# 8.0 MLV-SAT-V-23(L) LAUNCH VEHICLE

The Saturn V-23(L) vehicle (see Figure 8-1) is a modified Saturn V with lengthened first and third stages, and adapted for attachment of four 260-inch diameter liquid propellant pods. The modified Saturn V core and liquid propellant pods uses standard F-1 and J-2 engines.

The SAT-V-23(L) vehicle as defined in the trade study activity and studied in detail in Phase II activity is a feasible configuration and a logical candidate to provide payloads.in excess of those currently available with the Saturn V vehicle.

The Saturn V-24(L) vehicle (see Figure 1-1) is similar to SAT-V-23(L) except that first stage and liquid propellant pods used uprated 1.8 million pound thrust F-1 engines and the upper stages used various numbers and thrust levels of uprated engines as defined for the SAT-V-3B vehicle.

The SAT-V-24(L) vehicle was only studied during the Phase I study activity. A vehicle configuration could not be defined that fell within the 410 foot study ground rule height limitation as defined in Section 3.0.

## 8.1 CONFIGURATION SELECTION (PHASE I)

By varying the propellant weight between the core stages and pods, a number of related SAT-V-23(L) and SAT-V-24(L) vehicles resulted. Payload capability and vehicle costs were established for these two families of vehicles in order to choose a single baseline vehicle for more detailed analysis.

### 8.1.1 Candidate Configurations

During the trade study both two and three stage vehicles were considered. Propulsion and engine type for all stages and the liquid propellant pods for the SAT-V-23(L) vehicle was fixed to correspond to standard Saturn V engines as defined for the baseline AS-516 vehicle. Each of the four liquid propellant pods used two standard F-1 engines.

On the SAT-V-24(L) vehicle, five 1.8 million pound thrust uprated F-1 engines were used in the MS-IC-24(L) stage and two in each of the liquid propellant pods. MS-II-24(L) stage used various numbers and thrust levels of uprated engines as defined in the MLV-SAT-V-3B section. The MS-IVB-24(L) stage used a single uprated engine of the same type and thrust level as defined in the MS-II-24(L) stage.

Pod propellant capacity was determined by trading propellant between liquid core stages and the pods. Pod diameters ranging between 156 and 396 inches were considered.

### 8.1.2 Trade Studies

Figure 8-2 represents the propellant trade between the MS-IC-23(L) core stage and the liquid propellant pods for the SAT-V-23(L) vehicle. The lower set of curves is for the three stage 72-hour lunar injection mission and the upper set of curves for the two-stage 100 nautical mile earth orbit mission. As shown, the variation of performance as a function of pod-to-MS-IC burn time and propellant loading is not extremely sensitive for either two or three stage vehicles. The baseline SAT-V-23(L) was selected, therefore, to satisfy the 410 foot vehicle height limit.

