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GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

TECHNICAL INFORMATION SUMMARY
APOLLO 8 (AS-503)
APOLLO SATURN V SPACE VEHICLE

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSFC - Form 2846 (December 1966)

AS-503

TECHNICAL INFORMATION

SUMMARY

This document is prepared jointly by the Marshall Space Flight Center Laboratories R-AERO-P, R-ASTR-S, and R-P&VE-VN. The document presents a brief and concise description of the AS-503 Apollo Saturn Space Vehicle. Where necessary, for clarification, additional related information has been included.

It is not the intent of this document to completely define the Space Vehicle or its systems and subsystems in detail. The information presented herein, by text and sketches, describes launch preparation activities, launch facilities, and the space vehicle. This information permits the reader to follow the space vehicle sequence of events beginning a few hours prior to liftoff to its journey into space.

1. Mission Purpose:

The AS-503 (C Prime Mission) will be flown for the general purpose of maturing the Command Service Module, the Launch Vehicle Systems, and operations to the maximum degree consistent within the state of space vehicle development and flight experience gained from Apollo 7 (Mission C).

2. Mission Objectives:

The AS-503 (C Prime Mission) will be a manned space flight with an S-IVB second burn to inject the command service module into a free return, translunar trajectory (figure 1)..

Principal Detailed Test Objectives (D.T.O.) are:

a. Verify launch vehicle capability for spacecraft free return, Translunar Injection (TLI).

b. Demonstrate S-IVB restart capability.

c. Verify J-2 Engine modifications.

d. Confirm J-2 engine environment in S-II and S-IVB stages.

e. Confirm launch vehicle longitudinal oscillation environment during S-IC stage burn period.

f. Verify that modifications incorporated in S-IC stage suppress low frequency longitudinal oscillations.

g. Demonstrate helium heater repressurization system operation.

h. Verify capability to inject S-IVB/IU/LTA-B into a lunar "slingshot" trajectory.

i. Demonstrate capability to safe S-IVB stage.

Secondary Detailed Test Objectives:

Verify the onboard Command and Communications System (CCS) - ground system interface and operation in the deep space environment.

3. Mission Description:

The "Lunar Orbit Mission" for AS-503 has been divided into four phases: (1) the Launch Phase (2) the Parking Orbit Phase (3) Pre-Ignition Sequencing and Second Burn and (4) the Translunar Coast Phase.

Launch Phase. The Apollo Saturn V Vehicle (AS-503) will be launched from Pad "A", Launch Complex 39, Kennedy Space Center on a launch azimuth of 90 degrees and will roll to a flight azimuth which can vary from 72 to 108 degrees east of true north. This flight azimuth variable is dependent on date and time of launch. As the vehicle rises from the launch pad, a yaw maneuver is executed to insure that the vehicle does not collide with the tower in the event of high winds or engine failure. Once tower clearance has been accomplished, a tilt and roll maneuver is initiated to achieve proper flight attitude and flight azimuth orientation.

Boost to Earth Parking Orbit is accomplished as illustrated in figure 10. The S-IVB/IU/CSM will be inserted into a 100 NMI Earth Parking Orbit at approximately 11 minutes and 30 seconds ground elapsed time (G.E.T.) after liftoff. This insertion will follow the near depletion burn of the S-IC and S-II stages plus approximately a 158 second first burn of the S-IVB stage. During the S-IC burn, Launch Vehicle guidance is performed by a stored time tilt attitude program, while the Iterative Guidance Mode (IGM) will guide the vehicle during S-II and S-IVB stage burns. The vehicle will achieve cutoff (based on velocity) at approximately 11 minutes and 20 seconds.

Parking Orbit Phase. The vehicle is held at cutoff inertial attitude for 20 seconds after cutoff after which it is oriented to the local horizontal with position I down. The LH_2 continuous vent valve is opened to provide a small, continuous acceleration for propellant settling during the Parking Orbit.

The Vehicle will continue to coast in Earth Parking Orbit while the Launch Vehicle and Command and Service module are completely checked and verified prior to second burn. Any attitude maneuvers during the parking orbit will be manually controlled by the Astronauts.

The first opportunity for Translunar Injection (TLI) will occur over the Pacific during the second revolution while the second opportunity for TLI will occur over the Pacific during the third revolution.

In the event that the LV/CSM develops a condition which would impair a successful manned lunar orbital mission, the S/C will separate from the L/V in earth orbit. An unmanned second burn of the S-IVB will then be accomplished while the CSM continues with an alternate earth orbit mission.

Pre-Ignition Sequencing and Second Burn Phase. Pre-ignition sequencing is the phase which precedes the S-IVB second burn. It will begin over the Pacific or Indian Oceans (depending on date, time, or flight azimuth). At this time the vehicle will maneuver to a local horizontal attitude; the LH_2 propulsive vent will be closed and the O_2H_2 burner operation will begin to repressurize the stage for a second burn. The second S-IVB burn will be initiated while the vehicle is passing over the Pacific Ocean. This burn will inject the S-IVB/IU/LTA-B/CSM into a free-return, translunar trajectory. The Iterative Guidance Mode (IGM) will be used during this period. Immediately following S-IVB engine cutoff, the LH_2 continuous propulsion vent and the LOX and LH_2 non-propulsive vents will be opened.

Translunar Coast Phase. Approximately fifteen minutes after S-IVB cutoff, all vents will be closed and the vehicle will begin a maneuver to effect an inertial attitude for CSM separation and S-IVB/IU communications. At about 25 minutes after S-IVB second cutoff, the CSM will separate and the Spacecraft Lunar Module Adapter (SLA) panels will be jettisoned. The CSM will then maneuver to within 70 feet from the LV for station keeping, visual observation, and photography. After about a 15 minute period, the CSM will perform a 1 fps delta velocity maneuver to move away from the LV.

The maneuver required to place the vehicle, (S-IVB/IU/LTA-B) into the "slingshot" attitude will be initiated approximately 1 hour and 50 minutes after S-IVB second cutoff. After venting and LOX dump have been achieved, the vehicle will continue to coast along the slingshot trajectory path until it is positioned within the effective range of the moon's gravitational field. As the effect of gravitation is felt, it is expected that the LV may be injected into a solar orbit.

As the LV enters into the "slingshot" trajectory coast period described above, the Command and Service module will begin to coast toward the moon along the "Translunar Trajectory".

As the CSM is about to enter the effective range influenced by the lunar gravitational field, the necessary maneuver is initiated which will propel the CSM into lunar orbit. This final maneuver will not be attempted unless all required conditions for such an orbit are acceptable. If conditions are not acceptable, the CSM will continue on the free return trajectory. Approximately 8 to 10 lunar orbits are planned after which the CSM will return along the "lunar orbit return" and "trans-earth trajectory".

Separation of the Command Module, re-entry, splash down, and recovery in the Pacific Ocean will complete the mission.

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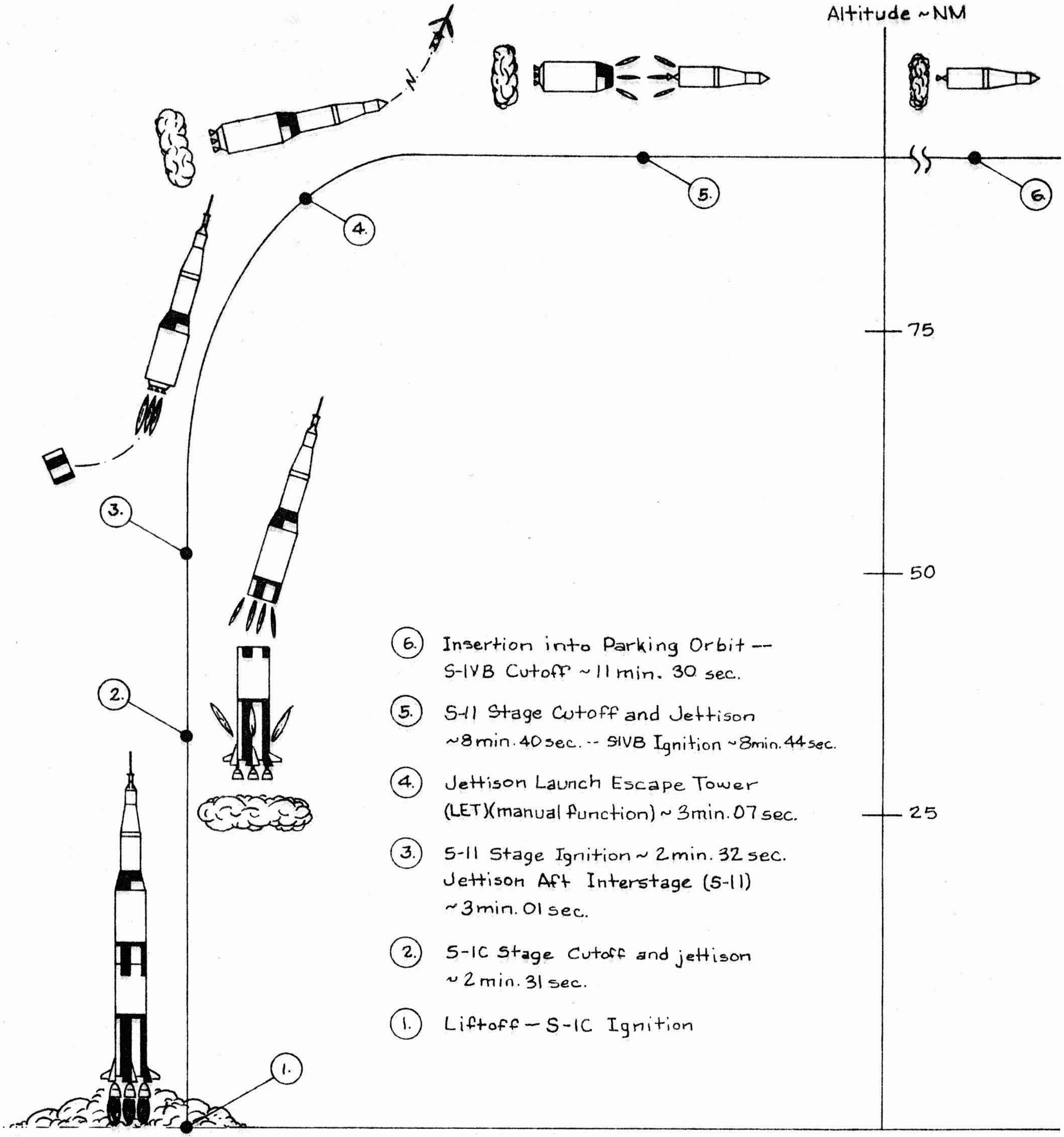

Figure 1

Mission Profile
Boost to Earth Orbit

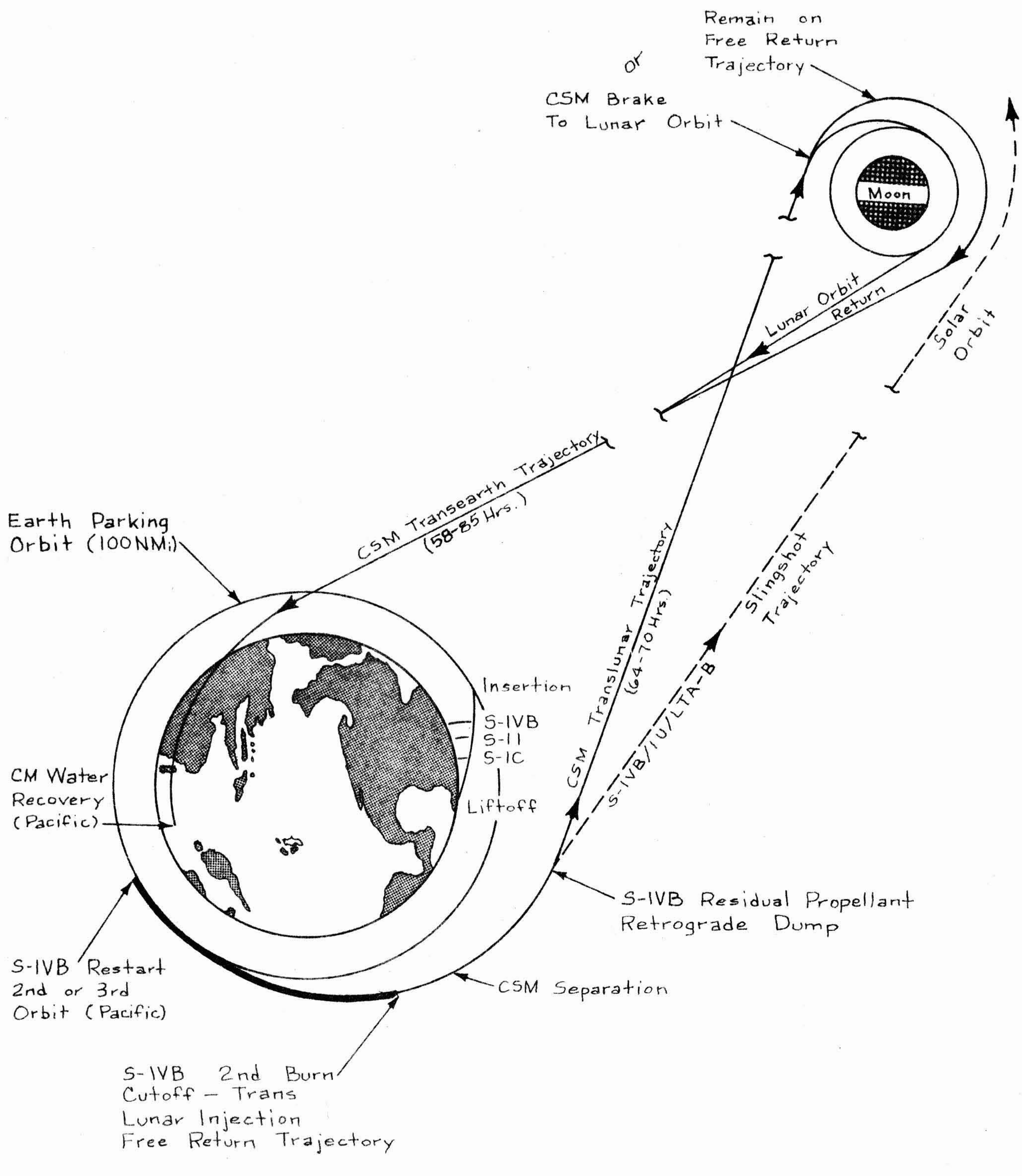

Figure 2

AS-503
Mission Profile – Lunar Orbit

LIST OF FIGURES

LIST OF FIGURES (Continued)

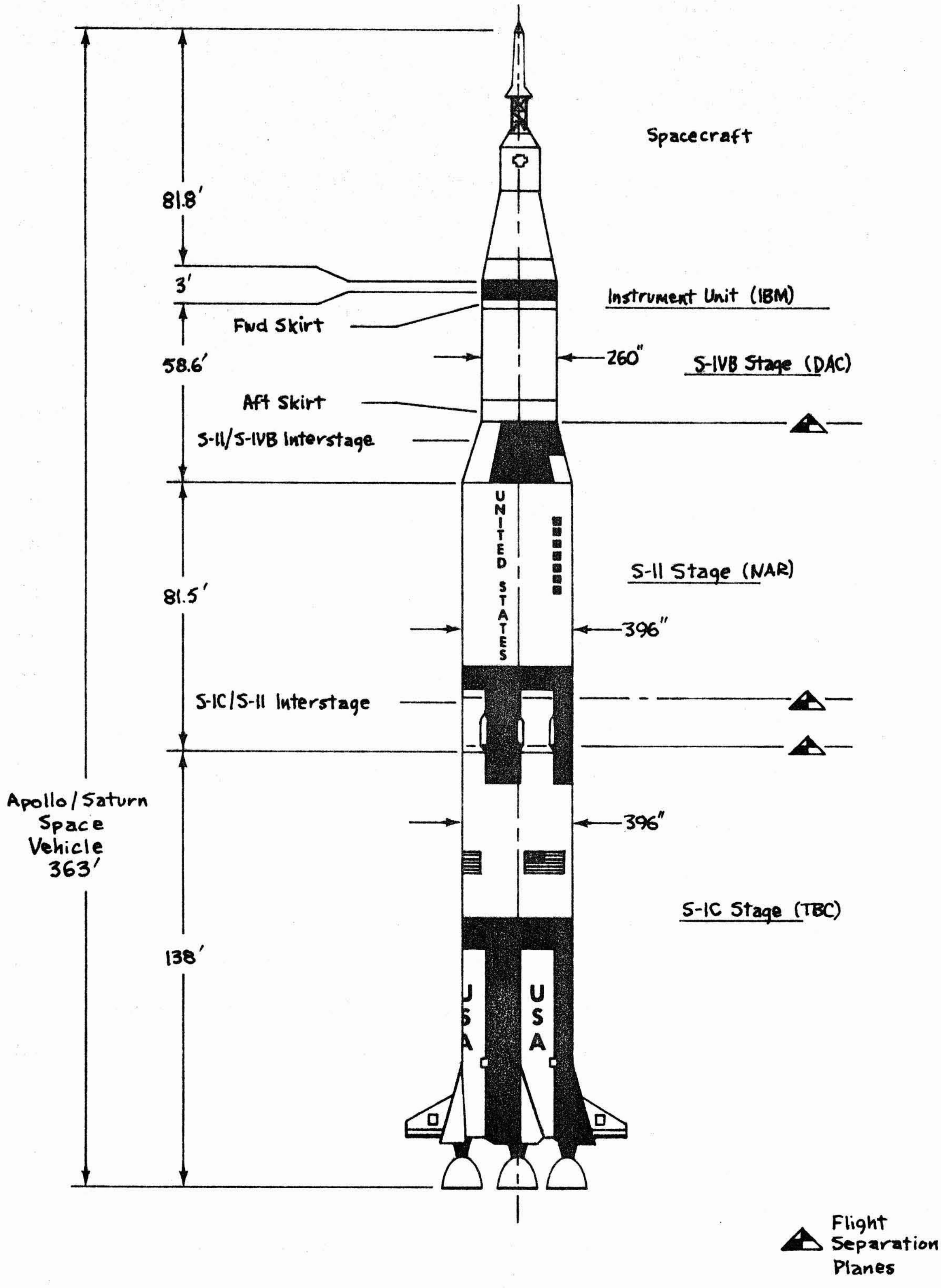

Figure 3

AS-503
Space Vehicle

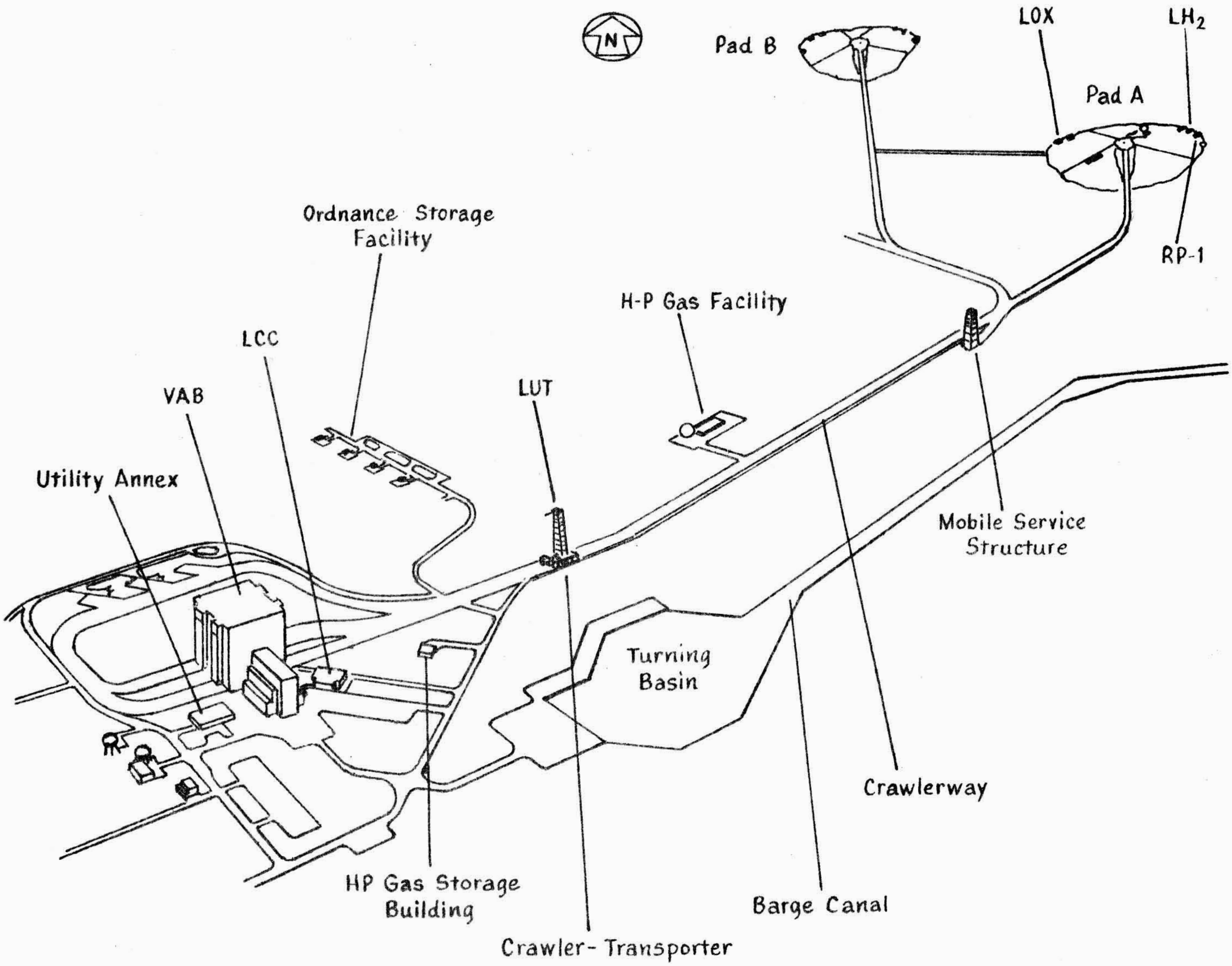

Figure 4

Launch Complex 39

MOBILE LAUNCHER

The Mobile Launcher, figure 4, is a transportable steel structure which provides the capability of moving the erected vehicle to the launch pad via the crawler-transporter. The umbilical tower, permanently erected on the mobile launcher base, is a means of ready access to all important levels of the vehicle during assembly, checkout and servicing prior to launch. The intricate vehicle-to-ground interfaces are established and checked out within the protected environment of the Vertical Assembly Building (VAB) and then moved undisturbed aboard the mobile launcher to the launch pad. The description of each mobile service arm (numbered arrows below) correspond to the numbered arrows on the Mobile Launcher illustrated on the opposite page (figure 4).

1 S-IC Intertank (preflight). Provides LOX fill and drain. Arm may be reconnected to vehicle from LCC. Retract time 8 seconds. Reconnect time ~5 minutes.

2 S-IC Forward (preflight). Provides pneumatic, electrical, and air conditioning interfaces. Retracted at T-16.2 seconds. Retract time 8 seconds.

3 S-II Aft (preflight). Provides access to vehicle. Retracted prior to liftoff as required.

4 S-II Intermediate (inflight). Provides LH_2 and LOX transfer, vent line, pneumatic, instrument cooling, electrical, and air-conditioning interface. Retract time 6.4 seconds.

5 S-II Forward (inflight). Provides GH_2 vent, electrical, and pneumatic interfaces. Retract time 7.4 seconds.

6 S-IVB Forward (inflight). Provides LH_2 and LOX transfer, electrical, pneumatic, and air-conditioning interfaces Retract time 7.7 seconds.

7 S-IVB Forward (inflight). Provides fuel tank vent, electrical, pneumatic, air-conditioning, and preflight conditioning interfaces. Retract time 8.4 seconds.

8 Service Module (inflight). Provides air-conditioning, vent line, coolant, electrical, and pneumatic interfaces. Retract time 9.0 seconds.

9 Command Module Access Arm (preflight). Provide Access to spacecraft through environmental chamber. Arm controlled from LCC. Retracted 12° park position until T-4 minutes.

Note:

Preflight arms are retracted and locked against umbilical tower prior to launch.

Inflight arms retract at vehicle liftoff on command from service arm control switches (located in hold-down arms).

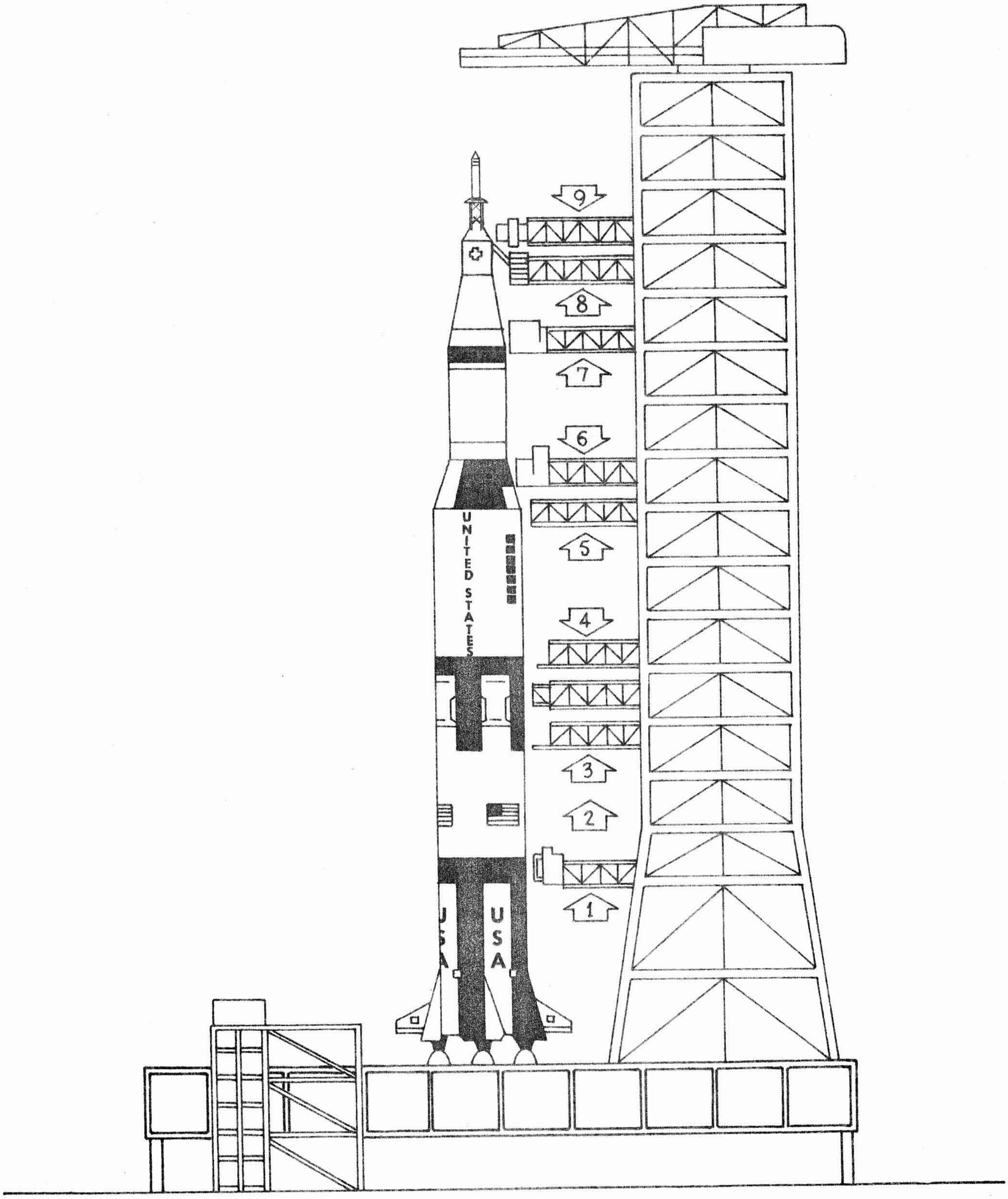

Figure 5

Saturn V
Mobile Launcher

LAUNCH VEHICLE SECURE RANGE SAFETY SYSTEMS

The Secure Range Safety Systems are located on the S-IC, S-II and S-IVB stages and are designed to provide a communication link for the transmission of coded commands from ground stations to the vehicle during boost phase. This transmission provides a positive means of terminating the flight of an erratic vehicle by initiating emergency engine cutoff and, if necessary, propellant dispersion.

The flight termination system in each powered stage consists of a range safety antenna subsystem, two secure command receivers, two Range Safety Controllers, two Secure Range Safety Decoders, two Exploding Bridge Wire (EBW) firing units, two EBW detonators and a common safe and arm device which connects the subsystem to the tank cutting charge. Electrical power for all elements appearing in duplicate is supplied from separate stage batteries.

Prior to launch, the safe and arm device is set to the "ARM" position by ground support equipment in the block house.

The S-IVB stage range safety receiver is commanded to an "OFF" condition by ground command at orbital insertion such that no destruct can take place after this safing action.

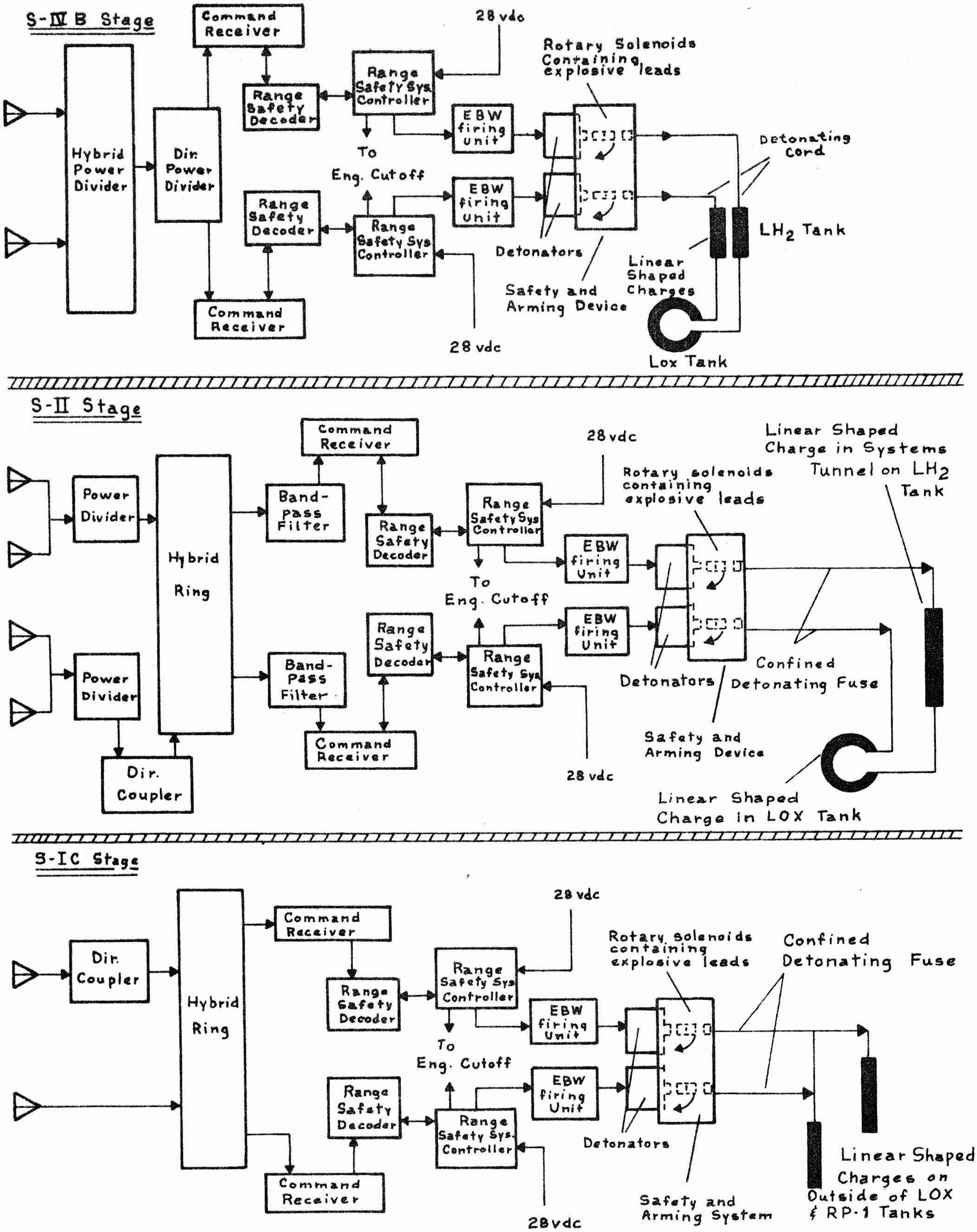

Figure 6

Secure Range Safety System

EMERGENCY DETECTION SYSTEM (EDS)

The Emergency Detection System (EDS), which is a part of the Crew Safety System, is designed to sense and react to emergency situations resulting from launch vehicle malfunctions which may arise during the mission. Protection of the Apollo Crew against vehicle failure is the prime function of the EDS.

