIC's should be incorporated, or at least considered, to permit adaptation with little or no construction differences.

The techniques, components, and their operational employment should be completely compatible with present and proposed systems. Each ship, submarine, or aircraft CIC should be able to be self-sustaining in conducting its own air defense, but should also be able to coordinate its efforts with other craft in the task force, sharing data, controlling CAP's, and participating in all manner of defensive and offensive maneuvers, whether those craft are fitted with present day equipments or with the more automatic devices proposed for future command ships. The choice of techniques should be such as to allow technical advances to be added as they become available, extending the useful life of the system for many years beyond that of "short-term" or "interim" equipments adopted without concern for a smooth transition as the technology and tactical employment demand.

SYSTEM DESCRIPTION

The Electronic Data System was designed primarily for use with the picket ship, because in this service are found most of the functions of air defense performed on the largest of command ships, differing in that ordinarily fewer targets are held under surveillance, and in that the problems of task-force coordination are not involved. Since the picket ship must often operate somewhat independently because of its station well in advance of the task force center, it must be self-sufficient in its ability to conduct air intercepts, and to defend itself against direct attack. The larger numbers of picket craft will, in the aggregate, involve more equipment than the command ships; they represent a greater investment, and a correspondingly larger conversion problem. The position of the picket ship at the "frontier" of the task force places upon it the responsibility for initial detection, interception, and reporting to the task force all contacts. Furthermore, the results of study and development should provide the foundation upon which to extend these techniques to the solution of the larger problems of coordination at the command-ship level.

Block Diagram

Collection and Storage of Data — In Fig. 1, the block diagram shows along the top row the primary sources of data, which are the search radar, the height radar, and the IFF from which determinations of plan position, height, size, and identity are made. Other sources of data (such as ECM, ASW, visual and radio reports) may be included. This information is translated into electrical form by the four operators shown in the second row. The number of operator positions and the assignment of duties here is somewhat arbitrary and not intended to dictate shipboard organization, but merely to demonstrate one method suitable for a ship of the picket destroyer class. A supervisor of the CIC team acts as a detector, putting into the plan store (shown on the next lower level), the target coordinates as observed on a PPI. The responsibility for keeping these coordinates corrected as the target moves, is assigned to one of two Trackers using an independent PPI. The HSI (Height, Size, and Identity) Operator may then proceed with the evaluation of the target utilizing the height-radar range-height indicator (RHI), the IFF in conjunction with the adjacent PPI, and supplementary data such as verbal reports, and enter the results in the HSI store shown on the third line.

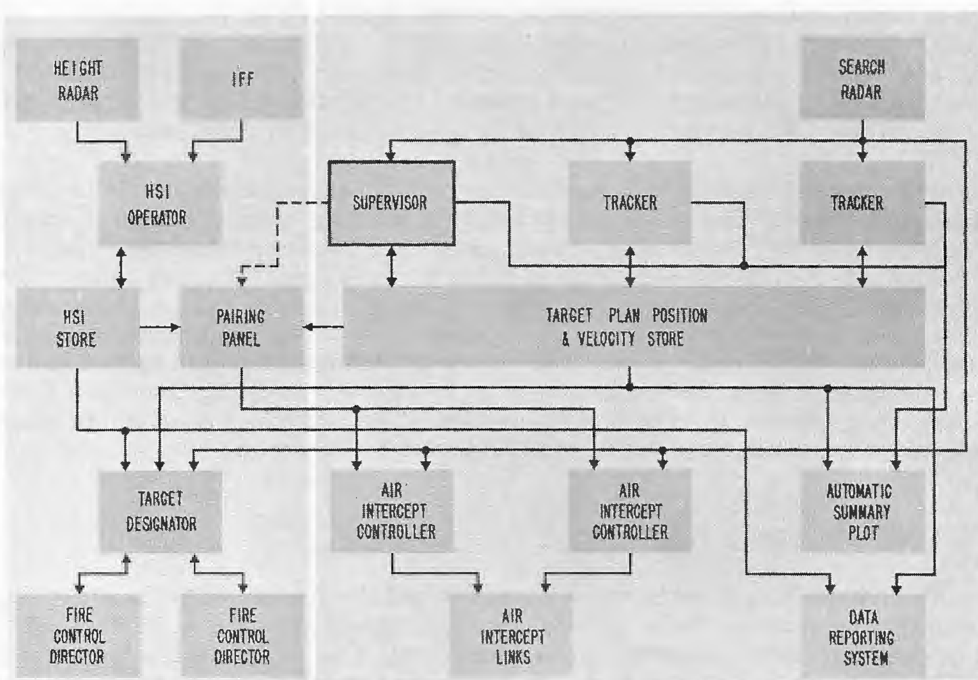

Fig. 1 - Electronic Data System Block Diagram

Summary Plotting — Target data thus stored may now be sampled without a conflict of interests. The Automatic Summary Plotting Board, shown on the fourth or "user" line, will maintain an up-to-date plot of all plan-position data, and will be so situated as to be viewed by all CIC personnel, thus providing recent history and coordinating all efforts.

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Air Intercept Assignments — From the information presented and available, the supervisor will choose targets to be assigned to the Air Intercept Controllers, also on the fourth line, pairing raids with optimum interceptors, and causing all pertinent data to be properly channeled by means of the Pairing Panel shown on the third line.

Three-Coordinate Target Designation — Targets entering the gunnery action ring or area, roughly 40 miles in radius, will be noted by the Gunnery Liaison Officer from the Automatic Summary Plotting Board (ASPB), at which time they should begin to appear on his short-range PPI. The Gunnery Liaison Officer switches the X-, Y-, and Z- coordinates on the chosen target in one operation by matching the target number with the director number. Thereafter the designation is given continuously and the director action is observed on the PPI. Since these three coordinates are already kept current by the CIC team, and since plan coordinates will be continuously predicted through aided tracking (automatically provided by Velocity Derivation), this method should give superior designation data and result in significantly lower acquisition times. For the benefit of the Gunnery Officer when stationed outside CIC, a small version of the ASPB (not shown on the block diagram) may be installed at his station, presenting relative-bearing data on all targets being automatically tracked by fire-control directors. Through this presentation, his assignment of gun batteries to directors can be carried out with dispatch. Overriding facilities at this point would permit the choice of target-designation data from Visual Sources for assignment to directors.

Data Transmission — The Data Reporting System also shown in the bottom row, as proposed, will sample all stored data, convert it to digital form, and transmit it over standard voice-communication channels to the command ship. Target data would be reported from each picket on a sequential basis timed by "transmit" orders to and from the command ship.

NRL Techniques

A number of equipments have been developed at the Laboratory aimed at meeting the operational requirements previously set forth. Many of them will have application in other data-handling and systems studies, and have been designed where possible as independent units. The features of the principal developments are as follows:

Electronic Pencil Coordinator — The Supervisor, Trackers, and Gunnery Liaison Officer are provided with search-radar Plan Position Indicators having a conducting-glass overlay which replaces the standard glass cover or reflection plotter assembly. The complete assembly is shown in a typical installation in Fig. 2. Figure 3 shows the conducting-glass plate and the mounting head dissembled to show the method of contacting the glass. In Fig. 4, it may be seen that the conducting surface of the glass is excited in a rectilinear fashion in two dimensions on a time-sharing basis allowing a single-contact "pencil" probe to be used to sample voltages proportional to the X- and Y-coordinates of the probe position when in contact with the glass surface. Synchronous detection circuitry is followed by the integration of each output, providing X and Y dc voltages. Suitable alignment controls permit a one-to-one correspondence with the radar presentation immediately below. Contact between the pencil and the glass conducting surface at any point is also detected, causing a multiple-contact relay to operate and control numerous tracking and display functions. Requiring only one vacuum tube (for the relay operation) and no dc power supply, the circuitry is relatively simple, and free from maintenance problems. The compact, light-weight chassis shown in Fig. 5 is readily adaptable to a variety of installations. It is shown installed as the third panel from the top of the rack in Fig. 2.

Fig. 2 - A typical EDS Detector or Tracker Console showing the Store Control Panel, the Retrace Insertion Unit, the Electronic Pencil Coordinator, the Communication Panel, and the EPC conducting-glass head in place over the SPA-8A PPI. The push-button box on the left of the PPI is associated with the Velocity Derivation feature for aided tracking.

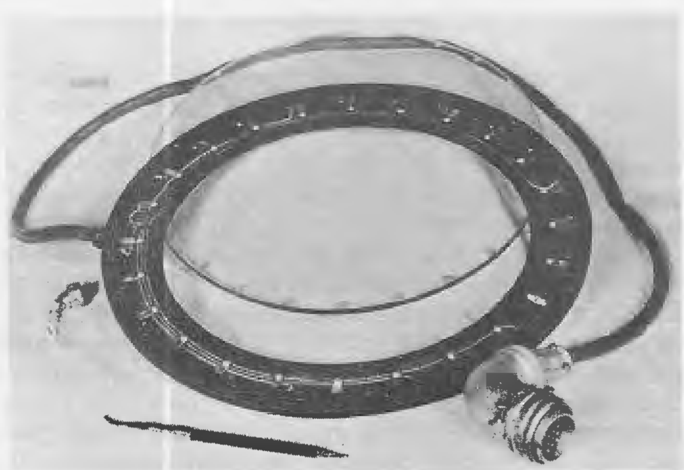

Fig. 3 - Dissembled mounting ring shows the 24 contacts which mate with silvered contacts on the conducting-glass plate

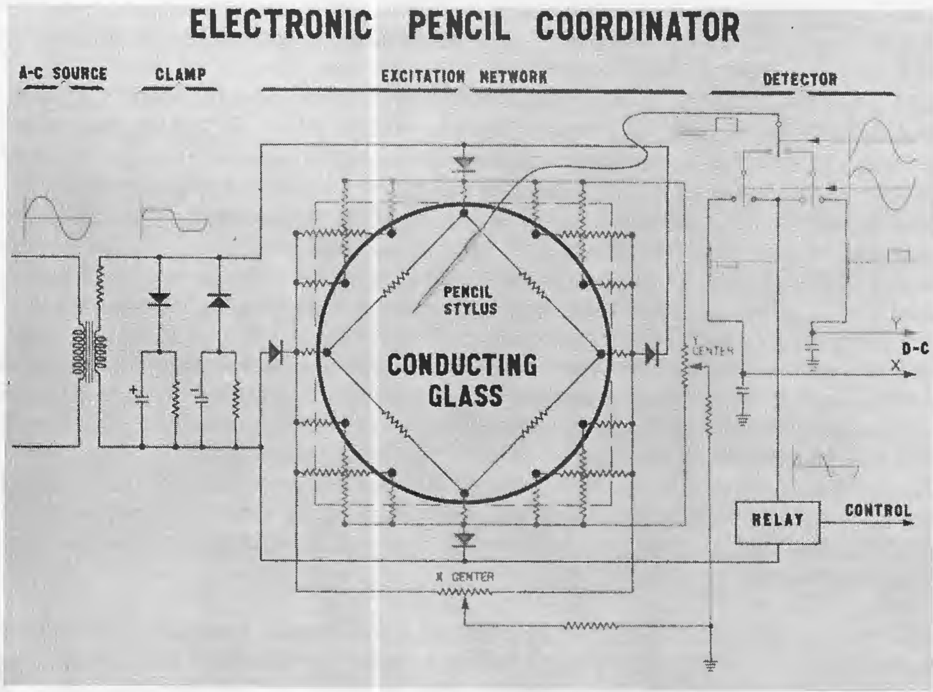

Fig. 4 - Simplified schematic of the EPC conducting-glass-excitation and pencil-probe detection circuitry

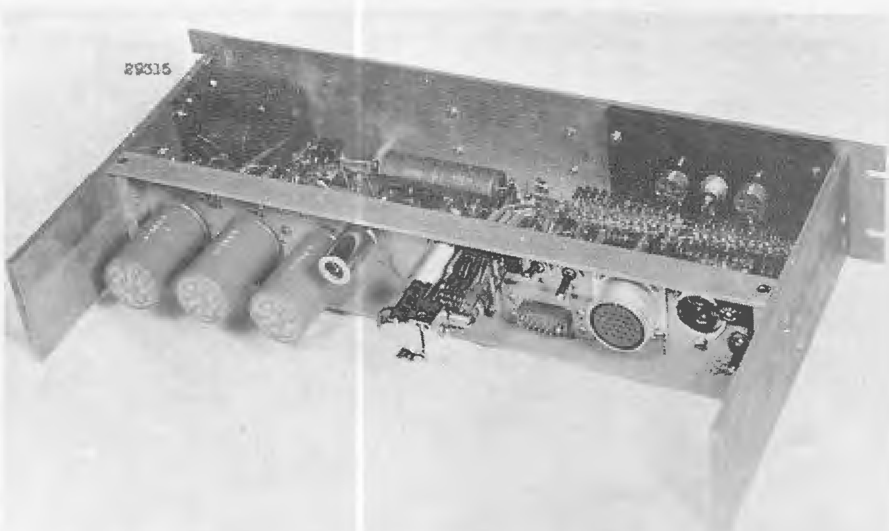

Fig. 5 - EPC Exciter-Detector chassis

Retrace Insertion Unit — An important concept in the use of the Electronic Pencil Coordinator (or for that matter any data takeoff device) is the ability to display the output in a manner which allows direct comparison with the coordinates of the target. To avoid any parallax problem, this is best accomplished by employing a "marker" or dot of light on the same screen as is used to present the raw radar PPI. Adjusting the output X and Y voltages when presented as a single marker for comparison with target coordinates, completes a feedback loop which enables the operator to attain a high level of accuracy. The Retrace Insertion Unit was proposed to accomplish this objective without any effect upon the normal functions of the fixed-coil type of search-radar indicator. It was also deemed important that this be accomplished with the same cathode-ray gun and deflection system used for displaying raw radar data to insure a high degree of alignment accuracy. Requiring a total of about 200 microseconds between the end of one display range sweep and the next trigger pulse, this retrace time, which is ordinarily unused, is employed by switching in X- and Y-coordinate voltages, brightening the marker, then switching off these voltages before the next range sweep. Enough time is allowed for the deflection coils to "settle" after each switching operation. When the long-persistence P-7 screen in used on the PPI, good color distinction is provided between radar echo and the inserted marker if no yellow viewing-filter is used. The marker shows as a constant-intensity blue-white pinpoint of light; the radar echo is more broad, and has a yellowish cast, which decays in intensity exponentially.

