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R-ASTR-S-67-65
September 15, 1967

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

TECHNICAL INFORMATION SUMMARY

AS-501

APOLLO SATURN V FLIGHT VEHICLE

PREPARED BY:
R-AERO-P
R-ASTR-S
R-P & VE-VNC

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

AS-501

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-501 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 purpose of the AS-501 mission is to develop the Saturn V launch vehicle for manned flights and to verify the adequacy of the Apollo Command Module heat shield at lunar reentry velocities.

The AS-501 mission is an unmanned, elliptical earth orbital flight.

2. Mission Objectives:

a. Demonstrate structure and thermal integrity, and compatibility of the launch vehicle and spacecraft, and determine structural loads and dynamic characteristics during powered and coasting flight.

b. Determine launch vehicle in-flight internal environment.

c. Verify launch support equipment compatibility, and mission support capability for launch and mission operations to high post-injection altitudes and Command Module recovery.

d. Demonstrate the S-IC and S-II stage propulsion systems and determine in-flight system performance parameter.

e. Demonstrate the launch vehicle guidance and control system during powered flight; achieve guidance cutoff and evaluate system accuracy.

f. Demonstrate S-IC/S-II dual plane separation and S-II/S-IVB separation.

g. Demonstrate launch vehicle sequencing system.

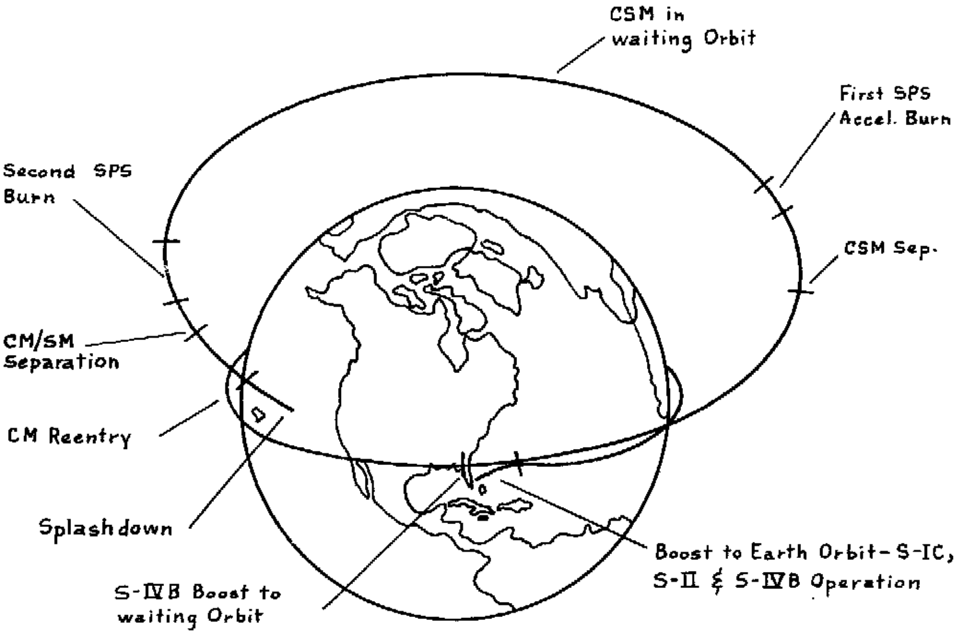
h. Evaluate performance of the emergency detection system (EDS) in an open-loop configuration.

i. Demonstrate S-IVB stage restart capability.

j. Verify adequacy of the Command Module heat shield for reentry at lunar return conditions.

3. Mission Profiles:

AS-501 will be launched from Launch Complex 39, Pad A, Kennedy Space Center (KSC); at a launch azimuth of 90°E of N. Shortly after liftoff (approximately 12 sec) the vehicle begins a roll maneuver to attain a flight azimuth of 72°E of N and maintains a near zero-lift (gravity turn) trajectory through the maximum dynamic pressure region. After S-IC burn and separation; S-II burn and separation, the first burn of the S-IVB will propel the S-IVB/IU/Spacecraft into a 100-nautical-mile parking orbit using the Iterative Guidance Mode (IGM). The vehicle will remain in this orbit for approximately two revolutions with its' longitudinal axis in the orbital plane and parallel to the local horizon. During the second revolution, when the vehicle is within tracking range of KSC, the S-IVB engine will be re-started to boost the vehicle into an elliptical atmosphere - intersecting waiting orbit with an apogee of approximately 9,000 nautical miles. Spacecraft separation occurs approximately 590 seconds after injection into waiting orbit. The coast time in waiting orbit between S-IVB cutoff and Command Module (CM) reentry is approximately 4.6 hours. Shortly after spacecraft separation a service propulsion system (SPS) burn and navigational corrections will be performed to achieve lunar return velocity and the proper reentry corridor. Following the second SPS burn, Command Module/Service Module (CM/SM) separation will occur and the CM will be reoriented for a guided lifting reentry which will produce the heat load desired to test the CM heat shield at lunar returning velocity. Splash-down will be near Hawaii.



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S-IVB STAGE

INSTRUMENT UNIT

SPACECRAFT

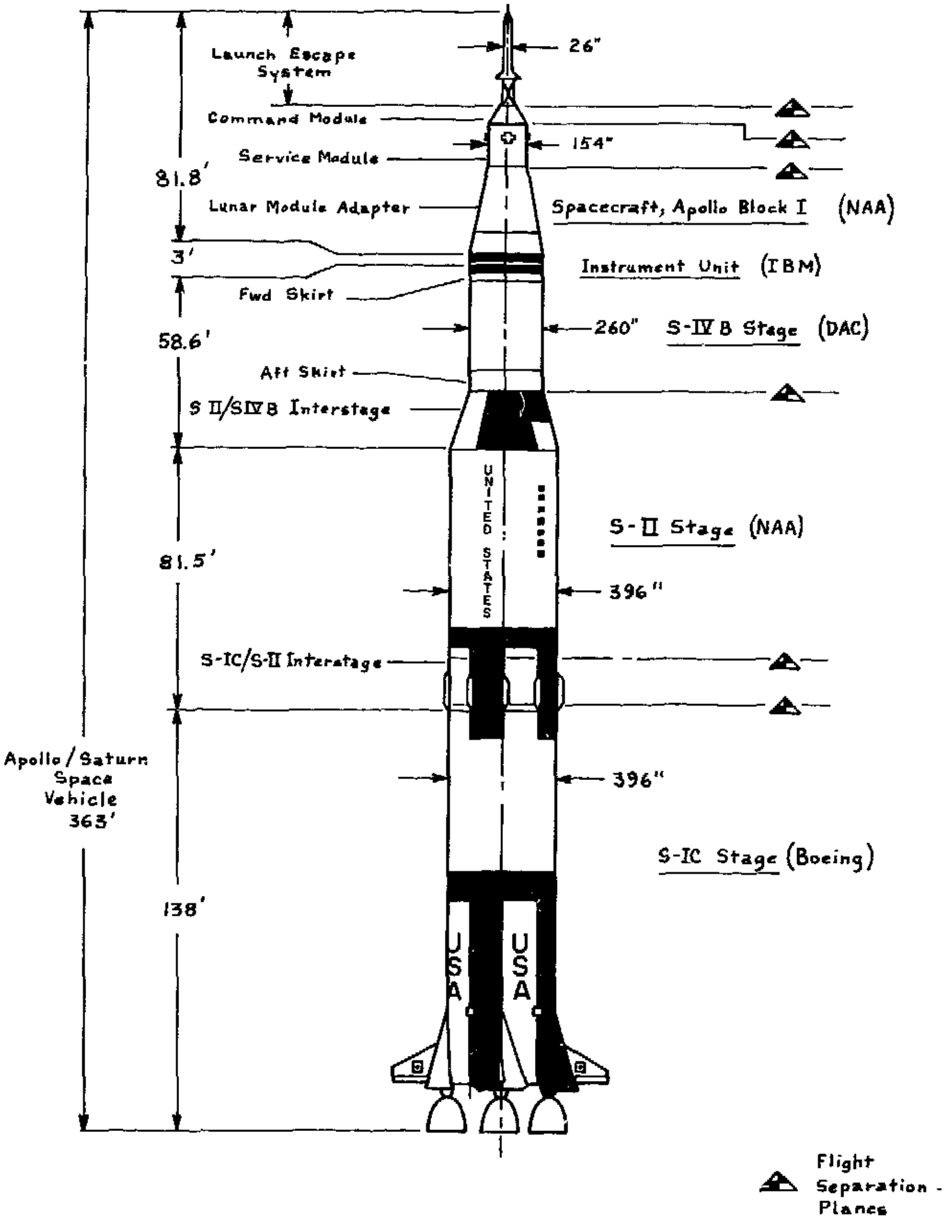
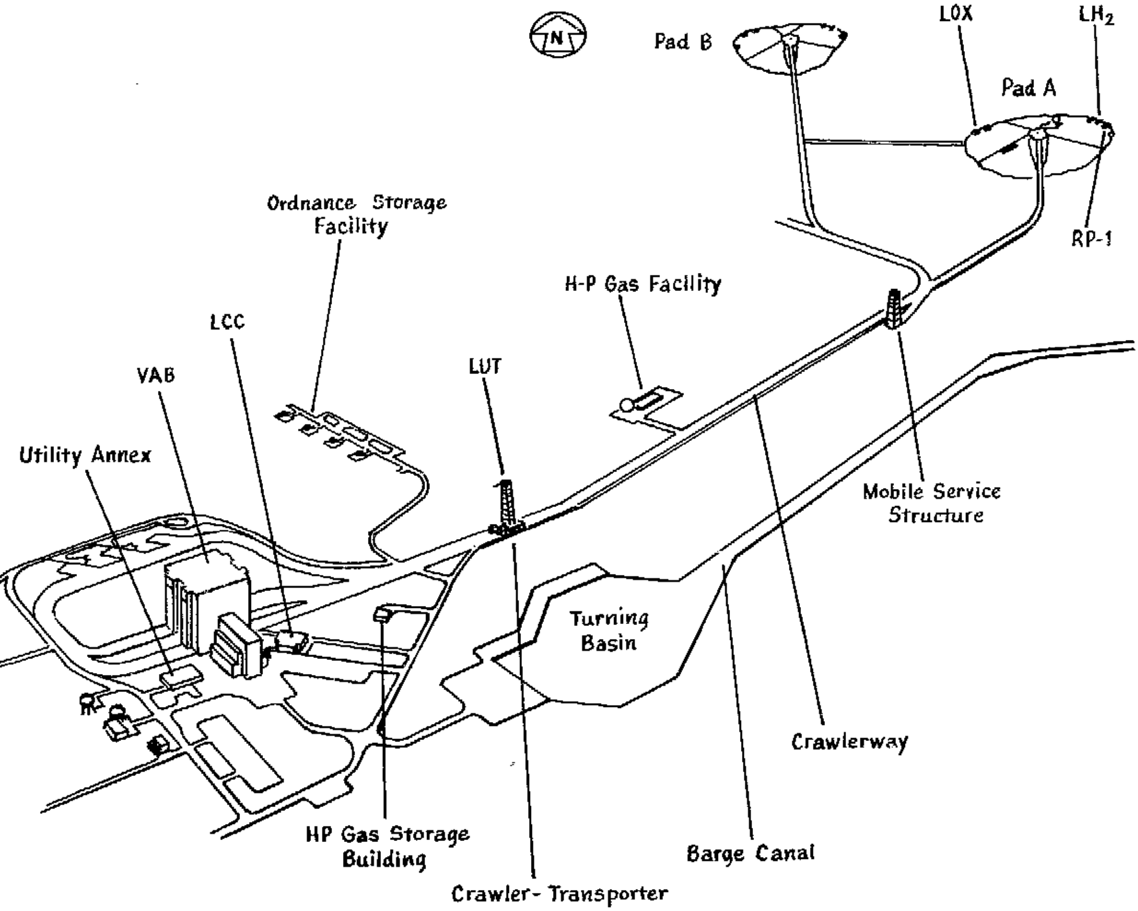


Figure 1

AS-501 Space Vehicle



Launch Complex 39

Figure 2

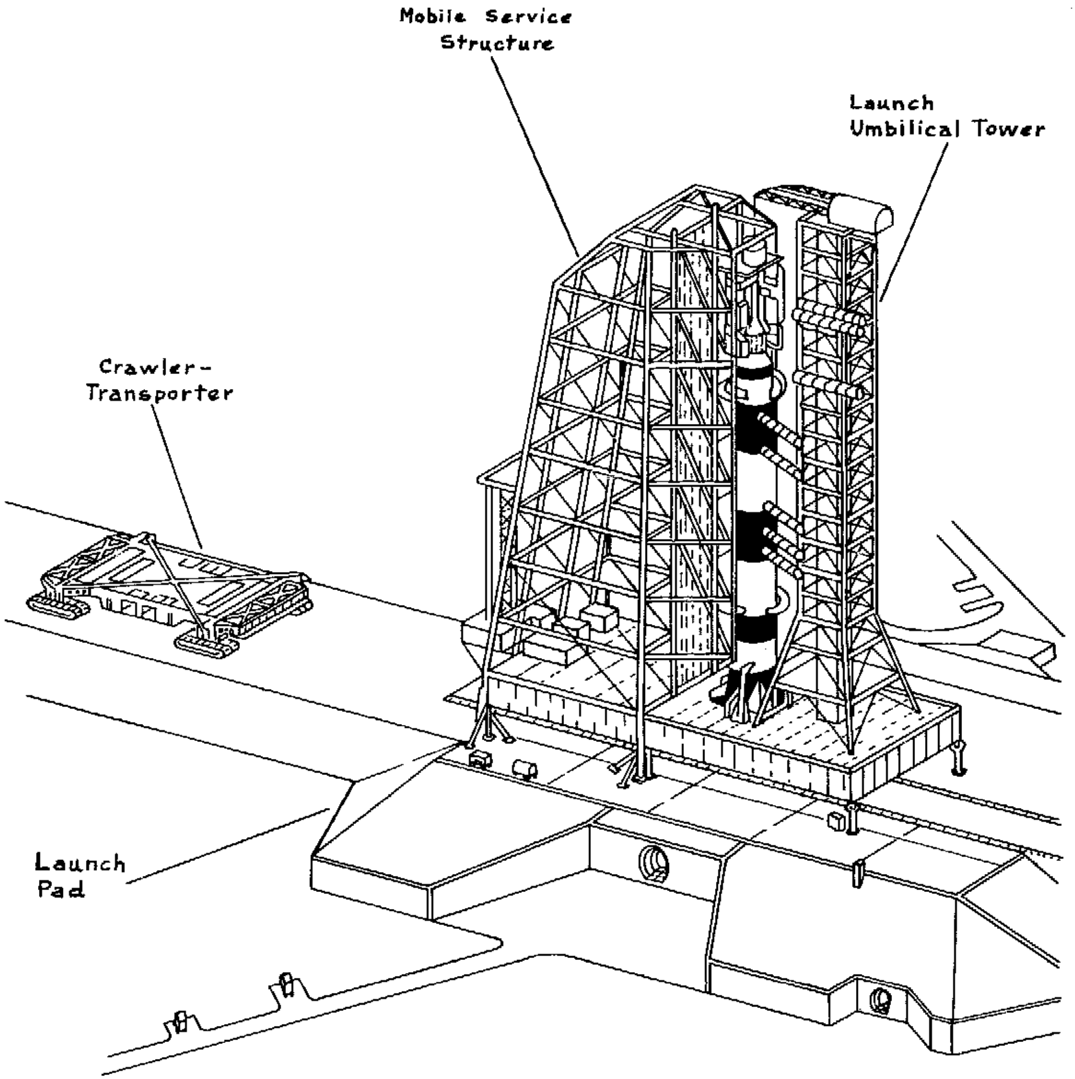


Figure 3

LC-39 Pad "A" Configuration

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LAUNCH VEHICLE SECURE RANGE SAFETY SYSTEMS

The secure range safety systems on the S-IC, S-II and S-IVB stages provide a communications link to transmit coded commands from ground stations to the vehicle during powered flight, providing a positive means of terminating the flight of an erratic vehicle by initiating emergency engine cutoff and if necessary, propellant dispersion.

Each powered stage contains two UHF radio receivers. Both command receivers on each of the three stages respond to the same command signals, each providing a backup system for the other.

The safety and arming device located on each stage is armed by a signal from the blockhouse before vehicle ignition. Following S-IVB cutoff the S-IVB range safety system is "safed" by a command from Range Safety Control to preclude accidental destruct.

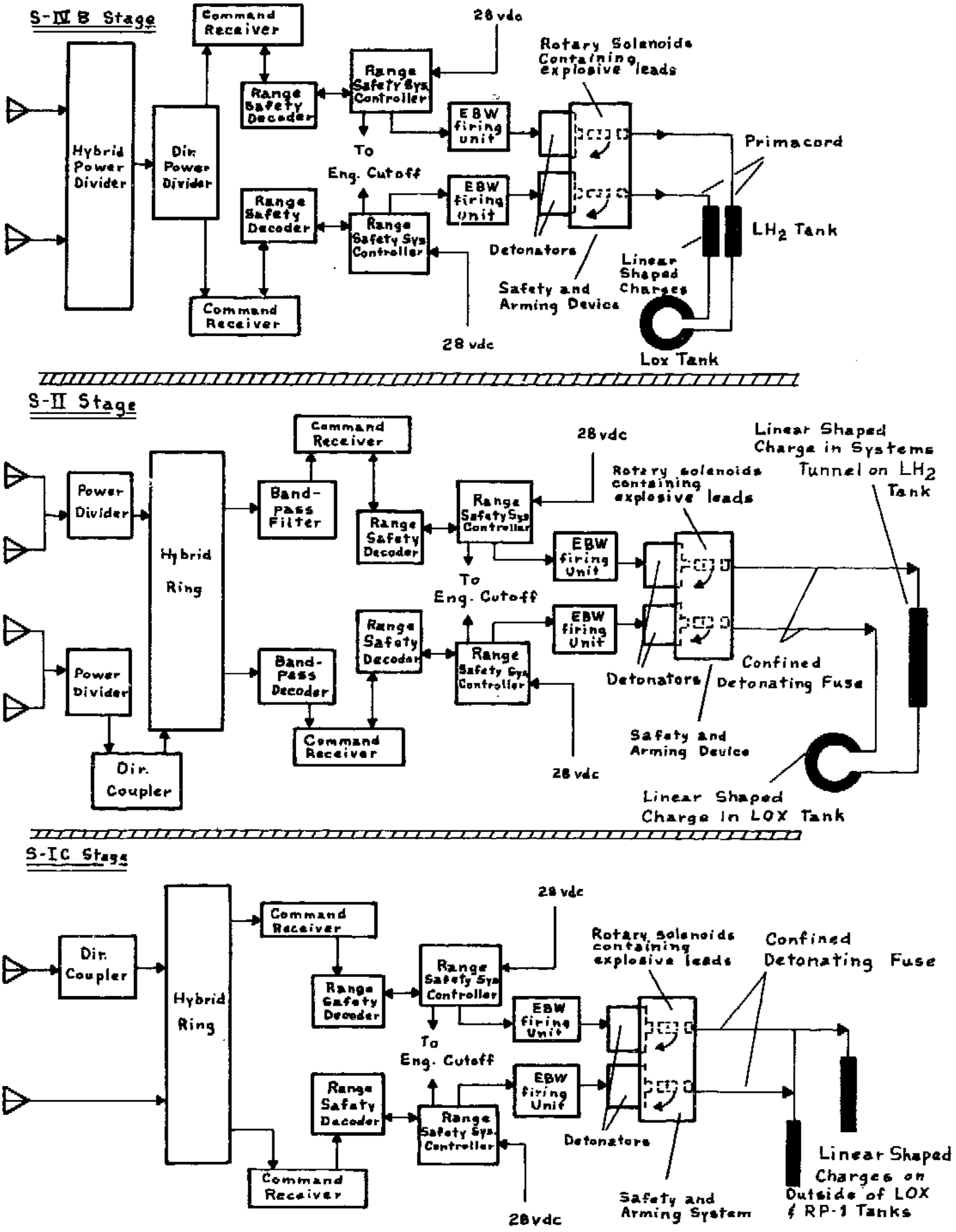


Figure 4

Secure Range Safety System

EMERGENCY DETECTION SYSTEM (EDS)

The purpose of the EDS is to sense onboard emergency situations which arise during the boost phase of the flight. On AS-501 the EDS will be flown in an open loop configuration which precludes automatic abort.

