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DISCOVERER I
SYSTEM TEST EVALUATION REPORT

Lockheed

MISSILES and SPACE DIVISION

LOCKHEED AIRCRAFT CORPORATION · SUNNYVALE, CALIF.

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WDZW 261
WDZW 61

LMSD-445138
20 April [redacted]
Copy E-8
58 Sheets

DISCOVERER I

SYSTEM TEST EVALUATION REPORT

Approved

for Charles G. Mathison
Lt. Col., USAF
Chairman STWG

Approved

for R. D. King, Manager
Test Management & Operations

DOWNGRADED AT 3 YEAR INTERVALS;
[redacted] YEARS.
DOD DIR 5200.10

LOCKHEED AIRCRAFT CORPORATION
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Sunnyvale, California

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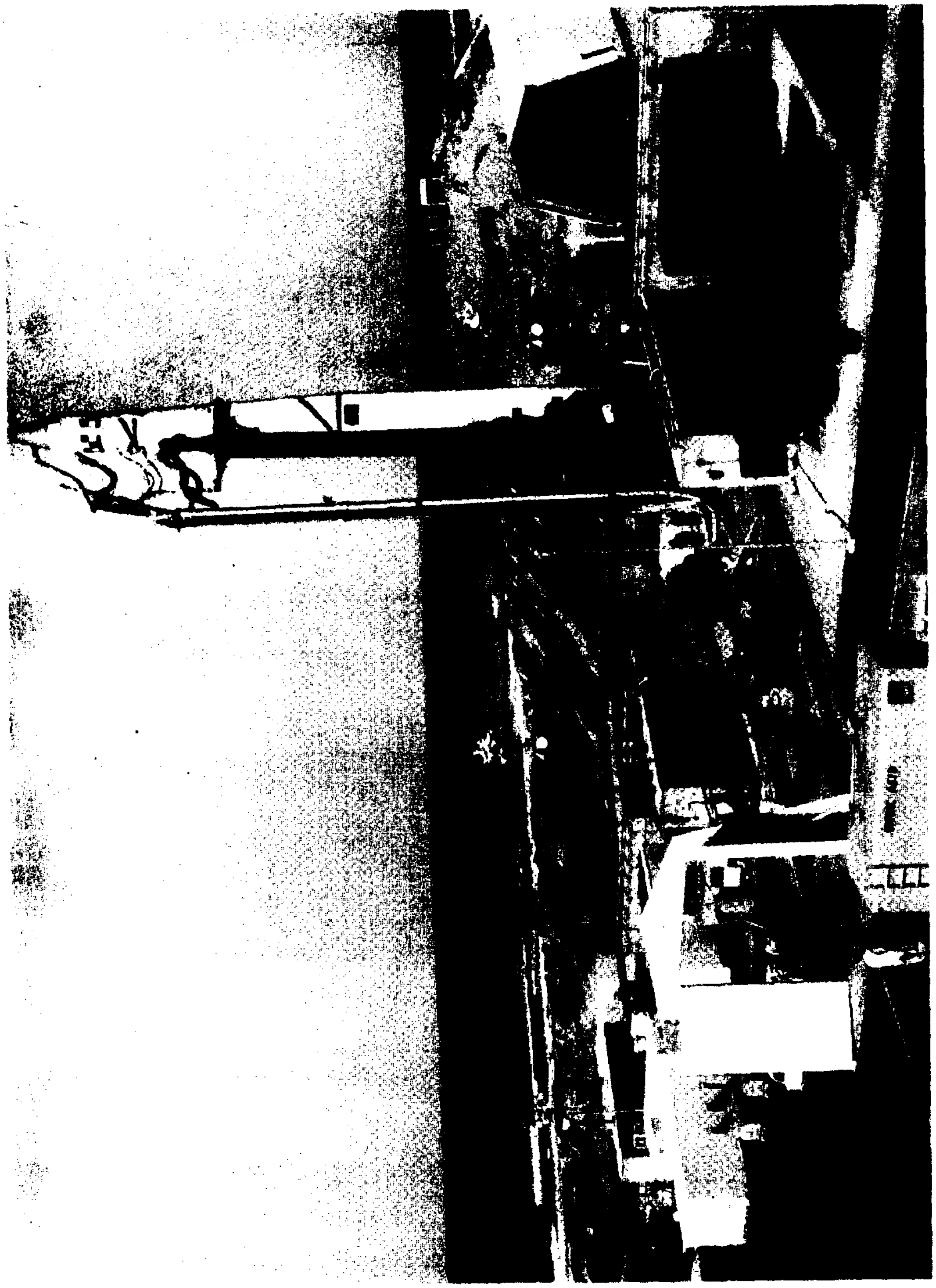
FOREWORD

This document has been prepared by the System Test Working Group in cooperation with the LMSD System Evaluation and Test Reports Department. It is submitted to fulfill a requirement of Contract AF 04(647)-97, Paragraph IVJ, WDT 58-19, and is presented as a final system test evaluation of the Discoverer I satellite launch.



Discoverer I/Thor on Pad 4 Vandenberg Air Force Base

FOREWORD

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SUMMARY

The Discoverer I Vehicle was successfully mated with the Thor 163 on 23 February 1959 at Vandenberg Air Force Base Pad 4. The initial countdown for the launching of this combination began at 0600 Pacific Standard Time (PST) on 25 February and proceeded to Thor pressurization during the final minutes of the countdown at 1304 PST. As a result of first-stage liquid oxygen pressurization difficulties occurring at this time, the countdown was "scrubbed".

An abbreviated, final countdown was initiated at 0800 PST on 28 February. The final countdown proceeded with only minor delays to time of lift-off at 1349:16 PST. Lift-off, first-stage boost, and separation were normal, although first-stage burning time extended to 160.75 seconds, approximately 3 seconds longer than nominal. Second-stage engine operation was normal, shutting down after 96.3 seconds of engine operation. Telemetry and radar tracking contact were lost shortly after engine burnout (orbital injection) and were not regained.

From the data available, all Thor and Discoverer I flight systems appeared to function normally. The ascent trajectory was slightly higher than nominal, and estimated conditions at orbital injection were such that the vehicle achieved an elliptical orbit with an estimated orbital lifetime of 13 days. The cause for the lack of sustained orbital contact with the vehicle is unknown.

Launch and ascent data coverage, both internal and external to the vehicle, was satisfactory. Ground support (in terms of both personnel

and equipment) at the launch complex, the remote tracking and telemetry stations, and the Development Control Center, Palo Alto was excellent. All primary objectives were achieved except for the ability to track and command orbital functions. Approximately 75 percent of the secondary and tertiary objectives were achieved.

Pad damage was relatively minor and was insufficient to affect schedules of subsequent launches.

INTRODUCTION

The Discoverer Program has been established by the Advanced Research Projects Agency (ARPA) through the agency of the Air Force Ballistic Missiles Directorate (AFBMD). The principal objective of this program, which utilizes the Discoverer/Thor combination, is the development of a space vehicle with functional capability as a carrier-satellite for the equipment and material of various scientific projects.

The first flight test vehicle in the Discoverer Program was damaged during final launch countdown when second-stage pyrotechnics ignited prematurely, as reported in Reference 1. The successful launching and injection into orbit of the Discoverer I satellite, utilizing the second flight test vehicle, was accomplished at Vandenberg Air Force Base on 28 February 1959. Detailed test reports documenting the results of the Discoverer I launching have been published by the prime contractors and the launch base joint working groups as indicated in References 2 thru 5. This final report has been prepared by the System Test Working Group as an evaluation of operational concepts and the system equipments which were employed to place the Discoverer I into orbit.

SECTION I
TEST OBJECTIVES AND RESULTS

SECTION I
TEST OBJECTIVES AND RESULTS

A. PRIMARY OBJECTIVES - GENERAL

Demonstration of orbital capability of Discoverer utilizing a Thor booster.

Result - The primary objective was satisfactorily achieved. Operation of all systems necessary to achieve orbital injection was satisfactory. However, a highly elliptical orbit was attained because orbit injection was not at perigee.

B. PRIMARY OBJECTIVES - SPECIFIC

1. Ground Support Equipment (GSE)

Provision of adequate ground support and checkout equipment through lift-off.

Result - Objective achieved. Ground support and checkout equipment proved adequate, except for a malfunction of the Thor automatic fueling sensor, which resulted in terminal countdown delays.

2. Thor Booster

Demonstration of launch, control, and separation from the Discoverer within specified performance requirement.

Result - Objective achieved. Thor functions all occurred within tolerance levels with separation occurring within approximately 1.6 degrees of the predicted flight-path angle.

3. Airframe and Adapter

Demonstration of structural integrity of the Discoverer and adapter and compatability of adapter with both stages.

Result - Objective achieved. The structure adequately withstood the aerodynamic loads, vibration, and heating effects of launch. No excessive loads occurred. Separation was satisfactory.

4. Propulsion System

Demonstration of ullage rocket operation, engine ignition, sufficient total impulse to achieve orbit, and proper propellant utilization.

Result - Objective achieved. Most functions were normal. Orbital velocity and altitude were reached after 96.3 seconds of second-stage engine operation.

5. Auxiliary Power Unit (A. P. U.)

Demonstration of satisfactory performance during ascent to orbit of all auxiliary power components, especially of batteries, inverters, and heater components.

Result - Objective achieved. Power supply operation during ascent appeared normal, with good recovery after load transients.

6. Guidance and Control System

Demonstration of the ability to time and control all Subsystem D functions, including maintenance of proper orientation during coast and boost.

Result - Objective achieved. An analysis of flight data shows that functions occurred at proper times and that proper attitude was maintained until second-stage ignition. A disturbance in pitch occurred at vehicle-engine start, resulting in a thrust angle below the horizontal. No verification of correct reorientation after orbital injection was recorded.

7. Telemetry and Tracking

Demonstration of the ability to monitor satisfactorily all primary vehicle functions, to command Subsystem "D" timer delay, and to track and command orbital functions.

Result - Objective partially achieved. Telemetry data from one station were 87 percent satisfactory for 514 seconds. "D" timer was successfully held. No beacon contacts were made after 510 seconds. No opportunity to make orbital-timer adjustments existed.

C. SECONDARY AND TERTIARY OBJECTIVES

1. Recovery

Evaluation of full-dress-rehearsal of recovery operation.

Result - Mission was satisfactorily conducted at the nominal time of 17th orbital pass. Aerial pickup was unsuccessful. Water pickup was successful.

2. Orbital Attitude

Evaluation of ability of Subsystem "D" timer to orient and maintain the vehicle in a nose-down attitude.

Result - Objective not achieved. No data are available to determine vehicle-orbital attitude.

3. Temperature Environment

Evaluation of temperature environment and distribution on the vehicle.

Result - Only partial data were obtained. Lower-than-predicted temperatures were recorded, and no thermal problems are indicated.

4. Tracking and Communications

Evaluation of inter-station communication network, orbital prediction using only azimuth and elevation data, and continuous operation of the continuous wave (CW) acquisition beacon.

