TECHNICAL INFORMATION SUMMARY

APOLLO-10 (AS-505)

APOLLO SATURN V
SPACE VEHICLE

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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AS-505

TECHNICAL INFORMATION

SUMMARY

This document is prepared jointly by the Marshall Space Flight Center Laboratories S&E-ASTR-S, S&E-AERO-P, and S&E-ASTN-VN. The document presents a brief and concise description of the AS-505 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:

AS-505, Apollo 10, Mission F, is described as a Lunar Mission Development Flight which has been designed to demonstrate crew/spac e vehicle/mission support facilities during a manned lunar mission and to evaluate lunar module performance in lunar environment.

2. Launch Vehicle Mission Objectives

The Principal Detailed Test Objective (DTO) is to demonstrate the AS-505 Launch Vehicle capability to inject the Apollo Spacecraft onto a free return, translunar trajectory.

The Secondary Detailed Test Objectives are:

- Verify J-2 engine modifications.
- Confirm J-2 engine environment in S-II and S-IVB stages.
- Confirm launch vehicle longitudinal oscillation environmental during S-IC stage burn.
- Verify that S-IC modifications will suppress low frequency longitudinal oscillations.

3. Mission Description

Mission F, AS-505, (Apollo 10), has a flight duration of approximately 10 days.

The AS-505 mission has been divided into the following phases which are described below: Launch to parking orbit, coast in parking orbit, injection into translunar trajectory, lunar orbit insertion, restart and injection into transearth trajectory, reentry and splash down.
Figures 1 and 2 illustrate the boost to earth parking orbit and the balance of the mission profile to include lunar orbit and reentry.

**Launch to Parking Orbit.** AS-505 will be launched from Kennedy Space Center, complex 39B on a flight azimuth between 72 and 108 degrees. 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 possible engine failure. Once tower clearance has been accomplished, a pitch and roll maneuver is initiated to achieve the proper flight attitude and flight azimuth orientation.

A successful boost sequence, as illustrated in Figure 1, will insert the S-IVB/IU/SC into a 100 NMI circular earth parking orbit.

**Coast in Earth Parking Orbit.** Coast in earth parking orbit will consist of approximately two or three revolutions during which time the LV and SC will be checked out in preparation for translunar injection. Two injection opportunities have been programmed for AS-505.

**Injection into Translunar Trajectory.** This phase will begin with the S-IVB stage restart sequence which will occur midway during the second revolution (1st opportunity) or during the third revolution (2nd opportunity). This burn will inject the vehicle into a translunar, free return, trajectory. After injection, the CSM separates from the S-IVB/IU, turns around, docks with the LM/S-IVB and performs LM extraction. During translunar coast, spacecraft midcourse corrections are made as required. Following LM extraction, the S-IVB stage will undergo a residual propellant, retrograde dump and safeing sequence. Thrust from available propellants in the launch vehicle auxiliary propulsion system and from main propulsion system venting is used to "propel" the expended S-IVB/IU to pass behind the moon and into a solar orbit. (Figure 2)

**Lunar Orbit Insertion.** As the SC enters the lunar gravitational field, a decision will be made as to whether to remain on a "free return trajectory" which presents a path to transearth trajectory, or to brake into lunar orbit. If conditions are "go" for lunar orbit, one Astronaut will enter the lunar module and check the status of the critical systems. He will then return to the CM prior to lunar orbit insertion.

The SM propulsion system (SPS) is used to deboost the spacecraft into a circular lunar orbit. During lunar orbit, two crew members enter the LM, CSM/LM separation occurs and LM checkout proceeds.

During this activity phase, a LM excursion will simulate the descent and ascent phases of a lunar landing mission. After the simulation phase, CSM/LM final docking occurs and the astronauts will deactivate the LM and return to the CM. After the LM crew returns to the CSM, the LM will be jettisoned.
Restart and Injection to Transearth Trajectory. The SM propulsion system is used once again, to boost the CSM out of lunar orbit and onto a transearth trajectory.

Reentry and Recovery. The command and service module are separated prior to atmospheric reentry. The Service Module Reaction Control System is used to assist in separation.

A range of 2000 nautical miles approximates the distance between the point of atmospheric reentry and the point at which splash-down occurs. Recovery will take place in the Pacific Ocean.
IECO - Inboard Engine Cutoff
OECO - Outboard Engine Cutoff
LET - Launch Escape Tower
IGM - Iterative Guidance Mode

Figure 1
Mission Profile
Boost to Earth Orbit
Figure 2

Trajectory Profile
Lunar Orbital Mission
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Figure 3

AS-505
Space Vehicle
• Pads "A" and "B" are located ~1500 ft. from the shoreline.

• The Vertical Assembly Building (VAB) and The Launch Control Center (LCC) are ~3 miles from the Launch Pads.
MOBILE LAUNCHER

The Mobile Launcher, figure 5, 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.

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.


3. S-11 Aft (preflight). Provides access to vehicle. Retracted prior to liftoff as required.


7. S-1VB Forward (inflight). Provides fuel tank vent, electrical, pneumatic, air-conditioning, and preflight conditioning interfaces. Retract time 8.4 seconds.


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).
Mobile Launcher:

- Umbilical Tower ~ 380 ft high
- Launcher Base ~ 25 ft high
- ~ 160 ft long
- ~ 135 ft wide
- ~ 45 ft square opening in base for S-IC exhaust
- Tower serviced by 2 hi-speed elevators (16 levels)
- Vehicle holddown arms (9) located 90° apart around vehicle base.
- Three Tail Service Mast (TSM) Assemblies support service lines to S-IC stage and provide a means for rapid retraction at liftoff.
GROUND SUPPORT INTERFACE

Test System

A computer controlled automatic checkout system is used to accomplish the Vertical Assembly Building (VAB) high bay and pad testing. An RCA 110A Computer and the other equipment necessary for service and check out are installed with the vehicle on the mobile launcher. Similar equipment, joined by an integration system (relay network), a facilities cabling tunnel and video cables for visual display is located in the Launch Control Center (LCC).

A Digital Data Acquisition System (DDAS) collects vehicle and support equipment responses to test commands and formulates test data for transmission to the LCC or ML.

Digital Events Evaluators (DEE) monitor the status of input lines and generate a time labeled printout for each change detected.

Final Countdown begins at T-102 hours. A countdown clock, located in the LCC, officially records this countdown.
Launch Control Center (LCC)  

Automatic Ground Control Station

Figure 6

Saturn Launch Operations Electrical Support Equipment Systems
LAUNCH VEHICLE SECURE RANGE SAFETY SYSTEMS

The Secure Range Safety Systems, located on the S-IC, S-II and S-IVB stages, provide a means to terminate the flight of an erratic vehicle by the transmission of coded commands from ground stations to the vehicle during boost phase. The Range Safety Officer (RSO) terminates the flight of an erratic vehicle (trajectory deviations) by initiating the emergency engine cutoff command and, if necessary, the propellant dispersion command.

The command destruct system in each stage is completely separate and independent of those in the other stages.

