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# ADVANCED LAUNCH VEHICLE CAPABILITIES FOR UNMANNED INTERPLANETARY MISSIONS (U)


by LUNAR AND INTERPLANETARY FLIGHT SECTION
Propulsion and Vehicle Engineering Laboratory


NASA

*George C. Marshall Space Flight Center, Huntsville, Alabama*

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TECHNICAL MEMORANDUM X-53102

# ADVANCED LAUNCH VEHICLE CAPABILITIES FOR UNMANNED INTERPLANETARY MISSIONS

By


Lunar and Interplanetary Flight Section
George C. Marshall Space Flight Center
Huntsville, Alabama


## ABSTRACT


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This report presents the results of a study on the capabilities of the Saturn IB, Saturn V and some selected advanced Saturn V vehicles for launching interplanetary payloads to the planets Mercury, Venus, Mars, Jupiter, and Saturn.

The performance capabilities of each vehicle configuration were computed and are presented as a function of the departure window, departure date, and transfer time for each of the missions investigated. A preliminary structural analysis was conducted for each configuration to assure compatibility with vehicle design criteria.

No attempt is made in this report to define the particular payload for these missions; however, a tabulation of experiments for unmanned interplanetary missions proposed by Jet Propulsion Laboratory and others is included as an appendix.


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TECHNICAL MEMORANDUM X-53102

# ADVANCED LAUNCH VEHICLE CAPABILITIES FOR UNMANNED INTERPLANETARY MISSIONS


By

*Lunar and Interplanetary Flight Section*

*Mission Analysis Group*

*Advanced Studies Office*

PROPULSION AND VEHICLE ENGINEERING LABORATORY


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# ADVANCED LAUNCH VEHICLE CAPABILITIES FOR UNMANNED INTERPLANETARY MISSIONS

## SUMMARY

A preliminary analysis has been conducted to evaluate the capabilities of some advanced launch vehicles for launching probes to the planets Mercury, Venus, Mars, Jupiter, and Saturn. The primary objective of this analysis was to determine the vehicle payload capabilities. No attempt was made to define a particular type of payload; however, a tabulation of experiments for unmanned probes proposed by Jet Propulsion Laboratory and others is included, with associated weight and power requirements, in the appendix.

The S-IB/Centaur, Saturn V, Saturn V/Centaur and six advanced versions of the Saturn V vehicle were included in this study. The best vehicle and weight data (March and April) available at the beginning of the performance analysis of this study were used. A preliminary loads analysis was conducted for each configuration to assure compatibility with vehicle design criteria.

An addendum to this report including the Titan III-C launch vehicle was released separately and is referenced herein.

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## SECTION I. INTRODUCTION

In order to accomplish the long range objective of manned exploration of space, the National Aeronautics and Space Administration must obtain information about the unknown - and often hostile - environment of interplanetary space. Presently envisioned missions for the Voyager and Mariner spacecraft will furnish some of the necessary data. Other missions which involve larger payloads, higher energy transfers, and, therefore, more advanced launch vehicle systems may be desirable. Larger payloads will be required because of the greater communication distances and greater power requirements for the extended duration missions.

This study was made to facilitate the planning of the missions requiring advanced launch vehicles. Performance capabilities were determined for the Saturn IB/Centaur, Saturn V, Saturn V/Centaur, and six advanced Saturn V configurations for missions to Mercury, Venus, Mars, Jupiter, and Saturn. These performance data are presented in graphical and tabular form as a function of Earth departure date, injection energy, transfer time, and Earth departure window. A preliminary structural analysis was made to assure that each launch vehicle configuration studied was consistent with accepted design criteria. A trajectory and a weight summary for each launch vehicle configuration are presented for a typical mission.

The same type of information as presented in this report can be obtained for the Titan III-C launch vehicle in Reference 1. This vehicle was presented separately due to the classification requirements for the Titan III-C performance.



## SECTION II: STUDY APPROACH

In order to arrive at realistic vehicle capabilities for launching interplanetary probes to Mercury, Venus, Mars, Jupiter and Saturn, a comprehensive analysis of the trajectory data of References 2 and 3 was conducted. From this analysis, the trajectory data were obtained for the feasible launch dates in the 1965 to 1980 time period.

Based on the above trajectory data, nine (9) launch vehicle configurations - assumed to span the state-of-the-art in chemical propulsion - were selected for a detailed analysis of their capability to perform these interplanetary missions. The launch vehicles selected were as follows:

1. Saturn IB/Centaur
2. Saturn V
3. Saturn V/Centaur
4. MLV - Saturn V-1
5. MLV - Saturn V-1/Centaur
6. MLV - Saturn V-2
7. MLV - Saturn V-2/Centaur
8. MLV - Saturn V-3
9. MLV - Saturn V-3/Centaur

Vehicles 4 through 9 represent various degrees of modification to the Saturn V launch vehicle. These modified vehicles are further identified in Section III.

A performance analysis from Earth to the interplanetary transfer injection point was conducted for each of the above vehicle configurations. The payload weight capability and the stage propellant loading for each configuration was determined for a number of injection energy requirements. The payload weight capabilities were then compared with the energy requirements of the interplanetary trajectories to arrive at vehicle capabilities for reasonable Earth departure windows.

An analysis was conducted for each vehicle configuration to assess the payload size and density on the load-carrying capabilities of the vehicle. The payload envelope and the structural limitations of the launch vehicle determine the minimum permissible payload density. A comparison of this minimum payload density was made with typical payload densities imposed by the mission requirements. From this comparison an indication can be obtained as to which configuration may require some structural redesign.

## SECTION III. VEHICLE ANALYSIS

### A. GENERAL

The following vehicles were included in this study:

1. Saturn IB/Centaur
2. Saturn V
3. Saturn V/Centaur
4. MLV-Saturn V-1
5. MLV-Saturn V-1/Centaur
6. MLV-Saturn V-2
7. MLV-Saturn V-2/Centaur
8. MLV-Saturn V-3
9. MLV-Saturn V-3/Centaur

Each of these vehicles was optimized to various energy levels that are required to accomplish unmanned probes to the planets Mercury, Venus, Mars, Jupiter, and Saturn. Figure 1 shows a summary of the payload capabilities of each vehicle.

Ground Rules

The performance analysis was based on the following ground rules throughout the study:

1. All trajectories computed for due east launch from Kennedy Space Center.

2. Lift-off thrust-to-weight was maintained at 1.25 when possible

3. Flight Performance Reserve is the propellant equivalent of 3/4 per cent (0.0075) of the mission $\Delta V$.

4. Minimum propellant burned suborbitally in third stage is 10,000 lb. The performance gain by burning less than 10,000 lb of propellant suborbitally is more than off set by the complexity of a dual burn of the stage.

5. Weight loss in orbit values based on orbital stay time of 4.5 hr for LOR mission except for Saturn IB/Centaur.

6. All missions were flown through a 185-km circular Earth orbit.





7. All missions unmanned; no launch escape system is not carried.

8. Centaur shroud dropped 20 seconds after second stage ignition.

The payload envelopes considered in this study are the presently accepted Saturn class vehicle envelopes and have not been modified for this preliminary analysis. For low density interplanetary payloads, modification may be necessary in future mission planning. In the configurations where the Centaur stage is used as a last injection stage, the payload volume is decreased by the amount required to package the Centaur stage and related equipment. By adding the Centaur stage, either higher energy levels, increased payload, or both are attained; however, the payload volume is decreased resulting in an increase in payload density required to accommodate the payload.

Figures 2 and 3 contain two families of density curves. Figure 2 gives the relationship of payload weight to the density provided by the Saturn class payload envelopes. Should it become necessary to modify the present payload envelope to accommodate less dense payload, the load transmitted to the launch vehicle would be increased accordingly. This might require a structural beef-up of the launch vehicle or launching at reduced wind conditions. Launching at reduced wind conditions may be impractical due to the random occurrence of launch opportunities. In the case of the uprated vehicles, the first and second stages are presently designed to conditions greater than those imposed by a nominal increase in the payload envelope and would require no major design changes. In the area of the third and fourth stages, the skirts and tank walls should be investigated under the increased loading conditions to determine whether redesign is required (Ref. 4).

Figure 3 gives the estimated payload density requirements for missions to each of the planets considered. The payload density requirements for some Mars and Venus missions have been established in the Mariner and Voyager studies. Using these data, payload densities have been estimated for other missions by taking into consideration the different requirements for power supply, transmitting equipment and antennas. The shape of the curves results from the fact that a particular mission requires a specified amount of very low density payload for antennas, etc. Any payload capability above this amount can be of more dense material; hence, the greater the payload capability, the greater the overall payload density.

In this analysis, the energy requirement is expressed in terms of Earth hyperbolic excess velocity, $V_\infty$, the velocity (speed) required to accomplish the mission over and above that required to escape the planet's gravitational attraction. The relation between the instantaneous velocity, $V_i$, escape velocity, $V_{esc}$, and the hyperbolic excess velocity, $V_\infty$, is given by $V_i^2 = V_{esc}^2 + V_\infty^2$. In this report, the units of $V_\infty$ have been normalized by dividing by the Earth's Mean Orbital Speed (29.7849 km/sec). The relationship between $V_\infty$ and other measures of energy used throughout the NASA can be related by $V_\infty^2 = C_3 = 2E$ where E represents the total energy of the vehicle relative to the planet.

In the remaining portion of this section, each vehicle is described separately in detail. Basic vehicle concepts were obtained from Reference 5.



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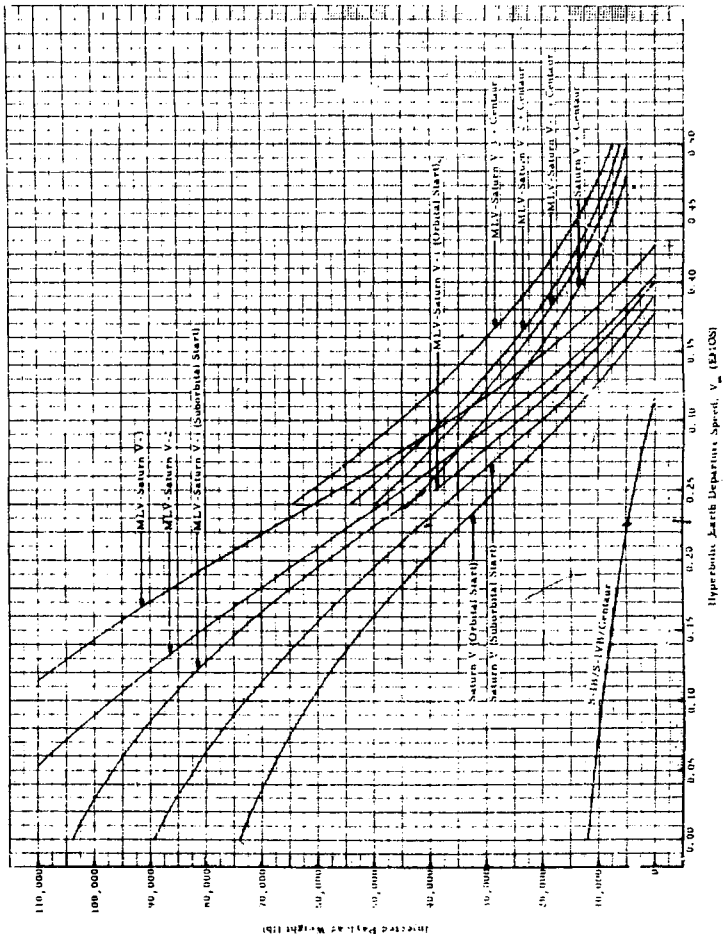


FIGURE 1. VEHICLE PAYLOAD WEIGHT SUMMARY FOR THE SATURN FAMILY OF VEHICLES

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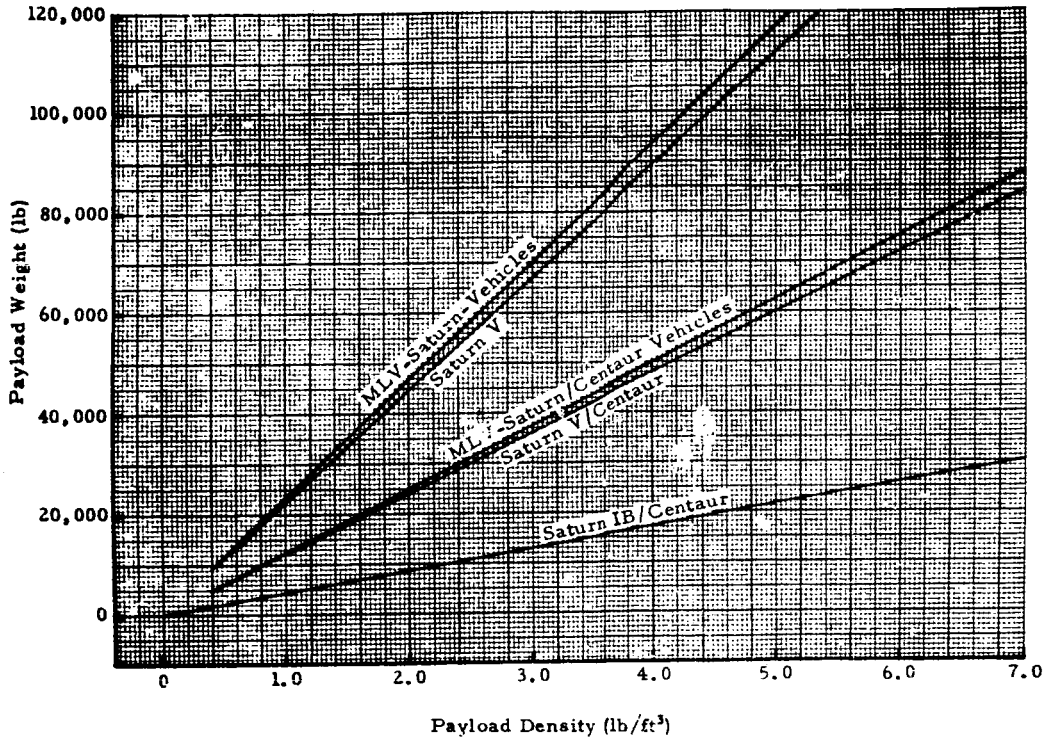


FIGURE 2. SATURN VEHICLE PAYLOAD DENSITY CAPABILITIES

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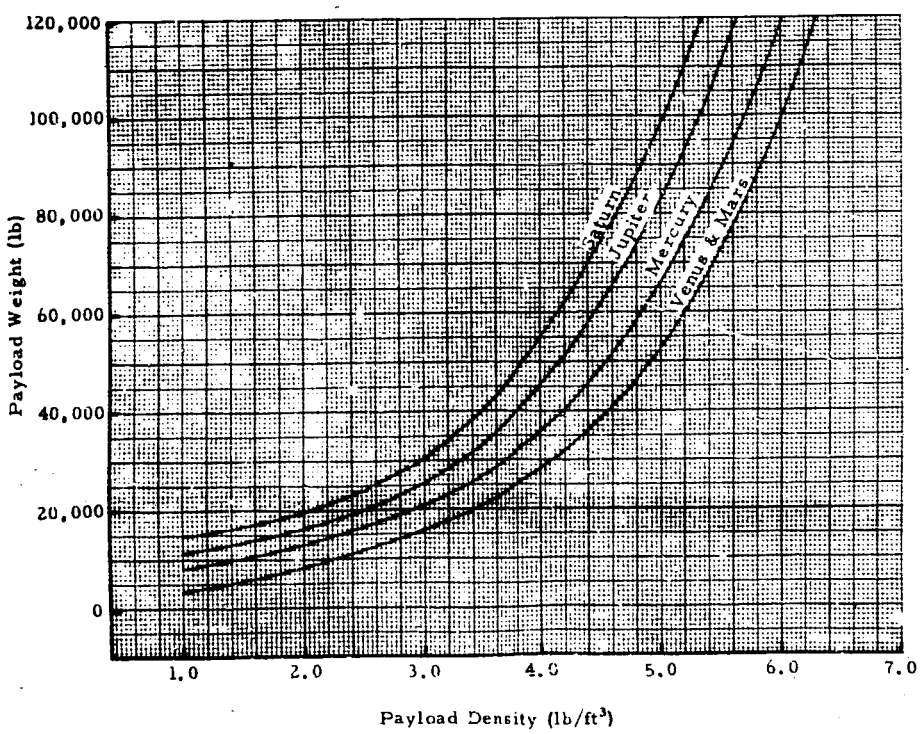


FIGURE 3. ESTIMATED PAYLOAD DENSITY REQUIREMENTS FOR MISSIONS TO MERCURY, VENUS, MARS, JUPITER, AND SATURN

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## B. SATURN IB/CENTAUR

The Saturn IB/Centaur (Figure 4) is composed of a standard Saturn IB vehicle to which the Centaur stage has been adapted. The configuration used in this study has the Centaur packaged within a 154-inch diameter shroud. The Saturn Instrument Unit is carried forward of the S-IVB stage and the Centaur stage carries its own instrument package. The payload volume is forward of the Centaur stage in the 154-inch diameter, 156-inch long shroud, and the double angle nose cone. Another version of the Saturn IB/Centaur in which the Centaur stage and the payload are housed in a 260-inch diameter shroud was configured after this study was in progress; however, it was not used in this study. The new configuration would permit less dense payloads, but would result in a slight decrease in performance from the configuration studied.

The lift-off thrust-to-weight ratio for the Saturn IB/Centaur was varied from 1.220 to 1.227 to obtain the maximum payload for various energy levels. The Centaur stage was ignited suborbitally and burned to injection into a 185-km parking orbit in all cases. The weight loss in orbit for the Centaur stage was based on a one-orbit coast. This allows up to 90 minutes to get in position such that after the second burn the major axis of the transfer trajectory is in the right direction. After the appropriate coast phase, the Centaur was reignited and burned to injection into the interplanetary transfer trajectory (Ref. 6).

The transfer injection conditions are shown in Figure 5 as a function of the Earth hyperbolic departure speed. Figure 6 shows a propellant weight summary of the Centaur stage. A weight summary is given in Table 1 for the Saturn IB/Centaur optimized to an Earth hyperbolic departure speed of $V_{\infty} = 0.250$ EMOS. This weight summary corresponds to the typical Saturn IB/Centaur trajectory shown in Table 2.

Since the Centaur stage was packaged in the payload envelope of the standard Saturn IB, the loads analysis of the standard Saturn IB vehicle as given in the Saturn IB Design Data Book (Ref. 7) is also valid for the S-IB and the S-IVB stages of the configuration used in this study.



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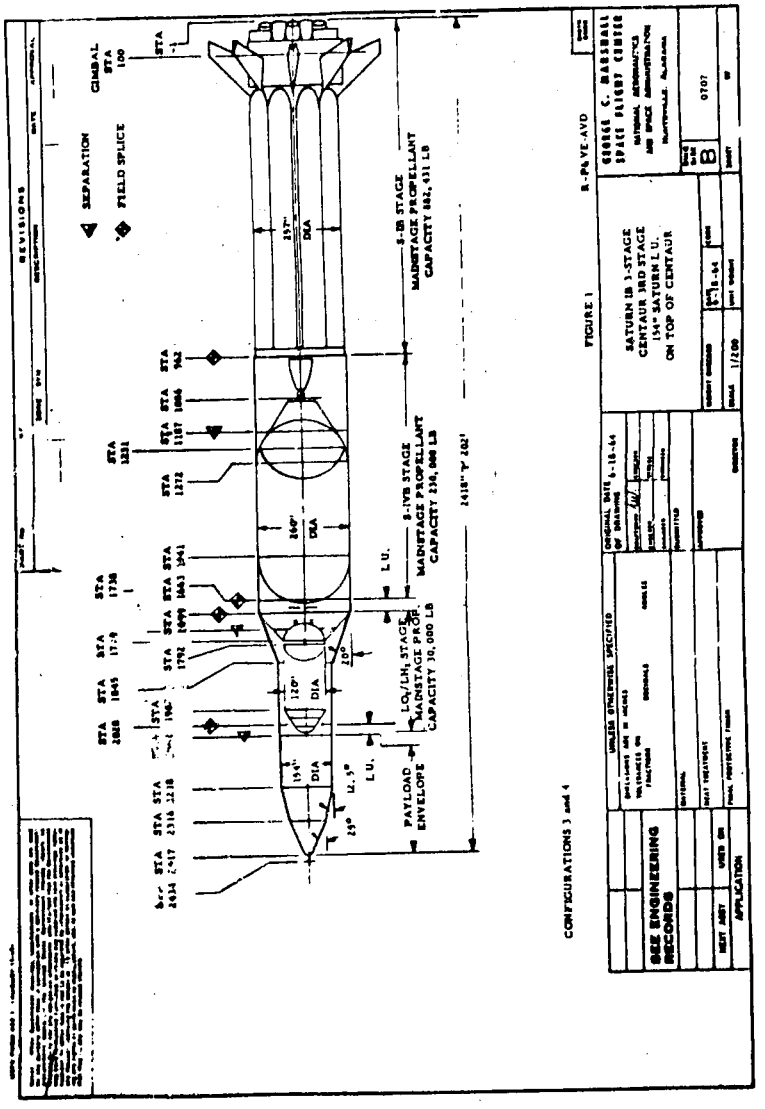


FIGURE 4. CONCEPTIONAL DESIGN OF THE S-IB/CENTAUR VEHICLE

Table 1. Vehicle Weight Summary for Three-Stage Saturn IB With Suborbital Start Centaur
$2E = 55.446186 \times 10^6\ m^2/sec^2$
$V_\infty = 0.25$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 8 × H-1 |
| H-1 Thrust (Sea Level) | | 200,000 lb |
| H-1 $I_{sp}$ (Sea Level) | | 258.8 sec |
| Engine Cant Angle | | 6° outboard; 3° inboard |
| Lift-off Weight | | 1,299,338 lb |
| Propellant Loading | | 882,431 lb |
| Cutoff Weight | | 416,907 lb |
| S-IB Dry Stage Weight | | 89,272 lb |
| S-IB/S-IVB Interstage | | 6,385 lb |
| Structure | 5,305 lb | |
| Retro-rocket Propellant | 1,080 lb | |
| Service Items | | 1,579 lb |
| Thrust Decay Propellants | | 4,301 lb* |
| Residuals | | 11,057 lb |
| S-IB/S-IVB Sep/Start Losses | | 670 lb |
| Ullage Rocket Propellant | 185 lb | |
| Fuel - Thrust Buildup | 165 lb | |
| Oxidizer - Thrust Buildup | 320 lb | |

*Includes 2,124 lb for inboard engine thrust decay and 1,750 lb for outboard engine thrust decay to 0.8 sec after outboard engine cutoff.







Table 1. Continued

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 1 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 303,643 lb |
| Propellant Loading | | 230,000 lb |
| Drop Weight - Centaur Shroud | | 3,850 lb |
| Cutoff Weight | | 69,793 lb |
| Propulsion Performance Reserve | | 575 lb |
| S-IVB Dry Stage Weight | | 22,730 lb |
| Instrument Unit | | 3,880 lb |
| Thrust Decay Propellants | | 100 lb |
| S-IB/Centaur Interstage | | 500 lb |
| Residuals and Reserve Propellants | | 1,943 lb |
| Fuel - Pressure Gas | 428 lb | |
| Fuel - Trapped | 507 lb | |
| Oxidizer - Pressure Gas | 436 lb | |
| Oxidizer - Trapped | 440 lb | |
| Auxiliary Propellant and Reserves | 97 lb | |
| Environmental Control Fluids | 35 lb | |
| Retro-rocket Propellants | | 240 lb |
| Roll Control Propellants | | 40 lb |
| Centaur Boiloff | | 94 lb |
| Weight Loss During S-IVB/Centaur Sep/Start | | 42 lb |

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Table 1. Concluded

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 2 × RL-10 |
| RL-10 Thrust (Vacuum) | | 15,000 lb |
| RL-10 $I_{sp}$ (Vacuum) | | 434 sec |
| Lift-off Weight | | 39,649 lb |
| Propellant - First Burn | | 4,142 lb |
| Cutoff Weight at 185 km Orbit | | 35,507 lb |
| Centaur Weight Loss in Orbit | | 350 lb |
| Centaur $H_2O_2$ for P.O. Thrust | 210 lb | |
| Centaur Attitude Control Propellant | 113 lb | |
| Centaur Chilldown, Ullage & Restart Propellants | 11 lb | |
| Thrust Decay Propellants | 16 lb | |
| Lift-off Weight - Second Burn | | 35,157 lb |
| Propellant - Second Burn | | 25,603 lb |
| Cutoff Weight | | 9,554 lb |
| Centaur Dry Stage Weight | | 5,348 lb |
| Structure | 934 lb | |
| Centaur Aft Interstage | 300 lb | |
| Propulsion System and Accessories | 1,216 lb | |
| Pressure System | 122 lb | |
| Flight Instrument Group | 270 lb | |
| Guidance and Instrumentation | 354 lb | |
| Controls Group | 117 lb | |
| Electrical Group | 290 lb | |
| Umbilicals and Ducts | 270 lb | |
| Permanent Insulation | 1,450 lb | |
| Separation Destruct | 25 lb | |
| Centaur $H_2O_2$ for Boost Pump | | 50 lb |
| Centaur Ullage Rocket Vernier Firing | | 10 lb |
| Thrust Decay Propellants | | 16 lb |
| Residuals | | 406 lb |
| Injected Payload Weight | | 3,724 lb |



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Table 2. Typical Trajectory Printout for S-IB/S-IVB/Centaur

$ZE = 55.446186\ km^2/sec^2$

$V_\infty = 0.25$ EMOS

| Stage | Time (sec) | Velocity (m/sec) | Altitude (km) | Flight Path Angle (deg) | Range (km) | C.D. | Q (lb/ft²) | Weight (lb) | Thrust (lb) | Mach | Ax. Accel. (m/sec²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S-IB | 0.00 | 00.0 | 0.00 | 0.00 | 0.0 | 0.677 | 0.0 | 1,299,338 | 1,594,522 | 0.0 | 2.21 |
| | 20.00 | 56.7 | 0.52 | 0.51 | 0.0 | 0.677 | 39.1 | 1,175,690 | 1,608,201 | 0.2 | 3.50 |
| | 40.00 | 142.0 | 2.46 | 4.79 | 0.1 | 0.677 | 202.4 | 1,052,043 | 1,644,403 | 0.4 | 5.09 |
| | 44.00 | 163.1 | 3.06 | 6.19 | 0.1 | 0.677 | 250.9 | 1,027,313 | 1,654,949 | 0.5 | 5.46 |
| | 48.00 | 185.7 | 3.75 | 7.75 | 0.2 | 0.677 | 302.8 | 1,002,584 | 1,666,193 | 0.6 | 5.86 |
| | 52.00 | 210.0 | 4.54 | 9.45 | 0.3 | 0.677 | 356.4 | 977,854 | 1,677,963 | 0.7 | 6.28 |
| | 56.00 | 236.0 | 5.41 | 11.26 | 0.5 | 0.677 | 409.6 | 953,125 | 1,690,020 | 0.7 | 6.75 |
| | 60.00 | 264.0 | 6.39 | 13.16 | 0.7 | 0.677 | 460.0 | 928,395 | 1,702,166 | 0.8 | 7.25 |
| | 64.00 | 293.8 | 7.47 | 15.12 | 1.0 | 0.810 | 503.9 | 903,666 | 1,714,146 | 0.9 | 7.55 |
| | 68.00 | 324.7 | 8.66 | 17.13 | 1.3 | 0.890 | 535.7 | 878,916 | 1,725,889 | 1.1 | 7.98 |
| | 72.00 | 358.0 | 9.95 | 19.18 | 1.8 | 0.877 | 556.4 | 854,267 | 1,736,555 | 1.2 | 8.67 |
| | 76.00 | 394.4 | 11.37 | 21.24 | 2.3 | 0.822 | 560.3 | 829,477 | 1,746,505 | 1.3 | 9.57 |
| | 75.07 | 385.6 | 11.03 | 20.76 | 2.2 | 0.835 | 564.8 | 835,200 | 1,744,285 | 1.3 | 9.33 |
| | 80.00 | 434.7 | 12.90 | 23.28 | 2.9 | 0.760 | 535.1 | 804,748 | 1,755,241 | 1.5 | 10.62 |
| | 100.00 | 706.2 | 22.73 | 32.71 | 8.2 | 0.470 | 302.1 | 681,100 | 1,740,469 | 2.4 | 16.70 |
| | 120.00 | 1109.1 | 37.06 | 40.10 | 18.9 | 0.342 | 76.3 | 557,453 | 1,786,493 | 3.5 | 27.81 |
| | 140.00 | 1676.7 | 57.15 | 45.48 | 37.6 | 0.274 | 14.2 | 433,805 | 1,787,263 | 5.1 | 33.61 |
| | 142.73 | 1770.9 | 60.43 | 46.08 | 40.9 | 0.265 | 11.0 | 416,908 | 1,787,287 | 5.6 | 35.33 |
| S-IVB | 142.73 | 2085.0 | 60.43 | 53.90 | 40.9 | 0.265 | 15.2 | 303,643 | 200,000 | 6.6 | .78 |
| | 162.73 | 2108.6 | 83.91 | 57.94 | 75.3 | 0.265 | 0.4 | 294,253 | 200,000 | 8.2 | 1.59 |
| | 162.73 | 2108.6 | 83.91 | 57.94 | 75.3 | 0.265 | 0.4 | 290,403 | 200,000 | 8.2 | 1.68 |
| | 164.00 | 2110.8 | 85.32 | 58.20 | 77.5 | 0.265 | 0.3 | 289,808 | 200,000 | 8.2 | 1.73 |
| | 184.00 | 2153.0 | 106.49 | 62.07 | 113.9 | 0.265 | 0.0 | 280,419 | 200,000 | 0.0 | 1.12 |
| | 200.00 | 2194.5 | 122.09 | 64.58 | 144.5 | 0.265 | 0.0 | 272,907 | 200,000 | 0.0 | 1.11 |
| | 300.00 | 2661.9 | 195.66 | 78.57 | 366.3 | 0.265 | 0.0 | 225,959 | 200,000 | 0.0 | 4.71 |
| | 400.00 | 3497.4 | 227.52 | 88.13 | 659.2 | 0.265 | 0.0 | 179,010 | 200,000 | 0.0 | 8.65 |
| | 500.00 | 4731.1 | 221.14 | 92.61 | 1052.8 | 0.265 | 0.0 | 132,062 | 200,000 | 0.0 | 13.66 |
| | 600.00 | 6539.5 | 194.17 | 92.10 | 1591.8 | 0.265 | 0.0 | 85,114 | 200,000 | 0.0 | 22.61 |
| | 632.63 | 7344.0 | 188.40 | 90.73 | 1811.2 | 0.265 | 0.0 | 69,793 | 200,000 | 0.0 | 27.93 |
| Centaur | 632.63 | 7344.0 | 188.40 | 90.73 | 1811.2 | 0.265 | 0.0 | 39,649 | 30,000 | 0.0 | 7.25 |
| | 692.27 | 7797.3 | 185.19 | 90.00 | 2249.7 | 0.265 | 0.0 | 35,507 | 30,000 | 0.0 | 8.29 |
| | 692.27 | 7797.3 | 185.19 | 90.00 | 2249.7 | 0.265 | 0.0 | 35,157 | 30,000 | 0.0 | 8.37 |
| | 700.00 | 7860.7 | 185.25 | 89.89 | 2308.5 | 0.265 | 0.0 | 34,622 | 30,000 | 0.0 | 8.51 |
| | 800.00 | 8800.3 | 192.33 | 88.95 | 3116.0 | 0.265 | 0.0 | 27,710 | 30,000 | 0.0 | 10.45 |
| | 900.00 | 9987.0 | 228.02 | 86.44 | 4022.7 | 0.265 | 0.0 | 20,797 | 30,000 | 0.0 | 13.58 |
| | 1000.00 | 11618.6 | 333.89 | 82.02 | 5048.1 | 0.265 | 0.0 | 13,885 | 30,000 | 0.0 | 19.96 |
| | 1062.65 | 13116.3 | 466.63 | 78.08 | 5763.9 | 0.265 | 0.0 | 9,554 | 30,000 | 0.0 | 29.03 |



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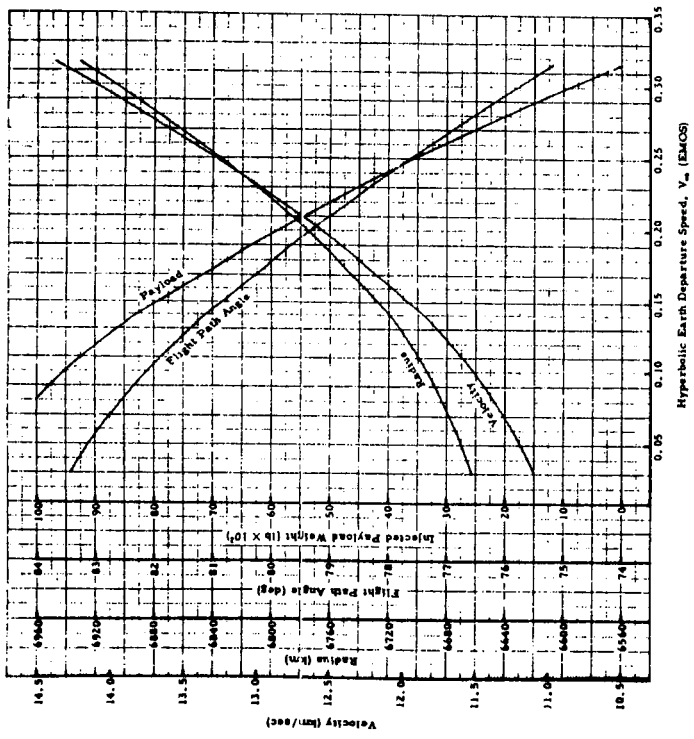


FIGURE 5. TRANSFER INJECTION CONDITIONS FOR THE S-1B/CENTAUR VEHICLE



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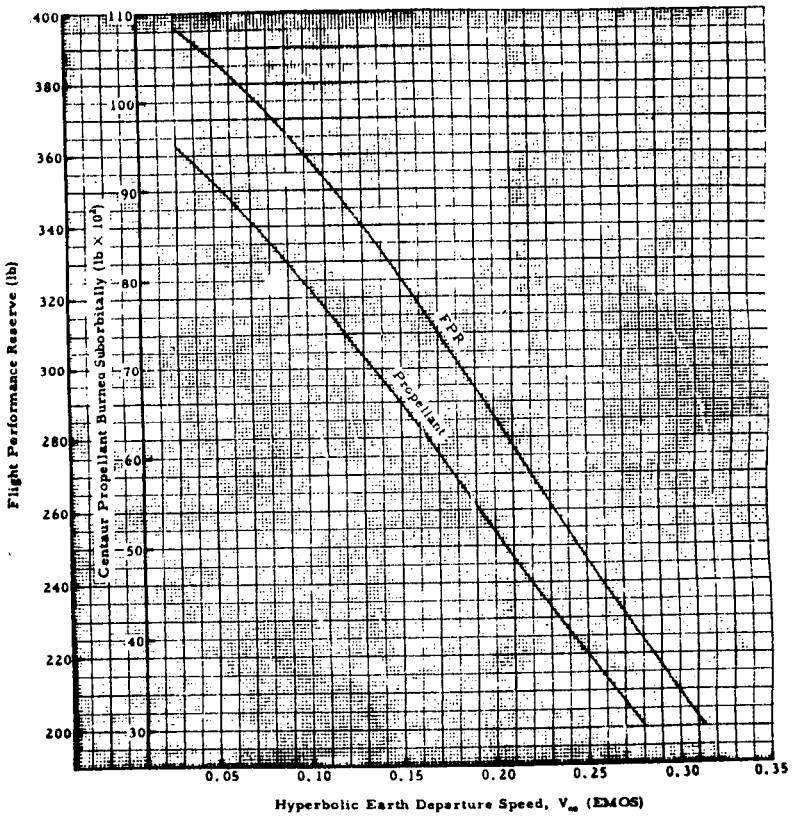


FIGURE 6. CENTAUR PROPELLANT WEIGHT SUMMARY AS A FUNCTION OF HYPERBOLIC EXCESS VELOCITY FOR THE S-1B/CENTAUR LAUNCH VEHICLE



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## C. SATURN V

The Saturn V configuration (see Figure 7) used in this study is the standard LOR configuration and has a mainstage propellant capacity of 4,400,000 lb for the S-IC stage, 930,000 lb for the S-II stage, and 230,000 lb for the S-IVB stage. Overall length of the vehicle is 4,270 inches. The Instrument Unit is located forward of the S-IVB stage. The payload volume is in the 260-inch diameter, 559-inch long cylindrical section, and the double angle nose cone.

The first stage of the Saturn V configuration contains 5 × F-1 engines; the second and third stages contain 5 × J-2 engines and 1 × J-2 engine, respectively.

Two flight approaches were studied using the Saturn V. In the first approach, the first two stages (S-IC and S-II) placed an off-loaded S-IVB into a 185-km Earth orbit. From this orbit the S-IVB stage was burned to attain the various energy levels.

In the second approach, the Saturn V was flown to the desired energy level through a 185-km orbit with a suborbital start on the S-IVB stage. In this case, the S-IVB was fully loaded in all instances.

As was expected, the vehicle with a suborbital start on the S-IVB stage gives a larger payload. The orbital start approach has two possible advantages, however. Only one start is required on the S-IVB which prevents the additional start losses imposed by two starts. Also, with only one start, the reliability of the vehicle would be greater. There could possibly be instances when these two advantages would override the additional payload capability obtained using suborbital start.

Tables 3 and 5 are weight summaries for the two approaches based on an energy level of $E = 60\ km^2/sec^2$ or $V_\infty = 0.3678$ EMOS. These weight summaries correspond to the typical trajectories presented in Tables 4 and 6. Figures 8 and 9 show the transfer injection conditions and an S-IVB propellant weight summary for the orbital start approach. These same parameters are presented for the suborbital approach in Figures 10 and 11.

A 1.25 lift-off thrust-to-weight ratio was maintained in all cases. This corresponds to a lift-off weight of 6,000,000 lb, which is definitely within the limitations assessed the vehicle (Ref. 8). Additional vehicle data can be obtained from the Saturn V Design Data Book (Ref. 9).



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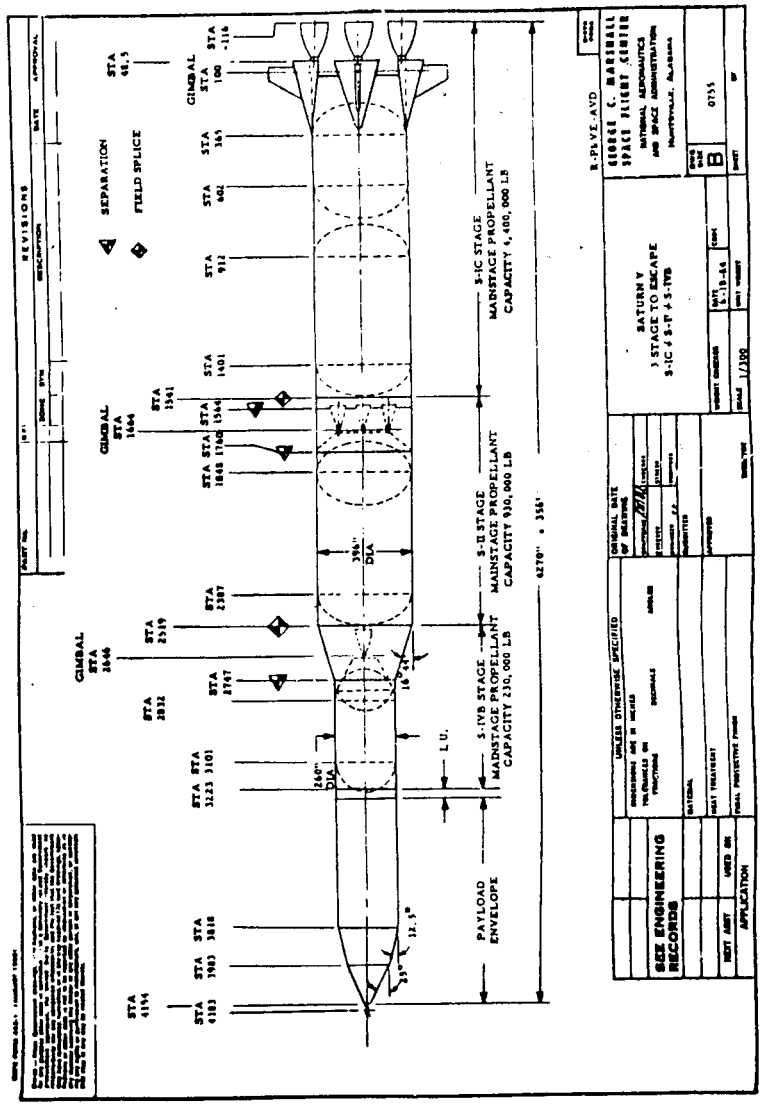


FIGURE 7. CONCEPTIONAL DESIGN OF THE SATURN V VEHICLE

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Table 3. Vehicle Weight Summary for Three-Stage Saturn V With Orbital Start S-IVB

$E = 60 \times 10^6\ m^2/sec^2$

$V_\infty = 0.3678$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F-1 |
| F-1 Thrust (Sea Level) | | 1,500,000 lb |
| F-1 $I_{sp}$ (Sea Level) | | 263.58 sec |
| Lift-off Weight | | 6,000,000 lb |
| Propellant Loading | | 4,333,004 lb |
| Cutoff Weight | | 1,666,986 lb |
| S-IC Dry Stage Weight | | 293,107 lb |
| Structure | 149,258 lb | |
| Propulsion System and Accessories | 134,052 lb | |
| Equipment and Instrumentation | 9,797 lb | |
| Short Interstage | | 1,247 lb |
| Propulsion Performance Reserve | | 30,000 lb |
| Service Items | | 682 lb |
| Thrust Decay Propellants | | 5,250 lb |
| Residuals | | 48,149 lb |
| Fuel - Pressure Gas | 725 lb | |
| Fuel - Trapped | 13,430 lb | |
| Oxidizer - Pressure Gas | 6,540 lb | |
| Oxidizer - Trapped | 24,825 lb | |
| Actuator Fluid - Trapped | 629 lb | |
| Retrorocket Propellant | 2,000 lb | |
| Weight Loss During S-IC/S-II Separation/Start | | 5,385 lb |
| S-II Ullage Rockets | 2,960 lb | |
| S-II Thrust Buildup | 2,425 lb | |



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Table 3. Continued

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 5 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 1,283,180 lb |
| Propellant Loading | | 923,691 lb |
| Drop Weight - Long Interstage | | 9,237 lb* |
| Cutoff Weight | | 350,252 lb |
| S-II Dry Stage Weight | | 82,771 lb |
| Structure | 51,574 lb | |
| Propulsion System and Accessories | 24,694 lb | |
| Equipment and Instrumentation | 6,503 lb | |
| Flight Performance Reserve at Orbit | | 5,670 lb |
| S-II/S-IVB Interstage | | 7,483 lb |
| Residuals | | 11,211 lb |
| Fuel - Pressure Gas | 1,741 lb | |
| Fuel - Trapped | 1,351 lb | |
| Fuel - Thrust Decay | 125 lb | |
| Fuel - Propellant Utilization Reserve | 232 lb | |
| Oxidizer - Pressure Gas | 4,265 lb | |
| Oxidizer - Trapped | 1,879 lb | |
| Oxidizer - Thrust Decay | 375 lb | |
| Oxidizer - Propellant Utilization Reserve | 1,158 lb | |
| Service Items | 85 lb | |
| S-IVB Ullage and Thrust Buildup | | 529 lb |
| Weight Loss in Orbit | | 4,877 lb |

*Dropped 30 sec after second stage ignition.



