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DISCOVERER XIII
(Agena 1057/Thor 231)

SYSTEM TEST EVALUATION
AND
PERFORMANCE ANALYSIS REPORT
(35-Day Report)

Contract AF 04(647)-558

Lockheed

MISSILES and SPACE

LOCKHEED AIRCRAFT CORPORATION

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FOREWORD

This document is the final system test evaluation and performance analysis report for the launch of Discoverer XIII from Vandenberg AFB on 29 June 1960. It has been prepared for the Air Force Ballistic Missile Division (AFBMD) to meet a requirement of Contract AF 04(647)-558 in accordance with Paragraph 1.4.1 of LMSD-445158-B, Discoverer Program.

446240-57-023

PRESIDENT EISENHOWER INSPECTS DISCOVERER XIII CAPSULE: *With the President are (left to right) Lt. Gen. Bernard Schriever, Air Force Sec. Dudley Sharp, Defense Sec. Thomas Gates, Air Force Chief of Staff Gen. T. D. White, Col. Lee Battle, the AFBMD Discoverer Project Officer, and Col. Charles Mathison, Test Director of 1694th Test Wing*

SUMMARY

Discoverer XIII (Thor 231/Agena 1057) was launched on the first attempt from Vandenberg AFB Complex 75-3-5 on 10 August 1960. All primary, secondary, and tertiary test objectives were met, including the achievement of a significant "first" in world-wide space technology: recovery of a capsule ejected from an orbiting satellite. The capsule was recovered from the ocean northwest of Hawaii by a helicopter operating from the USNS Haiti Victory, after visual acquisition by C-119 aircraft.

Launch countdown commenced at 0600 PDT. Liftoff occurred 7 hours and 38 minutes later, at 1337:54:40 PDT. Separation of the Agena from the Thor was completed at the prescribed time and altitude. Agena engine ignition, signalled by the Agena's D-timer, was followed by 118 seconds of engine operation. The engine was shut down by integrator command after the required inertial injection velocity had been attained.

Satisfactory Agena injection altitude and velocity resulted in an orbital perigee of 137 nautical miles, an apogee of 379 nautical miles, and a period of 94 minutes. Orbital lifetime of the satellite is calculated to be 84 days.

All commands transmitted to the orbiting Agena were successfully received, executed, and verified. Additionally, orbital timer operation was accurate, and all programmed events, including initiation of the recovery sequence on Pass 17, took place as specified.

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ILLUSTRATIONS (Continued)

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NOMENCLATURE

AET	Advanced Engineering Test
BSTS	Barking Sands Tracking Station
Blossom Time	Time of capsule parachute deployment
Chaff	Metallic radar target scattered at the time of capsule parachute deployment
Countdown	Step-by-step process leading to a missile launching
Countdown	Reduction in response of radar-beacon to interrogations caused by unsynchronized multiple-active tracking by two or more ground radars or by improper spacing between the command and interrogation pulses
CWAT	Continuous-wave acquisition transmitter
DAC	Douglas Aircraft Corporation
ETPD	Estimated time of parachute deployment
GE	General Electric Company
AAFB	Hickam Air Force Base
HCC	Hawaii Control Center
HTS	Hawaii Tracking Station
HATS	High Altitude Temperature Simulator
KTS	Kodiak Tracking Station
Lock-on	Automatic training of the radar antenna on the target, following initial acquisition, accomplished by a servo-control system which nulls-out error signals
MTS	Pt. Mugu Tracking Station
NBTS	New Boston Tracking Station
On-line	Instantaneous or near real-time data
PACC	Palo Alto Computer Center
PAM/FM	Pulse-amplitude-modulated subcarrier; frequency modulated carrier
PRF	Pulse-repetition-frequency

NOMENCLATURE (Continued)

RADARC	A sonobuoy marker device equipped with radio beacon and tracking lights
r-f	Radio frequency
System time	Time in seconds measured from 2400 Greenwich Mean Time (GMT); recycles every 24 hours
TLM-18	A high-gain, narrow-beam, VHF, automatic tracking antenna
TOC	Time-of-crossing of a satellite over a tracking station
Tri-helix	A medium-gain, wide-beam, manually steerable or slavable VHF antenna
VERLORT	Very-Long-Range-Tracking radar
VTS	Vandenberg Tracking Station

SECTION 1
INTRODUCTION

BACKGROUND

In the Discoverer Program a total of 13 flights have been launched from Vandenberg AFB. Eight Agena Satellites have been successfully injected into orbit (see Table 1). Present plans call for the launching of 17 additional vehicles before the program is concluded.

The principal objectives of the Discoverer Flights are the development of Thor-boosted Agena satellites capable of functioning as carrier vehicles for scientific material and the recovery of capsules ejected from these satellites while on orbit.

