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DISCOVERER XXVII

(Thor 322/Agena 1110)

SYSTEM TEST EVALUATION

AND

PERFORMANCE ANALYSIS REPORT

(35-Day Report)

Title Unclassified

Contract AF 04(647)-558

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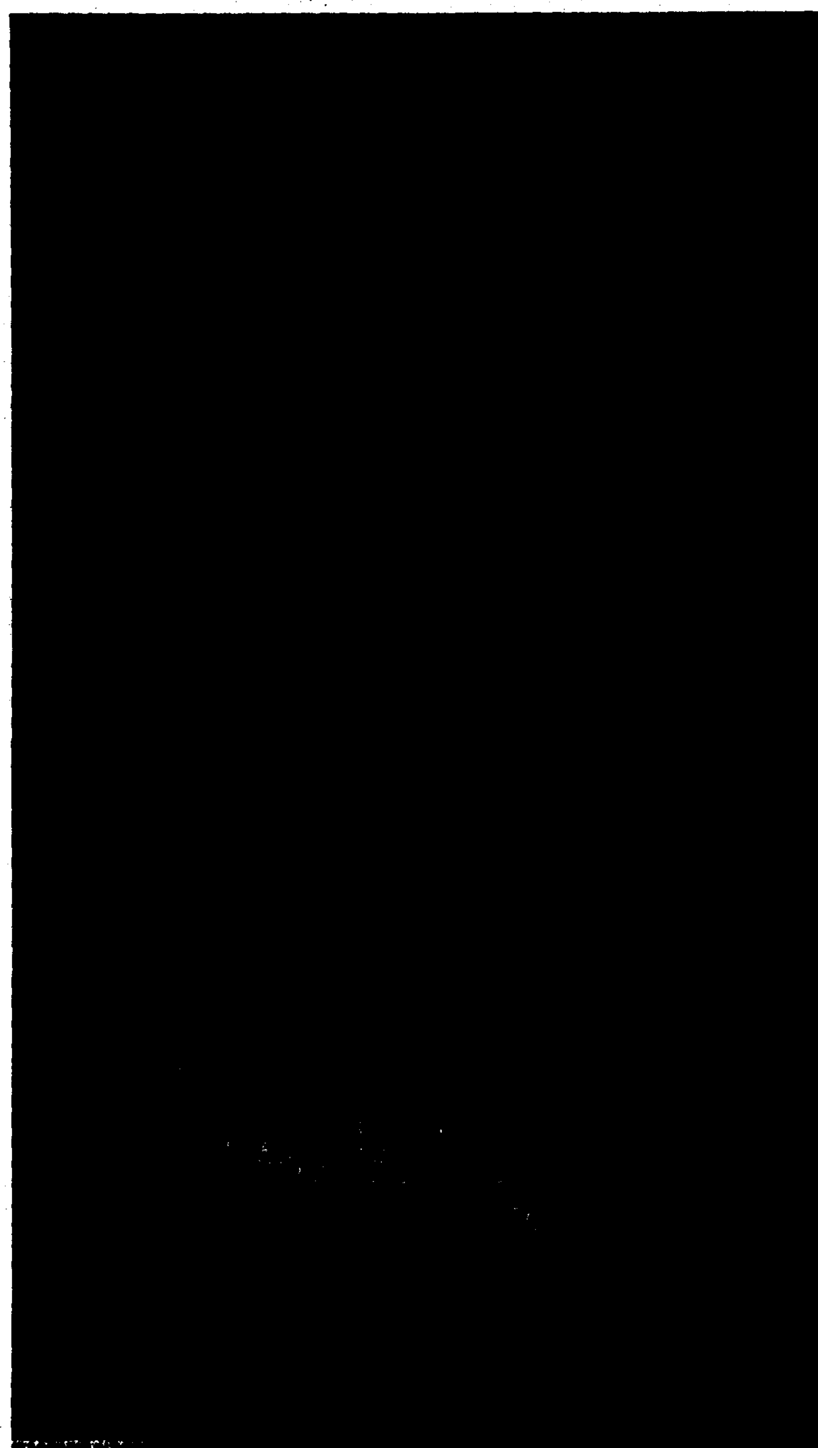

Discoverer XXVII (Thor 322/Agena 1110) at Liftoff From Complex SM-75-3, Pad 4, VAFB

FOREWORD

Administered by the Air Force Space Systems Division (AFSSD), the Discoverer Program has as its principal objectives the development of Thor-boosted Agena satellites capable of functioning as carriers for scientific materials, and the recovery of capsules ejected from orbiting Agenas.

