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This handbook provides a technical data summary for the Douglas-produced Saturn S-IV and S-IVB stages of the NASA Apollo Program. Material contained in the S-IVB stage of this handbook includes the S-IB and S-V vehicles. This book will be updated as changes and additional information become available. The Appendix contains Aerospace Fluid Characteristics, LOX and LH₂ Vapor Pressure Curves, and a List of Non-Standard Abbreviations.

The family of Saturn launch vehicles and a visual size comparison to the Washington National Monument are shown in the frontispiece. The Saturn IB launch vehicle, first to use the S-IVB stage, has a total length of approximately 225 feet, a total dry weight of approximately 190,000 pounds, and a total LO weight of approximately 1,275,000 pounds. The S-IB stage is powered by eight H-2 engines that develop a total thrust of approximately 1.6 million pounds. The S-IVB stage is powered by one J-2 engine that develops approximately 265,000 pounds of thrust.

The Saturn V launch vehicle has a total length of approximately 364 feet, and a total dry weight of approximately 510,000 pounds. The S-IC stage is powered by five F-1 engines that develop a total thrust of approximately 7.5 million pounds. The S-II stage is powered by five J-2 engines that develop a total thrust of approximately 1 million pounds. The S-IVB stage of the Saturn V launch vehicle is similar to the S-IVB stage of the Saturn IB launch vehicle. Major differences between the two S-IVB stage configurations are the S-IVB/S-V engine restart capability and the flared aft interstage for mating to the S-II stage.

Prepared by Logistics Support Publications
by direction of:
W. L. Osterhout, Jr.
Saturn Systems Development

October 1, 1965
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MISSION PROFILE—S-IV STAGE

Vehicle intended to launch interplanetary spacecraft and test second Apollo Command and Service Modules into Earth orbital-flights. Stage thrust, 90,000 lbs.; payload capability, 17,000 lbs., typical average, 125 miles; typical range, 90 miles; typical period, 90 minutes; stage burn time, 475 sec.; total stage weight, 14,100 lbs. dry; restorable capability not used.

STAGING

Liftoff +

- Funnel

103 S-IV TV Calibration—Zero and 100 per cent calibration reference signals provide accurate printed access to recorded T/M data.

117 Start S-IV LH2 Cooling—System preset with LH2/CH4 and overcooled in cold LH2/W system for thermal shock.

135 Start S-IV LOX Cooling—LOX system preset with LOX/G/CO2 and overcooled to condition LOX system from thermal shock.

140 Cutoff S-IV Engine 5, 6, 7, 8—S-IV inboard engines cutoff to ensure symmetrical flight trajectory.

141 S-IV Uplage Rocket Ignition—Uplage rocket erection.

145 Cutoff S-IV Engine 1, 2, 3, 4—S-IV outboard engines cutoff to drop launch vehicle axial acceleration to 0.

157 S-IV Uplage Rocket Ignition—Uplage rockets fire to settle propellants.

147 Separation—Transfer main structure, separating two stages.

147.1 S-IX to S-IV Control Transfer—IU exhaust transferred from S-IV stage controller to S-IV stage controller.

148 S-IV Helium Valve Open—Helium valve opening to provide LH2 tank additional ullage pressurization gas.

149 S-IV Engine Start—Each of 6 rocket ignition systems spurs for 4 seconds.

152 Enable S-IV Engine-OFF System—Engine-out system activated to shut down all engines if more than two fail to fire, preventing incorrect flight attitude.

154 Activate S-IV PU System—PU System activated to measure propellant consumption.

157 Jettison Uplage Rocket—Uplage rockets on an altitude, adding unneeded weight, are jettisoned.

159 Add S-IV Engine Cutoff—Engines locked into cutoff system preliminary to engine cutoff. Prevents uncontrolled engine cutoff.

164 Cutoff S-IV Engines—All S-IV engines cutoff simultaneously if commanded by IU or programmed basis, or earlier, if propellants are expended before correct time.

166 S-IV TV Calibration—Zero and 100 per cent reference signals prevent to assure correct T/M readings during duration of S-IV flight.
The S-IV stage structure consists of a forward interstage, propellant tanks, aft skirt, forward structure, and aft skirt.

**Aft Interstage Assembly**
- Made up of S-IV stage and S-1 stage.
- Consists of eight panel assemblies of aluminum honeycomb sandwich construction.
- Each panel has triangular vent port covered with a fabric panel. Vent ports allow venting of CO2 and H2O before separation.
- Aft interstage assembly is attached to S-IV stage by four bolts with torquable nuts. At separation, aft interstage assembly remains with spent S-1 stage.

**Aft Skirt Assembly**
- Consists of four aluminum honeycomb panels welded together.
- Then welded to aft cone assembly.
- Aft skirt is attached by four bolts with torquable nuts at flight separation plane between skirt and interstage. Four sinkage wedges are mounted on aft skirt assembly.

**Heat Shield**
- Constructed of fiberglass honeycomb and cloth, and aluminum doublers.
- Mounted on thrust structure to protect forward separation area from heat of engine flame.

**Thrust Structure**
- Aluminum skin, stringer-reinforced truncated cone. Large diameter is attached to aft dome of tank assembly by welding. Has attach points for engines, actuators, heat shield, and helium heater.

**Tank Assembly**
- Consists of the forward dome, cylindrical L1G tank, and aft tank assembly.
- Forward dome is constructed of six pie-shaped segments, forced, chem-welded, and welded. An entrance nozzle is provided for access to L1G tank. Cylindrical tank wall is fabricated of three aluminum panels mechanically milled in a waffle pattern, formed, and welded into an 18-foot, 4-inch diameter cylinder; then sealed to forward dome and aft tank assembly. Aft tank assembly consists of the aft dome assembly (similar to the forward dome) and common buildup (which forms aft end of the L1G tank and the forward dome of the LOX tank). Common buildup is constructed of two aluminum hemispheres bonded to a fiberglass honeycomb core.
- Each hemisphere is welded at 6° "orange peel" segments. Skirts are welded to aluminum rings in their periphery and sealed together by welding. Prior to landing propellants, tank skirt is trimmed to provide a port and sealed. The L1G tank forward dome and cylindrical assembly is sealed together with pyrophoric hexameta-phosphoric amide reinforced with steel. The L1G tank aft dome is covered with steel, aluminum, and fiberglass honeycomb, and skin is a fiberglass honeycomb with aluminum doublers.

**S-IV STRUCTURES**

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**S-IV VEHICLE DESIGNATIONS**

- The S-IV stage structure consists of a forward interstage, propellant tanks, aft skirt, forward structure, and aft skirt.
S-IV STRUCTURE LOCATIONS

AREA DESIGNATIONS

400 AFT INTERSTAGE (MFG. LONG BEACH)
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404
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408 LOX TANK ASSY
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STRUCTURE LOCATIONS

AFT INTERSTAGE Area
Engine No. 1
Engine No. 2
Engine No. 3
Engine No. 4
Engine No. 5
Engine No. 6
Tunnel Structure Area
LOX Tank Area
LH2 Tank Area
Forward Interstage
Retrorocket No. 1
Retrorocket No. 2
Retrorocket No. 3
Retrorocket No. 4
Tunnel Area
Noose Shield Area
Helium Heater and Control Sphere

Figure 3
The 17.75 ft diameter common bulkhead is formed by two separate 2024-T6 Al hemispheres welded of 6 "orange peel" segments. Hemispheres are bonded together with temperature-resistant stiffening fiberglass honeycomb. Air is vacuum-pumped from honeycomb, forming vacuum between hemispheres for excellent thermal barrier, thus preventing LOX from heating LH₂, or LH₂ from freezing LOX.
**Major Components**
- Thrust Chamber, Fluid and Oxidizer Turbopump Assembly, LOX Flow Control Valve, Spark Ignition Subsystem, Thrust Control Assembly, Miscellaneous Control Valves.

**Thrust Chamber**
- Tubular-walled with chamber sufficient; expansion area ratio, 40 to 1; chamber pressure, 360 psia; LOX to LH2 mass burn ratio, 5:1.

**Turbopump Assembly**
- Located outside thrust chamber at nozzle thrust; turbine drives fuel and oxidizer pumps for turbine power supplied from expanding fuel, turbine inlet temperature, \(-165^\circ F\); oxidizer pump inlet temperature, \(-269^\circ F\); fuel pump inlet temperature, \(-421^\circ F\); fuel pump inlet pressure, 599 to 622 psia; oxidizer pump inlet pressure, 45.5 psi; fuel pump inlet pressure, 33 psi; turbine power output, 643 to 688 hp; fuel pump two-stage centrifugal type, oxidizer pump one-stage centrifugal type.

**Thrust Control Assembly**
- Mounted on turbopump assembly; controls thrust chamber pressure by regulating turbine speed; supply pressure, 672 psi.

**Oxidizer Flow Control Valve**
- Mounted on turbopump near nozzle thrust; turbine chamber; controls oxidizer-to-fuel mass ratio for proper ignition, and as needed; mechanical stops limit variance of burn ratio to \(\pm 12\) percent.

**Spark Ignition Subsystem**
- Consists of oxidizer supply valve and ignition system; system uses \(\text{CH}_2\) from coolant tanks for fuel; oxidizer valve regulates LOX supply to combustion chamber; ignition operating voltage, 20 volt; ignition input current, 2.5 amperes; ignition spark rate, 20 sparks per sec, 0.5 joule per spark.

**GENERAL DESCRIPTION**

The propulsion system of the S-IV stage uses the Pratt & Whitney RL10-A-5 rocket engine and associated components. Each engine is a 12,000 pounds thrust, cantilaver-mounted engine capable of mining multiple start/after the coast periods in space. LH2 and LOX are used as propellants. Electrical signals control pressurized...
valve (10), injector plate (11), and into thrust chamber. Ignition occurs, engine accelerates to main stage operation.

Mainstage Operation: LH₂ enters valve (2). Pump (4) increases pressure. Regenerative cooling is provided at chamber (7). GH₂ passes through venturi (8). Thrust control valve (27) varies amount of GH₂ bypassed around turbine (9), maintaining constant chamber pressure and engine thrust. GH₂ flows through valve (10) and injector plate (11), and into thrust chamber to burn. Valve (25) pressurizes S-IV stage fuel tank with GH₂ and lubricates turbopump gearcase. Valve (26) vents gearcase. LOX enters valve (12) and pump (13) and pressure increases. LOX control valve (14) regulates LOX flow. LOX flows to thrust chamber. Positioner (15) controls valve (14) at 5:1 LOX to LH₂ ratio to minimize residual propellant at burnout.

Engine Cutoff: PU System arms All Engine Cutoff relay with 2 per cent of LOX mass remaining in tank. When one engine cuts off, remaining engines shut down. Switches (23) and (24) provide the engine cutoff signal, if pressure drops below 262 ± 10 psia. Switches (23) and (24) also control valves (10), (11), and (21). Valves (1) and (2) close. Valves (3) and (5) open. Valve (10) closes, cutting off fuel. Turbopump stops, engines cut off.
OXIDIZER SYSTEM

GENERAL DESCRIPTION

The S-IV stage oxidizer system is comprised of three LOX subsystems (LOX supply, LOX tank pressurization, and LOX tank venting) and two cold He systems. LOX is stored in a 2,263 cubic foot tank at approximately -297°F. A screen is installed at the tank outlet to prevent protrusion and to prevent contamination. LOX tank pressure is provided by a cold He system. Three He valves mounted in the LH2 tank supply a chamber that expands the gas and pressurizes the LOX tank to 40 psia during flight. Tank pressure-sensing switches protect the LOX tank from excessive high or low pressures, protect the tank during pressurization and flight, and provide indications of adequate pressure for lift-off. A vent system provides for relief of pressure during fill and mainstage operation. The LOX tank vent system is a combination vent and relief system. Two valves overcome all products of vaporization resulting from ground filling, and automatically relieve excessive pressure buildup in the tank by opening at 50 psia, and relieving at 47 psia. The two valves act independently of the tank pressure-sensing switches. During mainstage operation, the six RL10-A-5 rocket engines burn 6,750 gallons of stored oxidizer at an approximate rate of 1,100 gpm. Each engine is supplied by low pressure feed ducts, through a manifold located beneath the LOX tank感人.

OPERATION (See Figure 8)

Ground Operation

LOX Fill Sequence: Valves (1) and (2) close. Valves (3) and (4) open. Valve (5) opens. LOX for system pre-cool flows through ground supply disconnect (6). Pre-cool continues for 20 minutes. Mainfill starts, controlled by sensor (7). Loading rate is approximately 1,000 gpm. At 70 per cent full, spheres (8), (9), and (10) fill with cold He from ground source. At 98 per cent full, flow fill starts. Loading rate is reduced to 100 gpm. At 99.75 per cent full, anti-blowoff reseal initiates mainfill starts. Valves (5) and (4) close. Switch (11) monitors pressure during loading. Switch (12) monitors tank pressure at 42 to 45 psia. Valves (3) and (4) open for blowoff.

LOX Drain Sequence: Valves (1) and (2) close. Valves (3) and (4) close. Tank pressure is at 45 to 48 psia. Valve (5) opens. LOX flows out disconnect (6). Switch (12) monitors tank pressure.

OPERATION (Continued)

Pressurization Sequence: Valves (3) and (4) close. He flows through disconnect (13), valve (14), filter (15), valve (16), plenum (17), no-heater (18), union (19), and pressurizes LOX tank. Switch (31) closes valve (16). Switch (32) monitors pressure at 4 to 4.8 psia. Switch (20) controls overpressure at 51 to 53 psia.