Additional Discoverer objectives are the perfecting of equipment, techniques, and procedures for launching Thor-boosted Agena satellites; attaining orbit; and acquiring, recording, transmitting, receiving, and processing satellite functional and environmental data, as well as geophysical data. Section 5 of this report lists the objectives of Discoverer XIII. In addition to these specific goals, it is also expected that the ground system operational techniques and procedures at the tracking stations, control center, and launch-base will be refined as the program progresses. Specialized tests, including aero-medical research, will be executed during the series. A propulsion system capability for single restart and extended-duration operation will also be tested.

Finally, an important long-range objective of the Discoverer Program is the refinement of equipment and procedures which will be used in the more advanced MIDAS and Samos programs, as well as in future deep-space probes.

Table 1
DISCOVERER PROGRAM FLIGHT TEST SUMMARY

DISCOVERER VEHICLES AGENA/THOR	LAUNCH COMPLEX, TIME, AND DATE	COUNTDOWNS REQUIRED	PAYLOAD DESCRIPTION	RESULTS
1019/160	Complex 4 Attempted on 21 Jan 59	1	Non-recoverable, consisting of communications equipment	Malfunction during countdown caused ullage rockets, retrorockets, separation bolts, and horizon scanner fairing to fire when hydraulic motor was turned on. Design problem. Discoverer extensively damaged.
Discoverer I 1022/163	Complex 4 1349:16 PST 28 Feb 59	2	Non-recoverable, consisting of communications equipment	Injection angle -2.4° caused 13 day lifetime. No telemetry or radar orbit contact made. Sporadic CWAT contact reported. Vehicle believed damaged structurally and/or thermally at injection or during first pass.
Discoverer II 1018/170	Complex 4 1318:39 PST 13 Apr 59	1	Biomedical Research Capsule, containing four mechanical mice	Orbit achieved. Engine shutdown by command (source unknown, but believed due to relay malfunction). Capsule ejected but not recovered. 13 day lifetime recorded.
Discoverer III 1020/174	Complex 4 1309:20 PDT ? Jun 59	4	Biomedical Research Capsule, containing four live mice	Premature engine burnout due to fuel exhaustion. Insufficient velocity gained for orbit attainment. Below nominal performance (but within specification) achieved by Agena engine.
Discoverer IV 1023/179	Complex 5 1547:45 PDT 25 Jun 59	2	Recoverable Research Capsule	Premature engine burnout occurred, resulting in insufficient velocity for orbit attainment. Under-nominal performance (but within specification) achieved by Agena engine.
Discoverer V 1029/192	Complex 4 1200:08 PDT 13 Aug 59	6	Recoverable Research Capsule	Burnout due to propellant exhaustion. Orbit achieved. Capsule separated but not recovered. Recovery sequence believed not accomplished due to extreme cold effects on mercury battery. 46 day lifetime recorded.
Discoverer VI 1028/200	Complex 5 1224:44 PDT 19 Aug 59	2	Recoverable Research Capsule	Burnout due to propellant exhaustion Orbit achieved. Capsule separated but not recovered. Recovery sequence believed not accomplished. 63 day lifetime recorded.
Discoverer VII 1051/206	Complex 4 1228:41 PST 7 Nov 59	2	Recoverable Research Capsule	Successful launch and orbit. Slow separation experienced. Agena engine shut-down accomplished by integrator command. 400-cycle power failed after downrange telemetry lost signal and vehicle tumbling ensued. Nitrogen gas exhausted prior to Orbit 2 contact by Kodiak. Capsule could not be ejected. 19 day lifetime recorded.
Discoverer VIII 1058/212	Complex 5 1125:24 PST 20 Nov 59	1	Recoverable Research Capsule	Burnout due to propellant exhaustion following accelerometer-integrator malfunction. Excessive injection velocity resulted in eccentric orbit with perigee of 115 nm and apogee of 1047 nm. 103.7-minute period with satisfactory programming of capsule separation on Orbit 15. Re-entry sequence normal. No recovery although Recovery Force reported beacon reception for a short period. Over 90 days lifetime.

Table 1 (Continued)

DISCOVERER VEHICLES AGENA/THOR	LAUNCH COMPLEX, TIME, AND DATE	COUNTDOWNS REQUIRED	PAYLOAD DESCRIPTION	RESULTS
Discoverer IX 1052/218	4	4	Recoverable Research Capsule	Two major malfunctions at liftoff: Umbilical mast retraction delayed, failure of Agena's helium supply quick disconnect. Agena tumbled (no attitude control). Premature Thor main engine shutdown.
Discoverer X 1054/223	5	1	Recoverable Research Capsule	At liftoff, Thor booster pitch oscillations began diverging until main engine was gimballing from stop to stop. Discoverer deviated excessively from programmed flight path angle and destruct signal was transmitted at T + 56.36 seconds.
Discoverer XI 1055/234			Recoverable Research Capsule	Near polar orbit attained. Agena nose-down re-orientation for capsule separation accomplished. Retro and despin rocket firing confirmed as was thrust cone separation. Capsule beacon and telemetry recorded. Spin deficiency led to insufficient retro velocity. Capsule re-entry trajectory high and beyond predicted recovery area.
Discoverer XII 1053/160	4	1	Recoverable Research Capsule	Liftoff and ascent trajectories and injection velocity met requirements. However, Agena's velocity gain not horizontally directed. A nose-down attitude (caused by incorrect horizon scanner signals) resulted in a -8.3 degree injection plane.

