A-NEW: A NEW DATA-PROCESSING SYSTEM

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GENERAL

Although the basic concepts and objectives of anti-submarine warfare (ASW) have not changed, the threat of the deep-diving nuclear submarine has increased the requirements for greater effectiveness, speed, and reliability in all ASW systems. Project A-NEW is the Navy's program for integrating existing ASW sensors and subsystems into sub-hunting aircraft to meet this requirement. The heart of the A-NEW concept is a data-processing system which will assist flight crews in the performance of such functions as navigation (target search, localization, and classification), selection of tactics, and attack on hostile "targets".

The first experimental version of the A-NEW data processing system, designated XN-1, was initiated by the Naval Air Development Center at Johnsville, Pennsylvania, in December, 1962, following the completion of a study program to determine the feasibility of the concept. UNIVAC was selected as a team member for the XN-1 program. UNIVAC's role in the XN-1 system was threefold.

1. To assist NADC in defining XN-1 system functions;
2. To design and develop the required digital computing equipment;
3. To develop the computer programs necessary to carry out the system functions.

The target date for equipment delivery was 1 July 1963 and 31 October 1963 was established as the date for commencing the first flight tests with the equipment installed in a NP-3A aircraft (a modified Lockheed Electra). The delivery date was met by UNIVAC, the equipment being in operation at NADC on 2 July 1963. The remainder of this paper will describe the XN-1 hardware and system functions.

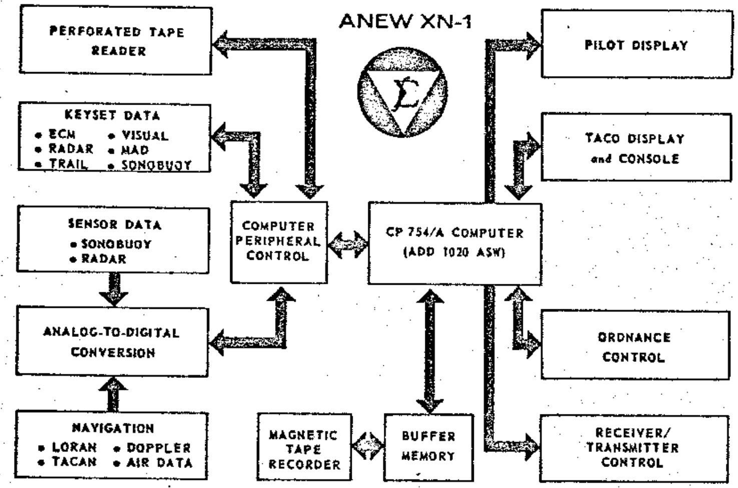

Fig. 1 Block Diagram of A-New XN-1 Equipment

HARDWARE

Figure 1 is a simplified block diagram of the A-NEW XN-1 equipment. The digital computing equipment supplied by UNIVAC consists of the following:

1. CP-754/A Computer (UNIVAC ADD 1020)
2. Computer Peripheral Control Unit
3. Buffer Core Memory
4. Perforated Tape Reader
5. Magnetic Tape Recorder
6. Computer Maintenance Test Bench

Other major components of the XN-1 data-processing system include:

1. Tactical Situation Display with operator controls
2. Sensor Operators' Keysets
3. Ordnance Display and Control
4. Receiver/Transmitter Control
5. Pilot's Display

The above equipment, with the exception of the computer test bench and pilot's display, is shown in Figure 2 as it is mounted in the aircraft.

The CP-754/A is a general-purpose, stored-program, parallel, binary computer. The computer uses 24-bit words for both instructions and

Figure 2 – YP3 concept with ANEW Mod 1

The computer logic circuitry and memory circuits are packaged in resistance-welded, cordwood blocks as shown in Figure 3. As many as 68 of these blocks are then mounted in a module and interconnected by welded wiring. One of the 19 modules in the CP-754/A computer is shown in Figure 4. In addition to the modules, the computer consists of two memory stacks, a power supply, an interconnection wiring panel and the computer case. The assembled computer is shown in Figure 5. Only silicon semiconductors are used, and all electrical components are of conventional size except for microdiodes within the memory. Designed to be air-cooled, the computer has a nominal power dissipation of 300 watts. This includes the power required by the internal power supply which operates from 3-phase 400-cps primary power. The entire computer occupies 2.84 cubic feet and weighs 145 pounds.

