TECHNICAL INFORMATION SUMMARY

APOLLO 8 (AS-503)

APOLLO SATURN V
SPACE VEHICLE

PREPARED BY:
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AS-503

TECHNICAL INFORMATION

SUMMARY

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

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

1. Mission Purpose:

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

2. Mission Objectives:

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

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

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

b. Demonstrate S-IVB restart capability.

c. Verify J-2 Engine modifications.

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

e. Confirm launch vehicle longitudinal oscillation environment during S-IC stage burn period.
f. Verify that modifications incorporated in S-IC stage suppress low frequency longitudinal oscillations.

g. Demonstrate helium heater repressurization system operation.

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

i. Demonstrate capability to safe S-IVB stage.

Secondary Detailed Test Objectives:

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

3. Mission Description:

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

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

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

Parking Orbit Phase. The vehicle is held at cutoff inertial attitude for 20 seconds after cutoff after which it is oriented to the local horizontal with position I down. The LH₂ continuous vent valve is opened to provide a small, continuous acceleration for propellant settling during the Parking Orbit.
The Vehicle will continue to coast in Earth Parking Orbit while the Launch Vehicle and Command and Service module are completely checked and verified prior to second burn. Any attitude maneuvers during the parking orbit will be manually controlled by the Astronauts.

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

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

Pre-Ignition Sequencing and Second Burn Phase. Pre-ignition sequencing is the phase which precedes the S-IVB second burn. It will begin over the Pacific or Indian Oceans (depending on date, time, or flight azimuth). At this time the vehicle will maneuver to a local horizontal attitude; the LH\(_2\) propulsive vent will be closed and the O\(_2\)H\(_2\) burner operation will begin to repressurize the stage for a second burn. The second S-IVB burn will be initiated while the vehicle is passing over the Pacific Ocean. This burn will inject the S-IVB/IU/LTA-B/CSM into a free-return, translunar trajectory. The Iterative Guidance Mode (IGM) will be used during this period. Immediately following S-IVB engine cutoff, the LH\(_2\) continuous propulsion vent and the LOX and LH\(_2\) non-propulsive vents will be opened.

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

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

As the LV enters into the "slingshot" trajectory coast period described above, the Command and Service module will begin to coast toward the moon along the "Translunar Trajectory".
As the CSM is about to enter the effective range influenced by the lunar gravitational field, the necessary maneuver is initiated which will propel the CSM into lunar orbit. This final maneuver will not be attempted unless all required conditions for such an orbit are acceptable. If conditions are not acceptable, the CSM will continue on the free return trajectory. Approximately 8 to 10 lunar orbits are planned after which the CSM will return along the "lunar orbit return" and "trans-earth trajectory".

Separation of the Command Module, re-entry, splash down, and recovery in the Pacific Ocean will complete the mission.
Insertion into Parking Orbit — S-IVB Cut-off ~ 11 min. 30 sec.

S-11 Stage Cut-off and Jettison ~ 8 min. 40 sec. — SIVB Ignition ~ 8 min. 44 sec.

Jettison Launch Escape Tower (LET) (manual function) ~ 3 min. 07 sec.

S-11 Stage Ignition ~ 2 min. 32 sec. Jettison Aft Interstage (S-11) ~ 3 min. 01 sec.

S-1C Stage Cut-off and Jettison ~ 2 min. 31 sec.

Liftoff — S-1C Ignition

Figure 1

Mission Profile
Boost to Earth Orbit
Figure 2

A5-503
Mission Profile - Lunar Orbit
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Figure 3

AS-503
Space Vehicle
Figure 4

Launch Complex 39
MOBILE LAUNCHER

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

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


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


5) S-II Forward (inflight). Provides LH2 vent, electrical, and pneumatic interfaces. Retract time 7.4 seconds.

6) S-IVB Forward (inflight). Provides LH2 and LOX transfer, electrical, pneumatic, and air-conditioning interfaces. Retract time 7.7 seconds.


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

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

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

Inflight arms retract at vehicle liftoff on command from service arm control switches (located in hold-down arms).
LAUNCH VEHICLE SECURE RANGE SAFETY SYSTEMS

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

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

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

The S-IVB stage range safety receiver is commanded to an "OFF" condition by ground command at orbital insertion such that no destruct can take place after this safing action.
Figure 6

Secure Range Safety System
EMERGENCY DETECTION SYSTEM (EDS)

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

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

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

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

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

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

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

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

Disconnected 1.U. Umbilical

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

Automatic Abort Capability
1. S-IC two engines out
2. Excessive angular rates

~ 2 min. 04 sec.

