

S-IV
S-IV B

1 Oct 1965

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FORWARD

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 150,000 pounds, and a total LO weight of approximately 1,275,000 pounds. The S-IB stage is powered by eight H-1 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 200,000 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.

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Saturn data summary handbook

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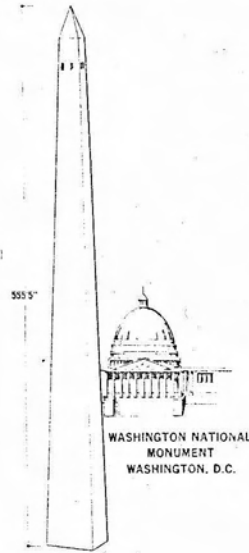
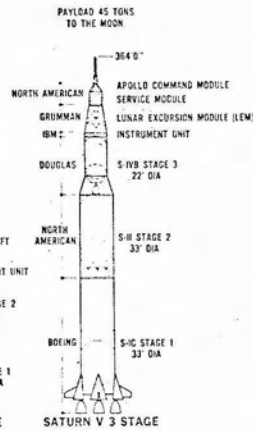
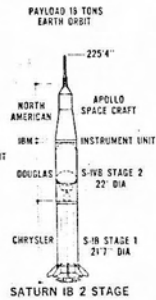
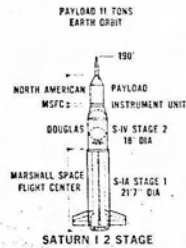
October 1, 1965

TABLE OF CONTENTS

Title	Page
Saturn S-IV Stage	1
Saturn S-I Configuration	2
Mission Profile--S-IV Stage	3
S-IV Vehicle Designations	4
S-IV Structures	5
S-IV Structure Locations	6
S-IV Common Bulkhead	7
S-IV Manufacturing Plan	8
RL10A-3 Component Locations	9
RL10A-3 Rocket Engine	10
RL10A-3 Functional Schematic	13
Oxidizer System	14
S-IV Oxidizer System Functional Schematic	16
Fuel System	17
S-IV Fuel System Functional Schematic	19
Control Pressure System	20
Control Pressure Functional Schematic	22
S-IV Flight Control	23
Hydraulic System	24
Hydraulic System Functional Schematic	26
Electrical Systems	27
Electrical System Block Diagram	28
S-IV Propellant Utilization	29
Propellant Utilization System	30
S-IV Propellant Utilization Functional Schematic	32
Telemetry Systems	33
S-IV Telemetry Data Capability	34
S-IV T/M System No. 1 and No. 2 Block Diagram	35
S-IV T/M System No. 3 Block Diagram	36
S-IV Ordnance	37
Separation System	38
S-IV Separation System Functional Schematic	39
Propellant Dispersion System	40

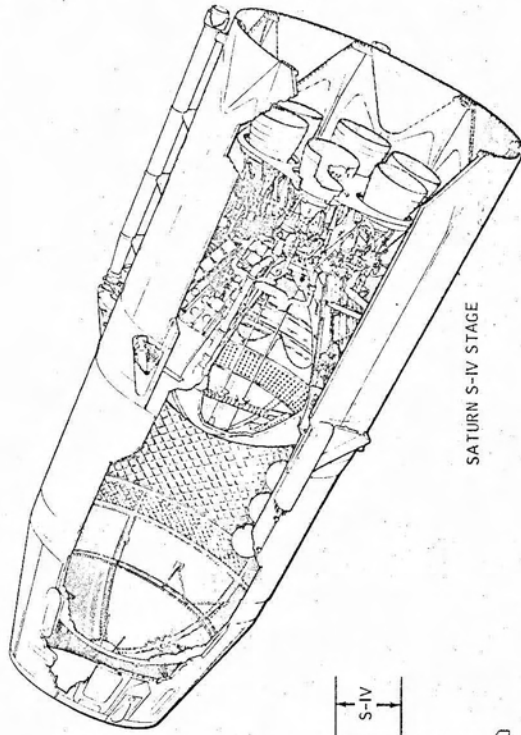
SATURN COMPARISON

Frontispiece

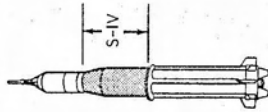


Title	Page
S-IV Propellant Dispersion Functional Schematic	42
Ullage Rockets (Ignition System)	43
S-IV Ullage Rocket Ignition Functional Schematic	44
Ullage Rockets (Jettison System)	45
S-IV Ullage Rocket Jettison Functional Schematic	46
S-IVB Stage of Saturn IB	47
Saturn IB Configuration	48
S-IVB/IB Profile View	49
S-IVB/S-I Mission Profile	50
S-IVB/S-I Vehicle Designations	52
S-IVB Structures	54
S-IVB Structure Locations	55
S-IVB Common Bulkhead	56
Manufacturing Plan	57
J-2 Engine Component Locations	58
J-2 Engine	59
J-2 Engine Operation (Simplified)	61
S-IVB/S-IB Oxidizer System	62
Oxidizer Tank Pressurization System Schematic	64
S-IVB/S-IB Fuel System	65
Fuel Tank Pressurization System Schematic	67
S-IVB/S-IB Pneumatic Control System	68
Pneumatic Control System Schematic	70
S-IVB Flight Control	71
Hydraulic System	72
Hydraulic System Functional Schematic	74
Auxiliary Propulsion System	75
Auxiliary Propulsion System Module	77
Auxiliary Propulsion System Control Schematic	78
S-IVB Electrical System	79
S-IVB Electrical System	80
Aft Electrical System Functional Schematic	82
Forward Electrical System Functional Schematic	83

Title	Page
S-IVB Propellant Utilization System	84
Propellant Utilization System Functional Schematic	85
Telemetry Systems	86
S-IVB Telemetry Data Capability	88
Telemetry System Functional Schematic	89
Digital Data Acquisition System Functional Schematic	90
Single Sideband/Frequency Modulation Functional Schematic	91
S-IVB Ordnance	92
Separation System	93
Separation System Components	94
Propellant Dispersion System	95
Propellant Dispersion System Functional Schematic	97
Ullage Rockets (Ignition System)	98
Ullage Control System Functional Schematic	99
Ullage Rockets (Jettison System)	100
S-IVB/S-IB Retrorocket System	101
Retrorocket System Functional Schematic	102
S-IVB Automatic Ground Checkout System	103
Automatic Ground Support Equipment Functional Schematic	104
Checkout Plan	105
S-IVB Stage of the Saturn V	107
Saturn V Launch Vehicle Configuration	108
S-IVB/S-V Mission Profile	109
S-IVB/S-V Staging	110
S-IVB/S-V Vehicle Designations	113
S-IVB/S-V Configuration	114
S-IVB/S-V Inboard Profile	117
S-IVB/S-V Exploded View	118
S-IVB/S-V Auxiliary Propulsion System	119
S-IVB/S-V Aft Interstage Assembly	120
S-IVB/S-V Retrorocket System	121
Auxiliary Propulsion System	122
Propellant Supply System Schematic	124
Electrical Control System Schematic	125



SATURN S-IV STAGE



SATURN S-I VEHICLE

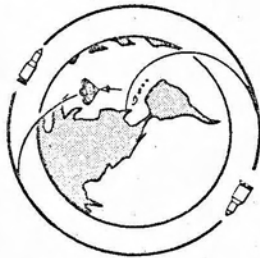


Figure 1

Appendix	Page
Aerospace Fluid Characteristics	127
LOX and LH ₂ Vapor Pressure Curves	128
List of Non-Standard Abbreviations	129

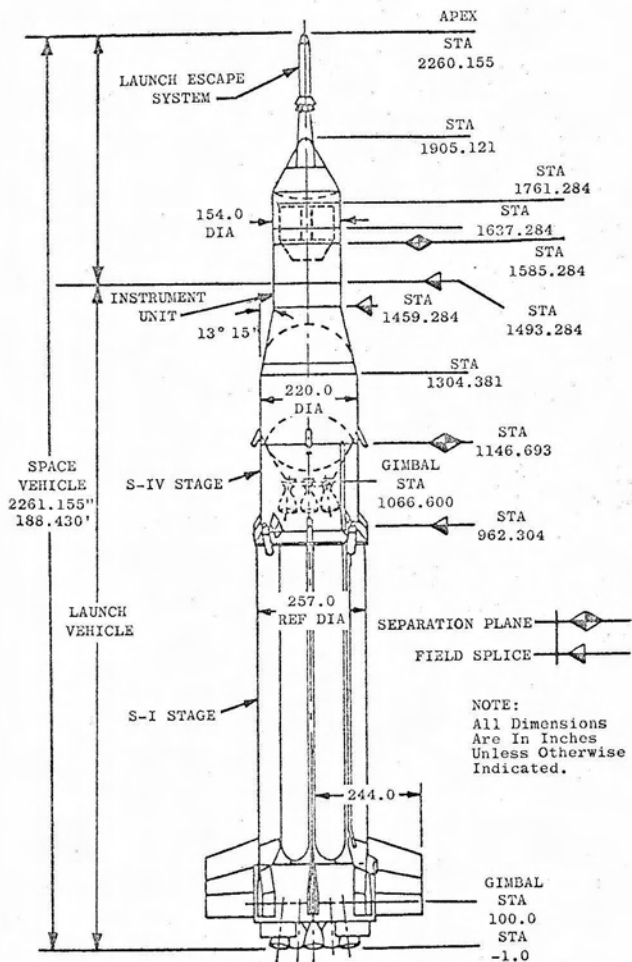


Figure 2

MISSION PROFILE--S-IV STAGE

Vehicle intended to launch boilerplate (engineering and test models) of Apollo Command and Service Modules into Earth orbital-flights. Stage thrust, 90,000 lbs; payload capability, 17,000 lbs; typical apogee, 125 miles; typical perigee, 90 miles; typical period, 90 minutes; stage burn time, 475 sec.; total stage weight, 14,100 lbs dry; restart capability not used.

Liftoff +
(in sec)

STAGING

- 102 S-IV T/M Calibrate--Zero and 100 per cent calibration reference signals provide accurate ground assessment of recorded T/M data.
- 112 Start S-IV LH₂ Cool-down--System primed with LH₂/GH₂ and overboarded to condition LH₂ system from thermal shock.
- 135 Start S-IV LOX Cool-down--LOX system primed with LOX/GOX and overboarded to condition LOX system from thermal shock.
- 139 Cutoff S-I Engines 5, 6, 7, 8--S-I inboard engines cutoff to assure symmetrical flight trajectory.
- 141 S-IV Ullage Rocket Ignition Charging--Tank ullage EBW systems charged preparatory to separation.
- 145 Cutoff S-I Engines 1, 2, 3, 4--S-I outboard engines cutoff to drop launch vehicle axial acceleration to 0.
- 147 S-IV Ullage Rocket Ignition--Ullage rockets fire to settle propellants.
- 147 Separation--Fragible nuts fracture, separating two stages.
- 147.1 S-I to S-IV Control Transfer--IU output transferred from S-I stage controller to S-IV stage controller.
- 148 S-IV Helium Heater LOX Valve Open--Helium heater operative to provide LH₂ tank additional ullage pressurization gas.
- 149 S-IV Engine Start--Each of 6 rocket ignition systems sparks for 4 seconds.
- 152 Enable S-IV Engine-Out System--Engine-out system enabled 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.
- 167 Jettison Ullage Rockets--Ullage rockets on aft interstage, adding unwanted weight, are jettisoned.
- 599 Arm S-IV Engine Cutoff--Engines locked into cutoff system preparatory to engine cutoff. Prevents unprogrammed engine cutoff.
- 604 Cutoff S-IV Engines--All S-IV engines cutoff simultaneously if commanded by IU on pre-programmed basis, or earlier, if propellants are expended before correct time.
- 636 S-IV T/M Calibrate - Zero and 100 per cent reference signals re-sent to assure correct T/M readings during duration of S-IV flight.

S-IV VEHICLE DESIGNATIONS

Stage Designation	Required at	Used for
Battleship Test Vehicle	SACTO	Test
All Systems Test Vehicle	SACTO	Test
Hydrostatic/Dynamics Test Vehicle	SM--MSFC	Test
Dynamics/Facilities	MSFC--KSC	Test
Flight Vehicle S-IV-5	KSC	Flight
Flight Vehicle S-IV-6	KSC	Flight
Flight Vehicle S-IV-7	KSC	Flight
Flight Vehicle S-IV-8	KSC	Flight
Flight Vehicle S-IV-9	KSC	Flight
Flight Vehicle S-IV-10	KSC	Flight

Battleship Test Vehicle was constructed of steel and was installed in a test stand at SACTO. The vehicle was used for development testing of RL10A-3 engines, PU and hydraulic systems, GSE, and facilities equipment.

All Systems Test Vehicle was a production configuration vehicle used for qualification testing of all major systems and subsystems.

Hydrostatic/Dynamics Test Vehicle is a production configuration vehicle used at Santa Monica for structural testing by water pressure. Common bulkhead is cryogenically tested with LN_2 . Vehicle was sent to MSFC where it was joined with S-I stage, and vibrated, to dynamically test on-board systems.

The Dynamics/Facilities Test Vehicle is a production configuration vehicle used at KSC where it was mated with S-I stage. Wet tests of LOX and LH_2 loading from facilities storage tanks demonstrate safety and efficiency of propellant loading. Integrated preliminary countdown and checkout of complete S-I vehicle were made.

SA-5 vehicle was launched successfully on January 29, 1964 from KSC in a 141.6-416.5 nautical mile, 94.8 minute orbit. Vehicle is still in orbit.

SA-6 vehicle was launched successfully on May 28, 1964 from KSC in a 99-129 nautical mile, 88.6 minute orbit. Vehicle re-entry occurred May 31, 1964.

SA-7 vehicle was launched successfully on September 18, 1964 from KSC in a 100-129 nautical mile orbit. Vehicle re-entry occurred September 22, 1964.

SA-9 vehicle was launched successfully on February 16, 1965 from KSC in a 271-405 nautical mile orbit. Vehicle is still in orbit.

SA-8 vehicle was launched successfully on May 25, 1965 from KSC in a 276-407 nautical mile orbit. Vehicle is still in orbit.

SA-10 vehicle was launched successfully on July 30, 1965 from KSC in a 283-290 nautical mile, 95.3 minute orbit. Vehicle is still in orbit.

S-IV STRUCTURES

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

Aft Interstage Assembly: Mates S-IV stage with S-I stage. Aft interstage assembly 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 GOX and GN_2 before separation. Aft interstage assembly is attached to S-IV stage by four bolts with frangible nuts. At separation, aft interstage assembly remains with spent S-I stage.

Aft Skirt Assembly: Consists of four aluminum honeycomb panels welded together; then welded to aft dome assembly. Aft skirt is attached by four bolts with frangible nuts at flight separation plane between skirt and interstage. Four ullage rockets are mounted on aft skirt assembly.

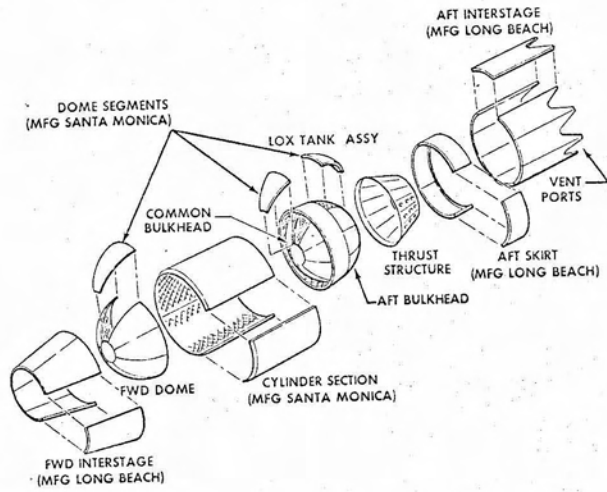
Heat Shield: Constructed of fiberglass honeycomb and cloth, and aluminum doublers. Mounted on thrust structure to protect forward propulsion area from heat of engine flame.

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 LH_2 tank, and aft tank assembly. Forward dome is constructed of six pie-shaped segments, formed, chem-milled, and welded. An entrance manhole is provided for access to LH_2 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 welded to forward dome and aft tank assembly. Aft tank assembly consists of the aft dome assembly (similar to the forward dome) and common bulkhead (which forms aft end of the LH_2 tank and the forward dome of the LOX tank). Common bulkhead is constructed of two aluminum hemispheres bonded to a fiberglass honeycomb core. Each hemisphere skin is welded of 6 "orange peel" segments. Skins are welded to aluminum rings on their periphery, and sealed together by welding. Prior to loading propellants, this cavity is vacuum-pumped and sealed. The LH_2 tank forward dome and cylindrical sidewall is insulated with polyurethane fiberglass-thread reinforced tubes. Insulated area is covered with a thin aluminum skin.

Forward Interstage: Mates with S-I stage structure. Consists of a forward interstage assembly and a forward interstage skirt.

S-IV STRUCTURE LOCATIONS



AREA DESIGNATIONS

- 400
- 401
- 402
- 403
- 404
- 405
- 406
- 407
- 408
- 409
- 410
- 411
- 412
- 413
- 414
- 415
- 416
- 417

STRUCTURE LOCATIONS

- Aft Interstage Area
- Engine No.1
- Engine No.2
- Engine No.3
- Engine No.4
- Engine No.5
- Engine No.6
- Thrust Structure Area
- LOX Tank Area
- LH₂ Tank Area
- Forward Interstage
- Retrorocket No.1
- Retrorocket No.2
- Retrorocket No.3
- Retrorocket No.4
- Tunnel Area
- Heat Shield Area
- Helium Heater and Control Sphere

SATURN S-IV STAGE
STRUCTURE LOCATIONS

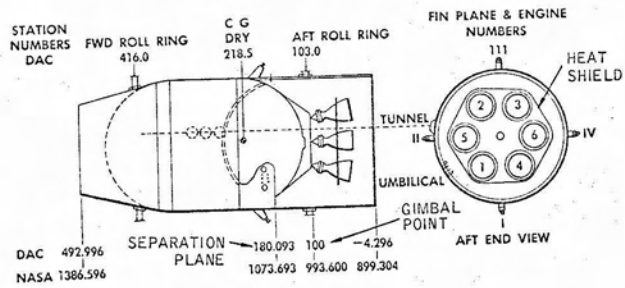


Figure 3

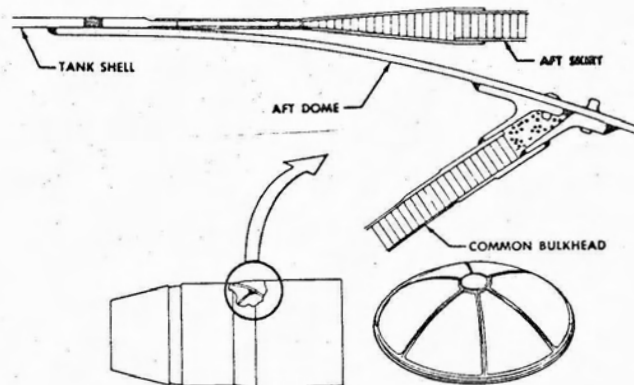
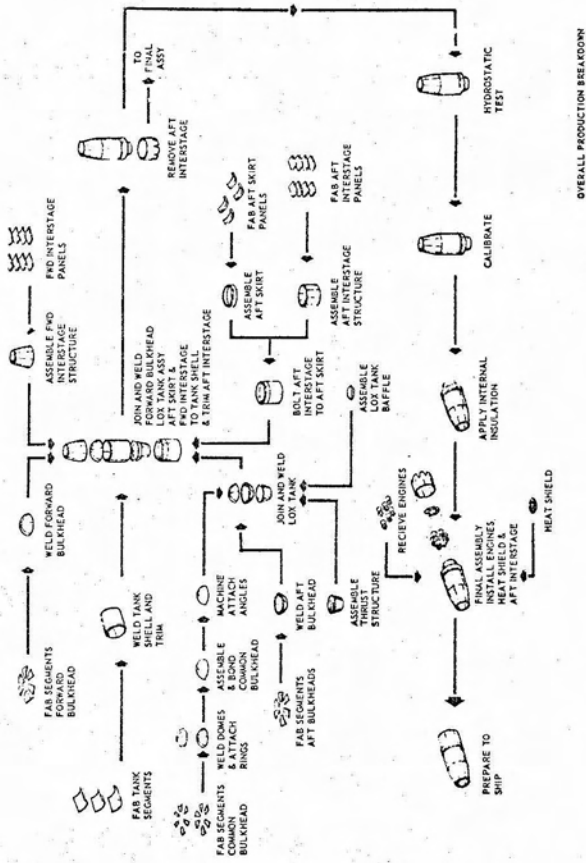


Figure 4

The 17.75 ft diameter common bulkhead is formed by two separate 2014-T6 A1 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 LH_2 , or LH_2 from freezing LOX.

S-IV MANUFACTURING PLAN



OVERALL PRODUCTION BREAKDOWN

Figure 5

RL10A-3 COMPONENT LOCATIONS

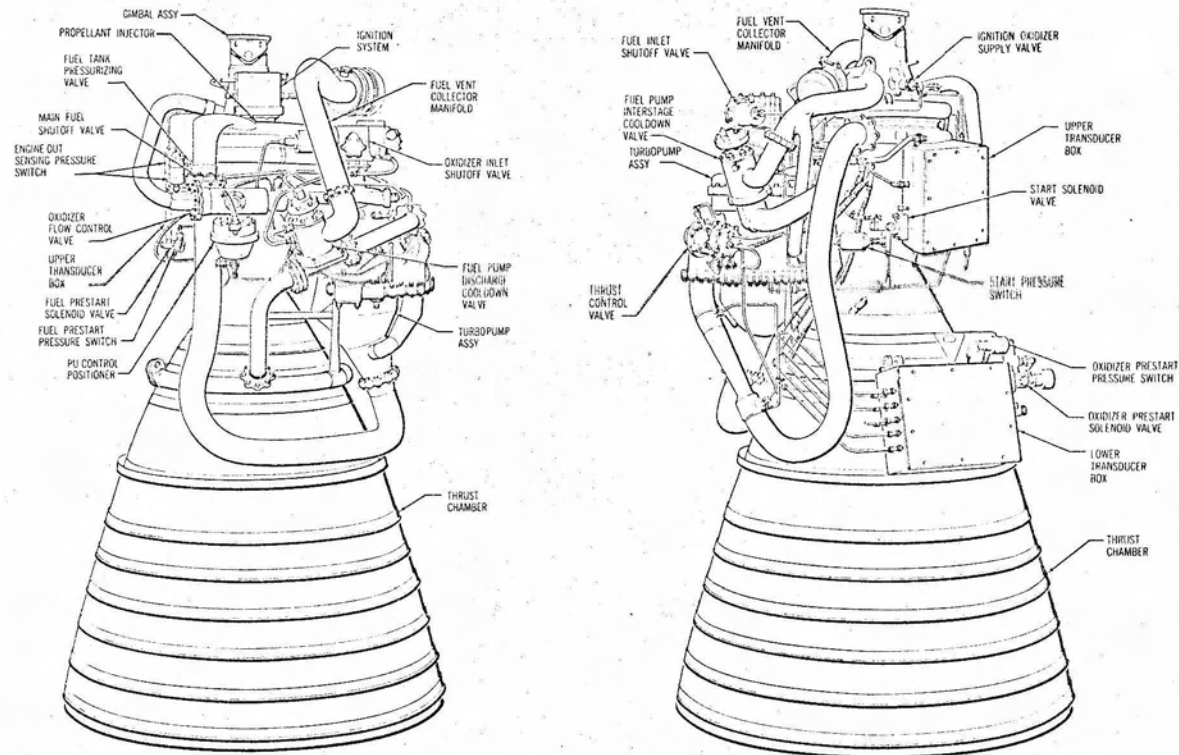


Figure 6

RL10A-3 ROCKET ENGINE

- Major Components - Thrust Chamber, Fuel and Oxidizer Turbopump Assembly, LOX Flow Control Valve, Spark Ignition Subsystem, Thrust Control Assembly, Miscellaneous Control Valves.
- Thrust Chamber - Tubular-walled with chamber stiffeners; expansion area ratio, 40 to 1; chamber pressure, 300 psia; LOX to LH₂ mass burn ratio, 5:1.
- Turbopump Assembly - Located outside thrust chamber at nozzle throat; turbine drives fuel and oxidizer pumps; turbine power supplied from expanding fuel; turbine inlet temperature, -169° F to -113° F; oxidizer pump inlet temperature, -269° F; fuel pump inlet temperature, -421° F; turbine inlet pressure, 599 to 622 psia; oxidizer pump inlet pressure, 48.5 psia; fuel pump inlet pressure, 33 psia; 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; servo supply pressure, 672 psi.
- Oxidizer Flow Control Valve - Mounted on turbopump near nozzle throat of thrust chamber; controls oxidizer-to-fuel mass ratio for proper ignition, and consumption of oxidizer to minimize propellant residual at burnout; mechanical stops limit variance of burn ratio to ±12 per cent.
- Spark Ignition Subsystem - Consists of oxidizer supply valve and ignition system; system uses GH₂ from cooldown tubes for fuel; oxidizer valve regulates GOX supply to combustion chamber; igniter operating voltage, 28 vdc; igniter input current, 2.5 amps; igniter spark rate, 20 sparks per sec, 0.5 joule per spark.