As prime contractor, Lockheed Missiles and Space Company, Space Systems Division, has overall responsibility for developing the program. Development of the Thor as a booster rocket for the Agena satellite has been carried out by the Douglas Aircraft Company.

This document is the final system test evaluation and performance report for the flight of Discoverer XXVII from Vandenberg Air Force Base on 21 July 1961. The report has been prepared in compliance with a requirement of Contract AF 04(647)-558 and in accordance with Paragraph 1.4.1 of LMSD-445158-B, Discoverer Program.

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SUMMARY

Discoverer XXVII, consisting of Thor booster 322 and Agena satellite 1110, was launched on the first attempt from Vandenberg AFB, Thor Complex SM-75-3, Pad 4, on 21 July 1961. The Agena carried a recoverable research payload in a Mark V capsule.

Beginning at liftoff, a divergent oscillation developed in the booster's pitch plane and continued until 59.62 seconds, when the Discoverer began to disintegrate. Disintegration of the Agena was preceded either by structural failure of the adapter, followed by automatic actuation of the destruct mechanism, or by structural failure of the Agena's propellant tanks at the midbody, followed by hypergolic reaction of the propellants.

An investigation by DAC has revealed that the malfunction which led to flight failure was within the Thor's main-engine pitch-rate shaping network. An open-circuit wiring error prevented pitch rate signals from reaching main-engine controls.

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SECTION 1
INTRODUCTION

The principal objectives of the Discoverer Program are (1) the development of Thor-boosted Agena satellites capable of functioning as carriers of scientific material, and (2) the recovery of capsules ejected from the satellites. Additional objectives for the program are the perfecting of equipment, techniques, and procedures for launching Thor-boosted Agena satellites; attaining orbit; and the recording, transmitting, receiving, and processing of satellite functional and environmental data, as well as geophysical and capsule-recovery data. It is also intended that system operational techniques and procedures, including tracking-station, control-center, and launch-base training, will be refined as the program progresses. Specialized tests, including aeromedical research, will be conducted during the series of flights.

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

Of the 27 Discoverer-Agena satellites launched from Vandenberg AFB to date, 18 have been injected into orbit. Present plans call for the launching of nine additional satellites in the Discoverer Program.

SECTION 2
FLIGHT PERFORMANCE

PRELAUNCH OPERATIONS

The launch countdown of Discoverer XXVII (Thor 322/Agena 1110) from Thor Complex SM-75-3, Pad 4, was initiated at 0615 PDT on 21 July 1961 and proceeded to liftoff after 9 hours and 21 minutes. Three holds totaling 56 minutes were imposed during the count.

LAUNCH AND ASCENT

Liftoff of Discoverer XXVII was successfully accomplished at 1535:00.46 PDT, with a clean umbilical disconnection and only minor pad damage.

Beginning at liftoff, booster instability in the pitch plane was evident. This instability ultimately resulted in structural failure of the Discoverer at approximately 59.62 seconds. A sequence of flight events is included as Table 2-1.

Tracking data obtained from the Mod II VERLORT at VTS and substantiated by FPS-16 skin-track radar at PMR show that the ascent trajectory of the Discoverer was nominal until approximately 56 seconds. Thereafter, it deviated (Figs. 2-1 and 2-2). When the Agena's S-band beacon was lost at approximately 184 seconds, the Agena was at 13,000 feet downrange. Data indicate that the Agena reached a maximum altitude of 34,500 feet, whereas the Thor continued upward and farther downrange. Loss of FPS-16 track at approximately 60 seconds prevented the plotting of the Thor's full trajectory.

