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Weapon System 117L
Communications and Control Subsystem

ENGINEERING ANALYSIS REPORT

(1693)

DISCOVERER PROGRAM

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Prepared for
Air Force Ballistic Missile Division,
Air Research and Development Command
United States Air Force
Inglewood, California

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Technical Operating Report

1693

WEAPON SYSTEM 117L
COMMUNICATIONS AND CONTROL SUBSYSTEM
ENGINEERING ANALYSIS REPORT, DISCOVERER PROGRAM

Prepared by

PHILCO CORPORATION
Western Development Laboratories
Palo Alto, California

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SUBSYSTEM ENGINEERING ANALYSIS

Contract Number AF04(647)-532
Exhibit B
AFBM Exhibit 58-1, Paragraph 3.15
AFBM Exhibit 60-63, Paragraphs 1.2.1.1
and 1.2.3

Prepared for

AIR FORCE BALLISTIC MISSILE DIVISION
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
Inglewood, California

FOREWORD

This Technical Operating Report on the definitized Contract AF04 (647)-532 is submitted in accordance with Exhibit "B" of that contract and Section III, Paragraph 3.15 of AFBM Exhibit 58-1.

This report was prepared by the Philco WDL C&C Systems Department in fulfilling the requirements of Paragraph 1.2.1.1 of AFBM Exhibit 60-63, dated 10 November 1960, Paragraph 1.2.3 of which covers preparation, publication, and distribution of reports.

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SECTION 1
GENERAL DESCRIPTION

1.1 Objectives

As its name implies, the Discoverer Program is the "test-bed" for the development of concepts and techniques and the collection of information believed useful for future programs. Thus, the long-range objectives are the refinement of equipment and procedures to be used in the Midas and Samos Programs and in future deep space probes.

One of the prime objectives of the Discoverer Program is to eject and recover a capsule from an orbiting vehicle. While in orbit, the satellite serves as a carrier for scientific materials and for the telemetry of functional, environmental, and geophysical data. The mission of the program also includes aero-medical research and other specialized tests according to the specific requirements of a particular flight.

The overall plan for Weapons System 117L calls for a series of programs including the Discoverer, Midas, and Samos satellites and is divided into a number of subsystem designated A through L. The Communications and Control Subsystem (Subsystem H) of the WS-117L Discoverer Program is the subject of this report.

Although this report is concerned primarily with Subsystem H (SS/H), topics relating to other subsystems, such as the vehicle descriptions, are included for purposes of continuity. Some items were in a state of change at this time and will be presented in future revisions to this report.

1.2 Subsystem Design Criteria

The criterion used throughout the design of the Ground-Space Communications and Control Subsystem was to utilize essentially existing equipment with only necessary modifications as required for the Discoverer Program. To establish the number of stations necessary for the Discoverer Program in time to meet the vehicle readiness schedule, equipment concepts requiring extensive development of new components or techniques were avoided. After preliminary analysis, the major equipment of the subsystem was designed and specified.

Some development and redesign of existing equipment was necessary, however, to insure harmonious operation with a reasonable amount of redundancy and reliability. In some cases, extensive redesign of circuitry was required to increase system performance and reliability; an example of this would be the incorporation of a low-noise front end utilizing a traveling-wave-tube amplifier in the very long range radar (Verlort). In other instances, equipment was redesigned to provide added capability, such as increased power output in the S-band beacon. A ground timing system, a fully automatic vehicle command and guidance control, and an automatic data transmission system were designed and fabricated. These and other units were developed specifically for the Discoverer Program.

Because of the rapid implementation and adaptation of existing equipment required to produce a workable system for Discoverer, it is natural to expect that numerous modifications would evolve as a result of operational experience during actual vehicle flights and the demands for support of other programs. These modifications are listed and briefly described in Appendix B.

1.3 Operational Requirements and Characteristics

Subsystem H equipment can be divided into two major categories: ground equipment and vehicle equipment. Ground equipment is designed to perform the functions necessary for vehicle acquisition and tracking, for orbital computation and programming, for vehicle command and control, and for the reception and recording of telemetry data. Vehicle equipment provides for the reception and decoding of commands and the transmission of telemetry data to the ground receivers. A simplified block diagram of Subsystem H is presented in Fig. 1-1.

1.3.1 Acquisition and Tracking Function

The Verlort radar system is the principal ground equipment for Discoverer vehicle acquisition and tracking. The radar system also provides the only means by which commands may be transmitted from the ground to the vehicle.