The RIU was originally developed in 1950 as a 4-channel model employing 40 tube-envelopes, but because of its importance to the proper operation of the system, additional effort was expended to improve its accuracy and simplicity. The present model, shown in Fig. 6, has a single-channel imput and employs only nine subminiature tube envelopes. Critical adjustments have been eliminated and provisions are incorporated for standardizing voltage inputs, and simplified zero and gain presents. The display of stored data is caused to bear a fixed relationship to the raw radar data regardless of the range-scale setting of the PPI. Into the same chassis are incorporated stable X and Y dc amplifiers for the EPC with provision for remote control of gain and centering, permitting the normal range and off-centering controls of the PPI to coordinate the pencil outputs automatically. The RIU is shown mounted in position in Fig. 2, the second panel from the top of the rack.

Fig. 6 - The Retrace Insertion Unit chassis showing the subminiature plug-in circuit packages

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The combination of the EPC and the RIU operating with a standard PPI now provides an operator with a method of extracting target data which is unmatched in speed, accuracy, and ease of handling. The pencil is essentially without inertia or friction, and utilizes the training every literate person has practiced since early schooling by writing, pointing, and drawing. The conducting glass provides a source of voltages which permits the point of control — the pencil point — to be in the line of sight with the point of action — the marker on the cathode-ray screen. This gives the operator a sense of close coordination and response in which the marker appears to be "attached" to the pencil point.

The human "servo" involving the eye, brain, arm, hand, and fingers is an ingenious two-speed system which, for coarse rapid movements, operates the entire arm (pivoted at the shoulder), and settles in the desired vicinity by resting the heel of the hand on a surface. Fine control proceeds at once through the movement of the fingers (pivoted at the knuckles) to complete the alignment. The result is limited in precision only by the resolution of the display and the vision of the operator. As shown by tests performed on early equipment, the entire operation takes less than one second to complete. Tests of a "free-motion pencil" on simulated equipment by the Canadian Defense Medical Research Laboratory showed that the average operator after a few minutes instruction could readily sustain 0.8 second per target repositioning over a continuous 30 minute period with 99.16% of the repositionings falling within 1% of the correct position.[4]

Capacitor Store — Early studies of data processing showed the necessity of employing a means of storing target-position electrical coordinates, since this offered the only practical solution to making this information immediately available to a wide variety of users on a mutually noninterfering basis. Analog storage appeared to require a minimum of electronic complexity and offered acceptable accuracy. Laboratory work in 1951 resulted in the development of a very high input impedance, single-triode cathode follower to "read" the coordinate voltage stored on a capacitor. Storage times exceeding 5 minutes for less than 1% decay of voltage were attained with standard tubes and capacitors. This has proved to be more than adequate for aircraft target data which are renewed by frequent tracker repositionings. By employing a pair of capacitors for the X and Y plan-position of each target, and a multiple-bank stepping switch, a means of channelling and storing the tracker outputs was provided.

As a repositioning operation is begun, the operator places his pencil over the PPI target blip. The pencil-controlled relay disconnects the selected pair of store capacitors from the RIU input and substitutes the EPC output until the stored voltage is to be altered. The actual storage is effected during a 0.1-second period following the lifting of the pencil from the glass, during which time the EPC charges the Store Capacitors. The "delayed storage" feature avoids modifying the store capacitor voltage during the marker alignment period. One pair of cathode-follower triodes (one twin-triode envelope) per user is all that is required to read out stored plan position data where velocity information is not required. Figures 7, 8, and 9 show the 24-Target Capacitor Store constructed in 1952. Stepping switches for five "users" are installed, providing for a Supervisor, two Trackers, the ASPB, and the Height Operator.

This store is soon to be redesigned to incorporate Velocity Derivation techniques for each target, requiring one cathode follower for each capacitor. Techniques have been devised to effect a cathode follower having essentially a gain of one and zero bias without manual presets, to be described under Velocity Derivation. A vapor-sealed chassis will contain the store capacitors, cathode followers, control relays, and only as many stepping

[4]Defence Research Medical Board (Ottawa), Report No. 61-2

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switches as there are operators who must modify capacitor potentials, which would nominally be three in the case of the EDS. External stepping or manual switch selectors may then be added to sample the plan data as required by the ASPB, the Height Operator, the Air Intercept Controller, the Target Designator, an electronic tactical display, and the Data Transmission System, each with category selection where desired.

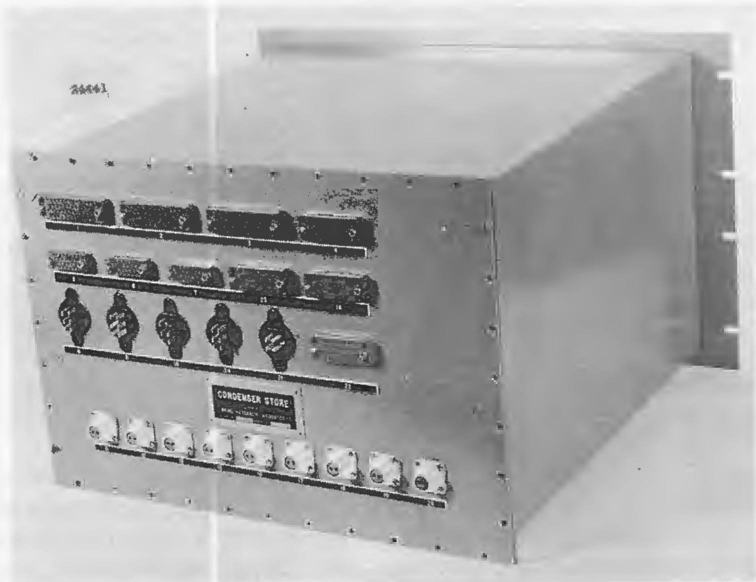

Fig. 7 - Capacitor Store mounted in a vapor-sealed, air-dried container

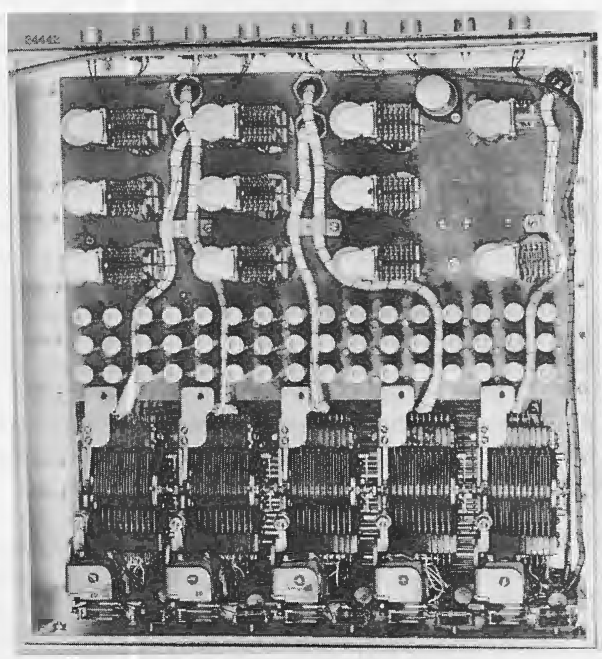

Fig. 8 - Bottom side of the Capacitor Store showing stepping switches, capacitors, and control relays.

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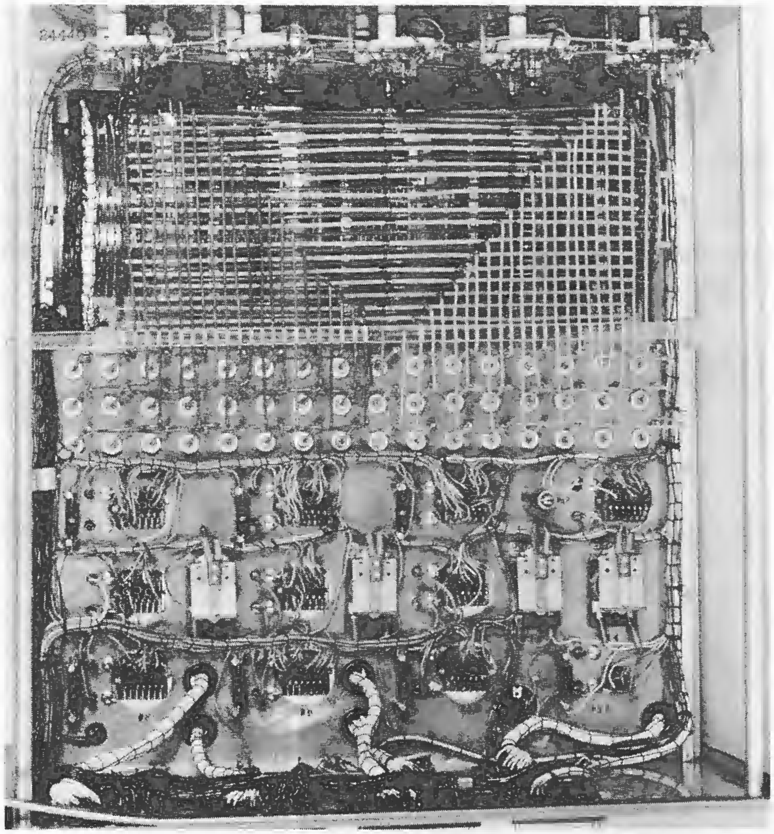

Fig. 9 - Top side of the Capacitor Store showing cathode followers, and wiring of stepping switches, capacitors, and control relays

Velocity Derivation — The automatic computation of velocity during the tracking procedure is a desirable addition to the EDS, and is readily adaptable to the Capacitor Store. Velocity data may be employed to:

(a) Provide aided tracking, relieving the Tracker of frequent repositionings on targets maintaining constant course and speed, thereby increasing his tracking capacity.

(b) Assist the Tracker during target fades and crossing tracks.

(c) Provide up-to-the-second target position data for all users through prediction.

(d) Aid in solving the "course and speed to fly," the feasibility of an intercept, or the choice of interceptors to be ordered by the Air Intercept Controller.

(e) Display a speed vector on an electronic tactical plot showing the course and speed of all targets tracked, thus satisfying the principal justification for an SPB's "history" and "time" and with a minimum of clutter on the display.

(f) Allow "category selection" on a basis of target course and/or speed.

(g) Permit "automatic threat evaluation" on a basis of "closing velocity."

(h) Aid in target evaluation by comparisons with known performance data on aircraft and missiles.

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To date, four tracks and one operator position have been modified for Velocity Derivation in order to demonstrate the techniques and determine its utility. In keeping with the simplicity of the Capacitor Store, the number of vacuum tubes has been held to a minimum. Assuming an operator would be assigned from eight to twelve targets, the total tube count, including the requirement for both the track position and the velocity read-out cathode followers, will be approximately five envelopes per track. The store equipment for four tracks, used in common by all operators is shown in Fig. 10. Each operator requires the equipment shown in Fig. 11 regardless of the number of tracks employed.

