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THORAD-AGENA PERFORMANCE FOR THE ORBITING GEOPHYSICAL OBSERVATORY VI MISSION

Lewis Research Center
Cleveland, Ohio 44135

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16. Abstract

The Thorad-Agena launch vehicle successfully placed the Orbiting Geophysical Observatory VI (OGO-VI) into an elliptical orbit with a perigee altitude of 399 km and an apogee altitude of 1099 km, at an inclination of 82° to the equator. The spacecraft, an instrumented earth-orbiting satellite, was launched from Vandenberg Air Force Base, California, in June 1969 for the purpose of conducting a series of scientific experiments. This report contains an evaluation of the performance of the Thorad-Agena system in support of the OGO-VI mission.

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APPENDIXES

THORAD-AGENA PERFORMANCE FOR THE ORBITING GEOPHYSICAL OBSERVATORY VI MISSION

Lewis Research Center

I. SUMMARY

The Thorad-Agena launch vehicle with the Orbiting Geophysical Observatory VI (OGO-VI) spacecraft was successfully launched from the Space Launch Complex 2 East, Vandenberg Air Force Base, California, on June 5, 1969, at 0642:45. 37 hours Pacific standard time. The Thorad boosted the Agena - OGO-VI into a suborbital coast ellipse. After separation of the Agena - OGO-VI from the Thorad, the Agena engine was started and the Agena - OGO-VI was injected into the desired near-polar elliptical orbit with a perigee altitude of 399 kilometers and an apogee altitude of 1099 kilometers. The OGO-VI was then successfully separated from the Agena and, following separation, the Agena performed a planned 90° yaw maneuver.

The Thorad and Agena vehicle systems performed satisfactorily throughout the mission. This report contains an evaluation of the Thorad-Agena system in support of the OGO-VI mission.

II. INTRODUCTION

by Roger S. Palmer

The purpose of the Orbiting Geophysical Observatory VI (OGO-VI) mission was to perform 26 scientific experiments (using an instrumented earth-orbiting satellite) to obtain data on neutral and charged particles, on cosmic rays, on magnetic fields, and on various ionospheric phenomena. The objectives of the launch vehicle were to inject the OGO-VI into a near-polar elliptical orbit, and for the Agena to perform a 90° yaw maneuver after the OGO-VI was separated from the Agena. The launch vehicle and the Agena - OGO-VI integration effort to support the mission were under the direction of the Lewis Research Center. The OGO-VI flight was the last in a series of six planned missions. A summary of these OGO missions is presented in table II-I.

A Thorad-Agena launch vehicle was used to place the OGO-VI in the desired orbit. This report discusses the Thorad-Agena performance for the OGO-VI mission, from lift-off through the 90° yaw maneuver by the Agena after spacecraft separation.

TABLE II-I. - SUMMARY OF OGO MISSIONS

	Mission					
	OGO-I	OGO-II	OGO-III	OGO-IV	OGO-V	OGO-VI
Launch date	9/4/64	10/14/65	6/6/66	7/28/67	3/4/68	6/5/69
Launch time	20:23 EST	05:12 PST	21:48 EST	06:21 PST	08:06 EST	06:43 PST
Launch site[a]	ETR	WTR	ETR	WTR	ETR	WTR
Type booster	Atlas LV-3A	Thrust-augmented Thor LV-2A	Atlas SLV-3	Thrust-augmented Thor LV-2A	Atlas SLV-3A	Thorad SLV-2G
Type Agena	B	D	B	D	D	D
Agena engine firing periods	2	1	2	1	2	1
Spacecraft weight, kg	486.7	520.7	513.9	561.1	598.3	620.1
Number of scientific experiments	20	20	20	20	25	26
Spacecraft orbit apogee altitude, km	149 107	[b]1512	122 465	907	145 758	1099
Spacecraft orbit perigee altitude, km	286	[b]414	275	416	279	399
Spacecraft orbit inclination to equator, deg	31.1	87.4	31.0	86.0	31.2	82.0
Spacecraft orbital period, hr	64	1.7	48.7	1.6	61.5	1.7

[a]ETR is Eastern Test Range, Kennedy Space Center, Florida; WTR is Western Test Range, Vandenberg Air Force Base, California.
[b]The planned orbit of 927-km apogee altitude and 334-km perigee altitude was not achieved because the ground radio guidance system failed to acquire the vehicle. OGO-II was the only OGO that did not achieve the planned orbit.

III. LAUNCH VEHICLE DESCRIPTION

by Eugene E. Coffey and Roger S. Palmer

The Thorad-Agena is a two-stage launch vehicle consisting of a Thorad first stage and an Agena second stage, connected by a booster adapter. The composite vehicle (fig. III-1), including the shroud and the booster adapter, is about 33 meters (109 ft) in length. The total weight at lift-off is approximately 91 625 kilograms (202 000 lbm). Figure III-2 shows the Thorad-Agena lift-off with OGO-VI.

The Thorad stage (fig. III-3) consists of a long-tank Thor and three solid-propellant rocket motors located 120° apart and attached to the long-tank Thor near the aft end. The long-tank Thor is 21.4 meters (70.3 ft) in length and 2.4 meters (8 ft) in diameter, except for the conical forward section which tapers to a diameter of about 1.6 meters (5.3 ft). The solid-propellant rocket motors are each about 7 meters (24 ft) in length and 0.8 meter (2.5 ft) in diameter, with a conical forward end. The Thorad is powered by a main engine with a sea-level-rated thrust of 756×10^{3} newtons (170 000 lbf), by two vernier engines with a total sea-level-rated thrust of 8.9×10^{3} newtons (2000 lbf), and by the three solid-propellant rocket motors with a total sea-level-rated thrust of 696×10^{3} newtons (156 450 lbf). The propellants for the Thorad main engine and for the vernier engines are liquid oxygen and high-grade kerosene. The propellant for the solid-propellant rocket motors is basically a solid grain of polybutadiene acrylic acid and ammonium perchlorate.

The vernier engines, the main engine, and the solid-propellant rocket motors are ignited in sequence prior to lift-off. The fixed-nozzle solid-propellant rocket motors burn for approximately 39 seconds. They are jettisoned at T + 102 seconds in order to assure impact of the solid-propellant rocket motor cases in a safe area (water impact). Thorad main engine cutoff occurs when the desired velocity for the planned suborbital ellipse is achieved, as determined by the radio guidance system or by propellant depletion. During powered flight, the Thorad main engine gimbals for pitch and yaw control and the vernier engines gimbal for roll control. After Thorad main engine cutoff, the vernier engines continue to thrust for 9 seconds to provide for vehicle attitude control and for fine trajectory corrections. After vernier engine cutoff, the Thorad is severed from the Agena by the firing of a Mild Detonating Fuse system located on the forward end of the booster adapter. The firing of a retrorocket system, mounted on the booster adapter, then separates the Thorad with booster adapter from the Agena.

The Agena second stage and the shroud protecting the OGO-VI spacecraft are shown in figure III-4. The diameter of the Agena is 1.5 meters (5 ft), and the length of the Agena and shroud is about 12 meters (40 ft). The Agena engine has a rated vacuum thrust of 71.2×10^3 newtons (16 000 lbf). This engine uses unsymmetrical dimethylhydrazine and inhibited red fuming nitric acid as propellants. During powered flight, pitch and yaw control are provided by gimbaling the Agena engine, and roll control is provided by a cold-gas (mixture of nitrogen and tetrafluoromethane) attitude control system (ACS). During periods of nonpowered flight, pitch, yaw, and roll control are provided by the cold-gas system. The cold-gas ACS is also used to perform the Agena yaw maneuver after OGO-VI separation. A fiber glass laminate clamshell shroud provides environmental protection for the spacecraft during ascent. This shroud is jettisoned 10 seconds after Agena engine start. The OGO-VI spacecraft is shown in figure III-5.

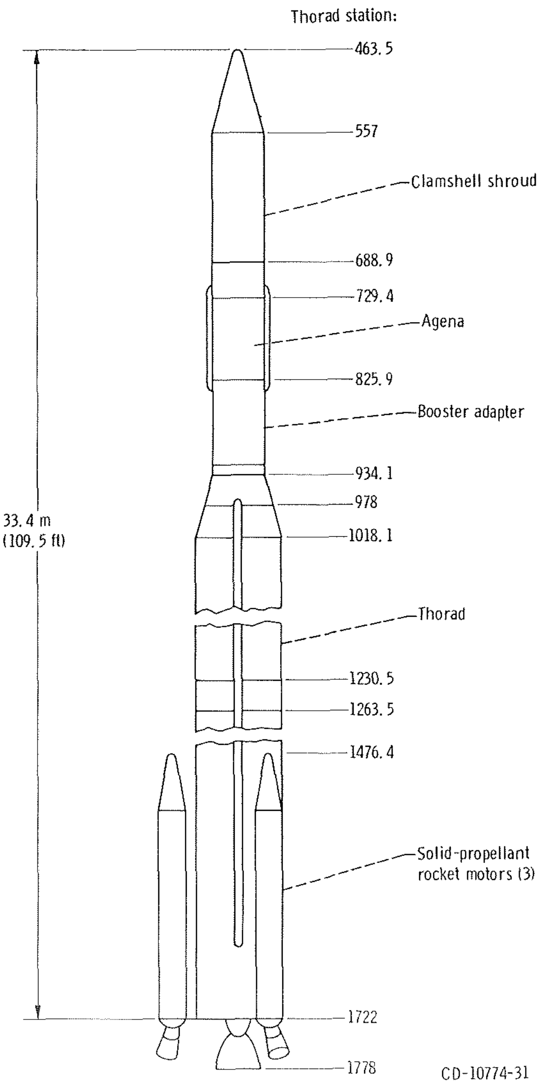


Figure III-1. - Composite space vehicle, OGO-VI.

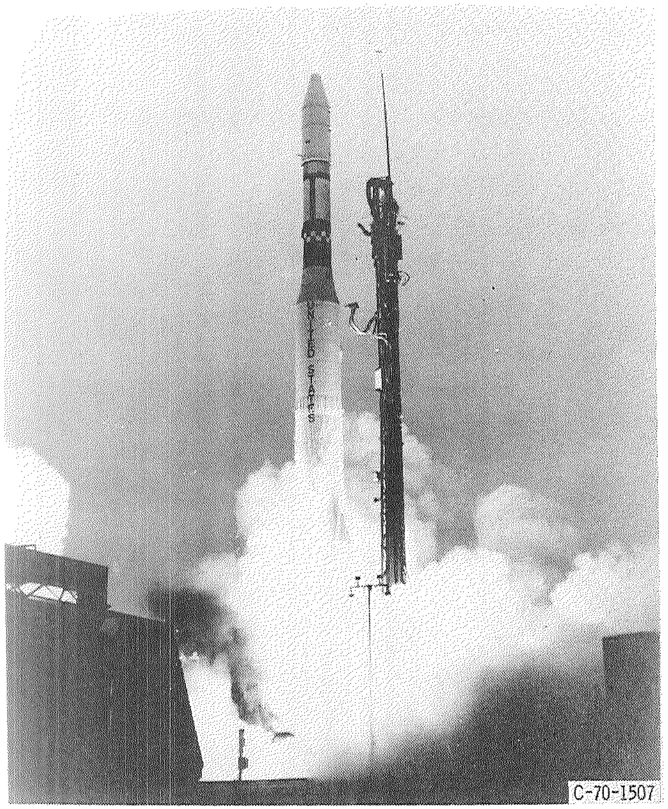


Figure III-2. - Thorad-Agena lift-off with OGO-VI.

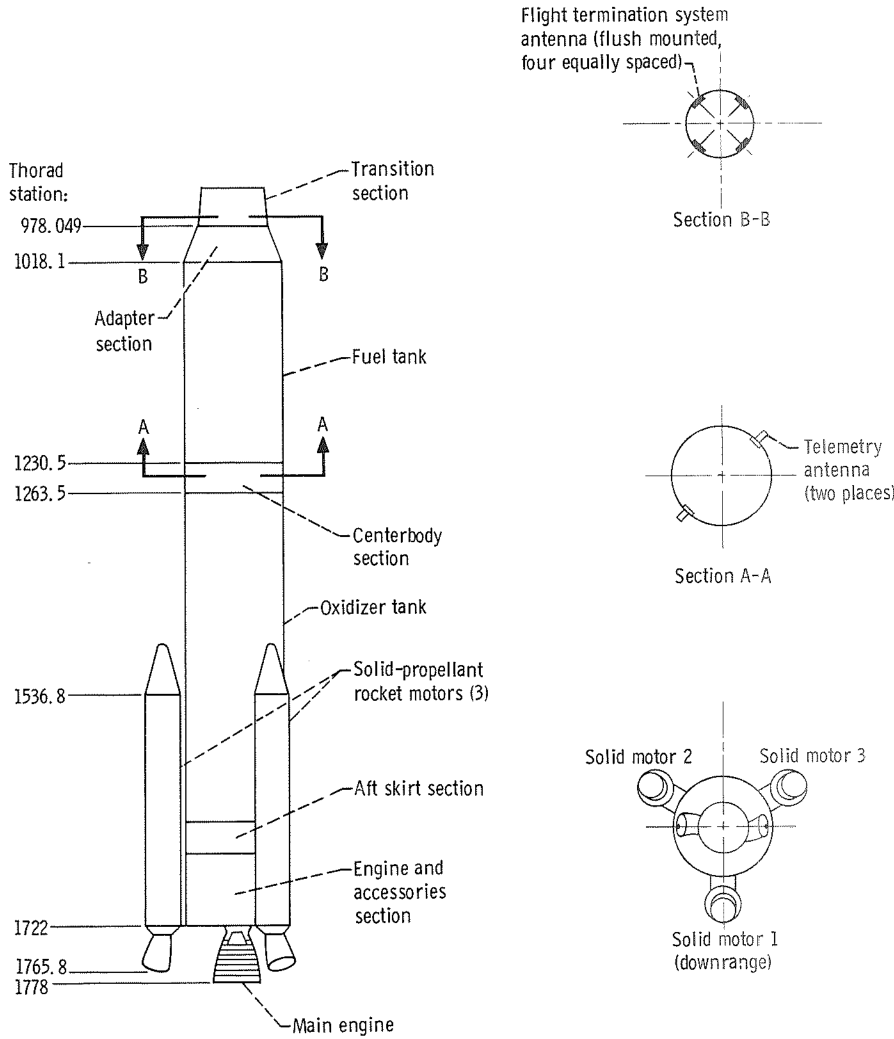


Figure III-3. - Thorad general configuration, OGO-VI.

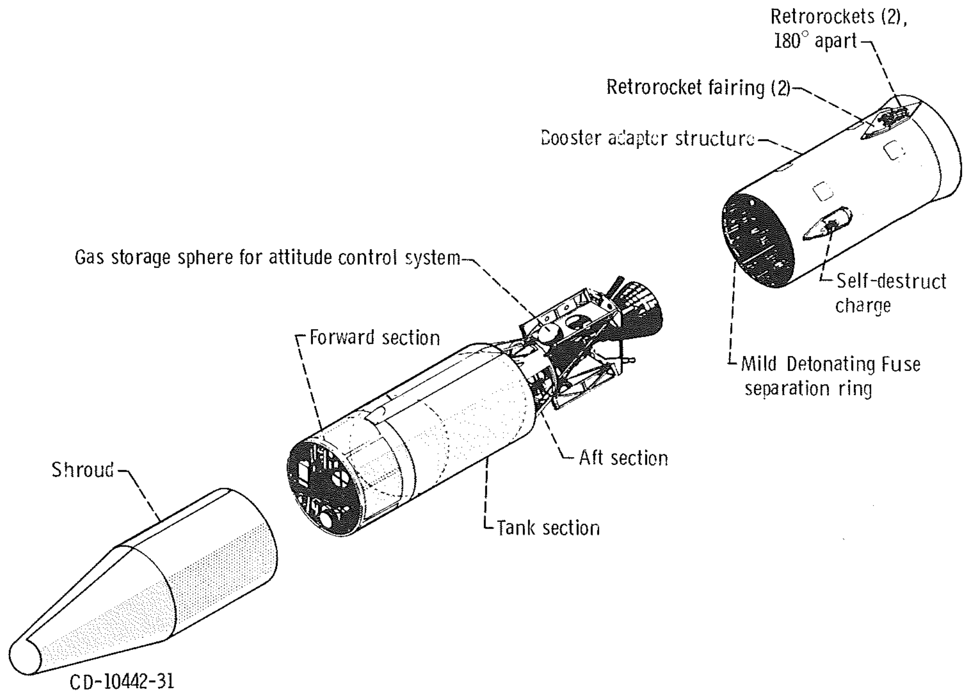


Figure III-4. - Agena, shroud, and booster adapter, OGO-VI.

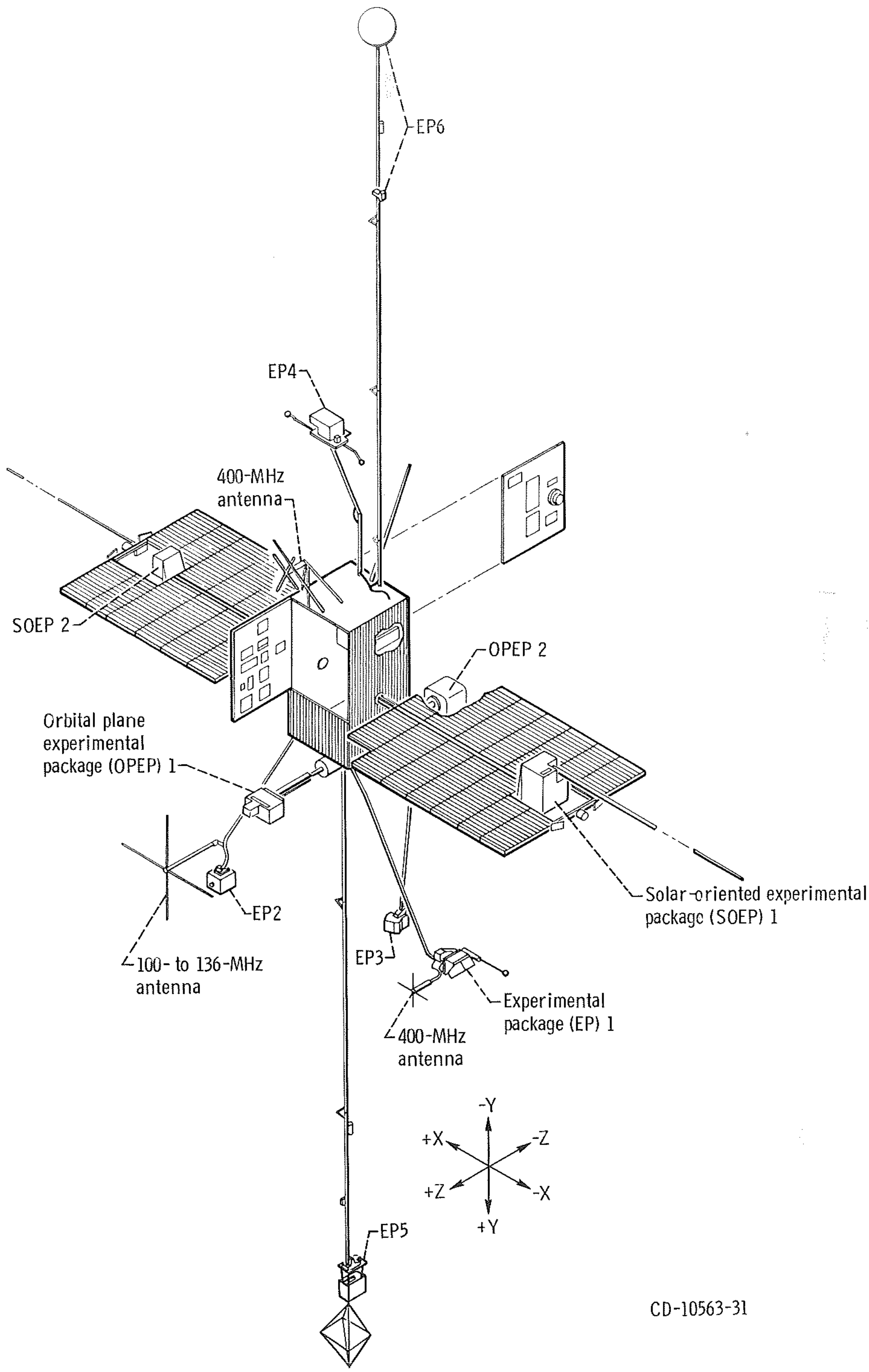


Figure III-5. - OGO-VI spacecraft in deployed configuration.

IV. TRAJECTORY AND PERFORMANCE

by James C. Stoll

OGO-VI was successfully launched from the Space Launch Complex 2 East (SLC-2E), Western Test Range, on June 5, 1969, at 0642:45.37 Pacific standard time. Actual and expected times for major flight events are given in appendix A.

TRAJECTORY PLAN

For the OGO-VI mission, the Thorad-Agena launch vehicle used a direct ascent flight (i.e., one thrust period of the Agena engine). The Thorad boosts the Agena - OGO-VI into a suborbital coast ellipse. Approximately halfway through the Thorad powered flight, the Thorad performs a dogleg maneuver (a yaw maneuver followed by a roll maneuver) to place the final orbit at an inclination of 82° to the equator. Following Thorad-Agena separation, the Agena engine is started and places the Agena - OGO-VI into an elliptical orbit with a 400-kilometer (216-n mi) perigee and a 1100-kilometer (594-n mi) apogee. The Agena performs a trajectory-shaping pitch maneuver (pitch down at a rate of 13.21 deg/min throughout the Agena powered phase) to provide for injection of the Agena - OGO-VI near the perigee of the elliptical orbit. Shortly after Agena engine cutoff, the Agena is oriented to the local horizontal in preparation for OGO-VI separation. The 620.1-kilogram (1367.1-lbm) OGO-VI spacecraft is separated from the Agena about 107 seconds after Agena engine cutoff. After OGO-VI separation, the Agena performs a 90° yaw maneuver to ensure that the Agena will not interfere with the OGO-VI during subsequent orbits. The planned ascent and initial orbit is shown in figures IV-1 and IV-2.