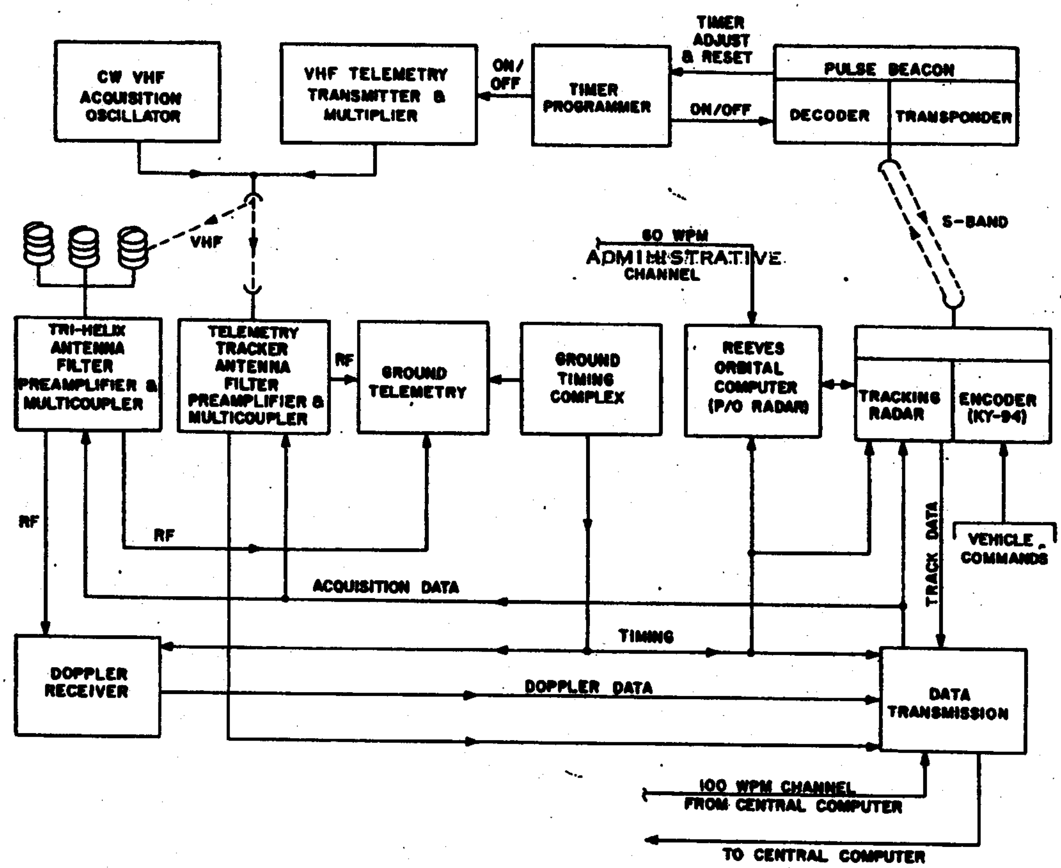

Fig. 1-1 Simplified Block Diagram of Subsystem H

Radar Tracking System. One Verlort radar system is installed at each SS/H Discoverer tracking station. The Verlort radar is designed to lock-on and automatically track the vehicle on receipt of pulse signals transmitted from the beacon transponder in the vehicle. The beacon is pre-set to respond only to time-coded radar pulses; it responds by transmitting 2-kw pulses which are then tracked by the radar in azimuth, elevation, and range. These coordinates are converted to digital form and processed by the data handling and control equipment into teletype format for transmission to the central computer at the Satellite Test Annex (STA). Additional outputs operate automatic plotboards and provide slaving data to control other tracking antennas of the station.

Acquisition. Prior to acquisition, the central computer transmits an acquisition program to the tracking stations. The acquisition program from the central computer contains azimuth, elevation, range, and time information to be applied to the radar at the correct time to position the antenna and range gate to a predicted moving point in space. This point describes the predicted vehicle orbit. In the event the acquisition program contains "rough spots" because of computer errors, missing data, or teletype transmission difficulties, a "coast" command may be given manually to disconnect the output of the acquisition programmer until the errors or discrepancies have passed.

Tracking. Once acquisition has been made, the vehicle is tracked by the radar to provide position data to the central computer and slaving data to the tri-helix antenna and the telemetry tracker, (a modified TLM-18, Philco R-1162). If lock-on is lost, the satellite may be reacquired by slaving the radar to the acquisition programmer or orbital computer. The orbital computer positions the radar antenna and range gate according to the continually updated orbital prediction. The original orbital computer computations are based on the six-parameter inputs contained in the acquisition summary message from the central computer.

As the radar tracks the vehicle, real-time tracking data is compared to the predicted data. Errors in the predicted data are displayed as meter readings to the operator who nulls these errors and updates the predicted orbit by adjusting appropriate controls.

<u>Doppler Tracking System</u>. The Doppler receiving system has two major purposes: (1) to acquire the satellite at the earliest possible moment during a pass, and (2) to provide tracking data to the central computer for calculating limited vehicle orbit parameters in case of failure of other tracking systems.

Should the Doppler system acquire the vehicle before the other tracking equipment when only predicted parameters are known, synchro outputs of the tri-helix antenna may be used to slave the radar antenna or the telemetry tracker until such time as they can acquire. For early acquisition, a wide beam VHF tri-helix antenna, coupled with the highly sensitive phase-coherent Doppler receiver, is used to receive the signal from a low-powered VHF CW acquisition transmitter in the vehicle. This also provides a signal for Doppler frequency measurement.

<u>Telemetry Tracking System.</u> The Philco R-1162 telemetry tracker is a high-gain antenna that automatically tracks the satellite on the FM/FM signal from the vehicle telemetry transmitter. The antenna receives telemetry data and provides azimuth and elevation tracking coordinates in digital form to be sent to the central computer as a supplement to the Verlort radar information. Additional outputs operate automatic plotboards and provide slaving data to control other equipment.