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Table 3. Concluded

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 1 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight - in Orbit | | 237,711 lb |
| Propellant Loading | | 200,922 lb |
| Cutoff Weight | | 36,789 lb |
| S-IVB Dry Stage Weight | | 27,351 lb |
| Structure | 14,220 lb | |
| Propulsion System and Accessories | 6,801 lb | |
| Equipment and Instrumentation | 6,330 lb | |
| Flight Performance Reserve | | 508 lb |
| Thrust Decay Propellants | | 100 lb |
| Residuals and Reserve Propellants | | 2,998 lb |
| Fuel - Pressure Gas | 866 lb | |
| Fuel - Trapped | 501 lb | |
| Fuel - Propellant Utilization Reserve | 125 lb | |
| Oxidizer - Pressure Gas | 454 lb | |
| Oxidizer - Trapped | 459 lb | |
| Oxidizer - Propellant Utilization Reserve | 450 lb | |
| Auxiliary Propellant | 100 lb | |
| Environmental Control Fluids | 43 lb | |
| Instrument Unit | | 4,081 lb |
| Injected Payload Weight | | 1,751 lb |



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Table 4. Typical Trajectory Printout for Saturn V Vehicle with Orbital Start S-IVB

$E = 60 \times 10^6\ m^2/sec^2$

$V_\infty = 0.3678$ EMOS.

| Stage | Time (sec) | Velocity (m/s) | Altitude (km) | Flight Path Angle (Deg) | Range (km) | L. Accel. M/sec² | kg/M² | Weight (lb) | Thrust (lb) | Mach | Ax. Accel. (m/sec²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S-IC | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 2.44 | 0.0 | 6,000,000 | 7,500,000 | 0.0 | 2.44 |
| | 20.00 | 61.8 | 0.57 | 1.16 | 0.0 | 3.82 | 225.8 | 5,430,956 | 7,574,668 | 0.2 | 3.82 |
| | 40.00 | 156.9 | 2.68 | 9.20 | 0.2 | 5.84 | 1179.4 | 4,861,912 | 7,816,341 | 0.5 | 5.84 |
| | 44.00 | 181.3 | 3.35 | 11.59 | 0.3 | 6.36 | 1470.3 | 4,748,103 | 7,882,373 | 0.6 | 6.36 |
| | 48.00 | 207.9 | 4.10 | 14.16 | 0.5 | 6.93 | 1785.3 | 4,634,294 | 7,952,306 | 0.6 | 6.93 |
| | 52.00 | 236.8 | 4.96 | 16.86 | 0.7 | 7.56 | 2114.9 | 4,520,486 | 8,024,819 | 0.7 | 7.56 |
| | 56.00 | 268.4 | 5.92 | 19.64 | 1.0 | 8.23 | 2446.2 | 4,406,677 | 8,098,420 | 0.8 | 8.23 |
| | 60.00 | 302.7 | 6.98 | 22.47 | 1.5 | 8.88 | 2761.7 | 4,292,868 | 8,171,510 | 1.0 | 8.88 |
| | 64.00 | 339.2 | 8.16 | 25.30 | 2.0 | 9.40 | 3027.9 | 4,179,059 | 8,242,378 | 1.1 | 9.40 |
| | 68.00 | 378.2 | 9.44 | 28.10 | 2.6 | 10.16 | 3231.3 | 4,065,250 | 8,309,352 | 1.3 | 10.16 |
| | 72.00 | 420.7 | 10.83 | 30.86 | 3.4 | 11.11 | 3365.3 | 3,951,442 | 8,371,113 | 1.4 | 11.11 |
| | 72.63 | 427.8 | 11.06 | 31.29 | 3.5 | 11.27 | 3379.0 | 3,933,524 | 8,380,042 | 1.4 | 11.27 |
| | 76.00 | 467.3 | 12.33 | 33.55 | 4.3 | 12.20 | 3301.8 | 3,837,633 | 8,425,611 | 1.6 | 12.20 |
| | 80.00 | 518.4 | 13.94 | 36.14 | 5.5 | 13.36 | 3152.7 | 3,723,824 | 8,471,775 | 1.8 | 13.36 |
| | 100.00 | 847.7 | 23.85 | 47.29 | 14.5 | 19.69 | 1782.9 | 3,154,780 | 8,597,795 | 2.9 | 19.69 |
| | 120.00 | 1312.9 | 37.03 | 55.41 | 31.2 | 27.09 | 538.2 | 2,585,736 | 8,626,645 | 4.1 | 27.09 |
| | 140.00 | 1949.5 | 53.84 | 61.09 | 58.6 | 37.27 | 133.7 | 2,016,692 | 8,630,973 | 5.8 | 37.27 |
| | 152.29 | 2461.0 | 66.32 | 63.62 | 82.3 | 46.49 | 50.5 | 1,666,986 | 8,631,476 | 8.2 | 46.49 |
| S-II | 152.29 | 2461.0 | 66.32 | 63.62 | 82.3 | 1.37 | 50.5 | 1,283,180 | 1,000,000 | 8.2 | 3.37 |
| | 160.00 | 2488.2 | 74.58 | 65.02 | 99.3 | 3.70 | 16.2 | 1,265,084 | 1,000,000 | 9.0 | 3.70 |
| | 160.00 | 2864.3 | 74.58 | 68.47 | 99.3 | 4.23 | 0.0 | 1,265,084 | 1,000,000 | 0.0 | 4.23 |
| | 160.00 | 2864.3 | 74.58 | 68.47 | 99.3 | 4.23 | 0.0 | 1,265,084 | 1,000,000 | 0.0 | 4.23 |
| | 182.29 | 2968.3 | 96.61 | 71.78 | 159.6 | 5.06 | 0.0 | 1,212,757 | 1,000,000 | 0.0 | 4.32 |
| | 182.29 | 2968.3 | 96.61 | 71.78 | 159.6 | 5.12 | 0.0 | 1,203,520 | 1,000,000 | 0.0 | 4.39 |
| | 184.00 | 2977.1 | 98.19 | 72.00 | 164.3 | 5.18 | 0.0 | 1,199,509 | 1,000,000 | 0.0 | 4.34 |
| | 200.00 | 3063.8 | 112.32 | 73.95 | 209.8 | 5.70 | 0.0 | 1,161,950 | 1,000,000 | 0.0 | 4.57 |
| | 300.00 | 3818.4 | 174.78 | 83.89 | 537.0 | 9.44 | 0.0 | 927,208 | 1,000,000 | 0.0 | 8.43 |
| | 400.00 | 4974.3 | 195.67 | 89.64 | 959.7 | 13.91 | 0.0 | 692,466 | 1,000,000 | 0.0 | 13.19 |
| | 500.00 | 6690.7 | 188.34 | 90.99 | 1519.8 | 21.28 | 0.0 | 457,724 | 1,000,000 | 0.0 | 21.18 |
| | 545.78 | 7797.4 | 185.01 | 90.00 | 1841.0 | 27.61 | 0.0 | 350,252 | 1,000,000 | 0.0 | 28.00 |
| S-IVB | 545.78 | 7797.4 | 185.01 | 90.00 | 1841.0 | 8.13 | 0.0 | 237,711 | 200,000 | 0.0 | 8.25 |
| | 600.00 | 8267.9 | 186.38 | 89.66 | 2263.9 | 9.19 | 0.0 | 212,257 | 200,000 | 0.0 | 9.19 |
| | 700.00 | 9296.1 | 201.92 | 88.07 | 3114.4 | 11.55 | 0.0 | 165,309 | 200,000 | 0.0 | 11.55 |
| | 800.00 | 10637.0 | 262.11 | 84.74 | 4071.5 | 15.74 | 0.0 | 118,360 | 200,000 | 0.0 | 15.74 |
| | 900.00 | 12628.2 | 419.62 | 79.34 | 5158.8 | 25.87 | 0.0 | 71,412 | 200,000 | 0.0 | 25.87 |
| | 973.75 | 15282.3 | 648.80 | 73.72 | 6148.8 | 52.77 | 0.0 | 36,789 | 200,000 | 0.0 | 52.77 |



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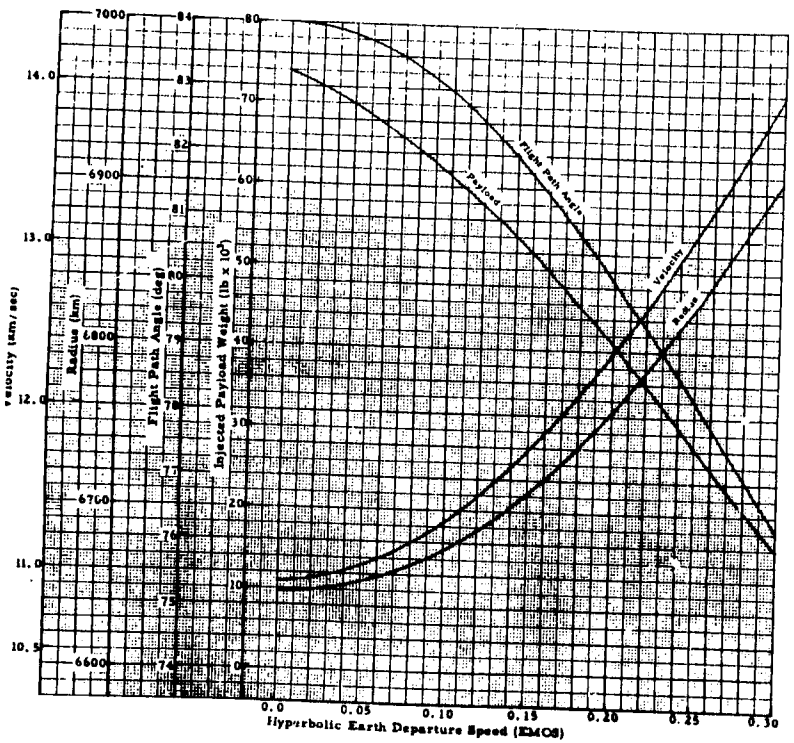


FIGURE 8. TRANSFER INJECTION CONDITIONS FOR THE S-IVB ORBITAL START SATURN V VEHICLE





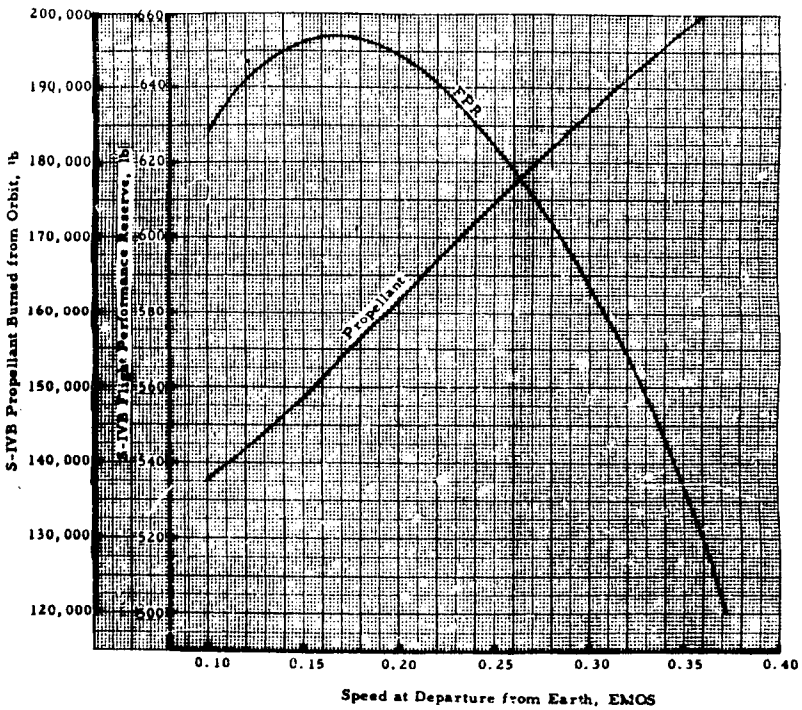


FIGURE 9. S-IVB PROPELLANT WEIGHT SUMMARY FOR THE ORBITAL START SATURN V VEHICLE

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Table 5. Vehicle Weight Summary for Three-Stage Saturn V With Suborbital Start S-IVB

$E = 60 \times 10^6\ m^2/sec^2$
$V_\infty = 0.3678$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F-1 |
| F-1 Thrust (Sea Level) | | 1,500,000 |
| F-1 $I_{sp}$ (Sea Level) | | 263.58 sec |
| Lift-off Weight | | 6,000,000 lb |
| Propellant Loading | | 4,318,750 lb |
| Cutoff Weight | | 1,681,250 lb |
| S-IC Stage Dry Weight | | 293,107 lb |
| Structure | 149,258 lb | |
| Propulsion System and Accessories | 134,052 lb | |
| Equipment and Instrumentation | 9,797 lb | |
| Short Interstage | | 1,247 lb |
| Propulsion Performance Reserve | | 13,100 lb |
| Service Items | | 682 lb |
| Thrust Decay Propellants | | 5,250 lb |
| Residuals | | 48,149 lb |
| Fuel - Pressure Gas | 725 lb | |
| Fuel - Trapped | 13,430 lb | |
| Oxidizer - Pressure Gas | 6,540 lb | |
| Oxidizer - Trapped | 24,825 lb | |
| Actuator Fluid - Trapped | 629 lb | |
| Retrorocket Propellant | 2,000 lb | |
| Weight Loss During S-IC/S-II Separation/Start | | 5,385 lb |
| S-II Ullage Rockets | 2,460 lb | |
| S-II Thrust Buildup | 2,425 lb | |



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Table 5. Continued

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 5 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 1,314,330 lb |
| Propellant Loading | | 930,000 lb |
| Drop Weight - Long Interstage | | 9,237 lb * |
| S-II Cutoff Weight | | 375,093 lb |
| S-II Dry Stage Drop Weight | | 82,771 lb |
| Structure | 51,574 lb | |
| Propulsion System and Accessories | 24,694 lb | |
| Equipment and Instrumentation | 6,503 lb | |
| S-II/S-IVB Interstage | | 7,483 lb |
| Residuals | | 11,211 lb |
| Fuel - Pressure Gas | 1,741 lb | |
| Fuel - Trapped | 1,351 lb | |
| Fuel - Thrust Decay | 125 lb | |
| Propellant Utilization Reserve | 232 lb | |
| Oxidizer - Pressure Gas | 4,265 lb | |
| Oxidizer - Trapped | 1,879 lb | |
| Oxidizer - Thrust Decay | 375 lb | |
| Propellant Utilization Reserve | 1,158 lb | |
| Service Items | 85 lb | |
| S-IVB Ullage and Thrust Buildup | | 529 lb |

*Dropped 30 sec after second stage ignition.



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Table 5. Concluded

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 1 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 273,099 lb |
| Propellant - First Burn | | 15,008 lb |
| Cutoff Weight at 185 km Orbit | | 258,091 lb |
| Weight Loss in Orbit | | 5,448 lb |
| Lift-off Weight - Second Burn | | 252,643 lb |
| Propellant - Second Burn | | 213,825 lb |
| S-IVB Cutoff Weight | | 38,818 lb |
| Flight Performance Reserve | | 1,671 lb |
| S-IVB Stage Dry Weight | | 27,351 lb |
| Structure | 14,220 lb | |
| Propulsion System and Accessories | 6,801 lb | |
| Equipment and Instrumentation | 6,330 lb | |
| Thrust Decay Propellants | | 100 lb |
| Residuals | | 2,998 lb |
| Fuel - Pressure Gas | 866 lb | |
| Fuel - Trapped | 501 lb | |
| Fuel - Propellant Utilization Reserve | 125 lb | |
| Oxidizer - Pressure Gas | 454 lb | |
| Oxidizer - Trapped | 459 lb | |
| Oxidizer - Propellant Utilization Reserve | 450 lb | |
| Auxiliary Propellant | 100 lb | |
| Environmental Control Fluids | 43 lb | |
| Instrument Unit | | 4,081 lb |
| Injected Payload Weight | | 3,121 lb |



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Table 6. Typical Trajectory Printout for Saturn V Vehicle with Suborbital Start S-IVB

$E = 60 \times 10^6\ m^2/sec^2$

$V_w = 0.3678$ EMOS

| Stage | Burning Time (sec) | Velocity (m/sec) | Altitude (km) | Flight Path Angle (deg) | Range (km) | L. Acc. (m/sec²) | Q (kg/m²) | Weight (lb) | Thrust (lb) | Mach | Ax. Acc. (m/sec²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S-IC | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 2.44 | 0.0 | 6,000,000 | 7,500,000 | 0.0 | 2.44 |
| | 20.00 | 61.8 | 0.57 | 1.15 | 0.0 | 3.82 | 225.8 | 5,430,956 | 7,574,668 | 0.2 | 3.82 |
| | 40.00 | 156.9 | 2.68 | 9.09 | 0.2 | 5.83 | 1179.2 | 4,861,912 | 7,816,355 | 0.5 | 5.83 |
| | 44.00 | 181.3 | 3.35 | 11.46 | 0.3 | 6.36 | 1469.7 | 4,748,103 | 7,882,401 | 0.6 | 6.36 |
| | 48.00 | 207.8 | 4.11 | 14.01 | 0.5 | 6.93 | 1784.3 | 4,634,294 | 7,952,355 | 0.6 | 6.93 |
| | 52.00 | 236.8 | 4.96 | 16.68 | 0.7 | 7.55 | 2113.3 | 4,520,486 | 8,024,901 | 0.7 | 7.55 |
| | 56.00 | 268.3 | 5.92 | 19.43 | 1.0 | 8.22 | 2443.6 | 4,406,677 | 8,098,545 | 0.8 | 8.22 |
| | 60.00 | 302.6 | 6.99 | 22.23 | 1.4 | 8.87 | 2757.8 | 4,292,868 | 8,171,689 | 1.0 | 8.87 |
| | 64.00 | 339.0 | 8.16 | 25.03 | 2.0 | 9.38 | 3022.3 | 4,179,059 | 8,242,621 | 1.1 | 9.38 |
| | 68.00 | 377.9 | 9.44 | 27.82 | 2.6 | 10.14 | 3223.7 | 4,065,250 | 8,309,666 | 1.3 | 10.14 |
| | 72.00 | 420.3 | 10.84 | 30.55 | 3.4 | 11.08 | 3355.2 | 3,951,442 | 8,371,495 | 1.4 | 11.08 |
| | 72.63 | 427.4 | 11.07 | 30.98 | 3.5 | 11.24 | 3367.5 | 3,933,534 | 8,380,430 | 1.4 | 11.24 |
| | 76.00 | 466.8 | 12.34 | 33.22 | 4.3 | 12.17 | 3288.2 | 3,837,633 | 8,426,039 | 1.6 | 12.17 |
| | 80.00 | 517.8 | 13.96 | 35.79 | 5.4 | 13.33 | 3136.6 | 3,723,824 | 8,472,231 | 1.8 | 13.33 |
| | 100.00 | 846.3 | 23.92 | 46.87 | 14.4 | 19.65 | 1758.9 | 3,154,780 | 8,598,144 | 2.9 | 19.65 |
| | 120.00 | 1310.4 | 37.20 | 54.96 | 30.9 | 27.03 | 522.9 | 2,585,736 | 8,626,758 | 4.1 | 27.03 |
| | 140.00 | 1945.8 | 54.20 | 60.61 | 58.1 | 37.20 | 128.3 | 2,016,692 | 8,630,999 | 5.8 | 37.20 |
| | 151.79 | 2433.3 | 66.30 | 63.05 | 80.6 | 45.98 | 49.5 | 1,681,241 | 8,631,475 | 8.1 | 45.98 |
| S-II | 151.79 | 2433.3 | 66.30 | 63.05 | 80.6 | 3.10 | 49.5 | 1,314,330 | 1,000,000 | 8.1 | 3.10 |
| | 160.00 | 2460.2 | 75.17 | 64.55 | 98.4 | 3.45 | 14.5 | 1,295,058 | 1,000,000 | 9.0 | 3.45 |
| | 160.00 | 2835.1 | 75.17 | 68.10 | 98.4 | 4.00 | 0.0 | 1,295,058 | 1,000,000 | 0.0 | 4.00 |
| | 160.00 | 2835.1 | 75.17 | 68.10 | 98.4 | 4.00 | 0.0 | 1,295,058 | 1,000,000 | 0.0 | 4.00 |
| | 181.79 | 2931.2 | 96.86 | 71.37 | 156.5 | 4.79 | 0.0 | 1,243,907 | 1,000,000 | 0.0 | 4.03 |
| | 181.79 | 2931.2 | 96.86 | 71.37 | 156.5 | 4.85 | 0.0 | 1,234,670 | 1,000,000 | 0.0 | 4.09 |
| | 184.00 | 2942.0 | 98.92 | 71.67 | 162.6 | 4.92 | 0.0 | 1,229,483 | 1,000,000 | 0.0 | 4.02 |
| | 200.00 | 3024.4 | 113.14 | 73.62 | 207.4 | 5.42 | 0.0 | 1,191,924 | 1,000,000 | 0.0 | 4.20 |
| | 300.00 | 3746.0 | 176.26 | 83.66 | 528.9 | 9.05 | 0.0 | 951,182 | 1,000,000 | 0.0 | 7.95 |
| | 400.00 | 4853.1 | 197.82 | 89.58 | 942.3 | 13.28 | 0.0 | 722,440 | 1,000,000 | 0.0 | 12.49 |
| | 500.00 | 6479.5 | 190.23 | 91.16 | 1486.7 | 19.96 | 0.0 | 487,698 | 1,000,000 | 0.0 | 19.78 |
| | 547.97 | 7564.4 | 185.58 | 90.25 | 1812.8 | 25.73 | 0.0 | 372,092 | 1,000,000 | 0.0 | 26.09 |
| S-IVB | 547.97 | 7564.4 | 185.58 | 90.25 | 1812.8 | 7.10 | 0.0 | 273,099 | 200,000 | 0.0 | 7.12 |
| | 579.94 | 7797.4 | 184.99 | 90.00 | 2051.3 | 7.47 | 0.0 | 258,091 | 200,000 | 0.0 | 7.60 |
| | 579.94 | 7797.4 | 184.99 | 90.00 | 2051.3 | 7.64 | 0.0 | 252,643 | 200,000 | 0.0 | 7.76 |
| | 600.00 | 7955.0 | 185.21 | 89.87 | 2204.9 | 8.04 | 0.0 | 243,224 | 200,000 | 0.0 | 8.04 |
| | 700.00 | 8842.8 | 192.70 | 88.88 | 3079.3 | 9.81 | 0.0 | 196,275 | 200,000 | 0.0 | 9.81 |
| | 800.00 | 9986.9 | 229.78 | 86.36 | 3926.2 | 12.55 | 0.0 | 149,327 | 200,000 | 0.0 | 12.55 |
| | 900.00 | 11437.5 | 335.07 | 82.07 | 4941.7 | 17.93 | 0.0 | 102,379 | 200,000 | 0.0 | 17.93 |
| | 1000.00 | 13838.1 | 574.82 | 75.63 | 6089.6 | 33.33 | 0.0 | 55,430 | 200,000 | 0.0 | 33.33 |
| | 1035.38 | 15248.2 | 714.80 | 72.69 | 6538.0 | 48.16 | 0.0 | 38,818 | 200,000 | 0.0 | 48.16 |



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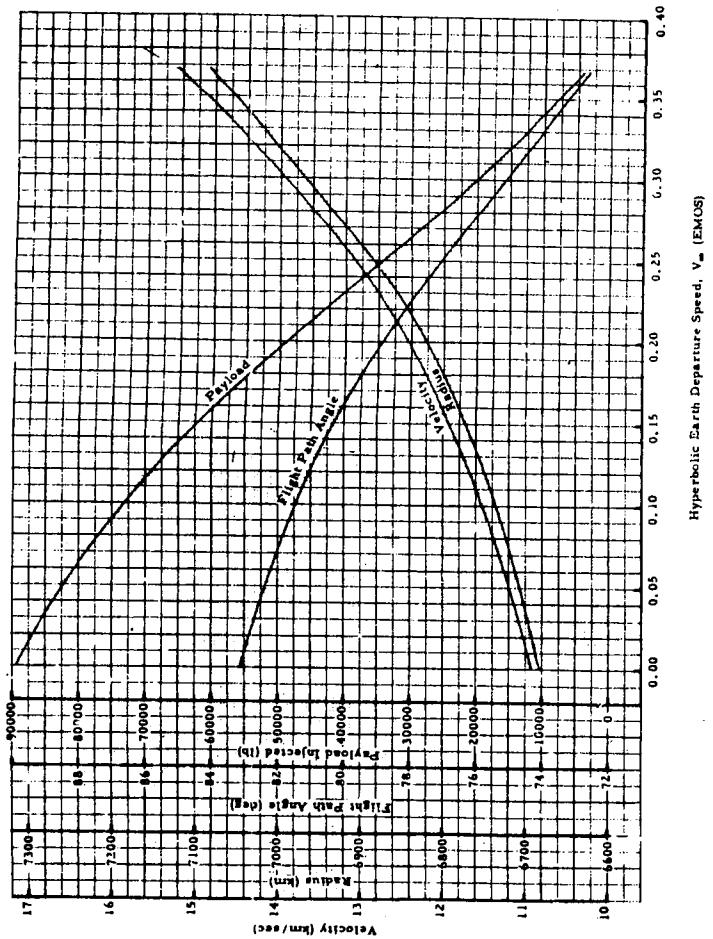


FIGURE 10. TRANSFER INJECTION CONDITIONS FOR THE SATURN V VEHICLE



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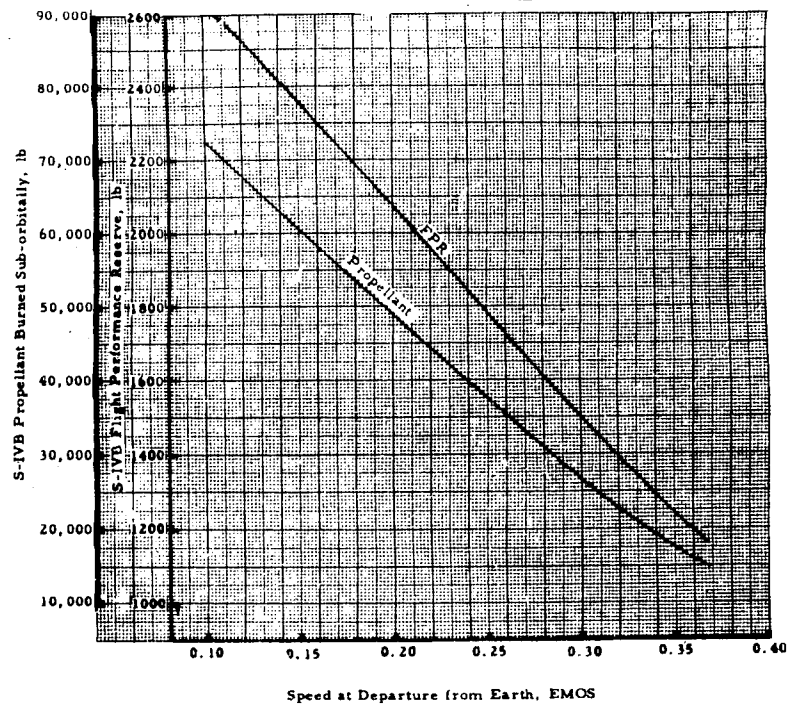


FIGURE 11. S-IVB PROPELLANT WEIGHT SUMMARY AS A FUNCTION OF HYPERBOLIC EXCESS VELOCITY FOR THE SATURN V VEHICLE



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## D. SATURN V/CENTAUR

This configuration is the basic Saturn V vehicle with a Centaur adapted as a fourth stage and packaged within the 260-inch diameter shroud (see Figure 12). The Centaur stage has a mainstage capacity of 30,000 lb. The payload volume is located in the 260-inch diameter, 210-inch long shroud, and the double angle nose cone. The overall length of the launch vehicle is 4,270 inches.

Two Instrument Units were used for best vehicle performance. The main unit is located forward between the S-IVB stage and Centaur stage. The second unit, which controls only the Centaur stage, is located within the Centaur shroud. For high-energy missions, it was found to be more feasible performancewise to place the two Instrument Units in this order rather than one large Instrument Unit in the Centaur stage. For missions of these types, every possible bit of energy must be gained by the Centaur stage, thus the single large Instrument Unit limits the payload capability of the vehicle.

A weight summary for the Saturn V/Centaur vehicle and typical trajectory is presented in Tables 7 and 8. The transfer injection conditions and a propellant weight summary for the S-IVB stage can be obtained from Figures 13 and 14. The S-IVB was burned suborbitally in all cases considered.

Since the Centaur stage was packaged within the payload envelope of the standard Saturn V, the stage structural data of the S-IC, S-II, and S-IVB stages contained in the Saturn V Design Data Book are also valid for this configuration.



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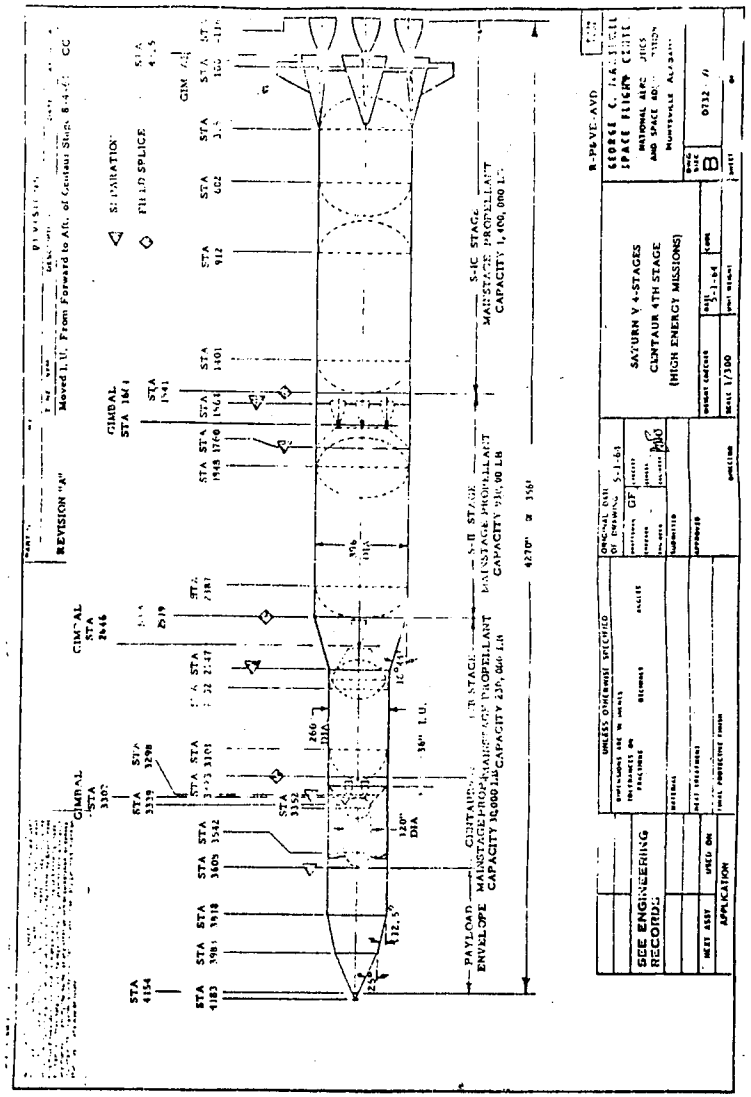


FIGURE 12. CONCEPTIONAL DESIGN OF THE SATURN V/CENTAUR VEHICLE

Table 7. Vehicle Weight Summary for Three Stage Saturn V + Centaur With Suborbital Start S-IVB

$E = 60 \times 10^6\ m^2/sec^2$

$V_\infty = 0.3678$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F-1 |
| F-1 Thrust (Sea Level) | | 1,500,000 lb |
| F-1 $I_{sp}$ (Sea Level) | | 263.58 sec |
| Lift-off Weight | | 6,000,000 lb |
| Propellant Loading | | 4,265,000 lb |
| Cutoff Weight | | 1,735,000 lb |
| S-IC Dry Stage Weight | | 293,107 lb |
| Structure | 149,258 lb | |
| Propulsion System and Accessories | 134,052 lb | |
| Equipment and Instrumentation | 9,797 lb | |
| Short Interstage | | 1,247 lb |
| Propulsion Performance Reserve | | 13,100 lb |
| Service Items | | 682 lb |
| Thrust Decay Propellants | | 5,250 lb |
| Residuals and Reserve Propellants | | 48,149 lb |
| Fuel - Pressure Gas | 725 lb | |
| Fuel - Trapped | 13,430 lb | |
| Oxidizer - Pressure Gas | 6,540 lb | |
| Oxidizer - Trapped | 24,825 lb | |
| Actuator Fluid - Trapped | 629 lb | |
| Retro-rocket Propellant | 2,000 lb | |
| Weight Loss During S-IC/S-II Sep/Start | | 5,385 lb |
| S-II Ullage Rockets | 2,960 lb | |
| S-II Thrust Buildup | 2,425 lb | |



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Table 7. Continued

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 5 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 1,368,080 lb |
| Propellant Loading | | 930,000 lb |
| Drop Weight - Long Interstage | | 9,237 lb ** |
| Drop Weight - Centaur Shroud | | 2,320 lb * |
| Cutoff Weight | | 426,523 lb |
| S-II Dry Stage Weight | | 82,771 lb |
| Structure | 51,574 lb | |
| Propulsion System and Accessories | 24,694 lb | |
| Equipment and Instrumentation | 6,503 lb | |
| S-II/S-IVB Interstage | | 7,483 lb |
| Residuals and Reserve Propellants | | 11,211 lb |
| Fuel - Pressure Gas | 1,741 lb | |
| Fuel - Trapped | 1,351 lb | |
| Fuel - Thrust Decay | 125 lb | |
| Fuel - Propellant Utilization Reserve | 232 lb | |
| Oxidizer - Pressure Gas | 4,265 lb | |
| Oxidizer - Trapped | 1,879 lb | |
| Oxidizer - Thrust Decay | 375 lb | |
| Oxidizer - Propellant Utilization Reserve | 1,158 lb | |
| Service Items | 85 lb | |
| S-IVB Ullage and Thrust Buildup | | 529 lb |

* Dropped 20 seconds after Second Stage Ignition.

** Dropped 30 seconds after Second Stage Ignition.

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Table 7. Continued

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 1 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 324,529 lb |
| Propellant - First Burn | | 55,162 lb |
| Cutoff Weight - in 185 km Orbit | | 269,367 lb |
| S-IVB Weight Loss in Orbit | | 5,448 lb |
| Centaur Weight Loss in Orbit | | 338 lb |
| Lift-off Weight - Second Burn | | 263,581 lb |
| Propellant - Second Burn | | 174,838 lb |
| Cutoff Weight | | 88,743 lb |
| S-IVB Dry Stage Weight | | 27,351 lb |
| Structure | 14,220 lb | |
| Propulsion System and Accessories | 6,801 lb | |
| Equipment and Instrumentation | 6,330 lb | |
| Thrust Decay Propellants | | 100 lb |
| Residuals and Reserve Propellants | | 2,998 lb |
| Fuel - Pressure Gas | 866 lb | |
| Fuel - Trapped | 501 lb | |
| Propellant Utilization Reserve | 125 lb | |
| Oxidizer - Pressure Gas | 454 lb | |
| Oxidizer - Trapped | 459 lb | |
| Propellant Utilization Reserve | 450 lb | |
| Auxiliary Propellant | 100 lb | |
| Environmental Control Fluids | 43 lb | |
| Instrument Unit | | 4,081 lb |
| S-IVB/Centaur Interstage | | 500 lb |
| S-IVB/Centaur Separation/Start Losses | | 154 lb |
| Centaur $H_2O_2$ for Boost Pumps | 50 lb | |
| Centaur Ullage Rocket Vernier Firing | 10 lb | |
| Centaur Ascent Boiloff | 94 lb | |



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Table 7. Concluded

| Vehicle Characteristics | | Fourth Stage |
|---|---|---|
| Propulsion | | 2 × RL-10 |
| RL-10 Thrust (Vacuum) | | 15,000 lb |
| RL-10 $I_{sp}$ (Vacuum) | | 434 sec |
| Lift-off Weight | | 53,559 lb |
| Propellant Loading | | 29,400 lb |
| Cutoff Weight | | 24,159 lb |
| Thrust Decay Propellants | | 16 lb |
| Flight Performance Reserve | | 600 lb |
| Centaur Dry Stage Weight | | 5,348 lb |
| Structure | 934 lb | |
| Propulsion System and Accessories | 1,216 lb | |
| Pressurization | 122 lb | |
| Guidance Group | 354 lb | |
| Controls Group | 117 lb | |
| Electrical Group | 290 lb | |
| Flight Instrument Group | 270 lb | |
| Destruct | 25 lb | |
| Centaur Aft Interstage | 300 lb | |
| Umbilicals and Ducts | 270 lb | |
| Permanent Insulation | 1,450 lb | |
| Residuals | | 406 lb |
| Injected Payload Weight | | 17,789 lb |



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Table 8. Typical Trajctory Printout for Saturn V + Centaur Vehicle with Suborbital Start S-IVB

$E = 60\ km^2/sec^2$

$V_\infty = 0.3678$ EMOS

| Stage | Time (sec) | Velocity (m/sec) | Altitude (km) | Flight Path Angle (deg) | Range (km) | C.D. | Q (lb/ft²) | Weight (lb) | Thrust (lb) | Mach | Ax. Accel. (m/sec²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S-IC | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.584 | 0.0 | 6,000,000 | 7,500,000 | 0.0 | 2.44 |
| | 20.00 | 61.8 | 0.57 | 1.11 | 8.0 | 0.584 | 46.2 | 5,430,956 | 7,574,668 | 0.2 | 3.82 |
| | 40.00 | 154.9 | 2.68 | 8.84 | 0.2 | 0.584 | 241.4 | 4,861,912 | 7,816,392 | 0.5 | 5.83 |
| | 44.00 | 181.2 | 3.35 | 11.14 | 0.3 | 0.584 | 300.7 | 4,748,103 | 7,882,471 | 0.6 | 6.35 |
| | 48.00 | 207.7 | 4.11 | 13.61 | 0.5 | 0.584 | 364.9 | 4,634,296 | 7,952,480 | 0.6 | 6.91 |
| | 52.00 | 234.5 | 4.96 | 16.21 | 0.7 | 0.584 | 432.0 | 4,520,486 | 8,025,106 | 0.7 | 7.53 |
| | 56.00 | 261.0 | 5.93 | 18.90 | 1.0 | 0.584 | 499.1 | 4,406,677 | 8,098,858 | 0.8 | 8.19 |
| | 60.00 | 302.1 | 6.99 | 21.62 | 1.4 | 0.654 | 562.8 | 4,292,868 | 8,172,140 | 1.0 | 8.84 |
| | 64.00 | 338.4 | 8.17 | 24.36 | 1.9 | 0.873 | 616.2 | 4,179,059 | 8,243,234 | 1.1 | 9.34 |
| | 68.00 | 377.3 | 9.46 | 27.07 | 2.5 | 0.913 | 656.3 | 4,065,250 | 8,310,455 | 1.2 | 10.09 |
| | 72.00 | 419.4 | 10.86 | 29.75 | 3.3 | 0.860 | 682.0 | 3,951,442 | 8,372,456 | 1.4 | 11.03 |
| | 72.50 | 425.0 | 11.04 | 30.08 | 3.4 | 0.859 | 684.2 | 3,937,122 | 8,379,586 | 1.4 | 11.15 |
| | 76.00 | 465.6 | 12.37 | 32.36 | 4.2 | 0.801 | 666.5 | 3,837,633 | 8,427,115 | 1.6 | 12.10 |
| | 80.00 | 516.3 | 14.01 | 34.88 | 5.3 | 0.728 | 634.1 | 3,723,824 | 8,473,377 | 1.7 | 13.25 |
| | 100.00 | 862.9 | 24.09 | 45.78 | 14.0 | 0.438 | 348.0 | 3,154,700 | 8,599,013 | 2.9 | 19.53 |
| | 120.00 | 1384.2 | 37.66 | 53.77 | 30.3 | 0.322 | 99.5 | 2,585,736 | 8,627,033 | 1.1 | 26.88 |
| | 140.00 | 1936.3 | 55.14 | 59.37 | 56.9 | 0.261 | 23.6 | 2,016,692 | 8,631,063 | 5.8 | 37.03 |
| | 149.90 | 2336.7 | 65.53 | 61.65 | 75.1 | 0.235 | 10.3 | 1,735,000 | 8,631,461 | 7.7 | 44.18 |
| S-II | 149.90 | 2336.7 | 65.53 | 61.65 | 75.1 | 0.235 | 10.3 | 1,368,080 | 1,000,000 | 7.7 | 2.57 |
| | 150.00 | 2336.9 | 65.64 | 61.47 | 75.3 | 0.235 | 10.2 | 1,367,848 | 1,000,000 | 7.7 | 2.57 |
| | 150.00 | 2703.4 | 65.64 | 65.61 | 75.3 | 0.235 | 3.6 | 1,367,848 | 1,000,000 | 8.9 | 3.20 |
| | 160.00 | 2737.4 | 76.32 | 67.24 | 100.0 | 0.235 | 3.0 | 1,344,374 | 1,000,000 | 10.2 | 3.59 |
| | 169.98 | 2774.8 | 86.72 | 68.85 | 124.9 | 0.235 | 0.4 | 1,321,132 | 1,000,000 | 10.8 | 3.97 |
| | 169.90 | 2774.8 | 86.72 | 68.85 | 124.9 | 0.235 | 0.4 | 1,318,812 | 1,000,000 | 10.8 | 3.99 |
| | 179.98 | 2816.4 | 96.45 | 70.37 | 150.8 | 0.235 | 0.1 | 1,295,338 | 1,000,000 | 0.0 | 3.54 |
| | 179.90 | 2816.4 | 96.45 | 70.37 | 150.8 | 0.235 | 0.1 | 1,286,101 | 1,000,000 | 0.0 | 3.60 |
| | 188.00 | 2852.7 | 103.95 | 71.46 | 172.1 | 0.235 | 0.0 | 1,267,089 | 1,000,000 | 0.0 | 3.24 |
| | 200.00 | 2909.6 | 114.52 | 72.92 | 204.5 | 0.235 | 0.0 | 1,238,921 | 1,000,000 | 0.0 | 3.50 |
| | 300.00 | 3577.0 | 178.37 | 83.16 | 511.8 | 0.235 | 0.0 | 1,004,181 | 1,000,000 | 0.0 | 7.10 |
| | 400.00 | 4607.8 | 281.59 | 89.31 | 905.0 | 0.235 | 0.0 | 769,441 | 1,000,000 | 0.0 | 11.34 |
| | 500.00 | 6181.7 | 195.63 | 91.16 | 1419.5 | 0.235 | 0.0 | 534,701 | 1,000,000 | 0.0 | 17.75 |
| | 546.08 | 7030.3 | 190.93 | 90.47 | 1712.4 | 0.235 | 0.0 | 426,523 | 1,000,000 | 0.0 | 22.69 |
| S-IVB | 546.08 | 7030.3 | 190.93 | 90.47 | 1712.4 | 0.235 | 0.0 | 324,529 | 200,000 | 0.0 | 5.74 |
| | 600.00 | 7365.8 | 187.53 | 90.47 | 2089.2 | 0.235 | 0.0 | 299,216 | 200,000 | 0.0 | 6.41 |
| | 663.58 | 7797.3 | 185.19 | 90.00 | 2557.3 | 0.235 | 0.0 | 269,367 | 200,000 | 0.0 | 7.28 |
| | 663.58 | 7797.3 | 185.19 | 90.00 | 2557.3 | 0.235 | 0.0 | 263,581 | 200,000 | 0.0 | 7.44 |
| | 700.00 | 8075.5 | 185.83 | 89.79 | 2838.1 | 0.235 | 0.0 | 246,482 | 200,000 | 0.0 | 7.92 |
| | 800.00 | 8947.4 | 195.98 | 88.62 | 3663.3 | 0.235 | 0.0 | 199,534 | 200,000 | 0.0 | 9.61 |
| | 900.00 | 10026.8 | 238.94 | 85.96 | 4578.1 | 0.235 | 0.0 | 152,585 | 200,000 | 0.0 | 12.21 |
| | 1000.00 | 11468.2 | 352.96 | 81.60 | 5596.1 | 0.235 | 0.0 | 105,637 | 200,000 | 0.0 | 17.28 |
| | 1035.98 | 12144.9 | 422.36 | 79.55 | 5991.0 | 0.235 | 0.0 | 88,743 | 200,000 | 0.0 | 20.54 |
| Centaur | 1035.98 | 12144.9 | 422.36 | 79.55 | 5991.0 | 0.235 | 0.0 | 53,559 | 30,000 | 0.0 | 3.93 |
| | 1100.00 | 12396.1 | 591.14 | 75.62 | 6702.0 | 0.235 | 0.0 | 49,134 | 30,000 | 0.0 | 3.95 |
| | 1200.00 | 12807.0 | 970.00 | 69.38 | 7773.8 | 0.235 | 0.0 | 42,221 | 30,000 | 0.0 | 4.36 |
| | 1300.00 | 13290.1 | 1495.06 | 63.16 | 8775.4 | 0.235 | 0.0 | 35,309 | 30,000 | 0.0 | 5.42 |
| | 1400.00 | 13921.8 | 2172.41 | 57.10 | 9691.7 | 0.235 | 0.0 | 28,397 | 30,000 | 0.0 | 7.39 |
| | 1461.30 | 14429.4 | 2666.98 | 53.50 | 10209.4 | 0.235 | 0.0 | 24,159 | 30,000 | 0.0 | 9.27 |

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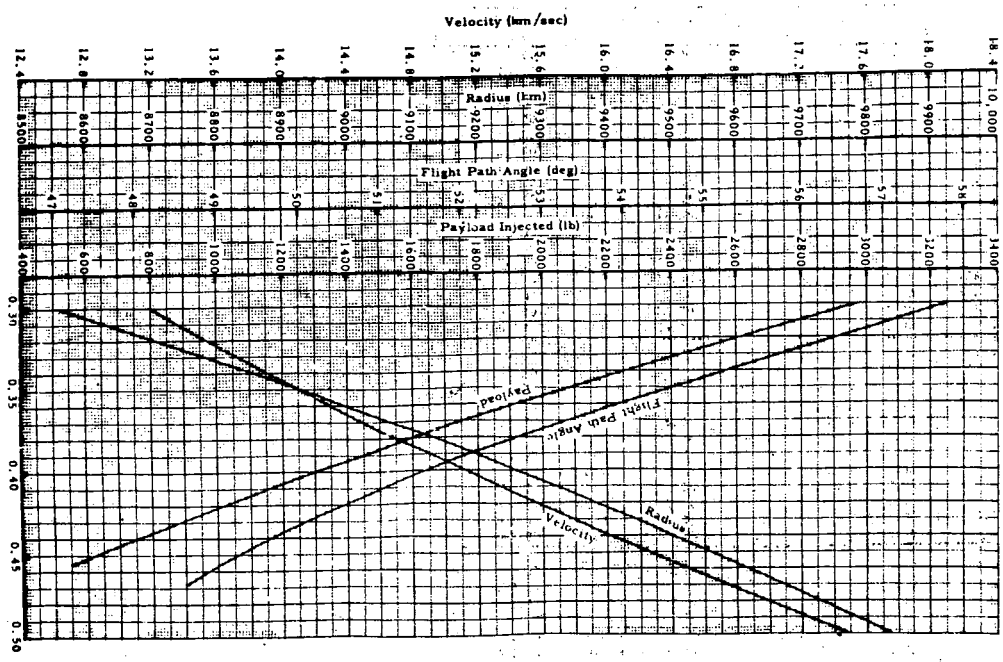


FIGURE 13. TRANSFER INJECTION CONDITIONS FOR THE SATURN V/CENTAUR VEHICLE

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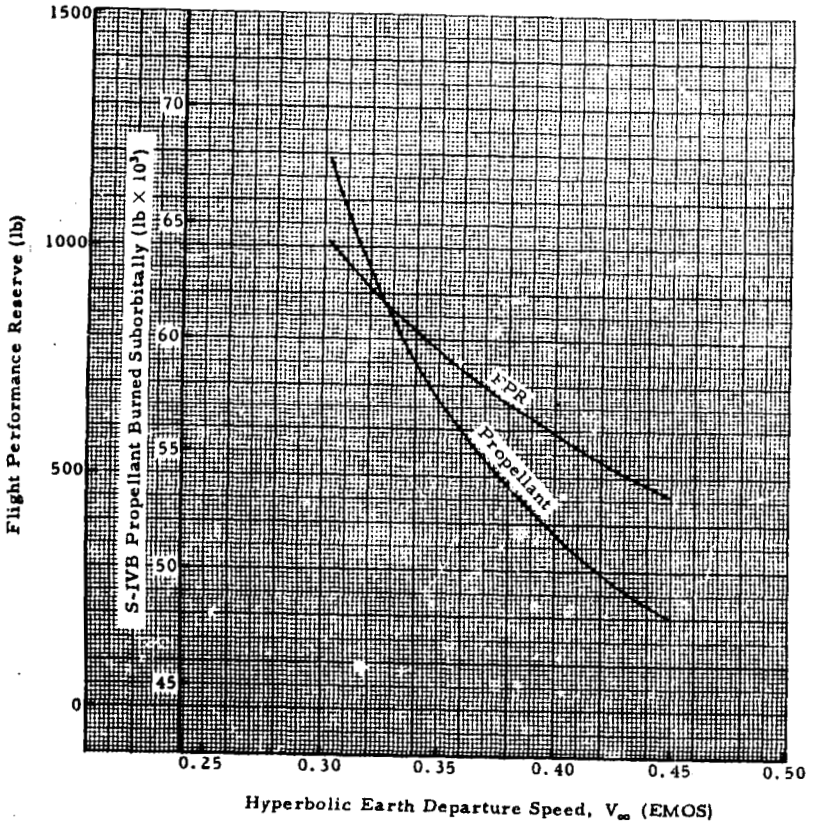


FIGURE 14. S-IVB PROPELLANT WEIGHT SUMMARY FOR THE SATURN V/CENTAUR VEHICLE





E. MLV-SATURN V-1

The MLV-Saturn V-1 configuration (Figure 15) used in this study is in the conceptual design phase and represents a minimal type uprating of the Saturn V vehicle. This configuration is based on using the 1.8 K thrust, uprated engines in the first stage. The propellant tank capacities of the first and second stages are increased to utilize the additional first stage thrust. The third, MS-IVB-1, stage is unchanged from the standard Saturn V configuration. The first stage has a mainstage propellant capacity of 5,400,000 lb, the second stage 1,000,000 lb and the third stage 230,000 lb. The overall vehicle length is 4,604 inches and the payload envelope is a 260-inch diameter, 583-inch length cylinder and the double angle nose cone.