In order to match the general purpose computer input/output channels to the unique requirements of the XN-1 system, a special logic unit was designed. This unit, designated the computer peripheral control unit (CPC), is a multipurpose digital control device that functions as a keyset central, a doppler radar pulse accumulator tape reader controller, a digital input multiplexer and a computer manual control panel. The keyset central portion of the CPC has an input capacity of four 24-bit word keysets and one 36-bit word keyset. The keyset central reduces these inputs to three 12-bit channels, also providing the control signals required by the keysets and the computer. The pulse accumulator is a ten-bit digital counter that counts distance pulses from the doppler radar system. The accumulator can be

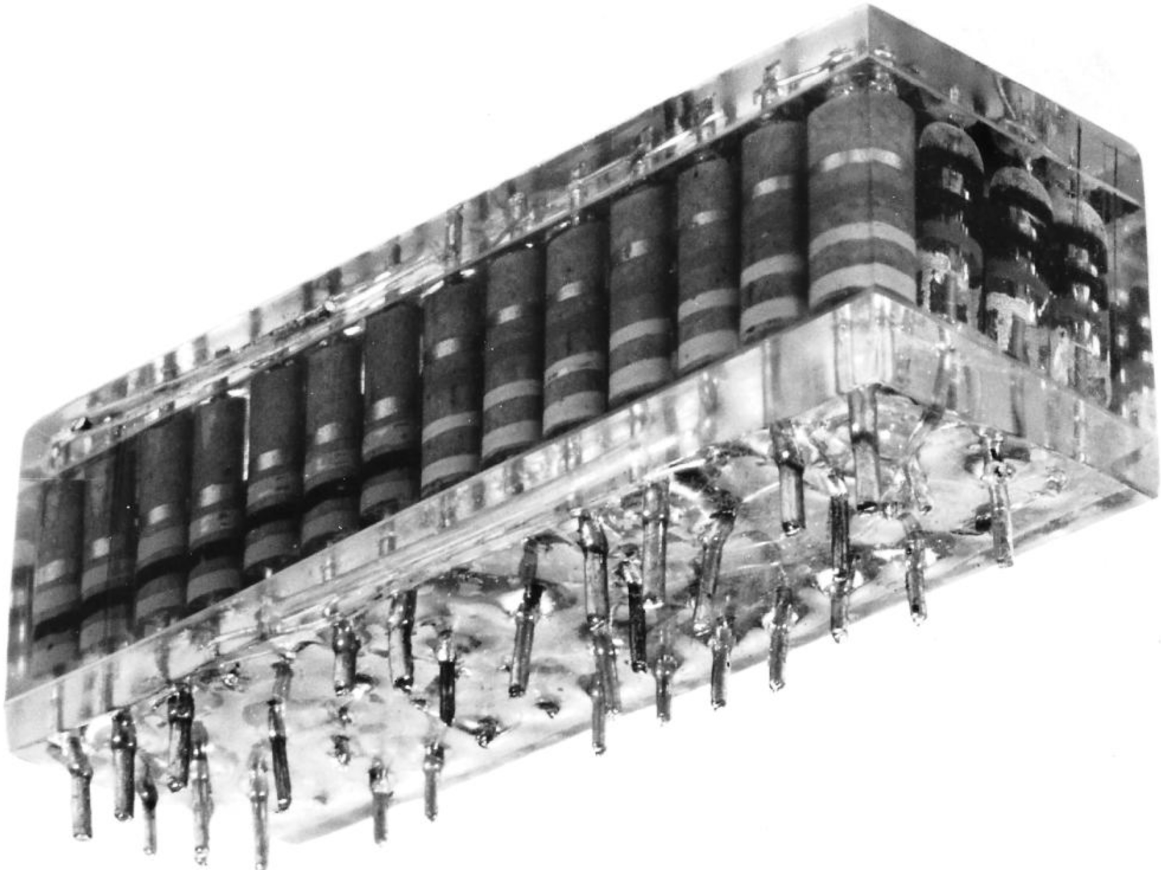

Figure 3 – CP-754/A electronic module

interrogated periodically by the computer. The tape reader controller provides the start-stop control and input data channel for the perforated tape reader. The digital input multiplexer provides direct input switching for ten 12-bit input channels. It also provides signals for controlling a remote, 11-channel analog-to-digital converter unit. All these inputs are switched into one 12-bit computer input channel. Channel selection is performed by a 5-bit channel selection word transmitted from the computer. The control panel portion of the CPC provides the capability to inspect and alter computer memory addresses, to manually initiate maintenance procedures and to initiate loading of the computer memory from perforated tape.

