TECHNICAL INFORMATION SUMMARY

APOLLO-9 (AS-504)

APOLLO SATURN V
SPACE VEHICLE

PREPARED BY:
R-ASTR-S
R-P&VE-VNC
R-AERO-P
AS-504

TECHNICAL INFORMATION

SUMMARY

This document is prepared jointly by the Marshall Space Flight Center Laboratories R-ASTR-S, R-AERO-P, and R-P&VE-VN. The document presents a brief and concise description of the AS-504 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:

Mission D will be flown to perform CSM/LM operations in earth orbit, particularly to evaluate lunar module system capabilities, to include LM rendezvous technique and the combined CSM/LM functions.

2. Mission Objectives:

AS-504 will be a manned space flight with an S-IVB second burn (high ellipse) and a third S-IVB burn to achieve earth escape.

The principal test objectives are:

a. CSM active docking, LM extraction and verification of S-IVB attitude control.


The secondary test objectives are:

a. Determine capability of S-band, high gain antenna to acquire, track and communicate with MSFN.

b. Verify one-man LM operational capabilities, obtain data on crew activities.
3. **Mission Description**

Mission D, AS-504 has been designed for a ten day duration.

The Space Vehicle Mission is divided into six phases: (1) launch, (2) parking orbit, (3) pre-ignition sequencing and second burn, (4) intermediate orbit coast, (5) pre-ignition sequencing and third burn, and (6) final coast.

**Launch Phase.** The Apollo Saturn V Space Vehicle, (AS-504), will be launched from Complex 39 pad A, Kennedy Space Center, and will be rolled to a flight azimuth of 72 degrees east of true north. 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 1. The S-IVB/IU/LM CSM will be inserted into a 103 nautical mile Earth Parking Orbit at approximately 10 minutes and 58 seconds ground elapsed time (G.E.T.) after liftoff. This insertion requires a complete burn of the S-IC and S-II stages and a partial S-IVB burn. During this phase, the flight performance of the S-IC stage will be monitored to observe the modifications which have been incorporated to suppress low frequency, launch vehicle, longitudinal oscillations.

**Parking Orbit Phase.** Following insertion into Parking Orbit, the vehicle will be commanded to maintain a cutoff attitude during which time a maneuver will be completed which will align the longitudinal axis parallel to the local horizontal and to establish and maintain an earth orbital rate. After approximately 2 hours and 34 minutes from liftoff, the space vehicle will be maneuvered to an inertial attitude which is suitable for transposition, docking, and extraction.

At approximately 2 hours and 40 minutes GET, using the CSM Reaction Control System (RCS) for maneuvering, the CSM will separate from the S-IVB/IU LM and the SLA panels will be jettisoned. Within a few seconds from separation, the CSM will be pitched 180 degrees and rolled 663 degrees so that it is positioned facing the S-IVB/LM. At approximately three hours GET, the CSM will complete a hard dock with the S-IVB/IU/LM while the vehicle is passing over western United States. Shortly after the space vehicle enters daylight, (4 hours - 10 minutes GET), the lunar module (LM) extraction is begun. The LM attach points are severed pyrotechnically thereby activating the spring thrusters which will give the CSM/LM a separation velocity. As soon as the CSM/LM is clear of the S-IVB/IU, the CSM RCS is used to move the CSM/LM away from the S-IVB/IU.

The command service module will prepare for the first Service Propulsion System (SPS) burn immediately following lunar module extraction. This maneuver is scheduled to take place while the space vehicle is over Hawaii at about 6 hours GET.
Pre-Ignition Sequencing and Second S-IVB Burn. After the CSM/LM separation an inhibit will be removed from the S-IVB/Te by ground command, allowing pre-ignition sequencing and the second S-IVB burn to be accomplished. During this phase of the mission, particular attention will be given to monitoring the operation of the O₂ - H₂ burner (helium heater). During pre-ignition sequencing, the O₂ - H₂ burner will be used as the primary pressurization system for the fuel tanks. The ambient pressurization system, used in previous Saturn V missions (AS-501 and 502) will be used as a backup in the event of O₂ - H₂ burner malfunction. The O₂ - H₂ burner uses LOX and LH₂ to heat the helium supplied by the cold helium spheres, which are located in the LH₂ tank. The heated helium gas expands and pressurizes the LOX and LH₂ tanks prior to restart. Using the ambient system as the backup will require a longer pre-ignition sequencing. The second burn will last approximately 62 seconds.

Pre-Ignition Sequencing and Third S-IVB Burn. At approximately 6 hours and 7 minutes GET, following removal of an inhibit by ground command, the S-IVB will ignite for the Third burn of approximately 5 minutes duration. Prime consideration during the pre-ignition sequence will be to demonstrate the O₂ - H₂ restart capability. The ambient system for pressurization will also be used. The O₂ - H₂ burner will be ignited for about a 2 minute period.

Final Coast. When the S-IVB Engine is cutoff for the third time, a maneuver will be initiated to align the S-IVB longitudinal axis parallel with the local horizontal. Passivation will begin at approximately 6 hrs 12 minutes GET. The vehicle will be maneuvered to a position in order to accomplish the following; LOX and LH₂ dump thru the J-2 engine, open the propulsive and non-propulsive vents in the LOX and LH₂ tanks, and to open the cold helium valve. These events will require approximately 63 minutes for completion.

Spacecraft Mission Summary

Since the Apollo Mission D has been defined as a combined command service module and lunar module operations mission, the following is a summary of the mission D highlights to briefly emphasize the principal events and the approximate time of their occurrence.