TRAJECTORY RESULTS

Winds Aloft

The winds aloft at launch were light and predominantly from the south with a peak velocity of 22.6 meters per second (74 ft/sec) occurring at an altitude of 10 211 meters

(33 500 ft). Wind data are shown in figure IV-3. The wind shears produced by abrupt changes in wind velocity were not severe.

The T - 0 (lift-off) weather balloon data were used to predict the maximum vehicle bending response and the maximum gimbal angle. The maximum vehicle bending response was calculated to be 32.4 percent of the critical value at Thorad station 1229.89 and to occur at an altitude of 10 070 meters (33 038 ft). The maximum booster gimbal angle was calculated to be 23.4 percent of the total available gimbal angle in the pitch plane and to occur at an altitude of 687.6 meters (2256 ft).

Thorad Boost Phase

Lift-off occurred from a launch pad azimuth of 259.5°. At T + 2.13 seconds, the Thorad started a programmed roll maneuver to achieve a launch azimuth of 187.0°. At T + 16.22 seconds, this roll maneuver was completed, and the vehicle began to pitch downrange at the programmed pitch rates.

The three solid-propellant rocket motors burned out at T + 37.2 seconds, but the solid-propellant rocket motor cases were not jettisoned until T + 102.1 seconds because of range safety considerations. At the time of jettison, the actual vehicle trajectory was about 1372 meters (4500 ft) high, 579 meters (1900 ft) less in range, and 213 meters (700 ft) to the right, as compared to the predicted trajectory.

The programmed dogleg maneuver (a yaw maneuver followed by a roll maneuver) was started at T + 104.45 seconds and was terminated at T + 124.22 seconds (see table IV-IV for inclination of final orbit). The radio guidance system then provided minor steering corrections to the Thorad from T + 124.60 to T + 213.9 seconds. The trajectory was designed for Thorad main engine cutoff to occur either by a radio guidance system command or by propellant depletion. For this mission, cutoff occurred by a radio guidance system command at T + 217.7 seconds, 2.2 seconds earlier than predicted. At this time, the actual trajectory was about 1127.8 meters (3700 ft) high, 1249.7 meters (4100 ft) less in range, and 213.4 meters (700 ft) to the right, as compared to the predicted trajectory. Also, at main engine cutoff, the velocity of the vehicle was 2.4 meters per second (8 ft/sec) lower than expected. These trajectory deviations were within the allowable tolerances. The Thorad vernier engine thrust was terminated by a time-delay relay 9.0 seconds after main engine cutoff. The insertion parameters at vernier engine cutoff are listed in table IV-I, and the resulting suborbital coast ellipse parameters are listed in table IV-II. The Thorad-Agena separation was commanded by the radio guidance system and occurred at T + 233.4 seconds. The total performance of the Thorad was satisfactory.

Agena Powered Phase

The trajectory-shaping pitch maneuver was started at T + 265.8 seconds at a pitch-down rate of 13.21 degrees per minute. This rate was maintained throughout the Agena powered phase. The Agena engine was started at T + 284.7 seconds, and 90-percent chamber pressure was achieved 1.2 seconds later. Agena engine cutoff occurred by radio guidance system command at T + 519.0 seconds. Thrust duration (measured from 90-percent chamber pressure to Agena engine cutoff) was 233.1 seconds, 2.3 seconds less than predicted. The shorter Agena thrust duration was a result of higher than expected orbit energy at Thorad main engine cutoff and higher than expected Agena engine thrust. The radio guidance system steering commands were small in pitch and yaw during the Agena powered phase. At Agena engine cutoff, the velocity was 7847.5 meters per second (25 746.4 ft/sec). Thrust decay added 9.8 meters per second (32.2 ft/sec), compared to a predicted 9.4 meters per second (30.9 ft/sec). The injection parameters at Agena engine cutoff are listed in table IV-III.

Agena Postpowered Phase

After Agena engine cutoff, the Agena longitudinal axis was alined to the local horizontal. Following this alinement, the OGO-VI spacecraft was separated from the Agena at T + 628.7 seconds by Agena timer command. At T + 631.7, the Agena began a 90° yaw maneuver so that it would not interfere with the OGO-VI on subsequent orbits.

The OGO-VI orbit was nearly perfect. The final orbit parameters for the OGO-VI and the Agena are listed in table IV-IV.

TABLE IV-I. - INSERTION PARAMETERS AT VERNIER ENGINE CUTOFF, OGO-VI

Parameter	Units	Actual value
Altitude	km	148.63
	n mi	80.25
Range	km	218.15
	n mi	117.79
Velocity	m/sec	3819.8
	ft/sec	12 532.1
Inclination	deg	79.89
Azimuth	deg	174.65
Flight path angle	deg	25.69
Radius	km	6520.56
	n mi	3520.82

TABLE IV-II. - SUBORBITAL COAST ELLIPSE PARAMETERS AT APOGEE, OGO-VI

Parameter	Units	Actual value
Radius	km	6701.32
	n mi	3618.43
Velocity	m/sec	3360.42
	ft/sec	11 025.0
Altitude	km	326.97
	n mi	176.55
Inclination	deg	79.89
Eccentricity	-----	0.81

TABLE IV-III. - INJECTION

PARAMETERS AT AGENA

ENGINE CUTOFF, OGO-VI

Parameter	Units	Actual value
Altitude	km	398.66
	n mi	215.26
Range	km	1508.36
	n mi	814.45
Velocity	m/sec	7847.5
	ft/sec	25 746.4
Inclination	deg	82
Flight path angle	deg	0.068
Radius	km	6774.05
	n mi	3657.70

TABLE IV-IV. - FINAL ORBIT

PARAMETERS, OGO-VI

Parameters	Units	Actual values	
		OGO-VI	Agena
Apogee altitude	km	1099.31	1093.87
	n mi	593.58	590.64
Apogee radius	km	7474.54	7469.08
	n mi	4035.93	4032.98
Perigee altitude	km	398.92	398.92
	n mi	215.40	215.40
Perigee radius	km	6774.00	6773.98
	n mi	3657.67	3657.66
Period	min	99.75	99.69
Inclination	deg	82.003	82.003
Eccentricity	----	0.04916	0.04880

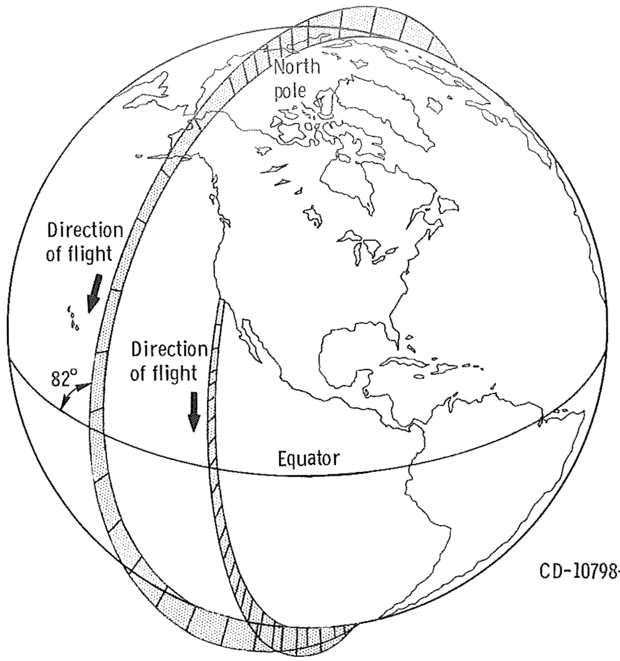


Figure IV-1. - OGO-VI - Agena ascent trajectory and initial orbit viewed from 100° W and 30° N.

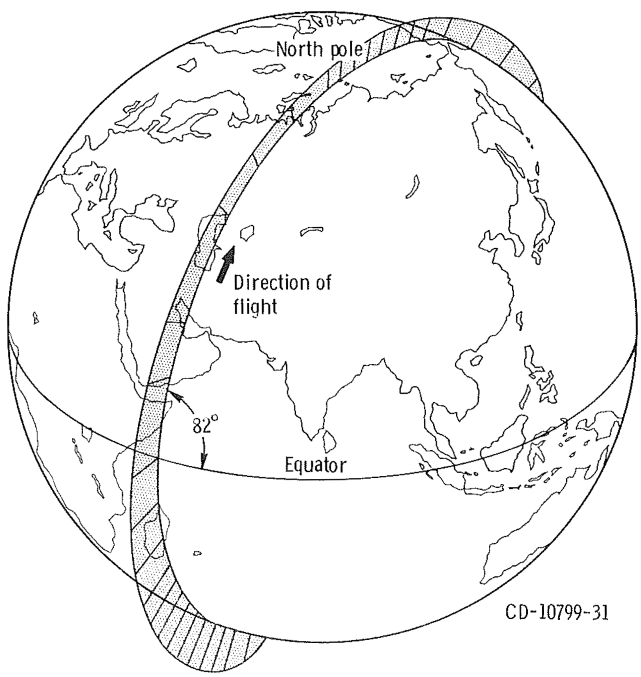


Figure IV-2. - OGO-VI - Agena initial orbit viewed from 80° E and 30° N.

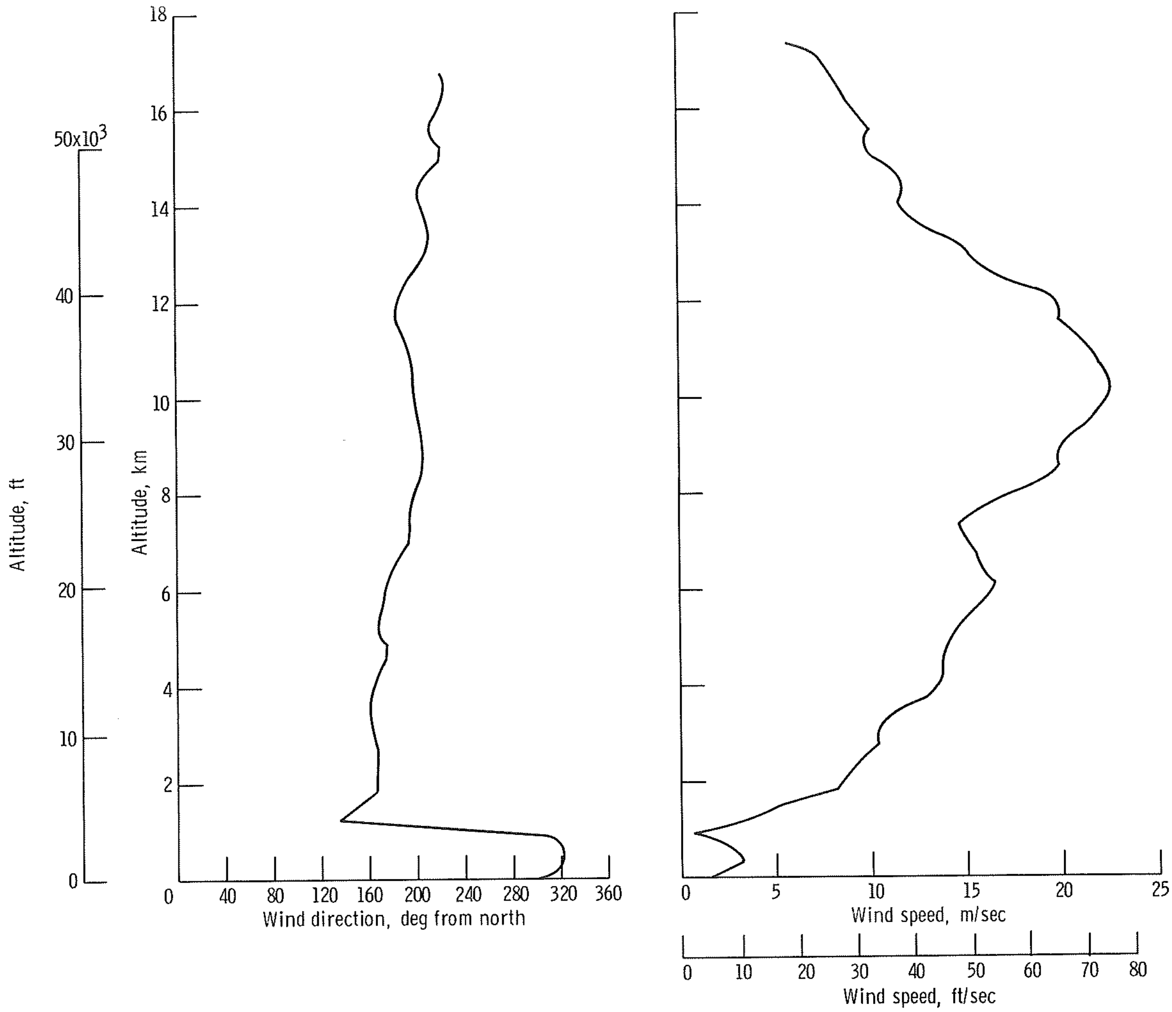


Figure IV-3. - Wind data, OGO-VI.

V. THORAD VEHICLE SYSTEM PERFORMANCE

VEHICLE STRUCTURE SYSTEM

by Robert N. Reinberger and Robert W. York

System Description

The Thorad airframe structure (fig. V-1) consists of seven sections: the transition section, the adapter section, the fuel tank, the center body section, the oxidizer tank, the aft skirt section, and the engine and accessories section. The Thorad is 21.4 meters (70.3 ft) in length and is 2.4 meters (8 ft) in diameter, except for the conical forward section which tapers to a diameter of about 1.6 meters (5.3 ft).

The transition section at the forward end of the Thorad is 1.1 meters (3.7 ft) long and consists of a truncated cone of semimonocoque construction. The transition section houses the flight control equipment, the electrical power components, the umbilical connection assembly, and the flight termination equipment. Access doors are provided for inspection and replacement of equipment.

The adapter section, also a truncated cone, is 1.0 meter (3.3 ft) long and connects the transition section to the fuel tank.

The fuel-tank assembly is 5.4 meters (17.7 ft) long. It is longitudinally butt-welded to form a cylinder from three sheets of 0.63-centimeter (0.25-in.) aluminum, milled on the interior surface in a waffle-like pattern to obtain the maximum strength-weight ratio. It has convex domes at either end, intermediate frames, circumferential and anti-vortex baffles, and a fuel-transfer tube and sump. The convex domes are bolted to the cylinder and have small welds to seal the joints.

The center body section, a semimonocoque construction, is 0.8 meter (2.7 ft) long and contains the Thorad telemetry equipment. Doors are provided for access to this section.

The oxidizer tank assembly, 8.6 meters (28.2 ft) long, is similar in construction to the fuel-tank assembly.

The aft skirt section is 0.9 meter (2.8 ft) long and contains the nitrogen pressurization tanks and associated components, and the oxidizer fill valve.

The engine and accessories section, 2.2 meters (7.1 ft) long, is a semimonocoque aluminum construction with stringers and ring frames. The main engine is attached through a gimbal block and tripod structure to three uniformly spaced thrust beams.

These beams transmit the engine thrust loads to the Thorad structure. While the vehicle is on the launcher, the three thrust beams and three launcher beams support the vehicle. All the liquid-propulsion support items, such as the turbopump, the lubrication unit, the gas generator, the hydraulic unit, the engine relay boxes and integrated-start airborne system, and the fuel fill valve are housed in this section. Three solid-propellant rocket motors are attached to the thrust beams.

System Performance

The structure system performance was satisfactory, and all flight loads were within the design limits. The peak longitudinal steady-state load of 6.3 g's occurred at Thorad main engine cutoff.

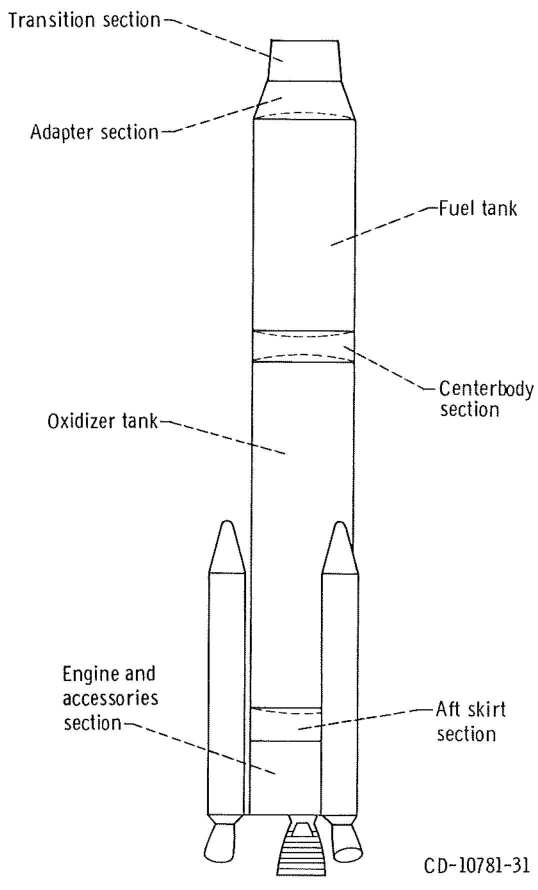


Figure V-1. - Thorad vehicle structure system, OGO-VI.

PROPULSION SYSTEM

by Charles H. Kerrigan and Daniel Bachkin

System Description

The Thorad propulsion system is composed of a liquid-propellant engine system (fig. V-2) and three solid-propellant rocket motors.

The liquid-propellant engine system consists of a main engine, two vernier engines, and an engine start system. These engines use liquid oxygen and RJ-1 (kerosene) for propellants. During the engine start sequence, electrically initiated pyrotechnic igniters are used to ignite gas generator propellants for driving the turbopumps; and hypergolic igniters are used to ignite the propellants in the thrust chambers of the main and vernier engines. The pneumatic control of the liquid-propellant engine system is discussed in Section V, PNEUMATIC SYSTEM.

The Thorad main engine, rated at 756×10^3 newtons (170×10^3 lbf) thrust at sea level, consists of a gimbaled thrust chamber, propellant valves, an oxidizer and a fuel turbopump driven by a gas generator, a fuel additive blender unit (FABU) system, and a heat exchanger. The FABU system provides a lubricant supply to the turbopump by utilizing fuel (from the fuel pump volute) mixed with lubricant additive contained in the FABU. Fixed-area orifices regulate the propellant flow to the thrust chamber and to the gas generator. There is no thrust control system to compensate for changes in propellant head pressure to the turbopumps.

Each gimbaled vernier engine is rated at 4.45×10^3 newtons (1000 lbf) thrust at sea level, with propellants supplied from the main engine turbopumps. Because the turbopumps do not operate after main engine cutoff, the vernier engines are supplied with propellants from the engine start tanks during the vernier solo phase of flight. For this phase, each vernier engine is rated at 3.68×10^3 newtons (830 lbf) thrust at sea level. The duration of the vernier engine solo phase is controlled by a time-delay relay that starts at main engine cutoff and provides the vernier engine cutoff command 9 seconds later.

The engine start system consists of two small propellant tanks and a pressurization system. These engine start tanks have a volume of approximately 0.028 cubic meter (1 cu ft) each and are filled and pressurized prior to launch to supply propellants for engine start. They remain pressurized and are refilled, from the turbopump, during flight to provide propellants for vernier engine operation after main engine cutoff.

The propellant grain for the three solid-propellant rocket motors is basically polybutadiene acrylic acid and ammonium perchlorate. Each solid motor is rated at 232×10^3 newtons (52 150 lbf) thrust at sea level. These motors are ignited by a signal from a pressure switch on the Thorad main engine thrust chamber. This switch actuates when the chamber pressure in the Thorad main engine reaches 258 newtons per square centimeter (375 psi) during the start sequence. The solid-propellant rocket motors provide thrust for about 39 seconds and are jettisoned 102 seconds after ignition. The jettison command is provided by a timer that starts at solid-propellant rocket motor ignition. These motors are mounted 120° apart on the Thorad engine and accessories section and have an 11° nozzle cant angle (see fig. III-3).

System Performance

The performance of the Thorad propulsion system for the OGO-VI mission was satisfactory. During the liquid-propellant engine start phase, engine valve opening times and starting sequence events were within tolerances. Performance parameters for the solid-propellant rocket motors and for the liquid-propellant engines were normal, as indicated by a comparison of measured with expected values. These data are tabulated in table V-I. The solid-propellant rocket motors burned for 37.2 seconds, and the solid-propellant rocket motor cases were jettisoned at T + 102.1 seconds as planned.

Main engine chamber pressure data indicated the occurrence of longitudinal oscillations on two different occasions for this flight. Chamber pressure fluctuations at a frequency of 23.5 hertz started at T + 110 seconds, reached a maximum peak-to-peak amplitude of 14 newtons per square centimeter (20 psi) at T + 114 seconds, and subsided at T + 119 seconds. These fluctuations were caused by vehicle response to the second longitudinal compression mode. This was the first NASA Thorad-Agena flight to exhibit this response. Shortly before main engine cutoff, as on previous Thorad flights, there was a coupling of the propulsion system response characteristics with the first longitudinal compression mode of the vehicle structure (i.e., POGO effect). During this coupling, from T + 201 to T + 215 seconds, the maximum peak-to-peak amplitude of the main engine chamber pressure fluctuations was 41.4 newtons per square centimeter (60 psi) at a frequency of 17.5 hertz. These values are typical for the POGO effect. (See Section VI, VEHICLE STRUCTURE SYSTEM for maximum POGO acceleration levels.)