The EDS is comprised of sensors which detect malfunctions and logic circuitry which initiate spacecraft displays and, in two cases, automatic abort of the CM. With the exception of the Q-ball, mounted on top of the LET, the EDS sensors are located in the launch vehicle. The system's relay logic is located primarily in the IU EDS Distributor and the CM Mission Events Sequence Controller.

The EDS has two modes of operation; "manual", which generates abort cues and "automatic" which initiates firing of the LES, and CM separation in the case of two S-IC engines out or angular overrates during S-IC powered flight. Figure is simplified block diagram of the AS-501 EDS. The automatic abort initiating portion of the system consists of the launch vehicle's rate sensing subsystem, the stage thrust sensing subsystem and the signal distribution and processing hardware which services these devices.

The angular overrate sensors (3 per axis in pitch, yaw, and roll) will initiate automatic abort of the CM during the period they are enabled (liftoff to about 136 seconds) whenever two sensors in any one axis simultaneously indicate excessive rates. Detection of the overrates is made by the sensor switch circuitry of the Control Signal Processor in the IU. The settings for these angular rate detectors are 5 degrees per second in pitch and yaw and 20 degrees per second in roll. The majority voting of the three switch outputs in each axis is done by relay logic in the EDS Distributor. A valid excess rate decision is forwarded by the EDS Distributor to the CM Mission Events Sequence Controller for abort initiation.

The S-IC stage engine thrust OK sensors (three per engine on all five engines) will also initiate abort during the period they are enabled (liftoff to about 135 seconds) when the voted output of the sensors from any two engines indicates that the thrust of those engines is below the 89% level. These sensors monitor the F-1 engine's fuel inlet manifold pressure. Majority voting of the three sensors for each engine is done in the EDS Distributor. A valid two engines out decision is sent to the Mission Events Sequence Controller for CM abort initiation.

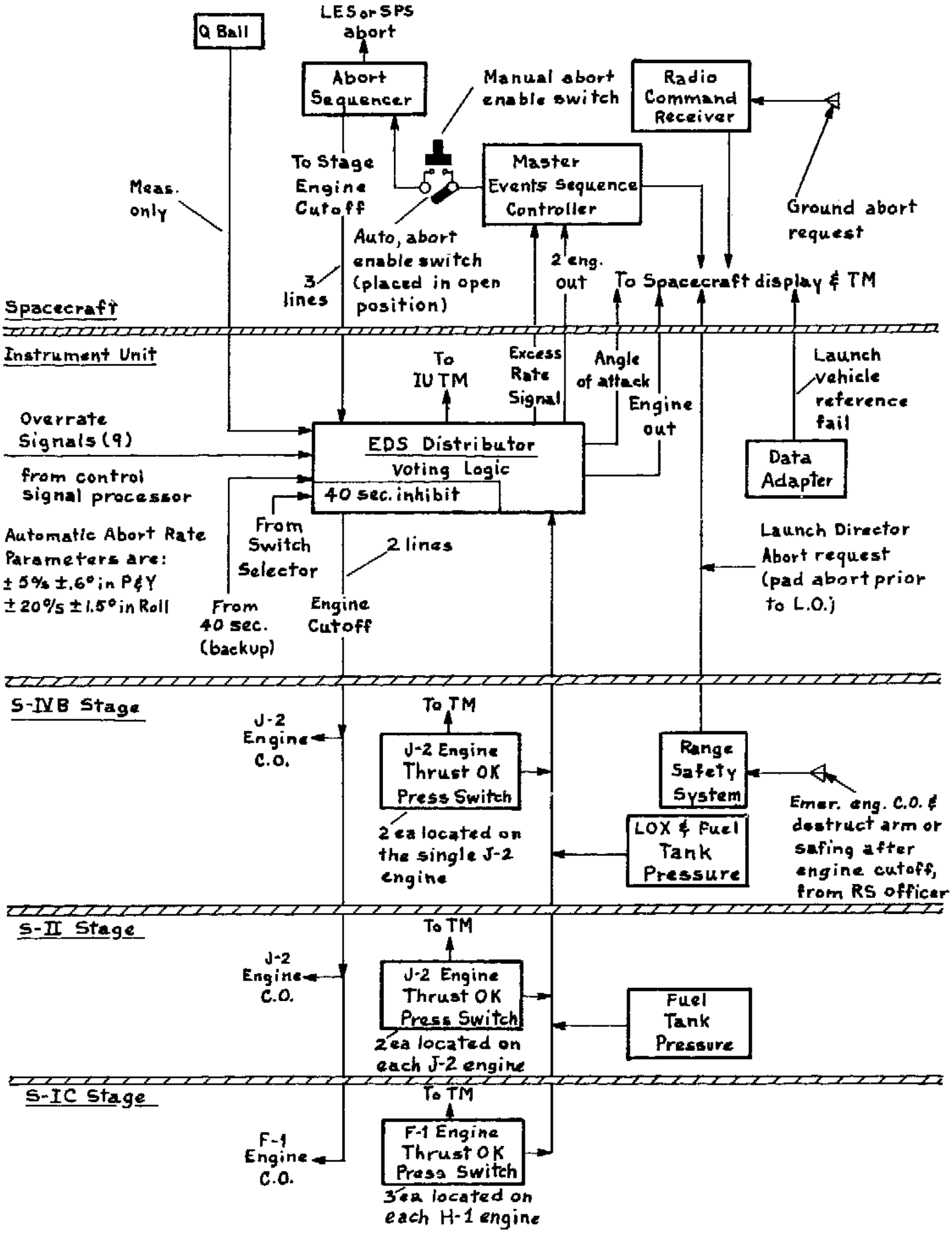
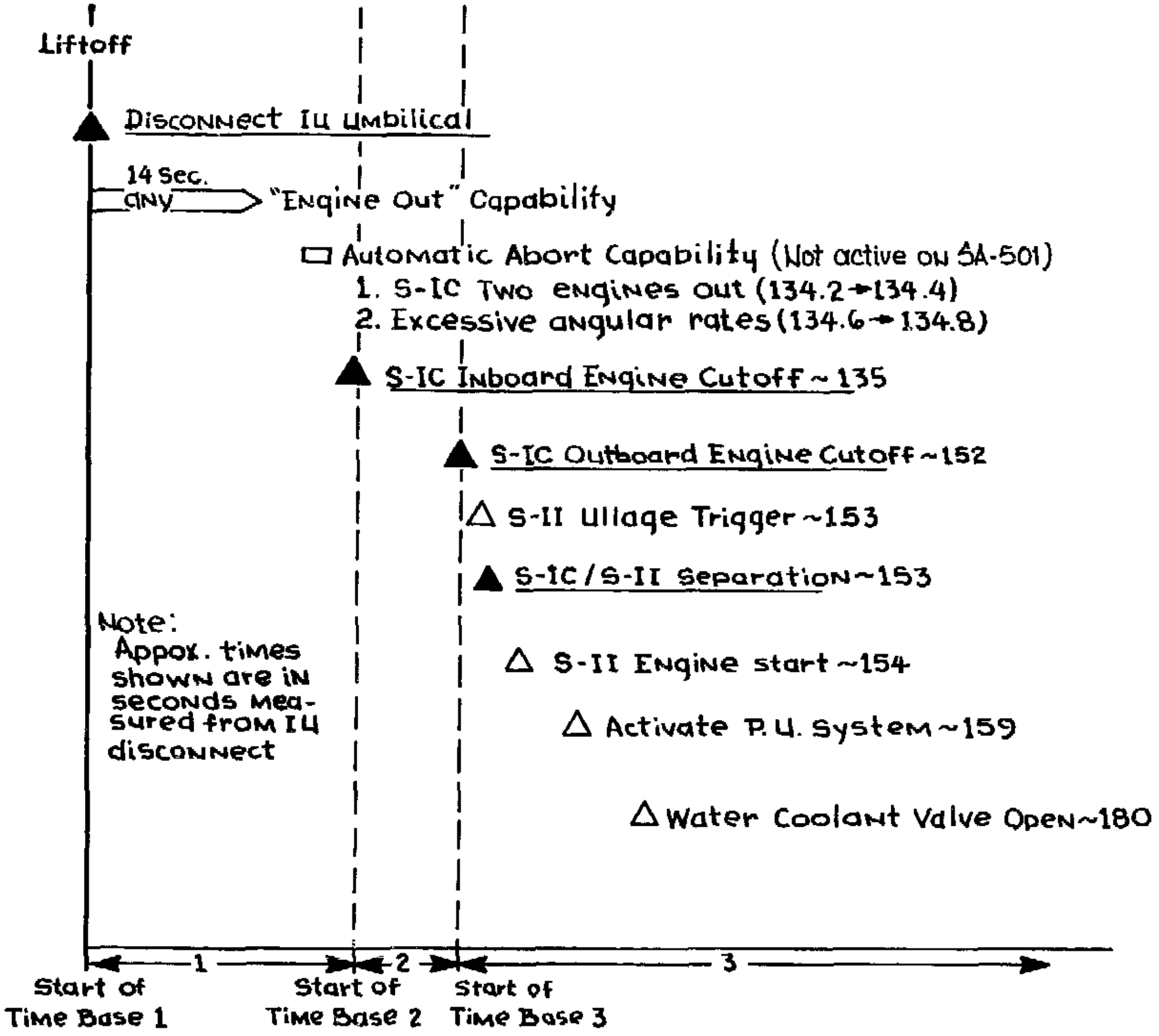


Figure 5

Emergency Detection System (EDS)