The CPC logic chassis is physically the same as that of a UNIVAC 1218 Computer, employing the same type of logic cards except for a few special input-output matchers. The chassis holds 420 logic cards, occupies 2.4 cubic feet, and weighs about 90 pounds.

The buffer core memory provides 4,096 24-bit words of auxiliary computer storage. The memory has a four-microsecond cycle time with a 1.5-microsecond access time. The computer can read or write randomly in the buffer memory address sequence, or it can read or write a consecutive group of addresses with the buffer doing the address incrementing. The buffer memory acts as a true buffer for only 128 words of its total capacity. These 128 words are used to store a block of data for the magnetic tape

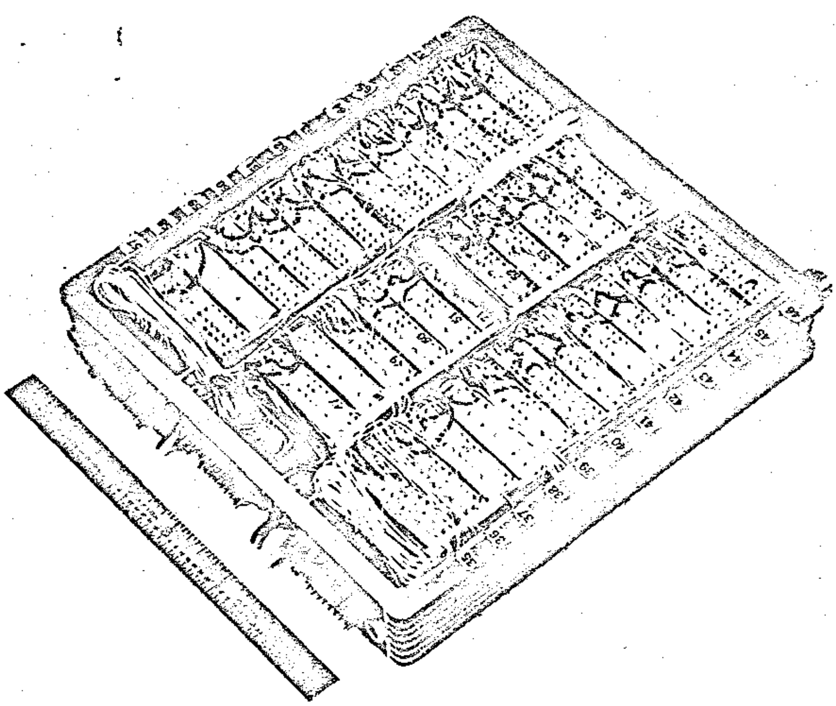

Fig. 4 A CP-754/A Computer Module Composed of Cordwood Blocks

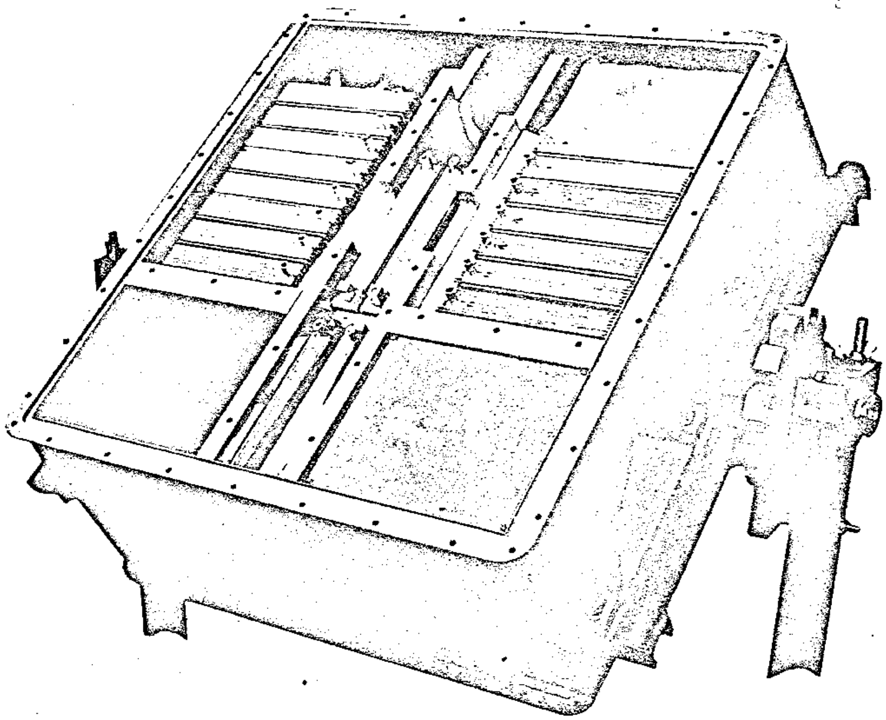

Fig. 5 Assembled CP-754/A Computer

recorder. Upon computer command, this data can be transferred from the buffer memory to magnetic tape. Readout for the magnetic tape recorder is interlaced with normal computer-buffer operation on a memory cycle basis so there is no interference between the two buffer memory users.

The buffer memory chassis is similar in size and construction to the CPC and uses the same type logic cards. The memory circuits and core assemblies are adapted from the UNIVAC 1224 Computer.

The computer, CPC, buffer memory and a power supply unit are all mounted in a special cabinet that provides shock and vibration isolation, controlled cooling air, and inter-unit working.

Mounted separately are the two tape units. The perforated tape reader is an 8-level photoelectric reader that provides reel-to-reel transporting of the tape at a read rate of 7.5 inches per second. The reels can hold about 500 feet of 0.0025 inch thick, polyester-base tape. The magnetic tape recorder employs fixed block length recording and is compatible with UNIVAC 1206 tape units. The tape transport is similar to 1206 service test tape handlers. It operates at a tape speed of 100 inches per second and records at a tape density in excess of 200 bits per inch. Normal tape capacity is 2,500 feet. The magnetic tape recorder control logic uses UNIVAC 1206 circuit cards.

The computer test bench is a ground-based maintenance unit used to perform electrical tests on the computer. It is also used to control the computer during the program checkout. It has provisions for perforated tape input to the computer and provides output via either perforated tape or a typewriter.

SYSTEM FUNCTIONS

As in most data-processing systems, operation is centered around the digital computer. The computer is responsible for integrating the inputs received from the various ASW sensors, determining the optimum tactics to employ, executing the tactic, computing the probability of success or failure, and navigating the aircraft. In order to implement these tasks, seven program modules were designed for the computer.