Result - Inter-station communications were satisfactory. Orbital prediction using only azimuth and elevation data was not evaluated. Continuous operation and acquisition of the CW beacon were not verified.

5. Optical Tracking

Evaluation of attitude and aerodynamic integrity of Thor/Discoverer.

Result - Metric optics data were obtained for a total period of 159.5 seconds, the trajectory data from which agree well with radar data. Attitude data were obtained through 47 seconds, verifying the pitch-command program and indicating no stability or structural problems.

6. Human Factors

Evaluation of crew proficiency and ground equipment design from human engineering standpoint.

Result - As a result of several dress rehearsals and two launch countdown operations for Discoverer I, many improvements in test procedures and use of equipment were effected, and valuable training was gained. Satisfactory equipment and crew proficiency were demonstrated by the efficient manner in which the countdown and launch preparations were conducted. However, the use of improper search procedures on-board the Downrange Telemetry Ship resulted in loss of critical data.

SECTION II
SYSTEM CONFIGURATION

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SYSTEM CONFIGURATION

FLIGHT SYSTEMS

The Discoverer I/Thor flight configuration (Figure 1) consisted of a second-stage orbital satellite in tandem with a modified-Thor booster as a first-stage launching device. The combined length of this configuration was approximately 78 feet. The total weight at lift-off was 113,902 (±250) pounds.

The Thor booster, Serial 163, was a complete operational-type IRBM, modified to accept the Discoverer (Figure 2). The Thor booster was approximately 65 feet in overall length and 8 feet in diameter through the cylindrical portion. The basic airframe was modified by the addition of the booster adapter (supplied by Lockheed) which was securely attached to the forward end of the Thor guidance section. The Discoverer was attached by explosive bolts to the adapter. The adapter also housed the two Discoverer retro-rockets which caused separation of the booster and satellite. Weight of the booster at lift-off was 106,731 pounds.

The Discoverer satellite, Serial 1022 was approximately 18.5 feet in over-all length and 5 feet in diameter through the largest cylindrical portion (Figure 1). Its airframe included propellant tanks, an extensible boom for stabilizing the vehicle statically while on orbit, pressure spheres, and engine mount and jettisonable structures. The orbital-boost engine (USAF Model No. XLR-81-BA-3), Serial 14, was manufactured by Bell Aircraft Corporation. The engine was rated at 15,150 pounds vacuum thrust, and included the supply of oxidizer (Inhibited Red Fuming Nitric

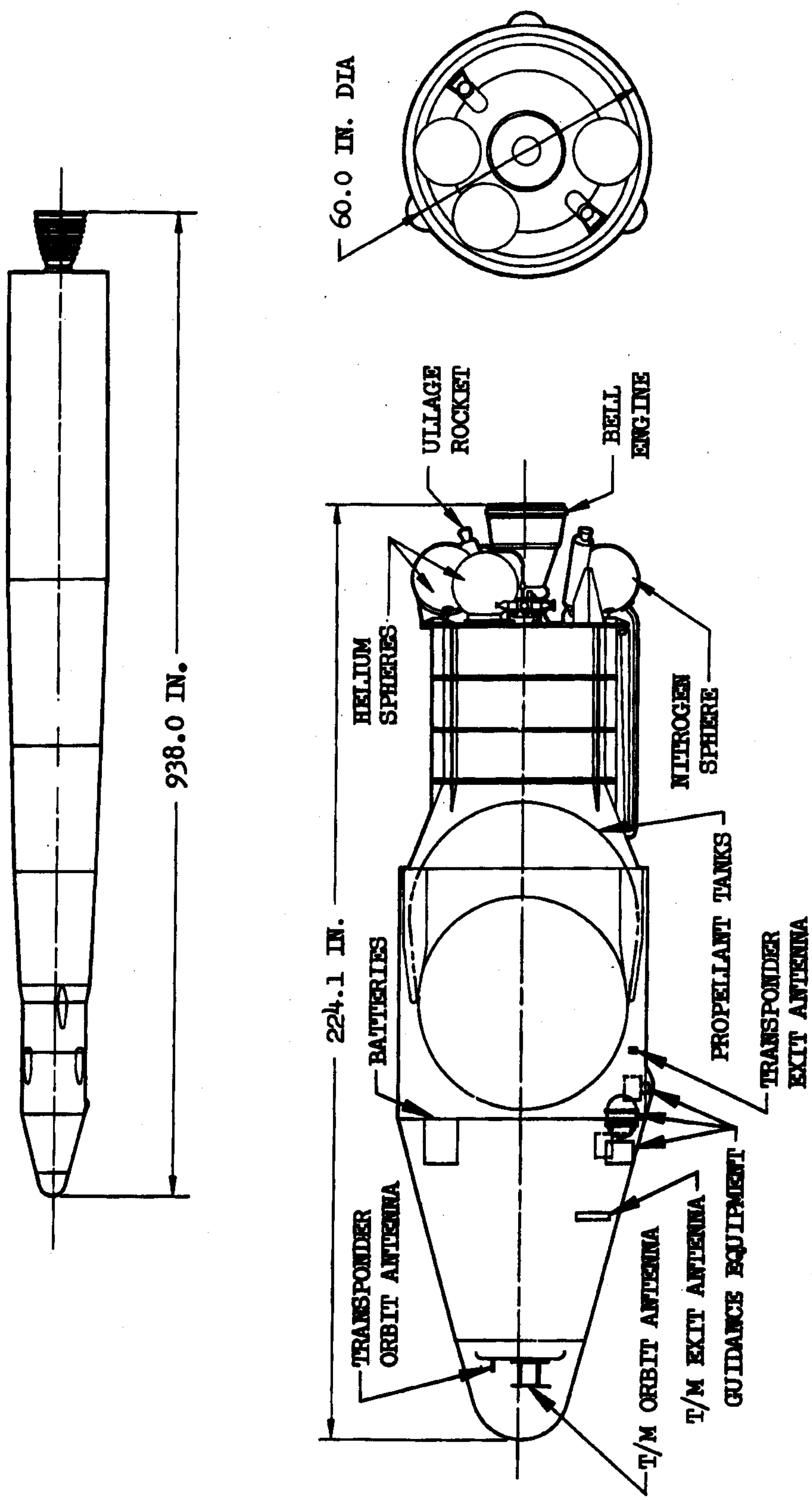

Figure 1. Discoverer I/Thor General Arrangement

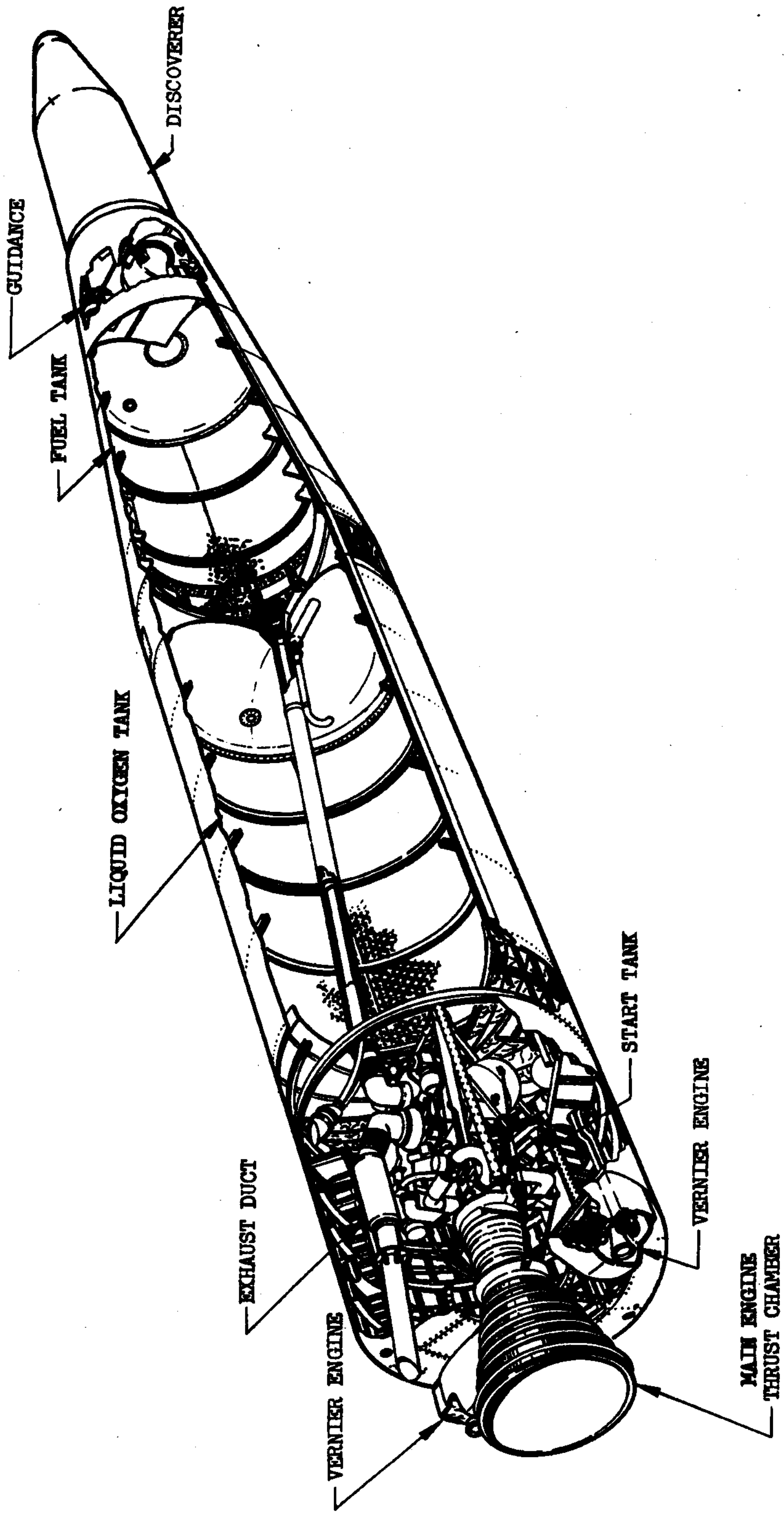

Figure 2. Thor Booster Configuration With Payload

Acid (IRFNA)) and of fuel (JP-4). Guidance and control equipment included components necessary for attitude orientation during the period from separation to establishment of the satellite vehicle on orbit and a "D" timer which provided necessary switching signals to vehicle equipments for control of flight events. The basic power source was from three primary silver peroxide-zinc-type batteries.

Discoverer vehicle instrumentation included the following: An S-band beacon, which accepted command signals from the ground and responded to coded radar signals for long-range tracking; a VHF continuous-wave acquisition beacon for identification and ground control tracking; and a FM/FM telemetering system of 15-channels capacity carrying a total of 97 in-flight measurements. (The Thor contained a PAM/FM/FM telemetering system carrying approximately 34 booster performance parameters on seven channels and an elementary "H" timer for controlling the cyclic operation of the radar beacon and telemetry equipments while in flight.); The basic weight of the satellite upon injection into orbit was 1474 pounds.