GENERAL DESCRIPTION

The propulsion system of the S-IV stage uses six Pratt & Whitney RL10A-3 rocket engines and associated components. Each rocket engine is a 15,000 pounds thrust, gimbal-mounted engine capable of making multiple starts after long coast periods in space. LH₂ and LOX are used as propellants. Electrical signals control pressurized

RL10A-3 ROCKET ENGINE (Continued)

GH₂ which is used to actuate valves for starting and stopping the engines. Ignition of the propellants is accomplished by an electrical ignition system. Each engine is equipped with a thrust control assembly that is a servo-operated, variable position valve which controls engine thrust by regulating the amount of fuel bypassing the turbine, thereby controlling turbine speed and fuel pumping. Engine service life is 2,820 sec.

Thrust chamber tubular construction permits use of a regenerative operating cycle. LH₂, used to cool the engine during operation, is turned into a gaseous state and re-used to drive the fuel and oxidizer turbopump.

OPERATION (See figure 7.)

Propellant Flow: LH₂ flows from stage fuel tank through valve (1), turbopump (2), valve (3), pump (4), valve (5), orifice (6), chamber (7), venturi (8), turbine (9), valve (10), injector plate (11), and into engine thrust chamber.

LOX flows from stage LOX tank through valve (12), pump (13), LOX control valve (14), and into engine thrust chamber. LOX control valve (14) controls LOX flow ratio through positioner (15). LH₂ ratio is not controlled. Thrust control valve (27) regulates engine thrust. Valve senses thrust chamber pressure and regulates turbine speed by bypassing GH₂ around turbine (9). Turbine speed determines quantity of LH₂ supplied to thrust chamber, as pressure is proportional to thrust produced.

Prestart: Prevents damage from thermal shock. At 41.6 seconds before ignition, valve (16) energizes. Switch (17) supplies talkback. He at 455 psig nominal opens valve (1). LH₂ at 30 to 38 psia flows from turbopump (2) to valve (3), where some is overboarded. Remainder passes through orifice (6), chamber (7), venturi (8), turbine (9), and valve (10). A controlled bleed flows through LOX injector (28).

LOX Prestart: Valve (18) opens approximately 10 seconds before engine start. Switch (19) supplies talkback. He opens valve (12), permitting LOX at 45 to 48 psia to flow through pump (13), valve (14), valve (20), and into engine thrust chamber.

Engine Start: Valve (21) opens 41.6 seconds after prestart signal. Switch (22) supplies talkback. Thrust chamber spark plug igniter (29) fires. Valve (10) opens, partially closing valves (3) and (5) to stabilize flow transients. Pump discharge pressure increases, closing valve (5). LH₂ vaporizes in chamber (7), and flows through venturi (8) and pump (9), causing turbopump rotation. GH₂ flows through

valve (10), injector plate (11), and into thrust chamber. Ignition occurs, engine accelerates to mainstage operation.

Mainstage Operation: LH₂ enters valve (1). 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 (18), (16), and (21). Valves (1) and (2) close. Valves (3) and (5) open. Valve (10) closes, cutting off fuel. Turbopump stops, engines cut off.

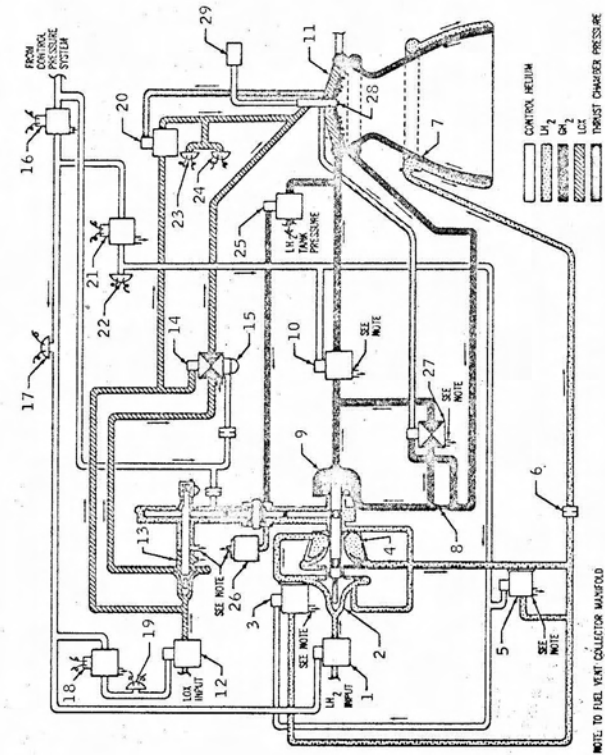


Figure 7

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 1,263 cubic foot tank at approximately -297° F. A screen is installed at the tank outlet to prevent vortexing and to provide filtration. LOX tank pressure is provided by a cold He system. Three He spheres mounted in the LH₂ tank supply a helium heater 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 prepressurization and flight, and provide indications of adequate pressure for liftoff. 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 overboard all products of vaporization resulting from ground filling, and automatically relieve excessive pressure buildup in the tank by opening at 50 psia, and reseating at 47 psia. The two valves act independently of the tank pressure-sensing switches. During mainstage operation, the six RL10A-3 rocket engines burn 8,750 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 sump.

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 10 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, fine fill starts: loading rate is reduced to 100 gpm. At 99.75 per cent full, anti-boiloff replenish cycling starts. Valves (3) and (4) close. Switch (11) maintains pressure during loading. Switch (12) maintains tank pressure at 41 to 45 psia. Valves (3) and (4) open for boiloff.

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.

OXIDIZER SYSTEM (Continued)

Prepressurization Sequence: Valves (3) and (4) close. He flows through disconnect (13), valve (14), filter (15), valve (16), plenum (17), He heater (18), union (19), and pressurizes LOX tank. Switch (11) controls valve (16). Switch (12) monitors pressure at 46 to 48 psia. Switch (20) controls overpressure at 51 to 53 psia.

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

Inflight Operation

Pressurization Sequence: 1.7 seconds before separation, 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), to He heater (18). Heated He then flows through union (19) into LOX tank. Switch (11) activates at 45 (+1, -0) psia, causing valve (39) to supply more heated He through orifice (40). Valve (39) closes at 46 to 48 psia. Ullage pressure of 45 to 48 psia is maintained in LOX tank. IU signal opens valve (2). LOX flows to engine. Depletion of LOX at 417 lb is signaled by sensor (7).

LOX Tank Venting: Valves (3) and (4) overboard GOX. Non-propulsive vent system opens vent valve on signal from engine out pressure switches (two per engine).

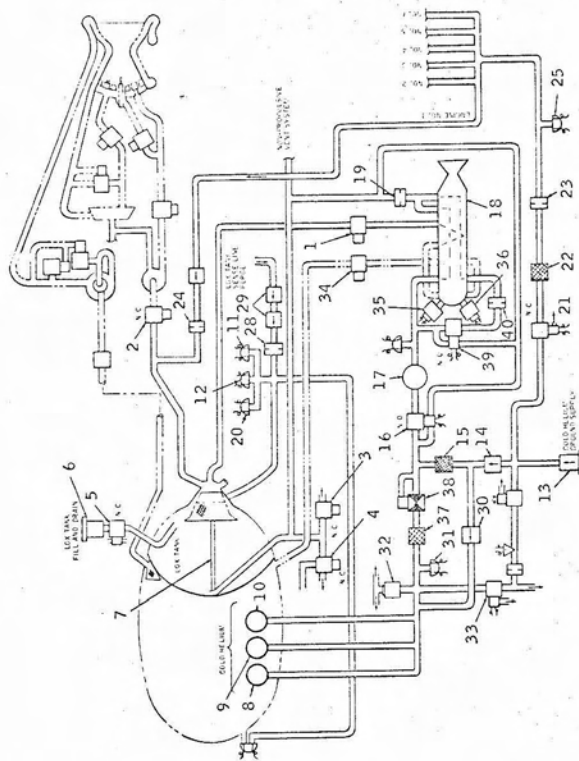


Figure 8

GENERAL DESCRIPTION

The S-IV stage fuel system is comprised of three LH₂ subsystems: LH₂ supply, LH₂ tank pressurization, and LH₂ tank venting. LH₂ is stored in an internally-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 vortexing. Pressurization of the LH₂ tank is provided by a GH₂ 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 ducts 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, mainfill starts; fuel is loaded at 2,000 gpm. At 95 per cent full, fine fill starts; loading rate is reduced to 500 gpm. At 99.8 per cent full, replenish cycling starts to resupply fuel lost through 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 dumped. 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 (10) provides GSE talkback.

FUEL SYSTEM (Continued)

Prepressurization Sequence: Vent valves (3) and (4) are closed. Cold He flows through adapter (8), valve (9), manifold (11) into LH₂ tank. Switch (25) cuts off flow at 36 to 38 psia. Switch (10) picks up at 34 to 36 psia and provides GSE talkback. He remains connected until LO.

Inflight Operation

Pressurization Sequence: GH₂ tapped off engine flows through valve (12), orifice (26), and manifold (11) into tank. Switch (13) opens if pressure is low (20 psia). GH₂ from engine bleed passes through orifice (15), manifold (11) into tank. Switch (16) opens valve (17) for backup GH₂ if pressure drops below 20 psia.

Step Pressurization Sequence: Sphere (18) filled before LO with GHe (ambient) through disconnect (19), and valves (20) and (27), supplies LH₂ tank pressure at 30 to 32 psia during engine prestart. Pressure is controlled by valves (22) and (23), and restrictor (21). Switch (24) provides electrical pressure indication. System is rendered inoperative 3 seconds after engine ignition.

Differential Pressure Sequence: Switch (14) senses LOX-LH₂ pressure differential and opens valve (3) if needed.

LH₂ Tank Venting Sequence: Valves (3) and (4) overboard GH₂, if tank pressure exceeds 44 psia. Non-propulsive vent system opens vent valve on signal from engine-out pressure switches (two per engine).

S-IV FUEL SYSTEM FUNCTIONAL SCHEMATIC

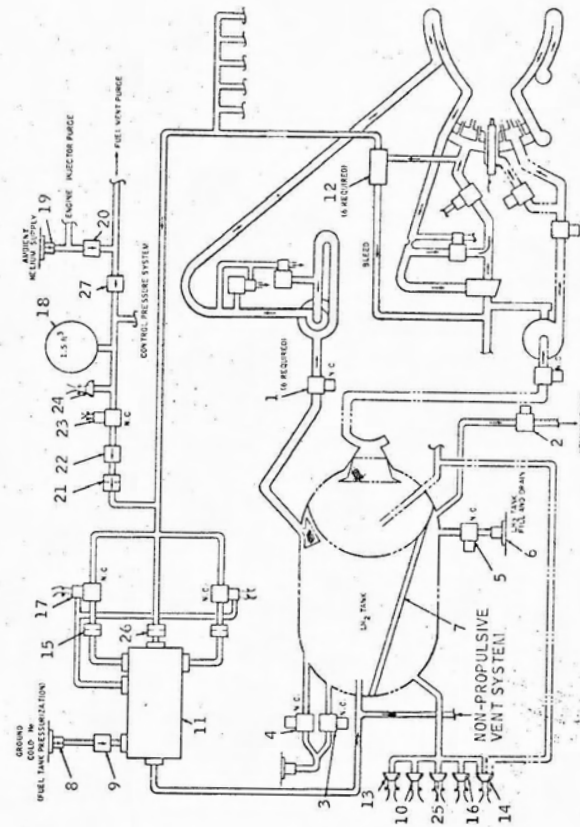


Figure 9

CONTROL PRESSURE SYSTEM

Major Components - Helium Control Sphere (1), Helium Control Pressure Regulator (1), Helium Control Relief Valve (1), Plenum Chamber (1).

Helium Control Sphere- Stores ambient GHe at 3,000 psig for operation of valves; storage capacity, 3.5 cubic feet; located on thrust structure near thrust axis.

Helium Control Pressure Regulator - Reduces and regulates control sphere pressure to 455 (±45, -25) psig to operate valves; maximum inlet pressure, 3,100 psig; maximum outlet pressure, 555 psig; response time, 0.050 sec; located on thrust structure.

Plenum Chamber - Prevents excessive rapid control pressure variations; operating pressure, 500 psig; located on 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 gearcase, the control positioner, and the fuel injector. Before LO, a ground source supplies GHe for purge requirements. At LO, fuel injector purge is terminated. The GHe purge system prevents possible malfunction of the purged components by eliminating the collection of atmospheric moisture, and by preventing LOX entry into the LOX tank sense line.

Operation (See figure 10.)

During countdown, GHe from ground source, fills sphere (1) through disconnect (2); valves (3), (4), and (5). GHe supply also flows through filter (7), valve (12), is regulated at 445 psia, and pressurizes pneumatic control system. Switch (6) provides GSE talkback when sphere pressure exceeds 2,840 psig. Valve (7) provides high-pressure protection, will relieve if pressure exceeds 3,300 (±150) psig. Valve (8) may be manually operated to depressurize sphere (1). During system operation, switches (10) and (11) will relieve high-pressure-supply to valve (7), and will close valve (12), if regulated pressure exceeds 550 (±8) psia. When regulated pressure

CONTROL PRESSURE SYSTEM (Continued)

drops to 510 (±10) psia, switches (10) and (11) will cut out. Plenum (15) damps 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 46)
- e. GHe heater propellant valves (25 and 26)
- f. GHe heater propellant 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)
- n. Start solenoid valve (42) and start pressure switch (43)

After LO, GHe flows through restrictor (45) to turbopump gearcase, control, and LOX sense line purge positioner (44).

S-IV FLIGHT CONTROL

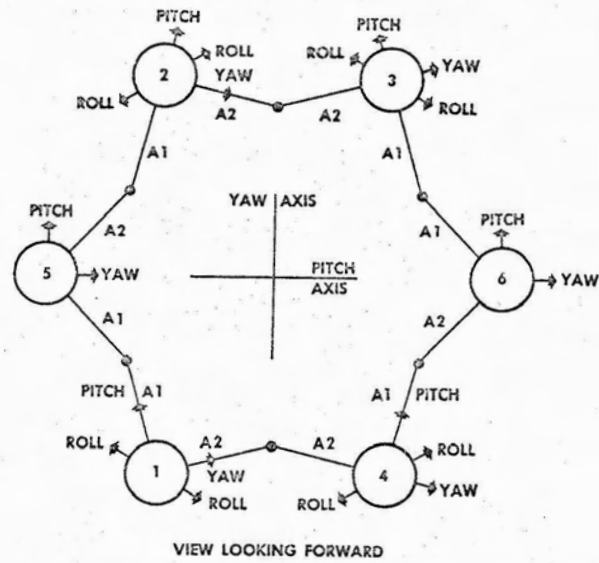


Figure 11

S-IV stage engine gimbaling action provides vehicle steering and stabilization after S-I 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 ±4° in a star pattern from the engine zero (trail) 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.

CONTROL PRESSURE FUNCTIONAL SCHEMATIC

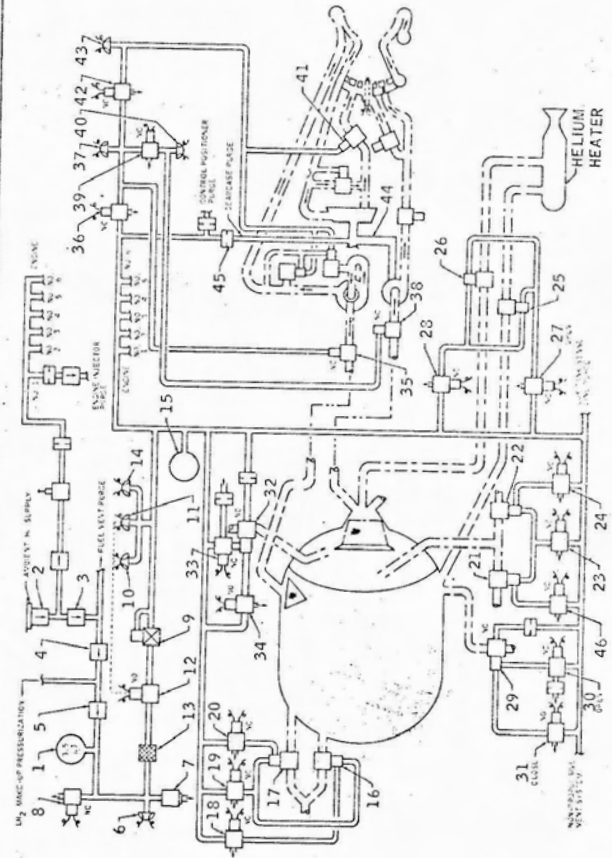


Figure 10

OPERATION (See figure 12.)

Hydraulic Fill and Bleed Sequence: During countdown, system accumulator is charged with GN₂ through disconnect (23). Hydraulic fluid is supplied following purge, through couplings (24) and (25) and bled through valves (26), (27), (28), (29), and (30). Fluid from ground supply flows through valve (31), filter (6), accumulator-reservoir (7), reservoir (8), 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), of valve (10), and pressurizes high-pressure side to 3,000 psig. Simultaneously, fluid flows through valve (11), filter (16) to inlet of servovalve (2). GSE signal closes solenoid (1), trapping 22 cu in. 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 (15), positioned by piston (38), indicates status of accumulator-reservoir pressure. Gage-switch (39) provides GSE talkback. Switch (40) prevents system fluid from overheating.

Inflight Sequence: 1.7 seconds before ignition, solenoid (1) energizes, and accumulator pressure is applied to servovalve (2), centering engines. After ignition, engine-driven pump (3) supplies fluid flow. 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 3,100 psig. Valves (13 and 14) will overboard fluid when return pressure exceeds 95 psig. Pot (41) 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 (18) or (19), 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 transients by repositioning control flapper (20).

Major Components per Engine	- Engine-Driven Hydraulic Pump (1), Motor-Driven Auxiliary Hydraulic Pump (1), Hydraulic Actuator Assemblies (2).
Engine-Driven Hydraulic Pump	- Vickers, nine-piston, constant-displacement, wobble-type pump; delivers 0.975 gpm at 3,450 psig (nominal); inlet pressure, 65 to 100 psig; pump operating speed, 11,400 rpm; mounted to turbopump gearcase accessory drive-pad flange with thermal isolator.
Motor-Driven Auxiliary Hydraulic Pump	- Vickers, nine-piston, variable-delivery pump; delivers 0.5 gpm at 2,950 psig (nominal); 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; one (-503) actuator is equipped with system accumulator; accumulator precharge pressure, 2,140 psig (GN ₂); accumulator capacity, 22 cu in.; 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 main-stage operation. Each engine has an independent, closed-loop hydraulic system. Auxiliary hydraulic pumps are used to gimbal engines during checkout. Prior to L0, auxiliary pumps are started. Pumps charge accumulator-reservoir assemblies on -503 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.

ELECTRICAL SYSTEMS

Components	- 28 VDC 15AH Batteries (2), 28 VDC 5AH Battery (2), Sequencer (1), Power Supply (1), Controllers (2), Power Distribution Box (1), Inverter-Converter (1), Flight Control Switch (1); all located on thrust structure except flight control switch.
Batteries	- Positive plate, silver oxide; negative plate, zinc; electrolyte, potassium hydroxide; sealed, pressurized unit; thermostat controlled at 80° F before LO.
Sequencer	- Metal enclosed, relay operated staging apparatus; receives signals from S-I stage, IU, PU system; provides sequenced commands to initiate predetermined time/sequence functions.
Power Supply (GFE)	- Input power, 28 vdc; output power, regulated 28, 18 vdc, 6 vdc, and regulated 18 vdc; unit supplies voltages to operate range safety receivers.
Controller (GFE)	- 28 vdc input and output; contains circuitry and circuit elements to fire one set of destruct equipment.
Power Distribution Box	- 28 vdc input and output; distribution point for power to propellant dispersion system, fuel system pressure switches and valves, and PU control unit.
Inverter-Converter	- Input, 28 vdc, output 115 vac; 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-I stage to S-IV stage at separation.

OPERATION (See figure 13.)

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 protect PU system from transients.