- S-IC Inboard Engine Cutoff ~ 2 min. 05 sec.
- S-IC Outboard Engine Cutoff ~ 2 min. 30 sec.
- S-11 Ullage Ignition ~ 2 min. 31 sec.
- S-1C/S-11 Separation ~ 2 min. 32 sec.
- S-11 Engine Start ~ 2 min. 32 sec.

- Activate Open Loop P.U. System ~ 2 min. 37 sec.
- S-11 Aft Interstage Separation ~ 3 min. 01 sec.
- Water Coolant Valve Open ~ 3 min. 02 sec.

Note: Approx. times shown are measured from liftoff

Start of Time Base 1 Start of Time Base 2 Start of Time Base 3

Time Base Divisions

Figure 8

S-1C/S-11 Stage Flight Sequencing
\( \Delta \text{LH}_2 \) Step Pressurization \( \approx 7\text{min.}31\text{sec.} \)

\( \Delta \) Enable LOX & LH\( _2 \) Depletion Cutoff \( \approx 8\text{min.}06\text{sec.} \)

\( \Delta \) S-11 Engine Cutoff \( \approx 8\text{min.}39\text{sec.} \)

\( \Delta \) S-IVB Ullage Ignition \( \approx 8\text{min.}40\text{sec.} \)

\( \Delta \) S-11/S-IVB Separation \( \approx 8\text{min.}41\text{sec.} \)

\( \Delta \) S-IVB Engine Start \( \approx 8\text{min.}44\text{sec.} \)

\( \Delta \) S-IVB Engine Velocity Cutoff \( \approx 11\text{min.}20\text{sec.} \)

\( \Delta \) APS Ullage on \( \approx 11\text{min.}22\text{sec.} \)

\( \Delta \) S-IVB Insertion into Earth Parking Orbit \( \approx 11\text{min.}30\text{sec.} \)

\( \Delta \) LH\( _2 \) Continuous Vent Open \( \approx 12\text{min.}20\text{sec.} \)

\( \Delta \) APS Ullage Off \( \approx 12\text{min.}48\text{sec.} \)

\( \Delta \) \* S-IVB Engine Restart Preparations \( \approx 2\text{hr.}41\text{min.} \)

**Note:**

Approx. times shown are measured from liftoff.

\*If restart is delayed until the second injection opportunity, this and the majority of subsequent events will occur approximately 1.5 hours later than shown.

---

Time Base Divisions

Figure 9

S-11/S-IVB Stage Flight Sequencing
\( \Delta \) O\(_2\)-H\(_2\) Burner On \( \sim 2\) hr.42 min.
\( \Delta \) LH\(_2\) Continuous Vent Closed \( \sim 2\) hr. 42 min.
\( \Delta \) LOX Chilldown Pump On \( \sim 2\) hr. 45 min.
\( \Delta \) LH\(_2\) Chilldown Pump On \( \sim 2\) hr. 45 min.
\( \Delta \) APS Ullage On \( \sim 2\) hr. 49 min.
\( \Delta \) LOX & LH\(_2\) Chilldown Pumps Off \( \sim 2\) hr. 51 min.
\( \Delta \) APS Ullage Off \( \sim 2\) hr. 51 min.
\( \Delta \) S-IVB Engine Start \( \sim 2\) hr.51 min.

\( \Delta \) S-IVB Engine Cutoff \( \sim 2\) hr. 56 min.
\( \Delta \) Translunar Injection \( \sim 2\) hr. 56 min.
\( \Delta \) LH\(_2\) Continuous Vent Open \( \sim 2\) hr. 56 min.
\( \Delta \) LH\(_2\) Continuous Vent Closed \( \sim 3\) hr.11 min.
\( \Delta \) Spacecraft Separation \( \sim 3\) hr. 21 min.
\( \Delta \) LH\(_2\) Continuous Vent Open \( \sim 4\) hr. 56 sec.
\( \Delta \) Initiate Passivation Sequence \( \sim 5\) hr. 08 min.
\( \Delta \) APS Ullage On \( \sim 5\) hr. 26 min.
\( \Delta \) Passivation Terminate \( \sim 6\) hr. 11 min.

Note:
Approx. times shown are measured from liftoff.
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GUIDANCE AND CONTROL SYSTEM (G&C)

Function and Description

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

1. Stable positioning of the vehicle to the commanded position with a minimum amount of sloshing and bending.
2. A first stage tilt attitude program which gives a near zero lift trajectory through the atmosphere.
3. Provides steering commands during S-II and S-IVB burns which guide the vehicle to a predetermined set of end conditions while maintaining a minimum propellant trajectory for earth orbit insertion.
4. Maintains the proper vehicle position during earth orbit.
5. Provides guidance during the second S-IVB burn, placing the vehicle in the proper waiting orbit.