GROUND SYSTEMS

Ground systems in support of Discoverer I were divided into the following operational elements:

a. Launch complex
b. Tracking and control stations
c. LMSD computer center
d. Recovery force

The integration of these elements under the joint direction of AFBMD and Lockheed was accomplished by the Development Control Center (DCC) located at Palo Alto, California, as depicted in Figure 3. System communications were controlled by the DCC as shown in Figure 4. Operations of the launch base and recovery force were under the direct control of Vandenberg and Hawaiian Control Centers, respectively.

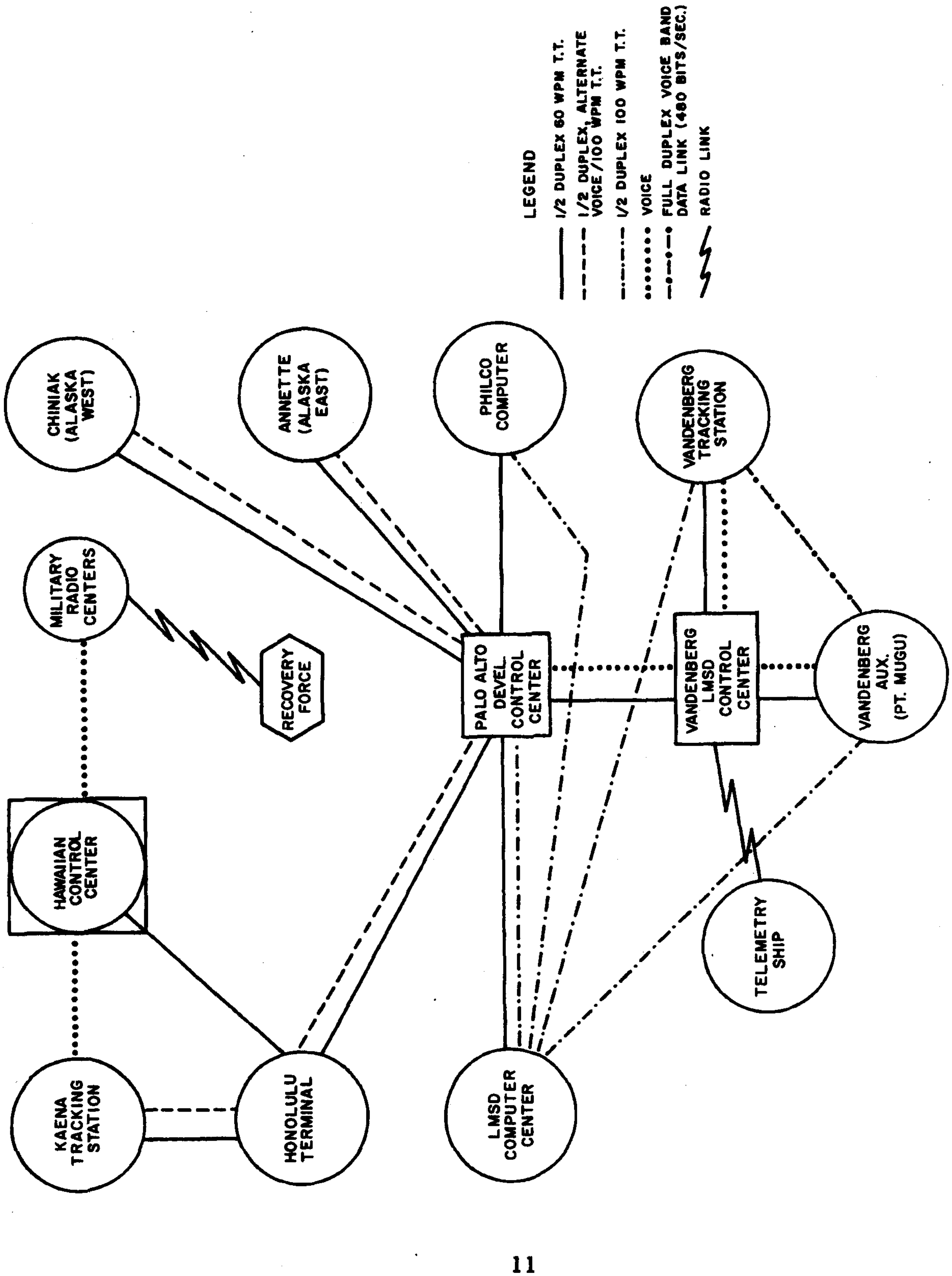

Figure 3. Discoverer I Test Operations Control

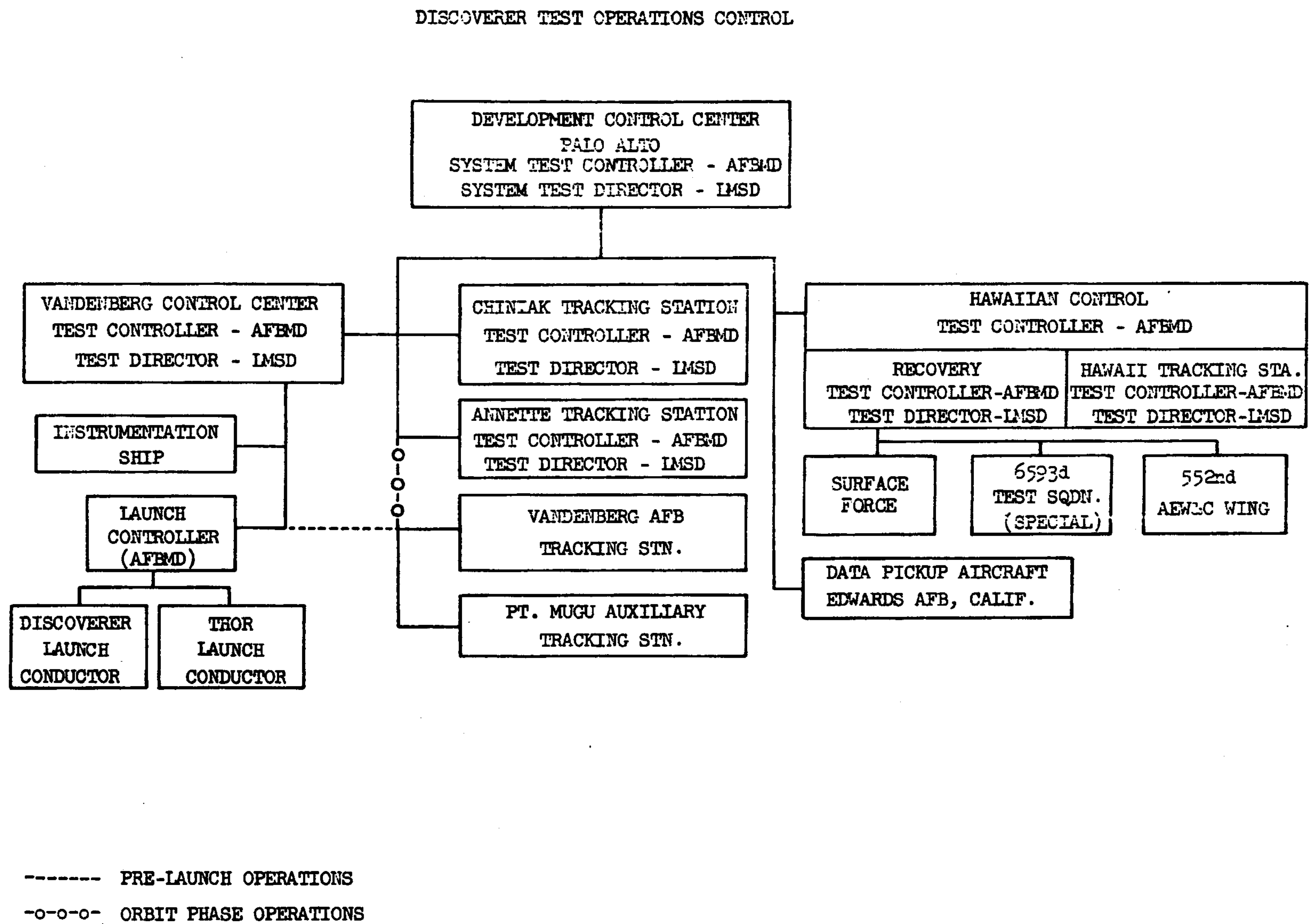

Figure 4. Discoverer I Communications

The launch complex consisted of those equipments and facilities necessary to checkout and house the Thor booster and Discoverer vehicle and the launch blockhouse and pad. Vandenberg Air Force Base, under the Strategic Air Command, supported Discoverer I through the First Missile Division by providing the following services:

a. Fuel and pyrotechnic storage facilities
b. Instrumentation and range safety systems
c. Launch pad fire and medical equipment and personnel
d. Security.

The Pacific Missile Range (PMR) provided support in the following areas:

a. Metric optics tracking and data reduction
b. Operational control of the telemetry ship
c. Additional range safety and security surveillance.

Five tracking and control stations supported Discoverer I operations:

a. Vandenberg Air Force Base, California
b. Naval Air Missile Test Center, Point Mugu, California
c. Kaena Point, Hawaii
d. Kodiak Island, Alaska
e. Annette Island, Alaska.

Each of these stations provided the capability to acquire, track, and command the Discoverer vehicle and to receive telemetry data. In addition, a ship was equipped for tracking and reception of telemetry signals and was located 950 nautical miles downrange in line with the predicted launch azimuth. Acquisition, tracking, and command data were transmitted over the communications net, as shown in Figure 4, between the tracking stations and the LMSD Computer Center.

The LMSD Computer Center at Palo Alto (closely connected with the DCC) provided the necessary processing of tracking data for determining the current status of the flight mission. (The Center employs a Remington-Rand 1103 AF computer and an extensive telephone and teletype network.)

Although not a recovery flight, Discoverer I test activities included a simulation of recovery operations in the Hawaiian area. The Recovery Force, under the direct control of the Hawaiian Control Center at Hickam Air Force Base, was deployed off the coast of Hawaii. The force consisted of eight C-119 aircraft, four RC-121D aircraft, one B-47 drop aircraft and three destroyers from the Pacific Fleet.

SECTION III
TEST DESCRIPTION

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TEST DESCRIPTION

PRE-LAUNCH OPERATIONS

Following completion of necessary pre-flight functional tests at Santa Cruz Test Base and the LMSD Systems Checkout Complex at Vandenberg Air Force Base, the Discoverer I vehicle was delivered to the launch pad on 4 February 1959. Subsequent mating with the Thor booster and combined systems tests were completed on 19 February. Target launch time (T-O) for the flight was established for 1245 PST 25 February 1959.

The countdown was to require 6 hours and 45 minutes. The first part, running from T-405 to T-15 minutes, was to consist almost entirely of LMSD functions. The second part, running from T-15 minutes to launch, was to consist of the Thor Interim Operational Capability (IOC) countdown and the remaining portion of the LMSD countdown. Because of first-stage pressurization and GSE difficulties, however, two countdowns were required.