HYDRAULIC SYSTEM FUNCTIONAL SCHEMATIC

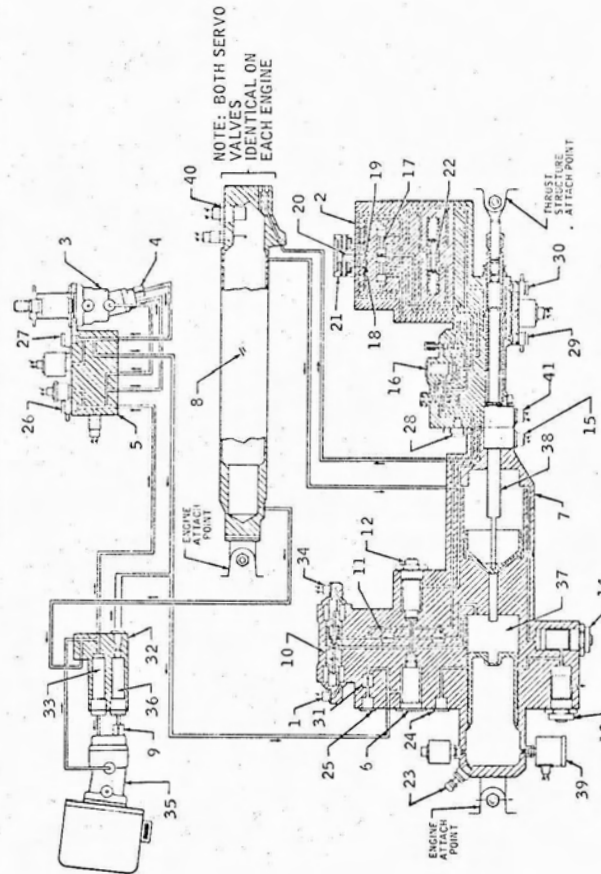


Figure 12

S-IV PROPELLANT UTILIZATION

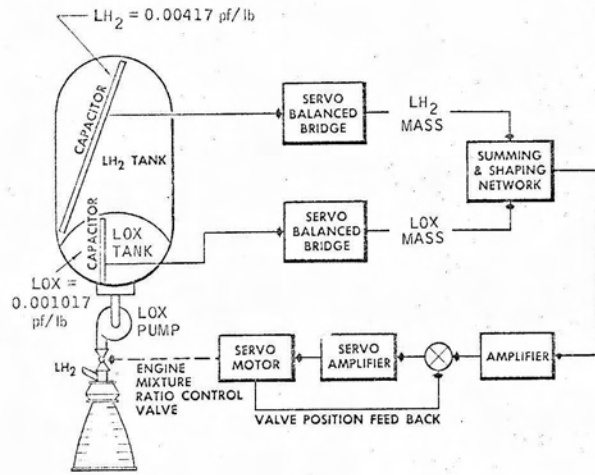


Figure 14

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 burn ratio of 5:1 LOX to LH₂ is closely maintained, while sustaining a mass ratio in the tanks of 5:1 also.

ELECTRICAL SYSTEM BLOCK DIAGRAM

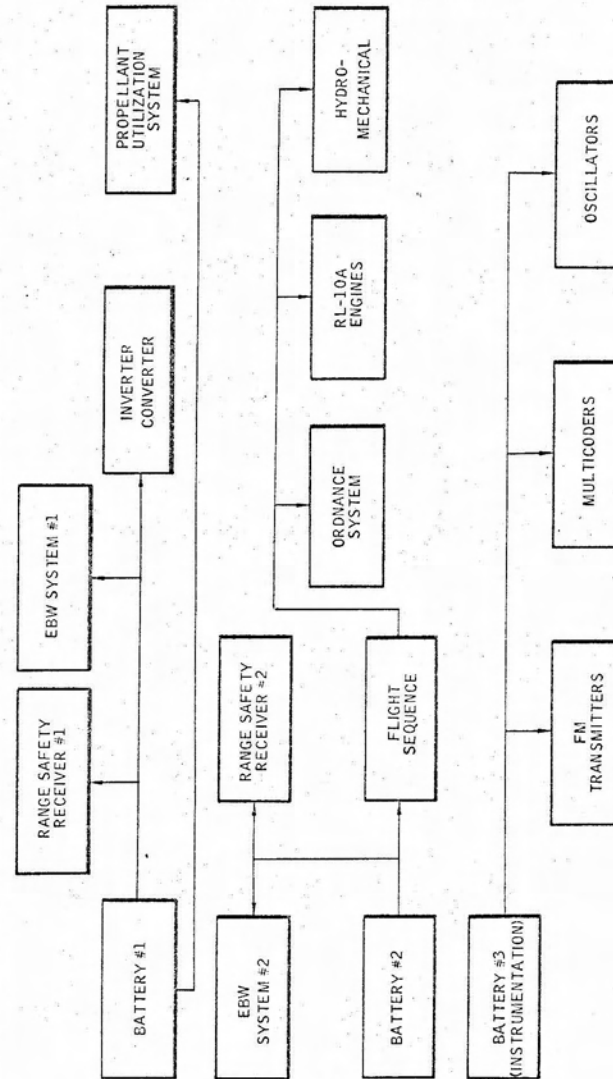


Figure 13

PROPELLANT UTILIZATION SYSTEM (Continued)

mechanical linkage, maintaining proper mixture ratio and using propellant in proper mass balance. T/M pots, driven by bridge servo motors, allow inflight determination of propellant mass. Loading pots, 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	- Fuel Mass Sensor (1), LOX Mass Sensor (1), PU Electronics Assembly.
LH ₂ Mass Sensor	- Capacitive type; 400 pf in air; 1,000 K at 500 vdc; temperature range, 100° F to -423° F; indicates fuel load mass; located in LH ₂ tank.
LOX Mass Sensor	- Capacitive type; 250 pf in air; 1,000 K at 500 vdc; temperature range, 120° F to -297° F; indicates LOX load mass; located in LOX tank.
PU Electronics Assembly	- Input power, 115 vac, 1 phase, 400 cycles/sec; 28 vdc from engine and control battery; contains electronics to provide propellant tank control signals; located on thrust 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 LO and ignition; generates mass ratio T/M and propellant depletion signals; limits unused propellant to approx 500 lb at engine cutoff. Achieved by varying LOX to LH₂ ratio within ±10 per cent of standard 5:1 value.

OPERATION (See figure 15)

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

TELEMETRY SYSTEMS

Measures, gathers, and transmits flight instrumentation data (acceleration, 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 shared, constant amplitude, varying width pulse train modulates FM/FM transmitter.

All use IRIG standard components.

Systems No. 1 and No. 2 (PDM/FM/FM) Functional Description (See figure 16.)

Transducers measure flight data, feed high (0-5 vdc) and low (0-15 mvdc) level inputs to multiplexer. Signals are commutated in time sharing multicoders and converted to PDM output. Filters suppress noise. SCO or VCO convert varying duration PDM signals to varying frequency PDM/FM signals. Mixer amplifier feeds PDM/FM signal to FM transmitter. PDM/FM/FM output signal feeds antenna triplexer, 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 Systems No. 1 and No. 2. Slow speed multiplexer replaces high level multicoder.

S-IV PROPELLANT UTILIZATION FUNCTIONAL SCHEMATIC

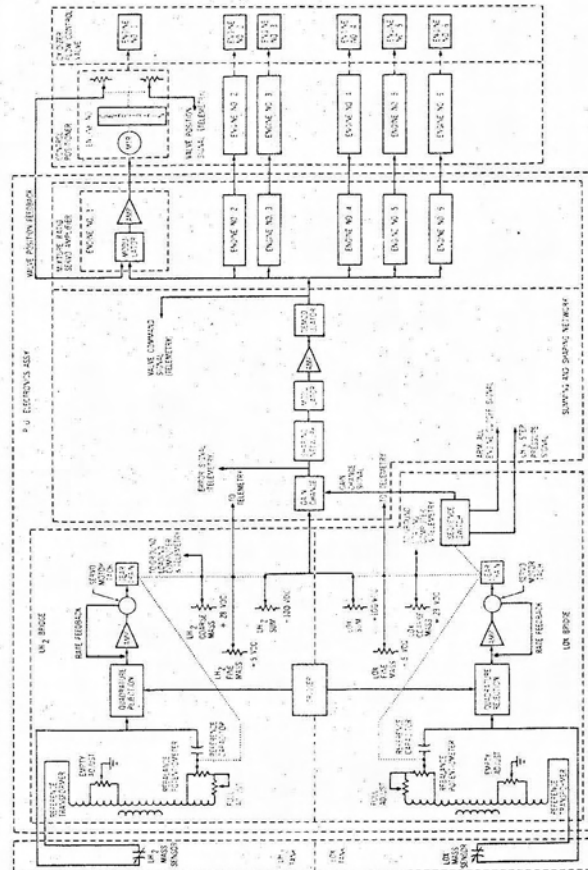


Figure 15

S-IV T/M SYSTEM NO. 1 AND NO. 2 BLOCK DIAGRAM

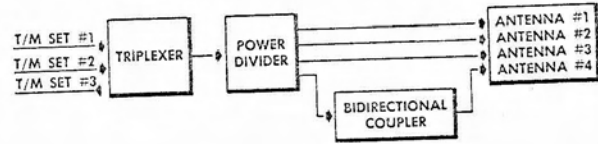
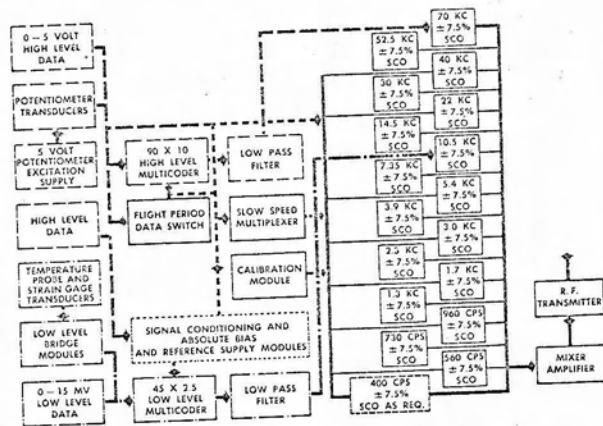


Figure 16

S-IV TELEMETRY DATA CAPABILITY

System	Sync Channels	Data Channels
No. 1		
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. 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
		354

S-IV ORDNANCE

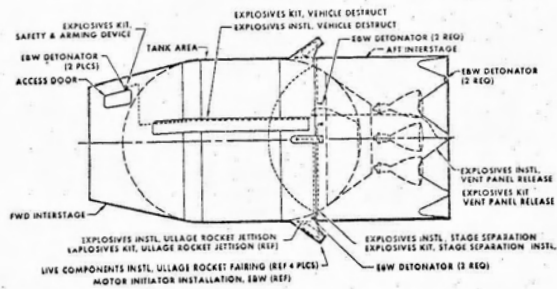


Figure 18

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

- S-I/S-IV separation system, used to separate the two stages.
- S-IV propellant dispersion system, used to shut down six rocket engines, and rupture propellant tanks.
- S-IV ullage rocket system, used to position propellants at pump inlets prior to engine start.

Inflight and ground T/M monitoring provided (for determining SAFE or ARMED status) on all systems.

S-IV T/M SYSTEM NO. 3 BLOCK DIAGRAM

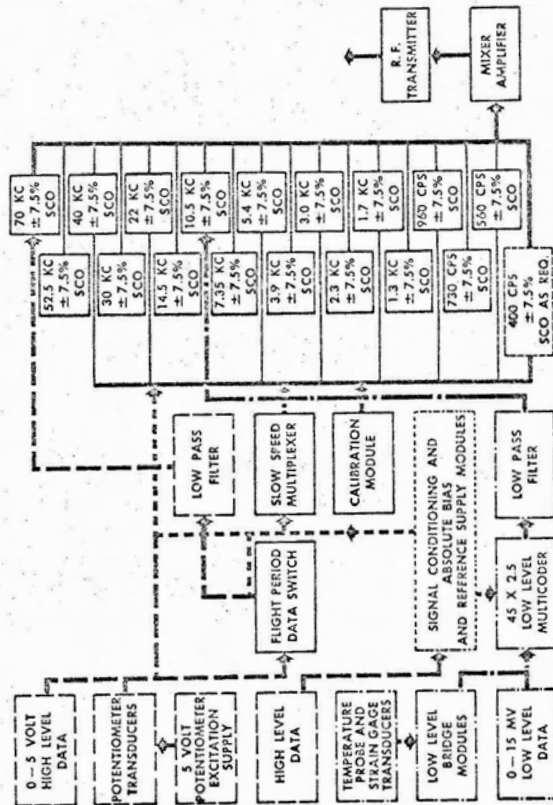


Figure 17

S-IV SEPARATION SYSTEM FUNCTIONAL SCHEMATIC

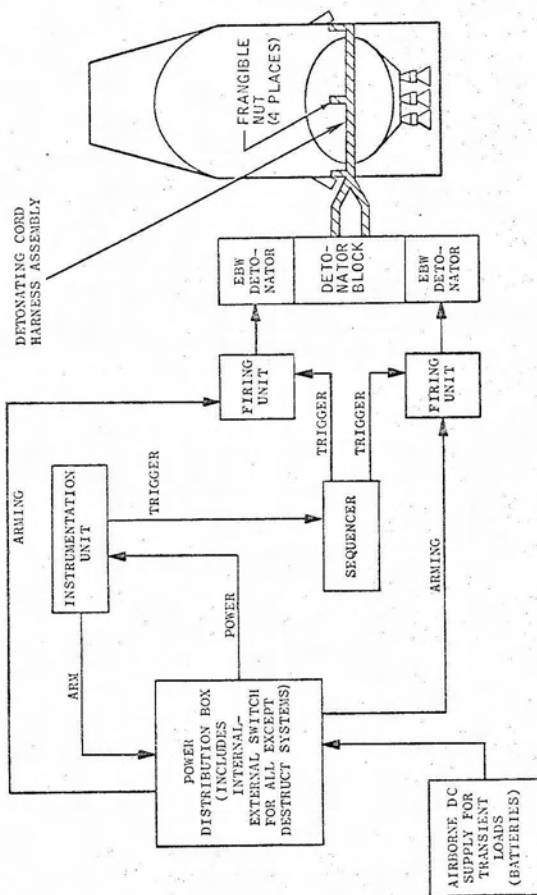


Figure 19

SEPARATION SYSTEM

- Components - Frangible Nuts (4), CDF Explosive Harness Assemblies (2), Detonator Block (1), EBW Detonators (2), Firing Units (2).
- Frangible Nut - PETN-filled nut; fractures in halves when detonated; bolts to four attach points between S-I/S-IV separation plane.
- 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; mica spark gap incorporated for safety.
- Firing Unit - Input voltage, 28 vdc, output voltage, 2,300 vdc at 1,500 A; housing contains electronics for initiating EBW detonators; operation requires charge and trigger signals.

OPERATION (See figure 19.)

At separation, four frangible nuts which retain stages are detonated by signal supplied through S-I sequencer. Nuts fracture, releasing two stages. Arming signal preceding separation charges two firing units. Charging (ARM) signal is applied to large storage capacitor (2,300 vdc). Trigger signal, applied approximately six seconds later, produces 5,000 V pulse to trigger gap tube. Tube ionizes, causing 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, is transmitter to MDF harness assemblies. Propagation of harness assemblies splits frangible nuts.

PROPELLANT DISPERSION SYSTEM (Continued)

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.

PROPELLANT DISPERSION SYSTEM

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, slot type; 52 ohm impedance; UHF (450 mc); two antennae per receiver.
Range Safety Receiver	- GFE; XTAL controlled transistorized, FM, superhetrodyne; 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-detonators; operation requires 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; mica spark 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-employed; rotor contains PETN, 1.4 grain booster charges (2).
CDF Harness Assembly	- Flexible, fabric and plastic sheath 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 sheath contains RDX core, 100 grains/ft; two attached to LH ₂ tank, one to LOX tank.

ULLAGE ROCKETS (IGNITION SYSTEM)

Components	- Ullage Rockets (4), Firing Units (8), EBW Motor Initiators(8).
Ullage Rockets	- Thiokol TX-280; solid propellant rockets; thrust, 3,460 pounds nominal at +70° F; burn time, 3.94 sec at 70° F; 58.8 pounds of propellant, ammonium perchlorate and polysulfide; exit nozzles canted 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, 28 vdc; output voltage, 2,300 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 (arm) signal, supplied before separation, is stepped up and applied to large storage capacitor (2,300 vdc). 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.

S-IV PROPELLANT DISPERSION FUNCTIONAL SCHEMATIC

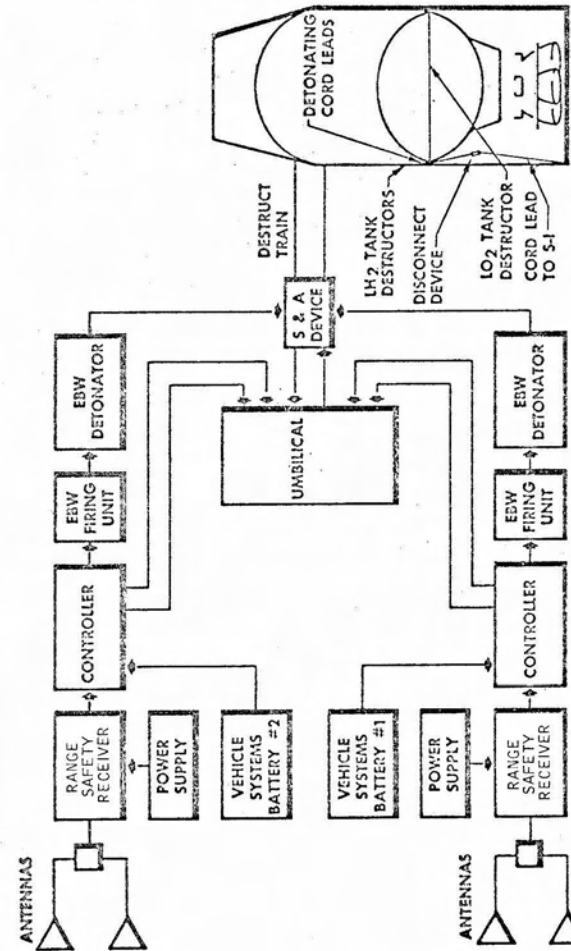


Figure 20

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 bolt installed perpendicular to tee fittings in threaded casing, nut fractures along length of casing.
- CDF Fuse Assemblies - Two grains/ft PETN charge covered with plastic and fabric sheath; dual fuses are swaged at each 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; manifolds 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 30 mg PETN primary charge; bridge wire contained in booster charge; high voltage/high current required for initiation; 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 (lead azide, 41 mg and PETN, 260 mg) are initiated, fracturing frangible nuts. Nut fracture releases preloaded spring; motor and fairing modules are jettisoned.