Main engine cutoff was initiated by a command from the radio guidance system at T + 217.7 seconds. Vernier engine cutoff occurred 9 seconds later. Transients were normal at solid-propellant rocket motor burnout and during shutdown of the main and vernier engines.

Residual propellants in the main tanks were calculated to be 216.8 kilograms (478 lbm) of fuel and 184.6 kilograms (407 lbm) of oxidizer. The fuel residual was calculated based on fuel float switch activation time. The oxidizer residual was calculated by using main engine performance data instead of the oxidizer float switch activation time because the oxidizer float switch activated prematurely. Based on these propellant residuals, the propellant consumption at main engine cutoff was calculated to be 99.4 percent. An extrapolation to propellant depletion, oxidizer depletion in this case, indicates that a propellant utilization of 99.8 percent was achieved.

TABLE V-I. - THORAD PROPULSION SYSTEM PERFORMANCE, OGO-VI

(a) Solid-propellant rocket motors

Performance parameter	Units	Flight values at-					
		T + 10 sec		T + 25 sec		T + 35 sec	
		Expected	Measured	Expected	Measured	Expected	Measured
Combustion chamber pressure, absolute:							
Motor 1	N/cm^2	403	401	491	480	454	444
	psi	585	582	712	696	658	644
Motor 2	N/cm^2	403	396	491	477	454	444
	psi	585	575	712	692	658	644
Motor 3	N/cm^2	403	403	491	480	454	444
	psi	585	584	712	696	658	644

(b) Liquid-propellant engines

Performance parameter	Units	Flight values at-					
		T + 30 sec		Main engine cutoff		Vernier engine cutoff	
		Expected	Measured	Expected	Measured	Expected	Measured
Main engine thrust chamber pressure, absolute	N/cm^2	412	407	376	367	---	---
	psi	600	593	547	534	---	---
Turbopump speed	rpm	6308	6300	5992	(b)	---	---
Vernier engine 2[a] thrust chamber pressure when pump-supplied, absolute	N/cm^2	268	262	246	246	---	---
	psi	389	382	356	358	---	---
Vernier engine 2[a] thrust chamber pressure when tank-supplied, absolute	N/cm^2	----	----	----	---	208	207
	psi	----	----	----	---	302	301

[a]Vernier engine 1 was not instrumented.
[b]Instrumentation malfunction from T + 111.6 sec to end of flight (see Thorad telemetry system section).

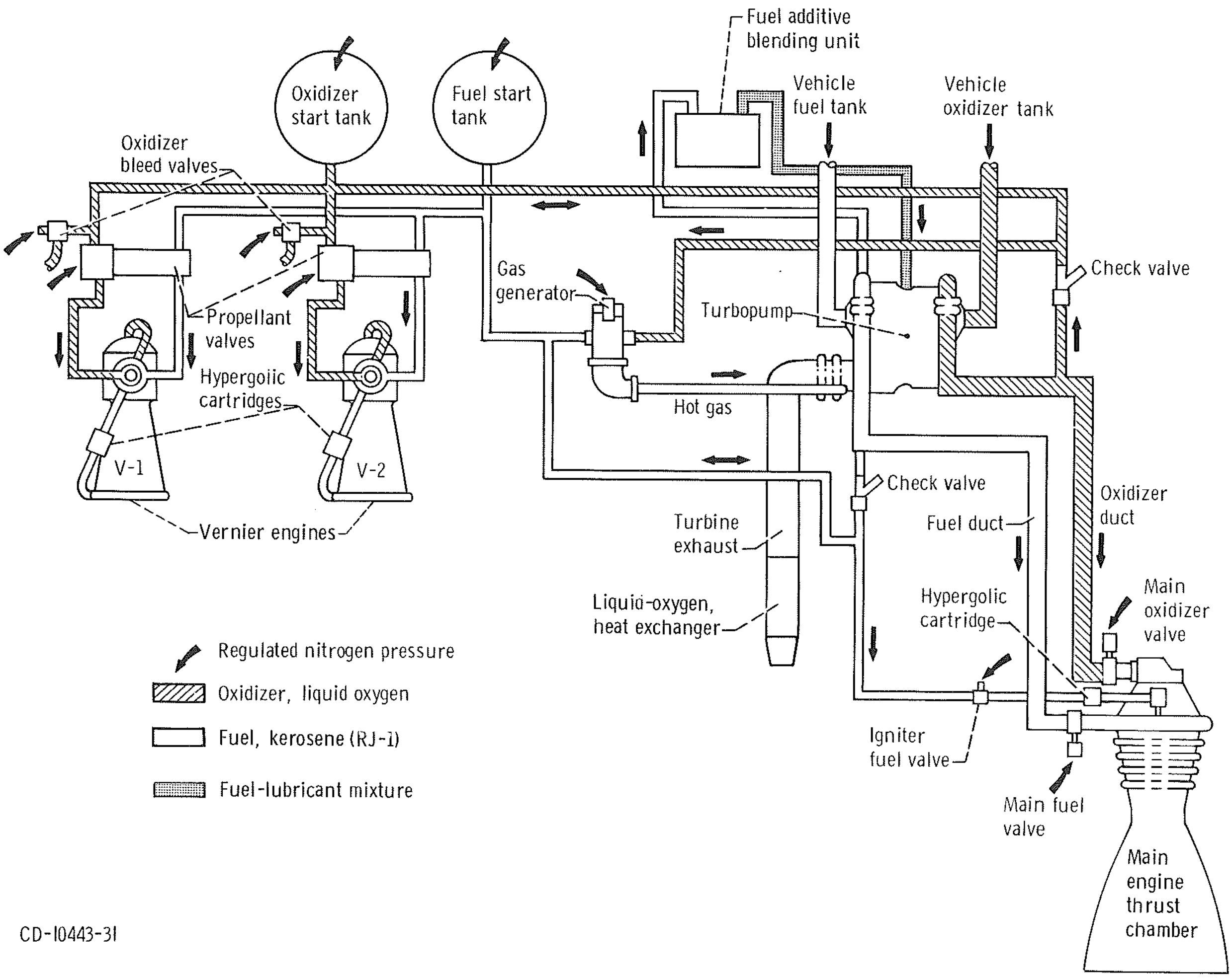


Figure V-2. - Thorad liquid-propellant engine system, OGO-VI.

HYDRAULIC SYSTEM

by Eugene J. Fourney and Daniel Bachkin

System Description

The Thorad hydraulic system provides hydraulic fluid at the pressures and flow rates required for gimbaling the main and vernier engines. The system consists of pump, reservoir, accumulator, filters, check valves and pressure relief valves, six actuator assemblies, hydraulic fluid, and the necessary lines and fittings. The positive displacement pump, mounted on the turbopump accessory unit, provides the flow rate and pressure of hydraulic fluid during the main engine thrust phase. The accumulator, which is precharged with nitrogen gas during ground operations, provides the required flow rate and pressure of hydraulic fluid for gimbaling the vernier engines during vernier engine solo operation. The reservoir provides hydraulic fluid to the pump inlet from the system return lines. Two actuator assemblies are provided for each thrust chamber. Each actuator assembly consists of a hydraulic actuator, a feedback potentiometer, and a servovalve. The servovalve controls the flow rate of hydraulic fluid for engine positioning.

System Performance

The hydraulic system functioned satisfactorily. The hydraulic system flight performance data are presented in table V-II.

TABLE V-II. - THORAD HYDRAULIC SYSTEM PERFORMANCE, OGO-VI

	Units	Normal range	Before engine ignition	Flight values at -					
				T + 10 sec	T + 21 sec	T + 31 sec	T + 60 sec	Main engine cutoff	Vernier engine cutoff
Supply pressure, absolute	N/cm^2	(a)	2082	2165	2165	2165	2165	2082	1758
	psi		3040	3155	3155	3155	3155	3040	2560
Return pressure, absolute	N/cm^2	(b)	67	41	41	60	56	54	59
	psi		98	60	60	88	81	78	86

[a]Normal range of the absolute value of the hydraulic supply pressure during main engine operation is from 2065 to 2340 N/cm^2 (3000 to 3400 psi). During vernier engine solo operation, the supply pressure normally decays by 265 to 345 N/cm^2 (300 to 500 psi).

[b]The normal range of the absolute return pressure is 31 to 65.5 N/cm^2 (45 to 90 psi) while the airborne hydraulic system is activated.

PNEUMATIC SYSTEM

by Eugene J. Fourney and Daniel Bachkin

System Description

The Thorad pneumatic system consists of the pneumatic control subsystem and the main-fuel-tank pressurization subsystem. High-pressure gaseous nitrogen is stored in four spherical stainless-steel tanks to supply pressure for the pneumatic system. A check valve in the system assures that one of these tanks can only provide nitrogen gas for the pneumatic control subsystem. The three remaining tanks provide nitrogen gas for pressurizing the fuel tank and, if required, provide nitrogen gas for operation of the pneumatic control subsystem.

The pneumatic control subsystem regulates gaseous nitrogen pressure for pressurization of the engine start subsystem, the liquid-oxygen pump seal cavity, and actuation of propellant valves. The system consists of a pneumatic control package, filter, two solenoid control valves, and the required fittings and connecting tubing. One of the solenoid control valves controls pneumatic pressure to the main oxidizer valve. The other solenoid control valve controls pneumatic pressure to the main fuel valve and the gas generator blade valve.

The main-fuel-tank pressurization subsystem bleeds high-pressure gaseous nitrogen through a fixed-area orifice to maintain the fuel-tank ullage pressure (absolute) between 8. 3 and 33. 9 newtons per square centimeter (12 to 49 psi) during flight. A heat exchanger in the main-engine gas generator exhaust system is used to convert liquid oxygen to gaseous oxygen to maintain the oxidizer-tank ullage absolute pressure between 22. 1 and 42. 1 newtons per square centimeter (32 to 61 psi) during flight.

System Performance

The Thorad pneumatic system performed satisfactorily. All pneumatic system parameters observed were satisfactory. System performance data are presented in table V-III.

TABLE V-III. - THORAD PNEUMATIC SYSTEM AND TANK PRESSURIZATION SYSTEM PERFORMANCE, OGO-VI

	Units	Normal range[a]	Flight values at-						
			T - 10 sec	T - 0 sec	T + 10 sec	T + 60 sec	T + 120 sec	Main engine cutoff	Vernier engine cutoff
Main-fuel-tank ullage pressure, absolute	N/cm^2	8.3 to 33.9	31.7	31.7	24.8	17.2	13.8	11.0	11.0
	psi	12 to 49	46.0	46.0	36.0	25.0	20.0	16.0	16.0
Main-oxidizer-tank ullage pressure, absolute	N/cm^2	22.1 to 42.1	33.0	31.7	24.8	26.2	24.8	24.1	24.1
	psi	32 to 61	48.0	46.0	36.0	38.0	36.0	35.0	35.0
Pneumatic-control-bottle pressure, absolute	N/cm^2	1665 to 2206	2080	2080	2000	2000	1965	1930	[b]1035
	psi	2400 to 3200	3000	3000	2900	2900	2850	2800	[b]1500

[a]Normal ranges apply only during main engine operation.

[b]Pressure change from main engine cutoff to vernier engine cutoff reflects use of nitrogen for pressurization of start tanks during vernier engine solo operation and pneumatic control subsystem operation.

GUIDANCE AND FLIGHT CONTROL SYSTEM

by Howard D. Jackson and James L. Swavely

The Thorad flight path is controlled by two interrelated systems: the Thorad flight control system and the radio guidance system. The flight control system directs the vehicle in a preprogrammed open-loop mode from lift-off through vernier engine cutoff. The radio guidance system will provide, if needed, pitch and yaw steering commands during approximately the last half of the Thorad powered flight. These steering commands provide corrections for vehicle deviations from the desired trajectory. The radio guidance system also provides discrete commands for Thorad main engine cutoff and Thorad-Agena separation. The radio guidance system's use during the Agena phase of flight is discussed in Section VI, GUIDANCE AND FLIGHT CONTROL SYSTEM.

System Description

The major components of the Thorad flight control system are the control electronic assembly and three rate gyros. The control electronic assembly contains a programmer, three displacement gyros, and associated electronic circuitry. These displacement gyros are single-degree-of-freedom, floated, hermetically sealed rate-integrating gyros. These gyros are mounted in an orthogonal configuration alining the input axis of each gyro to its respective vehicle axis of pitch, yaw, or roll. Each gyro provides an electrical output signal proportional to the difference in angular position of the measured axis from the gyro input (reference) axis.

The programmer provides the following discrete commands: start and stop of the roll, pitch, and yaw preprogrammed maneuvers, the solid-propellant rocket motor case jettison arm and backup jettison, enable radio guidance system steering, enable vernier engine yaw control, and enable main engine cutoff. The programmer uses a motor-driven prepunched tape. Slots in the prepunched tape activate relay circuits for the programmer commands. For this mission, the capability of the Thorad flight control system to accept radio guidance system pitch and yaw steering commands is enabled at T + 124 seconds. Between T + 124 seconds and main engine cutoff, all radio guidance system pitch and yaw steering commands are routed to the Thorad flight control system.

The three rate gyros are of the single-degree-of-freedom, spring-restrained type. The roll rate gyro is located in the center body section with its input axis alined to the vehicle roll axis. The pitch and yaw rate gyros are located adjacent to the fuel tank in a cable tunnel and are mounted with the input axes alined to the pitch and yaw vehicle axes. Each rate gyro provides an electrical output signal proportional to the angular rate of rotation of the vehicle about the gyro input (reference) axis.

The radio guidance system includes airborne equipment located in the Agena (a radar transponder and command receiver, a control package, two antennas, a directional coupler, and connecting waveguide); and ground-based equipment (a radar tracking station and a computer). The major functions (fig. V-3) are described in the following paragraphs:

The radar tracking station transmits a composite message-train containing an address code and the steering and discrete commands to the vehicle. The radar transponder and command receiver in the Agena receives the message-train and transmits a return pulse to the ground each time the address code is correct. The radar tracking station determines vehicle position (range, azimuth, and elevation) from the return pulses. The computer processes the position information, computes trajectory corrections, and issues appropriate steering and discrete commands which are transmitted to the Agena by the radar tracking station as just described. The steering and discrete commands are routed from the Agena to the Thorad through vehicle harnesses.

A dorsal and a ventral antenna are mounted on the forward section of the Agena and are connected through waveguide and the directional coupler to the radar transponder and command receiver. The location of the radar tracking station antenna with respect to the launch site is such that for prelaunch testing and early ascent, the dorsal antenna provides the greater signal strength to the ground antenna. As the vehicle pitches over and moves downrange, the ventral antenna provides the greater signal strength. The directional coupler attenuates the signal from the dorsal antenna to minimize interference effects between the dorsal and ventral antennas. Mission trajectory information determines the antenna configuration, the antenna orientation, and the type of directional coupler for each mission.

During the early portion of flight, multipath effects and ground-clutter effects could cause the radar tracking station to acquire (lock on) a false vehicle position. To avoid this problem the following procedure is used for radar tracking station acquisition (lock-on) of the vehicle. Before lift-off, the centerline of the ground radar antenna beam is manually pointed at the junction of the ground antenna horizon and the programmed trajectory. At lift-off, a timer in the ground station is started which closes the ground radar angle tracking loops at T + 6.1 seconds, the time at which the vehicle is predicted to fly through the radar beam. When the angle tracking loops are closed, the acquisition (lock-on) is complete and the radar tracking station will track the actual vehicle position.

As a backup to the angle-loop timer, the radar tracking station operator manually closes the angle tracking loops at T + 7 seconds. If the radar tracking station still does not acquire the launch vehicle, the ground antenna is slewed to 20 mils elevation to acquire at T + 11.3 seconds; then it is manually slewed through a planned series of pointing coordinates until acquisition is effected. These coordinates correspond to the expected vehicle positions at T + 14.2, T + 30, T + 50, and T + 70 seconds.

Range lock and frequency lock are accomplished before lift-off.

System Performance

The Thorad flight control system performance was satisfactory throughout flight. Lift-off transients in pitch, yaw, and roll were negligible, as indicated by main engine gimbal angle data (0.05° in pitch and 0.10° in yaw).

The maximum main engine gimbal angles at the time of greatest wind shear (~T + 55 sec) were well within the design allowable. Maximum angular displacements of the vehicle after radio guidance system enable at T + 124 seconds were 1.40° in pitch and 0.50° in yaw. Gimbal angles at main engine cutoff (T + 217.7 sec) were 0.21° in pitch and 0.15° in yaw. Angular displacements of the vehicle from the desired flight path when the Agena gyros were uncaged (T + 226.7 sec) were 0.05° in pitch, 0.05° in yaw, and 0.0° in roll. These angular displacements were within allowable limits and provided a satisfactory reference attitude for the Agena. Angular rates at Thorad-Agena separation (T + 233.4 sec) were 0.06 degree per second in pitch, 0.07 degree per second in yaw, and 0.03 degree per second in roll.

Roll rate gyro output oscillations noted during the Thorad phase of flight were as follows:

Time of flight, sec	Frequency, Hz	Maximum peak-to-peak oscillation, deg/sec
T + 102.2	1	0.32
T + 110 to T + 119	3	.96
T + 201 to T + 215	2.5	4.2

The oscillations at T + 102.2 seconds (immediately following solid-propellant rocket motor case jettison) were attributed to backlash in the linkage to the vernier engines and to nonlinearities in the servovalves. The oscillations between T + 110 and T + 119 seconds reflect the vehicle structure response to the second longitudinal compression mode discussed previously in the Thorad propulsion section. Oscillations between T + 201 and T + 215 seconds were attributed to the first longitudinal compression mode response

(POGO effect) discussed in the Thorad propulsion section. None of these oscillations were detrimental to the control system performance.

The radio guidance system (ground and airborne) performed satisfactorily throughout the guided portion of flight. The range and frequency loops of the radar tracking station were locked on the vehicle before lift-off. Signal strength at the radar tracking station before lift-off was satisfactory. The ground angle-loop timer started at lift-off and actuated at T + 6.1 seconds. The angle tracking loops were closed and vehicle acquisition (lock-on) occurred at T + 6.1 seconds. The manual backup angle-loop was closed at T + 7 seconds. The signal strength at the radar tracking station was satisfactory throughout flight. Signal strength fluctuations occurred, as expected, during the two-antenna interference region from T + 40 to T + 90 seconds when the received signal strengths from the dorsal and ventral antennas were within 10 decibels of each other. Radar tracking station data indicated the actual vehicle position was continuously tracked throughout the flight except for a 0.1-second period at T + 60 seconds. The performance of the ground-based computer was satisfactory throughout the countdown and vehicle flight.

Prior to lift-off, the airborne radio guidance system equipment indicated a received signal strength of -16 dBm (decibels referenced to 1 mW). The maximum received signal strength was -13 dBm at T + 130 seconds and decreased to -37 dBm by T + 519 seconds. The signal strength received by the vehicle was adequate throughout the operation of the radio guidance system.

All radio guidance system commands were satisfactorily generated by the computer, transmitted by the radar tracking station, and received and executed by the vehicle. Table V-IV shows planned and actual times of all radio guidance system commands.

TABLE V-IV. - RADIO GUIDANCE SYSTEM

COMMANDS, OGO-VI

Command	Time from lift-off, sec	
	Planned	Actual
Thorad steering (pitch and yaw):		
Commenced	124.3	124.6
Terminated	215.7	213.9
Thorad main engine cutoff	219.9	217.7
Thorad-Agena separation[a]	234.9	233.4
Agena steering (pitch and yaw)[a]:		
Commenced	299.5	297.3
Terminated	522.2	517.4
Agena engine cutoff[a]	523.5	519.0

[a]Commands to the Agena vehicle are discussed in Section VI of this report.

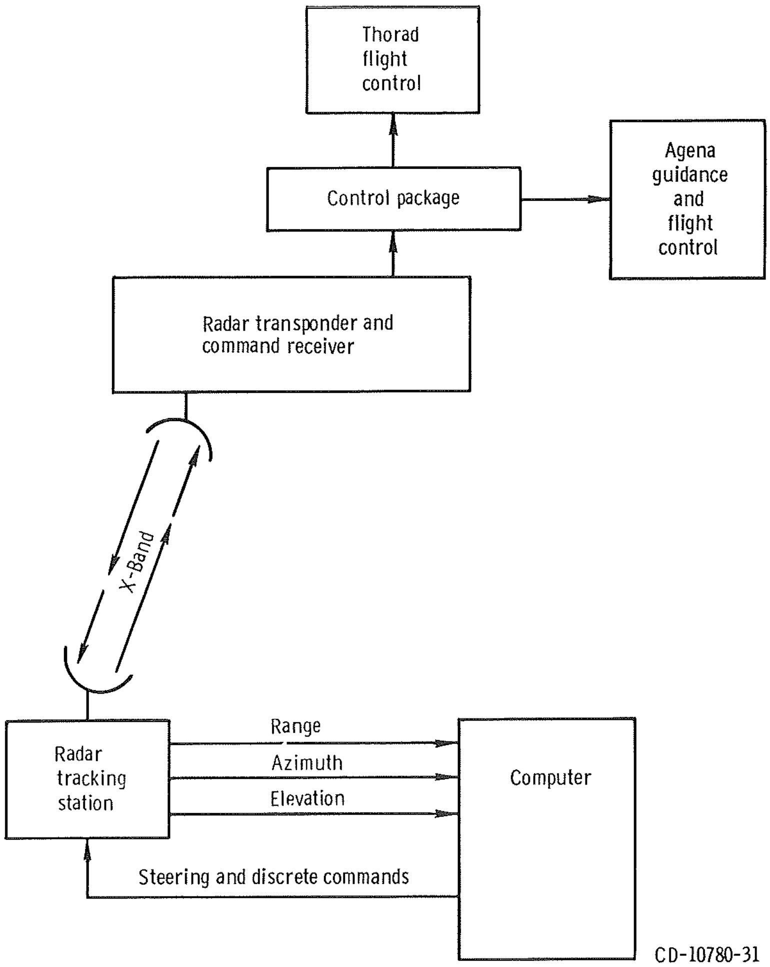


Figure V-3. - Block diagram of major functions of radio guidance system, OGO-VI.