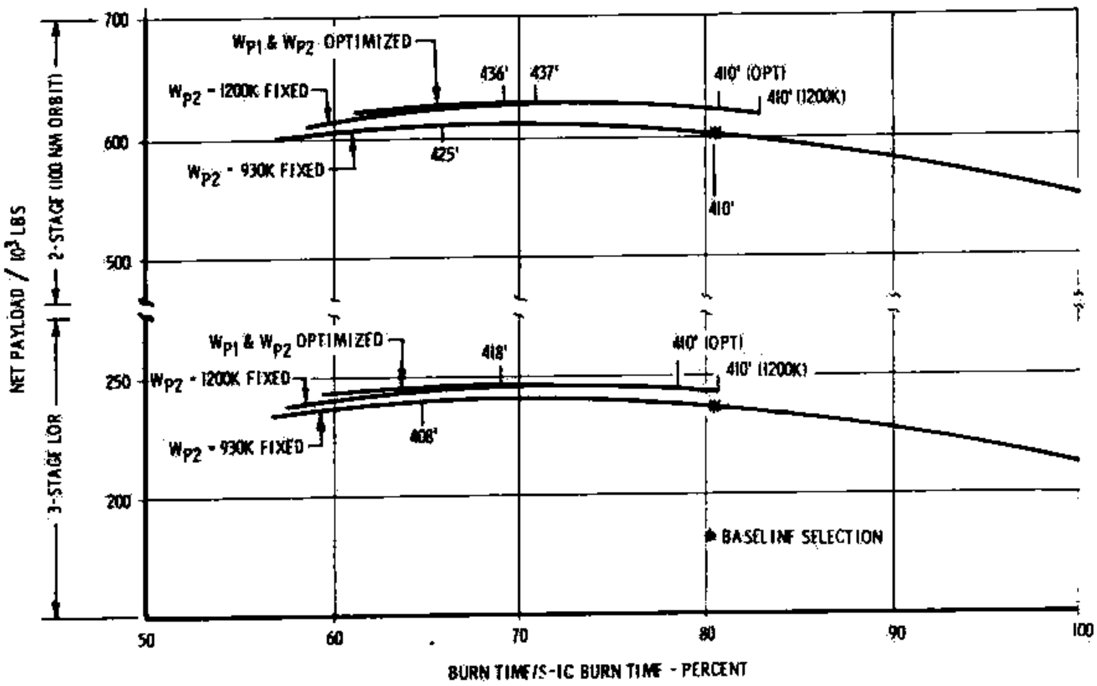


FIGURE 8-2 SAT-V-23(L) TRADE STUDY PERFORMANCE DATA

The SAT-V-23(L) first stage was lengthened 20 feet and the third stage lengthened 16.5 feet which was equivalent to the length and propellant capacity of the MLV-SAT-V-3B baseline vehicle.

Figure 8-3 shows net payload versus the number of engines (dashed lines) and thrust per engine (solid lines) on the MS-II-24(L) stage for vehicles with propellant optimized stages and vehicles with second stage limited to 15.5 feet length increase and third stage limited to 16.5 feet length increase. As shown on Figure 8-3, with fixed upper stages and a MS-II-24(L) thrust of 1.6 million pounds (lower family of curves), the minimum vehicle height for the SAT-V-24(L)was 507 feet at a payload of 348,000 pounds. Optimizing the propellant loading in the upper stages at a MS-II-24(L) thrust level of 1.6 million pounds would result in a payload of 369,000 pounds to 72-hour lunar injection and 860,000 pounds to 100 nautical mile orbit with a vehicle height of 536 feet. Also, at MS-II-24(L) thrust level of between 2.8 and 3.0 million pounds a payload of 410,000 pounds to LOR and 960,000 pounds to 100 nautical mile orbit can be obtained with a vehicle height of 600 feet. Since no vehicle fell within the 410 foot height limit, SAT-V-24(L) was not considered further.