G&C Hardware

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

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

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

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

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

ST-124M Stabilized Platform (3 Gyros & Accel, P, Y & R)

- **Accel. Signal Conditioner**

  - Velocity
  - Attitude Angles

LVDA

Control Computer (Filters, Scales sums and Distributes Input Signals)

- **LVDC**

- **Command Receiver & Decoder**

**Sequencing Signals To IU Systems**

**Switch Selector**

**Sequencing Signals To S-IVB Systems**

**Actuator Command Signals**

**Switch Selector**

**Switch Selector**

**Switch Selector**

**Sequencing Signals To S-II Systems**

**Sequencing Signals To S-IC Systems**

**5.1° Swivel Angle**

**0° Cant Angle**

**Mechanical Feedback (βf)**

**S-IVB Stage**

- To Auxiliary Propulsion System (APS)
- Provides Roll Control During Powered Flight & Pitch, Yaw & Roll Control During Coast

- To Eng. Pitch & Yaw Control Actuators

**S-II Stage**

- To Control Actuators For Engines 1, 2, 3 & 4 (P, Y, & R)

- Sequencing Signals To S-II Systems

- Switch Selector

**S-IC Stage**

- To Control Actuators For Engines 1, 2, 3 & 4 (P, Y, & R)

- Sequencing Signals To S-IC Systems

- Switch Selector

**Guidance and Control System Block Diagram**

*Figure 11*
### DIGITAL COMMAND SYSTEM CAPABILITY:

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

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<td>Time change to start coast phase maneuver</td>
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<td>Generalized switch selector</td>
<td>Specified switch selector function is issued at the first opportunity</td>
<td>From $T_5 + 0$ seconds to $T_6 + 560$ and from $T_7$ to EOM</td>
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<td>From $T_5 + 100$ seconds to $T_6 - 9$ and from $T_7 + 20$ seconds to EOM</td>
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<td>Telemeter single memory location</td>
<td>Contents of specified memory location are telemetered</td>
<td>From $T_5 + 100$ seconds to $T_6 - 9$ and from $T_7 + 20$ seconds to EOM</td>
</tr>
<tr>
<td>Terminate</td>
<td>Stop DCS processing and reset for a new command</td>
<td>From $T_5 + 0$ seconds to $T_6 + 560$ and from $T_7$ to EOM</td>
</tr>
<tr>
<td>Inhibit water control valve logic</td>
<td>Inhibit water valve from changing position</td>
<td>From $T_5 + 0$ seconds to $T_6 - 9$ and from $T_7$ until EOM</td>
</tr>
<tr>
<td>Switch antenna to omni, low gain, or high gain</td>
<td>Both PCM and CCS antennas are switched with these commands</td>
<td>From $T_5 + 100$ seconds to $T_6 - 9$ and from $T_7$ seconds until EOM</td>
</tr>
</tbody>
</table>

**EOM** — End of mission  
**T6 - 9** — Time at which the switchover from orbital navigation to boost navigation occurs.
D.C.S hardware can be enabled by spacecraft manual switch for command action during coast phase operation or prior to separation. However, commands will only be accepted by the flight program within the period of time programmed in the LVDC, as described on page 22.