For energy levels below $V_\infty$ = 0.25 EMOS, the MS-IVB-1 stage was ignited suborbitally and burned into a 185-km parking orbit. Above $V_\infty$ = 0.25 EMOS, the propellant burned suborbitally in the MS-IVB stage was less than the 10,000 lb established as a ground rule. A 4.5-hour orbital coast was allowed and then the MS-IVB-1 stage was reignited and burned to injection into the interplanetary trajectory. For the energy levels above $V_\infty$ = 0.25 EMOS, the vehicle was flown to orbit by the first two stages and the S-IVB stage was started in orbit and burned to the desired injection. The two-stage-to-orbit gives a possible 285,000-lb ignition weight for the MS-IVB-1 stage. With this ignition weight, the 230,000-lb capacity of the S-IVB stage makes it possible to achieve an energy level of $V_\infty$ = 0.3678 EMOS. Above an energy level of $V_\infty$ = 0.32 EMOS, it was necessary to off load payload, consequently the lift-off weight of the launch vehicle was reduced or the initial F/W was increased from 1.25 (Ref. 10).

Tables 9 and 10 contain a weight summary and typical trajectory for the suborbital start vehicle. Tables 11 and 12 present the same type information for the orbital start case, showing the slight ground rule violation in lift-off weight. The transfer injection parameters for both concepts are shown in Figures 16 and 17, respectively. Figure 18 shows a MS-IVB-1 propellant weight summary for both concepts.

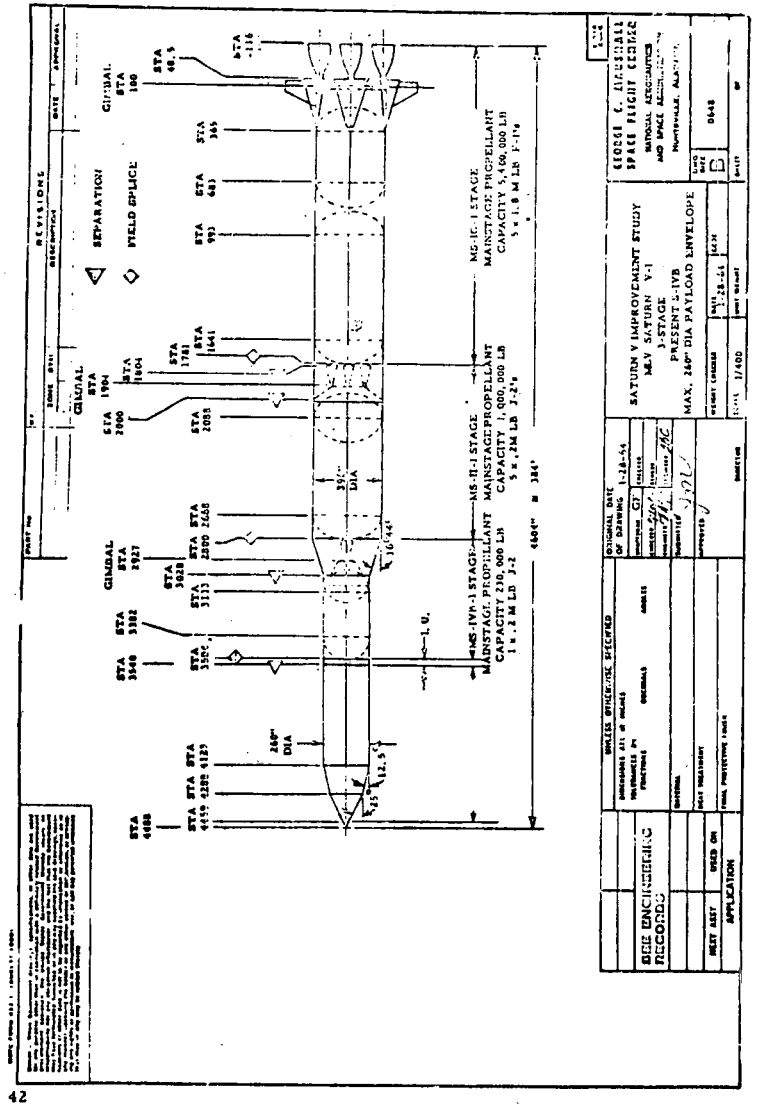


FIGURE 15. CONCEPTIONAL DESIGN OF THE MLV SATURN V-1 VEHICLE



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Table 9. Vehicle Weight Summary for Three-Stage MLV-Saturn V-1 With Suborbital Start MS-IVB-1
$E = 25\ km^2/sec^2$
$V_\infty = 0.2374$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F-1 |
| F-1 Thrust (Sea Level) | | 1,800,000 lb |
| F-1 $I_{sp}$ (Sea Level) | | 271 sec |
| Lift-off Weight | | 7,200,000 lb |
| Propellant | | 5,321,500 lb |
| Cutoff Weight | | 1,878,500 lb |
| MS-IC-1 Dry Stage Weight | | 349,000 lb |
| Structure | 188,334 lb | |
| Propulsion System and Accessories | 144,513 lb | |
| Equipment and Instrumentation | 10,000 lb | |
| Miscellaneous | 6,153 lb | |
| MS-IC-1/MS-II-1 Interstage | | 1,750 lb |
| Propulsion Performance Reserve | | 13,100 lb |
| Thrust Decay Propellants | | 6,300 lb |
| MS-IC-1 Residuals | | 60,747 lb |
| Fuel - Pressure Gas | 890 lb | |
| Fuel - Trapped | 16,665 lb | |
| Oxidizer - Pressure Gas | 7,900 lb | |
| Oxidizer - Trapped | 31,765 lb | |
| Actuator Fuel - Trapped | 630 lb | |
| Retro-rocket Propellant | 2,000 lb | |
| Frost | 865 lb | |
| Nitrogen | 32 lb | |
| Weight Loss During MS-IC-1/MS-II-1 Sep/Start | | 5,365 lb |
| Ullage Rocket Propellants | 2,960 lb | |
| Fuel - Engine Start | 285 lb | |
| Oxidizer - Engine Start | 1,600 lb | |

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Table 9. (Continued)

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 5 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 1,442,218 lb |
| Propellant | | 1,000,000 lb |
| MS-IC-1/MS-II-1 Large Interstage | | 11,940 lb* |
| Structure | 10,150 lb | |
| Electrical | 300 lb | |
| Ullage Hardware | 1,490 lb | |
| Cutoff Weight | | 430,278 lb |
| MS-II-1 Second Stage Dry Weight | | 92,000 lb |
| Structure | 60,215 lb | |
| Propulsion System and Accessories | 24,460 lb | |
| Equipment | 6,412 lb | |
| Miscellaneous | 913 lb | |
| Propulsion Performance Reserve | | 1,390 lb |
| Thrust Decay Propellants | | 500 lb |
| Residuals | | 9,450 lb |
| Fuel - Pressure Gas | 1,870 lb | |
| Fuel - Trapped | 1,351 lb | |
| Oxidizer - Pressure Gas | 4,265 lb | |
| Oxidizer - Trapped | 1,879 lb | |
| Service Items | 85 lb | |
| MS-II-1/MS-IVB-1 Interstage | | 8,110 lb |
| MS-II-1 Retro-rockets | | 2,500 lb |
| Weight Loss MS-1/MS-IVB-1 Sep/Start | | 550 lb |

* Dropped 30 seconds after second stage ignition.



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Table 9. (Concluded)

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 1 × RE-315 |
| RE-315 Thrust (Vacuum) | | 315,000 lb |
| RE-315 $I_{sp}$ (Vacuum) | | 444.6 sec |
| Lift-off Weight | | 315,778 lb |
| Propellant - First Burn | | 13,815 lb |
| Cutoff Weight - In 185-km orbit | | 301,963 lb |
| MS-IVB-1 Weight Loss in Orbit | | 5,295 lb |
| Fuel Vented | 3,400 lb | |
| Thrust Buildup | 485 lb | |
| Auxiliary Propellant - Attitude Control | 1,410 lb | |
| Lift-off Weight - Second Burn | | 296,668 lb |
| Propellant - Second Burn | | 214,237 lb |
| Cutoff Weight | | 82,431 lb |
| MS-IVB-1 Dry Stage Weight | | 28,800 lb |
| Structure | 15,640 lb | |
| Propulsion System and Accessories | 6,585 lb | |
| Equipment and Instrumentation | 6,080 lb | |
| Miscellaneous | 495 lb | |
| Flight Performance Reserve | | 1,550 lb |
| Propulsion Performance Reserve | | 575 lb |
| Thrust Decay Propellants | | 100 lb |
| Residuals | | 2,415 lb |
| Fuel - Trapped | 506 lb | |
| Fuel - Pressure Gas | 865 lb | |
| Oxidizer - Trapped | 440 lb | |
| Oxidizer - Pressure Gas | 454 lb | |
| Auxiliary Propellant Reserve | 115 lb | |
| Environmental Control Fluids | 35 lb | |
| Instrument Unit | | 3,500 lb |
| Injected Payload Weight | | 45,491 lb |



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Table 10. Typical Trajectory Printout for MLV-Saturn V-1 Vehicle with Suborbital Start MS-IVB-1

$E = 25 \times 10^6\ m^2/sec^2$
$V_\infty = 0.2374$ EMOS

| Stage | Time (sec) | Velocity (m/sec) | Altitude (km) | Flight Path Angle (deg) | Range (km) | C.D. | Q (kg/m²) | Weight (lb) | Thrust (lb) | Mach | Ax. Accel. (m/sec²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MS-IC-1 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.584 | 0.0 | 7,200,000 | 9,000,000 | 0.0 | 2.44 |
| | 20.00 | 61.3 | 0.57 | 1.08 | 0.0 | 0.581 | 45.6 | 6,535,793 | 9,074,309 | 0.2 | 3.77 |
| | 40.00 | 154.3 | 2.65 | 8.71 | 0.2 | 0.584 | 234.2 | 5,871,587 | 9,313,412 | 0.5 | 5.66 |
| | 48.00 | 203.6 | 4.05 | 13.52 | 0.5 | 0.584 | 352.6 | 5,605,904 | 9,447,647 | 0.6 | 6.68 |
| | 52.00 | 231.4 | 4.89 | 16.16 | 0.7 | 0.584 | 416.7 | 5,473,063 | 9,519,266 | 0.7 | 7.27 |
| | 56.00 | 261.8 | 5.83 | 18.91 | 1.0 | 0.584 | 481.1 | 5,340,222 | 9,592,025 | 0.8 | 7.90 |
| | 60.00 | 294.7 | 6.87 | 21.71 | 1.4 | 0.584 | 542.8 | 5,207,390 | 9,664,383 | 0.9 | 8.59 |
| | 64.00 | 329.9 | 8.02 | 24.53 | 1.9 | 0.646 | 596.1 | 5,074,559 | 9,734,733 | 1.1 | 9.07 |
| | 68.00 | 367.5 | 9.28 | 27.34 | 2.5 | 0.916 | 637.3 | 4,941,698 | 9,801,450 | 1.2 | 9.76 |
| | 72.00 | 408.3 | 10.63 | 30.11 | 3.2 | 0.883 | 665.0 | 4,808,856 | 9,863,206 | 1.4 | 10.62 |
| | 73.16 | 420.7 | 11.05 | 30.91 | 3.4 | 0.865 | 670.2 | 4,770,352 | 9,879,776 | 1.4 | 10.89 |
| | 76.00 | 452.7 | 12.10 | 32.83 | 4.1 | 0.820 | 657.6 | 4,676,015 | 9,918,171 | 1.5 | 11.61 |
| | 80.00 | 501.3 | 13.68 | 35.46 | 5.2 | 0.749 | 629.3 | 4,543,174 | 9,964,997 | 1.7 | 12.67 |
| | 100.00 | 811.8 | 23.29 | 46.93 | 13.8 | 0.455 | 345.6 | 3,878,967 | 10,094,682 | 2.8 | 18.50 |
| | 120.00 | 1247.4 | 35.90 | 55.43 | 29.7 | 0.330 | 117.5 | 3,214,761 | 10,125,830 | 3.9 | 25.28 |
| | 140.00 | 1837.7 | 51.71 | 61.47 | 55.6 | 0.270 | 31.2 | 2,550,554 | 10,130,794 | 5.5 | 34.31 |
| | 160.00 | 2654.5 | 71.33 | 65.61 | 95.1 | 0.224 | 6.1 | 1,886,348 | 10,131,540 | 9.3 | 48.70 |
| | 160.24 | 2666.0 | 71.59 | 65.85 | 95.7 | 0.224 | 5.9 | 1,878,510 | 10,131,542 | 9.3 | 48.93 |
| MS-II-1 | 160.24 | 2666.0 | 71.59 | 65.65 | 95.7 | 0.224 | 5.9 | 1,442,218 | 1,000,000 | 9.3 | 2.44 |
| | 162.00 | 2671.1 | 73.52 | 65.94 | 99.9 | 0.224 | 4.5 | 1,438,077 | 1,000,000 | 9.6 | 2.91 |
| | 162.00 | 3049.2 | 73.52 | 69.08 | 99.9 | 0.224 | 0.0 | 1,438,077 | 1,000,000 | 10.9 | 3.39 |
| | 180.00 | 3115.7 | 92.17 | 71.56 | 151.5 | 0.224 | 0.0 | 1,395,824 | 1,000,000 | 0.0 | 3.21 |
| | 190.24 | 3151.5 | 101.99 | 72.77 | 181.4 | 0.224 | 0.0 | 1,371,795 | 1,000,000 | 0.0 | 2.78 |
| | 190.24 | 3151.5 | 101.99 | 72.77 | 181.6 | 0.224 | 0.0 | 1,359,855 | 1,000,000 | 0.0 | 2.84 |
| | 200.00 | 3200.2 | 110.91 | 73.84 | 210.8 | 0.224 | 0.0 | 1,336,935 | 1,000,000 | 0.0 | 3.14 |
| | 300.00 | 3805.7 | 177.72 | 83.20 | 543.9 | 0.224 | 0.0 | 1,102,193 | 1,000,000 | 0.0 | 6.33 |
| | 400.00 | 4726.5 | 202.97 | 89.15 | 954.3 | 0.224 | 0.0 | 867,451 | 1,000,000 | 0.0 | 9.93 |
| | 500.00 | 6024.5 | 196.83 | 91.45 | 1471.7 | 0.224 | 0.0 | 632,709 | 1,000,000 | 0.0 | 14.94 |
| | 586.24 | 7614.0 | 185.73 | 90.25 | 2038.5 | 0.224 | 0.0 | 430,277 | 1,000,000 | 0.0 | 22.74 |
| MS-IVB-1 | 586.24 | 7614.0 | 185.73 | 90.25 | 2038.5 | 0.224 | 0.0 | 315,778 | 200,000 | 0.0 | 6.16 |
| | 600.00 | 7698.9 | 185.36 | 90.14 | 2140.9 | 0.224 | 0.0 | 309,316 | 200,000 | 0.0 | 6.31 |
| | 615.66 | 7797.3 | 185.20 | 90.00 | 2258.8 | 0.224 | 0.0 | 301,963 | 200,000 | 0.0 | 6.50 |
| | 615.66 | 7797.3 | 185.20 | 90.00 | 2258.8 | 0.224 | 0.0 | 296,668 | 200,000 | 0.0 | 6.61 |
| | 700.00 | 8391.5 | 188.03 | 89.48 | 2921.5 | 0.224 | 0.0 | 257,073 | 200,000 | 0.0 | 7.54 |
| | 800.00 | 9214.1 | 207.17 | 87.84 | 3774.2 | 0.224 | 0.0 | 210,124 | 200,000 | 0.0 | 8.99 |
| | 900.00 | 10214.1 | 267.49 | 84.84 | 4707.7 | 0.224 | 0.0 | 163,176 | 200,000 | 0.0 | 11.21 |
| | 1000.00 | 11519.1 | 405.64 | 80.32 | 5729.0 | 0.224 | 0.0 | 115,227 | 200,000 | 0.0 | 15.42 |
| | 1071.99 | 12838.4 | 584.19 | 76.00 | 6523.1 | 0.224 | 0.0 | 82,431 | 200,000 | 0.0 | 21.80 |



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Table 11. Vehicle Weight Summary for Three-Stage Modified Saturn V-1 With Orbital Start MS-IVB-1

$E = 60 \times 10^6\ m^2/sec^2$
$V_\infty = 0.3678$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F |
| F-1 Thrust (Sea Level) | | 1,800,000 lb |
| F-1 $I_{sp}$ (Sea Level) | | 271 sec |
| Lift-off Weight | | 6,700,000 lb |
| Propellant Loading | | 4,863,000 lb |
| Cutoff Weight | | 1,837,000 lb |
| MS-IC-1 Dry Stage Drop Weight | | 349,000 lb |
| Structure | 188,334 lb | |
| Propulsion System and Accessories | 144,513 lb | |
| Equipment and Instrumentation | 10,000 lb | |
| Miscellaneous | 6,153 lb | |
| MS-IC-1/MS-II-1 Interstage | | 1,750 lb |
| Propulsion Performance Reserve | | 13,100 lb |
| Thrust Decay Propellants | | 6,300 lb |
| MS-IC-1 Residuals | | 60,747 lb |
| Fuel - Pressure Gas | 890 lb | |
| Fuel - Trapped | 16,665 lb | |
| Oxidizer - Pressure Gas | 7,900 lb | |
| Oxidizer - Trapped | 31,765 lb | |
| Actuator Fuel - Trapped | 630 lb | |
| Retro-rocket Propellant | 2,000 lb | |
| Freon | 865 lb | |
| Nitrogen | 32 lb | |
| Weight Loss During MS-IC-1/MS-II-1 Sep/Start | | 5,385 lb |
| Ullage Rocket Propellants | 2,960 lb | |
| Fuel - Engine Start | 825 lb | |
| Oxidizer - Engine Start | 1,600 lb | |

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Table 11. (Continued)

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 5 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 1,400,718 lb |
| Propellant Loading | | 1,000,000 lb* |
| MS-IC-1/MS-II-1 Large Interstage | | 11,940 lb** |
| Structure | 10,150 lb | |
| Electrical | 300 lb | |
| Ullage Hardware | 1,490 lb | |
| Cutoff Weight | | 388,778 lb |
| MS-II-1 Second Stage Dry Weight | | 92,000 lb |
| Structure | 60,215 lb | |
| Propulsion System and Accessories | 24,460 lb | |
| Equipment | 6,412 lb | |
| Miscellaneous | 913 lb | |
| Propulsion Performance Reserve | | 1,390 lb |
| Thrust Decay Propellants | | 500 lb |
| Residuals | | 9,450 lb |
| Fuel - Pressure Gas | 1,870 lb | |
| Fuel - Trapped | 1,351 lb | |
| Oxidizer - Pressure Gas | 4,265 lb | |
| Oxidizer - Trapped | 1,879 lb | |
| Service Items | 85 lb | |
| MS-II-1/MS-IVB-1 Interstage | | 8,110 lb |
| MS-II-1 Retro-rockets | | 2,500 lb |
| MS-IVB-1 Weight Loss in Orbit | | 5,295 lb |
| Fuel Vented | 3,400 lb | |
| Thrust Buildup | 485 lb | |
| Auxiliary Propellant - Attitude Control | 1,410 lb | |

* Includes Flight Performance Reserve
** Dropped 30 sec after second stage ignition.



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Table 11. (Concluded)

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 1 × RE-315 |
| RE-315 Thrust (Vacuum) | | 315,000 lb |
| RE-315 $I_{sp}$ (Vacuum) | | 444.6 sec |
| Lift-off Weight | | 269,533 lb |
| Propellant | | 229,382 lb |
| Cutoff Weight | | 40,151 lb |
| MS-IVB-1 Dry Stage Weight | | 28,800 lb |
| Structure | 15,640 lb | |
| Propulsion System and Accessories | 6,585 lb | |
| Equipment and Instrumentation | 6,080 lb | |
| Miscellaneous | 495 lb | |
| Propulsion Performance Reserve | | 580 lb |
| Thrust Decay Propellants | | 100 lb |
| Residuals | | 2,415 lb |
| Fuel - Trapped | 506 lb | |
| Fuel - Pressure Gas | 865 lb | |
| Oxidizer - Trapped | 440 lb | |
| Oxidizer - Pressure Gas | 454 lb | |
| Auxiliary Propellant Reserve | 115 lb | |
| Environmental Control Fluids | 35 lb | |
| Instrument Unit | | 3,500 lb |
| Payload Injected | | 4,756 lb |

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Table 12. Typical Trajectory Printout for MLV-Saturn V-1 Vehicle with Orbital Start MS-IVB-1

$E = 60\ km^2/sec^2$
$V_\infty = 0.3678$ EMOS

| Stage | Time (sec) | Velocity (m/sec) | Altitude (km) | Flight Path Angle (deg) | Range (km) | C.D. | Q (lb/ft²) | Weight (lb) | Thrust (lb) | Mach | Ax. Accel. (m/sec²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MS-1C-1 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.584 | 0.0 | 6,700,000 | 9,000,000 | 0.0 | 3.35 |
| | 20.00 | 81.7 | 0.77 | 2.74 | 0.0 | 0.584 | 79.3 | 6,035,793 | 9,098,966 | 0.2 | 4.92 |
| | 40.00 | 202.1 | 3.49 | 14.54 | 0.4 | 0.584 | 368.9 | 5,371,587 | 9,395,566 | 0.6 | 7.32 |
| | 44.60 | 232.7 | 4.32 | 17.38 | 0.7 | 0.584 | 447.7 | 5,238,745 | 9,471,194 | 0.7 | 7.95 |
| | 48.00 | 265.8 | 5.26 | 20.29 | 1.0 | 0.584 | 528.1 | 5,105,904 | 9,548,840 | 0.8 | 8.64 |
| | 52.00 | 301.8 | 6.32 | 23.22 | 1.4 | 0.625 | 606.2 | 4,973,063 | 9,626,665 | 1.0 | 8.64 |
| | 56.00 | 340.1 | 7.48 | 26.14 | 2.0 | 0.870 | 674.3 | 4,840,221 | 9,702,724 | 1.1 | 9.85 |
| | 60.00 | 380.9 | 8.76 | 29.02 | 2.6 | 0.913 | 728.5 | 4,707,380 | 9,775,088 | 1.2 | 10.62 |
| | 64.00 | 425.2 | 10.15 | 31.84 | 3.4 | 0.866 | 766.8 | 4,574,539 | 9,842,200 | 1.4 | 11.57 |
| | 68.00 | 473.6 | 11.65 | 34.56 | 4.4 | 0.789 | 772.9 | 4,441,698 | 9,902,429 | 1.6 | 12.65 |
| | 66.47 | 454.6 | 11.06 | 33.53 | 4.0 | 0.817 | 781.0 | 4,492,568 | 9,880,211 | 1.5 | 12.22 |
| | 72.00 | 526.6 | 13.27 | 37.18 | 5.6 | 0.714 | 740.9 | 4,308,856 | 9,953,883 | 1.8 | 13.83 |
| | 76.00 | 584.3 | 15.01 | 39.68 | 7.0 | 0.642 | 694.5 | 4,176,015 | 9,996,325 | 2.0 | 15.06 |
| | 80.00 | 647.1 | 16.87 | 42.05 | 8.6 | 0.576 | 636.0 | 4,043,174 | 10,030,567 | 2.2 | 16.32 |
| | 100.00 | 1039.6 | 28.07 | 51.91 | 20.8 | 0.368 | 275.3 | 3,378,967 | 10,133,959 | 3.5 | 23.10 |
| | 120.00 | 1581.5 | 42.62 | 58.88 | 42.1 | 0.289 | 72.8 | 2,714,761 | 10,129,195 | 4.8 | 31.52 |
| | 140.00 | 2327.8 | 61.01 | 63.66 | 75.9 | 0.238 | 17.7 | 2,050,554 | 10,131,344 | 7.4 | 44.16 |
| | 146.43 | 2629.8 | 67.92 | 64.83 | 90.1 | 0.226 | 9.6 | 1,837,000 | 10,131,501 | 8.9 | 49.99 |
| MS-II-1 | 146.43 | 2629.8 | 67.92 | 64.83 | 90.1 | 0.226 | 9.6 | 1,400,718 | 1,000,000 | 8.9 | 2.91 |
| | 160.00 | 2672.9 | 82.57 | 67.11 | 122.5 | 0.226 | 0.9 | 1,368,864 | 1,000,000 | 10.4 | 3.44 |
| | 162.00 | 2679.9 | 84.64 | 67.44 | 127.4 | 0.226 | 0.6 | 1,364,169 | 1,000,000 | 10.4 | 3.52 |
| | 162.00 | 3061.7 | 84.64 | 70.38 | 127.4 | 0.226 | 0.8 | 1,364,169 | 1,000,000 | 11.9 | 3.98 |
| | 176.43 | 3122.8 | 98.87 | 72.39 | 169.1 | 0.226 | 0.0 | 1,330,295 | 1,000,000 | 0.0 | [illegible] |
| | 176.43 | 3122.8 | 98.87 | 72.39 | 169.1 | 0.226 | 0.0 | 1,318,355 | 1,000,000 | 0.0 | 4.08 |
| | 184.00 | 3158.0 | 105.86 | 73.34 | 191.5 | 0.226 | 0.0 | 1,300,585 | 1,000,000 | 0.0 | 4.78 |
| | 200.00 | 3237.0 | 119.75 | 75.12 | 239.8 | 0.226 | 0.0 | 1,263,027 | 1,000,000 | 0.0 | 5.88 |
| | 300.00 | 3915.7 | 180.75 | 84.22 | 580.8 | 0.226 | 0.0 | 1,028,285 | 1,000,000 | 0.0 | 7.25 |
| | 400.00 | 4932.9 | 200.85 | 89.70 | 1006.6 | 0.226 | 0.0 | 793,543 | 1,000,000 | 0.0 | 11.22 |
| | 500.00 | 6382.8 | 192.24 | 91.33 | 1551.0 | 0.226 | 0.0 | 558,801 | 1,000,000 | 0.0 | 17.16 |
| | 569.13 | 7797.3 | 185.20 | 90.00 | 2024.4 | 0.226 | 0.0 | 396,514 | 1,000,000 | 0.0 | 24.73 |
| MS-IVB-1 | 569.13 | 7797.3 | 185.20 | 90.00 | 2024.4 | 0.226 | 0.0 | 269,533 | 200,000 | 0.0 | 7.24 |
| | 600.00 | 8025.0 | 185.73 | 89.80 | 2261.7 | 0.226 | 0.0 | 255,042 | 200,000 | 0.0 | 7.62 |
| | 700.00 | 8860.0 | 194.89 | 88.74 | 3080.3 | 0.226 | 0.0 | 208,093 | 200,000 | 0.0 | 9.16 |
| | 800.00 | 9882.1 | 234.08 | 86.25 | 3984.6 | 0.226 | 0.0 | 161,145 | 200,000 | 0.0 | 11.[illegible] |
| | 900.00 | 11217.8 | 338.65 | 82.13 | 4986.6 | 0.226 | 0.0 | 114,197 | 200,000 | 0.0 | 15.76 |
| | 1000.00 | 13236.9 | 565.77 | 76.11 | 6101.5 | 0.226 | 0.0 | 67,248 | 200,000 | 0.0 | 26.60 |
| | 1057.72 | 15208.0 | 792.67 | 70.54 | 6810.2 | 0.226 | 0.0 | 40,151 | 200,000 | 0.0 | 44.80 |

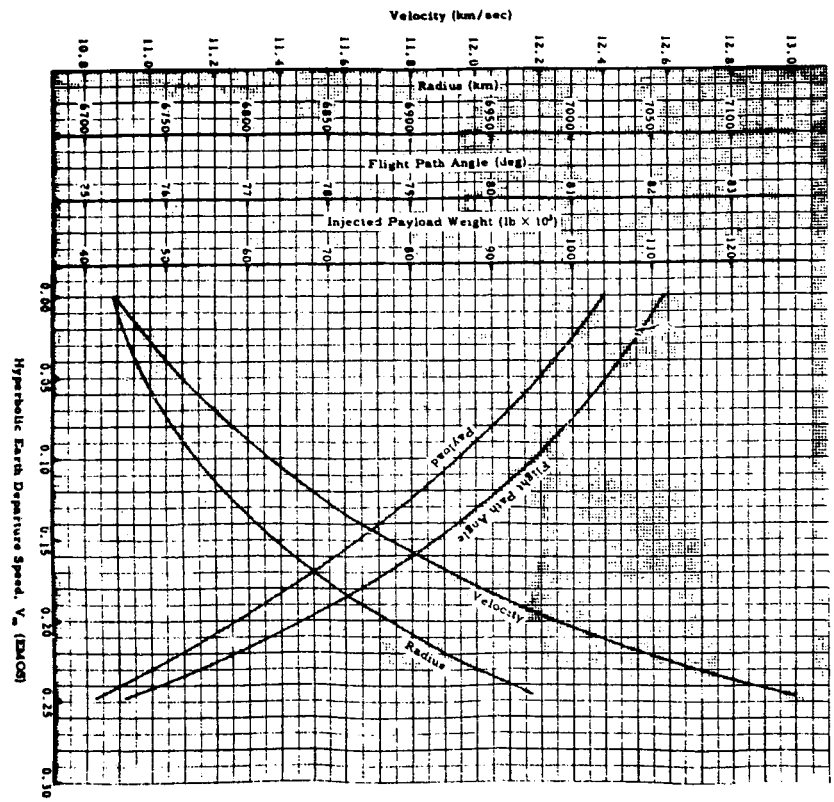


FIGURE 16. TRANSFER INJECTION CONDITIONS FOR THE MLV SATURN V-1 VEHICLE

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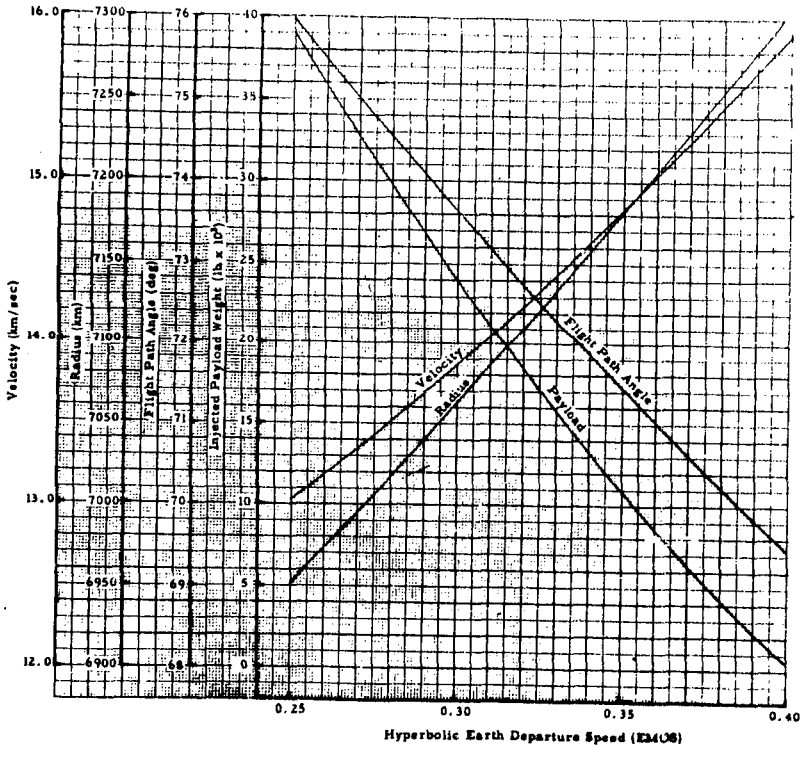


FIGURE 17. TRANSFER INJECTION CONDITIONS FOR THE ORBITAL START MLV SATURN V-1 VEHICLE







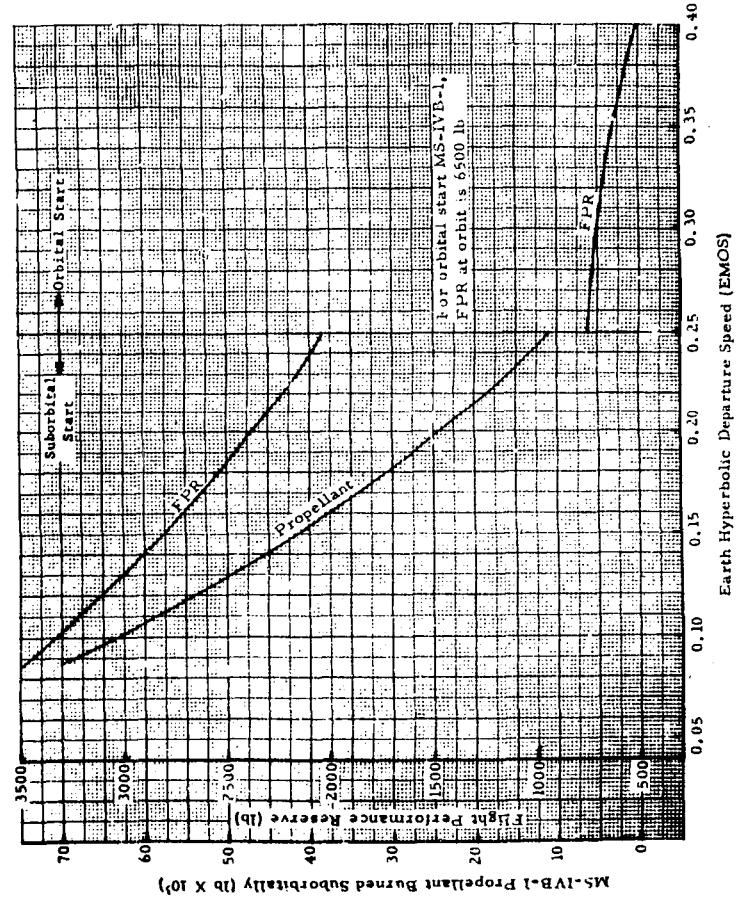


FIGURE 18. MS-IVB-1 PROPELLANT WEIGHT SUMMARY AS A FUNCTION OF HYPERBOLIC EXCESS VELOCITY FOR THE MLV-SATURN V-1 VEHICLE

## F. MLV-SATURN V-1/CENTAUR

The MLV-Saturn V-1/Centaur configuration (Figure 19) is the same as the MLV-Saturn V-1 with the addition of the Centaur as a fourth stage. The Centaur is packaged in the 260-inch diameter payload shroud of the MLV-Saturn V-1 vehicle. The payload envelope of this configuration is the 260-inch diameter, 234-inch long cylindrical section forward of the Centaur stage and the double angle nose cone. This configuration carries two Instrument Units. The Saturn Instrument Unit is located forward of the MS-IVB-1 stage and the Centaur Instrument Unit is located within the Centaur housing. Overall vehicle length is 4604 inches.

The MS-IVB-1 stage was started suborbitally and burned to orbit, reignited after an appropriate coast and burned to injection in all cases. A weight summary of the vehicle is presented in Table 13 and a corresponding trajectory in Table 14. The transfer injection conditions can be obtained from Figure 20 and a MS-IVB-1 propellant weight summary can be obtained from Figure 21. Both the MS-IVB-1 stage and Centaur stage were loaded to capacity in all cases.





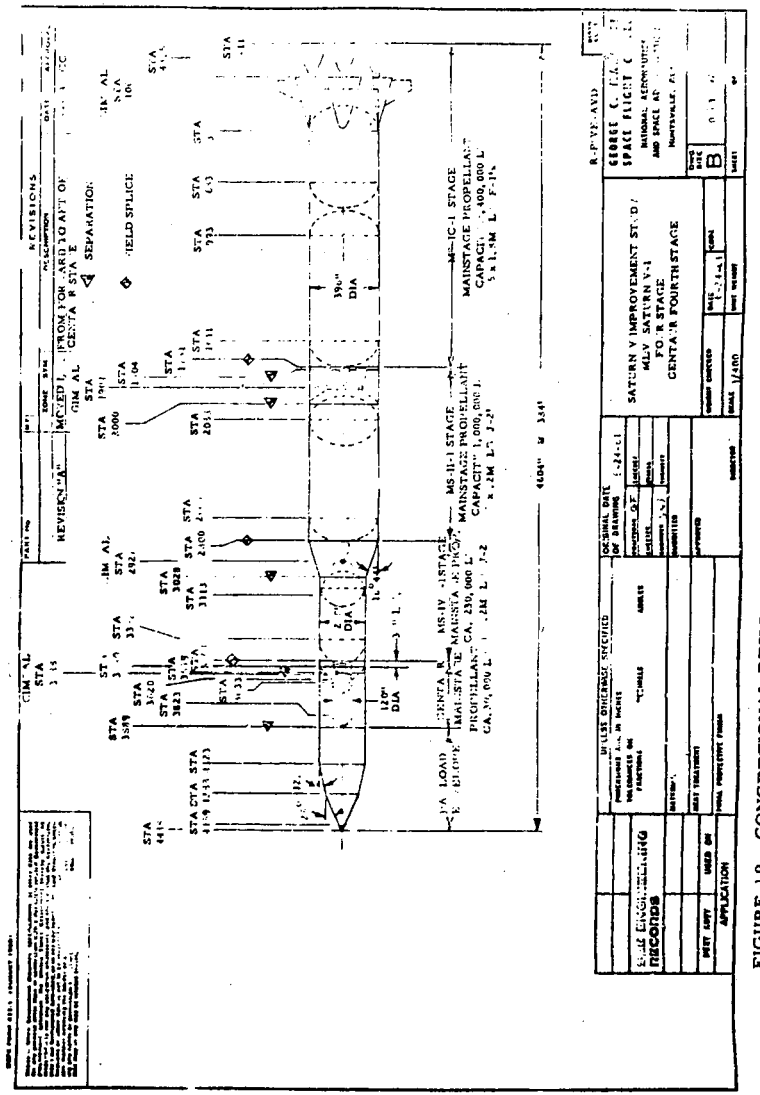


FIGURE 19. CONCEPTIONAL DESIGN OF THE MLV SATURN V-1/CENTAUR VEHICLE

Table 13. Vehicle Weight Summary for Three-Stage MLV-Saturn V-1 + Centaur With Suborbital Start MS-IVB-1

$E = 60 \times 10^6\ m^2/sec^2$

$V_\infty = 0.3678$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F-1 |
| F-1 Thrust (Sea Level) | | 1,800,000 lb |
| F-1 $I_{sp}$ (Sea Level) | | 271 sec |
| Lift-off Weight | | 7,200,000 lb |
| Propellant Loading | | 5,306,400 lb |
| Cutoff Weight | | 1,893,600 lb |
| MS-IC-1 Dry Stage Weight | | 349,000 lb |
| Structure | 188,334 lb | |
| Propulsion System and Accessories | 144,513 lb | |
| Equipment and Instrumentation | 10,000 lb | |
| Miscellaneous | 6,153 lb | |
| MS-IC-1/MS-II-1 Interstage | | 1,750 lb |
| Propulsion Performance Reserve | | 13,100 lb |
| Thrust Decay Propellants | | 6,300 lb |
| MS-IC-1 Residuals | | 60,747 lb |
| Fuel - Pressure Gas | 890 lb | |
| Fuel - Trapped | 16,665 lb | |
| Oxidizer - Pressure Gas | 7,900 lb | |
| Oxidizer - Trapped | 31,765 lb | |
| Actuator Fuel - Trapped | 630 lb | |
| Retro-rocket Propellant | 2,000 lb | |
| Frost | 865 lb | |
| Nitrogen | 32 lb | |
| Weight Loss During MS-IC-1/MS-II-1 Sep/Start | | 5,385 lb |
| Ullage Rocket Propellants | 2,960 lb | |
| Fuel - Engine Start | 825 lb | |
| Oxidizer - Engine Start | 1,600 lb | |



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Table 13. Continued

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 5 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 1,457,318 lb |
| Propellant Loading | | 1,000,000 lb |
| Centaur Shroud | | 2,320 lb * |
| MS-IC-1/MS-II-1 Large Interstage | | 11,940 lb ** |
| Structure | 10,150 lb | |
| Electrical | 300 lb | |
| Ullage Hardware | 1,490 lb | |
| Cutoff Weight | | 443,058 lb |
| MS-II-1 Second Stage Dry Weight | | 92,000 lb |
| Structure | 60,215 lb | |
| Propulsion System and Accessories | 24,460 lb | |
| Equipment | 6,412 lb | |
| Miscellaneous | 913 lb | |
| Propulsion Performance Reserve | | 1,390 lb |
| Thrust Decay Propellants | | 500 lb |
| Residuals | | 9,450 lb |
| Fuel - Pressure Gas | 1,870 lb | |
| Fuel - Trapped | 1,351 lb | |
| Oxidizer - Pressure Gas | 4,265 lb | |
| Oxidizer - Trapped | 1,879 lb | |
| Service Items | 85 lb | |
| MS-II-1/MS-IVB-1 Interstage | | 8,110 lb |
| MS-II-1 Retro-rockets | | 2,500 lb |
| Weight Loss MS-II-1/MS-IVB-1 Sep/Start | | 550 lb |

* Dropped 20 sec after second stage ignition.