The 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 and the system remains active until orbital insertion. After orbital insertion, the S-IVB stage range safety receiver is deactivated (Safed) by ground command from the Range Safety Officer.
The Emergency Detection System (EDS) is designed to sense and react to emergency situations resulting from launch vehicle malfunctions which may arise during the mission. Crew safety and protection is the primary function of the EDS. Triple redundant sensors and majority voting logic are used in the automatic abort system. Dual redundancy is used for most of the manual abort sensors. The redundancy in the sensing systems is designed to protect against inadvertent aborts.

**Automatic Aborts** – During most of the S-IC flight, the EDS provides the capability of automatically aborting the mission. The automatic abort system is enabled at liftoff and disabled by the crew at approximately 2 minutes or by the IU switch selector prior to S-IC inboard engine cutoff. The system responds to failure modes that lead to rapid vehicle breakup. The parameters and the associated limits monitored for an automatic abort are:

1. Loss of thrust on two or more S-IC engines
2. Vehicle rates in excess of ±4°/sec in pitch or yaw; or ±20°/sec in roll
3. Command Module to IU breakup.

**Manual Aborts** – After the automatic abort mode is disabled, aborts may be initiated manually by the astronauts. Manual aborts are initiated based on at least two separate and distinct indications. The indications may be a combination of EDS sensor displays, physiological indications, and ground information to the astronauts. EDS displays for the crew consist of lights and meters which indicate loss of thrust of each engine, staging sequences, launch vehicle attitude reference failure, angle of attack, tank ullage pressures, spacecraft attitude error and angular rates. The manual abort overrate limits are:

1. Pitch and Yaw - L/O to S-IC/S-II Staging - ±4°/sec
   - S-IC/S-II Staging to S-IV C/O - ±5°/sec
2. Roll - L/O to S-IVB C/O - ±20°/sec

Aborts performed during the launch phase will be performed by using either the Launch Escape System (LES) or the Service Propulsion System (SPS). The LES is used to propel the CM a safe distance from the launch vehicle and to ensure a water landing. The automatic abort sequence of events is dependent on the time (altitude) the abort is initiated. Aborts prior to 30 seconds do not terminate S-IC thrust in order to protect the launch area. The SPS aborts utilize the Service Module SPS engine to propel the CSM away from the launch vehicle, maneuver to a planned landing area or boost into a contingency orbit.
Liftoff

△ Disconnect IU Umbilical

△ Multiple Engine Cutoff Enable ~ 0 min. 14 sec.
△ EDS Engine Cutoff Enable ~ 0 min. 30 sec.

Automatic Abort Capability
1. S-1C two engines out
2. Excessive angular rates
~ 2 min. 14 sec.

△ S-1C Inboard Engine Cutoff ~ 2 min. 15 sec.

△ S-1C Outboard Engine Cutoff ~ 2 min. 41 sec.
△ S-11 Ullage Ignition ~ 2 min. 41 sec.

△ S-1C/S-11 Separation ~ 2 min. 41 sec.
△ S-11 Engine Ignition ~ 2 min. 42 sec.
△ Water Coolant Valve Opens ~ 3 min. 0 sec.

△ S-11 Att Interstage Separation ~ 3 min. 11 sec.
△ S-11 LOX Step Pressurization ~ 4 min. 21 sec.

NOTE:
Approximate times shown are measured from liftoff.

Start of
Time Base 1

Start of
Time Base 2

Start of
Time Base 3

Figure 10
S-1C/S-11 Stage
Right Sequencing
\( \Delta \) S-I Inboard Engine Cutoff \( \sim \) 7 min, 39 sec.
\( \Delta \) S-I LH\(_2\) Step Pressurization \( \sim \) 7 min, 41 sec.
\( \Delta \) S-I LOX \& LH\(_2\) Depletion Sensors Enable \( \sim \) 8 min, 13 sec.
\( \Delta \) S-I Outboard Engine Cutoff \( \sim \) 9 min, 14 sec.
\( \Delta \) S-IVB Ullage Ignition \( \sim \) 9 min, 14 sec.
\( \Delta \) S-I/S-IVB Separation \( \sim \) 9 min, 15 sec.
\( \Delta \) S-IVB Engine Ignition \( \sim \) 9 min, 56 sec.
\( \Delta \) S-IVB Engine Velocity Cutoff \( \sim \) 11 min, 40 sec.
\( \Delta \) S-IVB Ullage Engine On \( \sim \) 11 min, 40 sec.
\( \Delta \) \( S/C \) Control Disable \( \sim \) 11 min, 45 sec.
\( \Delta \) S-IVB Insertion Into Earth
Parking Orbit \( \sim \) 11 min, 53 sec.
\( \Delta \) S-IVB Ullage Engine Off
\( \sim \) 12 min, 49 sec.

**NOTE:**
Approximate times shown are measured from liftoff.

* If restart is delayed until the second injection opportunity this an major subsequent events will occur approximately 1.5 hours later than shown.

\[ 3 \quad 4 \quad 5 \quad 6 \]

**Start of Time Base 4** **Start of Time Base 5** **Start of Time Base 6**

**Figure 11**

S-I/S-IVB Stage
Flight Sequencing
△ S-IVB APS Voltage Off ~ 2 hr. 31 min.
△ S-IVB Restart ~ 2 hr. 31 min.
△ S-IVB LOX & LH$_2$ Point Level Sensor Enable ~ 2 hr. 36 min.
△ S-IVB Second Engine Cutoff ~ 2 hr. 37 min.
△ S-IVB LOX & LH$_2$ Point Level Sensor Disarm ~ 2 hr. 37 min.
△ LH$_2$ Vent Valve Open ~ 2 hr. 37 min.
△ S/C Control Enable ~ 2 hr. 37 min.
△ LH$_2$ Vent Valve Close ~ 2 hr. 52 min.
△ I.U. Command System Enable ~ 2 hr. 57 min.
△ S-IVB/CSM Separation ~ 3 hr. 02 min.

△ LH$_2$ Tank Latching Relief Valve Open On ~ 3 hr. 37 min.
△ LH$_2$ Tank Latching Relief Valve Open Off ~ 3 hr. 49 min.
△ S-IVB Propellant Dump & Sealing ~ 4 hr. 37 sec
△ S-IVB Engine, EDS Cutoff No. 2 ~ 4 hr. 37 sec.
△ S-IVB Passivation Enable ~ 4 hr. 49 min.
△ LOX Tank NPV Valve Open On ~ 4 hr. 54 min.
△ LOX Tank NPV Valve Open Off ~ 4 hr. 54 min.
△ S-IVB Passivation Disable ~ 5 hr. 16 min.

NOTE:
Approximate times shown are measured from liftoff.

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Flight Sequencing
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<td>Guidance Reference Release</td>
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<td></td>
<td>0:00:17</td>
<td>Initiated by terminal count sequencer</td>
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<td>Liftoff (I.U. Umbilical Release</td>
<td>T₁</td>
<td>0:00:00</td>
<td></td>
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<td>First S-IVB Engine Cutoff</td>
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<td>Restart Sequence</td>
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1. Translunar Injection Inhibit (S/C switch) Prior to Time Base 6
2. Translunar Injection Inhibit (S/C switch) During Time Base 6
3. Inhibit Removed by Ground Command After Time Base 7 + 2 Hours

**Nominal Mission**

NOTE:
During Time Base 5 the TDEE Ground Command will inhibit the initiation of Time Base 6 and Time Base 5 will continue to the EOM.