Figure 12: Digital Command System
<table>
<thead>
<tr>
<th>Reference Event</th>
<th>Time Base</th>
<th>G.E.T Hr/Min/Sec</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guidance Reference Release</td>
<td>T0</td>
<td>-0:00:17</td>
<td>Initiated by terminal count sequencer</td>
</tr>
<tr>
<td>Liftoff (IU Umbilical Release)</td>
<td>T1</td>
<td>0:00:00</td>
<td>Initiated by deactivation of IU lift off relay at umbilical disconnect or vertical acceleration</td>
</tr>
<tr>
<td>S-lC Center Engine Cutoff</td>
<td>T2</td>
<td>0:02:05</td>
<td>Initiated by S-lC inboard engine cutoff command from LVDC</td>
</tr>
<tr>
<td>S-1C Outboard Engine Cutoff</td>
<td>T3</td>
<td>0:02:31</td>
<td>Initiated by the propellant depletion sensors or the thrust-OK switches</td>
</tr>
<tr>
<td>S-ll Engines Cutoff</td>
<td>T4</td>
<td>0:08:40</td>
<td>Initiated by the propellant depletion sensors or the thrust-OK switches</td>
</tr>
<tr>
<td>First S-IVB Engine Cutoff</td>
<td>T5</td>
<td>0:11:20</td>
<td>Initiated by any two of four functions; S-IVB velocity cutoff issued by the LVDC, thrust-OK switches (2), or accelerometer reading</td>
</tr>
<tr>
<td>Initiation - Restart Sequence</td>
<td>T6</td>
<td>2:41:01</td>
<td>Initiated when LVDC solves the restart equation</td>
</tr>
<tr>
<td>Second S-IVB Engine Cutoff</td>
<td>T7</td>
<td>2:55:55</td>
<td>Initiated by any two of four functions; S-IVB velocity cutoff issued by the LVDC, thrust-OK switches (2), or accelerometer reading</td>
</tr>
<tr>
<td>Early S-ll/S-IVB Staging</td>
<td>T8a</td>
<td>Variable</td>
<td>Initiated by S-ll/S-IVB staging switch in the spacecraft during S-lI burn</td>
</tr>
<tr>
<td>Spacecraft Separation</td>
<td>T5a</td>
<td>Variable</td>
<td>Initiated by spacecraft launch vehicle separation</td>
</tr>
<tr>
<td>S-IVB Burner Malfunction</td>
<td>T6a</td>
<td>Variable</td>
<td>Initiated by burner malfunction signal from S-IVB stage -- T6 + 48 seconds to T6 + 341.3 seconds</td>
</tr>
<tr>
<td>S-IVB Burner Malfunction</td>
<td>T6b</td>
<td>Variable</td>
<td>Initiated by burner malfunction signal, S-IVB stage -- T6 + 341.3 seconds to T6 + 496.7 seconds</td>
</tr>
<tr>
<td>Translunar Injection Inhibit</td>
<td>T6c</td>
<td>Variable</td>
<td>Initiated by translunar injection switch in the spacecraft -- T6 + 0 seconds to T6 + 560 seconds</td>
</tr>
</tbody>
</table>
INSTRUMENTATION SYSTEMS

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

- Measuring Systems
- Telemetry Systems
- RF and Tracking Systems

Measuring

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

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

Telemetry

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

RF and Tracking

The Vehicle RF and Tracking Systems are described and illustrated on pages 26 and 27.
## Measurement Summary - L/V

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

### Measurement Summary - S/C

<table>
<thead>
<tr>
<th>Measurement Designation</th>
<th>CM</th>
<th>SM</th>
<th>S/C Total</th>
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<tbody>
<tr>
<td>Pressure</td>
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<td>37</td>
<td>55</td>
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<tr>
<td>Temperature</td>
<td>19</td>
<td>43</td>
<td>62</td>
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<tr>
<td>Discrete Event</td>
<td>84</td>
<td>5</td>
<td>89</td>
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<tr>
<td>Voltage, Current,</td>
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<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>44</td>
<td>3</td>
<td>47</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>30</td>
<td>55</td>
<td>85</td>
</tr>
<tr>
<td>Totals</td>
<td>195</td>
<td>143</td>
<td>338</td>
</tr>
</tbody>
</table>

**AS-503 Measurement Summary**
VEHICLE TRACKING SYSTEMS

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

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

The principal tracking systems used are:

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

**ODOP System (S-IC)**

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

**C-Band (IU and SC)**

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

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

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

Transponder

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

Transmit -- 6765 mc
Receive -- 5690 mc

Note: Different Pulse Code than C-Band in IU.

Unified S-Band System

Transponder

Transmit -- 2287.5 MHz
Receive -- 2106.4 MHz

Instrument Unit

C-Band Radar System

Transponder

Transmit -- 5765 MHz
Receive -- 5690 MHz

~ 400 watts

S-IC Stage

ODOP System

Transponder

Transmit -- 960 MHz
Receive -- 890 MHz

~ 1 watt

Vehicle Tracking Systems
SPACE VEHICLE WEIGHT VS. FLIGHT TIME

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

VEHICLE WEIGHT DATA (Approximate)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total at S-IC ignition</td>
<td>4,795,100</td>
</tr>
<tr>
<td>Total at holddown arm release</td>
<td>4,600,000</td>
</tr>
<tr>
<td>Total at O.E.C.O.</td>
<td>1,800,000</td>
</tr>
<tr>
<td>Total at S-II ignition</td>
<td>1,037,800</td>
</tr>
<tr>
<td>Total at S-II E.C.O.</td>
<td>470,000</td>
</tr>
<tr>
<td>Total at S-IVB first ignition</td>
<td>263,500</td>
</tr>
<tr>
<td>Total at S-IVB E.C.O.</td>
<td>192,250</td>
</tr>
<tr>
<td>Total at S-IVB second ignition</td>
<td>190,250</td>
</tr>
<tr>
<td>Total at S-IVB second E.C.O.</td>
<td>29,550</td>
</tr>
</tbody>
</table>
Figure 14

Vehicle Weight (Pounds)

6,000,000

1,000,000

500,000

100,000

60,000

30,000

Liftoff (0 sec)

0 200 400 600 800 25 hr 30 hr 40 hr

622,0100 lbs (Total Vehicle at Ignition)