Cold He Bubbling System: Heats LOX to satisfy temperature requirements at LOX pump inlet before engine startup. During countdown, cold He flows through valve (21), filter (22), restrictor (23), orifice (24), and into LOX ducts before LOX. Switch (25) monitors He at 310 to 330 psia. Switch (27), restrictor (28), and check valve (29) prevent LOX entry into tank pressure sensor line.

Inflight Pressurization System Fill: At countdown, He flows through disconnect (13), and valves (14) and (30). Switch (31) indicates pressure in spheres (8), (9), and (10). Valve (32) prevents overpressure. Valve (33) is closed.

Inflight Operation

Pressurization Sequence: 1.7 seconds before activation, valves (1), (34), (35), and (36) open. Cold He flows from spheres (8), (9), and (10) through filter (37), regulator (38), valve (16), plenum (17), no-heater (18). Heated He then flows through union (19) into LOX tank. Switch (11) activates at 45 (+1, -0) psia, carries valve (19) to supply more heated He through orifice (40). Valve (39) closes at 46 to 48 psia. LOX tank pressure at 45 to 48 psia is maintained in LOX tank. LOX signal opens valve (2). LOX flows to engine. Depletion of LOX at 41.7 lb is signaled by sensor (7).

LOX Tank Venting: Valves (3) and (4) overhead LOX. Non-propulsive vent system opens vent valve on signal from engine out pressure switches (flow per engine).
GENERAL DESCRIPTION

The S-IV stage fuel system is composed of three LH₂ subsystems: LH₂ supply, LH₂ tank pressurization, and LH₂ tank venting. LH₂ is stored in an interally-insulated, 4,197 cubic foot tank at -423°F. Tank outlets, at the base/side of the tank have anti-vortex filters to prevent cavitation and surging. Pressurization of the LH₂ tank is provided by a CH₄ bleed from the six rocket engines. Tank pressure-sensing switches are provided for protection from accidental over or underpressures. These switches also provide an indication of adequate pressure during LO and flight, and control pressure during mainstage operation. The fuel tank pressure is maintained between 31 and 37 psia to provide a standing column of LH₂ at each fuel pump inlet.

During mainstage operation, the six RL10A-3 rocket engines burn 28,000 gallons of stored fuel at an approximate rate of 3,600 gpm. Each engine is supplied through low-pressure feed lines connected to the fuel tank.

OPERATION (See Figure 9.)

Ground Operation

LH₂ Fill Sequence: LH₂ fill follows LOX fill. Valves (1) and (2) close, valves (3) and (4) open. Valve (5) opens admitting LH₂ at 30 psia/500 gpm through disconnect (6) to tank. Sensor (7) monitors fill. At 15 per cent full, main fill starts; fuel is loaded at 2,000 gpm. At 95 per cent full, fine fill starts; loading rate is reduced to 500 gpm. At 99.5 per cent full, replenish cycling starts to recirculate fuel into the boiloff. Tank is pressurized by ground He. Switch (25) prevents overpressure at 36 to 38 psia by actuating valve (4).

LH₂ Drain Sequence: Three He spheres in LH₂ tank are drained. LOX tank is pressurized to prevent tank damage. LOX and He heater valves close. Pressurizing He flows from adapter (8), valve (9), manifold (11), and LH₂ tank. Switch (25) closes ground He source at 36 to 38 psia during drain. Switch (40) provides GSE talkback.
FUEL SYSTEM (Continued)

Pre-Orchestration Sequence: Vent valves (3) and (4) are closed. Cold He flows through valves (5), valve (9), manifold (11) into LH₂ tank. Switch (25) cuts off flow at 36 to 38 psia. Switch (30) picks up at 34 to 36 psia and provides GSE talkback. It remains connected until LO.

Inflight Operation

Pressurization Sequence: GH₂ tank off engine flows through valve (12), orifice (26), and manifold (11) to LH₂. Switch (13) opens if pressure is low (20 psia). GH₂ from engine bleed passes through orifice (29), manifold (11) into tank. Switch (16) opens valve (17) for backup GH₂ if pressure drops below 20 psia.

Stop-Pressurization Sequence: Sphere (18) filled before LO with CO₂ (ambient) through disconnect (19), and valves (20) and (27) supplies LH₂ tank pressure at 30 to 32 psia during engine restart. Pressure is controlled by valves (21) and (23), and restrictor (21). Switch (24) provides electrical pressure indication. System is restored inoperative 3 seconds after engine ignition.

Differential Pressure Sequence: Switch (14) senses LOX-LH₂ pressure differential and opens valve (24) if needed.

LH₂ Tank Venting Sequence: Valves (3) and (4) opened GH₂ if tank pressure exceeds 44 psia. Non-repetitive vent system opens vent valve on signal from engine-out pressure switch in case per engine.

Figure 9
CONTROL PRESSURE SYSTEM

Major Components:
- Helium Control Spheres (11), Helium Control Pressure Regulator (11), Helium Control Relief Valve (11), Plenum Chamber (11).
- Helium Control Spheres - Stores ambient GHe at 3,000 psig for operation of valves; storage capacity: 3.5 cubic feet located in thrust structure near thrust axis.
- Helium Control Pressure Regulator - Reduces and regulates control sphere pressure to 455 psig. GHe is regulated to 445 psig to operate valves; maximum input pressure: 3,100 psig; maximum outlet pressure: 555 psig; response time: 0.050 sec; located in thrust structure.
- Plenum Chamber - Prevents excessive rapid control pressure variations; operating pressure: 500 psig; located in thrust structure.

GENERAL DESCRIPTION

The control pressure system (also referred to as the ambient helium system) contains components for storing, venting, regulating, filtering, and routing GHe under pressure to the pneumatically-operated valves on the S-IV stage. In addition to operating valves on the stage, the control pressure system supplies helium for purging of the turbopump generator, the control positioner, and the fuel injector. Before LO, a ground source supplies GHe for purge requirements. At LO, the fuel injector purge is terminated. The GHe purge system prevents possible malfunction of the purge components by eliminating the collection of atmospheric moisture, and by preventing LOX entry into the LOX tank sense line.

Operation (See figure 10.)

During cooldowns, GHe from ground source, fills sphere (1) through disconnect (21); valves (3), (41), and (5). GHe supply also flows through filter (7), valve (12), is regulated at 445 psig, and pressurizes pneumatic control system. Switch (6) provides GSS flow when sphere pressure exceeds 2,000 psig. Valve (7) provides high-pressure protection, will relieve if pressure exceeds 3,300 psig; valve (8) may be manually operated to depressurize sphere (1). During system operation, valves (10) and (11) will relieve high-pressure；supply to valve (7), and will close valve (12), if regulated pressure exceeds 550 psig. When regulated pressure drops to 510 (±10) psig, switches (19) and (21) will cut out. Plenum (15) damns pressure changes in regulated supply lines. Control pressure system operates following valves:

a. LH2 tank vent and relief valves (16 and 17)
b. LH2 vent open and close actuator solenoid valves (18, 19, and 20)
c. LOX tank vent and relief valves (21 and 22)
d. LOX vent open and close actuator solenoid valves (23, 24, and 26)
e. GHe heater propellant valves (25 and 26)
f. GHe heater interlock open and close actuator solenoid valves (27 and 28)
g. LH2 fill line valve (29), LH2 fill open and close actuator solenoid valves (30 and 31)
h. LOX fill line valve (32), LOX fill open and close actuator solenoid valves (33 and 34)
i. LH2 inlet shutoff valve (35)
j. LH2 pre-start solenoid valve (36), LH2 pre-start pressure switch (37)
k. LOX inlet shutoff valve (38)
l. LOX pre-start solenoid valve (39), LOX pre-start pressure switch (40)
m. LH2 main shutoff valve (41)

After LO, GHe flows through regulator (45) to turbopump generator, control, and LOX sense line shutoff isolation (46).
S-IV stage engine gimballing action provides vehicle steering and stabilization after S-1 stage and S-IV stage separation. Each engine is gimbaled by two hydraulic actuators, following commands issued by the flight control computer in the IU. Each engine cants 6° outboard, and is capable of being deflected 6° in a star pattern from the engine zero (0°) position. Peak engine position rate is 15°/sec, with a steady position rate of 5°/sec. S-IV stage engine Nos. 1, 2, 3, and 4 correct errors around the vehicle pitch, roll and yaw axis; engines 5 and 6 correct pitch and yaw only.
HYDRAULIC SYSTEM

OPERATION (See Figure 12-1)

HYDRAULIC FILL AND BLEED SEQUENCE: During countdown, system accumulator is charged with GN (through accessory); (25). Hydraulic fluid is supplied for following pumps, through couplings (24) and (23) and bleed through valves (26), (27), (28), (29), and (30). Fluid from ground supply flows through valve (31), filter (62), accumulator-reservoir (7), reservoir (60), manifold (32), filter (33), manifold (5), engine-driven pump (3), valves (4) and manifold (5) to accumulator-reservoir (7). Fluid returns to ground source through coupling (24).

Countdown Sequence: GSE signal closes solenoid (34) of sequence valve (10), activating auxiliary pump (35). Fluid flows to valve (9), filter (36), manifold (32), filter (6), valve (16), and pressure rises high-pressure side to 3,000 psig. Simultaneously, fluid flows through valve (11), filter (26) to inlet of servovalve (2); GSE signal closes solenoid (1), trapping 22 oz. of fluid in accumulator. Auxiliary pump is then deactivated. Residual pressure is bled to 70 psig through servovalves, accumulator-reservoir, and auxiliary pump return line. Coupling (24) permits bleedoff to ground source. Pot (155), positioner by piston (158), indicates status of accumulator-reservoir pressure. Gage switch (39) provides GSE talkback. Switch (42) prevents system fluid from overfilling.

Infield Sequence: 1.7 seconds before ignition, solenoid (1) energizes, and accumulator pressure is applied to servovalve (2), closing engines. After ignition, engine-driven pump (3) supplies fluid. Fluid is directed through valves (4) and manifold (5), filter (6), accumulator-reservoir (7), and reservoir (8). Valve (9) prevents fluid entry into auxiliary pump subsystem. Fluid flows to sequence valve (2) through filter (6). Valve (12) will bypass fluid, when pressure exceeds 3,160 psig. Valves (13) and (14) will bleed back fluid when return pressure exceeds 55 psig. Pot (151) provides electrical feedback for piston position control loop. Servovalves operate upon command from IU. Electrical steering signals applied to torque motor (21) position control flapper (20) to restrict flow through nozzles (22) or (29), dependent upon signal polarity. Pressure buildup in line of restricted nozzle shifts control spool (17) and opens high-pressure path to actuator. DPF network (22) dampens transient by repositioning control flapper (20).

HYDRAULIC SYSTEM

Major Components per Engine

- Engine-Driven Hydraulic Pump (1), Motor-Driven Auxiliary Hydraulic Pump (3), Hydraulic Actuator Assemblies (2).

Engine-Driven Hydraulic Pump

- Vickers, nine-piston, constant-displacement, wobble-type pump delivers 0.975 gpm at 3,450 psig; maximum; inlet pressure, 65 to 100 psig; pump operating speed, 11,400 rpm; mounted to hydraulic gearcase accessory drive-end flange with thermal isolator.

Motor-Driven Auxiliary Pump

- Vickers, nine-piston, variable-delivery pump delivers 0.5 gpm at 2,950 psig; maximum; inlet pressure, 0 to 100 psig; operating speed, 11,300 rpm; motor operates on 115 vac, 400-cycle, 3-phase, wye-connected power; horsepower, 1.4.

Hydraulic Actuator Assemblies

- Two actuators mounted 90° apart, attached between thrust structure and engine nozzle (-S03) actuator is equipped with system accumulator; accumulator pressure, 2,140 psig; accumulator capacity, 22 oz.; both actuators are linear, double-acting, with equal piston displacement; total stroke, 2.75 inch; feedback pot used for piston position control loop; each actuator equipped with flow-control type servovalve. Servovalves use DPF (dynamic pressure feedback) for damping.

GENERAL DESCRIPTION

Hydraulic system provides thrust vector steering for pitch, roll, and yaw during in-flight operation. Each engine has an independent, closed-loop hydraulic system. Auxiliary hydraulic pumps are used to supply engines during checkout. Prior to LO, auxiliary pumps are started. Pumps charge accumulator-reservoir assemblies on -S03 actuator assemblies, then are shut down. Stored fluid, under pressure, provides initial pressure for engine centering before S-IV stage engine ignition. Following engine ignition, hydraulic system pressure is supplied by engine-driven hydraulic pumps. Servovalves use torque motor to convert IU steering signals to proportional flow rates at actuators. DPF network in servovalve damps pressure surges in system by acting in opposition to control fluid flow.
Components
- 28 VDC 15AH Batteries (2), 20 VDC 5AH Battery (1), Sequencer (1), Power Supply (1), Controllers (2), Power Distribution Box (1), Inverter-Converter (1), Flight Control Switch (2), all located on firing station across flight control switch.

Batteries
- Positive plate, silver oxide; negative plate, zinc electrolyte; potassium hydroxide; scaled, pressurized unit; thermostat controlled at 80°F before LO.