*Figure 13* Time Base Sequencing
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. 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. The proper vehicle position during earth orbit.

5. 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.

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. During spacecraft control of the launch vehicle, the FCC receives attitude error signals from the Command Module Computer or the Astronaut hand controller.

The Switch Selectors in each stage are used to control the inflight sequencing as commanded from the LVDA/LVDC.
Figure 14

Guidance and Control System Block Diagram
**DIGITAL COMMAND SYSTEM CAPABILITY:**

The following summary describes the Digital Command Systems' capability:

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Periods of Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maneuver inhibit</td>
<td>Inhibits Spacecraft separation maneuver</td>
<td>From T5 + 0 seconds to T6 - 9 seconds and from T7 + 0 seconds to EOM</td>
</tr>
<tr>
<td>Maneuver update</td>
<td>Changes the time to start the separation maneuver</td>
<td>From T5 + 0 seconds to T6 - 9 seconds and from T7 + 0 seconds to EOM</td>
</tr>
<tr>
<td>Execute Maneuver A</td>
<td>Initiates maneuver to local horizontal in a retrograde position</td>
<td>From T7 + 0 seconds to EOM</td>
</tr>
<tr>
<td>Time base update</td>
<td>Changes the time base time</td>
<td>From T5 + 0 seconds to T6 - 9 seconds and from T7 + 0 seconds to EOM</td>
</tr>
<tr>
<td>Navigation update</td>
<td>Replaces onboard navigation state vector</td>
<td>From T5 + 100 seconds to T6 - 9 seconds and from T7 + 20 seconds to EOM</td>
</tr>
<tr>
<td>Target update</td>
<td>Replaces targeting quantities for second S-IVB burn</td>
<td>From T5 + 0 seconds to T6 - 9 seconds</td>
</tr>
<tr>
<td>TD &amp; E enable</td>
<td>Inhibits T6 so that TD &amp; E can be accomplished in earth orbit</td>
<td>From T5 + 0 seconds to T6 - 9</td>
</tr>
<tr>
<td>Time Base 8 enable</td>
<td>Initiates propellant dump and safeing sequence</td>
<td>From T7 + 2 hrs. to EOM</td>
</tr>
<tr>
<td>Sector dump</td>
<td>Initiates telemetry of specified memory sector</td>
<td>From T5 + 100 seconds to T6 - 9 seconds and from T7 + 20 seconds to EOM</td>
</tr>
<tr>
<td>Single memory</td>
<td>Initiates telemetry of specified memory location</td>
<td>From T5 + 100 seconds to T6 - 9 seconds and from T7 + 20 seconds to EOM</td>
</tr>
<tr>
<td>Generalized switch selector</td>
<td>Executes specified switch selector function</td>
<td>From T5 + 0 seconds to T6 + 560 seconds and from T7 + 0 seconds to EOM</td>
</tr>
<tr>
<td>Inhibit water control valve logic</td>
<td>Inhibit logic which changes the position of the water control valve</td>
<td>From T5 + 0 seconds to T6 - 9 seconds from T7 + 0 seconds to EOM</td>
</tr>
<tr>
<td>Switch antenna to omni, low or high gain</td>
<td>Initiates switching of both PCM and CCS antennas.</td>
<td>From T5 + 100 seconds to T6 - 9 seconds and from T7 + 0 seconds to EOM</td>
</tr>
<tr>
<td>Terminate</td>
<td>Stops DCS processing and resets system for a new command</td>
<td>From T5 + 0 seconds to T6 + 560 seconds and from T7 + 0 seconds to EOM</td>
</tr>
</tbody>
</table>

EOM---End of Mission
The Digital Command System (DCS) is not used during powered flight phases. During the orbital phases of the mission, the crew will place the UP-TLM-IU switch in the "Accept" position to enable the DCS hardware for the acceptance of ground commands. After Y/C separation, the IU switch selector enables the DCS hardware for ground commands. However, commands will only be accepted by the flight program within the period of time programmed in the LVDC as described on page 26.
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 receiving 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 30 and 31.
### Measurement Summary - L/V

<table>
<thead>
<tr>
<th>Measurement</th>
<th>S-1C Stage</th>
<th>S-11 Stage</th>
<th>S-1VB Stage</th>
<th>Inst. Unit</th>
<th>L/V Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration</td>
<td>3</td>
<td>11</td>
<td>-</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Acoustic</td>
<td>4</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Temperature</td>
<td>166</td>
<td>308</td>
<td>71</td>
<td>14</td>
<td>559</td>
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<tr>
<td>Pressure</td>
<td>177</td>
<td>182</td>
<td>70</td>
<td>10</td>
<td>439</td>
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<tr>
<td>Vibration</td>
<td>67</td>
<td>60</td>
<td>-</td>
<td>-</td>
<td>187</td>
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<tr>
<td>Flow Rate</td>
<td>35</td>
<td>10</td>
<td>4</td>
<td>4</td>
<td>53</td>
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<tr>
<td>Position</td>
<td>1</td>
<td>36</td>
<td>8</td>
<td>21</td>
<td>66</td>
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<tr>
<td>Signals</td>
<td>142</td>
<td>225</td>
<td>71</td>
<td>63</td>
<td>501</td>
</tr>
<tr>
<td>Liquid Level</td>
<td>18</td>
<td>6</td>
<td>7</td>
<td>-</td>
<td>31</td>
</tr>
<tr>
<td>Voltage, Current, Frequency</td>
<td>11</td>
<td>65</td>
<td>38</td>
<td>17</td>
<td>126</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>12</td>
<td>4</td>
<td>8</td>
<td>-</td>
<td>24</td>
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<tr>
<td>Angular Velocity</td>
<td>3</td>
<td>3</td>
<td>-</td>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>Strain</td>
<td>-</td>
<td>27</td>
<td>-</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td>RPM</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>-</td>
<td>17</td>
</tr>
<tr>
<td>Guidance and Control</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>RF and Telemetry</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16</td>
<td>16</td>
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<tr>
<td><strong>Totals</strong></td>
<td><strong>644</strong></td>
<td><strong>930</strong></td>
<td><strong>279</strong></td>
<td><strong>218</strong></td>
<td><strong>2077</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measurement</th>
<th>CM</th>
<th>SM</th>
<th>LM</th>
<th>S/C Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>18</td>
<td>37</td>
<td>103</td>
<td>158</td>
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<tr>
<td>Temperature</td>
<td>19</td>
<td>43</td>
<td>153</td>
<td>215</td>
</tr>
<tr>
<td>Discrete Event</td>
<td>84</td>
<td>5</td>
<td>303</td>
<td>392</td>
</tr>
<tr>
<td>Voltage, Current, Frequency</td>
<td>44</td>
<td>3</td>
<td>206</td>
<td>253</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>30</td>
<td>55</td>
<td>115</td>
<td>200</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>195</strong></td>
<td><strong>143</strong></td>
<td><strong>880</strong></td>
<td><strong>1218</strong></td>
</tr>
</tbody>
</table>

**Figure 14**

AS-505
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 determine the vehicle's trajectory. This requirement is satisfied by the RF Tracking Systems. The tracking data is used by mission control, range safety, and for post-flight evaluation of the vehicle's performance.