In general, the abort modes for operation of the EDS are:

Manual Abort - Based on Astronaut's judgment and decision.

Automatic Abort is initiated by excessive angular rates of the vehicle or by the loss of thrust in two or more engines in the S-IC stage during specified times of flight. The measurements are obtained from triple redundant sensors with majority voting logic.

The automatic abort rate limits are: ±4 degrees per second with a tolerance of ±.49 degrees in pitch and yaw and ±20 degrees per second with a tolerance of ±1.5 degrees in roll.

Auto abort is automatically enabled at liftoff, provided the EDS auto, LV rates auto and 2 engine out auto switches are enabled in the spacecraft.

The automatic abort mode is active only during first stage flight from liftoff until the crew manually inhibits the automatic abort at approximately 120 seconds; therefore an automatic abort always utilizes the LES for escape (the LES is jettisoned shortly after S-II ignition by the crew).

In order to afford protection for personnel and facilities in the launch area, thrust is not terminated with aborts prior to 30 seconds of flight time. The switch selector enables the EDS cutoff circuitry at 30 seconds of flight with a timer backup at 30 seconds.

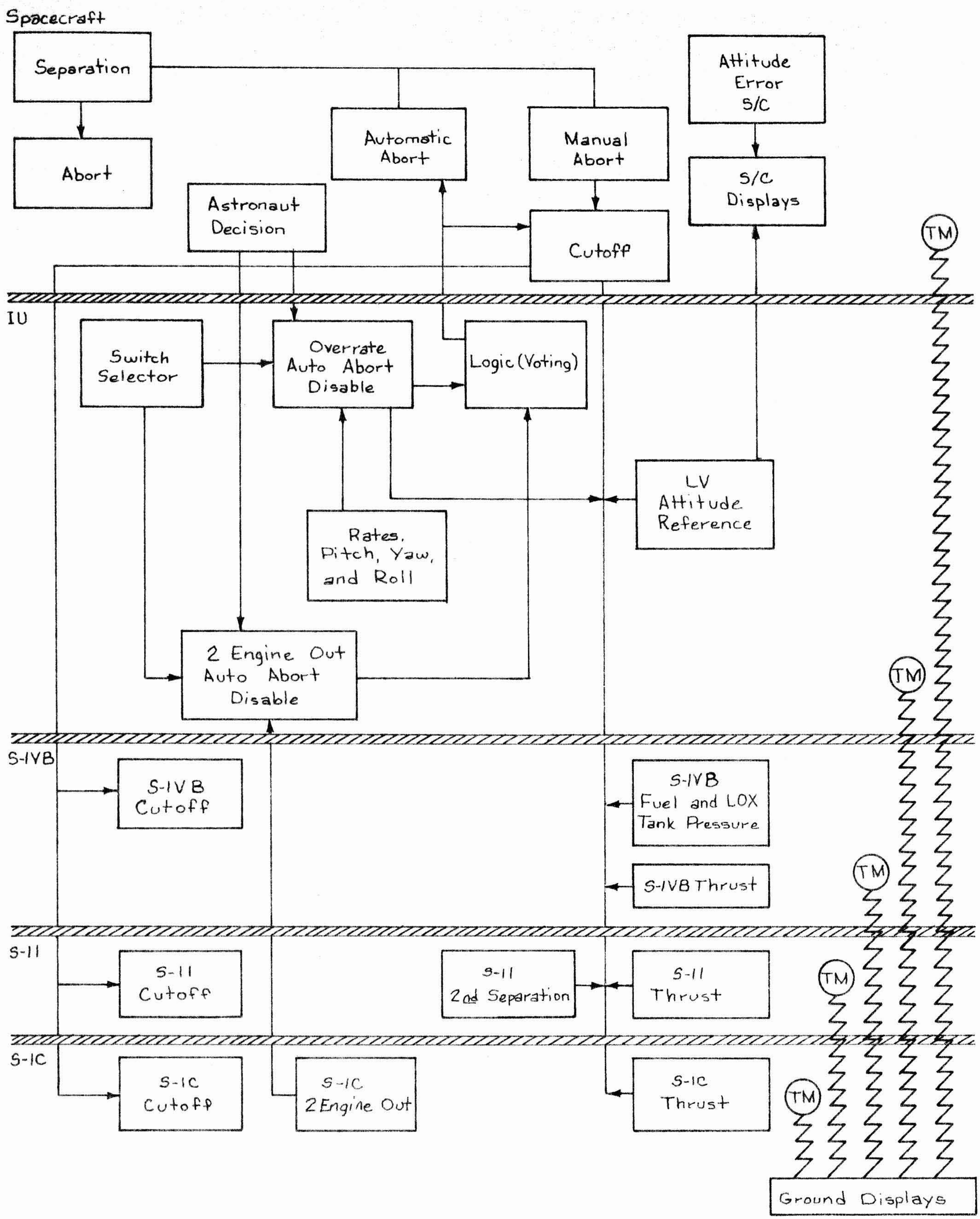

Figure 7

Emergency Detection System

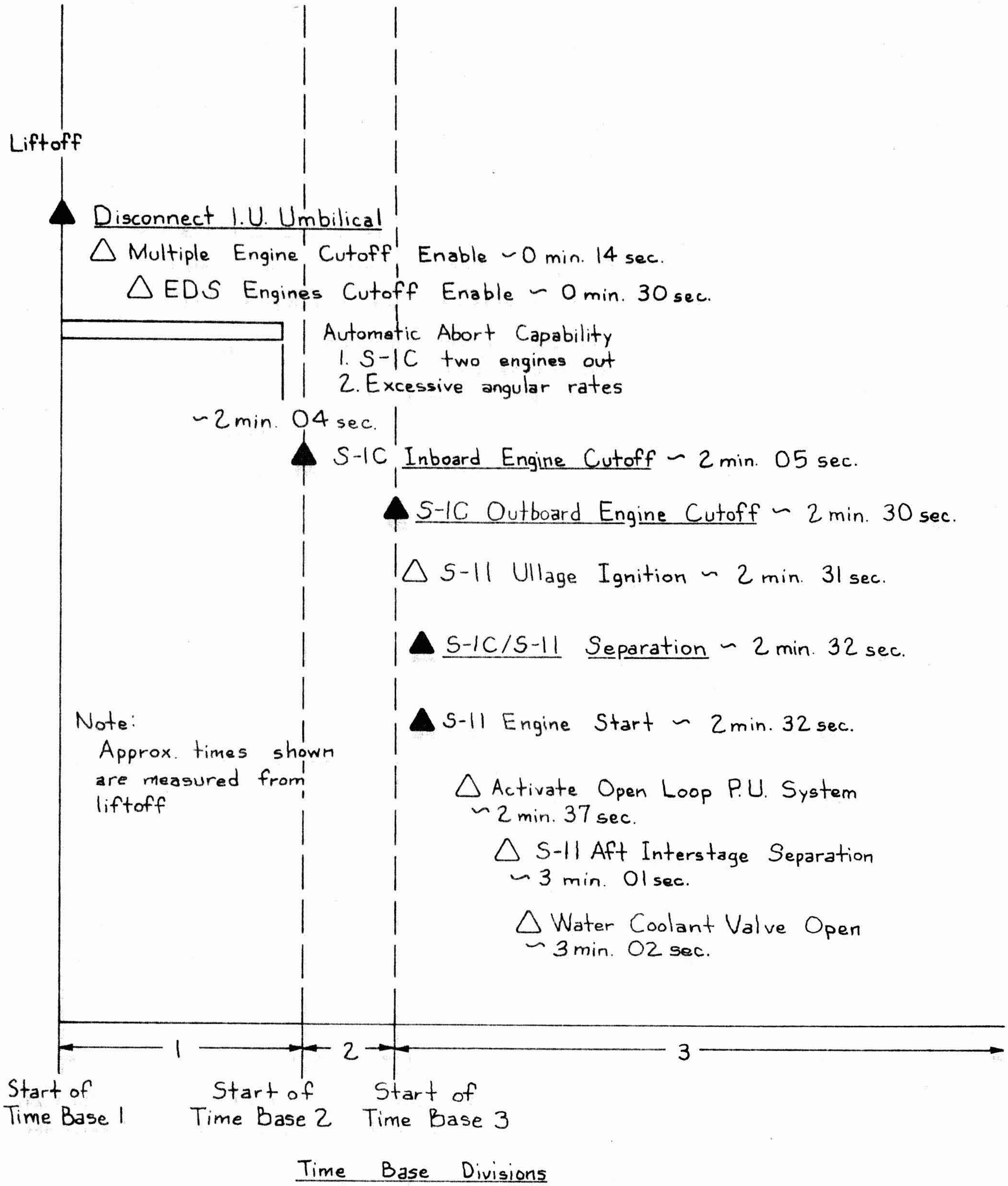

Figure 8

S-IC/S-II Stage Flight Sequencing

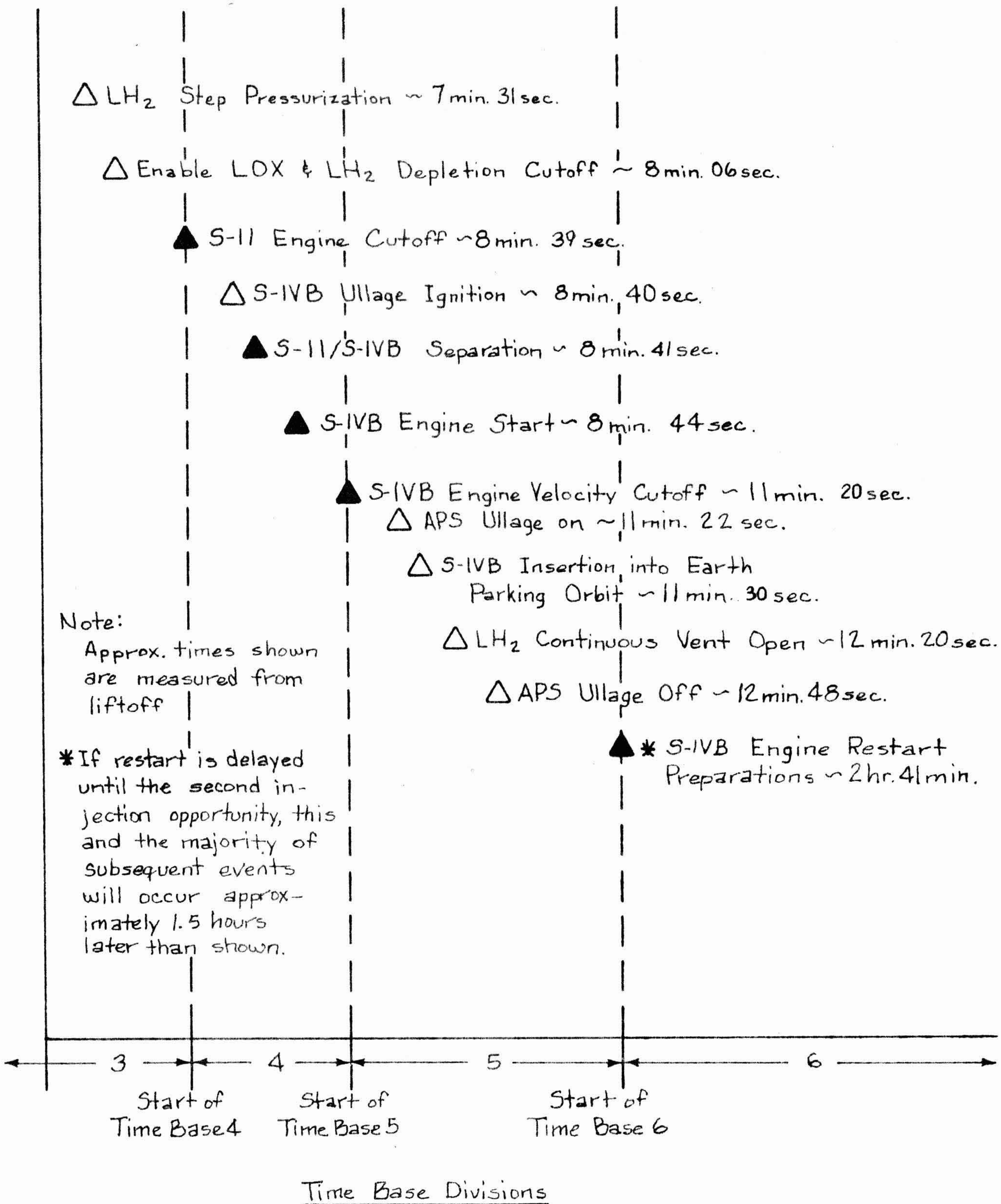

Figure 9

S-II/S-IVB Stage Flight Sequencing

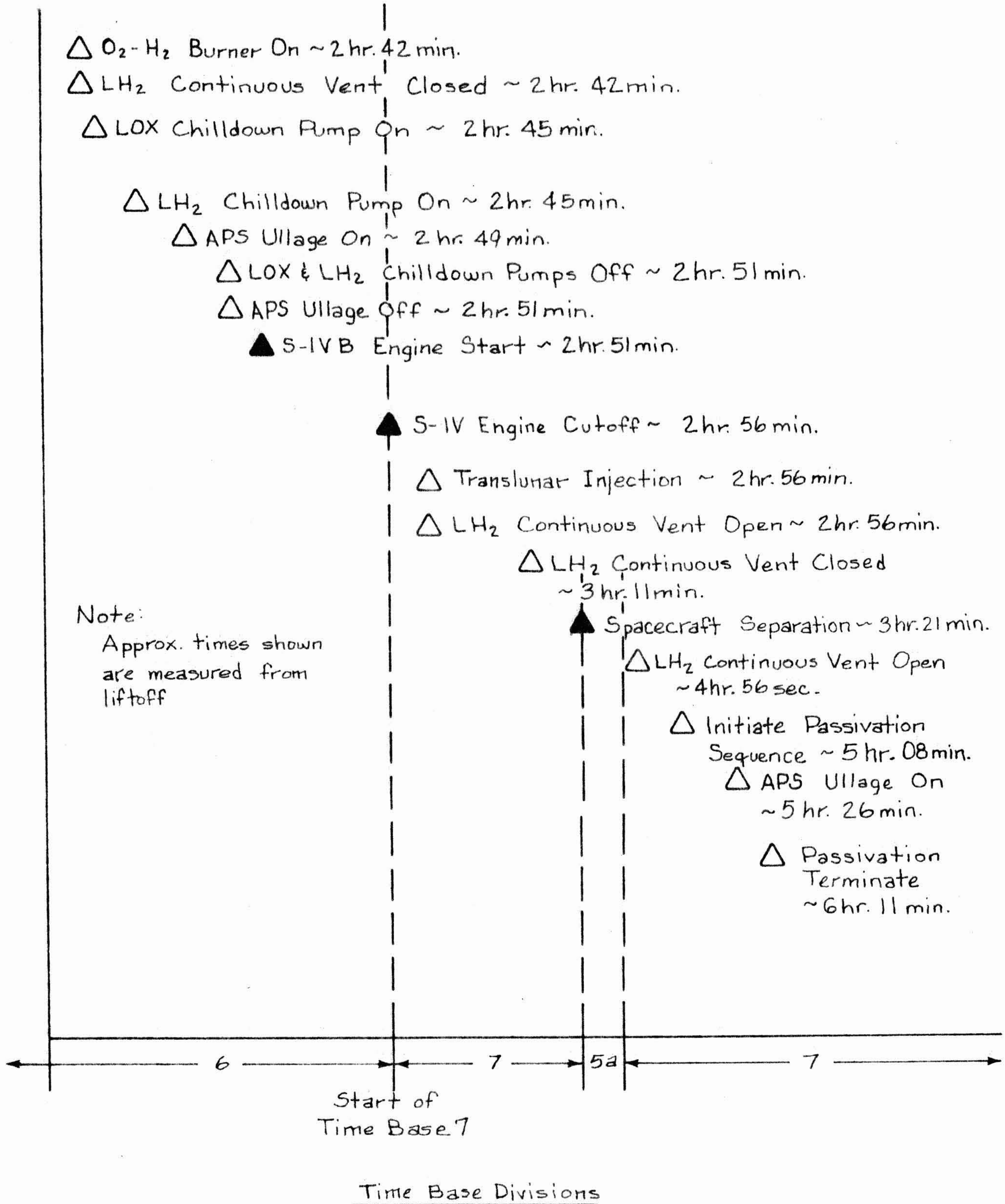

Figure 10

S-IVB Stage Flight Sequencing

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GUIDANCE AND CONTROL SYSTEM (G&C)

Function and Description

The G&C system provides the following basic functions during flight:

1. Stable positioning of the vehicle to the commanded position with a minimum amount of sloshing and bending.

2. A first stage tilt attitude program which gives a near zero lift trajectory through the atmosphere.

3. Provides steering commands during S-II and S-IVB burns which guide the vehicle to a predetermined set of end conditions while maintaining a minimum propellant trajectory for earth orbit insertion.

4. Maintains the proper vehicle position during earth orbit.

5. Provides guidance during the second S-IVB burn, placing the vehicle in the proper waiting orbit.

G&C Hardware

The Stabilized Platform (ST-124M) is a three gimbal configuration with gas bearing gyros and accelerometers mounted on the stable element. Gimbal angles are measured by redundant resolvers and inertial velocity is obtained from integrating accelerometers. (See figure 12.)

The Launch Vehicle Data Adapter (LVDA) is an input-output device for the Launch Vehicle Digital Computer (LVDC). The LVDA/LVDC components are digital devices which operate in conjunction to carry out the flight program. The flight program performs the following functions: (1) processes the inputs from the ST-124M, (2) performs navigation calculations, (3) provides the first stage tilt program, (4) calculates IGM steering commands, (5) calculates attitude errors, (6) issues launch vehicle sequencing signals.

The Control/EDS Rate Gyro Package contains nine rate gyros (triple redundant in three axes). Their outputs go to the Control Signal Processor (CSP) where they are voted and sent to the Flight Control Computer (FCC) for damping vehicle angular motion.

The FCC is an analog device which receives attitude error signals from the LVDA/LVDC and vehicle angular rate signals from the CSP. These signals are filtered and scaled, then sent as commands to the S-IC, S-II, and S-IVB engine actuators and to the Auxiliary Propulsion System (APS) Control Relay Packages. The Control Relay Packages accept FCC commands and relay these commands to operate propellant valves in the APS.

The Switch Selectors in each stage are used to relay Sequencing Commands from the LVDA/LVDC to other locations in the vehicle.

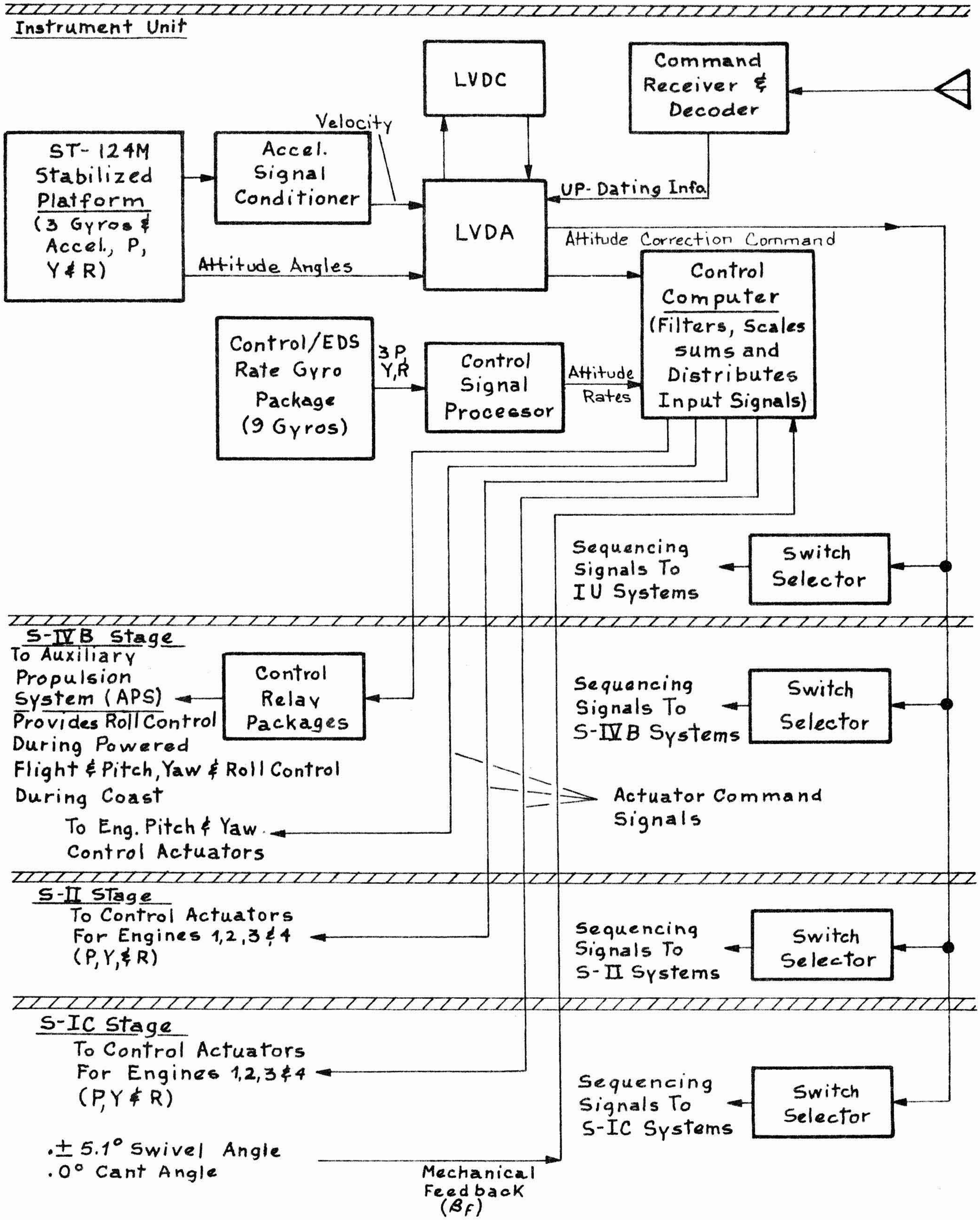


Figure 11

Guidance and Control System Block Diagram

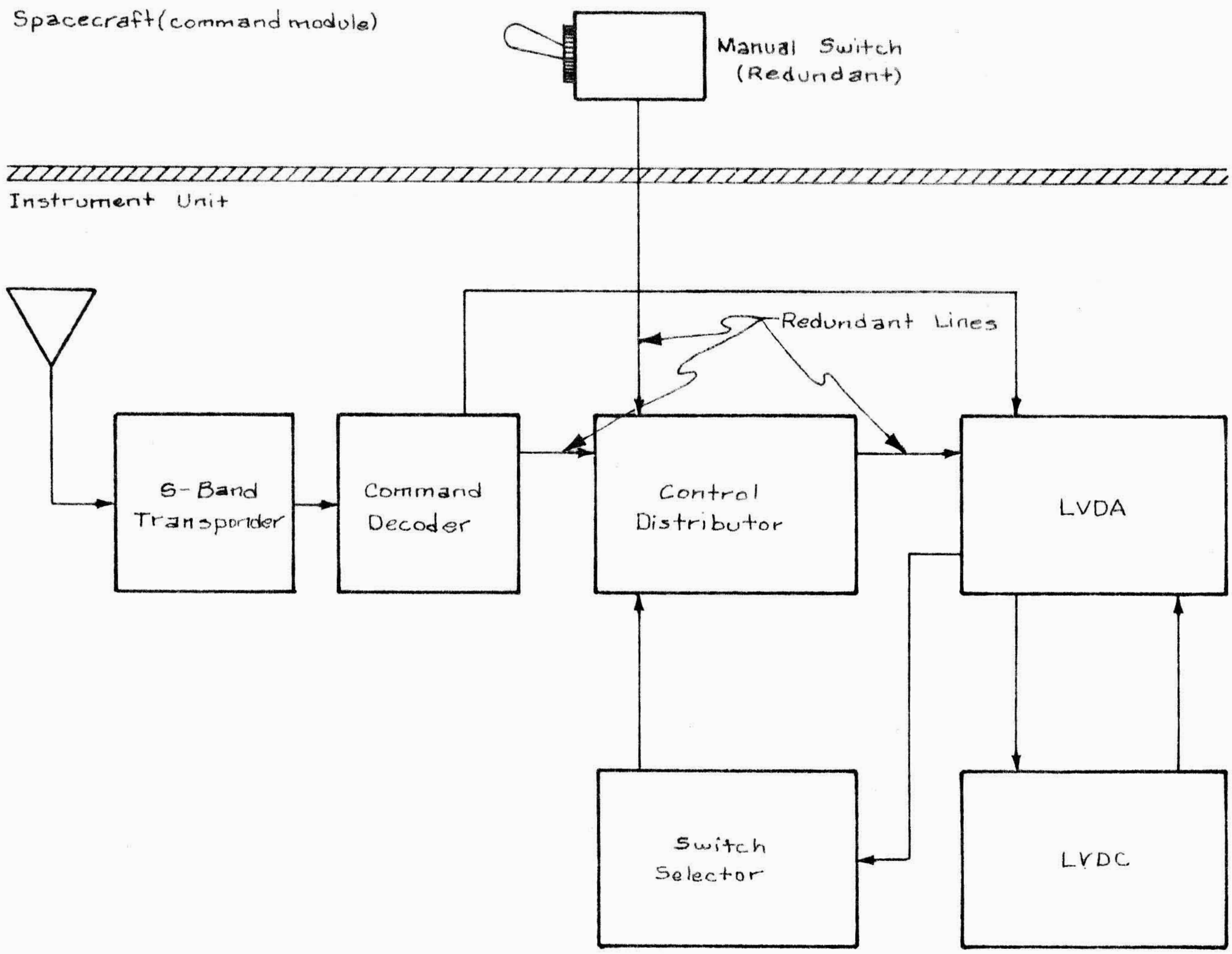
DIGITAL COMMAND SYSTEM CAPABILITY:

The following summary describes the AS-503 Digital Command Systems' capability:

Function	Description	Periods of Acceptance
Inhibit maneuver	Coast phase attitude maneuver inhibit	From T5 + 0 seconds until T6 - 9 and from T7 + 0 seconds until EOM
Maneuver update	Time change to start coast phase maneuver	From T5 + 0 seconds until T6 - 9 and from T7 + 0 seconds until EOM
Time base update	Time base time is advanced or retarded	From T5 + 0 seconds until T6 - 9 and from T7 + 0 seconds until EOM
Generalized switch selector	Specified switch selector function is issued at the first opportunity	From T5 + 0 seconds to T6 + 560 and from T7 to EOM
Sector dump	Contents of specified memory location are telemetered	From T5 + 100 seconds to T6 - 9 and from T7 + 20 seconds to EOM
Telemeter single memory location	Contents of specified memory location are telemetered	From T5 + 100 seconds to T6 - 9 and from T7 + 20 seconds to EOM
Terminate	Stop DCS processing and reset for a new command	From T5 + 0 seconds to T6 + 560 and from T7 to EOM
Inhibit water control valve logic	Inhibit water valve from changing position	From T5 + 0 seconds to T6 - 9 and from T7 until EOM
Switch antenna to omni, low gain, or high gain	Both PCM and CCS antennas are switched with these commands	From T5 + 100 seconds to T6 - 9 and from T7 seconds until EOM

EOM -- End of mission

T6 - 9 -- Time at which the switchover from orbital navigation to boost navigation occurs.



DCS hardware can be enabled by spacecraft manual switch for command action during coast phase operation or prior to separation. However,-commands will only be accepted by the flight program within the period of time programmed in the LVDC, as described on page 22.

Figure 12

Digital Command System

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Time Base References

Reference Event	Time Base	G.E.T. Hr/Min/Sec	Comments
Guidance Reference Release	T_0	-0:00:17	Initiated by terminal count sequencer
Liftoff (IU Umbilical Release)	T_1	0:00:00	Initiated by deactuation of IU liftoff relay at umbilical disconnect or vertical acceleration
S-IC Center Engine Cutoff	T_2	0:02:05	Initiated by S-IC Inboard engine cutoff command from LVDC
S-IC Outboard Engine Cutoff	T_3	0:02:31	Initiated by the propellant depletion sensors or the thrust-OK switches
S-II Engines Cutoff	T_4	0:08:40	Initiated by the propellant depletion sensors or the thrust-OK switches
First S-IVB Engine Cutoff	T_5	0:11:20	Initiated by any two of four functions; S-IVB velocity cutoff issued by the LVDC, thrust-OK switches (2), or accelerometer reading
Initiation-Restart Sequence	T_6	2:41:01	Initiated when LVDC solves the restart equation
Second S-IVB Engine Cutoff	T_7	2:55:55	Initiated by any two of four functions; SIVB velocity cutoff issued by the LVDC, thrust-OK switches (2), or accelerometer reading
Early S-II/S-IVB Staging	T_{4a}	Variable	Initiated by S-II/S-IVB staging switch in the spacecraft during S-II burn
Spacecraft Separation	T_{5a}	Variable	Initiated by spacecraft launch vehicle separation
S-IVB Burner Malfunction	T_{6a}	Variable	Initiated by burner malfunction signal from S-IVB stage--T6 +48 seconds to T6 + 341.3 seconds
S-IVB Burner Malfunction	T_{6b}	Variable	Initiated by burner malfunction signal, S-IVB stage--T6 + 341.3 seconds to T6 + 496.7 seconds
Translunar Injection Inhibit	T_{6c}	Variable	Initiated by translunar injection switch in the spacecraft--T6+ 0 seconds to T6+ 560 seconds

INSTRUMENTATION SYSTEMS

The Saturn V Instrumentation Systems are functionally divided into three parts on each stage. These separate divisions or subsystems are:

- Measuring Systems
- Telemetry Systems
- RF and Tracking Systems

Measuring

The purpose of the measuring systems is to detect the phenomena to be measured and to process and distribute this data to the input of each stage telemetry system. All measurements, regardless of their original characteristics, must be processed into electrical signals within a 0 to 5-volt range prior to delivery to the stage telemetry system. The telemetry system accepts these input signals for transmission to the ground recovery stations.

The following table contains a measurement breakdown for the launch vehicle and the spacecraft.

Telemetry

The Telemetry System for each stage of the vehicle must accept signals produced by the measuring portion of the instrumentation system, and accurately reproduce and transmit them to the ground stations. Measurement signals are accepted at a fixed input level, processed, and fed to the proper airborne antennas. In the case of checkout measurements, the signals are transmitted via breakaway cable arrangement to the ground checkout station prior to liftoff.