Sequencer
- Metal enclosed, relay operated switching assembly; receives signals from S-1 stage, IU, PU system; provides sequenced commands to initiate predetermined time/sequence functions.

Power Supply (GFE)
- Input power, 20 vdc output power, regulated 28, 18 vdc, 6 vdc, and regulated 28 vdc unit supplies voltages to operate range safety receivers.

Controller (GFE)
- 28 vdc input and output; contains relay and circuit elements to fire one set of destruct equipment.

Power Distribution Box
- 28 vdc input and output; distribution point for power to propulsion system, fuel system pressure switches and valves, and PU control unit.

Inverter-Converter
- Input, 28 vdc, output 115 vdc; solid state device supplies power to PU electronics.

Flight Control Switch
- Operating voltage, 20 to 32 vdc at 2A at 28 vdc; motor-driven 96 pole rotary switch transfers IU signals from S-4 stage to S-IV stage at separation.

OPERATION (See figure 1.3.)
Provides ac and dc power to S-IV stage only during checkout and flight. Battery No. 1 powers PU system, inverter-converter, range safety receiver No. 1 and EBW system No. 1. Battery No. 2 powers range safety receiver No. 2, EBW system No. 2, ordnance systems, rocket engines electrical systems, and hydromechanical apparatus. Battery No. 3, consisting of two 5AH batteries, powers FM transmitters, multicoders, and oscillators. Battery No. 1 and No. 2, both 15 AH, are isolated to prevent PU system from transients.

Figure 1.2
Optimum consumption of propellants is necessary if the S-IV stage is to operate at maximum efficiency. A PU system is used to continuously monitor the amount of LOX and LH₂ remaining in the tanks throughout fill and flight duration, and regulate the LH₂/LOX mixture ratio to insure near-simultaneous depletion of propellants. A firm ratio of 5:1 LOX to LH₂ is closely maintained, while sustaining a mass ratio in the tanks of 5:1 also.
PROPELLANT UTILIZATION SYSTEM (Continued)

Mechanical linkage, maintaining propellant mass and engine propellant isopropanol balance. T/M puts, driven by bridge servo motors, allow direct determination of propellant mass. Loadling puts, also driven by servo motors, provide indication of tank's mass during propellant loading and unloading. Gain change, needed to compensate for consumed propellant, is varied as a function of LOX mass and flight time by means of a sequence switch driven by the LOX bridge servo.

PROPELLANT UTILIZATION SYSTEM

Components
- LH2 Mass Sensor - Capacitive type; 400 ohm, 1,000 K at 500 volts; temperature range, 100°F to -42°F; indicates fuel load mass, located in LH2 tank.
- LOX Mass Sensor - Capacitive type; 250 ohm, 1,000 K at 500 volts; temperature range, 120°F to -29°F; indicates LOX load mass, located in LOX tank.
- PU Electronics Assembly - Input power, 115 vac, 1 phase, 400 cycles/sec; 28 vac from engine and control batteries contains electronics to provide propellant tank control signals, located on limit structure.

GENERAL DESCRIPTION

Propellant supply and consumption is controlled through PU system by determining LOX/LH2 mass ratio. System controls ground loading computer; determines propellant mass to 2 per cent accuracy at L0 and 5 per cent accuracy at L0L and L0H. System determines propellant load mass, located in LOX tank.

OPERATION (See figure 15)

Two motoring mass sensors (1 in each tank) provide capacitive output which is directly proportional to propellant mass. Higher dielectric constant of liquids used causes capacitance change as propellants are used. Mass sensor outputs, both of which are servo-balance, are fed into LH2 and LOX bridges. Empty and full adjust pots are used to calibrate system to extreme accuracy. Overrange rejection networks cancel out-of-phase, non-capacitive components of probe signal by sampling in-phase output at intervals when out-of-phase signal is minimal. Common-to-dark trigger gates sampling interval. Rate feedback corrects both servos. Servo motors independently drive coarse and fine mass and position servos. Servo motors control engine mixture ratio by indicating position feedback information, if propellant ratio balance is maintained. Error signal, the sum of both servos, is applied to RC shaper network, modulated, amplified, and fed to mixture ratio servo amplifier. Amplifier feeds motor positioner motor, which controls LOX flow control valve through
TELEMETRY SYSTEMS

Measure, process, and transmits flight instrumentation data (accleratlum, force, motion, pressure, strain, temperature, vibration, time-event functions, etc.) to ground stations.

Two modulation techniques are used:

a. FM/FM (Frequency modulated / Frequency modulation)
   - Constant amplitude, varying frequency signal modulates constant amplitude, varying frequency FM transmitter signal.

b. PDM/FM/FM (Pulse duration modulated FM/FM)
   - Time sliced, constant amplitude, varying width pulse train modulates FM/FM transmitter.

All use IRIG standard components.

System Nos. 1 and No. 2 (PDM/FM/FM Functional Description (See Figure 16))

Transducers measure flight data. High level (0-5 vdc) and low level (0-15 mvdc) inputs to multiplexer. Signals are commutated in time sharing multiplexers and converted to PDM output. Filters suppress noise. SCO or VCO convert varying duration PDM signals to varying frequency PDM/FM signals. Signal amplifier feeds PDM/FM signal to FM transmitter. PDM/FM/FM output signal feeds antenna multiplexer, combining output signals from other T/M systems. Composite signal feeds power divider to drive antenna system.

System No. 3 (PDM/FM/FM Functional Description (See Figure 17))

System operates substantially the same as System Nos. 1 and No. 2. Slow speed multiplexer replaces high level multiplexer.

Figure 15
### S-IV Telemetry Data Capability

<table>
<thead>
<tr>
<th>System</th>
<th>Sync Channels</th>
<th>Data Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Level PDM (0 to 5 vdc) 900 Samples per Second (90 x 10)</td>
<td>2</td>
<td>88</td>
</tr>
<tr>
<td>Low Level PDM (0 to 15 mVdc Full Scale) 112.5 Samples per Second (45 x 2 1/2)</td>
<td>2</td>
<td>43</td>
</tr>
<tr>
<td>18, Continuous FM-FM Channels (IRIG Bands, 1 through 18)</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>147</strong></td>
</tr>
</tbody>
</table>

| **No. 2** |               |              |
| High Level PDM (0 to 5 vdc) 900 Samples per Second (90 x 10) | 2           | 88           |
| Low Level PDM (0 to 15 mVdc Full Scale) 112.5 Samples per Second (45 x 2 1/2) | 2           | 43           |
| 18, Continuous FM-FM Channels (IRIG Bands, 1 through 18) | -           | 16           |
| **Total** |               | **147**      |

| **No. 3** |               |              |
| Low Level PDM (0 to 15 mVdc Full Scale) 112.5 Samples per Second (45 x 2 1/2) | 2           | 43           |
| Continuous FM-FM Channels (18) (IRIG Bands, 1 through 18) | -           | 17           |
| **Total** |               | **60**       |

**Total:** 354
S-IV ORDINARY

a. S-I/S-IV separation system, used to separate the two stages.

b. S-IV propellant dispersion system, used to shut down six rocket engines, and expel propellant tanks.

c. S-IV staging rocket system, used to position propellants at pump less prior to engine start.

In-flight and ground T/M monitoring provided for determining SAFE or ARMED status) on all systems.

Figure 18
S-IV SEPARATION SYSTEM FUNCTIONAL SCHEMATIC

OPERATION (See figure 19.)

At separation, four frangible nuts which retain stages are detonated by signal supplied through S-1 sequencer. Nuts fracture, releasing two stages. Among signal processing: separation charges two firing units. Charging (ARM) signal is applied to large storage capacitor (2,300 volts). Trigger signal, applied approximately six seconds later, produces 5,000 volts to trigger gap tube. Tube ionizes, causing storage capacitor to discharge through resistive EBW detonator. Propagation wave from EBW detonator booster charge initiates primary charge. Wave initiates booster charges in detonator block, is transmitted to MDF harness assemblies. Propagation of harness assemblies splits frangible nuts.

SEPARATION SYSTEM

Components
- Frangible Nuts (4), CDF Explosive Harness Assemblies (2), Detonator Block (1), EBW Detonators (2), Firing Units (2).

Frangible Nut
- PETN-filled nuts; fractures in stages when detonated by bolts at four attach points between S-1/S-IV separation planes.

CDF Explosive Harness Assembly
- Plastic and fabric sheath contains PETN core; approximately 2 grains per foot; propagation rate of 23,000 feet per second; two harness assemblies used for optimum reliability.

Detonator Block
- Mates CDF harness assemblies and EBW detonators; block contains 1.4 grain booster charges (2).

EBW Detonator
- Threaded connector containing 1.4 grain PETN booster charge and 30 mg PETN main charge; bridgewire contained in booster charge; high voltage/high current required for initiation; microspark gap incorporated for safety.

Firing Unit
- Input voltage, 28 volts; output voltage, 2,300 volts at 1,500 A; housing contains electronics for initiating EBW detonators; operation requires charge and trigger signals.
**OPERATION** (See figure 20.)

Prior to LO, receivers and firing units switched to internal power by controllers. At LO, receivers activated and Safety and Arming devices armed. If flight termination is required, coded trigger signal is transmitted on appropriate IRIG sub-carrier. RS receivers decode signal and command six RL10-A engines to cut off (through RS controllers). Coded trigger signal also is sent to firing units to initiate EBW detonators. Explosion is propagated through Safety and Arming device to CDF harnesses, then to linear-shaped charges attached to LH2 and LOX tanks. Charges sever tanks, causing propellant dispersion.

### Components

- **Antennae** (4), Range Safety Receivers (2), Range Safety System Controller Assemblies (2), EBW Firing Units (2), EBW Detonators (2), Safety and Arming Device (1), CDF Harness Assemblies (2), Flexible Linear-Shaped Charges (3).
- **Antennae** - Quarter wave, slit type; 52 ohm impedance; Unit 4956 each; two antennae per receiver.
- **Range Safety Receiver** - GFE; XTAL controlled transistorized, FM, supertetrodyne; ten channels; carrier frequency range, 406/450 mc; sub-carrier channels are ten standard IRIG frequencies; two sections (receiver and decoder).
- **Controllers** - GFE; provides relay control for system activate, arm, trigger, and monitor; 28 vdc output.
- **Firing Unit** - Input voltage, 28 vdc; output voltage 2,300 vdc at 1,500 A; housing contains electronics, for initiating EBW-detonatory detonators; can initiate arm and trigger signals.
- **EBW Detonator** - Threaded connector containing 1.4 grain PETN booster charge and 30 mg PETN primary charge; bridge wire contained in booster charge; high voltage/high current required for initiation; microspark gap incorporated for safety.
- **Safety and Arming Device** - Provides positive isolation (SAFE condition) between EBW detonators and CDF harness assemblies, or explosive continuity (ARM) for same; electrically-actuated, mechanically-operated, rotor-emplaced; rotor contains PETN, 1.4 grain booster charges (2).
- **CDF Harness Assembly** - Flexible, fabric and plastic sheet contains PETN core, 2 grains/ft; propagation rate of 23,000 ft/sec; dual fuses used for optimum reliability.
- **Flexible Linear-Shaped Charge** - Triangular-shaped aluminum sheet contains ROX core, 100 grains/ft; two attached to LH2 tank, one to LOX tank.
ULLAGE ROCKETS (IGNITION SYSTEM)

Components
- Ullage Rockets (4); Firing Units (8); EBW Motor Initiators (8).

Ullage Rockets
- Thiokol TX-200; solid propellant rockets; thrust, 3,460 pounds; burn time, 3.94 sec at 70°F; 58.8 pounds of propellant; ammonium perchlorate and polysulfide exit nozzles canted 25° from stage centerline; mounted on skirt.

EBW Initiators
- GFE; caustic oxide and magnesium charge; 2 mounted in boss on dome of rocket motor.

Firing Units
- Input voltage, 28 volts; output voltage, 2,300 volts at 1,500 A; housing contains electronics for EBW Initiators; operation requires arm and trigger signals.

OPERATION (See figure 21.)

Prior to separation, ullage rockets are fired by signal from S-I stage sequencer. Charging (are) signal, sustained before separation, is stepped up and applied to large storage capacitor (2,300 volts). Trigger signal produces 5,000 V pulse to trigger gap tube. Gap tube ionizes, causing storage capacitor to discharge through EBW Initiators. Detonation wave from initiators is transmitted to propellant igniter contained in perforated tube.

Hot particles and gases from igniter pellets cause ignition of solid propellant grain. Ullage rockets impart forward acceleration on S-IV stage to provide optimum ullage positioning and aid in separation.
ULLAGE ROCKETS (JETTISON SYSTEM)

Components

- Frangible Nuts (8), Firing Units (4), CDF Fuse Assemblies (4), Detonator Block (1).

Frangible Nuts

- Retaining pin holds 2 CDF fuse (tee fittings); attach bolts installed perpendicular to tee fittings in threaded casing; nut fractures along length of casing.

CDF Fuse Assemblies

- Two grain/ft PETN charge covered with plastic and fabric sheath; dual fuses are swaged at cool end into single end fittings containing 1.5 grain PETN charge; tee fittings incorporated for attachment to frangible nuts.

Detonator Block

- 2 input bosses; 4 output bosses; manifold 2 EBW detonators with 4 CDF fuse assemblies.

Firing Units

- Input voltage, 28 vdc; output voltage, 2,300 vdc at 1,500 A; housing contains electronics for initiating EBW detonators; operation requires arm and trigger signals.