Time Base Divisions

Figure 6

S-IC/S-II Stage Flight Sequencing

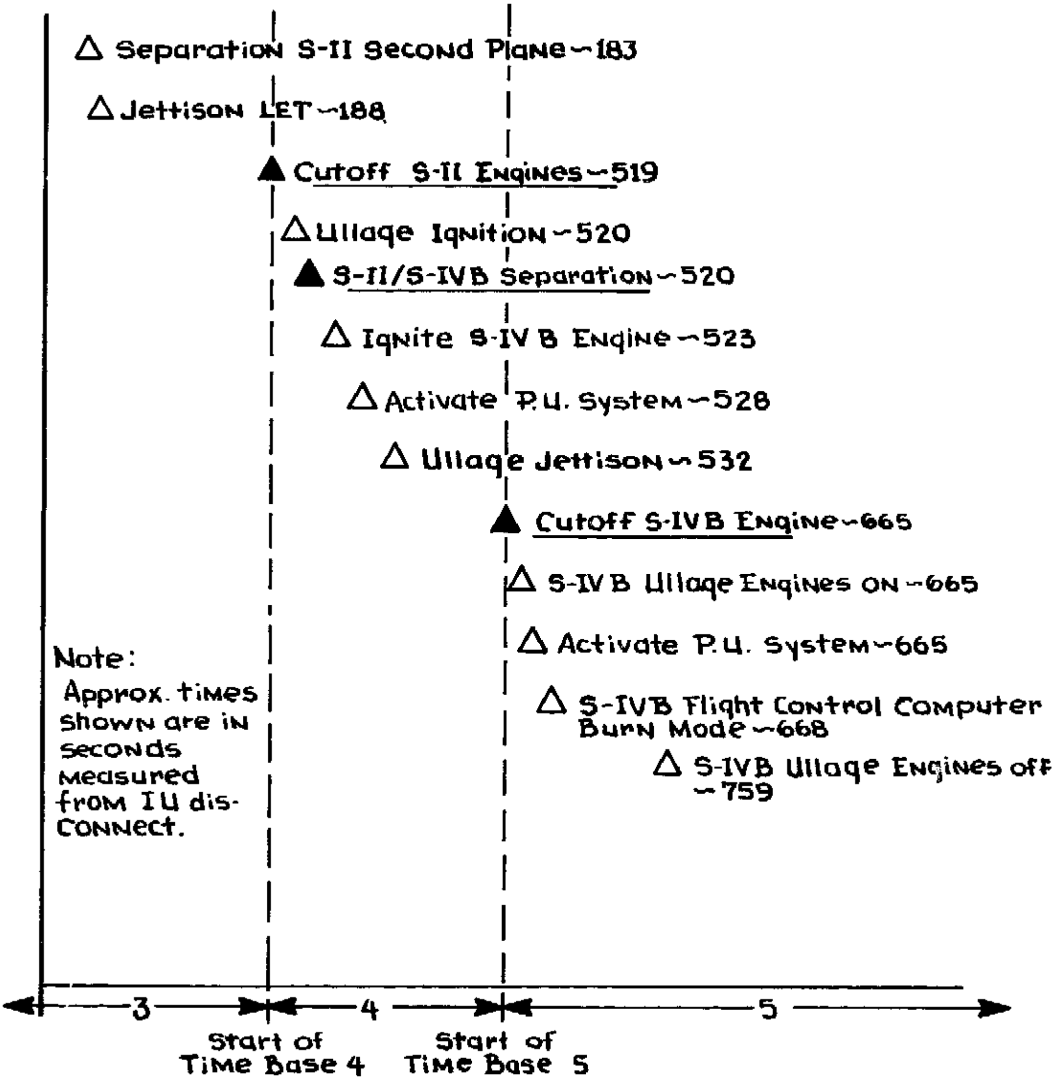


Figure 7

S-II/S-IVB Stage Flight Sequencing

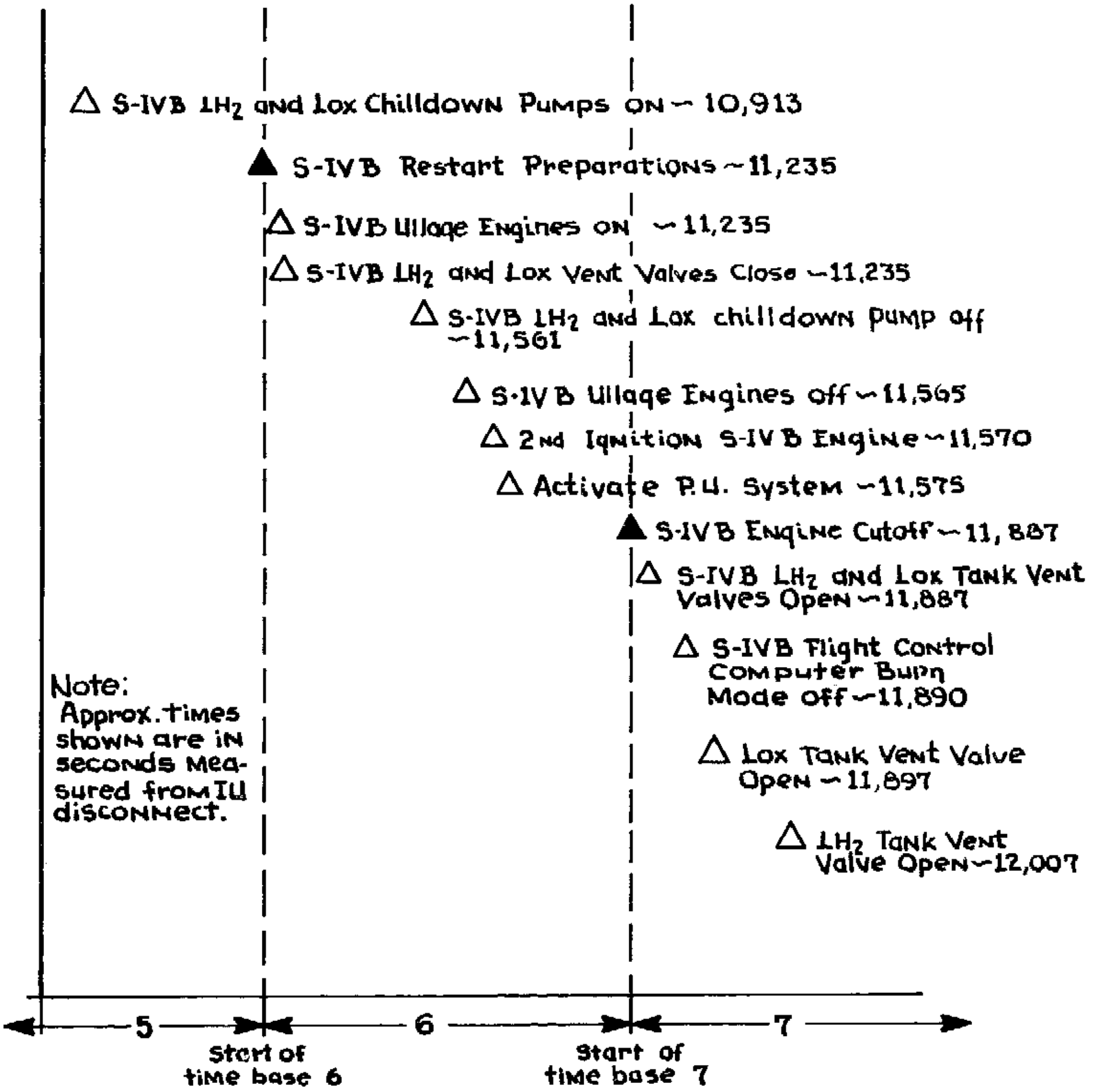
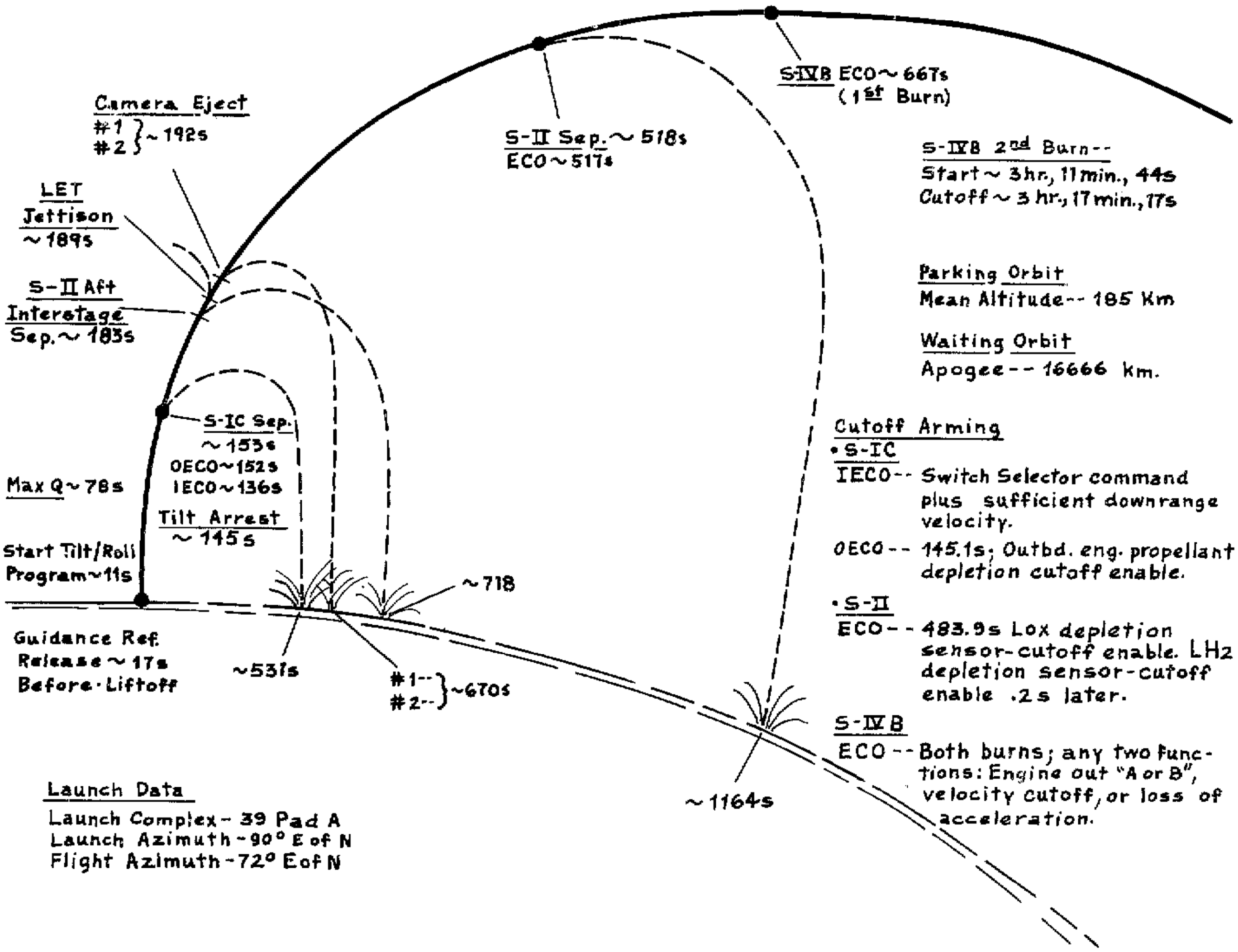


Figure 8

S-IVB Stage Flight Sequencing



S-IVB 2nd Burn--
Start ~ 3hr., 11min., 44s
Cutoff ~ 3 hr., 17 min., 17s

Parking Orbit
Mean Altitude -- 185 Km

Waiting Orbit
Apogee -- 16666 km.

Cutoff Arming

- S-IC

IECO -- Switch Selector command plus sufficient downrange velocity.

OECO -- 145.1s; Outbd. eng. propellant depletion cutoff enable.

- S-II

ECO -- 483.9s Lox depletion sensor-cutoff enable. LH_2 depletion sensor-cutoff enable .2s later.

S-IVB

ECO -- Both burns; any two functions: Engine out "A or B", velocity cutoff, or loss of acceleration.

Launch Data
Launch Complex - 39 Pad A
Launch Azimuth - 90° E of N
Flight Azimuth - 72° E of N

Figure 9

Trajectory Information
(Boost Phase)

GUIDANCE AND CONTROL SYSTEM (G&C)

Function and Description

The G&C system provides these basic functions during flight: (1) stable positioning of the vehicle to the command position with a minimum amount of sloshing and bending, (2) a first stage tilt program which gives a near zero lift trajectory through the atmosphere and produces reasonable end conditions at Outboard Engine Cutoff (OECO), (3) reduction of wind loads during the high dynamic pressure region, (4) steering commands during S-IVB burn which guide the vehicle to a predetermined set of end conditions while maintaining a minimum propellant trajectory, (5) final cutoff signal, (6) attitude signals for the sensing, computing, and actuation elements of the G&C system. A block diagram of the hardware used to implement these functions is shown in Figure .

The Stabilized Platform (ST-124M) is a three gimbal configuration with gas bearing gyros and accelerometers mounted on the stable element. Vehicle accelerations and rotations are sensed relative to this stable element. Gimbal angles are measured by redundant resolvers and inertial velocity is obtained from accelerometer head rotation in the form of encoder outputs (also redundant).

The Launch Vehicle Data Adapter (LVDA) is an input-output device for the LVDC. These two components are digital devices which operate in conjunction to carry out the flight program. This program performs the following functions: (1) Processes the inputs from the ST-124M, (2) performs navigation calculations, (3) provides first stage tilt program, (4) calculates IGM steering commands, (5) resolves gimbal angles and steering commands into the vehicle system for attitude error commands, (6) issues cutoff and sequencing signals.

The Control/EDS Rate Gyro Package contains 9 gyros (triplex redundant in 3 axes). Their outputs go to the Control Signal Processor (CSP) where they are voted and sent to the Control Computer for damping vehicle angular motion.

The Control Computer sends commands to the S-IC, S-II and S-IVB engine actuators and to the Control Relay Packages based on signals from the LVDA and rate gyros. These signals are filtered and scaled (see Figure 10), then summed in magnetic amplifiers. This computer provides redundant operation during S-IVB burn and coast.

The Control Relay Packages accept Control Computer commands and relay these commands to operate propellant valves in the Auxiliary Propulsion System (APS). All relays and valves are redundant.

The 8 hydraulic actuators of the S-IC and S-II stages are used to gimbal the outboard engines and provide control in all axes. The two hydraulic actuators of the S-IVB stage are used to gimbal the J-2 engine and provide control in pitch and yaw axes. The APS is used for control in all axes during S-IVB coast.

The Switch Selectors are used to relay sequencing commands from the LVDA to other locations in the vehicle. The cutoff signal and time based events are issued through the Switch Selectors.

Operation

The vehicle is erected on the launch pad with position I at a 90°E of N azimuth. The Stabilized Platform is aligned to 72° azimuth during countdown and held in an earth fixed position, perpendicular to the gravity vector. A roll presetting of 18° is used to eliminate the attitude error which would result from this difference in azimuth. The LVDC operates in ground routines prior to GRR and attitude error signals are set to null. At the instant of GRR, the platform becomes space fixed to establish the guidance coordinate system and the LVDC enters the flight mode. In this mode accelerometer processing, steering, navigation, telemetry, and other functions are performed exactly as they are after liftoff.

The Liftoff signal (IU umbilical disconnect) initiates time base 1. Eleven seconds later, the tilt program starts and the initial roll presetting is reset to zero. The vehicle rolls into alignment with the platform at 1°/second. There is no active path guidance during S-IC burn. Control is maintained by gimballing the four outboard engines on command from the Control Computer. Sequencing signals are issued to the various switch selectors to perform time dependent functions.

DIGITAL COMMAND SYSTEM CAPABILITY:

The following summary describes the AS-501 Digital Command Systems' overall command capability:

Function	Description	Periods of Acceptance
Inhibit	Coast phase attitude maneuver inhibit	From T_5 + 100 seconds until T_6 and from T_7 + 10 seconds until end of life
Time base update	Change the time to start coast phase attitude maneuver	From T_5 + 100 seconds until T_6 and from T_7 + 10 seconds until end of life
Time base update	Time base time is advanced or retarded at the next telemetry loss	From T_5 + 100 seconds until T_6 and from T_7 + 10 seconds till end of life
Navigation update	Navigation quantities are reset at the time specified	From T_5 + 100 seconds until T_6 and from T_7 + 10 seconds till end of life
Generalized switch selector	Specified switch selector function is issued at the first opportunity	From T_4 + 115 seconds until T_6 + 317 seconds and from T_7 + 10 seconds till end of life
Sector dump	Contents of specified memory sector are telemetered	From T_5 + 100 seconds until T_6 and from T_7 + 10 seconds till end of life
Telemeter single memory location	Contents of specified memory location are telemetered	From T_5 + 100 seconds until T_6 and from T_7 + 10 seconds till end of life
Terminate	Stop DCS processing and reset for a new command	From T_3 + 1.3 seconds until T_4; from T_4 + 115 seconds till T_6 + 317 seconds and from T_7 + 10 seconds till end of life
Abort to orbit	Use S-IVB to achieve orbit	From T_3 + 1.3 seconds till T_4
Inhibit transponder switching	Inhibits C-Band transponder switching	From T_5 + 100 seconds until T_6 and from T_7 + 10 seconds until end of life

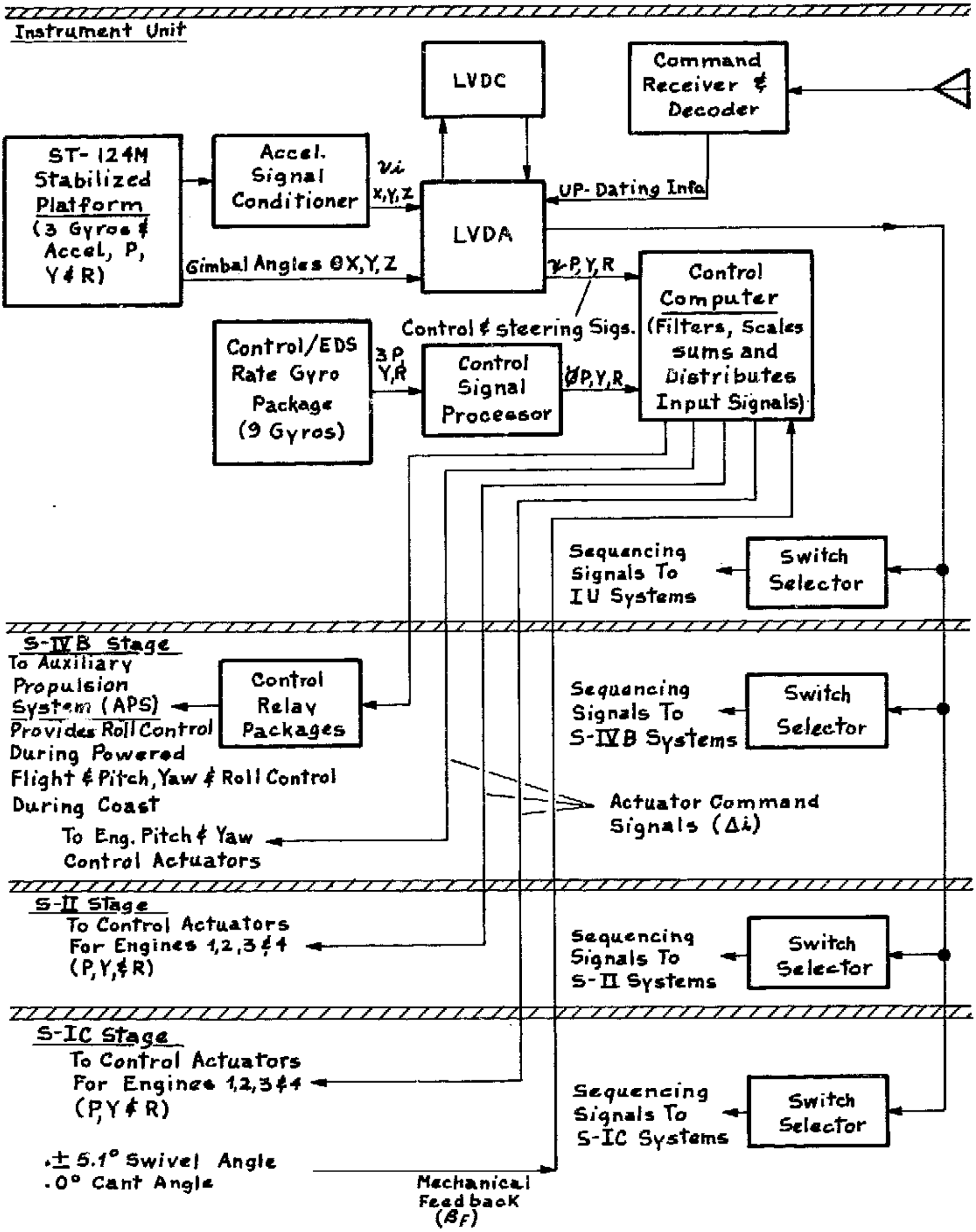


Figure 10

Guidance and Control System Block Diagram

VEHICLE TRACKING SYSTEMS

1. Azusa/GLOTRAC Systems. (IU)

The Azusa (Mark II) is an interferometer system using doppler and FM radar techniques for high-accuracy tracking during the launch phase. It is utilized for impact prediction and real-time display of vehicle position. GLOTRAC is a range and range rate tracking system for post-flight trajectory evaluation.

2. ODOP System. (S-IC)

The ODOP tracking system measures the range sum between ground stations and a vehicle by utilizing the total doppler shift in the frequency of a continuous wave radio carrier. It provides highly accurate position and velocity data during the early flight phase for post-flight trajectory evaluation.

3. C-Band Radar System. (IU & SC)

C-Band is a pulse radar system which is used for precise tracking during launch and orbit phases.

4. Unified S-Band System. (SC)

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

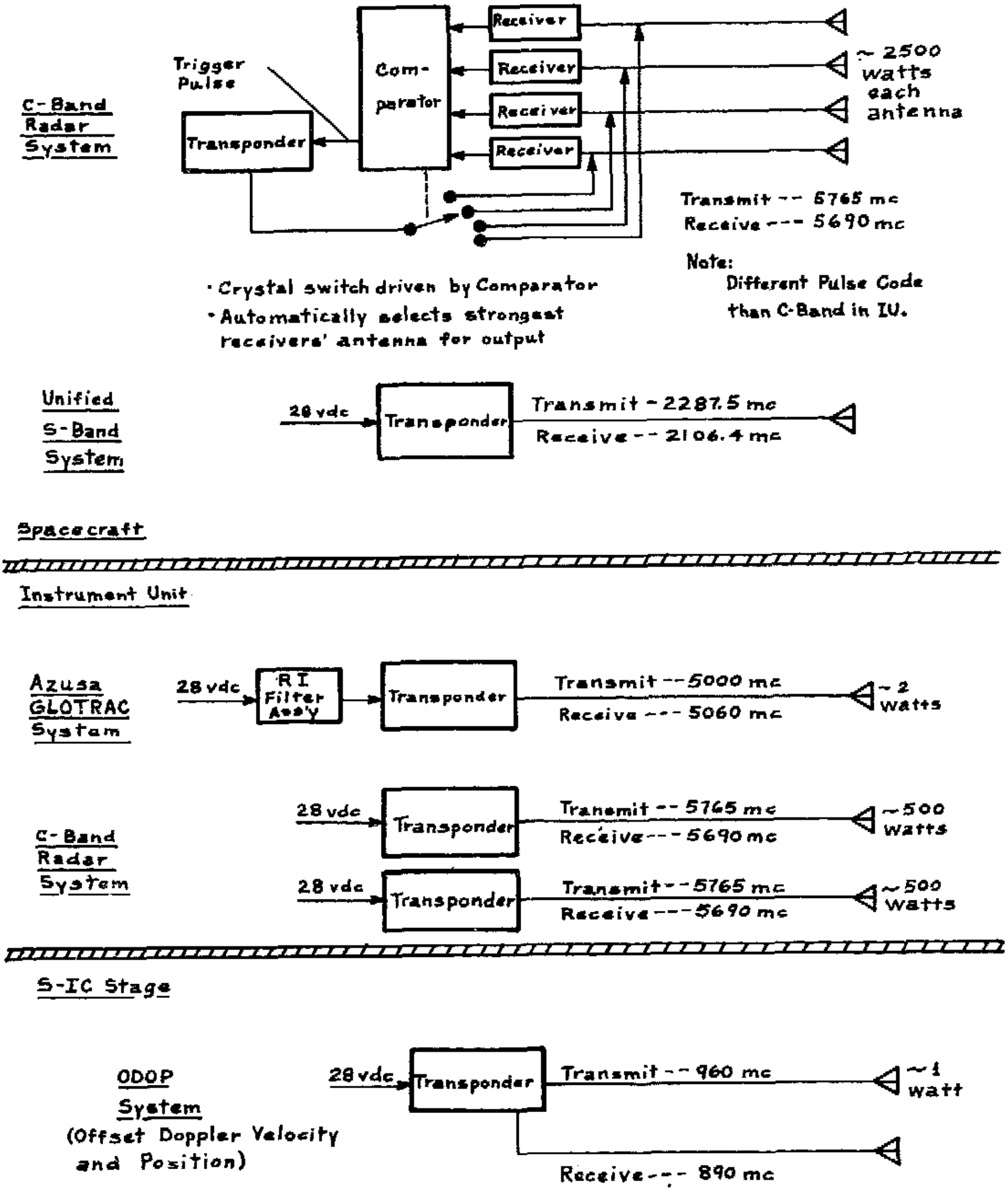


Figure 11

Vehicle Tracking Systems

SPACE VEHICLE WEIGHT VS. FLIGHT TIME

Propellant consumption during S-IC Stage flight (approximately 152 seconds) is approximately 4,320,000 pounds. Propellant consumption during S-II Stage flight (approximately 365 seconds) is approximately 938,700 pounds and during S-IVB Stage flight, including first and second burns, (approximately 459 seconds) is approximately 232,700 pounds.