The principal tracking systems used are:

- **C-band radar** - Used in the IU and spacecraft
- **Unified S-band system** - Used in the IU and spacecraft.

**ODOP System**

Note: The Offset Doppler System, previously used in the S-IC Stage, has been discontinued.

**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 are carried in the IU to provide radar tracking capabilities independent of vehicle attitude.

**Unified S-Band System (IU and SC)**

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

C-Band Radar System

Crystal switch driven by Comparator
Automatically selects strongest receiver's antenna for output

Unified Q-Band System

Instrument Unit

S-Band System

S-IC Stage

Note: The Offset Doppler, frequency measurement system, (ODOP), previously used in the S-IC Stage, has been discontinued.
**SPACE VEHICLE WEIGHT VS FLIGHT TIME**

Mainstage propellant consumption during S-IC Stage powered flight (approximately 158 seconds) is approximately 4,609,300 pounds. Propellant consumption during S-II Stage powered flight (approximately 390 seconds) is approximately 974,900 pounds and during S-IVB Stage powered flight including first ignition, restart and burn (approximately 525 seconds) is approximately 229,500 pounds.

<table>
<thead>
<tr>
<th>Vehicle Weight Data (Approximate)</th>
<th>Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total at S-IC Stage ignition</td>
<td>6,492,800</td>
</tr>
<tr>
<td>Total at holddown arm release</td>
<td>6,407,000</td>
</tr>
<tr>
<td>Total at S-IC Stage O.E.C.O.</td>
<td>1,839,700</td>
</tr>
<tr>
<td>Total at S-II Stage ignition</td>
<td>1,459,300</td>
</tr>
<tr>
<td>Total at S-II Stage O.E.C.O.</td>
<td>471,500</td>
</tr>
<tr>
<td>Total at S-IVB Stage ignition</td>
<td>364,300</td>
</tr>
<tr>
<td>Total at S-IVB Stage E.C.O.</td>
<td>191,350</td>
</tr>
<tr>
<td>Total at S-IVB Stage engine restart</td>
<td>291,000</td>
</tr>
<tr>
<td>Total at S-IVB Stage 2nd E. C.O.</td>
<td>131,800</td>
</tr>
<tr>
<td>Total at S-IVB Stage/CSM separation</td>
<td>131,600</td>
</tr>
<tr>
<td>Total at SC Translunar injection</td>
<td>94,500</td>
</tr>
</tbody>
</table>
6,492,800 lbs. (Total Vehicle at Ignition)
6,407,000 lbs. (Total Vehicle at Holddown Firm Release)(0 sec)

S-IC Stage Propellant Consumption 24,170 lbs/sec (Average)

S-IC Stage Outboard Engine Cutoff (~161 sec) (1,839,700)
S-IC/5-11 Stage Separation (~161 sec)
S-11 Stage Ignition (~192 sec) (~1,459,265 lbs)

S-11 Stage Propellant Consumption 2,580 lbs/sec (Average)

S-11 Stage Outboard Engine Cutoff (~53.2 sec) (~471,500 lbs)
S-11/5-IVB Stage Separation (~53.1 sec) (~471,100 lbs)

5-IVB Stage Ignition (~53 sec) (364,300)

5-IVB Stage Propellant Consumption 3,048 lbs/sec (Average)

5-IVB Stage/CSM into Earth Parking Orbit (~692 sec)

Begin 5-IVB Stage Engine Restart Preparation (~2 hr. 21 min)

5-IVB Stage Engine Restart (~2 hr 31 min) (129,000)

5-IVB Stage Engine Second Cutoff (~2 hr 31 min) (151,800)

5-IVB Stage/CSM Separation (3 hr. 02 min X ~151,600 lbs)

Spacecraft at Trans-Lunar Injection (~94,500 lbs)

Figure 18

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 hi-propellant system of liquid oxygen (LOX) as the oxidizer and RP-1 as the fuel. The S-IC stage interfaces structurally and electrically with the S-II stage (forward skirt structure).

- **The Forward Skirt**

  The Forward Skirt accommodates the forward umbilical plate, the electrical and electronic canisters, and the venting of the Lox tank and interstage cavity. The aluminum skin panels are stiffened by ring frames and stringers.

- **The Oxidizer Tank**

  The 345,000 gallon Lox tank is the structural link between the forward and intertank sections. Stiffened by machined "T" stiffeners the tank is internally equipped with ring baffles for additional stability as well as to reduce Lox sloshing. Ring baffles also provide support for four helium bottles.

- **The Intertank Section**

  The intertank section provides structurally continuity between the Lox and RP-1 tanks.

- **The RP-1 (Fuel) Tank**

  The RP-1 fuel tank, located between the thrust structure and the intertank section, is a cylindrical aluminum structure with a load capacity of 216,000 gallons. Antislosh ring baffles are located on the inner walls while cruciform baffles are located on the lower bulkhead. A lightweight foam material, bonded to the lower bulkhead, serves as an exclusive riser to minimize unusable residual fuel.

- **The Thrust Structure**

  The thrust structure provides support for the five engines, the base heat shield, engine fairings and fins, propellant lines, retro rockets and environmental control ducts. The lower thrust ring also has four hold-down points to restrain the vehicle, as necessary, from lifting off at full F-1 engine thrust.
Stage Weight
- Dry: ~ 295,200 Lbs.
- At Ignition: ~ 5,051,000
- At Separation: ~ 371,600

Figure 19
S-IC Stage Configuration
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 gasses 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 is achieved.

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.

![Engine Start Sequence in Seconds from Control Valve "Open" Signal](image-url)
Figure 20

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 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

![S-IC Propellant Load and Operational Sequence Diagram](image-url)
Figure 21

S-IC Stage Propellant System
S-IC STAGE THRUST VECTOR CONTROL SYSTEM

The four outboard F-1 engines are gimbal mounted on the stage thrust structure to provide attitude control during S-IC stage powered flight. Each independent gimbal system employs two hydraulic servo actuators. These servo actuators convert electrical command signals (Flight Control Computer) and hydraulic pressure into mechanical outputs which gimbal the outboard engines on the S-IC stage. An integral mechanical feedback, varied by piston position, modifies the effect of the control signal from the FCC. Built-in potentiometers sense servo actuator positions for telemetry as well as providing an interlock to preclude liftoff with an engine hardover.

Hydraulic pressure is supplied to the Thrust Vector Control System from a GSE pressure source during prelaunch checkout and engine start. The GSE pressure source utilizes RJ-1 ramjet fuel as the hydraulic fluid. During engine operation, hydraulic pressure is supplied from the fuel discharge of the engine turbo pump to the servo valve actuators. The fuel returns through a check valve to the fuel inlet of the turbo pump. RP-1, the fuel used by the S-IC stage, is used as the hydraulic fluid during engine operation.
From No.1 Turbopump fuel discharge

Manifold Filter

Turbopump fuel discharge duct

Gimbal Point

To No.2 Turbopump assembly input

Valve (Checkout)

Vehicle Thrust Structure Actuator Attachment Point

Hydraulic Actuator (2 per engine)

Servo Valve Controls Actuator Movement

Engine Actuator/Liftoff Interlock
(Potentiometer to insure that liftoff will not occur with a hardover pitch or yaw actuator)

Actuators (2 per engine)

Vehicle Yaw Axis

Outboard Engines (4) Gimbaled, Canted 0° at Nominal Thrust

+pitch

Vehicle Pitch Axis

Eng*2

Eng*3

Eng*5

Eng*4

Inboard Engine (1) Fixed Position, Canted 0°

IV Gimbal Point

Square Gimbal Pattern ±5.1° Engine Gimbal rate under load 5° per sec.