EBW Detonator

- Threaded connector containing 1.4 grain PETN booster charge and 20 mg PETN primary charge; bridge wire contained in booster charge; high voltage/high current required for initiating mica spark gap incorporated for safety.

OPERATION (See figure 22)

Firing units charged prior to separation of S-IV stage and S-I stage. Charging (ARM) signal is applied to large storage capacitor (2,300 vdc).

Trigger signal is applied through S-IV stage sequencer after ullage rocket burnout. Signal produces 5,000 V pulse to trigger gap tube. Tube ionizes, causing large storage capacitor to discharge through EBW detonator. Detonator propagates CDF fuses connected to detonator block. Detonation wave is transmitted to tee fittings at frangible nuts. Tee fitting charges flood aside, 41 mg and PETN, 260 mg) arc initiated, fracturing frangible nuts. Nut fracture releases preloaded spring motor and fairing modules are jettisoned.

Figure 21
5-IVS/5-IB MISSION PROFILE

Vehicle intended to launch three man Apollo spacecraft into Earth orbit for named and unnamed testing programs, including midcourse missile. Stage thrust, 200,000 pounds, payload capability, 35,000 pounds, typical apogee, 120 miles, typical perigee, 110 miles, typical period, 90 minutes, stage burn time, 470 seconds. Restart capability, not used. Total stage weight, 23,551 pounds dry.

STAGING

NOTE: Significant time-event functions listed below, reflect current mission requirements. These times are subject to change and should not be considered final.

**Countdown**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>t₀</td>
<td>Engine cutoff—Propellant nearly depleted; engine is stopped on fuel depletion or T/M command.</td>
</tr>
<tr>
<td>t₂</td>
<td>-0.5 +2.1</td>
</tr>
<tr>
<td>t₂</td>
<td>+2.9</td>
</tr>
<tr>
<td>Coast Period</td>
<td>- Up to 4-1/2 hours; following sequence repeats up to nine times over ground T/M stations, dependent on duration of orbit.</td>
</tr>
<tr>
<td>In Range of Ground Station</td>
<td>+1.0</td>
</tr>
<tr>
<td>In Range of Ground Station</td>
<td>+1.0</td>
</tr>
<tr>
<td>Out of Range of Ground Station</td>
<td>+9.9</td>
</tr>
<tr>
<td>Separation of S-IVB/ Payload</td>
<td>- May occur anytime during 4-1/2 hour maximum orbital coast period.</td>
</tr>
</tbody>
</table>

- **Conning**
- **Engine cutoff**—Propellant nearly depleted; engine is stopped on fuel depletion or T/M command.
- **Auxiliary pump**—Range safety receiver, inlet-converter, and PU system off—Systems, having functioned, are turned off to conserve remaining battery power.
- **T/M off**—T/M Recorder Transmitter on. Prepares vehicle data recorder for high-speed playback of data lost while out of line-of-sight.
- **Recorder Playback Command**—Recorder Command off, Playback Command off, turns off recorder playback, starts recorder recording data for next pass over ground station.
- **May occur anytime during 4-1/2 hour maximum orbital coast period.**
The Dynamics Vehicle tests will be performed at MSFC with a production configured vehicle with only the engine gimbal system installed. Deleted systems will be replaced with simulated mass so that stage weight, center of gravity, and moment of inertia duplicate the live S-IVB stage. Lateral and torsional vibration characteristics will be determined for the S-IVB stage, as well as for the assembled S-IB and S-V vehicles.

The Facilities Vehicle tests will be performed at AMR using a production-configured vehicle to conduct cold flow tests of propellant loading systems and facilities, GSE, and T/M. The S-IVB vehicle will be assembled with S-IB stage and IU for integrated system tests.

NOTE: All of the test vehicles except the Structure Vehicle will be converted to S-IVB/S-V configuration to further testing.

<table>
<thead>
<tr>
<th>Stage Designation</th>
<th>Required at</th>
<th>Used for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battleship Test Vehicle</td>
<td>SACTO</td>
<td>Test</td>
</tr>
<tr>
<td>Structure Test (Hydrostatic) Vehicle</td>
<td>M.B.</td>
<td>Test</td>
</tr>
<tr>
<td>Dynamics Test Vehicle</td>
<td>KSC</td>
<td>Test</td>
</tr>
<tr>
<td>Facilities Test Vehicle</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2001</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2002</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2003</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2004</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2005</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2006</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2007</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2008</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2009</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2010</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2011</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 2012</td>
<td>KSC</td>
<td>Flight</td>
</tr>
</tbody>
</table>

The Battleship Vehicle tests will be conducted at Sacramento. The vehicle is constructed of steel and used to test the propulsion system installation. Static firing tests will be conducted to verify subsystems and systems for both development and production design. A Battleship Vehicle is also furnished NASA at MSFC. NASA will conduct their own test program.

The Structure (Hydrostatic) tests will be conducted at Huntington Beach. The vehicle will be extensively instrumented, presenting over 300 channels of data. Tests will determine dynamic pressures, stresses, and deflections. After completion of hydrostatic testing, the vehicle will be used for structural testing of the thrust structure.
S-IVB STRUCTURES

S-IVB Structure of the S-IVB vehicle consists of the forward skirt assembly, propellant tank assembly, aft skirt assembly, thrust structure assembly, and aft interstage assembly.

Aft Interstage Assembly: A cylindrical structure fabricated from eight panels of aluminum skins, stiffened with stringers and circumferential attach angles fabricated from extensions. A frangible tension tie attaches it to the aft skirt. The aft interstage is assembled at Huntington Beach and shipped to AMR for assembly to the S-IVB stage. Individually, the aft interstage remains with the spent S-IVB stage after separation of the S-IVB and S-IV stages.

Aft Skirt Assembly: A cylindrical structure made of aluminum skin panels stiffened with stringers and circumferential attach angles at both ends. The aft skirt is attached to the tank assembly with bolts. Two auxiliary propulsion modules are attached to the aft skirt.

Thrust Structure Assembly: A truncated cone, fabricated of aluminum skins, formed, drilled, riveted to stringers and frames and attach angles at the large end, and fastened to the cast-aluminum engine mount at the smaller end. The thrust structure is bolted to the aft dome and provides the attach point for J-2 engine and distributes the J-2 engine thrust over the entire tank circumference.

Propellant Tank Assembly: Consists of the forward dome, cylindrical tank wall, and the LOX tank assembly. LOX tank assembly consists of the aft dome and common bulkhead, which isolates LH2 tank and LOX tank. The forward dome and aft dome are similarly constructed of nine pie-shaped segments of sheet aluminum structure, which is formed, drilled, and welded together. Each dome has attach flanges in the center for (1) an access door in the forward dome, and (2) the LOX tank assmbly in the aft dome. The cylindrical tank center section is fabricated from seven aluminum skins with a waffle pattern mechanically milled on the interior surface skin, which is formed, split-welded together, then welded to attach rings at both ends. The common bulkhead is constructed of a 1-5/8 inch thick honeycomb core, bonded between two hemispherical domes. The domes are fabricated by welding a contained center plate with nine fusion-welded aluminum skin segments to circumferential rings. Domes are then bonded to the honeycomb, and welded.

Forward Skirt Assembly: A cylindrical structure fabricated of aluminum skins, riveted to extruded stiffeners and intercostals, and to attach rings on the forward and aft circumferences. The forward skirt is bolted to the forward end of the tank assembly and to the RJ.

Figure 26
The 21.75 ft diameter common bulkhead is formed by two separate 2014-T6 Al hemispheres welded at 9 "orange peel" segments, joined circumferentially with two peripheral "Tee" bands. The hemispheres are bonded together with temperature resistant stiffening fiberglass honeycomb. At cryogenic temperatures, air entrapped in honeycomb freezes, forming near vacuum between hemispheres for excellent thermal barrier, thus preventing LOX from heating LH2 or LH2 from freezing LOX.
INSULATE TANK

CLEAN AND VAPOR DEGREASE

FINAL ASSEMBLY • JOIN FORWARD SKIRT, AFT SKIRT, THRUST STRUCTURE, PLUMBING, ELECTRICAL INSTALLATIONS

ASSEMBLE FORWARD SKIRT

ASSEMBLE AFT SKIRT

ASSEMBLE THRUST STRUCTURE

FAB FORWARD SKIRT PANELS

FAB AFT SKIRT PANELS

FAB THRUST STRUCTURE SKINS

SHIP TO SACRAMENTO

FAB AFT INSTAGE PANELS

ASSEMBLE AFT INTERSTAGE

SHIP TO KSC

Figure 28
FAB SEGMENTS  
FORWARD DOME  

FAB TANK  
SEGMENTS  

FWD  

FWD  

FAB SEGMENTS (9)  
AFT DOME  

WELD AFT  
DOME  

WELD SEALS  
BETWEEN RINGS  

LAYUP HONEYCOMB  
AND BOND FORWARD  
AND AFT  
DOMES OF  
COMMON BULKHEAD  

WELD SEGMENTS  
AND ATTACH RINGS  
OF  
COMMON BULKHEAD  
DOMES (AFT)  

WELD TANK SHELL  
AND TRIM  

WELD FORWARD  
DOME  

ASSEMBLE AND WELD  
FORWARD DOME,  
TANK SHELL, AND LOX TANK  

HYDROSTATIC TEST  
PROPellant TANKS  
ASSEMBLY
Major Components: Tiered chamber, LH₂ pumps, LOX pump, propellant utilization valve, spark ignition system, electrical control package, instrumentation system, pneumatic system, turbine start system, gas generator, heat exchanger, miscellaneous coolant valves.

Turbine Chamber: Tubular-walled with chamber stiffeners, expansion ratio, 27.5:1, regeneratively cooled.

LH₂ Pump: Turbine-driven, 7 stage, axial flow, self-lubricated pump; increases LH₂ pressure to chamber entry.

LOX Pump: Turbine-driven single stage, self-lubricated centrifugal pump; increases LOX pressure to chamber dieters. Accessory drive and an leak of pump.

Propellant Utilization Valve: PU system-controlled servomotor; bypasses a portion of LOX around LOX pump to maintain tank mass ratio.

Spark Ignition System: Four spark exciters, four spark plugs (2 in ASI chamber, 2 in gas generator), spark monitor.

Electrical Control Package: Controls staging of all J-2 engine functions. Solid-state logic circuitry, powered by 28 VDC from stage bus.

Instrumentation Package: Provides transducers and excitation for monitoring engine parameters. Output signals sent to stage T/M. Two packages, primary and auxiliary.

Pneumatic System: 1,000 cu in. sphere located inside LH₂ sphere, charged with Gla to 3,100 psia at -250°F. Controls all engine pneumatics. Regulated to 400 psia in pneumatic package.

GH₂ Sphere: Serves LH₂ and LOX turbines during engine start and restart; charged to 800 psia at -250°F. 7,300 cu in. sphere requires 7 seconds to exchange in mainstage operation.

Gas Generator: Provides burned LOX/LH₂ gases to sustain LOX and LH₂ turbopumps.

Heat Exchanger: Heats and expands cryogenic He from stage supply for pressurization of LOX tank. Utilizes heat from turbine exhaust.

Figure 29
J-2 ENGINE OPERATION (Simplified)

Figure 30

GENERAL DESCRIPTION

The propulsion system of the S-I/VE stage uses the Rocketdyne J-2 engine and associated components. The J-2 engine is capable of 200,000 pounds (kip) at altitude. It is thrust mounted, capable of making multiple restarts after long coast periods. LOX and LH₂ are used as propellants, with a nominal mixture ratio of 5:1. Electrical signals control pressurized GSE to activate valves for starting and stalling the engine.

Ignition of the engine is accomplished by an electrical spark plug ignition system. A servomechanism driven propellant utilization valve mounted on the LOX propulsion control engine LOX consumption, maintaining propellant tank mass ratio. Thrust chamber boring is performed by a regenerative LH₂ cycle, whereby the liquid is used to cool the engine during operation, and the fuel is burned into a gaseous state for fuel injection, combustion, etc.

OPERATION (See Figure 30.)

Upon an engine start command, the electrical control package energizes the helium control solenoid and ignition phase control solenoid in the pneumatic control package, closing the gas generator bleed valves and opening the ASI valve allowing LOX to flow to the ASI chamber. The ignition phase solenoid simultaneously opens the main fuel valve, routing LH₂ to the main combustion chamber to activate the fuel injection temperature pitching. The electrical control unit also sends a signal to the spark plug igniters for sufficient firing energy to spark plugs in the ASI chamber and the gas generator.

When the required temperature is detected by the fuel injector temperature pickup, the start tank discharge timer, which is energized at engine start, sends a signal to open the start tank discharge valve, allowing the start bottle to bleed down, thus supplying energy to the propellant turbopumps. At this time, a signal is sent to activate the ignition phase timer which, upon expiration, de-energizes the start tank solenoid, closing the start tank discharge valve. Simultaneously, a signal is received by the mainstage solenoid, which activates the LOX valve 1st stage and energizes the gas generator control valve. Upon activation of the LOX valve 1st stage, main chamber ignition occurs. When the gas generator ignites, the pump pressure-activated sequence valve opens and activates the LOX valve 2nd stage, and closes the LOX turbopump bypass valve causing the LOX turbopump to attain steady state speed. Transition to mainstage occurs when both propellant turbopumps have obtained steady state speed.