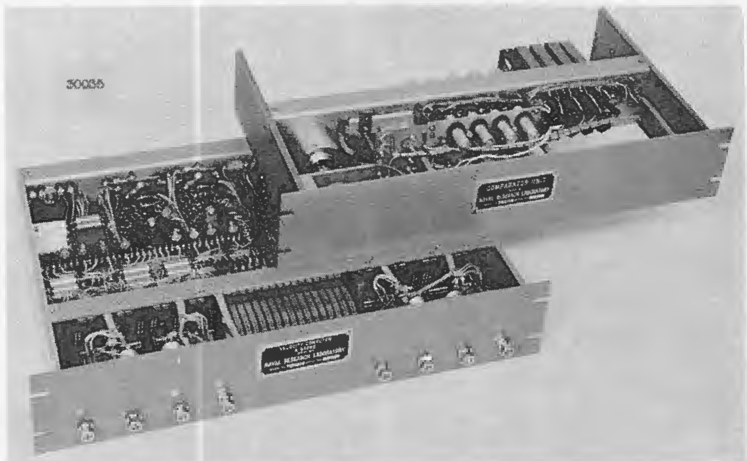

Fig. 10 - Velocity Derivation equipment used in common by all operators for four tracks. The Velocity Computer and Store is on the lower left; the Comparator Unit to obtain track vs. antenna bearing coincidence is

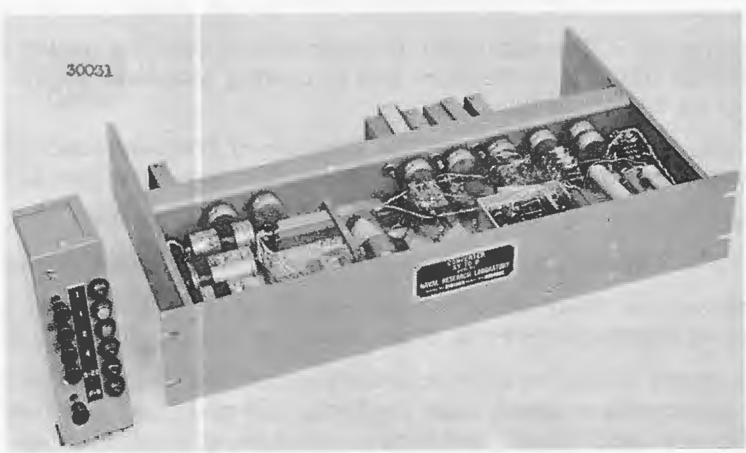

Fig. 11 - Velocity Derivation equipment used by each operator without regard to the number of tracks employed. The computer control box is on the left, and the XY to θ dc converter is on the right.

[redacted]

A number of operational features have been included as follows:

(a) Only one push-button operation is necessary to "clear" a channel and prepare for a new target.

(b) EPC positionings and repositionings are made at the discretion of the operator, without requiring him to choose the same antenna bearing each time or to be limited to a single or fixed number of antenna turns.

(c) Twenty-two antenna turns represent the period of time within which the operator is expected to make at least one, but perhaps no more than two, track repositionings to establish an accurate velocity. Further repositionings by the operator after the 22nd antenna turn do not affect the established velocity for a nonmaneuvering target. Permitting velocity to be computed over a number of antenna scans results in a corresponding increase in the accuracy of computed velocity and will integrate out many target and radar system variations such as fades, glints, and other short-term errors.

(d) The terms α and β have been used to describe system factors applied to repositioning and velocity computing functions. The term α is the proportion of X and Y repositioning entered into store, and β is the proportion of the change in velocity $\Delta\dot{X}$ and $\Delta\dot{Y}$ stored with each repositioning operation based upon adjacent antenna scans. In the case of Velocity Derivation, during the period of 23 antenna-scans, the so-called β, or velocity modification factor, remains 1.0. This is because repositionings are always based upon the initial target position, or reference point, unless a change in course or speed has been noted, in which case β may be modified to become 0.5 or 0.25. The α, or position modification factor, is always 1.0. The β factor term as herein used differs from that used by others, since VD maintains a fixed reference "point" for more than one antenna revolution.

(e) Discontinuous velocity integration is provided the tracker only, to correspond with the inherent discontinuity of the raw radar data, and permit him to make more accurate adjustments. The marker "jumps" at the instant the antenna crosses the target bearing, which means that the marker moves in step with the raw radar "paints" if the computed velocity is correct.

(f) Continuous velocity integration is presented to all other users of data, via a store cathode follower, providing the prediction of target position between radar scans.

(g) Target bearing is available as a dc output from a cathode follower. Slant range in dc form can also be stored and made available if desired for $R\theta$ data users at a cost of one more envelope per target.

In Fig. 12, it may be seen that Velocity Derivation is accomplished by sampling the position differential step-functions developed on the X and Y Store Capacitors at the time a repositioning is stored by the tracker. These differential voltages are increased by the ΔX - ΔY Amplifier to the scale required for Velocity Storage, then they are channeled by the tracker's store stepping-switch to the Velocity Store Capacitors. Individual cathode followers read out the $\dot{X}$ and $\dot{Y}$ velocity voltages for other users, and provide the source for the discontinuous and continuous integrations. A pair of transfer storage capacitors charged to the outputs of the Velocity Cathode Followers are employed as constant-current

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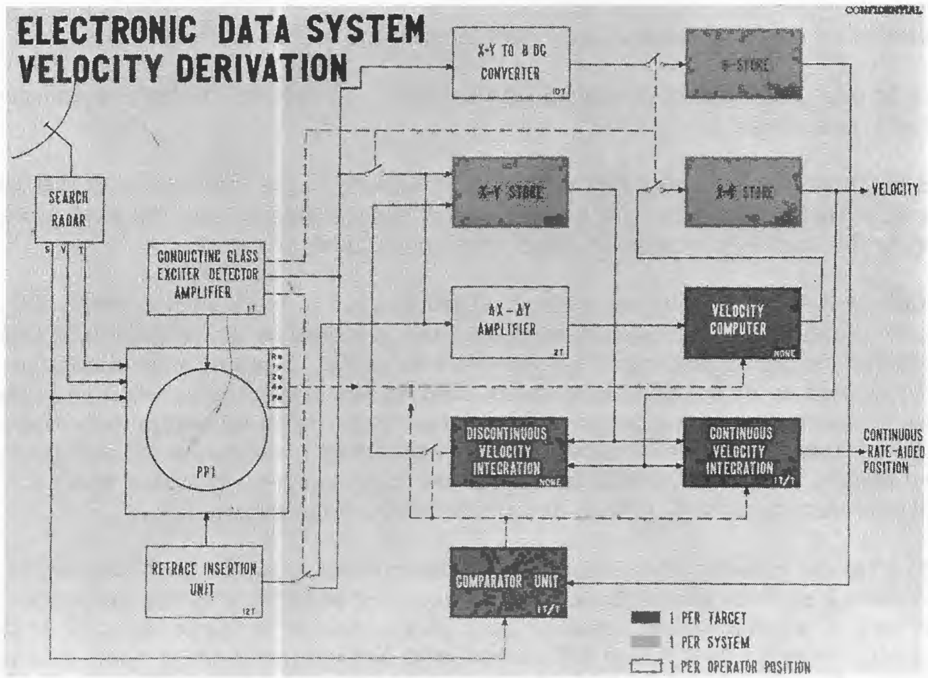

Fig. 12 - The EDS Velocity Derivation functional block diagram. The dark blocks are located at the central store and used in common. The white blocks are used by one operator.

generators, first to integrate into the X and Y position stores for 0.1 second through suitable resistors (discontinuous integration), then to integrate through other higher-valued resistors into capacitors placed in series with the position store and the cathode-follower grid (continuous integration). The discontinuous integration occurs at antenna coincidence, and corrects the position store to correspond with the predicted position of the raw radar blip on the PPI. The continuous integration operates during one entire antenna revolution until the next time the antenna and target bearings coincide, after which the accumulated voltage is cancelled and the process is repeated. Each time the Tracker repositions a target, the X and Y position voltages are applied to an XY to θ (dc) converter, whose target-bearing dc output is routed through another bank of the store stepping-switch to the same target's bearing-store capacitor. Excepting the ΔX - ΔY amplifier and the XY to θ(dc) converter, both of which are used in common for all targets, the computer chassis, shown on the lower left in Fig. 10, contains the components for the above functions on four VD targets.

Each track requires a one-tube comparator which is continuously comparing the output of the bearing-store cathode follower against a sawtooth voltage developed by a potentiometer rotated by an antenna synchro. The comparator, containing the antenna follower and components for four VD targets, is the upper right chassis in Fig. 10. At antenna-track coincidence, the integration relays operate, and a stepper switch (Velocity Computer) placed ahead of the Velocity Store advances one position to divide the output of the ΔX, ΔY amplifiers by the number of antenna turns since the initial position or reference point. Thus the antenna rotation rate establishes the time base upon which the velocity is computed from track position differentials. The five buttons at the indicator (the control box in Fig. 11, which has been mounted at the left side of the SPA-8a in Fig. 2) control the velocity computer operation, and signify: I = initiate; R = reposition tracking only (no rate change); and 1, 2, and 4 = the denominator in the fraction representing the β factor. The operator's ΔX and ΔY amplifiers, and the XY to θ (dc) converter are mounted in the chassis shown in Fig. 11.

In deriving velocity,

$$\dot{X} = \frac{D}{T}$$

where

$\dot{X}$ = the resolved coordinate of target velocity in knots,

D = the distance in nautical miles between the initial reference radar blip and the last observed echo, and

T = the total time between the first and last radar "paints" in hours,

and

$$T = Nt$$

where

t = the time for one antenna revolution, and

N = the number of antenna revolutions since the initial reference blip, as counted by the stepping-switch voltage divider.

Assuming the antenna rotation rate is a constant, t can be combined with the voltage gain established by the ΔX amplifier to form the factor

$$K = \frac{k}{t}$$

where

k = gain of ΔX amplifier.

Then

$$\dot{x} = \frac{Kd}{N}$$

where

$\dot{x}$ = computed velocity in volts representing $\dot{X}$, and

d = position voltage difference representing D.

The same would hold true for the resolved $\dot{Y}$ coordinate of target velocity. No accounting is taken of the ship's velocity, or the effect of the ship's maneuvers on the true

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antenna-rotation rate, since these errors are not serious. Eventually, correction means for these factors may be included.

The cathode followers and store condensers used in the position and velocity stores are deserving of mention. A study of a large number of tube types in 1951 to determine the one whose grid current due to all causes was at a minimum, determined that the type 955 could be designed into a circuit permitting it to present an input impedance about equal to the internal or self-impedance of a 1-μfd Sprague "Vitamin Q" capacitor. This combination permitted storage to an accuracy of better than 1% for 5 minutes. Reduced plate and filament voltages, and a large value of cathode resistor were essential design factors in attaining this storage time. The type 955 tube has since been replaced by the type 6021 dual-triode subminiature tube, which offers the advantages of still higher input impedence, longer life, and smaller size.

The original store, employing these high-impedance cathode followers on the output wiper arms of the stepping switch, did not encounter bias and gain errors, since the same x and y triodes were included in the feedback loop to the RIU and the PPI, allowing their outputs to be aligned with the target by the EPC. The addition of the Velocity Derivation feature necessitated that each store capacitor be read out continuously by a cathode follower, each with its own bias and gain values which are dependent on factors not constant with time. Some work has been done on a two-envelope (four-triode) "operational amplifier" which can be preset for a gain of one and for zero bias, but this would require 96 presets and 96 envelopes for a 24-target store. As an alternative, a circuit has been developed whereby a dual-triode cathode follower having high input impedance, low output impedance, essentially zero bias, and a gain of one, may be employed without any preset controls, aging, or drift problems. This is accomplished by inserting a bias store capacitor in series with the cathode-follower grid. At intervals of about 10 seconds, a scanning stepping switch samples the grid-cathode voltage of the cathode follower, and applies the measured value to the series bias capacitor, thus compensating for all errors at that operating point.

Automatic Summary Plotting Board — The Automatic Summary Plotting Board (ASPB), pictured in Fig. 13, consists of two servo systems receiving X and Y dc input data, and arranged to drive vertical and horizontal rods directly behind a vertical lucite panel, in accordance with the input data. A carriage arranged to move with the intersecting position of these rods, supports a solenoid assembly carrying a small pen and an inkwell. When energized, the solenoid presses the pen against the rear of the edge-lighted lucite plotting board, leaving a deposit of a special water-soluble white ink. Fluorescent lamps, controllable in intensity over a very wide range, edge-light the plastic with a brilliance many times that of the standard incandescent lamps. The Laboratory model has a working area of 36" × 36". The Bureau of Ships has contracted for a similar board with a 60" × 60" working area under the designation SPA-15, due for delivery early in 1955.

The control circuitry includes a plot controller, variable-gain dc amplifiers and clamps shown on the chassis in Fig. 14 and a stepping switch for sampling store-capacitor voltages. The average time of plotting is about 24 seconds for a full 24 tracks, depending upon their geographic distribution. Only those track stores in use in the system are plotted, permitting a reduction in the time for a complete cycle of all plots. The plot-controller times the plotting operation, causing the pen to print as soon as both x and y servos have settled, then (allowing for marking time) advances the store stepping-switch to the next active track. The dc amplifiers provide "rubber-range" gain, and centering presets to adapt the display to any range scale. The diode clamps prevent the servo system from damaging the ASPB mechanism when accidental excess voltages are applied.