613,4200 lbs (Total Holddown Arm Release) (0Sec)

S-IC Propellant Consumption ~ 29,380 lbs/sec (Average)

S-IC Stage Outboard Engine Cutoff (~150 sec)

S-IC Stage Separation (~152 sec)

S-IVB Stage Ignition (~152 sec) (~1,422,600 lbs)

S-11 Propellant Consumption ~ 2,500 lbs/sec (Average)

S-11 Stage Engine Cutoff (~519 sec)

S-11 Stage Separation (~521 sec)

S-IVB Stage Ignition (~524 sec) (~350,100 lbs)

S-IVB Stage Engine Cutoff (~680 sec)

S-IVB Propellant Consumption ~ 460 lbs/sec (Average)

S-IVB Stage Insertion into Earth Parking Orbit (~690 sec)

S-IVB Stage Engine Restart (~2 hr 51 min)

S-IV Stage Engine Cutoff (~2 hr 56 min)

LV/SC Separation (~3 hr 21 min)

SC at Inj<action (~87,700 lbs)

Space Vehicle Weight vs. Flight Time
S-IC STAGE STRUCTURE

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

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

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

Ejectable Camera Capsules

A Film Camera System consists of four individual camera subsystems.

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

- Two movie type cameras to film stage separation.

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

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

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

Airborne Television

An airborne TV System is installed in the S-IC stage to provide inflight, real time, visual performance about the S-IC stage engines as well as permanent storage of pictures televised.
Stage Weight
- Dry: ~ 305,650 Lbs.
- At Ignition: ~ 4,795,100 Lbs.
- At Separation: ~ 380,400 Lbs.

Figure 15
S-IC Stage Configuration
Stage Weight
- Dry: ~ 305,650 lbs.
- At Ignition: ~ 4,795,100 lbs.
- At Separation: ~ 380,400 lbs.
F-1 ENGINE OPERATION

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

The inboard engine is cutoff by a signal from the IU. Outboard engines are cutoff by optical type LOX depletion sensors with fuel depletion sensors as backup. A command from the IU supplies a command to the switch selector to enable the outboard engine cutoff circuitry. When two or more of the four LOX level sensors are energized, a timer is activated. Expiration of the timer energizes a stop solenoid for each engine which energizes the main LOX and main RP-1 valves. The sequence closing of the main LOX valve followed by sequence closing of the main RP-1 valve interrupts propellant flow and terminates engine operation.
LOX : RP-1 2.27:1
Mixture Ratio
Expansion Ratio 16:1
Igniters (2)
Thrust Chamber Pressure 1105 psi
1,500,000 lbs Thrust

Figure 16

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

**S-IC STAGE PROPELLANT LOAD AND OPERATIONAL SEQUENCE**
LOX

Gmnd
Proflure
S
Opt
(2)
Relief
Valve
(Pmrwr.
Switch
operaid)
Opeq-
31.5
priq
300opsig
He
Bo-i+les
(4)
f5r
P-
Tank
Pre
(15)
Open-
26.5
psia
Pressure
Verr-
4
&lid
Switch
Clor
24.2
via
Actuate
31.5
Psia
deacbah
29.7pria
RP-
I
Drairr
Val~er
Thwst
Structw@
RP-I
llhe
(2
pr
au)rine)
RPI
li
Lines
a+
li4,-
hvalws
(I
ifA%
2
RP-I)
LOX
Intevconned
Value
(4)
Heat
Excbanq~
Inhflqht
wc~rizatim
of
Rp-I
G
Tank.
nvertsLOXtPGOX
IhCliq
ht
LOX
Tank
p~~svri
zation.
-4,406,750
lbs.

F-1 Engine (9)

Total Propellant at Ignition
- 4,482,250 lbs.
Total Propellant consumed after Ignition
- 4,406,750 lbs.

Figure 17

S-IC Stage Propellant System
To No. 2 Turbo-pump assembly input

Valve Checkout

Vehicle Thrust Structure Actuator Attachment Point

Hydraulic Actuator (2 per engine)

Servo Valve Controls Actuator Movement

From No. 1 Turbopump fuel discharge

Turbopump fuel discharge duct

Manifold Filter

Gimbal Point

Actuators (2 per engine)

Vehicle Pitch Axis

Eng#1

Eng#2

Eng#3

Eng#4

Eng#5

Vehicle Yaw Axis

Outboard Engines (4)

(4) Gimballed, Canted 0° at Nominal Thrust

Inboard Engine

(1) Fixed Position, Canted 0° at Nominal Thrust

Square Gimbal Pattern ± 5.1°

Engine Gimbal rate under load 5° per sec.