** Dropped 30 sec after second stage ignition.



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Table 13. Continued

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 1 × RE-315 |
| RE-315 Thrust (Vacuum) | | 315,000 lb |
| RE-315 $I_{sp}$ (Vacuum) | | 444.6 sec |
| Lift-off Weight | | 328,558 lb |
| Propellant - First Burn | | 23,718 lb |
| Cutoff Weight - in 185 km orbit | | 304,840 lb |
| MS-IVB-1 Weight Loss in Orbit | | 5,295 lb |
| Fuel - Vented | 3,400 lb | |
| Thrust Buildup | 485 lb | |
| Auxiliary Propellants | 1,410 lb | |
| Centaur Weight Loss in Orbit | | 338 lb |
| Lift-off Weight - Second Burn | | 299,207 lb |
| Propellant - Second Burn | | 206,282 lb |
| Cutoff Weight | | 92,925 lb |
| MS-IVB-1 Dry Stage Weight | | 28,800 lb |
| Structure | 15,640 lb | |
| Propulsion System and Accessories | 6,585 lb | |
| Equipment and Instrumentation | 6,080 lb | |
| Miscellaneous | 495 lb | |
| Propulsion Performance Reserve | | 575 lb |
| Thrust Decay Propellants | | 100 lb |
| Residuals | | 2,415 lb |
| Fuel - Trapped | 506 lb | |
| Fuel - Pressure Gas | 865 lb | |
| Oxidizer - Trapped | 440 lb | |
| Oxidizer - Pressure Gas | 454 lb | |
| Auxiliary Propellant Reserve | 115 lb | |
| Environmental Control Fluids | 35 lb | |
| Instrument Unit | | 3,500 lb |
| S-IVB/Centaur Interstage | | 500 lb |
| MS-IVB-1/Centaur Separation Start Losses | | 154 lb |
| Centaur Boiloff | 94 lb | |
| Centaur $H_2O_2$ for Boost Pumps | 50 lb | |
| Centaur Ullage Rocket Vernier Firing | 10 lb | |





Table 13. (Concluded)

| Vehicle Characteristics | | Fourth Stage |
|---|---|---|
| Propulsion | | 2 × RL-10 |
| RL-10 Thrust (Vacuum) | | 15,000 lb |
| RL-10 $I_{sp}$ (Vacuum) | | 434 sec |
| Lift-off Weight | | 56,881 lb |
| Propellant Loading | | 29,210 lb |
| Cutoff Weight | | 27,671 lb |
| Flight Performance Reserve | | 790 lb |
| Centaur Dry Stage Weight | | 5,348 lb |
| Structure | 934 lb | |
| Propulsion System & Accessories | 1,216 lb | |
| Pressurization | 122 lb | |
| Guidance Group | 354 lb | |
| Controls Group | 117 lb | |
| Electrical Group | 290 lb | |
| Flight Instrument Group | 270 lb | |
| Destruct | 25 lb | |
| Centaur Aft Interstage | 300 lb | |
| Umbilicals and Ducts | 270 lb | |
| Permanent Insulation | 1,450 lb | |
| Residuals | | 406 lb |
| Injected Payload Weight | | 21,094 lb |

Table 14. Typical Trajectory Printout for MLV Saturn V - 1 /Centaur Vehicle with Suborbital Start

$E = 60\ km^2/sec^2$
$V_\infty = 0.3678$ EMOS

| Stage | Time (sec) | Velocity (m/sec) | Altitude (km) | Flight Path Angle (deg) | Range (km) | Q ($lb/ft^2$) | Weight (lbs) | Thrust (lbs) | Mach | Ax. Accel ($m/sec^2$) |
|---|---|---|---|---|---|---|---|---|---|---|
| MS-IC-1 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.0 | 7,200,000 | 9,000,000 | 0.0 | 2.44 |
| | 20.00 | 61.3 | 0.57 | 1.07 | 0.0 | 45.6 | 6,535,793 | 9,074,309 | 0.2 | 3.77 |
| | 40.00 | 154.3 | 2.65 | 8.64 | 0.2 | 234.2 | 5,871,587 | 9,313,420 | 0.5 | 5.66 |
| | 44.00 | 177.9 | 3.31 | 10.94 | 0.3 | 291.1 | 5,738,745 | 9,378,621 | 0.5 | 6.15 |
| | 48.00 | 203.5 | 4.05 | 13.43 | 0.5 | 352.4 | 5,605,904 | 9,447,676 | 0.6 | 6.68 |
| | 52.00 | 231.4 | 4.89 | 16.05 | 0.7 | 416.5 | 5,473,063 | 9,519,313 | 0.7 | 7.26 |
| | 56.00 | 261.7 | 5.83 | 18.78 | 1.0 | 480.8 | 5,340,222 | 9,592,097 | 0.8 | 7.89 |
| | 60.00 | 294.6 | 6.88 | 21.56 | 1.4 | 542.3 | 5,207,380 | 9,664,487 | 0.9 | 8.58 |
| | 64.00 | 329.8 | 8.03 | 24.36 | 1.8 | 595.4 | 5,074,539 | 9,734,875 | 1.1 | 9.66 |
| | 68.00 | 367.4 | 9.28 | 27.16 | 2.4 | 636.4 | 4,941,698 | 9,801,636 | 1.2 | 9.75 |
| | 72.00 | 408.0 | 10.64 | 29.92 | 3.2 | 663.7 | 4,808,856 | 9,863,434 | 1.4 | 10.61 |
| | 73.14 | 420.2 | 11.05 | 30.69 | 3.4 | 668.9 | 4,771,075 | 9,879,705 | 1.4 | 10.87 |
| | 76.00 | 452.4 | 12.11 | 32.62 | 4.1 | 655.9 | 4,676,015 | 9,918,431 | 1.5 | 11.60 |
| | 80.00 | 500.9 | 13.69 | 35.24 | 5.1 | 627.4 | 4,543,174 | 9,965,276 | 1.7 | 12.66 |
| | 100.00 | 811.0 | 23.33 | 46.66 | 13.7 | 362.8 | 3,878,967 | 10,094,909 | 2.7 | 18.47 |
| | 120.00 | 1245.9 | 36.00 | 55.14 | 29.5 | 115.4 | 3,214,761 | 10,125,910 | 3.9 | 25.24 |
| | 140.00 | 1835.3 | 51.93 | 61.16 | 55.3 | 30.3 | 2,550,554 | 10,130,814 | 5.4 | 34.26 |
| | 159.78 | 2640.6 | 71.49 | 65.26 | 94.1 | 5.9 | 1,893,600 | 10,131,541 | 9.2 | 48.45 |
| MS-II | 159.78 | 2640.6 | 71.49 | 65.26 | 94.1 | 5.9 | 1,457,318 | 1,000,000 | 9.2 | 2.71 |
| | 160.00 | 2641.2 | 71.74 | 65.30 | 94.7 | 5.7 | 1,456,806 | 1,000,000 | 9.3 | 2.72 |
| | 160.00 | 2641.2 | 71.74 | 65.30 | 94.7 | 0.0 | 1,456,806 | 1,000,000 | 9.3 | 2.72 |
| | 160.00 | 3017.7 | 71.74 | 68.55 | 94.7 | 0.0 | 1,456,806 | 1,000,000 | 10.6 | 3.22 |
| | 179.78 | 3088.1 | 92.42 | 71.32 | 150.7 | 0.0 | 1,410,370 | 1,000,000 | 0.0 | 3.09 |
| | 179.78 | 3088.1 | 92.42 | 71.32 | 150.7 | 0.0 | 1,408,050 | 1,000,000 | 0.0 | 3.10 |
| | 184.00 | 3104.6 | 96.54 | 71.84 | 162.9 | 0.0 | 1,398,148 | 1,000,000 | 0.0 | 2.90 |
| | 189.78 | 3127.8 | 102.06 | 72.51 | 179.8 | 0.0 | 1,384,575 | 1,000,000 | 0.0 | 2.63 |
| | 189.78 | 3127.8 | 102.06 | 72.51 | 179.8 | 0.0 | 1,372,635 | 1,000,000 | 0.0 | 2.69 |
| | 200.00 | 3171.3 | 111.42 | 73.63 | 210.0 | 0.0 | 1,348,644 | 1,000,000 | 0.0 | 2.99 |
| | [illegible].00 | 3765.3 | 178.58 | 83.06 | 539.6 | 0.0 | 1,113,907 | 1,000,000 | 0.0 | 6.15 |
| | [illegible].00 | 4671.4 | 204.23 | 89.10 | 945.3 | 0.0 | 879,166 | 1,000,000 | 0.0 | 9.72 |
| | 500.00 | 5946.9 | 198.28 | 91.48 | 1456.3 | 0.0 | 644,424 | 1,000,000 | 0.0 | 14.60 |
| | 585.78 | 7490.2 | 186.63 | 90.38 | 2011.8 | 0.0 | 443,058 | 1,000,000 | 0.0 | 22.04 |
| MS-IVB-1 | 585.78 | 7490.2 | 186.63 | 90.38 | 2011.8 | 0.0 | 328,558 | 200,000 | 0.0 | 5.87 |
| | 600.00 | 7574.6 | 185.99 | 90.30 | 2115.8 | 0.0 | 321,883 | 200,000 | 0.0 | 6.03 |
| | 636.30 | 7797.3 | 185.20 | 90.00 | 2386.9 | 0.0 | 304,840 | 200,000 | 0.0 | 6.43 |
| | 636.30 | 7797.3 | 185.20 | 90.00 | 2368.9 | 0.0 | 299,207 | 200,000 | 0.0 | 6.56 |
| | 700.00 | 8234.3 | 186.76 | 89.66 | 2882.8 | 0.0 | 269.301 | 200,000 | 0.0 | 7.23 |
| | 800.00 | 9019.8 | 200.73 | 88.29 | 3719.1 | 0.0 | 222,353 | 200,000 | 0.0 | 8.55 |
| | 900.00 | 9963.8 | 249.53 | 85.62 | 4633.5 | 0.0 | 175,405 | 200,000 | 0.0 | 10.49 |
| | 1000.00 | 11166.6 | 366.34 | 81.47 | 5633.2 | 0.0 | 128,456 | 200,000 | 0.0 | 13.97 |
| | 1075.68 | 12400.4 | 529.82 | 77.24 | 6450.4 | 0.0 | 92,925 | 200,000 | 0.0 | 19.26 |
| Centaur | 1075.68 | 12400.4 | 529.82 | 77.24 | 6450.4 | 0.0 | 56,881 | 30,000 | 0.0 | 3.32 |
| | 1100.00 | 12481.0 | 600.55 | 75.72 | 6720.6 | 0.0 | 55,200 | 30,000 | 0.0 | 3.31 |
| | 1200.00 | 12817.4 | 979.57 | 69.42 | 7795.6 | 0.0 | 48,288 | 30,000 | 0.0 | 3.50 |
| | 1300.00 | 13198.3 | 1501.95 | 63.24 | 8793.6 | 0.0 | 41,175 | 30,000 | 0.0 | 4.21 |
| | 1400.00 | 13682.1 | 2160.60 | 57.29 | 9700.1 | 0.0 | 34,463 | 30,000 | 0.0 | 4.48 |
| | 1498.25 | 14330.9 | 2966.90 | 51.75 | 10498.7 | 0.0 | 27,671 | 30,000 | 0.0 | 7.80 |







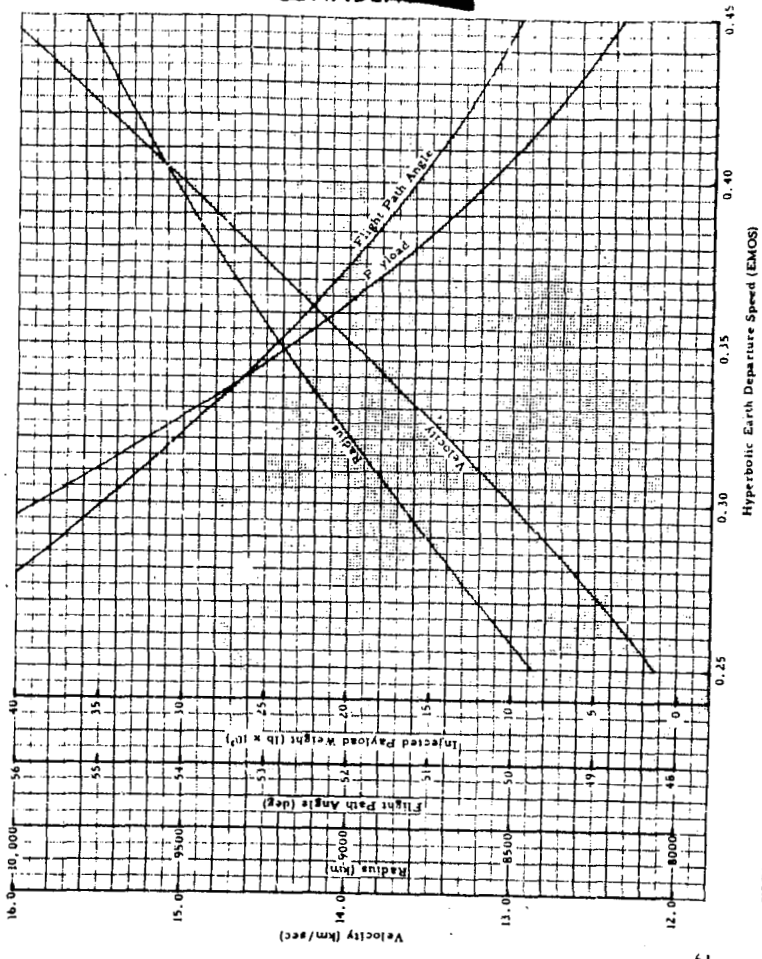


FIGURE 20. TRANSFER INJECTION CONDITIONS FOR THE MLV SATURN V-1/CENTAUR VEHICLE

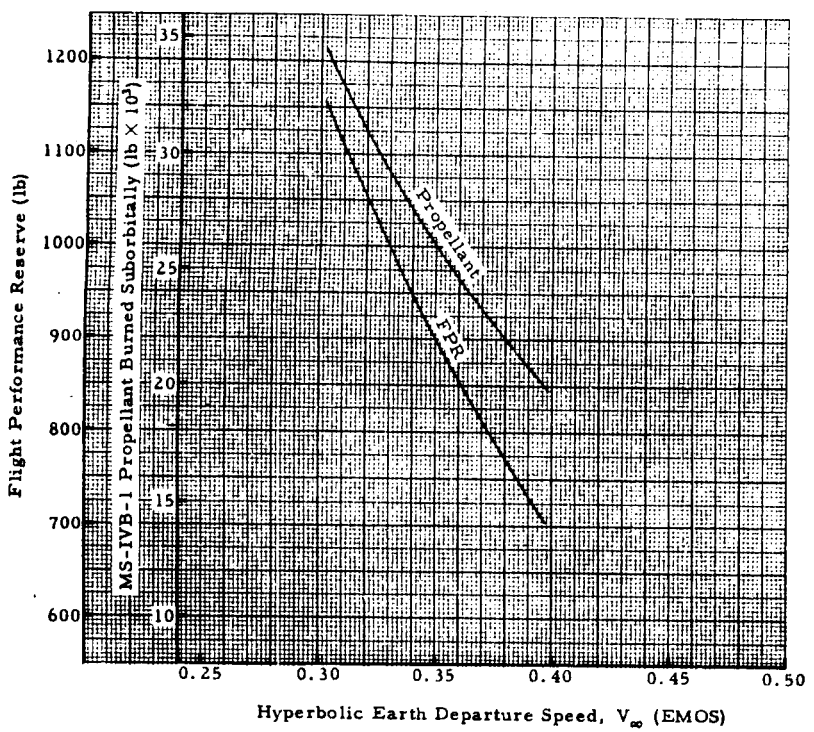


FIGURE 21. MS-IVB-1 PROPELLANT WEIGHT SUMMARY AS A FUNCTION OF HYPERBOLIC EXCESS VELOCITY FOR THE MLV SATURN V-1/CENTAUR VEHICLE







G. MLV-SATURN V-2

The MLV-Saturn V-2 configuration (Figure 22) is the same as the MLV-Saturn V-1 configuration except that the third stage has been replaced by a new stage having a propellant capacity of 350,000 lb and utilizing a 315,000-lb-thrust, high-chamber-pressure, LOX-hydrogen engine. The payload volume is in the 260-inch-diameter, 583-inch-long cylindrical section, and the double angle nose cone. The vehicle is 4920 inches long at lift-off.

Tables 15 and 16 give a weight summary and trajectory for the MLV-Saturn V-2 launch vehicle. The MS-IVB-2 stage was burned suborbitally in all cases. This vehicle was found to be an extremely excellent three-stage launch vehicle for missions to each of the planets considered and is possibly a good choice for manned missions. The payload capability, as indicated in a summary of transfer injection conditions in Figure 23, ranges from 1,000 to 98,000 lb for the range of energy levels required for all the missions considered.

Figure 24 shows a MS-IVB-2 propellant weight summary. The MS-IVB-2 stage was loaded to maximum capacity in each case considered.

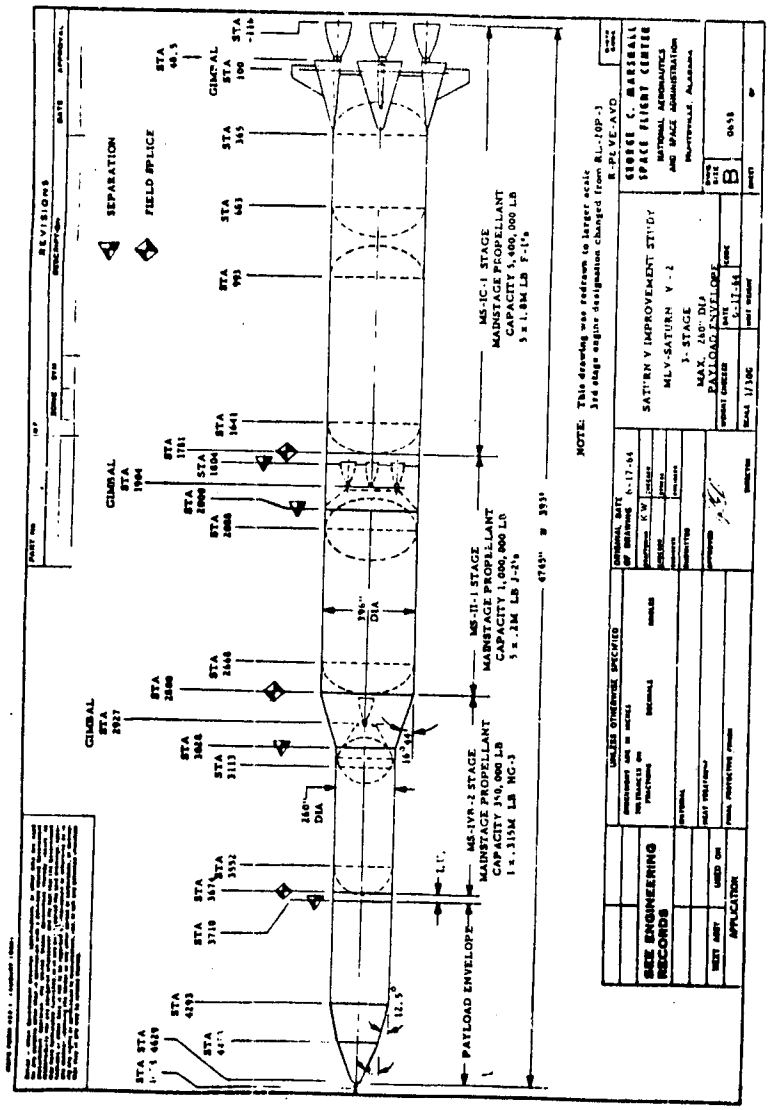


FIGURE 22. CONCEPTIONAL DESIGN OF THE MLV SATURN V-2 VEHICLE



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Table 15. Vehicle Weight Summary for Three-Stage MLV-Saturn V-2 With Suborbital Start MS-IVB-2

$E = 60 \times 10^6\ m^2/sec^2$

$V_\infty = 0.3678$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F-1 |
| F-1 Thrust (Sea Level) | | 1,800,000 lb |
| F-1 $I_{sp}$ (Sea Level) | | 271 sec |
| Lift-off Weight | | 7,200,000 lb |
| Propellant Loading | | 5,290,000 lb |
| Cutoff Weight | | 1,910,000 lb |
| MS-IC-1 Dry Stage Weight | | 349,000 lb |
| Structure | 188,334 lb | |
| Propulsion System and Accessories | 144,513 lb | |
| Equipment and Instrumentation | 10,000 lb | |
| Miscellaneous | 6,153 lb | |
| MS-IC-1/MS-II-1 Interstage | | 1,750 lb |
| Propulsion Performance Reserve | | 13,100 lb |
| Thrust Decay Propellants | | 6,300 lb |
| MS-IC-1 Residuals | | 60,747 lb |
| Fuel - Pressure Gas | 890 lb | |
| Fuel - Trapped | 16,665 lb | |
| Oxidizer - Pressure Gas | 7,900 lb | |
| Oxidizer - Trapped | 31,765 lb | |
| Actuator Fuel Trapped | 630 lb | |
| Retro-rocket Propellant | 2,000 lb | |
| Frost | 865 lb | |
| Nitrogen | 32 lb | |
| Weight Loss During MS-IC-1/MS-II-1 Sep/Start | | 5,385 lb |
| Ullage Rocket Propellants | 2,960 lb | |
| Fuel - Engine Start | 825 lb | |
| Oxidizer - Engine Start | 1,600 lb | |



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Table 15. Continued

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propuls[illegible] | | 5 × J-2 |
| J-2 Th[illegible] acuum) | | 200,000 lb |
| J-2 [illegible]) | | 426 sec |
| Lift-off [illegible] | | 1,473,718 lb |
| [illegible]opell[illegible] adings | | 936,500 lb |
| MS-IC-1, MS-II-1 Large Interstage | | 11,940 lb* |
| Structure | 10,150 lb | |
| Electrical | 300 lb | |
| Ullage Hardware | 1,490 lb | |
| Cutoff Weight | | 525,278 lb |
| MS-II Second Stage Dry Weight | | 92,000 lb |
| Structure | 60,215 lb | |
| Propulsion Systems and Accessories | 24,460 lb | |
| Equipment | 6,412 lb | |
| Miscellaneous | 913 lb | |
| Propulsion Performance Reserve | | 1,390 lb |
| Thrust Decay Propellants | | 500 lb |
| Residuals | | 9,450 lb |
| Fuel - Pressure Gas | 1,870 lb | |
| Fuel - Trapped | 1,351 lb | |
| Oxidizer - Pressure Gas | 4,265 lb | |
| Oxidizer - Trapped | 1,879 lb | |
| Service Items | 85 lb | |
| MS-II-1/MS-IVB-2 Interstage | | 9,430 lb |
| MS-II-1 Retro-rockets | | 2,500 lb |
| Weight Loss - MS-II-1/MS-IVB-2 Sep/Start | | 725 lb |

*Dropped 30 sec after Second Stage ignition.









Table 15. Concluded

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 1 × RE-315 |
| RE-315 Thrust (Vacuum) | | 315,000 lb |
| RE-315 $I_{sp}$ (Vacuum) | | 444.6 sec |
| Lift-off Weight | | 409,283 lb |
| Propellant - First Burn | | 86,137 lb |
| Cutoff Weight at 185 km Orbit | | 323,146 lb |
| Weight Loss in Orbit | | 8,290 lb |
| Fuel Vented | 5,565 lb | |
| Auxiliary Propellant - Ullage | 500 lb | |
| Auxiliary Propellant - Chilldown | 500 lb | |
| Auxiliary Propellant - Attitude Control | 935 lb | |
| Thrust Decay | 130 lb | |
| Thrust Buildup | 660 lb | |
| Lift-off Weight - Second Burn | | 314,856 lb |
| Propellant - Second Burn | | 262,261 lb |
| Cutoff Weight - Second Burn | | 52,595 lb |
| MS-IVB-2 Dry Stage Weight | | 34,800 lb |
| Structure | 20,060 lb | |
| Propulsion System and Accessories | 7,997 lb | |
| Equipment and Instrumentation | 6,080 lb | |
| Miscellaneous | 663 lb | |
| Propulsion Performance Reserve | | 575 lb |
| Thrust Decay Propellants | | 130 lb |
| Residuals | | 3,640 lb |
| Fuel - Trapped | 800 lb | |
| Fuel - Pressure Gas | 1,300 lb | |
| Oxidizer - Trapped | 700 lb | |
| Oxidizer - Pressure Gas | 690 lb | |
| Auxiliary Propellant Reserve | 115 lb | |
| Environmental Control Fluids | 35 lb | |
| Instrument Unit | | 3,500 lb |
| Injected Payload Weight | | 9,950 lb |

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'able 16. Typical Trajectory Printout for MLV Saturn V-2 Vehicle with Suborbital Start MS-IVB-2

$E = 60 \times 10^6\ m^2/sec^2$

$V_\infty = 0.3678$ EMOS

| Stage | Time (sec) | Velocity (m/sec) | Altitude (km) | Flight Path Angle (deg) | Range (km) | I. Accel. ($m/sec^2$) | Q ($kg/m^2$) | Weight (lb) | Thrust (lb) | Mach | Ax. Accel. ($m/sec^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MS-IC-1 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 2.44 | 0.0 | 7,200,000 | 9,000,000 | 0.0 | 2.44 |
| | 20.00 | 61.3 | 0.57 | 1.06 | 0.0 | 3.76 | 222.4 | 6,535,793 | 9,074,309 | 0.2 | 3.77 |
| | 40.00 | 154.3 | 2.65 | 8.62 | 0.2 | 5.66 | 1143.4 | 5,871,587 | 9,313,423 | 0.5 | 5.66 |
| | 44.00 | 177.9 | 3.31 | 10.91 | 0.3 | 6.15 | 1421.0 | 5,738,745 | 9,378,627 | 0.5 | 6.15 |
| | 48.00 | 203.5 | 4.05 | 13.39 | 0.5 | 6.68 | 1720.6 | 5,605,904 | 9,447,686 | 0.6 | 6.68 |
| | 52.00 | 231.4 | 4.89 | 16.01 | 0.7 | 7.26 | 2033.3 | 5,473,063 | 9,519,331 | 0.7 | 7.26 |
| | 56.00 | 261.7 | 5.83 | 18.73 | 1.0 | 7.89 | 2347.1 | 5,340,222 | 9,592,124 | 0.8 | 7.89 |
| | 60.00 | 294.6 | 6.88 | 21.50 | 1.3 | 8.57 | 2647.1 | 5,207,380 | 9,664,526 | 0.9 | 8.57 |
| | 64.00 | 329.7 | 8.03 | 24.30 | 1.8 | 9.05 | 2906.1 | 5,074,539 | 9,734,928 | 1.1 | 9.06 |
| | 68.00 | 367.3 | 9.28 | 27.09 | 2.4 | 9.75 | 3105.5 | 4,941,968 | 9,801,704 | 1.2 | 9.75 |
| | 72.00 | 407.9 | 10.64 | 29.84 | 3.2 | 10.60 | 3238.5 | 4,808,856 | 9,863,518 | 1.4 | 10.60 |
| | 73.09 | 419.7 | 11.03 | 30.59 | 3.4 | 10.86 | 3263.9 | 4,772,564 | 9,879,152 | 1.4 | 10.86 |
| | 76.00 | 452.3 | 12.11 | 32.54 | 4.1 | 11.59 | 3199.7 | 4,676,015 | 9,918,527 | 1.5 | 11.59 |
| | 80.00 | 500.7 | 13.69 | 35.15 | 5.1 | 12.65 | 3059.6 | 4,543,174 | 9,965,379 | 1.7 | 12.65 |
| | 100.00 | 810.7 | 23.35 | 46.56 | 13.7 | 18.46 | 1765.7 | 3,878,967 | 10,094,993 | 2.7 | 18.46 |
| | 120.00 | 1245.3 | 36.04 | 55.03 | 29.4 | 25.23 | 559.7 | 3,214,761 | 10,125,940 | 3.9 | 25.23 |
| | 140.00 | 1834.4 | 52.01 | 61.05 | 55.2 | 34.25 | 146.3 | 2,550,554 | 10,130,822 | 5.4 | 34.25 |
| | 159.29 | 2615.6 | 71.10 | 65.06 | 92.8 | 47.96 | 29.9 | 1,910,000 | 10,131,536 | 9.1 | 47.96 |
| MS-II-1 | 159.29 | 2615.6 | 71.10 | 65.06 | 92.8 | 2.60 | 29.9 | 1,473,718 | 1,000,000 | 9.1 | 2.60 |
| | 160.00 | 2617.4 | 71.88 | 65.18 | 94.5 | 2.63 | 26.8 | 1,472,047 | 1,000,000 | 9.2 | 2.63 |
| | 160.00 | 2617.4 | 71.88 | 65.18 | 94.5 | 2.63 | 26.8 | 1,472,047 | 1,000,000 | 9.2 | 2.63 |
| | 160.00 | 2993.7 | 71.88 | 68.47 | 94.5 | 3.14 | 35.1 | 1,472,047 | 1,000,000 | 10.5 | 3.14 |
| | 180.00 | 3063.2 | 92.67 | 71.29 | 150.6 | 3.77 | 0.8 | 1,425,098 | 1,000,000 | 0.0 | 2.91 |
| | 189.29 | 3099.0 | 101.58 | 72.40 | 177.4 | 3.92 | 0.1 | 1,403,295 | 1,000,000 | 0.0 | 2.41 |
| | 189.29 | 3099.0 | 101.58 | 72.40 | 177.4 | 3.98 | 0.1 | 1,391,355 | 1,000,000 | 0.0 | 2.47 |
| | 200.00 | 3143.2 | 111.36 | 73.57 | 208.9 | 4.28 | 0.0 | 1,366,210 | 1,000,000 | 0.0 | 2.73 |
| | 300.00 | 3720.2 | 178.50 | 82.91 | 534.8 | 7.26 | 0.0 | 1,131,468 | 1,000,000 | 0.0 | 5.83 |
| | 400.00 | 4601.4 | 205.18 | 88.88 | 935.[illegible] | 10.43 | 0.0 | 896,726 | 1,000,000 | 0.0 | 9.31 |
| | 500.00 | 5837.4 | 201.54 | 91.21 | 1437.3 | 1[illegible].57 | 0.0 | 661,984 | 1,000,000 | 0.0 | 14.03 |
| | 558.24 | 6785.7 | 194.40 | 90.80 | 1792.7 | 18.24 | 0.0 | 525,278 | 1,000,000 | 0.0 | 18.25 |
| MS-IVB-II | 558.24 | 6785.7 | 194.40 | 90.80 | 1792.7 | 7.45 | 0.0 | 409,284 | 315,000 | 0.0 | 7.13 |
| | 600.00 | 7108.7 | 190.24 | 90.80 | 2074.[illegible] | 8.02 | 0.0 | 379,694 | 315,000 | 0.0 | 7.89 |
| | 679.81 | 7797.3 | 185.20 | 90.00 | 2651.4 | 9.28 | 0.0 | 323,146 | 315,000 | 0.0 | 9.56 |
| | 679.81 | 7[illegible].3 | 185.20 | 90.00 | 2651.4 | 9.[illegible]2 | 0.0 | 314,856 | 315,000 | 0.0 | 9.81 |
| | 7[illegible].00 | 7[illegible].6 | 185.56 | 89.[illegible] | 2806.3 | 10.24 | 0.0 | 300,554 | 315,000 | 0.0 | 10.24 |
| | 800.00 | 9158.7 | 1[illegible].99 | 88.53 | 3636.9 | 13.21 | 0.0 | 229,703 | 315,000 | 0.0 | 13.21 |
| | 900.00 | 10720.[illegible] | 247.11 | [illegible]3.26 | 4592.[illegible] | 18.69 | 0.0 | 158,853 | 315,000 | 0.0 | 18.69 |
| | 1000.00 | 13180.9 | 400.88 | 79.52 | 5710.0 | 33.52 | 0.0 | 88,003 | 315,000 | 0.0 | 33.52 |
| | 1049.48 | 15333.6 | 554.03 | 75.42 | 6333.1 | 56.64 | 0.0 | 52,595 | 315,000 | 0.0 | 56.64 |

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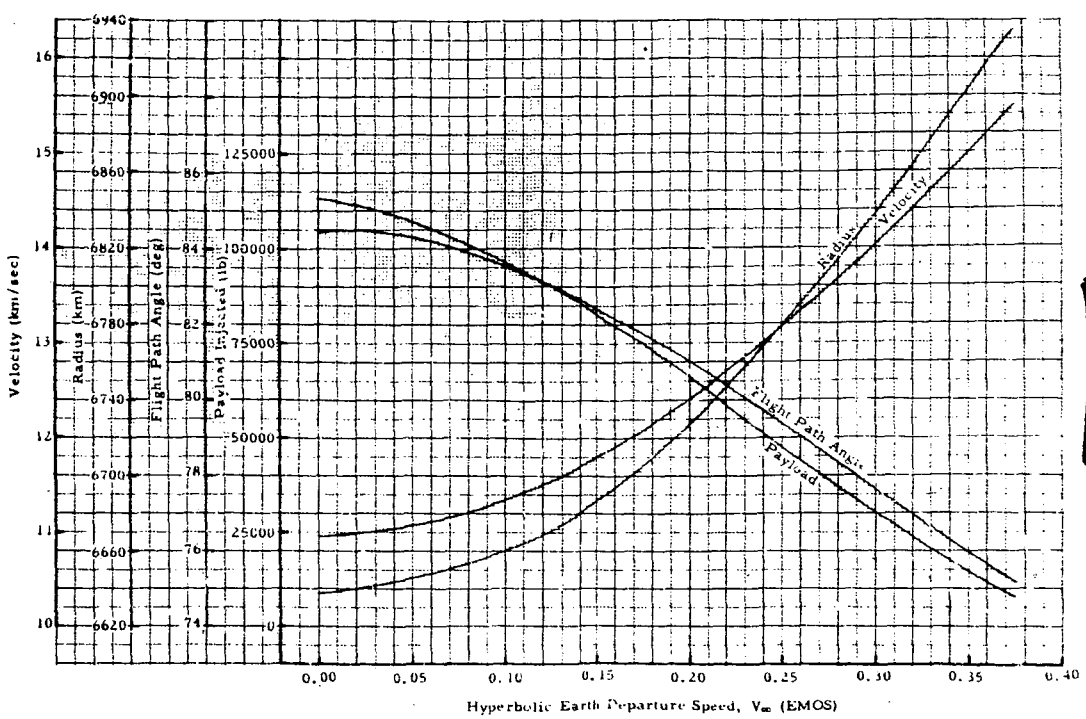


FIGURE 23. TRANSFER INJECTION CONDITIONS FOR THE MLV SATURN V-2 VEHICLE



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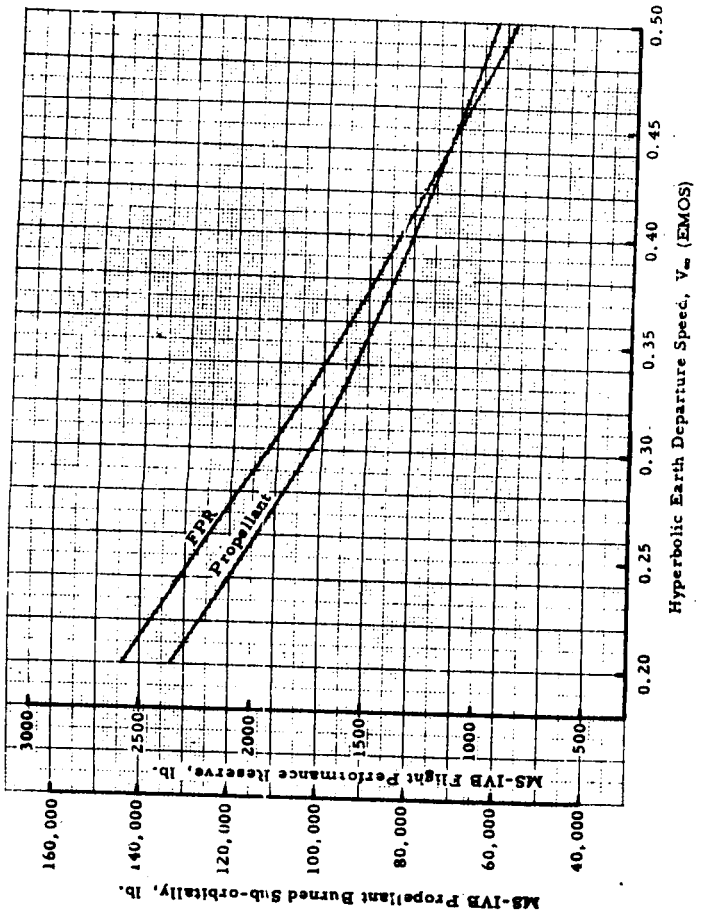


FIGURE 24. S-IVB-2 PROPELLANT WEIGHT SUMMARY AS A FUNCTION OF HYPERBOLIC EXCESS VELOCITY FOR THE MLV SATURN V-2 VEHICLE





## H. MLV-SATURN V-2 CENTAUR

The MLV-Saturn V-2 Centaur has the same design and characteristics as the three-stage MLV-Saturn V-2 with a Centaur fourth stage added (see Figure 25). The primary Instrument Unit is located aft the S-IVB stage. The Centaur Instrument Unit is contained within the Centaur housing. The payload volume is in the 260-inch-diameter, 234-inch-long shroud, and the double angle nose cone. Overall length of the vehicle is 4,745 inches.

A weight summary and trajectory for this launch vehicle is presented in Tables 17 and 18. Figures 26 and 27 show the transfer injection parameters and a MS-IVB-2 propellant weight summary for the various energy levels considered. The MS-IVB-2 stage and Centaur stage were loaded to maximum capacity in all cases (Ref. 9).

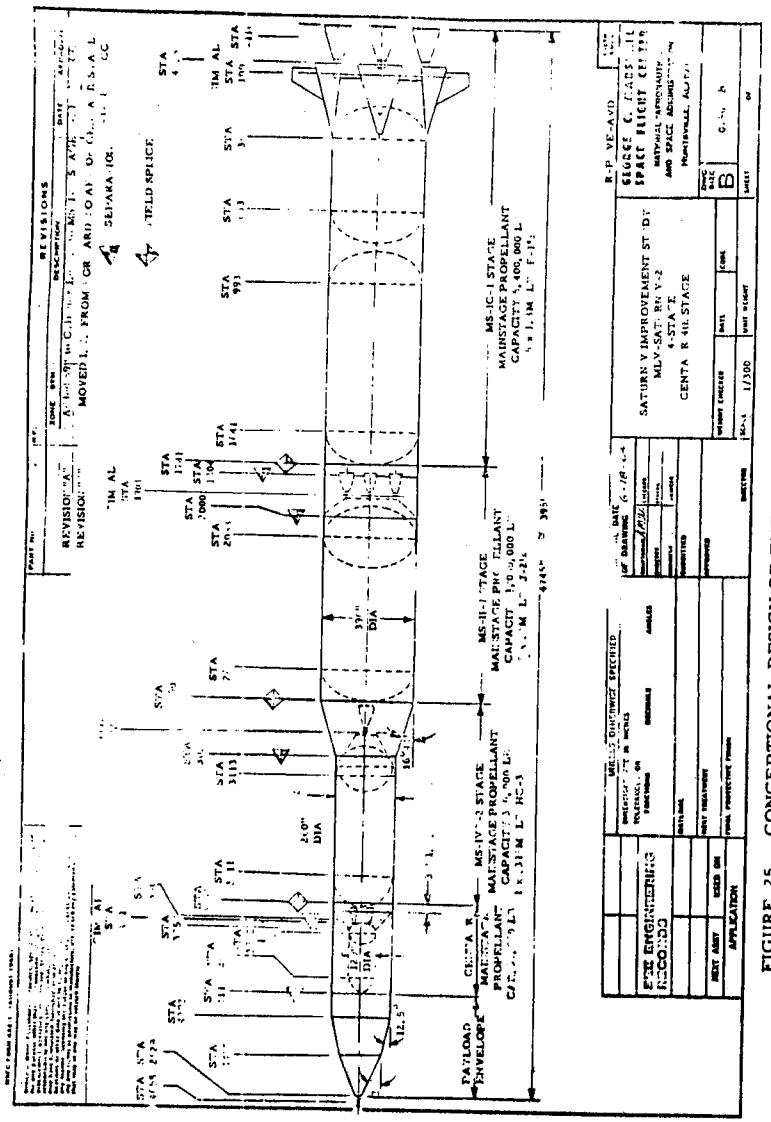


FIGURE 25. CONCEPTIONAL DESIGN OF THE MLV SATURN V-2/CENTAUR VEHICLE



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Table 17. Vehicle Weight Summary for Three-Stage MLV-Saturn V-2 + Centaur With Suborbital Start (MS-IVB-II

$E = 60 \times 10^6\ m^2/sec^2$

$V_\infty = 0.3678$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F-1 |
| F-1 Thrust (Sea Level) | | 1,000,000 lb |
| F-1 $I_{sp}$ (Sea Level) | | 271 sec |
| Lift-off Weight | | 7,200,000 lb |
| Propellant Loading | | 5,172,850 lb |
| Cutoff Weight | | 2,027,150 lb |
| MS-IC-1 Dry Stage Weight | | 349,000 lb |
| Structure | 188,334 lb | |
| Propulsion System and Accessories | 144,513 lb | |
| Equipment and Instrumentation | 10,000 lb | |
| Miscellaneous | 6,153 lb | |
| MS-IC-1/MS-II-1 Interstage | | 1,750 lb |
| Propulsion Performance Reserve | | 13,100 lb |
| Thrust Decay Propellants | | 6,300 lb |
| MS-IC-1 Residuals | | 60,747 lb |
| Fuel - Pressure Gas | 890 lb | |
| Fuel - Trapped | 16,665 lb | |
| Oxidizer - Pressure Gas | 7,900 lb | |
| Oxidizer - Trapped | 31,765 lb | |
| Actuator Fuel - Trapped | 630 lb | |
| Retro-rocket Propellant | 2,000 lb | |
| Frost | 865 lb | |
| Nitrogen | 32 lb | |
| Weight Loss During MS-IC-1/MS-II-1 Sep/Start | | 5,385 lb |
| Ullage Rocket Propellant | 2,960 lb | |
| Fuel - Engine Start | 825 lb | |
| Oxidizer - Engine Start | 1,600 lb | |



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Table 17. Continued

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 5 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 1,590,868 lb |
| Propellant Loading | | 1,000,000 lb |
| Drop Weight - Centaur Shroud | | 2,320 lb * |
| MS-IC-1/MS-II-1 Large Interstage | | 11,940 lb ** |
| Structure | 10,150 lb | |
| Electrical | 300 lb | |
| Ullage Hardware | 1,490 lb | |
| Cutoff Weight | | 576,608 lb |
| MS-II Second Stage Dry Weight | | 92,000 lb |
| Structure | 60,215 lb | |
| Propulsion System and Accessories | 24,460 lb | |
| Equipment | 6,412 lb | |
| Miscellaneous | 913 lb | |
| Propulsion Performance Reserve | | 1,390 lb |
| Thrust Decay Propellants | | 500 lb |
| Residuals | | 9,450 lb |
| Fuel - Pressure Gas | 1,870 lb | |
| Fuel - Trapped | 1,351 lb | |
| Oxidizer - Pressure Gas | 4,265 lb | |
| Oxidizer - Trapped | 1,879 lb | |
| Service Items | 85 lb | |
| MS-II-1/MS-IVB-2 Interstage | | 9,430 lb |
| MS-II-1 Retro-rockets | | 2,500 lb |
| Weight Loss - MS-II-1/MS-IVB-2 Sep/Start | | 725 lb |

*Dropped 20 sec after second stage ignition.
**Dropped 30 sec after second stage ignition.



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Table 17. Continued

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 1 X RE-315 |
| RE-315 Thrust (Vacuum) | | 315,000 lb |
| RE-315 Isp (Vacuum) | | 444.6 sec |
| Lift-off Weight | | 460,613 lb. |
| Propellant-First Burn | | 132,077 lb. |
| Cutoff Weight-In 185 km orbit | | 328,536 lb. |
| Weight Loss in Orbit | | 8,290 lb. |
| Fuel Vented | 5,565 lb | |
| Auxiliary Propellant - Ullage | 500 lb | |
| Auxiliary Propellant - Chilldown | 500 lb | |
| Auxiliary Propellant - Attidue Control | 935 lb | |
| Thrust Decay | 130 lb | |
| Thrust Buildup | 660 lb | |
| Centaur Weight Loss in Orbit | | 338 lb. |
| Liftoff Weight - Second Burn | | 319,908 lb. |
| Propellant - Second Burn | | 217,923 lb. |
| Cutoff Weight | | 101,985 lb. |
| MS-IVB-2 Dry Stage Weight | | 34,800 lb. |
| Structure | 20,060 lb | |
| Propulsion System and Accessories | 7,997 lb | |
| Equipment and Instrumentation | 6,080 lb | |
| Miscellaneous | 663 lb | |
| Instrument Unit | | 3,500 lb. |
| Propulsion Performance Reserve | | 575 lb. |
| Thrust Decay Propellants | | 130 lb. |
| Residuals | | 3,640 lb. |
| Fuel - Trapped | 800 lb | |
| Fuel - Pressure Gas | 1,300 lb | |
| Oxidizer - Trapped | 700 lb | |
| Oxidizer - Pressure Gas | 590 lb | |
| Auxiliary Propellant Reserve | 115 lb | |
| Environmental Control Fluids | 35 lb | |
| MS-IVB-2/Centaur Seperation/Start Losses | | 154 lb. |
| Centaur A O for Boost Pumps | 50 lb | |
| Centaur Ullage Rocket Vernier Firing | 10 lb | |
| Centaur Ascent Boiloff | 94 lb | |



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Table 17. (Concluded)

| Vehicle Characteristics | | Fourth Stage |
|---|---|---|
| Propulsion | | 2 × RL-10 |
| RL-10 Thrust (Vacuum) | | 15,000 lb |
| RL-10 $I_{sp}$ (Vacuum) | | 434 sec |
| Lift-off Weight | | 58,686 lb |
| Propellant | | 29,101 lb |
| Cutoff Weight | | 29,585 lb |
| Flight Performance Reserve | | 889 lb |
| Centaur Dry Stage Weight | | 5,348 lb |
| Structure | 934 lb | |
| Propulsion System & Accessories | 1,216 lb | |
| Pressurization | 122 lb | |
| Guidance Group | 354 lb | |
| Controls Group | 117 lb | |
| Electrical Group | 290 lb | |
| Flight Instrument Group | 270 lb | |
| Destruct | 25 lb | |
| Centaur Aft Interstage | 300 lb | |
| Umbilicals and Ducts | 270 lb | |
| Permanent Insulation | 1,450 lb | |
| Residuals | | 406 lb |
| Injected Payload Weight | | 22,942 lb |