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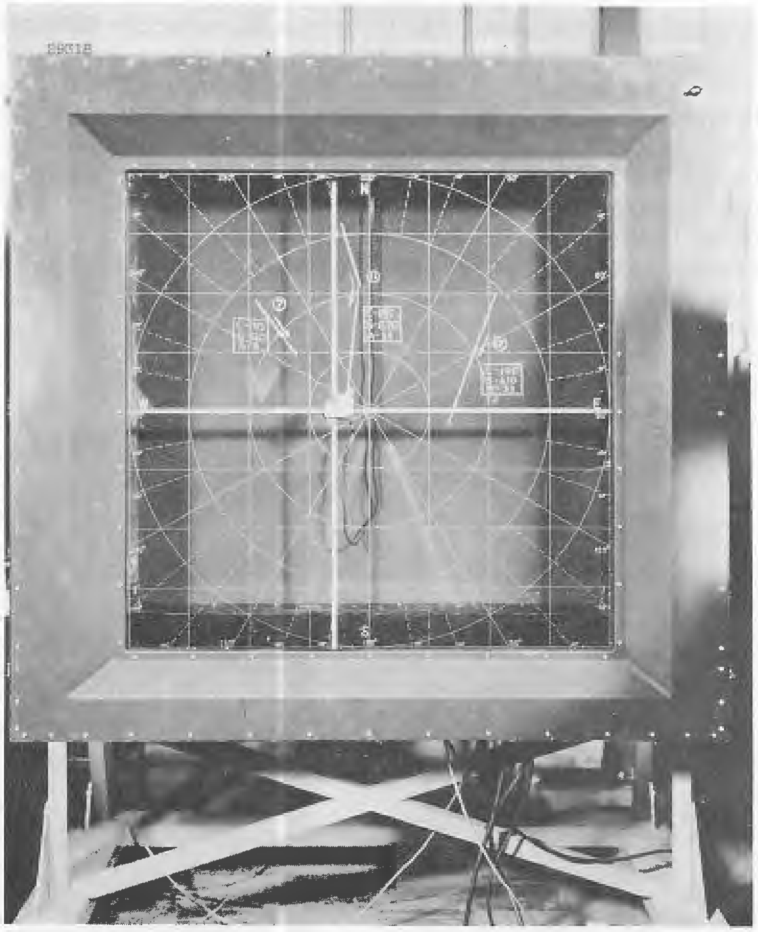

Fig. 13 - The Automatic Summary Plotting Board (Laboratory model) showing three tracks plotted by Velocity Derivation prediction. Colored crayon marks have been added manually to the front side.

Fig. 14 - The DC Amplifiers, Clamps and Plot Control used with the Automatic Summary Plotting board.

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Figure 13 displays three tracks, Nos. 7, 11, and 12, actually plotted by the ASPB from continuous integration data provided by the Velocity Derivation. The starting and ending of these tracks are not indicative of any time or distance limitations. Additional data has been written with china-marking crayon on the front of the ASPB to identify track number, course, speed, altitude, and identity (color). The Track Number Indicator Panel (Fig. 15) and the Target Data Indicator Panel (Fig. 16) aid the ASPB operator in obtaining this data. With larger numbers of tracks, this information could be reduced to track number, identity, and direction arrows to avoid clutter, since the remaining data is available elsewhere in store. An operator is necessary to apply the crayon marks and may also be used to erase old tracks from the rear of the panel. In the absence of Velocity Derivation, "time marks" may be added to each track (either manually or automatically) at intervals of about 5 minutes, permitting a suitably scaled ruler to read off speed directly.

Fig. 15 - The Track Number Indicator Panel, serving to identify the track number as it is plotted by the ASPB.

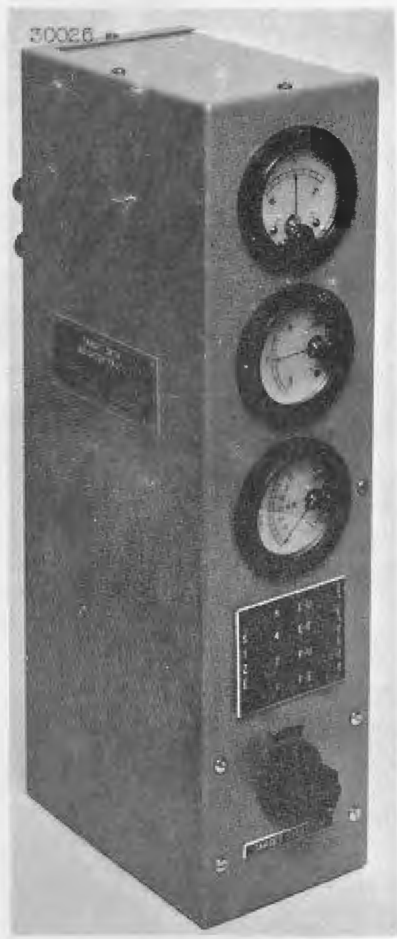

Fig. 16 - The Target Data Indicator Panel Permitting plan position, height, size, and identity to be selected by track number.

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The ASPB is placed as shown in Fig. 17 so as to be seen by all CIC operating personnel, and aids in the coordination of all functions of air defense including both air intercept and target designation. It provides history upon which tactical actions may be based. With the forthcoming availability of velocity data on all tracks, an electronic "tactical" display will be feasible, showing on a cathode-ray tube regenerated target position markers with course and speed vectors. Coupled with other features such as category selection and code painting, tactical displays may ultimately supplant the ASPB, since the history requirement would be met by providing course and speed displays directly. By this means, a virtually instantaneous display would be achieved. When properly instrumented with the RIU, a 24-channel electronic switch, and category selection switches, the standard fixed-coil PPI repeater could be switched from raw radar to a tactical presentation on demand, or mixed as desired.

Fig. 17 - The Electronic Data System installation at the Chesapeake Bay Annex. From left to right are the Target Designation Rack and Console, the Supervisor (detector) console, the HSI console, the ASPB, Tracker No. 1 console, Tracker No. 2 console, and the Air Intercept Controller console.

Telewriting – Telewriting is a feature made possible by the use of the EPC, which permit written communication between any PPI operator positions having the EPC and RIU. In addition, written information may be transmitted to the ASPB, a tactical display (if employed), to remote indicator positions (when equipped with the single-channel RIU), or

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over a data-reporting system. The marker brightness level is adjusted independent of the radar video to produce a wide range of persistence, allowing a written message to remain on the PPI from a few seconds up to a minute or more. The EPC pencil-controlled relay causes the marker to be brightened only when the pencil touches the glass, facilitating writing as with pencil and paper. Typical messages might include target identity, location, track number, sector assignment indication, or any information more readily passed by written or printed characters. In all probability, Telewriting would most often be paralleled by a voice circuit. The ASPB plotting cycle may be interrupted to allow writing by the EPC adjacent to printed tracks for numbering or identification if desired. Telewriting may be of particular value in coordinating a remote plot (such as one in the COTP) with the main plot in CIC.

Height Store — In the conduct of air defense, information on target height ranks in importance next to plan position and identity. In order that it be made available to all users of target plan data, storage is again dictated. Capitalizing on the fact that air targets maintain essentially constant altitude for relatively long periods of time, one operator, if given suitable facilities, can obtain height data on all 24 targets with sufficient frequency. The Height Size and Identity (HSI) Store panel shown in Fig. 18 employs one height potentiometer for each target. At the operator's command, each control is made to substitute for the height potentiometer in the range height indicator (RHI) on a sequential basis. Rotating the selected height knob causes the height line to be raised or lowered until the target, as observed on the RHI, is bisected. Height is then stored as a potentiometer-shaft position and may be displayed remotely or on the calibrated monitor-meter located near the top of the panel. A lamp, located with the group of any controls for each target, is turned on when that channel is in use in the system, notifying the operator that a target is to be evaluated. Depressing the push button adjacent to it engages all the controls of that group, enables the display of the stored HSI data on the monitor panel above, and connects stored height data to the height-line circuit of the RHI. A stepping switch in the Capacitor Store selects the corresponding X and Y plan position data and connects these coordinates to an XY-to-Rθ Converter with single-speed 5G-synchro outputs for range and bearing to be used in either of two ways.

In a preferred method of use, the output of the bearing synchro drives the antenna of the height-radar (such as an AN/SPS-8) to the target bearing, searchlighting the target long enough to permit the operator to evaluate height on the RHI. Thereupon, the next track is engaged and the operation is repeated. The range-synchro output can be inserted into an indicator to form a range line on the display, aiding in the location of the proper target, particularly when more than one target is located on the same bearing. This method overcomes a basic limitation of continuously rotating height radars caused by the very small number of hits per target when scanning vertically and horizontally simultaneously. Searchlighting the height antenna results in an appreciable increase in detection range. Height evaluation should proceed at rates of from 6 to 10 targets per minute, more than justifying the assignment of the height-radar antenna control to the HSI operator. At the cost of some additional complication, probably about 24 tube-envelopes, the antenna may be programmed to searchlight targets in the order of their true bearing.

The second method is required when continuously rotating search-radars such as the SX, the SPS-2, or the SPS-3 are employed. Here, however, the target-bearing synchro, instead of controlling the radar antenna, drives the RHI bearing gate, illuminating the display within predetermined bearing limits either side of the target. This method still offers speed and simplicity in height evaluation and storage, but target detection is somewhat less efficient than when the searchlighting procedure is used.

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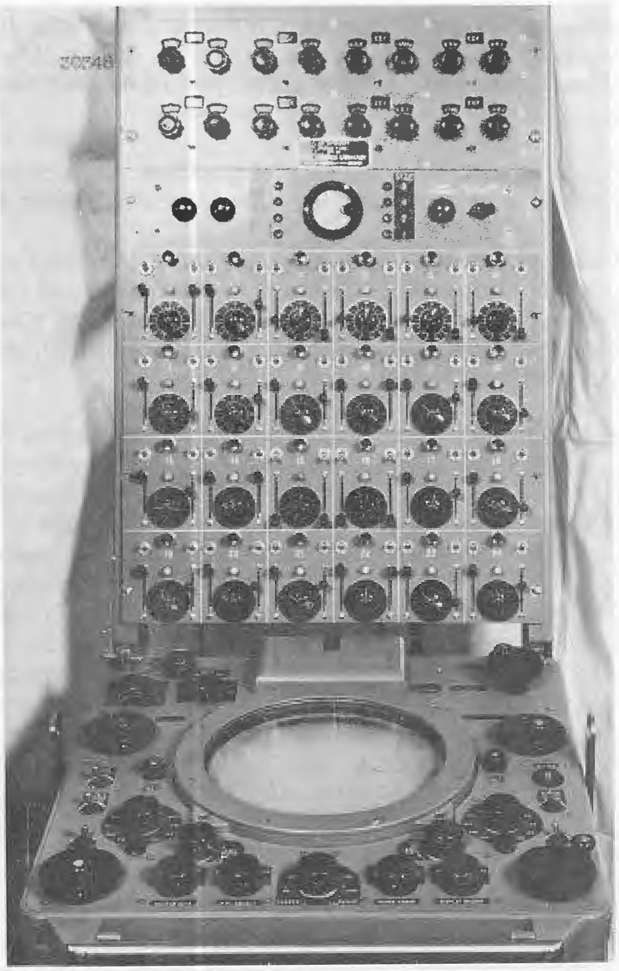

Fig. 18 - The Height, Size, and Identity Store panel mounted on an SPA-7 RHI. The Air Intercept Pairing Panel is located at the top of the rack.

Identity and Size Stores — IFF provides the principal source of identification data. The immediate proximity of the RHI and the PPI assigned to the HSI operator and the supervisor permits the former to have access to a combination of facilities most suitable for target identification. A four-position level switch, shown in Fig. 18, provides for setting as "friend" or "enemy," and as "unengaged" or "engaged" for each target, with an additional toggle switch to turn off the indicator lamps when the target has not yet been evaluated. Similar switching arrangements are provided for "Size," with four levels of 1, 2, 4, or 8 available to give an indication of the magnitude of the raid. Size data is estimated by the radar blip size or grouping as observed on both the RHI and PPI, and supplemented by radio reports. The Size and Identity switches may be connected to operate suitable lamps remotely, can be sampled by the data transmission system, and can be coupled to

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an electronic tactical or summary display in a manner which will afford category selection as required. When the HSI operator engages a target by depressing the proper panel pushbutton, the Size and Identity data stored are displayed along with the height on the monitor panel by illuminating labeled lamps in suitable colors.

<u>Coordinate Converters</u> – The conversion of position coordinates becomes essential when it is necessary to employ more than one means of describing target location.

The fixed-coil radar repeaters operate on the basis of resolving true antenna bearing and radar range into X and Y sweeps, which are recombined with range video in the cathode-ray tube display to present the PPI in polar form. Target data, stored in the rectangular form, is presented on the PPI via the RIU, which switches the deflection amplifiers between the XY data and the XY radar sweeps.

The stored XY data must be converted to R and θ information in size-5 synchro form for the height evaluation and for target designation. These requirements are met by the XY-to-Rθ converter, two of which are installed in the rack on the left in Fig. 19. The electronic and mechanical chassis for one conversion are shown also in Fig. 20. The X and Y dc inputs which are held in a local capacitor store are converted to 60-cps ac, and are applied to the quadrature fields of a resolver. One of two rotor outputs drives a servo system, positioning the resolver rotor to the point of zero output. This shaft position represents the target bearing, and a synchro transmitter provides the desired output when geared to the resolver. The resolver's second rotor output at quadrature with the first, is at a maximum at this shaft position, and the voltage amplitude represents range. A second servo drives a range synchro transmitter and a range potentiometer until the output of the latter balances the resolved range value. The use of a 25:1 gear ratio in each servo permits rapid alignment of the outputs when operating upon data supplied by the EPC. The range potentiometer has two additional gangs, electrically connected to a sine-cosine potentiometer, which is geared to the bearing servo. When properly excited, the electrical outputs of this combination are the X and Y values of the Rθ designation, and are applied to the electronic switch for presentation as one of the feedback markers to be aligned with a chosen target by the EPC.