ELECTRICAL SYSTEM

by Edwin R. Procasky and Baxter L. Beaton

System Description

The Thorad power requirements are supplied by three 28-volt silver-zinc alkaline batteries and a 400-hertz rotary inverter (fig. V-4). Distribution boxes are located throughout the vehicle to facilitate interconnection and switching of electrical functions. Two tunnels located externally to the propellant tanks are used to route cables between the transition, center body, and engine and accessory sections.

The main battery is rated at 20 ampere-hours and supplies all the vehicle power requirements, except for the telemetry system and the flight termination system. The power requirements for these systems are supplied by two other batteries. The telemetry battery, rated at 3 ampere-hours, supplies the telemetry system and flight termination subsystem 1 power requirements. The remaining battery, rated at 1 ampere-hour, supplies power to flight termination subsystem 2.

The rotary inverter (a dc motor-driven ac alternator) provides the 400-hertz 115/208-volt ac, three-phase power. The voltage output and frequency of the inverter are regulated to ±1.5 percent. The alternator is Y-connected with a grounded neutral.

System Performance

The main battery supplied the requirements of the dependent systems at normal voltage levels. The battery voltage at lift-off was 27.0 volts dc and increased to 28.4 volts dc by the time of Thorad main engine cutoff. The telemetry battery supplied power to the telemetry system and flight termination subsystem 1 at 28.8 volts dc throughout flight. The battery which supplied power to flight termination subsystem 2 was not monitored. The rotary inverter performance was satisfactory and was within ±1.5 percent voltage and frequency tolerances throughout the Thorad flight. The inverter frequency (after lift-off transients had stabilized) was 398.4 hertz and increased to 399.1 hertz by the time of main engine cutoff. The inverter output voltage was 115.1 volts dc during the flight.

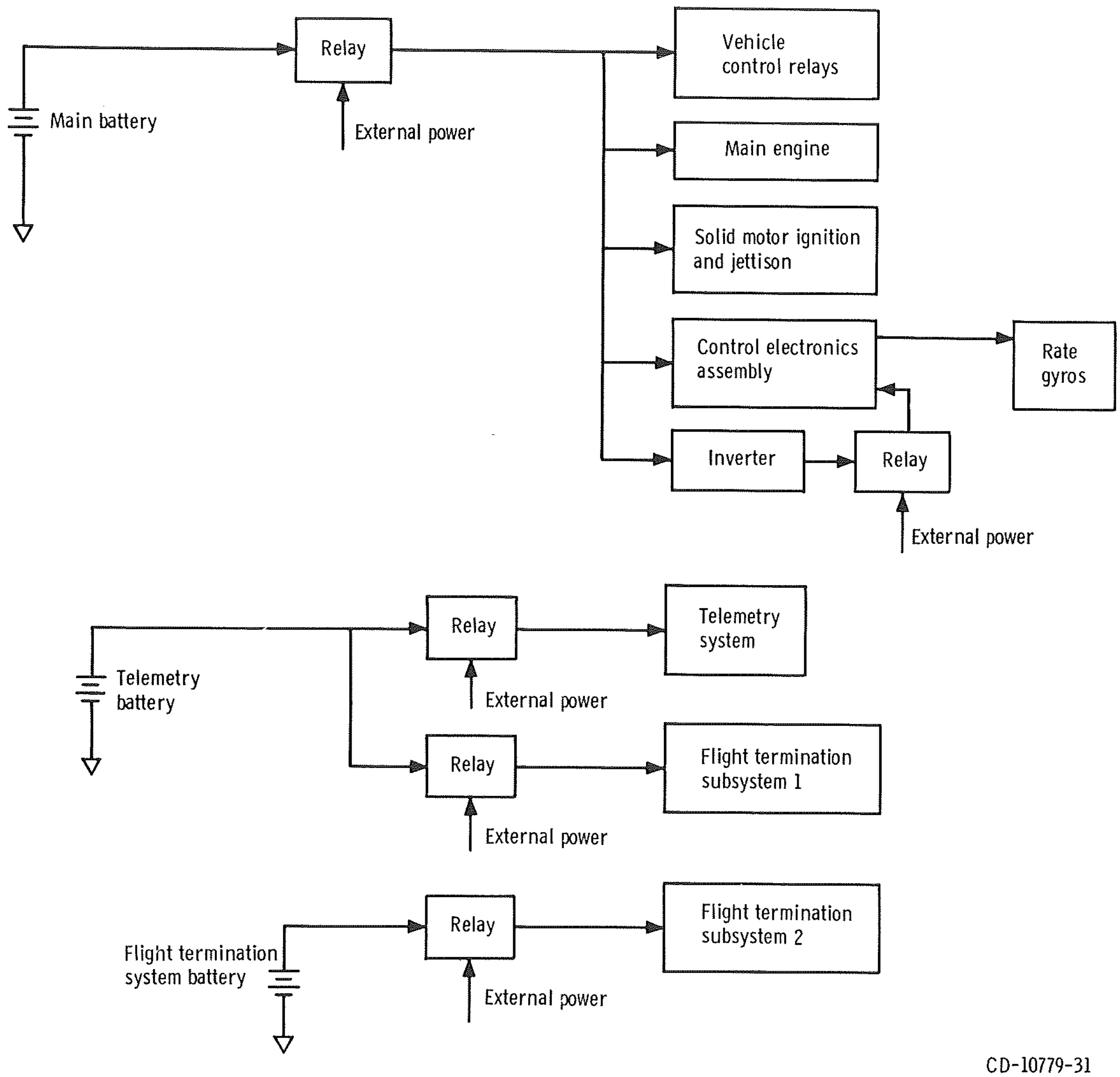


Figure V-4. - Thorad power distribution block diagram, OGO-VI.

TELEMETRY SYSTEM

by Richard L. Greene and Richard E. Orzechowski

System Description

The Thorad telemetry system consists of two antennas, a frequency modulated (FM) transmitter, signal conditioning circuitry, transducers, a 28-volt battery, and a multicoder. The telemetry system is located in the center body section. The transmitter operates on a frequency of 246.3 megahertz at a power output of 10 watts. The multicoder provides pulse duration modulation (PDM) of 43 commutated data channels to one FM subcarrier channel. Eight other FM subcarrier channels provide continuous data.

A total of 51 measurements are telemetered from the Thorad vehicle. Appendix B summarizes the launch vehicle instrumentation by measurement description.

System Performance

All instrumentation measurements returned valid data throughout the flight except for measurements PDM-1-27 (turbopump speed), PDM-1-28 (turbine inlet temperature), and PDM-1-35 (rate gyro cover inner-wall temperature). The data from the turbopump speed measurement PDM-1-27 indicated a step change of 200 rpm at T + 111.6 seconds. Analysis of other propulsion system data verified that no step change occurred. Consequently, data from measurement PDM-1-27, after T + 111.6 seconds, are considered to be invalid. The turbine inlet temperature measurement PDM-1-28 returned anomalous data near the end of Thorad flight. The temperature sensor for measurement PDM-1-35 malfunctioned prior to lift-off, and no valid data were obtained. The satisfactory vehicle performance verified that all these were data anomalies. Radiofrequency signal strength was adequate during flight, as evidenced by good quality data. Carrier frequency was stable, and no data reduction difficulties were encountered. No direct measurements of telemetry system performance or of system environment were made. Appendix C (fig. C-2) shows the specific coverage provided by the supporting telemetry stations.

FLIGHT TERMINATION SYSTEM

by Richard L. Greene and Richard E. Orzechowski

System Description

The Thorad flight termination system (fig. V-5) consists of two identical and redundant subsystems designed to destroy the vehicle on receipt of ground command signals. Each subsystem includes two antennas (located on opposite sides of the Thorad), a command receiver, a safe-arm mechanism, and destructor cords. The antenna locations are shown on figure III-3. The safe-arm mechanisms are armed by lanyards at lift-off. After lift-off, the range safety officer can command destruction, if required, by transmitting a coded signal to the command receivers. Each command receiver will supply an electrical signal to two detonators in a Thorad safe-arm mechanism and, prior to Thorad-Agena separation, to a detonator in the Agena destruct initiator. Either detonator on a safe-arm mechanism will initiate the two destructor cords (one on each side of the Thorad propellant tanks) and, through other destructor cords, will initiate a shaped charge on the forward end of each solid-propellant rocket motor. A 0.1-second time delay in the Thorad safe-arm mechanisms ensures that the Agena destruct initiator receives the destruct signal before the Thorad is destroyed.

The Agena destruct components are discussed in Section VI, COMMUNICATION AND CONTROL SYSTEM.

System Performance

Both command receivers in the Thorad flight termination system functioned satisfactorily during flight. The data indicated that the vehicle received adequate signal strength for the operation of each flight termination subsystem and that the signal level remained essentially constant throughout the period in which destruct capability was required. No flight termination commands were required, nor were any commands inadvertently generated by any vehicle system.

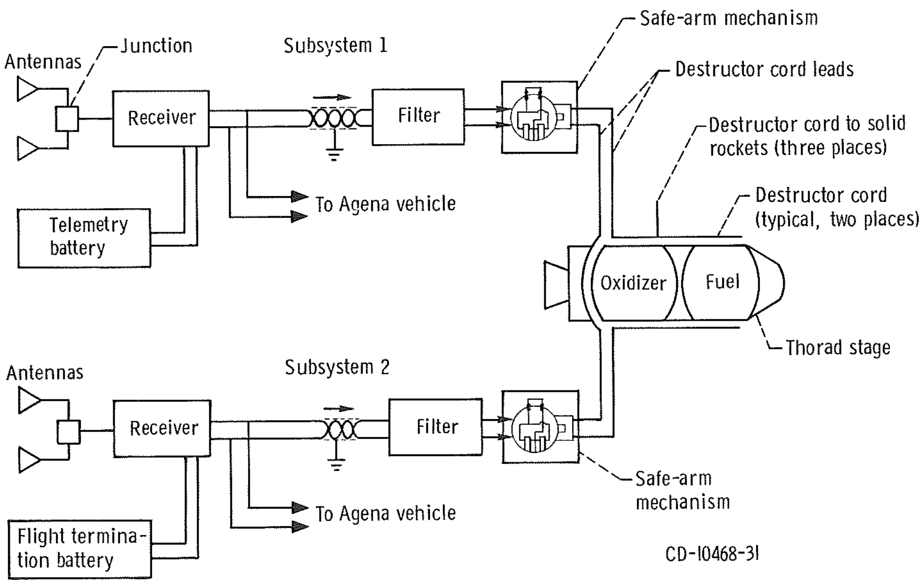


Figure V-5. - Thorad flight termination system, OGO-VI. (Batteries also shown on fig. V-4.)

VI. AGENA VEHICLE SYSTEM PERFORMANCE

VEHICLE STRUCTURE SYSTEM

by Robert N. Reinberger and Robert W. York

System Description

The Agena vehicle structure system (fig. VI-1) consists of four major sections: the forward section, the propellant tank section, the aft section, and the booster adapter assembly. Together they provide the aerodynamic shape, the structural support, and the environmental protection for the vehicle. The forward section is basically an aluminum structure with beryllium and magnesium panels. This section encloses most of the electrical, guidance, and communication equipment and provides the mechanical and electrical interface for the spacecraft adapter and shroud. The propellant tank section consists of two integral aluminum tanks, with a sump below each tank to assure the supply of propellants for engine starts in space. The aft section consists of an engine mounting cone structure and an equipment mounting rack. The magnesium-alloy booster adapter section supports the Agena and remains with the Thorad after Thorad-Agena separation.

System Performance

The measured dynamic environment of the structure system was within design limits. The longitudinal oscillation (POGO effect) measured on the Agena structure at station 247 reached a maximum of 3.90 g's (zero to peak) at T + 205.03 seconds.

A second-mode longitudinal oscillation occurred (as discussed previously in the Thorad propulsion and guidance and flight control sections) between T + 110 and T + 119 seconds. The Agena structural response to these oscillations was insignificant. Appendix D presents significant dynamic data at selected times.

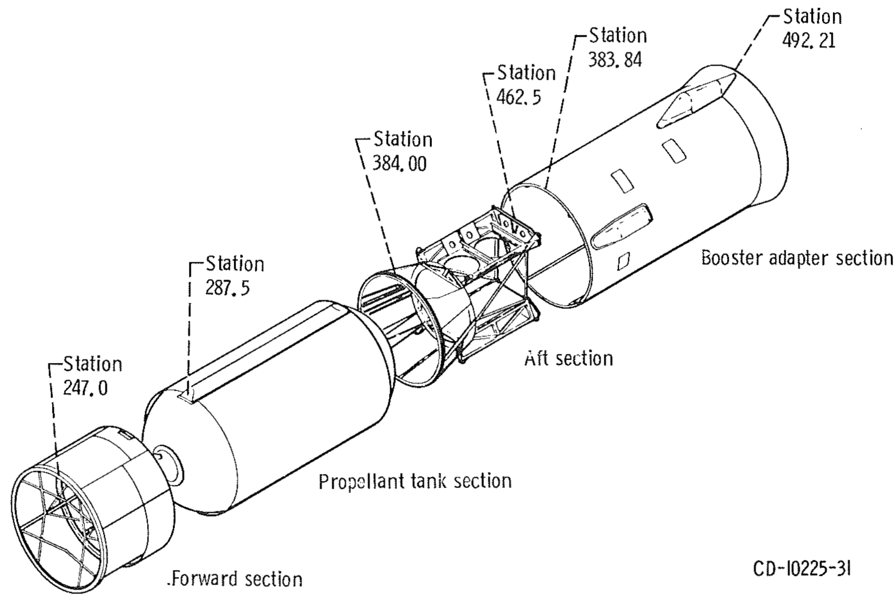


Figure VI-1. - Agena vehicle structure system, OGO-VI.

SHROUD SYSTEM

by Robert N. Reinberger

System Description

The shroud system for the OGO-VI flight is the standard Agena clamshell (SAC) shroud with minor mission modifications incorporated. It provides environmental protection for the spacecraft before launch and during ascent. The SAC shroud (fig. VI-2) is 5.72 meters (18.78 ft) long and weighs 324.77 kilograms (716 lbm). It consists of an aluminum transition ring and two shroud halves. The shroud halves form a fairing with a 1.65-meter (5.42-ft) diameter cylindrical section, a 15° half-angle conical section, and a 0.61-meter (2-ft) diameter hemispherical nose cap. The shroud halves are constructed of fiber glass strengthened by internal aluminum longerons at the split line and also by semicircular frames. Microquartz thermal insulation blankets in the cylindrical section and a foil covering in the conical section of each shroud half provide thermal protection for the spacecraft. The shroud halves are held together by a nose latch, two flat bands around the cylindrical section, and a V-band around the base of the cylindrical section. The top, middle, and bottom bands are tensioned to 22 250, 11 570, and 35 600 newtons (5000, 2600, and 8000 lbf), respectively.

The V-band clamps the shroud to the transition ring, which is approximately 5.1 centimeters (0.17 ft) high and is bolted to the forward end of the Agena. Both the shroud and the spacecraft adapter are attached to the transition ring. A metal diaphragm attached to the transition ring isolates the shroud cavity from the Agena. During ascent, this cavity is vented through four ports in the cylindrical section of the shroud. These ports are equipped with flappers which permit venting in an outward direction only.

Shroud jettison is commanded by the Agena timer 10 seconds after Agena engine start. At this time, Agena electrical power is used to fire squibs which actuate the two pyrotechnic boltcutters in the nose latch assembly and the two explosive bolts in each of the three bands. The operation of at least one boltcutter in the nose latch and one bolt in each of the bands is required for shroud release. Two pairs of springs in each shroud half thrust against the transition ring and provide the energy to rotate each shroud half about hinges mounted on the transition ring. At the time of shroud separation, the Agena has a longitudinal acceleration of approximately 1 g. At this acceleration level, each shroud half rotates through an angle of about 75° before it leaves the hinges and falls free. The shroud separation springs provide sufficient energy to successfully jettison the shroud halves at vehicle longitudinal acceleration levels up to 3.5 g's.

The shroud system is instrumented with four temperature transducers and two pressure transducers. The temperature transducers are located on the inner surface of the shroud fiber glass skin at Agena stations 236.4, 125.4, 44.0, and 21.88 (near the stagnation point). One pressure transducer measures the differential pressure across the shroud wall and is located at Agena station 161.97; the other pressure transducer measures the absolute pressure in the shroud cavity and is located at Agena station 157.18.

System Performance

The performance of the shroud system was satisfactory. The histories of the shroud internal wall temperatures are presented in figure VI-3. The maximum temperature measured was 310 K (98° F). This temperature was measured by the transducer located internally near the stagnation point.

The history of the shroud wall differential pressure is presented in figure VI-4. The differential pressure was essentially zero during the early phase of the flight. During the transonic phase (T + 30 to T + 50 sec) of the flight, the differential pressure ($\Delta P = P_{ambient} - P_{shroud}$) increased to a maximum value of -1.62 newtons per square centimeter (-2.36 psi). This increase was caused by shock waves on the vehicle during transonic flight. After the transonic phase, the differential pressure returned to essentially zero for the remainder of the flight.

The history of the shroud cavity absolute pressure is presented in figure VI-5. The absolute pressure decayed during flight, as predicted, and was nearly zero at T + 120 seconds.

Shroud pyrotechnics were fired at T + 294.7 seconds, and the shroud was satisfactorily jettisoned. The Agena was stable at this time, and no measurable Agena roll, pitch, or yaw rates developed as a result of shroud jettison.

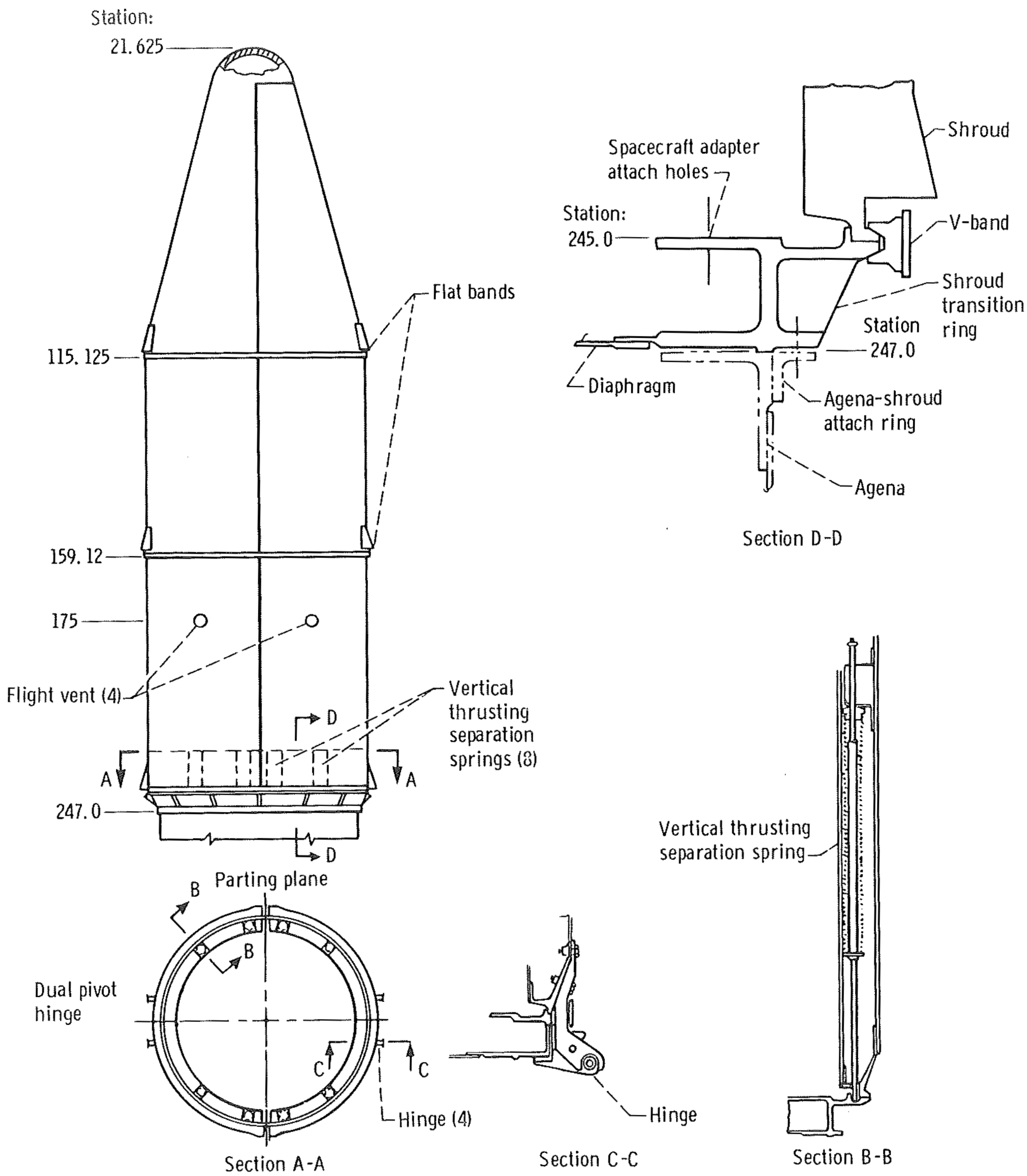


Figure VI-2. - Standard Agena clamshell shroud, OGO-VI.