FLIGHT MECHANICS

Beginning at liftoff, a diverging, rigid-body oscillation in the vehicle pitch plane was recorded. The frequency of the oscillation was approximately

Table 2-1
SEQUENCE OF FLIGHT EVENTS

EVENT	SYSTEM TIME (SEC)	FLIGHT TIME (SEC)
Liftoff	81300.46	0
Thor Pitch Oscillation Starts	81300.46 +	0 +
Thor Roll Program Complete	81315.46	15
Agena Pitch Actuator Oscillations Stop	81340.46	40
First Major Positive Pitch Rate Starts	81347.98	47.52
Second Major Positive Pitch Rate Starts	81357.09	56.63
Flash at Agena Nose (probably sun reflection)	81359.27	59.27
Agena Telemeter Signal Loss	81360.08	59.62
Agena CWAT Signal Loss	81360.08	59.62
Agena Pitch Accelerometer Indicates Maximum G's Prior to Failure	81360.08	59.62
Agena Accelerometers Fail (all indicate zero volts during intermittent telemeter reception)	81360.08	59.62
Thor Fuel-Pump Inlet Pressure Drop Starts	81360.08	59.62
Thor Electrical Power Loss (except telemetry)	81360.08	59.62
Thor Main-Engine and Vernier-Engine Cutoff (70% P_c)	81360.21	59.75
Flame Near Adapter Section	81360.27	59.81
Two Small Flames Near Tail of Thor	81360.44	59.98
Solid Flames on Thor	81361.29	60.83
Last Evidence of Agena Telemeter Operation	81375.83	75.37
Thor Telemeter Signal Strength Drops	81376.27	78.64
White Burst of Gas (probably escaping liquid oxygen)	81379.27	78.81
Thor Commutators Stop	81379.90	79.44
Destruct Armed	81393.46	93.00
Destruct Command	81395.56	95.10