SCOPE OF THIS REPORT

This document contains the detailed evaluation of all data relating to the Discoverer XIII flight. Included are the results of investigations into problem areas; and, if indicated, recommendations. This report amplifies the information given in LMSD-445905-57, Discoverer XIII Preliminary System Test Report (7- to 10-Day Report), and supersedes the earlier document in any instance where the data is at variance.

Organization of this report is in three parts. The first part, Test Description, describes the configuration of Discoverer XIII, and gives a chronological history of the flight. The second part, Test Evaluation, analyzes performance of important elements. The third part is the Appendix, which includes additional data to support the discussions in text.

TEST DESCRIPTION

SECTION 2
DESCRIPTION OF FLIGHT ELEMENTS

The system configuration for Discoverer XIII consisted of a DAC Thor first-stage booster (Figure 1) and an LMSD Agena second-stage satellite vehicle (Figure 2) with the necessary first- and second-stage support equipment, launch complex, command and communication system, and capsule Recovery Force. The configuration was similar to that of previous Discoverer Flights, with the exception of flight and ground system elements related to capsule recovery. The notable configuration differences for the flight elements are given in this section; those for the ground elements are given in Section 3.

COMBINED VEHICLES

The Agena satellite vehicle Model 2205, Serial 1057, was mated by a structural adapter section (supplied by LMSD) to a modified IOC Thor booster SM-75, Serial 231, utilizing an MB-3 Block I engine. The length of Discoverer XIII was approximately 79 feet, and its total weight at liftoff was 117,260 (±250) pounds. The Agena weight statement and the Discoverer cg and moment of inertia are presented in Appendix A.

RECOVERABLE CAPSULE

The recoverable capsule payload (Figures 3 and 4) for this flight was a special "diagnostic" configuration which contained a five-channel FM/FM telemetry system to transmit separation, re-entry, and recovery equipment operations data to ground stations. The additional equipment permits a