(See figures 1 and 2)

<table>
<thead>
<tr>
<th>EVENT</th>
<th>APPROXIMATE Ground Elapsed Time (GET)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(DAY: HR: MIN)</td>
</tr>
<tr>
<td>Phase I</td>
<td></td>
</tr>
<tr>
<td>- Boost to Earth Orbit (S-IVB/CSM)</td>
<td>~ 0:00:11</td>
</tr>
<tr>
<td>- S-IVB/CSM Separation (SLA Panel Jettison)</td>
<td>~ 0:02:39</td>
</tr>
<tr>
<td>- CSM/LM Docking and LM Extraction</td>
<td>~ 0:02:53</td>
</tr>
<tr>
<td>- S-IVB 2nd Burn (High Ellipse)</td>
<td>~ 0:04:45</td>
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<td>EVENT</td>
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<td>(DAY: HR: MIN)</td>
</tr>
<tr>
<td>Phase I (continued)</td>
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</tr>
<tr>
<td>- Docked (CSM/LM) SPS 1st burn</td>
<td>~ 0:06:00</td>
</tr>
<tr>
<td>- S-IVB 3rd burn (Escape)</td>
<td>~ 0:06:07</td>
</tr>
<tr>
<td>Phase II</td>
<td></td>
</tr>
<tr>
<td>- Docked (CSM/LM) 2nd., 3rd., 4th. SPS burn:</td>
<td>2nd-- 0:23:44</td>
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<td>3rd-- 1:03:14</td>
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<td></td>
<td>4th-- 1:06:20</td>
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<tr>
<td>Phase III</td>
<td></td>
</tr>
<tr>
<td>- Docked burn of the LM Decent Propulsion (DPS).</td>
<td>~ 2:06:35</td>
</tr>
<tr>
<td>Phase IV</td>
<td></td>
</tr>
<tr>
<td>- Astronaut Extra Vehicular Activity (EVA). Two of the 3-man crew will move in tethered mode from CSM to LM.</td>
<td>~ 2:19:00</td>
</tr>
<tr>
<td>- Crew will operate a 5th SPS burn of the CSM for undocking.</td>
<td>~ 3:10:12</td>
</tr>
<tr>
<td>Phase V</td>
<td></td>
</tr>
<tr>
<td>- LM undocks from CSM (LM is manned)</td>
<td>~ 3:21:00</td>
</tr>
<tr>
<td>- LM staging will separate the Ascent from the Decent Portion of the LM</td>
<td>~ 4:06:52</td>
</tr>
<tr>
<td>- Following an undocked APS burn, the CSM and LM will rendezvous and the crew will return to the CSM.</td>
<td>~ 4:09:18</td>
</tr>
<tr>
<td>Period VI</td>
<td></td>
</tr>
<tr>
<td>- LM will jettison from the CSM</td>
<td>~ 4:21:00</td>
</tr>
<tr>
<td>- APS (LM) Final Burn (to move jettisoned LM out of plane)</td>
<td>~ 4:22:19</td>
</tr>
<tr>
<td>- 6th SPS burn of CSM</td>
<td>~ 4:27:30</td>
</tr>
</tbody>
</table>
EVENT APPROXIMATE
Ground Elapsed Time (GET)
(DAY: HR: MIN)

Period VI

- 7th SPS burn of CSM (to establish favorable
deorbit conditions) - - - - - - - - - - - - - - - - - 5:06:23

- From the 5th to the 9th day, the crew activities
consist primarily of navigation sightings, inertial
measurements, S/C equipment usage and rest periods.

- At ~ 9 days and 19 hours the crew will begin preparation
for re-entry.

- SPS deorbit burn of CSM - - - - - - - - - - - - - - - - 9:21:46

- SM jettisoned from CM - - - - - - - - - - - - - - - - - 9:22:36

- CM re-entry - - - - - - - - - - - - - - - - - - - - - - - 9:35:00

Parachute descent and splashdown will follow re-entry.
Approximately 10 days from lift off, the Command
Module will splash down in the Atlantic at a point
1000 NMI East of Cape Kennedy.
1. Lift off
2. S-IC/S-11 Separation ~ 2 min. 40 sec.
3. S-11 Stage Ignition ~ 2 min. 41 sec.
   Aft Interstage Separation ~ 3 min. 10 sec.
4. LET Jettison ~ 3 min. 15 sec.
5. S-11 Stage Cutoff and Jettison ~ 8 min. 52 sec.
   S-IVB Ignition ~ 8 min. 54 sec.
6. S-IVB First Cutoff ~ 10 min. 49 sec.
   Insertion into Parking Orbit ~ 10 min. 58 sec.