1. Navigation
2. Search and Correlation
3. Contact Conversion
4. Automatic Tracking
5. Extend Track
6. Attack
7. Post Flight Analysis

NAVIGATION

The Navigation program is designed to compute the aircraft's position continuously in both a long-range and short-range reference frame. The computer uses LORAN inputs to compute the long-range position of the aircraft every minute.

The computer program utilizes doppler data and dead reckoning to compute the aircraft position in the short-range reference navigation frame and update the long-range position. A short-range reference frame is required when the aircraft is attempting to localize the submarine, this reference giving greater accuracy. When a sonobuoy pattern is deployed in the water, the aircraft flies over one of the buoys, and an "On Top" indication is transmitted to the computer. The program then synchronizes the buoy position and proceeds to navigate in the short-range reference frame. If the aircraft flies over the same buoy a second time, a second "On Top" is transmitted to the computer. The program again synchronizes the buoy and aircraft positions. The second "On Top" allows the computer to compute a navigation bias based on the time between successive "On Tops" and the distance differential. The bias is then introduced into the short-range navigation computation to compensate for the effects of wind and currents on the sonobuoy, and wind on the aircraft. Even though the short-range navigation is used during localization, long-range navigation is also performed so that an accurate long-range aircraft position will be available when the localization phase is terminated.

In addition to determining aircraft position, the computer will compute steering orders to direct the aircraft to any designated point. The computer can be requested to provide steering information in either the long-range or short-range navigation frame. The computer communicates its steering orders to the pilot via the bearing distance heading indicator (BDHI) which displays a velocity vector to the pilot, and the ground track plotter (GTP-4) upon which the computer can inscribe up to 10 points representing a flight itinerary. A plot of the aircraft's path is also depicted on the GTP-4 plotter.

In the event LORAN is unavailable or inoperative, the long-range navigation system can be resynchronized by radar or visual contacts. That is, the known latitude and longitude of an object can be inserted into the computer via a keyset. When a radar return is received from the object, the program will compute the long-range position of the aircraft with respect to the object. Short-range navigation is always used to update the long-range position until a new long-range computation is performed.