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Table 18. Typical Trajectory Printout for MLV Saturn V - 2 / Centaur Vehicle with Suborbital Start MS-IVB-2

| Stage | Time (sec) | Velocity (m/sec) | Altitude (km) | Flight Path Angle (deg) | Range (km) | C.D. | Q (lb/ft²) | Weight (lb) | Thrust (lb) | Mach | Ax. Accel. (m/sec.²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MS-IC-1 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.384 | 0.0 | 2,400,000 | 9,100,000 | 0.0 | 2.44 |
| | 20.00 | 61.1 | 0.57 | 0.49 | 0.0 | 0.384 | 45.6 | 9,535,793 | 9,074,105 | 0.2 | 2.78 |
| | 40.00 | 154.2 | 2.65 | 8.02 | 0.1 | 0.384 | 273.9 | 9,111,499 | 9,111,499 | 0.5 | 5.84 |
| | 60.00 | 277.7 | 5.51 | 16.16 | 0.3 | 0.384 | 290.4 | 8,738,775 | 9,128,775 | 0.5 | 6.12 |
| | 80.00 | 401.2 | 9.06 | 22.47 | 0.4 | 0.384 | 151.3 | 8,505,404 | 9,147,451 | 0.6 | 6.64 |
| | 100.00 | 520.0 | 13.40 | 24.92 | 0.6 | 0.384 | 414.6 | 8,473,063 | 9,139,708 | 0.7 | 7.21 |
| | 120.00 | 631.0 | 17.84 | 27.46 | 0.9 | 0.384 | 477.8 | 8,340,222 | 9,142,797 | 0.8 | 7.81 |
| | 140.00 | 731.6 | 22.06 | 29.86 | 1.1 | 0.384 | 537.7 | 8,207,389 | 9,165,301 | 0.9 | 8.49 |
| | 160.00 | 825.0 | 26.05 | 32.45 | 1.3 | 0.384 | 594.4 | 8,074,556 | 9,216,342 | 1.1 | 9.46 |
| | 180.00 | 911.9 | 29.84 | 34.90 | 1.5 | 0.384 | 645.9 | 7,941,698 | 9,288,643 | 1.2 | 10.46 |
| | 200.00 | 993.7 | 33.40 | 37.92 | 1.8 | 0.384 | 691.9 | 7,808,856 | 9,385,630 | 1.4 | 11.43 |
| | 220.00 | 1,070.0 | 36.79 | 40.88 | 2.0 | 0.384 | 733.8 | 7,676,015 | 9,500,945 | 1.5 | 12.46 |
| | 240.00 | 1,140.0 | 39.96 | 43.89 | 2.3 | 0.384 | 771.7 | 7,543,174 | 9,637,927 | 1.7 | 13.49 |
| | 260.00 | 1,205.0 | 42.97 | 46.92 | 2.6 | 0.384 | 805.4 | 7,410,333 | 9,797,071 | 1.8 | 14.57 |
| | 280.00 | 1,265.0 | 45.82 | 49.89 | 2.9 | 0.384 | 835.1 | 7,277,492 | 9,978,844 | 2.0 | 15.64 |
| | 300.00 | 1,320.0 | 48.50 | 52.80 | 3.2 | 0.384 | 860.7 | 7,144,651 | 10,181,931 | 2.2 | 16.73 |
| | 320.00 | 1,371.0 | 51.02 | 55.66 | 3.5 | 0.384 | 882.3 | 7,011,810 | 10,406,554 | 2.4 | 17.81 |
| | 340.00 | 1,418.0 | 53.39 | 58.49 | 3.8 | 0.384 | 900.0 | 6,878,969 | 10,653,000 | 2.6 | 18.90 |
| | 360.00 | 1,461.0 | 55.61 | 61.33 | 4.1 | 0.384 | 914.0 | 6,746,128 | 10,921,000 | 2.8 | 19.99 |
| | 380.00 | 1,501.0 | 57.69 | 64.19 | 4.4 | 0.384 | 924.4 | 6,613,287 | 11,209,000 | 3.0 | 21.09 |
| | 400.00 | 1,538.0 | 59.64 | 67.07 | 4.7 | 0.384 | 931.3 | 6,480,446 | 11,516,000 | 3.2 | 22.19 |
| | 420.00 | 1,572.0 | 61.46 | 69.97 | 5.0 | 0.384 | 935.0 | 6,347,605 | 11,841,000 | 3.4 | 23.29 |
| | 440.00 | 1,603.0 | 63.15 | 72.89 | 5.3 | 0.384 | 935.8 | 6,214,764 | 12,184,000 | 3.6 | 24.39 |
| | 460.00 | 1,632.0 | 64.72 | 75.83 | 5.6 | 0.384 | 933.8 | 6,081,923 | 12,543,000 | 3.8 | 25.49 |
| | 480.00 | 1,658.0 | 66.17 | 78.78 | 5.9 | 0.384 | 929.3 | 5,949,082 | 12,918,000 | 4.0 | 26.59 |
| | 500.00 | 1,682.0 | 67.51 | 81.74 | 6.2 | 0.384 | 922.4 | 5,816,241 | 13,307,000 | 4.2 | 27.69 |
| | 520.00 | 1,704.0 | 68.74 | 84.71 | 6.5 | 0.384 | 913.3 | 5,683,400 | 13,710,000 | 4.4 | 28.79 |
| | 540.00 | 1,724.0 | 69.87 | 87.68 | 6.8 | 0.384 | 902.2 | 5,550,559 | 14,126,000 | 4.6 | 29.89 |
| | 560.00 | 1,742.0 | 70.91 | 90.66 | 7.1 | 0.384 | 889.2 | 5,417,718 | 14,553,000 | 4.8 | 30.99 |
| | 580.00 | 1,759.0 | 71.86 | 93.63 | 7.4 | 0.384 | 874.4 | 5,284,877 | 14,991,000 | 5.0 | 32.09 |
| | 600.00 | 1,774.0 | 72.73 | 96.61 | 7.7 | 0.384 | 858.0 | 5,152,036 | 15,438,000 | 5.2 | 33.19 |
| | 620.00 | 1,788.0 | 73.52 | 99.58 | 8.0 | 0.384 | 840.1 | 5,019,195 | 15,894,000 | 5.4 | 34.29 |
| | 640.00 | 1,800.0 | 74.24 | 102.55 | 8.3 | 0.384 | 821.0 | 4,886,354 | 16,358,000 | 5.6 | 35.39 |
| | 660.00 | 1,811.0 | 74.89 | 105.52 | 8.6 | 0.384 | 801.0 | 4,753,513 | 16,829,000 | 5.8 | 36.49 |
| | 680.00 | 1,821.0 | 75.48 | 108.49 | 8.9 | 0.384 | 780.4 | 4,620,672 | 17,306,000 | 6.0 | 37.59 |
| | 700.00 | 1,830.0 | 76.02 | 111.46 | 9.2 | 0.384 | 759.4 | 4,487,831 | 17,788,000 | 6.2 | 38.69 |
| | 720.00 | 1,838.0 | 76.51 | 114.43 | 9.5 | 0.384 | 738.3 | 4,354,990 | 18,274,000 | 6.4 | 39.79 |
| | 740.00 | 1,845.0 | 76.96 | 117.40 | 9.8 | 0.384 | 717.3 | 4,222,149 | 18,762,000 | 6.6 | 40.89 |
| | 760.00 | 1,851.0 | 77.37 | 120.37 | 10.1 | 0.384 | 696.4 | 4,089,308 | 19,251,000 | 6.8 | 41.99 |
| | 780.00 | 1,856.0 | 77.74 | 123.34 | 10.4 | 0.384 | 675.7 | 3,956,467 | 19,740,000 | 7.0 | 43.09 |
| | 800.00 | 1,860.0 | 78.08 | 126.31 | 10.7 | 0.384 | 655.2 | 3,823,626 | 20,228,000 | 7.2 | 44.19 |
| | 820.00 | 1,863.0 | 78.39 | 129.28 | 11.0 | 0.384 | 635.0 | 3,690,785 | 20,714,000 | 7.4 | 45.29 |
| | 840.00 | 1,865.0 | 78.67 | 132.25 | 11.3 | 0.384 | 615.1 | 3,557,944 | 21,196,000 | 7.6 | 46.39 |
| | 860.00 | 1,866.0 | 78.93 | 135.22 | 11.6 | 0.384 | 595.5 | 3,425,103 | 21,673,000 | 7.8 | 47.49 |
| | 880.00 | 1,866.0 | 79.17 | 138.19 | 11.9 | 0.384 | 576.2 | 3,292,262 | 22,143,000 | 8.0 | 48.59 |
| | 900.00 | 1,865.0 | 79.39 | 141.16 | 12.2 | 0.384 | 557.2 | 3,159,421 | 22,604,000 | 8.2 | 49.69 |
| | 920.00 | 1,863.0 | 79.59 | 144.13 | 12.5 | 0.384 | 538.5 | 3,026,580 | 23,054,000 | 8.4 | 50.79 |
| | 940.00 | 1,860.0 | 79.78 | 147.10 | 12.8 | 0.384 | 520.1 | 2,893,739 | 23,491,000 | 8.6 | 51.89 |
| | 960.00 | 1,856.0 | 79.95 | 150.07 | 13.1 | 0.384 | 502.0 | 2,760,898 | 23,913,000 | 8.8 | 52.99 |
| | 980.00 | 1,851.0 | 80.11 | 153.04 | 13.4 | 0.384 | 484.2 | 2,628,057 | 24,317,000 | 9.0 | 54.09 |
| | 1000.00 | 1,845.0 | 80.26 | 156.01 | 13.7 | 0.384 | 466.7 | 2,495,216 | 24,703,000 | 9.2 | 55.19 |
| | 1020.00 | 1,838.0 | 80.40 | 158.98 | 14.0 | 0.384 | 449.5 | 2,362,375 | 25,069,000 | 9.4 | 56.29 |
| | 1040.00 | 1,830.0 | 80.53 | 161.95 | 14.3 | 0.384 | 432.6 | 2,229,534 | 25,414,000 | 9.6 | 57.39 |
| | 1060.00 | 1,821.0 | 80.65 | 164.92 | 14.6 | 0.384 | 416.0 | 2,096,693 | 25,737,000 | 9.8 | 58.49 |
| | 1080.00 | 1,811.0 | 80.76 | 167.89 | 14.9 | 0.384 | 399.7 | 1,963,852 | 26,037,000 | 10.0 | 59.59 |
| | 1100.00 | 1,801.0 | 80.86 | 170.86 | 15.2 | 0.384 | 383.7 | 1,831,011 | 26,313,000 | 10.2 | 60.69 |
| | 1120.00 | 1,790.0 | 80.95 | 173.83 | 15.5 | 0.384 | 368.0 | 1,698,170 | 26,564,000 | 10.4 | 61.79 |
| | 1140.00 | 1,779.0 | 81.04 | 176.80 | 15.8 | 0.384 | 352.6 | 1,565,329 | 26,789,000 | 10.6 | 62.89 |
| | 1160.00 | 1,767.0 | 81.12 | 179.77 | 16.1 | 0.384 | 337.5 | 1,432,488 | 26,987,000 | 10.8 | 63.99 |
| | 1180.00 | 1,755.0 | 81.19 | 182.74 | 16.4 | 0.384 | 322.7 | 1,299,647 | 27,157,000 | 11.0 | 65.09 |
| | 1200.00 | 1,742.0 | 81.25 | 185.71 | 16.7 | 0.384 | 308.2 | 1,166,806 | 27,298,000 | 11.2 | 66.19 |
| | 1220.00 | 1,729.0 | 81.31 | 188.68 | 17.0 | 0.384 | 293.9 | 1,033,965 | 27,410,000 | 11.4 | 67.29 |
| | 1240.00 | 1,716.0 | 81.36 | 191.65 | 17.3 | 0.384 | 279.9 | 901,124 | 27,492,000 | 11.6 | 68.39 |
| | 1260.00 | 1,702.0 | 81.41 | 194.62 | 17.6 | 0.384 | 266.2 | 768,283 | 27,543,000 | 11.8 | 69.49 |
| | 1280.00 | 1,688.0 | 81.45 | 197.59 | 17.9 | 0.384 | 252.7 | 635,442 | 27,562,000 | 12.0 | 70.59 |
| | 1300.00 | 1,674.0 | 81.49 | 200.56 | 18.2 | 0.384 | 239.5 | 502,601 | 27,548,000 | 12.2 | 71.69 |
| | 1320.00 | 1,659.0 | 81.52 | 203.53 | 18.5 | 0.384 | 226.6 | 369,760 | 27,500,000 | 12.4 | 72.79 |
| | 1340.00 | 1,644.0 | 81.55 | 206.50 | 18.8 | 0.384 | 213.9 | 236,919 | 27,417,000 | 12.6 | 73.89 |
| | 1360.00 | 1,629.0 | 81.57 | 209.47 | 19.1 | 0.384 | 201.5 | 104,078 | 27,298,000 | 12.8 | 74.99 |
| | 1380.00 | 1,614.0 | 81.59 | 212.44 | 19.4 | 0.384 | 189.3 | 29,585 | 27,142,000 | 13.0 | 76.09 |
| | 1400.00 | 1,599.0 | 81.61 | 215.41 | 19.7 | 0.384 | 177.4 | 29,585 | 26,949,000 | 13.2 | 77.19 |
| | 1420.00 | 1,583.0 | 81.62 | 218.38 | 20.0 | 0.384 | 165.7 | 29,585 | 26,719,000 | 13.4 | 78.29 |
| | 1440.00 | 1,568.0 | 81.63 | 221.35 | 20.3 | 0.384 | 154.3 | 29,585 | 26,452,000 | 13.6 | 79.39 |
| | 1460.00 | 1,552.0 | 81.64 | 224.32 | 20.6 | 0.384 | 143.2 | 29,585 | 26,148,000 | 13.8 | 80.49 |
| | 1480.00 | 1,537.0 | 81.65 | 227.29 | 20.9 | 0.384 | 132.3 | 29,585 | 25,807,000 | 14.0 | 81.59 |
| | 1500.00 | 1,521.0 | 81.66 | 230.26 | 21.2 | 0.384 | 121.7 | 29,585 | 25,429,000 | 14.2 | 82.69 |
| | 1520.00 | 1,506.0 | 81.66 | 233.23 | 21.5 | 0.384 | 111.4 | 29,585 | 25,014,000 | 14.4 | 83.79 |
| | 1540.00 | 1,490.0 | 81.67 | 236.20 | 21.8 | 0.384 | 101.3 | 29,585 | 24,562,000 | 14.6 | 84.89 |
| | 1560.00 | 1,475.0 | 81.67 | 239.17 | 22.1 | 0.384 | 91.5 | 29,585 | 24,073,000 | 14.8 | 85.99 |
| | 1580.00 | 1,459.0 | 81.67 | 242.14 | 22.4 | 0.384 | 81.9 | 29,585 | 23,547,000 | 15.0 | 87.09 |
| | 1600.00 | 1,444.0 | 81.67 | 245.11 | 22.7 | 0.384 | 72.6 | 29,585 | 22,984,000 | 15.2 | 88.19 |
| | 1620.00 | 1,428.0 | 81.67 | 248.08 | 23.0 | 0.384 | 63.5 | 29,585 | 22,384,000 | 15.4 | 89.29 |
| | 1640.00 | 1,413.0 | 81.67 | 251.05 | 23.3 | 0.384 | 54.6 | 29,585 | 21,747,000 | 15.6 | 90.39 |
| | 1660.00 | 1,397.0 | 81.67 | 254.02 | 23.6 | 0.384 | 45.9 | 29,585 | 21,073,000 | 15.8 | 91.49 |
| | 1680.00 | 1,382.0 | 81.67 | 256.99 | 23.9 | 0.384 | 37.4 | 29,585 | 20,362,000 | 16.0 | 92.59 |
| | 1700.00 | 1,366.0 | 81.67 | 259.96 | 24.2 | 0.384 | 29.1 | 29,585 | 19,614,000 | 16.2 | 93.69 |
| | 1720.00 | 1,351.0 | 81.67 | 262.93 | 24.5 | 0.384 | 21.0 | 29,585 | 18,829,000 | 16.4 | 94.79 |
| | 1740.00 | 1,335.0 | 81.67 | 265.90 | 24.8 | 0.384 | 13.1 | 29,585 | 18,007,000 | 16.6 | 95.89 |
| | 1760.00 | 1,320.0 | 81.67 | 268.87 | 25.1 | 0.384 | 5.4 | 29,585 | 17,148,000 | 16.8 | 96.99 |
| | 1780.00 | 1,304.0 | 81.67 | 271.84 | 25.4 | 0.384 | 0.0 | 29,585 | 16,252,000 | 17.0 | 98.09 |
| | 1800.00 | 1,289.0 | 81.67 | 274.81 | 25.7 | 0.384 | 0.0 | 29,585 | 15,319,000 | 17.2 | 99.19 |
| | 1820.00 | 1,273.0 | 81.67 | 277.78 | 26.0 | 0.384 | 0.0 | 29,585 | 14,350,000 | 17.4 | 100.29 |
| | 1840.00 | 1,258.0 | 81.67 | 280.75 | 26.3 | 0.384 | 0.0 | 29,585 | 13,344,000 | 17.6 | 101.39 |
| | 1860.00 | 1,242.0 | 81.67 | 283.72 | 26.6 | 0.384 | 0.0 | 29,585 | 12,302,000 | 17.8 | 102.49 |
| | 1880.00 | 1,227.0 | 81.67 | 286.69 | 26.9 | 0.384 | 0.0 | 29,585 | 11,223,000 | 18.0 | 103.59 |
| | 1900.00 | 1,211.0 | 81.67 | 289.66 | 27.2 | 0.384 | 0.0 | 29,585 | 10,107,000 | 18.2 | 104.69 |
| | 1920.00 | 1,196.0 | 81.67 | 292.63 | 27.5 | 0.384 | 0.0 | 29,585 | 8,955,000 | 18.4 | 105.79 |
| | 1940.00 | 1,180.0 | 81.67 | 295.60 | 27.8 | 0.384 | 0.0 | 29,585 | 7,766,000 | 18.6 | 106.89 |
| | 1960.00 | 1,165.0 | 81.67 | 298.57 | 28.1 | 0.384 | 0.0 | 29,585 | 6,541,000 | 18.8 | 107.99 |
| | 1980.00 | 1,149.0 | 81.67 | 301.54 | 28.4 | 0.384 | 0.0 | 29,585 | 5,279,000 | 19.0 | 109.09 |
| | 2000.00 | 1,134.0 | 81.67 | 304.51 | 28.7 | 0.384 | 0.0 | 29,585 | 3,980,000 | 19.2 | 110.19 |
| | 2020.00 | 1,118.0 | 81.67 | 307.48 | 29.0 | 0.384 | 0.0 | 29,585 | 2,644,000 | 19.4 | 111.29 |
| | 2040.00 | 1,103.0 | 81.67 | 310.45 | 29.3 | 0.384 | 0.0 | 29,585 | 1,271,000 | 19.6 | 112.39 |
| | 2060.00 | 1,087.0 | 81.67 | 313.42 | 29.6 | 0.384 | 0.0 | 29,585 | 0 | 19.8 | 113.49 |
| | 2080.00 | 1,072.0 | 81.67 | 316.39 | 29.9 | 0.384 | 0.0 | 29,585 | 0 | 20.0 | 114.59 |
| | 2100.00 | 1,056.0 | 81.67 | 319.36 | 30.2 | 0.384 | 0.0 | 29,585 | 0 | 20.2 | 115.69 |
| | 2120.00 | 1,041.0 | 81.67 | 322.33 | 30.5 | 0.384 | 0.0 | 29,585 | 0 | 20.4 | 116.79 |
| | 2140.00 | 1,025.0 | 81.67 | 325.30 | 30.8 | 0.384 | 0.0 | 29,585 | 0 | 20.6 | 117.89 |
| | 2160.00 | 1,010.0 | 81.67 | 328.27 | 31.1 | 0.384 | 0.0 | 29,585 | 0 | 20.8 | 118.99 |
| | 2180.00 | 994.0 | 81.67 | 331.24 | 31.4 | 0.384 | 0.0 | 29,585 | 0 | 21.0 | 120.09 |
| | 2200.00 | 979.0 | 81.67 | 334.21 | 31.7 | 0.384 | 0.0 | 29,585 | 0 | 21.2 | 121.19 |
| | 2220.00 | 963.0 | 81.67 | 337.18 | 32.0 | 0.384 | 0.0 | 29,585 | 0 | 21.4 | 122.29 |
| | 2240.00 | 948.0 | 81.67 | 340.15 | 32.3 | 0.384 | 0.0 | 29,585 | 0 | 21.6 | 123.39 |
| | 2260.00 | 932.0 | 81.67 | 343.12 | 32.6 | 0.384 | 0.0 | 29,585 | 0 | 21.8 | 124.49 |
| | 2280.00 | 917.0 | 81.67 | 346.09 | 32.9 | 0.384 | 0.0 | 29,585 | 0 | 22.0 | 125.59 |
| | 2300.00 | 901.0 | 81.67 | 349.06 | 33.2 | 0.384 | 0.0 | 29,585 | 0 | 22.2 | 126.69 |
| | 2320.00 | 886.0 | 81.67 | 352.03 | 33.5 | 0.384 | 0.0 | 29,585 | 0 | 22.4 | 127.79 |
| | 2340.00 | 870.0 | 81.67 | 355.00 | 33.8 | 0.384 | 0.0 | 29,585 | 0 | 22.6 | 128.89 |
| | 2360.00 | 855.0 | 81.67 | 357.97 | 34.1 | 0.384 | 0.0 | 29,585 | 0 | 22.8 | 129.99 |
| | 2380.00 | 839.0 | 81.67 | 360.94 | 34.4 | 0.384 | 0.0 | 29,585 | 0 | 23.0 | 131.09 |
| | 2400.00 | 824.0 | 81.67 | 363.91 | 34.7 | 0.384 | 0.0 | 29,585 | 0 | 23.2 | 132.19 |
| | 2420.00 | 808.0 | 81.67 | 366.88 | 35.0 | 0.384 | 0.0 | 29,585 | 0 | 23.4 | 133.29 |
| | 2440.00 | 793.0 | 81.67 | 369.85 | 35.3 | 0.384 | 0.0 | 29,585 | 0 | 23.6 | 134.39 |
| | 2460.00 | 777.0 | 81.67 | 372.82 | 35.6 | 0.384 | 0.0 | 29,585 | 0 | 23.8 | 135.49 |
| | 2480.00 | 762.0 | 81.67 | 375.79 | 35.9 | 0.384 | 0.0 | 29,585 | 0 | 24.0 | 136.59 |
| | 2500.00 | 746.0 | 81.67 | 378.76 | 36.2 | 0.384 | 0.0 | 29,585 | 0 | 24.2 | 137.69 |
| | 2520.00 | 731.0 | 81.67 | 381.73 | 36.5 | 0.384 | 0.0 | 29,585 | 0 | 24.4 | 138.79 |
| | 2540.00 | 715.0 | 81.67 | 384.70 | 36.8 | 0.384 | 0.0 | 29,585 | 0 | 24.6 | 139.89 |
| | 2560.00 | 700.0 | 81.67 | 387.67 | 37.1 | 0.384 | 0.0 | 29,585 | 0 | 24.8 | 140.99 |
| | 2580.00 | 684.0 | 81.67 | 390.64 | 37.4 | 0.384 | 0.0 | 29,585 | 0 | 25.0 | 142.09 |
| | 2600.00 | 669.0 | 81.67 | 393.61 | 37.7 | 0.384 | 0.0 | 29,585 | 0 | 25.2 | 143.19 |
| | 2620.00 | 653.0 | 81.67 | 396.58 | 38.0 | 0.384 | 0.0 | 29,585 | 0 | 25.4 | 144.29 |
| | 2640.00 | 638.0 | 81.67 | 399.55 | 38.3 | 0.384 | 0.0 | 29,585 | 0 | 25.6 | 145.39 |
| | 2660.00 | 622.0 | 81.67 | 402.52 | 38.6 | 0.384 | 0.0 | 29,585 | 0 | 25.8 | 146.49 |
| | 2680.00 | 607.0 | 81.67 | 405.49 | 38.9 | 0.384 | 0.0 | 29,585 | 0 | 26.0 | 147.59 |
| | 2700.00 | 591.0 | 81.67 | 408.46 | 39.2 | 0.384 | 0.0 | 29,585 | 0 | 26.2 | 148.69 |
| | 2720.00 | 576.0 | 81.67 | 411.43 | 39.5 | 0.384 | 0.0 | 29,585 | 0 | 26.4 | 149.79 |
| | 2740.00 | 560.0 | 81.67 | 414.40 | 39.8 | 0.384 | 0.0 | 29,585 | 0 | 26.6 | 150.89 |
| | 2760.00 | 545.0 | 81.67 | 417.37 | 40.1 | 0.384 | 0.0 | 29,585 | 0 | 26.8 | 151.99 |
| | 2780.00 | 529.0 | 81.67 | 420.34 | 40.4 | 0.384 | 0.0 | 29,585 | 0 | 27.0 | 153.09 |
| | 2800.00 | 514.0 | 81.67 | 423.31 | 40.7 | 0.384 | 0.0 | 29,585 | 0 | 27.2 | 154.19 |
| | 2820.00 | 498.0 | 81.67 | 426.28 | 41.0 | 0.384 | 0.0 | 29,585 | 0 | 27.4 | 155.29 |
| | 2840.00 | 483.0 | 81.67 | 429.25 | 41.3 | 0.384 | 0.0 | 29,585 | 0 | 27.6 | 156.39 |
| | 2860.00 | 467.0 | 81.67 | 432.22 | 41.6 | 0.384 | 0.0 | 29,585 | 0 | 27.8 | 157.49 |
| | 2880.00 | 452.0 | 81.67 | 435.19 | 41.9 | 0.384 | 0.0 | 29,585 | 0 | 28.0 | 158.59 |
| | 2900.00 | 436.0 | 81.67 | 438.16 | 42.2 | 0.384 | 0.0 | 29,585 | 0 | 28.2 | 159.69 |
| | 2920.00 | 421.0 | 81.67 | 441.13 | 42.5 | 0.384 | 0.0 | 29,585 | 0 | 28.4 | 160.79 |
| | 2940.00 | 405.0 | 81.67 | 444.10 | 42.8 | 0.384 | 0.0 | 29,585 | 0 | 28.6 | 161.89 |
| | 2960.00 | 390.0 | 81.67 | 447.07 | 43.1 | 0.384 | 0.0 | 29,585 | 0 | 28.8 | 162.99 |
| | 2980.00 | 374.0 | 81.67 | 450.04 | 43.4 | 0.384 | 0.0 | 29,585 | 0 | 29.0 | 164.09 |
| | 3000.00 | 359.0 | 81.67 | 453.01 | 43.7 | 0.384 | 0.0 | 29,585 | 0 | 29.2 | 165.19 |
| | 3020.00 | 343.0 | 81.67 | 455.98 | 44.0 | 0.384 | 0.0 | 29,585 | 0 | 29.4 | 166.29 |
| | 3040.00 | 328.0 | 81.67 | 458.95 | 44.3 | 0.384 | 0.0 | 29,585 | 0 | 29.6 | 167.39 |
| | 3060.00 | 312.0 | 81.67 | 461.92 | 44.6 | 0.384 | 0.0 | 29,585 | 0 | 29.8 | 168.49 |
| | 3080.00 | 297.0 | 81.67 | 464.89 | 44.9 | 0.384 | 0.0 | 29,585 | 0 | 30.0 | 169.59 |
| | 3100.00 | 281.0 | 81.67 | 467.86 | 45.2 | 0.384 | 0.0 | 29,585 | 0 | 30.2 | 170.69 |
| | 3120.00 | 266.0 | 81.67 | 470.83 | 45.5 | 0.384 | 0.0 | 29,585 | 0 | 30.4 | 171.79 |
| | 3140.00 | 250.0 | 81.67 | 473.80 | 45.8 | 0.384 | 0.0 | 29,585 | 0 | 30.6 | 172.89 |
| | 3160.00 | 235.0 | 81.67 | 476.77 | 46.1 | 0.384 | 0.0 | 29,585 | 0 | 30.8 | 173.99 |
| | 3180.00 | 219.0 | 81.67 | 479.74 | 46.4 | 0.384 | 0.0 | 29,585 | 0 | 31.0 | 175.09 |
| | 3200.00 | 204.0 | 81.67 | 482.71 | 46.7 | 0.384 | 0.0 | 29,585 | 0 | 31.2 | 176.19 |
| | 3220.00 | 188.0 | 81.67 | 485.68 | 47.0 | 0.384 | 0.0 | 29,585 | 0 | 31.4 | 177.29 |
| | 3240.00 | 173.0 | 81.67 | 488.65 | 47.3 | 0.384 | 0.0 | 29,585 | 0 | 31.6 | 178.39 |
| | 3260.00 | 157.0 | 81.67 | 491.62 | 47.6 | 0.384 | 0.0 | 29,585 | 0 | 31.8 | 179.49 |
| | 3280.00 | 142.0 | 81.67 | 494.59 | 47.9 | 0.384 | 0.0 | 29,585 | 0 | 32.0 | 180.59 |
| | 3300.00 | 126.0 | 81.67 | 497.56 | 48.2 | 0.384 | 0.0 | 29,585 | 0 | 32.2 | 181.69 |
| | 3320.00 | 111.0 | 81.67 | 500.53 | 48.5 | 0.384 | 0.0 | 29,585 | 0 | 32.4 | 182.79 |
| | 3340.00 | 95.0 | 81.67 | 503.50 | 48.8 | 0.384 | 0.0 | 29,585 | 0 | 32.6 | 183.89 |
| | 3360.00 | 80.0 | 81.67 | 506.47 | 49.1 | 0.384 | 0.0 | 29,585 | 0 | 32.8 | 184.99 |
| | 3380.00 | 64.0 | 81.67 | 509.44 | 49.4 | 0.384 | 0.0 | 29,585 | 0 | 33.0 | 186.09 |
| | 3400.00 | 49.0 | 81.67 | 512.41 | 49.7 | 0.384 | 0.0 | 29,585 | 0 | 33.2 | 187.19 |
| | 3420.00 | 33.0 | 81.67 | 515.38 | 50.0 | 0.384 | 0.0 | 29,585 | 0 | 33.4 | 188.29 |
| | 3440.00 | 18.0 | 81.67 | 518.35 | 50.3 | 0.384 | 0.0 | 29,585 | 0 | 33.6 | 189.39 |
| | 3460.00 | 2.0 | 81.67 | 521.32 | 50.6 | 0.384 | 0.0 | 29,585 | 0 | 33.8 | 190.49 |
| | 3480.00 | 0.0 | 81.67 | 524.29 | 50.9 | 0.384 | 0.0 | 29,585 | 0 | 34.0 | 191.59 |
| | 3500.00 | 0.0 | 81.67 | 527.26 | 51.2 | 0.384 | 0.0 | 29,585 | 0 | 34.2 | 192.69 |
| | 3520.00 | 0.0 | 81.67 | 530.23 | 51.5 | 0.384 | 0.0 | 29,585 | 0 | 34.4 | 193.79 |
| | 3540.00 | 0.0 | 81.67 | 533.20 | 51.8 | 0.384 | 0.0 | 29,585 | 0 | 34.6 | 194.89 |
| | 3560.00 | 0.0 | 81.67 | 536.17 | 52.1 | 0.384 | 0.0 | 29,585 | 0 | 34.8 | 195.99 |
| | 3580.00 | 0.0 | 81.67 | 539.14 | 52.4 | 0.384 | 0.0 | 29,585 | 0 | 35.0 | 197.09 |
| | 3600.00 | 0.0 | 81.67 | 542.11 | 52.7 | 0.384 | 0.0 | 29,585 | 0 | 35.2 | 198.19 |
| | 3620.00 | 0.0 | 81.67 | 545.08 | 53.0 | 0.384 | 0.0 | 29,585 | 0 | 35.4 | 199.29 |
| | 3640.00 | 0.0 | 81.67 | 548.05 | 53.3 | 0.384 | 0.0 | 29,585 | 0 | 35.6 | 200.39 |
| | 3660.00 | 0.0 | 81.67 | 551.02 | 53.6 | 0.384 | 0.0 | 29,585 | 0 | 35.8 | 201.49 |
| | 3680.00 | 0.0 | 81.67 | 553.99 | 53.9 | 0.384 | 0.0 | 29,585 | 0 | 36.0 | 202.59 |
| | 3700.00 | 0.0 | 81.67 | 556.96 | 54.2 | 0.384 | 0.0 | 29,585 | 0 | 36.2 | 203.69 |
| | 3720.00 | 0.0 | 81.67 | 559.93 | 54.5 | 0.384 | 0.0 | 29,585 | 0 | 36.4 | 204.79 |
| | 3740.00 | 0.0 | 81.67 | 562.90 | 54.8 | 0.384 | 0.0 | 29,585 | 0 | 36.6 | 205.89 |
| | 3760.00 | 0.0 | 81.67 | 565.87 | 55.1 | 0.384 | 0.0 | 29,585 | 0 | 36.8 | 206.99 |
| | 3780.00 | 0.0 | 81.67 | 568.84 | 55.4 | 0.384 | 0.0 | 29,585 | 0 | 37.0 | 208.09 |
| | 3800.00 | 0.0 | 81.67 | 571.81 | 55.7 | 0.384 | 0.0 | 29,585 | 0 | 37.2 | 209.19 |
| | 3820.00 | 0.0 | 81.67 | 574.78 | 56.0 | 0.384 | 0.0 | 29,585 | 0 | 37.4 | 210.29 |
| | 3840.00 | 0.0 | 81.67 | 577.75 | 56.3 | 0.384 | 0.0 | 29,585 | 0 | 37.6 | 211.39 |
| | 3860.00 | 0.0 | 81.67 | 580.72 | 56.6 | 0.384 | 0.0 | 29,585 | 0 | 37.8 | 212.49 |
| | 3880.00 | 0.0 | 81.67 | 583.69 | 56.9 | 0.384 | 0.0 | 29,585 | 0 | 38.0 | 213.59 |
| | 3900.00 | 0.0 | 81.67 | 586.66 | 57.2 | 0.384 | 0.0 | 29,585 | 0 | 38.2 | 214.69 |
| | 3920.00 | 0.0 | 81.67 | 589.63 | 57.5 | 0.384 | 0.0 | 29,585 | 0 | 38.4 | 215.79 |
| | 3940.00 | 0.0 | 81.67 | 592.60 | 57.8 | 0.384 | 0.0 | 29,585 | 0 | 38.6 | 216.89 |
| | 3960.00 | 0.0 | 81.67 | 595.57 | 58.1 | 0.384 | 0.0 | 29,585 | 0 | 38.8 | 217.99 |
| | 3980.00 | 0.0 | 81.67 | 598.54 | 58.4 | 0.384 | 0.0 | 29,585 | 0 | 39.0 | 219.09 |
| | 4000.00 | 0.0 | 81.67 | 601.51 | 58.7 | 0.384 | 0.0 | 29,585 | 0 | 39.2 | 220.19 |
| | 4020.00 | 0.0 | 81.67 | 604.48 | 59.0 | 0.384 | 0.0 | 29,585 | 0 | 39.4 | 221.29 |
| | 4040.00 | 0.0 | 81.67 | 607.45 | 59.3 | 0.384 | 0.0 | 29,585 | 0 | 39.6 | 222.39 |
| | 4060.00 | 0.0 | 81.67 | 610.42 | 59.6 | 0.384 | 0.0 | 29,585 | 0 | 39.8 | 223.49 |
| | 4080.00 | 0.0 | 81.67 | 613.39 | 59.9 | 0.384 | 0.0 | 29,585 | 0 | 40.0 | 224.59 |
| | 4100.00 | 0.0 | 81.67 | 616.36 | 60.2 | 0.384 | 0.0 | 29,585 | 0 | 40.2 | 225.69 |
| | 4120.00 | 0.0 | 81.67 | 619.33 | 60.5 | 0.384 | 0.0 | 29,585 | 0 | 40.4 | 226.79 |
| | 4140.00 | 0.0 | 81.67 | 622.30 | 60.8 | 0.384 | 0.0 | 29,585 | 0 | 40.6 | 227.89 |
| | 4160.00 | 0.0 | 81.67 | 625.27 | 61.1 | 0.384 | 0.0 | 29,585 | 0 | 40.8 | 228.99 |
| | 4180.00 | 0.0 | 81.67 | 628.24 | 61.4 | 0.384 | 0.0 | 29,585 | 0 | 41.0 | 230.09 |
| | 4200.00 | 0.0 | 81.67 | 631.21 | 61.7 | 0.384 | 0.0 | 29,585 | 0 | 41.2 | 231.19 |
| | 4220.00 | 0.0 | 81.67 | 634.18 | 62.0 | 0.384 | 0.0 | 29,585 | 0 | 41.4 | 232.29 |
| | 4240.00 | 0.0 | 81.67 | 637.15 | 62.3 | 0.384 | 0.0 | 29

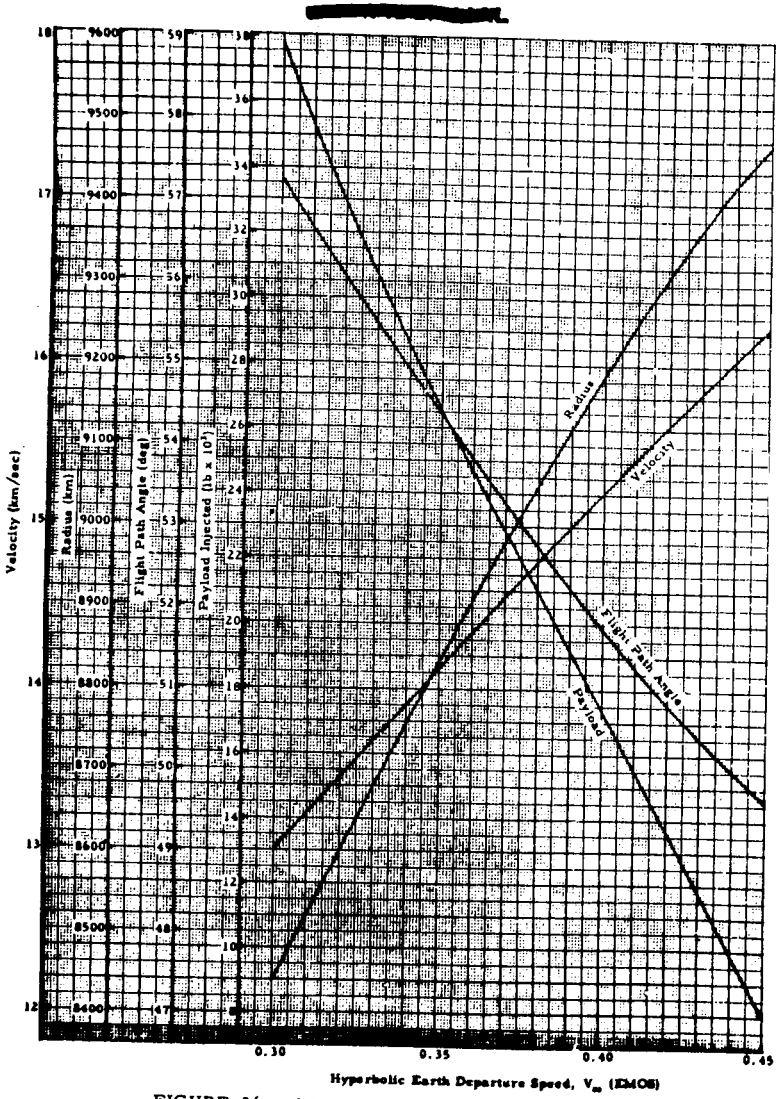


FIGURE 26. TRANSFER INJECTION CONDITIONS FOR THE MLV SATURN V-2\CENTAUR VEHICLE







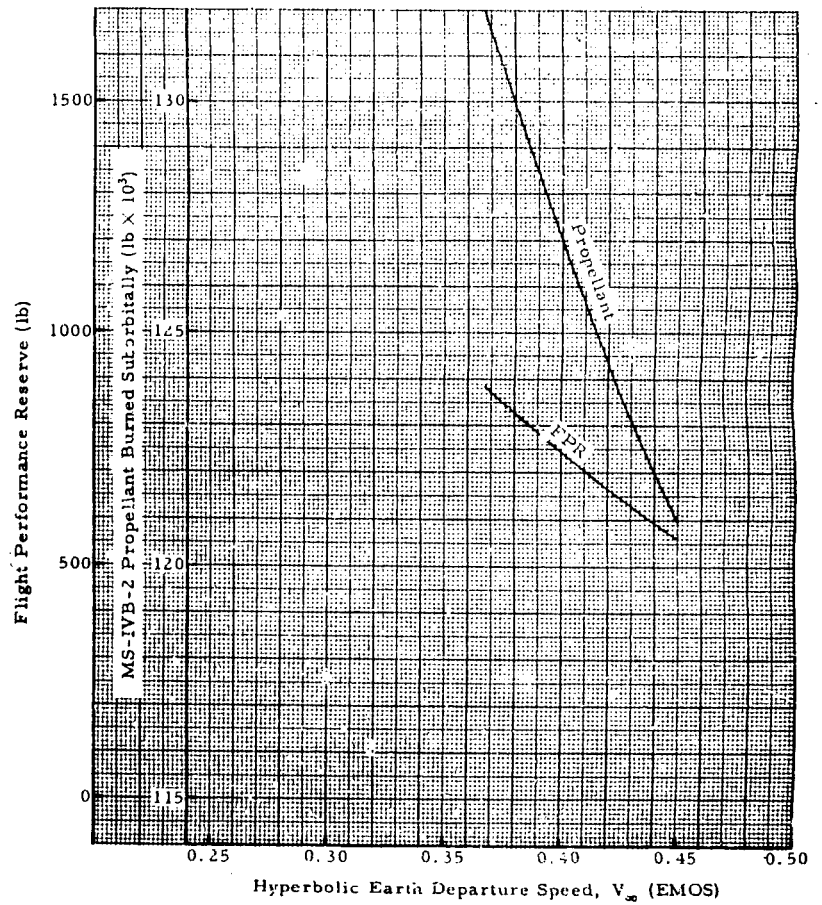


FIGURE 27. MS-IVB-2 PROPELLANT WEIGHT SUMMARY AS A FUNCTION OF HYPERBOLIC EXCESS VELOCITY FOR THE MLV SATURN V-2/ CENTAUR VEHICLE

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## I. MLV-SATURN V-3

The MLV-Saturn V-3 configuration (Figure 28) is the same as the MLV-Saturn V-2 configuration except that the second stage has been replaced by a new stage having a propellant capacity of 1,200,000 lb and containing 5 X RE-315 engines with a thrust of 315,000 lb each. The Instrument Unit is located forward of the MS-IVB-2 stage. Payload volume is in the 260-inch-diameter,583-inch (maximum) long cylindrical section, and the double angle nose cone. Overall length of the vehicle is 4920 inches.

The MLV-Saturn V-3 vehicle was the largest three-stage concept studied. The payloads for this vehicle were, of course, much greater than any of the other three-stage vehicles studied.

A weight summary for this vehicle is given in Table 19 and a corresponding trajectory is given in Table 20. Figures 29 and 30 represent performance parameters for this vehicle. Figure 29 contains the transfer injection conditions and Figure 30 contains a propellant weight summary for the MS-IVB-2 third stage.

For ultra high energy missions, i.e., Jupiter or Saturn, this vehicle is definitely useful. The payloads range from 27,000 to 37,000 lb for such a mission.



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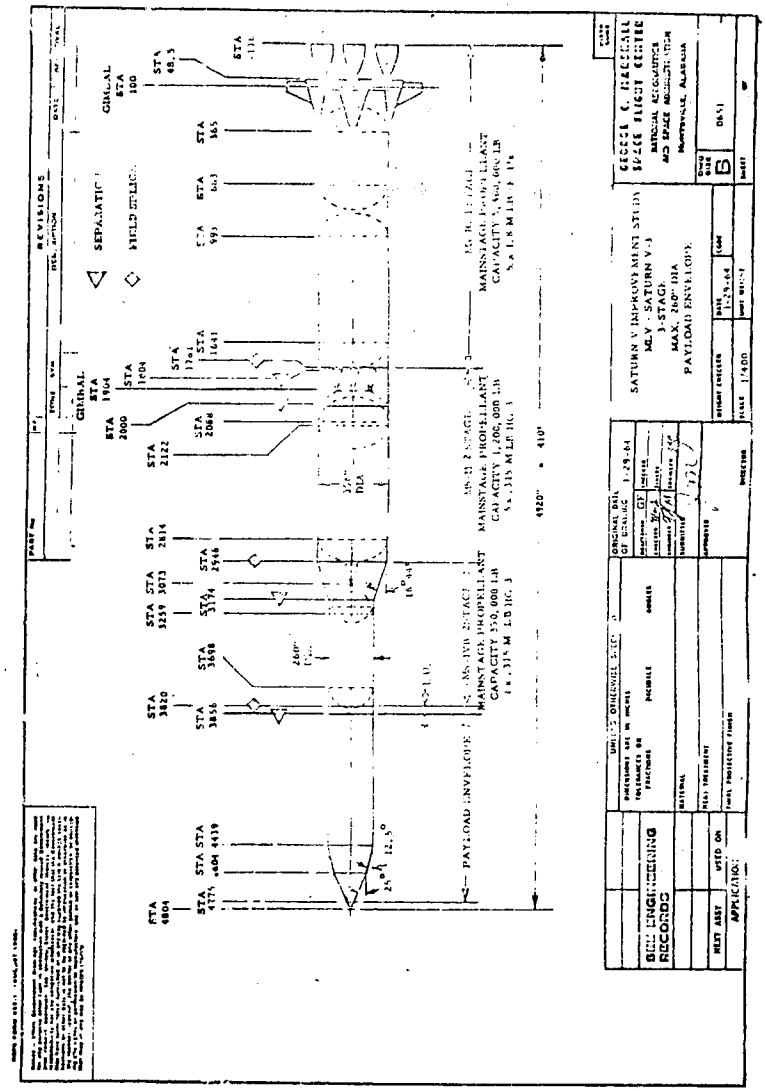


FIGURE 28. CONCEPTIONAL DESIGN OF THE MLV SATURN V-3 VEHICLE

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Table 19. Vehicle Weight Summary for Three-Stage MLV-Saturn V-3 With Suborbital Start MS-IVB-2

$E = 60 \times 10^6\ m^2/sec^2$
$V_\infty = 0.3678$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F-1 |
| F-1 Thrust (Sea Level) | | 1,800,000 lb |
| F-1 $I_{sp}$ (Sea Level) | | 271 sec |
| Lift-off Weight | | 7,200,000 lb |
| Propellant Loading | | 4,999,100 lb |
| Cutoff Weight | | 2,200,900 lb |
| MS-IC-1 Dry Stage Weight | | 349,000 lb |
| Structure | 188,334 lb | |
| Propulsion System and Accessories | 144,513 lb | |
| Equipment and Instrumentation | 10,000 lb | |
| Miscellaneous | 6,153 lb | |
| MS-IC-1/MS-II-2 Interstage | | 1,750 lb |
| Propulsion Performance Reserve | | 13,100 lb |
| Thrust Decay Propellants | | 6,300 lb |
| MS-IC-1 Residuals | | 60,747 lb |
| Fuel - Pressure Gas | 890 lb | |
| Fuel - Trapped | 16,665 lb | |
| Oxidizer - Pressure Gas | 7,900 lb | |
| Oxidizer - Trapped | 31,765 lb | |
| Actuator Fuel Trapped | 630 lb | |
| Retro-rocket Propellant | 2,000 lb | |
| Frost | 865 lb | |
| Nitrogen | 32 lb | |
| Weight Loss During MS-IC-1/MS-II-2 Sep/Start | | 6,260 lb |
| Ullage Rocket Propellants | 2,960 lb | |
| Fuel - Engine Start | 1,120 lb | |
| Oxidizer - Engine Start | 2,180 lb | |







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Table 19. Continued

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 5 × RE-315 |
| RE-315 Thrust (Vacuum) | | 315,000 lb |
| RE-315 $I_{sp}$ (Vacuum) | | 444.6 sec |
| Lift-off Weight | | 1,763,743 lb |
| Propellant Loading | | 1,200,000 lb |
| MS-IC-1/MS-II-2 Long Interstage | | 11,940 lb* |
| Structure | 10.150 lb | |
| Electrical | 300 lb | |
| Ullage Hardware | 1,490 lb | |
| Cutoff Weight | | 551,803 lb |
| MS-II Second Stage Weight | | 109,000 lb |
| Structure | 72,720 lb | |
| Propulsion System and Accessories | 27,800 lb | |
| Equipment | 6,412 lb | |
| Miscellaneous | 2,068 lb | |
| Propulsion Performance Reserve | | 1,390 lb |
| Thrust Decay Propellants | | 650 lb |
| Residuals | | 12,010 lb |
| Fuel - Pressure Gas | 2,240 lb | |
| Fuel - Trapped | 1,750 lb | |
| Oxidizer - Pressure Gas | 5,500 lb | |
| Oxidizer - Trapped | 2,420 lb | |
| Service Items | 100 lb | |
| MS-II-2/MS-IVB-2 Interstage | | 9,430 lb |
| MS-II-2 Retro-rockets | | 3,000 lb |
| Weight Loss - MS-II-1/MS-IVB-2 Sep/Start | | 725 lb |

*Dropped 30 sec after Second Stage ignition.