S-IV ULLAGE ROCKET IGNITION FUNCTIONAL SCHEMATIC

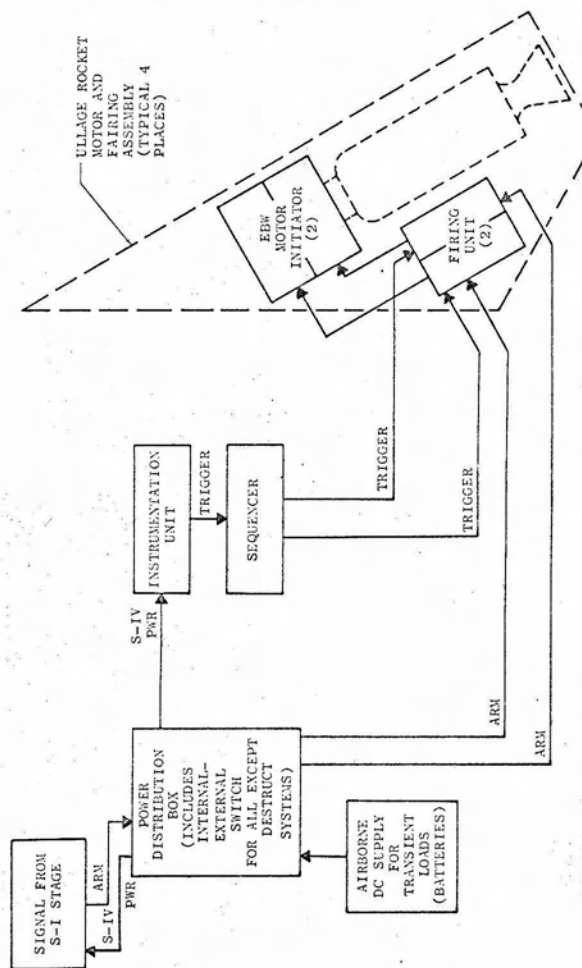


Figure 21

S-IVB STAGE OF SATURN IB

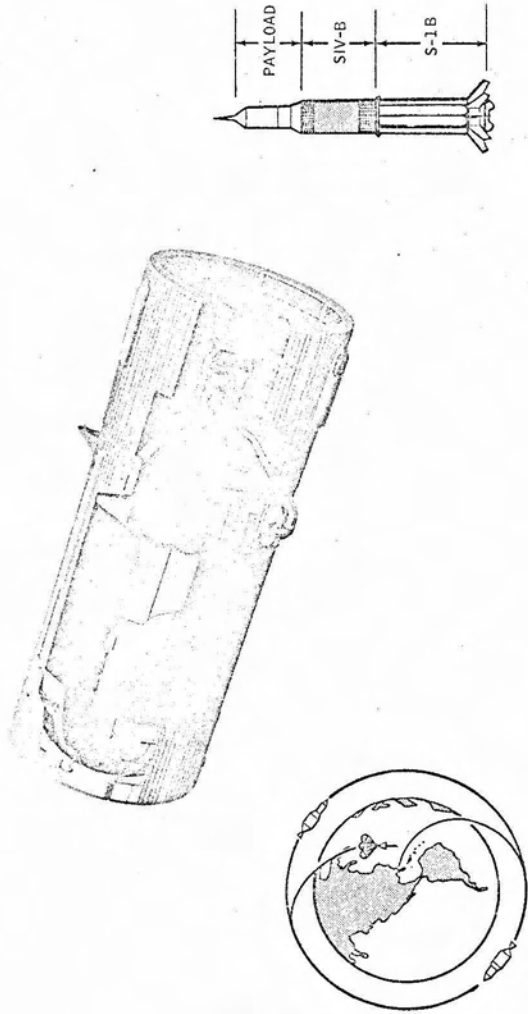


Figure 23

S-IV ULLAGE ROCKET JETTISON FUNCTIONAL SCHEMATIC

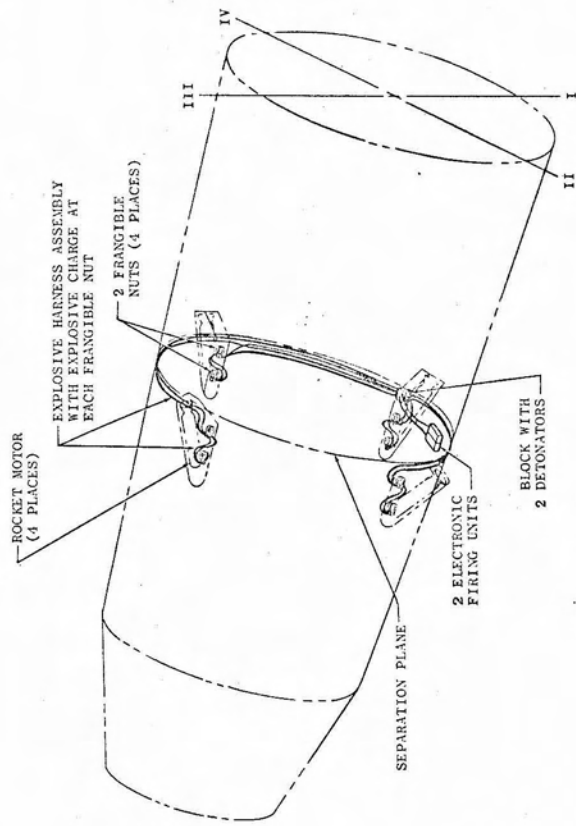


Figure 22

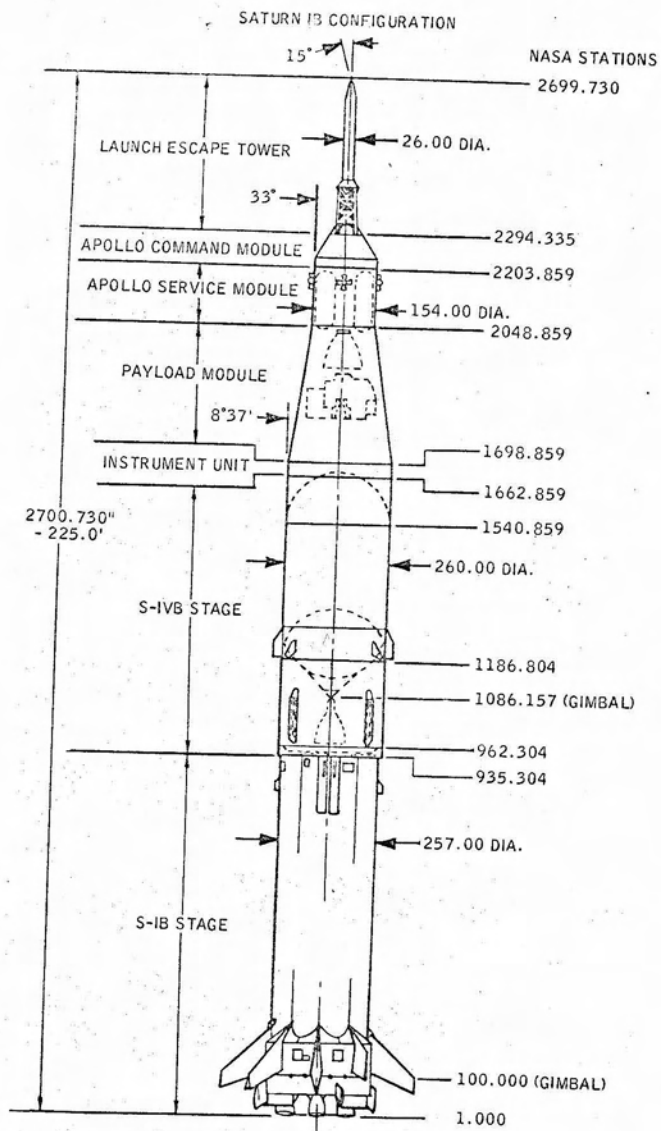


Figure 24

S-IVB/IB PROFILE VIEW

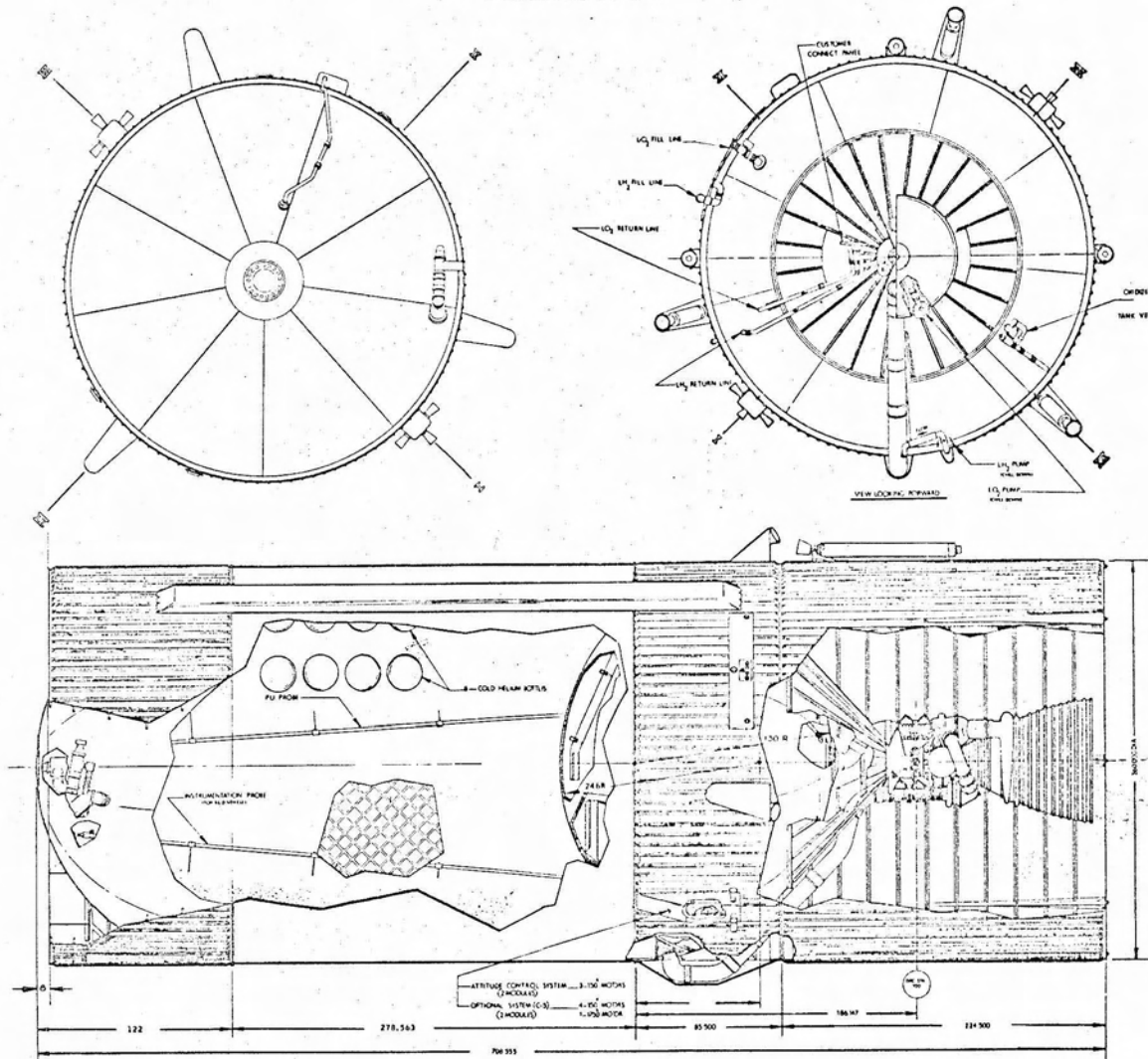


Figure 25

(Countdown)	
t_2+0	Engine cutoff--Propellant nearly depleted; engine is stopped on fuel depletion or IU command.
$t_2+0.5 \rightarrow +2.1$	Auxiliary pump, range safety receiver, inverter-converter, and PU system off--Systems, having functioned, are turned off to conserve remaining battery power.
$t_2+29.1$	T/M off.
Coast Period	- Up to 4-1/2 hours; following sequence repeats up to nine times over ground T/M stations, dependent on duration of orbit.
In Range of Ground Station +1.0	- T/M Recorder Transmitter on. Prepares vehicle data recorder for high-speed playback of data lost while out of line-of-sight.
In Range of Ground Station	- Recorder Playback Command. Plays back stored data over ground station.
Out of Range of Ground Station -9.9	- Record Command on, Playback Command off, turns off recorder playback, starts recorder recording data for next pass over ground station.
Separation of S-IVB/Payload	- May occur at anytime during 4-1/2 hour maximum orbital coast period.

51

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S-IVB/S-IB MISSION PROFILE

Vehicle intended to launch three man Apollo spacecraft into Earth orbit for manned and unmanned testing program, including rendezvous rehearsal. 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)	
t_0-1500	Purge engine thrust chamber--Clears J-2 engine of flammable gases.
t_0-610	Auxiliary hydraulic pump on--System pressure normal--engine centered.
t_0-600	LOX chilldown--Cools LOX plumbing for thermal shock preconditioning.
t_0-597	LH ₂ chilldown--Cools LH ₂ plumbing for thermal shock preconditioning.
$t_0-180 \rightarrow -70$	Pressurize LH ₂ and LOX tanks--Cold He prepressurizes tanks to ensure NPSH at engine ignition.
t_0-30	DC power to internal--GSE power switched off; vehicle battery power switched on.
(Liftoff) t_0-0	Range Safety Receivers on--Propellant dispersion system activated.
t_0-90	Charge S-IB retrorocket ignition--Retrorocket EBW system primed to fire retrorockets at separation.
$t_0+127.5 \rightarrow +132.2$	T/M calibrate on--Calibration reference signals sent to ensure accurate T/M ground readback.
$t_1-2.5$	Charge ullage ignition--Ullage EBW system primed to fire ullage rockets at separation.
$t_1-0.1$	Fire ullage rockets--Ullage rockets increase axial acceleration, settling propellants in tanks.
t_1-0	Fire S-IB retrorockets--Retrorockets fire, braking spent S-IB stage and S-IVB aft interstage.
$t_1+1.6$	Start J-2 engine--Sufficient clearance between S-IB and S-IVB allows engine to be started.
t_1+6	Activate PU--PU system in operation as propellant sloshing from separation has subsided.
$t_1+12.3$	Charge ullage jettison--Ullage rocket jettison EBW system primed to blow off ullage assemblies after separation.
$t_1+14.8$	Jettison ullage rockets--Spent retrorockets are jettisoned to decrease weight.

The Dynamics Vehicle tests will be performed at MSFC with a production configured vehicle with only the engine gimbaling 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.

<u>Stage Designation</u>	<u>Required at</u>	<u>Used for</u>
Battleship Test Vehicle	SACTO	Test
Structure Test (Hydrostatic) Vehicle	H.B.	Test
Dynamics Test Vehicle	MSFC	Test
Facilities Test Vehicle	KSC	Test
Flight Vehicle No. 2001	KSC	Flight
Flight Vehicle No. 2002	KSC	Flight
Flight Vehicle No. 2003	KSC	Flight
Flight Vehicle No. 2004	KSC	Flight
Flight Vehicle No. 2005	KSC	Flight
Flight Vehicle No. 2006	KSC	Flight
Flight Vehicle No. 2007	KSC	Flight
Flight Vehicle No. 2008	KSC	Flight
Flight Vehicle No. 2009	KSC	Flight
Flight Vehicle No. 2010	KSC	Flight
Flight Vehicle No. 2011	KSC	Flight
Flight Vehicle No. 2012	KSC	Flight

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.

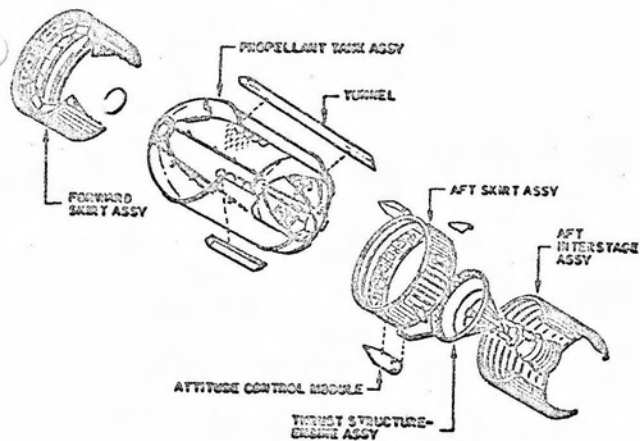


Figure 26

S-IVB structure of the S-IB 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 skin, stiffened with stringers and circumferential attach angles fabricated from extrusions. 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. Inflight, the aft interstage remains with the spent S-IB stage after separation of the S-IVB and S-IB 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, chem-milled, 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, etch-milled, and welded together. Both domes have attach flanges in the center for (1) an access door in the forward dome, and (2) the LOX tank sump 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, seam-welded together, then welded to attach rings at both ends. The common bulkhead is constructed of a 1-3/4 inch fiberglass honeycomb core, bonded between two hemispherical domes. The domes are fabricated by welding a contoured 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 IU.

S-IVB COMMON BULKHEAD

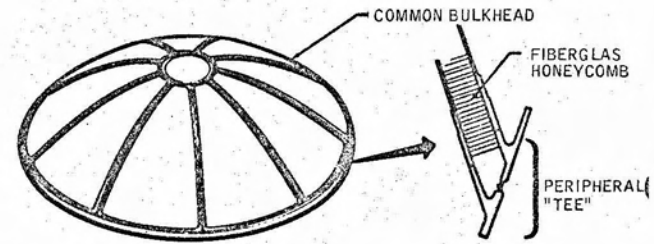


Figure 27

The 21.75 ft diameter common bulkhead is formed by two separate 2014-T6 A1 hemispheres welded of 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.

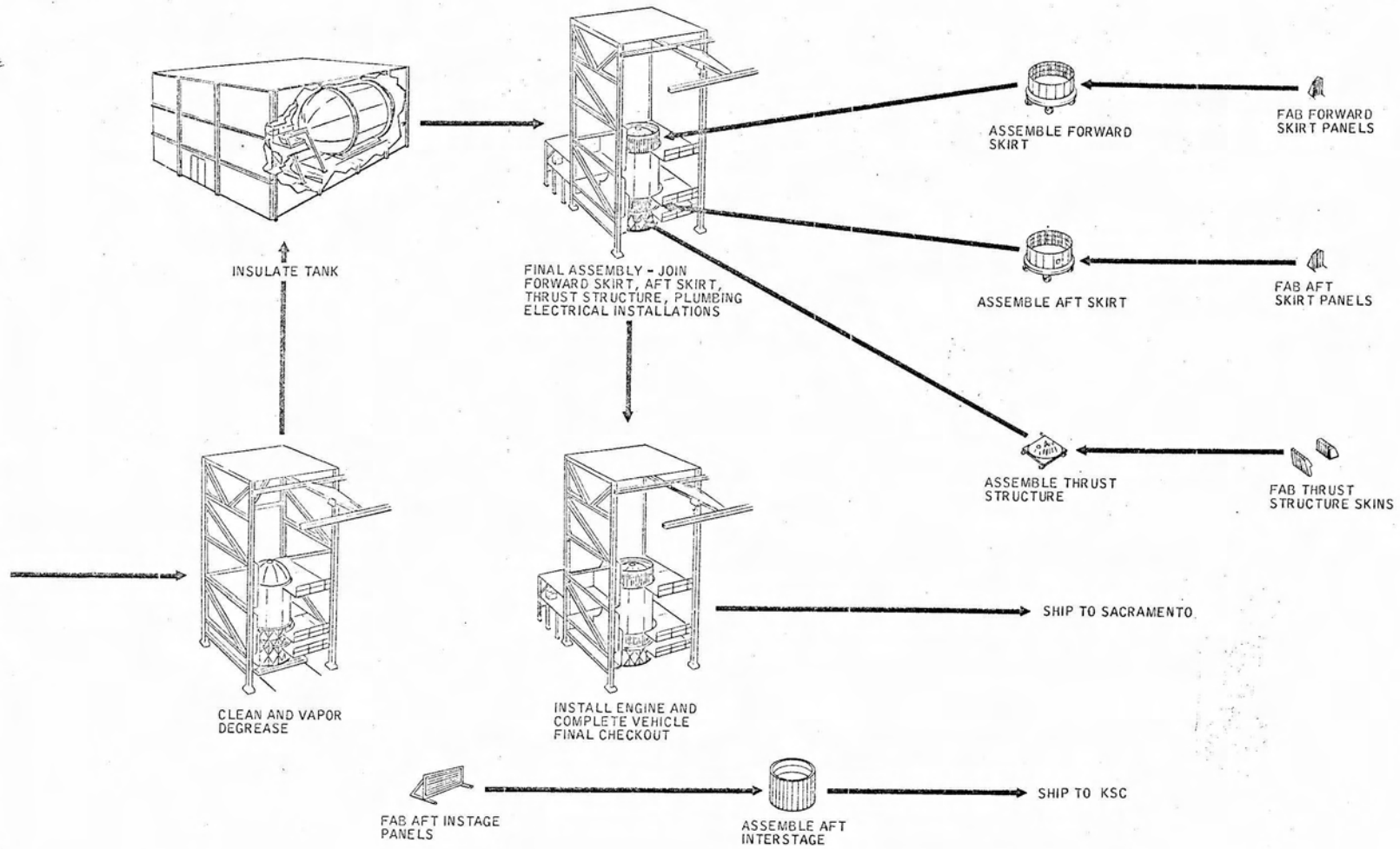
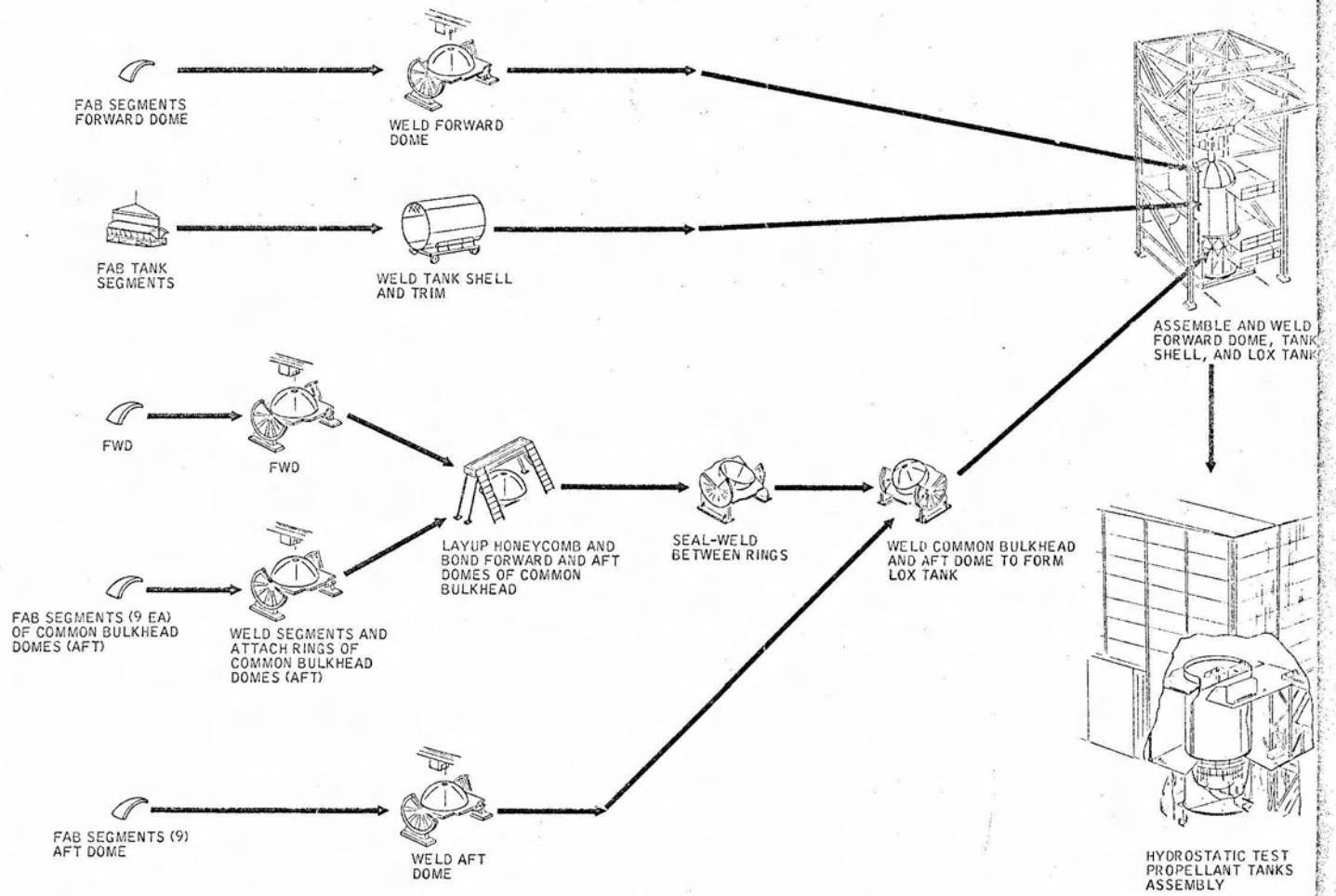


Figure 28



J-2 ENGINE

Major Components	- Thrust chamber, LH ₂ pump, LOX pump, propellant utilization valve, spark ignition system, electrical control package, instrumentation system, pneumatic system, turbine start sphere, gas generator, heat exchanger, miscellaneous control valves.
Thrust Chamber	- Tubular-walled with chamber stiffeners, expansion ratio, 27.5:1, regeneratively cooled.
LH ₂ Pump	- Turbine driven, 7 stage, axial flow, self-lubricated pump; increases LH ₂ pressure to chamber ducting.
LOX Pump	- Turbine-driven single stage, self-lubricated centrifugal pump; increases LOX pressure to chamber ducts. Accessory drive pad on back 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 buss.
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 GH ₂ sphere, charged with GHe to 3,100 ±100 psia at -250° F. Controls all engine pneumatics. Regulated to 400 psia in pneumatic package.
GH ₂ Sphere	- Spins LH ₂ and LOX turbines during engine start and restart; charged to 800 psia at -250° F. 7,300 cu in. sphere requires 7 seconds to recharge in mainstage operation.
Gas Generator	- Provides burned LOX/LH ₂ gases to sustain LOX and LH ₂ turbopumps.
Heat Exchanger	- Heats and expands cryogenic He from stage supply for pressurization of LOX tank. Utilizes heat from turbine exhaust.

J-2 ENGINE COMPONENT LOCATIONS

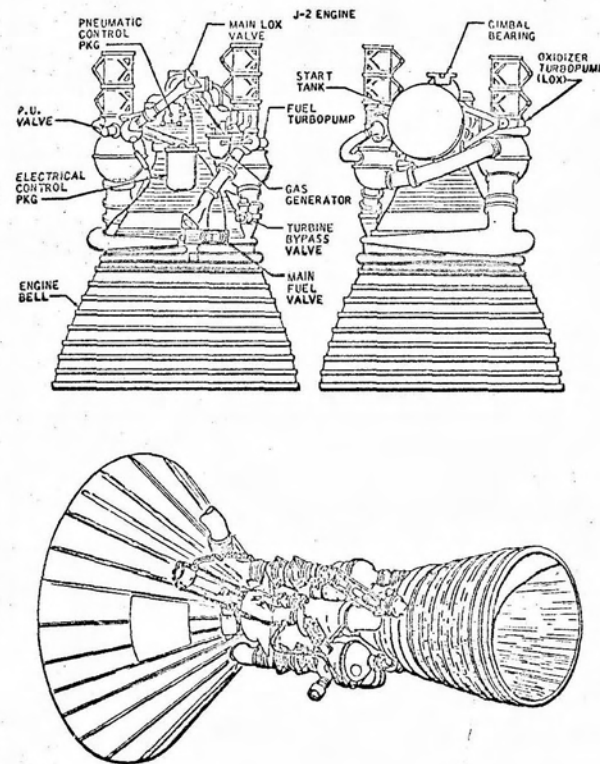


Figure 29

it is heated and expanded. Another portion flows through undersize orifice (12) 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 (5) 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 39.5 ± 0.5 psia, the flight pressure switch (5) picks up, closing solenoid valve (9). LOX tank pressure thus cycles between 37 and 40 psia. At engine cutoff, the flight pressure switch (5) is changed back to control of the onboard 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 tee assembly with a pneumatically-operated vent-relief valve (1), and a relief valve (13). Pneumatic operation is provided by the LOX vent actuation module using the helium gas from the pneumatic control module. The vent 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 relieves pressure in excess of 44 psia and reseats at 41 psia. The relief valve is set for 45 psia, reseats 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 portion of the vent-relief valve is pneumatically opened and closed upon actuation of the solenoid in the LOX vent actuation module. The valve is opened at the initiation of tank fill and closed prior to pre-pressurization. COX from either the vent-relief valve or relief valve is ported overboard through a 5 inch line.