+pitch

+yaw

+roll

Figure 18

S-IC Stage Thrust Vector Control System
Figure 19
S-IC Stage
Measuring System
Figure 20

S-IC Stage Telemetry System
Notes:
All components shown are located in the Thrust Frame Area except as noted.

Figure 21
S-IC Stage Electrical Power and Distribution System
**S-II STAGE STRUCTURE**

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

In addition to the J-2 rocket engines, the structural air frame of the S-II stage mounts a forward and aft skirt, an aft interstage, a liquid oxygen and liquid hydrogen tank plus the associated piping, valves, wiring, electrical and electronic equipment.
Nota: The retro-rockets for S-II Stage separation are located in the S-IVB aft interstage.

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

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

Thrust chamber pressure 776 psia at 5.0:1
Expansion ratio 27.5:1
Mixture ratio LOX:RH2 5.5:45:1
Programmed by weight.

Figure 23

J-2 Engine System 511 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
CHI from J-2 Engine during S-II burn for LH₂ Tank pressurization

LH₂ Tank pressure Regulator opens ~ 250 seconds after S-II Ignition and remains open.

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

LH₂ Tank
~155,600 lbs at Ignition

LOX Tank
~792,700 lbs at Ignition

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

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

LH₂ Fill and Drain

LH₂ from J-2 Engine during S-II

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

Figure 24
S-II Stage Propellant System
S-II STAGE PROPELLANT MANAGEMENT SYSTEM

The propellant management system, in conjunction with the switch selector, controls mass propellant loading and engine mixture ratios (LOX to 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 by the LVDC/LVDA. When the initial phase of IGM is completed, (nominally engine start plus 287 seconds), the LVDC/LVDA will command the PU valve to a mixture ratio of 4.5:1.

Engine cutoff is initiated when any two of the five capacitance probes, in either tank, indicate dry.
Mixture ratio is normally 5:1 unless switch selector has commanded 4:5:1 or 5:6:1 mixture ratio.
The four outboard engines are gimbal mounted to provide attitude control during powered flight. Attitude control is maintained by gimballing one or more of the engines. Power for gimballing is supplied by four independent engine mounted hydraulic control systems.

Pitch, yaw, and roll control, during powered flight, is maintained by actuator control of the engine thrust vector.
Figure 26
S-11 Stage Thrust Vector Control System
Transducer or Signal Sources
Thermocouple
Strain Gauge
Microphone (acoustic)
Voltage, current Sensor, etc.
Accelerometer (longitudinal, pitch, yaw acceleration)
Accelerometer (Vibration)

Temp. reference junction

Measurement Rack Selector
1 DC Amplifier
2 DC Amplifier
3 AC Amplifier
4 Special Module
5 AC Amplifier
6 AC Amplifier

Power Supply

5 vdc
28 vdc

Meas. Dist.

To Other Measuring Racks

Measuring Racks (27) in S-IC Stage

Signals (liftoff, c.c., etc.)

Potentiometer (pressure gauge, long accel., etc.)

Continuous liquid level

Digital Data

28 vdc

0-5 vdc

5 vdc

To Telemetry System

Voltage Dividing Network

Figure 27

G-11 Stage Measuring System
Dividers

Tranymittw 248.6

PCM/DDAS

Measvn'9 packs

Cali

Data

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Antennas

To GSE

~20

Watts

RF

Multiplexer

(2)

Filters

Low Pass

(2)

Hybrid

Junction

RF

Coupler

(2)

Power

Dividers

(2)

Transmitter

P-1

248.6mc.

Transmitter

Assemblies

F-1, F-2, F-3

241.5mc (F-1)

234.0mc (F-2)

229.9mc (F-3)

P-1

PCM/DDAS

Ass'y

Transmitter

Assemblies

S-1, S-2

227.2mc (S-1)

236.2mc (S-2)

SS/FM

Asays (2)

(51, S-2)

Tape Control

Relay

Recorder Assy

Tape Recorder

Multiplexer

BTI

Slow Speed

Multiplexer

Remote Sub-

Multiplexer

(7)

Measuring Racks

TM Calibrator

Assy

B.C.

Multiplexer

Multiplexer

(3)

(A-1, A-2, A-3)

* Data Recorders on from ~74 sec.

to ~163 sec. and from 488 sec. until

timer commands playback after

separation

Figure 28

S-II Stage Telemetry System

57
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S-IVB STAGE

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

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

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

Main Tunnel

Fwd. umbilical plate

Auxiliary Tunnel

Coldplates (16) (for equipment mounting)

APs Modules (2)

Ullage Motors (3)

Forward Skirt (length ~ 10 ft.)

Command Antennas (2)

LH2 Tank

Helium Spheres (8)

LOX Tank

Aft Skirt (length ~ 7 ft.)