RF and Tracking

The Vehicle RF and Tracking Systems are described and illustrated on pages 26 and 27.

Measurement Summary - L/V

Measurement Designation	S-IC Stage	S-II Stage	S-IVB Stage	Inst. Unit	L/V Total
Acceleration	3	11	-	4	18
Acoustic	4	5	-	1	10
Temperature	252	325	120	58	755
Pressure	234	198	88	13	533
Vibration	80	61	-	28	169
Flow Rate	35	10	4	11	60
Position	1	44	8	21	74
Signals	133	223	74	112	542
Liquid Level	22	6	7		35
Voltage, Current, Frequency	11	65	38	42	156
Miscellaneous	22	4	10	-	36
Angular Velocity	3	3	-	33	39
Strain	71	27	-	32	130
RPM	5	10	2	-	17
Guidance and Control	-	-	-	69	69
RF and Telemetry	-	-	-	26	26
Totals	876	992	351	450	2669
ESE Display	97	82	100	177	456
Auxiliary Display	64	81	63	18	226
Flight Control	28	80	86	104	298

Measurement Summary - S/C

	CM	SM	S/C Total
Pressure	18	37	55
Temperature	19	43	62
Discrete Event	84	5	89
Voltage, Current, Frequency	44	3	47
Miscellaneous	30	55	85
Totals	195	143	338

AS-503
Measurement Summary

VEHICLE TRACKING SYSTEMS

In the Saturn V Space Vehicle there is a continuous requirement to transmit information to ground stations in order to track the vehicle. This requirement is filled by the RF Systems.

The RF System functions to transmit (via RF carrier) all vehicle flight evaluation data as well to evaluate vehicle performance (flight path) for ground receiving stations. These functions are accomplished through the use of Antenna and Tracking Systems.

The principal tracking systems used are:

- ODOP (offset doppler) system - Used in the S-IC stage
- C-band radar - Used in the IU and spacecraft
- Unified S-band system - Used in the spacecraft.

ODOP System (S-IC)

An offset doppler, frequency measurement system is an elliptical tracking system which measures the total doppler phase shift in a ultra-high frequency (UHF) continuous wave (CW) signal transmitted to the S-IC stage. The system uses a fixed station (ground) transmitter, a vehicle-borne transponder and three or more fixed station (ground) receivers.

C-Band (IU and SC)

C-Band is a pulse radar system which is used for precise tracking during launch and orbit phases. Two C-Band radar transponders carried in IU to provide radar tracking capabilities independent of vehicle attitude.

Unified S-Band System (SC)

The Unified Side Band (USB) System provides tracking capability to the USB ground stations.

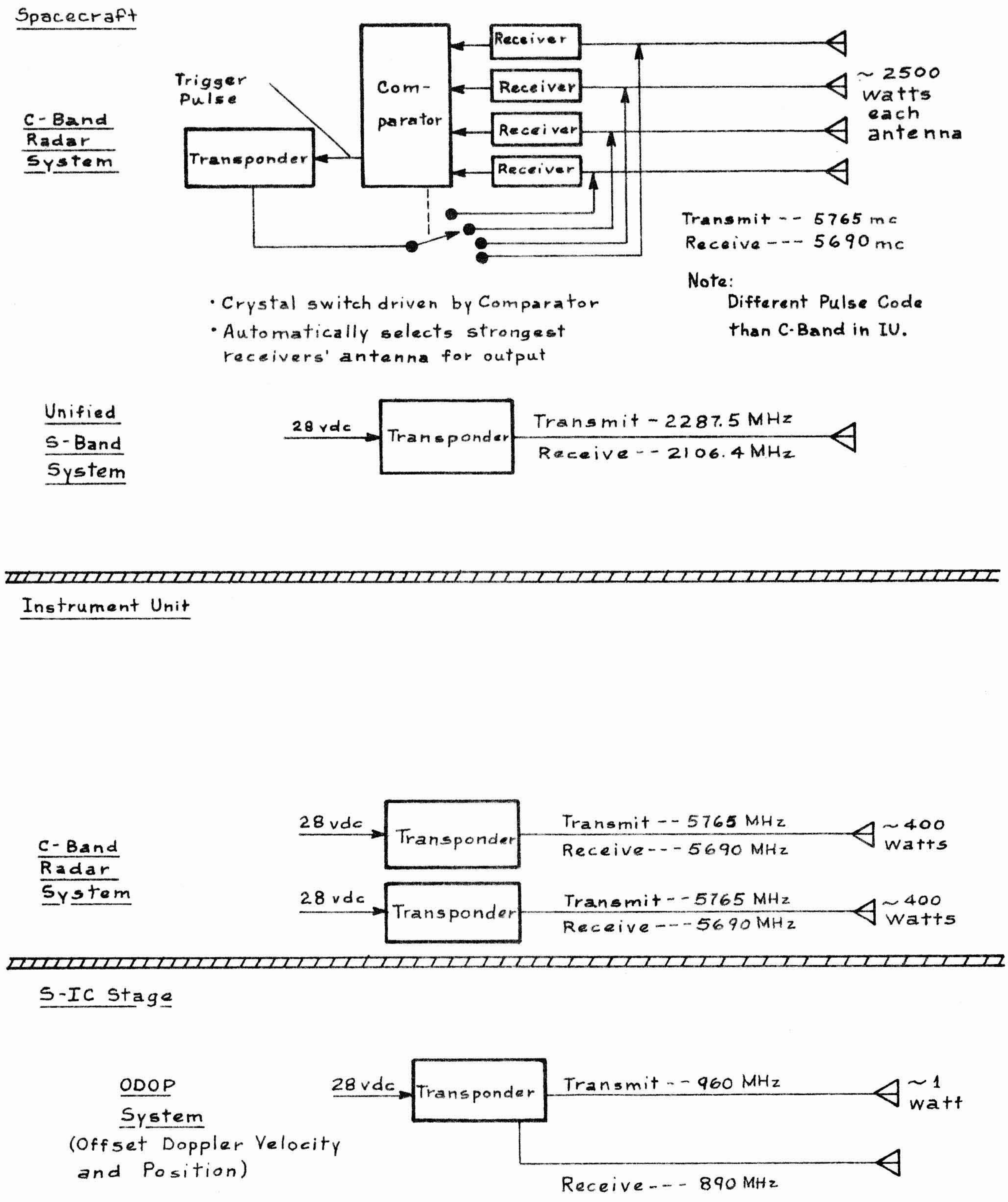


Figure 13

Vehicle Tracking Systems

SPACE VEHICLE WEIGHT VS. FLIGHT TIME

Mainstage propellant consumption during S-IC stage flight (approximately 150 seconds) is 4,400,000 pounds. Propellant consumption during S-II stage powered flight (approximately 367 seconds) is approximately 933,100 pounds and during S-IVB stage powered flight, including first and second burns, (approximately 443 seconds) is approximately 233,950 pounds.

VEHICLE WEIGHT DATA (Approximate)	Pounds
Total at S-IC ignition	4,795,100
Total at holddown arm release	4,600,000
Total at O.E.C.O.	1,800,000
Total at S-II ignition	1,037,800
Total at S-II E.C.O.	470,000
Total at S-IVB first ignition	263,500
Total at S-IVB E.C.O.	192,250
Total at S-IVB second ignition	190,250
Total at S-IVB second E.C.O.	29,550

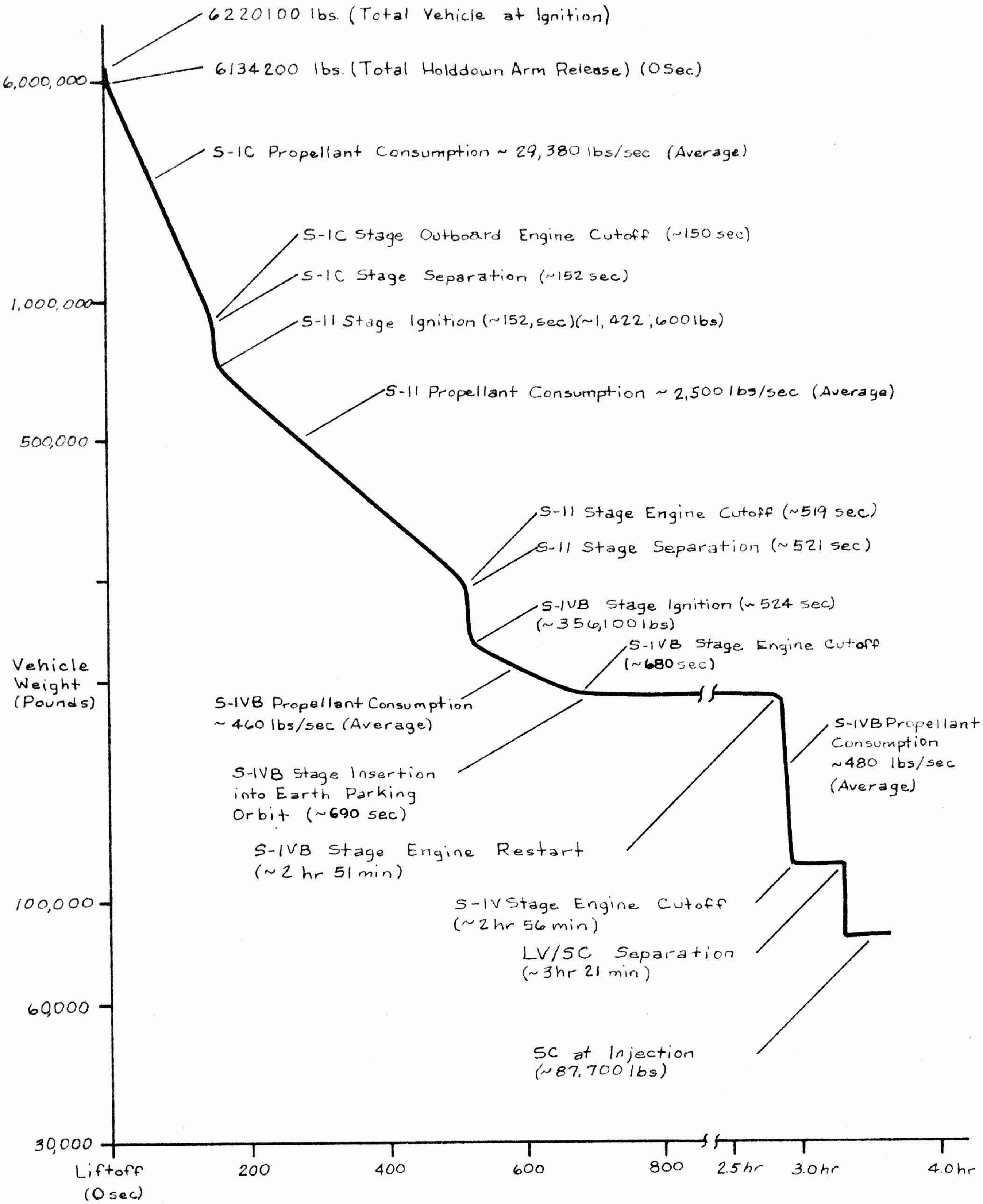


Figure 14

Space Vehicle Weight vs. Flight Time

S-IC STAGE STRUCTURE

The S-IC stage is approximately 138 feet long and 33 feet in diameter and is powered by five liquid-fueled Rocketdyne F-1 engines which generate a nominal thrust of 7,610,000 pounds. Stage engines are supplied by a bi-propellant system of liquid oxygen (LOX) as the oxidizer and RP-1 as the fuel.

The stage interfaces structurally and electrically with the S-II stage (forward skirt structure).

Mounted on the structural airframe, the stage consists of an RP-1 fuel tank, a LOX tank, five F-1 engines, electrical and pneumatic control as well as emergency flight termination equipment. Eight retro rockets, used during S-IC/S-II stage separation, will cause the S-IC stage to back away from the flight vehicle when fired.

Ejectable Camera Capsules

A Film Camera System consists of four individual camera subsystems.

- Two pulse type cameras record LOX behavior immediately before and during flight. Battery powered strobe lights illuminate the interior of the LOX tank for this filming.

- Two movie type cameras to film stage separation.

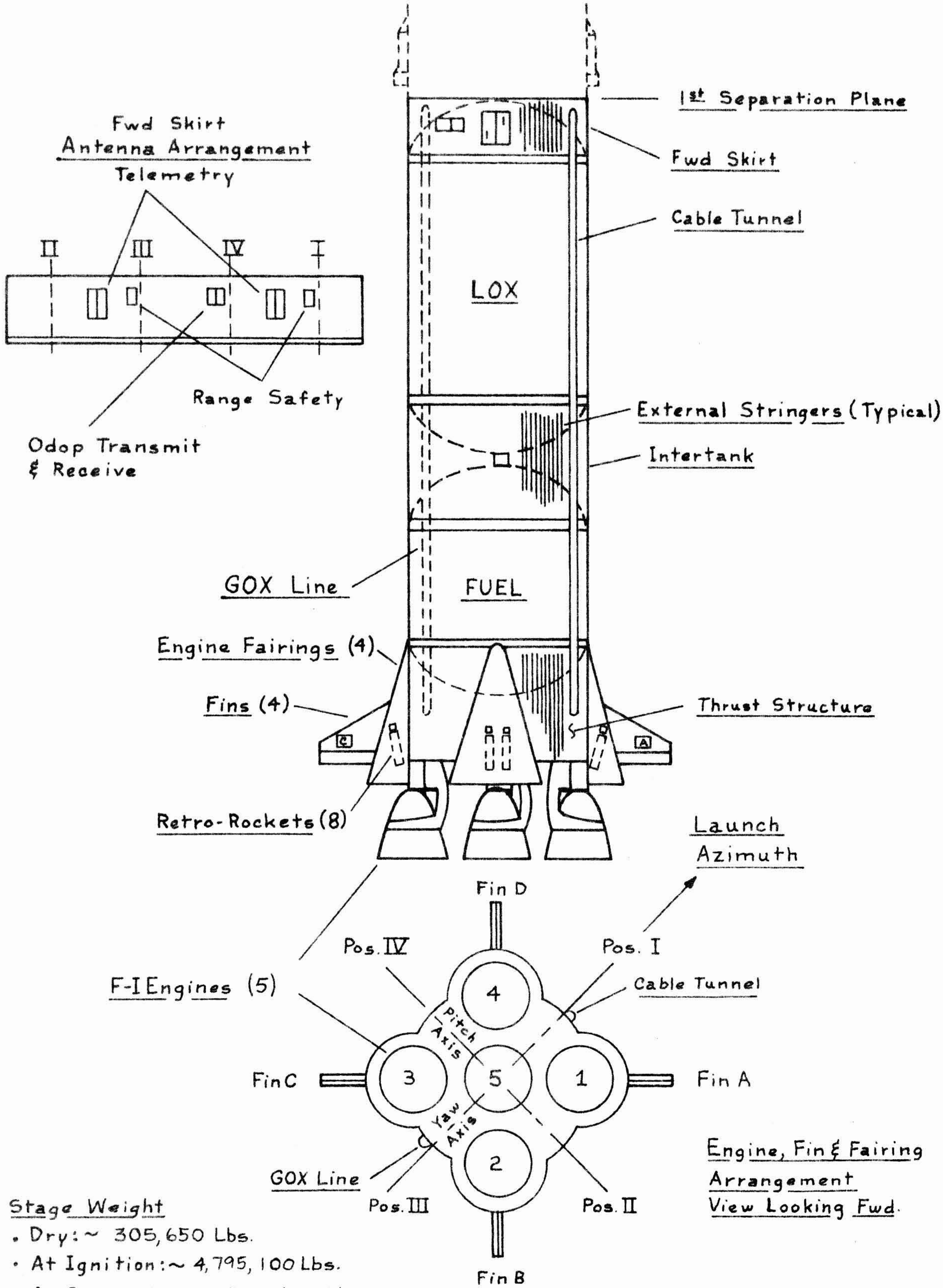
Separation cameras begin filming at about four seconds before stage separation and continue until capsule ejection (approximately 25 seconds after separation).

Immediately following ejection, the camera capsule stabilization flaps are deployed. After the camera capsule descends to an altitude of 4,300 meters, a paraballoon is inflated, which causes the stabilization flaps to fall away. Six seconds after the paraballoon is inflated, a recovery radio transmitter and flashing light beacon located on the paraballoon are turned on.

After touchdown, the camera capsule effuses a dye marker to aid visual sighting of the capsule, and a shark-repellant to protect the camera capsule, the paraballoon, and the camera recovery team.

Airborne Television

An airborne TV System is installed in the S-IC stage to provide inflight, real time, visual performance about the S-IC stage engines as well as permanent storage of pictures televised.



Stage Weight
- Dry: ~ 305,650 Lbs.
- At Ignition: ~ 4,795,100 Lbs.
- At Separation: ~ 380,400 Lbs.

Figure 15

S-IC Stage Configuration

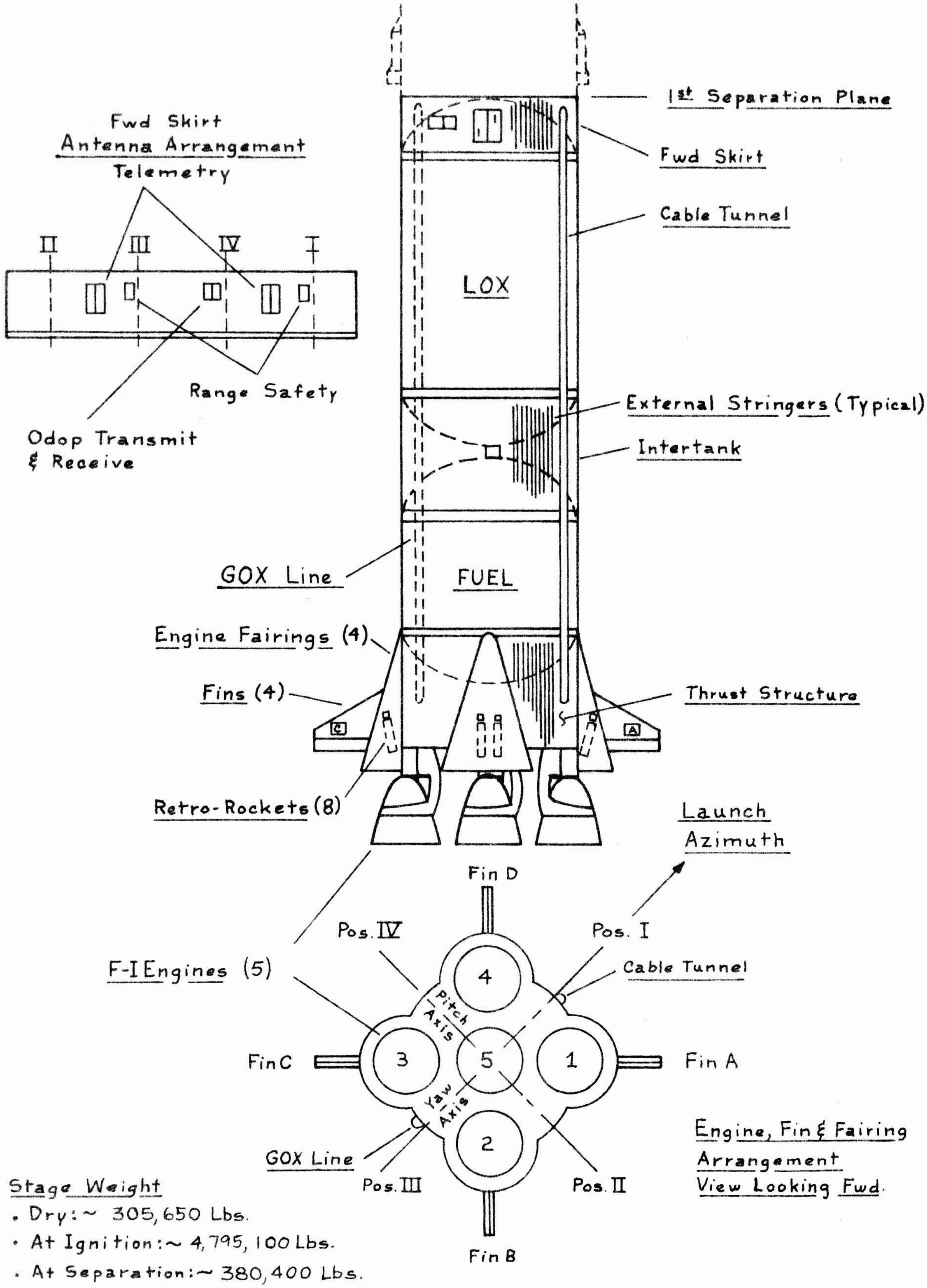


Figure 15

S-IC Stage Configuration

F-1 ENGINE OPERATION

The F-1 engine is started by ground support equipment. Ground fluid pressure opens ports in the main LOX valves. Opening of the main LOX valves admits LOX under tank pressure to the thrust chamber and allows control fluid to enter the gas generator. Opening of the gas generator valve permits LOX and RP-1 to enter the gas generator combustion chamber where it is ignited and the hot gases are discharged into the thrust chamber where they are ignited by the turbine exhaust igniters. When the RP-1 reaches approximately 375 psig a valve in the hypergol cartridge opens allowing LOX and RP-1 to build up pressure against the hypergol burst diaphragm. At approximately 500 psig the diaphragm ruptures allowing hypergol and RP-1 to enter the thrust chamber causing spontaneous combustion upon contact with the LOX, thereby establishing primary ignition. As thrust pressure builds up the RP-1 valves open admitting RP-1 to the thrust chamber and the transition to mainstage operation.

The inboard engine is cutoff by a signal from the IU. Outboard engines are cutoff by optical type LOX depletion sensors with fuel depletion sensors as backup. A command from the IU supplies a command to the switch selector to enable the outboard engine cutoff circuitry. When two or more of the four LOX level sensors are energized, a timer is activated. Expiration of the timer energizes a stop solenoid for each engine which energizes the main LOX and main RP-1 valves. The sequence closing of the main LOX valve followed by sequence closing of the main RP-1 valve interrupts propellant flow and terminates engine operation.

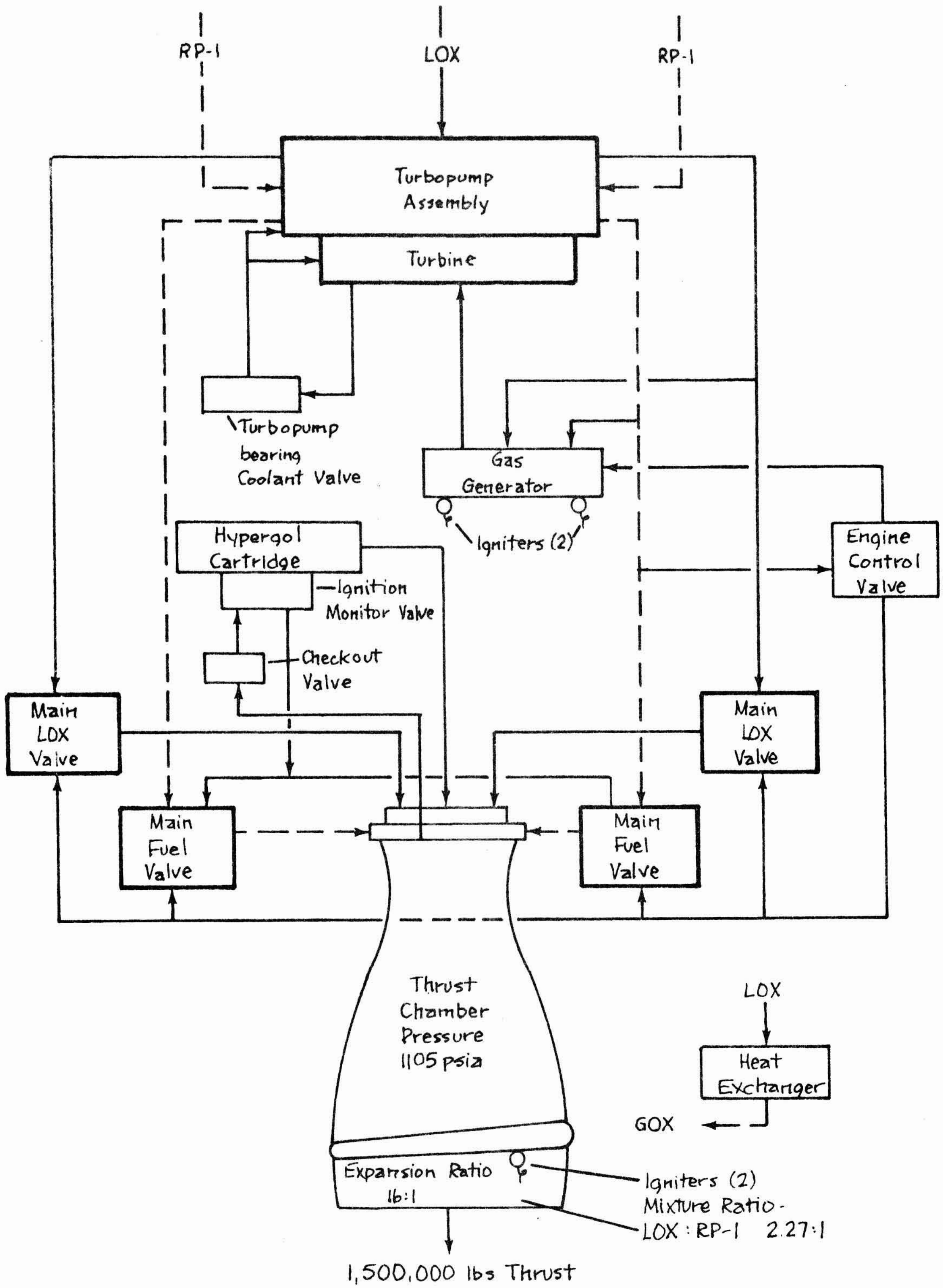


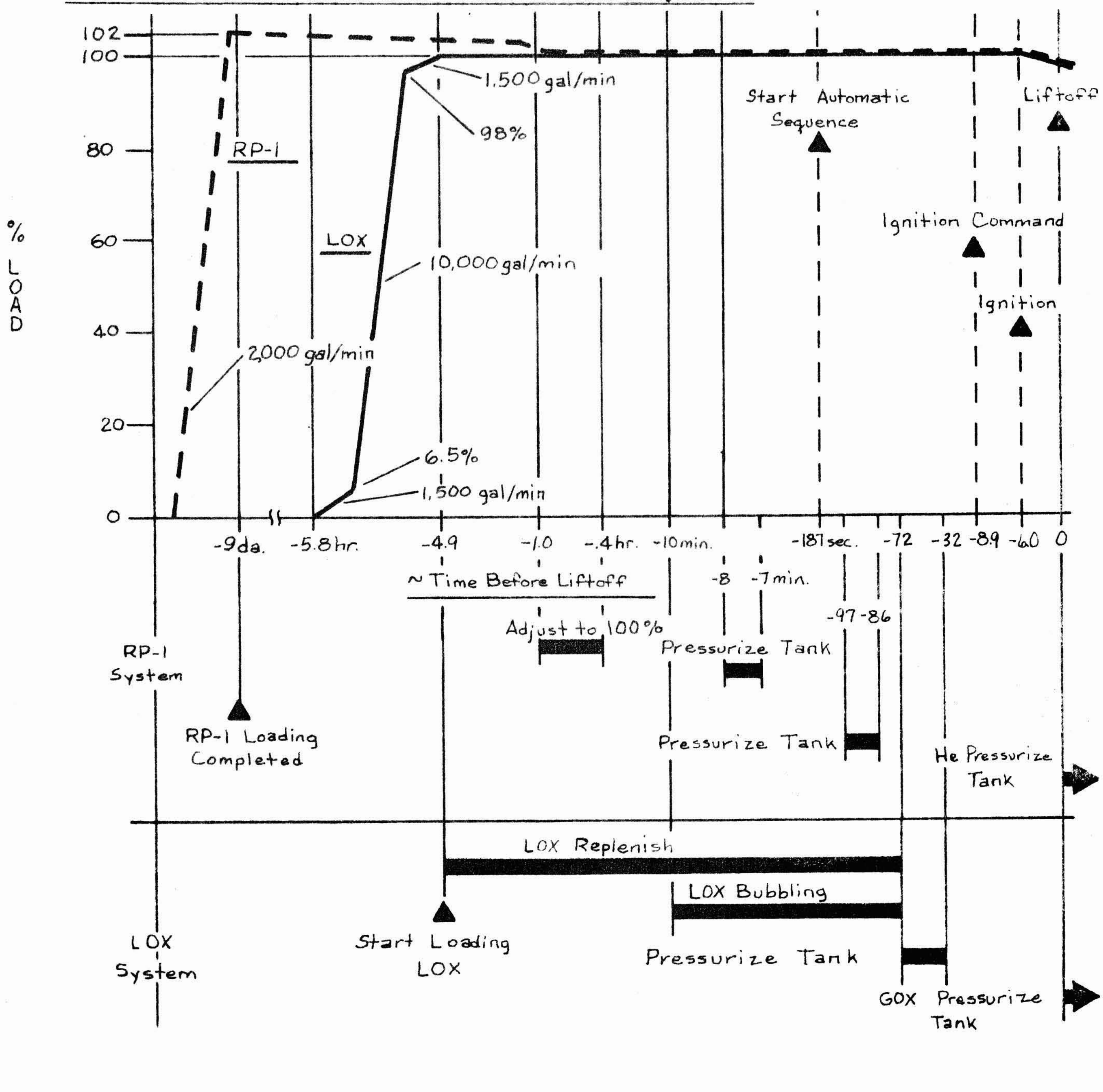
Figure 16

F-1 Engine System

S-IC STAGE PROPELLANT SYSTEM

The S-IC stage propellant system is composed of one LOX tank, one RP-1 tank, propellant lines, control valves, vents, and pressurization subsystems. Loading of LOX and RP-1 tanks is controlled by ground computers. RP-1 loading is completed approximately nine days prior to liftoff. LOX bubbling, through lines 1 and 3, is started at the beginning of LOX chilldown operation and is continued throughout LOX loading and again before liftoff to prevent possible geysering. Prior to liftoff the RP-1 tank and the LOX tank is pressurized by helium from a ground source. At liftoff the RP-1 tank is pressurized with helium stored in bottles located in the LOX tank and heated by passing the helium through the heat exchanger. LOX tank pressurization is maintained by LOX bled from the engine and converted to GOX in the heat exchanger.