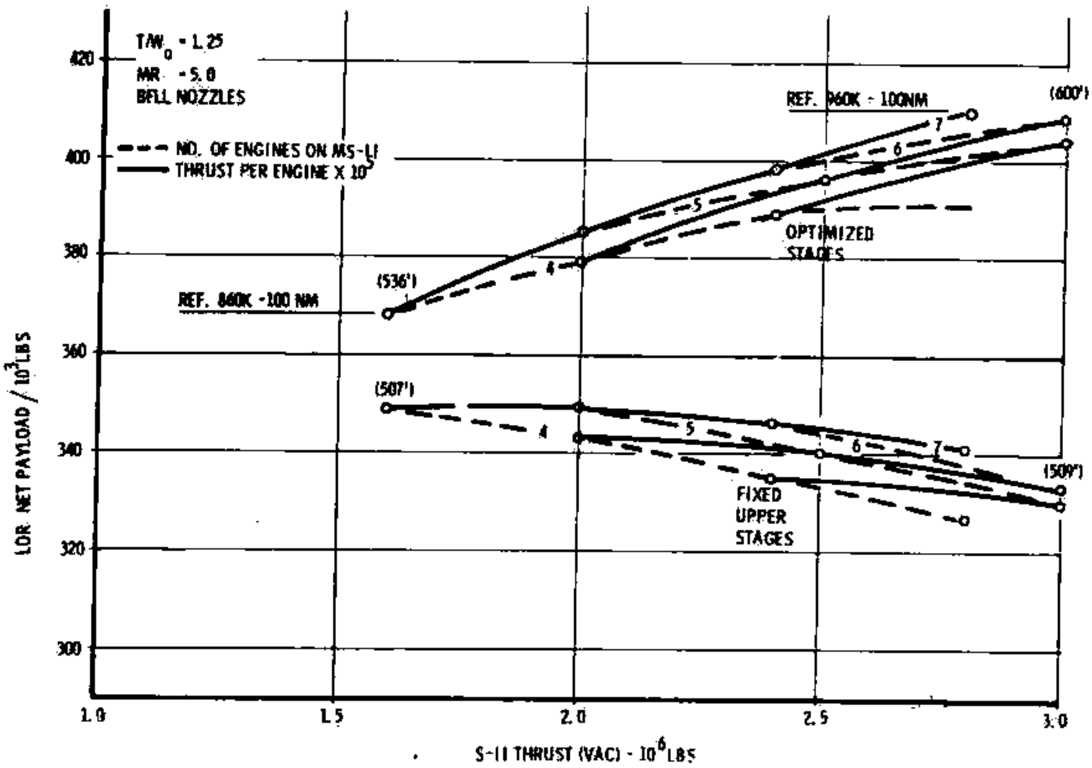


FIGURE 8-3 SAT-V-24(L) TRADE STUDY PERFORMANCE DATA

Trade studies of liquid propellant pod diameter size ranging between 156 to 396 inches show that vehicle and program cost are relatively insensitive to pod diameters between 200 to 300 inches. A 260-inch diameter pod was selected for best overall vehicle geometry.

## 8.2 DESIGN STUDY VEHICLE (PHASE II)

The baseline SAT-V-23(L) vehicle chosen during the Phase I activity was defined in detail, its capabilities and characteristics were determined and its resource requirements established.

### 8.2.1 Vehicle Description

The selected baseline vehicle incorporates a 16.5-foot longer third stage, standard length second stage, and 20-foot longer first stage thrust augmented by four 260-inch diameter liquid propellant pods.

The 131-foot long pods (as shown in Figure 8-4) attach to the MS-IC-23(L) stage at the outboard engine locations, use S-IC technology, structural concepts, and systems. Each pod has two standard F-1 engines which gimbal to supplement the control capabilities of the core vehicle Each pod is an independent stage which can be checked out and test fired as a unit.

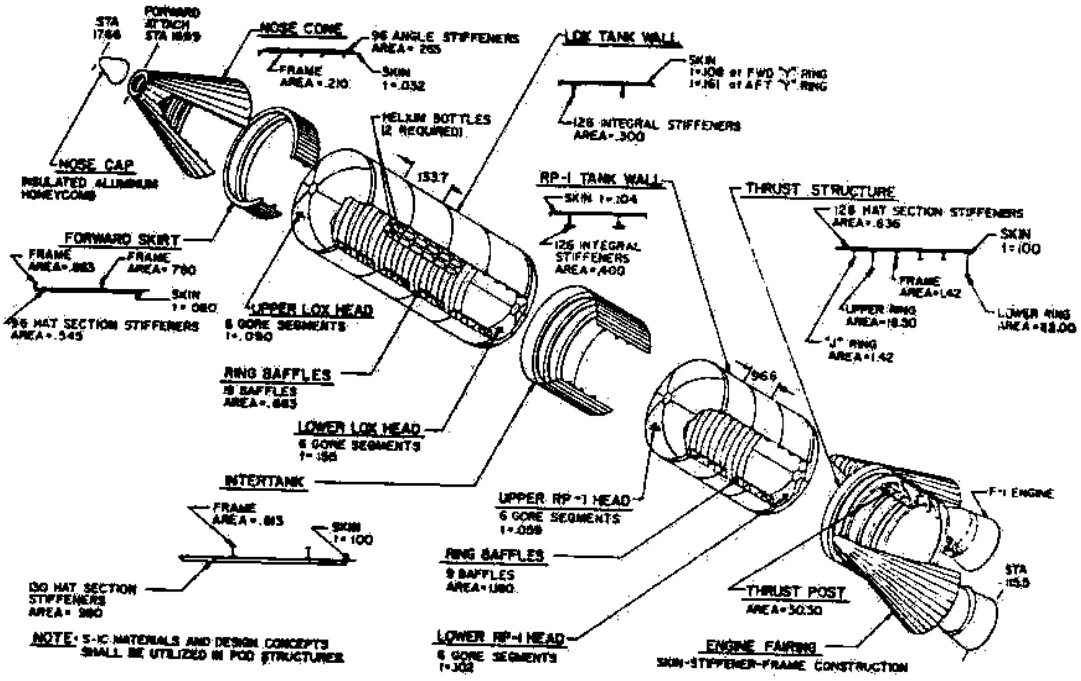


FIGURE 8-4 LIQUID PROPELLANT POD DESIGN

### 8.2.2 Design Study Results

The SAT-V-23(L) two-stage payload capability to 100 nautical mile orbit is 579,300 pounds and its 72-hour lunar injection payload is 220,200 pounds.