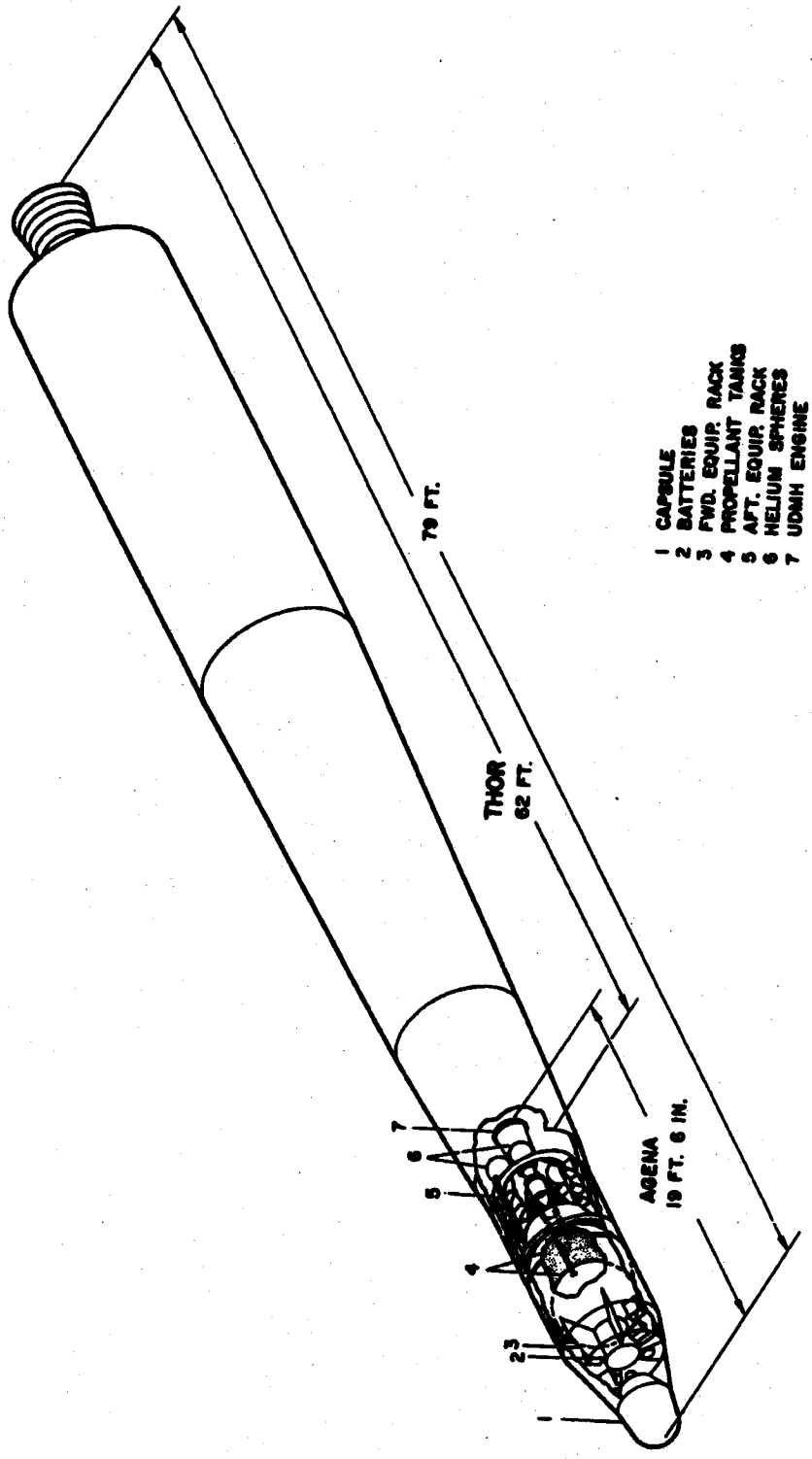

Figure 1 Agena 1057/Thor 231 Configuration

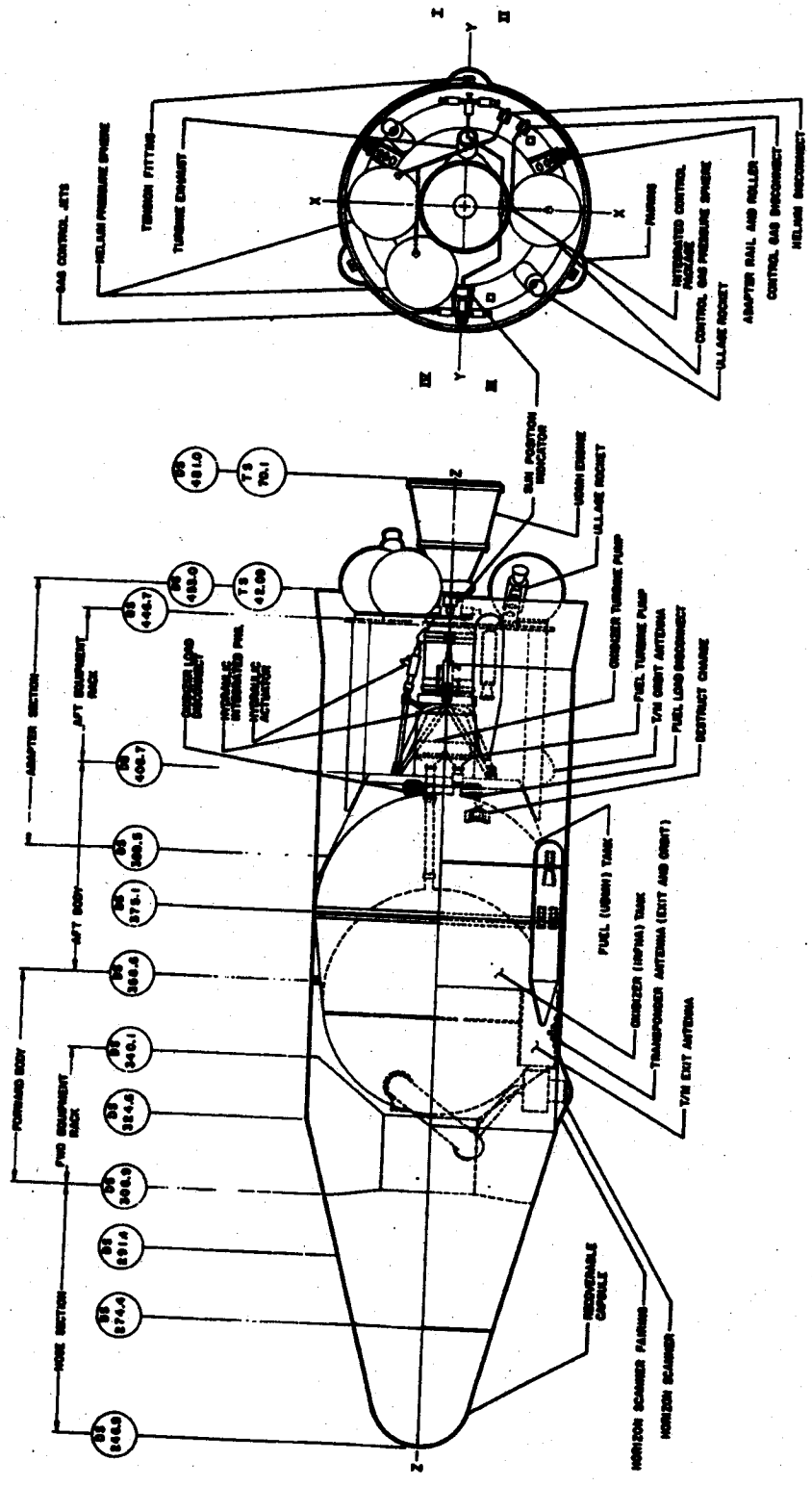

Figure 2 Agena Inboard Profile