S-IC PROPELLANT LOAD AND OPERATIONAL SEQUENCE



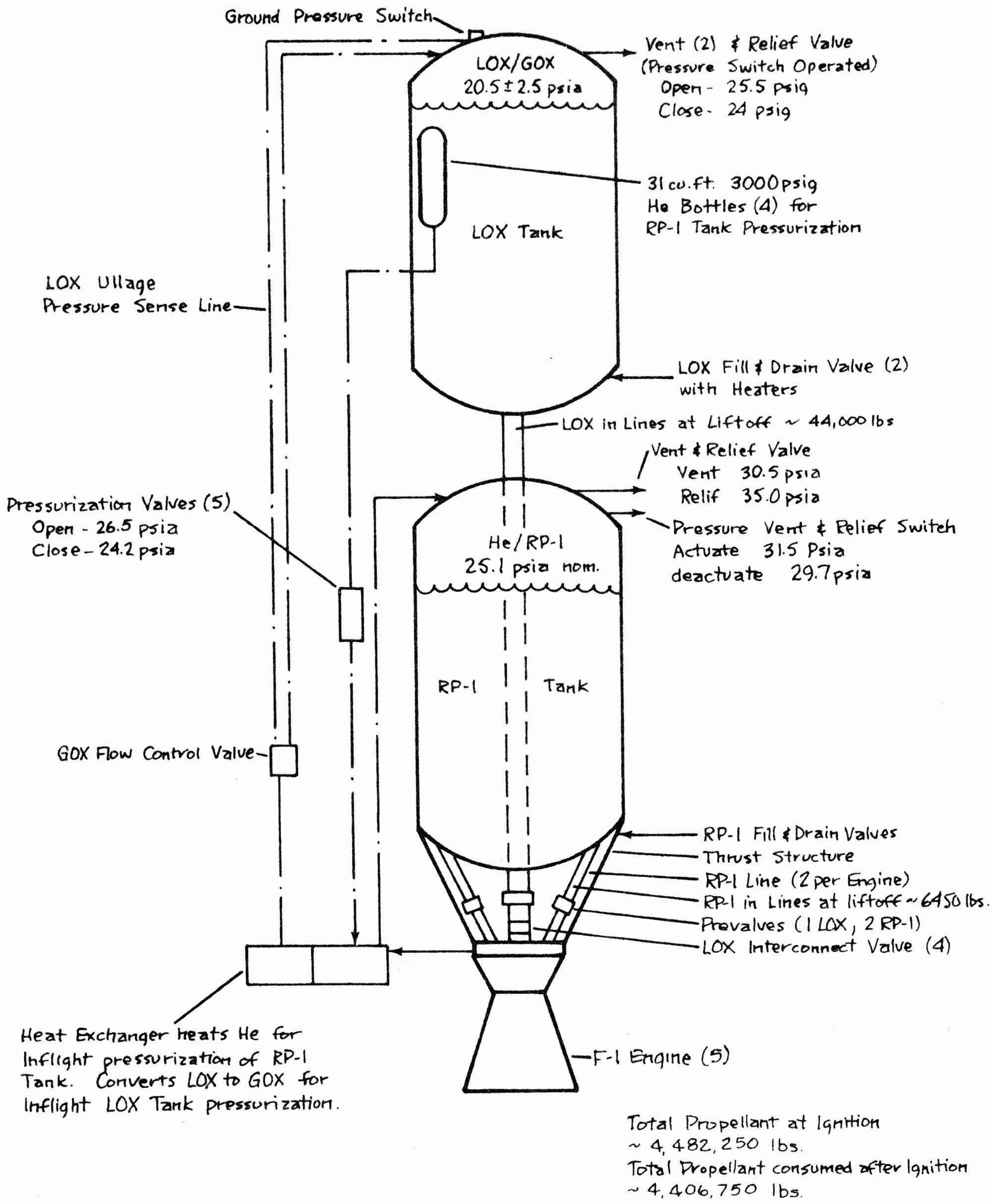


Figure 17

S-IC Stage Propellant System

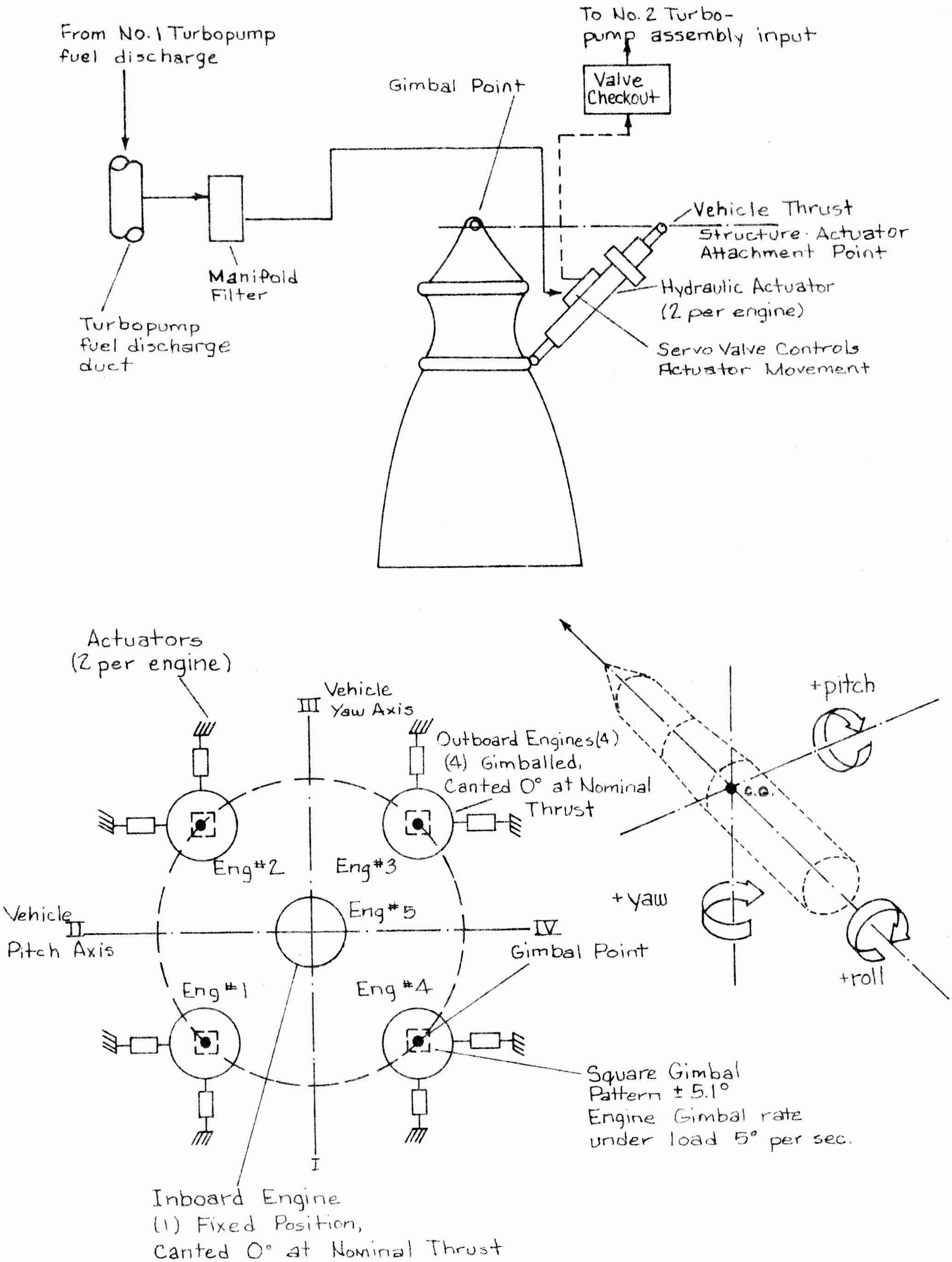


Figure 18

S-IC Stage Thrust Vector Control System

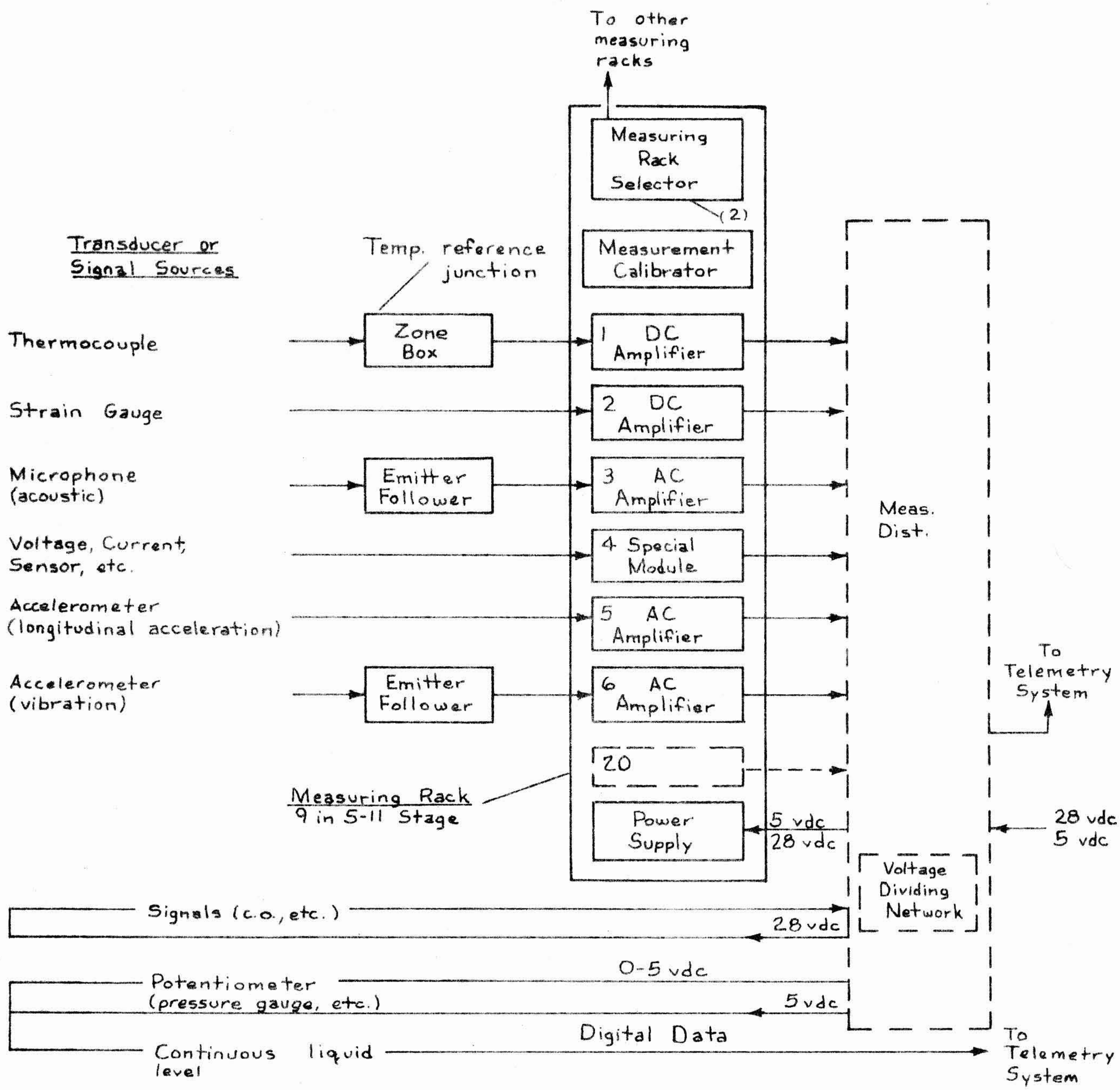


Figure 19

S-IC Stage Measuring System

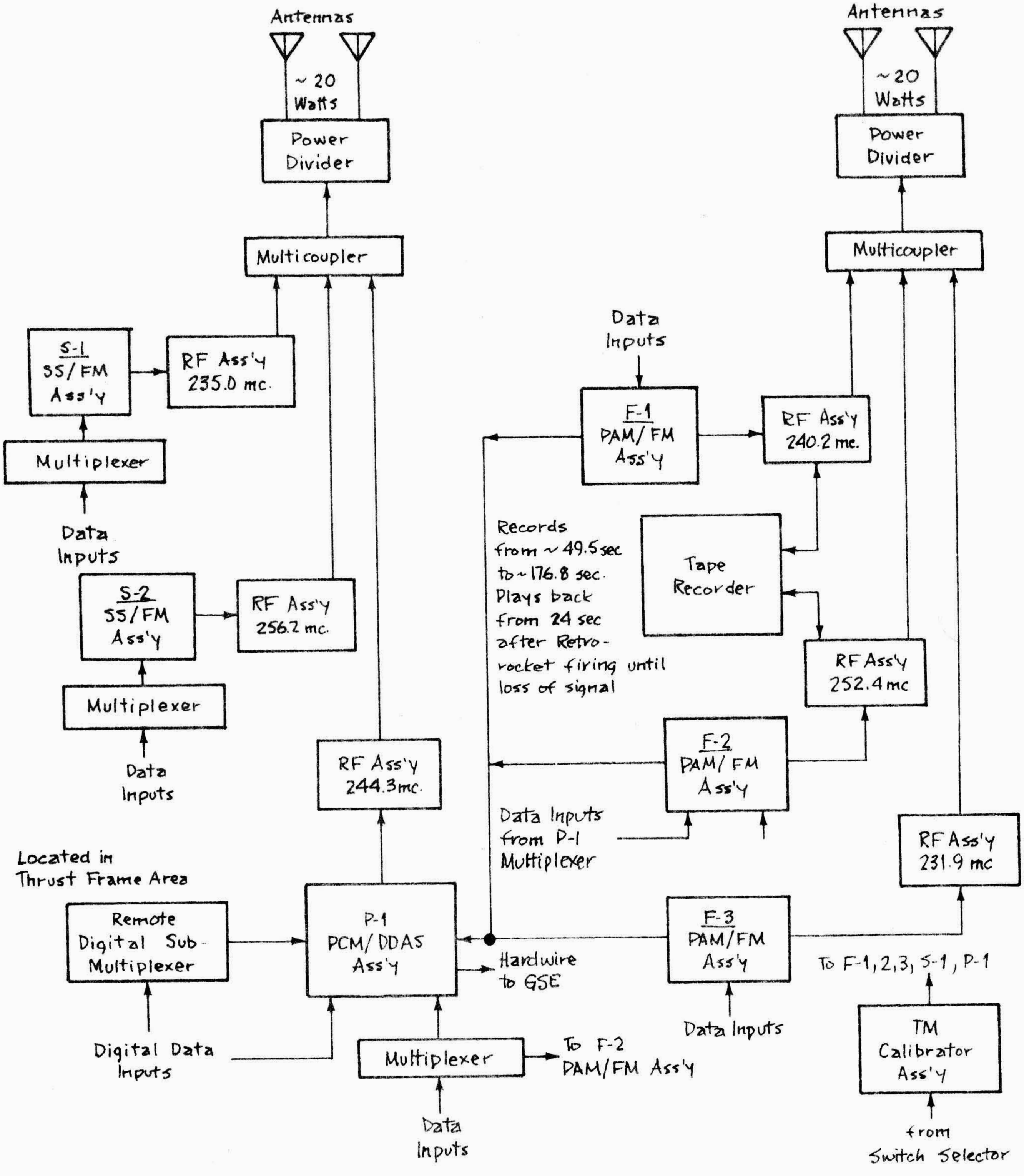
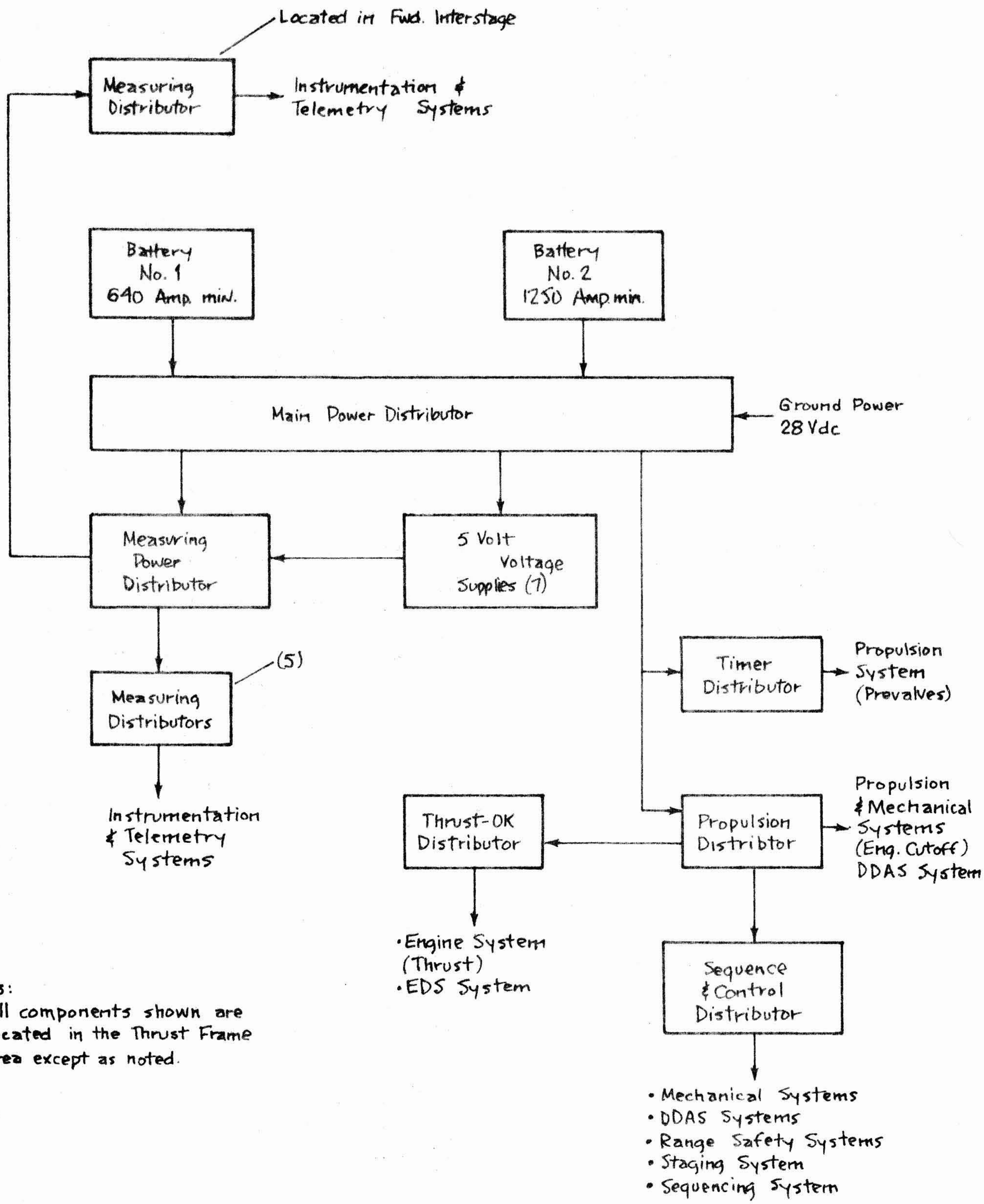


Figure 20

S-IC Stage Telemetry System



Notes:
All components shown are located in the Thrust Frame Area except as noted.

Figure 21

S-IC Stage Electrical Power and Distribution System

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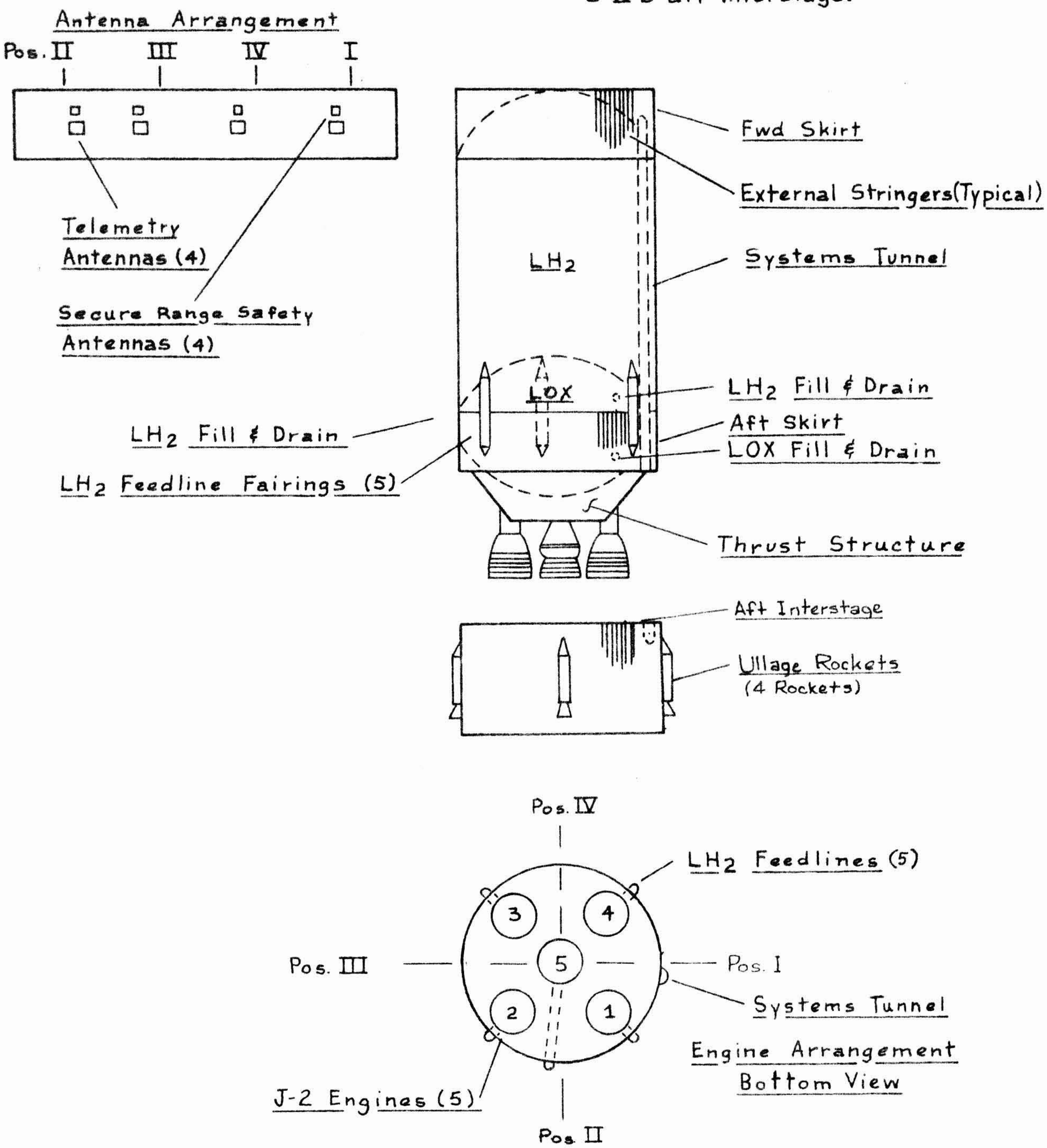
S-II STAGE STRUCTURE

The S-II stage is a large cylindrical booster approximately 81 feet in length and 33 feet in diameter. The stage is powered by five liquid propellant J-2 rocket engines which combine to develop a total thrust of 1,140,000 pounds.

In addition to the J-2 rocket engines, the structural air frame of the S-II stage mounts a forward and aft skirt, an aft interstage, a liquid oxygen and liquid hydrogen tank plus the associated piping, valves, wiring, electrical and electronic equipment.

Note: The retro-rockets for S-II Stage separation are located in the S-IVB aft interstage.



Stage Weight

- Dry: ~ 88,600 lbs.
- At S-II Ignition: ~ 1,037,800 lbs.
- At S-II Cutoff: ~ 104,700 lbs.

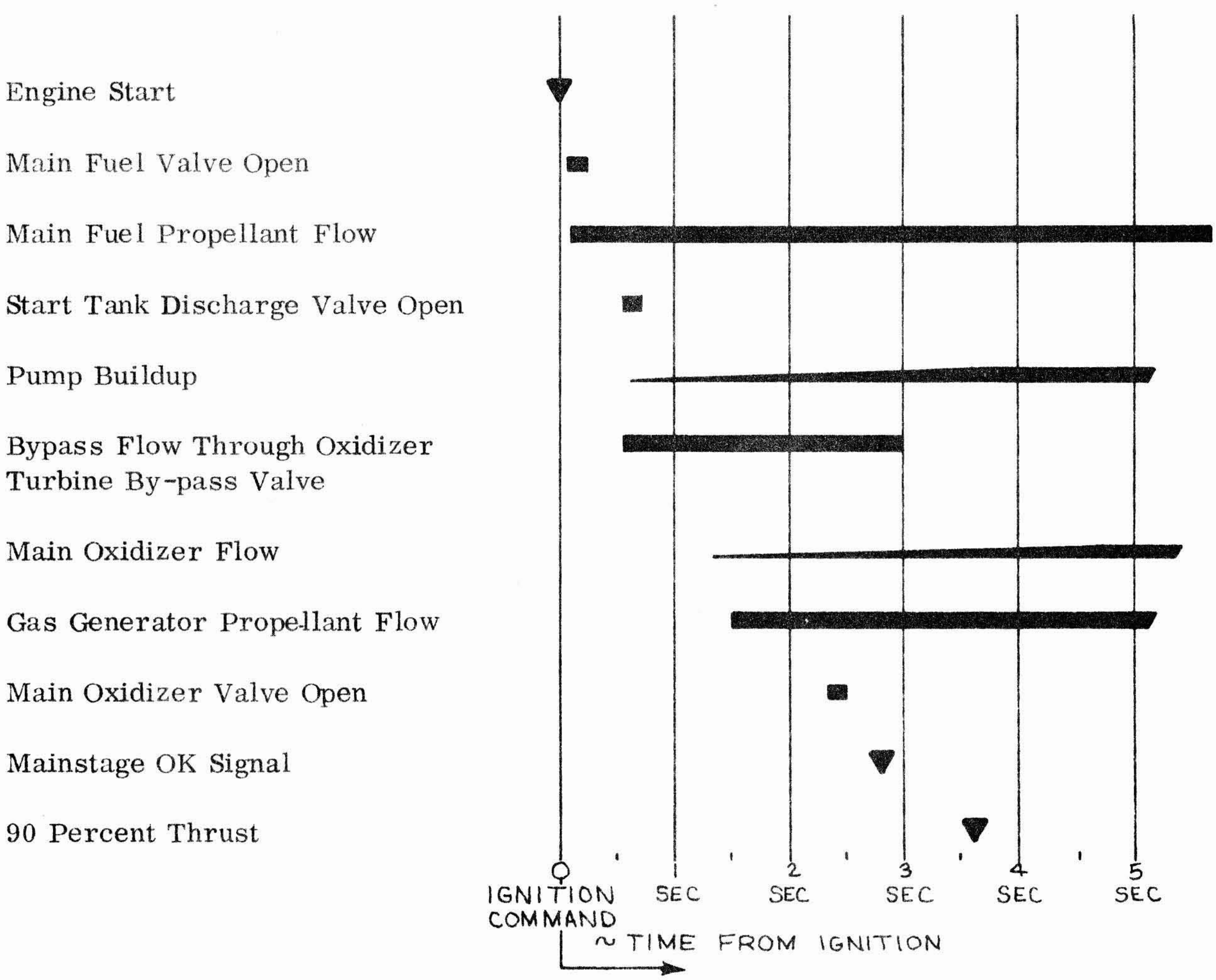
Figure 22

S-II Stage Configuration

J-2 ENGINE OPERATION S-II STAGE

The operating cycle of the J-2 Engine consists of prestart, start, steady-state operation and cutoff sequences. During prestart, LOX and LH_2 flow through the engine to temperature-condition the engine components, and to assure the presence of propellant in the turbopumps for starting. Following a timed cooldown period, the start signal is received by the sequence controller which energizes various control solenoid valves to open the propellant valves in the proper sequence. The sequence controller also energizes spark plugs in the gas generator and thrust chamber to ignite the propellant. In addition, the sequence controller releases GH_2 from the start tank. The GH_2 provides the initial drive for the turbopumps that deliver propellant to the gas generator and the engine. The propellant ignites, gas generator output accelerates the turbopumps, and engine thrust increases to main stage operation. At this time, the spark plugs are de-energized and the engine is in steady-state operation.

Steady-state operation is maintained until a cutoff signal is received by the sequence controller. The sequence controller de-energizes the solenoid valves which in turn close the engine propellant valves in the proper sequence. As a result, engine thrust decays and the cutoff sequence is complete.