There are three main modes of operation for the telemetry tracker antenna system: (1) standby, (2) manual, and (3) automatic. The system is placed in the standby mode when it is not tracking, or after the antennas have been positioned manually to the sector where a signal is expected to appear. In the manual mode of operation, the antenna can be slewed in azimuth and elevation, as desired. If an r-f signal is received during the manual mode, the system will go into the automatic mode. Automatic tracking continues until the r-f signal level falls below 1.5 microvolts or until the antenna is pulled away from the signal by manual slewing.

The telemetry tracker antenna system is capable of being directed in azimuth and elevation by an external slaving source. Possible sources of this information are the Verlort radar, tri-helix antenna, and the acquisition programmer.

1.3.2 Central Computer Function

The central computer for the Discoverer program is the Remington Rand 1103AF computer, which is located at LMSD, Sunnyvale. Tracking data arrives at the central computer from the tracking stations in digital form, punched on 5-level teletype tape. The computer smooths the data and integrates it, using the equations of motion. From these calculations, the computer generates acquisition data to be routed back to the tracking stations, where it is used to assist in acquiring the vehicle on future passes. The central computer also generates predicted orbital parameters, which are used by the radar computing equipment, and certain timing and command signals, which are routed to the vehicle via tracking station radar-beacon links.

1.3.3 Ground Station Command and Control

Administrative and operational control of the SS/H ground station complex is centered at the Satellite Test Annex at Sunnyvale. Various interstation telephone and teletype facilities provide the necessary channels to integrate the system.

At the tracking station, command and control functions are at three control positions: (1) the shift supervisor's console, (2) the acquisition and tracking console, and (3) the vehicle command console. The positions are located in the administration and control van or building.

The shift supervisor's console (see Fig. 4-35) provides displays and controls that enable the operator to ascertain the operational status of the entire station prior to and during a pass. Station readiness before a launch is verified by the shift supervisor to the STA over the interstation communication channels. All maintenance and operational activities are coordinated by the shift supervisor.

As systems supervisor for the tracking equipment, the operator at the acquisition and tracking operating position of the master control console (see Fig. 4-37) monitors the progress of all tracking equipment, controls the flow of tracking and slave data, and is responsible for the overall system integration of the tracked equipment into an operational unit. During warmup, checkout, acquisition, and tracking operations, he determines the operational readiness of all equipment under his supervision and reports this information to the shift supervisor.

Vehicle commands are initiated at the vehicle command position of the master control console and sent to the satellite by coded-pulse, time-modulated signals from the S-band tracking radar as the satellite passes within range of the tracking station. The commands are received by the beacon transponder in the vehicle and decoded by the command decoder, which actuates relays that cause the command to be acted upon. If the command has been received correctly, a command verification signal is returned to the ground station.

1.3.4 Telemetry Data

Environmental and other information from the vehicle is transmitted as subcarrier modulation by the VHF telemetry transmitter and received by the telemetry tracking antenna or tri-helix antenna at the tracking station. The telemetry data is routed directly to the receivers and FM demultiplex equipment in the telemetry area. The telemetry data from the vehicle is recorded on magnetic tape and the required real-time readouts are transmitted to the STA via voice line.

1.3.5 Timing Function

A ground timing system supplies the time reference, or base, by which all station activities are synchronized. Although each station has its own timing system, all stations are synchronized to a single time reference known as system time (ST). System time, along with certain other pertinent time indications, is displayed prominently throughout the station at designated operating and control locations. All tracking, acquisition, and telemetry data are labeled with respect to time. Vehicle functions are precisely programmed with respect to system time.

Ground Timing. The heart of the ground timing system is the dual-unit central timing generator, which generates the basic timing signals to be used throughout each station. Remote timing terminal units distribute the timing signals from the timing generator on a 1-kc amplitude modulated carrier, and remote time indicators display the timing signals.

Both sections of the dual timing generator operate continuously . One unit is connected to the system; the other unit is used as a backup. Each unit is synchronized by a 1-second standard time signal broadcast from radio stations WWV and WWVH. The radio signal is received on a fixed-tuned receiver provided as part of the installation. Provision is made at each of the central timing units to compensate for differences in propagation time from WWV or WWVH to each of the tracking sites, thereby permitting station times to be within 8 milliseconds of each other.

1.3.6 Data Transmission and Display Function

Data transmission for SS/H is primarily concerned with the flow of antenna slaving data, predicted orbital data, and tracking data (1) between tracking stations and the central computer, and (2) between equipment, operating positions, and display units within a station.

Interstation data transmission is in digital form, while intrastation transmission channels use digital, synchro, and analog techniques. Digital data transmission is used to transmit high-accuracy data over relatively long distances. Synchro data transmission is used as a backup for the intrastation digital data transmission system. Plotboard data are transmitted by d-c digital, synchro, and analog means. Angular data to operate antenna position indicators are transmitted by synchro means only.