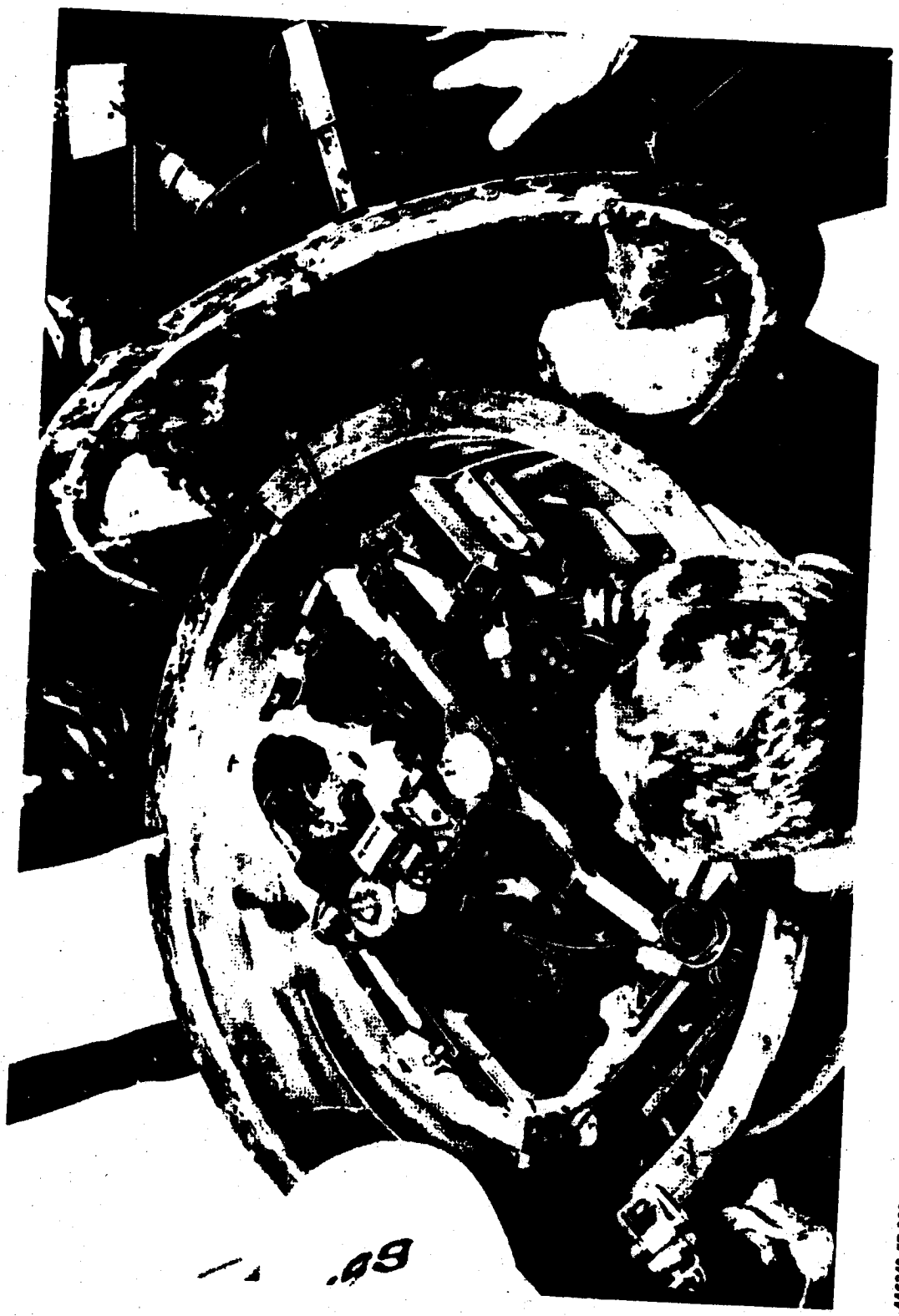

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Figure 3 Discoverer XIII Diagnostic Payload Undergoing Postflight Inspection at LMSD