The computer contains automatic interrupt capability which is utilized by the navigation program. Every 1/20 of a second the computer program is interrupted, and program control is routed to the navigation program. The interrupts provide constant time intervals for numerical integration and extrapolation of aircraft position. Thus, every 1/20 second the navigation program is entered and the decision is made as to whether or not a new aircraft position should be computed using LORAN, dead reckoning or doppler. Dead reckoning and doppler computations are made every half second. If it is not time to compute a new position, the program uses an extrapolation technique to update the aircraft position. This enables the navigation program to provide a new position every 1/20 second for tactical display.

SEARCH AND CORRELATION

During the search and correlation mode of operation, the computer program accepts inputs from the long-range sensors (radar, ECM, sonar, and visual). The sensor operators inform the computer that sensor information be converted from analog to digital form and read into the computer.

Each operator is responsible for track assignment. That is, the operator must assign a track number to any sensor information being transmitted to the computer. The computer program is responsible for smoothing the data points assigned to a track and estimating a position error based on the contributing sensor and the raw datum points. A datum point refers to the position of any object which is detected by a sensor. The operators also insert into the computer various types of amplifying information concerning the return. The amplifying information normally inserted is:

Quality (Strength of return)

Category (Ship, sub, aircraft, unknown)

Identity (Friend, foe or unknown)

Information associated with a particular sensor may also be inserted. For example, if a radar return were received, the operator could insert IFF (Identification Friend or Foe). Whenever sensor information is inserted, the program makes a time assignment to the return. The time is obtained from the computer's internal real-time clock. The computer program will maintain up to 50 general tracks.

The program will, on demand, present all sensor information to the Tactical Coordination (TACO). The TACO is the officer responsible for coordinating all information and supervising the localization, tracking and attack on the submarine. As such he is responsible for making all major decisions in the ASW operation. To assist him in decision making, he has a computer control, an alphanumeric display, a system console, and a keyset. The primary function of the TACO console during the search mode is to allow the TACO to request sensor information. TACO can request the program to display selectively one or more of the following sensor information categories:

1. Radar Contacts
2. ECM Contacts
3. Visual Contacts
4. Sonar Contacts
5. MAD Contacts

TACO can also request that the sensor information be displayed by category groupings (submarines, ships, and unknown). In addition, TACO can request the computer to display all amplifying information concerning a target track or the geometric loci which contributed to the solution of the last raw datum point. Other display functions are provided to aid TACO in the various modes of operation. Several of these are listed to indicate the display capability provided under computer control:

1. Recenter display;
2. Rescale display;
3. Flash new sensor inputs automatically;
4. Erase selectively any information datum from display and computer;
5. Generate and continuously reposition a line with a given range and bearing;
6. Compute continuously the range and bearing of some designated point with respect to the aircraft;
7. Display continuously the line of sight about the aircraft;
8. Display continuously the MAD range circle about the aircraft;

9. Present the aircraft's track history;
10. Display the loci which were used to compute a datum point;
11. Display part or all of the amplifying information concerning a target;
12. Display selectively any target track;
13. Predict the past, present, or future position of any target;
14. Display the range and bearing of a track or point relative to the display center;
15. Display selectively track or information categories;
16. Present visual verification of inserted information;
17. Transfer any track and its amplifying information from one point on the display to another;
18. Display probability uncertainty areas about a track;
19. Display effective range circles for sonobuoys;
20. Display intercept point for a track and aircraft.

During the search mode of operation, TACO monitors all sensor information and utilizes the various display functions to determine which tracks most probably represent submarines. In the event several sensors have received information concerning a datum, TACO can correlate the information and insert the results of the correlation into the computer via his keyset to be recalled and displayed upon request.

CONTACT CONVERSION

When TACO feels that a target track or datum point may represent a submarine, he can elect to pursue the object by entering the contact conversion mode. The program then begins to provide steering data to enable the aircraft to intercept the object and presents, in the form of a tableau, all available aircraft expendables (sonobuoys, charges, etc.). The tableau contains the type and number of sonobuoys, chargebuoys, and SUS's (Sound Underwater Source) remaining in the aircraft. TACO then selects those types of expendables which he wishes used in the localization of the datum. The program then computes the effective range and optimum depth settings for the selected expendables. The results, together with the parameters which were used in the computation, are presented via the display for TACO review. When TACO has acknowledged the display, the program computes five different tactics for possible employment. Each tactic has a probability of success associated with it and requires a different number of expendables. The results of the computation are presented to the TACO in the form of a "Payoff Matrix", which contains the probability of success, the number of expendables required, the time required to execute the tactic, and the pattern radius. After reviewing the "Payoff Matrix", TACO can select any one or none of the five tactics. If none of the tactics appears adequate for the situation, TACO can generate his own tactic by positioning sonobuoys on the display in any desired geometric pattern.