Slave Tracking Data. Station tracking antennas can be slaved to each other or to an acquisition program generated at the central computer. The acquisition and tracking controller determines which synchro tracking data is to be applied to the slave bus; this data is used as a slaving source to position other local antennas. The data appears as angular position information; i.e., azimuth and elevation, on the outer ring of the tracking equipment control position indicators.

1.3.7 Communications Function

The types of ground station communication circuits include teletype, telephone, and radio, interconnecting the launch, tracking, telemetry, and control facilities for the transmission of SS/H data, operating instructions, and administrative orders.

The communication function is divided into two separate systems: (1) the interstation communication system, which consists of the circuits and channels necessary to connect all of the ground tracking stations together into an integrated network; and (2) the intrastation communication system, which consists of the circuits and equipment necessary to support on-station activities and to terminate the interstation system.

1.4 Vehicle Functions

The Discoverer flights are designated for reference purposes by Roman numerals, and the vehicle is identified by a four digit number. A summary table of flights to the present time is given in Appendix D. Flights through Flight XV used the Agena-A Discoverer satellite, while subsequent flights have or will probably use the Agena-B. The active orbit lifetime for flights through Flight XV was 27 hours, but the flights to follow will have an active orbit up to 100 hours.

The Discoverer Satellite airframe as indicated in Fig. 1-2 consists of the following: forward midbody assembly, including the forward equipment rack; the aft midbody assembly; aft equipment rack; adapter assembly including provisions for retro-rockets; propellant tanks; pressure spheres; and fairings. The recovery capsule is carried in the forward end of the airframe.

The vehicle communications and control subsystem is shown in Fig. 1-3.

The Discoverer satellite S-Band transponder, located in the forward equipment rack, supplies response pulses to the Verlort radar coded interrogations. These responses are used at the Verlort radar as a means of determining vehicle position. The transponder also receives, decodes, and delivers ground-to-space real-time commands for operation of vehicle functions. The S-Band transponder equipment includes a decoder and an antenna.