The basic simplicity of converting shaft position Rθ data to XY dc information by means of potentiometers, and the satisfactory degree of accuracy attainable have justified its use in the EDS. It is also employed in the conversion of the R and θ synchro data fed back from the fire-control director to permit the train of the director radar and its range-gate setting to be displayed on the designation PPI. Cathode followers are used to drive the linear potentiometers from the sine-cosine potentiometers, thereby preventing loading errors on the latter. Bias and gain controls provide the means for calibration of each channel independently. The sine-cosine potentiometers and the dual linear potentiometers available for this conversion require about two inch-ounces of torque to break the standing friction of the slider arms and bearings. This friction prevents the synchros from being used directly to drive these potentiometers because of the shaft position errors which would result in their indicated outputs, and because of the electrical errors which would be reflected back into the stator lines, affecting other synchros in the system. A typical solution to this problem requires the use of a servo system, including a synchro control-transformer, a servo amplifier, a power supply, a motor, and a gear train, to drive the sine-cosine and linear potentiometers.

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Fig. 19 - The Target Designation Console and coordinate converter rack including equipment for designating to two fire control director radars.

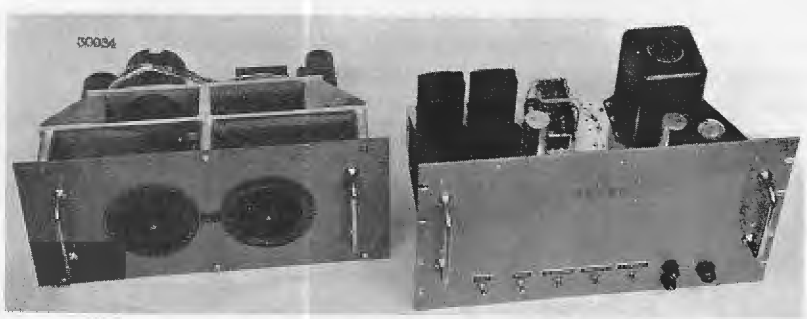

Fig. 20 - The XY-to-Rθ Converter as employed in Target Designation for transmitting synchro data to a fire-control director radar. A similar converter is employed to gate the RHI, and to searchlight a target with the height radar.

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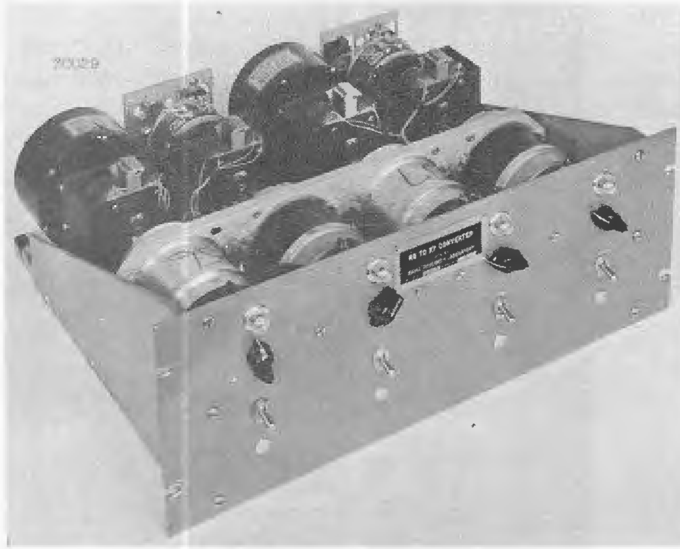

Fig. 21 - The Vibrator Servo-Drive, employed in converting Rθ synchro data to XY dc voltages for display of director present position feedback.

A Vibrator Synchro Drive, shown in Fig. 21, has been developed to avoid this electronic and mechanical complexity. The synchros are coupled directly to the respective shafts of the two potentiometers. The potentiometer housings are supported by resilient rubber mountings, which are in turn fastened to the solid base upon which the synchros are mounted. A resonant-reed vibrator is attached solidly to the potentiometer housing and arranged to impart torsional vibration to it in a plane perpendicular to the common shafts. The vibrator is designed to operate directly from the 115-volt 60-cycle supply, using a germanium power diode to impulse-drive the reed at the fundamental supply-voltage frequency. The amplitude of the vibration is adjusted so as to be just insufficient to break the standing friction, with no torque applied to the shaft by the synchro. When a small amount of torque is applied by the synchro (for example, in a clockwise direction), the dithering or vibrating torque will alternately aid and oppose the synchro torque. When aiding, the sum of the two is sufficient to break the standing friction, allowing the system to move in the clockwise direction. When opposing, the net torque falls below that necessary to overcome the standing friction, preventing the system from moving in a counterclockwise direction. In this manner, the potentiometer shaft is moved by "steps" at a 60-cycle rate toward a null position, at which the synchro no longer supplies any torque. The vibrator actually provides driving power during this operation until the equilibrium state is reached. Settling times of about one second have been observed.

Accuracy measurements indicate that the system is capable of counteracting virtually all of the effects of friction in both the potentiometer and the synchro, achieving a resolution of better than 0.2 degree. This indicates that the shaft is positioned to at least the basic accuracy of the synchro motor when the load is attached. The vibrator technique is of value when the system accuracy is required during static or near-static conditions, as is the case when the fire-control director is completing the acquisition phase or automatically tracking its target.

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Elevation Angle Computer — In order that the EDS may enable a fire-control director to attain a further reduction in the acquisition time, the third coordinate must be supplied in the target-designation process. Rapid and accurate designations in range and bearing, particularly when Velocity Derivation supplies a continuously integrated and predicted target position, are of considerable value in improving director acquisition times. It still remains for the director operator to search in elevation angle until the target is observed in the acquisition-gate display. The problem therefore becomes one of supplying this coordinate without having to evaluate it as a separate operator function.

Elevation angle, ϕ, may be determined when two sides of the right triangle are known. Since height is evaluated and stored by the HSI operator, and slant-range is already available in the XY-to-Rθ conversion for the designation, these may be inserted directly in the formula $\phi = \text{Sin}^{-1} H/R_S$. The value ϕ may be computed by employing a resolver in a servo system, and with an elevation-angle synchro-generator output. Since the height of an aircraft remains constant for extended periods of time, the variations in range result in corresponding variations in the computed value of elevation angle even though no height changes are made or required. Although the design of this computer has been investigated, the prototype has not been constructed, since a considerable saving in the complexity of this approach can be effected by the use of a meter indication.

The two movements of a crossed-pointer meter of the type commonly used with the aircraft Instrument Landing System may be connected to the dc outputs of height store and the computed slant-range already available. By means of a properly calibrated dial such as the scale used on the meter shown in Fig. 23, elevation angle ϕ may be read directly at the intersection of the two meter needles. With this meter located at the position of the fire-control-director operator, it is possible for him to press the button to accept the range and bearing designation with one hand, and to observe the elevation-angle indication, at the same time adjusting the elevation angle handwheel with the other hand to the corresponding value. For this reason, little or no time would be saved by the operator if ϕ were to be electronically computed and automatically designated as a third synchro input to the director. Another attractive method would employ a 90° sine-function potentiometer coupled either to the director-antenna elevation servo or to the corresponding handwheel control. When arranged as shown in Fig. 24, either manual control or a simple servo loop could drive the antenna elevation-angle control to a null, representing the desired elevation angle.

"ADCON" and "DACON" - A Data Reporting System is proposed for the EDS to permit stored information to be passed between units of the Task Fleet. Standard voice communication transmitters and receivers are to be employed at HF and MF to attain the ranges necessary to maintain contact between the more widely dispersed units which will be characteristic of future tactical formations. Time-shared simplex reporting will allow each ship's EDS to present its information in turn, utilizing only so much time as is required to transmit data on target channels in use, followed by a code group notifying the command ship of the completion of transmission, the latter then directing the next ship to report.

To achieve the maximum economy of bandwidth, rate of data transmission, and range, the analog-stored data will be converted to binary digital form, and delivered in serial form, to a communication-transmitter audio input together with the necessary synchronizing pulses and next-to-transmit codes. The receiver output will be decoded and reassembled for presentation instantaneously on a tactical display with a long-persistence tube, complete with category selection as desired. Alternatively, it could be stored in the digital form and presented repetitively as desired on a flicker-free, short-persistance, cathode-ray tactical display. This summary of the Fleet tactical situation will permit every unit to

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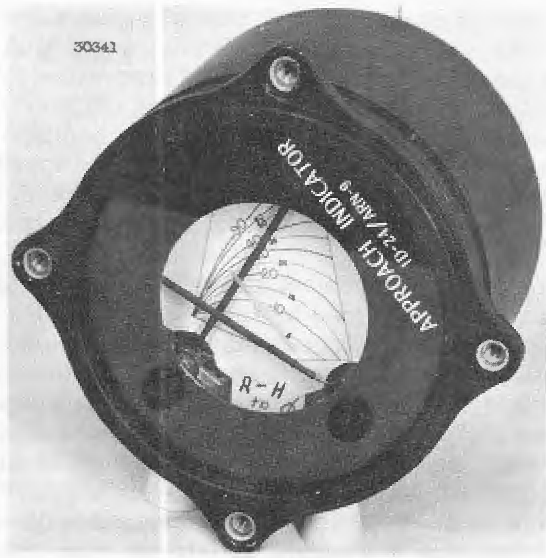

Fig. 23 - A cross-pointer meter converted to compute elevation angle ϕ from height and slant range inputs

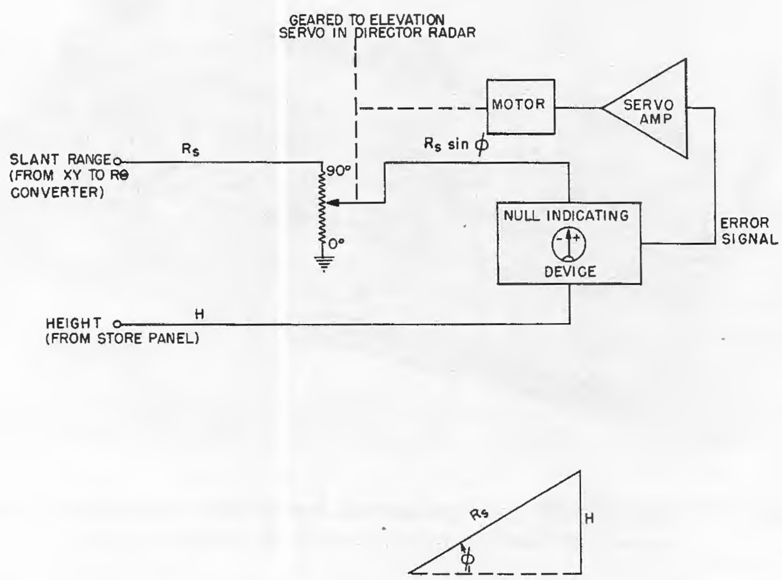

Fig. 24 - A proposed system for manual or automatic elevation angle positioning of fire control radar antenna to complete three-coordinate target designation.

coordinate its activities with those of all the others, under the direction and guidance of doctrine and the orders of the command ship.

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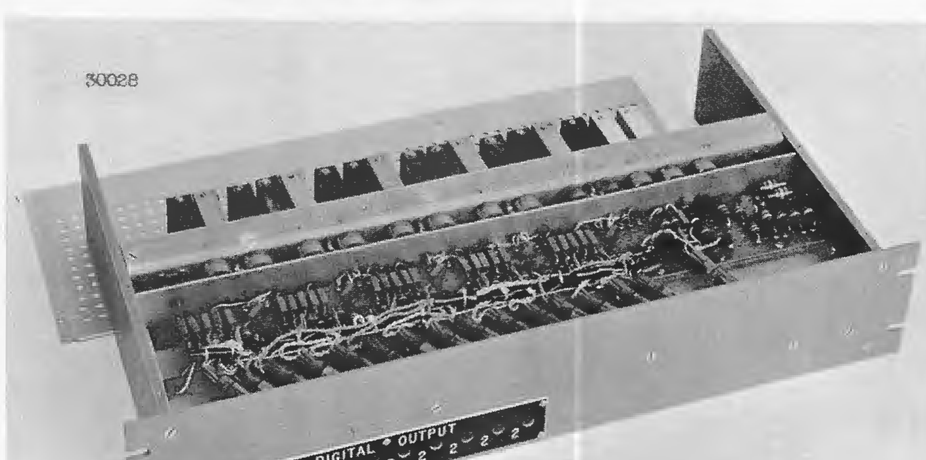
The essential components of these "black boxes" which will connect the EDS with the communication transmitter, and the communication receiver with the summary tactical indicator, are known as the ADCON and the DACON respectively. These are contractions of the titles "Analog-to-Digital" and "Digital-to-Analog CONverters." Possessing 10 digits (2^{10} or 1024 elements) of absolute accuracy, and encoding or decoding times of 50 milliseconds (with even newer designs in process to permit operation within 100 microseconds), these converters can operate on the data as presented, with no significant time required for the coding-decoding processes. The ADCON is shown in Fig. 25.