- Major Components - Tank pressurization system and vent-relief system.
- Tank Pressurization System - Pressurizes tank with helium to maintain proper tank pressure to ensure net suction head pressure at LOX pump to prevent cavitation and possible damage to pump. Contains LOX tank pressurization control module, cold helium fill module, J-2 heat exchanger, and cold helium storage spheres.
- Vent-Relief System - Vent-relief system provides relief of pressure during fill and flight. Contains pneumatically-operated vent relief valve and a spring-loaded relief valve.

GENERAL DESCRIPTION

The S-IVB/S-IB uses LOX as the oxidizer. LOX is stored at -297° F in the LOX tank which has a volume of 2,828 cu ft. This allows a usable oxidizer weight of 191,667 pounds at 100 per cent full, with an ullage volume of 73.5 cu ft. LOX tank pressurization is provided by helium gas from eight storage spheres located in the fuel tank. A vent system provides relief of pressure during fill and flight. A screen is provided at the tank outlet as a filler and to prevent vortexing. Tank pressure-sensing switches protect the LOX tank from unforeseen LOX fill flow rates, provide indication of adequate pressure for LO, maintain tank pressure at the proper value, and protect the tank from over-pressurization during flight.

OPERATION

Oxidizer Tank Pressurization System: Oxidizer tank pressurization is controlled by LOX pressurization module (figure 31). At the beginning of LOX tank fill, the vent-relief valve (1) is opened. During rapid fill, LOX is supplied to the tank at a maximum rate of 1,000 gpm, and is then reduced to 200 gpm during slow fill. When slow fill is complete, the vent-relief valve (1) 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 a cold helium ground supply (2) applied through solenoid valve (3). Cold helium for inflight pressurization is stored in eight spheres (4) charged to $3,100 \pm 100$ psi at -360° F located in the LH₂ tank. The flight pressure sensing switch (5) (sensing tank ullage 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 drops 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 anticipated.

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 (6) will go to its open position, allowing cold helium to flow from the cold helium supply through the regulator (10) reducing pressure to 450 ± 25 psia 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

- Major Components** - Tank pressurization system and vent-relief system.
- Tank Pressurization System** - Pressurizes fuel tank to maintain proper net suction head pressure for the fuel pump and prevent cavitation and possible fuel pump damage. Contains fuel tank pressurization control module.
- Vent-Relief System** - Vents fuel tank during fill and in flight. Contains two pneumatically controlled valves and a spring-loaded relief valve.

GENERAL DESCRIPTION

The S-IVB/S-IB utilizes hydrogen as fuel. LH₂ is stored in an insulated cylindrical tank of 10,426 cu ft volume. LH₂ at -423° F is pressurized with GHe from ground source to 30.5 ±.5 psia. Usable capacity is 38,333 pounds LH₂ with a residual of approximately 300 pounds at 100 per cent load. During firing in flight, the tank is pressurized with GH₂ from J-2 engine bleedoff.

OPERATION (See figure 32.)

Fuel Tank Pressurization: The fuel tank ullage must be maintained at proper operating pressures to assure a net positive suction head at the LH₂ pump inlet to prevent cavitation and possible pump destruction. 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. At the start of final topping, vent valve (1) is closed and pressurization is initiated with He from ground source at 600 psi, -360° F. The fuel tank is pre-pressurized to 30.5 ±.5 psia. Minimum LO pressure is 28.5 ±.5 psia. During boost and prior to engine start, the fuel tank does not require venting as no appreciable pressure rise is anticipated. Tank pressure will remain nearly at LO valve, ensuring sufficient pressure for engine start.

GH₂ is bled from the J-2 engine tapoff (2) at 750 psia, -260° F to maintain pressure during engine firing. Pressure is controlled by the fuel tank pressurization control module. GH₂ flows from engine bleed through an undersize orifice (3) to the fuel tank. Control valve (4) and step valve (5) are held closed. Flow through the undersize orifice (3) is not sufficient to maintain tank pressure when engine fires and fuel is being pumped out. Pressure decay is sensed and control valve (4) opens at 28 psia admitting flow through a larger orifice (6) until pressure builds to 31 psia and control valve (4) closes. Step pressure valve (5) is held closed for 301.6 seconds of engine burn, then opens allowing pressure to build up to vent pressure at 43 psia, venting overboard at relief valve (7).

Vent-Relief System: The fuel tank vent-relief system consists of a combination vent-relief valve (1), a relief valve (7) and an overboard vent. The combination vent-relief valve (1) is controlled by the LH₂ vent actuation module. During fuel tank filling, this valve is pneumatically opened and closed by actuation of a solenoid in the fuel vent actuation module venting through the LH₂ umbilical vent. The solenoid is energized by an overpressure switch. Valve (1) is opened at fill initiation and is closed at start

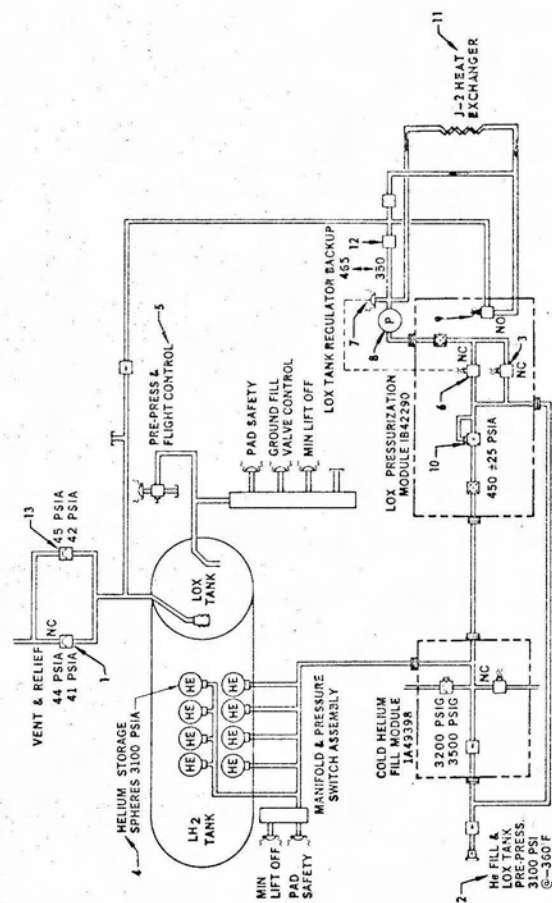


Figure 31

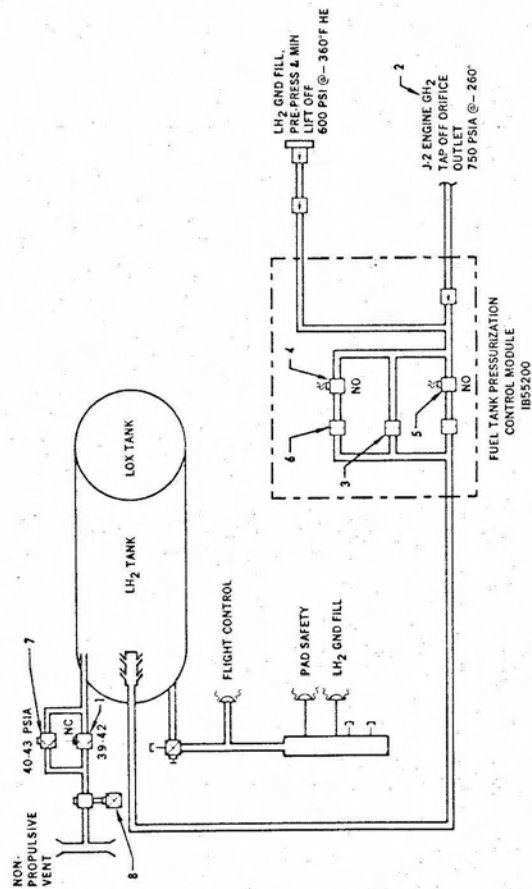


Figure 32

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.

GENERAL DESCRIPTION (See figure 33.)

GHe provides pressure to operate all S-IVB stage pneumatically-operated valves except the engine valves. GHe is supplied from a sphere pre-charged to 3,100 ±100 psia at 70° F from ground facilities. This sphere located on the forward side of the thrust structure 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 535 ±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 valve, the GHe system also provides He 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 operate the following valves:

- a. Engine start tank vent valve
- b. Pilot-operated directional vent valve
- c. Fuel tank vent-relief valve
- d. Fuel fill and drain valve
- e. LOX fill and drain valve
- f. Fuel pre-valve
- g. LOX pre-valve
- h. LOX vent-relief valve
- i. LH₂ chilldown valve
- j. LOX chilldown valves

S-IVB/S-IB PNEUMATIC CONTROL SYSTEM

Major Components	- Control Helium Storage Sphere, Pneumatic Power Control Module, Chilldown Pump Purge Control Module, Engine Pump Purge Control Module, Plenum Chamber, and six Actuation Control Modules.
Control Helium Storage Sphere	- Stores ambient GHe for operation of pneumatically-operated valves. Capacity, 4.5 cu ft. Pressure, 3,100 ±100 psia at 70° F. Located on thrust structure.
Pneumatic Power Control Module	- Filters and reduces GHe from storage sphere at 3,100 psia to 475 ±25 psig for operation of pneumatic valves. Contains a filter, regulator, pressure-sensing switch, and two solenoid operated valves.
Chilldown Pump Purge Control Module	- Reduces GHe at 475 ±25 psig to 49-53 psig and furnishes it to purge the motor-driven LOX chilldown pump. Contains a pressure reducing orifice, pressure-sensing switch, and solenoid operated valve.
Engine Pump Purge Control Module	- Reduces GHe at 475 ±25 psig to 105-130 psig and furnishes it to purge the LH ₂ and LOX turbine seal cavities. Contains a pressure reducing orifice, pressure-sensing switch, and solenoid operated valve.
Plenum Chamber	- Located downstream from pneumatic power control module to absorb surges of GHe pressure which can possibly reach 535 psig.
Actuation Control Module	- There are six actuation control modules to operate LOX fill and drain valve, LH ₂ fill and drain valve, LOX and LH ₂ pre-valves, LOX vent-relief valve, LH ₂ vent-relief valve, and pilot-operated directional vent valve. Each actuation control module contains two solenoid operated three-way control valves.

S-IVB FLIGHT CONTROL

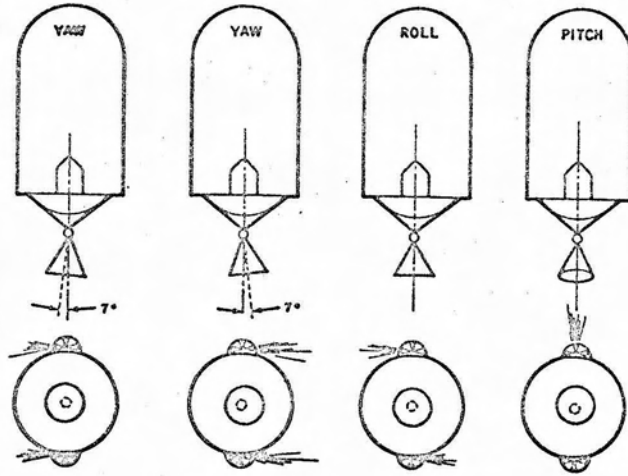


Figure 34

Flight control achieved by gimbaling 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 attitude 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 gimbaling engine $\pm 7^\circ$ in a square pattern. APS will correct attitude errors of $\pm 1^\circ$.

PNEUMATIC CONTROL SYSTEM SCHEMATIC

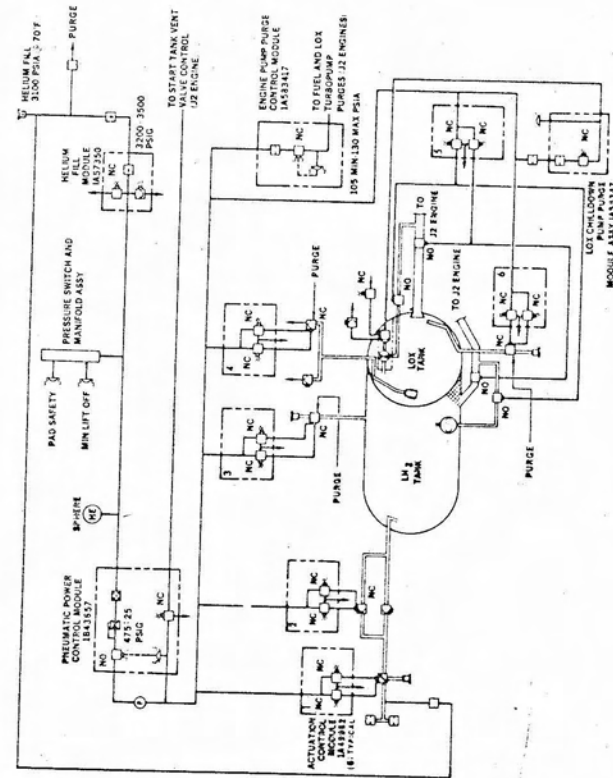


Figure 33

HYDRAULIC SYSTEM (Continued)

DPF network in servovalve damps pressure surges in system by acting in opposition to control fluid flow.

OPERATION (See figure 35.)

Auxiliary Hydraulic Pump Circuit - Coast Mode/Unpowered 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 psig. Fluid from cavity (4) flows to inlet of actuator assemblies (8) and (9), is directed to servovalves (10) and (11) and is returned to reservoir (6) through valves (12) and (13). Flow from reservoir (6) is routed through pump (14) case drain and returned to pump (1) 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 (14) through valve (16) when outlet pressure exceeds residual system pressure, and is directed to actuators (8) and (9) through filter (3) and accumulator (4). If IU signal is applied to servovalves (10) and (11), control spools (17) and (18) are shifted to operate actuating cylinders. Return line fluid flows through valves (12) and (13), reservoir (6) to pump (14) inlet. Valve (19) provides system high pressure protection and is adjusted to crack at 3,900 psig. Valves (20) and (21) provide low-pressure system protection and will vent fluid overboard when pressure exceeds 275 psig.

HYDRAULIC SYSTEM

Major Components	- Engine-Driven Hydraulic Pump (1), Motor-Driven Auxiliary Hydraulic Pump (1), Accumulator-Reservoir Assembly (1), Hydraulic Actuator Assemblies (2)
Engine-Driven Hydraulic Pump	- Vickers, variable-displacement, yoke-type; delivers 8 gpm at 8,000 rpm; pressure compensator regulates pump pressure at 3,650 psig; driven from LOX turbopump by quill shaft (shears at 1,100-1,200 in. lb to protect turbopump); thermal isolator between pump and turbopump.
Motor-Driven Auxiliary Hydraulic Pump	- Variable-displacement, pressure compensated; delivers 1.5 gpm at 3,650 psig; motor turns 13,000 rpm; motor operating voltage, 56 vdc.
Accumulator-Reservoir Assembly	- Reservoir volume, 167 cu in.; accumulator volume, 285 cu in.; accumulator pre-charge pressure, 2,350 psig; GN ₂ ; contains two inter-acting pistons.
Hydraulic Actuator Assemblies	- Mounted 90° apart; actuating cylinder is linear, double-acting; total stroke is 2.9 inches; delivers 42,000 pounds force; actuator has mechanical midstroke lock; servovalve is flow-control type with dynamic pressure feedback (damping); mechanical feedback (actuator-to-servo) used for engine position control loop.

GENERAL DESCRIPTION

Hydraulic system provides thrust vector steering (pitch and yaw only) for stage during main engine burn. Main engine is gimballed $\pm 7^\circ$ from stage centerline by two hydraulic actuator assemblies. Steering signals from IU are translated by servovalves to operate hydraulic actuators. Engine-driven pump operates only during mainstage burn. Motor-driven pump acts as backup to engine-driven pump during mainstage burn, provides centering during unpowered flight, and maintains acceptable temperature and viscosity of hydraulic fluid during coast, by periodically cycling fluid. Accumulator-reservoir Assembly is an integral housing which contains reservoir and accumulator sections. Reservoir section is pressurized to working pressure (approximately 169 psig) by either pump; initial pressure (approximately 65 psig) is provided by accumulator pre-charge. Servovalve uses torque motor to convert IU 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** - Tapco, 150 lb thrust per engine; chamber pressure, 100 psig; pulse-type engines equipped with molybdenum throat liner and refrasil 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 37 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 IU. Control engines are pulse fired in pairs to initiate 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 returned 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 GN₂ to flow through check valves (5) and (6) and return to supply source through fuel and oxidizer vent disconnects. Prior to propellant loading, He sphere is pressurized. He from ground source flows through valve (7) and pressurizes tank to 3,000 psig. Valve (8) provides high-pressure protection, will relieve at 3,500 psig, reseating at 3,200 psig. He control pressure is regulated to 200 ± 5 psig in redundant regulator contained in He

HYDRAULIC SYSTEM FUNCTIONAL SCHEMATIC

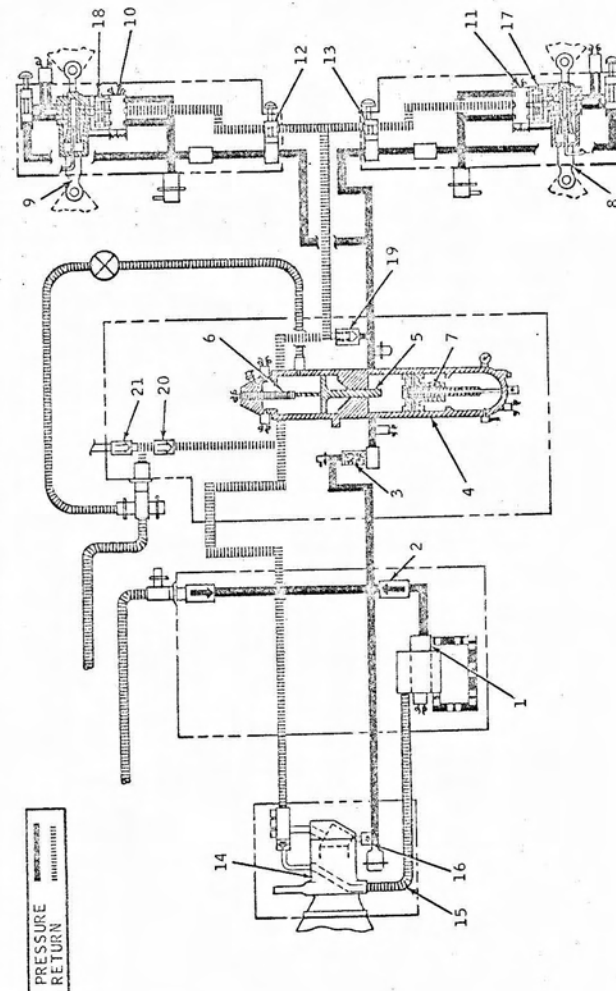


Figure 35

AUXILIARY PROPULSION SYSTEM MODULES

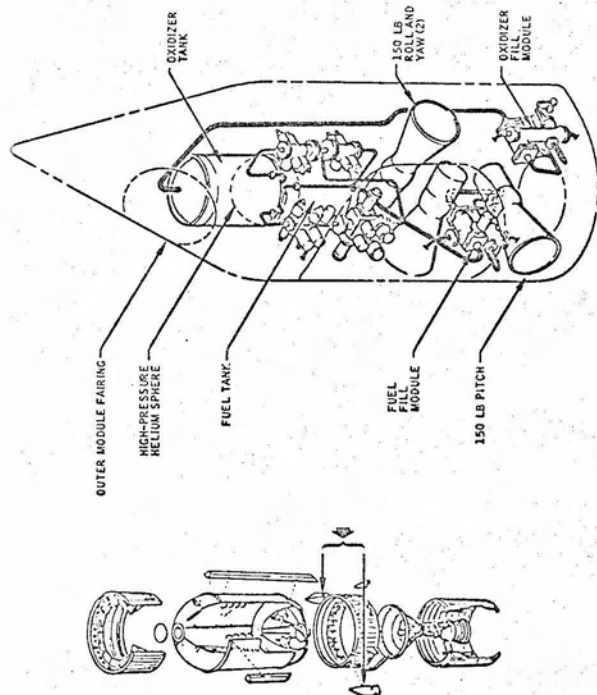


Figure 36

control module. Regulator (9) 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 dumped 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.

Electrical Control Circuit: Upon command, 28 vdc power from IU control module energizes relays K5, K6, K7, and K8 closing contacts. Contacts of K5 and K6 open oxidizer valves A and B and open fuel valves 1 and 2. Contacts of K7 and K8 open oxidizer valves C and D and open fuel valves 3 and 4. System is quad-redundant for optimum reliability.