Mission Profile
Boost to Earth Orbit

Figure 1
Figure 2

Mission Profile
Space Vehicle Trajectory
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENERAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Mission Profile -- Boost to Earth Orbit</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Mission Profile -- Space Vehicle Trajectory</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>AS-504 Space Vehicle</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>KSC - Launch Complex 39</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>Saturn V Mobile Launcher</td>
<td>13</td>
</tr>
<tr>
<td>SPACE VEHICLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Secure Range Safety System</td>
<td>15</td>
</tr>
<tr>
<td>7</td>
<td>Emergency Detection System</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>S-IC/S-II Stage Flight Sequencing</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>S-II/S-IVB Stage Flight Sequencing</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>S-IVB Stage Flight Sequencing</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>S-IVB Stage Flight Sequencing (cont'd)</td>
<td>21</td>
</tr>
<tr>
<td>12</td>
<td>Time Base Inhibits</td>
<td>23</td>
</tr>
<tr>
<td>13</td>
<td>Guidance and Control System Block Diagram</td>
<td>25</td>
</tr>
<tr>
<td>14</td>
<td>Digital Command System</td>
<td>27</td>
</tr>
<tr>
<td>15</td>
<td>AS-504 Measurement Summary</td>
<td>29</td>
</tr>
<tr>
<td>16</td>
<td>Vehicle Tracking Systems</td>
<td>31</td>
</tr>
<tr>
<td>17</td>
<td>Space Vehicle Weight vs Flight Time</td>
<td>33</td>
</tr>
<tr>
<td>S-IC STAGE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>S-IC Stage Configuration</td>
<td>35</td>
</tr>
<tr>
<td>19</td>
<td>F-1 Engine System</td>
<td>37</td>
</tr>
<tr>
<td>20</td>
<td>S-IC Stage Propellant System</td>
<td>39</td>
</tr>
<tr>
<td>21</td>
<td>S-IC Stage Thrust Vector Control System</td>
<td>41</td>
</tr>
<tr>
<td>22</td>
<td>S-IC Stage Measuring System</td>
<td>42</td>
</tr>
<tr>
<td>23</td>
<td>S-IC Stage Telemetry System</td>
<td>43</td>
</tr>
<tr>
<td>24</td>
<td>S-IC Stage Electrical Power and Distribution System</td>
<td>44</td>
</tr>
<tr>
<td>S-II STAGE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>S-II Stage Configuration</td>
<td>47</td>
</tr>
<tr>
<td>26</td>
<td>J-2 Engine System - S-II Stage</td>
<td>49</td>
</tr>
<tr>
<td>27</td>
<td>S-II Stage Propellant System</td>
<td>51</td>
</tr>
<tr>
<td>28</td>
<td>S-II Stage Propellant Management System</td>
<td>53</td>
</tr>
<tr>
<td>29</td>
<td>S-II Stage Thrust Vector Control System</td>
<td>55</td>
</tr>
<tr>
<td>30</td>
<td>S-II Stage Measuring System</td>
<td>56</td>
</tr>
<tr>
<td>31</td>
<td>S-II Stage Telemetry System</td>
<td>57</td>
</tr>
<tr>
<td>32</td>
<td>S-II Stage Electrical Power and Distribution System</td>
<td>58</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES (Continued)

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>S-IVB STAGE</strong></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>S-IVB Stage Configuration</td>
<td>61</td>
</tr>
<tr>
<td>34</td>
<td>J-2 Engine System S-IVB Stage</td>
<td>63</td>
</tr>
<tr>
<td>35</td>
<td>S-IVB Stage Propellant System</td>
<td>65</td>
</tr>
<tr>
<td>36</td>
<td>S-IVB Stage Propellant Management System</td>
<td>67</td>
</tr>
<tr>
<td>37</td>
<td>S-IVB Stage Thrust Vector Control System</td>
<td>69</td>
</tr>
<tr>
<td>38</td>
<td>Auxiliary Propulsion System</td>
<td>71</td>
</tr>
<tr>
<td>39</td>
<td>S-IVB Stage Measuring System</td>
<td>72</td>
</tr>
<tr>
<td>40</td>
<td>S-IVB Stage Telemetry System</td>
<td>73</td>
</tr>
<tr>
<td>41</td>
<td>S-IVB Stage Electrical Power and Distribution System</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td><strong>INSTRUMENT UNIT</strong></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Instrument Unit Configuration</td>
<td>77</td>
</tr>
<tr>
<td>43</td>
<td>Instrument Unit Measuring System</td>
<td>78</td>
</tr>
<tr>
<td>44</td>
<td>Instrument Unit Telemetry System</td>
<td>79</td>
</tr>
<tr>
<td>45</td>
<td>Instrument Unit Electrical Power and Distribution System</td>
<td>80</td>
</tr>
<tr>
<td>46</td>
<td>IU/S-IVB Environmental Control System</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td><strong>SPACECRAFT</strong></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Spacecraft Configuration</td>
<td>87</td>
</tr>
<tr>
<td>48</td>
<td>Spacecraft Telecommunication System</td>
<td>88</td>
</tr>
<tr>
<td>49</td>
<td>Spacecraft Electrical Power and Distribution System</td>
<td>89</td>
</tr>
<tr>
<td>50</td>
<td>Spacecraft Guidance and Navigation System</td>
<td>90</td>
</tr>
<tr>
<td>51</td>
<td>Lunar Module (LM)</td>
<td>91</td>
</tr>
<tr>
<td>52</td>
<td>Lunar Module Engine Locations</td>
<td>92</td>
</tr>
<tr>
<td>53</td>
<td>LM Guidance and Navigation Section</td>
<td>93</td>
</tr>
<tr>
<td>54</td>
<td>LM Communications Subsystem</td>
<td>94</td>
</tr>
</tbody>
</table>
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. 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 5).

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.


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
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-I1 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 also at 30 seconds.
Figure 7

Emergency Detection System
Liftoff

- Disconnect I.U. Umbilical

- Multiple Engine Cutoff Enable ~ 0 min. 14 sec.

- EDS Engine Cutoff Enable ~ 0 min. 30 sec.

Automatic Abort Capability
1. 5-1C two engines out
2. Excessive angular rates

~ 2 min. 13 sec.

- 5-1C Inboard Engine Cutoff ~ 2 min. 14 sec.

Note:
Approximate times shown are measured from liftoff.

- 5-1C Outboard Engine Cutoff ~ 2 min. 40 sec.

- 5-11 Ullage Ignition ~ 2 min. 40 sec.

- 5-1C/5-11 Separation ~ 2 min. 40 sec.

- 5-11 Engine Start ~ 2 min. 42 sec.

- Activate Closed Loop P.U. System ~ 2 min. 46 sec.