The first countdown was initiated on schedule at 0600 PST on 25 February and proceeded with negligible delay to final first-stage pressure checks just minutes prior to completion of the terminal count. At this time, 1304 PST, first-stage liquid-oxygen pressurization difficulties were encountered, which resulted in a non-scheduled hold. After several unsuccessful attempts were made to complete first-stage pressurization, the countdown was "scrubbed" at 1653 PST.

The Discoverer/Thor was retained in the erected position while Douglas personnel defueled the first-stage booster, corrected the pressurization problem, and accomplished necessary re-checks. Immediate reschedule of the countdown for the following day was not possible when it was discovered that a leak had developed in the first-stage fuel system.

The final abbreviated countdown was initiated on 28 February and proceeded without incident to T-7 minutes. At this time, difficulties were encountered: first with the liquid-oxygen-loading sensor and then with the fuel-loading sensor. After several minutes, the liquid-oxygen sensor apparently corrected itself, manual fuel override was imposed, and, after a total delay of approximately 1 hour, the countdown was continued to lift-off.

FLIGHT OPERATIONS

The launch trajectory and sequence of events closely followed the planned program. The test vehicle was launched vertically, and the booster satisfactorily rolled the vehicle from the pad attitude azimuth of 181° 28' 53.86" to the flight-path (departure) azimuth of 182° 48'. Vertical flight continued for 10 seconds, after which time the Thor booster initiated the required pitch program.

The Thor boost phase extended for 160.75 seconds, first-stage main-engine cut-off occurring upon depletion of propellants.

As the main-stage propellants exhausted, the rapid decrease in engine-chamber pressure released a pressure switch which set the time for vernier cut-off. The vernier engines were started prior to lift-off and continued for 9.05 seconds after main-engine cut-off.

Nominally, at 161 seconds after launch, the first sequence signal was given by the Subsystem "D" timer for uncaging the inertial reference gyros. Ten seconds later, 171.2 seconds from launch, the timer initiated the signals for firing the explosive separation bolts, activating the pneumatic control system, commanding jettison of the nose cone, and igniting the retro-rockets on the adapter. The vehicle then staged.

After separation, the second-stage vehicle pitch programmed to the horizontal. The horizon scanner was then activated and its shroud ejected. During the coast phase, the vehicle was under pitch horizon scanner control.

The Subsystem "D" timer initiated the signal to activate the hydraulic control system and fire the ullage rockets at 321.0 seconds. Approximately 17 seconds later, the orbital-boost engine was ignited and the pitch and yaw pneumatic controls turned off.

During orbital-boost, vehicle orientation was determined by the Pre-programmed Inertial Reference Package (IRP). Engine thrust was terminated by exhaustion of the propellants at 96.3 seconds after engine ignition. Shortly thereafter, the hydraulic system was shut down and the propellant tanks vented. The vehicle was then programmed to pitch down 90 degrees at 40 degrees-per-minute by the pneumatic control system. Venting of the helium tanks, which occurs simultaneously with the command to pitch over, was verified by test data and occurred at 452.1 seconds. The last programmed event to occur prior to loss of data was a "D" timer command to calibrate the telemeter at 455.5 seconds. All telemetering channels not required for the orbital phase were turned off at this time. The flight sequence of events, as verified by available telemetry data, is given in Table 1. Sustained contact with the vehicle after 510 seconds was not accomplished.

A three-dimensional view of the launch trajectory is displayed in Figure 5.

TABLE 1

Sequence of Flight Events, Discoverer I

Event	Flight Time, Seconds Actual	Flight Time, Seconds Predicted
Lift-off ("D" timer start)	0*	--
Thor Main Engine Burnout	160.75	157.8
Thor Vernier Engine Burnout	169.80	166.8
Retro Rockets Fire	171.2	171
Initiation of Separation Motion	172.2	172
Separation Complete	174.6	
Ullage Rockets Fire	321.0	321
Discoverer Engine Start Sequence	337.1	337
Engine Start (pressure buildup)	338.2	
Engine Shutdown	434.5	434.5
Loss of Telemetry Data	514	Normal horizon limitations
Loss of Radar Track	510	Normal horizon limitations

* 1349:16 PST

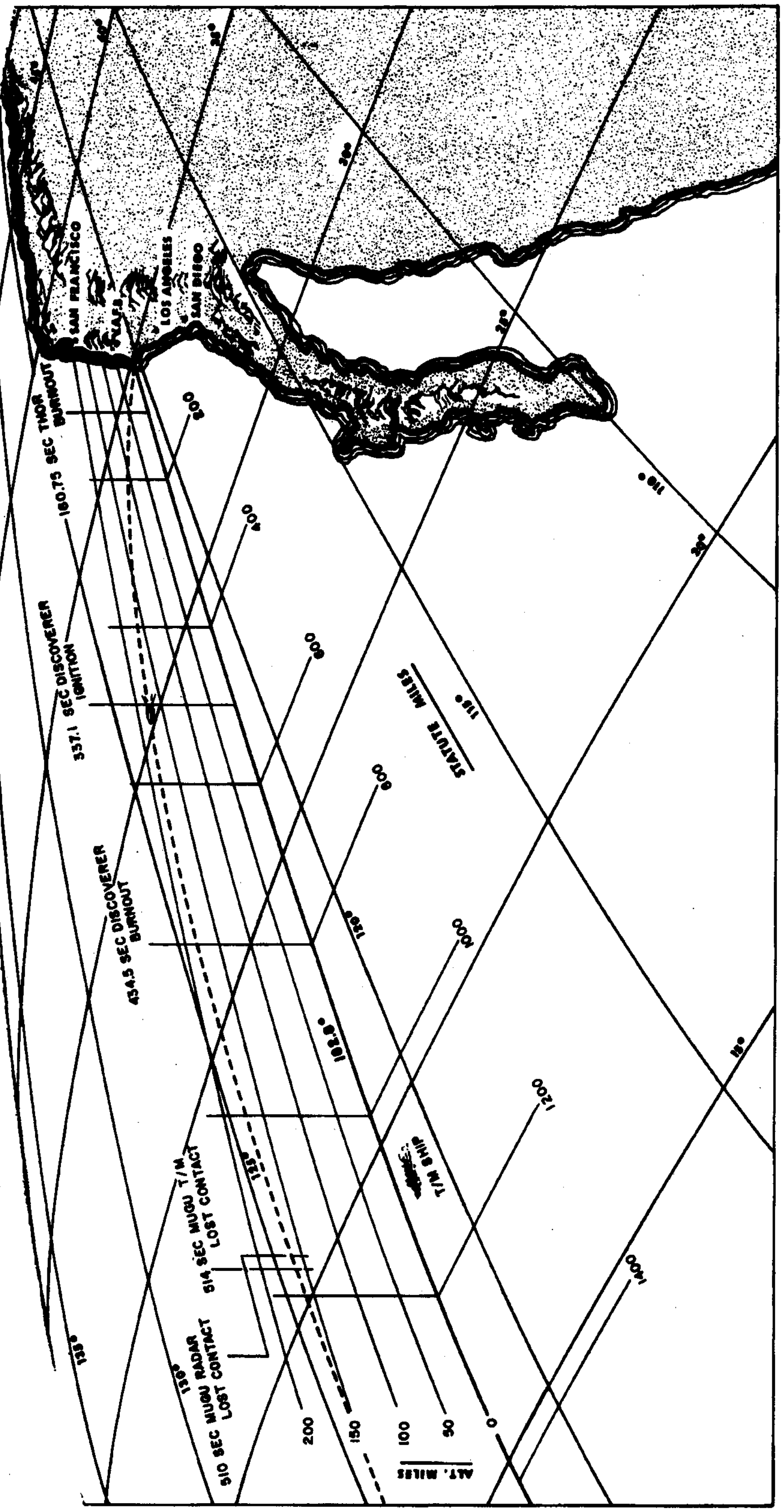

Figure 5. Three-Dimensional Launch Trajectory, Discoverer I

SECTION IV
TEST EVALUATION

SECTION IV
TEST EVALUATION

OVER-ALL SYSTEM PERFORMANCE

System Test Conduct

Test conduct was generally acceptable and according to plan. Except for several delays experienced during the final minutes of both countdowns, no significant procedural or equipment difficulties were encountered. The major delay arising during launch countdown was associated with first-stage propellant loading. Because of IOC Thor ground support equipment, the terminal countdown (during which first-stage propellant loading is accomplished) is completely automatic. This portion of the countdown was planned to require approximately 15 minutes. However, because of problems experienced with the liquid-oxidizer loading and fueling sequence, the IOC procedure was modified for this launch to incorporate holds necessary to resolve fuel and liquid-oxygen-sensor abnormalities. The modified, automatic countdown required approximately 1 hour and 18 minutes.

System operations as conducted by the Development Control Center were excellent. A few minor communications problems arose on R-1 day, but these were remedied well in advance of the countdown. System test procedures were well exercised and appeared adequate.

In view of the intensified and prolonged effort on the part of all launch and system test personnel and the highly successful result, their proficiency was considered excellent.

Trajectory

The launch trajectory and sequence of events followed the planned program (Reference 6). At the time of main-engine cut-off, the actual flight path was approximately 1.6 degrees higher than the nominal flight path. The actual ascent trajectory, as obtained from Pt. Mugu radar and metric optics data, is compared with predicted data in Figures 6 through 8. The metric optics (phototheodolite) data show close agreement with the radar.

Comparison of the predicted with the actual flight-trajectory, as obtained from the Pt. Mugu radar (corrected for refraction and earth curvature), shows a deviation in flight-path angle and altitude during orbital boost, so that orbit injection and perigee altitude did not occur simultaneously. This would cause a highly elliptical orbit.

No sustained tracking of the vehicle was attained after 510 seconds. For this reason, the orbital parameters could only be estimated from actual conditions at the time of injection as determined by Pt. Mugu radar data. The estimated orbital parameters are given in Table 2.

TABLE 2

Injection Conditions and Initial Orbit Parameters

Orbit Inclination (Degrees)	89.96
Insertion Altitude (Statute Miles)	183
Insertion Velocity (Feet-per-Second)	26,000
Insertion Angle (Degrees)	-2.5*
Period (Minutes)	95.9
Eccentricity	0.0587
Perigee (Statute Miles)	99.3
Apogee (Statute Miles)	605
Lifetime (Days)	13

* Note: Includes -0.64 degree due to radar refraction.