When TACO has completed generating his own tactic or selected a computer-generated tactic, he signals the computer that the buoy configuration currently available should be executed.

The computer in turn sends sequential commands to the ordnance station. The command specifies, via a digital readout unit, the location of the expendable, the depth to which it should be set, and the launch chute in which it is to be deposited.

As the chutes are being loaded, the program transmits steering commands to the pilot which will enable the expendables to be dropped at the proper positions. At the closest point of approach, the computer program automatically drops the expendable and computes the impact point. As the buoys are dropped, the buoy symbol is moved on the display from the desired drop point to the actual drop point.

If the tactic is a computer-generated tactic, the program computes and displays a monitoring schedule. The monitoring schedule specifies the sequence in which the sonobuoy transmitters will be monitored and the chargebuoys or SUS's detonated, and the length of time required to monitor each buoy. TACO may, if he desires, modify the monitoring schedule. If the tactic was generated by TACO, he must determine his own monitoring schedule and must inform the computer via keyset input.

When the expendables have been deployed, the program automatically detonates the chargebuoys at the correct times and tunes the radio receivers to monitor the proper sonobuoys. The monitoring control is automatic unless the sensor operator overrides the computer. Override capability is provided since the operators may wish additional time to evaluate returns, or unforseen changes may occur in the tactical environment.

Any contacts received from the buoys are transmitted to the computer in the form of range and bearing after being converted from analog to digital form. The sensor operators may also insert amplifying information such as quality, identity, classification, and cavitation via the keysets. The program computes target position from the range and bearing and establishes target tracks. The tactical situation in the form of target positions, contributing loci, position of expendables, etc., is presented on the display by the computer as the situation develops.

EXTEND TRACK

Normally, both the computer and TACO-generated tactics consist of various types of barriers through which the submarine must pass to escape. Thus, when returns have been received and a track established by the computer, TACO must decide whether to continue tracking, to extend the tracking by dropping additional sonobuoys if the submarine is penetrating the barrier, or to attack the sub immediately. Normally, TACO will decide to extend tracking in order to establish a better track before attacking. To do this, TACO enters the extend track mode. When the program enters the extend track mode, it presents the extend track decision tableau which contains several options. The TACO can again select one of several computer generated extend track tactics or generate one of his own. If TACO selects to originate his own tactic, the geometric buoy configuration is generated in the same manner as in the contact conversion phase. Similarly, if TACO selects a computer-generated extend track tactic, the computer arrives at the solution in much the same manner as it did during the contact conversion phase.

ATTACK

If several returns have been received and the computer has established a firm track, TACO may elect to attack the submarine. In the attack mode, the computer first presents the type and number of weapons available. TACO must then select the weapon type he wishes to use in attacking the submarine. When TACO has made his selection, the program computes the optimum depth setting and presents them to TACO for approval or modification. When TACO has approved the weapon depth setting, the computer computes and displays the "Attack Payoff Matrix". The "Attack Payoff Matrix" contains the probabilities of success associated with one and two weapon drops for various drop geometries. In addition, it displays the relative eventual probabilities of success if continued tracking or extended tracking is employed. The later two are displayed to prevent a premature attack. TACO then selects that configuration which he feels will most probably result in a kill. If an attack configuration is selected, the program displays those points where the weapons should be dropped and issues appropriate steering orders to the pilot. If TACO is not satisfied with any of the computer tactics, he can designate those points where he feels weapon drops should be made. In this case, the program also issues steering orders to direct the pilot over the drop area. Since the XN-1 is an experimental prototype system, no weapons are actually dropped by the computer. Instead a special type active sonobuoy is employed. The sonobuoy returns are used to determine whether or not a kill would have resulted if an actual weapon had been dropped.

POST FLIGHT ANALYSIS

Since the primary function of the XN-1 system is to measure the effectiveness of a data processing system in actual ASW operations and to improve the system for later fleet implementation, an extensive post flight analysis procedure was developed. The procedure entails recording the entire contents of the computer's variable memory (DRO and buffer) on magnetic tape. The data is recorded once each minute under computer control. At the completion of each flight, the magnetic tapes will be read on a ground-based UNIVAC 1206 Computer. This computer will be used with a console and display to review and analyze the flight data and decisions.