Figure 22

S-IC Stage Thrust Vector Control System
Measuring Racks (27)

To other measuring racks

Transducer or Signal Sources

Thermocouple

Strain Gauge

Microphone (acoustic)

Voltage, Current, Sensor, etc.

Accelerometer (longitudinal acceleration)

Accelerometer (vibration)

Note: AC Amplifiers No. 7 thru 20 located in measuring rack.

Temp. reference junction

Zone Box

Mutter Follower

3 AC Amplifier

4 Special Module

5 AC Amplifier

6 AC Amplifier

Power Supply

Meas. Dist.

28 vdc

5 vdc

28 vdc

Digital Data

5 vdc

Signals (c.o., etc.)

Potentiometer (pressure gauge, etc.)

0-5 vdc

Continuous liquid level

Voltage Dividing Network

To Telemetry System

To Telemetry System

Figure 23

3-IC Stage Measuring System
- PAM/FM/FM is used to transmit data in the frequency range below 100 Hertz.
- PCM/FM provide data acquisition link for analog and digital data, plus a redundant means for monitoring the three PAM links.
- SS/FM links S1 and S2 transmit acoustical and vibration data in the frequency range of 50 to 3000 Hertz.
- The VSWR Monitor is used to monitor the performance of the telemetry antenna system and the output of the telemetry transmitter.
Notes:
All components shown are located in the Thrust Frame Area except as noted.
**S-IC Battery Characteristics**

**Type:**
- Dry charge
- Silver-Zinc Oxide
- Electrolyte consists of Potassium Hydroxide in Pure Water.

**Nominal Voltage:** 28 ± 2 vdc (1.5 vdc per cell)

**Current Ratings:**
- Battery No. 1 - 640 amps/min
- Battery No. 2 - 1250 amps/min

**Gross Weight:**
- Battery No. 1 - 22 lbs
- Battery No. 2 - 55 lbs
S-II STAGE 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-propelled J-2 rocket engines which combine to develop a total thrust of 1,150,000 pounds.

- **Body Shell Structure**

  The body shell structure consists of the forward skirt, aft skirt and interstage. Each unit is a cylindrical aluminum alloy shell of semimonocoque construction. The units are stiffened externally by stringers and are stabilized internally by circumferential ring frames.

- **Thrust Structure**

  The thrust structure is of semimonocoque construction in the form of a truncated cone. The structure is stiffened circumferentially by ring frames and stringers. Thrust longerons and a cruciform assembly for the center engine, support and distribute the thrust loads of the J-2 engines. A fiberglass honeycomb heat shield protects the stage base area from excessive temperature during S-II boost.

- **Propellant Tank Structure**

  The Liquid Hydrogen (LH2) tank consists of a long cylinder with a forward convex bulkhead and an aft concave bulkhead. The aft bulkhead is common to the LOx tank. The LH2 tank wall is composed of six cylindrical sections which incorporate longitudinal and circumferential stiffeners. The LOx tank consists of ellipsoidal fore and aft halves with waffle-stiffened gore segments. Slosh baffles are incorporated to control propellant sloshing and cruciform baffles to prevent vortices at the tank outlet ducts.

- **System Tunnel**

  The systems tunnel houses electrical cables, pressurization lines and the propellant dispersion ordnance. The tunnel is attached externally from the S-II stage aft skirt to the forward skirt.
Antenna Arrangement

Telemetry Antennas (4)
Secure Range Safety Antennas (4)

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

Fwd Bulkhead
Fwd Skirt
External Stringers (Typical)
Systems Tunnel
Aft Bulkhead
LH₂ Fill & Drain
Aft Skirt
LOX Fill & Drain
Thrust Structure
Aft Interstage
Ullage Rockets (4)

Stage Weight
- Dry: ~ 84,600 lbs.
- At S-II Ignition: ~ 1,067,800 lbs.
- At S-II Cutoff: ~ 98,900 lbs.
- At S-II Separation: ~ 98,600 lbs.

Figure 26
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.

Engine Start
Main Fuel Valve Open
Main Fuel Propellant Flow
Start Tank Discharge Valve Open
Pump Buildup
Bypass Flow Through Oxidizer Turbine By-pass Valve
Main Oxidizer Flow
Gas Generator Propellant Flow
Main Oxidizer Valve Open
Mainstage OK Signal
90 Percent Thrust
Propellant utilization valve varies engine mixture ratio by bypassing LOX from the pump.

LOX Pump

LOX Turbine

PU Valve

Main LOX Valve

Gas Gen.

LOX Turbine bypass valve

LOX for LOX tank pressurization

GOX for LOX tank pressurization

Heat Exchanger

Expansion Ratio 27.5:1

Thrust chamber pressure 776 psia at S:O:1

injector

Expansion Ratio 27.5:1

200,000 lbs Thrust

Mixture ratio

LOX: LH₂ 5.5 - 4.3:1

Programmed by weight.

Figure 27

J-2 Engine System S-II Stage
S-II STAGE PROPELLANT SYSTEM

The S-II Stage propellant system is composed of integral LOX/LH₂ 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/LH₂ 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 LH₂ tank is pressurized by GH₂ bleed from the thrust chamber hydrogen injector manifold: pressurization is maintained by the LH₂ Pressure Regulator.

S-II PROPELLANT LOAD AND OPERATIONAL SEQUENCE
GHZ from J-2 Engine during S-II burn for LH₂ Tank pressurization

LH₂ Tank Vent Valve (2)
Open 36 psia
Close 34 psia

LH₂ Tank pressure
Regulator opens ~299 seconds after S-II ignition and remains open.

LH₂ Fill and Drain

LOX Tank Vent Valve (2)
Open 42 psia
Close 39 psia

LOX Fill and Drain

Heat Exchanger
Converts LOX to GOX for LOX Tank pressurization during S-II powered flight.

J-2 Engine (5)

Total propellant at ignition
~982,700 lbs
Total propellant consumed after ignition ~974,900 lbs.
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 LH₂) to ensure balanced consumption of LOX and LH₂.

Capacitance probes, mounted in the LOX and LH₂ 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 mixture ratio by the LVDC/LVDA. When the initial phase of IGM guidance is completed, (nominally engine start plus 318 seconds), the LVDC/LVDA through the S-II switch selector will command the PU valve to a mixture ratio of 4.5:1.

Outboard engine cutoff is initiated when any two of the five capacitance probes, in either tank, indicate dry. Prior to this cutoff, the LVDC/LVDA through the S-II switch selector commands S-II center engine cutoff.
The diagram illustrates the S-11 Stage Propellant Management System. It shows the flow of LH₂ and LOX mass probe signals to a bridge, then to a summing and shaping circuit. The signals are further processed and sent to a valve control amplifier, which in turn controls the valve position feedback. The system also includes components such as the LH₂ switch selector, which manages the mixture ratio command. The diagram highlights the interaction between various components to ensure proper propellant management during the S-11 stage.
S-II STAGE THRUST VECTOR CONTROL SYSTEM

The four outboard J-2 engines are gimbal mounted to provide thrust vector control during powered flight. Attitude control is maintained by gimballing the outboard engines in conjunction with electrical control signals from the IU flight control computer.