When an engine cutoff signal is received by the electrical control package, it de-energizes the mainstage and ignition phase solenoid valves and de-energizes the helium control solenoid de-energizer timer. This, in turn, permits closing pressure to the fuel valve, oxidizer valve, and the ASI oxidizer valve. The gas generator control valve, oxidizer turbopump bypass valve, and propellant bleed valves close to complete the engine cutoff sequence.

During steady state firings of the S-I/VE/S-V, the start tank, which provided the energy for start, is refilled. Upon command from the sequence controller, LH₂ and LOX are routed again to the thrust chamber where the ASI system initiates the engine operation. The pneumatic supply system is designed to provide sufficient helium for these starts.
S-IVB/S-IB OXIDIZER SYSTEM (continued)

It is heated and expanded. Another portion flows through undersize orifice (2) to the LOX pressurization line, where it is mixed with the output from the heat exchanger. The combined flow is directed into the LOX tank. Flow through two orifices is insufficient to maintain tank pressure during engine firing. As LOX tank pressure decays to 37.5 ± 0.5 psia, the flight pressure switch (3) drops out allowing solenoid valve (9) to go to its normally-open position. This permits additional flow from the heat exchanger (11) to increase LOX tank pressure. When LOX tank pressure reaches 59.5 ± 0.5 psia, the flight pressure switch (3) picks up, closing solenoid valve (9). LOX tank pressure then cycles between 27 and 40 psia. At engine cutoff, the flight pressure switch (5) is closed to control the cold helium shutoff valve (6), closing the valve as soon as pressure reaches 40 psia in the LOX tank.

Oxidizer Tank Vent Relief System: The LOX tank vent-relief system consists of a low-speed valve with a pneumatically-actuated vent relief valve (2), and a relief valve (3). Pneumatic operation is provided by the LOX vent actuation module using the helium gas from the pneumatic control module. The relief portion of the vent-relief valve is capable of exhausting all LOX vapor resulting from tank fill. The relief portion of the vent-relief valve automatically reseals pressure in excess of 44 psia and resets at 41 psia. The relief valve resets at 45 psia, resets at 42 psia, and operates in the event the vent-relief valve fails. During fill of the LOX tank, the vent portion of the vent-relief vent section opens at 44 psia, resets at 41 psia, and operates in the event the vent-relief valve fails. The relief valve is pneumatically opened and closed upon actuation of the solenoid in the LOX vent actuation module. The valve is open at the initiation of tank fill and closed prior to pre-pressurization. GOX from either the vent-relief valve or relief valve is vented overboard through a 5 inch line.

Oxidizer Tank Pressurization System: Oxidizer tank pressurization is accomplished by LOX pressurization module (Figure 31). At the beginning of LOX tank fill, the vent-relief valve (3) is open. During tank fill, LOX is supplied to the tank at a maximum rate of 1,000 gpm, and is reduced to 200 gpm during slow fill. When fill is complete, the vent-relief valve (3) is closed and pre-pressurization begins until desired pressure has been reached. The LOX tank is pre-pressurized to 39.5 ± 0.5 psia by cold helium from ground supply through solenoid valve (2). Cold helium for lift-off pressurization is stored in eight solenoid valves (4) charged to 3,100 ± 100 psig at 450°F in the lift tank. The flight pressure sensing switch (5) (sensing tank fill pressure) controls pre-pressurization by opening and closing the onboard shutoff valve (6) for cold helium pressurant flow, and in this way acts as a regulator. Switch (7) picks up at 465 ± 10 psig and closes onboard shutoff valve (6) and shunts out at 350 ± 10 psig and opens shutoff valve (6). In case of regulator failure during flight, pressure switch (7) and plenum chamber (8) act as a backup regulator. During boost, no pressure vent or relief is actuated.

When engine ignition is detected, flight pressure switch (5) is changed over from control of the onboard shutoff valve to control of solenoid valve (9). On-board shutoff valve (4) will be in its open position, allowing cold helium to flow from the cold helium supply through the regulator (Q) reducing pressure to 450 ± 25 psig through the onboard shutoff valve (6), past the plenum chamber (8) and pressure switch (7), into a manifold. A portion of the cold helium flows to the engine heat exchanger (11), where
The S-I/VS/40 utilizes hydrogen as fuel. LH₂ is stored in an insulated cylindrical tank of 30,426 cu ft volume. LH₂ at -429° F is pressurized with 

The S-I/VS/40 utilizes hydrogen as fuel. LH₂ is stored in an insulated cylindrical tank of 30,426 cu ft volume. LH₂ at -429° F is pressurized with Gh from ground source to 30.5 psia. Usable capacity is 30,333 pounds LH₂ with a residual of approximately 300 pounds at 100% per cent load. During firing in flight, the tank is pressurized with LH₂ from J-2 engine boost/flow. 

**Operation** (See figure 32.)

Fuel Tank Pressurization: The fuel tank fillage must be maintained at proper operating pressures to ensure a non-positive suction head at the LH₂ pump inlet to prevent cavitation and possible pump damage. During rapid fill phase, LH₂ is supplied at the rate of 3,000 gpm. Vent valve (1) is opened. The final topping fill rate is 250 gpm. Vent valve (1) is closed and pressurization is initiated with 

Figure 31
of fuel tank pre-pressurization. Venting during boost is not anticipated but is provided for by relief valve (7) which is spring-loaded to vent at 43 psia and close at 40 psia. Venting is overboard in flight. Vent-relief valve (7) is controlled to open at 43 psia and close at 40 psia. A pilot-operated directional valve directs vented gases to the stage umbilical (8) during ground operation, or to the dual 4-inch overboard vent line in flight.
The pneumatic control system of the S-IVB engine provides pressure to operate all S-IVB stage pneumatically-operated valves except the engine valves. GHe is supplied to a sphere pre-charged to 3,100 ±100 psia at 70°F from ground facilities. This sphere is located on the forward side of the thrust structure. The pneumatic control module is pre-conditioned to above 70°F by the environmental control system while on the ground. The pneumatic control module filters and regulates this pressure to 475 ±25 psig to the other control modules. It is protected from regulator failure by a normally-open solenoid valve controlled by a downstream pressure-sensing switch.

At pressures greater than 35 ±10 psig, the pressure switch picks up and closes the valve. At pressures below 450 ±10 psig, the pressure switch drops out and allows the solenoid to open, thus acting as a backup regulator. Pressure surges are absorbed by the plenum chamber. In addition to operating valves, the GHe system also provides fuel for purging the LH₂ and LOX turbine seal cavities, and gas generator fuel manifold. This starts ten minutes before admitting propellants to the engine. GHe is supplied to the following valves:

- Engine start tank vent valve
- Pilot-operated directional valve
- Fuel tank vent-relief valve
- Fuel fill and drain valve
- LOX fill and drain valve
- GHe pre-valve
- LOX pre-valve
- LOX vent-relief valve
- LH₂ chilldown valve
- LOX chilldown valve

The pneumatic control system contains six actuation control modules to operate LOX fill and drain valves, LH₂ fill and drain valves, LOX and LH₂ pre-valves, LOX vent-relief valve, LH₂ vent-relief valve, and all pneumatically-operated directional vent valves. Each actuation control module contains two solenoid operated three-way control valves.
Flight control achieved by gimballing J-2 engine during mainstage operation. Hydraulic system provides thrust vector steering in pitch and yaw planes only. Roll control is accomplished by a series of APS module firings. APS also provides thrust for altitude control in outer atmosphere where conventional aerodynamic controls are ineffective. APS corrects attitude errors in pitch, yaw, or roll axes by pulse firing APS modules. All steering and attitude control signals are supplied by the IU. Hydraulic system is capable of gimballing engine ±7° in a square pattern. APS will correct attitude errors of ±1°.
OPERATION (See Figure 35.)

Auxiliary Hydraulic Pump Circuit - Coast Mode/Uncoupled Flight: Fluid flows from pump (1) through valve (2) and filter (3) to cavity in accumulator (4), acts against piston (5) to pressurize reservoir (6) to working pressure. Piston (7) balances system pressure at 3,650 psi. Fluid from cavity (4) flows to inlet of actuator assemblies (8) and (9), is directed to servovalves (10) and (11) and is assumed to return (6) through valves (12) and (13). Flow from reservoir (6) is routed through pump (14) eases drain and returns to pump (12) inlet through line (15). Valve (16) prevents backflow to pump (14) and retains system pressure for limited time.

Engine-Driven Hydraulic Pump Circuit - Powered Flight: Fluid flows from pump (16) through valve (18) when outlet pressure exceeds residual system pressure, and is directed to actuators (10) and (11) through filter (13) and accumulator (4). If U signal is applied to servovalves (10) and (11), control spools (17) and (18) are shifted to activate actuating cylinders. Return line fluid flows through valves (12) and (13), reverses (6) to pump (14) inlet. Valve (19) provides system high pressure protection and is adjusted to operate at 3,900 psi. Valves (20) and (21) provide low-pressure system protection and will vent fluid overboard when pressure exceeds 275 psi.

GENERAL DESCRIPTION

Hydraulic system provides limited vector steering (pitch and yaw only) for stage during main engine burn. Main engine is positioned at 35' from stage centerline by two hydraulic actuator assemblies. Steaming signals from I1 are translated by servovalves to operate hydraulic actuators. Engine-driven pump operates only during main engine burn. Motor-driven pump acts as backup to engine-driven pump during main engine burn, provides cooling during uncoupled flight, and maintains acceptable temperature and viscosity of hydraulic fluid during cruise, by periodically cycling fluid. Accumulator-reservoir assembly is integral housing which contains reservoir and accumulator sections. Reservoir section is pressurized to working pressure (approximately 169 psi) by either pump. Initial pressure (approximately 65 psi) is provided by accumulator pre-charge. Servovalve uses torque motor to convert I1 signals to proportional flow rates at actuator.
AUXILIARY PROPULSION SYSTEM

Major Components
- Auxiliary Propulsion Modules (2) each module contains three attitude control engines and propellant control system; auxiliary propulsion system modules are mounted 180° apart, on aft skirt.

Attitude Control Engines
- Torca, 150 lb thrust per engine; chamber pressure, 100 psi; pulse-type engines equipped with molybdenum thrust liner and refractory chamber liner for ablative cooling; chamber operating temperature, approximately 5,500° F.

Propellant Control Systems
- Integral, bellows-type propellant tank incorporates He sphere, fuel tank, and oxidizer tank; centrally-located He sphere provides positive expulsion pressure for fuel and oxidizer tanks; fuel tank stores 23 lb of MMH; oxidizer tank stores 33 lb nitrogen tetroxide; propellants are hypergolic, closed loop system.

GENERAL DESCRIPTION (See figure 36.)

Attitude control engines provide three axes control for S-IVB stage during coast phase. Roll control is also provided by system during mainstage operation. Reaction-type control is provided by pulse firing engines in short bursts (65 ms min duration). All control signals supplied directly from LL. Control engines are pulse fired in pairs to indicate and stop attitude correction.

OPERATION (See figure 37.)

Fuel and Oxidizer Control Pressure Circuit: Fuel and oxidizer systems are re-circulated from ground source by opening valves (1), (2), (3), and (4), allowing fuel and/or oxidizer to flow through tanks and feed lines. Fuel and oxidizer return from engine vent ports is routed to respective supply source through fuel and oxidizer vent disconnects. Systems are purged by opening valves (2) and (4) permitting He to flow through check valves (5) and (6) and return to supply source through (7) and oxidizer vent disconnects. Prior to propellant loading, He sphere is pressurized. He from ground source flows through valve (8) and pressures tanks to 3,000 psig. Valve (9) provides high-pressure protection, will relieve at 3,500 psig, resetting at 3,200 psig. He control pressure is regulated to 200 ± 5 psig in redundant regulator contained in He
AUXILIARY PROPULSION SYSTEM

Auxiliary propulsion system (continued)

Auxiliary propulsion system is normally open to provide system pressure. If normally open regulator fails, pressure too high high-pressure switch is activated, sets relay K4, and opens regulator (10). Low-pressure switch will set relay K4 and open regulator (10) if pressure is too low. Regulated pressure will be changed by valves (11) and (12) if pressure exceeds 325 psig. During operation, system will maintain propellants at engine fuel/oxidizer inlet valves at 200 psig pressure. On ground high-pressure He system and regulated He pressure may be vented through solenoid valves energized from GSE power.

Provides electrical power for operation of vehicle subsystems. Consists of four independent systems:

a. Forward system No. 1 (28 vdc) powers T/M, range safety receiver No. 1, switch selector.

b. Forward system No. 2 (28 vdc) powers PU system, inverter-converter, range safety receiver No. 2.

c. Aft system No. 1 (28 vdc) powers J-2 engine components, pressurization systems, auxiliary propulsion components, stage sequencer.

d. Aft system No. 2 (56 vdc) powers auxiliary hydraulics pump motor, LOX and LH2 chilldown inverters, which supply ac to chilldown pumps.