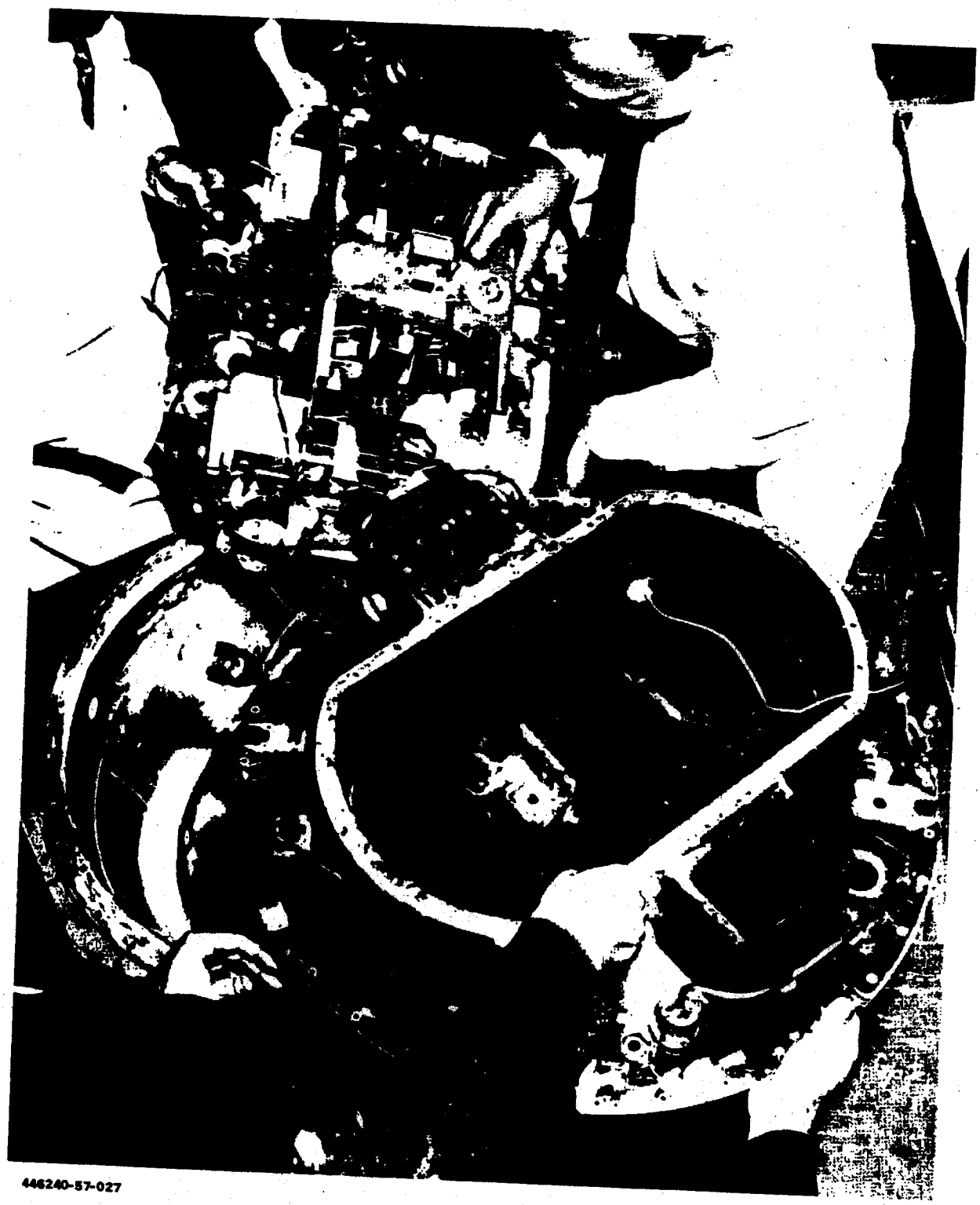

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Figure 4 Discoverer XIII Diagnostic Payload Postflight Inspection: Several Components were Removed

more complete postflight qualitative analysis of the recovery operations than has been possible on previous flights.

An 8-watt transmitter replaced the 1.2-watt transmitter normally installed to relay the following data: gyro, accelerometer, battery voltage, temperature, pressure, and breakwire telltale functions from capsule separation until parachute deployment. A continuous-tape recorder was installed to record the capsule re-entry and recovery functions in real-time and to play back through the transmitter with a 2-minute time delay so that telemetry data during capsule descent through the ionization layer would not be lost.

In addition to the instrumentation and the capsule VHF beacon, a transistorized S-band beacon transponder and its power supply were installed on the capsule thrust cone so that computer determinations of the re-entry trajectory and impact location could be made.

A cold gas manifold system replaced the separate spin-up and de-spin rocket system. Following ejection of the capsule from the satellite, the required impulse to spin and de-spin the capsule was provided from 3000-psi pressurized cold gas (Freon-nitrogen) spheres (one for each system), activated by squib valves.

To ensure pod separation prior to spin-up, the thrust-cone programmer times were changed as follows:

Function	Time (sec)*
Pod Separation	T + 1.5
Spin-up	T + 3.4
Retro-rocket Fire	T + 4.65
De-spin	T + 15.40
Thrust-Cone Separation	T + 16.9

* *T-0 is defined as electrical disconnect from the Agena power supply*

To enhance the possibility of recovery in the event of extended surface search, an additional battery was installed to power the VHF beacon after impact for approximately 20 hours, rather than 10 hours. The water-soluble plug installed to initiate capsule submersion after 30 hours was removed from this capsule.