The gimballing system consists of four independent closed-loop hydraulic control subsystems which provide power for engine gimballing. The primary components of the subsystem are an auxiliary pump, a main pump, an accumulator/reservoir manifold assembly and two servo actuators (see page 55). The auxiliary pump is electrically driven from the GSE to provide hydraulic fluid circulation prior to launch. The main pump is mounted to and driven by the engine LOX turbopump. The accumulator/reservoir manifold assembly consist of a high pressure accumulator which receives high pressure fluid from the pump and a low pressure reservoir which receives return fluid from the servo actuators. The servo actuator is a power control unit that converts electrical signals and hydraulic power into mechanical outputs that gimbal the engine.

During the prelaunch period, the auxiliary hydraulic pump circulates the hydraulic fluid to preclude fluid freezing during propellant loading. Circulation is not required during the S-IC burn due to the short duration burn. After S-IC/S-II separation, an S-II switch selector command unlocks the accumulator lock up valves, releasing high pressure fluid to each of the servo actuators. The accumulators provide gimballing power prior to the main hydraulic pump operation (S-IC/S-II separation transients). During S-II mainstage operation, the main hydraulic pump supplies high pressure fluid to the servo actuators. The return fluid from the actuators is routed to the reservoir which stores hydraulic fluid at sufficient pressure to supply a positive pressure at the main pump inlet.
I,
---
I\~o\~c:
dux,
l/rar3/
Puma
used
during
pr-el~cnch &tor
Auxil
ary
Pump

Vehicle Pitch Axis

Vehicle Yaw Axis

Inboard Engine (1)
Fixed Position
Canted 0° at Nominal Thrust

Low Pressure ~170 psig

Vehicle Thrust Structure Attachment Point

Hydraulic Actuators (2)

Servo Valve

Accumulator pressurized from ground with Gmz at 2350±50 psig at 70°F

Note: Auxiliary Pump used only during prelaunch

Main Pump

Reservoir

Accumulator

Motor

Auxiliary Pump

Inflight use - Driven by Engine Turbo Pump at 8000 RPM output 8.0 gpm at 3600 psig

Precharged to 475 psig

Electric Motor Driven at 13,000 RPM output 1.5 gpm at 3600 psig

Actuators (2 per engine)

Vehicle Yaw Axis

Vehicle Pitch Axis

Eng#1

Eng#2

Eng#3

Eng#4

Eng#5

Outboard Engine(s)
Gimbaled Canted 0° at Nominal Thrust

Gimbal Point

Square Gimbal Pattern ±1°
Engine Gimbal Rate Under Load 9° per sec.

S-11 Stage Thrust Vector Control System

Figure 30

55°
Figure 9

S-11 Stage Telemetry System
Instrumentation & Telemetry Systems

Instrumentation Power Supply

Measuring Power Distributor

Ground Power 28 Vdc

Main Battery 28 Vdc 35 Amp. hr.

Range Safety System #2

Power Distributor

Propellant Monitoring & Management Systems

Sequence Controller

Separation System

Engine Ignition Power

Range Safety System #1

Recirculation Battery No. 2 28 Vdc 35 Amp. hr.

Recirculation Battery No. 1 28 Vdc 35 Amp. hr.

Recirculation Inverters (5) 56 Vdc

5 Volt Measuring Voltage Supply

Instrumentation Battery 28 Vdc 35 Amp. hr.

Instrumentation & Telemetry Systems

Ground Power 56 Vdc AC Pumps

Figure 33: S-II Stage Electrical Power & Distribution System
**S-II Battery Characteristics**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Dry charge</td>
</tr>
<tr>
<td></td>
<td>Silver Zinc Oxide</td>
</tr>
<tr>
<td></td>
<td>Electrolyte consists of Potassium Hydroxide</td>
</tr>
<tr>
<td></td>
<td>in Pure Water.</td>
</tr>
</tbody>
</table>

**Nominal Voltage:** 28 ± 2 vdc

**Current Rating:** 35 amp/hours

**Gross Weight:** 165 lbs each

**Note:** There are four 28 volt batteries used in the S-II Stage however since the recirculation system requires a 56 volt source, two batteries, (28 volts each) are connected in series.
S-IVB STAGE STRUCTURE

The S-IVB, the third booster stage, is approximately 59 feet in length with a stage weigh, at liftoff of approximately 269,300 pounds. The S-IVB stage is powered by a single J-2 engine capable of providing 232,000 pounds of thrust at first burn and 211,000 pounds during second burn.

- The Forward Skirt Assembly

  The forward skirt is the load supporting member between the LH₂ tank and the Instrument Unit. The forward umbilical plate, antennas, the LH₂ tank flight vents and tunnel fairings are attached externally to this skirt.

- Propellant Tank Assembly

  The propellant tank assembly is a cylindrical aluminum structure with a hemispherical shaped dome at each end. Lox and \( \text{H}_2 \) are separated by a common bulkhead of sandwich type construction which is bonded and separated by a fiberglass-phenolic honeycomb core.

- LH₂ Tank

  The LH₂ tank is equipped with polyurethane insulation blocks which are covered with fiberglass and a sealant coating to minimize LH₂ boiloff. These blocks are bonded to an intertank waffle-like structure which provides structural rigidity.

- Lox Tank

  The Lox tank is located in the lower end of the propellant structure and is surrounded by the aft skirt assembly. The Lox tank is equipped internally with a slosh baffle, a chilldown pump, a 13.5 foot propellant utilization probe, temperature and level sensors, and fill, pressurization and ventpipes.

- Aft Skirt Assembly

  The aft skirt assembly is the load bearing structure between the Lox tank and the aft interstage.

- Thrust Structure

  The thrust structure is an inverted, truncated cone attached at its larger end to the aft dome of the Lox tank and at the smaller end to the J-2 engine mount.

- Aft Interstage

  The aft interstage is a truncated cone that provides load support structure between the S-II and the S-IVB stages. S-II retro rocket mounts are attached to this stage. The aft interstage remains with the S-II at interstage separation.
**Figure 34**

**S-IVB Stage Configuration**

**S-IVB Stage Weights**
- Dry: ~ 29,300 lbs.
- At S-IVB Ignition: ~ 26,600 lbs.
- At S-IVB Cutoff: ~ 191,350 lbs.
- At S-IVB 2nd Cutoff: ~ 29,000 lbs.
- At S-IVB Separation: ~ 28,600 lbs.

- View Looking Aft
  - Main Tunnel
  - Forward umbilical plate
  - Auxiliary Tunnel
  - Coldplates (16) (for equipment mounting)
  - Ullage Motors (3)
  - APS Modules (2)

- Telemetry Antennas (4)
  - Forward Skirt (length ~ 10 ft)
  - Command Antennas (2)
  - LH2 Tank
  - Helium Spheres (9)
  - LOX Tank
  - Aft Skirt (length ~ 7 ft)
  - Ullage Motors (3)
  - Thrust Structure
  - Retrorockets (4)
  - Aft Interstage (length ~ 18.7 ft)
  - J-2 Engine
  - APS Module (2) 180° apart
  - LOX Tank relief orifice
  - Separation Plane
  - Helium Spheres (6)
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 LH₂ 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 GH₂ from the start tank. The GH₂ 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.