- 5-11 Att Interstage Separation ~ 3 min. 10 sec.

- 5-11 Lox & LHe Depletion Sensors Enable ~ 8 min. 18 sec.

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
S-II Engine Cutoff ~ 8 min. 51 sec.
- S-IVB Ullage Ignition ~ 8 min. 52 sec.
- S-II/S-IVB Separation ~ 8 min. 52 sec.
- S-IVB Engine Start ~ 8 min. 55 sec.
  - Activate Open Loop P.U. System ~ 9 min. 00 sec.
- S-IVB Engine Velocity Cutoff ~ 10 min. 48 sec.
  - S-IVB Ullage On ~ 10 min. 49 sec.
  - S-IVB Insertion into Earth Parking Orbit ~ 10 min. 58 sec.
  - S-IVB Ullage Off ~ 12 min. 17 sec.
- S-IVB/Spacecraft Separation ~ 2 hr. 40 min.
- Begin S-IVB Engine Restart Preparations ~ 4 hrs. 36 min.

Note:
Approximate times shown are measured from liftoff.

Start of Time Base 4  |  Start of Time Base 5  |  Start of Time Base 6

Time Base Divisions

Figure 9

S-II/S-IVB Flight Sequencing
\[
\begin{align*}
\triangle & O_2H_2 \text{ Burner On} \sim 4 \text{ hrs. 37 min.} \\
\triangle & LOX \text{ Chilldown Pump On} \sim 4 \text{ hrs. 40 min.} \\
\triangle & LH_2 \text{ Chilldown Pump On} \sim 4 \text{ hrs. 40 min.} \\
\triangle & O_2H_2 \text{ Burner Off} \sim 4 \text{ hrs. 45 min.} \\
\triangle & LOX \text{ Chilldown Pump Off} \sim 4 \text{ hrs. 46 min.} \\
\triangle & LH_2 \text{ Chilldown Pump Off} \sim 4 \text{ hrs. 46 min.} \\
\triangle & S-1VB \text{ Engine 1st Restart} \sim 4 \text{ hrs. 46 min.} \\
\updownarrow & S-1VB \text{ Engine Cutoff} \sim 4 \text{ hrs. 47 min.} \\
\updownarrow & S-1VB \text{ Ullage On} \sim 4 \text{ hrs. 47 min.} \\
\updownarrow & S-1VB \text{ Ullage Off} \sim 4 \text{ hrs. 47 min.} \\
\updownarrow & \text{Begin 2nd S-1VB Engine Restart} \\
\quad & \text{Preparation} \sim 6 \text{ hrs. 00 min.} \\
\triangle & LOX \text{ Chilldown Pump On} \sim 6 \text{ hrs. 02 min.} \\
\triangle & LH_2 \text{ Chilldown Pump On} \sim 6 \text{ hrs. 02 min.} \\
\triangle & O_2H_2 \text{ Burner On} \sim 6 \text{ hrs. 04 min.} \\
\triangle & S-1VB \text{ Ullage On} \sim 6 \text{ hrs. 05 min.} \\
\triangle & O_2H_2 \text{ Burner Off} \sim 6 \text{ hrs. 05 min.} \\
\triangle & LOX \text{ Chilldown Pumps Off} \\
\quad & \sim 6 \text{ hrs. 06 min.} \\
\triangle & LH_2 \text{ Chilldown Pump Off} \\
\quad & \sim 6 \text{ hrs. 06 min.} \\
\triangle & S-1VB \text{ Ullage Off} \sim 6 \text{ hrs. 07 min.} \\
\triangle & S-1VB \text{ Engine 2nd Restart} \\
\quad & \sim 6 \text{ hrs. 07 min.}
\end{align*}
\]

Note:
Approximate times shown are measured from liftoff.

Figure 10
S-1VB Stage
Flight Sequencing
5-IVB Engine Cutoff ~ 6 hrs. 11 min.
△ Start LOX Dump ~ 6 hrs. 13 min.
△ LOX Dump Cutoff ~ 6 hrs. 24 min.
△ Start LH₂ Dump ~ 6 hrs. 24 min.
△ LH₂ Dump Cutoff ~ 6 hrs. 42 min.