Ullage Motors (3)

Thrust Structure

Retrorockets (4)

Telemetry Antennas (4)

S-IVB Stage Weights

- Dry: ~ 26,000 lbs.
- At S-IVB Ignition: ~ 263,500 lbs.
- At S-IVB Cutoff: ~ 192,250 lbs.
- At S-IVB 2nd Cutoff: ~ 24,650 lbs.

Figure 3D

S-IVB Stage Configuration
View Looking Aft

Main Tunnel

Fwd. 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 (8)

LOX Tank

Aft Skirt
(length ~ 7 ft)

Ullage Motors (3)

Thrust Structure

Retrorockets (4)

S-IVB Stage Weights

- Dry: ~ 26,000 lbs.
- At S-IVB Ignition: ~ 263,500 lbs.
- At S-IVB Cutoff: ~ 192,250 lbs.
- At S-IVB 2nd Cutoff: ~ 29,850 lbs.

Figure 30.

S-IVB Stage Configuration
**J-2 ENGINE OPERATION S-IVB STAGE**

The operating cycle of the J-2 Engine consists of prestart, start, steady-state operation and cutoff sequences. During prestart, LOX and 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

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<td>5 SEC</td>
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</tbody>
</table>

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Propellant utilization valve varies engine mixture ratio by bypassing LOX from the pump.

GH₂ for LH₂ Tank Pressurization

GOX for LOX Tank Pressurization

Heat Exchanger

Expansion Ratio 21.5:1

200,000 lbs Thrust

Mixture Ratio
LOX : LH₂  5.0-4.5:1

Figure 31
J-2 Engine System
S-IVB Stage
S-IVB STAGE PROPELLANT SYSTEM

The S-IVB Stage propellant system is composed of integral LOX/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 helium heater, to maintain positive pressure across the common tank bulkhead and to satisfy engine net positive suction head. The LH₂ pressurization strengthens the stage in addition to satisfying net positive suction head requirements. After engine ignition the pressure is maintained by GH₂ tapped from the engine supply.

S-IVB PROPELLANT LOAD AND OPERATIONAL SEQUENCE
GH\textsubscript{2} from J-2 Engine injector for LH\textsubscript{2} tank pressurization during first and second S-IVB Stage burn.

LH\textsubscript{2} Tank
~ 42,500 lbs at ignition

LOX Tank
~ 182,900 lbs at ignition

LH\textsubscript{2} Fill and Drain
LOX Fill and Drain

35 cu.ft. 3000 psi GHe spheres (9)
Inflight LOX Tank pressurization.

3.5 cu.ft. 3000 psi GHe spheres (2)
for J-2 Engine restart

4.4 cu.ft. 3000 psi GHe spheres (6)
LH\textsubscript{2} Tank pressurization during coast mode.

\textbf{Total propellant at ignition}
~ 236,250 lbs.
\textbf{Total propellant consumed after ignition}
~ 234,250 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.

Capacitance probes, mounted in the LOX and LH₂ containers, monitor the mass of the propellants during powered flight. During flight, the LOX/LH₂ capacitance probes are not utilized to control the propellant mixture ratio. This mode is considered to be an "open-loop", time-shift operation. During engine start and first burn, the ratio of LOX to LH₂ is 5.0 to 1. The ratio at restart is 4.5 to 1 and shortly after the engine reaches 90 percent thrust the mixture ratio is shifted to 5.0 to 1 which will be used for the second burn.

Engine cutoff is initiated when any two of the five capacitance probes, in either tank, indicate dry.
Mixture ratio is normally 5:1 unless switch selector has commanded 4:5:1 or 5:5:1 mixture ratio.

Figure 33

S-IVB Stage Propellant Management System
S-IVB STAGE THRUST VECTOR CONTROL SYSTEM

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

Pitch and yaw control, during powered flight, is maintained by actuator control of the engine thrust vector. Roll control of the stage is maintained by properly sequencing the pulse-fired hypergolic propellant thrust motors in the APS. When the stage enters the coast mode, the APS thrust motors control the stage in all three axes.
Low Pressure ~169 psig

Vehicle Thrust Structure Attachment Point

Hydraulic Actuators (2)

Servo Valve

Engine Actuator Attachment

Accumulator pressurized from ground with GN2 at 2350±50 psia at 70°F

8.0 gpm at 3550 psig

In-flight use-

Driven by Engine Turbo Pump at 8000 RPM output

Precharged to 475 psig

Electric Motor Driven at 13,000 RPM output 1.5 gpm at 3550 psig

Electrical Nozzles

Vehicle Roll Axis

Vehicle Pitch Axis

Vehicle Yaw Axis

Gimbal Point

Actuators (2)

Engine Gimballed;
Canted 0° at Nominal Thrust

Gimbal Pattern (looking forward)

Square Gimbal pattern ± 7° Engine gimbal rate under load ~ 8° per sec.