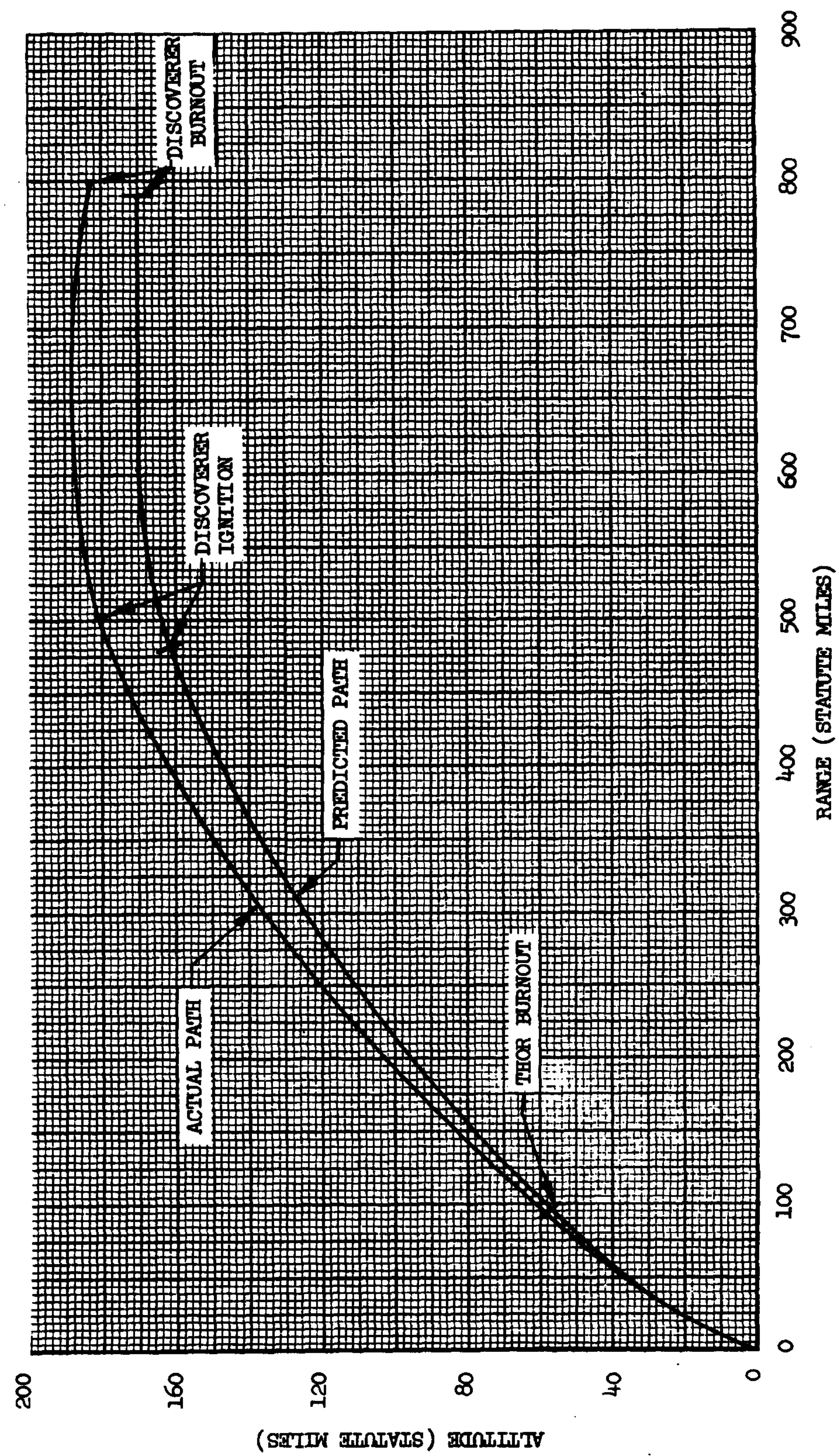

Figure 6. Ascent Trajectory, Discoverer I

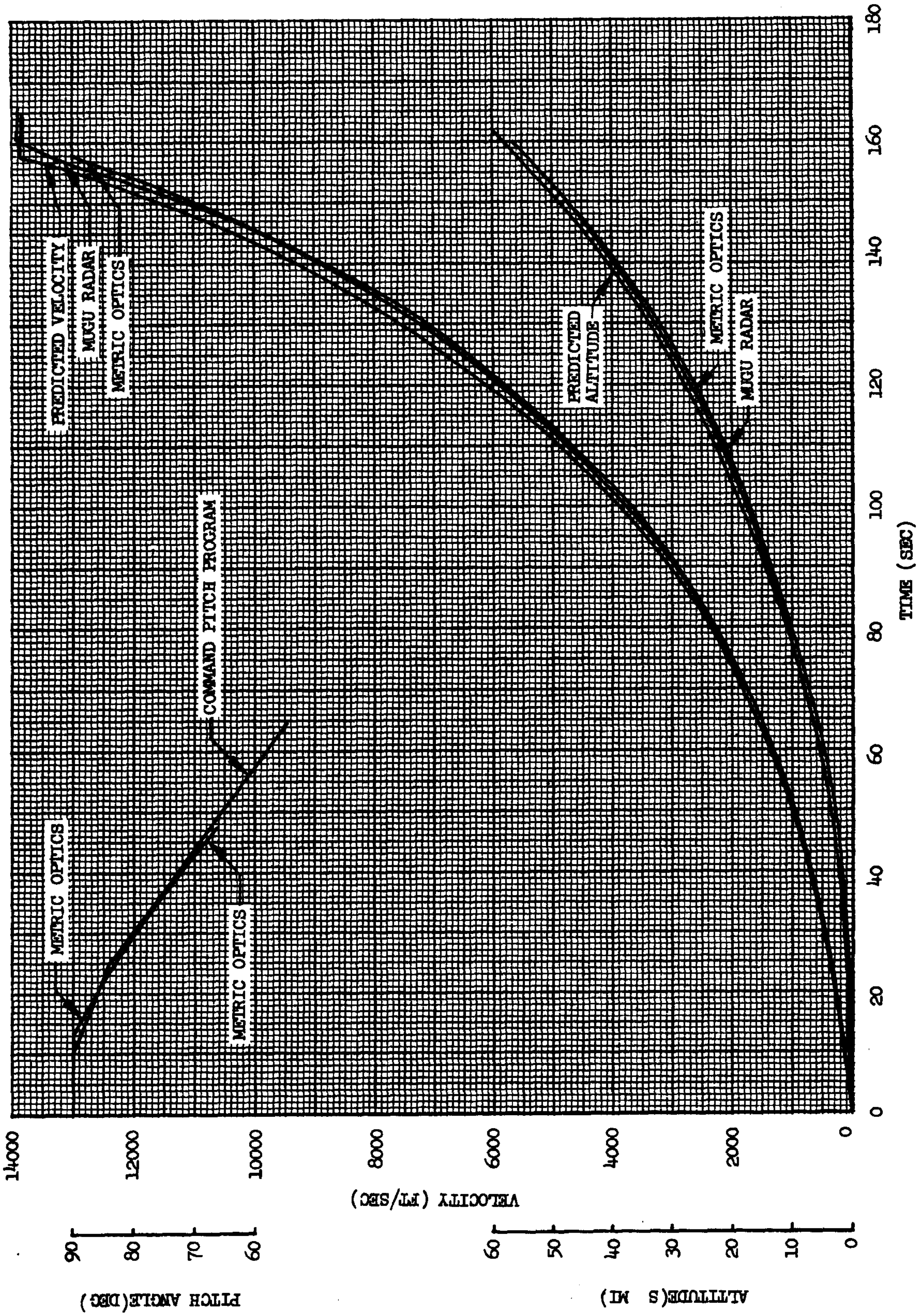

Figure 7. Time History of Velocity, Altitude, and Pitch Program During Thor Boost

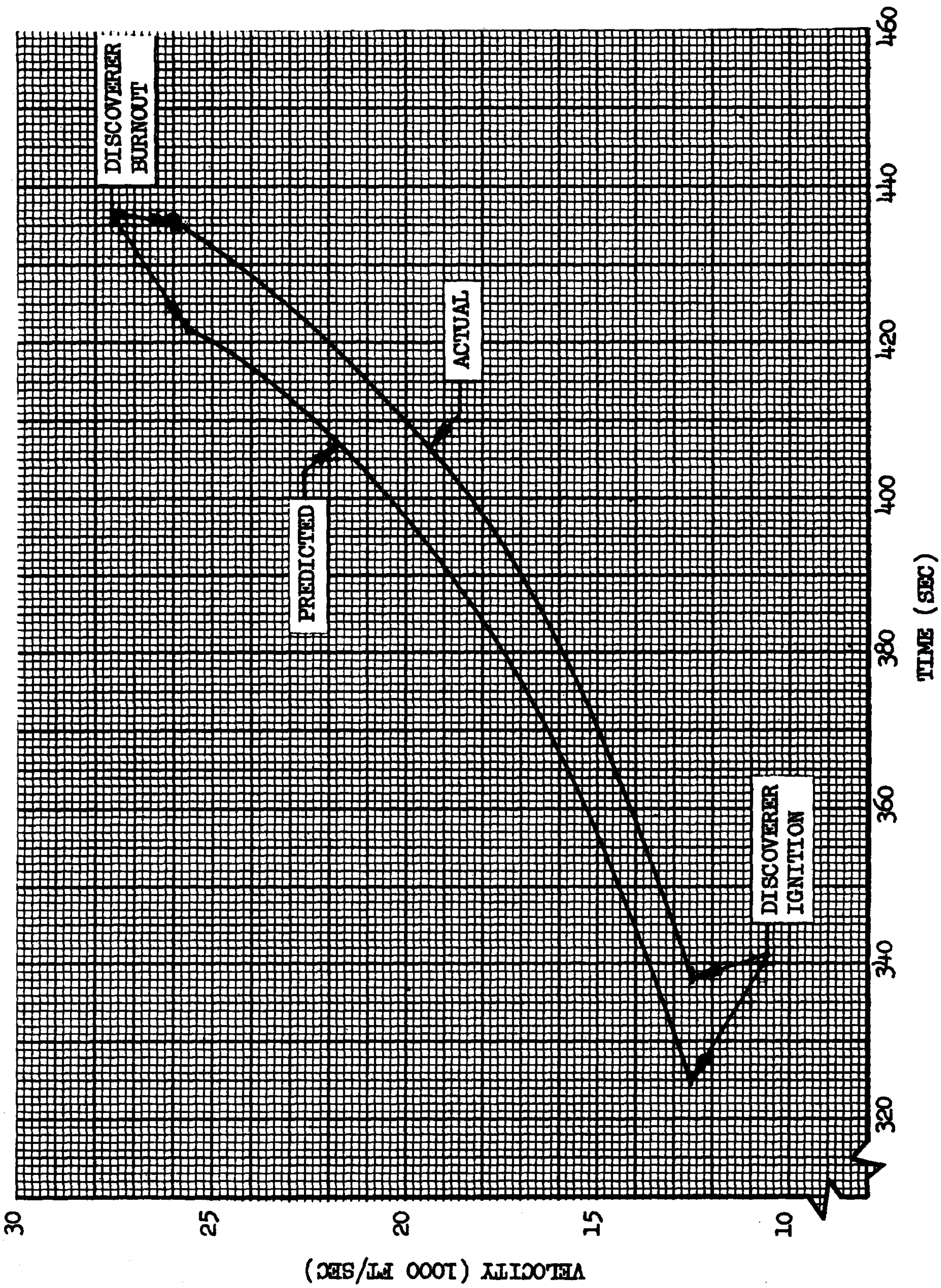

Figure 8. Time History of Velocity During Second-Stage Engine Operation

A total of 110 contacts with the vehicle were reported to the LMSD Development Control Center (DCC) in Palo Alto during the two weeks following the orbital injection of Discoverer I. Of these observations, 37 were sporadic receptions of the 232.4 mc continuous-wave acquisition beacon, and all 37 were considered as possible observations of the vehicle. None of the five visual observations reported could be accepted as valid sightings of the vehicle. There was insufficient information to validate 11 observations made by General Electric at Ithica, New York, and by the Philco Company at Palo Alto and Philadelphia. These observations were made with the controversial Kraus method.