In event of one engine of the S-IC Stage malfunctions and is cutoff during flight, the remaining engines will consume the propellant intended for the "dead" engine. Burning time of the stage would increase, and the overall vehicle performance loss would be minimized.

VEHICLE WEIGHT DATA (Approximate)	Pounds
Total at S-IC ignition	6,220,700
Total at liftoff	6,121,300
Total at S-IC O.E.C.O	1,799,200
Total at S-II ignition	1,415,700
Total at S-II E.C.O	463,200
Total at S-IVB first ignition	352,000
Total at S-IVB first E.C.O	277,000
Total at S-IVB 2nd ignition	273,900
Total at S-IVB 2nd E.C.O	119,100
Total at S-IVB/SC separation	67,100

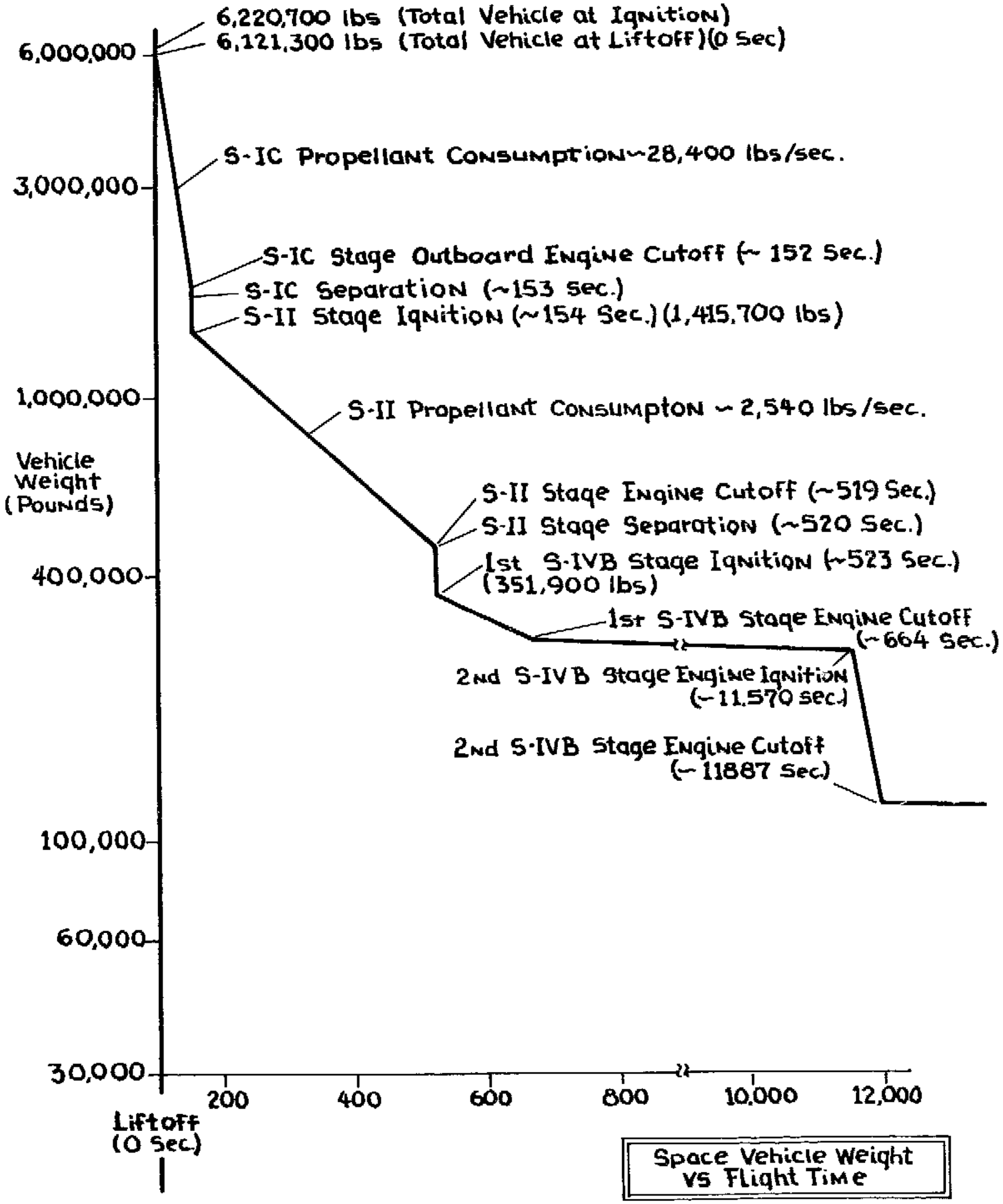
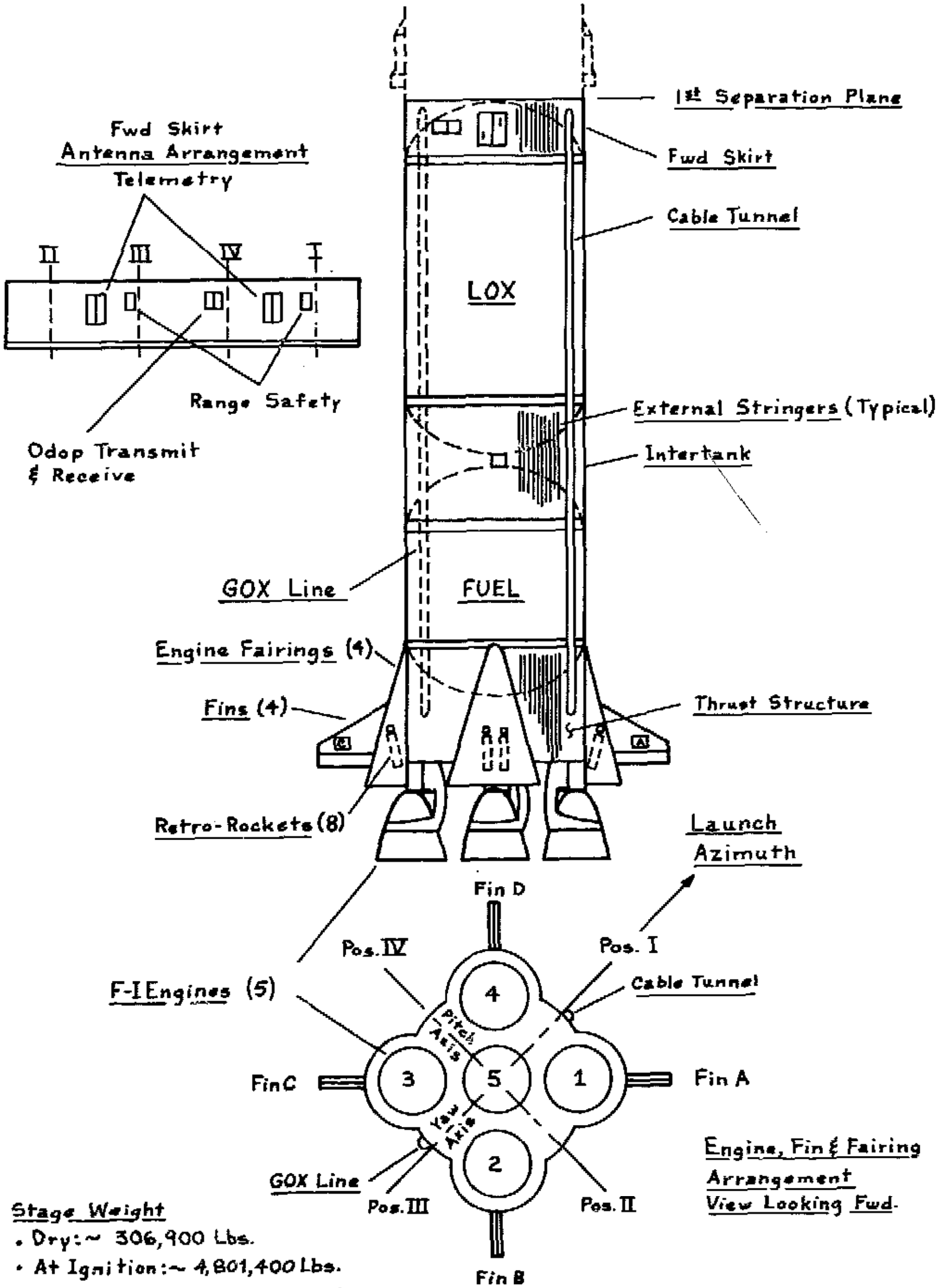

6,220,700 lbs (Total Vehicle at Ignition)
6,121,300 lbs (Total Vehicle at Liftoff)(0 Sec)
6,000,000
S-IC Propellant Consumption~28,400 lbs/sec.
3,000,000
S-IC Stage Outboard Engine Cutoff (~ 152 Sec.)
S-IC Separation (~153 sec.)
S-II Stage Ignition (~154 Sec.)(1,415,700 lbs)
1,000,000
S-II Propellant Consumpton ~ 2,540 lbs/sec.
Vehicle Weight (Pounds)
S-II Stage Engine Cutoff (~519 Sec.)
S-II Stage Separation (~520 Sec.)
1st S-IVB Stage Ignition (~523 Sec.) (351,900 lbs)
400,000
1st S-IVB Stage Engine Cutoff (~664 Sec.)
2nd S-IVB Stage Engine Ignition (~11,570 sec.)
2nd S-IVB Stage Engine Cutoff (~11887 Sec.)
100,000
60,000
30,000
200
400
600
800
10,000
12,000
Liftoff (0 Sec.)
Space Vehicle Weight VS Flight Time

Figure 12

S-IC STAGE STRUCTURE

The S-IC stage is approximately 138 feet long and 33 feet in diameter and has five liquid-fueled Rocketdyne F-1 engines which generate a total thrust of 7,500,000 pounds. The engines are supplied fuel by a bi-propellant system of liquid oxygen (LOX) as the oxidizer and RP-1 as the fuel.

The S-IC stage structure consists of a thrust structure to which the engines attach, an RP-1 fuel tank, a LOX tank, an intertank structure separating the LOX and fuel tanks, and a forward skirt structure which provides an interface surface for the Saturn S-II stage.



Stage Weight
- Dry: ~ 306,900 Lbs.
- At Ignition: ~ 4,801,400 Lbs.
- At Separation: ~ 373,500 Lbs.

Figure 13

S-IC Stage Configuration

F-1 ENGINE OPERATION

The F-1 Engine is started by ground support equipment. The start signal ignites pyrotechnic igniters in the gas generator which permits LOX under tank pressure to discharge into the thrust chamber. When the LOX valve is partly open RP-1 and LOX under tank pressure flows to the gas generator combustion chamber accelerating the turbopump increasing the LOX and RP-1 discharge pressure. When the RP-1 discharge pressure 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 will rupture 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.

Inboard engine is cutoff by a signal from the IU. Outboard engines are cutoff by optical type LOX depletion sensors with fuel depleting 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 the stop solenoid for each engine which energizes prevalve close relays. Closing of the prevalves interrupts propellant flow and terminates engine operation.