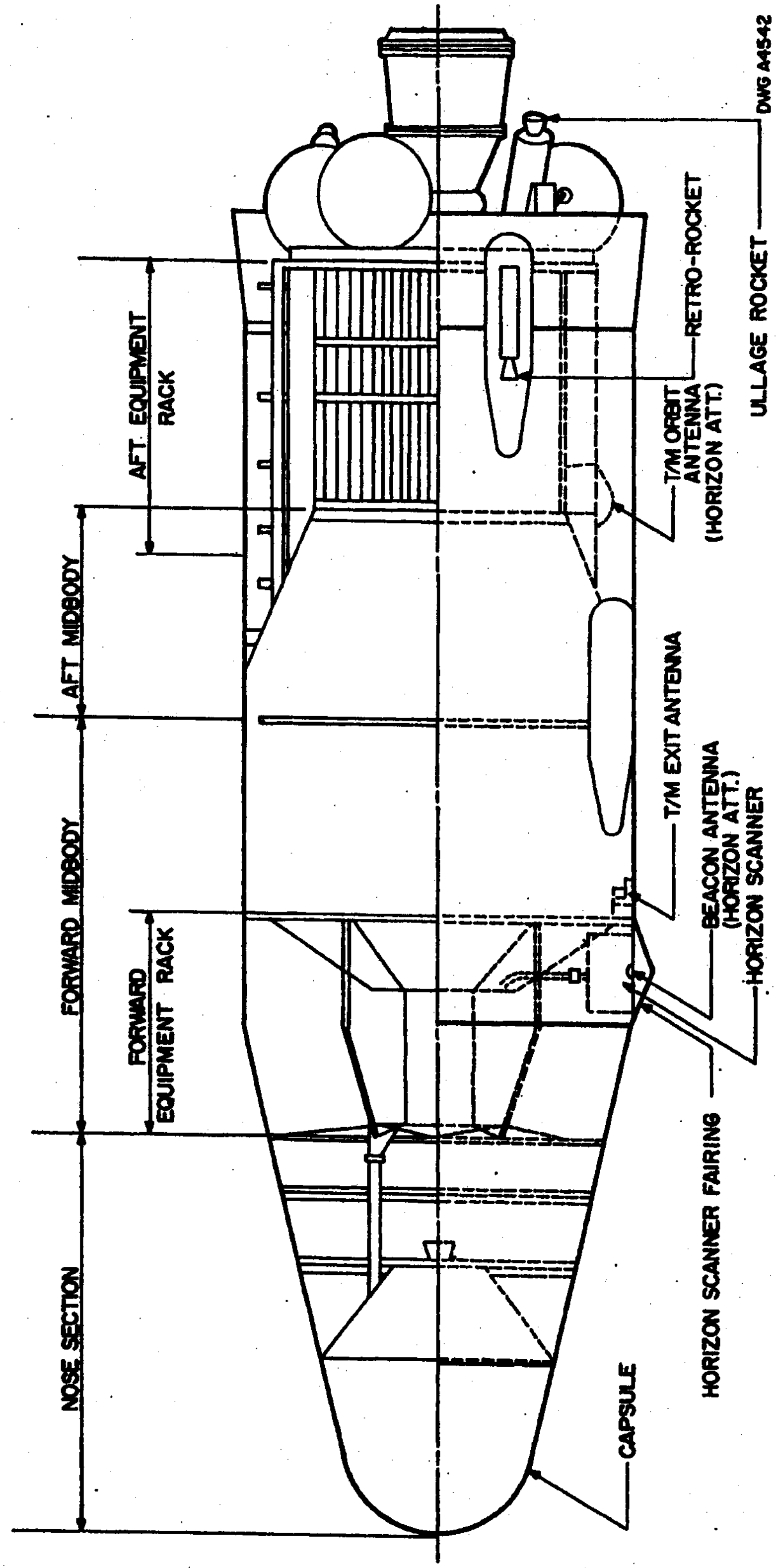

Fig. 1-2 Discoverer Satellite Airframe

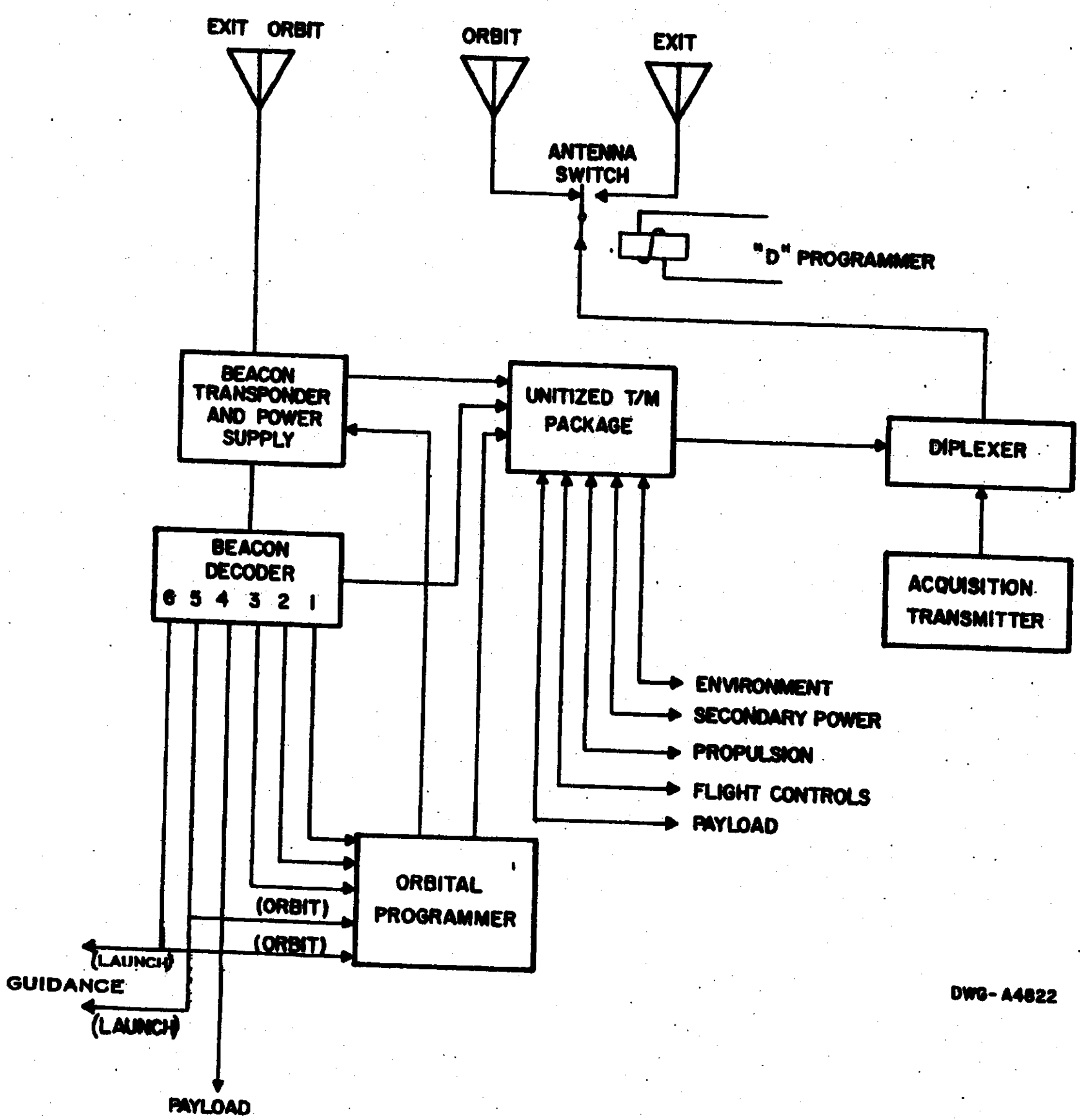

Fig. 1-3 Vehicle Communications and Control, Simplified Block Diagram

The acquisition beacon is located in the forward equipment rack. This unit operates continuously, providing backup in the event that other acquisition methods are unsuccessful. The transmitter is a low-power, crystal-controlled, UHF CW transmitter whose output is diplexed into a common antenna with the VHF telemetry transmitter. The acquisition beacon is isolated from the telemetry transmitter by a two channel diplexer.