System Design Performance

The performance of the Discoverer I/Thor combination and the complex of associated ground equipment generally exceeded expectations. Both the Thor and Discoverer vehicle subsystems performed satisfactorily during the period of flight covered by available data (to 514 seconds). Discoverer subsystems performance after 514 seconds is not known, although the absence of orbital telemeter and tracking information indicates that a malfunction of some significant nature occurred in the vehicle. All available test data have been thoroughly analyzed in an attempt to determine the cause but without success. Changes in subsequent Discoverer vehicles (which have already been accomplished) are expected to ensure adequate ground-space communications on future Discoverer flights.

The complex of tracking and control stations (including the Palo Alto Computer and DCC) operated satisfactorily throughout the test, with the exception of the Vandenberg Tracking Station and the down-range telemetry ship. All necessary telemetry and tracking stations' equipments were operative during expected orbital passes and were adequately directed by the DCC. Operational difficulties encountered with the VAFB tracking station and the telemetry ship have been investigated thoroughly and have been corrected for subsequent operations.

The basic objective of the early (first and second) Discoverer/Thor vehicles has been achieved; i.e., demonstration of orbital capability. This system is, therefore, considered entirely suitable for the continued pursuit of Discoverer program objectives.

THOR PERFORMANCE

The Thor primary objective, to place the Discoverer vehicle at a given point in space with a specified orientation and velocity, was satisfactorily accomplished. Separation of the Discoverer from the Thor booster, starting at 172.2 seconds from lift-off, was successful. Ascent-trajectory calculations, based upon VERLORT radar data, show the vehicle flight path to have been between 1.0 and 2.2 degrees above nominal, with an altitude excess of 14,000 feet. This deviation is well within the specified tolerance (±4-degree flight path angle) and is believed to be due to programmer errors and pitch-gyro drift. A lateral 1.0-degree displacement of the actual trajectory east from nominal is compatible to the measured wind conditions and -0.1-degree yaw thrust misalignment.

The velocity at main-engine cut-off was 13,920 feet-per-second, compared to a nominal of 13,763 (±500) feet-per-second. A total lift-off thrust of 152,300 pounds was determined, with a cut-off thrust of 173,500 pounds. (Cut-off thrust was somewhat low and was caused by a 2 percent drop in main-chamber pressure at 59 seconds after lift-off, which also resulted in lowered flow rates and a 3-3/4-second delayed main-engine cut-off.) Residual propellants at cut-off were 0.0 (±0.2) percent of the usable propellants.

The Thor control and hydraulic systems performed satisfactorily, with the pitch and roll program having occurred properly, and stability having been maintained through a wind shear condition without advantage of fins. The electronic equipment performed satisfactorily. Instrumentation performance was generally satisfactory except for the high noise-to-signal strength ratio observed on pulse amplitude modulation (PAM) channels. In addition, the PAM data values were slightly higher than duplicate FM data, the reasons for which are still unknown.

The tertiary objectives of evaluation of countdown procedure, pre-launch techniques, and ground support equipment were satisfactorily accomplished, indicating adequate countdown procedures and GSE for the Thor/Discoverer program.

A comprehensive report covering the Thor booster performance for this flight is presented in Reference 5. Over-all Thor performance was considered excellent.

DISCOVERER SUBSYSTEMS PERFORMANCE

Subsystem A - Airframe

The vehicle airframe and adapter satisfactorily withstood the aerodynamic and vibration loads and heating effects of launch. Even though the launch conditions were not critical, the longitudinal adapter loads were 22-1/2 percent above predicted, due to a more abrupt Thor-thrust build-up than expected. The measured longitudinal natural frequency of 16.6 cps and the bending natural frequency of 4.6 cps agreed well with the predicted values.

Wind shear at about 30,000 feet altitude subjected the vehicle to approximately 80 percent of its allowable design bending moment, but it was within the allowable magnitude for vehicle launch. The resulting sideslip angle (approximately 7 degrees) and accompanying high dynamic pressure resulted in an estimated nose-cone differential pressure equal to the maximum design value.

Data obtained from analysis of accelerometer records indicated that design loads were not exceeded except immediately prior to Thor burnout when the 11.2-g longitudinal-acceleration adapter design load was exceeded by 0.2 g. This load condition was not accompanied by significant bending moments and hence was not critical.

Separation was effected satisfactorily. The relative separation velocity of 3.06 feet-per-second equalled the predicted velocity.

The thrust build-up upon Discoverer-engine ignition was more abrupt than predicted and resulted in an increase in dynamic loads and acceleration. However, no critical loads were sustained.

Approximately 30 seconds after engine ignition, a pitch oscillation of 1.7 cps resulted from oxidizer slosh. This measurement compared favorably with the predicted coupled natural frequency of 1.66 cps at this fuel load. The oscillations damped satisfactorily 33 seconds later as propellant load was reduced.

Usable skin temperature data were recorded at four stations, three of which were on the nose cap, and one was on the adapter. All measurements were below predicted values. Analysis of this data indicates that equipment in the forward equipment rack was operating well within specified limits.

Vibration records show shock and vibration levels were low, except at lift-off, during firing of the explosive bolts, and during Discoverer-engine ignition. Analysis of the data recorded during these times indicated shock and vibration levels approaching design limits. However, there was no evidence of structural or equipment failure.

Subsystem B - Propulsion

Propulsion system operability was demonstrated by the achievement of design and test objectives. The propulsion system provided the necessary velocity increment required to attain orbital status, and it affirmed the ability of the ullage rockets, the electrical, mechanical, and pressurization systems to provide engine operation in a near-vacuum environment. Operational results were well within the specified limits. However, engine performance parameters were slightly higher than were predicted.

Table 3 itemizes only the significant engine-performance parameters and compares then with their predicted values.

TABLE 3

Engine Performance Values

	Parameter	Predicted	Actual
1.	Thrust, lb	15,350	15,800 (avg.)
2.	Thrust chamber pressure, psi	501	515 (avg.)
3.	Engine burning, sec	98.3	96.3
4.	Specific impulse, sec	268	268 (calculated)
5.	Propellant flow total, sec	57.21	58.97 (calculated)
6.	Mixture ratio	4.24	No data
7.	Turbine speed, rpm	23,380	No data

Subsystem C - Vehicle Internal Electrical Systems

Even though malfunctions of the electrical system accounted for most delays encountered during captive and pre-launch systems tests, electrical system performance during countdown, launch, and ascent was satisfactory. Verification of electrical systems performance was demonstrated by proper operation of other systems functions (telemetry, guidance, propulsion) and by telemetry data (power-supply parameters) received during the first 514 seconds after launch. Electrical power recovery was demonstrated at initiation of separation and hydraulic system activation. There are no data available which indicate the possibility of any electrical power system malfunction.

Subsystem D, Guidance and Flight Controls

The Guidance and Flight Control System operated within specified limits throughout the period of flight documented by available telemeter data. Inadequate data in some areas prevented positive conclusions as to the subsystem operation, but proper functions were verified which indicated occurrance by correlating concurrent events or data in related systems. All flight events controlled by the guidance system during ascent-to-orbit occurred within the specified time tolerance (±0. 5 seconds).

Telemetered attitude gyros indicated that during coast phase the vehicle was controlled within specified limits by the pneumatic control system. Operation of the attitude gyros and the horizon scanner was satisfactory. The 40-degree-per-minute pitch-down command (given prior to horizon scanner pitch operation) brought the vehicle to within 3 degrees of the intended horizontal attitude.

At engine ignition, substantial shocks were recorded with a corresponding engine movement resulting. At this time, gyro oscillations were indicated which may have caused the pitch attitude and rate gyros to hit one or both stops. Within 2 seconds, however, these oscillations were damped out by subsequent engine movement. (Possibly, the gyro reference had been shifted considerably with subsequent trajectory deviations as discussed earlier in this report.)

Approximately 30 seconds after engine ignition, oxidizer slosh caused a pitch and normal acceleration oscillation with a frequency of approximately 1.7 cps. These data correlate closely with the predicted body-fuel coupled oscillation.

Subsystem H - Ground-Space Communications

The performance of Subsystem H equipment, insofar as can be evaluated, was excellent. Because data were not recorded after 514 seconds, a definitive evaluation could not be made in some cases.

Radar (S-band) beacon performance was within specification during the ascent and early orbit phase. The beacon signal was tracked by the Pt. Mugu radar for 510 seconds after launch to approximately 1000 nautical miles. Valid beacon performance data recorded during or after beacon turn-off at 573 seconds are not available.

Acquisition (CW) beacon performance was within specification, and Doppler data received was normal until approximately 440 seconds after launch, when a frequency decrease incompatible with the known vehicle trajectory was observed. (It is postulated that this frequency shift may be attributed to an internal temperature increase.)

No data on beacon performance during antenna switch-over and succeeding orbital passes were recorded.

The Elementary (Subsystem H) timer was turned on at the proper time of 213 seconds as indicated by the presence of the sub-cycle monitor tone. No other data exist with which timer performance can be evaluated.

The radar beacon (UHF) and acquisition/telemetry (VHF) exit antennas, as well as the VHF diplexer, performed satisfactorily as indicated by the received data. No information is available on the switch-over to orbit antennas, which should have occurred at 584 seconds, or of the resulting operation of the diplexer and VHF or UHF orbit antennas. It cannot be determined if the failure to receive orbital data was due to antenna failure, faulty switch-over, or to some other internal failure. It is noteworthy that the telemeter received-signal strength for the telemeter ship's forward antenna dropped sharply at 584 seconds, the time of antenna switch-over. However, the validity of the telemeter ship data is somewhat questionable, so this occurrence cannot be considered definitely indicative of failure to switch antennas.

It has been concluded that the 45 primary parameters, of the total 91 telemetered, produced 85 percent usable data, and the remaining 46 secondary parameters produced 90 percent usable data. Seven measurements failed, and five more produced unreliable data.

The telemeter output was, in general, relatively free from noise. There were some minor noise problems on commutated channels 12 and 14, which caused slight difficulty in decommutation. However, complete data loss was in no case attributable to internal telemeter noise.

GROUND SYSTEMS PERFORMANCE

Launch Complex

The system checkout complex was operated satisfactorily throughout the systems test period of Discoverer I. The problem areas were few and, for the most part, have since been remedied. At present, the checkout complex is being adapted to an expanded and more efficient mode of operation. An additional checkout console is being installed to provide dual vehicle-testing capabilities at the facility. Areas are being designated and equipped for subsystem checkout.

The systems checkout complex as an over-all testing facility performed well.

Prior to launch, some difficulty was encountered with the electrical-cable connectors between the blockhouse and the vehicle. Because of moisture saturation, it became necessary to replace one patch cable. The other cables worked satisfactorily after drying.