Engine Start
Main Fuel Valve Open
Main Fuel Propellant Flow
Start Tank Discharge Valve Open
Pump Buildup
Bypass Flow Through Oxidizer
Turbine By-pass Valve
Main Oxidizer Flow
Gas Generator Propellant Flow
Main Oxidizer Valve Open
Mainstage OK Signal
90 Percent Thrust

IGNITION COMMAND
TIME FROM IGNITION
0 SEC 1 SEC 2 SEC 3 SEC 4 SEC 5 SEC
Propellant utilization valve varies engine mixture ratio by bypassing LOX from the pump.

LOX

Pump

LOX

Turbine

Main LOX

Valve

Gas

Gen

LH2

Pump

LH2

Turbine

Start

Tank

GH2 for LH2 Tank

Pressurization

GOX for LOX Tank

Pressurization

Heat

Exchanger

Injector

Thrust

Chamber

(Pressure

716psi)

Expansion Ratio

21.5:1

200,000 lbs Thrust

Mixture Ratio

LOX : LH2 5.0 : 4.5 : 1

Figure 35

J-2 Engine System
S-IVB Stage
S-IVB STAGE PROPELLANT SYSTEM

The S-IVB stage propellant system is composed of integral LOX/LH₂ 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 LH₂ tank, which is expanded by passing through the heat exchanger, to maintain positive pressure across the common tank bulkhead and to satisfy engine net positive suction head. LH₂ tank pressurization during S-IVB stage burn is maintained by GH₃ from the J-2 engine injector. Pressurization of the LH₂ tank strengthens the stage in addition to satisfying engine net positive suction head.

Repressurization of the propellant tanks, prior to J-2 engine restarts, is attained by passing cold helium, from the helium spheres in the LH₂ tank, through the O₂/H₂ burner. The heated helium is then routed to the propellant tanks. Should the O₂/H₂ burner fail, ambient repressurization will ensure propellant tank pressure for engine restarts.

S-IVB PROPELLANT LOAD AND OPERATIONAL SEQUENCE
GH2 from J-2 Engine injector for LH2 tank pressurization during first and second S-IVB Stage burn.

LH2 Vent Valve

GH2/LH2 28-31 psia

GH2

1 H2 Tank ~ 43,400 lbs at ignition

LOX/GH2 38-41 psia

LOX Tank ~190,800 lbs. at ignition

LH2 Fill and Drain

LOX Vent Valve

LOX Fill and Drain

4.4 cu.ft. 3100 psi GHe spheres (b) LH2 Tank pressurization during coast mode.

Figure 36

SIVB Stage Propellant System

Total propellant at ignition ~ 229,500 lbs.
Total propellant consumed after ign. on ~ 229,500 lbs.
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 LH₂) to ensure balanced consumption of LOX and LH₂.

The capacitance probes, located in the LOX and LH₂ tanks, monitor the mass of the propellants. During flight, the LOX and LH₂ capacitance probes are not utilized to control the propellant mixture ratio. The mixture ratio is controlled by switch selector outputs which are used to operate the propellant utilization (PU) valve. The PU valve is a rotary valve which controls the quantity of LOX flowing to the engine.

The PU valve is commanded to its null position to obtain an engine mixture ratio (EMR) of 5:1 (LOX/LH₂) prior to engine start. The PU valve remains at the 5:1 position during the first burn. Prior to engine restart (first opportunity) the PU valve is commanded by the switch selector to an EMR of 4.5:1 and remains at this position until approximately 2 minutes of S-IVB burn. Then the PU valve is commanded to its null position (5:1) by the switch selector. However, if the S-IVB restart is delayed to the second opportunity, the EMR is shifted from 4.5:1 to 5:1 by the switch selector at about the time the engine reaches 90 percent thrust.
Mixture ratio is normally 50:1 unless switch selector has commanded a 4.5:1 mixture ratio.
S-IVB THRUST VECTOR CONTROL SYSTEM

The single J-2 Engine is gimbal mounted on the longitudinal axis of the S-IVB Stage to provide pitch and yaw control during S-IVB powered flight. Engine gimballing is accomplished by an independent closed loop hydraulic system which supplies power to the two servo-actuators. The two servo-actuators may extend or retract individually or simultaneously. Gimbal position is proportional to the magnitude of an electrical input to the electro-hydraulic servo valve located on each actuator. Mechanical feedback from the actuator to the servo valve completes the closed engine position loop.

During S-IC and S-II stage burns, the actuators hold the engine position to null. This is accomplished by utilizing the electrically driven auxiliary hydraulic pump. The auxiliary hydraulic pump is also used during orbit to periodically circulate the hydraulic fluid to prevent freezing. During the S-IVB burn, the main hydraulic pump, driven by the engine, provides the necessary pressure and circulation for actuator operation (pitch and yaw control). Roll control is provided by the Auxiliary Propulsion System (see page 71).
S-IVB Stage Thrust Vector Control System

Figure 38
AUXILIARY PROPULSION SYSTEM

The S-IVB Auxiliary Propulsion System (APS) provides vehicle attitude control during powered flight in the roll axis only and during S-IVB coast provides control in the pitch, yaw, and roll axes. Attitude corrections are made by firing the control engines, individually or in combination, in short bursts of approximately 65 ms minimum duration. Commands from the Flight Control Computer actuate fuel and oxidizer solenoid valve clusters that admit hypergolic propellants to the control engine combustion chambers.

The attitude control engines are located in two aerodynamically shaped modules, 180 degrees apart, on the aft end of the S-IVB stage (positions I and III). Each module contains four hypergolic engines, three 150 pound thrust attitude control engines and one 70 pound thrust ullage engine. The 70 pound thrust (ullage) engine in each module is used to settle the main stage propellants after S-IVB cutoff and again prior to restart. One control engine of each module is used to control the vehicles' attitude in pitch, while the other two are used for yaw and roll control.

Each APS module contains its own propellant supply and pressurization system. The hypergolic propellants used by the engines are monomethyl hydrazine (MMH) for the fuel and nitrogen tetroxide (N₂O₄) for the oxidizer. Helium is the pressurant used in the system.
Figure 39

Auxiliary Propulsion System
Transducers or Signal Sources

Resistance Thermometer

Crystal Vibration Pickup

Strain Gauge

Signals (Switches, etc.)

Signals (Switches, etc.)

Voltages (Battery, etc.)

Pressure Transducers
(Strain Gauge Type)

A.C. Amplifier

28 Vdc

5 Vdc

Voltage Sources

Potentiometer Type
(Pressure Gauge, etc.)

Signal Conditioner

- Signal Conditioning Assemblies
  (7 in forward skirt, 4 in aft skirt #1 in aft interstage)

- Bridge Boxes
- Isolation Boxes
- Distributors
  (Voltage dividing network)

Slide to TM

Slide to TM

Figure 40

S-IVB Stage Measuring System
Note: Most forward Interstage Components Are Mounted On Coldplates

![Diagram of power distribution system]

**Figure 42**

5-IVB Stage Electrical Power and Distribution System
S-IVB Battery Characteristics

Type:  
- Dry Charge  
- Silver-Zinc Oxide  
- Electrolyte - Potassium Hydroxide in Pure Water

Nominal Voltage:  28 (±2) vdc (1.5 vdc per cell)

Note: Aft Battery No. 2 uses two 28 volt batteries, series connected to provide a 56 volt output.