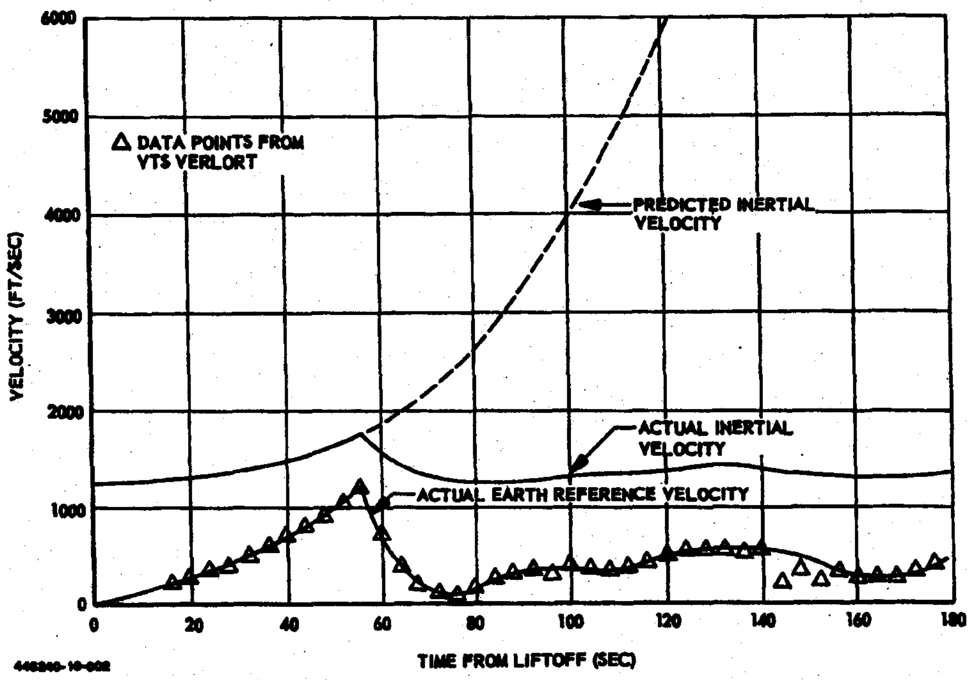

Figure 2-1 Velocity During Thor Boost

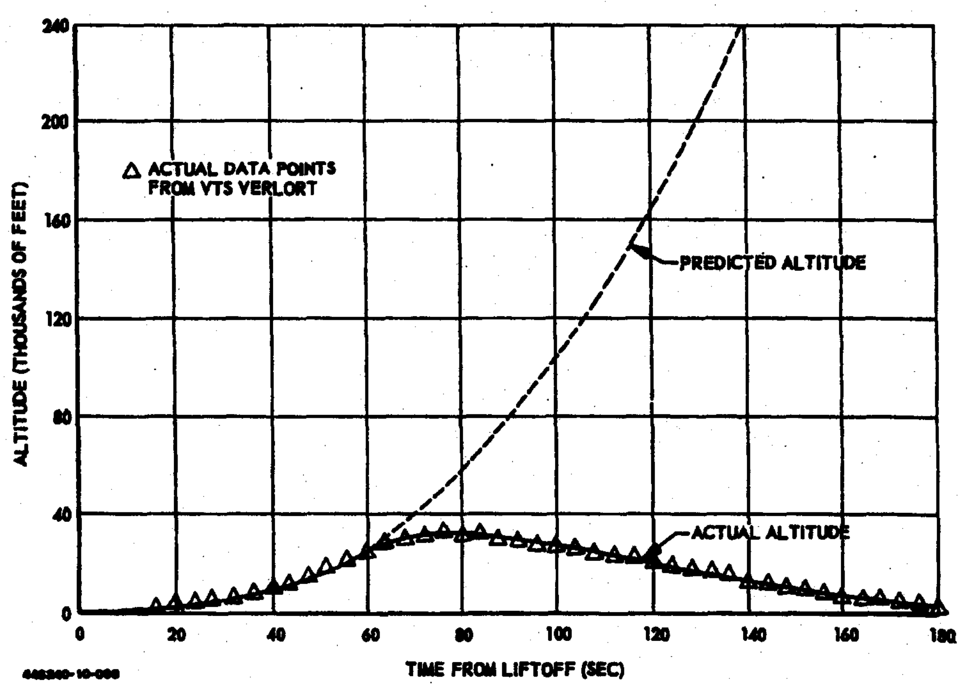

Figure 2-2 Altitude During Thor Boost

0.3 cps, which is the natural rigid-body frequency of the Discoverer. The oscillation was apparent on the Thor pitch attitude error, pitch rate, engine pitch position, and normal accelerometer data. (Loss of the Thor's control-system pitch-rate damping would cause such an oscillation.) At approximately 10 seconds after liftoff, a similar oscillation was apparent in the yaw plane, but at a considerably lower amplitude. The cause of this yaw-plane oscillation was structural cross-coupling from the pitch plane.

All Thor pitch-plane parameters went off scale 10 seconds after liftoff. The oscillation continued to diverge until the main engine reached a maximum gimbal of plus or minus 7 degrees. Up to 47.52 seconds, the pitch motions were relatively symmetrical about the flight path; however, at this time, a large pitch-up motion began. This was followed by a second pitch-up motion of greater magnitude beginning at 56.63 seconds, which led to vehicle break-up at 59.62 seconds.

The following events occurred at approximately 59.62 seconds, substantiating Discoverer disintegration at this time: (1) Thor electrical power in the transition section was lost, which in turn initiated main- and vernier-engine cutoff; (2) Thor fuel-pump inlet pressure began to drop; (3) Agena normal accelerometer went to the band edge in the positive direction (+3.25 g's, pitch-up); (4) Agena telemetry data were lost when signal strength dropped below the threshold of reception. Weak, sporadic signals indicated continued Agena telemetry operation from 59.62 to 75.37 seconds. These indications provided no useful data on commutated channels other than to show that the commutators and VCO's continued to operate. All three continuous channels used for accelerometers indicated zero volts (not zero g's) during the intermittent reception period after 59.62 seconds. This suggests a failure in accelerometer circuitry as a result of Agena structural failure. (5) The Agena continuous-wave acquisition transmitter signal was lost, probably because of damage to the antenna system shared with the FM/FM telemetry system.