Communication Panel — A requirement has existed for a means of communication between CIC positions currently provided by "squawk boxes," but unsatisfactory because of the combined noise level they create in combination with radio speakers having attendant high-background noise levels. The panel shown in Fig. 26 contains intercommunication facilities for a total of eight "master" stations with flashing lamps to "call-up," continuous lamps to indicate "answering" conditions, and half-brilliance levels to warn other stations of channels in use. An additional five-channel rotary switch is incorporated to select an "External Net" such as CIC, AI, Navigation, Gunnery, or UHF. The chosen net is mixed at all times with intercom audio, and each has independent audio-level adjustments. One audio amplifier-mixer consisting of a single dual-triode tube-envelope is required at each master station.



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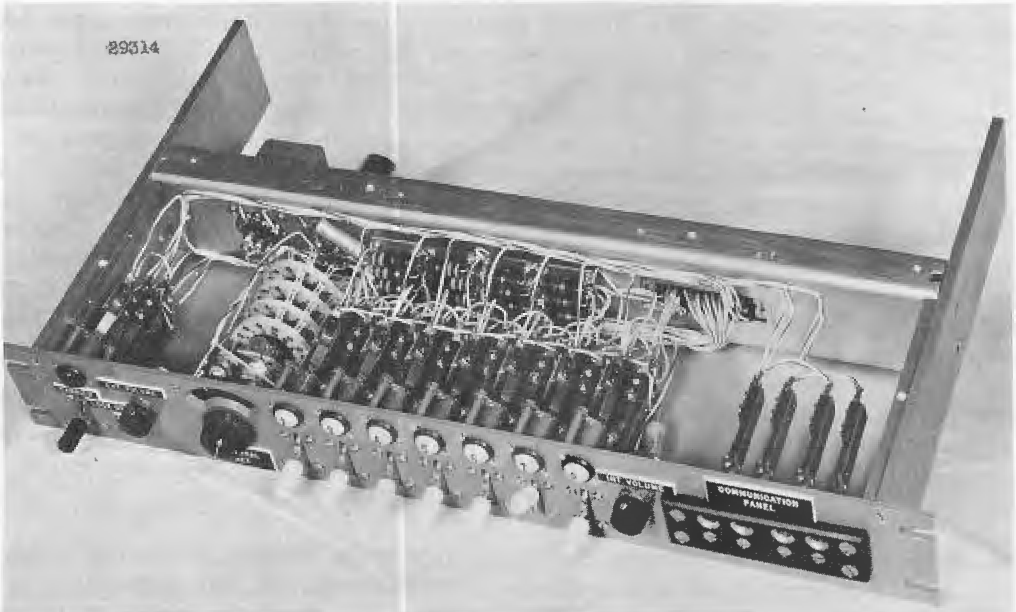

Fig. 26 - The Communication Panel, providing master station intercom facilities and continuous monitoring of a selected external net.

"homes" on the track number so depressed; then, because the down position is a spring return one, the switch returns to the middle position when released by the operator. In this manner, random selection of tracks by track number for display on the PPI via the RIU is permitted.

A numbered lamp is located above each lever switch and is connected so as to be illuminated when the stepping switch stops on the corresponding store track number. This serves to identify the track number of the single track marker displayed one at a time on the PPI. Sequential progression through the tracks in use (those lever switches set in the middle position) is controlled either by a foot switch, or by the EPC pencil-controlled relay when functioning in the Automatic Sequential Tracking mode. The foot switch permits advancing to the next track without touching the pencil to the glass when no marker position correction is needed during Automatic Sequential Tracking. A switch on the Store Control Panel selects either the Manual or Automatic Sequential Tracking mode of operation. The Store Scan Switch is provided to cause the stepping switch to scan or self-step itself through all tracks in rapid fashion. Brightening of track markers during the scanning of the store is effected only on those tracks in use, resulting in a complete situation or tactical display superimposed upon the raw radar picture. The display rate is about one complete cycle per second. A maximum scan rate of three cycles per second is possible, but the slower rate was found to be entirely satisfactory owing to the P-7 CRT screen storage, and reduces wear on the stepping switches. Qualitative experiments indicate that about one cycle for each two seconds is the lower limit acceptable for a store scanning rate under these conditions.

The Supervisor's Store Control Panel has switching facilities for the Telewriting feature control. Five switch positions are supplied, labeled "Tracking," "ASPB," "T-1," "T-2," and "T-1 and T-2." "Tracking" represents the normal operating condition, permitting detection,

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tracking, and store scanning. The "ASPB" position allows the interruption of the ASPB plotting cycle to permit writing to appear wherever directed by the EPC with automatic control over the marking to coincide with contact between the pencil and glass. As soon as this switch position is released, the ASPB continues plotting. A third position is labeled T-1. When engaged, Tracker No. 1's tracking cycle is interrupted. The supervisor may write on his own EPC any desired message which will appear on both his and T-1's display. T-1 may reply in like manner, but the supervisor has priority control over the marker. A fourth position is marked T-2, and operates in a like manner for Tracker No. 2. The fifth position is labeled T-1 and T-2, and allows writing to both simultaneously. Again the supervisor has priority, but thereafter, the first one (T-1 or T-2) to touch his pencil to the glass, acquires and retains control until he lifts his pencil. In this switch position, all three indicators repeat the message written at any one indicator.

Telewriting techniques may be extended to any other indicator suitably equipped with an RIU, and, if two-way writing is desired, with an EPC. Thus, COTP and Gunnery Control may be in "written" communication with CIC, defining areas or sectors of interest, or labeling track numbers or assignments of responsibility.

Power Supply — A power supply, developed to provide the regulated +150, +100, and -150 voltages in common to all EDS equipments, is shown in Fig. 27. Capacities of 2, 0.5, and 2 amperes, respectively, afford a 100% reserve. An adjustable precision voltage for standardizing all indicator calibration is also provided. The ac supply is regulated and distributed throughout the EDS.

OPERATIONAL PROCEDURE

Air Intercept Phase

Detection, Assignment, and Tracking — All track initiations or detections are performed by the Supervisor at a console similar to the one in Fig. 2. Since the Supervisor and Tracker positions are identical except for Telewriting feature, detection could occur at any of the three positions, but it is believed to be more effectively performed by the Supervisor in a system of this size, freeing the Trackers to concentrate on their primary function without distraction. When a new target is detected, the Supervisor locates an unused track number, engages it by bringing the respective SCP lever switch from the up position completely through to the down position, holds it there until the track marker appears on the PPI (never more than 1 second), then releases it to the middle position. The marker is positioned at the value left on the capacitors from a previous use, and is therefore disregarded at the moment. The EPC pencil point is touched to the glass at a position over the target. The marker now appears underneath the pencil, and, with a minor adjustment of pencil position, is made to coincide with the centroid of the radar blip. When the pencil is lifted, the new marker position is stored, and the assignment is made to a Tracker. This is done in the present equipment by either voice or Telewriting. The Supervisor chooses a Tracker and notifies him to "take track one." The Tracker engages the proper SCP lever switch, and the track number is then included in his tracking cycle. Reposition tracking continues by the Tracker, sequencing on a continuous basis through those targets assigned to him. Tracks no longer of interest by being "killed," or leaving the range of detectability may be ordered cancelled upon the decision of the Supervisor. Both he and the Tracker concerned will throw the lever switch for that track to the "up" position.

[redacted]

Fig. 27 - The EDS regulated power supply

Target detection continues by the Supervisor, who, by the operation of the Store Scan switch, may display all markers assigned to Trackers. Any target blips without associated track markers are entered into the EDS by returning the scanning switch to normal, selecting and engaging an unoccupied store, and proceeding as described earlier. The store-scanning operation also enables the Supervisor to observe the effectiveness and accuracy with which the Trackers are keeping the markers aligned with the targets. Mutually exclusive displays of either Tracker's group of assigned tracks may be selected during scanning. Verbal orders via the Communication Panel or Telewriting may be employed to alert a Tracker to an item in question.

Velocity Computation and Aided Tracking — When Velocity Derivation is available, the operator facilities necessary to compute velocity are provided each Tracker. From the operator position, the only outward evidence is the addition of a panel containing five push buttons marked "I" (Initiate), 1, 2, 4, and "R" (reposition tracking only) such as the one shown on the left of the rack in Fig. 2. This is being replaced by the smaller control panel shown on the left of the indicator in Fig. 2 and in Fig. 11. Target detection and assignment proceed as before. When the Tracker has engaged the new track marker, he presses the "I" button, holding it until the "I" lamp comes on. At any time thereafter he may insert the initial position. He may then proceed to the next and succeeding tracks, using either the automatic-sequential tracking feature or the manual-sequential tracking foot-switch. As each track passes its 23rd antenna coincidence following the initial or reference position, it will thereafter be in a "reposition tracking" status, in which no velocity correction is entered by a repositioning operation, but the value of velocity computed earlier continues unaffected. This condition is signalled by the lamp adjacent to the "R" button for the target being displayed.

Providing up to 22 antenna scans allows nearly 2-1/2 minutes (at a 10-rpm antenna rate) to establish an accurate velocity with either manual or automatic sequential tracking. More than one repositioning may be employed if necessary any time during this period, correcting position, velocity, and bearing each time. If, prior to the 24th antenna scan, for any reason the operator wishes to insert a repositioning without affecting the stored velocity, he may do so by depressing the "R" button, which disconnects his ΔX and ΔY computer amplifiers momentarily.

A target maneuver, such as a change in course or speed, when detected or suspected, may be dealt with in accordance with the degree of certainty apparent to the operator. If he is not yet sure of a maneuver, but wishes to take some account of the fact that the target may have veered from the predicted position shown by the marker, he may depress either the 4 or the 2 button, signifying that the reference "point" has been moved forward to a position either 4 or 2 antenna scans prior to the last. This has the effect of applying only 1/4 or 1/2 of the position differential as a computed correction to the value of velocity held in store. If further diversion of target and track marker occurs, additional repositionings may be necessary at reasonable intervals before the new velocity value has stabilized. To follow more closely a rapidly maneuvering target, the operator would depress button 1, which establishes the reference position as the one just prior to the last radar "paint," giving full velocity correction each time it is used. Some extensive experience in use under actual tactical conditions will be necessary before the use of these controls can be set forth in a firm doctrine. Furthermore, it is yet to be determined whether the 4 and 2 buttons are both required, are insufficient, or whether they represent a satisfactory compromise.

Transfer of Tracks — A shift in the tracking load may be found necessary by the Supervisor. This may occur if tracking has been assigned by sectors, and a target crosses from one Tracker's sector to that of another. By verbal orders, the Supervisor directs one Tracker to take on the track number being transferred, to which he reacts as in the case of a new target track assignment. The other Tracker is told to cancel that track number, in response to which he removes it from his tracking cycle. Since position, velocity, track bearing, and counting of antenna turns are stored in common, these values are not disturbed by the transfer of control.

Automatic Summary Plotting Board — When one or more tracks have been entered into the EDS, the Automatic Summary Plotting Board may be turned on. Each new track number assigned is accompanied by the development of a new track on the ASPB. A Track Number Indicator Panel, Fig. 15, is mounted on the ASPB and displays the track (store)

[redacted]

number being plotted by the board at that moment. The ASPB operator may then label the track number with a china-marking crayon on the front of the board. Advice from the Supervisor will assist in resolving questioned tracks by voice or Telewriting onto the ASPB. A Target Data Indicator Panel, Fig. 16, will permit the ASPB operator to select all target data on any track number, allowing him to post the data alongside the tracks, or perhaps on an adjacent status board. Target identity can be shown on the ASPB by the choice of crayon color used. Directional arrows, course speed, and altitude data can be added as shown on Fig. 13 if desired. In the absence of Velocity Derivation, the approximate course and speed can be computed readily by the ASPB operator. One method would be for him to place rapidly a crayon mark on the most recent plot of each track. This is repeated at some interval, perhaps 5 minutes later. This could also be done automatically by a 5-minute timer causing the ASPB to apply these marks. A suitably scaled rule may now be used to determine speed on all targets by direct measurement. Course may be estimated by observation. Manual erasure must be employed by the ASPB operator when targets are cancelled, or when the board becomes too cluttered with old data. Opening the rear door stops the ASPB and permits the operator to use a rag to wipe off old tracks or the part of them no longer desired. Closing the door allows the ASPB to continue with the track number where it left off.

Height Determination — The HSI operator is stationed at the range-height indicator, adjacent to the Supervisor, in order to effect the closest possible coordination in target evaluation. The introduction of a new track into the EDS causes an indicator lamp to light adjacent to that track number on the HSI panel, shown in Fig. 18. Engraved lines encompass the height size and identity evaluation controls for a single track. The engagement button, just above the lamp, is depressed to activate the controls for that track. The RHI will then display the region surrounding the track bearing, with a range line positioned at the track range. The knob in the track control group operates the RHI height line, and is rotated until the line passes through the target blip. Height is now stored as the potentiometer setting, and may be read directly in feet on the monitor panel meter above, or on a similar meter located remotely at a user's position such as the Target Data Indicator Panel for the ASPB operator.