The orbital programmer, located in the forward equipment rack, turns on vehicle equipment cyclically, and is capable of initiating the recovery sequence of events for ejection of the recovery capsule. An alternate cycle of different composition from the normal cycle can be accommodated. Ground commands can reset and change periods.

An S-Band transponder antenna, located in the forward midbody, and VHF antennas, one is the forward midbody for ascent and one in the aft equipment rack for orbit, are carried for the ascent and orbit phases.

The VHF ascent and orbit antennas are multiplexed to serve both the telemeter transmitter and the acquisition beacon transmitter.

An FM/FM telemeter, in the forward equipment rack, is carried to obtain and transmit orbital-stage functional, environmental, and other scientific data.

1.5 Station Installations

There are five principal tracking stations (Fig. 1-4) for the Discoverer Program, and they are located as follows:

a. Vandenberg Air Force Base, California
b. Point Mugu, California
c. Kaena Point, Hawaii
d. Kodiak Island, Alaska
e. New Boston, New Hampshire

Point Mugu is used primarily for ascent tracking, telemetry, and guidance commanding. The requirement for transmission of guidance commands from Point Mugu is scheduled to be eliminated in the near future. The Bell Telephone Laboratory (BTL) guidance system at VAFB is presently being evaluated for compatibility with the Discoverer Vehicle configuration. It is anticipated that the Point Mugu tracking station will be phased out upon satisfactory completion of BTL system tests.

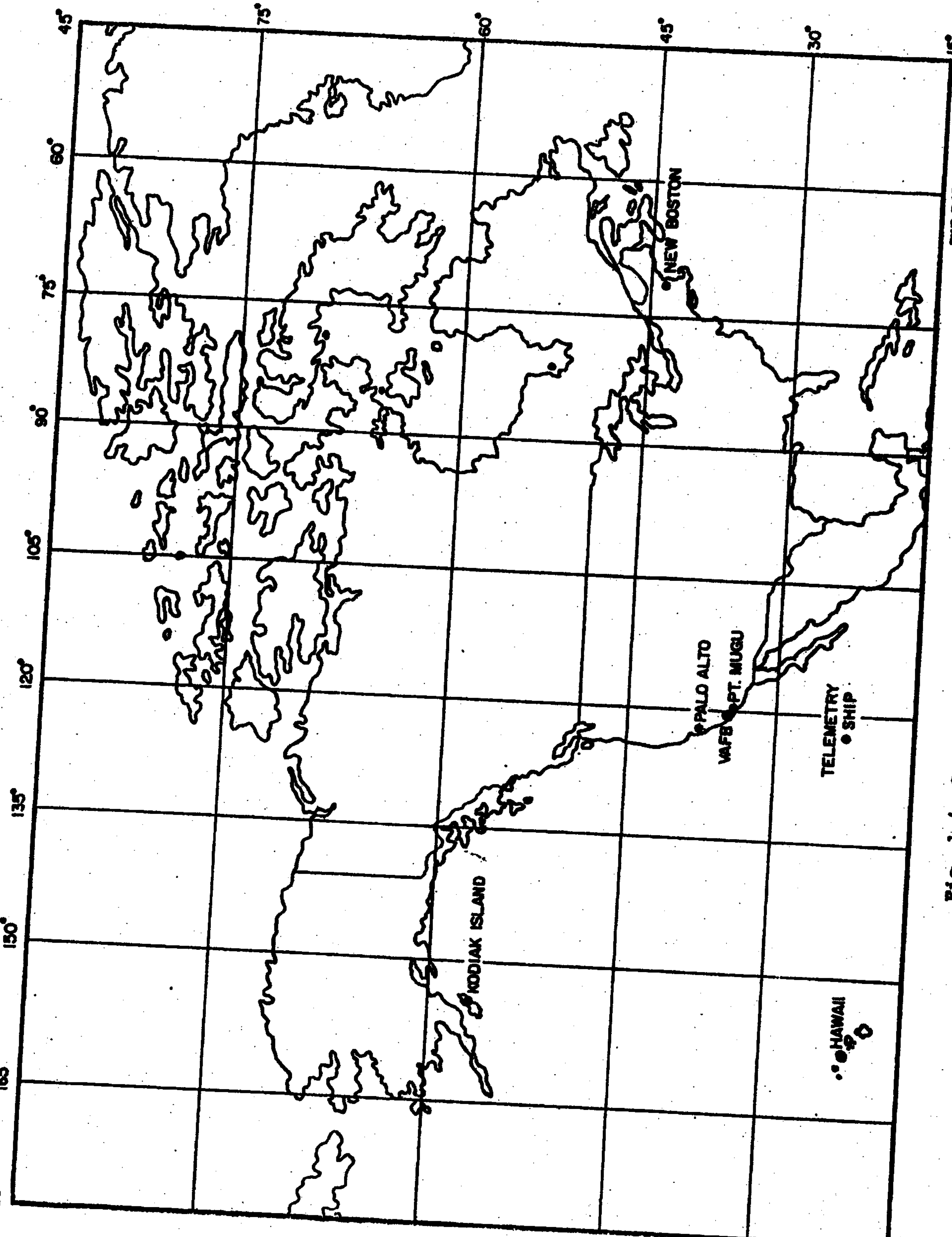

Fig. 1-4 Ground Station Complex, Discoverer Program

Ascent tracking and telemetry functions would then be performed solely by the Vandenberg tracking station.