The following events were recorded by motion pictures taken from Mount Tranquillone and by a T-33 aircraft (because the weather was overcast from approximately 1000 to 2000 feet, photographic coverage taken from the launch complex was inadequate for evaluative purposes): Flames first appeared near the adapter area at 59.81 seconds. (Agena telemetry recorded loads in excess of structural integrity at 59.62 seconds.) By 60.83 seconds, flames and smoke enveloped the Discoverer. Still ascending, the Thor emerged from the smoke almost tail first, trailing flames from the forward fuel tank section. At approximately 78.81 seconds, a burst of white smoke was emitted from the remaining portion of the Thor. The liquid oxygen tank is believed to have exploded at this time.

The high loads imposed upon the Agena at Discoverer breakup could have precipitated either of the following sequences:

a. Excessively high flight loads could have caused the midbody to break immediately forward of the fuel tank in the vicinity of Station 294. This break would probably cause the rupture of the Agena tanks, followed by failure of the remaining structure.

b. Failure could have occurred at the separation interface, Station 388.55, either by shear or by tension loads. If this occurred, the destruct mechanism would have been actuated because of premature separation of the Agena from the booster.

Thor telemetry signal strength dropped at 78.64 seconds, and the commutators began slowing down. Both transducer-regulated 5-volt supplies began to drop at 78.71 seconds. By 79.44 seconds, Thor Channel 14 and 15 commutators had stopped. At 93 seconds, the destruct system arming signal was sent; and at 95.1 seconds, the command-destruct signal was transmitted. Since both the Thor and Agena had disintegrated by this time, it is doubtful that the destruct signal had any effect. At 292 seconds, the Thor telemetry signal strength increased for a few seconds and several sync pulses were recorded. At 312 seconds, the Thor telemetry carrier signal was lost when the Thor impacted in the ocean.

THOR SUBSYSTEMS PERFORMANCE

With the exception of the flight-control system, Thor propulsion, hydraulic, electrical power, and instrumentation subsystems performed satisfactorily.

Flight-Control System

Operation of the Thor flight-control system was unsatisfactory from liftoff, when a diverging, rigid-body oscillation in the pitch plane began, as discussed under "Flight Mechanics."

By comparing the phase and amplitude of main-engine pitch position with that of the rate and attitude demodulator output data, the main engine was found to be lagging the attitude signal by approximately 200 degrees. This value was theoretically shown to be the correct engine response if the rate demodulator signal were not received at the d-c amplifier input. The main engine was responding to the attitude error signal only. A schematic of the flight-control system (pitch plane) is presented in Figure 2-3.

A comparison of the rate demodulator output with the derivative (slope) of the attitude demodulator output data showed them to be coincident, indicating