[redacted]

Table 19. Concluded

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 1 × RE-315 |
| RE-315 Thrust (Vacuum) | | 315,000 lb |
| RE-315 $I_{sp}$ (Vacuum) | | 444.6 sec |
| Lift-off Weight | | 415,598 lb |
| Propellant - First Burn | | 54,386 lb |
| Cutoff Weight at 185 km Orbit | | 361,212 lb |
| Weight Loss | | 8,290 lb |
| Fuel Vented | 5,565 lb | |
| Auxiliary Propellant - Ullage | 1,265 lb | |
| Auxiliary Propellant - Chilldown | 500 lb | |
| Auxiliary Propellant - Attitude Control | 170 lb | |
| Thrust Decay | 130 lb | |
| Thrust Buildup | 660 lb | |
| Lift-off Weight - Second Burn | | 352,922 lb |
| Propellant - Second Burn | | 294,100 lb |
| Cutoff Weight | | 58,822 lb |
| MS-IVB-2 Dry Stage Weight | | 34,800 lb |
| Structure | 20,060 lb | |
| Propulsion System and Accessories | 7,997 lb | |
| Equipment and Instrumentation | 6,080 lb | |
| Miscellaneous | 663 lb | |
| Propulsion Performance Reserve | | 575 lb |
| Thrust Decay Propellants | | 130 lb |
| Residuals | | 3,640 lb |
| Fuel - Trapped | 800 lb | |
| Fuel - Pressure Gas | 1,300 lb | |
| Oxidizer - Trapped | 700 lb | |
| Oxidizer - Pressure Gas | 690 lb | |
| Auxiliary Propellant Reserve | 115 lb | |
| Environmental Control Fluids | 35 lb | |
| Instrument Unit | | 3,500 lb |
| Injected Payload Weight | | 16,177 lb |



[redacted]

[redacted]

Table 20. Typical Trajectory Printout for MLV Saturn V-3 Vehicle with Suborbital Start MS-IVB-2

$E = 60\ km^2/sec^2$

$V_m = 0.3678$

| Stage | Time (sec) | Velocity (m/sec) | Altitude (km) | Flight Path Angle (deg) | Range (km) | CD | Q (lb/ft²) | Weight (lbs) | Thrust (lbs) | Mach | Ax. Accel. (m/sec²) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MS-IC-1 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.584 | 0.0 | 7,200,000 | 9,000,000 | 0.0 | 2.44 |
| | 20.00 | 61.3 | 0.57 | 1.01 | 0.0 | 0.584 | 45.6 | 6,535,793 | 9,074,309 | 0.2 | 3.76 |
| | 40.00 | 154.7 | 2.63 | 8.21 | 0.2 | 0.584 | 234.0 | 5,871,587 | 9,313,476 | 0.5 | 5.65 |
| | 44.00 | 177.8 | 3.31 | 10.39 | 0.3 | 0.584 | 290.6 | 5,738,745 | 9,378,730 | 0.5 | 6.13 |
| | 48.00 | 203.3 | 4.05 | 12.75 | 0.4 | 0.584 | 351.7 | 5,605,904 | 9,447,871 | 0.6 | 6.65 |
| | 52.00 | 231.1 | 4.90 | 15.25 | 0.6 | 0.584 | 415.2 | 5,473,063 | 9,519,636 | 0.7 | 7.23 |
| | 56.00 | 261.2 | 5.84 | 17.85 | 0.9 | 0.584 | 478.7 | 5,340,222 | 9,592,595 | 0.8 | 7.85 |
| | 60.00 | 293.9 | 6.89 | 20.51 | 1.3 | 0.584 | 539.1 | 5,207,380 | 9,665,207 | 0.9 | 8.52 |
| | 64.00 | 328.8 | 8.04 | 23.19 | 1.7 | 0.843 | 550.8 | 5,074,539 | 9,735,860 | 1.1 | 8.99 |
| | 68.00 | 366.1 | 9.31 | 25.87 | 2.3 | 0.914 | 630.0 | 4,941,698 | 9,802,714 | 1.2 | 9.67 |
| | 72.00 | 406.4 | 10.68 | 28.52 | 3.0 | 0.885 | 655.3 | 4,808,856 | 9,865,607 | 1.4 | 10.51 |
| | 72.96 | 416.6 | 11.03 | 29.15 | 3.2 | 0.870 | 659.6 | 4,776,811 | 9,878,870 | 1.4 | 10.73 |
| | 76.00 | 450.3 | 12.16 | 31.12 | 3.9 | 0.824 | 644.5 | 4,676,015 | 9,920,217 | 1.5 | 11.48 |
| | 80.00 | 498.3 | 13.76 | 33.64 | 4.9 | 0.754 | 613.8 | 4,543,174 | 9,967,195 | 1.7 | 12.52 |
| | 100.00 | 804.9 | 23.61 | 44.72 | 13.1 | 0.458 | 342.3 | 3,878,967 | 10,096,453 | 2.7 | 18.26 |
| | 120.00 | 1234.8 | 36.73 | 53.02 | 28.3 | 0.334 | 101.9 | 3,214,761 | 10,126,440 | 3.9 | 24.96 |
| | 140.00 | 1818.4 | 53.47 | 58.96 | 53.3 | 0.271 | 24.8 | 2,550,554 | 10,130,945 | 5.4 | 33.95 |
| | 150.00 | 2187.5 | 63.41 | 61.20 | 70.5 | 0.242 | 11.8 | 2,218,451 | 10,131,414 | 7.1 | 40.14 |
| | 150.00 | 2553.7 | 63.41 | 63.63 | 70.5 | 0.242 | 0.0 | 2,218,451 | 10,131,414 | 8.2 | 40.81 |
| | 150.53 | 2575.3 | 63.97 | 65.72 | 71.7 | 0.242 | 0.0 | 2,200,900 | 10,131,428 | 8.4 | 41.19 |
| MS-IIC-2 | 150.53 | 2575.3 | 63.97 | 65.72 | 71.7 | 0.242 | 0.0 | 1,761,743 | 1,575,000 | 8.4 | 4.80 |
| | 160.00 | 2622.8 | 73.77 | 67.36 | 94.0 | 0.242 | 0.0 | 1,730,188 | 1,575,000 | 9.4 | 5.23 |
| | 180.53 | 2739.9 | 93.38 | 70.76 | 144.7 | 0.242 | 0.0 | 1,657,468 | 1,575,000 | 9.9 | 5.62 |
| | 180.53 | 2739.9 | 93.38 | 70.76 | 144.7 | 0.242 | 0.0 | 1,645,528 | 1,575,000 | 0.0 | 5.69 |
| | 184.00 | 2761.7 | 96.49 | 71.27 | 153.6 | 0.242 | 0.0 | 1,633,228 | 1,575,000 | 0.0 | 5.67 |
| | 200.00 | 2868.4 | 110.11 | 72.45 | 195.9 | 0.242 | 0.0 | 1,575,548 | 1,575,000 | 0.0 | 6.06 |
| | 300.00 | 3792.1 | 170.26 | 84.13 | 511.9 | 0.242 | 0.0 | 1,222,297 | 1,575,000 | 0.0 | 10.74 |
| | 400.00 | 5227.5 | 189.87 | 89.67 | 944.8 | 0.242 | 0.0 | 868,046 | 1,575,000 | 0.0 | 17.05 |
| | 489.27 | 7189.2 | 186.93 | 90.20 | 1476.6 | 0.242 | 0.0 | 551,803 | 1,575,000 | 0.0 | 27.84 |
| MS-IVB-2 | 489.27 | 7189.2 | 186.93 | 90.20 | 1476.6 | 0.242 | 0.0 | 415,598 | 315,000 | 0.0 | 7.28 |
| | 500.00 | 7269.3 | 186.64 | 90.23 | 1552.0 | 0.242 | 0.0 | 407,997 | 315,000 | 0.0 | 7.44 |
| | 546.03 | 7797.3 | 185.19 | 90.00 | 2035.0 | 0.242 | 0.0 | 361,212 | 315,000 | 0.0 | 8.55 |
| | 566.03 | 7797.3 | 185.19 | 90.00 | 2035.0 | 0.242 | 0.0 | 352,922 | 315,000 | 0.0 | 8.75 |
| | 600.00 | 8104.1 | 185.66 | 90.82 | 2397.4 | 0.242 | 0.0 | 328,857 | 315,000 | 0.0 | 9.36 |
| | 700.00 | 9150.6 | 196.52 | 88.48 | 3431.2 | 0.242 | 0.0 | 258,007 | 315,000 | 0.0 | 11.73 |
| | 800.00 | 10503.5 | 247.11 | 85.35 | 4078.9 | 0.242 | 0.0 | 187,157 | 315,000 | 0.0 | 15.77 |
| | 900.00 | 12467.9 | 389.08 | 80.11 | 5158.3 | 0.242 | 0.0 | 116,306 | 315,000 | 0.0 | 25.06 |
| | 981.14 | 15288.5 | 638.07 | 73.88 | 6163.1 | 0.242 | 0.0 | 58,822 | 315,000 | 0.0 | 50.26 |

[redacted]



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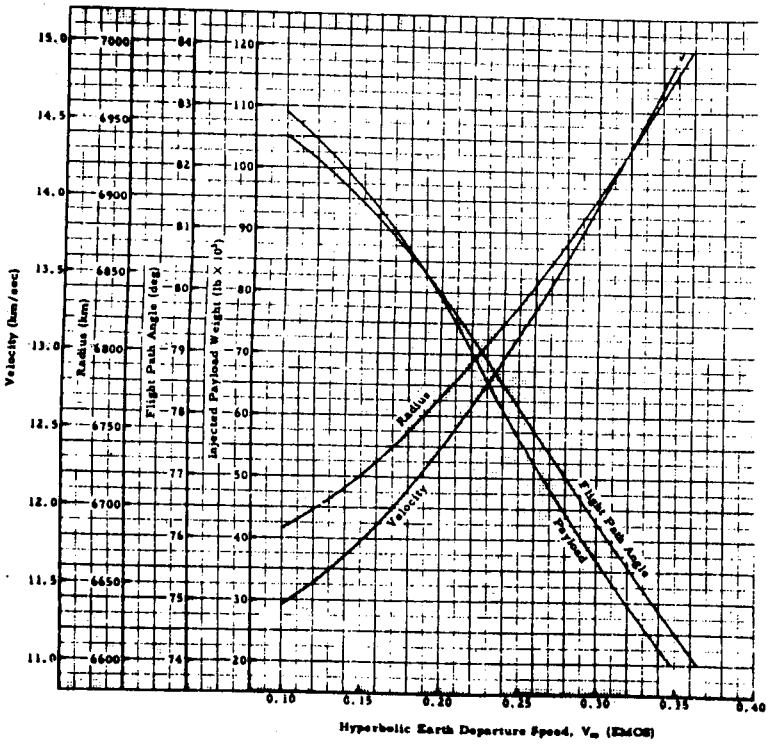


FIGURE 29. TRANSFER INJECTION CONDITIONS FOR THE MLV SATURN V-3 VEHICLE







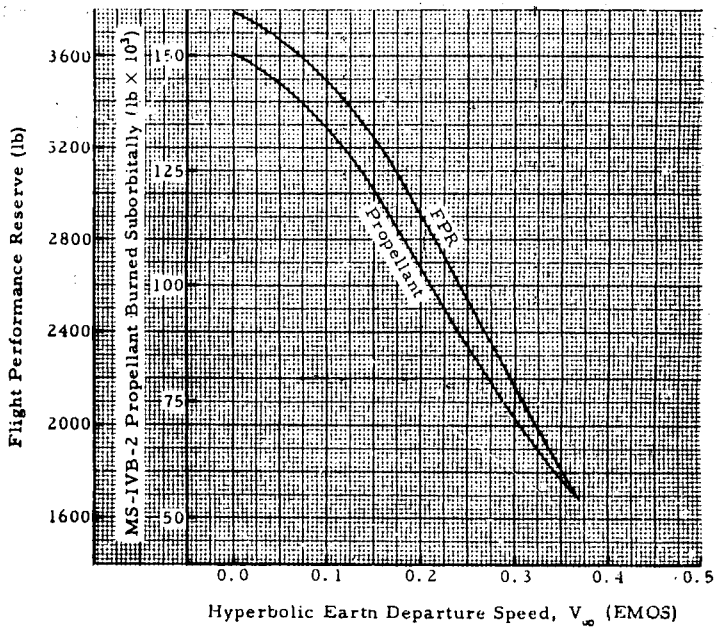


FIGURE 30. MS-IVB-2 PROPELLANT WEIGHT SUMMARY AS A FUNCTION OF HYPERBOLIC EXCESS VELOCITY FOR THE MLV SATURN V-3 VEHICLE

[redacted]

## J. MLV-SATURN V-3/CENTAUR

The MLV-Saturn V-3/Centaur launch vehicle (Figure 31) is a MLV-Saturn V-3 vehicle with a Centaur stage added inside of the payload shroud. The Instrument Unit is located forward the MS-IVB-2 stage. A single Instrument Unit is housed in the 260-inch-diameter Centaur shroud. The vehicle payload volume is 234-inch diameter by 234-inch-long cylinder plus the standard double angle nose cone. At lift-off, the vehicle is 4920 inches long.

Tables 21 and 22 contain a vehicle weight summary and trajectory for the MLV-Saturn V-3/Centaur vehicle. Figure 32 shows the transfer injection conditions as a function of the earth hyperbolic excess speed. The MS-IVB-2 propellant burned prior to orbit and flight performance reserve is shown in Figure 33.



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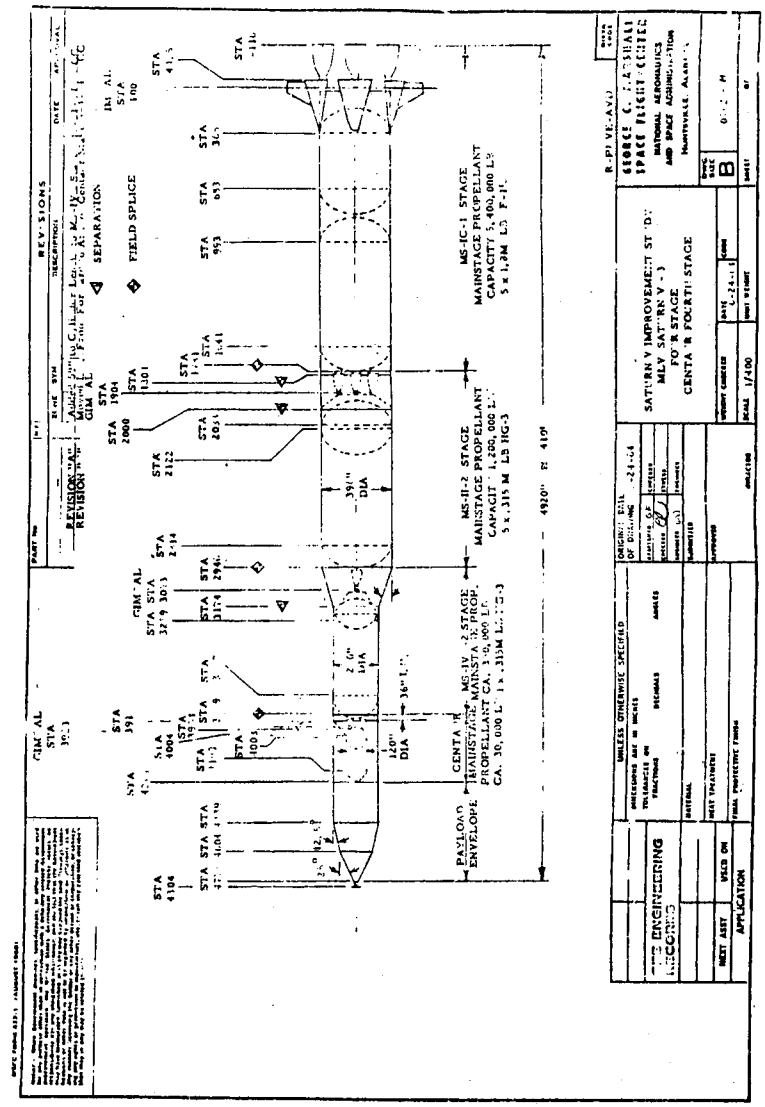


FIGURE 31. CONCEPTIONAL DESIGN OF THE MLV SATURN V-3/CENTAUR VEHICLE



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Table 21. Vehicle Weight Summary for Three Stage MLV-Saturn V-3 + Centaur with Suborbital Start MS-IVB-2

$E = 60 \times 10^6 \text{ in}^2/\text{sec}^2$

$V_\infty = 0.3678$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F-1 |
| F-1 Thrust (Sea Level) | | 1,800,000 lb |
| F-1 $I_{sp}$ (Sea Level) | | 271 sec |
| Lift-off Weight | | 7,200,000 lb |
| Propellant Loading | | 4,946,550 lb |
| Cutoff Weight | | 2,253,450 lb |
| MS-IC-1 Dry Stage Drop Weight | | 349,000 lb |
| Structure | 188,334 lb | |
| Propulsion System and Accessories | 144,513 lb | |
| Equipment and Instrumentation | 10,000 lb | |
| Miscellaneous | 6,153 lb | |
| MS-IC-1/MS-II-2 Interstage | | 1,750 lb |
| Propulsion Performance Reserve | | 13,100 lb |
| Thrust Decay Propellants | | 6,300 lb |
| MS-IC-1 Residuals | | 60,747 lb |
| Fuel - Pressure Gas | 890 lb | |
| Fuel - Trapped | 16,665 lb | |
| Oxidizer - Pressure Gas | 7,900 lb | |
| Oxidizer - Trapped | 31,765 lb | |
| Actuator Fuel Trapped | 630 lb | |
| Retro-rocket Propellant | 2,000 lb | |
| Frost | 865 lb | |
| Nitrogen | 32 lb | |
| Weight Loss During MS-IC-1/MS-II-2 Sep/Start | | 6,260 lb |
| Ullage Rocket Propellants | 2,960 lb | |
| Fuel - Engine Start | 1,120 lb | |
| Oxidizer - Engine Start | 2,180 lb | |





Table 21. Continued

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 5 × RE-315 |
| RE-315 Thrust (Vacuum) | | 315,000 lb |
| RE-315 $I_{sp}$ (Vacuum) | | 441.6 sec |
| Lift-off Weight | | 1,816,293 lb |
| Propellant Loading | | 1,200,000 lb |
| Centaur Shroud | | 2,320 lb* |
| MS-IC-1/MS-II-2 Long Interstage | | 11,940 lb |
| Structure | 10,150 lb | |
| Electrical | 300 lb | |
| Ullage Hardware | 1,490 lb | |
| Cutoff Weight | | 602,033 lb |
| MS-II Second Stage Dry Weight | | 109,000 lb |
| Structure | 72,720 lb | |
| Propulsion System and Accessories | 27,800 lb | |
| Equipment | 6,412 lb | |
| Miscellaneous | 2,068 lb | |
| Propulsion Performance Reserve | | 1,390 lb |
| Thrust Decay Propellants | | 650 lb |
| Residuals | | 12,010 lb |
| Fuel - Pressure Gas | 2,240 lb | |
| Fuel - Trapped | 1,750 lb | |
| Oxidizer - Pressure Gas | 5,500 lb | |
| Oxidizer - Trapped | 2,420 lb | |
| Service Items | 100 lb | |
| MS-II-2/MS-IVB-2 Interstage | | 9,430 lb |
| MS-II-2 Retro-rockets | | 3,000 lb |
| Weight Loss - S-II/S-IVB Sep/Start | | 725 lb |

*Dropped 20 seconds after Second Stage Ignition.

**Dropped 30 seconds after Second Stage Ignition.

Table 21. Continued

| Vehicle Characteristics | | Third Stage |
|---|---|---|
| Propulsion | | 1 × RE-315 |
| RE-315 Thrust (Vacuum) | | 315,000 lb |
| RE-315 $I_{sp}$ (Vacuum) | | 444.6 sec |
| Lift-off Weight | | 465,828 lb |
| Propellant - First Burn | | 93,722 lb |
| Cutoff Weight - in 185 km Orbit | | 372,106 lb |
| MS-IVB-2 Weight Loss in Orbit | | 8,290 lb |
| Fuel Vented | 5,565 lb | |
| Auxiliary Propellant - Ullage | 1,265 lb | |
| Auxiliary Propellant - Chilldown | 500 lb | |
| Auxiliary Propellant - Attitude Control | 170 lb | |
| Thrust Decay | 130 lb | |
| Thrust Buildup | 660 lb | |
| Centaur Weight Loss in Orbit | | 338 lb |
| Lift-off Weight - Second Burn | | 363,478 lb |
| Propellant - Second Burn | | 256,278 lb |
| Cutoff Weight | | 107,200 lb |
| MS-IVB-2 Dry Stage Weight | | 34,800 lb |
| Structure | 20,060 lb | |
| Propulsion System and Accessories | 7,997 lb | |
| Equipment and Instrumentation | 6,080 lb | |
| Miscellaneous | 663 lb | |
| Propulsion Performance Reserve | | 575 lb |
| Thrust Decay Propellants | | 130 lb |
| Residuals | | 3,640 lb |
| Fuel - Trapped | 800 lb | |
| Fuel - Pressure Gas | 1,300 lb | |
| Oxidizer - Trapped | 700 lb | |
| Oxidizer - Pressure Gas | 690 lb | |
| Auxiliary Propellant Reserve | 115 lb | |
| Environmental Control Fluids | 35 lb | |
| Instrument Unit | | 3,500 lb |
| MS-IVB-2/Centaur Interstage | | 500 lb |
| MS-IVB-2/Centaur Separation/Start Losses | | 154 lb |
| Centaur $H_2O_2$ for Boost Pumps | 50 lb | |
| Centaur Ullage Rocket Vernier Firing | 10 lb | |
| Centaur Ascent Boiloff | 94 lb | |



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Table 21. Concluded

| Vehicle Characteristics | | Fourth Stage |
|---|---|---|
| Propulsion | | 2 × RL-10 |
| RL-10 Thrust (Vacuum) | | 15,000 lb |
| RL-10 $I_{sp}$ (Vacuum) | | 434 sec |
| Lift-off Weight | | 63,901 lb |
| Propellant Loading | | 29,042 lb |
| Cutoff Weight | | 34,859 lb |
| Thrust Decay Propellants | | 16 lb |
| Flight Performance Reserve | | 958 lb |
| Centaur Dry Stage Weight | | 5,348 lb |
| Structure | 934 lb | |
| Propulsion System and Accessories | 1,216 lb | |
| Pressurization | 122 lb | |
| Guidance Group | 354 lb | |
| Controls Group | 117 lb | |
| Electrical Group | 290 lb | |
| Flight Instrument Group | 270 lb | |
| Destruct | 25 lb | |
| Centaur Aft Interstage | 300 lb | |
| Umbilicals and Ducts | 270 lb | |
| Permanent Insulation | 1,450 lb | |
| Residuals | | 406 lb |
| Injected Payload Weight | | 28,131 lb |



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Table 22. Typical Trajectory Printout for MLV Saturn V-3 /Centaur Vehicle with Suborbital Start MS-IVB-2

$E = 60\ km^2/sec^2$
$V_\infty = 0.3678$ EMOS

| Stage | Time (sec) | Velocity (m/sec) | Altitude (km) | Flight Path Angle (deg) | Range (km) | CD | Q (lb/ft²) | Weight (lb) | Thrust (lb) | Mach | Ax. Accel. m/sec² |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MS-IC-1 | 0.00 | 0.0 | 0.00 | 0.00 | 0.0 | 0.584 | 0.0 | 7,200,000 | 9,000,000 | 0.0 | 2.44 |
| | 20.00 | 61.3 | 0.57 | 1.00 | 0.0 | 0.584 | 45.6 | 6,535,793 | 9,074,109 | 0.2 | 3.76 |
| | 40.00 | 154.2 | 2.65 | 8.11 | 0.2 | 0.584 | 233.9 | 5,871,587 | 9,133,489 | 0.5 | 5.65 |
| | 48.00 | 177.7 | 3.31 | 10.27 | 0.3 | 0.584 | 298.5 | 5,738,745 | 9,178,754 | 0.5 | 6.13 |
| | 48.00 | 203.3 | 4.06 | 12.60 | 0.4 | 0.584 | 351.5 | 5,605,904 | 9,447,913 | 0.6 | 6.65 |
| | 52.00 | 231.0 | 4.90 | 15.08 | 0.6 | 0.584 | 414.9 | 5,473,063 | 9,519,706 | 0.7 | 7.22 |
| | 56.00 | 261.1 | 5.84 | 17.65 | 0.9 | 0.584 | 478.2 | 5,340,222 | 9,592,702 | 0.8 | 7.84 |
| | 60.00 | 293.8 | 6.89 | 20.27 | 1.3 | 0.584 | 538.4 | 5,207,380 | 9,665,303 | 0.9 | 8.50 |
| | 64.00 | 328.6 | 8.05 | 22.93 | 1.7 | 0.846 | 589.8 | 5,074,537 | 9,736,074 | 1.1 | 8.97 |
| | 68.00 | 365.8 | 9.31 | 25.58 | 2.3 | 0.914 | 628.7 | 4,941,698 | 9,803,191 | 1.2 | 9.65 |
| | 72.00 | 404.0 | 10.69 | 28.20 | 3.0 | 0.886 | 653.5 | 4,808,856 | 9,865,149 | 1.4 | 10.48 |
| | 76.94 | 415.9 | 11.02 | 28.81 | 3.2 | 0.871 | 657.6 | 4,777,787 | 9,878,801 | 1.4 | 10.70 |
| | 76.00 | 449.9 | 12.17 | 30.78 | 3.8 | 0.824 | 642.0 | 4,676,015 | 9,920,604 | 1.5 | 11.45 |
| | 80.00 | 497.7 | 13.78 | 33.28 | 4.8 | 0.756 | 610.8 | 4,543,174 | 9,967,411 | 1.7 | 12.49 |
| | 100.00 | 803.6 | 23.67 | 44.28 | 12.9 | 0.459 | 338.0 | 3,878,967 | 10,096,783 | 2.7 | 18.23 |
| | 120.00 | 1232.4 | 36.89 | 52.54 | 28.6 | 0.335 | 99.2 | 3,214,761 | 10,120,549 | [illegible] | 24.90 |
| | 140.00 | 1816.6 | 53.81 | 58.45 | 52.8 | 0.271 | 23.8 | 2,550,554 | 10,130,971 | 5.4 | 31.88 |
| | 148.95 | 2141.1 | 62.77 | 60.48 | 67.9 | 0.244 | 12.2 | 2,253,450 | 10,131,347 | 6.3 | 39.33 |
| MS-II-2 | 148.95 | 2141.1 | 62.77 | 60.48 | 67.9 | 0.244 | 12.2 | 1,816,293 | 1,575,000 | 6.9 | 3.76 |
| | 150.00 | 2145.1 | 63.88 | 60.69 | 69.9 | 0.244 | 10.7 | 1,812,559 | 1,575,000 | 7.0 | 3.81 |
| | 150.00 | 2509.9 | 63.88 | 65.27 | 69.9 | 0.244 | 14.6 | 1,812,559 | 1,575,000 | 8.1 | 4.49 |
| | 160.00 | 2557.1 | 74.12 | 67.05 | 92.8 | 0.244 | 3.8 | 1,777,134 | 1,575,000 | 9.2 | 4.95 |
| | 168.95 | 2603.2 | 82.82 | 68.63 | 113.9 | 0.244 | 0.9 | 1,745,443 | 1,575,000 | 10.1 | 5.36 |
| | 168.95 | 2603.2 | 82.82 | 68.63 | 113.9 | 0.244 | 0.9 | 1,743,123 | 1,575,000 | 10.1 | 5.37 |
| | 178.95 | 2659.2 | 92.04 | 70.29 | 138.2 | 0.244 | 0.1 | 1,707,698 | 1,575,000 | 0.0 | 5.25 |
| | 178.95 | 2659.2 | 92.04 | 70.29 | 138.2 | 0.244 | 0.1 | 1,695,758 | 1,575,000 | 0.0 | 5.11 |
| | 188.00 | 2713.8 | 99.97 | 71.63 | 160.8 | 0.244 | 0.0 | 1,663,684 | 1,575,000 | 0.0 | 5.14 |
| | 200.00 | 2790.7 | 109.93 | 73.23 | 191.8 | 0.244 | 0.0 | 1,621,174 | 1,575,000 | 0.0 | 5.52 |
| | 300.00 | 3671.7 | 169.52 | 83.91 | 498.3 | 0.244 | 0.0 | 1,266,923 | 1,575,000 | 0.0 | 10.03 |
| | 400.00 | 5035.5 | 190.10 | 89.46 | 916.3 | 0.244 | 0.0 | 912,672 | 1,575,000 | 0.0 | 15.95 |
| | 487.69 | 6826.2 | 189.13 | 90.05 | 1461.0 | 0.244 | 0.0 | 602,033 | 1,575,000 | 0.0 | 25.11 |
| MS-IVB-2 | 487.69 | 6826.2 | 189.13 | 90.05 | 1416.0 | 0.244 | 0.0 | 465,828 | 315,000 | 0.0 | 6.28 |
| | 500.00 | 6907.7 | 188.99 | 90.15 | 1498.1 | 0.244 | 0.0 | 457,106 | 315,000 | 0.0 | 6.45 |
| | 600.00 | 7636.5 | 185.46 | 90.17 | 2203.6 | 0.244 | 0.0 | 386,255 | 315,000 | 0.0 | 7.96 |
| | 619.97 | 7797.3 | 185.22 | 90.00 | 2353.3 | 0.244 | 0.0 | 372,106 | 315,000 | 0.0 | 8.30 |
| | 619.97 | 7797.3 | 185.22 | 90.00 | 2353.1 | 0.244 | 0.0 | 363,478 | 315,000 | 0.0 | 8.50 |
| | 700.00 | 8532.6 | 188.18 | 89.41 | 2987.4 | 0.244 | 0.0 | 306,777 | 315,000 | 0.0 | 9.97 |
| | 800.00 | 9453.7 | 211.96 | 87.36 | 3846.9 | 0.244 | 0.0 | 235,927 | 315,000 | 0.0 | 12.67 |
| | 900.00 | 11140.3 | 293.03 | 83.44 | 4860.6 | 0.244 | 0.0 | 185,077 | 315,000 | 0.0 | 17.69 |
| | 981.69 | 12912.5 | 444.01 | 78.63 | 5774.1 | 0.244 | 0.0 | 107,200 | 315,000 | 0.0 | 27.12 |
| Centaur | 981.69 | 12912.5 | 444.01 | 78.63 | 5774.1 | 0.244 | 0.0 | 63,901 | 30,000 | 0.0 | 2.91 |
| | 1000.00 | 12965.2 | 493.27 | 77.37 | 5990.0 | 0.244 | 0.0 | 62,635 | 30,000 | 0.0 | 2.85 |
| | 1100.00 | 13240.5 | 856.20 | 70.50 | 7130.2 | 0.244 | 0.0 | 55,723 | 30,000 | 0.0 | 2.73 |
| | 1200.00 | 13527.9 | 1375.62 | 63.87 | 8181.3 | 0.244 | 0.0 | 48,810 | 30,000 | 0.0 | 3.10 |
| | 1300.00 | 13878.8 | 2045.61 | 57.63 | 9124.6 | 0.244 | 0.0 | 41,898 | 30,000 | 0.0 | 4.01 |
| | 1400.00 | 14349.7 | 2860.54 | 51.85 | 9956.9 | 0.244 | 0.0 | 34,986 | 30,000 | 0.0 | 5.52 |
| | 1491.85 | 14359.8 | 2876.82 | 51.75 | 9971.2 | 0.244 | 0.0 | 34,859 | 30,000 | 0.0 | 5.55 |



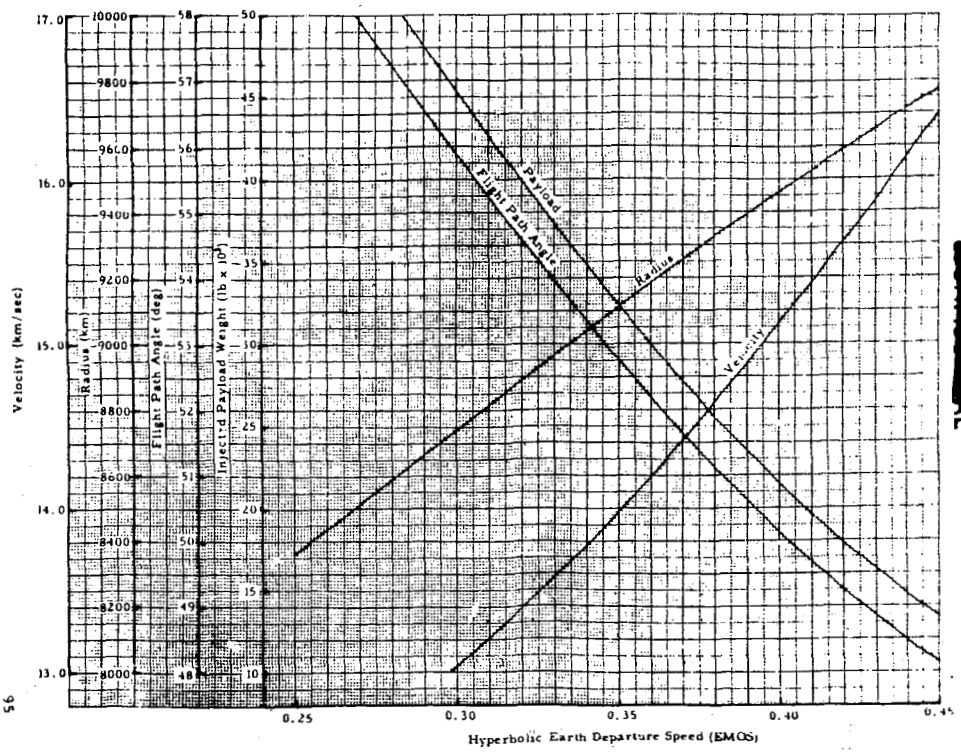


FIGURE 32. TRANSFER INJECTION CONDITIONS FOR THE MLV SATURN V-3/ CENTAUR VEHICLE

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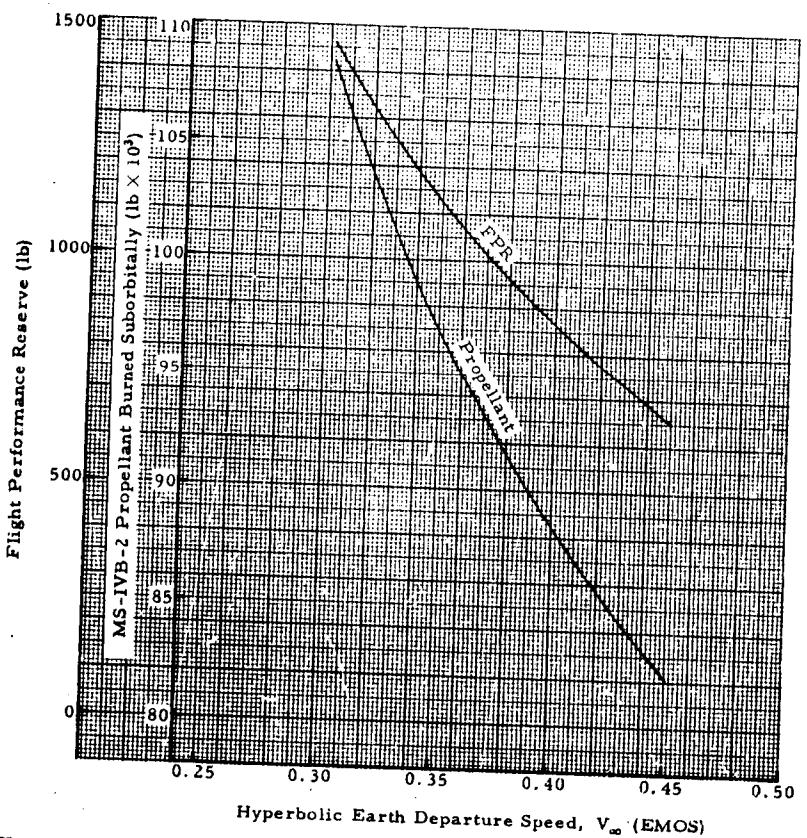


FIGURE 33. MS-IVB-2 PROPELLANT WEIGHT SUMMARY AS A FUNCTION OF HYPERBOLIC EXCESS VELOCITY FOR THE MLV SATURN V-3/ CENTAUR VEHICLE

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## SECTION IV. MISSION ANALYSIS

A representative mission profile to each of the planets considered is outlined in Tables 23 through 27. Figures 33 through 42 show a scaled sketch of the transfer geometry for each outlined profile. These profiles illustrate the use of this study program for mission planning.

In Table 23, a profile is presented for a Mercury mission using the Saturn V launch vehicle. The vehicle propellant requirements are given as well as the conditions that must be met at the Earth's sphere of influence to get into the correct trajectory plane to accomplish the mission.

This same information is itemized for missions to the other planets studied in Tables 24 through 27. The standard Saturn V was selected for the representative profile. A Centaur stage was added for the planet Saturn mission due to the high-energy requirement which is beyond the Saturn V capability. The vehicle selection and launch dates are not necessarily the best for the entire range of study. The Saturn V vehicle was selected because it is the most familiar vehicle which can accomplish each mission. The year of departure was selected at random.

Tables 28 through 35 contain an Earth departure window summary for each of the planets considered. A 15-, 20-, 30-, and 40-day launch period for each year was selected with the minimum energy requirement. The Julian launch dates given represent the first day of launch and the last day of launch for each departure window. The month and date of launch for this Gregorian Calendar year can be interpolated from the conversion list included as Table 36. Additional trajectory parameters for these launch dates can be determined from References 2 and 3.

The maximum payloads given in Tables 28 through 35 represent the total payload that can be launched any day during the launch window.

Table 23. Mission Profile to Mercur,
From Julian Date 244-0148 (October 19, 1968)
to 244-0163 (November 3, 1968) With a Saturn V Launch Vehicle

| | |
|---|---|
| Energy Requirement (for 15-day Launch Window) | 0.230 EMOS |
| Maximum Saturn V Payload | 40,300 lb |
| First Stage Propellant Loading | 4,290,000 lb |
| Second Stage Propellant Loading | 923,000 lb |
| Third Stage Propellant Loading | 230,000 lb |
| Burning Time to Injection | 1029.58 sec |
| Coast Between First Stage Cutoff and Second Stage Ignition | 4.2 sec |
| Coast Between Second Stage Cutoff and Third Stage Ignition | 0.0 sec |
| Coast Time in Orbit | 4.5 hrs |
| Total Time from Launch to Injection (maximum) | 4 hrs 47 min 14 sec |
| Velocity at Injection | 12.80 km/sec |
| Flight Path Angle at Injection | 77.84 deg |
| Radius at Injection | 6857.0 km |
| The following elements are based on an October 24, 1968 (244-0156) injection: | |
| Earth to Mercury Transfer Time | 116 days |
| Right Ascension of Departure Hyperbolic Asymptote | + 317.9 deg |
| Declination of Departure Hyperbolic Asymptote | - 15.7 deg |
| Inclination of Transfer Trajectory to Plane of Earth's Orbit | + 0.13 deg |
| Heliocentric Departure Velocity from Earth | 0.793 EMOS |
| Heliocentric Flight Path Angle at Earth Departure | + 87.7 deg |
| Eccentricity of Heliocentric Transfer Trajectory | 0.377 |
| Semi-major Axis of Heliocentric Transfer Trajectory | 0.723 AU |





Table 23. Concluded

| | |
|---|---|
| True Anomaly at Injection from Earth | + 176.2 deg |
| Inclination of Transfer Trajectory to Plane of Mercury's Orbit | + 6.87 deg |
| Heliocentric Arrival Velocity at Mercury | 1.743 EMOS |
| Magnitude of Hyperbolic Excess Velocity at Mercury | 0.440 EMOS |
| True Anomaly at Arrival | + 371.4 deg |
| Heliocentric Flight Path Angle at Arrival | + 93.1 deg |
| Right Ascension of Arrival Hyperbolic Asymptote | + 251.4 deg |
| Declination of Arrival Hyperbolic Asymptote | + 28.2 deg |

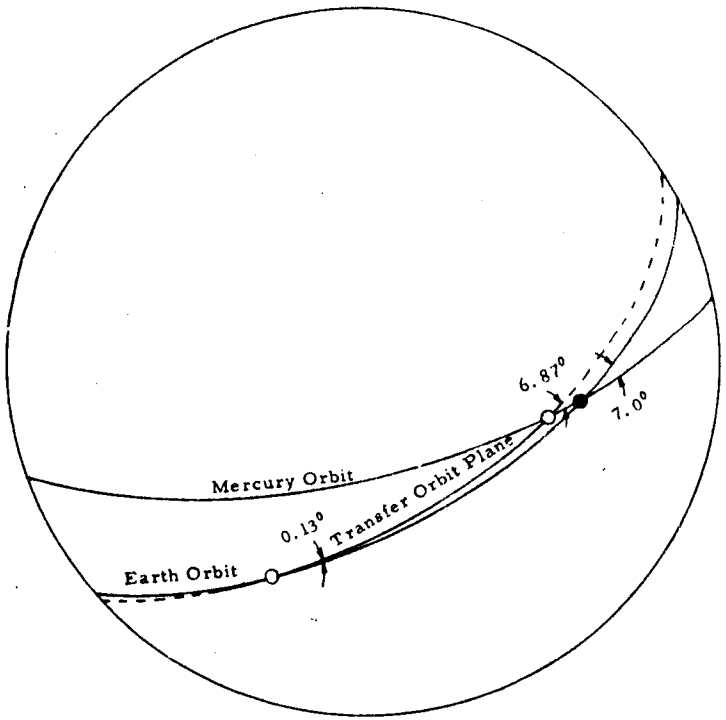


FIGURE 34. EARTH - MERCURY TRANSFER GEOMETRY FOR LAUNCH ON OCTOBER 24, 1968



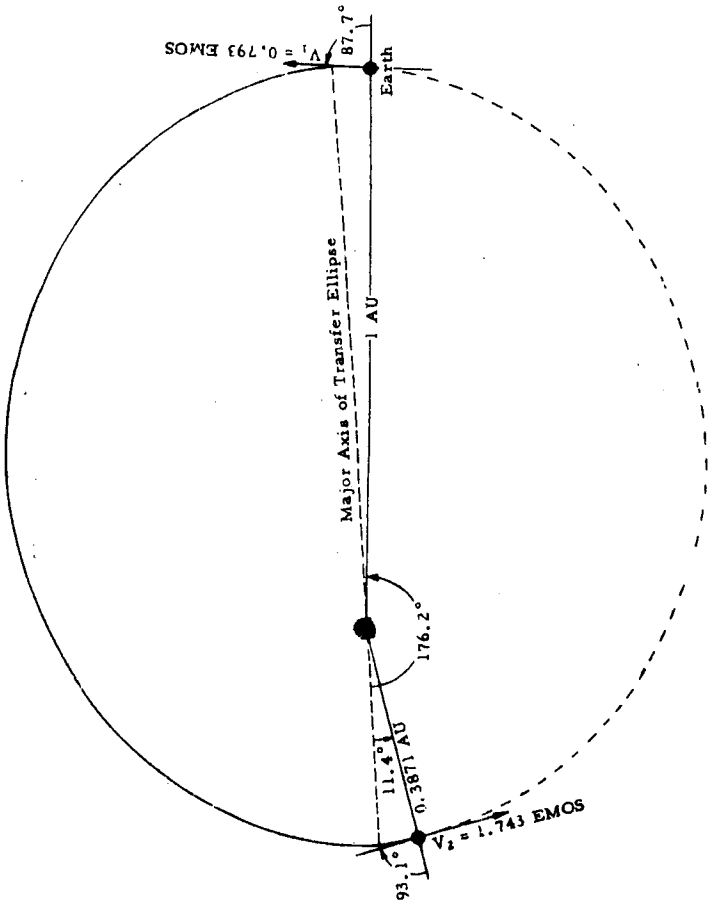


FIGURE 35. RELATIONSHIPS IN THE EARTH - MERCURY TRANSFER PLANE FOR LAUNCH ON OCTOBER 24, 1968

Table 24. Mission Profile to Venus
From Julian Date 244-9651 (June 10, 1967)
to 244-9666 (June 25, 1967) With a Saturn V Launch Vehicle

| | |
|---|---|
| Energy Requirement (for 15-Day Launch Window) | 0.104 EMOS |
| Maximum Saturn V Payload | 72,100 lb |
| First Stage Propellant Loading | 4,269,300 lb |
| Second Stage Propellant Loading | 907,300 lb |
| Third Stage Propellant Loading | 230,000 lb |
| Burning Time to Injection | 1020.60 sec |
| Coast Between First Stage Cutoff and Second Stage Ignition | 4.2 sec |
| Coast Between Second Stage Cutoff and Third Stage Ignition | 0.0 sec |
| Coast Time in Orbit | 4.5 hrs |
| Total Time From Launch to Injection (maximum) | 4 hrs 47 min |
| Velocity at Injection | 11.55 km/sec |
| Flight Path Angle at Injection | 81.38 deg |
| Radius at Injection | 6738.2 km |

The following elements are based on a June 17, 1967 (244-9658) injection:

| | |
|---|---|
| Earth-to-Venus Transfer Time | 120 days |
| Right Ascension of Departure Hyperbolic Asymptote | + 144.4 deg |
| Declination of Departure Hyperbolic Asymptote | - 11.2 deg |
| Inclination of Transfer Trajectory to Plane of Earth's Orbit | - 2.63 deg |
| Heliocentric Departure Velocity from Earth | 0.901 EMOS |
| Heliocentric Flight Path Angle at Earth Departure | + 92.2 deg |
| Eccentricity of Heliocentric Transfer Trajectory | 0.178 |
| Semi-major Axis of Heliocentric Transfer Trajectory | 0.865 AU |





Table 24. Concluded

| | |
|---|---|
| True Anomaly at Injection from Earth | + 190.2 deg |
| Inclination of Transfer Trajectory to Plane of Venus' Orbit | - 0.92 deg |
| Heliocentric Arrival Velocity at Venus | 1.270 EMOS |
| Magnitude of Hyperbolic Excess Velocity at Venus | 0.122 EMOS |
| True Anomaly at Arrival | + 333.1 deg |
| Heliocentric Flight Path Angle at Arrival | + 86.0 deg |
| Right Ascension of Arrival Hyperbolic Asymptote | + 49.5 deg |
| Declination of Arrival Hyperbolic Asymptote | - 9.6 deg |

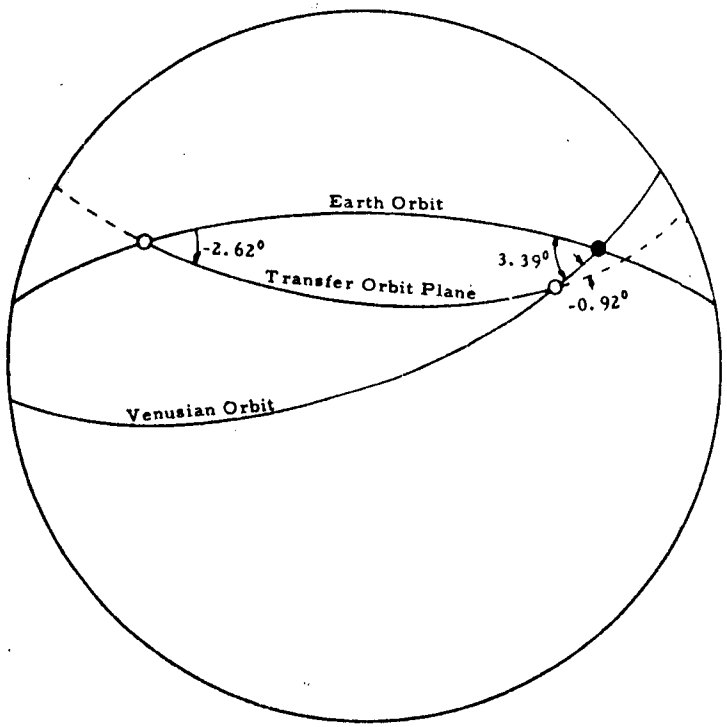


FIGURE 36. EARTH - VENUS TRANSFER GEOMETRY FOR LAUNCH ON JUNE 17, 1967



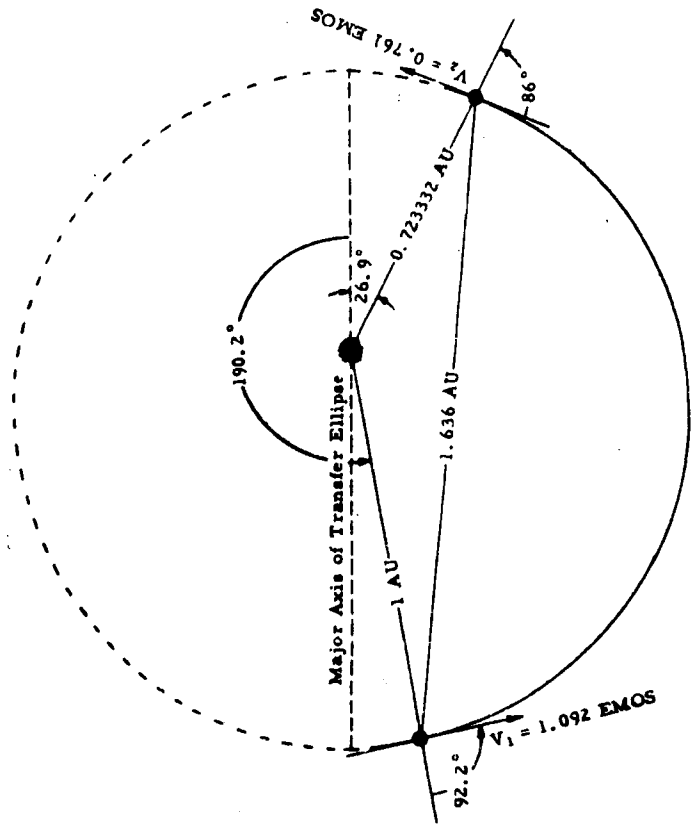


FIGURE 37. RELATIONSHIPS IN THE EARTH - VENUS TRANSFER PLANE FOR LAUNCH ON JUNE 17, 1967

Table 25. Mission Profile to Mars
From Julian Date 244-0306 (March 26, 1969)
to 244-0321 (April 10, 1969) With a Saturn V Launch Vehicle

| | |
|---|---|
| Energy Requirement (for 15-Day Launch Window) | 0.096 EMOS |
| Maximum Saturn V Payload | 73,800 lb |
| First Stage Propellant Loading | 4,268,500 lb |
| Second Stage Propellant Loading | 906,600 lb |
| Third Stage Propellant Loading | 230,000 lb |
| Burning Time to Injection | 1020.10 sec |
| Coast Between First Stage Cutoff and Second Stage Ignition | 4.2 sec |
| Coast Between Second Stage Cutoff and Third Stage Ignition | 0.0 sec |
| Coast Time in Orbit | 4.5 hrs |
| Total Time from Launch to Injection (maximum ) | 4 hrs 47 min 4 sec |
| Velocity at Injection | 11.49 km/sec |
| Flight Path Angle at Injection | 81.54 deg |
| Radius at Injection | 6733 km |
| The following elements are based on a March 30, 1969 (244-0310) injection: | |
| Earth-to-Mars Transfer Time | 300 days |
| Right Ascension of Departure Hyperbolic Asymptote | + 288.3 deg |
| Declination of Departure Hyperbolic Asymptote | - 8.2 deg |
| Inclination of Transfer Trajectory to Plane of Earth's Orbit | + 1.21 deg |
| Heliocentric Departure Velocity from Earth | 1.092 EMOS |
| Heliocentric Flight Path Angle at Earth Departure | 90 deg |
| Eccentricity of Heliocentric Transfer Trajectory | 0.191 |
| Semi-major Axis of Heliocentric Transfer Trajectory | 1.235 AU |