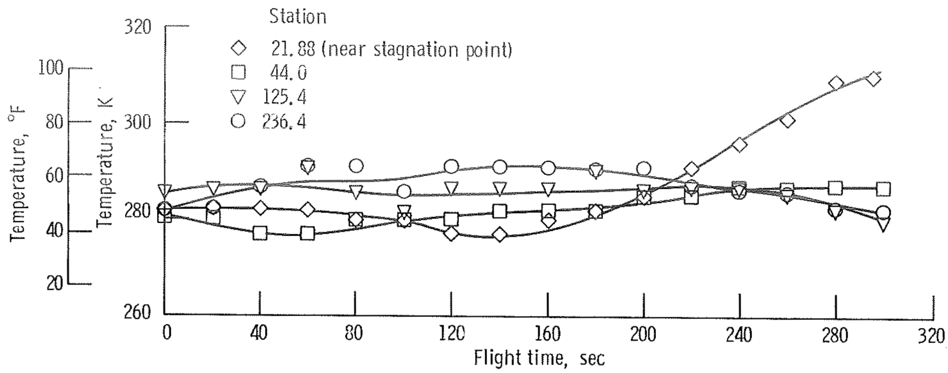


Figure VI-3. - Shroud internal wall temperature history, OGO-VI.

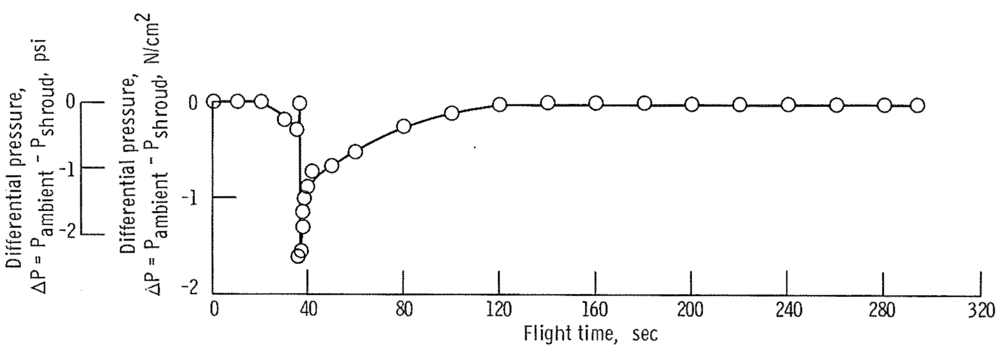


Figure VI-4. - Shroud wall differential pressure, OGO-VI.

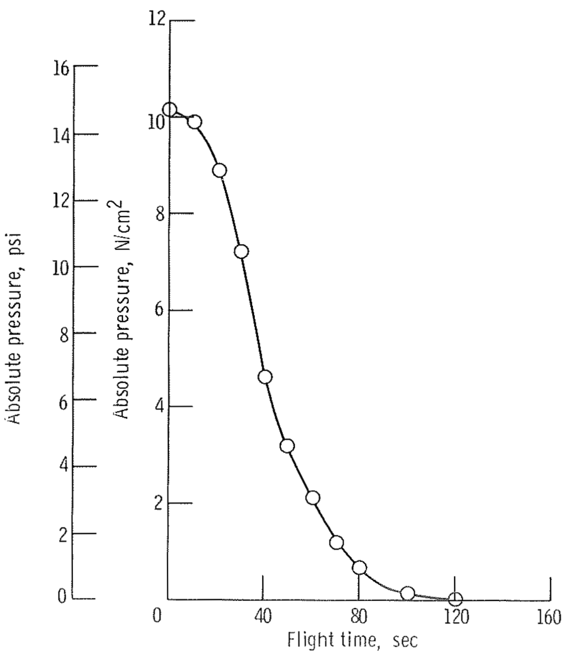


Figure VI-5. - Shroud cavity absolute pressure, OGO-VI.

PROPULSION SYSTEM

by Robert J. Schroeder

System Description

The Agena propulsion system (fig. VI-6) consists of a propellant tank pressurization system, a propellant management system, and an engine system. Also considered to be part of the propulsion system are the Thorad-Agena separation system and the Agena vehicle pyrotechnic devices.

The propellant tank pressurization system provides the required propellant tank pressures and consists of a helium supply tank and a pyrotechnically operated helium control valve. Before lift-off, the ullage volume in the propellant tanks is pressurized with helium from a ground supply source. The helium control valve is activated 1.5 seconds after initiation of the Agena engine start to permit helium gas to flow from the supply tank through fixed-area orifices to each propellant tank. After the Agena engine cutoff, the helium control valve is again activated to isolate the oxidizer tank from the helium supply. This prevents the mixing of oxidizer and fuel vapors that could occur if pressures in the propellant tanks were permitted to reach the same level.

The propellant management system consists of the following major items: propellant fill disconnects to permit the loading of fuel and oxidizer, feedlines from the propellant tanks to the engine pumps, and tank sumps to retain a sufficient amount of propellants for Agena engine start in a near-zero-gravity environment.

The Agena engine system consists of a liquid-bipropellant engine which uses unsymmetrical dimethylhydrazine as fuel and inhibited red fuming nitric acid as oxidizer. Rated thrust in a vacuum is 71 172 newtons (16 000 lbf) with a nozzle expansion area ratio of 45. The engine has a regeneratively cooled thrust chamber, a radiation-cooled nozzle extension, and a turbopump-fed propellant flow system. Turbine rotation is initiated for engine start by igniting a solid-propellant start charge. The turbine is driven during steady-state operation by hot gas produced in a gas generator. Propellants to the gas generator are supplied by the turbopump. Engine thrust vector control is provided by the gimbal-mounted thrust chamber. Two hydraulic actuators provide the force for thrust chamber pitch and yaw movement in response to signals produced by the Agena guidance and flight control system.

The Thorad-Agena separation is accomplished by initiating a Mild Detonating Fuse which severs the booster adapter circumferentially near the forward end. The Thorad with booster adapter is then separated from the Agena by firing two solid-propellant retrorockets mounted on the booster adapter. Rated average sea-level thrust of each retrorocket is 2180 newtons (490 lbf) with an action time of 0.93 second. Guide rails on the booster adapter mate with rollers on the Agena aft rack to maintain clearance and alinement during separation.

Pyrotechnic devices are used to perform a number of functions on the Agena. These devices include squibs, igniters, detonators, and explosive bolt cartridges. Squibs are used to open and close the helium control valve, to eject the horizon sensor fairings, and to activate shroud boltcutters. Igniters are used for the engine solid-propellant start charge and for the retrorockets. Detonators are used for the self-destruct charge and for the Mild Detonating Fuse separation charge. Explosive bolt cartridges are used to rupture the release devices for shroud jettison.

System Performance

The Agena engine start was initiated by the Agena timer at T + 284.7 seconds. Telemetered data from the engine switch group monitor indicated a normal start sequence of the engine control valves. Ninety-percent combustion chamber pressure was attained at T + 285.9 seconds. The average steady-state thrust generated by the Agena engine was 72 791 newtons (16 364 lbf), compared with an expected value of 72 017 newtons (16 190 lbf). Agena engine cutoff was commanded by the radio guidance system at T + 519.0 seconds. The engine thrust duration, measured from 90-percent chamber pressure to cutoff, was 233.1 seconds. This was 2.3 seconds less than the expected value of 235.4 seconds. The actual thrust duration and thrust level indicate that engine performance was within the allowable limits.

The propellant tank pressurization system supplied the required tank pressures during the Agena powered phase. This was evidenced by the fuel and oxidizer pump inlet pressure values, which were within 1.4 newtons per square centimeter (2 psi) of the expected values.

The Thorad-Agena separation system performance was normal. Separation was commanded by the radio guidance system at T + 233.4 seconds. This command resulted in the ignition of the Mild Detonating Fuse and the two retrorockets. Complete separation of the Agena from the Thorad occurred 2.6 seconds later when the booster adapter guide rails cleared the last rollers on the Agena aft rack.

All the Agena pyrotechnic devices performed their intended functions satisfactorily.

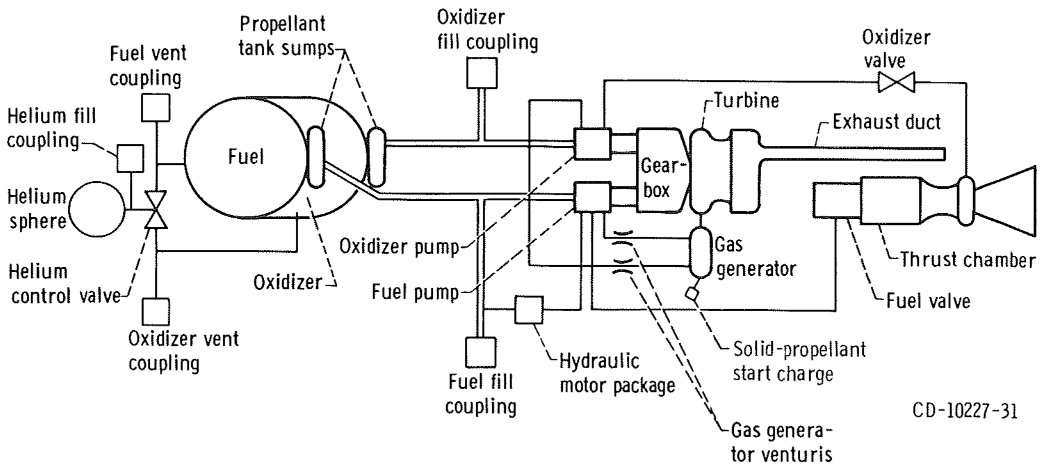


Figure VI-6. - Agena engine propulsion system schematic, OGO-VI.

ELECTRICAL SYSTEM

by Edwin R. Procasky and Baxter L. Beaton

System Description

The Agena electrical system (fig. VI-7) supplies all power requirements for the pyrotechnic, propulsion, flight termination, guidance and flight control, radio guidance, and telemetry systems. The electrical system consists of the power source equipment, the power conversion equipment, and the distribution network.

The power source equipment consists of two silver-zinc primary-type batteries (minimum design rating of 424 W-hr each) and two nickel-cadmium secondary-type batteries. One primary-type battery (the main battery) supplies power to the main vehicle loads that use unregulated power and to the power conversion equipment. The other primary-type battery (the pyrotechnic battery) supplies power to all Agena vehicle pyrotechnics, except the destruct charges in the flight termination system. The pyrotechnic battery is also connected to the main battery through a diode so that it can support the load on the main battery. However, the diode isolates the main battery loads from pyrotechnic transients and from pyrotechnic loads. The two secondary-type batteries are used with the flight termination system.

The power conversion equipment consists of one solid-state inverter and two dc-dc converters. The power conversion equipment converts unregulated dc power to regulated ac and regulated dc power. The inverter supplies 115 volts ac (± 2 percent) at 400 hertz (± 0.02 percent) to the guidance and flight control system. One dc-dc converter supplies regulated ± 28.3 volts dc to the guidance and flight control system. The other dc-dc converter supplies regulated 28.3 volts dc to the radio guidance system and to the telemetry system.

System Performance

The Agena electrical system satisfactorily supplied power to all electrical loads throughout the flight, as indicated by comparison of measured with expected values. The electrical system performance data are summarized in table VI-I.

The battery (main and pyrotechnic) load profile was as expected for this mission. The inverter and converter voltages were within specification at lift-off and remained essentially constant throughout the flight. The inverter frequency was not monitored on the Agena; however, the satisfactory performance of the guidance and flight control system indicated the inverter frequency was normal and stable.

At approximately T + 484 seconds, an Agena pyrotechnic circuit shorted to the vehicle structure. Approximately 8 seconds later, the circuit was opened by a fuse-resistor. There were no programmed events during this period. This short circuit did not affect the performance of the Agena.

TABLE VI-I. - AGENA ELECTRICAL SYSTEM FLIGHT PERFORMANCE SUMMARY, OGO-VI

Measurement	Range	Measurement number	Values at-			
			Lift-off	Engine start	Engine cutoff	Spacecraft separation
Pyrotechnic battery voltage	22.5 to 29.5	C141	27.0	27.0	27.0	27.0
Main battery voltage	22.5 to 29.5	C1	26.7	26.3	26.7	26.7
Battery current, A	-------------	C4	13	16	13	13
Converter output:						
+28.3-V dc regulated (guidance and flight control)	27.7 to 28.9	C3	28.0	28.0	28.0	28.0
-28.3-V dc regulated (guidance and flight control)	-27.7 to -28.9	C5	-28.3	-28.3	-28.3	-28.3
Inverter output:						
Phase AB, V ac, rms	112.7 to 117.3	C31	116.1	116.1	116.1	116.1
Phase BC, V ac, rms	112.7 to 117.3	C32	114.5	114.5	114.5	114.5
Converter output:						
+28.3-V dc regulated (telemetry)	27.7 to 28.9	C2	28.3	28.3	28.3	28.3
+28.3-V dc regulated (radio guidance)	27.7 to 28.9	BTL6	28.4	28.4	28.4	28.4

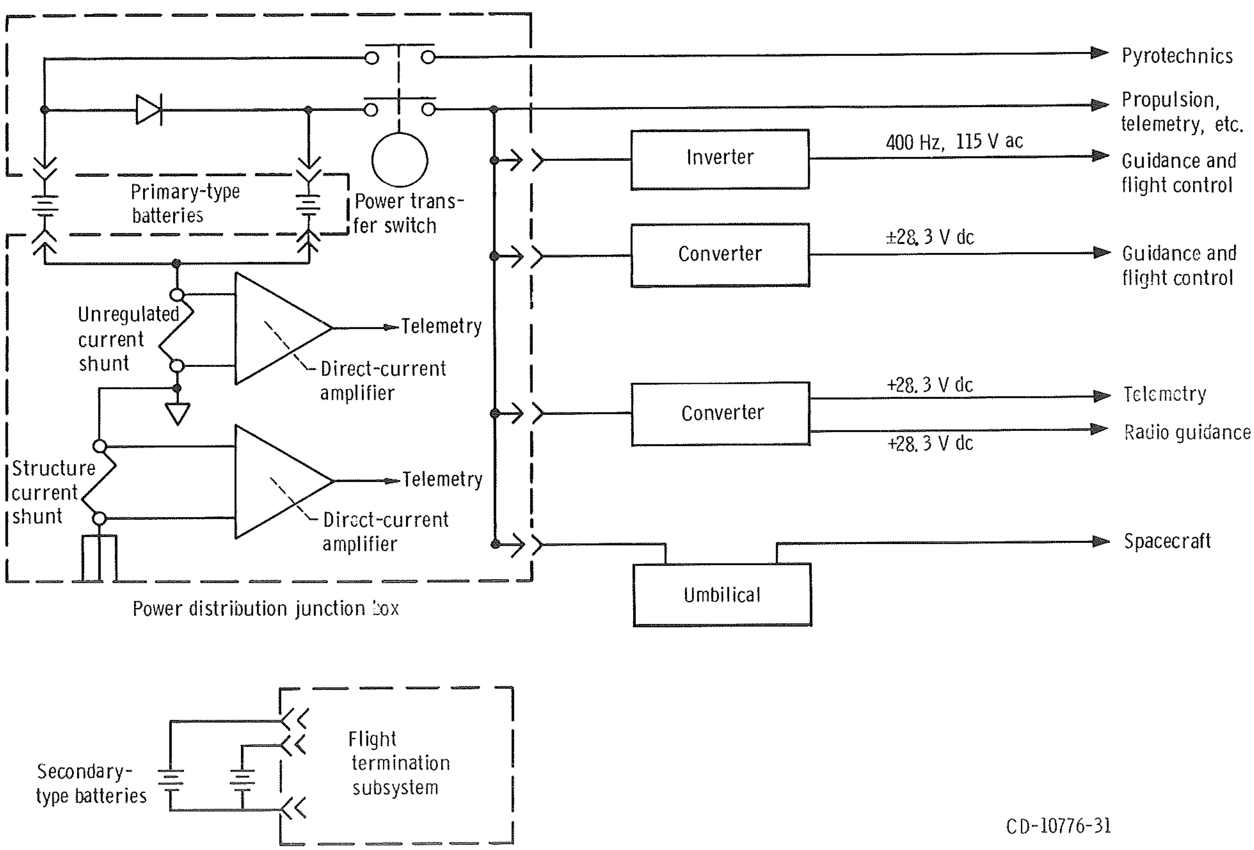


Figure VI-7. - Agena electrical system, OGO-VI.

GUIDANCE AND FLIGHT CONTROL SYSTEM

by Howard D. Jackson

The Agena flight path is controlled by two interrelated systems: the Agena guidance and flight control system and the radio guidance system. The Agena guidance and flight control system directs the Agena, after Thorad-Agena separation, in a preprogrammed open-loop mode. The radio guidance system will supply, if needed, pitch and yaw steering commands during the Agena powered phase. These steering commands provide corrections for vehicle deviations from the desired trajectory. The radio guidance system also provides a discrete command for Agena engine cutoff. The radio guidance system description, location of components, and use during the Thorad phase of flight is provided in Section V, GUIDANCE AND FLIGHT CONTROL SYSTEM.

System Description

The Agena guidance and flight control system consists of three subsystems: a guidance subsystem, a control subsystem, and a timer to provide flight programming. A block diagram of the system is shown in figure VI-8.

The Agena guidance subsystem consists of an inertial reference package (IRP), horizon sensors, a velocity meter, and a guidance junction box. All components of the guidance subsystem are located in the guidance module in the Agena forward section. Primary attitude reference is provided by three orthogonal rate-integrating gyros in the IRP. (These gyros are uncaged at Thorad vernier engine cutoff.) The infrared horizon sensors, consisting of a left and right optical sensor (head) and a mixer box, provide pitch and roll error signals to the IRP. For this mission, the pitch horizon sensor signal is inhibited until after Agena engine cutoff. The Agena yaw attitude is referenced to the attitude of the vehicle at the time of Thorad vernier engine cutoff. The velocity meter consists of an accelerometer, an electronics package, and a counter. The velocity meter accelerometer senses vehicle longitudinal acceleration. The velocity meter electronics processes the acceleration information and produces an output pulse each time the velocity increases by a fixed increment. The velocity meter counter generates an engine cutoff command when a predetermined number of pulses (i.e., the sum of the velocity increments equals the total velocity to be gained) have been received. For this mission, the velocity meter engine cutoff command is a backup for the radio guidance system engine cutoff command. The guidance junction box serves as a center for guidance signals and contains relays for control of operating modes and gains.

The Agena flight control subsystem, which controls vehicle attitude, consists of a flight control electronics unit, a pneumatic (cold gas) attitude control system, a hydraulic attitude control system, and a flight control junction box. Attitude error signals from the IRP are conditioned and amplified by the flight control electronics to operate the cold-gas and hydraulic systems. During Agena nonpowered flight, the cold-gas system consisting of six thrusters provides roll, pitch, and yaw control. These thrusters are located in the Agena aft section and operate on a mixture of nitrogen and tetrafluoromethane. During the Agena powered flight, the hydraulic system provides pitch and yaw control by means of two hydraulic actuators which gimbal the Agena engine thrust chamber; and the cold-gas system provides roll control. A patch panel in the flight control junction box provides the means for preprogramming the interconnections of the guidance and flight control system to meet mission requirements.

The Agena timer programs the Agena flight events and is operated by a three-phase synchronous motor. This timer can program 22 usable discrete events, within a maximum running time of 6000 seconds. Each event controls a group of switches (two, three, or four switches per group) and operates normally open and normally closed contacts in each switch. The timer motor is started before lift-off; however, a brake is engaged which prevents the timer from operating until it is automatically released at Thorad main engine cutoff.

The radio guidance system steering control is transferred from the Thorad to the Agena within the airborne control package at Thorad-Agena separation. All radio guidance system pitch and yaw steering commands (generated by the ground-based computer and transmitted to the Agena) are then routed to the Agena guidance and flight control system. The capability of the Agena guidance and flight system to accept radio guidance system pitch and yaw steering commands is enabled before Agena engine start and disabled after Agena engine cutoff, by the Agena timer.

The radio guidance system provides the discrete command to the Agena for cutoff of the Agena engine. The ground-based computer determines the time for this discrete command, based on in-flight performance of the Thorad and the Agena.

After the radio guidance system has completed its planned period of operation, the airborne components are turned off. For this mission, the Agena timer performs this function 33 seconds after the OGO-VI separation command.

System Performance

The guidance and flight control system performance was satisfactory throughout the flight.

All flight events were initiated within tolerance by the Agena timer. A comparison of the expected and actual times of programmed events is given in appendix A. The rates imparted to the Agena at Thorad-Agena separation (T + 233.4 sec) and the attitude errors at cold-gas activation (T + 236.0 sec) were within the range of values experienced on previous flights, and are shown in the following table:

Rates imparted to Agena at separation, deg/sec			Attitude errors at cold-gas activation, deg		
Yaw	Roll	Pitch	Yaw	Roll	Pitch
Negligible	[a]0.4 CW	1.86 down	0.28 right	[a]0.33 CW	0.2 down

[a]Clockwise roll rate, see fig. VI-9.

The deadband limits of the attitude control system were ±0.2° pitch, ±0.18° yaw, and ±0.6° roll. The yaw attitude error was reduced to within the deadband limit within 5.8 seconds.

At T + 265.8 seconds, the Agena timer initiated a programmed pitchdown rate of 13.21 degrees per minute, which was maintained throughout the Agena powered flight. (See IV. TRAJECTORY AND PERFORMANCE for discussion of pitchdown rates.) For the Agena powered flight, the radio guidance steering was enabled in pitch and yaw, with the horizon sensors controlling only the roll gyro.

Agena engine start was commanded at T + 284.7 seconds, and at this time the vehicle was stable in all axes with the attitude errors within the attitude control system deadbands. Gas generator turbine spinup at Agena engine start resulted in a roll rate and induced a maximum roll displacement error as follows:

Roll rate, deg/sec	Maximum roll error, deg	Time to reverse initial rate, sec
[a]1.82 CW	[a]2.69 CW	2.0

[a]Clockwise roll rate, see fig. VI-9.