Notes:
Approximate times shown are measured from liftoff.
<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>$T_0$</td>
<td>- 0:00:17</td>
<td>Initiated by terminal count sequencer</td>
</tr>
<tr>
<td>Liftoff (I.U. Umbilical Release)</td>
<td>$T_1$</td>
<td>0:00:00</td>
<td>Initiated by deactuation of I.U. liftoff relay at umbilical disconnect or vertical acceleration</td>
</tr>
<tr>
<td>S-1C Center Engine Cutoff</td>
<td>$T_2$</td>
<td>0:02:14</td>
<td>Initiated by S-1C Inboard engine cutoff command from LVDC</td>
</tr>
<tr>
<td>S-1C Outboard Engine Cutoff</td>
<td>$T_3$</td>
<td>0:02:40</td>
<td>Initiated by the propellant depletion sensors or the thrust-OK switches</td>
</tr>
<tr>
<td>S-1B Engines Cutoff</td>
<td>$T_4$</td>
<td>0:08:51</td>
<td>Initiated by the propellant depletion sensors or the thrust-OK switches</td>
</tr>
<tr>
<td>First S-IVB Engine Cutoff</td>
<td>$T_5$</td>
<td>0:10:48</td>
<td>Initiated by any two of four functions; S-IVB velocity cutoff issued by LVDC thrust-OK switches (2), or accelerometer reading</td>
</tr>
<tr>
<td>Initiation-Restart Sequence</td>
<td>$T_6$</td>
<td>4:36:12</td>
<td>Initiated when LVDC solves the restart equation; inhibit must be removed by ground command</td>
</tr>
<tr>
<td>Second S-IVB Engine Cutoff</td>
<td>$T_7$</td>
<td>4:46:52</td>
<td>Initiated by any two of four functions; S-IVB cutoff issued by the LVDC, thrust-OK switches (2), or accelerometer reading</td>
</tr>
<tr>
<td>Initiation-Second Restart Sequence</td>
<td>$T_8$</td>
<td>5:59:35</td>
<td>Initiated a fixed time from initiation of $T_6$; $T_7$ must also have been accomplished</td>
</tr>
<tr>
<td>Third S-IVB Engine Cutoff</td>
<td>$T_9$</td>
<td>6:11:14</td>
<td>Initiated by any two of four functions; S-IVB cutoff issued by LVDC, thrust-OK switches (2), or accelerometer</td>
</tr>
<tr>
<td>Early S-11/S-1V Staging</td>
<td>$T_{4a}$</td>
<td>Variable</td>
<td>Initiated by 9-11/S-1V staging switch in the spacecraft during S-11 burn</td>
</tr>
<tr>
<td>S-IVB Burner Malfunction</td>
<td>$T_{6a}$</td>
<td>Variable</td>
<td>Initiated by burner malfunction signal from S-IVB stage -- $T_{4a}$ 148 seconds to $T_6$ +496.9 seconds</td>
</tr>
<tr>
<td>Delayed Initiation Restart Sequence</td>
<td>$T_{8a}$</td>
<td>6:10:16</td>
<td>Initiated when $T_6$ is not accomplished. Inhibit must be removed by ground command</td>
</tr>
</tbody>
</table>
Inhibits must be removed by group command before:

1. 4:36:02 G.E.T.
2. 5:59:25 G.E.T.
3. 6:24:55 G.E.T.
4. 6:10:06 G.E.T.
5. 6:18:39 G.E.T.

Figure 12

Time Base Inhibit
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 13).

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)

Velosity

Attitude Angles

LVDA

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

UP-Dating Info

Attitude Correction Command

Switch Selector

Switch Selector

Switch Selector

Sequencing Signals To IU Systems

Sequencing Signals To S-IVB Systems

Sequencing Signals To S-II Systems

Sequencing Signals To S-IC Systems

Control/EDS Rate Gyro Package (9 Gyros)

Control Signal Processor

3P, Y, R

Attitude Rates

Control Relay Packages

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)

S-IC Stage
To Control Actuators For Engine 4 (P, Y & R)

± 5.1° Swivel Angle
0° Cant Angle

Mechanical Feedback (θf)

Guidance and Control System Block Diagram

Figure 13
### DIGITAL COMMAND SYSTEM CAPABILITY:

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

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Periods of Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhibit maneuver</td>
<td>Coast phase attitude maneuver inhibit</td>
<td>From T5 + 0 seconds until T6 - 9 or T5 to T8 - 9 or T5 to T9 - 1</td>
</tr>
<tr>
<td>Maneuver update</td>
<td>Time change to start coast phase maneuver</td>
<td>From T5 + 100 to T6 - 9 and T7 + 15 to T8 - 9 and from T9 + 15 to EOM</td>
</tr>
<tr>
<td>Time base update</td>
<td>Time base time is advanced or retarded</td>
<td>From T5 to T6 - 9 and T7 to T8 - 9 and from T9 to EOM</td>
</tr>
<tr>
<td>Generalized switch selector</td>
<td>Specified switch selector function is issued at the first opportunity</td>
<td>From T5 + 0 seconds to T6 + 570 and from T7 to T8 + 450 and from T9 to EOM</td>
</tr>
<tr>
<td>Sector dump</td>
<td>Contents of specified memory location are telemetered</td>
<td>From T5 + 100 seconds to T6 - 9 and from T7 + 15 seconds to T8 - 9 and from T9 + 15 to EOM</td>
</tr>
<tr>
<td>Telemeter single memory location</td>
<td>Contents of specified memory location are telemetered</td>
<td>From T5 + 100 seconds to T6 - 9 and from T7 + 15 seconds to T8 - 9 and from T9 + 15 to EOM</td>
</tr>
<tr>
<td>Terminate</td>
<td>Stop DCS processing and reset for a new command</td>
<td>Anytime any other DCS command is acceptable</td>
</tr>
<tr>
<td>Inhibit water control valve logic</td>
<td>Inhibit water valve from changing position</td>
<td>From T5 + 0 seconds to T6 - 9 and from T7 + 0 and T8 - 9 and from T9 to 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 T5 + 100 seconds to T6 - 9 and from T7 + 15 to T8 - 9 and from T9 + 15 to EOM</td>
</tr>
<tr>
<td>Restart maneuver enable</td>
<td>Remove programmed inhibit of maneuvers</td>
<td>From T5 to T6 - 9 and from T7 to T8 - 9; or from T5 to T8A - 9; or from T5 (or T7) to T9 - 1</td>
</tr>
</tbody>
</table>

EOM -- End of mission
DCS hardware can be enabled by spacecraft manual switch for command action during coast phase operation or prior to separation. However, commands will only be accepted by the flight program within the period of time programmed in the LVDC, as described on page 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 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 30 and 31.
### Measurement Summary - L/V