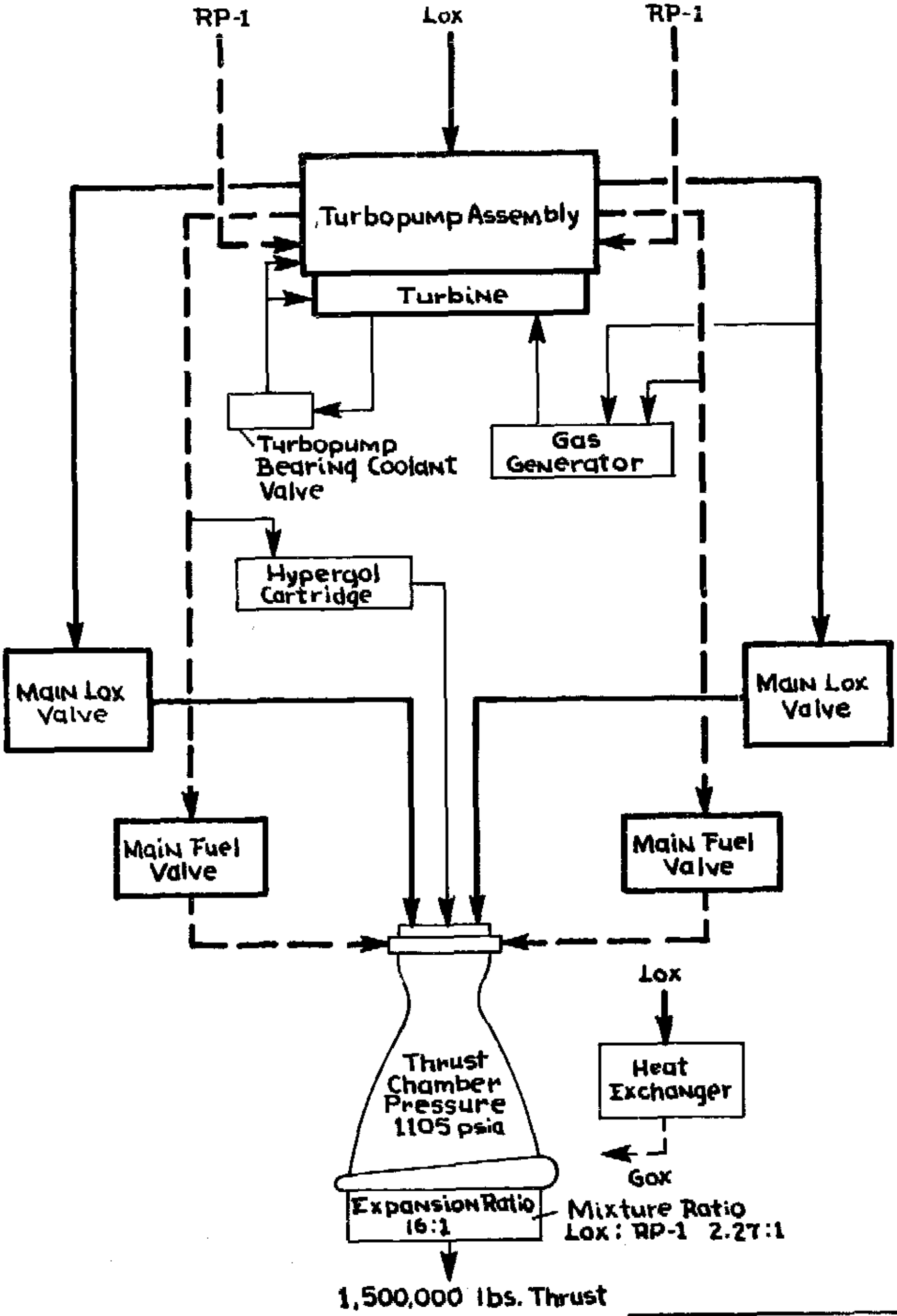


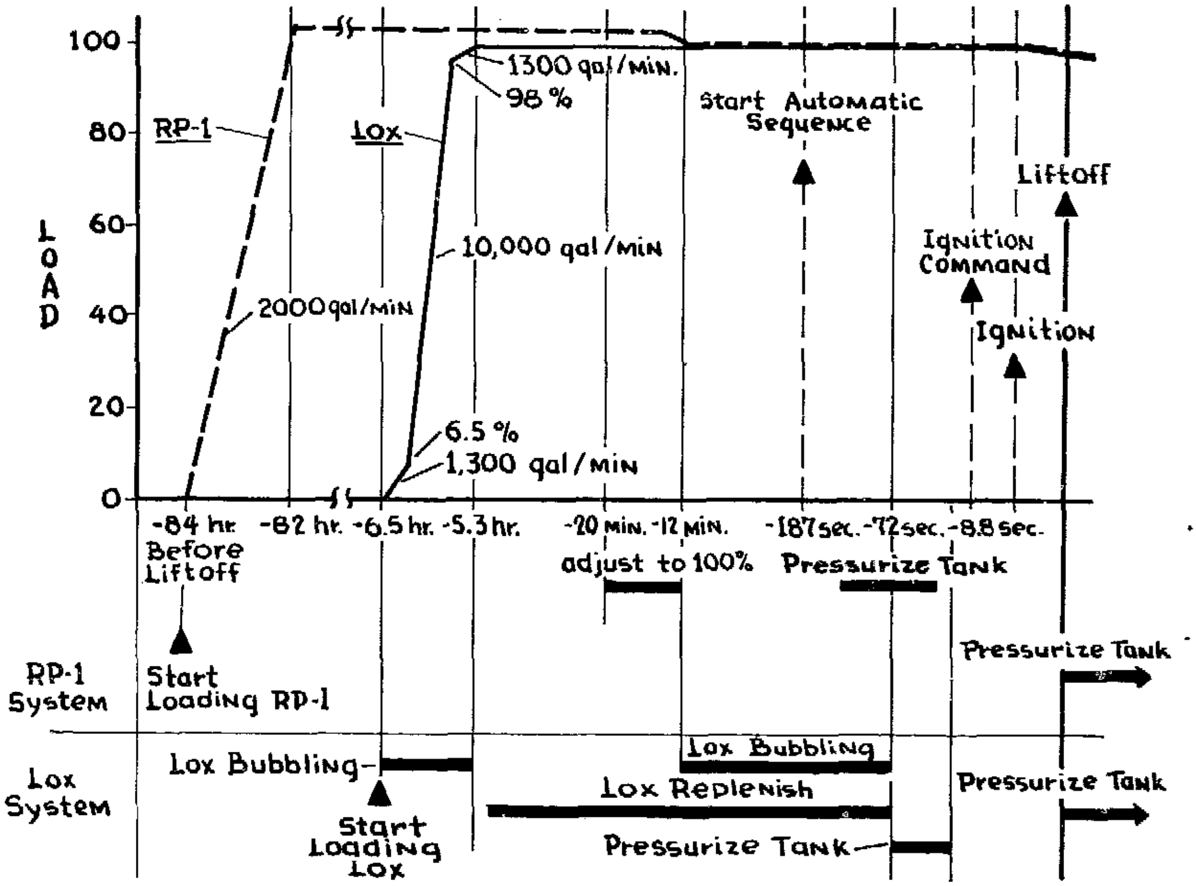
Figure 14

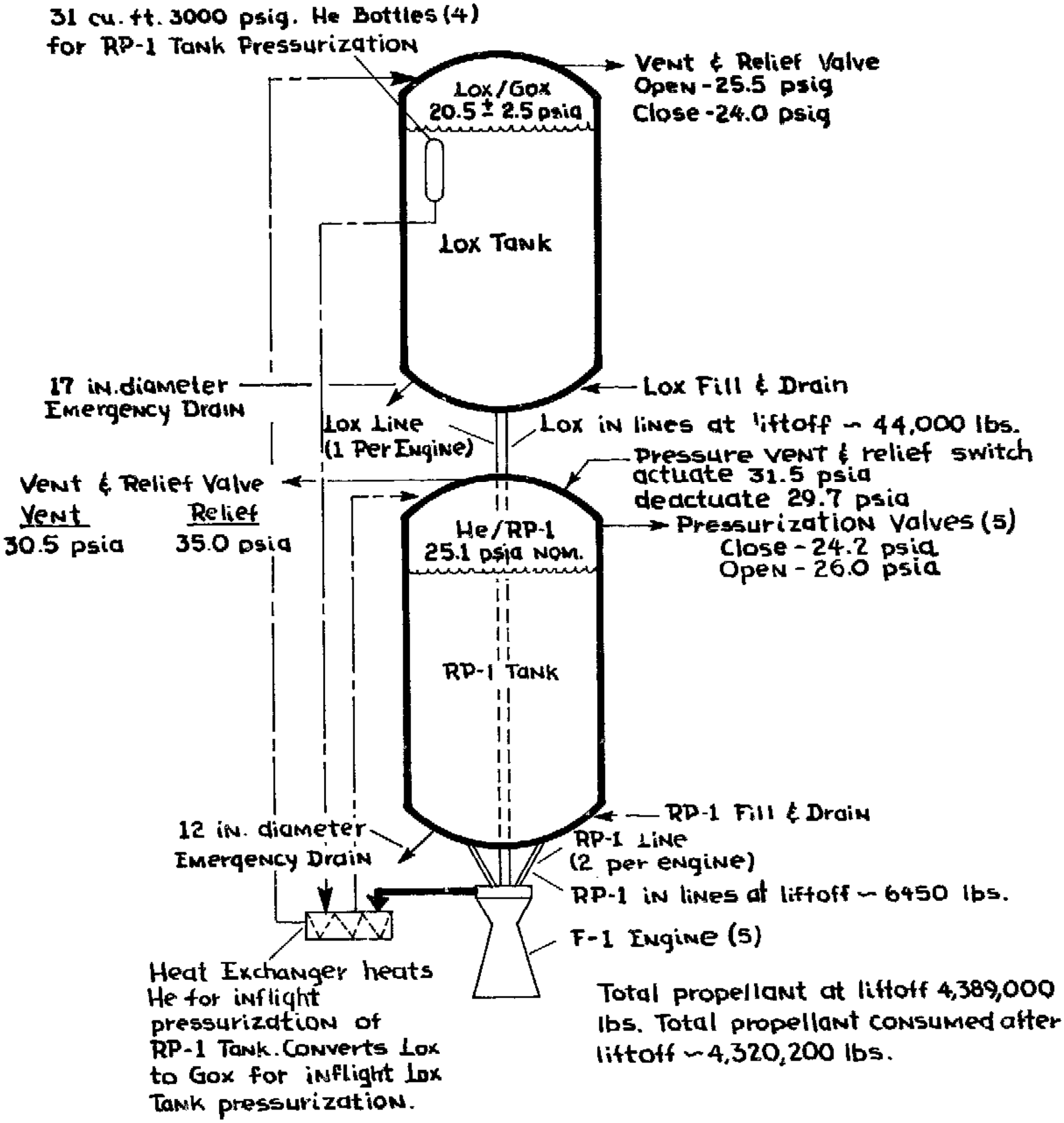
F-1 Engine System

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 at a considerable time prior to start of LOX loading. LOX bubbling begins and continues through the LOX tank loading to prevent possible LOX geysering. Approximately 90 seconds prior to ignition command the RP-1 tank is pressurized from a ground source. Approximately 60 seconds prior to ignition command the LOX tank is pressurized from a ground source. Prior to start of automatic sequence and up to 72 seconds before liftoff ground source helium is bubbled through the LOX lines and tank to prevent stratification in engine LOX suction lines. After liftoff the LOX tank pressurization is maintained by GOX converted from LOX in the heat exchanger. The RP-1 tank is pressurized with He stored in bottles in the LOX tank and heated by passing the He through the heat exchanger.

S-IC PROPELLANT LOAD AND OPERATIONAL SEQUENCE





Total propellant at liftoff 4,389,000 lbs. Total propellant consumed after liftoff ~4,320,200 lbs.

Figure 15

S-IC Stage
Propellant System

S-IC STAGE THRUST VECTOR CONTROL SYSTEM

Each of the four outboard F-1 engines is gimbal mounted on the stage thrust structure to provide engine thrust vectoring for vehicle attitude control and steering. Two hydraulic actuators are utilized to gimbal each engine in response to signals from the Flight Control Computer located in the Instrument Unit.

The thrust vector control system is part of the engine system. During engine operation, high pressure control fluid is supplied from the turbopump assembly to the servo valve and actuators. The fluid returns to the inlet of the turbopump assembly.

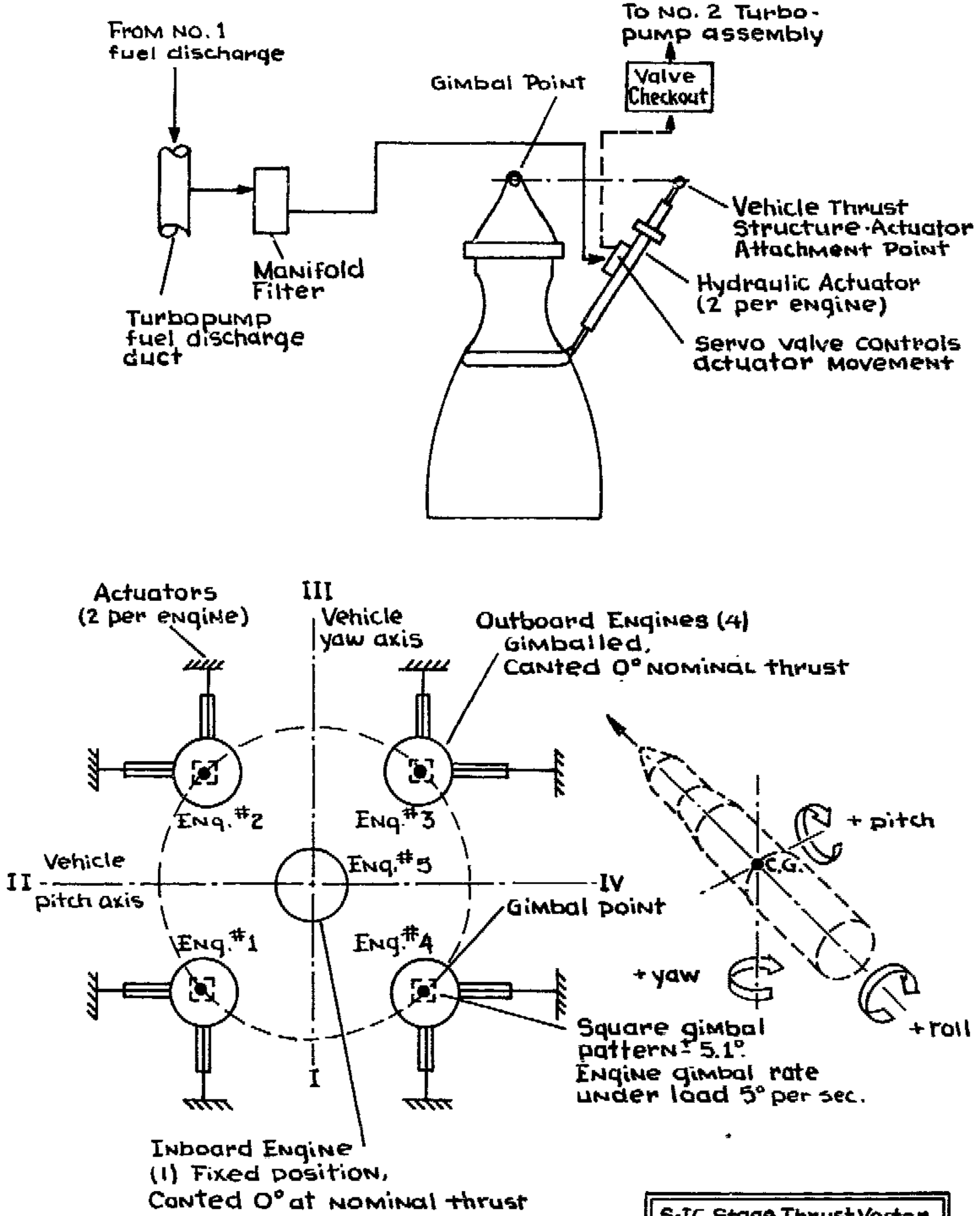


Figure 16

S-IC Stage Thrust Vector Control System

Measurement Summary			
System	Flight	ESE Display	ESE Record
1. Temperature	252	5	21
2. Pressure	230	7	31
3. Vibration	80	-	-
4. Flow Rate	35	-	-
5. Signals	143	51	-
6. Liquid Level	19	-	-
7. Voltage, Current, Freq.	11	7	11
8. Strain	71	-	-
9. Misc.	31	-	
Totals ~	872	70 *	63 *

* All ESE Display & Record Measurements Are Also Flight Measurements.

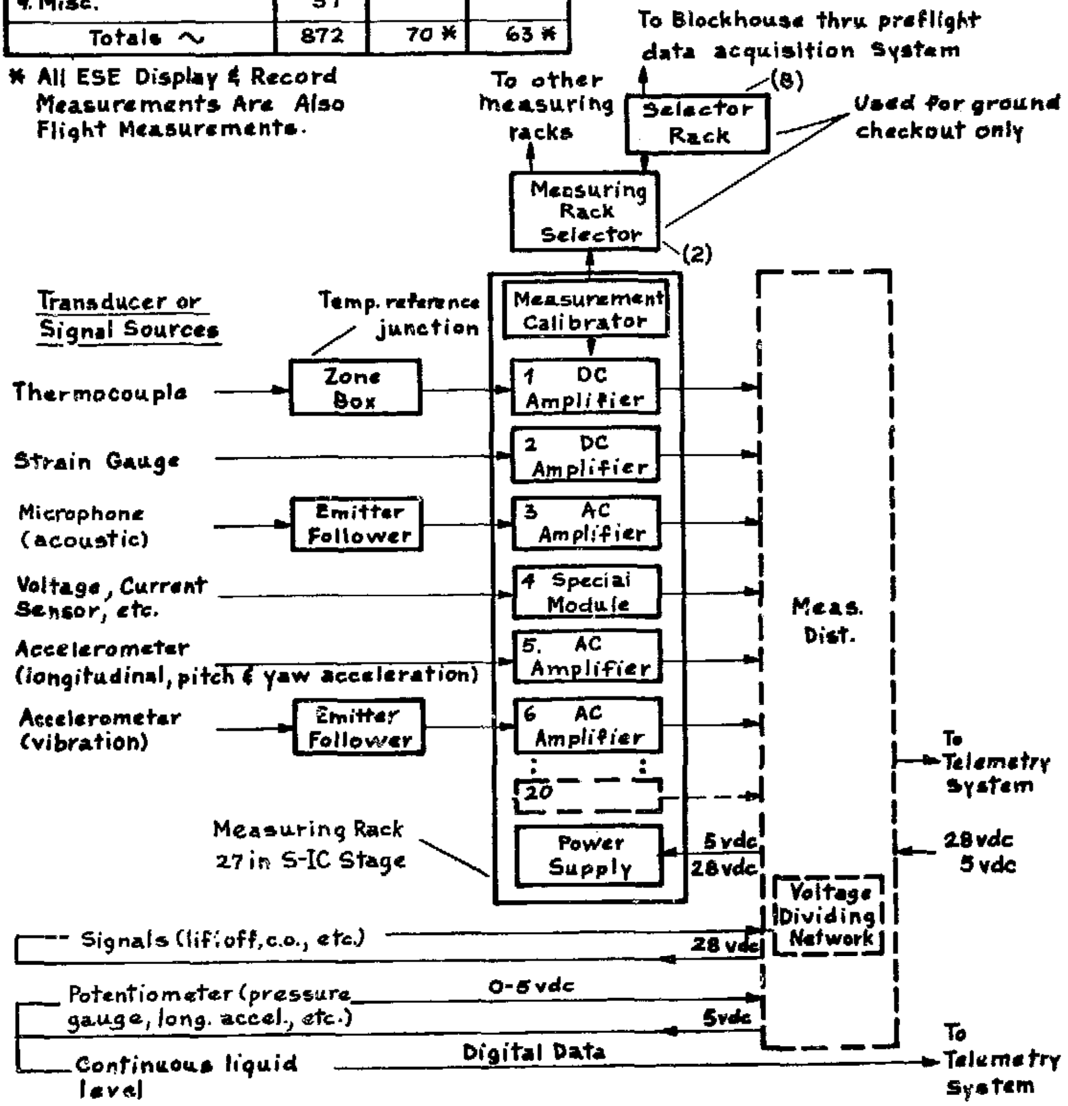


Figure 17

S-IC Stage Measuring System

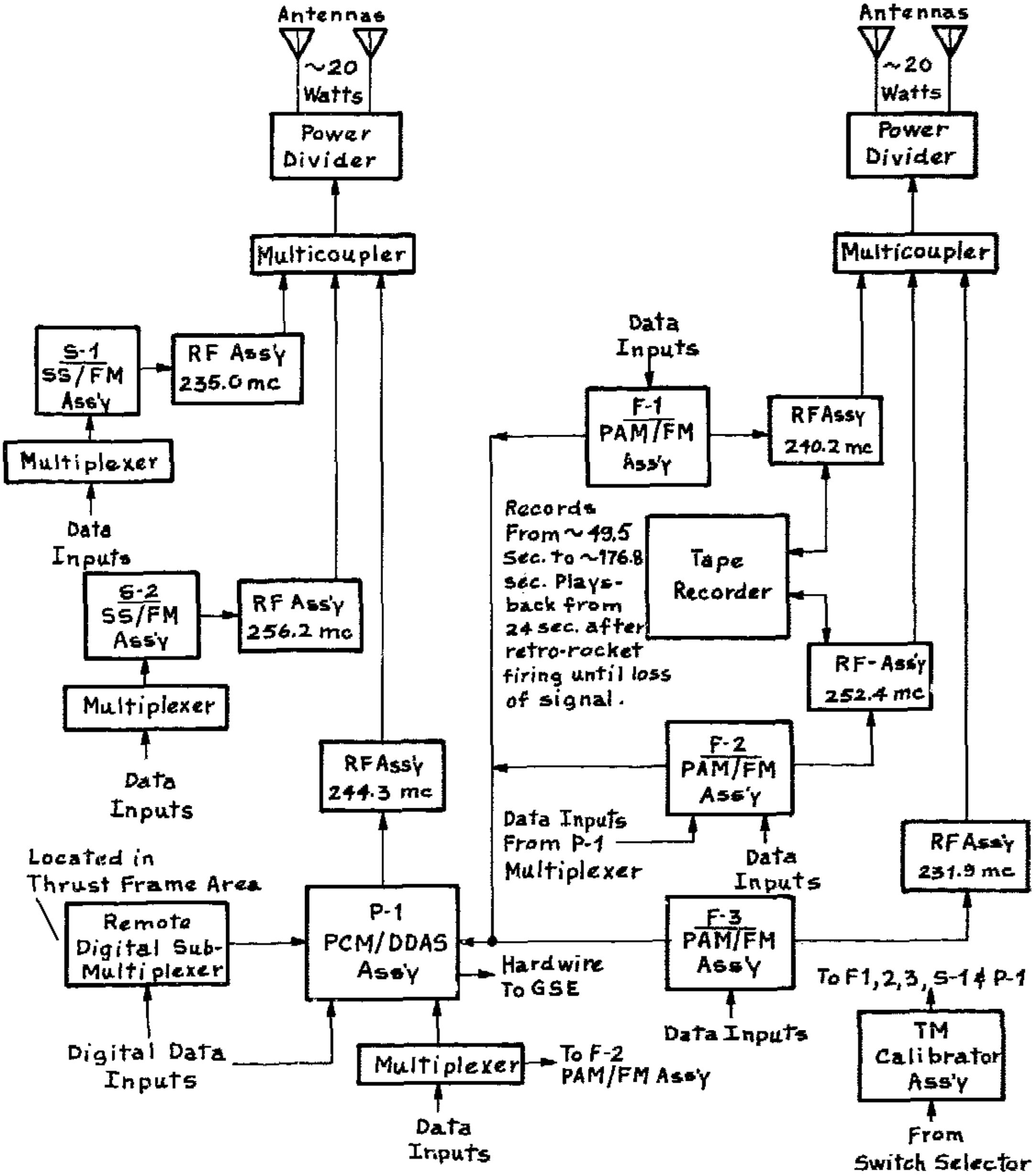
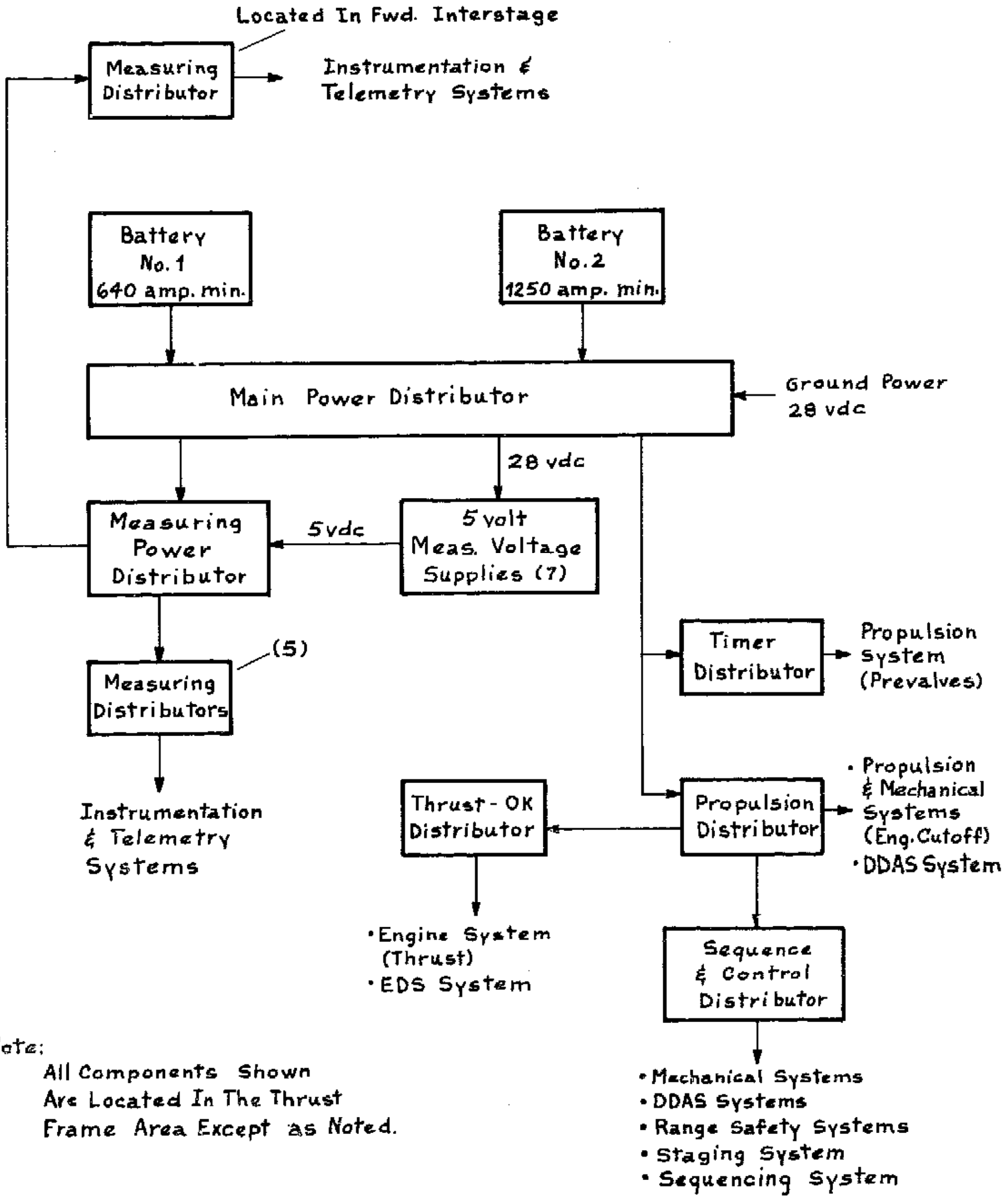


Figure 18

S-IC Stage
Telemetry System



Note:
All Components Shown Are Located In The Thrust Frame Area Except as Noted.