Table 25. Concluded

| | |
|---|---|
| True Anomaly at Injection from Earth | 0.01 deg |
| Inclination of Transfer Trajectory to Plane of Mars' Orbit | - 2.88 deg |
| Heliocentric Arrival Velocity at Mars | 0.761 EMOS |
| Magnitude of Hyperbolic Excess Velocity at Mars | 0.173 EMOS |
| True Anomaly at Arrival | + 205.0 deg |
| Heliocentric Flight Path Angle at Arrival | + 84.4 deg |
| Right Ascension of Arrival Hyperbolic Asymptote | + 346.8 deg |
| Declination of Arrival Hyperbolic Asymptote | - 19.6 deg |

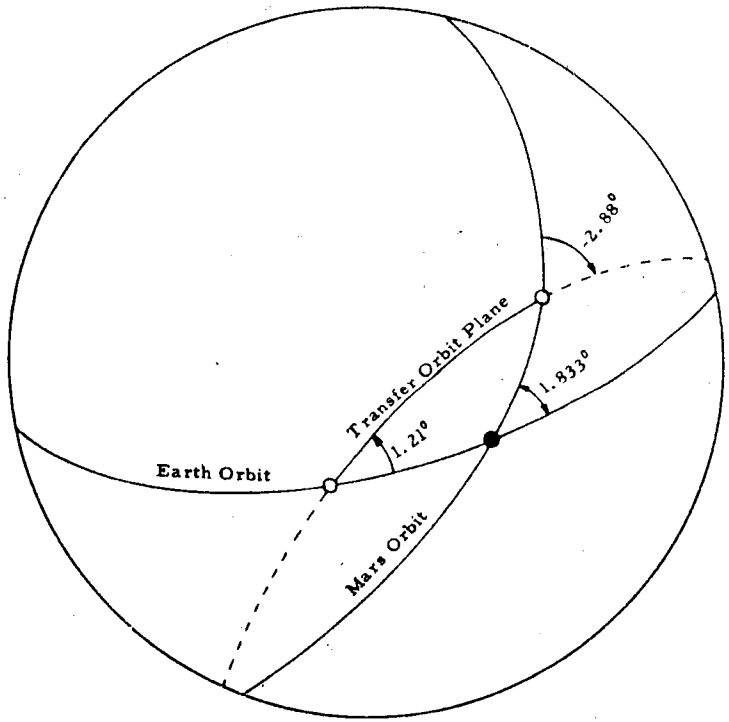


FIGURE 38. EARTH - MARS TRANSFER GEOMETRY FOR LAUNCH ON MARCH 30, 1969



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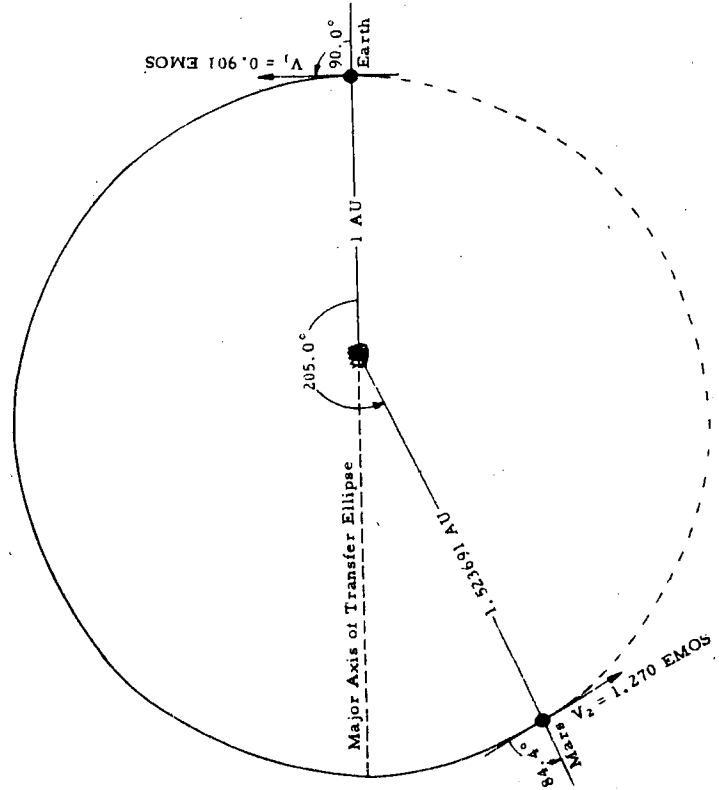


FIGURE 39. RELATIONSHIPS IN THE EARTH - MARS TRANSFER PLANE FOR LAUNCH ON MARCH 30, 1969

Table 26. Mission Profile to Jupiter
From Julian Date 244-0986 (February 4, 1971)
to 244-1001 (February 19, 1971) With a Saturn V Launch Vehicle

| | |
|---|---|
| Energy Requirement (for 15-Day Launch Window) | 0.316 EMOS |
| Maximum Saturn V Payload | 16,000 lb |
| First Stage Propellant Loading | 4,304,000 lb |
| Second Stage Propellant Loading | 930,000 lb |
| Third Stage Propellant Loading | 230,000 lb |
| Burning Time to Injection | 1034.52 sec |
| Coast Between First Stage Cutoff and Second Stage Ignition | 4.2 sec |
| Coast Between Second Stage Cutoff and Third Stage Ignition | 0.0 sec |
| Coast Time in Orbit | 4.5 hrs |
| Total Time from Launch to Injection (maximum) | 4 hrs 47 min 19 sec |
| Velocity at Injection | 14.24 km/sec |
| Flight Path Angle at Injection | 74.22 deg |
| Radius at Injection | 6998 km |
| The following elements are based on a February 12, 1971 (244-0993) injection: | |
| Earth-to-Jupiter Transfer Time | 750 days |
| Right Ascension of Departure Hyperbolic Asymptote | + 204.8 deg |
| Declination of Departure Hyperbolic Asymptote | - 13.3 deg |
| Inclination of Transfer Trajectory to Plane of Earth's Orbit | - 0.68 deg |
| Heliocentric Departure Velocity from Earth | 1.310 EMOS |
| Heliocentric Flight Path Angle at Earth Departure | + 84.2 deg |
| Eccentricity of Heliocentric Transfer Trajectory | 0.696 |
| Semi-major Axis of Heliocentric Transfer Trajectory | 3.205 AU |







Table 26. Concluded

| | |
|---|---|
| True Anomaly at Injection from Earth | + 14.3 deg |
| Inclination of Transfer Trajectory to Plane of Jupiter's Orbit | + 1.88 deg |
| Heliocentric Arrival Velocity at Jupiter | 0.277 EMOS |
| Magnitude of Hyperbolic Excess Velocity at Jupiter | 0.239 EMOS |
| True Anomaly at Arrival | + 167.2 deg |
| Heliocentric Flight Path Angle at Arrival | + 115.6 deg |
| Right Ascension of Arrival Hyperbolic Asymptote | + 323.5 deg |
| Declination of Arrival Hyperbolic Asymptote | + 0.6 deg |

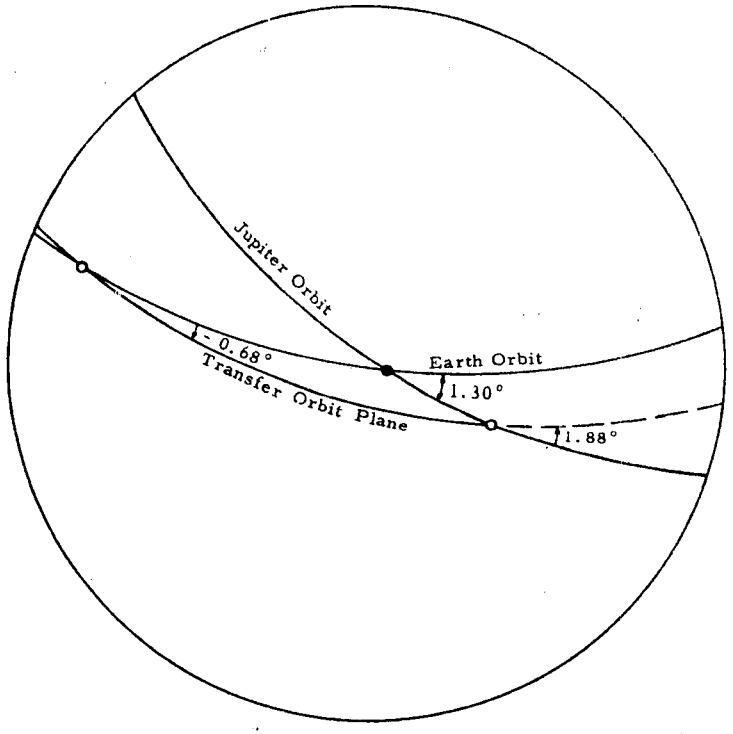


FIGURE 40. EARTH - JUPITER TRANSFER GEOMETRY FOR LAUNCH ON FEBRUARY 12, 1971



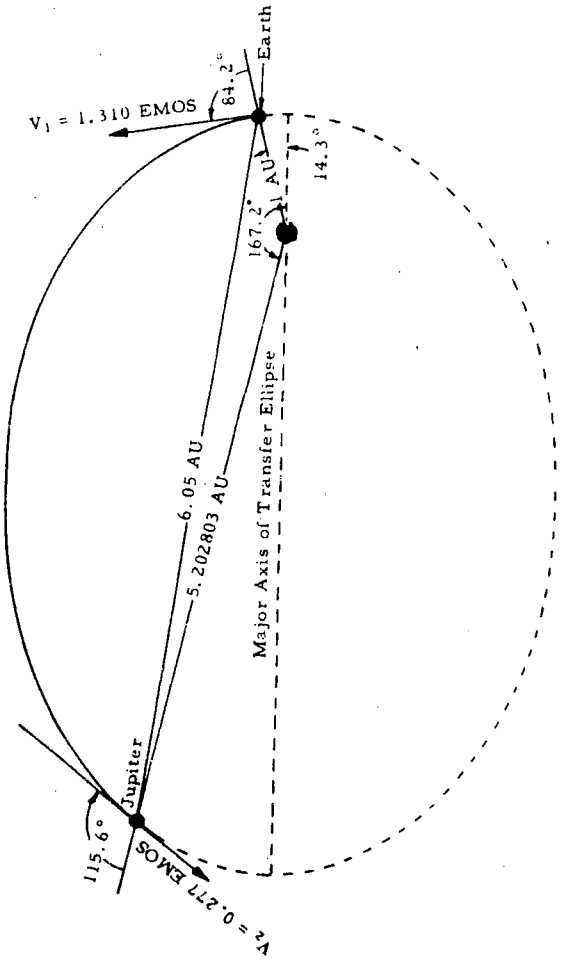


FIGURE 41. RELATIONSHIPS IN THE EARTH - JUPITER TRANSFER PLANE FOR LAUNCH ON FEBRUARY 12, 1971

Table 13. Vehicle Weight Summary for Three-Stage MLV-Saturn V-1 + Centaur With Suborbital Start MS-IVB-1

$E = 60 \times 10^6\ m^2/sec^2$

$V_\infty = 0.3678$ EMOS

| Vehicle Characteristics | | First Stage |
|---|---|---|
| Propulsion | | 5 × F-1 |
| F-1 Thrust (Sea Level) | | 1,800,000 lb |
| F-1 $I_{sp}$ (Sea Level) | | 271 sec |
| Lift-off Weight | | 7,200,000 lb |
| Propellant Loading | | 5,306,400 lb |
| Cutoff Weight | | 1,893,600 lb |
| MS-IC-1 Dry Stage Weight | | 349,000 lb |
| Structure | 188,334 lb | |
| Propulsion System and Accessories | 144,513 lb | |
| Equipment and Instrumentation | 10,000 lb | |
| Miscellaneous | 6,153 lb | |
| MS-IC-1/MS-II-1 Interstage | | 1,750 lb |
| Propulsion Performance Reserve | | 13,100 lb |
| Thrust Decay Propellants | | 6,300 lb |
| MS-IC-1 Residuals | | 60,747 lb |
| Fuel - Pressure Gas | 890 lb | |
| Fuel - Trapped | 16,665 lb | |
| Oxidizer - Pressure Gas | 7,900 lb | |
| Oxidizer - Trapped | 31,765 lb | |
| Actuator Fuel - Trapped | 630 lb | |
| Retro-rocket Propellant | 2,000 lb | |
| Frost | 865 lb | |
| Nitrogen | 32 lb | |
| Weight Loss During MS-IC-1/MS-II-1 Sep/Start | | 5,385 lb |
| Ullage Rocket Propellants | 2,960 lb | |
| Fuel - Engine Start | 825 lb | |
| Oxidizer - Engine Start | 1,600 lb | |





Table 13. Continued

| Vehicle Characteristics | | Second Stage |
|---|---|---|
| Propulsion | | 5 × J-2 |
| J-2 Thrust (Vacuum) | | 200,000 lb |
| J-2 $I_{sp}$ (Vacuum) | | 426 sec |
| Lift-off Weight | | 1,457,318 lb |
| Propellant Loading | | 1,000,000 lb |
| Centaur Shroud | | 2,320 lb * |
| MS-IC-1/MS-II-1 Large Interstage | | 11,940 lb ** |
| Structure | 10,150 lb | |
| Electrical | 300 lb | |
| Ullage Hardware | 1,490 lb | |
| Cutoff Weight | | 443,058 lb |
| MS-II-1 Second Stage Dry Weight | | 92,000 lb |
| Structure | 60,215 lb | |
| Propulsion System and Accessories | 24,460 lb | |
| Equipment | 6,412 lb | |
| Miscellaneous | 913 lb | |
| Propulsion Performance Reserve | | 1,390 lb |
| Thrust Decay Propellants | | 500 lb |
| Residuals | | 9,450 lb |
| Fuel - Pressure Gas | 1,870 lb | |
| Fuel - Trapped | 1,351 lb | |
| Oxidizer - Pressure Gas | 4,265 lb | |
| Oxidizer - Trapped | 1,879 lb | |
| Service Items | 85 lb | |
| MS-II-1/MS-IVB-1 Interstage | | 8,110 lb |
| MS-II-1 Retro-rockets | | 2,500 lb |
| Weight Loss MS-II-1/MS-IVB-1 Sep/Start | | 550 lb |

* Dropped 20 sec after second stage ignition.
** Dropped 30 sec after second stage ignition.

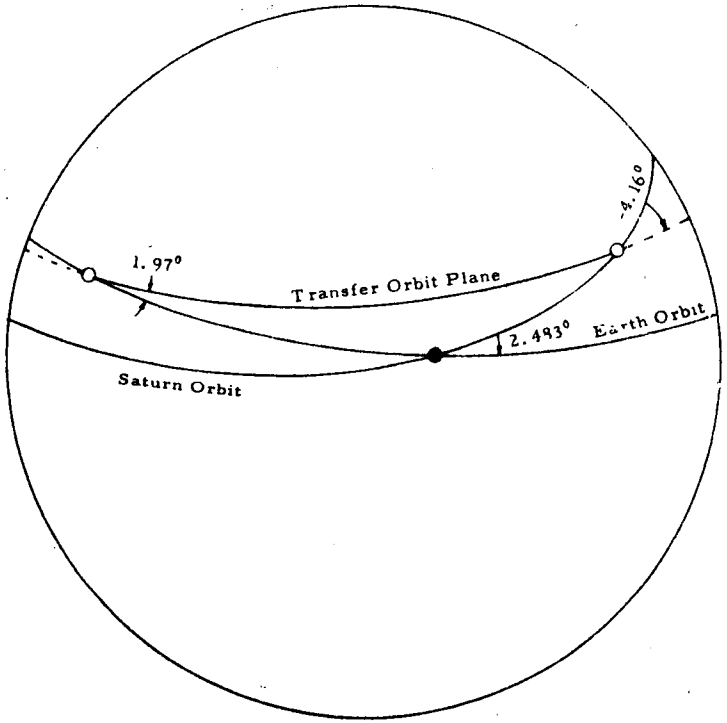


FIGURE 42. EARTH - SATURN TRANSFER GEOMETRY FOR LAUNCH ON AUGUST 30, 1973



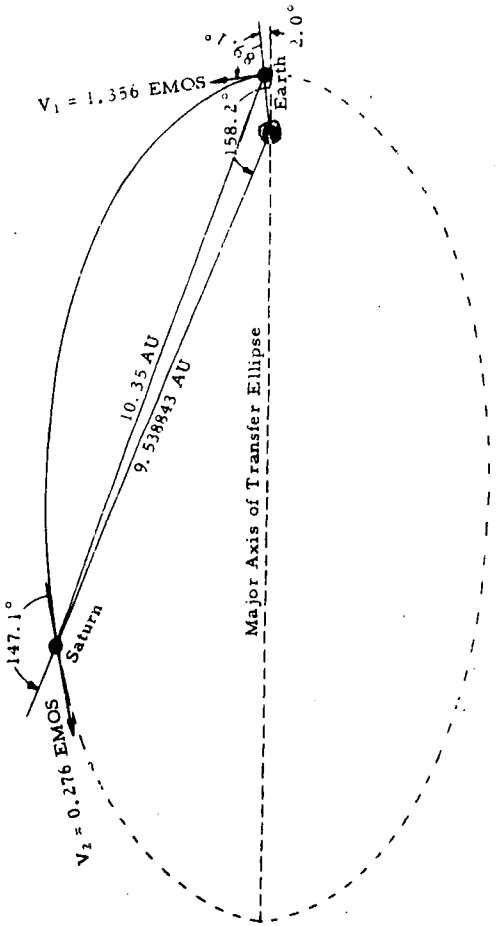


FIGURE 43. RELATIONSHIPS IN THE EARTH - SATURN TRANSFER PLANE FOR LAUNCH ON AUGUST 30, 1973

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## Table 28. Ten- and Fifteen-Day Launch Windows for Mercury Probes from 1968 to 1980

| Gregorian Calendar Year | Julian Departure Date From | Julian Departure Date To | Earth Departure Speed (EMOS) | Maximum Payload (lb): S-IB/S-IVB/Centaur | Saturn V (Orbital Start) | Saturn V (Suborbital Start) | Saturn V + Centaur | MLV Saturn V-1 | MLV-Saturn V-1 + Centaur | MLV Saturn V-2 | MLV-Saturn V-2 + Centaur | MLV Saturn V-3 | MLV-Saturn V-3 + Centaur | Range in Transfer Times (days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ten-Day Launch Window** | | | | | | | | | | | | | | |
| 1968 | 4-0152 | 4-0162 | 0.225 | 4,750 | 34,700 | 41,700 | 47,500 | 49,700 | 53,950 | 54,000 | 59,000 | 67,000 | 70,000 | 120-122 |
| 1969 | 4-0504 | 4-0514 | 0.227 | 4,600 | 34,200 | 41,200 | 46,900 | 49,000 | 53,300 | 53,400 | 58,400 | 66,300 | 69,400 | 120-121 |
| 1970 | 4-0856 | 4-0866 | 0.235 | 4,300 | 32,100 | 38,900 | 45,000 | 46,000 | 51,400 | 50,350 | 55,800 | 62,800 | 66,400 | 120-121 |
| 1971 | 4-0977 | 4-0987 | 0.255 | 3,350 | 27,000 | 33,100 | 40,200 | 37,500 | 45,800 | 43,100 | 49,750 | 54,300 | 59,400 | 98-106 |
| 1972 | 4-1322 | 4-1332 | 0.238 | 4,100 | 31,400 | 38,000 | 44,250 | 45,000 | 50,400 | 49,300 | 54,900 | 61,500 | 65,200 | 99-102 |
| 1973 | 4-2018 | 4-2028 | 0.222 | 4,900 | 35,400 | 42,600 | 48,100 | 50,700 | 55,000 | 55,200 | 60,600 | 68,400 | 71,200 | 100-102 |
| 1974 | 4-2351 | 4-2361 | 0.229 | 4,500 | 33,700 | 40,500 | 46,400 | 48,100 | 52,700 | 52,500 | 57,750 | 65,900 | 68,500 | 118-121 |
| 1975 | 4-2703 | 4-2713 | 0.222 | 4,900 | 35,400 | 42,600 | 48,100 | 50,700 | 55,000 | 55,200 | 60,000 | 68,400 | 71,200 | 120-122 |
| 1976 | 4-2834 | 4-2844 | 0.285 | 1,900 | 19,600 | 24,400 | 33,400 | 28,500 | 37,300 | 33,000 | 41,500 | 42,000 | 49,800 | 94-100 |
| 1977 | 4-3182 | 4-3192 | 0.264 | 2,950 | 24,800 | 30,500 | 38,100 | 34,800 | 43,500 | 40,000 | 47,200 | 50,650 | 56,400 | 98-100 |
| 1978 | 4-3524 | 4-3534 | 0.247 | 3,700 | 29,000 | 35,400 | 42,100 | 41,500 | 47,800 | 45,900 | 52,100 | 57,600 | 62,000 | 98-101 |
| 1979 | 4-3872 | 4-3882 | 0.234 | 4,400 | 32,400 | 39,200 | 45,200 | 46,400 | 51,600 | 50,750 | 56,100 | 61,300 | 66,700 | 99-102 |
| **Fifteen-Day Launch Window** | | | | | | | | | | | | | | |
| 1968 | 4-0148 | 4-0163 | 0.230 | 4,500 | 33,400 | 40,300 | 46,200 | 47,800 | 52,600 | 52,200 | 57,400 | 65,000 | 68,200 | 120-124 |
| 1969 | 4-0500 | 4-0515 | 0.234 | 4,400 | 32,400 | 39,200 | 45,200 | 46,400 | 51,600 | 50,750 | 56,100 | 63,300 | 66,700 | 120-126 |
| 1970 | 4-0851 | 4-0866 | 0.238 | 4,100 | 31,400 | 38,000 | 44,250 | 45,000 | 50,400 | 49,300 | 54,900 | 61,500 | 65,200 | 118-122 |
| 1971 | 4-0974 | 4-098[illegible] | 0.258 | 3,200 | 26,300 | 32,300 | 39,500 | 36,600 | 45,100 | 42,100 | 48,900 | 53,000 | 58,400 | 94-104 |
| 1972 | 4-1318 | 4-13[illegible] | 0.242 | 4,000 | 30,400 | 36,900 | 43,400 | 43,450 | 49,400 | 47,800 | 53,600 | 59,800 | 63,800 | 98-105 |
| 1973 | 4-2015 | 4-2030 | 0.225 | 4,750 | 34,700 | 41,700 | 47,500 | 49,700 | 53,950 | 54,000 | 59,000 | 67,000 | 70,000 | 99-106 |
| 1974 | 4-2348 | 4-2363 | 0.232 | 4,450 | 32,900 | 39,800 | 45,700 | 47,100 | 52,100 | 51,500 | 56,750 | 64,100 | 67,400 | 118-123 |
| 1975 | 4-2698 | 4-2713 | 0.227 | 4,600 | 34,200 | 41,200 | 46,900 | 49,000 | 53,300 | 53,400 | 58,400 | 66,300 | 69,400 | 120-124 |
| 1976 | 4-2832 | 4-2847 | 0.287 | 1,800 | 19,150 | 23,900 | 33,100 | 27,900 | 37,900 | 32,300 | 41,000 | 41,500 | 49,200 | 92-100 |
| 1977 | 4-3179 | 4-3194 | 0.267 | 2,700 | 24,000 | 29,600 | 37,400 | 33,800 | 42,750 | 39,000 | 46,400 | 49,400 | 55,400 | 94-101 |
| 1978 | 4-3521 | 4-3536 | 0.249 | 3,600 | 28,500 | 34,900 | 41,600 | 41,000 | 47,400 | 45,250 | 51,500 | 56,900 | 61,400 | 96-102 |
| 1979 | 4-3869 | 4-3884 | 0.238 | 4,100 | 31,400 | 38,000 | 44,250 | 45,000 | 50,400 | 49,300 | 54,900 | 61,500 | 65,200 | 98-104 |

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## Table 29. Thirty- and Forty-Day Launch Windows for Mercury Probes from 1968 to 1980

| Gregorian Calendar Year | Julian Departure Date From | Julian Departure Date To | Earth Departure Speed (EMOS) | Maximum Payload (lb): S-IB/S-IVB/Centaur | Saturn V (Orbital Start) | Saturn V (Suborbital Start) | Saturn V + Centaur | MLV Saturn V-1 | MLV-Saturn V-1 + Centaur | MLV Saturn V-2 | MLV-Saturn V-2 + Centaur | MLV Saturn V-3 | MLV-Saturn V-3 + Centaur | Range in Transfer Times (days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Thirty-Day Launch Window** | | | | | | | | | | | | | | |
| 1968 | 4-0140 | 4-0170 | 0.249 | 3,600 | 28,500 | 34,900 | 41,600 | 41,000 | 47,400 | 45,250 | 51,500 | [illegible] | [illegible] | [illegible] |
| 1969 | 4-0492 | 4-0522 | 0.251 | 3,500 | 28,000 | 34,300 | 41,100 | 39,750 | 46,900 | 44,500 | 50,900 | [illegible] | [illegible] | [illegible] |
| 1970 | 4-0845 | 4-0875 | 0.255 | 3,350 | 27,000 | 33,100 | 40,200 | 37,500 | 45,800 | 43,100 | 49,750 | 54,300 | [illegible] | [illegible] |
| 1971 | 4-0968 | 4-0998 | 0.267 | 2,700 | 24,[illegible] | 29,600 | 37,400 | 33,800 | 42,750 | 39,000 | 46,400 | 49,400 | [illegible] | [illegible] |
| 1972 | 4-1312 | 4-1342 | 0.256 | 3,300 | 26,800 | [illegible] | 40,000 | 37,100 | 45,600 | 42,750 | 49,050 | [illegible] | [illegible] | [illegible] |
| 1973 | 4-2004 | 4-2034 | 0.257 | 3,250 | 26,600 | 32,200 | 39,800 | 37,100 | 45,400 | 42,400 | 49,050 | [illegible] | [illegible] | [illegible] |
| 1974 | 4-2342 | 4-2372 | 0.245 | 3,800 | 29,600 | 35,900 | 42,500 | 42,250 | 48,600 | 46,700 | 52,700 | [illegible] | [illegible] | [illegible] |
| 1975 | 4-2690 | 4-2720 | 0.247 | 3,700 | 29,000 | 35,400 | 42,100 | 41,500 | 47,800 | 45,900 | 52,100 | 57,600 | [illegible] | [illegible] |
| 1976 | 4-2825 | 4-2855 | 0.316 | 1,350 | 17,000 | 21,250 | 31,200 | 25,200 | 35,700 | 29,000 | 35,300 | 38,000 | [illegible] | [illegible] |
| 1977 | 4-3172 | 4-3202 | 0.276 | 2,200 | 21,000 | 26,000 | 34,100 | 30,200 | 39,600 | 35,800 | 43,000 | 44,200 | [illegible] | [illegible] |
| 1978 | 4-3513 | 4-3543 | 0.261 | 3,000 | 25,000 | 30,750 | 38,300 | 35,000 | 44,000 | 40,250 | 47,300 | 52,000 | [illegible] | [illegible] |
| 1979 | 4-3859 | 4-3889 | 0.251 | 3,500 | 28,000 | 34,150 | 41,000 | 39,800 | 46,400 | 44,500 | 50,900 | [illegible] | [illegible] | [illegible] |
| **Forty-Day Launch Window** | | | | | | | | | | | | | | |
| 1968 | 4-0134 | 4-0174 | 0.264 | 2,950 | 24,800 | 30,500 | 38,100 | 34,800 | 43,500 | 40,000 | 47,200 | [illegible] | [illegible] | [illegible] |
| 1969 | 4-0485 | 4-0525 | 0.269 | 2,600 | 23,400 | 29,000 | 37,000 | 33,100 | 42,250 | 38,200 | 45,800 | [illegible] | [illegible] | [illegible] |
| 1970 | 4-0790 | 4-0830 | 0.266 | 2,800 | 24,200 | 30,000 | 37,600 | 34,100 | 43,000 | 39,150 | 46,550 | [illegible] | [illegible] | [illegible] |
| 1971 | 4-0961 | 4-1001 | 0.276 | 2,100 | 21,600 | 27,000 | 35,500 | 32,100 | 40,500 | 36,600 | 43,800 | [illegible] | [illegible] | [illegible] |
| 1972 | 4-1305 | 4-1345 | 0.267 | 2,700 | 24,000 | 29,600 | 37,400 | 33,800 | 42,750 | 39,000 | 46,400 | [illegible] | [illegible] | [illegible] |
| 1973 | 4-1994 | 4-2034 | 0.249 | 3,600 | 28,500 | 34,900 | 41,600 | 41,000 | 47,400 | 45,250 | 51,500 | [illegible] | [illegible] | [illegible] |
| 1974 | 4-2337 | 4-2377 | 0.257 | 3,250 | 26,600 | 32,100 | 39,800 | 37,100 | 45,400 | 42,400 | 49,050 | [illegible] | [illegible] | [illegible] |
| 1975 | 4-2684 | 4-2724 | 0.268 | 2,650 | 23,800 | 29,250 | 37,300 | 33,500 | 42,500 | 38,500 | 46,000 | [illegible] | [illegible] | [illegible] |
| 1976 | 4-2820 | 4-2860 | 0.306 | 750 | 14,700 | 18,600 | 29,150 | 21,400 | 31,500 | 24,000 | 32,200 | [illegible] | [illegible] | [illegible] |
| 1977 | 4-3164 | 4-3204 | 0.288 | 1,250 | 16,600 | 20,700 | 30,750 | 23,600 | 35,200 | 27,500 | 39,100 | [illegible] | [illegible] | [illegible] |
| 1978 | 4-3508 | 4-3548 | 0.271 | 2,500 | 22,500 | 27,250 | 36,100 | 32,000 | 41,250 | 36,750 | 44,750 | [illegible] | [illegible] | [illegible] |
| 1979 | 4-3858 | 4-3898 | 0.265 | 3,000 | 24,700 | 30,250 | 38,000 | 34,500 | 43,250 | 39,600 | 46,800 | [illegible] | [illegible] | [illegible] |

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Table 30. Ten- to Forty-Day Launch Windows for Venus Probes from 1967 to 1980

| Gregorian Calendar Year | Julian Departure Date From | Julian Departure Date To | Earth Departure Speed (EMOG) | Maximum Payload (lb) S-IB/S-IVB/ Centaur | Saturn V (Orbital Start) | Saturn V (Suborbital Start) | Saturn V + Centaur | MLV Saturn V-1 | MLV-Saturn V-1 + Centaur | MLV Saturn V-2 | MLV-Saturn V-2 + Centaur | MLV Saturn V-3 | MLV-Saturn V-3 + Centaur | Range in Transfer Times (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ten-Day Launch Window** | | | | | | | | | | | | | | |
| 1967 | 4-9655 | 4-9665 | 0.102 | 9,625 | 60,900 | 72,500 | 79,000 | 86,400 | 90,150 | 96,300 | 104,600 | 113,100 | 119,200 | 119-120 |
| 1970 | 4-0810 | 4-0820 | 0.101 | 9,640 | 61,100 | 72,650 | 79,200 | 86,500 | 90,400 | 96,500 | 104,900 | 113,400 | 119,500 | 113-124 |
| 1972 | 4-1402 | 4-1412 | 0.121 | 8,800 | 57,600 | 67,350 | 74,200 | 81,700 | 84,750 | 90,400 | 97,500 | 107,500 | 115,800 | 102-114 |
| 1973 | 4-1994 | 4-2004 | 0.125 | 8,550 | 57,000 | 67,400 | 73,200 | 80,700 | 83,700 | 89,000 | 96,000 | 106,300 | 113,700 | 102-110 |
| 1975 | 4-2573 | 4-2583 | 0.102 | 9,425 | 60,900 | 72,500 | 79,000 | 86,400 | 90,150 | 96,300 | 104,600 | 113,100 | 119,200 | 122-124 |
| 1978 | 4-3730 | 4-3740 | 0.099 | 9,475 | 61,700 | 73,100 | 79,750 | 87,000 | 91,000 | 97,150 | 105,600 | 113,850 | 119,900 | 120-142 |
| 1980 | 4-4325 | 4-4335 | 0.122 | 8,750 | 57,500 | 68,100 | 74,000 | 81,500 | 84,500 | 90,100 | 97,250 | 107,350 | 115,600 | 100-110 |
| **Fifteen-Day Launch Window** | | | | | | | | | | | | | | |
| 1967 | 4-9651 | 4-9666 | 0.104 | 9,350 | 60,600 | 72,100 | 78,600 | 85,900 | 89,650 | 95,660 | 103,800 | 112,600 | 118,700 | 108-125 |
| 1970 | 4-0808 | 4-0823 | 0.102 | 9,425 | 60,900 | 72,500 | 79,000 | 86,400 | 90,150 | 96,300 | 104,600 | 113,100 | 119,200 | 108-125 |
| 1972 | 4-1401 | 4-1416 | 0.122 | 8,700 | 57,500 | 68,100 | 74,000 | 81,500 | 84,500 | 90,100 | 97,250 | 107,350 | 115,600 | 100-115 |
| 1973 | 4-1993 | 4-2008 | 0.126 | 8,550 | 56,800 | 67,200 | 73,00 | 80,500 | 83,400 | 88,800 | 96,750 | 106,000 | 113,350 | 100-112 |
| 1975 | 4-2568 | 4-2583 | 0.104 | 9,350 | 60,600 | 72,100 | 7 .00 | 85,900 | 89,650 | 95,600 | 103,800 | 112,600 | 118,700 | 120-128 |
| 1978 | 4-3727 | 4-3742 | 0.100 | 9,650 | 61,600 | 73,300 | 80,000 | 87,300 | 91,400 | 97,500 | 106,000 | 114,200 | 120,300 | 116-142 |
| 1980 | 4-4321 | 4-4336 | 0.127 | 8,650 | 57,400 | 67,900 | 73,700 | 81,200 | 84,150 | 89,700 | 96,800 | 107,000 | 114,700 | 100-118 |
| **Thirty-Day Launch Window** | | | | | | | | | | | | | | |
| 1967 | 4-9648 | 4-9678 | 0.112 | 9,080 | 59,400 | 70,400 | 76,600 | 84,000 | 87,400 | 93,300 | 101,000 | 110,600 | 116,700 | 106-126 |
| 1970 | 4-0800 | 4-0830 | 0.105 | 9,300 | 60,500 | 71,800 | 78,250 | 85,600 | 89,300 | 95,100 | 103,400 | 112,500 | 118,600 | 103-130 |
| 1972 | 4-1390 | 4-1420 | 0.126 | 8,580 | 56,800 | 67,200 | 73,000 | 80,500 | 83,400 | 88,800 | 95,750 | 106,000 | 113,150 | 100-124 |
| 1973 | 4-1983 | 4-2013 | 0.132 | 8,400 | 55,700 | 65,900 | 71,200 | 78,900 | 81,600 | 86,800 | 93,400 | 104,000 | 110,400 | 100-140 |
| 1975 | 4-2560 | 4-2590 | 0.108 | 9,300 | 60,000 | 71,200 | 77,500 | 85,000 | 88,500 | 94,500 | 102,500 | 111,650 | 118,050 | 120-130 |
| 1978 | 4-3719 | 4-3749 | 0.103 | 9,440 | 60,750 | 72,300 | 78,400 | 86,100 | 89,900 | 95,950 | 104,200 | 112,900 | 119,000 | 104-146 |
| 1980 | 4-4311 | 4-4341 | 0.128 | 8,400 | 56,600 | 66,800 | 72,300 | 80,000 | 87,750 | 84,100 | 95,000 | 105,400 | 112,400 | 100-124 |
| **Forty-Day Launch Window** | | | | | | | | | | | | | | |
| 1967 | 4-9644 | 4-9684 | 0.128 | 8,600 | 56,500 | 66,500 | 72,300 | 80,000 | 82,750 | 88,100 | 95,000 | 105,400 | 112,400 | 96-130 |
| 1970 | 4-0794 | 4-0834 | 0.108 | 9,200 | 60,000 | 71,200 | 77,500 | 85,000 | 88,500 | 94,500 | 102,500 | 111,650 | 118,050 | 97-132 |
| 1972 | 4-1382 | 4-1422 | 0.130 | 8,590 | 56,100 | 66,300 | 71,800 | 79,400 | 82,100 | 87,500 | 94,000 | 104,600 | 111,200 | 99-128 |
| 1973 | 4-1977 | 4-2017 | 0.139 | 8,100 | 54,400 | 64,100 | 69,400 | 77,000 | 79,500 | 84,500 | 90,500 | 101,500 | 107,000 | 94-146 |
| 1975 | 4-2553 | 4-2593 | 0.114 | 9,000 | 59,000 | 69,900 | 76,000 | 83,500 | 86,800 | 92,600 | 100,100 | 110,000 | 115,500 | 118-132 |
| 1978 | 4-3713 | 4-3753 | 0.106 | 9,270 | 60,400 | 71,600 | 78,000 | 85,400 | 89,100 | 95,000 | 103,000 | 112,100 | 117,600 | 101-150 |
| 1980 | 4-4304 | 4-4344 | 0.134 | 8,300 | 55,400 | 65,400 | 70,700 | 78,400 | 81,000 | 86,150 | 92,500 | 103,400 | 109,500 | 95-125 |

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Table 31. Ten- to Forty-Day Launch Windows for Mars Probes from 1969 to 1980

| Gregorian Calendar Year | Julian Departure Date From | Julian Departure Date To | Earth Departure Speed (EMOS) | Maximum Payload (lb) S-IB/S-IVB/ Centaur | Saturn V (Orbital Start) | Saturn V (Suborbital Start) | Saturn V + Centaur | MLS Saturn V-1 | MLS-Saturn V-1 + Centaur | MLS Saturn V-2 | MLS-Saturn V-2 + Centaur | MLS Saturn V-3 | MLS-Saturn V-3 + Centaur | Range in Transfer Times (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ten-Day Launch Window** | | | | | | | | | | | | | | |
| 1969 | 4-0308 | 4-0318 | 0.095 | 9,700 | 62,100 | 74,000 | 80,600 | 87,900 | 92,200 | 98,400 | 107,000 | 114,800 | 121,000 | 299-300 |
| 1971 | 4-1091 | 4-1101 | 0.095 | 9,700 | 62,100 | 74,000 | 80,600 | 87,900 | 92,200 | 98,400 | 107,000 | 114,800 | 121,000 | 200-210 |
| 1973 | 4-1888 | 4-1898 | 0.128 | 8,600 | 58,500 | 66,800 | 72,300 | 80,000 | 82,750 | 88,100 | 95,000 | 105,400 | 112,400 | 200-201 |
| 1975 | 4-2666 | 4-2676 | 0.148 | 7,850 | 52,600 | 62,000 | 67,000 | 74,500 | 76,700 | 81,400 | 86,900 | 98,400 | 102,900 | 200-220 |
| 1977 | 4-3431 | 4-3441 | 0.144 | 8,000 | 53,400 | 64,000 | 68,000 | 75,600 | 77,900 | 82,800 | 88,500 | 99,850 | 104,750 | 200-300 |
| 1979-80 | 4-4192 | 4-4202 | 0.128 | 8,600 | 56,500 | 66,800 | 72,300 | 80,000 | 82,750 | 88,100 | 95,000 | 105,400 | 112,400 | 200-300 |
| **Fifteen-Day Launch Window** | | | | | | | | | | | | | | |
| 1969 | 4-0306 | 4-0321 | 0.096 | 9,550 | 61,900 | 73,700 | 80,400 | 87,600 | 91,800 | 98,000 | 106,600 | 114,500 | 120,700 | 299-301 |
| 1971 | 4-1088 | 4-1103 | 0.096 | 9,550 | 61,900 | 73,700 | 80,400 | 87,600 | 91,800 | 98,000 | 106,600 | 114,500 | 120,700 | 200-222 |
| 1973 | 4-1885 | 4-1900 | 0.131 | 8,400 | 55,900 | 66,000 | 71,500 | 79,100 | 81,800 | 87,200 | 93,700 | 104,300 | 110,900 | 200-206 |
| 1975 | 4-2661 | 4-2676 | 0.149 | 7,800 | 52,400 | 61,800 | 66,700 | 74,300 | 76,400 | 81,000 | 86,500 | 98,000 | 102,400 | 200-222 |
| 1977 | 4-3430 | 4-3445 | 0.146 | 7,950 | 53,000 | 63,000 | 68,000 | 75,400 | 78,000 | 82,750 | 88,500 | 99,800 | 104,700 | 200-300 |
| 1979-80 | 4-4190 | 4-4205 | 0.130 | 8,500 | 56,100 | 66,300 | 71,800 | 79,400 | 82,100 | 87,500 | 94,000 | 104,600 | 111,200 | 200-300 |
| **Thirty-Day Launch Window** | | | | | | | | | | | | | | |
| 1969 | 4-0295 | 4-0325 | 0.098 | 9,500 | 61,600 | 73,300 | 80,000 | 87,300 | 91,400 | 97,500 | 106,000 | 114,200 | 120,300 | 298-302 |
| 1971 | 4-1081 | 4-1111 | 0.100 | 9,450 | 61,300 | 73,000 | 79,500 | 86,800 | 90,700 | 96,800 | 105,300 | 113,600 | 119,700 | 200-240 |
| 1973 | 4-1878 | 4-1908 | 0.136 | 8,250 | 55,000 | 64,900 | 70,250 | 77,800 | 80,400 | 85,500 | 91,750 | 102,600 | 108,900 | 200-222 |
| 1975 | 4-2655 | 4-2685 | 0.159 | 7,400 | 50,300 | 59,300 | 64,000 | 71,300 | 73,300 | 80,200 | 82,500 | 94,400 | 97,600 | 200-245 |
| 1977 | 4-3423 | 4-3453 | 0.155 | 7,500 | 51,200 | 60,300 | 65,000 | 72,400 | 74,500 | 79,000 | 84,000 | 95,800 | 99,500 | 200-300 |
| 1979-80 | 4-4193 | 4-4223 | 0.142 | 8,100 | 53,800 | 63,500 | 68,500 | 76,100 | 78,600 | 83,500 | 89,300 | 100,500 | 105,600 | 200-300 |
| **Forty-Day Launch Window** | | | | | | | | | | | | | | |
| 1969 | 4-0288 | 4-0328 | 0.100 | 9,450 | 61,300 | 73,000 | 79,500 | 86,800 | 90,700 | 96,800 | 105,300 | 113,600 | 119,700 | 282-310 |
| 1971 | 4-1076 | 4-1116 | 0.140 | 8,150 | 54,100 | 64,000 | 69,000 | 76,700 | 79,250 | 84,200 | 90,190 | 101,300 | 106,500 | 200-245 |
| 1973 | 4-1872 | 4-1912 | 0.142 | 8,100 | 53,800 | 63,500 | 68,500 | 76,100 | 78,600 | 83,500 | 89,300 | 100,500 | 105,600 | 200-230 |
| 1975 | 4-2650 | 4-2690 | 0.169 | 7,000 | 48,200 | 56,800 | 61,400 | 68,300 | 70,200 | 74,200 | 78,400 | 90,400 | 93,100 | 200-300 |
| 1977 | 4-3419 | 4-3459 | 0.164 | 7,250 | 49,300 | 58,100 | 62,600 | 69,800 | 71,700 | 75,900 | 80,500 | 92,500 | 95,400 | 200-300 |
| 1979-80 | 4-4179 | 4-4219 | 0.152 | 7,650 | 51,800 | 61,000 | 65,800 | 73,300 | 75,400 | 80,000 | 85,300 | 96,900 | 101,000 | 200-300 |

Table 32. Ten- and Fifteen-Day Launch Windows for Jupiter Probes from 1968 to 1980

| Gregorian Calendar Year | Julian Departure Date From | Julian Departure Date To | Earth Departure Speed (EMOS) | Maximum Payload: S-IB/S-IVB/ Centaur | Saturn V (Orbital Start) | Saturn V (Suborbital Start) | Saturn V + Centaur | MLV Saturn V-1 | MLV-Saturn V-1 + Centaur | MLV Saturn V-2 | MLV-Saturn V-2 + Centaur | MLV Saturn V-3 | MLV-Saturn V-3 + Centaur | Range in Transfer Time (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ten-Day Launch Window** | | | | | | | | | | | | | | |
| 1968 | 4-0189 | 4-0199 | 0.312 | 400 | 13,400 | 17,000 | 28,000 | 20,800 | 32,100 | 24,200 | 34,800 | 32,000 | 42,100 | 800-900 |
| 1969-70 | 4-0583 | 4-0593 | 0.298 | 1,100 | 16,500 | 20,700 | 30,850 | 24,800 | 35,350 | 28,600 | 38,250 | 37,200 | 46,000 | 820-900 |
| 1971 | 4-0977 | 4-0987 | 0.299 | 1,050 | 16,100 | 20,400 | 30,600 | 24,400 | 35,000 | 28,400 | 38,000 | 36,800 | 45,700 | 800-820 |
| 1972 | 4-1377 | 4-1387 | 0.304 | 800 | 15,100 | 19,000 | 29,500 | 23,000 | 34,000 | 26,600 | 36,700 | 35,000 | 44,300 | 700-800 |
| 1973 | 4-1779 | 4-1789 | 0.311 | 400 | 13,500 | 17,100 | 28,100 | 21,000 | 32,500 | 24,500 | 35,000 | 32,600 | 42,400 | 700-800 |
| 1974 | 4-2184 | 4-2194 | 0.310 | 500 | 13,700 | 17,500 | 28,400 | 21,400 | 32,700 | 24,800 | 35,400 | 32,700 | 42,600 | 700-800 |
| 1975 | 4-2588 | 4-2598 | 0.304 | 800 | 15,100 | 19,000 | 29,500 | 23,000 | 34,000 | 26,600 | 36,700 | 35,000 | 44,300 | 800-900 |
| 1976 | 4-2985 | 4-2995 | 0.309 | 500 | 14,000 | 17,600 | 28,500 | 21,500 | 32,900 | 25,000 | 35,500 | 33,000 | 42,800 | 800-860 |
| 1977 | 4-3387 | 4-3397 | 0.319 | - | 11,300 | 15,100 | 26,600 | 18,900 | 30,600 | 22,000 | 33,200 | 29,400 | 40,000 | 700-800 |
| 1978 | 4-3784 | 4-3794 | 0.324 | - | 10,600 | 14,000 | 25,600 | 17,500 | 29,600 | 20,500 | 32,100 | 27,700 | 38,900 | 700-800 |
| 1979 | 4-4181 | 4-4191 | 0.323 | - | 10,8[illegible] | 14,100 | 25,800 | 17,700 | 29,800 | 20,800 | 32,300 | 28,000 | 39,000 | 700-900 |
| **Fifteen-Day Launch Window** | | | | | | | | | | | | | | |
| 1968 | 4-0187 | 4-0202 | 0.317 | - | 12,250 | 15,600 | 26,600 | 19,400 | 31,150 | 22,000 | 33,600 | 30,200 | 40,700 | 800-960 |
| 1969-70 | 4-0580 | 4-0595 | 0.302 | 900 | 15,600 | 19,500 | 30,000 | 23,500 | 34,400 | 2[illegible],400 | 37,300 | 35,600 | 44,900 | 800-900 |
| 1971 | 4-0986 | 4-1001 | 0.302 | 900 | 15,600 | 19,500 | 30,000 | 23,500 | 34,400 | 27,400 | 37,300 | 35,600 | 44,900 | 800-960 |
| 1972 | 4-1385 | 4-1400 | 0.308 | 600 | 14,300 | 18,000 | 28,800 | 21,900 | 33,100 | 25,500 | 35,900 | 33,500 | 43,100 | 700-800 |
| 1973 | 4-1778 | 4-1793 | 0.313 | 300 | 13,100 | 16,600 | 27,750 | 20,500 | 32,000 | 23,900 | 34,500 | 31,500 | 41,800 | 800-900 |
| 1974 | 4-2181 | 4-2196 | 0.313 | 300 | 13,100 | 16,600 | 27,750 | 20,500 | 32,000 | 23,900 | 34,500 | 31,500 | 41,800 | 700-800 |
| 1975 | 4-2585 | 4-2600 | 0.307 | 650 | 14,500 | 18,200 | 29,000 | 22,100 | 33,400 | 25,750 | 36,000 | 33,800 | 43,500 | 800-900 |
| 1976 | 4-2984 | 4-2999 | 0.311 | 400 | 13,500 | 17,100 | 28,100 | 21,000 | 32,500 | 24,500 | 35,000 | 32,600 | 42,400 | 800-900 |
| 1977 | 4-3384 | 4-3399 | 0.322 | - | 11,100 | 14,400 | 26,000 | 18,000 | 30,000 | 21,100 | 32,500 | 28,400 | 39,400 | 700-800 |
| 1978 | 4-3781 | 4-3796 | 0.328 | - | 9,900 | 13,000 | 25,000 | 16,500 | 28,800 | 19,400 | 31,100 | 26,400 | 37,800 | 700-900 |
| 1979 | 4-4179 | 4-4194 | 0.325 | - | 10,400 | 13,600 | 25,500 | 17,200 | 29,400 | 20,200 | 31,900 | 27,400 | 38,500 | 700-900 |