Succeeding targets entered into the system are similarly engaged and evaluated. Height determinations are renewed as regularly as possible, by progressing through the active track numbers on a repetitive basis. Certain tracks of high priority may require more frequent height determination, for which a program other than sequentially by track number may be employed. When a track is cancelled, that height control is reduced to zero.

Identification — The use of IFF will permit identification of the target during height evaluation. The HSI operator will observe the results on the adjacent Supervisor's PPI. Once the target has been identified, the corresponding four-position lever switch on the left side of the control group is moved to the proper identity, and status of engagement (Friendly or Enemy, and Engaged or Unengaged). The toggle switch above the lever control is turned on to illuminate the corresponding lamp on the monitor panel, which signifies the evaluation of identity has been made. Once an intercept involving that track is assigned, the unengaged status is changed to engaged. When the track is cancelled, the toggle switch is turned down, or off.

Size Evaluation — The determination of size is seldom as positive as the factors already treated. It may be estimated by close examination of both the PPI and the RHI, which effectively give the plan and profile views of the raid. An expanded and off-centered PPI with tangential "A" scope video deflection in addition to Z-axis modulation, has been demonstrated by the Naval Electronics Laboratory. This type of presentation would be

 [redacted]

particularly suitable for size evaluation, since minor radar-signal amplitude variations are displayed with good resolution. Other sources may include the basic knowledge of the friendly group size, and radio reports from other observers. The values are set in on the other four-position lever switch, according to the nearest size number in the 1-2-4-8 progression; then the corresponding toggle switch is turned on. The choice of four discrete levels for each of the size and identity categories was arbitrary, and may readily be modified if found necessary.

Air Intercept Assignment – The Supervisor determines which targets shall be paired to carry out each intercept. Factors such as separation, course, speed, and others are considered in accordance with doctrine and probabilities of kill, to determine which CAP interceptors are to be assigned to specific raids. The Air Intercept Pairing Panel is located at the top of the rack in Fig. 18, and is also shown in Fig. 28. It contains eight pairs of 24-position switches to accommodate 8 intercepts. The friend and enemy track numbers are set up respectively on a pair of switches representing an intercept channel. These switches remain in position until the intercept is broken off by enemy kill or escape. They also serve as a tally of the assignments made and in progress. Plan position, velocity, height, and size for both targets are transmitted on a continuous basis to the Air Intercept Controller for display.

Air Intercept Control – The Block Diagram, Fig. 1, provides for two Air Intercept Controllers. Each controller can handle at least two intercepts, providing the "tally-ho" or AI radar-contact times by the interceptors are not too closely spaced. Equipment for the solution of the intercept problem on the PPI by the adjustment of simple manual controls, is under development at the Laboratory. Known as the Triangle System, it accepts the plan position and velocity of the two targets, such as provided by the EDS, and enables the operator to determine the feasibility of an intercept, as well as to compute the course, speed, and time to fly at frequent intervals during the intercept. The data on the enemy will then be transmitted automatically to the plane via the Discrete Address system By this means, the number of intercepts controllable by each AIC may be increased to four.

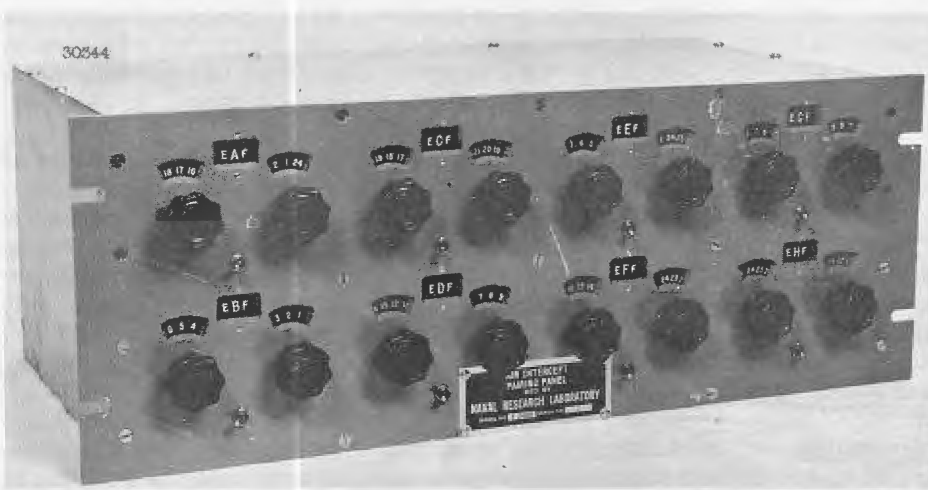

Fig. 28 - The Air Intercept Pairing Panel with facilities for 16 targets or 8 intercepts

[redacted]

The Air Intercept Controller Console is shown in Fig. 29 and in addition to the SPA8-a indicator, it is equipped with an Eight Channel Switch, a Retracte Insertion Unit, an Air Intercept Controller Panel and a Communication Panel, reading from the top of the rack down. A reflection plotter is also employed. Each intercept channel supplied to the AIC will convey the data paired by the Supervisor as enemy and friend designations. The track plan-position information is modulated for display on the PPI according to the intercept channel number, and its identity. The Eight-Channel Electronic Switch shown in Fig. 22, operating one step per radar pulse, connects each of eight sources to the single channel input of the RIU, so that the modulated track-markers will appear in rapid succession on the PPI. Each intercept channel, will then be represented by a pair of markers of identical shapes but different sizes, such as squares, rectangles, circles, or ellipses. One of the pair will be about 1.6 times the size of the other, and will represent the enemy. The smaller will identify the friend. These markers serve to point out and identify the interception assignment to the AIC. As soon as the intercept is under way, the markers may be removed selectively if they tend to obscure the radar echoes, but may be brought back at will by the operator. At the Air Intercept Controller Panel, Fig. 30, height data on each pair of targets is combined on a single meter for each intercept channel so as to display the altitude of the friendly interceptor relative to the enemy (H_e minus H_f). An additional meter and four "size" lamps may be switched to present either enemy or friendly data on absolute height and size. Target numbers for friend and enemy may be written by crayon on the glass of the height meter if that information is needed. A reflection plotter is supplied to the AIC to aid his solution of the intercept problem when carried out by current doctrine. The Communication Panel described earlier supplies facilities for maintaining contact with the intercepting aircraft.

Status Boards — The EDS requirement for status boards is not particularly different from that required at present, except where the data concerning velocity, height, size, and identity are stored electronically, and need not be otherwise posted. Tactical requirements vary with the ship and its missions to such an extent that the status boards must be adapted to the situation. Call signs, UHF buttons, nets and their frequencies, availability and condition of aircraft, ECM data, and reports from other craft are typical of the data best suited to status boards because of their variety and the relative infrequency with which they are changed. When raid numbers are used, as in current doctrine, the status board will provide cross-referencing between track or store numbers and the raid numbers, since track numbers are used throughout the EDS at each console and on the ASPB. Further study and evaluation may show that a combination of numbers and letters may provide a single raid label, overcoming the need for both the track (store) and raid numbers.

Target Designation

Alert from Summary Plot — A circle enclosing the gunnery action area may be inscribed on the ASPB. A radius of about 40 miles is adequate for all ordinance excepting the longer range guided-missiles. Enemy targets entering this area will be observed by the Gunnery Liaison Officer, since he is located so as to have full view of the ASPB. Being alerted to the entry of a new target, he will readily locate it on the short-range PPI (also about 40 miles display radius) at the TD position. Normally, such a target is held under surveillance until it is well within the designation range, which is limited to a maximum of 72,000 yards. Current fire-control radars have a maximum range limitation of about 40,000 yards in the acquisition of targets. These factors, plus knowledge of engagement status, are applied to the selection of a director capable of bearing upon the target. Figure 19 shows the complete CIC equipment for target designation to and from two fire-control directors. Two more directors could be accommodated by an additional rack similar to

 [redacted]

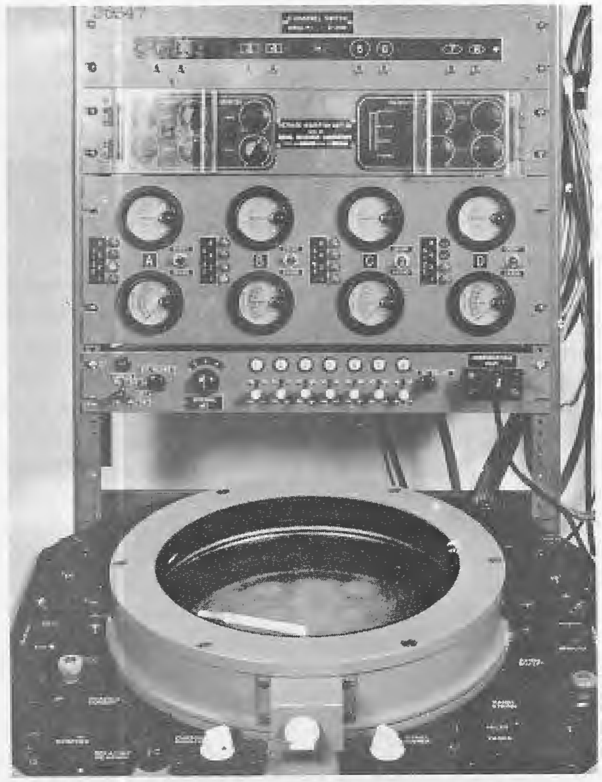

Fig. 29 - The Air Intercept Controller Console

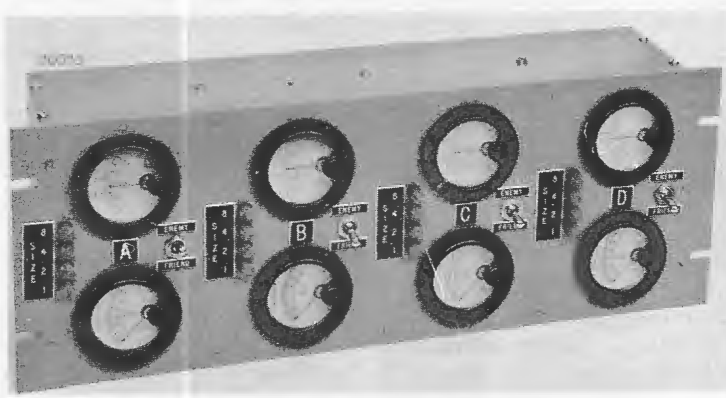

Fig. 30 - The Air Intercept Controller Panel with height and size facilities for each of eight targets involved in controlling four intercepts.

the one at left of the indicator. Figure 31 shows the Target Designator's operating position. The Target-Director Indicator Panel which is mounted on the rack is shown also in Fig. 32.

[redacted]

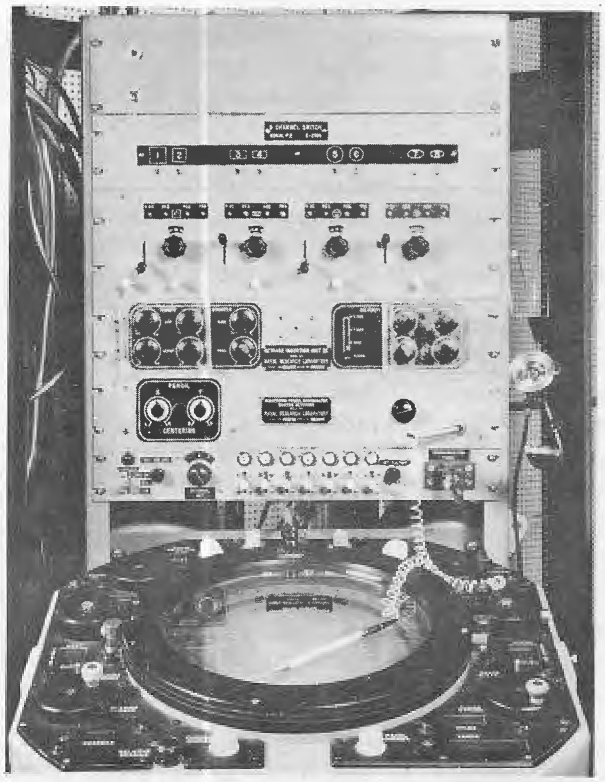

Fig. 31 - The Target Designation Console operator's position

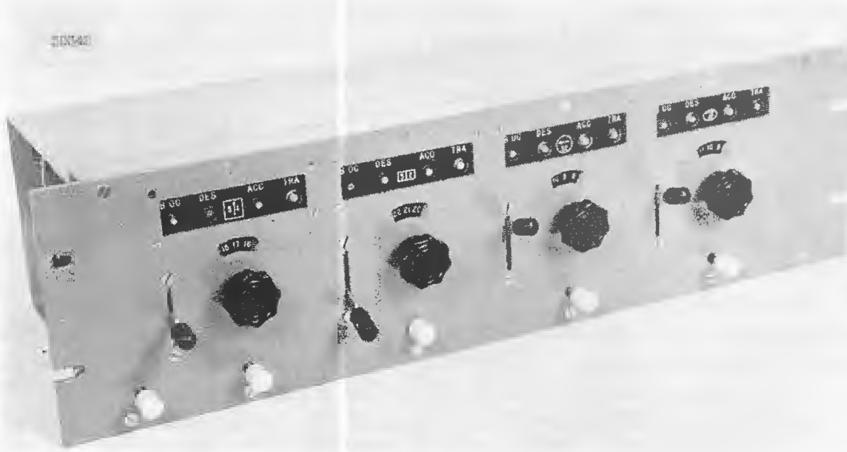

Fig. 32 - The Target-Director Assignment Panel permitting designations from the EPC or from the EDS Store.