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Stage 5-1C</th>
<th>Stage 5-11</th>
<th>Stage 5-1VB</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>5</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Temperature</td>
<td>190</td>
<td>330</td>
<td>75</td>
<td>16</td>
<td>611</td>
</tr>
<tr>
<td>Pressure</td>
<td>177</td>
<td>188</td>
<td>79</td>
<td>10</td>
<td>454</td>
</tr>
<tr>
<td>Vibration</td>
<td>70</td>
<td>63</td>
<td>-</td>
<td>-</td>
<td>133</td>
</tr>
<tr>
<td>Flow Rate</td>
<td>35</td>
<td>10</td>
<td>4</td>
<td>4</td>
<td>53</td>
</tr>
<tr>
<td>Position</td>
<td>1</td>
<td>44</td>
<td>8</td>
<td>21</td>
<td>74</td>
</tr>
<tr>
<td>Signals</td>
<td>132</td>
<td>223</td>
<td>72</td>
<td>105</td>
<td>532</td>
</tr>
<tr>
<td>Liquid Level</td>
<td>22</td>
<td>6</td>
<td>7</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>Voltage, Current,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>11</td>
<td>65</td>
<td>38</td>
<td>38</td>
<td>152</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>12</td>
<td>4</td>
<td>9</td>
<td>-</td>
<td>25</td>
</tr>
<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>27</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>60</td>
<td>60</td>
</tr>
<tr>
<td>RF and Telemetry</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Totals</td>
<td>666</td>
<td>989</td>
<td>294</td>
<td>296</td>
<td>2245</td>
</tr>
<tr>
<td>ESE Display</td>
<td>97</td>
<td>82</td>
<td>100</td>
<td>177</td>
<td>456</td>
</tr>
<tr>
<td>Auxiliary Display</td>
<td>64</td>
<td>81</td>
<td>63</td>
<td>18</td>
<td>226</td>
</tr>
<tr>
<td>Flight Control</td>
<td>28</td>
<td>80</td>
<td>86</td>
<td>104</td>
<td>298</td>
</tr>
</tbody>
</table>

### Measurement Summary - S/C

<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>
</tr>
<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,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>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>Totals</td>
<td>195</td>
<td>143</td>
<td>880</td>
<td>1218</td>
</tr>
</tbody>
</table>

Figure 15

AS-504
Measurement Summary

29
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.
Crystal switch driven by Comparator
Automatically selects strongest receivers' antenna for output

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

Unified S-Band System

Instrument Unit

S-IC Stage

Vehicle Tracking Systems
SPACE VEHICLE WEIGHT VS. FLIGHT TIME

Mainstage propellant consumption during S-IC stage powered flight (approximately 159 seconds) is 4,660,200 pounds. Propellant consumption during S-II stage powered flight (approximately 372 seconds) is approximately 972,200 pounds and during S-IVB stage powered flight, including first ignition and subsequent second and third ignitions, (approximately 422 seconds) is approximately 230,700 pounds.

VEHICLE WEIGHT DATA (Approximate)                  Pounds

Total at S-IC stage ignition               6,483,200
Total at holddown arm release           6,396,900
Total at S-IC stage O.E.C.O.             1,827,900
Total at S-II stage ignition            1,449,400
Total at S-II stage E.C.O.              463,400
Total at S-IVB stage first ignition      358,200
Total at S-IVB stage E.C.O.             289,900
Total at spacecraft separation          195,000
Total at S-IVB stage second ignition    192,200
Total at S-IVB stage second E.C.O.       163,600
Total at S-IVB stage thrid ignition     162,500
Total at S-IVB stage third E.C.O.        34,400
Figure 17

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.

TV Camera and Film Camera Systems are not installed in the S-IC stage for AS-504.
Stage Weight
- Dry: ~ 295,200 Lbs.
- At Ignition: ~ 503,100 Lbs.
- At Separation: ~ 369,600 Lbs.

Figure 18
S-IC Stage Configuration
F-1 ENGINE OPERATION

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

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

Turbopump Assembly

Turbine

Gas Generator

Igniters (2)

Engine Control Valve

Main LOX Valve

Main Fuel Valve

Thrust Chamber Pressure 1105 psia

Expansion Ratio 6:1

1,500,000 lbs Thrust

Figure 19

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.
LOX/Ullage Pressure Sense Line

Ground Pressure Switch

LOX Fill & Drain Valve (2) with Heaters

LOX in Lines at Lift-off ~ 44,100 lbs.

LOX Fill & Drain Valve (2) (Pressure Switch Operated)
Open - 25.5 psig
Close - 24 psig

31 cu-ft. 3000 psig He Bottles (4) for RP-1 Tank Pressurization

Pressurization Valves (5)
Open - 26.5 psig
Close - 24.2 psig

LOX Tank

He/RP-1
25.1 psig nom.

RP-1 Tank

RP-1 Fill & Drain Valves
Thrust Structure
RP-1 Line (2 per Engine)
RP-1 in Lines at Lift-off ~ 6450 lbs.
Flow Valves (1 LOX, 2 RP-1)
LOX Interconnect Valve (4)

Heat Exchanger heats He for Inflight pressurization of RP-1 Tank. Converts LOX to GOX for Inflight LOX Tank pressurization.

F-1 Engine (5)

Total Propellant at Ignition
~ 4,730,900 lbs.

Total Propellant consumed after Ignition
~ 4,660,200 lbs.