AUXILIARY PROPULSION SYSTEM CONTROL SCHEMATIC

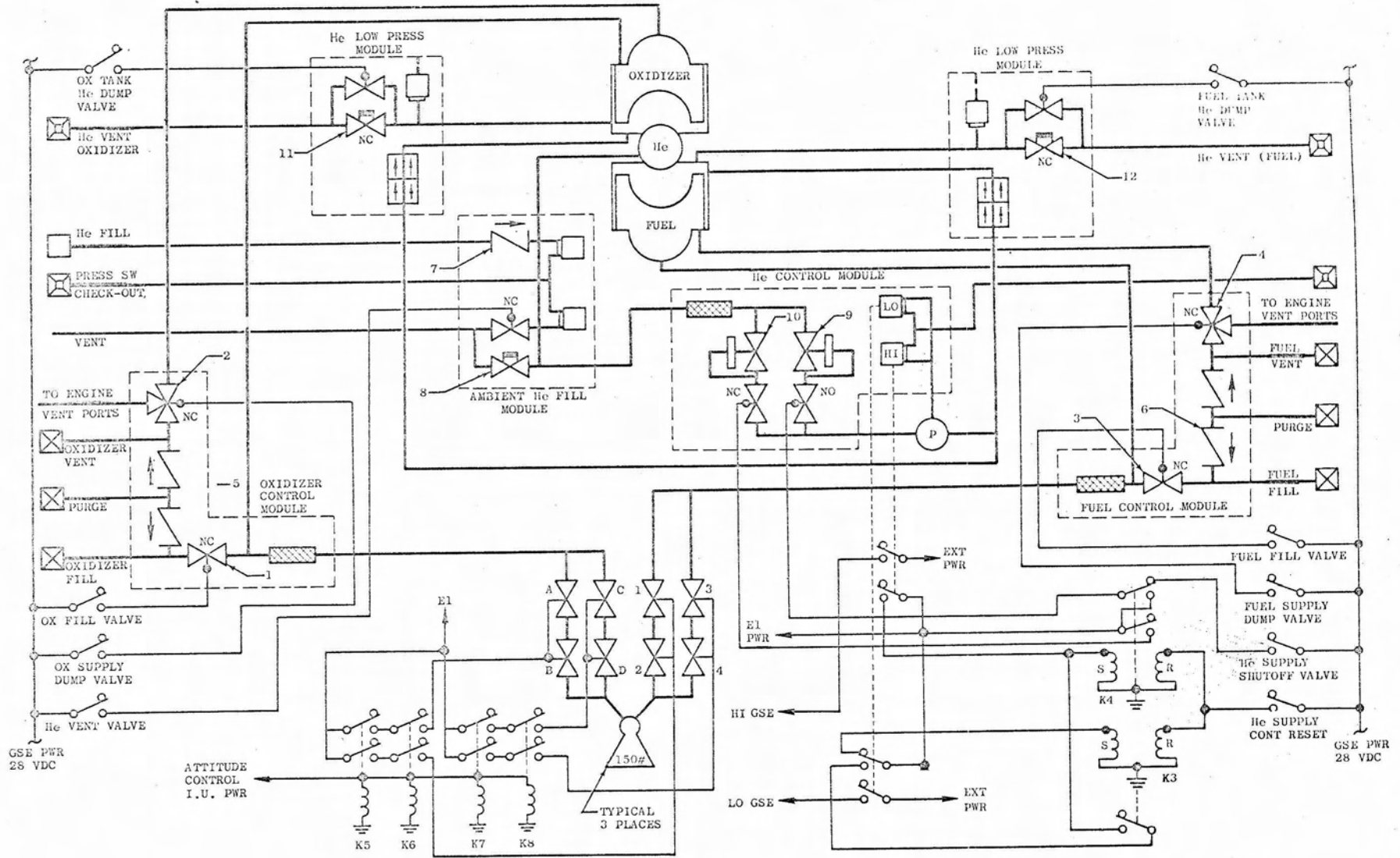


Figure 37

S-IVB ELECTRICAL SYSTEM

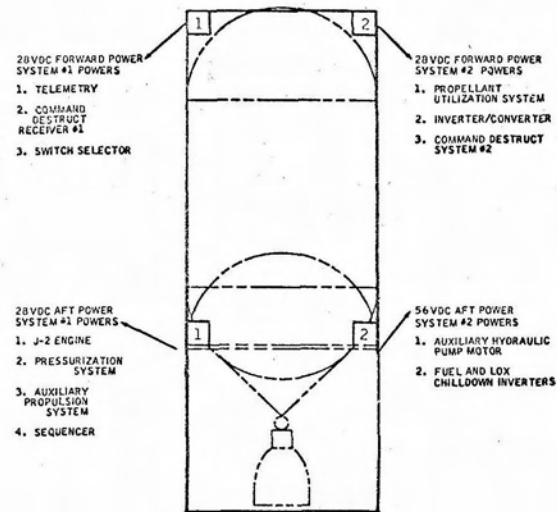


Figure 38

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 hydraulic 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

Major Components	- 28 vdc, approx 270 AH Battery (1), 28 vdc, approx 55 AH Battery (1), 28 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 (1), Sequencer (1).
Batteries	- Positive plate, silver oxide; negative plate, zinc; electrolyte, potassium hydroxide; sealed, pressurized unit; temperature-controlled; service life, 72 hrs.
Internal-External Busses No. 1 and No. 2	- Power distribution point for all flight operational equipment in respective section.
Talkback Bus	- Returns stage status information to GSE. Externally powered only during test.
Internal-External Switch	- GSE-controlled transfer switch changes over power from GSE to stage batteries.
Power Distribution Box	- Distribution point for external or internal power to equipment located in stage.
Switch Selector	- (GFE) Translates IU digital commands to S-IVB stage commands. 8-bit monitored output of 113 possible commands.
Sequencer	- Receives commands from switch selector. Contains mag-latch relays, controlling all stage functions.

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 ullage 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

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 actuate 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

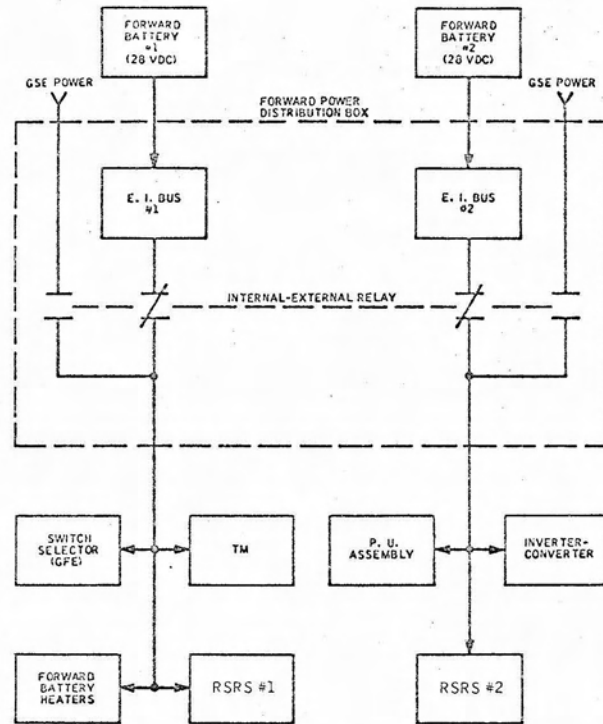


Figure 40

AFT ELECTRICAL SYSTEM FUNCTIONAL SCHEMATIC

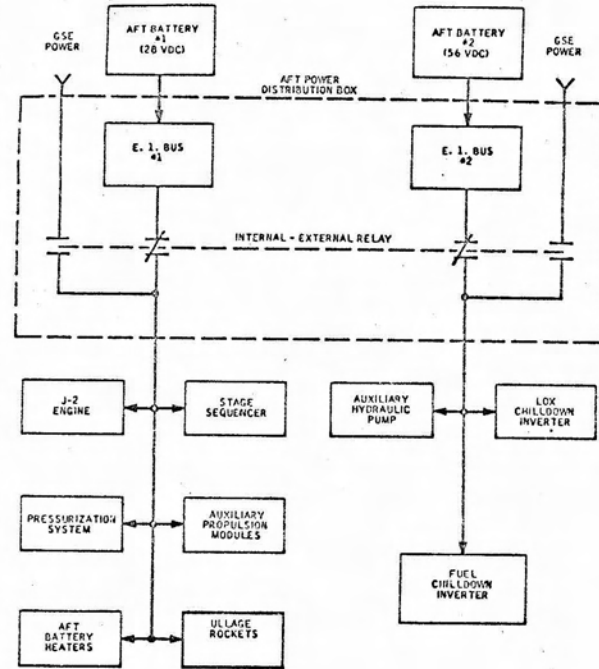


Figure 39

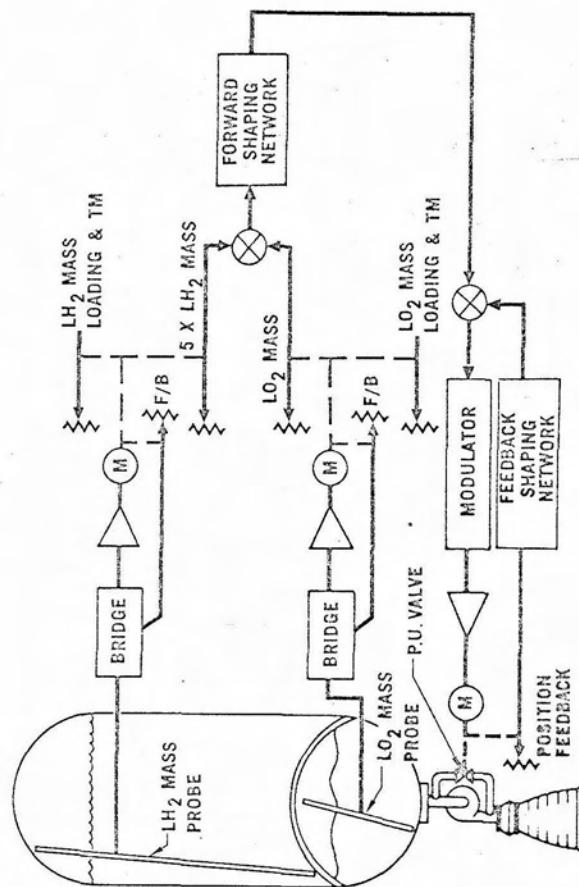


Figure 41

S-IVB PROPELLANT UTILIZATION SYSTEM

- Major Components - Fuel Mass Sensor (1), LOX Mass Sensor (1), PU Electronics Assembly, Inverter/Converter.
- Fuel Mass Sensor - Capacitive type; 1,200 picofarads in air; 1,000 k 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 k 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 propellant tank control signals; located in fwd skirt.
- Inverter/Converter - Converts 28 vdc from forward No. 2 battery into precise ac and dc voltages for PU electronic assembly.

OPERATION (See figure 41.)

Metering 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 usable load).

Sensors feed LH₂ and LOX bridge, which are servo-balanced. Quadrature nets cancel probe errors, at triggered intervals. Amplified signals applied to pot shaft positioning motors. Feedback damps servomotors. Pots control PU system operation. Sigs of LH₂ and LOX pots fed to shaping network. Amplified, modulated signal is applied to mixture ratio servo. Servo motor controls position of PU valve, varying engine mixture ratio to compensate for tank mass unbalance. PU valve feedback pot nulls 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 site.

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

Multiplexed inputs are mixed with CCO subharmonic, amplified, and single sidebanded with filter (filter passes upper band). SSB/AM signal is amplified, and mixed with incremental subharmonics of CCO. Information is contained in base band spectrum of modulator output. 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 kc CCO provides all translation and reference tones, no cross-modulation or data loss occurs if CCO drifts, as all subsequent shifts are proportionate. A pilot tone, which is sub-harmonic of 910 kc 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.

Measures, gathers, and transmits flight instrumentation data (acceleration, force, motion, 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 (PAM) are converted from analog to digital format (bits) which modulate FM transmitter.
- d. SS/FM - Multiplexed inputs are audio modulated (AM) then single side-banded. AM/SS channels modulate FM transmitter.

Systems No. 1, No. 2, No. 3 (PAM/FM/FM) Functional Description (See Figure 42.)

Transducers measure flight data, feed high (0 to 5 vdc) 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, ± 30 per cent SCOs and converted to varying frequency (FM) output. IRIG channels 1 through 15 accept prime data. All 16 channels are mixed to form composite FM signal, which is fed to transmitter. Transmitters No. 1 and No. 3 are duplexed into single antenna. Transmitter No. 2 is duplexed with PCM system transmitter (No. 4) and SS/FM, into 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,

*PCM/FM System also referred to as DDAS

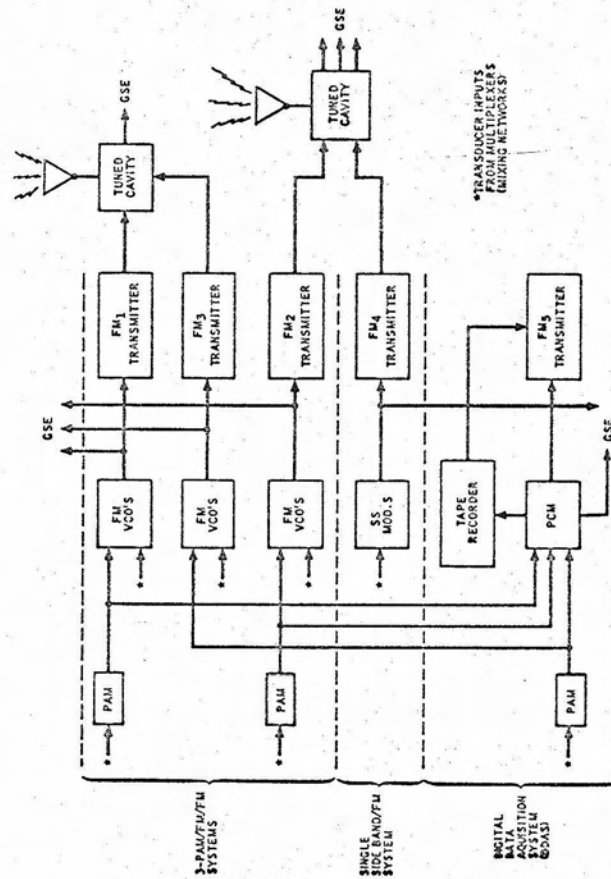


Figure 42

S-IVB TELEMETRY DATA CAPABILITY

System	Sync Channels	Data Channels	
		Cont.	Sampled
No. 1			
High Level PAM (0 to 5 vdc) 3,600 Samples per Second (30 x 120)	3		27*
15 Continuous FM/FM Channels (IRIG Bands 1 through 15)	-	15	
No. 2			
High Level PAM (0 to 5 vdc) 3,600 Samples per Second (30 x 120)	3		27*
15 Continuous FM/FM Channels (IRIG Bands 1 through 15)	-	15	
No. 3			
High Level PAM (0 to 5 vdc) 3,600 Samples per Second (30 x 120)	3		27*
15 Continuous FM/FM Channels (IRIG Bands 1 through 15)	-	15	
15 SSB/FM Channels	-	15**	
		60	61*

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

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

SINGLE SIDEBAND/FREQUENCY MODULATION FUNCTIONAL SCHEMATIC

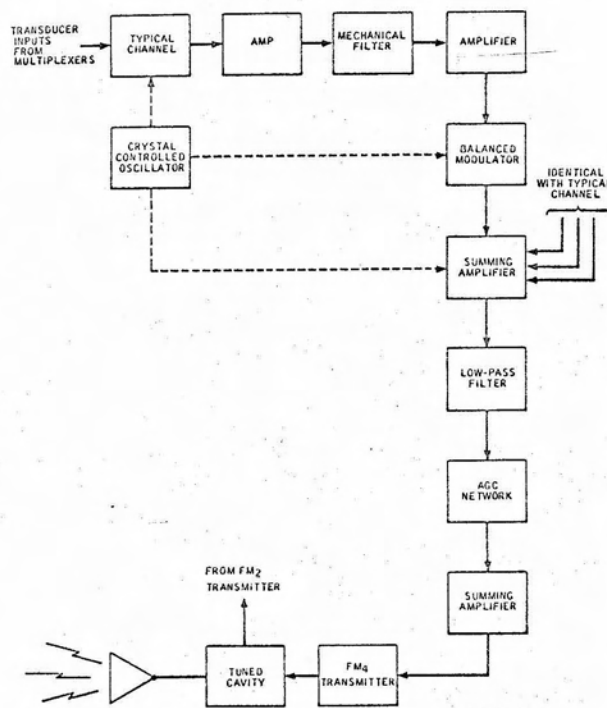


Figure 44

DIGITAL DATA ACQUISITION SYSTEM FUNCTIONAL SCHEMATIC

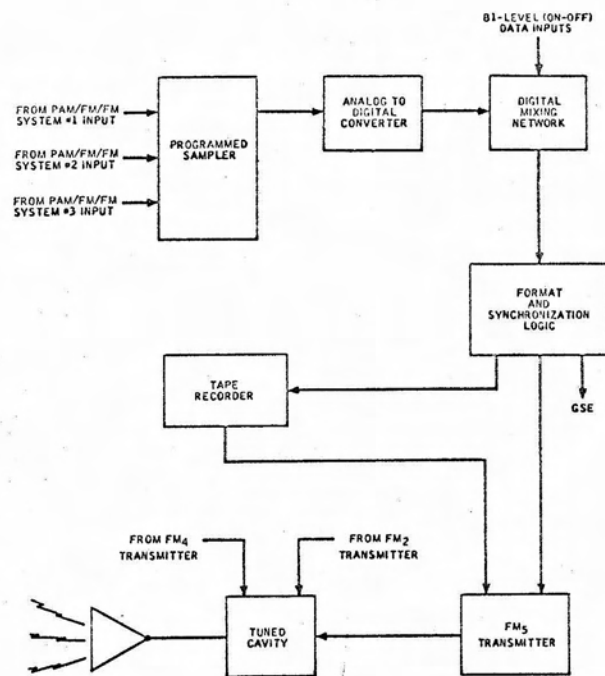


Figure 43

SEPARATION SYSTEM

- Major Components - MDF Explosive Harness Assembly (2), Detonator Block (1), EBW Detonator (2), Firing Unit (2).
- Separation Joint - Tension Tie connecting Aft Interstage and Aft Skirt; 7075-T6 AL, approximately 0.050 in. thick located directly over channel containing MDF.
- MDF Explosive Harness Assembly - Flexible, metal sheath contains PETN core, approximately 10 grains per foot; propagation rate of 23,000 feet per second; two harness assemblies used for optimum reliability; both harness assemblies completely surround stage.
- Detonator Block - Mates MDF harness assemblies and EBW detonators.
- 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; mica spark gap incorporated for safety.
- Firing Unit - Input voltage, 28 vdc; output voltage, 2,300 vdc at 1,500 amps; housing contains electronics to initiate EBW detonators; operation requires charge (ARM) and trigger signals.

OPERATION (See figure 46.)

- Firing units charged following S-IB engine cutoff. Charging (ARM) signal is stepped up and applied to large storage capacitor (2,300 vdc). Signal, applied approximately six seconds later is stepped up to 5,000 V pulse, to trigger gap tube. Tube ionizes, causing storage capacitor to discharge through respective EBW detonator. Propagation wave from EBW detonator booster charges initiates primary charge. Wave initiates booster charges in detonator block and is transmitted to MDF harness assemblies. Propagation of harness assemblies cuts tension tie to permit stage separation. All separation signals supplied by S-IB stage sequencer.

S-IVB ORDNANCE

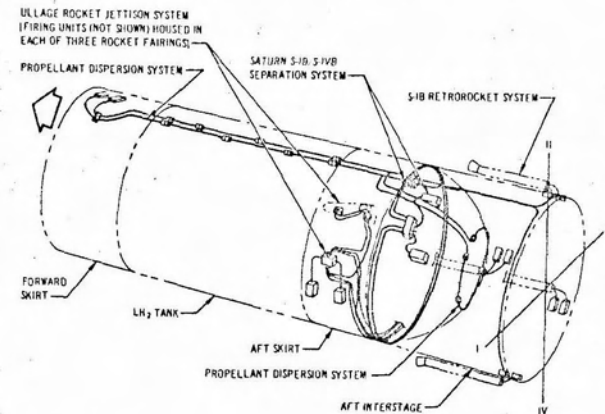


Figure 45

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

- S-IB and S-IVB stage separation system used to separate two stages.
- S-IB and S-IVB stage retrorocket system used to decelerate lower stage.
- S-IVB stage propellant dispersion system used to shut down J-2 engine and rupture propellant tanks.
- 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	- Quarter wave, slot type; 52 ohm impedance; UHF (450 mc); two antennae.
Range Safety Receivers	- GFE; crystal-controlled transistorized, FM, superhetrodyne; ten channels; carrier frequency range, 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 monitor; 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 LH ₂ tank, one to LOX tank.

SEPARATION SYSTEM COMPONENTS

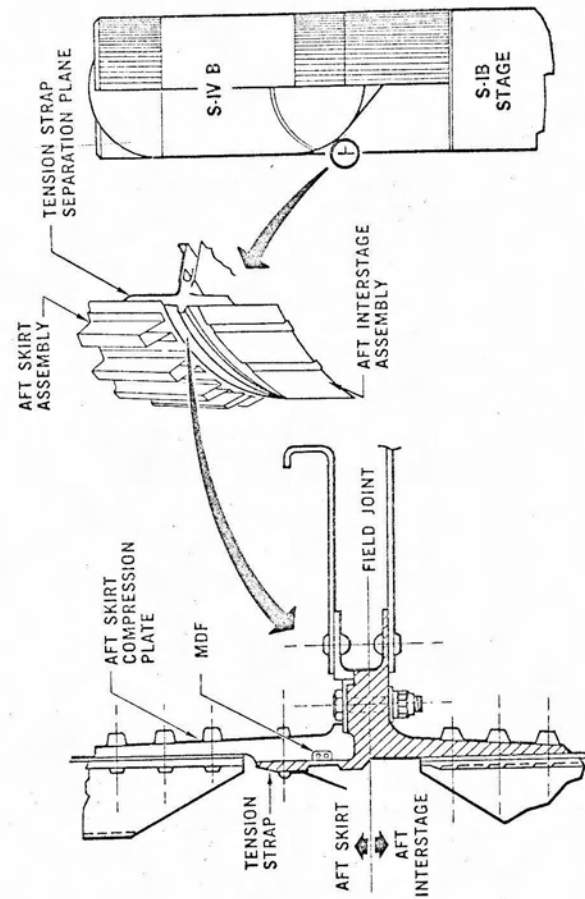


Figure 46

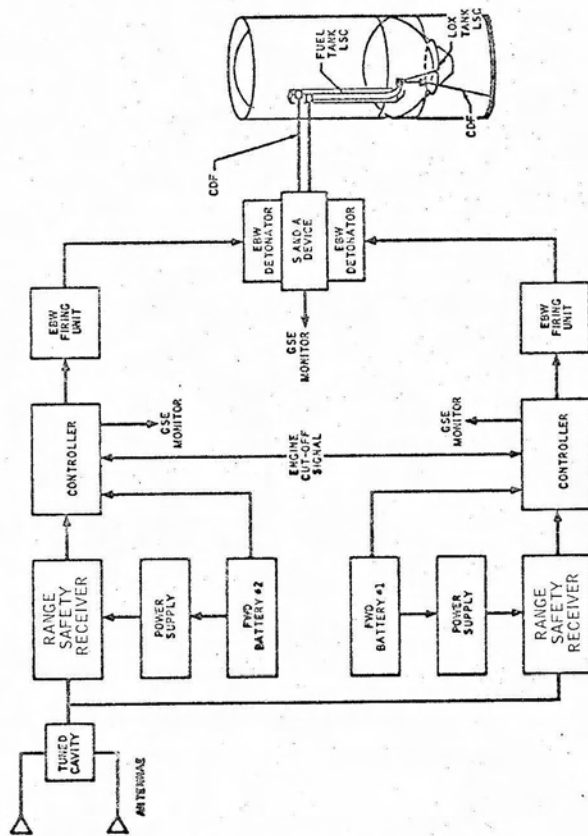


Figure 47

OPERATION (See figure 47.)

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 IRIG 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 primacord harnesses, then to fin-ear-shaped charges attached to LH₂ and LOX tanks. Charges rupture tanks causing propellant dispersion.