Target Assignment to Director — The track number, observed on the ASPB, is paired with the chosen director on the Target-Director Assignment Panel (TDAP). Four knobs on this panel (labeled 51, 52, 32, and 31) represent the four directors. If the "B-OC" lamp above one of the knobs is glowing continuously, it is "Busy" accepting a designation from another source, When it is flashing, it signifies "Own Control," ready to accept a designation. If it is extinguished, the director is inoperative. The knob of the switch associated with a director whose availability is indicated, is rotated to the target number, and the three-position "designate" switch is turned on by moving from middle (off) to up position. This brightens the designate lamp, (DES), the associated designation marker on the PPI which should coincide with the target, and also alerts the director operator by buzzer and lamp at his station to "accept" the designation. While the director is "accepting," the corresponding ACC lamp on the TDAP is lit, signifying that the designation order is being obeyed. Simultaneously, the corresponding director symbol on the PPI should move to show the director response and should coincide with the designation marker. The director symbol or feedback marker on the PPI displays the current director bearing and range-gate setting of the fire-control radar. It has a distinctive size and shape (such as a square, rectangle, circle, or ellipse) to permit identification with a specific director. The associated designation marker for that director is of the same shape, but smaller in size. When the director has acquired and begun automatic tracking, the TRA lamp by that knob on the TDAP will be turned on, after which the designation marker on the PPI may be turned off by moving the designate switch to the middle position. Should the director lose the target, the designation can be renewed by turning on the designate switch to realert the director operator.

Conducting-Glass Target Designation — Designations may be made directly from the EPC, also provided at this position, in lieu of the target data tracked in the EDS. This may occur when a new target appears suddenly within designation range, and must be handled at once without waiting for detection and tracking to be initiated at another position. An available director is engaged by bringing its "designate" lever switch to the "down" or EPC position, and depressing the push-button just below the switch, permitting a designation marker to be aligned directly by the EPC. The director response to the designation action continues as before, but in this case the designation must be renewed frequently. The target designator engages the proper push-button, repositioning the designation marker each time until acquisition occurs, since no Velocity Derivation has been included in this facility to predict target position. Height information is supplied for conversion to elevation angle, ϕ, at the director only when the EDS stored data is used for the designation. When the EPC is used, a "5^0" lamp at the director lights, which signifies that standard doctrine for search in elevation angle should be used, since no correct elevation-angle data is being transmitted.

Designation Independent of EDS — The target designation equipment has been designed so as to permit its use independent of the EDS stored data. Plan designations are made from the EPC, and routed by the push buttons on the lower section of the TDAP. It is also feasible to engage more than one button at a time to transmit the same designation to two or more directors simultaneously. Depressing one or more of these buttons turns on the corresponding designation channel marker (s) on the PPI. The specified director operator (s) is (are) alerted when the EPC pencil first aligns the designation. By use of the EPC, it is possible to rapidly align the designation marker (s) with the target. In rapid succession, the other designations may be set up by the EPC, which is coupled to each channel in turn by the push-buttons.

These facilities are similar to the requirements of the BuOrd Type-D TDS specifications. One operator should readily be able to designate to at least 4 directors, and possibly

[redacted]

more, especially when his work is supervised by the GLO, who assumes the responsibility for decisions concerning relative threat, choice of director assignments, and pertinent tactical problems.

Weapons Control Station — With some minor modifications, including the elimination of the features exclusively devoted to Air Intercept Control, the EDS could readily provide a basis for a Weapons Guided Missile and Gunnery-Control Station, with a nominal tracking capacity of perhaps 12 targets, or more if desired. Eight to 12 directors would be controlled by a minimum of personnel. One detector, one tracker, and one evaluator would supply all data from two PPI consoles and one RHI console, with one or two relative-bearing tactical displays for the Gunnery Officer and his assistants to work out optimum target-director-gun battery engagements as well as general tactical strategy for the ship's ordnance.

Other Data

ECM — Electronic Countermeasures data must be incorporated into any data-processing system which attempts to utilize all tactical data and provide a maximum of Fleet protection. ECM intercept is capable of very early warning and evaluation by entirely passive means, and might be depended upon as a sole source of data during radar silence conditions. Facilities can be provided to permit coded bearing data to be displayed on the tactical display through category selection so as to indicate significant intercepts in summary form. Additional ECM data will appear on suitable status boards.

ASW — The nature of ASW data sources has posed some minor problems in the application of data system of the EDS type. ASW location devices operate on sonar and other physical target data which is generally less reliable than that obtained by radar, ECM, and optics on surface and airborne targets. The problem here lies in the necessity of establishing the reliability of the target data, and identifying it as such, as well as the type of source from which the data was obtained. This, coupled with the probability that the maximum number of targets (and consequently the tracking capacity) would be small by comparison with those encountered in the air-defense problem and with the fact that the targets move much slower would call for a considerably different approach to the data-handling problem. Nonetheless, most of the electronic techniques of the EDS could be adapted to the ASW data-processing requirements.

Significant summary data from a hunter-killer ASW team could be added to the tactical display, as in the case of the ECM data, permitting command to be advised of positive contact data. The category-selection facilities would present this data in any combination with other stored EDS data.

Navigation — It is conceivable that the EDS may offer some aid in the problems of navigation. Specialized equipment adapted to this purpose could be installed in the COTP. If assigned to the tracking of surface craft, the problems of station keeping and surface tactics would be eased. Automatic plots may be of assistance in the routine keeping of ships positions. Further study of this problem must precede a more detailed proposal, but some indication of the utility of this feature may be obtained in the forthcoming operational evaluation.

PROGNOSIS

Production Contract

A contract has been placed (early FY 1955) by BuShips Code 824 with Motorola for the construction of some of the basic equipments constituting the air-intercept portion of the EDS. These are to include the components required by the supervisor and two trackers. Specifically, the items involved are three EPC's; three RIU's; the Capacitor Store complete with Velocity Derivation for 24 targets; three Store Control Panels; the ASPB D-C Amplifiers Clamps and Servo Plot Control; and an XY-Rθ converter for each operator position.

The Laboratory has recommended to BuShips that the contractor be allowed to substitute the HSI Store and the Pairing Panel for two of the three XY-Rθ converters. The third converter would be required at the HSI position to gate the RHI and control the height radar antenna bearing. Delivery of this equipment to OpDevFor for shipboard evaluation is tentatively set for about January 1956. The design of the EDS will permit all of the features described herein to be added progressively as desired later without intermediate conversion problems.

Evaluation Program

NRL — The CIC Facility Branch of the Laboratory's Applications Research Division has undertaken the operational evaluation of the EDS beginning 1 October 1954. A number of enlisted men have been procured as operator subjects for the evaluation period. Among the data being sought are the effect of the tracking load on accuracy and the maximum delays in storing and displaying target data in all categories; the individual tracker's target capacity and tracking rate with and without Velocity Derivation; the potentialities of the target designation system in reducing the designation time and over-all acquisition times; the general effectiveness of the electronic equipment innovations; and the suitability of the personnel organization and flow of tactical data. On the basis of these findings, methods of implementing any recommendations will be studied. As an example, some indication of the relative amount of effort demanded of the Supervisor and HSI Operator may show the need for further assistance in this area under conditions nearing the system design capacity. The optimum length of watches is affected by the degree of concentration and tension required and the convenience of the facilities provided. The factors disclosed on these and other features will also be available in time to offer some guidance on the commercial contract mentioned above.

OpDevFor — It is expected that an OpDevFor evaluation of the portion of the EDS under contract for BuShips may have to wait until early 1956 for the delivery of the first model from the contractor. Such features as the HSI Store, the Air Intercept Control facilities, and the Target Designation Equipments may not be included in this model. The equipment to be supplied by the contractor will, however, have been specifically designed to meet specifications against the extremes of vibration, shock, and temperature encountered in Naval service.

Assuming that the NRL evaluation and the subsequent modifications proceed with reasonable dispatch, and without serious unforeseen delays, an improved EDS model at NRL could be made available for OpDevFor evaluation in advance of the first commercial model. The evaluation of the commercial equipment would be able to take advantage of this earlier evaluation which would give much needed data on problems of installation and maintenance on board ship, as well as performance data under actual operational use, and could be of further advantage in guiding the contractor's designs in their final stages.

FUTURE WORK

Following the NRL evaluation, it is anticipated that the redesign of the Capacitor Store will be undertaken. Among the advantages to be incorporated are: Velocity Derivation for all 24 tracks with accompanying control facilities for at least two operators; continuous cathode follower outputs for all stores; category selection circuitry for tactical displays, with provisions for adding code painting techniques; the incorporation of improved capacitors for higher temperature conditions; the incorporation of a centralized junction panel; and an increase in the target capacity, if justified. The Store Control Panels will also be redesigned to take advantage of improved lever switches with desirable safety locking features and increased contact capacity to allow additional control and display features. Some consideration will be given to the possible advantages which might be obtained by providing the Supervisor with the controls to assign the tracking of a given target directly to a chosen tracker without requiring any communication with or acceptance by the tracker. Under this method, no Store Control Panel is required by the tracker, and his job is further simplified. The Supervisor's task would, however, be increased somewhat; the system flexibility would be reduced; and the principle of interchangeability of positions would have to be abandoned.

CONCLUSIONS

The Electronic Data System offers a means of increasing the combat-target data-handling capacity of the CIC organization. Considerable study has been directed toward the inclusion of all phases of CIC operation into the design potentialities of the EDS in order that the tactical control of aircraft, ships, and weapons may become more rapid and accurate under conditions of high-speed multiple attacks. The incorporation of relatively simple, common, electronic analog stores for all target information, and many other data-processing innovations provide basic techniques which facilitate data extraction, display, processing, or transmitting remotely on a selective basis. An analysis of current and probable future requirements in this field indicates that they can be met by these techniques which have been demonstrated individually and in concert.

By using existing installations where practicable, a minimum of additional equipment will be imposed on the CIC organization, probably avoiding a shipyard overhaul. Most, if not all, elements of the EDS could be installed by ship's personnel. Each ship converted for the use of the EDS would continue to operate in company with unconverted craft compatibly, differing only in its superior target-handling capacity, accuracy, and speed. Although it is classed as an interim system, the flexibility of the design will allow it to remain in use for many years beyond the introduction of the "long-range" data-handling systems under study at this time.

ACKNOWLEDGMENTS

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APPENDIX A
Tube Complement and Weights

The following is a tabulation of the vacuum tube complement of the Electronic Data System as of the present time. There are occasional minor changes in this number, usually resulting in a reduction, due to continuing efforts to improve its suitability for Naval Service. Unit weights have also been tabulated and totaled. The major sections of the EDS are treated separately. These features may be added in various combinations as desired. This list does not include the standard radar indicators which are presumed to be installed prior to the introduction of the EDS.

Unit	Tube Envelopes	Unit Weight (lbs.)	No. of Units	Tube Totals	Weight Totals (lbs.)
Capacitor Store	5	50	1	5	50
Supervisor or Tracker Console:					
EPC	1	10	3	3	30
RIU III	8	8	3	24	24
Commun. Panel	1	5	3	3	15
Total per Console	11	23			
Power Supply	20*	325 *	1	20*	325*
				55	444
DCACPC (ASPB)	9	7	1	9	7
ASPB	0	300	1	0	300
ASPB Servo	4	25	2	8	50
ASPB Servo Power	2	50	1	2	50
TNIP	0	1	1	0	1
TDIP	2	5	1	2	5
				21	413
Velocity Derivation	5 track		24 tracks		
				120	
HSI Store	0	20	1	0	20
XY-Rθ (RHI)	10**	100**	1	10**	100**
AIPP	0	15	1	0	15
				130	135
Air Intercept Controllers (Two handling four intercepts each)					
RIU III	9	8	2	18	16
8CES	25	8	2	50	16
AICP	0	12	2	0	24
Commun. Panel	1	5	2	2	10
				70	66

*This power supply has a 100% reserve for the EDS when all features described in this report are included

**Redesign of these items should result in reductions in both the weight and electronic circuitry

 [redacted]

Unit	Tube Envelopes	Unit Weight (lbs.)	No. of Units	Tube Totals	Weight Totals (lbs.)
Target Designation (4 Directors)					
EPC	1	10	1	1	10
RIU III	9	8	1	9	8
XY-Rθ	11**	100**	4	44**	400**
Rθ-XY	0	12	8	0	96
Cathode Followers	8	8	1	8	8
SCES	25	8	1	25	8
TDAP	0	10	1	0	10
Commun. Panel	1	5	1	1	5
				88	545

* * *

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