Figure 20

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

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

The thrust vector control system is part of the engine system. During engine operation, high pressure control fluid is supplied from the turbopump assembly to the servo valve and actuators. The fluid returns to the inlet of the turbopump assembly.
From No. 1 Turbopump fuel discharge

To No. 2 Turbopump assembly input

Valve Checkout

Vehicle Thrust Structure Actuator Attachment Point

Hydraulic Actuator (2 per engine)

Servo Valve Controls Actuator Movement

Turbopump fuel discharge duct

Manifold Filter

Gimbal Point

Actuators (2 per engine)

Vehicle Yaw Axis

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

Vehicle Pitch Axis

Eng #1

Eng #2

Eng #3

Eng #4

Eng #5

Vehicle Yaw Axis

- pitch

+ pitch

+ yaw

+ roll

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

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

Figure 21

S-IC Stage Thrust Vector Control System

41
Notes:
All components shown are located in the Thrust Frame Area except as noted.
S-II STAGE STRUCTURE

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

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

Antenna Arrangement

- Telemetry Antennas (4)
- Secure Range Safety Antennas (4)
- LH2 Feedline Fairings (5)

Stage Weight
- Dry: ~ 84,600 lbs.
- At S-II Ignition: ~ 1,059,600 lbs.
- At S-II Cutoff: ~ 97,000 lbs.
- At S-II Separation: ~ 96,500 lbs.
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.
Propellant utilization valve varies engine mixture ratio by bypassing LOX from the pump.

LOX Pump
- P.U. Valve
- LOX Turbine
- Main LOX Valve

LH₂ Pump
- LH₂ Turbine
- Start Tank
- LH₂ Valve

Gas Gen.

GH₂ for LH₂ tank pressurization

GOX for LOX tank pressurization

Heat Exchanger

Injector
- Thrust chamber pressure: 776 psia at 5.0:1
- Expansion Ratio: 27.5:1

200,000 lbs Thrust

Mixture ratio
LOX:LH₂ 5.5 - 45:1
Programmed by weight.

Figure 26
J-2 Engine System
S-11 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
LH₂ Tank pressure
Regulator opens ~ 298 seconds after S-II ignition and remains open.

LH₂ Tank
~ 158,200 lbs. at ignition

LOX Tank
~ 820,500 lbs. at ignition

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

Total propellant at ignition
~978,800 lbs.
Total propellant consumed after
ignition ~ 972,200 lbs.
The propellant management system provides a means of monitoring and controlling propellants during all phases of stage operation. Continuous capacitance probes and point level sensors in the LOX and LH₂ tanks monitor propellant mass.

During powered flight, the capacitance probes provide outputs used to operate the propellant utilization (PU) system to monitor the amount of LOX flowing to the J-2 engine and also to minimize propellant residuals at engine cutoff. At J-2 engine start, a mixture ratio of 5.0:1 is utilized. At PU actuation (5.5 seconds after engine start) the mixture ratio shifts to 5.5:1 for the first portion of the engine burn. During the last portion of the burn the mixture ratio shifts to 4.7:1 striving for simultaneous depletion of LOX and LH₂ for maximum stage performance. Engine cutoff is initiated when any two of the five capacitance probes in either propellant tank indicates dry.
S-Ⅱ STAGE THRUST VECTOR CONTROL SYSTEM

The four outboard engines are gimbal mounted to provide attitude control during powered flight. Attitude control is maintained by gimbaling one or more of the engines. Power for gimbaling 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.
The S-11 Stage Thrust Vector Control System diagram demonstrates the integration of various components and control mechanisms. It includes:

- **Vehicle Thrust Structure** withAttachment Point and Hydraulic Actuators (2).
- **Gimbal Point** for precise control.
- **Servo Valve** for fluid control.
- **Reservoir** and **Accumulator** for pressure management.
- **Main Pump** and **Auxiliary Pump** for inflight use.
- **Motor** and **Electric Motor** for power output.
- **Low Pressure** (~170 psig) and **Pressurized from ground with CO2 at 2350±50 psig at 70°F** for different operational pressures.
- **Inboard Engine (1)**, Fixed Position, Canted 0° at Nominal Thrust.
- **Outboard Engines (4)**, Canted 0° at Nominal Thrust.
- **Square Gimbal Pattern ±7°** for Engine Gimbal Rate Under Load 9° per sec.

The diagram also highlights the **Vehicle Pitch Axis**, **Vehicle Yaw Axis**, and **Vehicle Thrus Structure** for comprehensive control and directionality. The figure is labeled as Figure 29.
Figure 32

S-II Stage Electrical Power & Distribution System
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)

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)

S-IVB Stage Weights
- Dry: ~ 25,300 lbs.
- At S-IVB Ignition: ~ 256,900
- At S-IVB Cutoff: ~ 190,700
- At S-IVB 2nd Cutoff: ~ 157,900
- At S-IVB 3rd Cutoff: ~ 28,700

Figure 33

S-IVB Stage Configuration
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.
Mixtuw Ratio 200,000 lbs Thrust

LOX Pump

LOX Turbine

Main LOX Valve

Gas Gen

LOH Pump

LOH Turbine

Start Tank

LOH Turbine bypass valve

Main LH2 Valve

LOH for LH2 Tank Pressurization

GOH2 for LOH Tank Pressurization

Heat Exchanger

Thrust Chamber (Pressure 776 psi)

Expansion Ratio 21.5:1

Mixture Ratio LOH : LH2 5.0:4.5:1

200,000 lbs Thrust

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

Figure 3.4

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 GH₂ 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

![Diagram of propellant load and operational sequence for S-IVB stage.](image-url)
GH2 from J-2 Engine injector for LH2 tank pressurization during first, second, and third S-IVB Stage burn.

3.5 cu.ft. 3100 psia GHe spheres (9) inflight LOX Tank pressurization.

LH2 Tank
~ 43,500 lbs. at ignition

LOX Tank
~ 188,900 lbs. at ignition

3.5 cu.ft. 3100 psia GHe spheres (2) for J-2 Engine restart

4.4 cu.ft. 3100 psia GHe spheres (6)
LH2 Tank pressurization during coast mode.