Minimal attitude control (hydraulic and cold gas) was required during Agena powered flight, and the vehicle attitude remained very close to gyro null positions. Radio guidance system steering commands were slight in both pitch and yaw.

Engine cutoff occurred by a radio guidance system command at T + 519.0 seconds when the Agena had attained the required velocity increment. The roll transient caused by engine cutoff (i.e., turbine spindown and turbine exhaust decay) was 2.21° counterclockwise. This normal roll transient was reduced to within the attitude control system deadband in 14 seconds. At 11.7 seconds after Agena engine cutoff, the programmed pitch rate was changed to 13.21 degrees per minute pitchup. Simultaneously, the pitch horizon sensor was connected to the pitch gyro to properly orient the vehicle longitudinal axis with respect to the local horizontal. At 68.7 seconds after engine cutoff, the programmed pitch rate was changed to 3.54 degrees per minute pitchdown (geocentric rate). Horizon sensor, gyro, and attitude control data show that the vehicle attained the proper attitude (longitudinal axis parallel to the local horizontal) for OGO-VI separation. Attitude errors were within the deadband limits at OGO-VI separation. Subsequent to OGO-VI separation, the Agena performed a programmed 90° yaw maneuver.

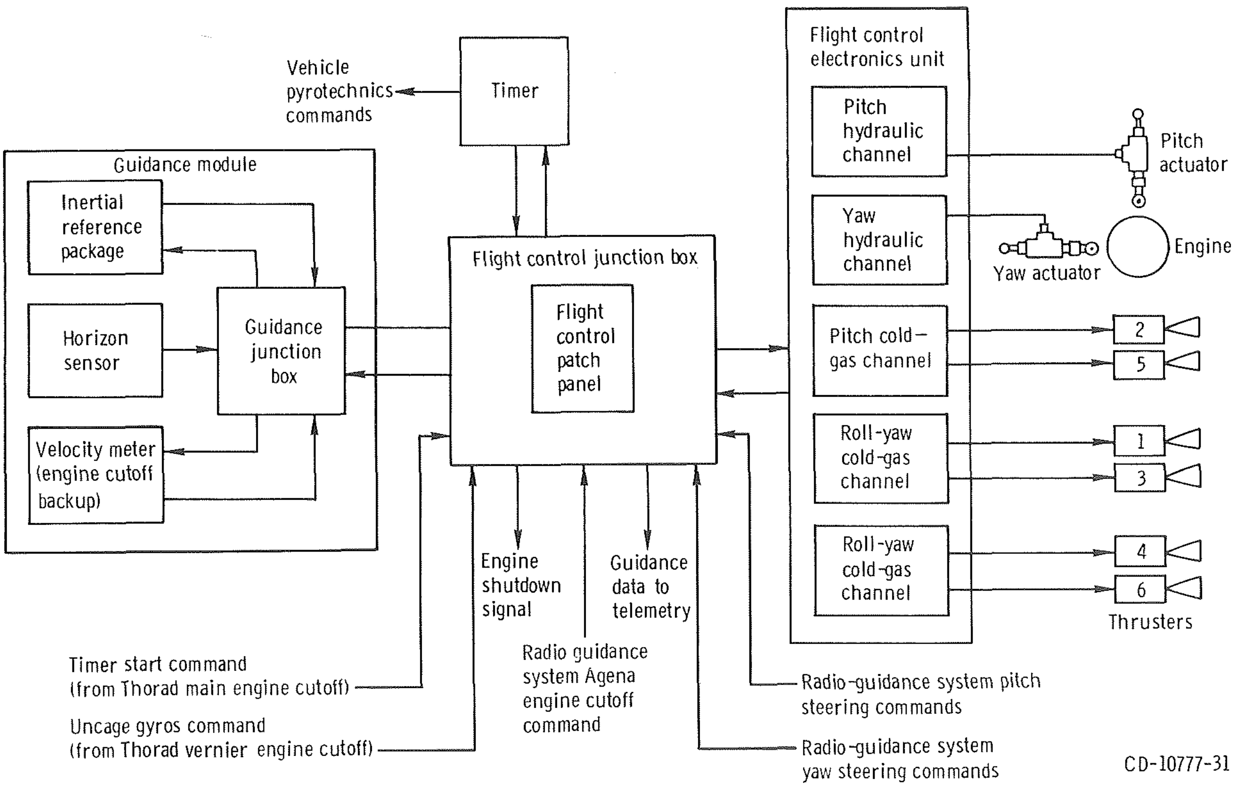


Figure VI-8. - Agena guidance and flight control system block diagram and radio guidance system functions, OGO-VI.

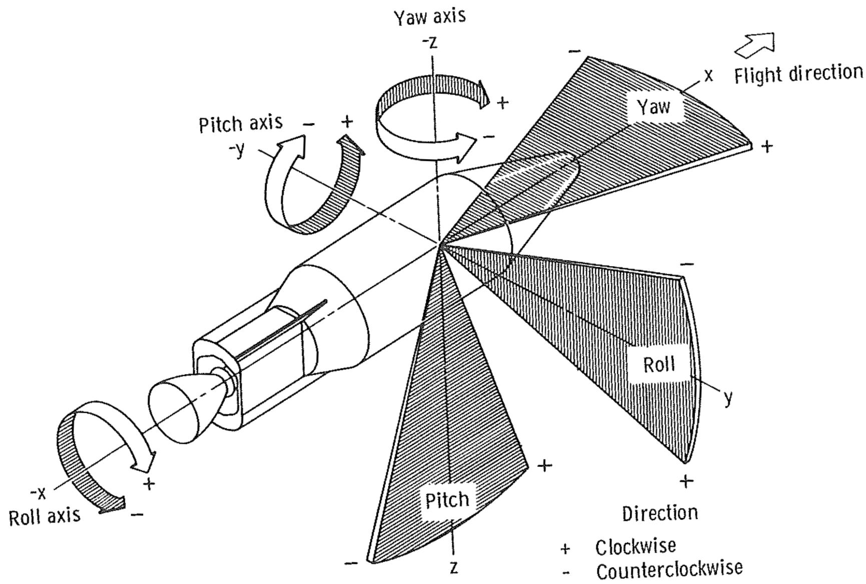


Figure VI-9. - Agena vehicle axes and vehicle movement designations, OGO-VI. (Clockwise (cw) and counter clockwise (ccw) roll reference applies when looking forward along the Agena longitudinal axis.)

COMMUNICATION AND CONTROL SYSTEM

by Richard L. Greene

System Description

The Agena communications and control system consists of telemetry, tracking, and flight termination subsystems with associated power supplies and cabling.

The telemetry subsystem is mounted in the Agena forward section. It monitors and transmits the Agena functional and environmental measurements during flight. The frequency modulation/frequency modulation (FM/FM) telemetry unit contains a transmitter, voltage-controlled oscillators, a cummutator, a switch and calibrate unit, a radiofrequency (RF) switch, and an antenna. Regulated 28 volts dc power for telemetry is supplied from a dc-dc converter. The RF switch connects the telemetry output either to the umbilical for ground checkout or to the antenna for flight. The transmitter operates on a frequency of 244. 3 megahertz at a power output of 2 watts. The telemetry subsystem consists of ten continuous subcarrier channels and two commutated subcarrier channels.

A total of 62 measurements is telemetered from the Agena vehicle. Appendix B summarizes the launch vehicle instrumentation by measurement description. Five continuous subcarrier channels are used for acceleration and vibration data, three continuous channels are used for radio guidance system measurements, one continuous channel for gas thruster valve activity, and one continuous channel is time-shared by the velocity meter accelerometer and the velocity meter counter. The turbine speed signal does not utilize a subcarrier channel but directly modulates the transmitter during engine operation. The remaining 50 measurements are monitored on the two commutated subcarrier channels. These channels are commutated at five revolutions per second with 60 segments on each channel.

The airborne tracking subsystem includes a C-band radar transponder, an RF switch, and an antenna. The transponder receives coded signals from the tracking radar on a carrier frequency of 5630 megahertz and transmits coded responses on a carrier frequency of 5555 megahertz at a minimum pulsed-power output of 200 watts at the input terminals of the antenna. The coded responses are at pulse rates (pulse repetition frequency) from 0 to 1600 pulses per second. The pulse rate is dependent upon the rates transmitted from the ground tracking stations and the number of stations simultaneously interrogating the transponder. The RF switch connects the output of the transponder either to the umbilical for ground checkout or to the antenna for flight.

The Agena flight termination subsystem (located on the booster adapter) provides a range safety flight termination capability for the Agena from lift-off until Thorad-Agena separation. This subsystem is composed of two batteries, interconnecting wiring assemblies, two separation switches, a destruct initiator with two detonators, and a destruct charge. Flight termination can be initiated by a signal either from the Thorad command receivers prior to Thorad-Agena separation, or automatically if Thorad-Agena separation occurs before Thorad main engine cutoff (i.e., prematurely). The automatic portion of the system is disabled at Thorad main engine cutoff to permit a normal Thorad-Agena separation.

A time-delay circuit in the Thorad safe-arm mechanisms ensures destruction of both stages by delaying Thorad destruct initiation until 0.1 second after Agena destruct initiation. Agena destruct is effected by ignition of a shaped charge, mounted on the booster adapter, which ruptures the propellant tanks and causes mixing of the hypergolic propellants.

System Performance

The telemetry subsystem performance was satisfactory throughout the flight. Signal strength data from all ground telemetry stations indicated an adequate and continuous signal level from the vehicle telemetry transmitter from lift-off through the Agena yaw maneuver. Analysis of the telemetry data indicated that the performance of the voltage-controlled oscillators, the switch and calibrate unit, the dc-dc converter, and the commutator were satisfactory. Usable data were obtained from all Agena telemetered instrumentation. Appendix C (fig. C-2) presents the coverage provided by the supporting telemetry stations.

The tracking subsystem performance was satisfactory throughout the flight. The C-band transponder transmitted a continuous response to received interrogations for the required tracking periods.

The Agena flight termination subsystem was not monitored during flight. However, because of the system redundancy, it is assumed the system was capable of destructing the Agena throughout the Thorad powered phase.

VII. LAUNCH OPERATIONS

by Frank E. Gue

PRELAUNCH ACTIVITIES

The major prelaunch events at the Western Test Range (WTR) are shown in table VII-I. During prelaunch tests, the following significant problems occurred and were satisfactorily resolved:

(1) An electrical short was found in the Thorad vehicle wire harness that connects the control electronic assembly to the rate distribution junction box. The harness was replaced.

(2) An electrical short in the Thorad-fuel-tank-pressurizing solenoid valve caused damage to the vehicle dc junction box. This valve and an identical redundant valve were replaced with modified valves. The dc junction box was removed from the vehicle, repaired, and reinstalled.

(3) The Thorad control electronics assembly was replaced because of unexplained transient voltages.

(4) The Agena inverter was replaced because of an out-of-specification voltage on phase BC.

(5) The Agena flight control electronics assembly was replaced because of intermittent noise on the yaw servomonitor channel.

COUNTDOWN AND LAUNCH

The Thorad-Agena successfully lifted off with OGO-VI from Space Launch Complex 2 East, Vandenberg Air Force Base, on June 5, 1969 at 0642:45. 37 Pacific standard time. No significant vehicle or ground system problems were encountered during the countdown. One technical hold of 10 minutes duration was imposed at T + 7 minutes. This hold was required because of an antenna problem on the Range Instrumentation Ship Swordknot.

TABLE VII-I. - MAJOR PRELAUNCH EVENTS, OGO-VI

Date	Event
9/19/68	Thorad arrived at Vandenberg Air Force Base
3/03/69	Agena arrived at Vandenberg Air Force Base
3/29/69	Spacecraft arrived at Vandenberg Air Force Base
4/24/69	Thorad on stand
4/28/69	Agena on stand
5/09/69	Thorad-Agena mating
5/12/69	Thorad-Agena erection
5/14/69	Agena-spacecraft mating
5/22/69	Simulated countdown
6/04/69	Countdown initiation
6/05/69	Launch

VIII. CONCLUDING REMARKS

The Orbiting Geophysical Observatory VI (OGO-VI) was the last in a series of six planned missions for the Orbiting Geophysical Observatory Program and was launched on June 5, 1969.

The Thorad-Agena launch vehicle successfully placed the 620-kilogram scientific experimentation satellite into the desired near-polar elliptical orbit with a perigee altitude of 399 kilometers and an apogee altitude of 1099 kilometers, at an inclination of 82^{o} to the equator. The satellite will perform 26 different experiments designed to gather scientific data on neutral and charged particles, on cosmic rays, on magnetic fields, and on various other ionsphere phenomenon.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, May 19, 1970,
493-01.

APPENDIX A

SEQUENCE OF MAJOR FLIGHT EVENTS, OGO-VI

by Richard L. Greene

Nominal time, sec	Actual time, sec	Event	Initiated by-	Event monitor[a]
0	0	Lift-off (0642:45.37 pst)	-----------------------	Lift-off switch
38.6	37.2	Solid-propellant rocket motor burnout	-----------------------	Solid-motor chamber pressure[b]
102.0	102.1	Solid-propellant rocket motor case jettison	Thorad timer	Sequence 3[b]
219.9	217.7	Thorad main engine cutoff	Radio guidance	Main engine chamber pressure[b]
219.9	217.7	Start Agena timer	Thorad main engine cutoff	Guidance and control monitor (D14)
228.9	226.7	Vernier engine cutoff and Agena horizon sensor fairing jettison	Thorad time-delay relay	Vernier engine chamber pressure[b]
235.4	233.4	Thorad-Agena separation	Radio guidance	Longitudinal acceleration (PL30)
235.7	233.7	Transfer radio guidance steering to Agena and connect horizon sensor roll output to roll gyro	Pullaway plug	Radio guidance steering relay (BTL5)
237.9	236.0	Activate pneumatic attitude control system	Separation switch	Guidance and control monitor (D14)
238.9	-----	Enable radio guidance system yaw steering	Agena timer	(c)
267.9	265.8	Initiate -13.21-deg/min pitch rate		Pitch torque rate (D73)
267.9	265.8	Enable radio guidance system pitch steering		(c)
286.9	284.7	Agena engine start		Switch group Z (B13)
288.1	285.9	Agena engine at 90-percent chamber pressure	Chamber pressure	Chamber pressure (B91)
296.9	294.7	Shroud separation	Agena timer	Shroud separation monitor (AD032)
523.5	519.0	Agena engine cutoff	Radio guidance	Chamber pressure (B91)
532.9	530.7	Transfer to +13.21-deg/min pitch rate and connect horizon sensor pitch output to pitch gyro	Agena timer	Pitch torque rate (D73)
589.9	587.7	Transfer to -3.54-deg/min pitch rate		Pitch torque rate (D73)
630.9	628.7	Agena-spacecraft separation		Spacecraft separation monitor (PL60)
633.9	631.7	Initiate +180-deg/min yaw rate		Yaw torque rate (D51)
663.9	661.7	Remove yaw rate		Yaw torque rate (D51)

[a]All events except those noted were monitored on Agena telemetry. The designation in parentheses is the monitor measurement designation. (See appendix B for the measurement range and channel assignment.)
[b]These events were identified from the Thorad telemetry data.
[c]No direct measurement to identify the event.

APPENDIX B

LAUNCH VEHICLE INSTRUMENTATION SUMMARY, OGO-VI

by Richard L. Greene and Richard E. Orzechowski

THORAD TELEMETRY

Measurement number	Measurement title	Channel number	Measurement range	
			SI units	U.S. customary units
FM-1-01	Inverter frequency	1	370.0 to 430 Hz	
FM-1-09	Vernier engine 2 chamber pressure, absolute	9	0 to 344.5 N/cm^2	0 to 500 psi
FM-1-10	Sequence 2;	10	0 to 5.00 V	
	Solid-motor ignition arm			
	Solid-motor ignition			
	Solid-motor jettison arm			
	Solid-motor jettison command			
FM-1-11	Main engine chamber pressure, absolute	11	0 to 551.5 N/cm^2	0 to 800 psi
FM-1-12	Sequence 1;	12	0 to 5.00 V	
	Programmer start			
	Liquid-oxygen-tank float switch			
	Fuel-tank float switch			
	Main engine cutoff			
	Vernier engine cutoff			
FM-1-13	Solid-motor 1 chamber pressure, absolute	13	0 to 551.5 N/cm^2	0 to 800 psi
FM-1-A	Solid-motor 3 chamber pressure, absolute	A	0 to 551.5 N/cm^2	0 to 800 psi
FM-1-C	Solid-motor 2 chamber pressure, absolute	C	0 to 551.5 N/cm^2	0 to 800 psi
PDM-1-01	5-Volt transducer calibrations voltage	Ch E, seg 1	0 to 5.00 V	
PDM-1-02	Instrumentation ground	Ch E, seg 2	0 to 5.00 V	
PDM-1-03	Main engine pitch position	Ch E, seg 3	-5.00° to 5.00°	
PDM-1-04	Main engine yaw position	Ch E, seg 4	-5.00° to 5.00°	
PDM-1-05	Vernier engine 1 pitch-roll position	Ch E, seg 5	-45.0° to 45.0°	
PDM-1-06	Vernier engine 1 yaw position	Ch E, seg 6	-28.0° to -8.0°	
PDM-1-07	Vernier engine 2 pitch-roll position	Ch E, seg 7	-45.0° to 45.0°	
PDM-1-08	Vernier engine 2 yaw position	Ch E, seg 8	8.0° to 28.0°	
PDM-1-09	Pitch attitude error	Ch E, seg 9	-5.00° to 5.00°	
PDM-1-10	Yaw attitude error	Ch E, seg 10	-5.00° to 5.00°	
PDM-1-11	Roll attitude error	Ch E, seg 11	-7.00° to 7.00°	
PDM-1-12	Pitch rate	Ch E, seg 12	-5.00 to 5.00 deg/sec	
PDM-1-13	Yaw rate	Ch E, seg 13	-5.00 to 5.00 deg/sec	
PDM-1-14	Roll rate	Ch E, seg 14	-8.00 to 8.00 deg/sec	
PDM-1-15	Pitch command	Ch E, seg 15	-4.00 to 4.00 deg/sec	
PDM-1-16	Yaw command	Ch E, seg 16	-4.00 to 4.00 deg/sec	
PDM-1-17	Actuator potentiometer positive voltage	Ch E, seg 17	0 to 30.0 V	
PDM-1-18	Actuator potentiometer negative voltage	Ch E, seg 18	-30.0 to -13.0 V	
PDM-1-19	400-Hertz phase-A inverter voltage	Ch E, seg 19	109.0 to 121.0 V	
PDM-1-20	5-Volt potentiometer excitation voltage	Ch E, seg 20	0 to 5.00 V	
PDM-1-21	Control electronic amplifier plus 165 volts dc	Ch E, seg 21	0 to 200 V	
PDM-1-22	Main engine chamber pressure, absolute	Ch E, seg 22	0 to 551.5 N/cm^2	0 to 800 psi
PDM-1-23	Main-battery voltage	Ch E, seg 23	0 to 32.0 V	
PDM-1-24	Telemetry-battery voltage	Ch E, seg 24	0 to 32.0 V	
PDM-1-25	Hydraulic supply pressure, absolute	Ch E, seg 25	0 to 2756 N/cm^2	0 to 4000 psi
PDM-1-26	Hydraulic return pressure, absolute	Ch E, seg 26	0 to 137.8 N/cm^2	0 to 200 psi
PDM-1-27	Turbopump speed	Ch E, seg 27	0 to 8000 rpm	
PDM-1-28	Turbine inlet temperature	Ch E, seg 28	144.4 to 1255.4 K	-200° to 1800° F
PDM-1-29	Fuel-pump inlet pressure, absolute	Ch E, seg 29	0 to 137.8 N/cm^2	0 to 200 psi
PDM-1-30	Sequence 3:	Ch E, seg 30	0 to 5.00 V	
	Solid motor 1 jettisoned			
	Solid motor 2 jettisoned			
	Solid motor 3 jettisoned			
PDM-1-31	Vernier engine 1 housing temperature (left)	Ch E, seg 31	255 to 810.9 K	0° to 1000° F
PDM-1-32	Vernier engine 2 housing temperature (right)	Ch E, seg 32	255 to 810.9 K	0° to 1000° F
PDM-1-33	Engine pneumatic bottle pressure, absolute	Ch E, seg 33	0 to 3447 N/cm^2	0 to 5000 psi
PDM-1-34	Control electronics amplifier - 165 V dc	Ch E, seg 34	-200 to 0 V	
PDM-1-35	Rate-gyro-cover inner-wall temperature	Ch E, seg 35	213 to 623 K	-76° to 662° F
PDM-1-36	Skin temperature (center body section)	Ch E, seg 36	213 to 623 K	-76° to 662° F
PDM-1-37	Flight-termination-receiver 1 automatic gain control voltage	Ch E, seg 37	0 to 5 V	
PDM-1-38	Flight-termination-receiver 2 automatic gain control voltage	Ch E, seg 38	0 to 5 V	
PDM-1-39	Liquid-oxygen-pump inlet pressure, absolute	Ch E, seg 39	0 to 68.9 N/cm^2	0 to 100 psi
PDM-1-40	Main-fuel-tank top pressure, absolute	Ch E, seg 40	0 to 68.9 N/cm^2	0 to 100 psi
PDM-1-41	Gas-generator liquid-oxygen injector pressure, absolute	Ch E, seg 41	0 to 551.5 N/cm^2	0 to 800 psi
PDM-1-42	Liquid-oxygen-tank top pressure, absolute	Ch E, seg 42	0 to 68.9 N/cm^2	0 to 100 psi
PDM-1-43	Liquid-oxygen-pump inlet temperature	Ch E, seg 43	88 to 102.6 K	-300.0° to -275.0° F