The changes in vehicle guidance circuitry required extensive modification of corresponding ground support equipment. Numerous problems were encountered, resulting in the necessity of installing an electrical trailer for guidance checkout. A new, guidance warm-up control panel was used to replace the automatic control features of the existing blockhouse guidance system control console. This problem is presently being rectified.

All mobile units (helium trailer, air conditioner, transporter-erector, fuel and acid trucks, hi-lift) operated satisfactorily. The fuel in truck 3 was contaminated and was not utilized in support of the launch.

The pad facility for loading propellants operated satisfactorily. Acid had been in the system for approximately 36 hours with only a slight leak occurring at a threaded fitting connected to a manual control valve on the revetment. This was kept under constant water flush to eliminate any hazard. As a result of the "scrubbed" countdown of 25 Febrary, it was necessary to unload propellants and reload some 48 hours later to prepare for the 28 February launching. This operation was performed satisfactorily.

The pressurization system performed exceptionally well, also. Only a minor nitrogen leak in the pneumatics cabinet was experienced, as a result of a faulty "O" ring located in one of the regulators. Under 2200 psi, the "O" ring was adequate for sealing purposes, but above this pressure level, the leak became more significant. This has since been repaired.

Tracking Stations

Vandenberg Tracking Station. The performance of Vandenberg Tracking Station was adversely affected by noisy RF signals and the initial proximity of the vehicle. Equipment performance and operating procedures were satisfactory with the exception of the problem areas delineated below.

No usable data were gained from the Vandenberg Tracking Station Mod II radar. The difficulties were partly procedural and partly due to faulty equipment.

(When the vehicle is on the launch pad, it is difficult to keep the vehicle's radar beacon signal from saturating the tracking station radar located only 6 miles away. To prevent saturation, a great deal of signal attenuation must be used at the radar, and this attenuation must be slowly and accurately removed as the range to the vehicle increases after launch. Coupled with this restriction is the fact that if the radar gets off track the proper amount of attenuation required to regain the signal is unknown. Too little attenuation will result in false targets appearing, and too much attenuation will result in no target.)

The actual sequence of events and the azimuth, elevation, and range data generated by the radar are compared to metric optics data in Figure 9.

Initially, the radar was in automatic track with smoothing or damping applied so that no jumping would occur. The radar was on track until approximately 40 seconds after launch when the azimuth began to deviate slowly and smoothly for reasons unknown. At approximately 70 seconds after launch, the elevation angle kept increasing at the same rate as it previously had but became diverged from the true angle. This occurrence was accompanied by a drop in AGC voltage, indicating a decrease in signal strength.

This smooth azimuth and elevation divergence continued until T + 118 seconds, when it became apparent to the radar operator that tracking was lost. At this time, the tracking was switched to manual by the operator in an attempt to regain track. At T + 120 seconds, the transmitter was turned off (changed from active to passive track) as requested by Pt. Mugu. Also at T + 120 seconds the radar was slaved to the slave data buss. However, the data source for the slave data buss at this time was the radar itself, so the radar became slaved to itself with consequential servo instability. This is evidenced by Figure 9 in the period from T + 120 to 176 seconds. At T + 176 seconds, the radar was put in passive manual track and remained there, but the target was not again acquired well enough to achieve automatic angle tracking.

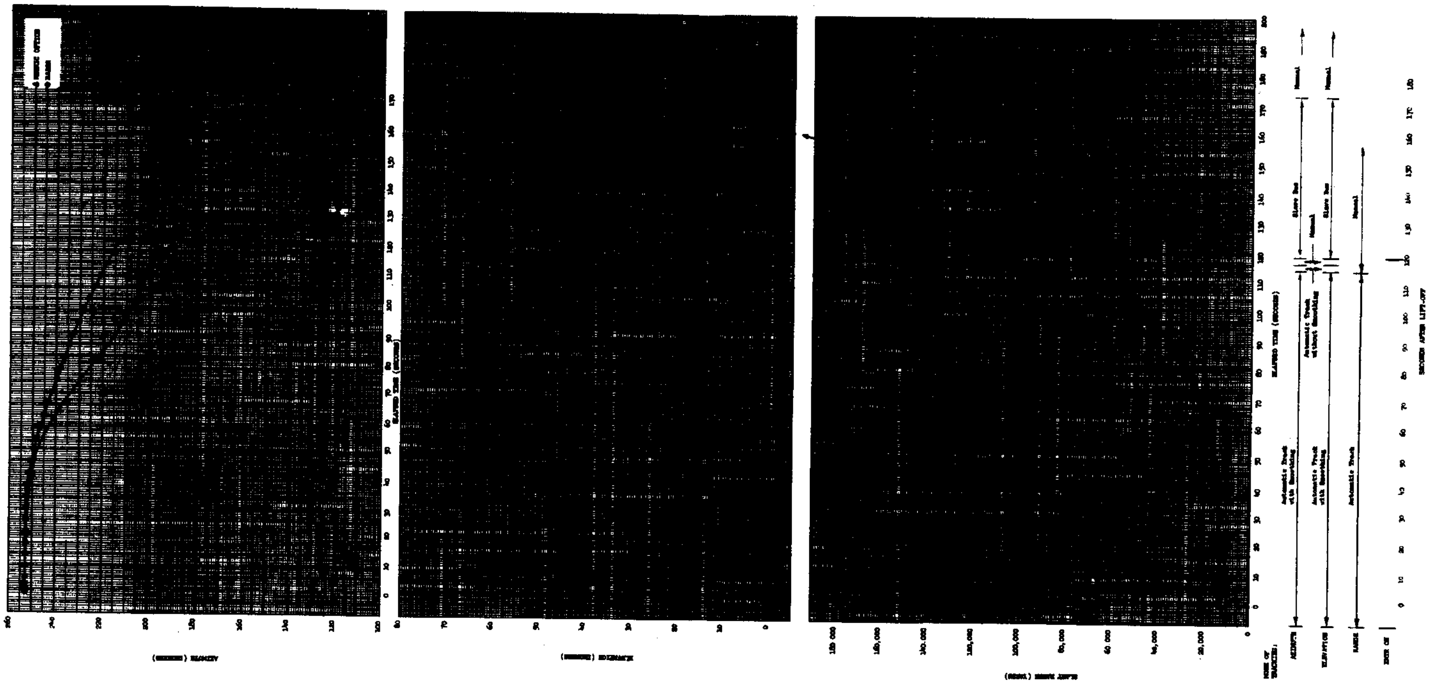

Figure 9. Vandenberg AFB Radar Data

Additionally, the TLM-18 (telemetry tracker) was adversely affected due to the proximity of the signal source and produced no usable tracking data. At lift-off, the antenna was pointed at the pad but did not follow the vehicle course, since there was an abundance of signal reflected from the pad area for it to lock on. At T + 30 seconds the TLM-18 regained automatic track on the vehicle acquisition transmitter. At T + 189 seconds, since the acquisition beacon signal strength was beginning to drop, the operator attempted to switch tracking to the telemetry transmitter, but the target was lost. (Once again this was probably due to an over-abundance of signal.) Automatic track was regained at T + 337 seconds on the telemetry transmitter and held there until T + 536 seconds when the track was lost.

Pt. Mugu Tracking Station. Performance and operation of the Pt. Mugu tracking station was more than adequate, and no major problems were encountered. The radar trajectory and telemetry data, used in the final flight analyses, were those collected at Pt. Mugu.

Telemetry Ship. Because of the considerable interest in conditions at the time of antenna switch over and subsequent performance, the data obtained by the telemetry ship were adjudged most critical. The failure to acquire any usable data from this station is primarily attributed to operational difficulties. The only equipment failure was in the preamplifier of the aft tri-helix antenna. This failure did not make the antenna inoperative, but it did raise the noise level substantially, as evident in Figure 10.

At the time of launch, the telemetry ship was located at approximately 120° 40' W longitude and 18° 57' N latitude headed true north. Figure 10 is employed to show the pertinent tracking, relative location, and signal strength data as a function of time. It is shown that search by

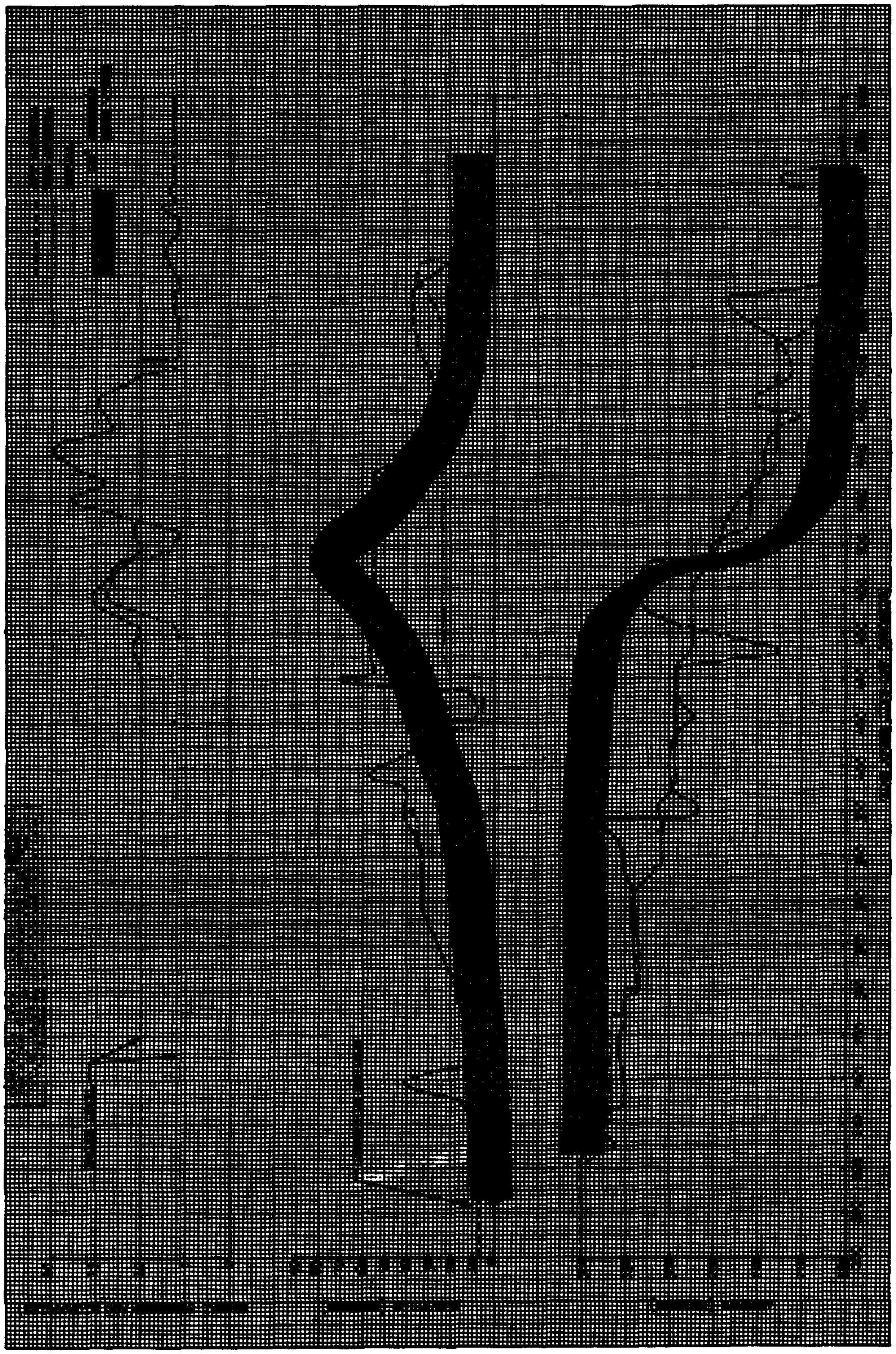

Figure 10. Telemetry Ship Antenna Data

both antennas was initiated approximately 225 seconds after launch and led the vehicle through its trajectory. On only one occasion is it indicated that the vehicle was within the 20-degree beam width of the antennas - this occurring for the aft antennas at approximately 475 seconds.