Total propellant at ignition
~ 232,400 lbs.
Total propellant consumed after ignition ~ 230,700 lbs.
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 second and third engine restart is 4.5 to 1. Shortly after the engine reaches 90% thrust, the mixture ratio is shifted to 5.0 to 1 which will be used for the second burn (burn to intermediate orbit) and the third burn.
Mixture ratio is normally 50:1 unless switch selector has commanded 4.5:1 or 5.5:1 mixture ratio.
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

Gimbal Point

Engine Actuator Attachment

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

Main Pump

Reservoir

Accumulator

Inflight use-

Driven by Engine Turbo Pump at 8000 RPM output 8.0 gpm at 3550 psig

Air Tank

Motor

Auxiliary Pump

Precharged to 475 psig

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

APS Nozzles

Vehicle Yaw Axis

Gimbal Point

Vehicle Roll Axis

Vehicle Pitch Axis

Engine Gimballed; Canted 0° at Nominal Thrust

_indexed_r

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

Gimbal Pattern (looking forward)

Figure 37

S-IVB Stage Thrust Vector Control System
AUXILIARY PROPULSION SYSTEM

The APS consists of two self-contained attitude control modules mounted 180 degrees apart on the aft skirt of the S-IVB stage. Each attitude control module contains four thrust motors which use hypergolic propellant nitrogen tetroxide ($\text{N}_2\text{O}_4$) 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 3B

Auxiliary Propulsion System
Note: Most forward Interstage Components Are Mounted On Coldplates

---

Power Distributor

Ground Power 28 vdc

Battery #1
28 vdc
300 amp hr.
To Range Safety System No. 1

Static Inv./Conv.
Ass'y
To PU

Control Distributor
To PU

Measuring Voltage Supply 5 vdc
To Measuring Systems

Battery #2
28 vdc
25 amp hr.
To Range Safety System No. 2

---

Ground Power 56 vdc

Battery #2
56 vdc
50 amp hr.
To Battery Heaters

Control Distributor
To EDS

Sequencer
To J-2 Engine

To Control Relay Packages

Measuring Voltage Supply 5 vdc
To Measuring Systems

---

Ground Power 28 vdc

To Battery Heaters

Battery #1
28 vdc
300 amp hr.

To Ullage Rockets

To Switch Selector

From Switch Selector
To Pressurization System

---

Figure 41

S-IVB Stage Electrical Power and Distribution System

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74
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.
Weight:
- Dry ~ 4100 lbs.
- Serviced ~ 4300 lbs.

**Figure 42**

Instrument Unit Configuration
Figure 43
Instrument Unit
Measuring System
Diagram of Instrument Unit Electrical Power and Distribution System.
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.
SPACECRAFT DESCRIPTION

The Spacecraft for the AS-504 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-504 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

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.

During the AS-504 Mission, the prime test objectives relative to the Lunar Module will consist of: docking of the CSM/LM followed by LM extraction, a docked DPS burn, Extra Vehicular activity which includes astronaut travel (tethered) between LM and CSM, undocked DPS burn, LM staging, APS/CSM rendezvous and docking, and LM jettison.
Figure 47 illustrates the spacecraft configuration. Lunar Module is shown contained in the spacecraft Lunar Module Adapter (SLA). SLA panels are jettisoned at S-IVB-CSM separation.

Figure 51 is a detailed illustration of the Lunar Module.

Figure 52 illustrates the Lunar Module ascent and descent engine locations. Both will be tested during the mission.

Figure 53 contains a block diagram of the primary guidance and navigation system.

Figure 54 is a block diagram of the LM communications subsystem.
Weights:
- Lift-off: ~103,800 lbs.
- At Injection: 95,000 lbs.
(LES wgt. not included)
Figure 49

Spacecraft Electrical Power & Distribution System
Astronaut

Displays Indication at Control Panels

Coupling Display Unit

Navigation Base (sextant, telescope)

Inertial Measuring Unit

IMU Electronics (accelerometer, stabilization loop)

Command Module Computer

Power Supplies

Figure 50: Spacecraft Guidance and Navigation System
Figure 51
Lunar Module (LM)
Figure 53

LM Guidance and Navigation Section
VHF Inflight Antenna

EVA Antenna

3-Band Omni Antenna

3-Band Steerable Antenna

5-Band Enlable Antenna

VHF Diplexer

VHF Transmitters/Receivers (2)

Audio Centers (2)

Signal Processor Array

Premodulation Processor (PMP)

PCM Telemetry

Subsystem Sensors

LGC

Headsets

Digital Uplink Assembly

TV Camera

DOEA (Voice Tape Recorder)

(In Instrumentation Subsystem)

Figure 54

LM Communications Subsystem
DISTRIBUTION

DIR
Dr. von Braun (1)

DIR-T
Dr. Rees (5)

DEP-T
Mr. Neubert (40)

PA
Mr. Jones (2)

I-DIR
Gen. O'Connor (1)
Dr. Mrazek (1)
Dr. Farish (50)

I-K
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I-E-A
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I-RL-(MSC Liaison)
Mr. Hamilton (200)

KSC (LVO-5)
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KSC (SO)
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I-V-MGR-O
Mr. Bramlet (1)

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Mr. Bell (1)

I-V-E
Mr. Beaman (5)

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Mr. Moody (1)

I-V-F
Mr. Rowan (1)

I-V-G
Mr. Smith (1)

I-V-P
Mr. Sneed (1)

I-V-S-IC
Mr. Urlaub (1)

I-V-S-IVB
Mr. McCulloch (1)

I-V-S-II
Mr. Godfrey (1)

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Mr. Duerr (1)

I-K-V
Mr. Shute (5)

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Library (2)

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R-DIR
Mr. Weidner (2)

R-OM
Mr. Fellows (5)

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I-V-E
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