AGENA TELEMETRY

Measurement number	Measurement title	Channel number[a]	Measurement range	
			SI units	U.S. customary units
AD032	Shroud separation monitor	15-44	(b)	
AD040	Inside shroud temperature, station -21.88	16-20	273 to 533 K	32° to 500° F
AD042	Inside shroud temperature, station -236.4	16-22	273 to 533 K	32° to 500° F
AD044	Inside shroud temperature, station -125.4	16-24	273 to 533 K	32° to 500° F
AD045	Inside shroud temperature, station -44.0	16-26	273 to 533 K	32° to 500° F
B1	Fuel-pump inlet pressure, gage	15-15	0 to 68.9 N/cm^2	0 to 100 psi
B2	Oxidizer-pump inlet pressure, gage	15-17	0 to 68.9 N/cm^2	0 to 100 psi
B11	Oxidizer-venturi inlet pressure, absolute	15-19/49	0 to 1034 N/cm^2	0 to 1500 psi
B12	Fuel-venturi inlet pressure, absolute	15-23/53	0 to 1034 N/cm^2	0 to 1500 psi
B13	Switch group Z (propulsion system monitor)	15-7/22/37/52	(b)	
B31	Fuel-pump inlet temperature	15-6	255 to 311 K	0° to 100° F
B32	Oxidizer-pump inlet temperature	15-8	255 to 311 K	0° to 100° F
B35	Turbine speed	(c)	0 to 600 Hz	
B91	Combustion-chamber pressure, gage	15-4/34	328 to 379 N/cm^2	475 to 550 psi
BTL1	Radio-guidance magnetron monitor	9	(b)	
BTL2	Radio-guidance combined events monitor	13	(b)	
BTL4	Radio-guidance automatic gain control monitor	8	-70 to 0 dBm	
BTL5	Radio-guidance steering relay monitor	16-30	(b)	
BTL6	Radio-guidance regulated plus 28 V dc	16-19/49	22 to 30 V dc	
C1	28-V dc unregulated supply	16-40	22 to 30 V dc	
C2	+28-V dc regulated (telemetry)	16-33	22 to 30 V dc	
C3	+28-V dc regulated (guidance and control)	15-12	22 to 30 V dc	
C4	28-V dc unregulated current	16-13/44	0 to 100 A	
C5	-28-V dc regulated (guidance and control)	15-30	-30 to -22 V dc	
C21	400 Hz, three phase; inverter temperature	15-14	255 to 367 K	0° to 200° F
C31	400 Hz, three phase; phase AB voltage	15-18	90 to 130 V ac	
C32	400 Hz, three phase; phase BC voltage	15-20	90 to 130 V ac	
C38	Structure current	15-10/25/40/55	0 to 50 A	
C141	Pyrotechnic bus voltage	15-5/35	22 to 30 V dc	
D14	Guidance and control monitor	16-27	(b)	
D41	Horizon sensor pitch output	16-45	-5° to 5°	
D42	Horizon sensor roll output	16-46	-5° to 5°	
D46	Gas valve cluster 1, temperature	15-39	228 to 339 K	-50° to 150° F
D47	Gas valve cluster 2, temperature	15-36	228 to 339 K	-50° to 150° F
D51	Yaw torque rate	16-38	-200 to 200 deg/min	
D54	Horizon sensor head temperature (right hand)	15-47	228 to 367 K	-50° to 200° F
D55	Horizon sensor head temperature (left hand)	15-46	228 to 367 K	-50° to 200° F
D59	Control gas supply pressure, absolute	16-47	0 to 2758 N/cm^2	0 to 4000 psi
D60	Hydraulic oil pressure, gage	15-21	0 to 2758 N/cm^2	0 to 4000 psi
D66	Roll torque rate	16-41	-50 to 50 deg/min	
D68	Pitch actuator position	15-3	-2.5° to 2.5°	
D69	Yaw actuator position	15-24	-2.5° to 2.5°	
D72	Pitch gyro output	16-36	-10° to 10°	
D73	Pitch torque rate	16-35	-200 to 200 deg/min	
D74	Yaw gyro output	16-39	-10° to 10°	
D75	Roll gyro output	16-42	-10° to 10°	
D83	Velocity-meter accelerometer	14	0 to 2000 pulses/sec	
D86	Velocity-meter cutoff switch	16-28	(b)	
D88	Velocity-meter counter	14	Binary code (50 bits/sec)	
D129	Inertial reference package internal case temperature	15-54	255 to 341 K	0° to 155° F
D149	Gas valves 1 to 6 monitor	7	(d)	
H47	Beacon-receiver pulse repetition rate	15-27	0 to 1600 pulses/sec	
H48	Beacon-transmitter pulse repetition rate	15-28	0 to 1600 pulses/sec	
PL2	Shroud differential pressure	16-18	-1.7 to 1.7 N/cm^2	-2.5 to 2.5 psi
PL3	Shroud internal pressure, absolute	16-12	0 to 10.3 N/cm^2	0 to 15 psi
PL20	Longitudinal vibration	18	-50 to 50 g's	
PL22	Lateral vibration (Z axis)	17	-50 to 50 g's	
PL30	Longitudinal acceleration	11	-4 to 12 g's	
PL33	Radial acceleration (Z axis)	12	-5 to 5 g's	
PL31	Radial acceleration (Y axis)	10	-5 to 5 g's	
PL50	Explosive bolt actuation monitor	16-31	(b)	
PL60	Payload separation monitor	16-54	(b)	

[a]The first number indicates the Inter-Range Instrumentation Group (IRIG) subcarrier channel used. The second number indicates the commutated position for the measurement. If no second number is indicated, the channel was used continuously for the designated transducer.

[b]Events are determined by a step change in voltage.

[c]The turbine speed signal does not utilize a subcarrier channel but directly modulates the transmitter during engine operation.

[d]A unique voltage level is associated with any one or a combination of several gas valve firings.

APPENDIX C

TRACKING AND DATA ACQUISITION

by Richard L. Greene

The launch vehicle trajectory as projected on a world map is presented in figure C-1. The land based radar and telemetry tracking stations that provided data coverage for the ascent phase of OGO-VI were the Western Test Range and the NASA Telemetry Station at Vandenberg Air Force Base, the Point Mugu and San Nicolas Island stations at Pacific Missile Range, and the Manned Space Flight Network (MSFN) station at Guaymas, Mexico. In addition to these land stations, a Range Instrumentation Ship (RIS Swordknot) located in the Pacific Ocean provided telemetry coverage. The Agena final orbit, after OGO-VI - Agena separation, was determined by radar data coverage provided by the Eastern Test Range (ETR) station at Pretoria, South Africa.

TELEMETRY DATA

Telemetry signals from the Thorad-Agena launch vehicle were received and recorded on magnetic tape at tracking stations continuously from lift-off through the Agena yaw maneuver that followed OGO-VI - Agena separation. The data recorded on magnetic tape at each supporting station were used for postflight analysis of the launch vehicle performance. Real-time monitoring at the launch site of all Thorad and Agena telemetry measurements from lift-off through Agena engine cutoff, permitted verification of the occurrence of the launch vehicle flight events and a quick-look evaluation of the launch vehicle performance. OGO-VI - Agena separation and the Agena yaw maneuver were monitored by the RIS Swordknot and the MSFN station at Guaymas. The times for OGO-VI - Agena separation and for the yaw maneuver were voice-reported to Vandenberg Air Force Base by radio and cable communication circuits. Figure C-2 shows the specific time internal of telemetry coverage provided by each station.

RADAR DATA

C-band radar data (time, elevation, azimuth, and range) were provided for both real-time operations and postflight analysis. The radar data was processed in real time to permit monitoring the launch vehicle flight performance for range safety purposes and for generating information to assist the Pretoria station in acquiring radar track of the vehicle approximately one-half orbit after injection. These data were also used for computation of orbital elements and injection conditions after Agena engine cutoff, and for the Agena final orbit after OGO-VI - Agena separation. Figure C-3 shows the specific time intervals of radar coverage provided by each of the supporting stations.

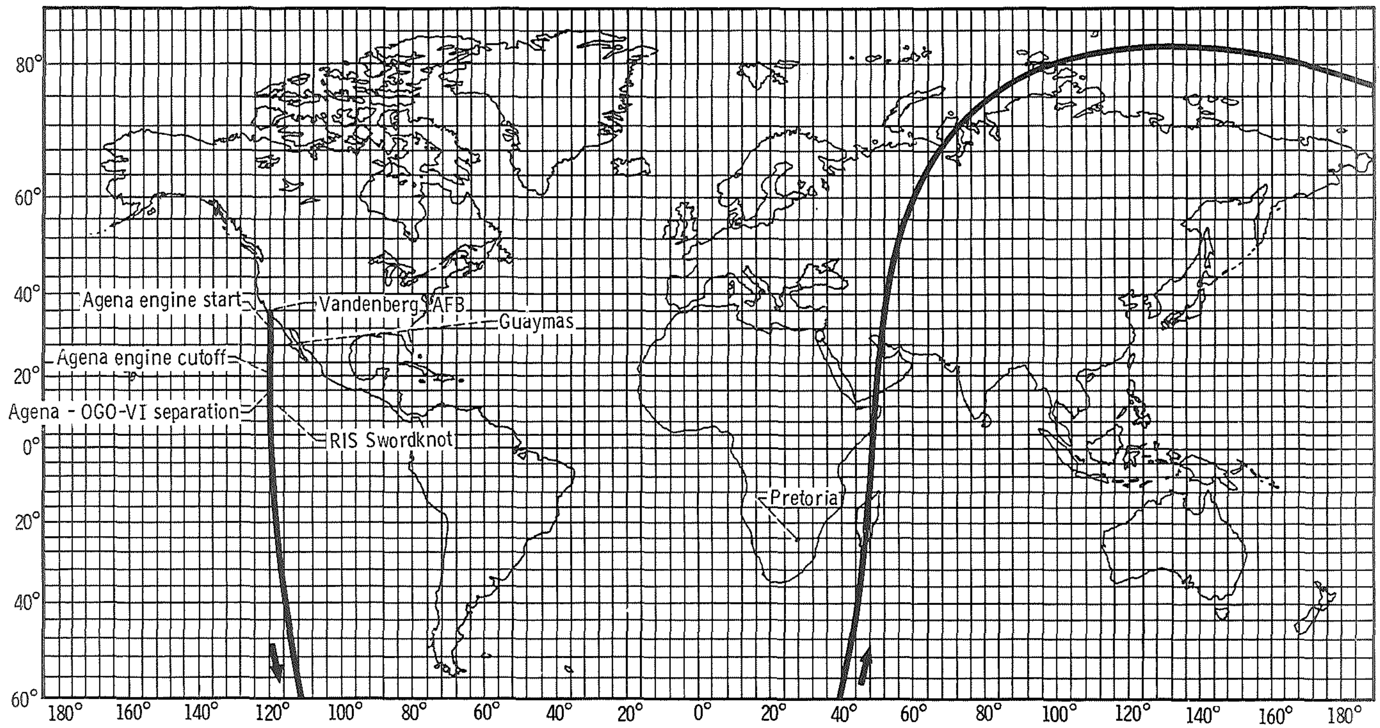


Figure C-1. - Ground trace of OGO-VI launch.

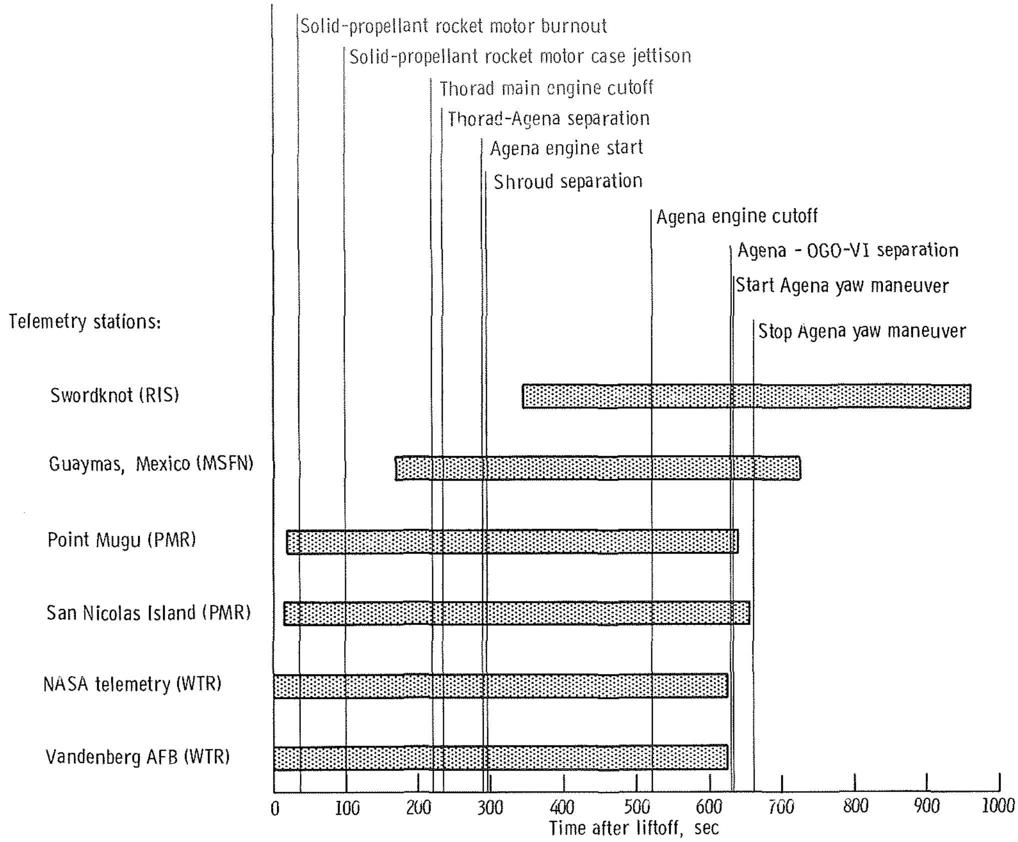


Figure C-2. - Launch vehicle telemetry coverage, OGO-VI.

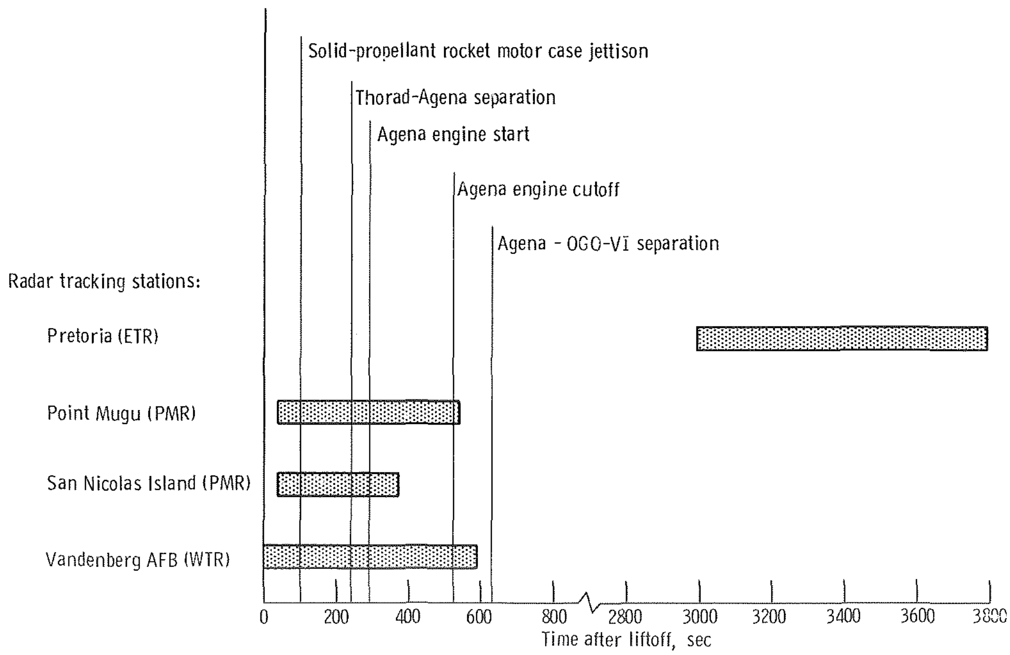


Figure C-3. - Launch vehicle radar coverage, OGO-VI.

APPENDIX D

VEHICLE FLIGHT DYNAMICS

by Dana H. Benjamin

Flight dynamics data were obtained from three accelerometers installed in the Agena forward section and from two vibration transducers on the spacecraft adapter. A summary of dynamic instrumentation locations and characteristics is presented in figure D-1.

Table D-I presents the actual flight times at which significant dynamic disturbances were recorded. Table D-II shows the maximum acceleration levels and corresponding frequencies recorded at times of significant dynamic disturbances during flight. All acceleration levels are shown in g's zero to peak.

Data traces of the dynamic environment recorded by all five instruments for the events summarized in table D-II are presented in figures D-2 to D-12.

TABLE D-I. - SUMMARY OF DYNAMIC

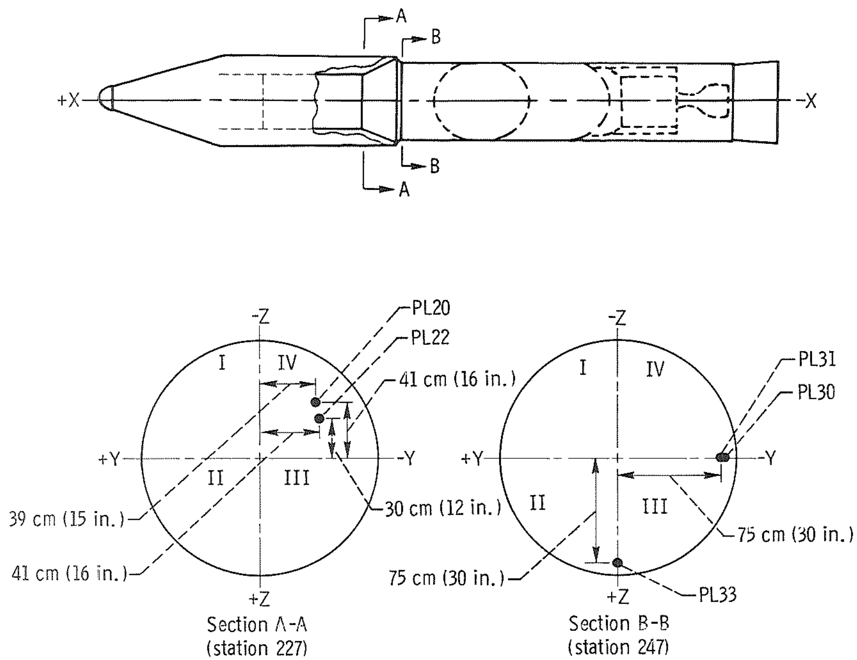
DISTURBANCES, OGO-VI

Dynamic disturbance	Time of dynamic disturbance, sec after lift-off
Lift-off	0.67
During transonic region	37.58
Solid-propellant rocket motor case jettison	102.37
Peak longitudinal oscillation (POGO)	205.03
Thorad main engine cutoff	217.90
Agena horizon sensor fairing jettison	226.70
Thorad-Agena separation	233.40
Agena engine start	285.62
Shroud separation	294.69
Agena engine cutoff	519.00
Agena - OGO-VI separation	628.71

TABLE D-II. - SUMMARY OF DYNAMIC ENVIRONMENT, OGO-VI

Dynamic disturbance	Time of dynamic disturbance, sec after lift-off	Accelerometer						Vibrometer			
		Channel 10		Channel 11		Channel 12		Channel 17		Channel 18	
		Measurement									
		PL-31 Radial (Y-axis)		PL-30 Longitudinal (X-axis)		PL-33 Radial (Z-axis)		PL-22 Lateral (Z-axis)		PL-20 Longitudinal (X-axis)	
		g's (zero to peak)	Frequency, Hz	g's (zero to peak)	Frequency, Hz	g's (zero to peak)	Frequency, Hz	g's (zero to peak)	Frequency, Hz	g's (zero to peak)	Frequency, Hz
Lift-off	0.67	0.5	110	0.8	140	1.6	420	5	800	4	800
During transonic region	37.58	[a].4 .8	[a]600 60	2.6	54	2.2	420	4	600	4	1000
Solid-propellant rocket motor case jettison	102.37	.08	27	(b)	(b)	.4	420	(b)	(b)	(b)	(b)
Peak longitudinal oscillation (POGO)	205.03	.1	360	3.9 [c]5.0	17.6	[a].4 .4	[a]420 35.6	(b)	(b)	4.6	17.6
Thorad main engine cutoff	217.90	.2	120	.4	120	.3	110	(b)	(b)	(b)	(b)
Agena horizon sensor fairing jettison	226.70	[a].5 1.8	[a]610 310	[a].8 2.4 2.4	[a]600 220 110	[a]2.0 [d]4.0	[a]110 [d]220	18	800	14	600
Thorad-Agena separation	233.40	[a].5 .5	[a]650 110	1.5	110	[a]1.5 1.6 2.1	[a]500 400 330	26	1000	20	800 to 1000
Agena engine start	285.62	.2	85	.8	80	.4	110	(b)	(b)	(b)	(b)
Shroud separation	294.69	2.0	130	5.6	140	2.9	360	54	1000	50	1000
Agena engine cutoff	519.00	.9	170	1.4	100	1.9	140	3	360	4	800
Agena - OGO-VI separation	628.71	.9	400	1.9	240	[e]~5	180	48	450	45	1100

[a]Indicates frequencies and acceleration levels of two or more superimposed vibrations.
[b]No detectable response.
[c]Steady-state value.
[d]Single pulse.
[e]The amplitude of one "spike" exceeded the 5 g's instrumentation calibration.