This problem was attributable to improper search procedures resulting from a lack of up-to-date information regarding the time of expected emergence of the vehicle over the ship's horizon. The correct information, although late in arrival, has been supplied to the ship's personnel and should obviate repetition of this difficulty in subsequent operations.

Hawaiian Control Center and Recovery Force

A recovery simulation exercise, performed in conjunction with Discoverer I operations and intended as a full-dress-rehearsal of the first recovery vehicle launching, was conducted as planned. The test was successful in achieving the stated objectives and provided valuable operational training. The exercise involved the deployment of the recovery force as shown in Figure 11 and was under the direction of the Hawaiian Control Center (HCC). Few operational difficulties were encountered, although several radar equipment malfunctions were reported.

Control of the destroyers, C-119 pickup aircraft, and the RC-121 radar acquisition aircraft during the operation was satisfactory. The two recovery capsules dropped from a B-47 aircraft were successfully acquired by the RC-121 aircraft using the metallic chaff and silvered-parachute radar detection aids. Excellent

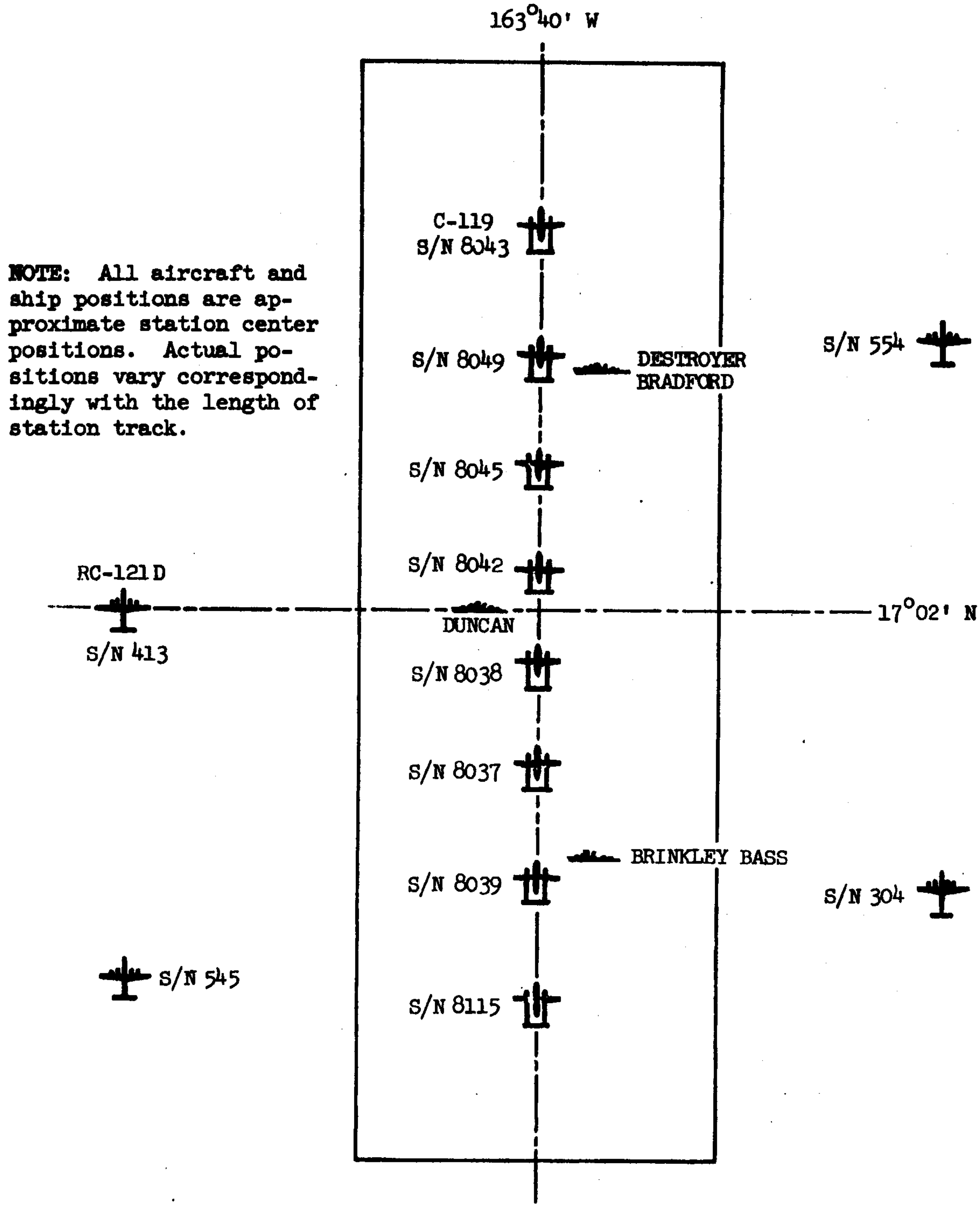

Figure 11. Recovery Force Deployment Pattern for Recovery Simulation

results from the Discoverer Direction Finding System (DDF) were obtained by both the destroyers and C-119 aircraft.

The major shortcomings of the mission were the failure to accomplish aerial recovery on the first drop and the lack of beacon signal from the second capsule after water impact. Aerial pickup of the capsule on the first drop was unsuccessful due to failure of the parachute-capsule rigging. The second capsule was successfully recovered from the water, as planned, although the absence of a beacon signal would have seriously hampered the search had the capsule not been visually sighted prior to impact.

The general communication pattern for the operation was such that the ships and recovery aircraft were controlled by the RC-121 control aircraft. The control aircraft, in turn, reported to the HCC, and HCC reported to the DCC. Under this system, it was noted that the over-all air-to-air communications were satisfactory, but ship-to-air communications were marginal and, at times, required message-relaying between participants to accomplish the mission.

No problems were encountered on the HCC-to-DCC network. For the dress rehearsal, the network was monitored by the HCC at all times. Actual participation was principally limited to communication checks and the receiving of impact area refinements and sending of reports on the recovery force status.

SUPPORT PERFORMANCE

Pacific Missile Range NAMTC

The presentation and quality of the theodolite launch trajectory data supplied to LMSD by the Test Data Division of the Pacific Missile Range were considered excellent.

Pitch and yaw data were computed as requested were within accuracy requirements. Roll data, however, are considered marginal because of insufficient reading leverage of the reference spiral painted on the first-stage-booster airframe. An extended spiral would remedy this situation.

The accuracy of the theodolite data was considered to be well within the 0.5-mil requirement. Tabulations of the FPS-16 radar data were included with the theodolite data. A comparison of the data from the two tracking systems shows close agreement, further verifying the quality of the PMR data.

Weather conditions on the day of the launch were good in the VAFB area, which resulted in theodolite data that was usable from the local camera stations. Ground fog prevented the usable extended coverage that could have been obtained with better weather at the Pt. Mugu and San Nicholas Island theodolites.

Satisfactory magnetic tapes of the launch telemetry were received from the PMR facilities at San Nicholas Island and Pt. Arguello, but utilization of these tapes was not necessary because of the usable Pt. Mugu radar data. (These tapes would be invaluable in the event all primary data were lost.)

Space-track

Space-track was alerted for the launch and was prepared to track Discoverer I. Numerous inputs received from Space-track were listed as possible sightings.

General Electric Company, Ithaca, New York

General Electric at Ithaca, New York, was prepared to track the vehicle by means of a modified Kraus technique. This technique has been used in satellite observations since September 1958 with some success when utilizing accurate ephemerides. A total of 47 sightings were reported by the use of this method. Some of these observations may have been Discoverer I passes; but because this technique is neither fully understood nor proven, it is impossible to determine which contacts were genuine.

Recovery Simulation

The following participating agencies satisfactorily supported the recovery simulation operation, conducted at the nominal time of the 17th orbital pass:

- Three destroyers supplied by the U.S. Navy
- RC-121 aircraft -- 552nd AEW & C Wing
- C-119 aircraft -- 6593rd Test Squadron
- B-47 aircraft -- Air Force Flight Test Center, EAFB
- Hawaiian Sea Frontier (HAWSEAFRON) communications personnel
- Airways and Communications System personnel -- 1957th AACS
- 1st Weather Wing (Wheeler AFB) Detachment 4
- 57th Weather Reconnaissance Squadron
- 76th Air Rescue Squadron.

A substantial amount of data from the simulated recovery operation in Hawaii was hand-carried to LMSD, Palo Alto, arriving at approximately T + 88 hours (scheduled time). This data consisted essentially of magnetic tapes, operation logs, commentaries and a preliminary test report on the recovery simulation.

It was originally intended that each component of the recovery force would submit to the Hawaiian Control Center completed data forms along with a written report on the respective operation. The HCC would then formulate a preliminary report on the over-all recovery operation and submit it, along with the total package of component reports, to LMSD, Palo Alto. The preliminary report submitted by the HCC was not as complete as it could have been because the data packages received from the participating agencies were somewhat incomplete. Other data-gathering discrepancies noted were a lack of the descent point of the capsule and the corresponding locations of all recovery force craft, a lack of data concerning the size and reliability of the radar targets acquired on the chaff and parachute, and a lack of photo coverage.

Necessary action is being taken to insure a more thorough coverage in the future.

SECTION V
CONCLUSIONS

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CONCLUSIONS

1. Orbital capability of the Discoverer I/Thor combination was satisfactorily demonstrated.

2. Ground support and checkout equipment operation was satisfactory except for malfunctioning propellant sensors.

3. Thor booster performance was in accordance with specifications.

4. The structural integrity of the Discoverer I/Thor combination was satisfactory.

5. Operation of the Discoverer vehicle subsystems was satisfactory except for an apparent malfunction of unknown origin which prevented reception of orbital telemetry and tracking signals.

6. Recovery rehearsal operations were conducted with satisfactory results.

7. The system complex of tracking and control stations, including the Palo Alto computer and Development Control Center communications network, performed satisfactorily. The Development Control Center, in conjunction with the launch base, successfully accomplished the integration and direction of over-all operations.

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