Table 37 Concluded



Table 33. Thirty- and Forty-Day Launch Windows for Jupiter Probes from 1968 to 1980

| Gregorian Calendar Year | Julian Departure Date From | Julian Departure Date To | Earth Departure Speed (EMOS) | Maximum Payload (lb): Saturn V (Orbital Start) | Saturn V (Suborbital Start) | Saturn V Centaur | MLS Saturn V-1 | MLS-Saturn V-1 Centaur | MLS Saturn V-2 | MLS-Saturn V-2 Centaur | MLS Saturn V-3 | MLS-Saturn V-3 Centaur | Range in Transfer Times (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Thirty-Day Launch Window** | | | | | | | | | | | | | |
| 1968 | 4-0179 | 4-0209 | 0.336 | 8,100 | 11,900 | 23,600 | 14,350 | 27,000 | 17,000 | 29,400 | 23,500 | 35,600 | 600-900 |
| 1969-70 | 4-0573 | 4-0603 | 0.323 | 10,800 | 14,100 | 25,800 | 17,700 | 29,800 | 20,800 | 32,300 | 28,000 | 39,000 | 700-900 |
| 1971 | 4-0969 | 4-0999 | 0.316 | 10,250 | 15,800 | 27,200 | 19,600 | 31,250 | 22,900 | 33,750 | 30,500 | 41,000 | 700-900 |
| 1972 | 4-1369 | 4-1399 | 0.322 | 11,100 | 14,400 | 26,000 | 18,000 | 30,000 | 21,100 | 32,500 | 28,400 | 39,400 | 600-900 |
| 1973 | 4-1773 | 4-1803 | 0.326 | 10,250 | 13,400 | 25,250 | 16,900 | 29,200 | 19,800 | 29,100 | 27,000 | 38,200 | 600-900 |
| 1974 | 4-2176 | 4-2206 | 0.326 | 10,250 | 13,400 | 25,250 | 16,900 | 29,200 | 19,800 | 29,100 | 27,000 | 38,200 | 600-900 |
| 1975 | 4-2577 | 4-2607 | 0.323 | 10,800 | 14,[illegible]00 | 25,800 | 17,700 | 29,800 | 20,800 | 32,300 | 28,000 | 39,000 | 540-900 |
| 1976 | 4-2976 | 4-3006 | 0.325 | 10,450 | 13,600 | 25,400 | 17,100 | 29,350 | 20,100 | 29,600 | 27,300 | 38,400 | 600-900 |
| 1977 | 4-3377 | 4-3407 | 0.337 | 7,900 | 10,750 | 23,700 | 14,000 | 26,800 | 16,700 | 29,200 | 23,350 | 35,400 | 600-900 |
| 1978 | 4-3776 | 4-3806 | 0.345 | 6,250 | 9,000 | 21,750 | 12,000 | 25,500 | 12,000 | 27,500 | 20,500 | 33,500 | 600-900 |
| 1979 | 4-4172 | 4-4202 | 0.345 | 6,250 | 9,000 | 21,750 | 12,000 | 25,500 | 12,000 | 27,500 | 20,500 | 33,500 | 600-900 |
| **Forty-Day Launch Window** | | | | | | | | | | | | | |
| 1968 | 4-0173 | 4-0213 | 0.355 | 4,200 | 6,800 | 20,000 | 9,500 | 23,250 | 14,200 | 25,500 | 17,500 | 31,200 | 500-850 |
| 1969-70 | 4-0567 | 4-0607 | 0.344 | 6,500 | 9,250 | 22,000 | 12,250 | 25,250 | 12,250 | 27,750 | 21,000 | 33,750 | 600-900 |
| 1971 | 4-0962 | 4-1002 | 0.331 | 9,200 | 12,250 | 24,300 | 16,000 | 28,000 | 18,350 | 30,500 | 25,200 | 36,900 | 600-900 |
| 1972 | 4-1364 | 4-1404 | 0.340 | 7,250 | 10,100 | 22,250 | 13,250 | 26,200 | 15,750 | 28,500 | 22,100 | 34,600 | 500-850 |
| 1973 | 4-1767 | 4-1807 | 0.344 | 6,500 | 9,250 | 22,000 | 12,250 | 25,250 | 12,250 | 27,750 | 21,000 | 33,750 | 500-850 |
| 1974 | 4-2171 | 4-2211 | 0.341 | 7,000 | 9,600 | 22,300 | 13,000 | 25,400 | 16,000 | 28,700 | 22,650 | 34,900 | 500-900 |
| 1975 | 4-2573 | 4-2613 | 0.338 | 7,700 | 10,500 | 23,000 | 13,700 | 26,600 | 16,400 | 28,950 | 23,000 | 35,200 | 500-900 |
| 1976 | 4-2972 | 4-3012 | 0.347 | 7,900 | 10,750 | 23,200 | 14,000 | 26,800 | 16,700 | 29,200 | 23,250 | 35,400 | 600-900 |
| 1977 | 4-3372 | 4-3412 | 0.352 | 4,800 | 7,500 | 20,500 | 10,350 | 23,900 | 12,500 | 26,000 | 18,500 | 31,800 | 500-900 |
| 1978 | 4-3772 | 4-3812 | 0.366 | 2,200 | 4,550 | 18,200 | 7,100 | 21,350 | 8,800 | 23,300 | 14,500 | 28,500 | 500-900 |
| 1979 | 4-4168 | 4-4208 | 0.369 | 1,700 | 4,000 | 17,750 | 16,500 | 20,800 | 8,200 | 22,800 | 13,250 | 28,000 | 500-900 |

Table 34. Fifteen- and Twenty-Day Launch Windows for Saturn Probes from 1968 to 1980

| Gregorian Calendar Year | Julian Departure Date From | Julian Departure Date To | Earth Departure Speed (EMOS) | Maximum Payload: Saturn V (Suborbital Start) | Saturn V + Centaur | MLV Saturn V-1 | MLV-Saturn V-1 + Centaur | MLV Saturn V-2 | MLV-Saturn V-2 + Centaur | MLV Saturn V-3 | MLV-Saturn V-3 + Centaur | Range in Transfer Times (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fifteen-Day Launch Window** | | | | | | | | | | | | |
| 1968 | 4-0025 | 4-0040 | 0.374 | 3,000 | 16,900 | 5,400 | 20,000 | 7,000 | 21,900 | 12,500 | 26,900 | 1400-1800 |
| 1969 | 4-0404 | 4-0419 | 0.366 | 4,600 | 17,250 | 7,150 | 21,400 | 9,000 | 23,300 | 14,750 | 28,600 | 1400-1800 |
| 1970 | 4-0781 | 4-0796 | 0.356 | 6,600 | 19,900 | 9,500 | 23,200 | 11,500 | 25,300 | 17,500 | 30,900 | 1500-1800 |
| 1971 | 4-1157 | 4-1172 | 0.355 | 6,800 | 20,000 | 9,700 | 23,400 | 11,800 | 25,500 | 17,800 | 31,100 | 1500-1700 |
| 1972 | 4-1536 | 4-1551 | 0.362 | 5,400 | 18,900 | 8,100 | 22,100 | 10,000 | 24,100 | 15,900 | 29,100 | 1400-1600 |
| 1973 | 4-1917 | 4-1932 | 0.370 | 3,800 | 17,600 | 6,400 | 20,650 | 8,000 | 22,600 | 13,600 | 27,700 | 1220-1500 |
| 1974 | 4-2298 | 4-2313 | 0.377 | 2,500 | 16,700 | 4,750 | 19,750 | 6,750 | 21,750 | 12,250 | 26,600 | 1200-1500 |
| 1975 | 4-2677 | 4-2692 | 0.383 | 1,300 | 15,500 | 4,000 | 18,500 | 4,800 | 20,300 | 10,000 | 25,000 | 1200-1500 |
| 1976 | 4-3057 | 4-3072 | 0.389 | - | 14,600 | 2,300 | 17,500 | 3,500 | 19,350 | 8,600 | 23,700 | 1200-1500 |
| 1977 | 4-3437 | 4-3452 | 0.392 | - | 14,200 | 1,600 | 17,000 | 2,800 | 18,800 | 7,800 | 23,100 | 1200-1600 |
| 1978 | 4-3816 | 4-3831 | 0.393 | - | 14,000 | 1,500 | 16,800 | 2,500 | 18,600 | 7,500 | 22,900 | 1200-1700 |
| 1979 | 4-4194 | 4-4209 | 0.391 | - | 14,400 | 1,800 | 17,200 | 3,000 | 19,000 | 8,000 | 23,300 | 1100-1800 |
| **Twenty-Day Launch Window** | | | | | | | | | | | | |
| 1968 | 4-0022 | 4-0042 | 0.378 | 2,400 | 16,300 | 4,600 | 19,400 | 6,000 | 21,200 | 11,500 | 26,000 | 1200-1800 |
| 1969 | 4-0402 | 4-0422 | 0.369 | 4,000 | 17,700 | 6,500 | 20,800 | 7,200 | 22,750 | 13,800 | 28,000 | 1400-1800 |
| 1970 | 4-0779 | 4-0799 | 0.361 | 5,600 | 19,000 | 8,350 | 22,300 | 10,200 | 24,300 | 16,100 | 29,750 | 1400-1800 |
| 1971 | 4-1154 | 4-1174 | 0.358 | 6,200 | 19,600 | 9,000 | 23,800 | 11,000 | 24,900 | 17,000 | 30,500 | 1500-1800 |
| 1972 | 4-1534 | 4-1554 | 0.366 | 4,600 | 17,250 | 7,150 | 21,400 | 9,000 | 23,300 | 14,750 | 28,600 | 1300-1700 |
| 1973 | 4-1915 | 4-1935 | 0.374 | 3,000 | 16,900 | 5,400 | 20,000 | 7,000 | 21,900 | 12,500 | 26,900 | 1200-1600 |
| 1974 | 4-2295 | 4-2315 | 0.381 | 1,800 | 15,750 | 4,000 | 18,750 | 5,300 | 20,600 | 10,600 | 25,400 | 1200-1600 |
| 1975 | 4-2675 | 4-2695 | 0.389 | - | 14,600 | 2,300 | 17,500 | 3,500 | 19,350 | 8,600 | 23,700 | 1100-1600 |
| 1976 | 4-3055 | 4-3075 | 0.394 | - | 13,900 | 1,300 | 16,700 | 2,400 | 18,500 | 7,400 | 22,700 | 1100-1700 |
| 1977 | 4-3435 | 4-3455 | 0.397 | - | 13,400 | 750 | 16,200 | 1,750 | 18,000 | 6,500 | 22,100 | 1100-1700 |
| 1978 | 4-3814 | 4-3834 | 0.397 | - | 13,400 | 750 | 16,200 | 1,750 | 18,000 | 6,500 | 22,100 | 1200-1800 |
| 1979 | 4-4193 | 4-4213 | 0.395 | - | 13,750 | 1,000 | 16,500 | 2,100 | 18,300 | 7,000 | 22,500 | 1200-1800 |

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Table 35. Thirty- and Forty-Day Launch Windows for Saturn Probes from 1968 to 1980

| Gregorian Calendar Year | Julian Departure Date From | Julian Departure Date To | Earth Departure Speed (EMOS) | Maximum Payload: Saturn V (Suborbital Start) | Saturn V + Centaur | MLV Saturn V-1 | MLV-Saturn V-1 + Centaur | MLV Saturn V-2 | MLV-Saturn V-2 + Centaur | MLV Saturn V-3 | MLV-Saturn V-3 + Centaur | Range in Transfer Times (Days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Thirty-day Launch Window** | | | | | | | | | | | | |
| 1968 | 4-0017 | 4-0047 | 0.391 | - | 14,400 | 1,800 | 17,200 | 3,000 | 19,000 | 8,000 | 23,300 | 1100-1800 |
| 1969 | 4-0396 | 4-0426 | 0.384 | 1,100 | 15,400 | 3,300 | 18,300 | 5,600 | 20,100 | 9,800 | 24,750 | 1200-1800 |
| 1970 | 4-0774 | 4-0804 | 0.376 | 2,600 | 16,300 | 5,000 | 19,200 | 6,500 | 21,000 | 12,000 | 26,000 | 1200-1800 |
| 1971 | 4-1150 | 4-1180 | 0.369 | 4,000 | 17,700 | 6,500 | 20,800 | 7,200 | 22,750 | 13,800 | 28,000 | 1200-1800 |
| 1972 | 4-1530 | 4-1560 | 0.375 | 2,700 | 16,700 | 5,200 | 19,700 | 6,700 | 21,700 | 12,200 | 26,600 | 1200-1800 |
| 1973 | 4-1911 | 4-1941 | 0.384 | 1,100 | 15,400 | 3,300 | 18,300 | 5,600 | 20,100 | 9,800 | 24,750 | 1100-1800 |
| 1974 | 4-2292 | 4-2322 | 0.391 | - | 14,400 | 1,800 | 17,200 | 3,000 | 19,000 | 8,000 | 23,300 | 1100-1700 |
| 1975 | 4-2672 | 4-2702 | 0.401 | - | 13,000 | - | 15,600 | 900 | 17,400 | 5,600 | 21,400 | 1000-1800 |
| 1976 | 4-3052 | 4-3082 | 0.401 | - | 13,000 | - | 15,600 | 900 | 17,400 | 5,600 | 21,400 | 1000-1800 |
| 1977 | 4-3431 | 4-3461 | 0.410 | - | 11,800 | - | 14,300 | - | 16,000 | 3,500 | 19,700 | 1000-1800 |
| 1978 | 4-3810 | 4-3840 | 0.411 | - | 11,600 | - | 14,100 | - | 15,800 | 3,400 | 19,500 | 1000-1800 |
| 1979 | 4-4188 | 4-4218 | 0.410 | - | 11,800 | - | 14,300 | - | 16,000 | 3,500 | 19,700 | 1000-1800 |
| **Forty-Day Launch Window** | | | | | | | | | | | | |
| 1968 | 4-0013 | 4-0053 | 0.410 | - | 11,800 | - | 14,300 | - | 16,000 | 3,500 | 19,700 | 1000-1800 |
| 1969 | 4-0391 | 4-0431 | 0.405 | - | 12,400 | - | 15,000 | - | 16,700 | 4,700 | 20,650 | 1000-1800 |
| 1970 | 4-0770 | 4-0810 | 0.397 | - | 13,400 | 750 | 16,200 | 1,750 | 18,000 | 6,500 | 22,100 | 1000-1800 |
| 1971 | 4-1147 | 4-1187 | 0.388 | 500 | 14,800 | 2,300 | 17,600 | 3,700 | 19,500 | 8,750 | 24,000 | 1100-1800 |
| 1972 | 4-1526 | 4-1566 | 0.390 | - | 14,500 | 2,100 | 17,300 | 3,200 | 19,150 | 8,300 | 23,500 | 1000-1800 |
| 1973 | 4-1902 | 4-1942 | 0.400 | - | 13,100 | - | 15,800 | 1,100 | 17,500 | 5,900 | 21,600 | 1000-1800 |
| 1974 | 4-2287 | 4-2327 | 0.410 | - | 11,800 | - | 14,300 | - | 16,000 | 3,500 | 19,700 | 1000-1800 |
| 1975 | 4-2668 | 4-2708 | 0.419 | - | 10,600 | - | 13,000 | - | 14,700 | 1,500 | 18,100 | 900-1800 |
| 1976 | 4-3048 | 4-3088 | 0.425 | - | 10,000 | - | 12,250 | - | 13,800 | - | 17,100 | 900-1800 |
| 1977 | 4-3428 | 4-3468 | 0.431 | - | 9,300 | - | 11,500 | - | 13,000 | - | 16,100 | 900-1800 |
| 1978 | 4-3806 | 4-3846 | 0.433 | - | 9,000 | - | 11,250 | - | 12,750 | - | 15,800 | 900-1800 |
| 1979 | 4-418[illegible] | 4-4224 | 0.433 | - | 9,000 | - | 11,250 | - | 12,750 | - | 15,800 | 900-1800 |

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Table 36. Julian Date to Gregorian Calendar Date Conversion for the Years 1965 through 1980

| Year | Jan. 0.5 | Feb. 0.5 | Mar. 0.5 | Apr. 0.5 | May 0.5 | Jun. 0.5 | Jul. 0.5 | Aug. 0.5 | Sept. 0.5 | Oct. 0.5 | Nov. 0.5 | Dec. 0.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1965 | 243-8761 | 8792 | 8820 | 8851 | 8881 | 8912 | 8942 | 8973 | 9004 | 9034 | 9065 | 9095 |
| 1966 | 9126 | 9157 | 9185 | 9216 | 9246 | 9277 | 9307 | 9338 | 9369 | 9399 | 9430 | 9460 |
| 1967 | 9491 | 9522 | 9550 | 9581 | 9611 | 9642 | 9672 | 9703 | 9734 | 9764 | 9795 | 9825 |
| 1968 | 9856 | 9887 | 9916 | 9947 | 9977 | *0008 | *0038 | *0069 | *0100 | *0130 | *0161 | *0191 |
| 1969 | 244-0222 | 0253 | 0281 | 0312 | 0342 | 0373 | 0403 | 0434 | 0465 | 0495 | 0526 | 0556 |
| 1970 | 0587 | 0618 | 0646 | 0677 | 0707 | 0738 | 0768 | 0799 | 0830 | 0860 | 0891 | 0921 |
| 1971 | 0952 | 0983 | 1011 | 1042 | 1072 | 1103 | 1133 | 1164 | 1195 | 1225 | 1256 | 1286 |
| 1972 | 1317 | 1348 | 1377 | 1408 | 1438 | 1469 | 1499 | 1530 | 1561 | 1591 | 1622 | 1652 |
| 1973 | 1683 | 1714 | 1742 | 1773 | 1803 | 1834 | 1864 | 1895 | 1926 | 1956 | 1987 | 2017 |
| 1974 | 2048 | 2079 | 2107 | 2138 | 2168 | 2199 | 2229 | 2260 | 2291 | 2321 | 2352 | 2382 |
| 1975 | 2413 | 2444 | 2472 | 2503 | 2533 | 2564 | 2594 | 2625 | 2656 | 2686 | 2717 | 2747 |
| 1976 | 2778 | 2809 | 2838 | 2869 | 2899 | 2930 | 2960 | 2991 | 3022 | 3052 | 3083 | 3113 |
| 1977 | 3144 | 3175 | 3203 | 3234 | 3264 | 3295 | 3325 | 3356 | 3387 | 3417 | 3448 | 3478 |
| 1978 | 3509 | 3540 | 3568 | 3599 | 3629 | 3660 | 3690 | 3721 | 3752 | 3782 | 3813 | 3843 |
| 1979 | 3874 | 3905 | 3933 | 3964 | 3994 | 4025 | 4055 | 4086 | 4117 | 4147 | 4178 | 4208 |
| 1980 | 4239 | 4270 | 4299 | 4330 | 4360 | 4391 | 4421 | 4452 | 4483 | 4513 | 4544 | 4574 |

1965 Jan. 0.5 ET = 2,438,761.0 = Greenwich Noon, January 1, 1965.



# SECTION V. CONCLUSIONS

Many phases of the interplanetary probe missions remain to be investigated; however, this study is intended as a basic framework for the continuation of a more detailed effort in probe mission planning.

The Saturn family of vehicles has a high payload capability for probing the environment of interplanetary space. With a selected vehicle of this family, missions with the Voyager, Mariner, advanced Pioneer or similar payloads are possible to the planets, c[illegible]d. The higher energy missions will require payloads of low [illegible] nd hence large volumes. This low payload density in conjunct[illegible] the vehicle height limitations imposed by the launch facilities at K[illegible] may prevent effective utilization of the payload weight capability of some of the vehicles.

The Saturn IB/Centaur has a good potential for launching relatively small payloads to Mercury, Venus, and Mars. This vehicle is a likely choice for launching the Voyager spacecraft.

The Saturn V vehicle is capable of launching probes to all the planets, except Saturn, with reasonable payload capability. The Saturn V was designed and sized to perform the LOR mission and hence is inefficient when used for high-energy missions. The addition of a fourth stage such as the Centaur makes a highly effective launch vehicle for the high-energy missions.

The MLV-Saturn V vehicles show good potential for use in the interplanetary exploration program. The MLV-Saturn V-1 provides a sizeable increase in performance over the Saturn V and less complexity since an orbital start is optimum for the MS-IVB stage instead of a suborbital start. The MLV-Saturn V-2 has good capability for performing all missions analyzed. The MLV-Saturn V-3, which includes more modifications to the Saturn V of any of the vehicles studied, also has the highest payload weight capability of any of the three-stage vehicles.

In all of the uprated Saturn V vehicles, the addition of the Centaur as a fourth stage extends their capabilities to much higher energy levels. The payload volume, however, is decreased by the amount required to package the Centaur stage.

No attempt was made in this study to specify payloads for the missions analyzed; however, a tabulation of possible experiments is presented in the Appendix. This study provides the ground work necessary for the design of specific payloads for these missions.

## APPENDIX

## SCIENTIFIC OBJECTIVES OF PLANETARY PROBES

The scientific objectives of the planetary exploration program are to obtain data leading to a clearer understanding of the origin and history of the solar system and to conduct a study of life or prelife forms wherever they may be found. No attempt is made in this study to build a scientific payload to the planets considered; however, a table has been compiled on each planet indicating particular experiments which might be performed.

Instrumentation designed to collect data of Mars and Venus are shown in Tables 37 and 38. This list was compiled by Jet Propulsion Laboratory and obtained from Reference 12. The list is limited to experiments that can be performed by unmanned probes. Instrumentation for Mercury, Jupiter, and Saturn probes was not as readily available. Due to Mercury's short distance from the Sun, solar experiments would probably be included in its probe payload. In Tables 39 and 40, typical scientific experiments which might be performed by the spacecraft at Mercury and Jupiter are shown respectively. No official information could be obtained on experiments for Saturn probes.

In planning the Mercury, Jupiter, and Saturn probe payloads, many of the experiments contained on probes to Mars and Venus may be desired and used with increased power supply. The SNAP type of power supply should provide sufficient transmitter power for the deep space missions considered in this study. Table 41 gives a list of typical values for presently attainable space communication systems for the unmanned missions considered (Ref. 13).

With the Deep Space Instrumentation Facility (DSIF) ground antenna at Goldstone limited to about 210 feet in diameter, the spacecraft antenna system for missions to Jupiter and Saturn will probably be no larger than 9 to 10 feet in diameter in the foreseeable future. This size antenna results in pointing accuracy requirements which are barely compatible with the state-of-the-art in control system engineering (Ref. 14).

## Table 37. Typical Experiments That Might Be Performed By a Venusian Probe

| Instrumentation | Instrument Gross Measurement Capabilities | Approximate Weight | Approximate Power | Volume or Dimensions | Additional Constraints |
|---|---|---|---|---|---|
| **Aerometeorometer** | | | | | |
| Static temperature | 180-800° K, ±1% of ambient (accuracy of measurement) | 5 oz | 70 mw | 1" dia. × 3" lg | |
| Static pressure | $10^2$ to $2.5 \times 10^6$ newtons/$m^2$ ±50 for $10^2$ to $1.5 \times 10^4$ ±1% above $1.5 \times 10^4$ (accuracy of measurement) | 5 oz | 100 mw | 1.6" dia. × 2" long | Sampling mechanism must provide free-stream conditions to the sensor during capsule descent. |
| Density | $2 \times 10^{-4}$ to 30 kg/$m^3$ ±1% of ambient (accuracy of measurement) | 12 oz (γ ray) 24 oz (γ ray) | 250 mw 2.0 watt | 15 in.³ (γ ray) | |
| Velocity of sound | 250 to 380 m/sec 1% of ambient (accuracy of measurement) | 10 o | 300 mw | 2.3" dia. × 2" long | |
| Mass spectrometer | Determination of the composition of the atmosphere in the mass range of 12 to 50 amu | 6 lb | 6 watt | 10" × 5" × 3" | Representative sample of the atmosphere is required. |
| Gas chromatograph | Determination of the composition of the atmosphere | 7.0 lb | 4.5 watt | 5" × 5" × 8" | |
| **Simple composition** | | | | | |
| $H_2O$ (vapor) | (1 atm): dynamic range 190 to 240° K Dew point: 0.1 to 100 ppm | 1.5 lb | 1 watt | 3" × 3" × 3" | Representative sample of the atmosphere is required. |
| $O_2$ | (1 atm): dynamic range 0.01 ppm (3 orders of magnitude per sensor) | 1.5 lb | 1 watt | 5" × 3" × 3" | |
| $O_3$ | (1 atm): dynamic range $10^{-3}$ to 1 ppm | 1.5 lb | 1 watt | 3" dia. × 6" | |
| A | (1 atm): dynamic range 0.1 to 100% | 1.5 lb | 1 watt | 10" × 2" × 2" | Representative sample of the atmosphere is required. |
| $N_2$ | (1 atm): dynamic range 1 to 100% | 1 lb | 1 watt | 5" × 3" × 3" | |
| $CO_2$ | (1 atm): dynamic range 0.1 to 100% | 1 lb | 1 watt | 4" × 3" × 4" | |
| Alpha scattering | Compositional analysis of surface material | 7 lb | 2 watt | 3" × 3" × 3" sensor 5" × 7" × 7" elec. | Placement of sensor head slightly above planetary surface |
| Soil mechanics experiment | Measurement of load-bearing strength, cohesive modulus, frictional modulus, and bearing stability of surface | 13 lb | 3 watt | 12" dia. × 24" | Axis vertical held 4 inches above surface |
| Microwave spectrometer | Planetary: Determine the molecular composition of the atmosphere (clouds, below clouds, at surface) by observing the microwave spectrum of the characteristics lines | 30 lb | 13 watt | 0.6 ft³ | Beam width less than 2 degrees, aligned toward planet vertical |
| Extended microwave spectrometer | Planetary: Will measure quantities stated for the microwave spectrometer and also will give a geographic temperature study of Venusian surface. | 35 lb | 15 watt | 0.7 ft³ | Two meter circular antenna, aligned toward planet vertical |
| Ultraviolet spectrometer | Planetary: Determination of the abundance and height distributions of the principal atmospheric constituents obtained from ultraviolet spectra of the day, night, and twilight portions of Venus with emphasis on lighted side. | 22 lb | 12 watt | 9" × 10" × | Sampled appropriately in space and time |



## Table 37. Continued

| Instrumentation | Instrument Gross Measurement Capabilities | Approximate Weight | Approximate Power | Volume or Dimensions | Additional Constraints |
|---|---|---|---|---|---|
| Cosmic-ray spectrum analyzer | Interplanetary: To investigate the intensity and the gradient of flux of charged particles in space as functions of nuclear species and time. | 18 lb | 2 watt | 18" × 6" × 6" | Four mutually perpendicular telescopes 30-60° cone angles |
| Plasma instrument (electrostatic analyzer) | Interplanetary: To measure the flux of positive and negative components of solar plasma traveling outward from the sun with good energy and directional resolution. To correlate these data with the magnetic field measurements. | 7 lb | 1.25 watt | 6" × 8" × 8" | Covers seven sections of a solid angle of 4 steradians centered on the Sun |
| Plasma instrument (Faraday cup) | Interplanetary: To determine the particle number density, the distribution of velocity vector, and the temporal and spatial distributions of the interplanetary plasma. To correlate these data with the magnetic field measurements. | 20 lb | 4 watt | 16" × 10" × 10" | Four 60° cone angles toward, away, and perpendicular to the Sun |
| Cosmic dust (A) | Interplanetary: To measure the flux of cosmic dust particles as function of direction, distance from the sun, and momentum with respect to the spacecraft. | 2.5 lb | 0.2 watt | 5" × 5" × 5" | One plate perpendicular to ecliptic |
| Micrometeoroid detector (A) | Interplanetary: Direct measurement of the velocity and cumulative mass distribution of the cosmic dust of the Zodiacal cloud and in the vicinity of the planets. | 8 lb | 0.5 watt | 10" × 10" × 6" | Three tubes in ecliptic plane, toward, away from and 90° from the Sun; one tube perpendicular to ecliptic |
| Bistatic radar | Interplanetary: To obtain information on the absolute electron density in interplanetary space and the fluctuation of this density as a function of time. Planetary: Obtain information on the electron-density profile of the ionosphere about Venus by progressive and selective absorptions of the Earth-transmitted signals during the occulting pass. | 6-8 lb | 2 watt | 4" × 4" × 12" excluding antennas | Occulting of spacecraft by planet required, antennas to be oriented to Earth. Antennas: 40-cm and 300-cm dipoles |
| Infrared television | Planetary: To obtain infrared pictures of cloud structure and surface configuration through possible breaks in the cloud layers. | 10-15 lb | 6-10 watt | 6" dia. × 12" | Aligned toward planet vertical |
| Infrared spectrometer | Simultaneous mapping of composition of surface and correct radiation temperature from orbiting vehicle. | 12 lb | 15 watt | 12" dia. × 15" | Point to vertical |
| γ-ray spectrometer | Gross compositional analysis for naturally radioactive materials. Interplanetary γ-radiation analysis. | 8 lb | 2 watt | 200 in³ | No radioactive source on lander |
| Seismic refractometer | Active seismic experiment to establish time-distance relationships giving the nature of the upper surface layers to a depth of one-third the shot-to-receiver distance. | 40 lb | Minimal | 300 in³ | Precise dispersal of explosive charges and geophones to 500 feet |

| Instrumentation | Instrument Gross Measurement Capabilities | Approximate Weight | Approximate Power | Volume or Dimensions | Additional Constraints |
|---|---|---|---|---|---|
| Particle flux | Interplanetary. Used in conjunction with the ion chamber to monitor the energetic particle and photon radiation in interplanetary space. Provides semiquantitative information about the energy and particle types composing the radiation. | 2.5 lb | 0.35 watt | 4"×5"×6" | Close to ion chamber, spacecraft to subtend minimum solid angle |
| Ion chamber | Interplanetary: To measure the total ionizing radiation (cosmic rays) and the variation with time and position in the solar system. | 1.3 lb | 0.101 watt | 6" sphere | Close to particle flux, spacecraft to subtend minimum solid angle |
| Trapped radiation detectors | Planetary: To search for magnetically trapped charged particles in the vicinity of Venus. If present, to study their intensity, directional and spatial distributions. Also interplanetary cosmic rays. | 4 lb | 0.7 watt | 4"×5"×5" | 30-degree cone angles, toward and away from the sun |
| Medium-energy proton directional monitor | Interplanetary: Observation on the temporal and spatial variation of cosmic-ray intensity. | | | 4"×5"×5" | Not specified |
| | Planetary: To search for magnetically trapped charged particles in the vicinity of Venus. If such are present, to measure the spatial extent and the anisotropy of the particle fluxes in the low-intensity regions of the trapping regions. | 3 lb | 1 watt | | Not specified |
| High-energy proton directional monitor | Interplanetary: To provide information about the temporal, spatial, and directional variations of galactic cosmic-ray flux. | 4 lb | 0.5 watt | 3"×4"×4" | 60-degree angle visibility parallel to ecliptic, 60-degree cone angle visibility perpendicular to ecliptic; 60-degree |
| Infrared spectrometer | Planetary: Determination of those minor constituents of the upper cloud structure whose absorption spectra are in the infrared region. Measurement of the atmospheric profile of temperature and pressure. | 29 lb | 7 watt | 12" dia. × 15" | Aligned toward planet vertical, requires detector cooling |
| Ultraviolet photometer (A) | Planetary: Determination of the presence of particular constituents of the upper atmosphere by means of filter spectroscopy. | 1.5 lb | 1.5 watt | 3" dia. × 5" | Aligned toward planet vertical |
| Infrared radiometer | Planetary: Investigation of the structure of the atmosphere by making measurements of the effective radiation temperature of the Venusian cloud tops. | 3 lb | 3 watt | 5"×7"×4" | Aligned toward planet vertical |
| Microwave radiometer | Planetary: Thermal mapping of the surface (33 mm) and structure of atmosphere (8 mm). Additional data to establish the precise shape of the spectral transition curve from the centimeter value of 600° K to the millimeter value of 100° K. This information is related to surface temperature and kinetic temperature of the atmosphere. | 24 lb | 4 watt | 0.5 ft³ | Two meter circular antenna, 2-degree beamwidth, aligned toward planet vertical |
| Magnetometer | Planetary: To establish the existance of a planetary field and to determine its characteristics, magnitude, direction, multipolarity, and orientation. To investigate the nature of the interface between planetary and interplanetary magnetic field. | 5 lb | 5 watt | 4"×4"×6" | Reduction of spacecraft magnetic field required; orientation in planetary coordinates must be known |



Table 38. Typical Experiments That Might Be Performed By a Martian Probe

| Instrument | Instrument Gross Measurement Capabilities | Approximate Weight | Approximate Power | Volume or Dimensions | Additional Constraints |
|---|---|---|---|---|---|
| Aerometeorometer: | | | | | |
| Static temperature | 100-500 °K accuracy 1% | 5 oz | 70 mw | 1" dia. × 3" long | Sampling mechanism must provide free-stream conditions to the sensor during capsule descent |
| Static pressure | $100 \times 15 \times 10^3$ newtons/m² accuracy ± 60 newtons/m² | 2 oz | 100 mw | 1.6" dia. × 2" long | |
| Density | $2 \times 10^{-5}$ to $10 \times 10^{-4}$ gm/cc, accuracy 1% | 12 oz (3 ray) 24 oz (5 ray) | 250 mw 2.0 watt | 15 in.³ (5 ray) | |
| Velocity of Sound | 250 to 380 m/sec, accuracy 1% | 10 oz | 300 mw | 2.3" dia. × 2" long | |
| Mass spectrometer | Determination of the composition of the atmosphere in the mass range of 12 to 50 amu | 6 lb | 6 watt | 10"×5"×3" | Representative sample of the atmosphere is required. |
| Gas chromatograph | Determination of the composition of the atmosphere | 7.0 lb | 4.5 watt | 5"×5"×8" | |
| Simple composition | | | | | |
| $H_2O$ (vapor) | (0.1 atm) dynamic range 1 to 1000 ppm. 190 to 240° K | 1.5 lb | 1 watt | 3"×3"×3" | Representative sample of the atmosphere is required. |
| $O_2$ | (0.1 atm): same as Venus | 1.5 lb | 1 watt | 5"×3"×3" | |
| $O_3$ | (0.1 atm): dynamic range $10^{-2}$ to 10 ppm | 1.5 lb | 1 watt | 3" dia. ×6" | |
| A | (0.1 atm): dynamic range 3 to 100% | 1.5 lb | 1 watt | 10"×2"×2" | |
| $N_2$ | (0.1 atm): dynamic range 0.1 to 100% | 1 lb | 1 watt | 4"×3"×4" | |
| $CO_2$ | (0.1 atm): dynamic range 1 to 100% | 1 lb | 1 watt | 4"×3"×4" | |
| Alpha scattering | Compositional analysis of surface material | 7 lb | 2 watt | 3"×3"×3" sensor 5"×7"×7" elec. | Placement of sensor head slightly above planetary surface. |
| Soil mechanics experiments | Measurement of load-bearing strength, shear strength, cohesive modulus, frictional modulus and bearing stability of surface | 13 lb | 3 watt | 12" dia. ×24 | Axis vertical held 4" above surface. |
| Microwave spectrometer | Planetary: Determine the molecular composition of the atmosphere (clouds, below clouds, at surface) by observing the microwave spectrum of the characteristic lines. | 30 lb | 13 watt | 0.6 ft³ | Beam width less than 2°, aligned toward planet vertical. |
| Extended microwave spectrometer | Planetary: Will measure quantities stated for the microwave spectrometer and also will give a geographic temperature study of Venusian surface. | 35 lb | 15 watt | 0.7 ft³ | Two meter circular antenna, aligned toward planet vertical. |
| Ultraviolet spectrometer | Planetary: Determination of the abundance and height distributions of the principal atmospheric constituents obtained from ultraviolet spectra of the day, night, and twilight portions of Mars with emphasis on lighted side. | 22 lb | 12 watt | 9"×10"× | Sampled appropriately in space and time. |
| Infrared spectrometer | Planetary: Determination of those minor constituents of the upper cloud structure whose absorption spectra are in the infrared region. Measurement of the atmospheric profile of temperature and pressure. | 29 lb | 7 watt | 12" dia. ×15" | Aligned toward planet vertical, requires detector cooling. |
| Ultraviolet photometer (A) | Planetary: Determination of the presence of particular constituents of the upper atmosphere by means of filter spectroscopy. | 1.5 lb | 1.5 watt | 3" dia. ×5" | Aligned toward planet |
| Infrared radiometer | Planetary: Investigation of the structure of the atmosphere by making measurements of the effective radiation temperature of the Martian cloud tops. | 3 lb | 3 watt | 5"×7"×4" | Aligned toward planet vertical |

Table 38. Continued

| Instrumentation | Instrument Gross Measurement Capabilities | Approximate Weight | Approximate Power | Volume or Dimensions | Additional Constraints |
|---|---|---|---|---|---|
| Microwave radiometer | Planetary: Thermal mapping of the surface (33 mm) and structure of atmosphere (8 mm). Additional data to establish the precise shape of the spectral transition curve from the centimeter value of 600° K to the millimeter value of 400° K. This information is related to surface temperature and kinetic temperature of the atmosphere. | 24 lb | 4 watt | 0.5 ft³ | Two meter circular antenna, 2° beamwidth aligned toward planet vertical |
| Magnetometer | Planetary: To establish the existence of a planetary field and to determine its characteristics, magnitude, direction, multipolarity, and orientation. To investigate the nature of the interface between planetary and interplanetary magnetic fields. | 5 lb | 5 watt | 4"×4"×6" | Reduction of spacecraft magnetic field required. Orientation in planetary coordinates must be known |
| Particle flux | Interplanetary: Used in conjunction with the ion chamber to monitor the energetic particle and photon radiation in interplanetary space. Provides semiquantitative information about the energy and particle types composing the radiation. | 2.5 lb | 0.35 watt | 4"×5"×6" | Close to ion chamber, spacecraft to subtend minimum solid angle. |
| Ion chamber | Interplanetary: To measure the total ionizing radiation (cosmic rays) and the variation with time and position in the solar system. | 1.3 lb | 0.101 watt | 6" sphere | Close to particle flux, spacecraft to subtend minimum solid angle. |
| Trapped radiation detectors | Planetary: To search for magnetically trapped charged particles in the vicinity of Mars. If present, to study their intensity, directional and spatial distributions. Also interplanetary cosmic rays. | 4 lb | 0.7 watt | 4"×5"×5" | 30° cone angles, toward and away from the sun. |
| Medium-energy proton directional | Interplanetary: Observation of the temporal spatial variations of cosmic-ray intensity. | | | 4"×5"×5" | Not specified |
| | Planetary: To search for magnetically trapped charged particles in the vicinity of Mars. If such are present, to measure the spatial extent and the anisotropy of the particle fluxes in the low-intensity regions of the trapping regions. | 3 lb | 1 watt | | Not specified |
| High-energy proton directional monitor | Interplanetary: To provide information about the temporal, spatial, and directional variations of galactic cosmic-ray flux. | 4 lb | 0.5 watt | 3"×4"×4" | 60° angle visibility parallel to ecliptic; 60° cone angle visibility perpendicular to ecliptic; 60° cone angle toward the sun. |
| Cosmic-ray spectrum analyser | Interplanetary: To investigate the intensity and the gradient of flux of charged particles in space as functions of nuclear species and time. | 18 lb | 2 watt | 18"×6"×6" | Four mutually perpendicular telescopes: 30° to 60° cone angles. |
| Plasma instrument (electrostatic analyser) | Interplanetary: To measure the flux of positive and negative components of solar plasma travelling outward from the sun with 300° energy and directional resolution. To correlate these data with the magnetic field and the low energy plasma. | 7 lb | 1.25 watt | 6"×8"×8" | Covers seven sections of a solid angle of 4 sterad centered on the sun. |
| Plasma instrument (Faraday cup) | Interplanetary: To determine the particle number density, the distribution of velocity vector, and the temporal and spatial distributions of the interplanetary plasma. To correlate these data with the magnetic field measurements. | 20 lb | 4 watt | 36"×10"× | Four 40° cone angles, toward, away, and perpendicular to the sun. |



Table 38. Concluded

| Instrumentation | Instrument Gross Measurement Capabilities | Approximate Weight | Approximate Power | Volume or Dimensions | Additional Constraints |
|---|---|---|---|---|---|
| Cosmic dust (A) | Interplanetary: To measure the flux of cosmic dust particles as a function of direction, distance from the sun, and momentum with respect to the spacecraft. | 2.5 lb | 0.2 watt | 5"×5"×5" | One plate perpendicular to ecliptic. |
| Micrometeoroid detector (A) | Interplanetary: Direct measurement of the velocity and cumulative mass distribution of the cosmic dust of the Zodiacal cloud and in the vicinity of the planets. | 8 lb | 0.5 watt | 10"×10"×6" | Three tubes in ecliptic plane, toward away from and 90° from the sun; one tube perpendicular to ecliptic. |
| Bistatic radar | Interplanetary: To obtain information on the absolute electron density in interplanetary space and the fluctuation of this density as a function of time. | 6-8 lb | 2 watt | 4"×4"×12" excluding antennas | Occulting of spacecraft by planet required; antennas to be oriented to Earth; Antennas: 40-cm and 300-cm dipoles |
| | Planetary: Obtain information on the electron-density profile of the ionosphere about Mars by progressive and selective absorptions of the Earth-transmitted signals during the occulting pass. | 10-15 lb | 6-10 watt | 6' dia. ×12" | Aligned toward planet vertical |
| Infrared television | Planetary: To obtain infrared pictures of cloud structure and surface configuration through possible breaks in the cloud layers. | 12 lb | 15 watt | 12" dia. ×15" | Point to vertical |
| Infrared spectrometer | Simultaneous mapping of composition of surface and correct radiation temperature from orbiting vehicle. | 8 lb | 2 watt | 200 in.³ | No radioactive sources on lander. |
| γ-ray spectrometer | Gross compositional analysis for naturally radioactive materials. Interplanetary γ-radiation analysis. | 40 lb | Minimal | 300 in.³ | Precise dispersal of explosive charges and geophones to 500 feet. |
| Seismic refractometer | Active seismic experiment to establish time-distance relationships giving the nature of the upper surface layers to a depth of one-third the shot-to-receiver distance. | | | | |

Table 39. Typical Scientific Experiments Which Might Be Performed By a Probe to Mercury

| Instrument | Function |
|---|---|
| Flux gate magnetometer | To measure the steady state magnetic flux up to 10 gamma in the vicinity of Mercury. |
| Nuclear resonance magnetometer | |
| Curved plate plasma detector | To determine the content, direction, density and energy of the particles in the solar plasma or solar wind. |
| Ion chamber | To measure the rate of ionization caused by the particles over specialized energy ranges. |
| Geiger - Mueller tubes | To measure particle radiation. |
| Mass spectrograph | To determine the amount of particles of various masses that are present. |
| Micrometeoroid detector | To study cosmic dust particles and their origin. |
| Lyman alpha detector | To observe the amount of Sun radiation concentrated in the Lyman - Alpha spectra to aid in the analysis of the variations in solar emissions as well as helping to determine the amount of Lyman - Alpha radiation coming from galactic and extra-galactic sources. |
| Radio frequency experiment | To determine velocity of radio waves in vicinity of Mercury. |
| VLF solar spectrum experiment | To provide information on solar very low frequency emissions which are below the critical frequency of the ionosphere. |



Table 40. Typical Scientific Experiments Which Might Be Performed By a Probe to Jupiter

| Instrument | Function |
|---|---|
| Magnetometer | To perform magnetic - field measurements in interplanetary space and adjacent to Jupiter. |
| Spectrophotometer | To perform spectrophotometric measurements of the Jovian Atmosphere. |
| Geiger tubes - scintillation counter | To obtain radiation data. |
| Microwave - radiometer | To perform microwave - radiometry measurements of the Jovian radiation belts and ionosphere. |
| Radar | For radar probing of the Jovian Atmosphere and planetary surface. |
| Video | To obtain high-resolution video pictures of the Jovian cloud structure. |
| Erosion gages | To obtain meteoroid data. |

In addition, experiments to explore the Asteroid Belt might be considered.

Table 41. Typical Values for Presently Attainable Space Communication Systems

| | Spacecraft-to-Earth Link | | | Spacecraft-to-Earth Link | | |
|---|---|---|---|---|---|---|
| | Venus | Mars | Edge of Solar System* | Venus | Mars | Edge of Solar System |
| Distance from Earth ($M_c$) | $3.7 \times 10^7$ | $1.4 \times 10^8$ | $4.4 \times 10^9$ | $3.7 \times 10^7$ | $1.4 \times 10^8$ | $4.4 \times 10^9$ |
| Space Loss (db) | 255 | 267 | 297 | 255 | 267 | 297 |
| Modulation Loss (db) | 4 | 4 | 4 | 8 | 8 | 8 |
| Misc. System Loss (db) | 4 | 4 | 4 | 4 | 4 | 4 |
| Spacecraft Antenna Gain (db) | 26 | 23 | 34 | 0 | 19 | 31 |
| Ground Antenna Gain (db) | 53 | 53 - 61 | 61 | 51 | 51 | 51 |
| Transmitting Power (watts) | 3 | 10 | 50 | 100K | 10K | 100K |
| Receiving Noise Spectral Density (dbm/cps) | -181 | -181 | -181 | -164 | -164 | -169 |
| Performance Margin (db) | 6 | 6 | 6 | 12 | 9 | 6 |
| Data Rate (bits/sec) | 5.6 | 5.6 | 2.2 | 1 | 1 | 1 |

* Refers to deep space missions to the vicinity of Mercury, Jupiter, and Saturn.





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ADVANCED LAUNCH VEHICLE CAPABILITIES
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By Lunar and Interplanetary Flight Section

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