Figure 19

S-IC Stage Electrical Power And Distribution System

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S-II STAGE STRUCTURE

The stage structure includes: an aft interstage, an aft skirt and thrust structure, a heat shield, a LOX tank, an LH_2 tank, and a fo[illegible] skirt.

The stage has five J-2 engines which generate a total thrust of 1,000,000 pounds.

EJECTABLE CAMERA CAPSULES

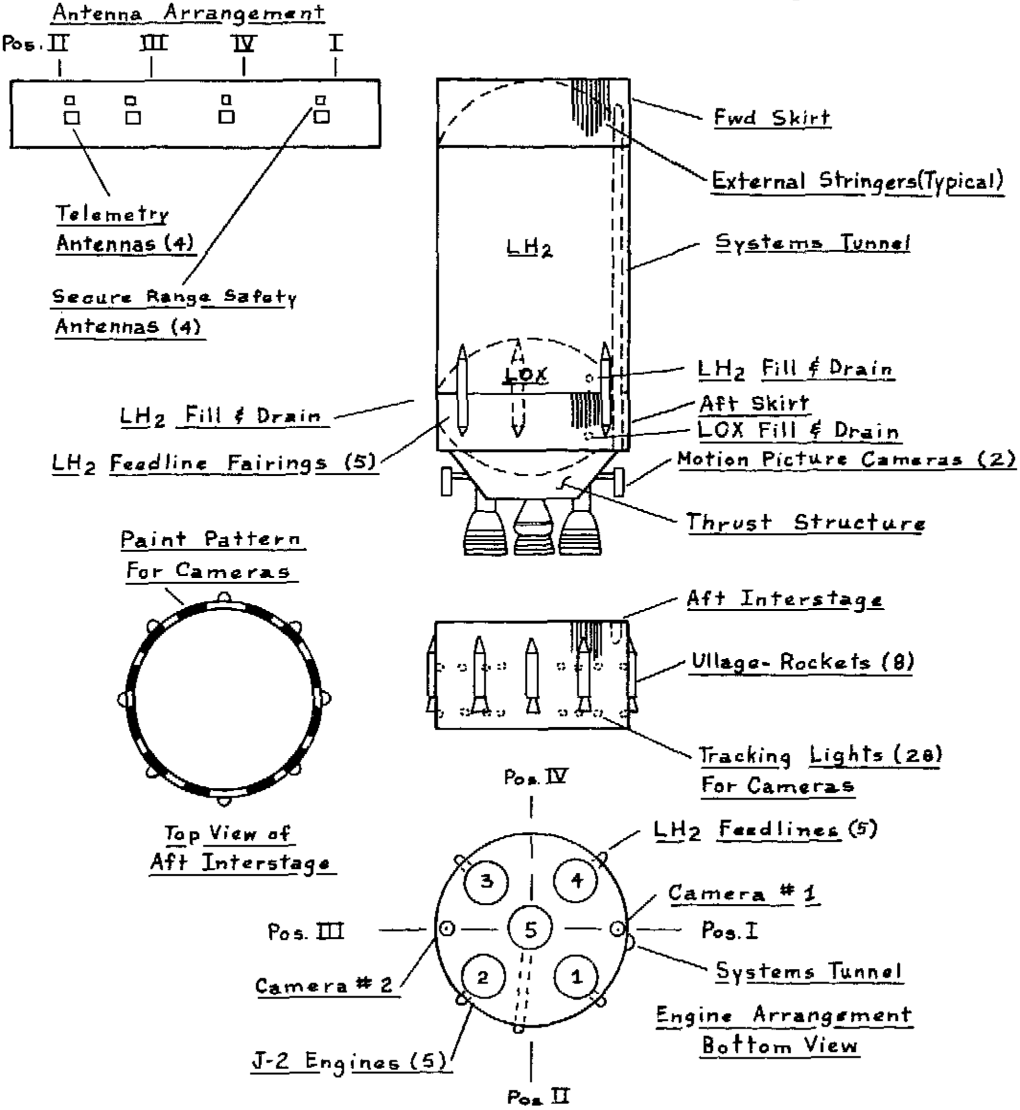
Two recoverable film cameras will be flown on the S-II stage of the first two Saturn V launch vehicles. These cameras are mounted on the thrust structure as shown on opposite page. The primary objective of these cameras is to view second-plane S-IC/S-II separation. The secondary objectives are to view S-IC/S-II first-plane separation and J-2 engine ignition.

The cameras are turned on by the switch selector shortly before first-plane separation and operate for approximately 40 seconds. The film is "marked" one-tenth of a second before first-plane separation, one-tenth of a second after engine start and one-tenth of a second after second-plane separation. The camera capsules are ejected approximately 8 seconds after second-plane 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, paraballoon, and the recovery team.

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



Stage Weight
- Dry: ~ 88,200 Lbs.
- At S-IC Ignition: ~ 1,035,300 Lbs.
- At S-II Cutoff: ~ 103,500 Lbs.

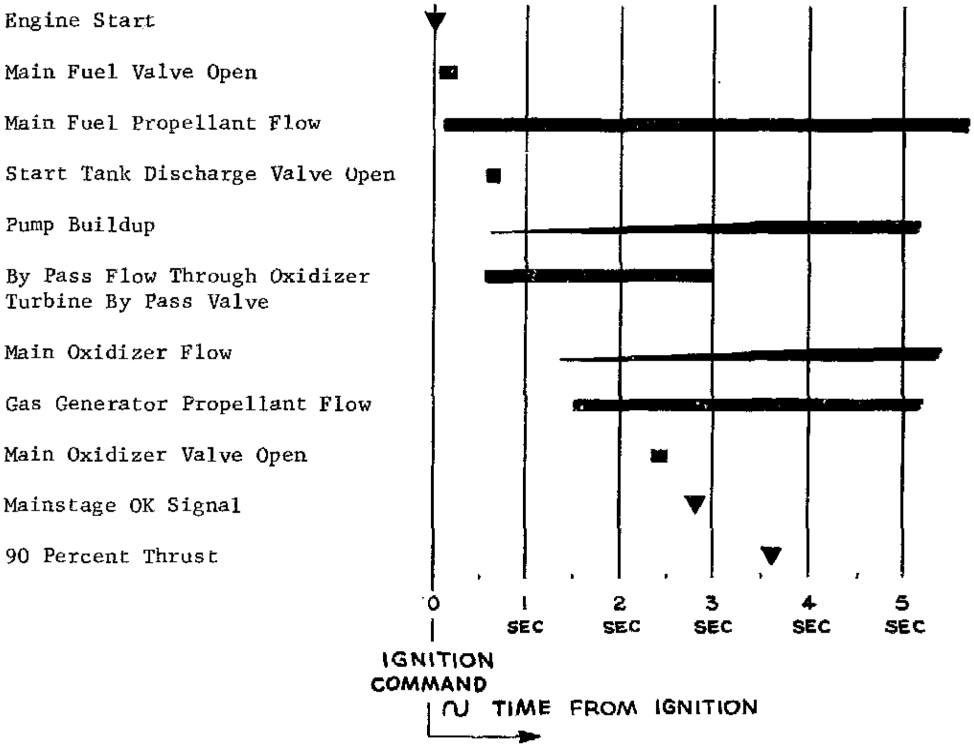
Figure 20

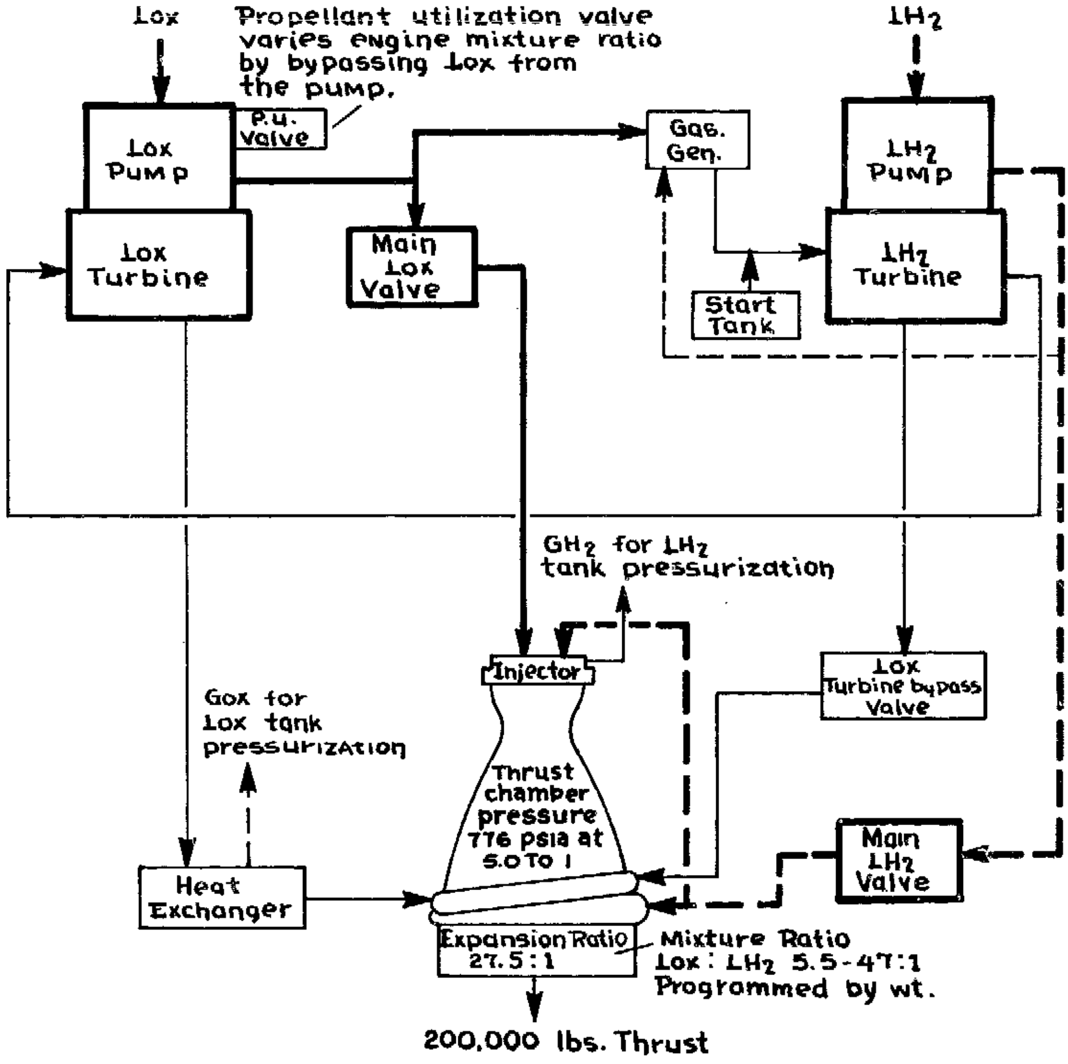
S-II Stage Configuration

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.





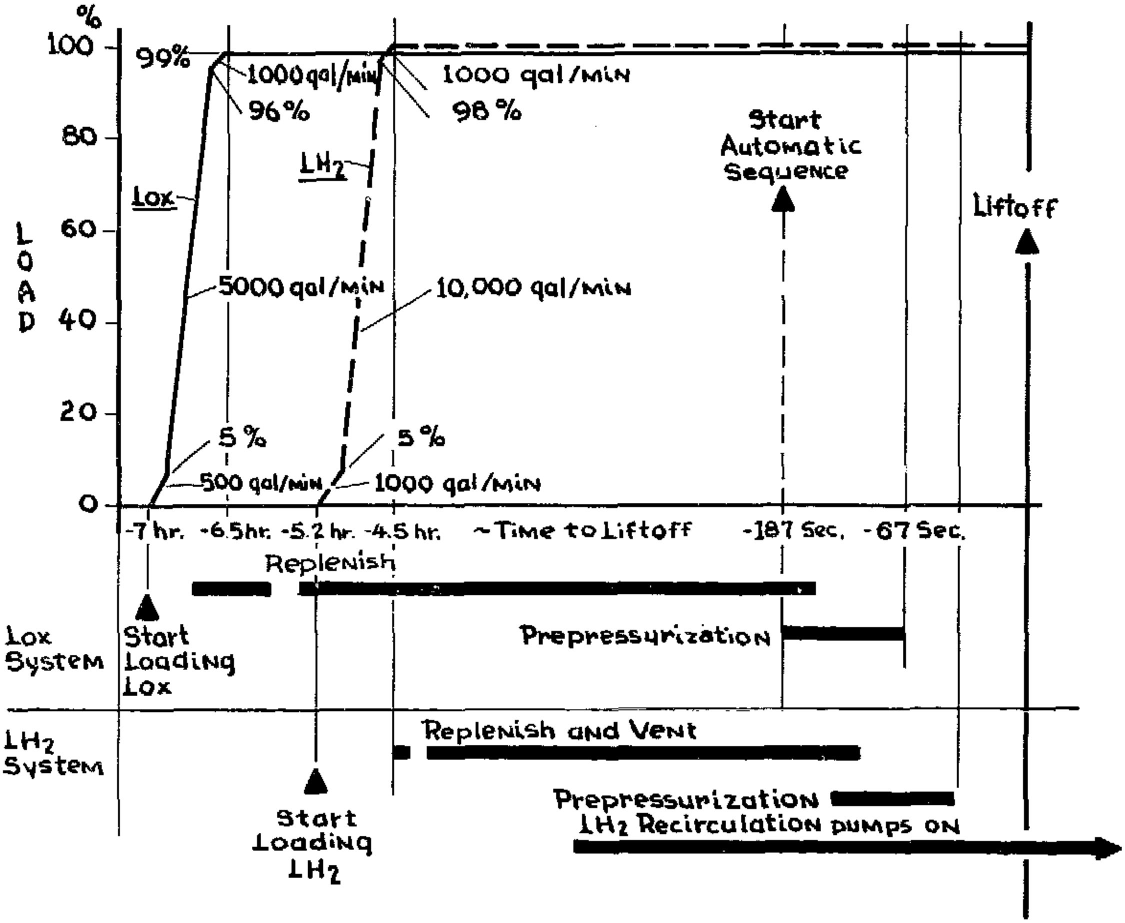
J-2 Engine System
S-II Stage

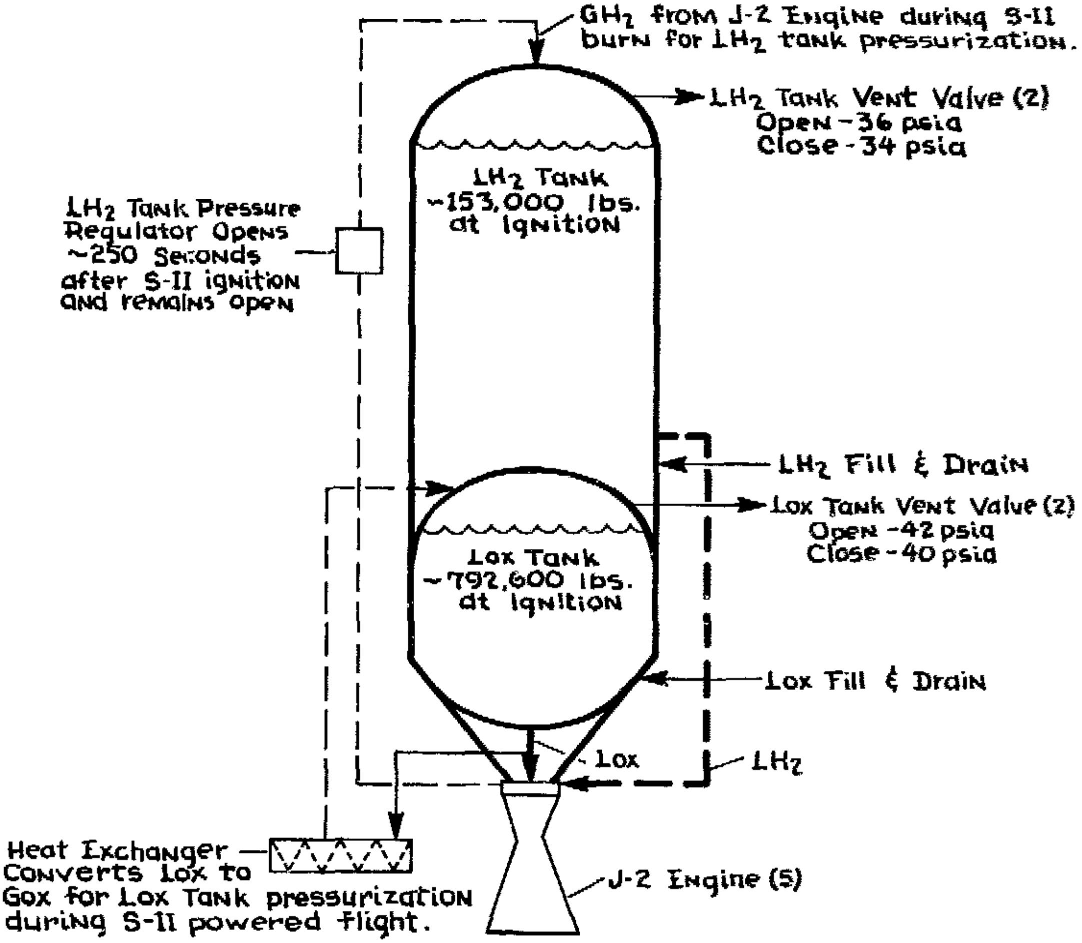
Figure 21

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 liftoff ~946,700 lbs.
Total propellant consumed after liftoff ~938,700 lbs.