ULLAGE CONTROL SYSTEM FUNCTIONAL SCHEMATIC

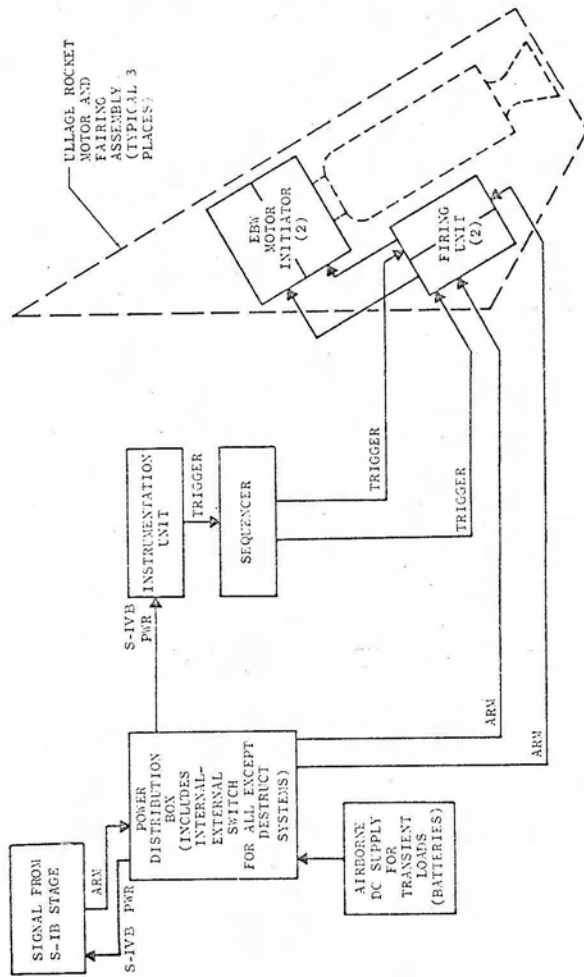


Figure 48

ULLAGE ROCKETS (IGNITION SYSTEM)

Major Components - Ullage Rockets (3), Firing Units (6), EBW Motor Initiators (6).

Ullage Rockets - Thiokol TX-280, solid propellant rockets; thrust, 3,390 lb (nominal) at +70° F; burn time, 3.94 sec at 70° F; 58.8 lb of propellant, ammonium perchlorate and polysulfide; exit nozzles canted 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, 28 vdc; output voltage, 2,300 at 1,500 amps; housing contains electronics for detonating EBW initiators; operation requires charge (ARM) and trigger signals.

OPERATION (See figure 48.)

Ullage rockets are fired by signal from S-1VB sequencer. Charge (ARM) signal is stepped up and applied to large storage capacitor (2,300 vdc). Trigger signal is stepped up (5,000 v) 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 causes ignition of solid propellant grain. Ullage rockets impart forward acceleration on S-1VB stage to provide optimum ullage positioning and aid in separation.

S-IVB/S-IB RETROROCKET SYSTEM

Major Components	- Retrorockets (4), Firing Units (8), EBW Initiators (8).
Retrorocket	- Thiokol TE-29-IB, solid propellant (ammonium perchlorate and polysulfide); thrust, 35,600 lbs (nominal) at 70° F; burn time, 1.5 sec at 70° F; exit nozzles canted 9° from stage centerline; mounted on aft interstage.
EBW Initiator	- GFE, threaded connector contains cupric oxide and magnesium charge; mounted in dome of rocket motor.
Firing Units	- Input voltage, 28 vdc; output voltage, 2,300 vdc at 1,500 amps; housing contains electronics for detonating EBW initiators, operation; requires charge (ARM) and trigger signals.

OPERATION (See figure 49.)

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

ULLAGE ROCKETS (JETTISON SYSTEM)

Major Components	- Frangible Nut (6), Firing Unit (2), CDF Fuse (6), Detonator Block (1), EBW Detonator (2).
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 foot PETN charge covered with plastic and fabric sheath; three fuses are swaged 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 vdc; output voltage, 2,300 vdc at 1,500 amps; housing contains electronics for initiating EBW detonator; 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 initiation; mica spark gap incorporated for safety.

OPERATION

Firing units charged prior to S-IVB and S-IB stage separation. Charge (ARM) signal is stepped up (2,300 vdc) and applied to large storage capacitor. Trigger signal, applied through S-IVB sequencer after rocket burnout, is stepped up (5,000 v) to trigger gap 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; ullage rocket assemblies (3) are jettisoned.

S-IVB 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 unit, located between computer complex and operational end items, handles 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 consoles; telemetry ground stations; time synchronization unit; patch panels; safety item 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. Stimuli conditioner--Supplies test activation signals to equipment in stage under test, such as a relay or component.
- c. Test point and stimuli 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.

103

RETROCKET SYSTEM FUNCTIONAL SCHEMATIC

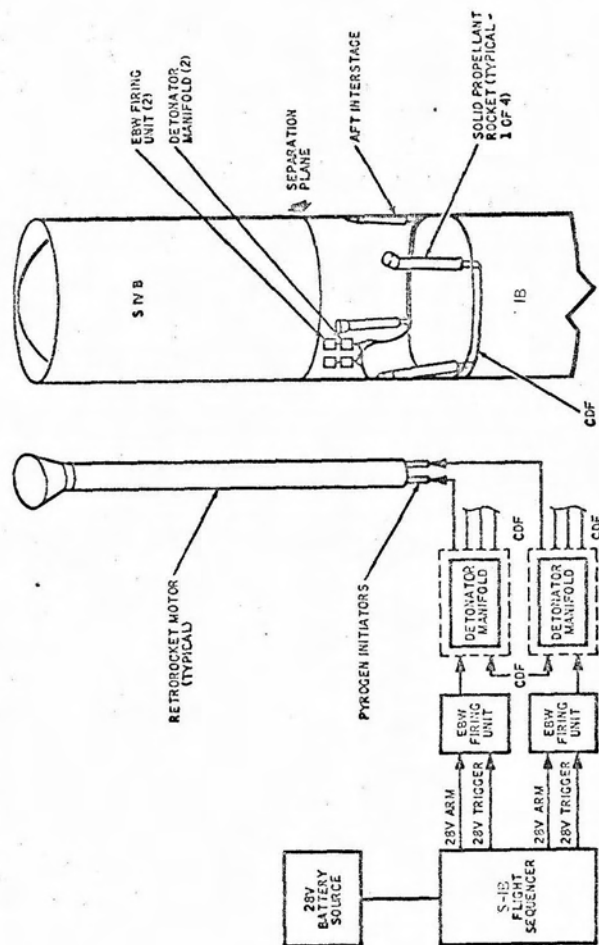


Figure 49

102

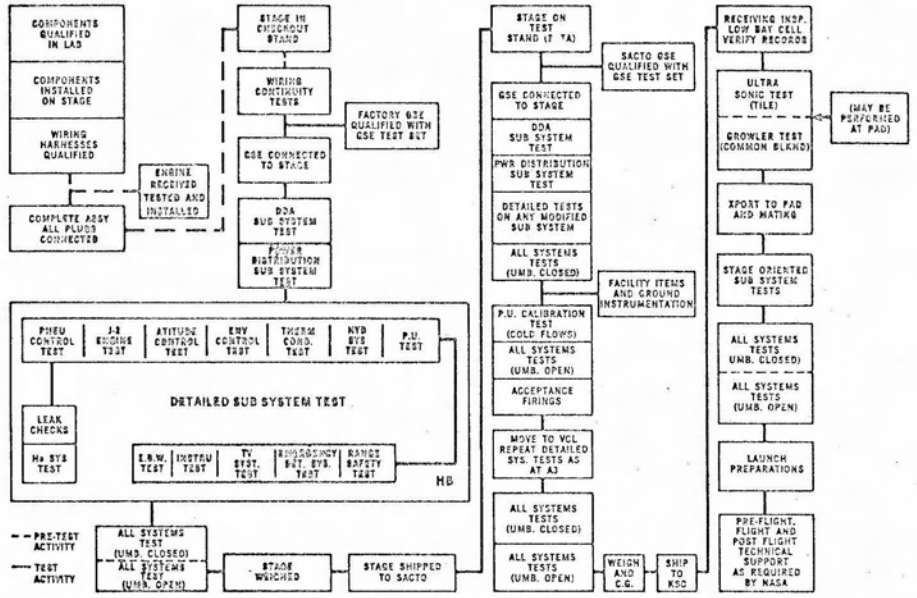


Figure 51

105/206

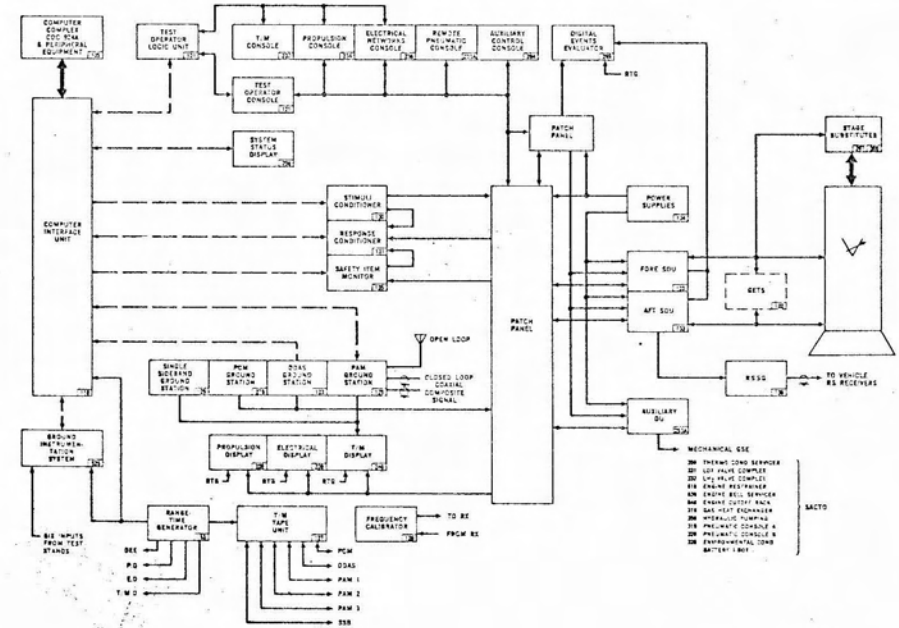


Figure 52

104

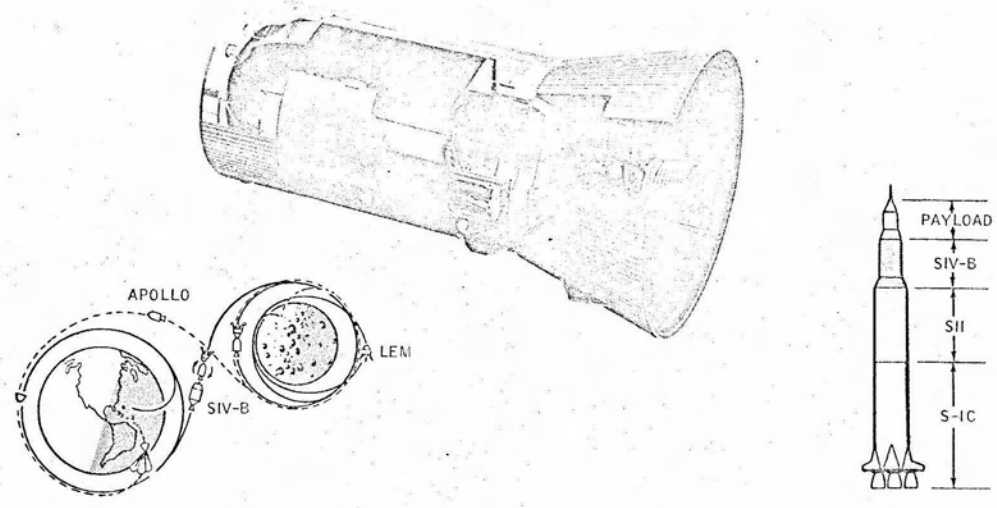


Figure 52

107

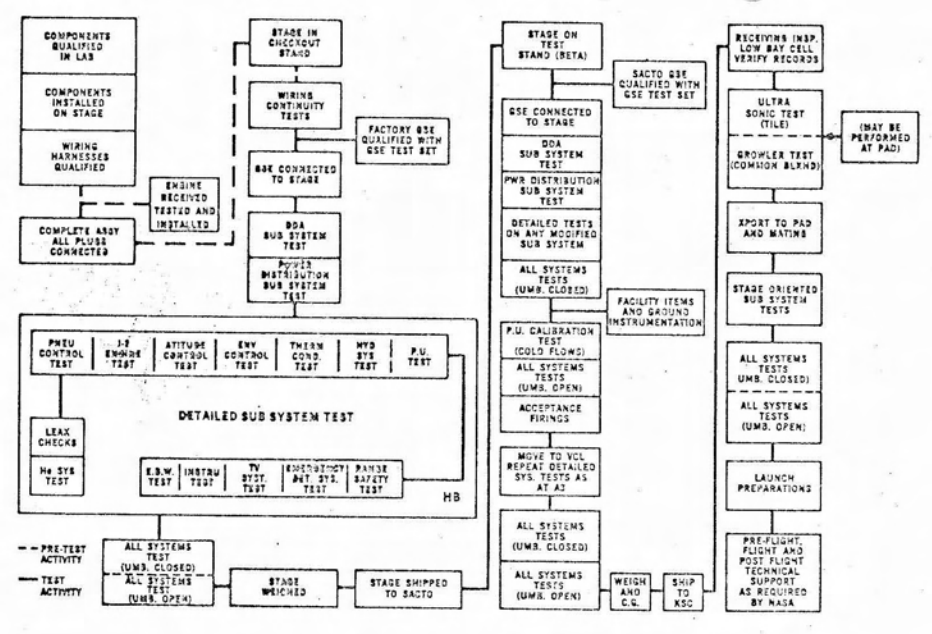


Figure 51

105/106

S-IVB/S-V MISSION PROFILE

Vehicle intended to launch and insert into lunar trajectory manned Apollo spacecraft and unmanned interplanetary 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 translunar trajectory. During orbit, vehicle systems are checked out via PCM/FM.

Launch window is calculated, J-2 engine restarts, vehicle is steered 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 moon. In moon orbit, LEM detaches and orbits, seeking landing site. Two men land on moon in LEM. One man explores moon, other checks out LEM. Up to 48 hours later, LEM blasts off to rejoin one man in Apollo. LEM is jettisoned. Apollo service module propulsion steers Apollo out of moon 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.

SATURN V LAUNCH VEHICLE CONFIGURATION

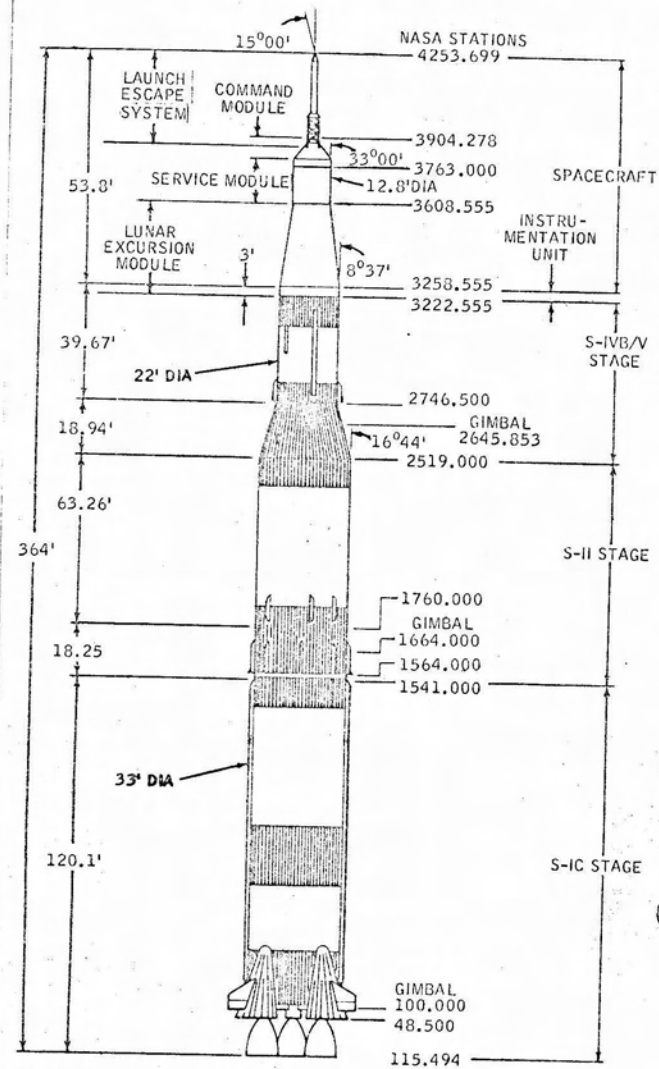


Figure 53

Countdown

$t_2 +0.8$	PU System off--PU measurements are unneeded, since propellant is no longer being consumed, and the quantity of remaining propellant is known.
$t_2 +1.1$	Engine Control and instrumentation heaters on--Extremely cold temperature of space demands equipment be warmed.
$t_2 +2.1$	Range Safety Receivers off--Propellant Dispersion system disabled to prevent inadvertent destruction of stage.
$t_2 +1.5$ to 1.7	SS Band Flight T/M Transmitters off, Orbital T/M Transmitters off deactivates orbital data link.
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^{-4} G's acceleration. Propulsive 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 (of ground station)	Orbit transmitter group on--Switches on a ground station command.
In range	Data lost out of line-of-sight replayed at high speed.
Out of range -10.0	Orbit transmitter group turned off, recorder turned on.
$t_3 -330.2$	Auxiliary hydraulic pump on--Operates to move J-2 preparatory to lunar insertion.
$t_3 -327$	(2) 70 lb thrust ullage engines fire to settle propellants.
$t_3 -326.0$	Fuel vent valve opens.
$t_3 -325.2$	LH ₂ tank repressurized--Insures LH ₂ pump NPSH for J-2 restart.
$t_3 -324.8$	LH ₂ chilldown--Prepares LH ₂ plumbing for restart.

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

Countdown

$t_0 -1260$	Purge engine thrust chamber--Clears J-2 engine of flammable gases.
$t_0 -960$	Thrust chamber purge off.
$t_0 -610$	Auxiliary hydraulic pump on--Recirculates fluid to maintain constant pressure.
$t_0 -600$	LOX chilldown--Cools LOX plumbing for thermal shock preconditioning.
$t_0 -597$	LH ₂ chilldown--Cools LH ₂ plumbing for thermal shock preconditioning.
$t_0 -90 \rightarrow 50$	Pressurize LH ₂ and LOX tanks--Cold He prepressurizes tanks to insure NPSH at engine ignition.
$t_0 -60$	DC power to internal--GSE power switched off. Vehicle battery power switched on.
(Liftoff) $t_0 -0$	Launch vehicle/payload leaves pad.
$t_1 -403$ $t_1 -398.5$	T/M calibration--Calibration reference signal sent to insure accurate T/M ground readback.
$t_1 -0.1$	Ullage rocket ignition--Additional axial acceleration insures bottoming of liquids in tanks.
$t_1 -0$	S-II/S-IVB Separation--Tension tie ruptures, parting stages.
$t_1 +1.6$	J-2 engine start--Delayed separation signal from S-II stage fires J-2 ignition system, starting engine.
$t_1 +6.0$	Activate PU--PU system is made operational as propellant sloshing from separation has subsided.
$t_2 +0$	Engine first burn cutoff--When Earth parking orbit is achieved, J-2 engine is cut off.
$t_2 +0.5$	Auxiliary hydraulic pump to coast mode--During coast, J-2 engine hydraulic is kept warm.

S-IVB/S-V VEHICLE DESIGNATIONS

Stage Destination	Required at	Used for
*Battleship Test Vehicle	SACTO	Test
*Dynamics Vehicle	MSFC	Test
*Facility Checkout Vehicle	KSC	Test
Flight Vehicle No. 501	KSC	Flight
Flight Vehicle No. 502	KSC	Flight
Flight Vehicle No. 503	KSC	Flight
Flight Vehicle No. 504	KSC	Flight
Flight Vehicle No. 505	KSC	Flight
Flight Vehicle No. 506	KSC	Flight

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

S-IVB/S-V STAGING (Continued)

Countdown	
$t_3 -322.0$ 29.9	T/M on and calibration--T/M turned on and recalibrated for restart.
$t_3 -319.9$	LOX chilldown--Prepares LOX plumbing for restart.
$t_3 -21.7$	LOX tank repressurized--Insures NPSH LOX pump for J-2 restart.
$t_3 -0$	S-IVB restart--Engine refires to increase axial acceleration for lunar insertion.
$t_3 +3.0$	70 lb thrust ullage engines off.
$t_3 +5.5$	PU Activate--Propellants, once again being consumed, require ratio and depletion monitoring.
$t_3 +64.5$	Arm point level sensors--Engine cutoff enable.
$t_4 +0$	Engine cutoff command--Predetermined IU or PU instigated signal cuts off J-2 engine.
$t_4 +0.5$ 3.1	Auxiliary hydraulic pump, PU inverter, heaters and T/M systems turned off. Conserves stage batteries for T/M and APS operation.

Approximately 2-1/2 hours later in translunar trajectory, S-IVB/Apollo payload separate.

the 1-inch line, out the aft facing orifices. This provides approximately 10^{-4} G's acceleration to the stage to keep the propellant 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 psia. 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 psia, both vents are closed, and repressurization of the fuel tank will begin.

Repressurization is accomplished by opening a solenoid valve in the repressurization control module. GHe from 7 of the ambient He storage spheres located on the thrust structure will repressurize the tank to a step pressure of 35.5 to 37.5 psia 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, pressurization of the fuel tank is maintained at the step pressure by GH_2 bleed from the J-2 engine exactly as during first burn. (See S-IVB/S-IB description.)

Pneumatic Control System

The S-IVB/S-V pneumatic control system adds one additional actuation control module, which controls operation of the LH_2 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 purge 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 170 AH to fulfill longer mission, higher power requirements of J-2 engine restart, repressurization requirements, stage sequencer, and APS module.

Propellant Utilization System

The PU system adds a fuel boiloff bias cutoff relay. Approximately 4,000 pounds of excess LH_2 are loaded to account for an estimated orbital boiloff of 2,500 to 3,600 pounds. The LH_2 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 LH_2

General

The S-IVB/S-V and S-IVB/S-IB configurations are essentially similar. However, S-V configuration translunar excursion mission demands a heavier payload and requires engine restart capability, which necessitates certain structural and systems changes. These changes are noted in the sections that follow.

Structures

Aft Interstage: A truncated cone structure of aluminum skin panels externally stringer-stiffened, riveted construction bolted to the aft skirt at the smaller forward end. This joint forms the S-II and S-IVB stages separation plane. The aft end bolts to the S-II forward skirt.

Aft Skirt: Cylindrical section structure of aluminum skin panels stringer-stiffened with extruded attach angles at each end. Has more stringers of heavier cross-section than S-IVB/S-IB configuration.

Forward Skirt: Same comments as for aft skirt above.

Oxidizer System

Because of the necessity of engine restart, the LOX tank on S-IVB/S-V must be repressurized during the coast phase and prior to restart. This is controlled by the oxidizer tank repressurization module. He for repressurization is supplied by 2 of 10 spheres containing GHe at 3,100 psia located on the outer side of the thrust structure. During coast phase, the LOX tank is vented through vent-relief valve releasing over-pressure on command from IU. Prior to engine restart, the LOX tank is repressurized to 37 to 40 psia. During second burn, the LOX tank pressure is maintained by the cold He from storage spheres in the LH_2 tank and the heat exchanger in the same manner as during first burn. (See description S-IVB/S-IB fuel tank pressurization.)