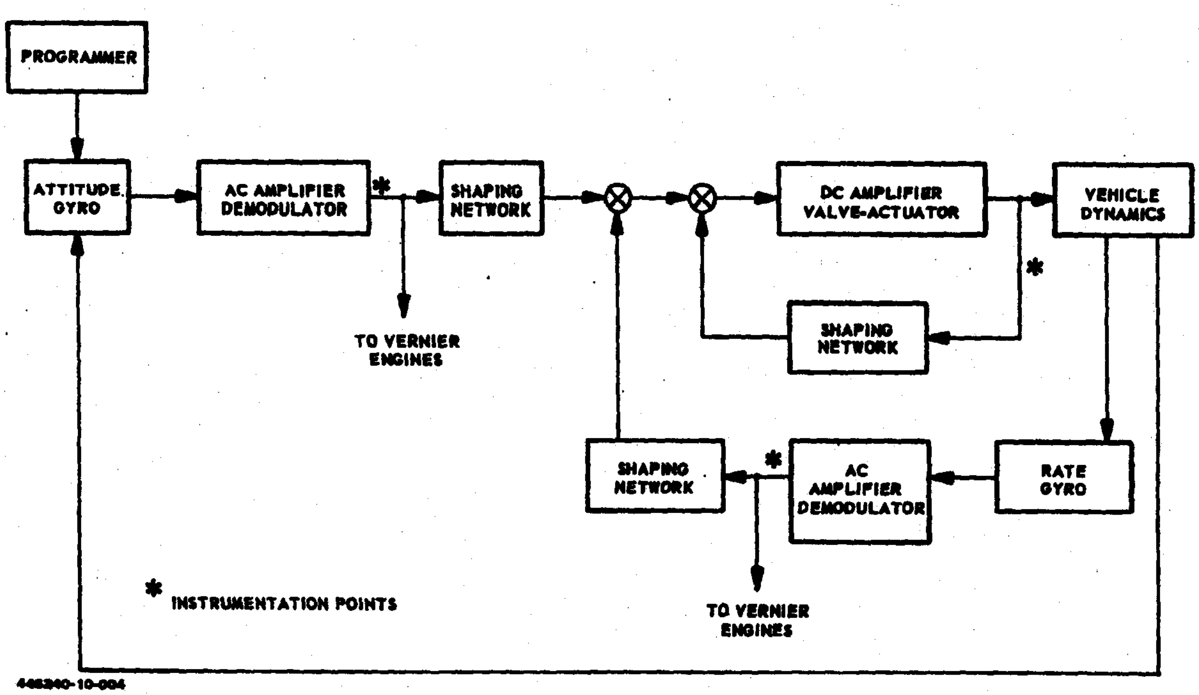

Figure 2-3 Flight-Control System (Pitch Plane)

proper operation of the pitch rate gyro and its associated a-c amplifier-demodulator. The vernier engines were responding properly to both the attitude and rate demodulator outputs, further confirming that the pitch rate gyro and its associated a-c amplifier-demodulator were operating properly. On the basis of these facts, the malfunction must have been within the main engine's pitch-rate shaping network.

A postflight review of engineering documentation affecting changes to the control electronics assembly was made by DAC personnel. It was revealed that during VAFB laboratory checks, a pin on the connector between the main-engine shaping network and the programmer was broken. The wire to this broken pin was moved to a spare pin on the same connector, and the plug on the programmer side was rewired for continuity. Later, it was necessary to replace the programmer. However, records indicate that the programmer connector was never re-modified to match the standard programmer. Therefore, the programmer side of the plug was not compatible with the modified plug from the main-engine shaping network. The result was an open circuit which prevented the pitch-rate gyro signal from reaching the main engine controls. This open-circuit condition is also the only condition that satisfies all the characteristics encountered during the flight.

The polarity check performed at the launch emplacement did not include a test of the main-engine shaping network, because this test results in severe gimbaling of the engine. To prevent possible structural damage, the main engine is temporarily disconnected from the circuitry during this test. Therefore, when the rate gyros were physically displaced, only the vernier-engines responded (Fig. 2-4). Thus, discontinuity in the main-engine shaping network circuitry was not detected during this test.

Corrective action to be taken on all future Discoverer boosters will be as follows: (1) The auxiliary shaping network will be removed. This network was originally installed to raise the d-c loop gains, thereby reducing velocity direction errors at main-engine cutoff. However, when the BTL guidance system was added, the need for this network was eliminated. This elimination