Use of this vehicle was also considered for application where the baseline core vehicle (without the liquid pods) could fly alone or with two strap-on liquid pods. The payloads identified for these alternates are shown on Table 8-1.

TABLE 8-I THREE-STAGE 72-HOUR LUNAR INJECTION PAYLOAD CAPABILITY

| No. of Pods | $P_L$ - $10^3$ Lbs. |
|---|---|
| 0 | 80 |
| 2 | 155 |
| 4 | 220 |

Significant load criteria and other data pertinent to vehicle design are shown on Table 8-II with comparative Saturn V values.

The control requirement of the SAT-V-23(L) requires that the four outboard engines on the core vehicle and all eight engines on the pods gimbal. The maximum gimbal requirements during max q flight is 4.1 degrees of the 5.15 degrees maximum available. Aerodynamic fins are not used.

The aerodynamic heating of the MS-IC-23(L) forward skirt has increased from 167°F (Saturn V) to 215°F due to the shock patterns from the pod nose cones. This increased temperature is not a problem.

Base heating of the MS-IC-23(L) increases from 1900°F (Saturn V) to 2200°F. The heat shield can withstand the increased base temperature.

Communications for some stations will be "blacked out" due to the exhaust plume interference. Other stations, however, will have clear communications during these periods and can provide continuous communications. Crew safety studies show the abort lead time to be 15 to 20 percent greater than for the Saturn V. These abort lead times can be reduced by increasing the escape system rocket motor capability.

| | -23(L) | SAT V* |
|---|---|---|
| LOAD CRITERIA | | |
| MAX q (LBS/FT²) | 792 | 766 |
| g's AT MAX q α | 1.90 | 1.954 |
| HEIGHT (FT) | 410 | 363 |
| CONTROL | | |
| MODE | 12 GIMBALED F-1'S | GIMBALED F-1'S |
| MAX. DEFLECTION ANGLE IN FLIGHT | 4.1 DEG | 3.5 DEG. |
| HEATING | | |
| TYP. AERODYNAMIC (S-IC FWD. SKT.) MAX TEMP | 215°F | 167°F |
| BASE (MAX TEMP.) | 2200°F | 1900°F |

* BASELINE 516 WITH $T_0/W_0$ - 1.25

TABLE 8-II SIGNIFICANT LOAD CRITERIA

Digital simulation of separation dynamics for the expended pods demonstrates that a positive core/pod separation clearance is obtained and that axial clearance occurs at 1.83 seconds after separation.

The additional propellant in the first and third stages and the four liquid propellant pods increases the 0.4 psi on-pad over-pressure distance to a value 28 percent greater than the distance between Pad A and Pad B on Launch Complex 39. Waivers for this distance will be required for joint usage of these pads when either pad contains a fueled core with fueled pods. The acoustic level will require protection of personnel during launch operations.

Combined structural loads and acoustic environments are illustrated in Figure 8-5. The design loads have increased substantially and result in vehicle dry weights which are approximately 25 percent higher than those for the AS-516. The acoustical environment is higher than Saturn V specifications for some vehicle areas on the first stage. Acoustic re-qualification of approximately 70 percent of the acoustically sensitive components on this stage will be required.