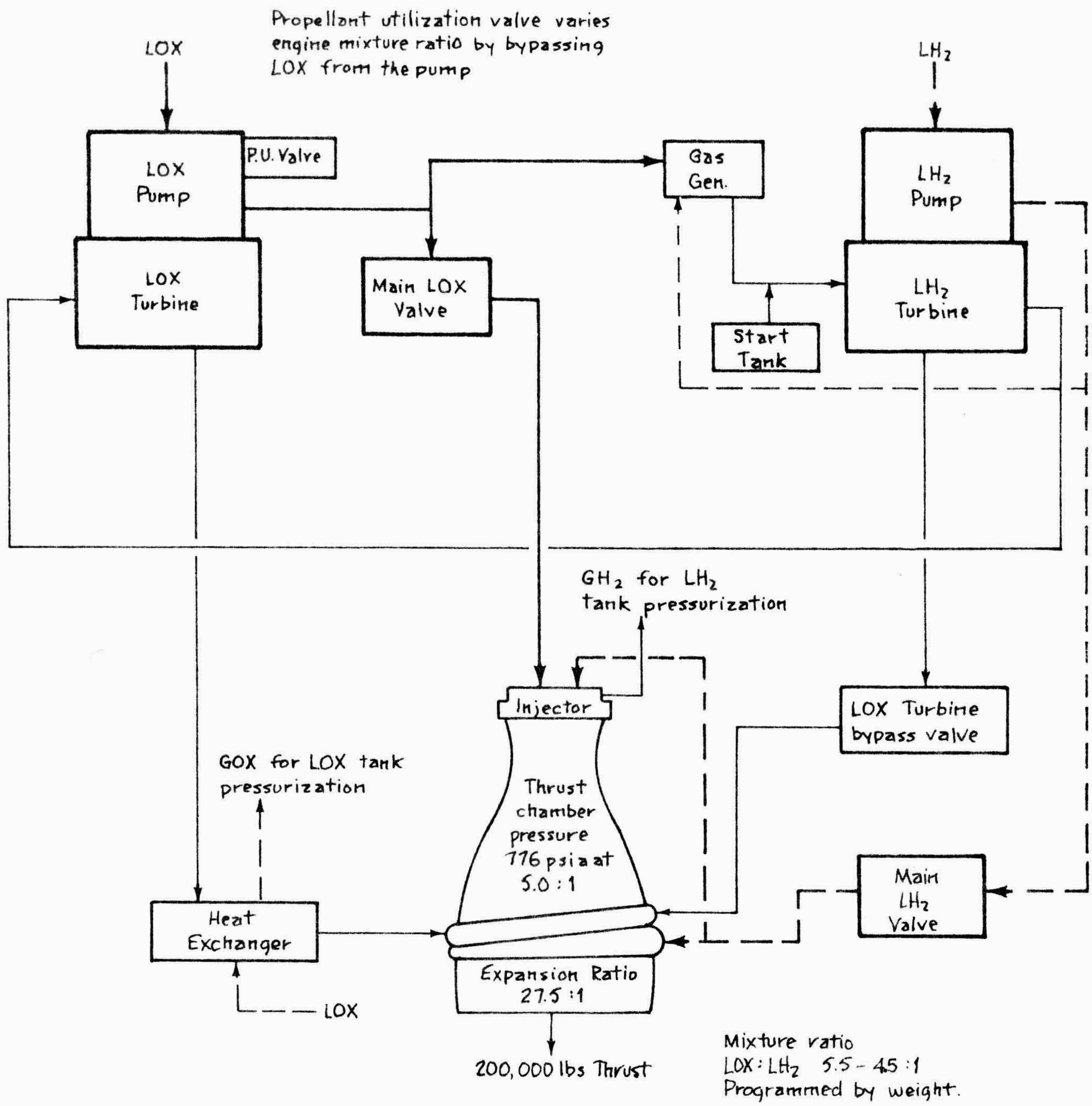


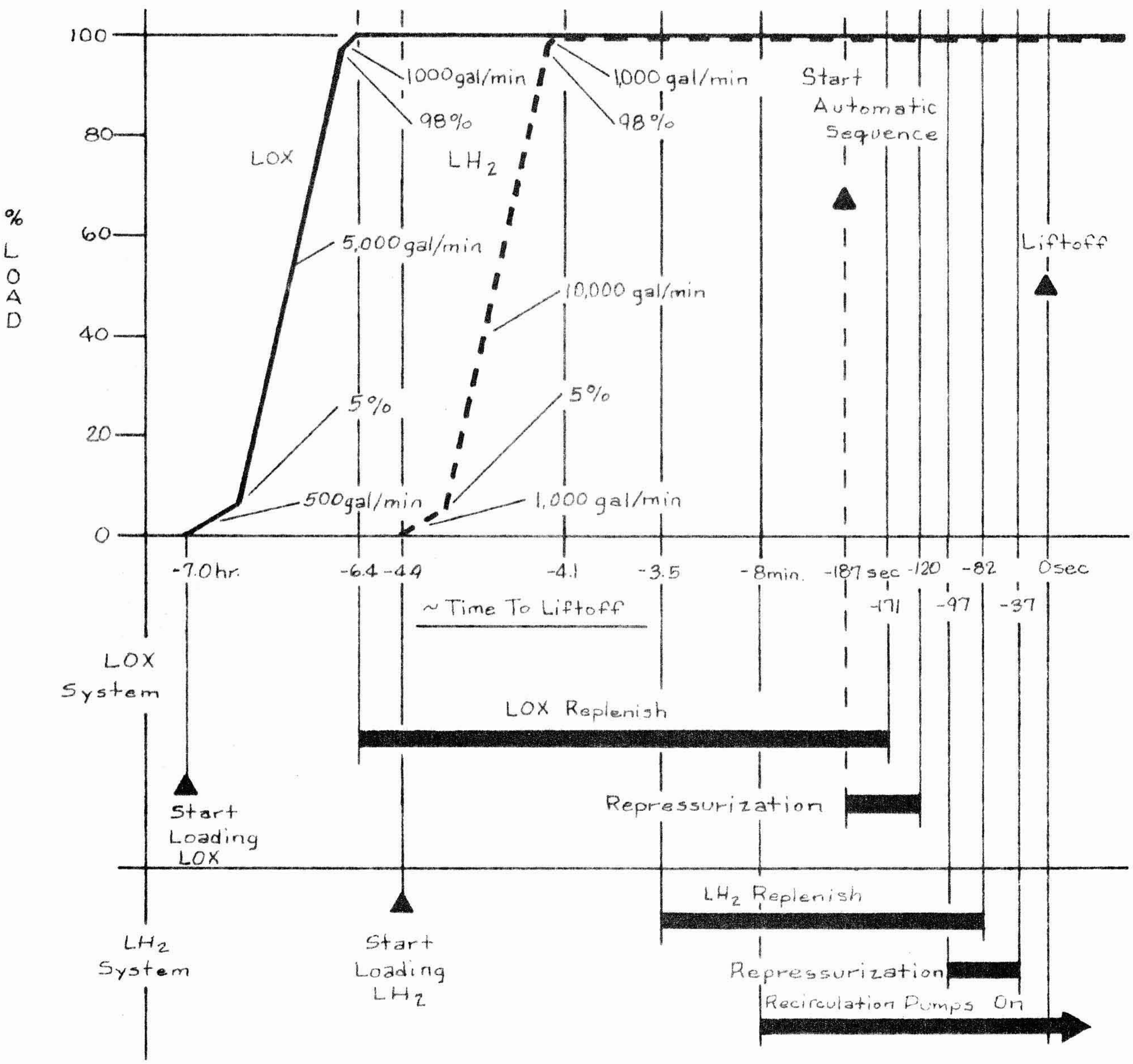
Figure 23

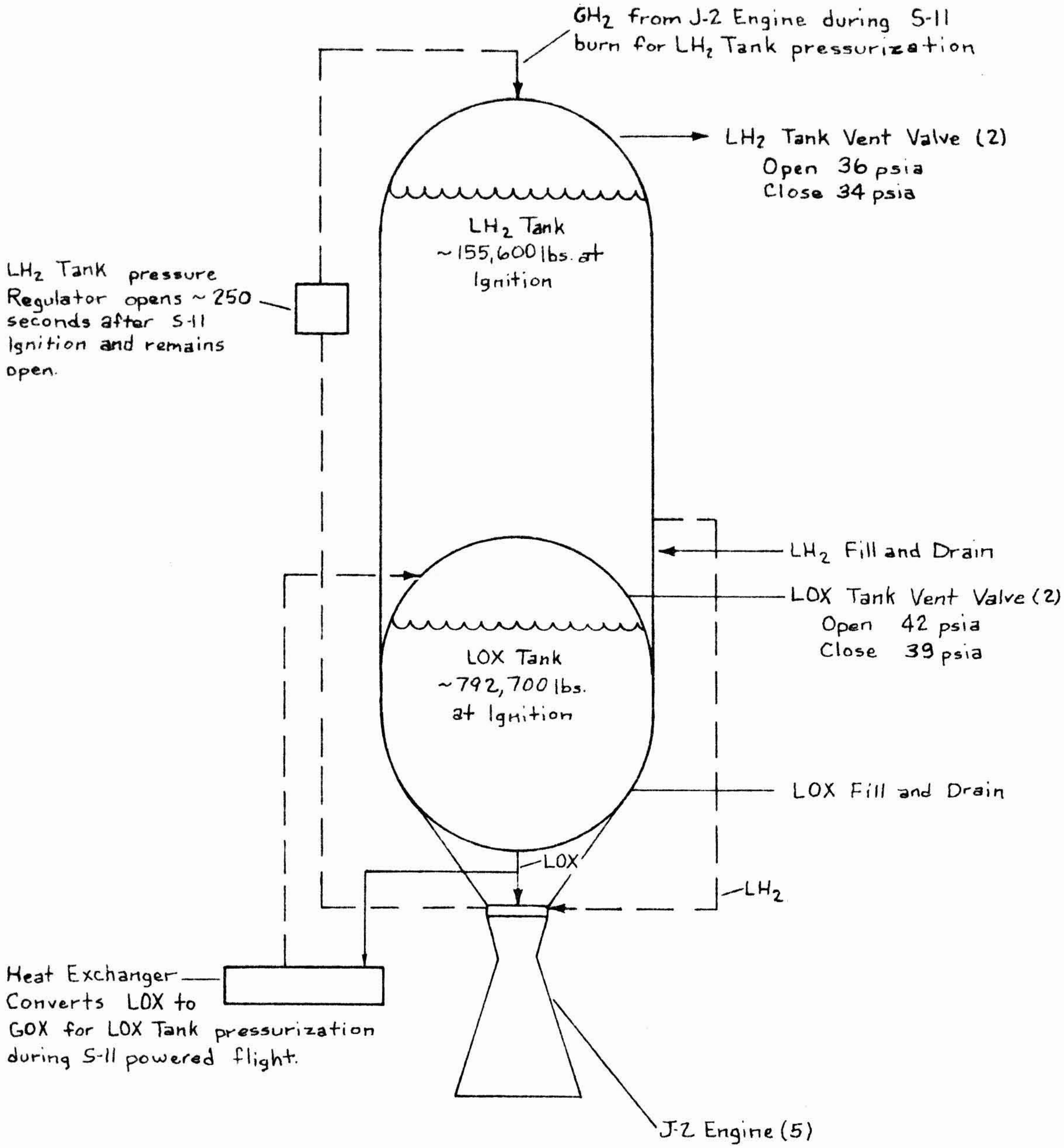
J-2 Engine System
S-II Stage

S-II STAGE PROPELLANT SYSTEM

The S-II Stage propellant system is composed of integral LOX/LH_2 tanks, propellant lines, control valves, vents, and prepressurization subsystems. Loading of propellant tanks and flow of propellants is controlled by the propellant utilization systems. The LOX/LH_2 tanks are prepressurized by ground source gaseous helium. During powered flight of the S-II Stage, the LOX tank is pressurized by GOX bleed from the LOX heat exchanger. The LH_2 tank is pressurized by GH_2 bleed from the thrust chamber hydrogen injector manifold: pressurization is maintained by the LH_2 Pressure Regulator.

S-II PROPELLANT LOAD AND OPERATIONAL SEQUENCE





Total propellant at Ignition ~948,300 lbs.
Total propellant consumed after Ignition ~937,700 lbs.

Figure 24

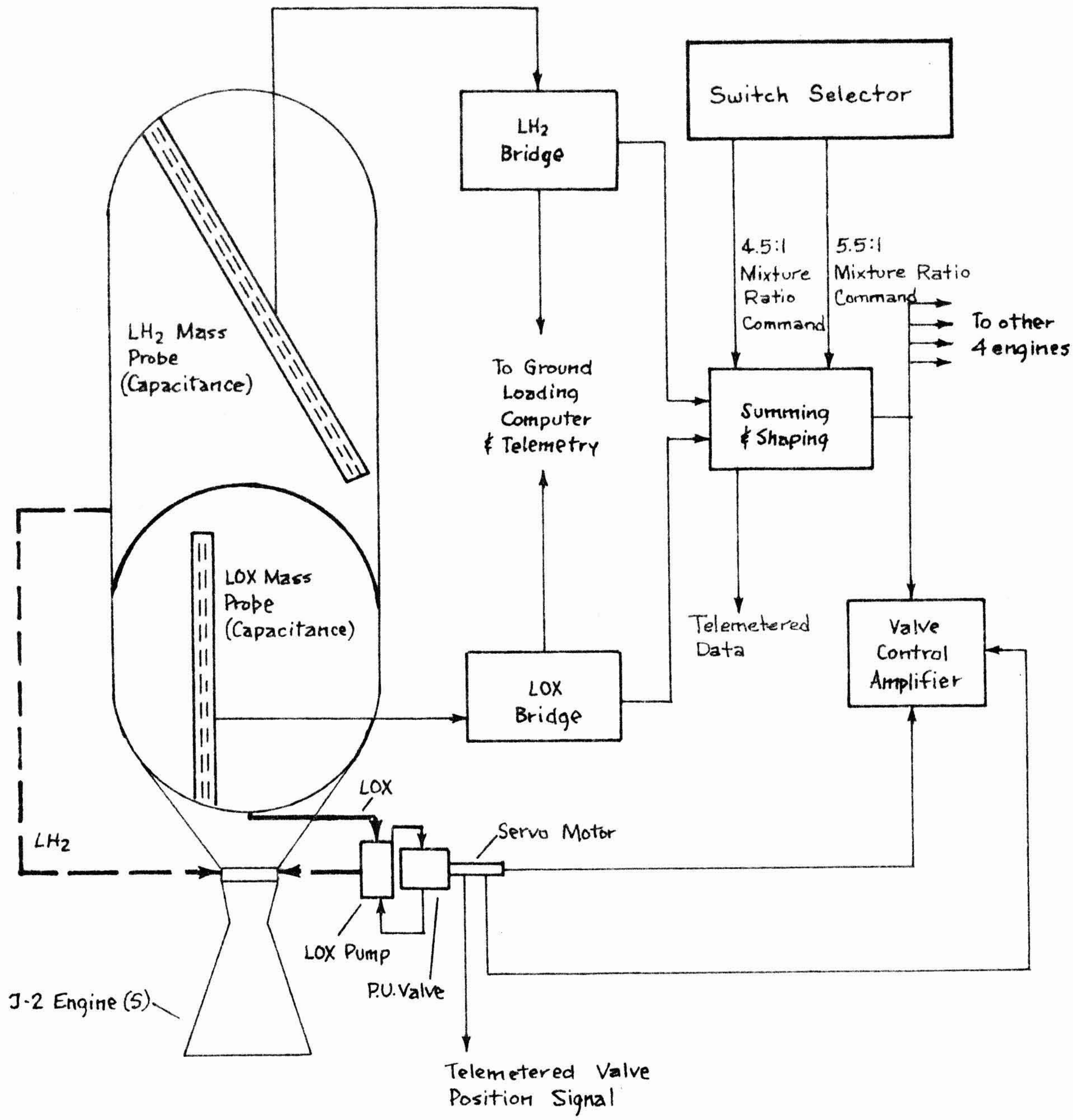
S-II Stage Propellant System

S-II STAGE PROPELLANT MANAGEMENT SYSTEM

The propellant management system, in conjunction with the switch selector, controls mass propellant loading and engine mixture ratios (LOX to LH_2) to ensure balanced consumption of LOX and LH_2.

Capacitance probes, mounted in the LOX and LH_2 containers, monitor the mass of the propellants during powered flight. At engine start the mixture ratio is set to 5.0:1 and then at approximately 5 seconds after engine start, the PU system is armed in the open loop mode and the PU valve is commanded to 5.5:1 by the LVDC/LVDA. When the initial phase of IGM is completed, (nominally engine start plus 287 seconds), the LVDC/LVDA will command the PU valve to a mixture ratio of 4.5:1.

Engine cutoff is initiated when any two of the five capacitance probes, in either tank, indicate dry.



Mixture ratio is normally 5.0:1 unless switch selector has commanded 4.5:1 or 5.5:1 mixture ratio.

Figure 25

S-II Stage Propellant Management System

S-II STAGE THRUST VECTOR CONTROL SYSTEM

The four outboard engines are gimbal mounted to provide attitude control during powered flight. Attitude control is maintained by gimballing one or more of the engines. Power for gimballing is supplied by four independent engine mounted hydraulic control systems.

Pitch, yaw, and roll control, during powered flight, is maintained by actuator control of the engine thrust vector.

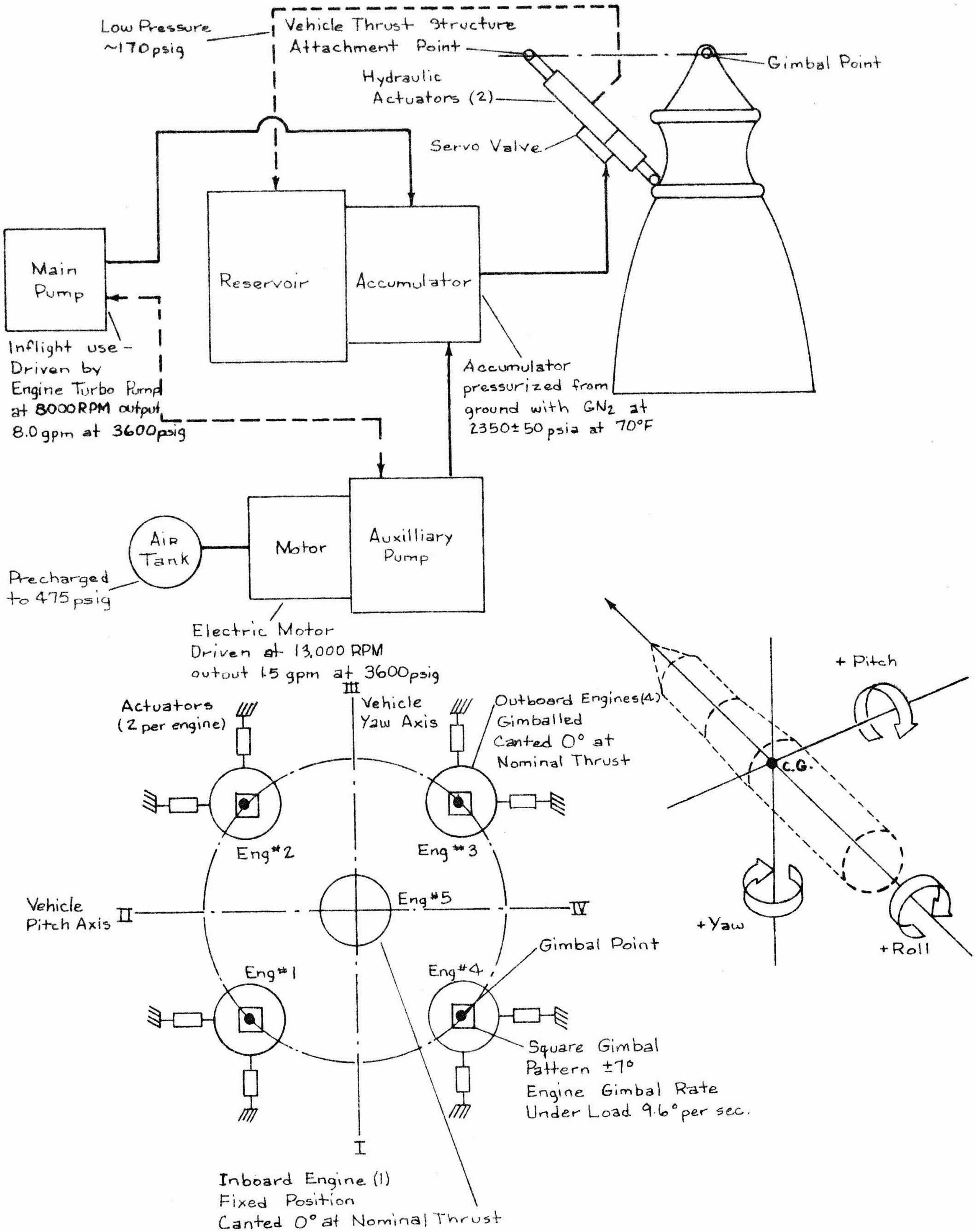


Figure 26

S-II Stage Thrust Vector Control System

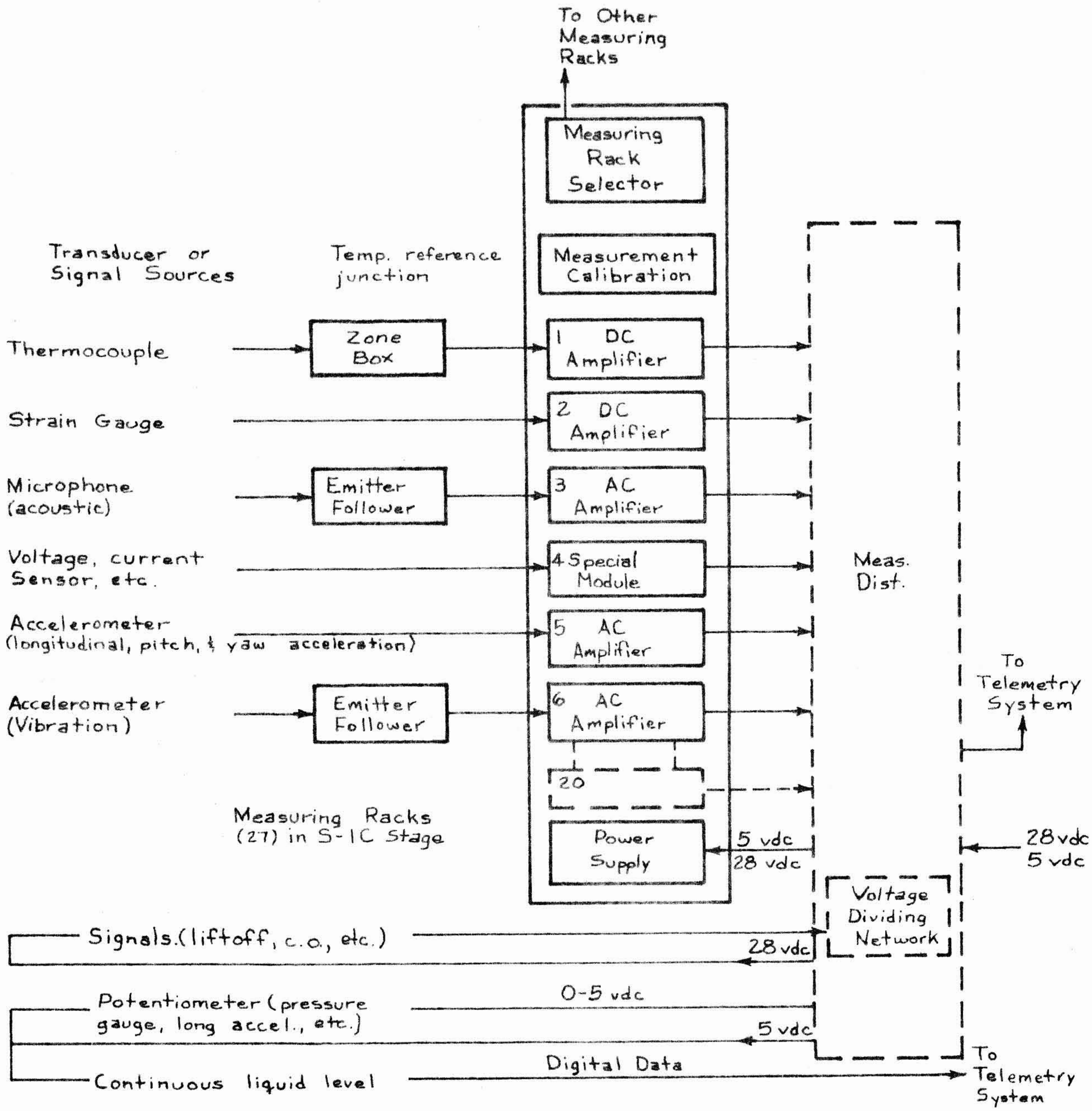
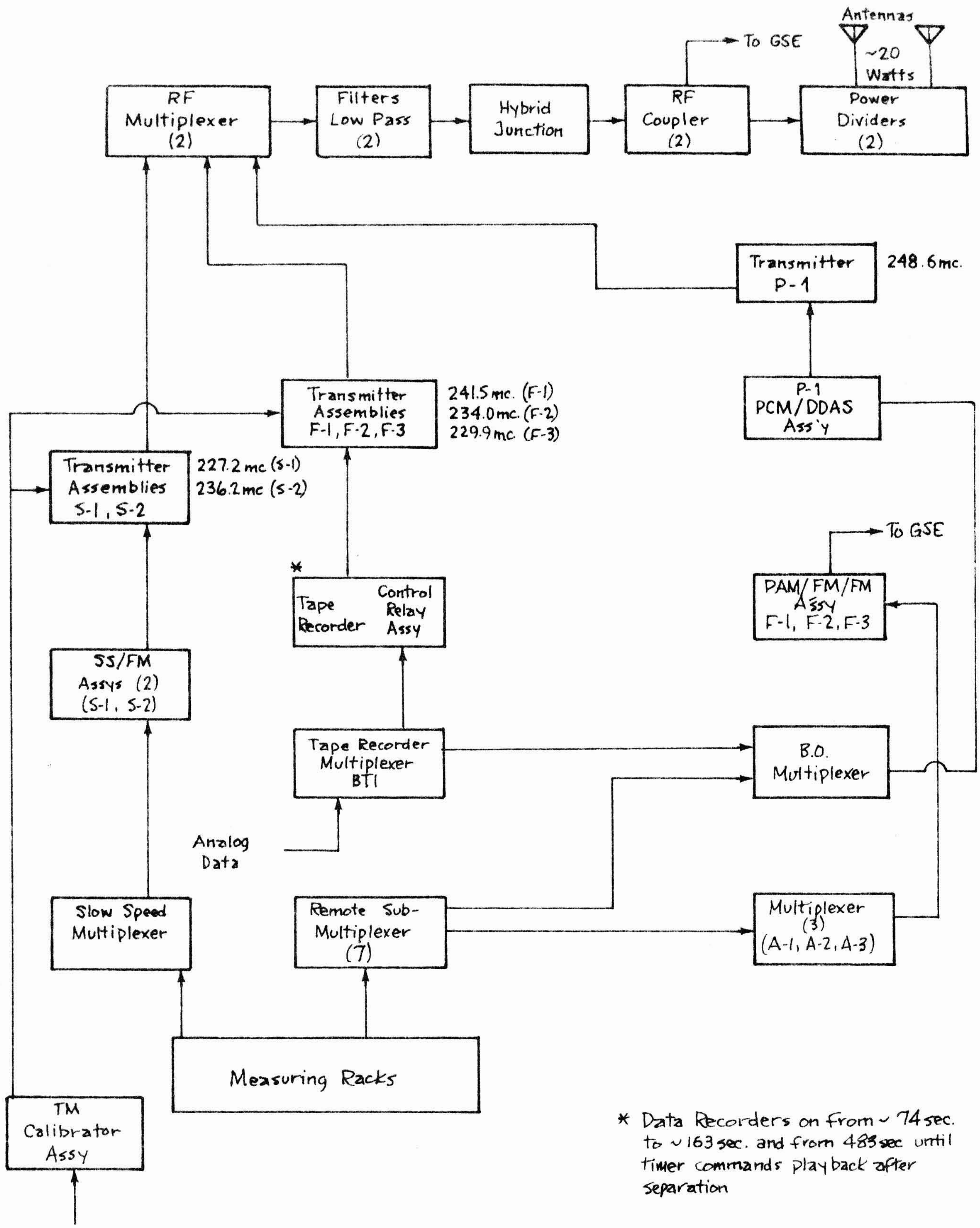


Figure 27

S-II Stage Measuring System



* Data Recorders on from ~ 74 sec. to ~ 163 sec. and from 483 sec until timer commands play back after separation

Figure 28

S-II Stage Telemetry System

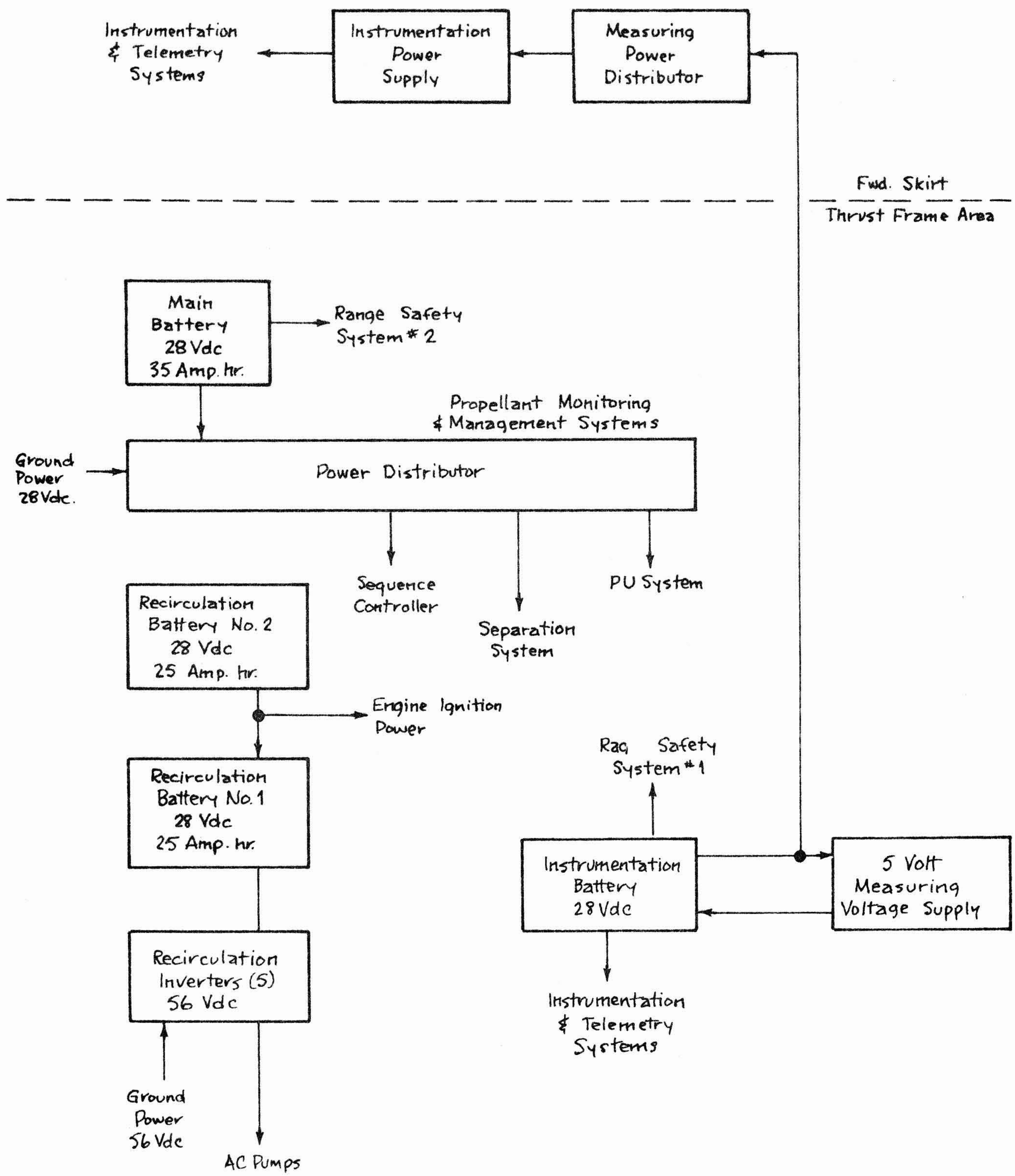


Figure 29

S-II Stage Electrical Power & Distribution System

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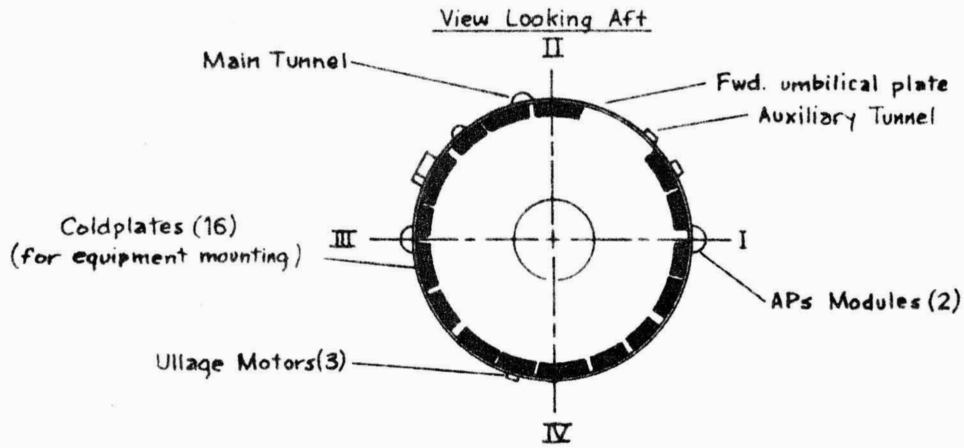
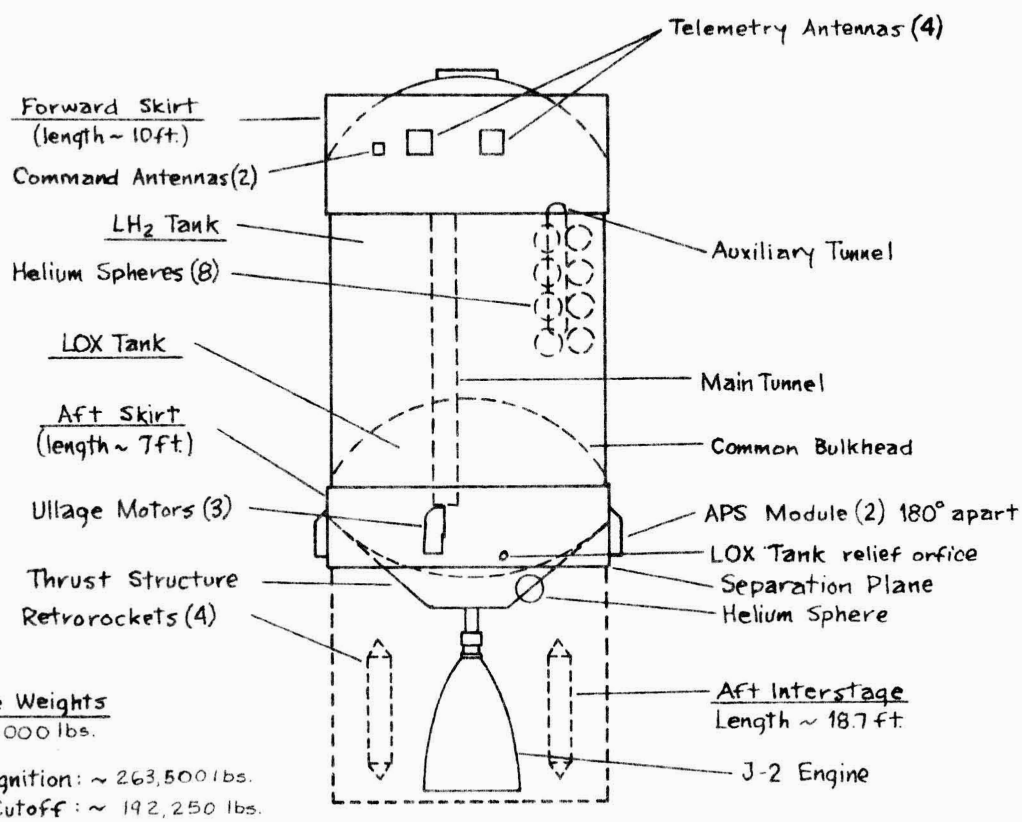
S-IVB STAGE

The Saturn S-IVB is the third of the three booster stages. A single J-2 engine is designed to boost the payload into earth parking orbit during the first burn. A second stage burn is designed to provide vehicle position and velocity for lunar intercept.