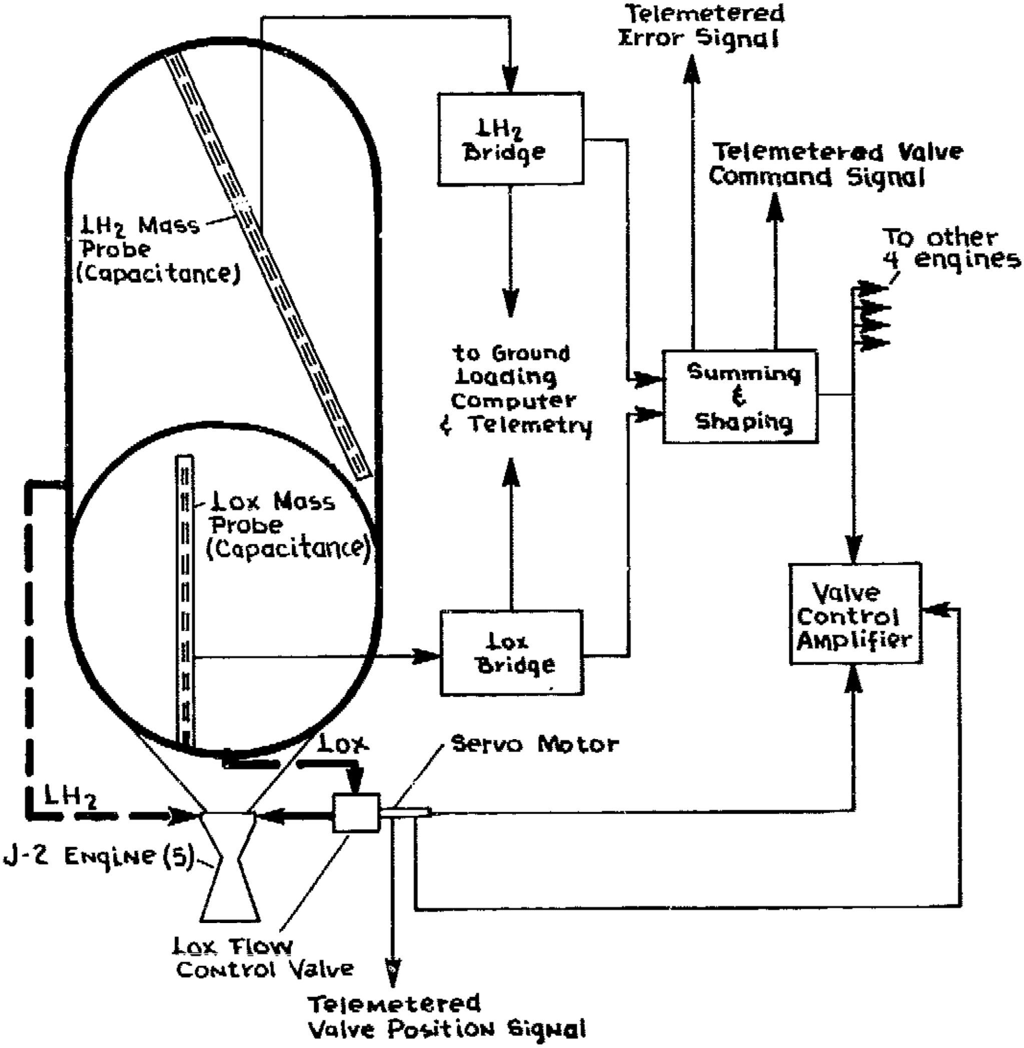
Figure 22

S-II Stage
Propellant System

S-II STAGE PROPELLANT MANAGEMENT SYSTEM

The propellant utilization (PU) system controls 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 PU activation (5.5 seconds after J-2 ignition) the capacitance probes sense the LOX to LH_2 imbalance and commands the engine to burn at the high rate engine mixture ratio of 5.5:1. When the high mixture ratio is removed, the PU system will then command the engine to burn the reference mixture ratio of 4.7:1, striving for simultaneous depletion of LOX and LH_2 for maximum stage performance. Engine cutoff is initiated when any two of the five capacitance probes in either tank indicate dry.



S-II Stage Propellant Management System

Figure 23

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.

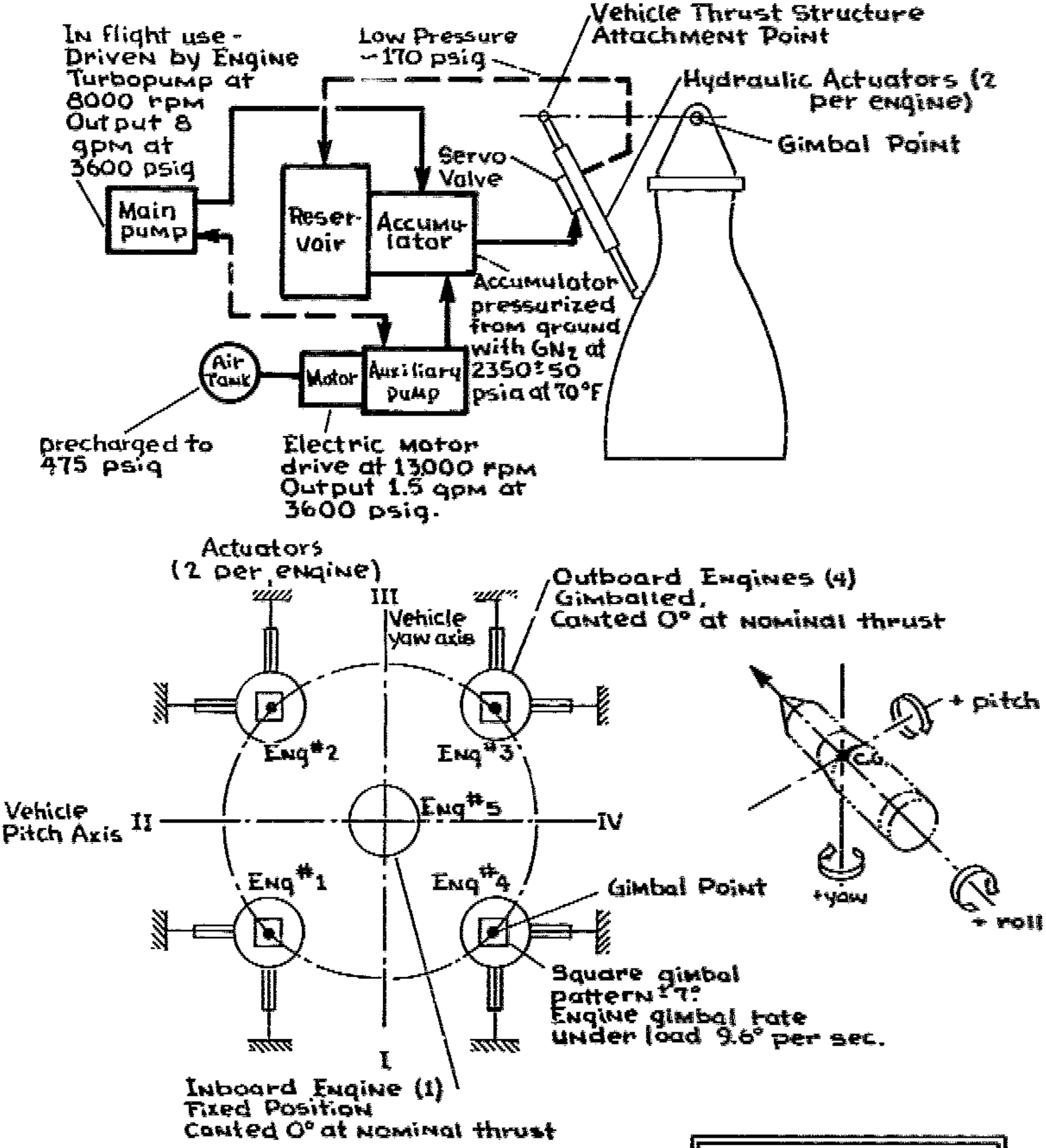


Figure 24

S-II Stage Thrust Vector Control System

Measurement Summary			
System	Flight	ESE Display	ESE Record
1. Temperature	326	19	34
2. Pressure	203	22	30
3. Vibration	60		
4. Flow Rate	10		
5. Signals	228	120	
6. Liquid Level	4	2	2
7. Voltage, Current, Freq.	63	19	9
8. Strain	16		
9. Misc.	66	5	4
Totals ~	976	187 *	79 *

* All ESE Display & Record Measurements Are Also Flight Measurements.