AGENA SATELLITE

A principal difference in the Agena vehicle for this flight was brought about by a weight reduction program. In order to accommodate the required capsule instrumentation and to achieve the required performance margin, it was necessary to remove all AET equipment, the JHU/APL Doppler beacon, and optical tracking lights.

The 5.0-degree yaw program (left) for realigning velocity vectors during the ascent coast period was removed on this flight so that the desired orbital path on Pass 17 could be achieved. The D-timer PAYLOAD-EJECT command was changed from 93.4 to 94.5 seconds after D-timer restart. To achieve a higher orbit, the nominal D-timer hold was increased from 20 seconds to 39 seconds, to delay Agena ignition an additional 19 seconds. For improved low-rate capabilities, the rate gyro telemetry sensitivities were increased from ±10 to ±2 deg/sec. Control gas loading was reduced from 40 to 37 pounds as part of the general weight reduction effort. The horizon scanner was modified to reduce transient susceptibility, and the rubber gasket between the case and cover was replaced with a beryllium-copper gasket to shield against r-f radiation.

To ensure that the Agena engine would operate to propellant exhaustion prior to integrator cutoff (in the case of a minimum Command 6), the maximum integrator setting was changed from 13,800 to 14,200 (±30) ft/sec.

SECTION 3
DESCRIPTION OF GROUND ELEMENTS

Configuration of the ground elements of the Discoverer XIII flight was essentially the same as that for previous flights. The nominal capsule impact point was moved from that of previous tests to latitude 24° N. This change was to provide HTS with telemetry coverage of the parachute deployment sequence at the nominal latitude for all orbit periods within 1 minute of nominal. This impact latitude also provided KTS coverage of the complete separation and retro sequence.

The launch telemetry ship USS King County was replaced by the FS Ship AG-161. The replacement ship was equipped with a quad-helix antenna in addition to a single helix. There was no Doppler receiving or recording capability on board the vessel. Otherwise, the configuration of the ship was basically the same as that of the King County.

The Recovery Force and recovery tracking system consisted of the following: Six C-119J and two RC-121 aircraft and the Haiti Victory were dispersed in the primary recovery area; and the Dalton Victory, three C-119J, two RC-121, one WV-2, four JC-54 telemetry receiving, one C-130 recovery aircraft, and the Pvt. Joe E. Mann telemetry ship were deployed to provide capsule detection and telemetry reception capabilities from the recovery area extending 1800 nautical miles downrange. The facilities at Barking Sands, Kauai, and South Point, Hawaii, were used to determine the approximate capsule trajectory. A temporary telemetry receiving station was installed on Christmas Island to extend further the capsule detection and telemetry receiving range.

The newly activated New Boston Tracking Station (not yet operational) participated in tracking operations to check out equipment and to train personnel.

SECTION 4
CHRONOLOGICAL DESCRIPTION OF TEST

PRELAUNCH OPERATIONS

After pre-launch system tests were completed, all stations were evaluated as being fully operational with the exception of Vandenberg Tracking Station. That station's Doppler coder remained inoperative throughout the launch. New Boston Tracking Station was not an operational station for this flight, but it was active for checkout and training purposes.

The one countdown required to launch Discoverer XIII began at 0600 PDT on 10 August 1960 and proceeded smoothly to a successful liftoff 7 hours and 38 minutes later. A countdown chronology is presented in Table 2.

LAUNCH AND ASCENT

Liftoff was successfully accomplished at 1337:54:40 PDT with a clean umbilical separation and only minor pad damage.

The vehicle was launched vertically and then rolled to a departure azimuth of 174° (172° predicted). All programmed events occurred in proper sequence. The ascent, as determined by VTS and MTS real-time data, appeared to be slightly high and west of the nominal flight path. Thor main-engine cutoff was approximately 1.5 seconds sooner than expected, but within required tolerance. Separation was successfully completed at the prescribed time.

Data received and utilized by the Reeves computer at MTS during vehicle ascent and coast resulted in the transmission of 49.27 seconds of Command 5 (which extended D-timer hold to 51.60 seconds) and 13.03 seconds of