The basic structural assembly of the S-IVB stage consists of; the forward skirt, propellant tanks, an aft skirt, thrust structure and aft interstage.

The two Auxiliary Propulsion System (APS) modules are located 180° apart on the aft skirt. Each module contains four engines; three 150-pound thrust and one 70 pound thrust. This APS system provides stage attitude control and main stage propellant control during coast flight.



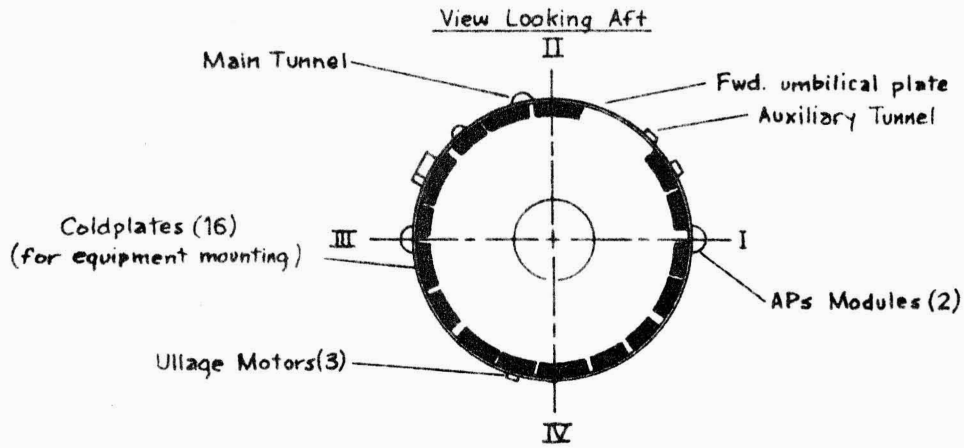


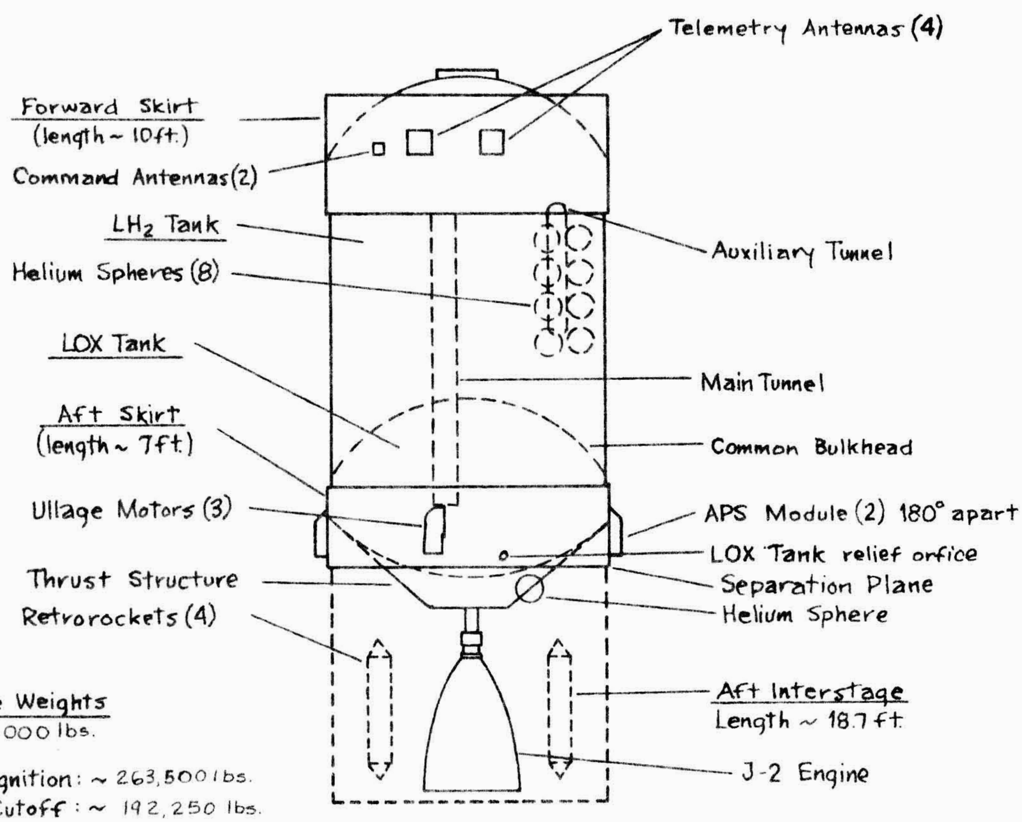
S-IVB Stage Weights

- Dry: ~ 26,000 lbs.
- At S-IVB Ignition: ~ 263,500 lbs.
- At S-IVB Cutoff: ~ 192,250 lbs.
- At S-IVB 2nd Cutoff: ~ 29,550 lbs.

Figure 30

S-IVB Stage Configuration





S-IVB Stage Weights

- Dry: ~ 26,000 lbs.
- At S-IVB Ignition: ~ 263,500 lbs.
- At S-IVB Cutoff: ~ 192,250 lbs.
- At S-IVB 2nd Cutoff: ~ 29,550 lbs.

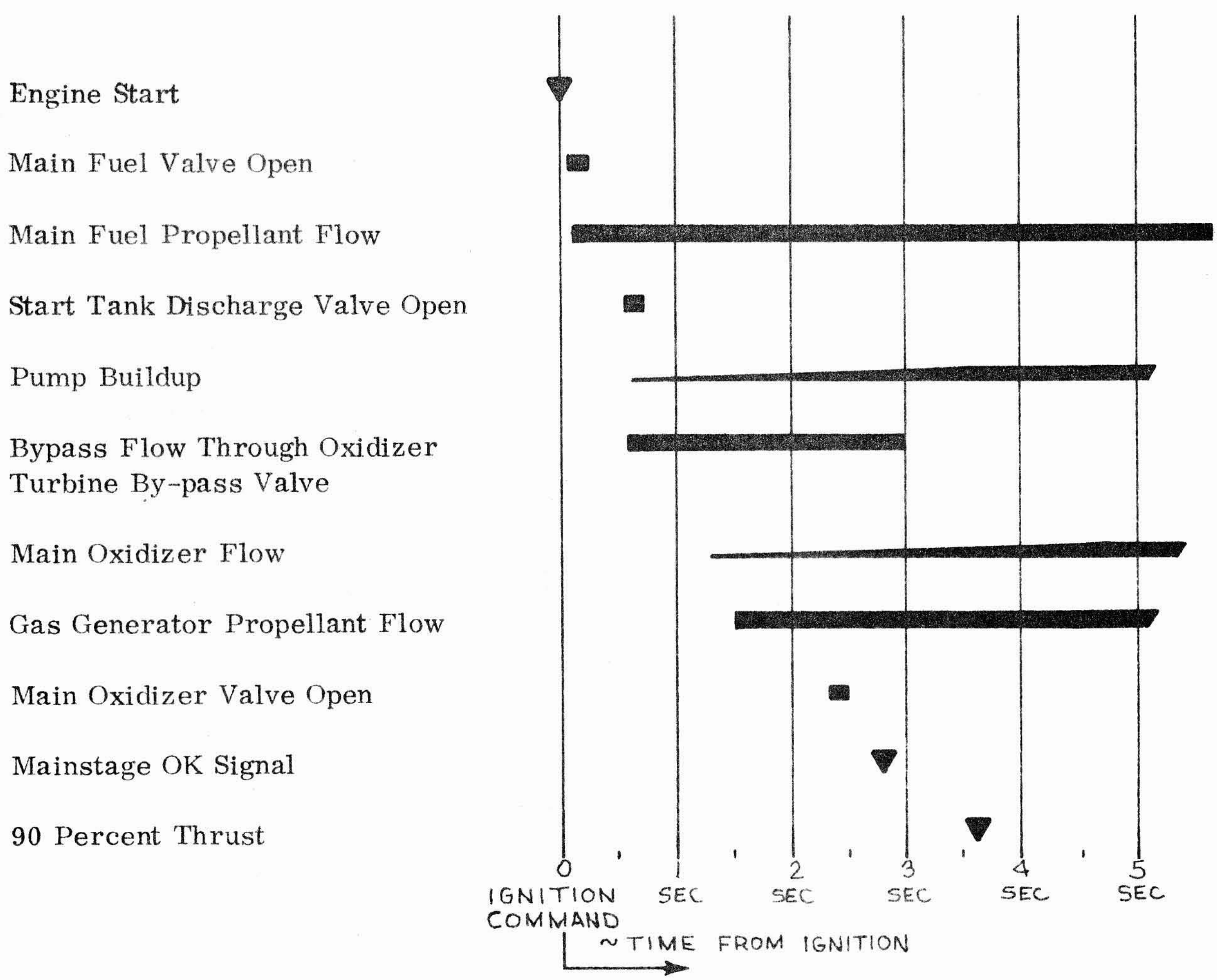
Figure 30

S-IVB Stage Configuration

J-2 ENGINE OPERATION S-IVB STAGE

The operating cycle of the J-2 Engine consists of prestart, start, steady-state operation and cutoff sequences. During prestart, LOX and LH_2 flow through the engine to temperature-condition the engine components, and to assure the presence of propellant in the turbopumps for starting. Following a timed cooldown period, the start signal is received by the sequence controller which energizes various control solenoid valves to open the propellant valves in the proper sequence. The sequence controller also energizes spark plugs in the gas generator and thrust chamber to ignite the propellant. In addition, the sequence controller releases GH_2 from the start tank. The GH_2 provides the initial drive for the turbopumps that deliver propellant to the gas generator and the engine. The propellant ignites, gas generator output accelerates the turbopumps, and engine thrust increases to main stage operation. At this time, the spark plugs are de-energized and the engine is in steady-state operation.

Steady-state operation is maintained until a cutoff signal is received by the sequence controller. The sequence controller de-energizes the solenoid valves which in turn close the engine propellant valves in the proper sequence. As a result, engine thrust decays and the cutoff sequence is complete.



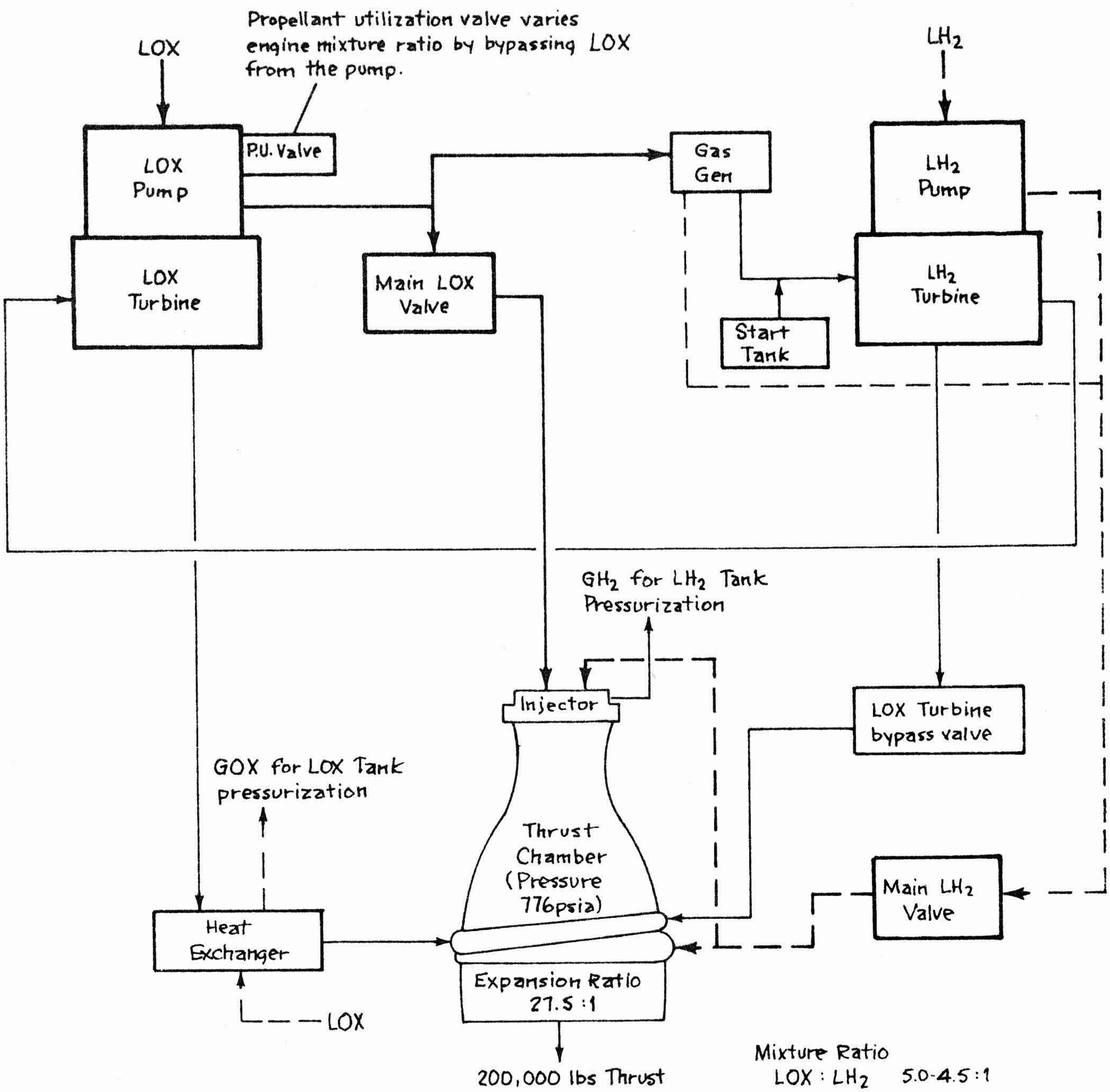


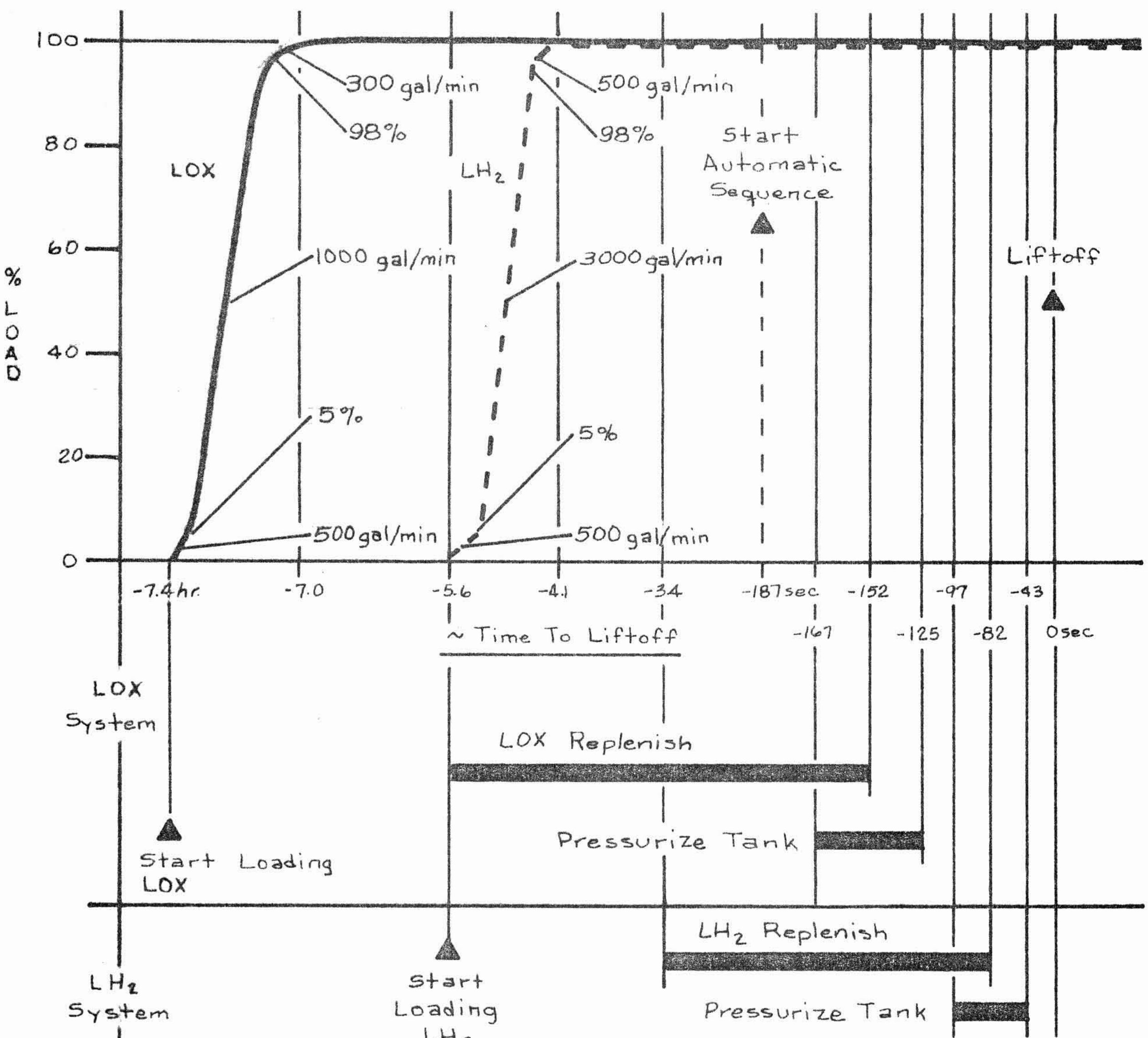
Figure 31

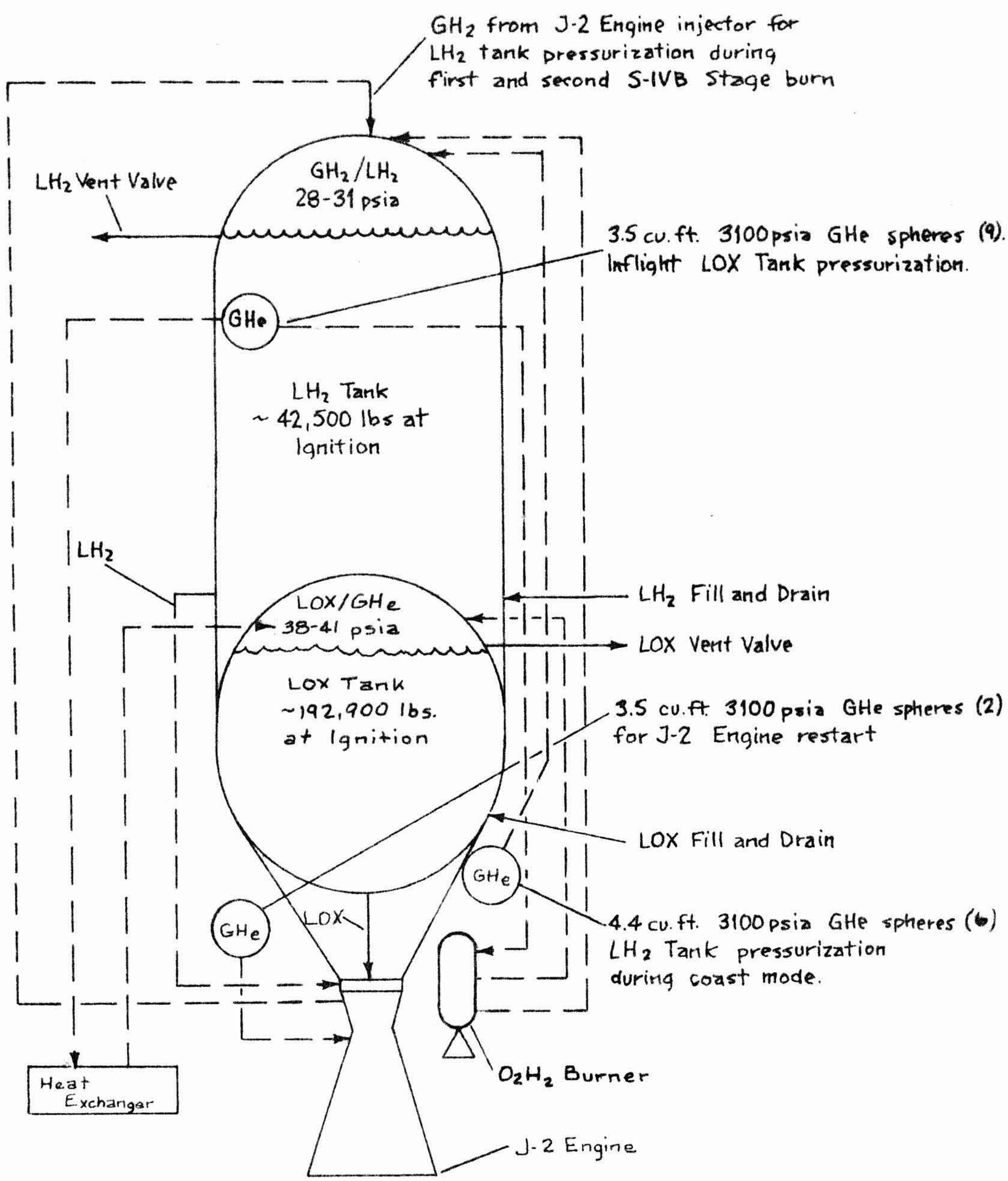
J-2 Engine System
S-IVB Stage

S-IVB STAGE PROPELLANT SYSTEM

The S-IVB Stage propellant system is composed of integral LOX/LH_2 tanks, propellant lines, control valves, vents, and pressurization subsystems. Loading of the propellant tanks and flow of propellants is controlled by the propellant utilization system. Both propellant tanks are initially pressurized by ground source cold helium. LOX tank pressurization during S-IVB stage burn is maintained by helium supplied from spheres in the LH_2 tank, which is expanded by passing through the helium heater, to maintain positive pressure across the common tank bulkhead and to satisfy engine net positive suction head. The LH_2 pressurization strengthens the stage in addition to satisfying net positive suction head requirements. After engine ignition the pressure is maintained by GH_2 tapped from the engine supply.

S-IVB PROPELLANT LOAD AND OPERATIONAL SEQUENCE





Total propellant at ignition ~ 236,250 lbs.
Total propellant consumed after ignition ~ 234,250 lbs.

Figure 32

S-IVB Stage Propellant System

S-IVB STAGE PROPELLANT MANAGEMENT SYSTEM

The propellant management system, in conjunction with the switch selector, controls mass propellant loading and engine mixture ratios (LOX to LH_2) to ensure balanced consumption of LOX and LH_2.

Capacitance probes, mounted in the LOX and LH_2 containers, monitor the mass of the propellants during powered flight. During flight, the LOX/LH_2 capacitance probes are not utilized to control the propellant mixture ratio. This mode is considered to be an "open-loop", time-shift operation. During engine start and first burn, the ratio of LOX to LH_2 is 5.0 to 1. The ratio at restart is 4.5 to 1 and shortly after the engine reaches 90 percent thrust the mixture ratio is shifted to 5.0 to 1 which will be used for the second burn.

Engine cutoff is initiated when any two of the five capacitance probes, in either tank, indicate dry.

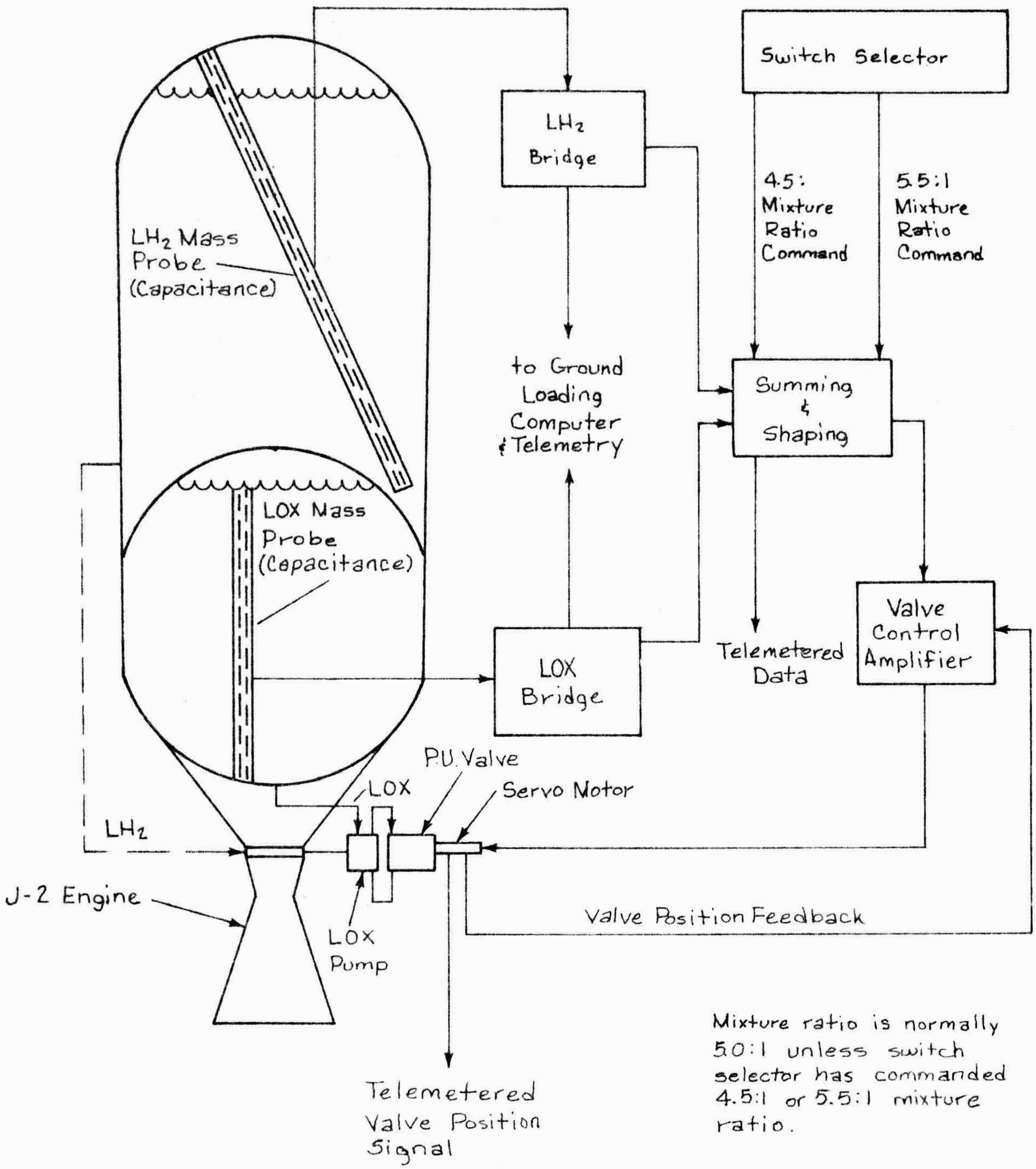


Figure 33

S-IVB Stage Propellant Management System

S-IVB STAGE THRUST VECTOR CONTROL SYSTEM

The single J-2 Engine is gimbal mounted on the longitudinal axis of the S-IVB Stage. Power for gimballing is supplied by a hydraulic control system mounted on the engine.

Pitch and yaw control, during powered flight, is maintained by actuator control of the engine thrust vector. Roll control of the stage is maintained by properly sequencing the pulse-fired hypergolic propellant thrust motors in the APS. When the stage enters the coast mode, the APS thrust motors control the stage in all three axes.

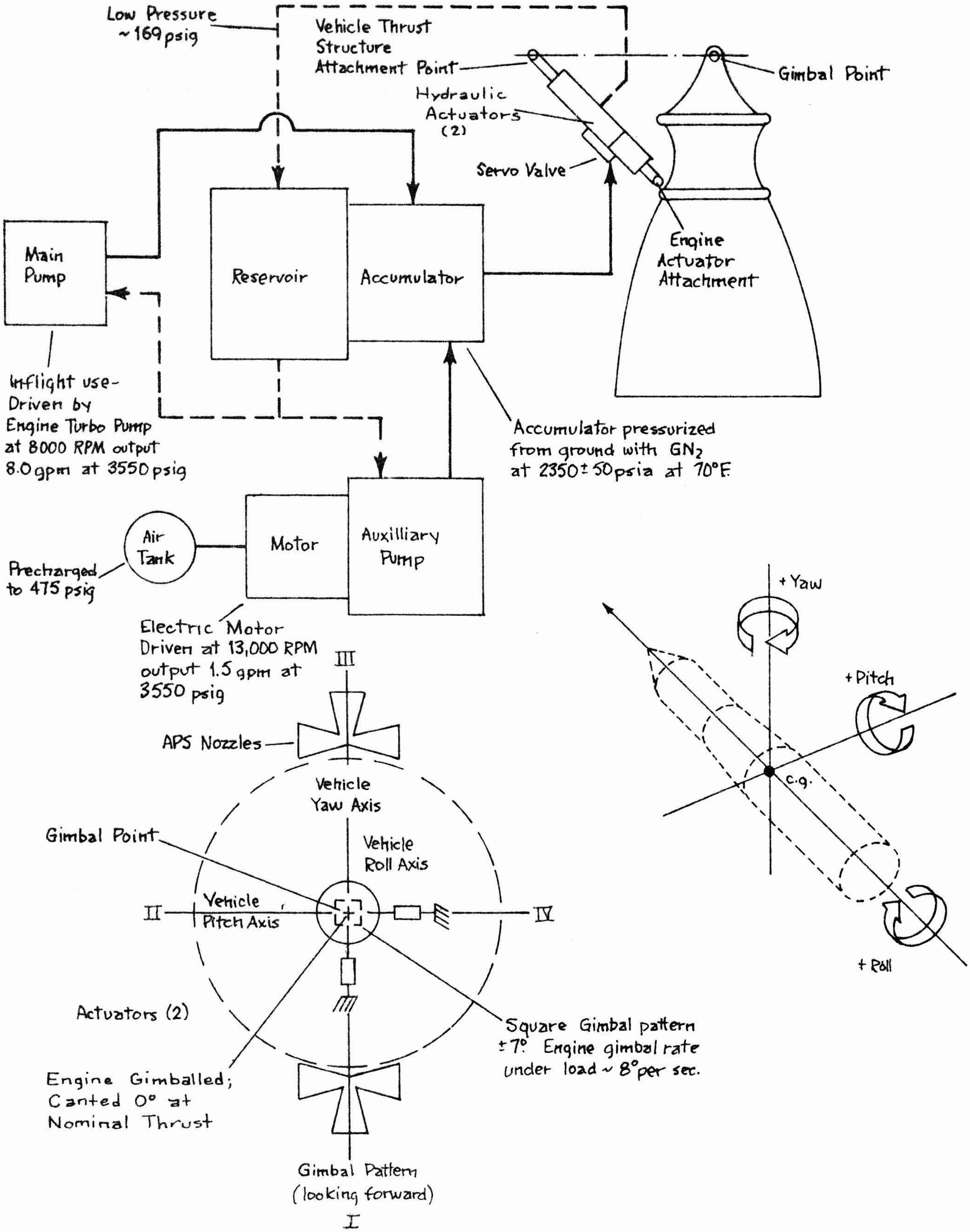


Figure 34

S-IVB Stage Thrust Vector Control System

AUXILIARY PROPULSION SYSTEM

The APS consists of two self-contained attitude control modules mounted 180 degrees apart on the aft skirt of the S-IVB stage. Each attitude control module contains four thrust motors which use hypergolic propellant nitrogen tetroxide (N_2O_4) and monomethylhydrazine (MMH) . The thrust motors are pulse-fired and no ignition system is required. Three thrust motors in each module provide pitch, yaw and roll control during the S-IVB coast mode of operation, and roll control during S-IVB powered flight. An ullaging engine is included in each module to settle propellants.