<table>
<thead>
<tr>
<th>Batches</th>
<th>Fwd. #1</th>
<th>Fwd. #2</th>
<th>Aft #1</th>
<th>Aft #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Rating:</td>
<td>300 Ampere Hours</td>
<td>25 Ampere Hours</td>
<td>300 Ampere Hours</td>
<td>78 Ampere Hours</td>
</tr>
<tr>
<td>Gross Weight:</td>
<td>83 lbs</td>
<td>20 lbs</td>
<td>83 lbs</td>
<td>150 lbs</td>
</tr>
</tbody>
</table>
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. 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.

The IU Stage contains:

- Guidance, Navigation and Control Equipment
- Telemetry Systems
- Tracking Systems
- Crew Safety Systems
- Environmental Control System

The guidance, navigation and control equipment contained in the IU includes that which is necessary for vehicle guidance and control during boost through orbital coast and subsequently for translunar injection.

Telemetry along with measuring systems is used to monitor certain conditions and events which take place in the IU and to transmit these monitored signals to ground receiving stations.

Tracking systems assist the determination of the vehicle's trajectory. Tracking data is used for mission control, range safety and post flight evaluation of vehicle performance.

Crew Safety is provided by the Emergency Detection System, a portion of which is located in the IU stage. EDS senses conditions in the vehicle during boost phase which could cause vehicle failure.

Environmental Control maintains an acceptable operating environment during pre-flight and flight operations.
Data Adapter and Digital Computer

Guidance & Control

Control Computer

Unit 602

Coldplates (16) for Equipment Mounting

Instrumentation

Electrical Power & Distribution

Access Door

Umbilical Plate

Honeycomb Panel (2)

Splice (3)

Dia. 260 inches

View Looking After

Antenna Arrangement

Weight:

* Dry ~ 4,250 lbs.

Serviced ~ 4,400 lbs.

Figure 43

Instrument Unit Configuration
To other measuring racks

Used for ground checkout only

Measuring Racks (10)

Measuring Rack Selector

Measurement Calibrator

1 DC Amplifier

2 AC Amplifier

3 DC Amplifier

Power Supply

28 vdc

5 vdc

Transducer or Signals Sources

Thermocouple

Accelerometer (Vibration)

Error Signals (computer # platform)

Note: DC Amplifiers No. 4 thru 20 are included in measuring rack

Signals (First Motion, Separation, etc.)

28 vdc

Potentiometer Type (press, gauge, long, accel. etc.)

0-5 vdc

Guidance System

0-5 vdc

Digital Data

28 vdc

To Telemetry System

28 vdc

5 vdc

Voltage Dividing Network

To T. Entry System

Instrument Unit

Measuring System
Figure 45

Instrument Unit
Telemetry System
Figure 46

Instrument Unit Electrical Power and Distribution System
IU Stage Battery Characteristics

Type:  
- Dry charge
- Silver-Zinc Oxide
- Electrolyte - Potassium Hydroxide in Pure Water.

Nominal Voltage: 28 ± 2 vdc (1.5 vdc per cell)

Current Rating: 350 amp/hours

Gross Weight: 165 lbs per battery (3 batteries are used in the IU Stage)
ENVIRONMENTAL CONTROL SYSTEM (ECS)

The Environmental Control System (ECS) has been developed to maintain an acceptable operating environment for the IU/S-IVB equipment during preflight and inflight operations.

The ECS is made up of the following:

- **Thermal Conditioning System** - maintains a circulating Methanol Water coolant temperature of approximately 59° ± 1° F.

- **Preflight Purging System** - maintains a supply of temperature and pressure regulated air/GN₂ in the IU/S-IVB equipment.

- **Gas Bearing Supply System** - furnishes GN₂ to the ST-124-M3 inertial platform gas bearings.

- **Hazardous Gas Detection System** - monitors the IU/S-IVB forward interstage area for the presence of hazardous vapors.
Methanol-Water (closed system)

Methanol-Water (GSE supplied)

\[ \begin{align*}
\text{Coolant inlet fitting} \\
\text{Equipment mounting Surface} \\
\text{Coolant outlet fitting} \\
\text{Coolant core}
\end{align*} \]

Typical Coldplate

\[ \text{Figure 47} \]

\[ \text{II/S-IVB Environmental Control System} \]
SPACECRAFT DESCRIPTION

The Spacecraft for the AS-505 mission is composed of:

- Launch Escape System (LES)
- Command Module (CM)
- Service Module (SM)
- Lunar Module (LM)
- Spacecraft Lunar Module Adapter (SLA)

Launch Escape System

The Launch Escape System, 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 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 gimballled 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

The Lunar Module consists primarily of an Ascent and Descent Stage. The Ascent Stage, which contains the crew compartment, is equipped with a Reaction Control System which provides thrust capability, an ingress and egress hatch to the crew's compartment, VHF, S-Band and Rendezvous Radar capabilities plus numerous instrumentation and controls. The Descent Stage, consists primarily of a descent engine and four retractable landing gear assemblies. Over all weight of the Lunar Module is approximately 32,000 pounds.

Spacecraft Lunar Module Adapter

The Spacecraft Lunar Module Adapter (SLA) joins the Service Module (SM) to the S-IVB/IU. The SLA encloses the Lunar Module. Adapter panels which enclose the Lunar Module are jettisoned prior to docking and Lunar Module extraction.
Weights:
- Lift off: 107,400 lbs.
- At Injection: 98,500 lbs.
  *(LES wgt. included)*
- LES weight: 8900 lbs.
- Command Module: 12,500 lbs.
- Service Module: 10,600 lbs.
- Lunar Module: 30,850 lbs.
SPS Deorbit Burn and CM/SM Separation

CM Reentry

Drogue Chutes Deployed

~1 min after parachute descent begins, drogue chutes are jettisoned and main chutes are deployed.

Main Chutes Released
(Reeled)

Main Chutes Fully Deployed

Note:
The desired flotation mode after splashdown is with CM Apex Up.

To achieve this mode, the flotation bags are released from the forward hatch causing the module to float upright.

Apex Down

Flotation Bags

Apex Up

Main Chutes Released at Splashdown
Figure 49

CM Telecommunication System
Figure 50
Spacecraft Electrical Power & Distribution System
Figure 58

LM Engine Locations
Figure 54

LM Guidance and Navigation Section
<table>
<thead>
<tr>
<th>DIRECTION</th>
<th>ADDRESSEE</th>
<th>ADDRESS</th>
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<tbody>
<tr>
<td>DIR</td>
<td>Dr. von Braun</td>
<td>A&amp;T-MS-IL</td>
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<td>AD-S</td>
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<td>S&amp;E-SSL-DIR</td>
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<td>Dr. Farish</td>
<td>S&amp;E-CSE</td>
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<td>I-K</td>
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<td>S&amp;E-COMP</td>
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<td>S&amp;E-QUAL-J</td>
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