The original station configuration included a station at Annette, Alaska. Operational experience revealed that this station provided unnecessary redundancy and Annette was phased out in December 1959.

The equipment complement for each station is given in Table 1-1.

Two general types of installation are utilized for the Discoverer Program; (1) stations made up entirely of mobile van-mounted equipment, such as Point Mugu and New Boston; and (2) those stations made up of both van-mounted and permanent building installations, such as Hawaii, Vandenberg, and Kodiak. Detailed information on the individual sites is available in existing documents. A brief description of tracking station configuration and equipment layout is included in the following paragraphs.

1.5.1 <u>Vandenberg Tracking Station</u>

The Vandenberg tracking station occupies a section of Vandenberg Air Force Base (formerly Cooke AFB). The tracking station installation is located in two areas separated by a distance of approximately 13,000 feet. The station configuration is shown in Figs. 1-5 and 1-6.

<u>Transmitting Area</u>. The transmitting area is made up of the following major facilities:

a. Radar van
b. Radar pedestal and antenna
c. Optical tracker
d. Data transmission van
e. Boresight towers (2)
f. Diesel generators

<u>Receiving Area</u>. The receiving area contains the following facilities:

a. VHF telemetry building
b. Telemetry tracker antenna
c. Tri-helix antenna
d. WWV antenna
e. Boresight tower