Fuel System

S-IVB/S-V stage will use a continuous propulsive vent system during coast phase. Also, a repressurization control module and 7 ambient He storage spheres are added to repressurize the tank for engine restart. Approximately 0.1 second before first burn engine cutoff, the fuel tank propulsive vent is opened. During 4-1/2 hour coast phase, the increased ullage pressure, caused by solar radiation, is vented through

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-V INBOARD PROFILE

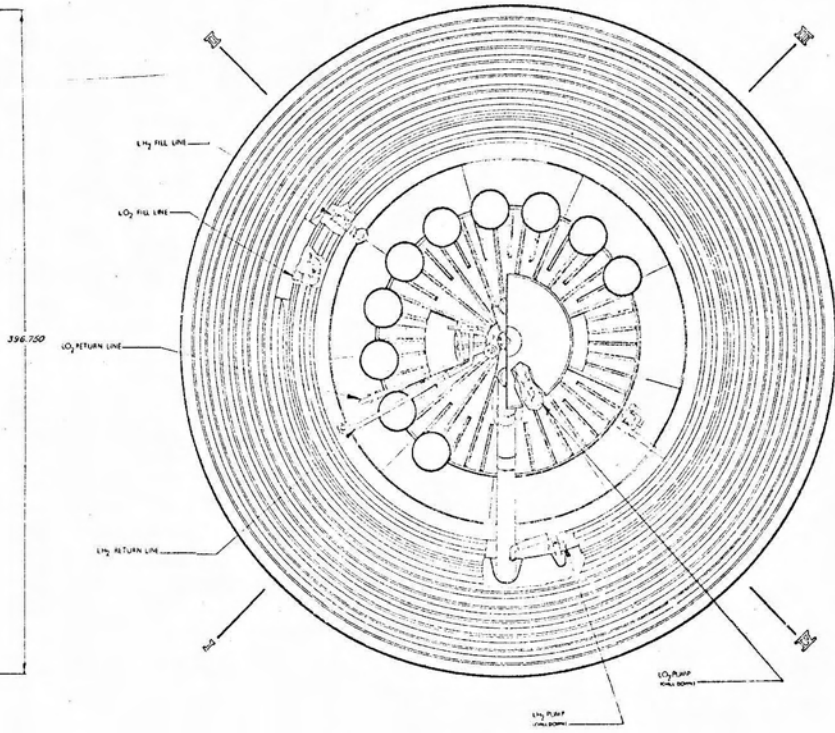
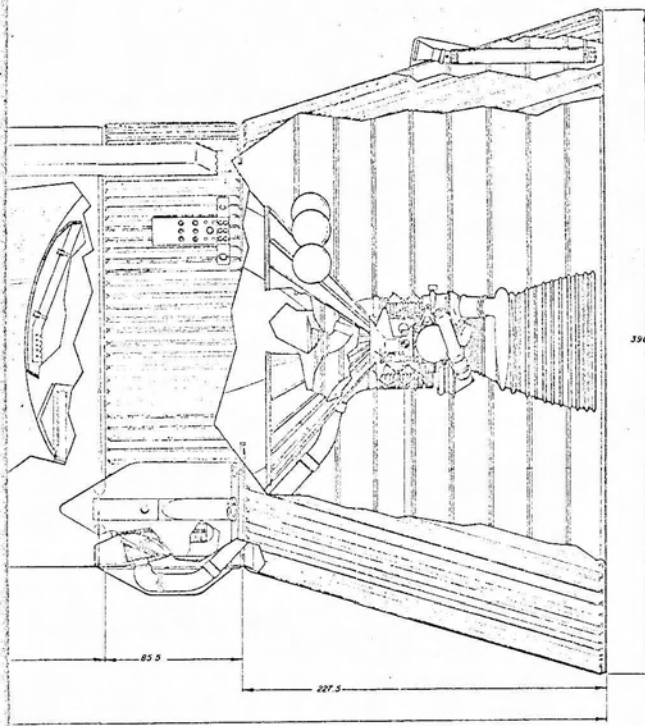
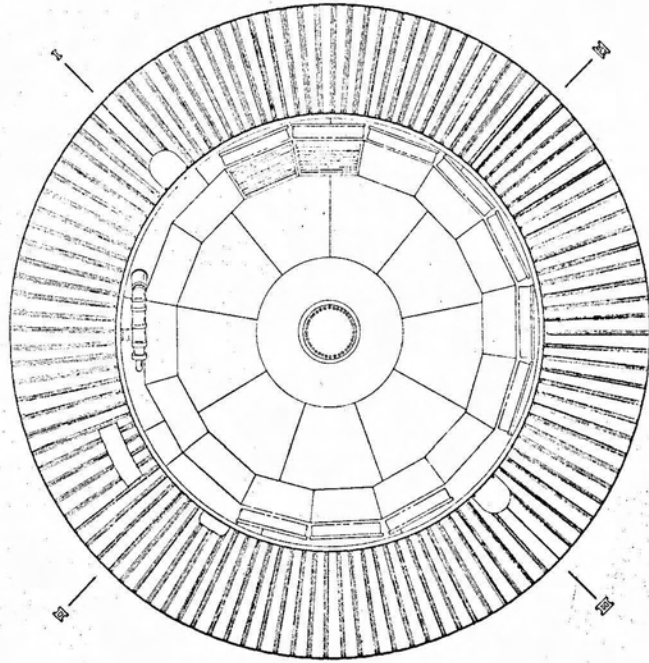
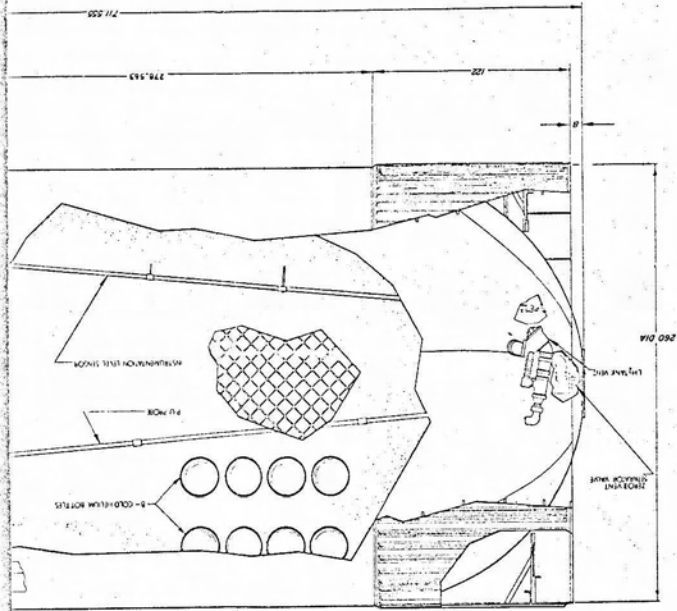


Figure 54



AI-S

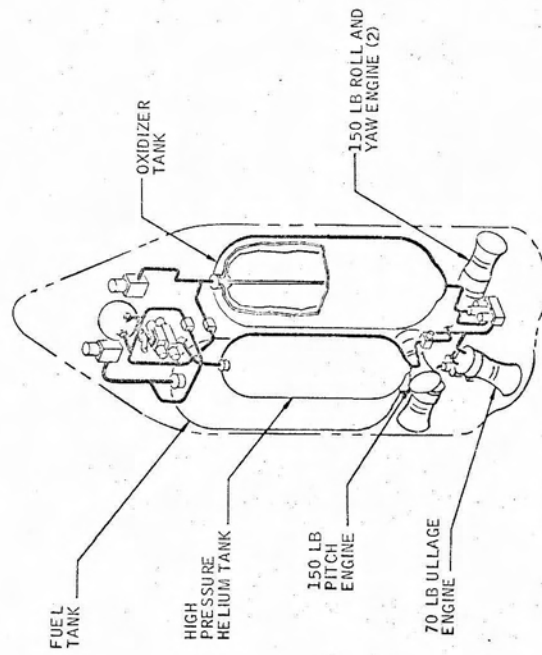


Figure 56

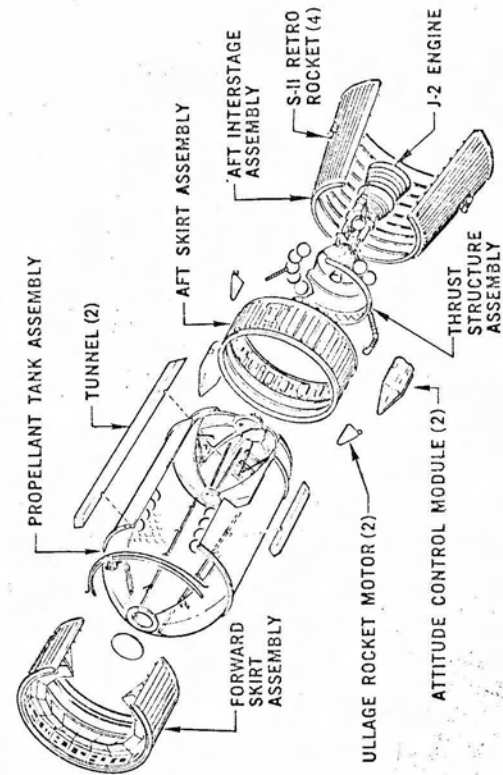


Figure 55

Components	- Retrorockets (4), Firing Units (2), EBW Detonators (2), Detonator Manifold (2), CDF Fuse Assemblies (3), Pyrogen Initiators (8).
Retrorocket	- Thiokol TE-29-1B 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 grains 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 grain 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, 2,300 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 (5,000V) to trigger gap tube. Tube ionizes, causing storage capacitor to discharge through respective EBW detonator. Propagation wave from detonator is manifolded to 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.

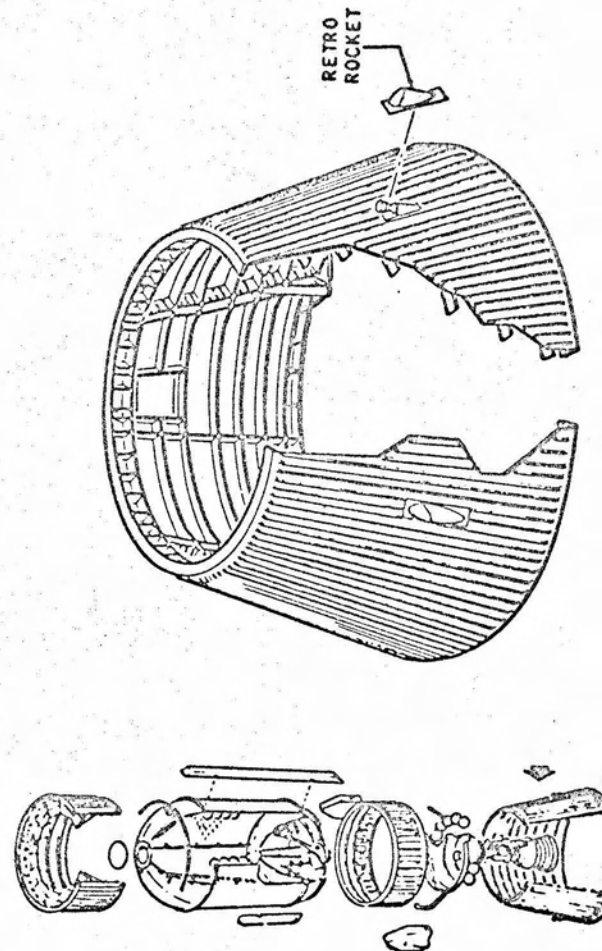


Figure 57

source flows through valve (9) and pressurizes tank to 3,000 psig. Control pressure is regulated to 200 psig by redundant regulator (10). Normally-open regulator controls pressure. If regulator fails (pressure too high), high-pressure switch is actuated, sets relay K4, opens second regulator. If pressure is too low, low-pressure switch sets relays K1 and K4, opening second regulator. Regulated pressure may be dumped 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 contact -1 of each relay opens 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/external power. Fuel and oxidizer valves are opened permitting two ullage engines to burn for 330 sec.

Components	- Auxiliary Propulsion Modules (2). Modules mounted on aft skirt 180° apart; each module contains three attitude control engines, one ullage engine, a propellant control system, and two He pressure-operated propellant tanks.
Attitude Control Engines	- Tapco, 150 lb thrust per engine; 100 psi chamber pressure pulse-type engines; Molybdenum throat liner, refrasil chamber liner for ablative cooling; chamber operating temperature approximately 5,500° F.
Ullage Engine	- Rocketdyne, 70-lb thrust, 100 psi chamber pressure Gemini "OAMS" engine.
Propellant Control System	- Positive expulsion pressure is supplied by He storage sphere, charged to 3,000 psig, regulated down to 200 psig; electrically-operated valves control flow of propellants; closed loop system.
Propellant Tanks	- Positive expulsion, bladder-type tanks; oxidizer tank stores 150 lb of nitrogen tetroxide (N ₂ O ₄); fuel tank stores 115 lb of MMH; propellants are hypergolic.

OPERATION

Attitude Control: Attitude control engines provide three axes control for vehicle during coast phase. System also provides attitude control to assist service module during translunar docking maneuvers. Reaction-type control is provided by pulse firing engines in short (65 ms minimum 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 moment (direction) depends on which pair fires first.

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

Fuel and Oxidizer Control Pressure Circuit (See figure 58.)

Fuel and oxidizer systems are recirculated from ground source by opening fill and vent valves (1), (2), (3), and (4), allowing fuel and/or oxidizer to flow through tanks. Systems may be purged by opening valves (5 and 6) and valves (3 and 4). GN₂ flows through check valves (7 and 8), through tanks and is returned to source through valves (3 and 4). Prior to propellant loading, He tank is pressurized. He from ground

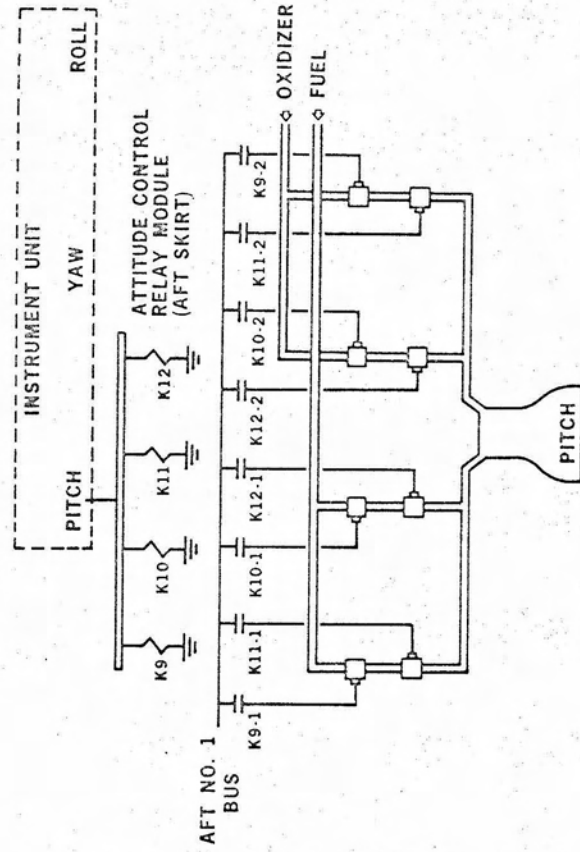
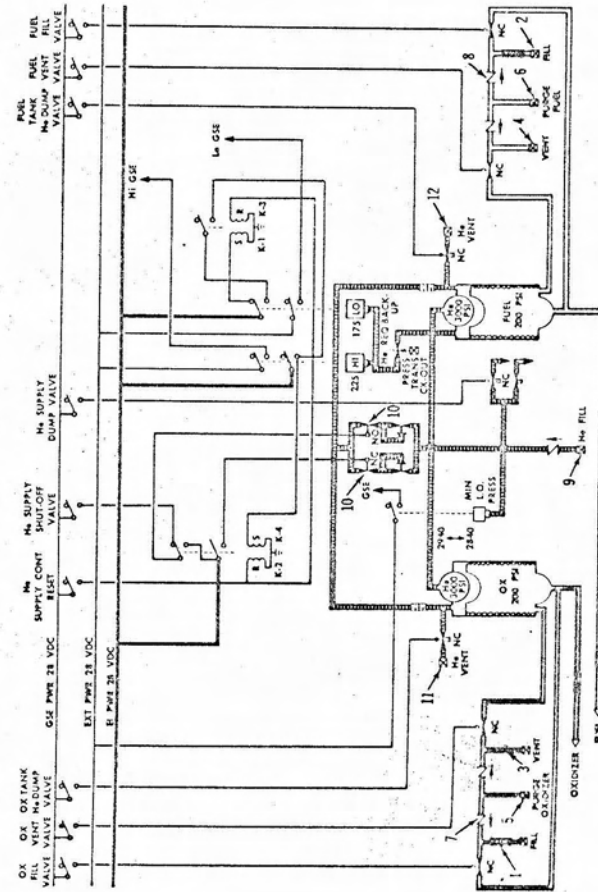


Figure 59



AEROSPACE FLUID CHARACTERISTICS

	<u>Liquid Hydrogen</u>	<u>Liquid Oxygen</u>	<u>Liquid Helium</u>	<u>Liquid Nitrogen</u>	<u>Monomethyl Hydrazine</u>	<u>Nitrogen Tetroxide</u>
Pounds per Gallon	.594	9.54	1.045	6.75	7.29	11.94
Color	Clear	Pale Blue	Clear	Pale Yellow	Clear	Brown
Molecular Weight	2.016	32.0	4.0	28.016	46.075	92.016
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	471.53
Celsius	-259.4	-218.75	-269.7	-210.0	-52.5	-11.2
Kelvin	13.7	54.41	3.46	63.16	220.66	261.96
Critical Temp. °F	-399.96	-181.04	-450.2	-232.8	593.6	316.8
Critical Press. Psia	188.16	736.47	32.0	491.7	1195.1	1469

Absolute Zero - 459.69° F = 0° Rankine = 273.16° Celsius = 0° Kelvin

LOX AND LH₂ VAPOR PRESSURE CURVES

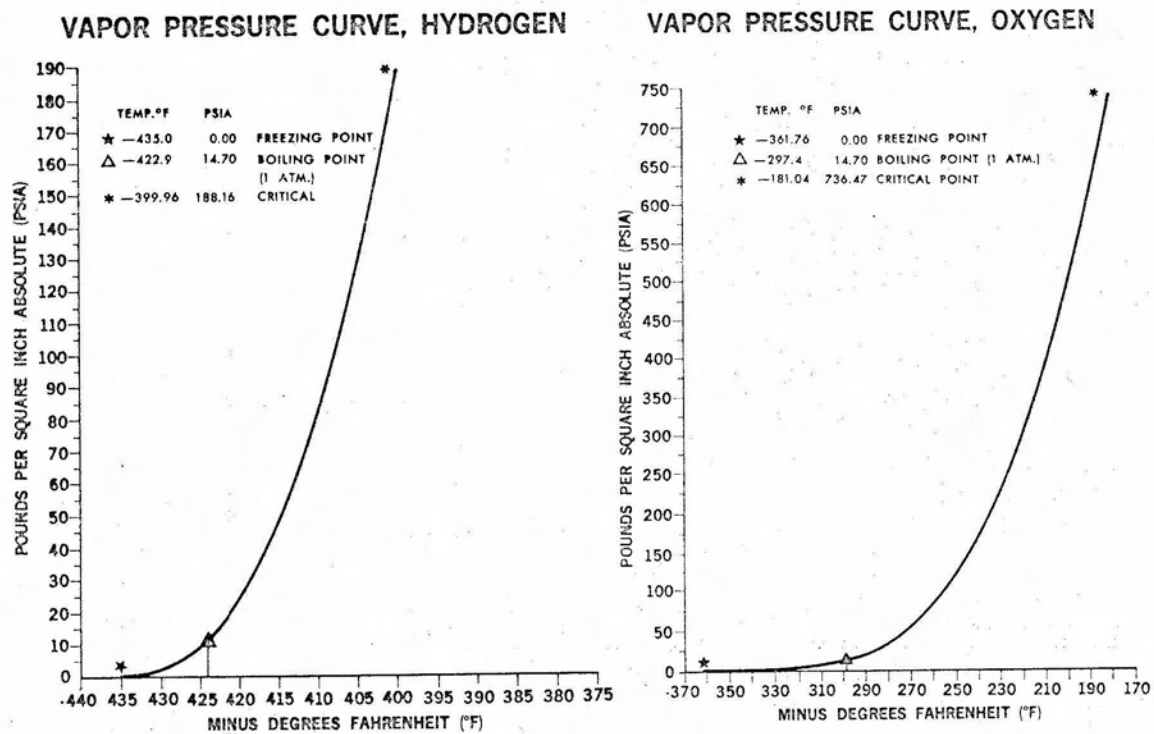


FIGURE 60

LIST OF NON-STANDARD ABBREVIATIONS

AH	Ampere Hour
APS	Auxiliary Propulsion System
ASJ	Augmented Spark Igniter
CCO	Crystal Controlled Oscillator
CDF	Confined Detonating Fuse
DDAS	Digital Data Acquisition System
DEE	Digital Events Evaluator
DPF	Dynamic Pressure Feedback
EBW	Exploding Bridgewire
ED	Electrical Display
FM	Frequency Modulated
GETS	Ground Equipment Test Set
GFE	Government Furnished Equipment
GIS	Ground Instrumentation System
GSE	Ground Support Equipment
HB	Huntington Beach
IRIG	Inter-Range Instrumentation Group
IU	Instrument Unit
KSC	Kennedy Space Center
LEM	Lunar Excursion Module
LO	Liftoff
LSC	Linear Shaped Charge
MDF	Mild Detonating Fuse
MMH	Monomethyl Hydrazine
MSFC	Marshall Space Flight Center
NPSH	Net Positive Suction Head
NRZ	Non-Return-to-Zero
OAMS	Orbital Attitude Maneuvering System
PAM	Pulse Amplitude Modulated
PAM/FM/FM	Pulse Amplitude Modulated, Frequency Modulated, FM Carrier
PCM	Pulse Code Modulated
PCM/FM	Pulse Code Modulated FM Carrier
PD	Propulsion Display
PDM	Pulse Duration Modulated

LIST OF NON-STANDARD ABBREVIATIONS (Continued)

PETN	Pentaerythrite Tetrinitrate
PU	Propellant Utilization
RDX	Cyclonex
RS	Range Safety
RSRS	Range Safety Receiver System
RSSG	Range Safety Signal Generator
RTG	Range Time Generator
S&A	Safety and Arming
SACTO	Sacramento Test Facility
SCO	Subcarrier Oscillators
SDU	Signal Distribution Unit
SM	Santa Monica
SSB	Single Sideband
SS/FM	Single Sideband Modulated FM Carrier
T/M	Telemetry
T/M D	Telemetry Display
VCO	Voltage Controlled Oscillator
XTAL	Crystal