All electrical systems use silver oxide and zinc plate batteries; operational life, 72 hrs.
### S-IVB Electrical System

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major Components</strong></td>
<td>- 20 Vdc, approx 270 Ah Battery (2), 26 Vdc, approx 55 Ah Battery (2), 26 Vdc, approx 3 Ah Battery (1), 56 Vdc, approx 22 Ah Battery (1), Internal-External Busses (4), Talkback Bus (1), Internal-External Switch (4), Power Distribution Boxes (3), Switch Selector (2), Sequence (1).</td>
</tr>
<tr>
<td><strong>Batteries</strong></td>
<td>- Positive plate, silver oxide; negative plate, zinc electrolyte; potassium hydrosulfite; sealed, pressurized unit; temperature-controlled; service life, 72 hrs.</td>
</tr>
<tr>
<td><strong>Internal-External Busses No. 1 and No. 2</strong></td>
<td>- Power distribution point for all flight operational equipment in respective section.</td>
</tr>
<tr>
<td><strong>Talkback Bus</strong></td>
<td>- Returns stage status information to GSE. Externally powered only during test.</td>
</tr>
<tr>
<td><strong>Internal-External Switch</strong></td>
<td>- GSE-controlled transfer switch charges over power from GSE to stage batteries.</td>
</tr>
<tr>
<td><strong>Power Distribution Box</strong></td>
<td>- Distribution point for external or internal power to equipment located in stage.</td>
</tr>
<tr>
<td><strong>Switch Selector</strong></td>
<td>- (GFE) Translates IU digital commands to S-IVB stage commands. 8-bit monitored output of 113 possible commands.</td>
</tr>
<tr>
<td><strong>Sequence</strong></td>
<td>- Receives commands from switch selector. Contains non-latch relays, controlling all stage functions.</td>
</tr>
</tbody>
</table>

### Operation

**Aft System**  
Aft power system No. 1 (28 Vdc approx 55 Ah) powers Internal J-2 engine systems, pressurization systems, aft battery heaters, stage sequencer, APS modules, and allage rockets.

**Aft power system No. 2 (56 Vdc approx 22 Ah)** powers auxiliary hydraulic pump, LOX chilldown and LH₂ chilldown inverters. Inverters require 3-phase ac power, necessitating higher voltage battery. Both batteries located in aft skirt. Aft power distribution box (in aft skirt) is distribution point for internal and external power. Internal-external switch, controlled by GSE, connects ground power for stage checkout. GFE
S-IVB ELECTRICAL SYSTEM (continued)

Switch selector translates sequencing commands from IU to stage commands. Contains error checking circuitry. Stage sequencer receives signals from switch selector, sets or resets relays to activate stage functions.

Forward System: Forward power system No. 1 (28 Vdc approx 270 AH) powers T/M, range safety system No. 1, switch selector and forward battery heaters. Forward power system No. 2 (28 Vdc approx 3 AH) powers PU system, inverter-converter, and range safety No. 2 system. Both batteries located in forward skirt. Forward power distribution box (in forward skirt) is distribution point for internal (flight) and external (checkout) power. Internal-external switch, controlled by GSE, connects ground power for stage checkout.
FORWARD ELECTRICAL SYSTEM FUNCTIONAL SCHEMATIC

AFT ELECTRICAL SYSTEM FUNCTIONAL SCHEMATIC

Figure 40

Figure 39
PROPELLANT UTILIZATION SYSTEM FUNCTIONAL SCHEMATIC

S-IVB PROPELLANT UTILIZATION SYSTEM


Fuel Mass Sensor - Capacitive type; 1,200 picofarads in air; 1,000 picofarads at 500 VDC; temperature range, 100° F to -423° F; indicates fuel load mass located in LH2 tank.

LOX Mass Sensor - Capacitive type; 350 picofarads in air; 1,000 picofarads at 500 VDC; temperature range, 120° F to -297° F; indicates LOX load mass located in LOX tank.

PU Electronics Assembly - Input power, ac and dc from inverter/converter; 28 Vdc from forward No. 2 battery; contains electronics to provide propulsion tank control signals located in fwd skin.

Inverter/Converter - Converts 28 Vdc from forward No. 2 battery into precise ac and dc voltages for PU electronic assembly.

OPERATION (See figure 41.)

Motorizing probes provide capacitance output directly proportional to tank propellant mass. Changing level of dielectric (LOX or LH2) changes capacitive value of probe, which is fed into PU electronics assembly. Assembly signals position servo motor, which controls LOX bypass valve on J-2 rocket engine within ±10 per cent of 5:1 engine mixture ratio, keeping remaining propellant mass and engine consumption ratio in balance. Maintains propellant residual to ~575 lbs (0.25% total inside load).

Sensors feed LH2 and LOX brine, which are servo-balanced. Qualitative error cancel probe errors, at irregular intervals. Amplified signals applied to pot shaft positioning motors. Feedback damps servomotors. Pots control PU system operation. Supply of LH2 and LOX feeds to shaping network. Amplified, radiated signal is applied to mixture ratio servo. Servo motor controls position of PU valve, keeping engine mixture ratio to compensate for tank mass imbalance. PU valve 'feedback' jet motor amplifier output. Additional pots supply T/M and mass loading signals.
bi-level, in NRZ code. In flight, output is applied directly to FM transmitter No. 4. PCM/FM system also is used for automatic countdown. Analog-to-digital converter output is fed through VCO to GSE.

A tape recorder is utilized to store a portion of sampled data for playback command by ground station.

**System No. 5 (SS/FM) Functional Description (See Figure 44.)**

Multiplexed inputs are mixed with CCO subharmonics, amplified, and single sideband with filter (filter passes upper band). SS/FM signal is amplified, and mixed with incremental subharmonics of CCO. Information is contained in base band spectrum of modulator outputs. Modulator outputs are applied to summing amp. Composite output of summing amp is applied to low pass filter where harmonics are removed. No pre-emphasis schedule is applied; all channels are controlled by AGC network to allow maximum modulation of transmitter at all times. Output of AGC network is summed and applied to transmitter No. 4. Since 910 ke CCO provides all translation and reference tones, no cross-modulation or data loss occurs if CCO drifts, as all subsequent shifts are proportional. A pilot tone, which is sub-harmonic of 910 ke CCO, is also applied to summing amp. Since this continuous tone is suppressed or amplified with each incremental service channel, it establishes input signal intensity during data retrieval.

**TELEMETRY SYSTEMS**

Measures, patterns, and transmits flight instrumentation data (acceleration, force, pressure, strain, temperature, vibration, time-event functions, etc.) to ground stations.

Four modulation techniques used:

a. **FM/FM** - Constant amplitude, varying frequency signals (FM) modulate constant amplitude, varying frequency (FM) transmitter.

b. **PAM/FM/FM** - Multiplexer converts inputs to time-shared, varying amplitude pulse train which modulates FM sub-carrier channel. Sub-carrier output (FM) modulates FM transmitters.

c. **PCM/FM** - Multiplexer outputs (PCM) are converted from analog to digital format (digital) which modulate FM transmitter.

d. **SS/FM** - Multiplexed inputs are analog modulated (SS) then single sideband. All SS channels modulate FM transmitter.

**System No. 1, No. 2, No. 3 (PCM/FM/FM) Functional Description (See Figure 42.)**

Transmitters measure flight data, feed high 60 to 5 stress level inputs to multiplexer (low level—0 to 30 mvdc—are amplified first). Signals are multiplexed and output is varying amplitude, constant width pulses, which are applied to 70 kc data converters and converted to varying frequency (FM) output. IRIK channels 1 through 16 contain a.m. signals. All 16 channels are mixed to form composite FM signal, which is fed to transmitter. Transmitters No. 1 and No. 3 are duplicated into single antenna. Transmitter No. 2 is duplicated with PCM system transmitter No. 4 and SS/FM, each single antenna.

**System No. 4 (PCM/FM) Functional Description (See Figure 43.)**

System No. 1, No. 2, and No. 3 multiplexer outputs are sampled for transmission on PCM/FM at discrete intervals. PAM output train is converted from analog to digital format in converter. Transmitter input is 10-bit words comprising 72 kilobit frame.
## TELEMETRY SYSTEM FUNCTIONAL SCHEMATIC

### S-IVB TELEMETRY DATA CAPABILITY

<table>
<thead>
<tr>
<th>System</th>
<th>Sync Channels</th>
<th>Data Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>3</td>
<td>27*</td>
</tr>
<tr>
<td></td>
<td>High Level PAM (0 to 5 vdc)</td>
<td>3,600 Samples per Second (30 x 120)</td>
</tr>
<tr>
<td>No. 2</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>High Level PAM (0 to 5 vdc)</td>
<td>3,600 Samples per Second (30 x 120)</td>
</tr>
<tr>
<td>No. 3</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>High Level PAM (0 to 5 vdc)</td>
<td>3,600 Samples per Second (30 x 120)</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

* Sampled data channels may be sub-commutated x 10, providing a maximum data channel capability of 690.

** R&D Flights may be deleted on non-rated flights.

---

**Figure 42**
SINGLE SIDEBAND/FREQUENCY MODULATION FUNCTIONAL SCHEMATIC

DIGITAL DATA ACQUISITION SYSTEM FUNCTIONAL SCHEMATIC

Figure 44

Figure 43
SEPARATION SYSTEM

Major Components
- MDF Explosive Harness Assembly (2), Detonator Block (1), EBW Detonator (2), Firing Unit (2).

Separation Joint
- Tension Tie connecting Adj Interstage and Adj Skirt: 7075-T6 AL, approximately 0.050 in. thick located directly over channel containing MDF.

MDF Explosive Harness Assembly
- Flexible, metal sheet contains PETN core, approximately 10 grains per foot: propagation rate of 22,000 feet per second; two harness assemblies used for optimum reliability; both harness assemblies completely surround stage.

Detonator Block
- Alloys MDF harness assemblies and EBW detonators.

EBW Detonator
- Threaded connector containing 1.4 grain PETN booster charge and 30 am PETN main charge; lapped plate contained in booster charge; high voltage/high current required for initiation; microspark gap incorporated for safety.

Firing Unit
- Input voltage, 23 VDC; output voltage, 2,300 VDC; 1,500 amp; house contains electronics to initiate EBW detonators; operation requires charge (ARM) and trigger signals.

Operation (See figure 46.)
- Firing units charged following S-18 engine cutoff. Charging (ARM) signal is stepped up and applied to large storage capacitor (2,500 VDC). Signal, applied approximately six seconds later is stepped up to 5,000 VDC, to trigger firing. Time lapsed, charging storage capacitor to discharge through respective EBW detonator. Propagation wave from EBW detonator booster charge initiates primary charge. Wave initiates booster charges in detonator block and is transmitted to MDF harness assemblies. Propagation of harness assemblies uses tension tie to permit stage separation. All separation signals supplied by S-18 stage sequencer.

Figure 46

Reliable, small, light, high energy explosive devices used in following systems:

a. S-18 and S-18B stage separation system used to separate two stages.

b. S-18 and S-18B stage retrorocket system used to decelerate lower stage.

c. S-18B stage propellant dispersion system used to shut down J-2 engine and rupture propellant tanks.

d. Ullage control system used to settle propellants in tanks for engine start.
**PROPELLANT DISPERSION SYSTEM**

**Major Components**
- Antennae (2), Range Safety Receivers (2), Range Safety System Controllers (2), Firing Units (2), EBW Detonators (2), S&A Device (1), Primacord Harness Assemblies (2), Linear-Shaped Charges (2).

**Antennae**
- Qutar wave, slot type; 52 ohm impedance, UHF (450 mc); two antennae.

**Range Safety Receivers**
- GFE, crystal-controlled transistorized, FM, superhetodyne; ten channels; carrier frequency 406,450 mc; sub-carrier channels are ten standard IRIG frequencies; two sections (receiver and decoder).

**Range Safety System Controllers**
- Provides relay control for system activate, arm, trigger, and monitory 28 vdc output.

**Firing Unit**
- Input voltage, 28 vdc; output voltage, 2,300 vdc at 1,500 amps; housing contains electronics for initiating EBW detonators; operation requires charge (ARM) and trigger signals.

**EBW Detonator**
- Threaded connector containing PETN booster charge and primary charge; bridgewire contained in booster charge; high voltage/high current required for initiation; mica spark gap incorporated for safety.

**S&A Device**
- Provides positive isolation (SAFE) between EBW detonators and primacord harness assemblies or explosive continuity (ARM); electrically-actuated, mechanically-operated, rotor employed; rotor contains PETN, 1.4 grain booster charges (2).

**Primacord Harness Assembly**
- Flexible, fabric and plastic sheath contains PETN core, 60 grains per foot; propagation velocity of 23,000 feet per second; dual harness assemblies used for optimum reliability.

**Linear Shaped Charge**
- Triangular-shaped, aluminum sheath contains RDX core, 150 grains per foot; two attached to LH2 tank, one to LOX tank.
Prior to LO, receivers and firing units switch to inter power. At LO, receivers are activated and S&A devices are in ARM position. In event flight termination is required, coded arm and trigger signals are transmitted (signal transmitted on appropriate IRIS sub-carrier). RS receivers decode signals and command J-2 engine cutoff through RS controllers. Coded trigger signal is sent to firing units to initiate EDW detonators. Explosion is propagated through S&A device to proximate lamphouses, then to line-shafted charges attached to LH2 and LOX tanks. Charges initiate tanks contain propellant dispersion.
ULLAGE ROCKETS (IGNITION SYSTEM)

**Major Components**
- Ullage Rockets (36), Firing Units (6), EBW Motor Initiators (6).

**Ullage Rockets**
- Thiokol TX-200, solid propellant rockets (thrust: 3,390 lb (nominal) at +70° F; burn time: 3.9 sec at 70° F; 56.8 lb of propellant; ammonium perchlorate and polysulfide exit nozzles centered 35° from stage centerline, mounted on aft skirt.