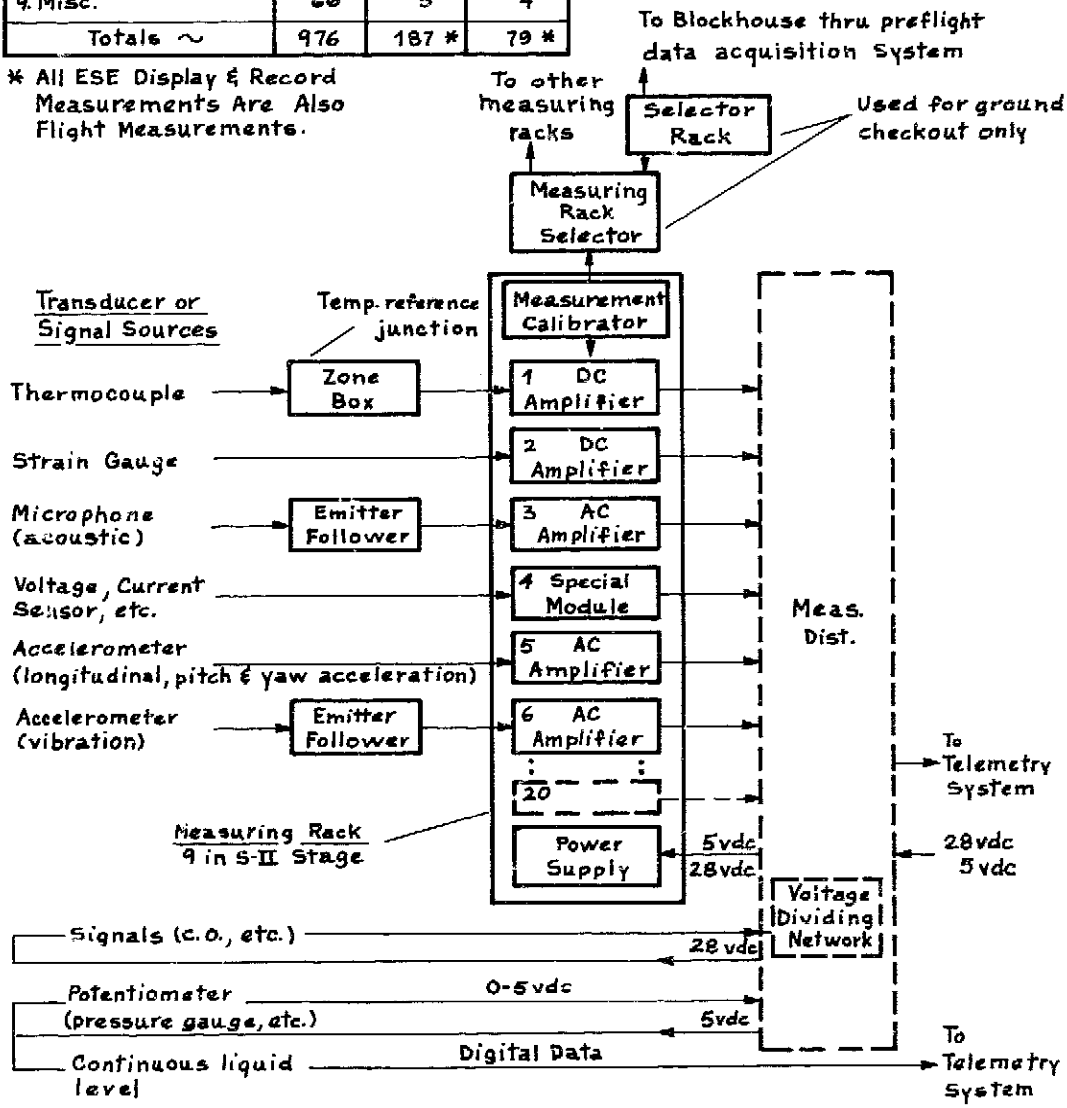


Figure 25

S-II Stage Measuring System

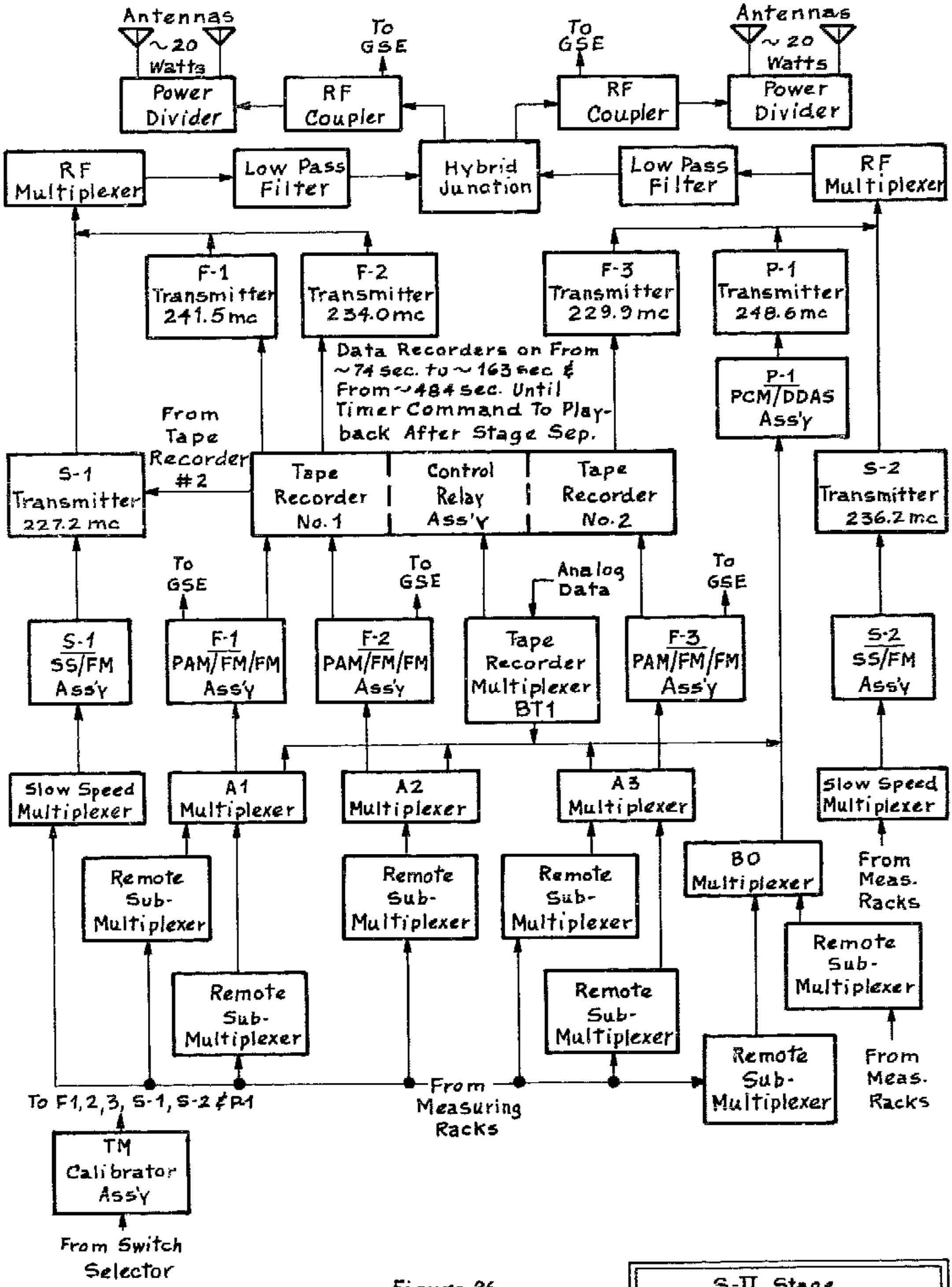


Figure 26

S-II Stage
Telemetry System

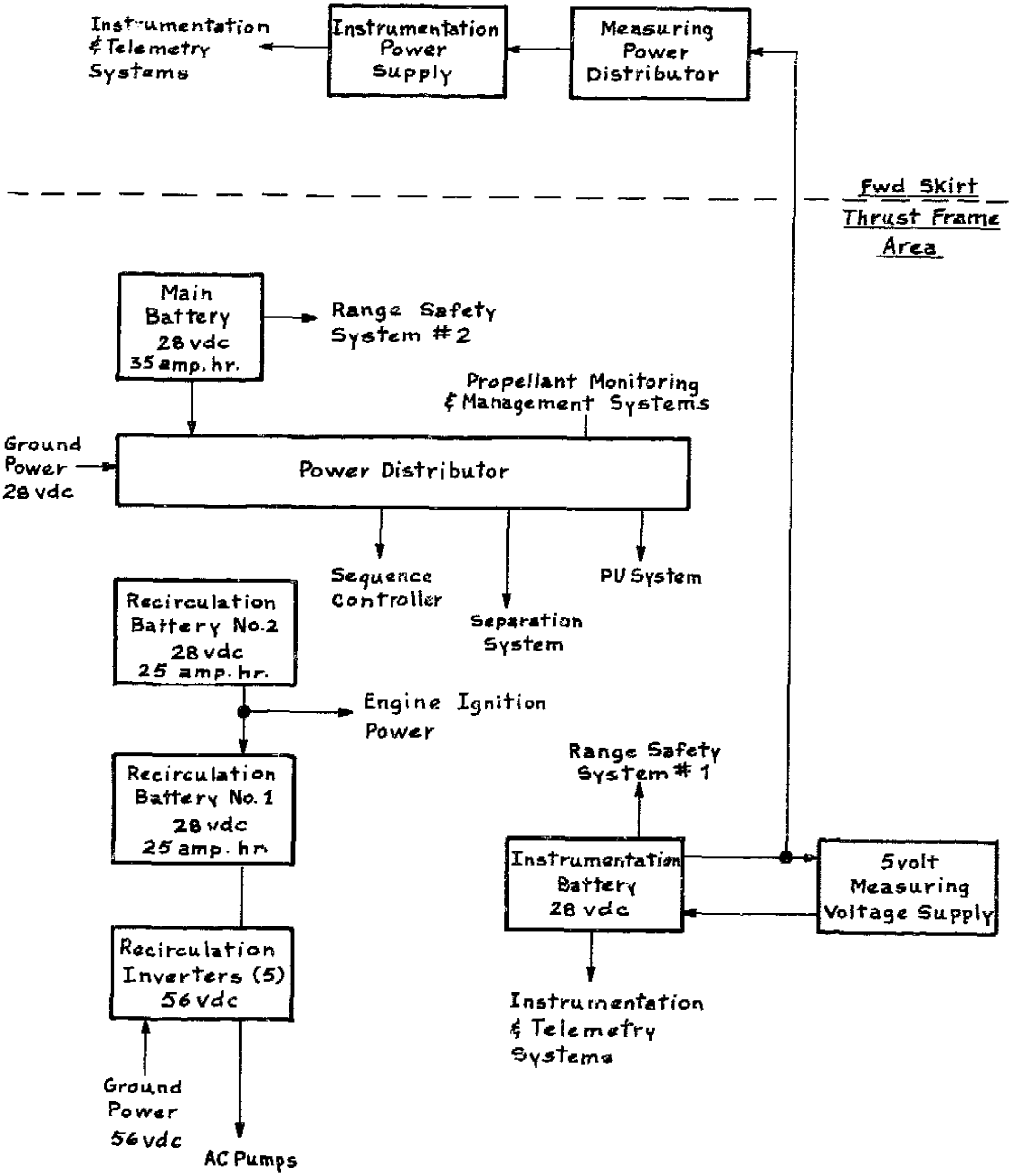


Figure 27

S-II Stage Electrical Power & Distribution System

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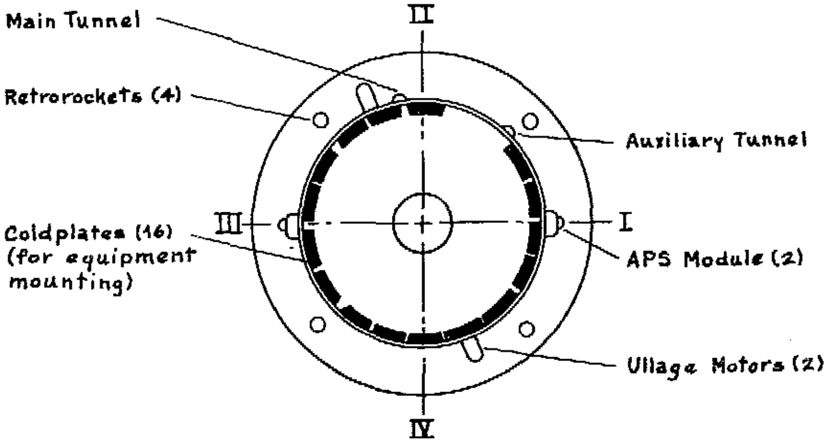
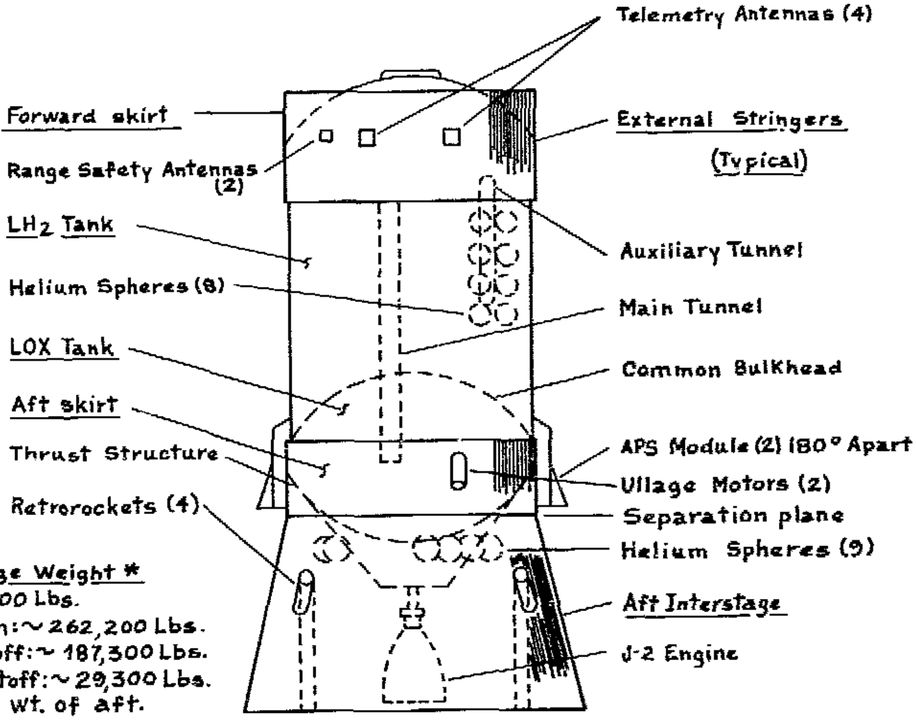
S-IVB STAGE STRUCTURE

The stage structure consists of an aft interstage, an aft skirt, a thrust structure, an LH_2 tank, a LOX tank, and a forward skirt.

A single gimballed J-2 engine of 200,000 pounds nominal thrust is mounted on the stage centerline.



Top View Looking Aft



S-IVB Stage Weight *

- Dry: ~26,500 Lbs.
- At Ignition: ~262,200 Lbs.
- At 1st Cutoff: ~187,300 Lbs.
- At 2nd Cutoff: ~29,300 Lbs.

*Excludes wt. of aft interstage

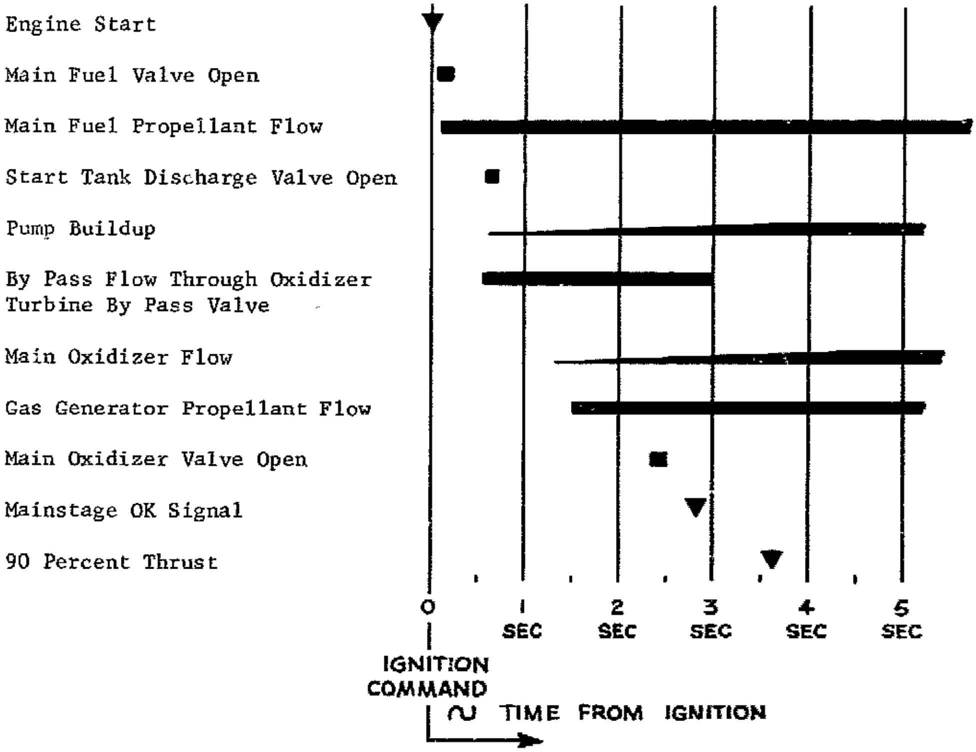
Figure 28

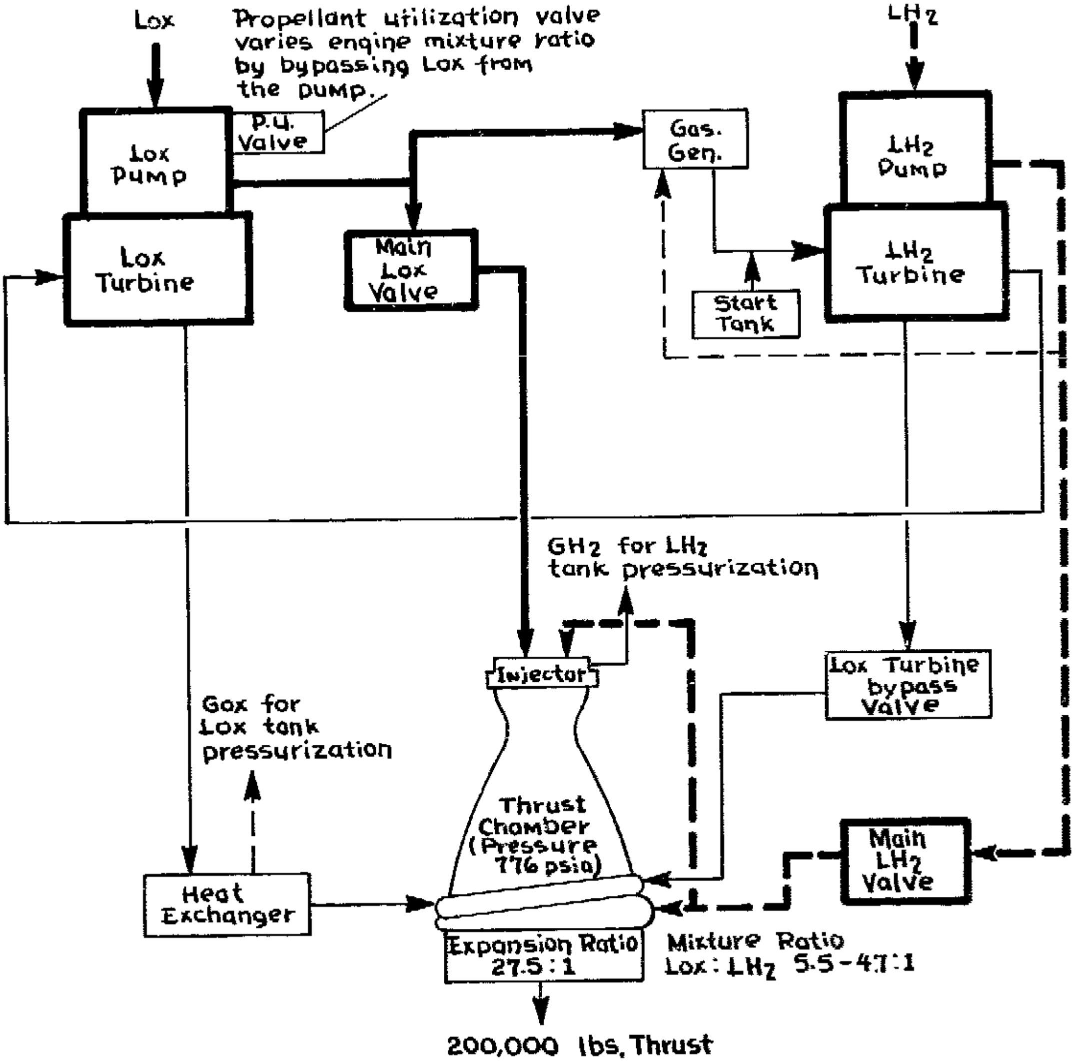
S-IVB Stage Configuration

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.





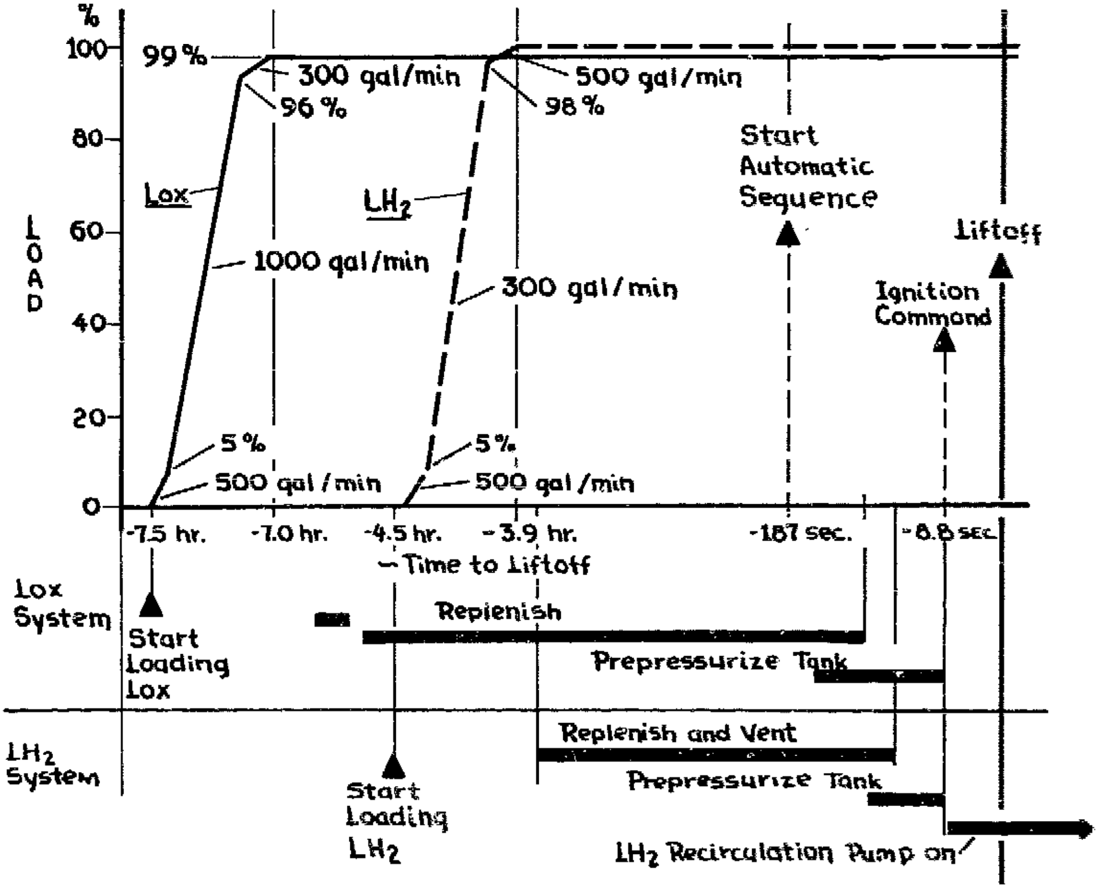
J-2 Engine System
S-IV-B Stage

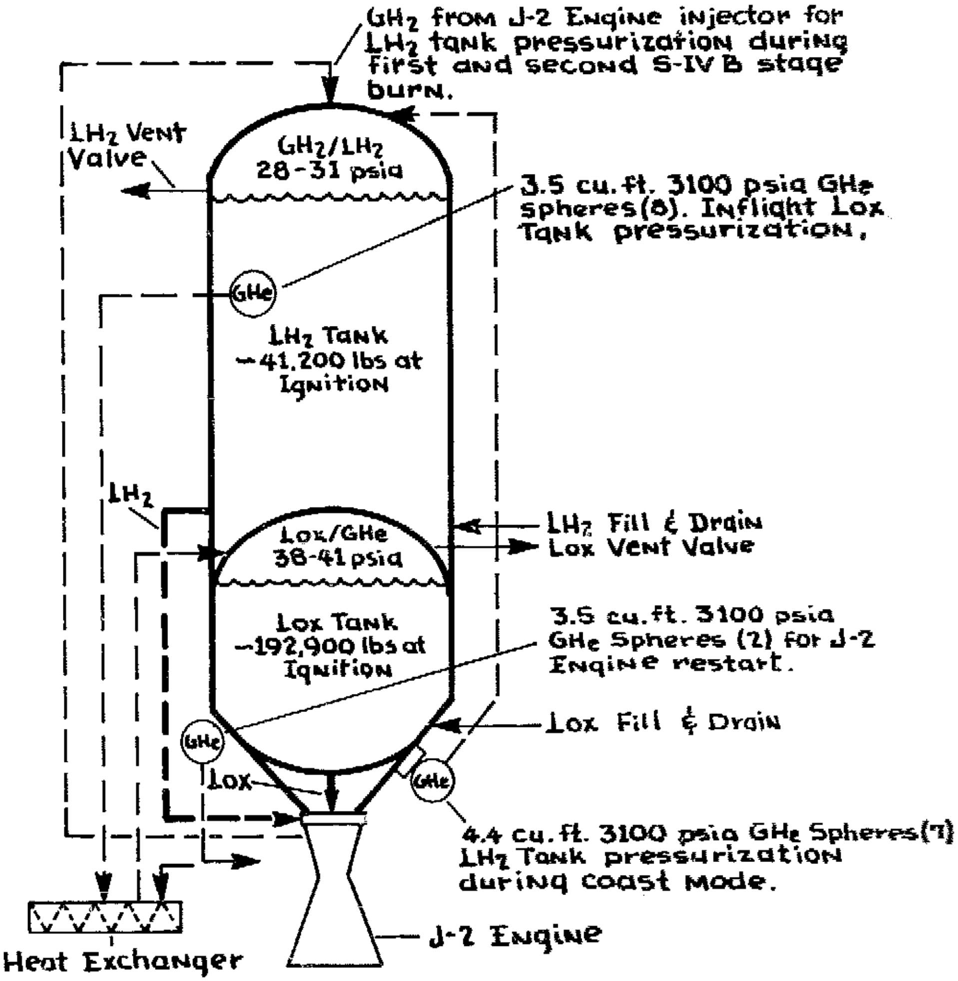
Figure 29

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 liftoff ~234,100 lbs.
Total propellant consumed after liftoff ~232,700 lbs.

Figure 30

S-IVB Stage Propellant System