Table 2

COUNTDOWN CHRONOLOGY

Task	Time Scheduled		Actual Countdown Time		
	Start Time (min)	Duration (min)	Start Time PDT	Start Time (min)	Duration (min)
1. Pre-Countdown Operations and Countdown Initiation	T-375	10		T-375	14
2. Shelter Removal Vehicle Erection	T-365	35	0614	T-361	29
3. R-F Checkout	T-350	40	0643	T-332	93
4. Lanyard Connection and Fuel Truck Activation	T-330	35	0812	T-243	26
5. Destruct Test	T-295	30	0838	T-217	52
6. Orbital Stage Arm	T-265	35	0930	T-165	31
7. Connect First Stage Destruct System	T-265	35	0930	T-165	39
Hold 1*			0945	T-150	76
8. Propellant Line Fill	T-230	50	1009	T-150	54
9. Countdown Evaluation	T-180	30	1101	T-150	1
10. Electronics Warm-up	T-150	90	1105	T-146	15
11. Range R-F Checks	T-145	30	1107	T-144	15
12. Propellant Tanking	T-115	30	1126	T-125	40
13. Secure Propellant Trucks	T-85	25	1206	T-85	26
14. Guidance and Flight Control Checkout	T-60	30	1232	T-76	30
15. Pressurization	T-60	30	1232	T-59	30
16. Countdown Evaluation	T-30	17m15s	1246	T-45	17
Hold 2**			1303	T-15	11
17. Terminal Countdown	T-12m 45s	12m45s	1316	T-13	22
Hold 3***			1317	T-12	6
Hold 4****			1333	T-2	3
Liftoff	T-0		1337:54		

Table 2 (Continued)

HOLD SUMMARY

* *Hold 1 was imposed for work to catch up with the count after earlier delays. Use of a diagnostic capsule instead of the standard AET package increased the time required for completion of Task 3. In addition, a DAC destruct receiver had to be replaced during Task 5*

** *Hold 2: At completion of Task 16 at 1303 PDT, the count was T–28 and jumped to T–15. The count was held until 1314 PDT to await approval of the Range Safety Officer before starting terminal countdown (train schedule conflict). Effectively, this was a countdown jump of 2 minutes.*

*** *Hold 3 was called during Phase I of the countdown when a Thor power supply did not come on. The problem was solved when personnel were sent to the DAC pad electrical trailer to reset a circuit breaker.*

**** *Hold 4 was called during Phase V of the terminal countdown because of a misunderstanding involving VERLORT radar van personnel and the Range Safety Officer.*

Command 6 (controls velocity-integrator setting). Both commands were received by the vehicle and were executed.

Agena engine start (90 percent thrust) occurred at T + 302.45, and nominal thrust was obtained. The duration of engine burning was 118.99 seconds as compared to 121.93 seconds nominal. However, engine shutdown was by integrator command and was not due to fuel depletion.

Telemetry contact was maintained until T + 784 seconds (downrange telemetry ship fade).

Table 3 compares the predicted times of launch events with the actual times these events occurred. Table 4 tabulates the trajectory and initial orbit parameters.

ORBIT OPERATIONS

Prior to launch, nominal acquisition messages were sent to all stations. On the basis of launch tracking data received by the PACC from MTS and VTS, initial orbit elements were calculated and a new acquisition message generated and sent to KTS for Pass 1. Acquisitions messages were also sent to the other tracking stations (HTS, VTS, and MTS) for use during Pass 1.

Pass 1

Pass 1 acquisition of the Agena's CWAT by KTS was made 88 seconds later than predicted by the PACC. KTS also tracked the vehicle on radar and recorded Agena telemetry. Since beacon acquisition was later than predicted, a RESET command was sent at System Time 79799. The 65°N and 60°N reference latitude crossings were 123 seconds later than the computer acquisition message had predicted for KTS. An INCREASE command was sent and verified and four STEP commands were sent, which extablished an orbital timer period of 5655 seconds. No difficulty was experienced in verifying RESET, INCREASE, DECREASE and STEP commands.

Table 3

LAUNCH SEQUENCE OF EVENTS

Event	Predicted Time (sec)	Actual Time (sec)
Liftoff *	0	0
Main Engine Cutoff	164.5	163.0
Vernier Engine Cutoff	173.5	172.47
Start Fairchild Timer	179.0	179.28
Explosive Bolts Fire	180.5	180.91
Pneumatics ON	180.5	180.91
Retrorockets Fire	181.0	181.41
Command -45°/minute Pitch Rate	192.0	192.42
Start D-timer Hold	221.0	221.31
(D-timer Hold Duration)	37.78	51.60
Command -2°/minute Pitch Rate	221.0	221.31
Command 5 ON	223.0	223.64
Command 5 OFF	258.78	272.91
(Duration)	35.78	51.60
Command 6 ON	258.78	272.91
Command 6 OFF	274.60	285.94
(Duration)	15.82	13.03
Fire Ullage Rockets	288.6**	288.97
Preactivate Hydraulics	288.6**	288.97
Helium Bypass Valve Open	300.6**	300.96
Thrust Attainment (90% P_c)	302.1**	302.45
Engine Burnout (70% P_c)	424.03**	421.42
(Duration)	121.93	118.97
Command -40°/minute Yaw Rate	431.6**	431.92
Fire Vent Valves	431.6**	431.92
Hydraulics OFF	431.6	431.92

* *1337:54.40 PDT; System Time 74274.40 seconds ; 2037:54.40 GMT. Times are accurate to ±0.2 sec. (commutated data)*

** *Based upon actual D-timer hold of 51.6 seconds*