**EBW Initiators**
- GFE: cupric oxide and magnesium charge; 2 mounted in boss on dome of rocket motor.

**Firing Units**
- Input voltage, 20 volt; output voltage, 2,300 at 1,300 amperes; housing contains electronics for deactivating EBW initiators; operation requires charge (ARU) and trigger signals.

**OPERATION**
(See figure 48.)

Ullage rockets are fired by signal from S-IVB sequencer. Charge (ARU) signal is stepped up and applied to large storage capacitor (2,300 volt). Trigger signal is stepped up (5,000 volt) to trigger gap tube. Gap tube ionizes, causing storage capacitor to discharge through EBW initiators. Detonation wave from initiators is transmitted to propellant ignitor contained in perforated tube. Hot particles and gases from igniter pellets cause ignition of solid propellant grains. Ullage rockets impart forward acceleration on S-IVB stage to provide optimum ullage positioning and aid in separation.
S-IVB/S-IVC RETROROCKET SYSTEM

Major Components
- Retrorockets (4), Firing Units (6), EBW Initiators (6).

Retrorocket - Thiokol TE-29-15, solid propellant (ammonium perchlorate and polysulfide) thrust, 35,600 lbs (nominal) at 70°F; burn time, 1.5 sec at 70°F; exit nozzle contd 9° from stage centerline; mounted on aft interstage.

EBW Initiator - GFE, threaded connector contains copper oxide and magnesium charge; mounted in base of rocket motor.

Firing Units - Input voltage, 28 volts; output voltage, 2,300 volts at 1,500 amps; housing contains electronics for detonating EBW initiators, operating requires charge (ARM) and trigger signals.

OPERATION (See Figure 42.)

Firing units charged prior to S-IVB/S-IVC separation. Firing unit oscillator provides ac for step-up transformer primary. Transformer output filtered and applied to storage capacitor (2,300 volts). Trigger signal applied following separation. Signal is converted to ac, filtered (pulsating dc) and transformer coupled to gas tube (5,000 volts). Tube ionizes, causing storage capacitor to discharge through respective EBW initiators. Propagation wave from Initiator is transmitted to igniter plugs contained in perforated tube. Hot particles and gases form igniter plugs cause ignition of solid propellant grain. Retains impact deceleration force on S-IVB to aid separation. All surge signals supplied by S-IVB sequencer.

VULCAN ROCKETS (JETITION SYSTEM)

Major Components
- Frangible Nut (6), Firing Unit (2), CDF Fuses (6), Detonator Block (1), EBW Detonator (12).

Frangible Nuts - Threaded nut body provides bosses for two CDF fuse assembly T-fittings; attach bolt installed perpendicular to T-fittings in threaded casing, nut fractures along length of casing.

CDF Fuses - Two grains per fuse PETN charge covered with plastic and fabric sheathing; three fuses are inserted at each end into single end fittings; end fittings contain 1.5 grain booster charges; T-fittings incorporated into fuse assemblies for attachment to frangible nuts.

Detonator Block - Two input bosses, two output bosses; block used to manifold 2 EBW detonators to 6 CDF fuses.

Firing Units - Input voltage, 28 volts; output voltage, 2,300 volts at 1,500 amps; housing contains electronics for detonating EBW detonators; operation requires charge (ARM) and trigger signals.

EBW Detonator - Threaded connector containing 1.4 grain PETN booster charge and 30 mg PETN primary charge; bridgewire contained in booster charge; high current/high voltage required for initiating mica spark gap incorporated for safety.

OPERATION

Firing units charged prior to S-IVB and S-IVC stage separation. Charge (ARM) signal is stepped up (2,300 volts) and applied to tube storage capacitor. Trigger signal, applied through S-IVB sequencer after rocket burnout, is stepped up (5,000 volts) to ignite gas tube. Tube ionizes, causing storage capacitor to discharge through EBW detonator. Detonator propagates CDF fuses connected to detonator block. Detonation wave is transmitted to tee-fittings at frangible nuts; tee-fitting charges (lead azide, 41 mg, and PETN, 260 mg) are initiated, fracturing frangible nuts. Nut fracture releases pre-loaded spring; village rocket assemblies (13) are jettisoned.
S-IVD AUTOMATIC GROUND CHECKOUT SYSTEM

Stage is checked out by automatic, high speed equipment. System uses electronic digital computer and ancillary equipment to control, and to sequence. Interface units, located between computer complex and operational and items, handle level conversions, format changes, etc.

Major end items include systems status display unit, using projected displays on TV tube showing schematic or diagrammatic representation of system under test; stimuli and response conditioning units; operator console; telemetry ground stations; time synchronization unit; switch panels; safety line monitors; etc. Test Operator Station has overall control and override capability at all times.

Operational Philosophy

a. Computer--Stores test instructions, controls test sequencing and may perform diagnostic search and malfunction isolation. Program is stored on magnetic tape and computer magnetic core.

b. Stimulus conditioner--Supplies test activation signals to equipment in stage under test, such as a relay or component.

c. Test point and stimulus switching--Routes all input and output signals to appropriate points.

d. Computer comparator--Compares returned test data against internally stored standards. Conversion routine used to change test data into a suitable form, usually as "go" or "no-go" signals.

e. Visual displays--Real time indications of signal, test value, test number, and function.

f. Readout devices--Present concurrent and permanent records of testing.
S-IVB/S-V MISSION PROFILE

Vehicle intended to launch and insert into lunar trajectory manned Apollo spacecraft and unmanned extravehicular flight experiments. S-IVB stage thrust, 200,000 lb payload capability, 45 tons. Total stage weight, 27,500 lb dry. Restart capability—initial stage start for boost into Earth orbit; second start for lunar trajectory insertion.

First stage booster separates at LO + 150 seconds. Second stage separates at LO + 540 seconds. S-IVB J-2 engine ignites at altitude of 86 miles at 14,200 mph (20,800 fps). Engine burns about 160 seconds, establishing parking Earth orbit of 110 miles and cuts off. Vehicle assembly orbits up to 4-1/2 hours, enabling astronauts to perform navigational sightings, establish time and velocity coordinates for trans-lunar trajectory. During orbit, vehicle systems are checked out via PCM/FM.

Launch window is calculated, J-2 engine restarts, vehicle is scored out of Earth orbit. Engine burns 310 seconds to establish escape velocity of 25,000 mph (36,600 fps). After J-2 cutoff, assembly coasts for 2-1/2 hours. S-IVB APS is used to correct final vehicle/spacecraft attitude.

Spacecraft detaches, reverses itself, and performs docking maneuvers with LEM (still attached to IU and S-IVB). Maneuver is completed, IU and S-IVB are jettisoned. Apollo and LEM continue to mean. In mean orbit, LEM detaches and orbits, seeking landing site. Two men land on mean in LEM. One man explores upon, other checks out LEM. Up to 48 hours later, LEM blasts off to rejoins one man in Apollo. LEM is jettisoned. Apollo service module propulsion stops Apollo out of mean orbit to Earth. Apollo service module is jettisoned. Apollo command module re-enters atmosphere at 25,000 mph. After slowing sufficiently, Apollo parachutes into ocean, and is picked up.

---

Figure 53
**S-IVB/S-V STAGING (Continued)**

<table>
<thead>
<tr>
<th>Countdown</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 -0.8</td>
<td>PU System off--PU measurements are unneeded, since propellant is no longer being consumed, and the quantity of remaining propellant is known.</td>
</tr>
<tr>
<td>3 +1.1</td>
<td>Engine Control and Instrumentation recoveries are off; extremely cold temperature of space demands equipment be warmed.</td>
</tr>
<tr>
<td>3 +2.1</td>
<td>Range Safety Receivers off--Propellant Dispersion system disabled to prevent inadvertent destruction of stage.</td>
</tr>
<tr>
<td>3 +1.5</td>
<td>SS Band Flight T/M Transmitters off, Orbital T/M Transmitters off--Activates orbital data link.</td>
</tr>
</tbody>
</table>

Coast period--During 4-1/2 hour coast period, the increased fuel tank ullage pressure caused by solar radiation is vented out of aft facing nozzles to provide approximately $10^{-6}$G's acceleration. Propulsion venting commences approximately 0.1 sec before first burn engine cutoff. Approximately 8 minutes before engine restart, the 4-inch diameter non-propulsive vent opens and pressure decays to 24.5 psia. Both vents close and repressurization of fuel tank begins.

During coast period, following T/M operating sequence repeats 6 to 9 times:

| In range +1.0 | Orbit transmitter group on--Switches on a ground station command. Orbital standpipe of ground station.
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>In range</td>
<td>Data link out of line--All equipment at high speed.</td>
</tr>
<tr>
<td>Out of range</td>
<td>Orbit transmitter group turned off, recorder turned on.</td>
</tr>
<tr>
<td>3 -3.30.2</td>
<td>Auxiliary hydraulic pump on--Operates to move J-2 propellants to liquid rocket engine.</td>
</tr>
<tr>
<td>3 -3.27</td>
<td>J-2 70 lb thrust ullage engines fire to settle propellants.</td>
</tr>
<tr>
<td>3 -3.26.0</td>
<td>Fuel vent value opens.</td>
</tr>
<tr>
<td>3 -3.25.2</td>
<td>LH$_2$ tank repressurized--Issues LH$_2$ pump NPSH for J-2 restart.</td>
</tr>
<tr>
<td>3 -3.24.8</td>
<td>LH$_2$ chilldown--Prepares LH$_2$ plumbing for restart.</td>
</tr>
</tbody>
</table>

**NOTE:** Significant event-time functions listed herein reflect current mission requirements. These times are subject to change, and should not be considered final. 

<table>
<thead>
<tr>
<th>Countdown</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 -1260</td>
<td>Pulse engine thrust chamber--Clears J-2 engine of flammable gases.</td>
</tr>
<tr>
<td>1 -960</td>
<td>Thrust chamber purge off.</td>
</tr>
<tr>
<td>1 -910</td>
<td>Auxiliary hydraulic pump on--Recirculates fluid to maintain constant pressure.</td>
</tr>
<tr>
<td>1 -900</td>
<td>LOX chilldown--Cools LOX plumbing for thermal shock preconditioning.</td>
</tr>
<tr>
<td>1 -970</td>
<td>LH$_2$ chilldown--Cools LH$_2$ plumbing for thermal shock preconditioning.</td>
</tr>
<tr>
<td>1 -90 - 90</td>
<td>Pressurize LH$_2$ and LOX tanks--Cold the propellants tanks to insure NPSH at engine ignition.</td>
</tr>
<tr>
<td>1 -60</td>
<td>DC power to internal--CSE power switched off. Vehicle battery power switched on.</td>
</tr>
</tbody>
</table>

(Li1/Al) 1 -0 | Launch vehicle/payload leaves pad. |
<p>| 1 -403    | T/M calibration--Calibration reference signal sent to insure accurate T/M ground readback. |
| 1 -396.5  | T/M calibration--Calibration reference signal sent to insure accurate T/M ground readback. |
| 1 -0.1    | Ullage rocket ignition--Additional axial acceleration insures bottoming of liquids in tanks. |
| 1 +0      | S-IVB/S-IVB Separation--Tension tie nozzles, parting stages. |
| 1 +1.6    | J-2 engine start--Delay separation signal from S-IV stage fires J-2 ignition system, starting engine. |
| 1 +6.0    | Activate PU--PU system is made operational as propellant slaming from separation is sustained. |
| 1 +0      | Engine first burn cutoff--When Earth parking orbit is achieved, J-2 engine is cut off. |
| 1 +0.5    | Auxiliary hydraulic pump to coast mode--During coast, J-2 engine hydraulic is kept warm. |</p>
<table>
<thead>
<tr>
<th>Stage Destination</th>
<th>Required at</th>
<th>Used for</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-IVB Test Vehicle</td>
<td>SACTO</td>
<td>Test</td>
</tr>
<tr>
<td>Dynamics Vehicle</td>
<td>MSFC</td>
<td>Test</td>
</tr>
<tr>
<td>Facility Checkout Vehicle</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 501</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 502</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 503</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 504</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 505</td>
<td>KSC</td>
<td>Flight</td>
</tr>
<tr>
<td>Flight Vehicle No. 506</td>
<td>KSC</td>
<td>Flight</td>
</tr>
</tbody>
</table>

These vehicles are the same vehicles constructed for S-IVB, then modified to S-IVB/S-V configuration for this testing program. See S-IVB/S-IVB section for description of test purposes.