Gimbal Point

Figure 34

8.1WB Stage Thrust Vector Control System
AUXILIARY PROPULSION SYSTEM

The APS consists of two self-contained attitude control modules mounted 180 degrees apart on the aft skirt of the S-IVB stage. Each attitude control module contains four thrust motors which use hypergolic propellant nitrogen tetroxide ($\text{N}_2\text{O}_4$) and monomethylhydrazine (MMH). The thrust motors are pulse-fired and no ignition system is required. Three thrust motors in each module provide pitch, yaw and roll control during the S-IVB coast mode of operation, and roll control during S-IVB powered flight. An ullaging engine is included in each module to settle propellants.
Figure 3.5

Auxiliary Propulsion System
Transducers or Signal Sources

- Resistance Thermometer
- Crystal Vibration Pickup
- Strain Gauge
- Signals (Switches, etc.)
- Voltages (Battery, etc.)
- Pressure Transducers (Strain Gauge Type)
- Signals (Switches, etc.)

A.C. Amplifier

Signal Conditioning Assemblies
- 7 in forward skirt #10 in aft skirt #1 in aft interstage
- Bridge Boxes
- Isolation Boxes
- Distributors (Voltage dividing network)

28 Vdc

5 Vdc Voltage Sources

Potentiometer Type (Pressure Gauge, etc.)

5 Vdc To TM

S-IVB Stage Measuring System

Figure 36
Figure 37

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

Figure 38
S-IVB Stage Electrical Power and Distribution System
Figure 37

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

**Figure 38**

S-IVB Stage Electrical Power and Distribution System
INSTRUMENT UNIT

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

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

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

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

Data Adapter and Digital Computer

Unit 603

Guidance & Control

Instrumentation

Unit 602

Coldplates for Equipment Mounting

Electrical Power & Distribution

Tracking

Access Door

Umiblical Plate

Honeycomb Panel (2)

Splice (3)

Dia. 260 inches

View Looking At

Omni PCM/CCS Transmit

CCS Receive

PCM Dir Transmit

Cable Tray & Purge Duct

Omni PCM/CCS Transmit

CCS Receive

C-Band Radar

C-Band Radar

Antenna Arrangement

Figure 39

Instrument Unit Configuration

Weight:
* Dry ~ 4,700 lbs.
Serviced ~ 4,900 lbs.
To other measuring racks

Transducer or Signals Sources

- Thermocouple
- Accelerometer (Vibration)
- Error Signals (Computer # platform)

Measuring Rack (Total - 10)

1. DC Amplifier
2. AC Amplifier
3. DC Amplifier

Power Supply

Used for ground checkout only

Meas. Dist.

Signals (First Motion, Separation, etc.)

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

Guidance System

Digital Data

28vdc 5vdc

Voltage Dividing Network

To Telemetry System

Instrument Unit

Measuring System
Figure 41

Instrument Unit
Telemetry System
Figure 4.2

Instrument Unit Electrical Power and Distribution System
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ENVIRONMENTAL CONTROL SYSTEM (ECS)

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

Prior to liftoff, a temperature controlled methanol-water solution is supplied and circulated through the coldplates from the GSE. After liftoff the ECS is a self-contained unit which begins operation 3 minutes after liftoff when the sublimator is activated.
Methanol-Water (~105°C @ 50°F), Methanol-Water (GSE supplied). . . . Tapped holes
coolant inlet fitting

Heat Exchanger

GND Supply

Filter

Data Adapter

Digital Computer

Coldplates (16 required) (30 in sq.)

Fit cont. comp.

ST-12A

Typical Coldplate

Figure 43

II/III: Environmental Control System
SPACECRAFT DESCRIPTION

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

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

Launch Escape System

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

Command Module

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

Service Module

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

Lunar Module Adapter

The LM Adapter joints the SM to the S-IVB/IU. This unit will enclose the Lunar Module Test Article, LTA-B.
Saturn Lunar Module Adapter (SLA) Panels jettisoned prior to SC/LV separation.
Astronaut

Displays
Indication at Control Panels

Attitude Errors
IU
Drive Rates

Navigation Data
Navigation Base
(Sextant, telescope)

Coupling Display Unit

Total Attitude
Align Error

Inertial Measuring Unit

G&N Error Data
Guidance Commands

Prime Power

Command Module Computer

ΔV Pulses

IMU Electronics
(Accelerometer, stabilization loop)

Inertial Subsystem Power

Power Supplies

Figure 47
Spacecraft Guidance & Navigation System

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