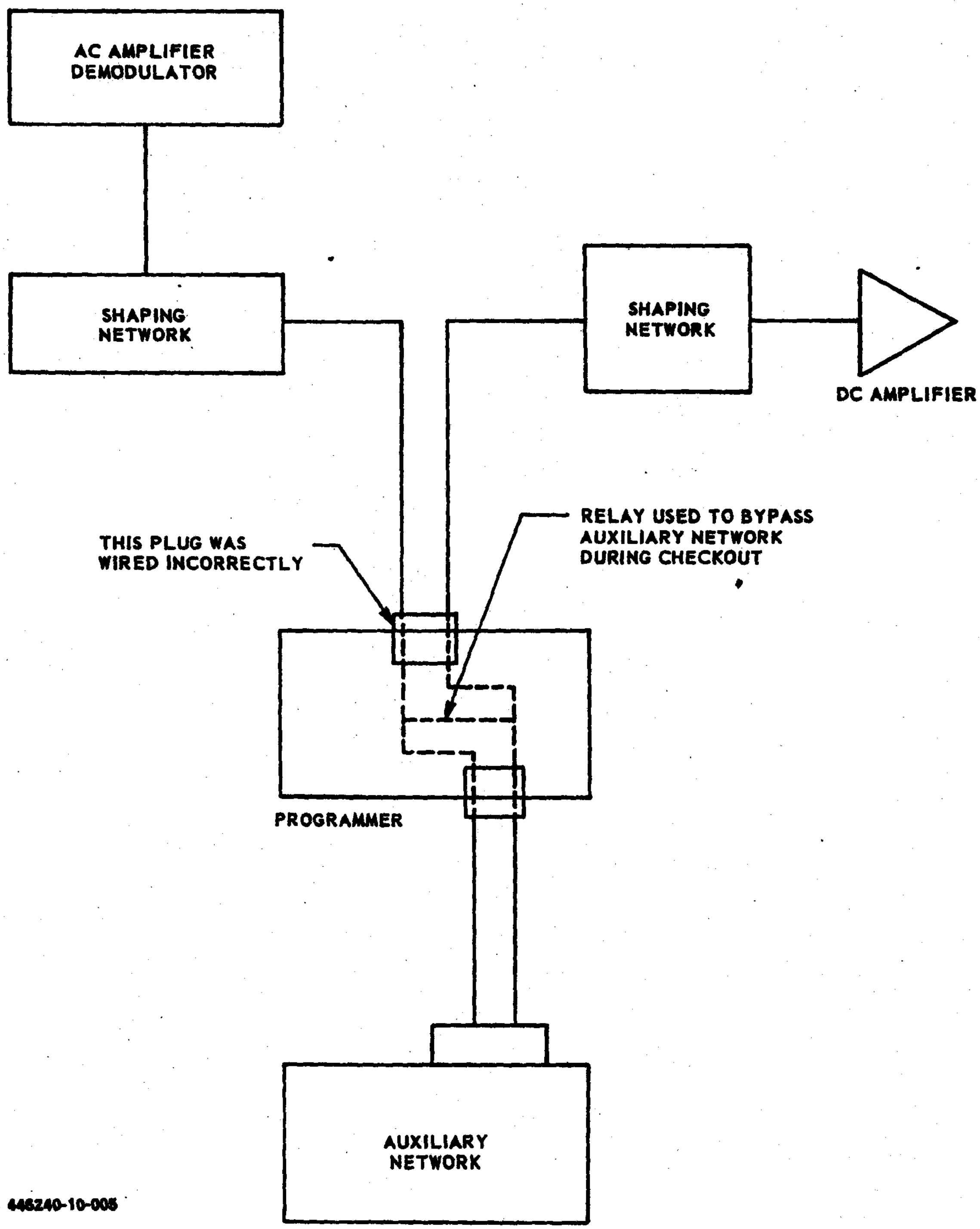

Figure 2-4 Shaping Network Schematic

will also obviate the need for the rate gyro signal to be routed through the programmer. (2) The main shaping network boards within the control electronics assembly will be encapsulated to reduce the possibility of terminals being broken or shorted subsequent to checkout. (3) The launch emplacement polarity check will be revised so that complete end-to-end system continuity and polarity will be confirmed. This will be accomplished by physically moving the rate gyros and monitoring movement of all engines. (4) Also, the polarity check will be run three times with a separate meter read during each run. Previously, all three meters were read simultaneously.

Propulsion System

Thor propulsion system performance was satisfactory until vehicle breakup. The start sequence, transition to mainstage, and mainstage operation were normal. Abnormal engine gimbaling in the pitch plane had no detrimental effect on engine performance or propellant supply and pressurization systems.

Main-engine cutoff was initiated by loss of the forward electrical power supply at 59.62 seconds. By 59.75 seconds, the main-engine chamber pressure reached 70 percent. Since the propellant valves are held open during flight by electrical power, loss of this power will close these valves and result in engine cutoff.

Hydraulic System

Performance of the Thor hydraulic system was satisfactory. Although maximum engine excursions were encountered, hydraulic requirements did not exceed the system capacity.

Electrical Power System

Performance of the electrical system was satisfactory until the time of vehicle breakup, when the power supply in the transition section was lost. The telemetry power supply, which is located between the propellant tanks along with the telemetry equipment, operated satisfactorily until 79.44 seconds (when the commutators stopped), although the telemetry carrier signal was received until Thor impact in the ocean.

Instrumentation System

Instrumentation system performance was satisfactory until the commutators stopped at 79.44 seconds. Successful transmission and receipt of all flight data were recorded up to this time, although random noise and short-duration dropouts occurred from 36.7 to 57.5 seconds.

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