### S-IVB/S-V Staging (Continued)

<table>
<thead>
<tr>
<th>Countdown</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 -222.0</td>
<td>J/M on and calibration--T/M turned on and recalibrated for restart.</td>
</tr>
<tr>
<td>1/2 -219.9</td>
<td>LOX chilldown--Prepares LOX plumbing for restart.</td>
</tr>
<tr>
<td>1/2 -21.7</td>
<td>LOX tank depressurized--Issues NPSH LOX pump for J-2 restart.</td>
</tr>
<tr>
<td>1/2 -0</td>
<td>S-IVB restart--Engine refires to increase axial acceleration for lunar insertion.</td>
</tr>
<tr>
<td>1/2 +3.0</td>
<td>70 lb thrust ullage engines off.</td>
</tr>
<tr>
<td>1/2 +5.5</td>
<td>PU Activate--Propellants, once again being consumed, require ratio and depletion monitoring.</td>
</tr>
<tr>
<td>1/2 +64.5</td>
<td>Arm point level sensors--Engine cutoff enabled.</td>
</tr>
<tr>
<td>1/2 +0</td>
<td>Engine cutoff command--Predetermined J/U or PU instigated signal cuts off J-2 engine.</td>
</tr>
<tr>
<td>1/2 +0.5</td>
<td>Auxiliary hydraulic pumps, PU inverter, heaters and T/M systems turned off. Conserves stage batteries for T/M and APS operation.</td>
</tr>
<tr>
<td>1/2 3.1</td>
<td>Approximately 2-1/2 hours later in translunar trajectory, S-IVB/Apollo payload separate.</td>
</tr>
</tbody>
</table>
the 1-inch line, not the aft facing nozzles. This provides approximately 10^-6 G's acceleration to the stage to keep the propellants in the back of the tank. The vent-relief valve and parallel relief valve will protect the tank from over-pressure, should pressure rise above 42 psi. Near the end of the orbital coast phase, approximately 8 minutes before engine restart, the 4-inch non-propulsive vent line will be commanded open in addition to the 1-inch propulsive vent. Tank pressure will decay to 24.5 psi, both vents are closed, and represurization of the fuel tank will begin.

Repressurization is accomplished by opening a solenoid valve in the represurization control module. GHe from 7 of the ambient He storage spheres located at the thrust structure will represurize the tank to a step pressure of 35.5 to 37.5 psi for the duration of the second burn period. Two 70-lb thrust aft facing rocket motors will burn for approximately five minutes prior to J-2 engine restart. For positive propellant settling, after J-2 engine restart, represurization of the fuel tank is maintained at the step pressure of 35.5 to 37.5 psi from the J-2 engine exactly as during first burn.

(See S-IVB/S-IVC description.)

Pneumatic Control System

The S-IVB/S-IVC pneumatic control system adds one additional actuation control module, which controls operation of the LH2 tank propulsive vent. The module contains two solenoid-operated control valves which open and close the GHe supply to the pneumatically-operated propulsive vent valve. Also, the pneumatic system provides GHe to pump engine turbopump seal cavities for 10 minutes after first burn engine cutoff to remove contaminants and prevent seal damage.

Electrical System

The aft battery No. 1 has an approximate rating of 110 Ah to fulfill longer mission, higher power requirements of J-2 engine restarting, represurization requirements, stage sequence, and APS module.

Propellant Utilization System

The PU system adds a fuel boiloff bias cutoff relay. Approximately 4,000 pounds of excess LH2 are added to account for an estimated ambient boiloff of 2,500 to 3,600 pounds. The LH2 probe does not "see" this boiloff until engine restart with the mixture ratio set at 5:1; then the fuel boiloff bias cutoff relay drops out and the LH2...
tank probe "sees" the actual remaining fuel load and adjusts the J-2 engine PU valve until the tank mass ratio is returned to 5:1.

 telemetry System

T/M system is the same as S-IVB/S-IB. In order to retain reliable reception of data out to 30,000 miles, the PCM/FM system will utilize narrow band transmission during final two hours of S-IVB flight.
S-IVB/S-V RETROROCKET SYSTEM

Components:
- Retrorockets (4), Firing Units (2), EBW Detonators (2), Detonator Manifold (2), CDF Fuse Assemblies (2), Pyrogen Initiators (8).

- Retrorocket:
  - Thiokol TE-29-16 solid propellant, 9-inch diameter, 110-inch length, 384-pound weight, 35,700 pounds (nominal) thrust per engine, burn time: 1.5 sec (nominal).

- CDF Fuse Assembly:
  - Flexible; fabric and plastic sheath contains PETN core, 2 grans per foot, propagation rate of 23,000 ft/sec, eight fuses required for redundant rocket initiators.

- Detonator Manifold:
  - One input port/four output ports; provides explosive continuity between EBW detonators and CDF fuses.

- EBW Detonator:
  - Threaded connector contains 1.4 gram PETN primary charge and 30 mg PETN booster charge; bridgewire contained in booster charge; high voltage/high current required for initiation; mica spark gap incorporated for safety.

- Firing Units:
  - Input voltage, 28 VDC; output voltage, 2,500 VDC at 1,500 A; housing contains electronics for initiating EBW detonator; operation requires charge (ARM) and trigger signals.

OPERATION

Firing units charged prior to S-IVB/S-V separation. Charging (ARM) signal is stepped up and applied to large storage capacitor (2,300 VDC). Trigger signal applied to initiate separation. Signal is stepped up (5,000 V) to trigger gap tube. Tube ionizes, causing storage capacitor to discharge through respective EBW detonator. Propagation wave from detonator is transmitted through CDF fuses, transmitted to pyrogen initiators and ignition of retrorockets effected. System is double-redundant, ensuring optimum reliability. All separation signals supplied by S-II sequencer.
AUXILIARY PROPULSION SYSTEM (Continued)

source flows through valve (3) and pressurizes tank to 3,000 psig. Control pressure is regulated to 200 psig by redundant regulator C01. Normally-open regulator controls pressure. If regulator fails (pressure too high), high-pressure switch is actuated, sets relay K4, opening second regulator. If pressure is too low, low-pressure switch actuates relays K1 and K4, opening second regulator. Regulated pressure may be bypassed by opening valve (11), oxidizer, or valve (12), fuel. Control pressure will maintain propellants under 200 psig pressure at engine control valves.

Electrical Control Circuit (See figure 59.)

Attitude Control: Upon command, 28 vdc power from IU energizes control relays. Closed contacts (1) of each relay open oxidizer valves, and closed contact (2) of each relay opens fuel valves to the specific 150 lb thrust engines as required for pitch, roll, and yaw.

System is quad-redundant for optimum reliability.

Ullage Control: Signal supplied by IU through switch selector set relays providing 28 vdc internal/systemal power. Fuel and oxidizer valves are opened permitting two ullage engines to burn for 330 sec.

AUXILIARY PROPULSION SYSTEM

Components
- Auxiliary Propulsion Modules (12). Modules mounted on aft skirt 180° apart. Each module contains three attitude control engines, one ullage engine, a propellant control system, and two no pressure-operated propellant tanks.

Attitude Control Engines
- Thrust, 150 lbf thrust per engine; 100 psig chamber pressure. Pulse-type engines: Molybdenum thrust liners, refractory liner for ablative coating chamber operating temperature approximately 5,500° F.

Ullage Engine
- Rocketdyne, 70-lbf thrust, 100 psig chamber pressure Gemini "DAIMS" engine.

Propellant Control System
- Positive expulsion pressure is supplied by He scavenge tank, charged to 3,000 psig, regulated down to 200 psig; electrically-operated valves control flow of propellants; closed loop system.

Propellant Tanks
- Positive expulsion, blader-type tanks; oxidizer tank stores 150 lb of nitrogen tetroxide (N2O4); fuel tank stores 115 lb of MMH; propellants are hypergolic.

OPERATION

Attitude Controls: Attitude control engines provide three axes control for vehicle during launch. System also provides attitude control to assist service module during translunar docking maneuvers. Reaction-type control is provided by pulse firing engines in short (0.5 sec maximum duration) bursts. All control signals supplied directly from IU. Engines are pulse-fired in opposing pairs; one pair initiates correction, one pair stops correction. Initial manual direction depends on which pair fires first.

Ullage Control: Approximately 330 sec before J-2 engine restart, two 70-lbf ullage engines are fired to settle propellants. Ullage engines burn simultaneously for 330 sec.

Fuel and Oxidizer Control Pressure Circuit (See figure 56.)

Fuel and oxidizer systems are recirculated from ground source by opening FV and V1 and vent valves (11), (12), (31), and (41), allowing fuel and/or oxidizer to flow through tanks. Systems may be purged by opening valves (5) and (6) and valves (3 and 41). H2O flows through check valves (7 and 8), through tanks and is returned to source through valves (3 and 41). Prior to propellant loading, He tank is pressurized. He from ground.
<table>
<thead>
<tr>
<th>Liquid Hydrogen</th>
<th>Liquid Oxygen</th>
<th>Liquid Helium</th>
<th>Liquid Nitrogen</th>
<th>Monomethyl Hydrazine</th>
<th>Nitrogen Tetroxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>594</td>
<td>9.54</td>
<td>1.045</td>
<td>6.75</td>
<td>7.29</td>
<td>11.94</td>
</tr>
<tr>
<td>Clear</td>
<td>Pale Blue</td>
<td>Clear</td>
<td>Pale Yellow</td>
<td>Clear</td>
<td>Brown</td>
</tr>
<tr>
<td>2.016</td>
<td>32.0</td>
<td>4.0</td>
<td>28.016</td>
<td>46.075</td>
<td>92.016</td>
</tr>
</tbody>
</table>

**BOILING POINT**
- **Fahrenheit**: -422.9, -297.4, -452.09, -320.5, 192.5, 70.07
- **Rankine**: 36.8, 162.29, 7.6, 139.19, 652.19, 529.76
- **Celsius**: -252.7, -182.44, -268.93, -195.83, 89.16, 21.15
- **Kelvin**: 20.4, 90.72, 4.23, 77.33, 362.32, 294.31

**FREEZING POINT**
- **Fahrenheit**: -435.0, -361.76, -453.46, -346.0, -62.5, 11.84
- **Rankine**: 24.7, 97.93, 6.23, 113.69, 397.19, 472.53
- **Celsius**: -259.4, -210.75, -269.7, -210.0, -52.5, -11.2
- **Kelvin**: 13.7, 54.41, 3.46, 63.16, 220.66, 261.98

**Critical Temp. °F**
- -399.96
- -281.04
- -450.2
- -232.8
- 593.6
- 316.8

**Critical Press. Psia**
- 188.16
- 736.47
- 32.0
- 491.7
- 1195.1
- 1469

\[ \text{Assumed Zero} = 459.69° F = 0° \text{ Rankine} = 273.16° \text{ Celsius} = 0° \text{ Kelvin} \]
LOX AND LH₂ VAPOR PRESSURE CURVES

**VAPOUR PRESSURE CURVE, HYDROGEN**

-440 345 430 425 420 415 410 405 400 395 390 385 380 375

- Minus Degrees Fahrenheit (°F)
- Pounds Per Square Inch Absolute (PSIA)
- Points:
  - 133.0 0.00 Freezing Point
  - 142.9 14.70 Boiling Point (1 atm)
  - 159.96 183.16 Critical

**VAPOUR PRESSURE CURVE, OXYGEN**

-370 350 330 310 300 270 250 220 210 190 170

- Minus Degrees Fahrenheit (°F)
- Pounds Per Square Inch Absolute (PSIA)
- Points:
  - -101.76 0.00 Freezing Point
  - -295.5 14.70 Boiling Point (1 atm)
  - -151.64 252.65 Critical Point

Figure 60
**LIST OF NON-STANDARD ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH</td>
<td>Ancillary Hour</td>
</tr>
<tr>
<td>APS</td>
<td>Auxilliary Propulsion System</td>
</tr>
<tr>
<td>ASI</td>
<td>Augmented Stable Ignsion</td>
</tr>
<tr>
<td>CCO</td>
<td>Crystal Controlled Oscillator</td>
</tr>
<tr>
<td>CDF</td>
<td>Confined Detonating Fuse</td>
</tr>
<tr>
<td>DDAS</td>
<td>Digital Data Acquisition System</td>
</tr>
<tr>
<td>DEE</td>
<td>Digital Events Evaluator</td>
</tr>
<tr>
<td>DPF</td>
<td>Dynamic Pressure Feedback</td>
</tr>
<tr>
<td>EWI</td>
<td>Exploding Bridgewire</td>
</tr>
<tr>
<td>ED</td>
<td>Electrical Display</td>
</tr>
<tr>
<td>FM</td>
<td>Frequency Modulated</td>
</tr>
<tr>
<td>GETS</td>
<td>Government Furnished Equipment Test Set</td>
</tr>
<tr>
<td>GFE</td>
<td>Government Furnished Equipment</td>
</tr>
<tr>
<td>GIS</td>
<td>Ground Instrumentation System</td>
</tr>
<tr>
<td>GSE</td>
<td>Ground Support Equipment</td>
</tr>
<tr>
<td>HB</td>
<td>Huntington Beach</td>
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<td>IRIG</td>
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<td>IU</td>
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<td>LEM</td>
<td>Lunar Excursion Module</td>
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<tr>
<td>MDF</td>
<td>Mild Detonating Fuse</td>
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<td>MH</td>
<td>Monomethyl Hydrazine</td>
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<td>MSFC</td>
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<td>NPSH</td>
<td>Net Positive Suction Head</td>
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<td>NRTZ</td>
<td>Non-Return-to-Zero</td>
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<tr>
<td>OAMS</td>
<td>Orbital Attitude Maneuvering System</td>
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<tr>
<td>PAM</td>
<td>Pulse Amplitude Modulated</td>
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<tr>
<td>PAM/FM/FM</td>
<td>Pulse Amplitude Modulated, Frequency Modulated, FM Carrier</td>
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<tr>
<td>PCM</td>
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<td>Pulse Code Modulated FM Carrier</td>
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<td>PD</td>
<td>Propulsion Display</td>
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<td>PDM</td>
<td>Pulse Duration Modulated</td>
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<td>Abbreviation</td>
<td>Description</td>
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<td>PETN</td>
<td>Pentacyanoazide Tetrazolzone</td>
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<td>Voltage Controlled Oscillator</td>
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