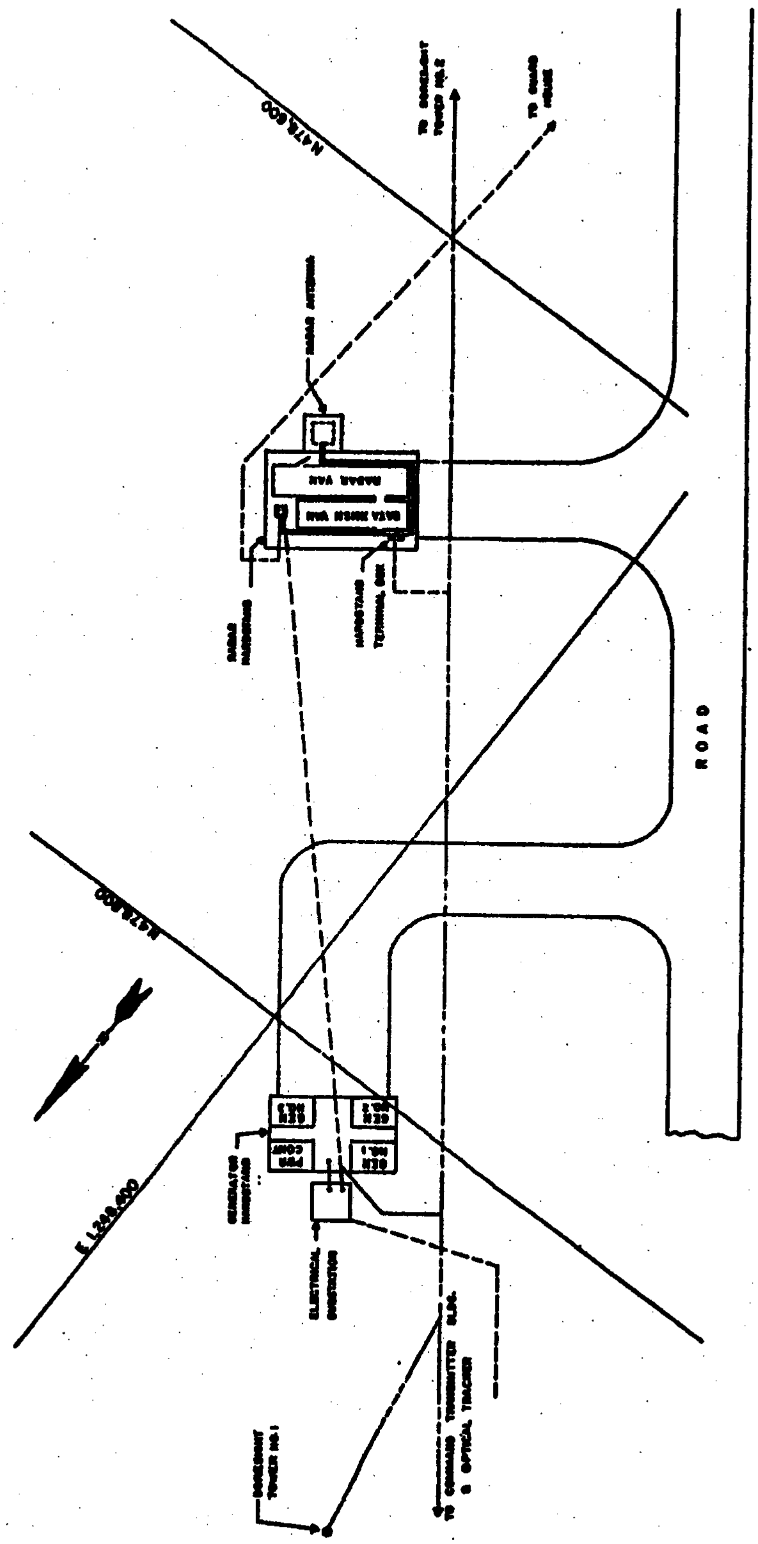

Fig. 1-5 Vandenberg Tracking Station Transmitting Area

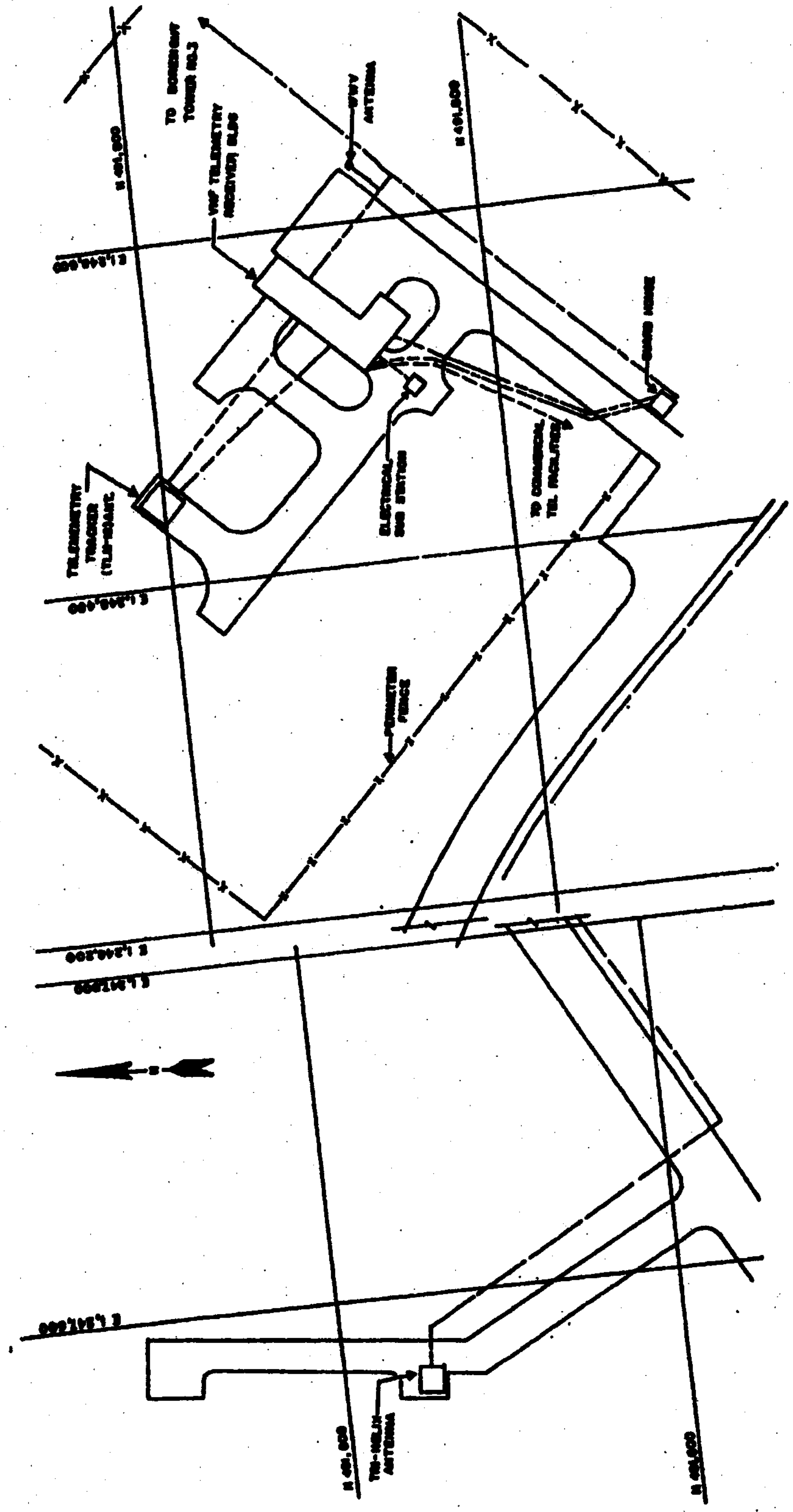

Fig. 1-6 Vandenberg Tracking Station Receiving Area

TABLE 1-1

TRACKING STATIONS - MAJOR EQUIPMENT

EQUIPMENT	VAFB	MUGU	HAWAII	CHINIAK	NEW BOSTON
Verlort Radar	X	X	X	X	X
Telemetry Tracker	X		X		
Tri-Helix Antenna	X	X	X	X	X
Doppler Receiver and Recorder	X	X	X	X	X
Communications	X	X	X	X	X
Data Transmission	X	X	X	X	X
Control Consoles and Display	X	X	X	X	X
Optical Tracker	X				
Reeves Guidance Computer		X			
Telemetry Receiving and Recording	X	X	X	X	X
Timing	X	X	X	X	X