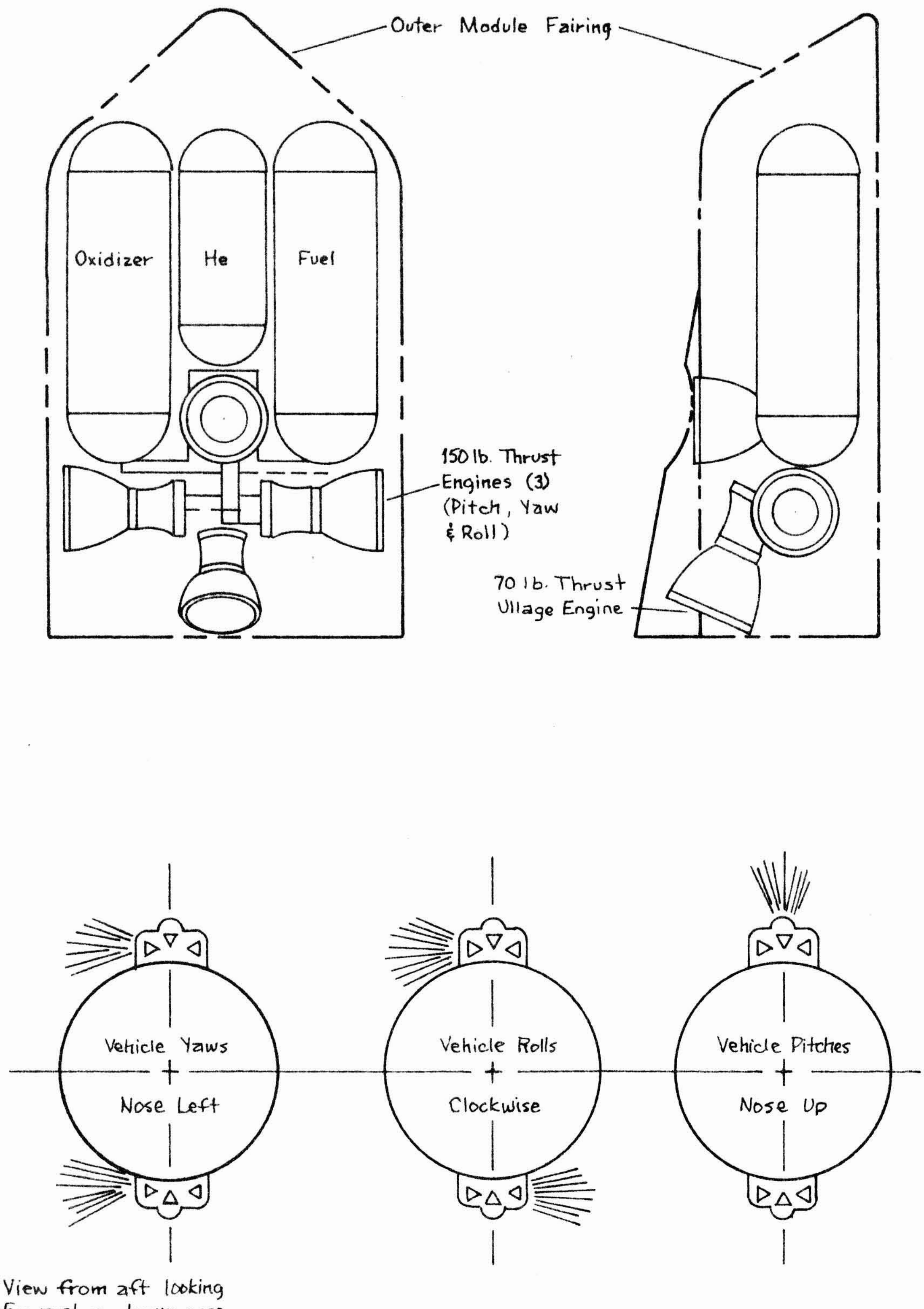


Figure 35

Auxilliary Propulsion System

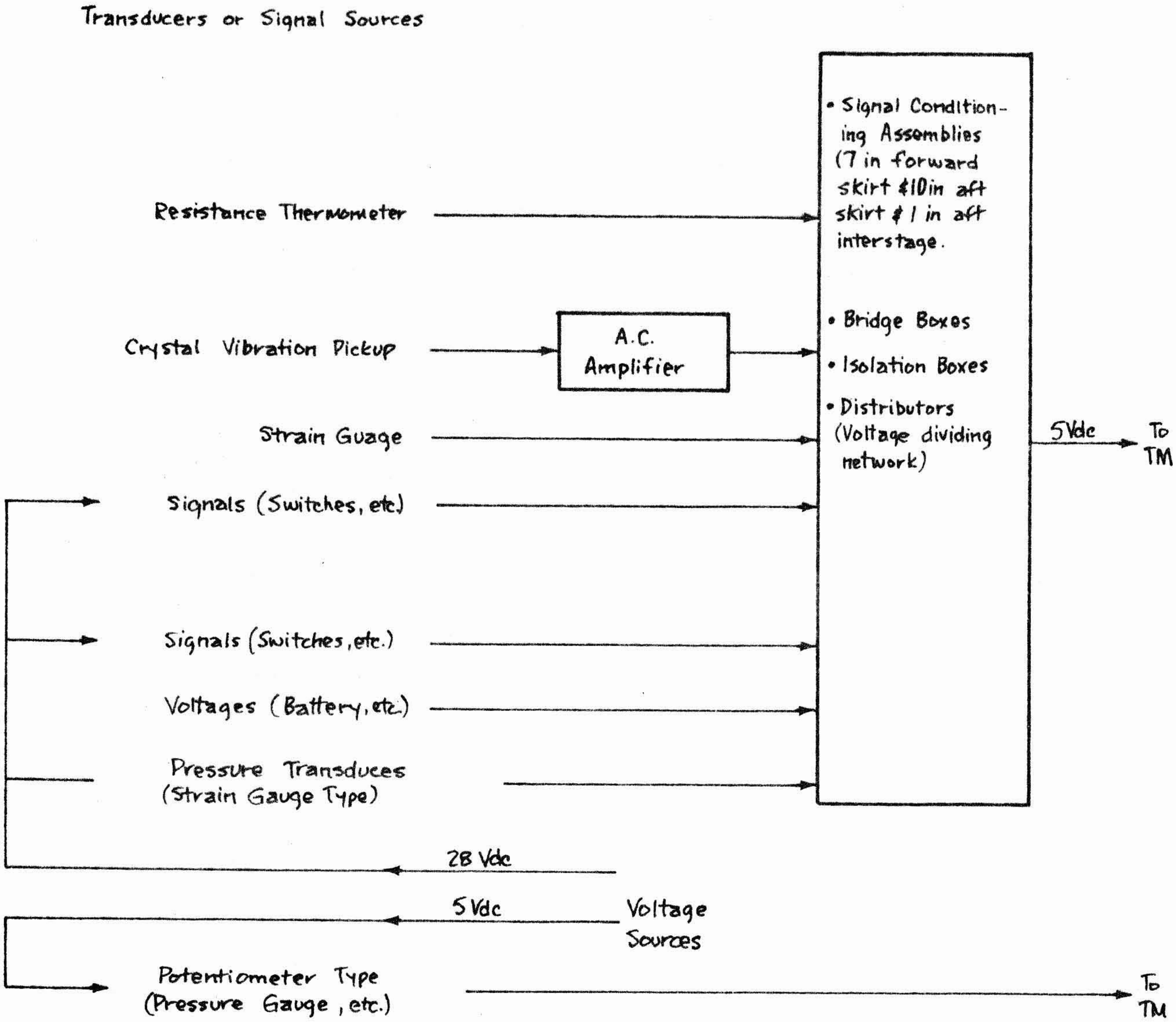


Figure 36

S-IVB Stage Measuring System

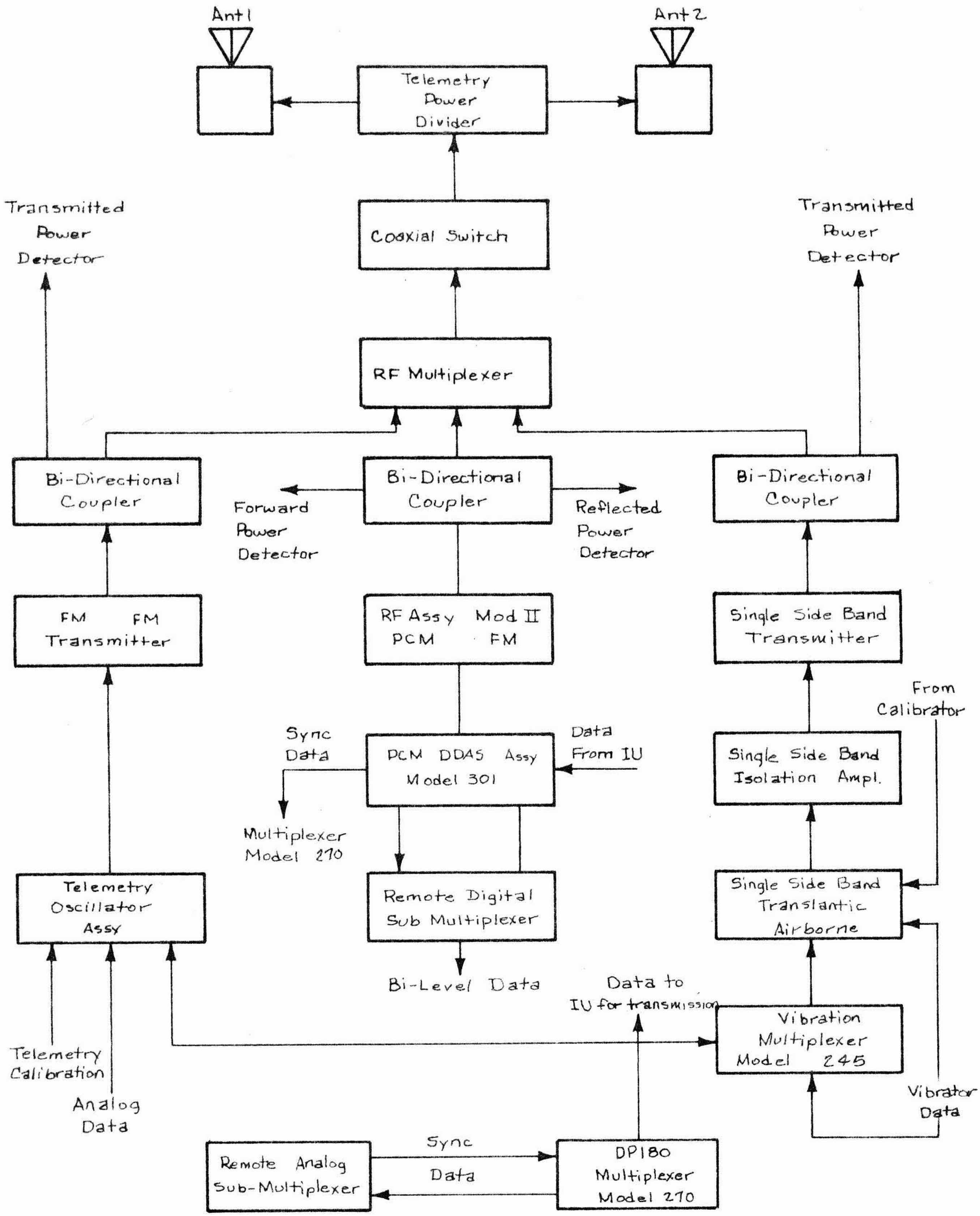


Figure 37

S-IVB Telemetry System

Note: Most forward Interstage Components Are Mounted On Coldplates

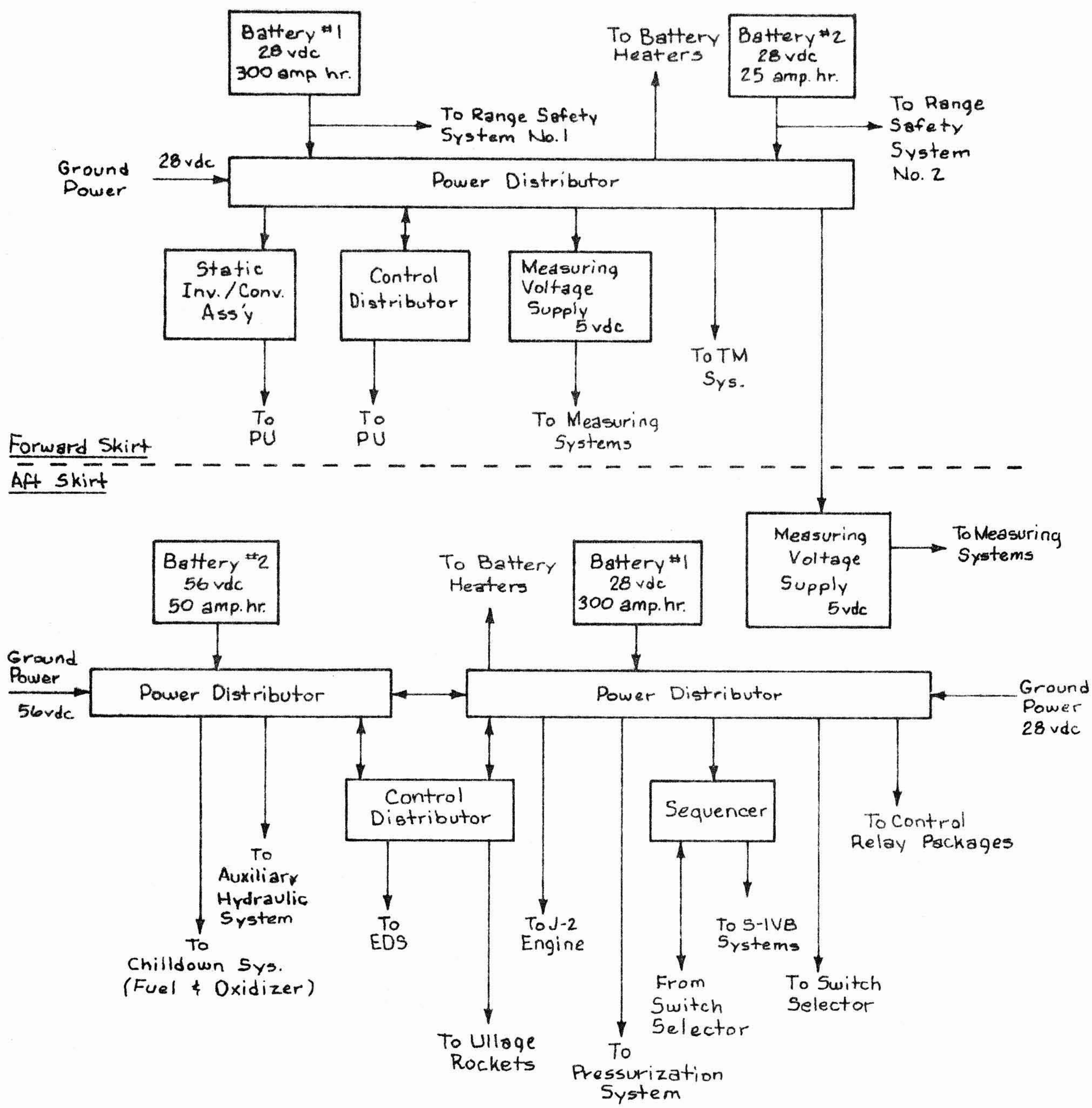


Figure 38

S-IVB Stage Electrical Power and Distribution System

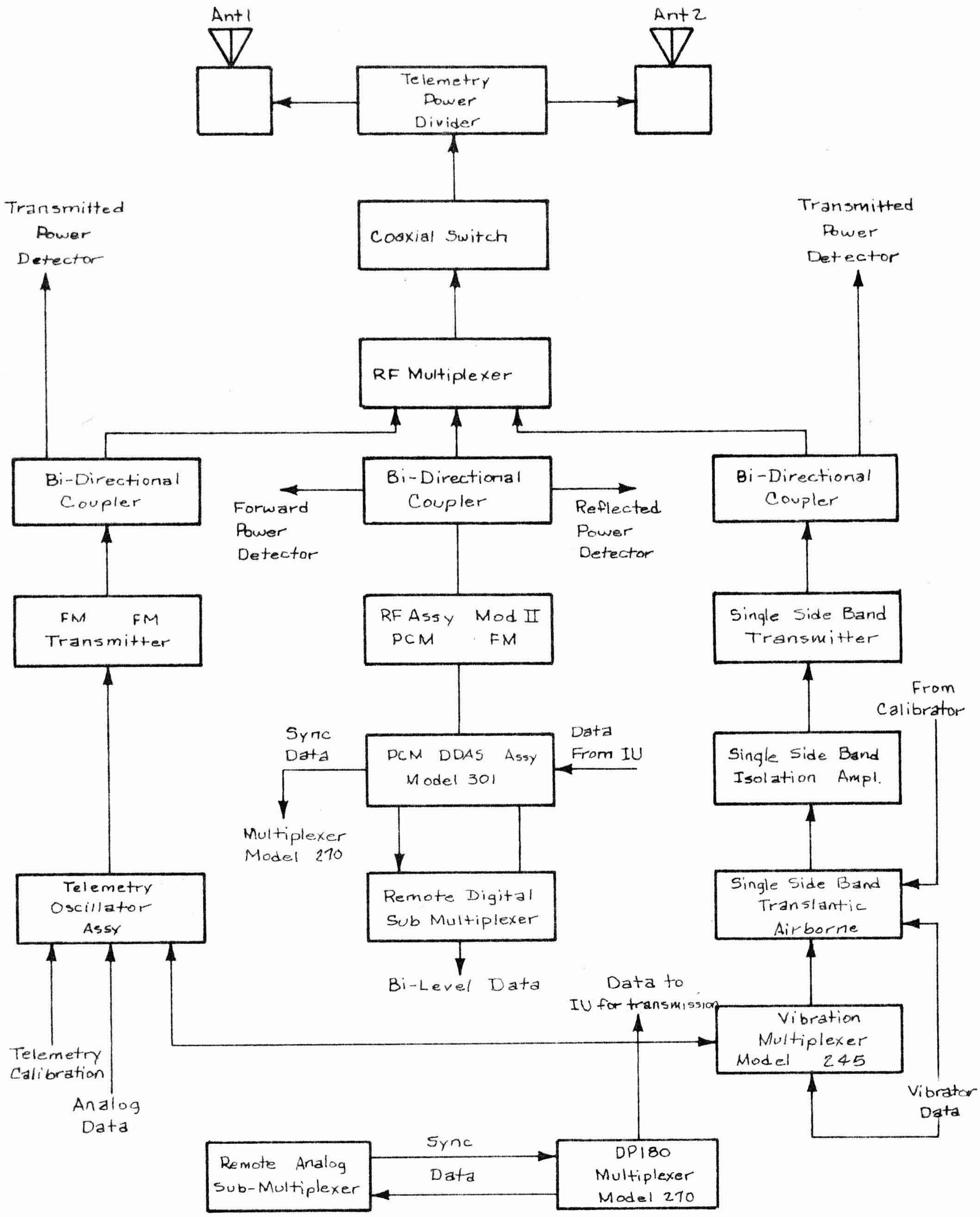


Figure 37

S-IVB Telemetry System

Note: Most forward Interstage Components Are Mounted On Coldplates

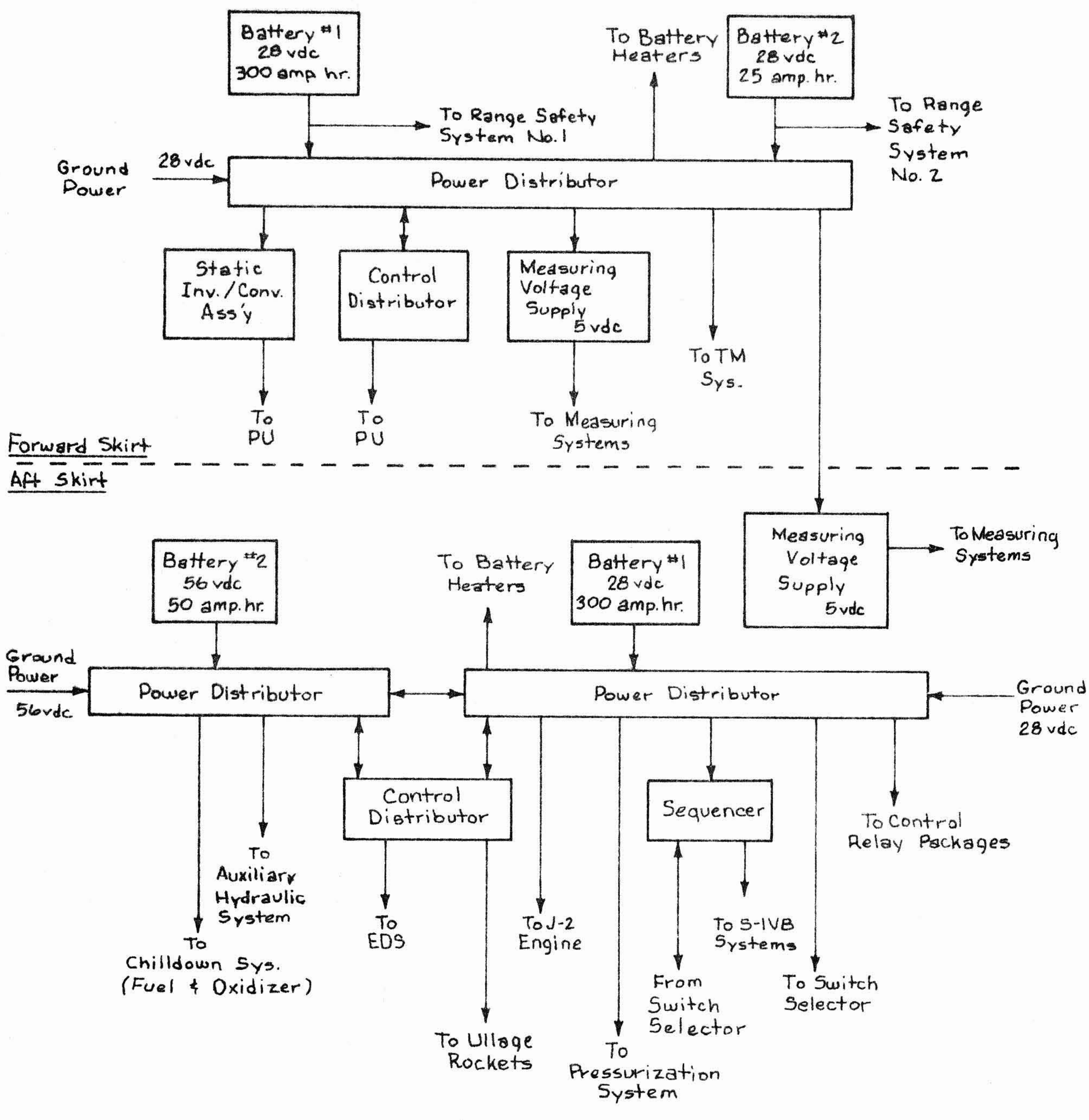


Figure 38

S-IVB Stage Electrical Power and Distribution System

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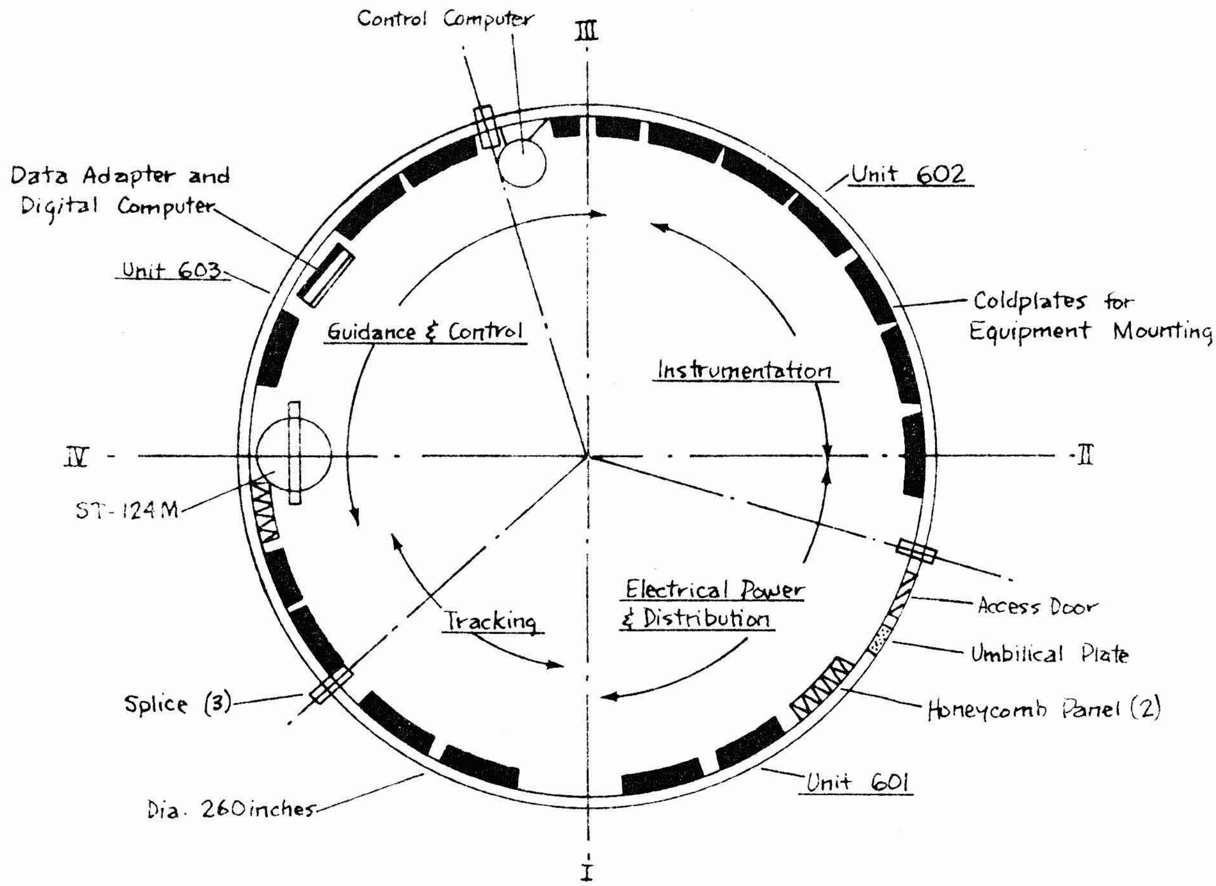
INSTRUMENT UNIT

The Instrument Unit is a cylindrical structure approximately 260 inches in diameter and 36 inches high which is attached to the forward end of the S-IVB stage.

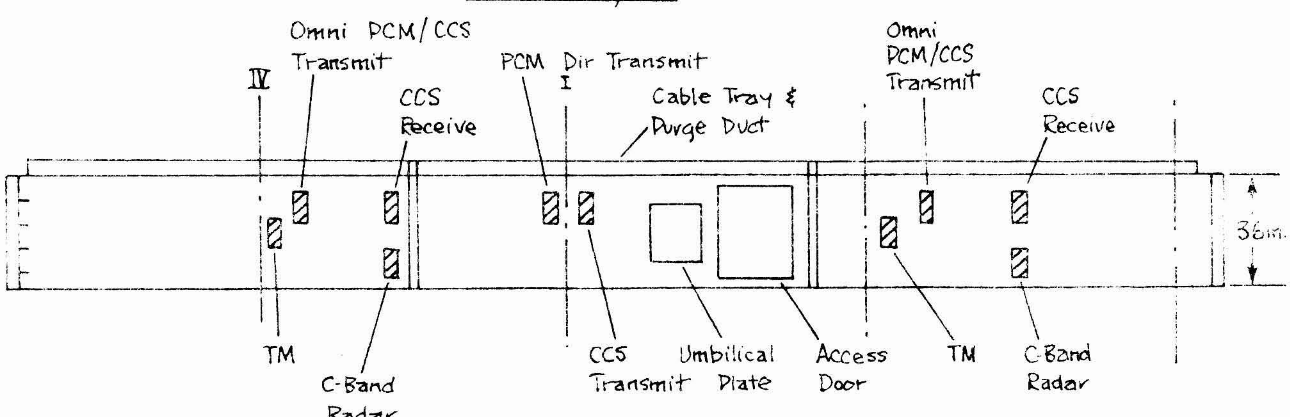
The IU contains the guidance, navigation, and control equipment necessary for vehicle guidance through earth orbit and subsequent mission trajectory.

IU structure is composed of an aluminum alloy honeycomb sandwich material which was selected for its high strength-to-weight ratio, acoustical insulation, and thermal conductivity properties.

The cylinder is composed of three 120 degree segments -- the access door segment, the flight control computer segment, and the ST-124-M segment.



View Looking Aft



Antenna Arrangement

Weight:
- Dry ~ 4,700 lbs.
  Serviced ~ 4,900 lbs.