Channel	Measurement			Frequency response, Hz	Range, g's	Transducer sensitive axis
	Description	Number	Station			
10	Y-axis acceleration	PL31	247	0 to 130	±5	Y-direction
11	X-axis acceleration	PL30	247	0 to 130	-4 to +12	X-direction
12	Z-axis acceleration	PL33	247	0 to 130	±5	Z-direction
17	Z-axis vibration	PL22	227	20 to 1500	±50	Z-direction
18	X-axis vibration	PL20	227	20 to 2000	±50	X-direction

Figure D-1. - Dynamic instrumentation location, OGO-VI.

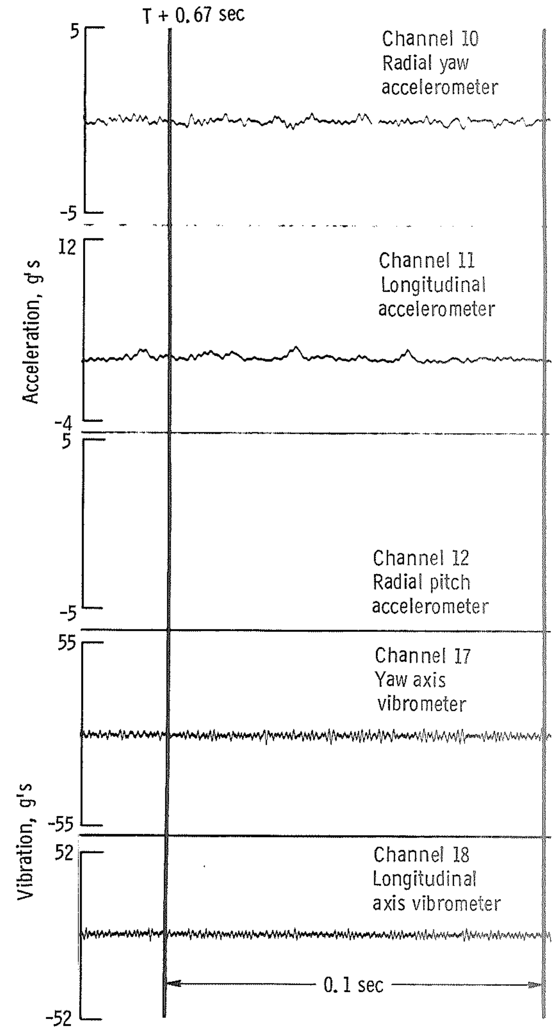


Figure D-2. - Dynamic data near lift-off, OGO VI.

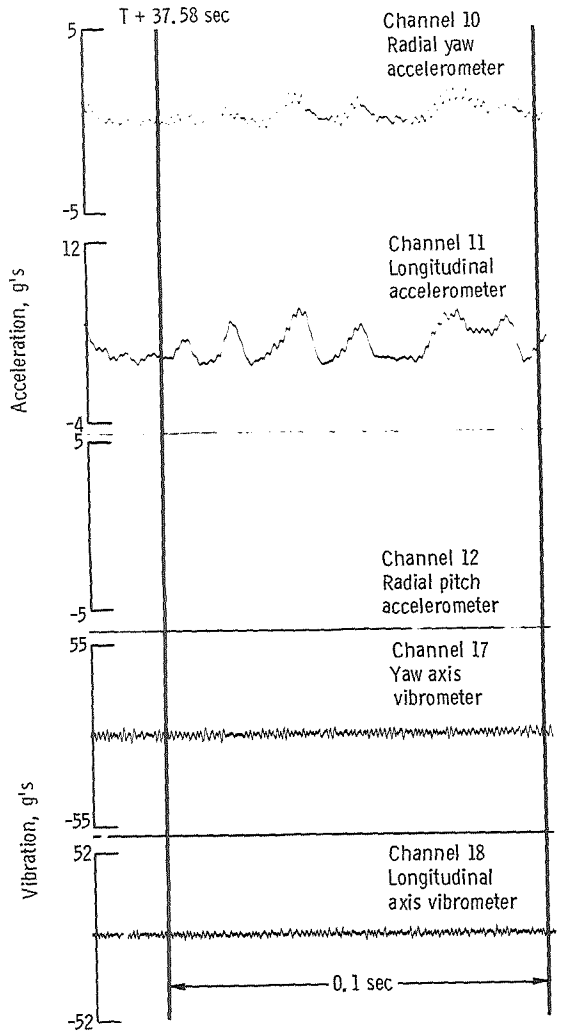


Figure D-3. - Dynamic data during transonic region, OGO-VI.

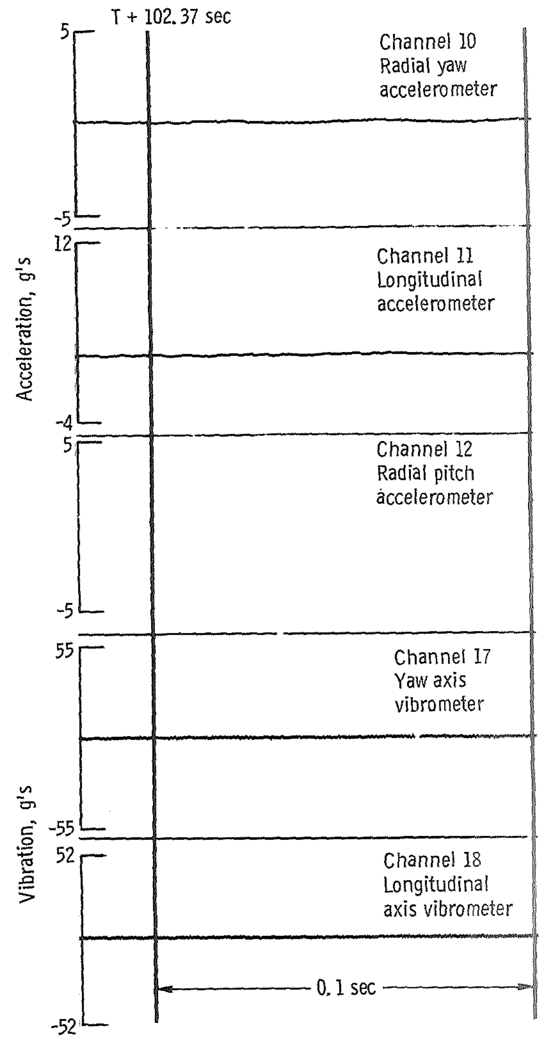


Figure D-4. - Dynamic data near solid-propellant rocket motor case jettison, OGO-VI.

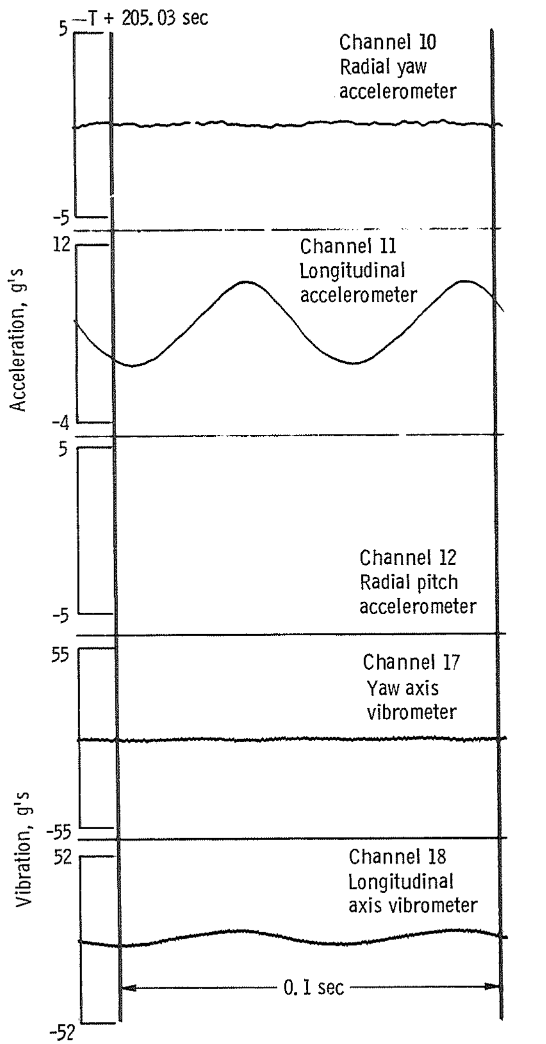


Figure D-5. - Dynamic data at peak longitudinal oscillation (POGO), OGO-VI.

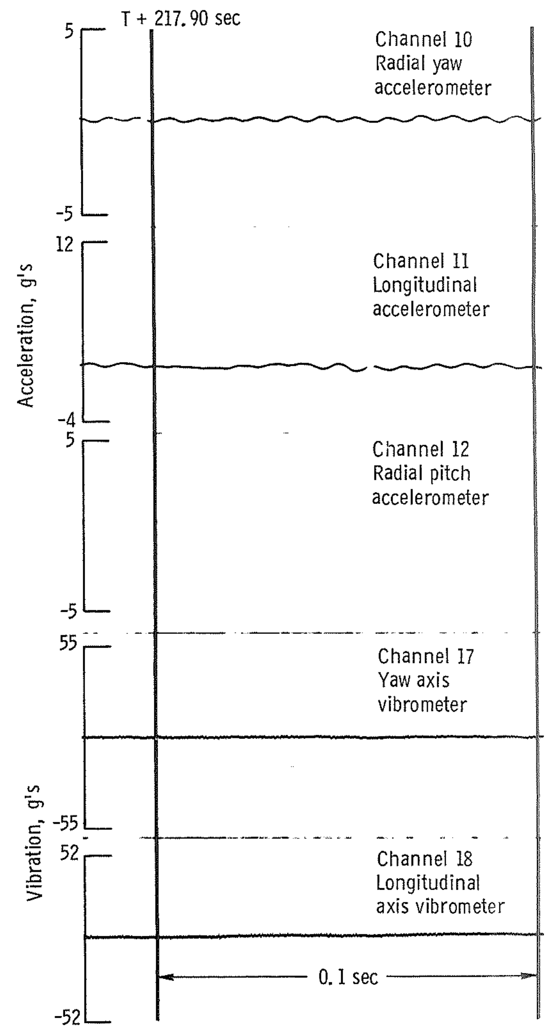


Figure D-6. - Dynamic data near Thorad main engine cutoff, OGO-VI.

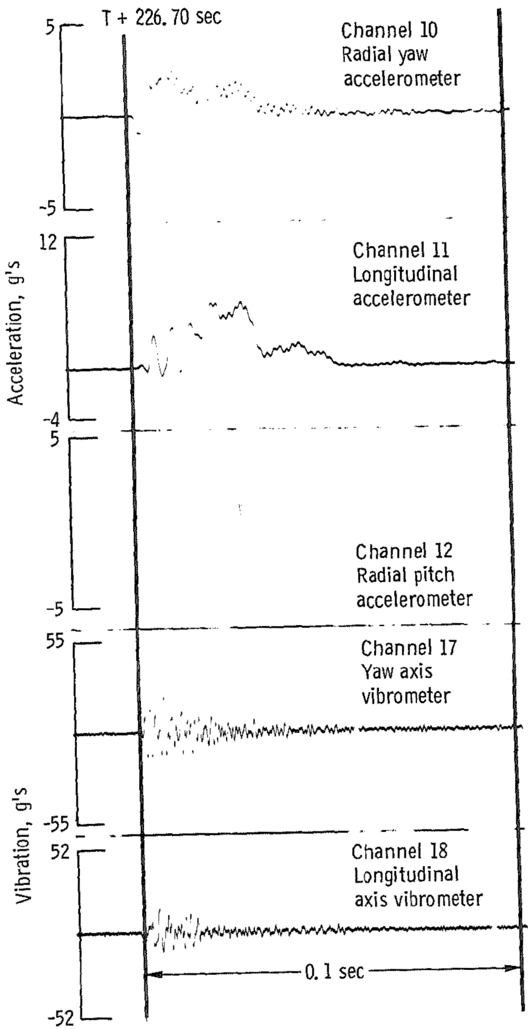


Figure D-7. - Dynamic data at Agena horizon sensor fairing jettison, OGO-VI.

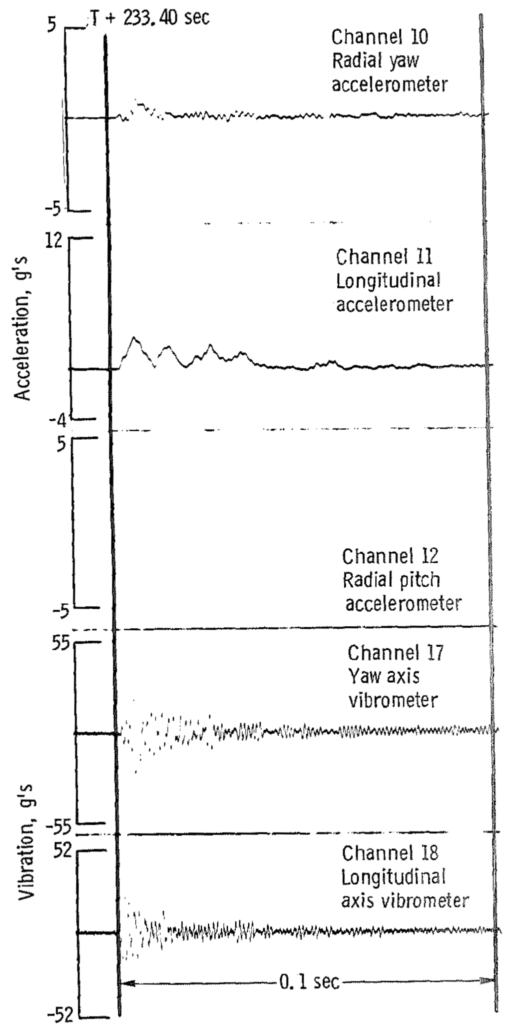


Figure D-8. - Dynamic data at Thorad-Agena separation, OGO-VI.

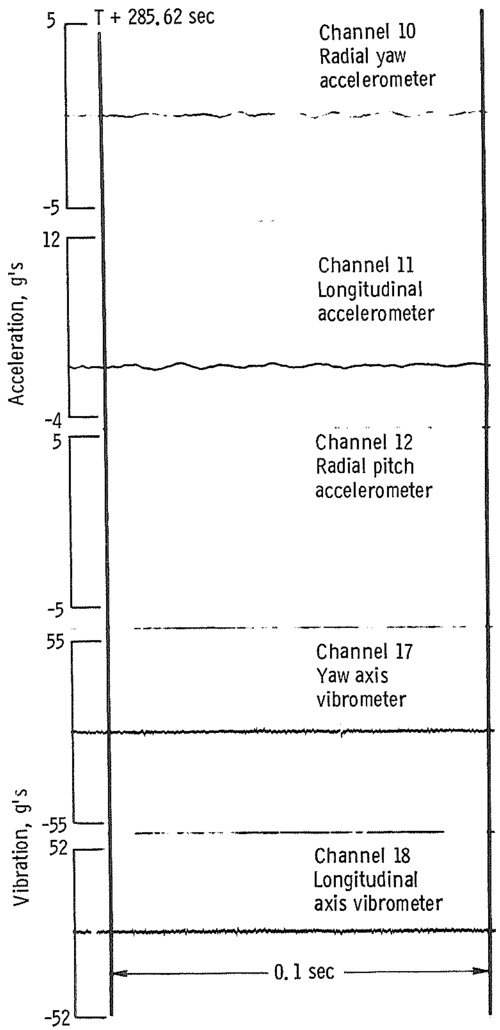


Figure D-9. - Dynamic data near Agena engine start, OGO-VI.

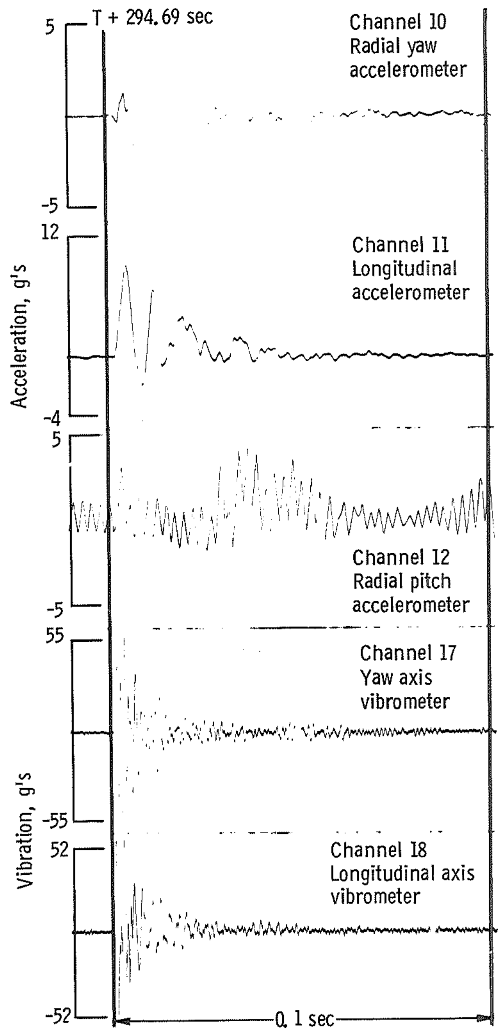


Figure D-10. - Dynamic data at shroud separation, OGO-VI.

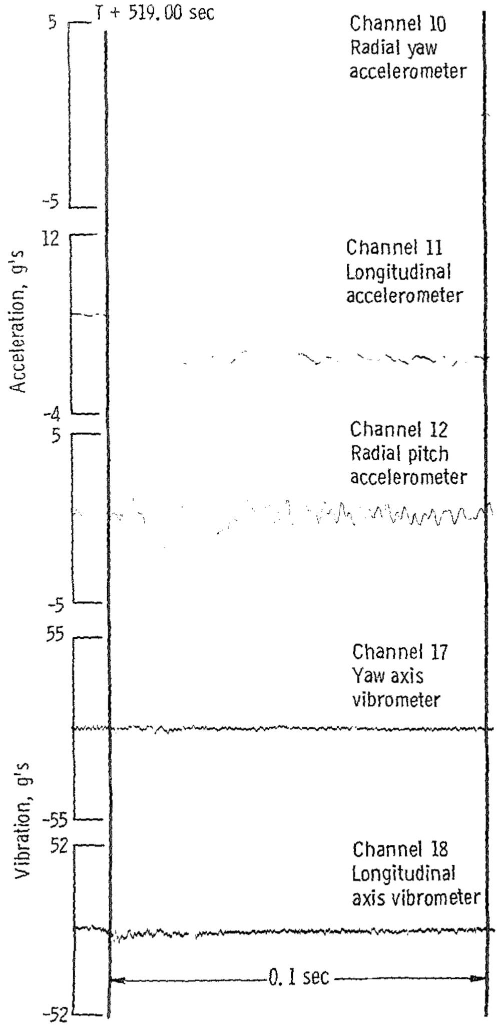


Figure D-11. - Dynamic data at Agena engine cutoff, OGO-VI.

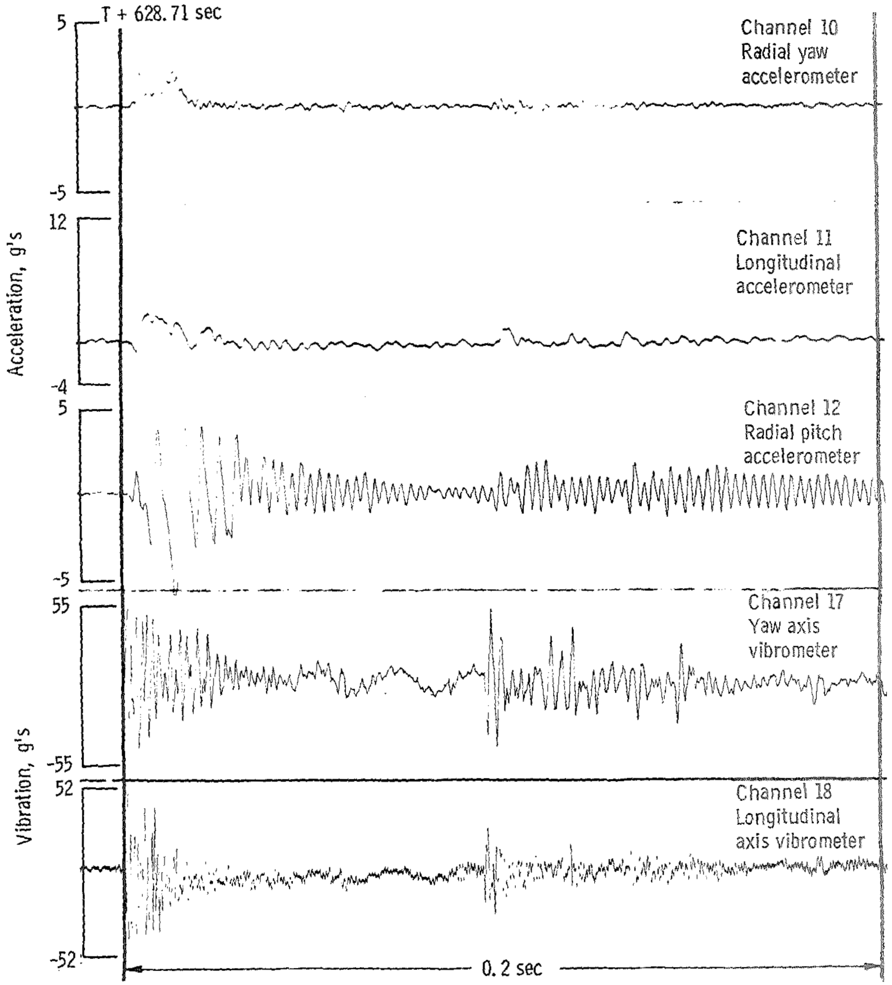


Figure D-12. - Dynamic data at Agena-spacecraft separation, OGO-VI.

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