Figure 39

Instrument Unit Configuration

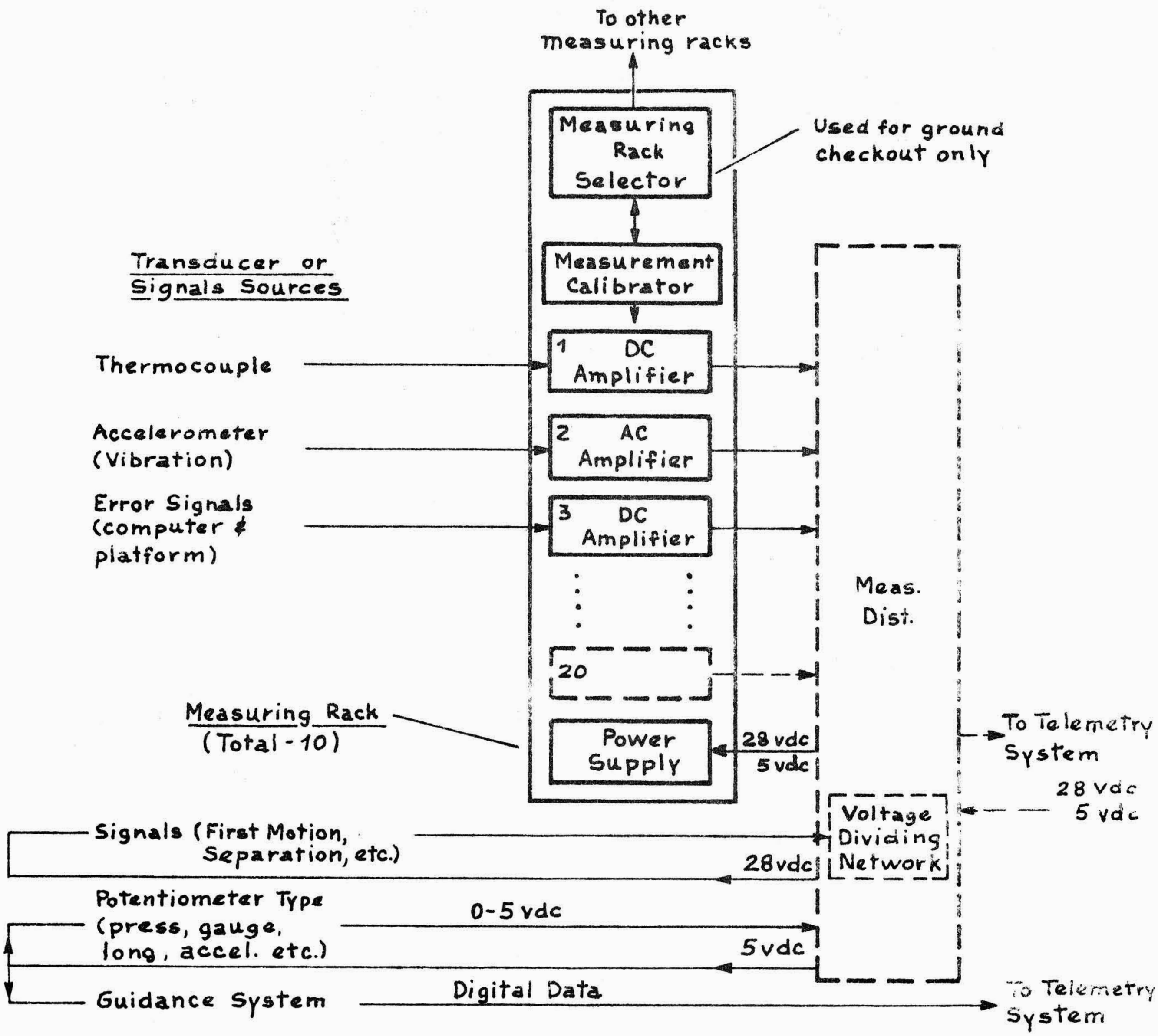


figure 40

Instrument Unit Measuring System

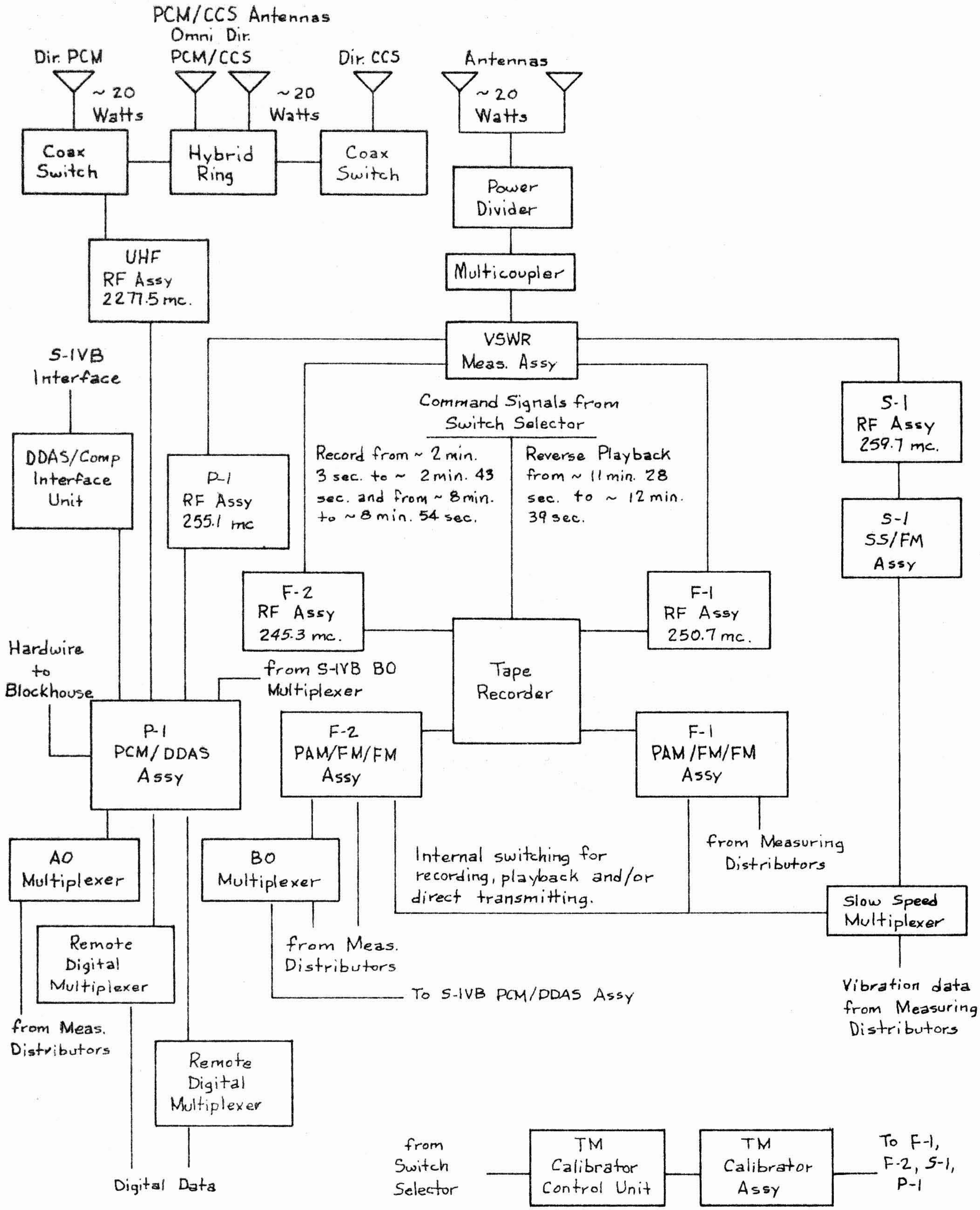


Figure 41

Instrument Unit Telemetry System

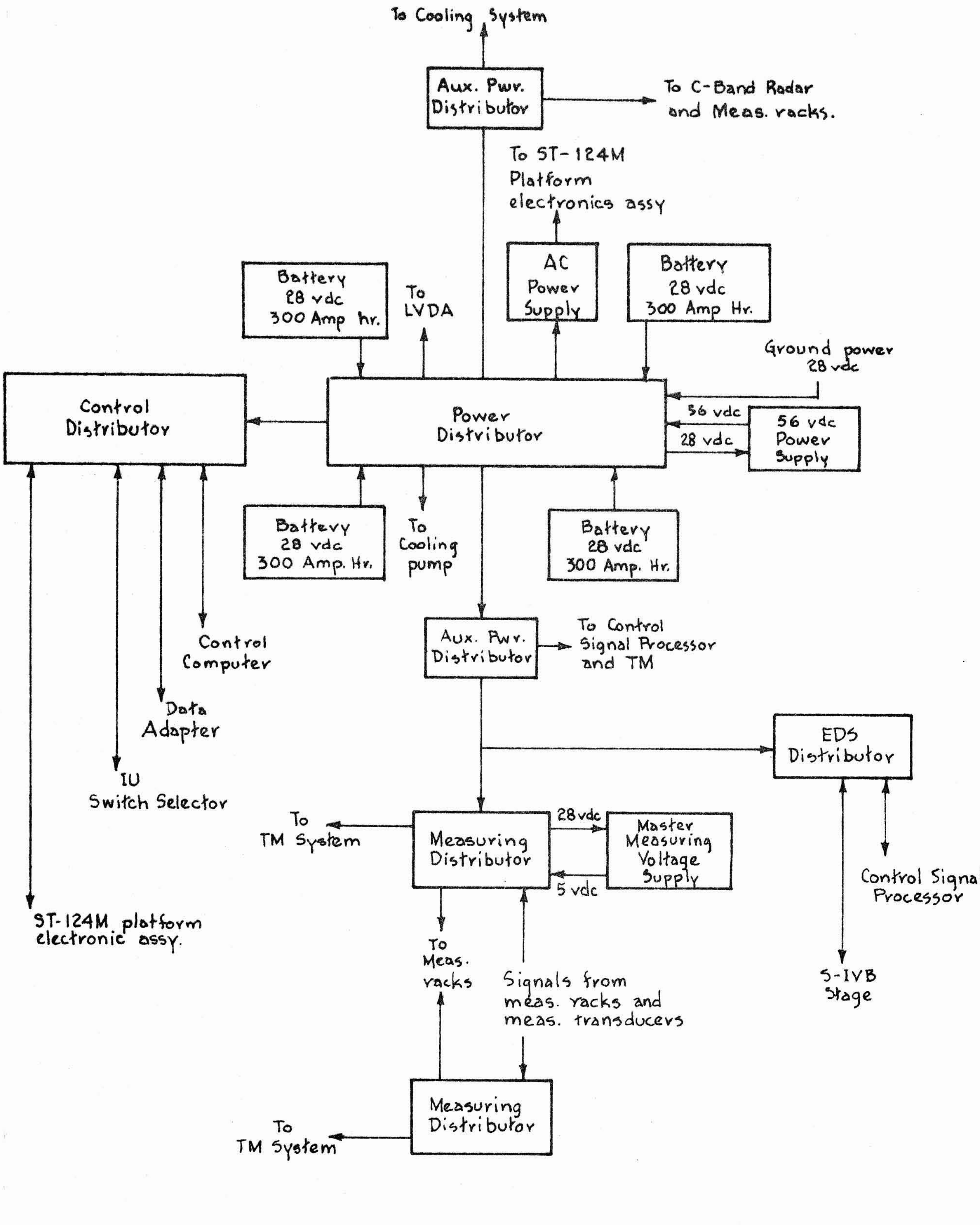


Figure 42

Instrument Unit Electrical Power and Distribution System

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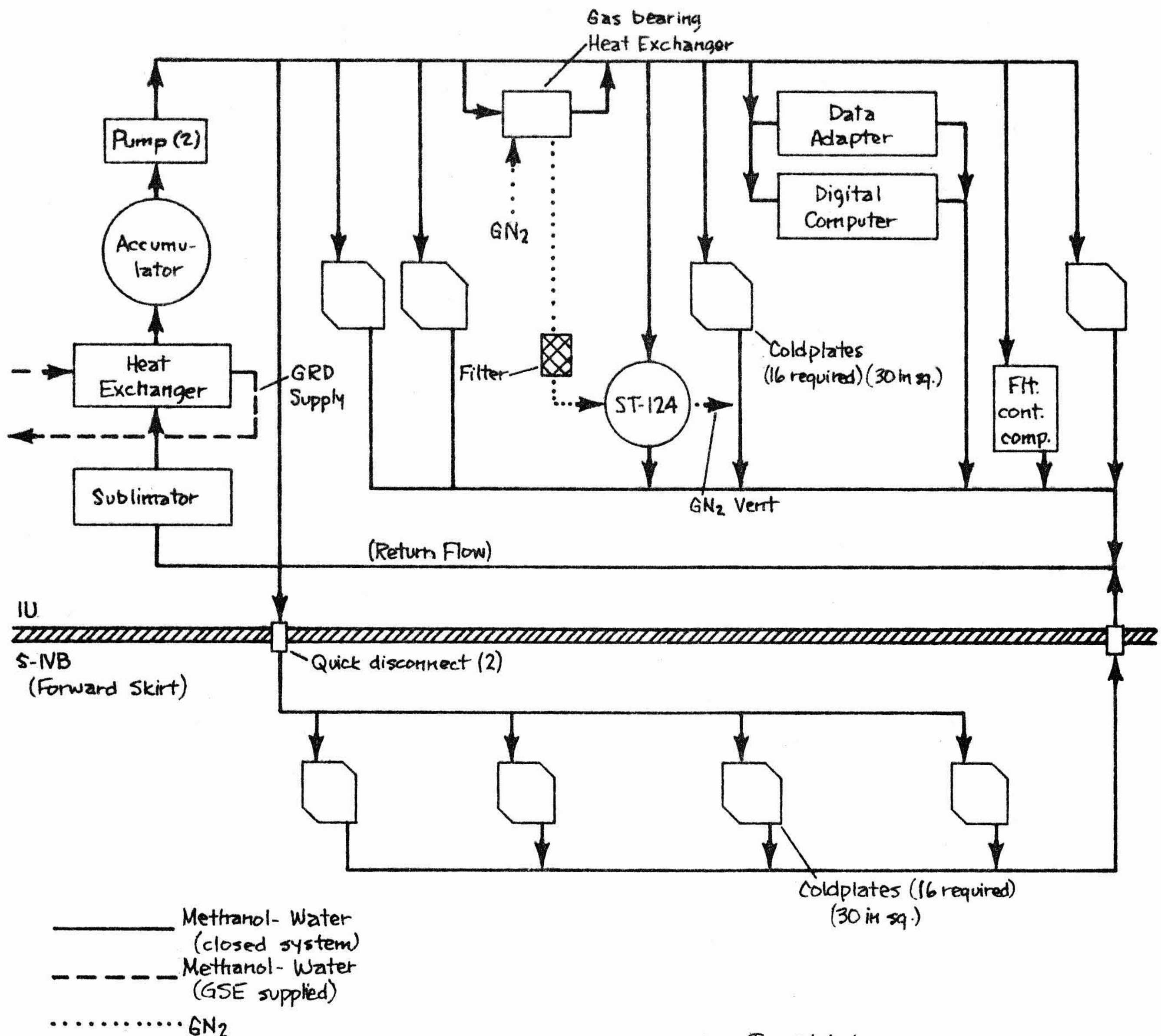
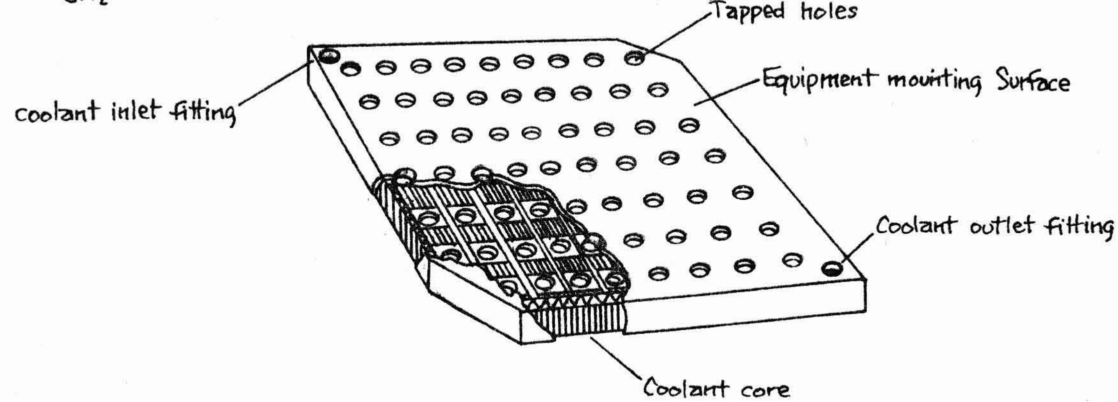
ENVIRONMENTAL CONTROL SYSTEM (ECS)

Heat generated by the electronic equipment located in the S-IVB forward skirt and the IU is absorbed by circulating a methanol-water solution through the coldplate network.

Prior to liftoff, a temperature controlled methanol-water solution is supplied and circulated through the coldplates from the GSE. After liftoff the ECS is a selfcontained unit which begins operation 3 minutes after liftoff when the sublimator is activated.





Typical Coldplate

Figure 43

IU/S-IVB Environmental Control System

SPACECRAFT DESCRIPTION

The Spacecraft for the AS-503 mission is composed of:

Launch Escape System (LES)
Command Module (CM)
Service Module (SM)
Lunar Module Adapter (LMA)
Lunar Test Article (B) (LTA-B)

Launch Escape System

The LES, which is jettisoned approximately 35 seconds after S-II Ignition, is made up of a Launch Escape Tower (LET), and a three-motor propulsion system (Tower Jettison, Launch Escape and Pitch Control Motors).

Command Module

The Command Module for AS-503 is a Block II Configuration. The module's inner structure, or pressure vessel, is separated from the outer structure by a layer of insulation. A heat shield structure is made up in three segments consisting of a forward heat shield, a crew compartment heat shield, and an aft shield. The CM is slightly over 11 feet in length and is about 12 feet in diameter. A propulsion system consists of Reaction Control Engines which may operate pulsed or continuous.

Service Module

The Service Module may be described as a cylindrical, aluminum, shell which is made up of honeycomb-sandwich panels and a forward and aft bulkhead. One gimballed propulsion engine (capable of up to 30 restarts) and a reaction control system (4 clusters, 4 chambers each) make up the SM Propulsion System. The Command and Service Module are joined by 3 tension ties each of which is equipped with explosive charges for SM/CM separation.

Lunar Module Adapter

The LM Adapter joints the SM to the S-IVB/IU. This unit will enclose the Lunar Module Test Article, LTA-B.

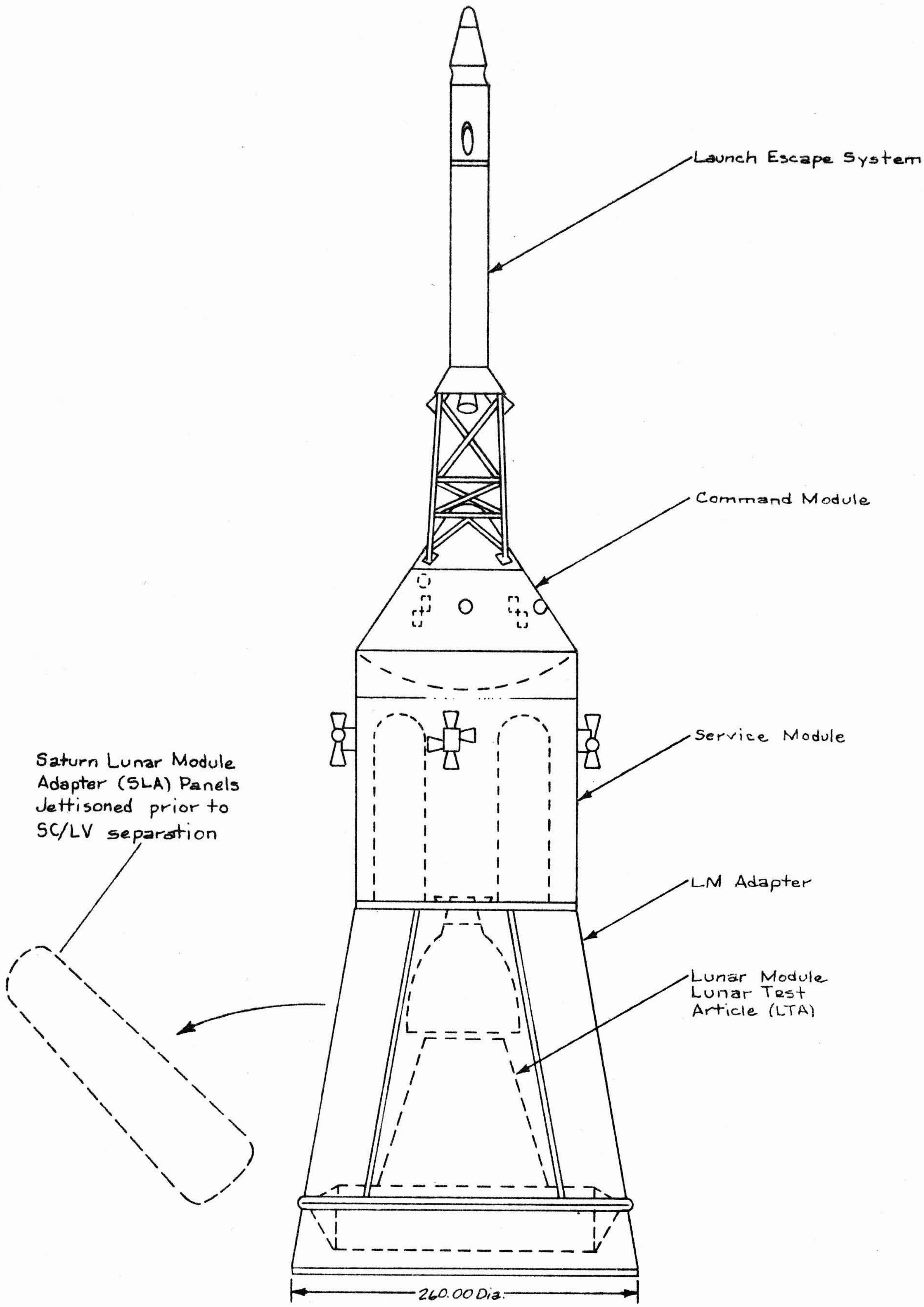


Figure 44

Spacecraft Configuration

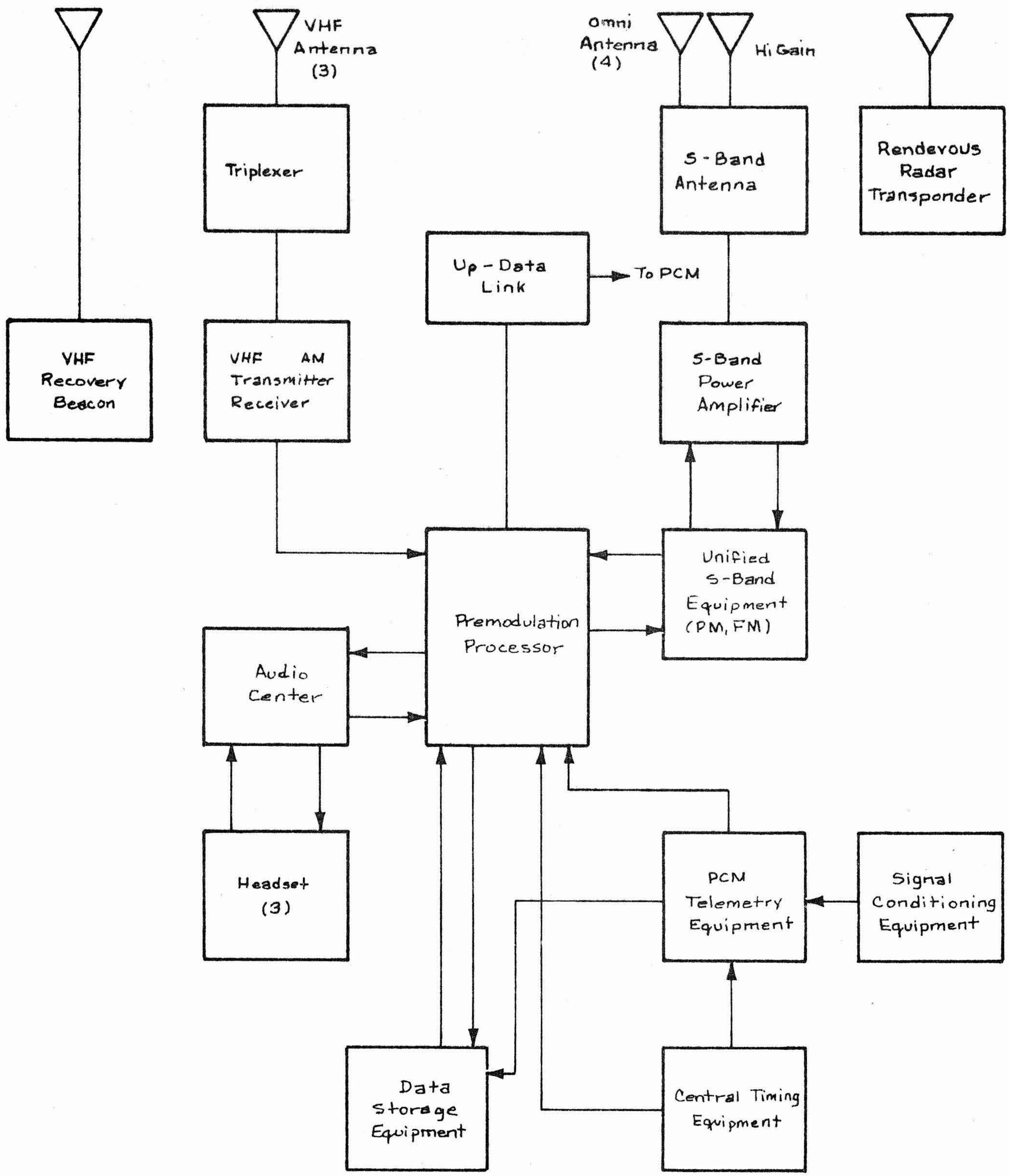


Figure 45

Telecommunication System

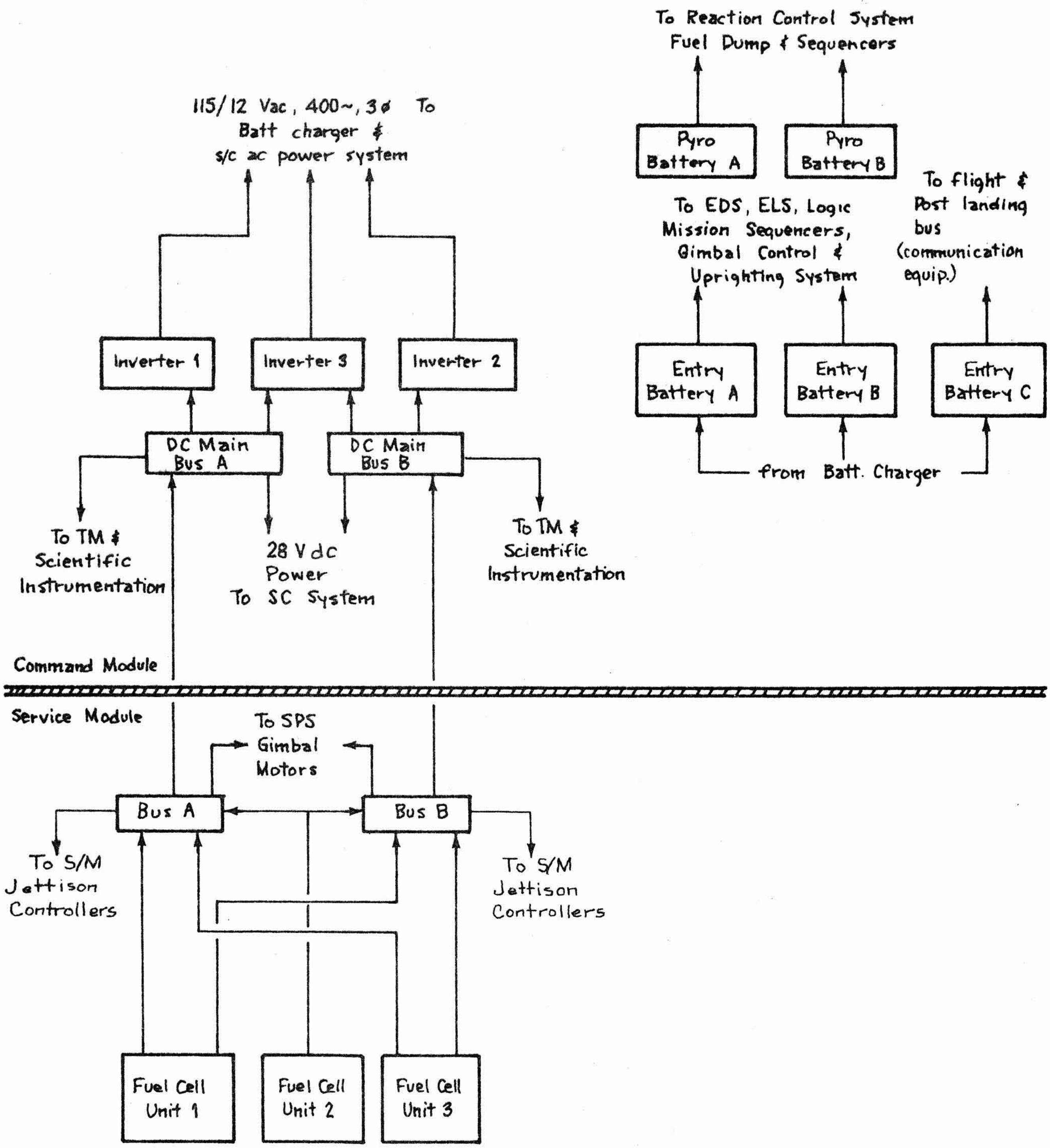


Figure 46

Spacecraft Electrical
Power & Distribution System

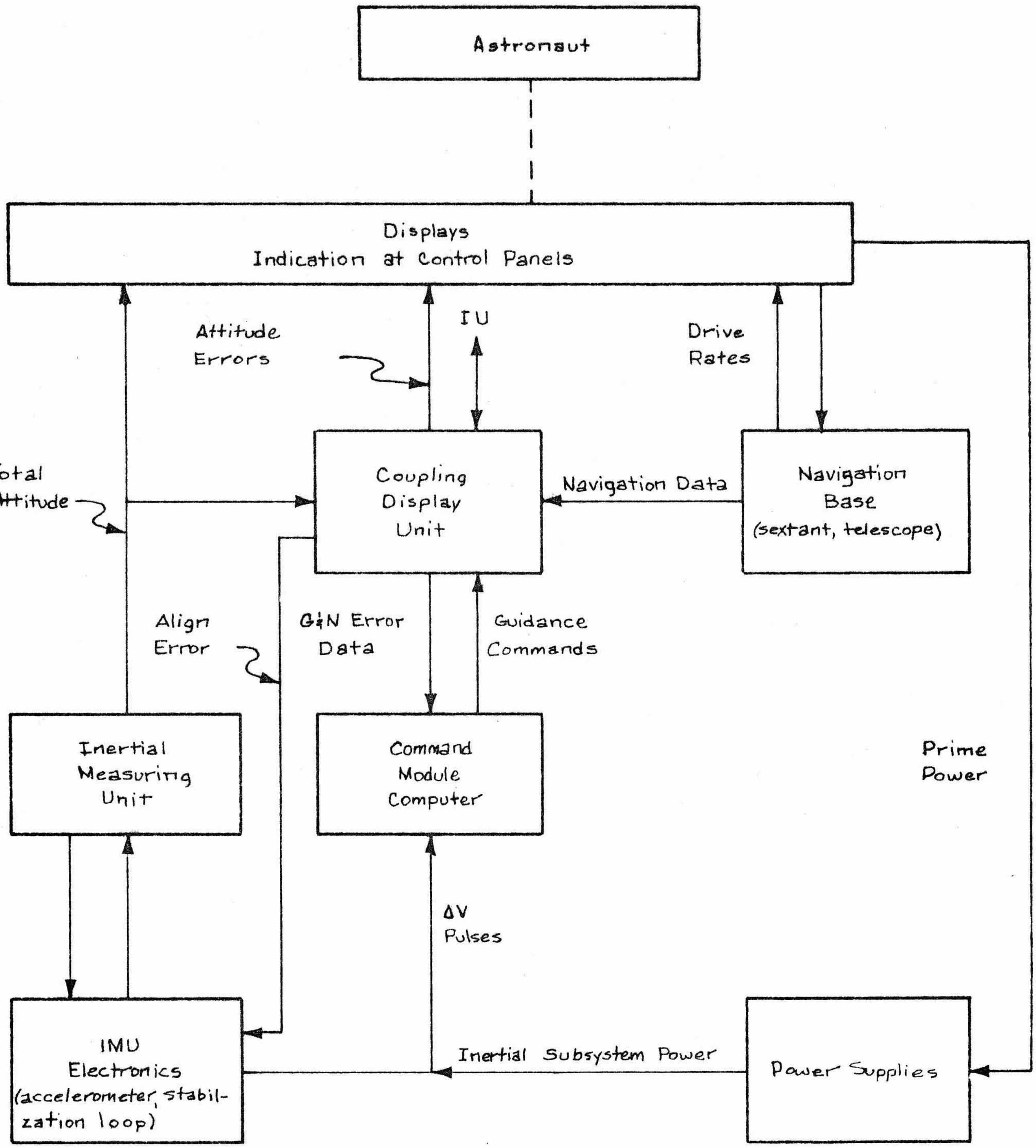


Figure 47

Spacecraft Guidance & Navigation System

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