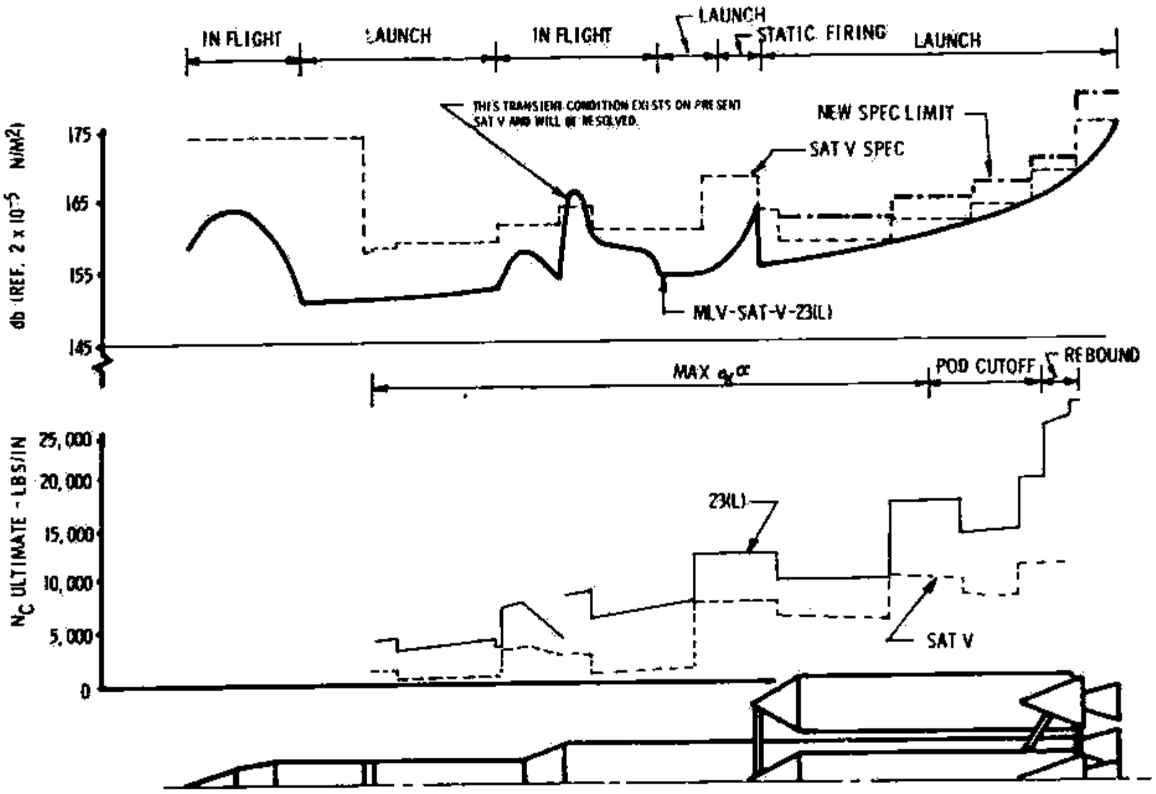


FIGURE 8-5 ACOUSTIC ENVIRONMENT AND STRUCTURAL LOADS

- The impact of structural load increase on the core vehicle is shown in Figure 8-6.

## 8.3 Resources

Existing and new facilities will be employed to manufacture and test the MLV-SAT-V-23(L). These facilities are to be used on a non-interference basis with the Saturn V production schedules. The present stage and I U manufacturers were assumed to be contractors for the MLV-SAT-V-23(L) components.

A dynamic test vehicle, structural test components, and two R&D vehicles are required. The MS-IC-23(L) stage and the four liquid pods of the dynamic test vehicle will be refurbished after test and used as flight articles.

Thirty MLV-SAT-V-23(L) operational vehicles at a rate of six per year for five years form the basis for the production cost

A new dynamic test stand is required because the SAT-V-23(L) launch weight exceeds Saturn V dynamic test stand foundation capability by 30 percent.

### MS-IC-23(L)

The impact of the first stage changes on manufacturing and test facilities is created primarily by the increased stage length and material thickness The revision to tooling for MS-IC-23(L) is the same as made for the MS-IC-3B since the stage lengths are identical and material thickness is similar.

### Liquid Propellant Pods - MS-IC-23(L)

Pod requirements are similar to those of any new stage. New structure will be qualified and its ultimate load carrying capability determined. A full pod structure is constructed for this purpose. Operating components (propulsion, mechanical, electrical/electronic) presently used on S-IC and in an unchanged or less severe environment on the pod do not require further testing. The bulk of pod components fall in this category.

Pod post-manufacturing testing can be accomplished in the existing S-IC test cells at Michoud.

A static firing test stage (battleship weight) is provided to qualify the two engine cluster.

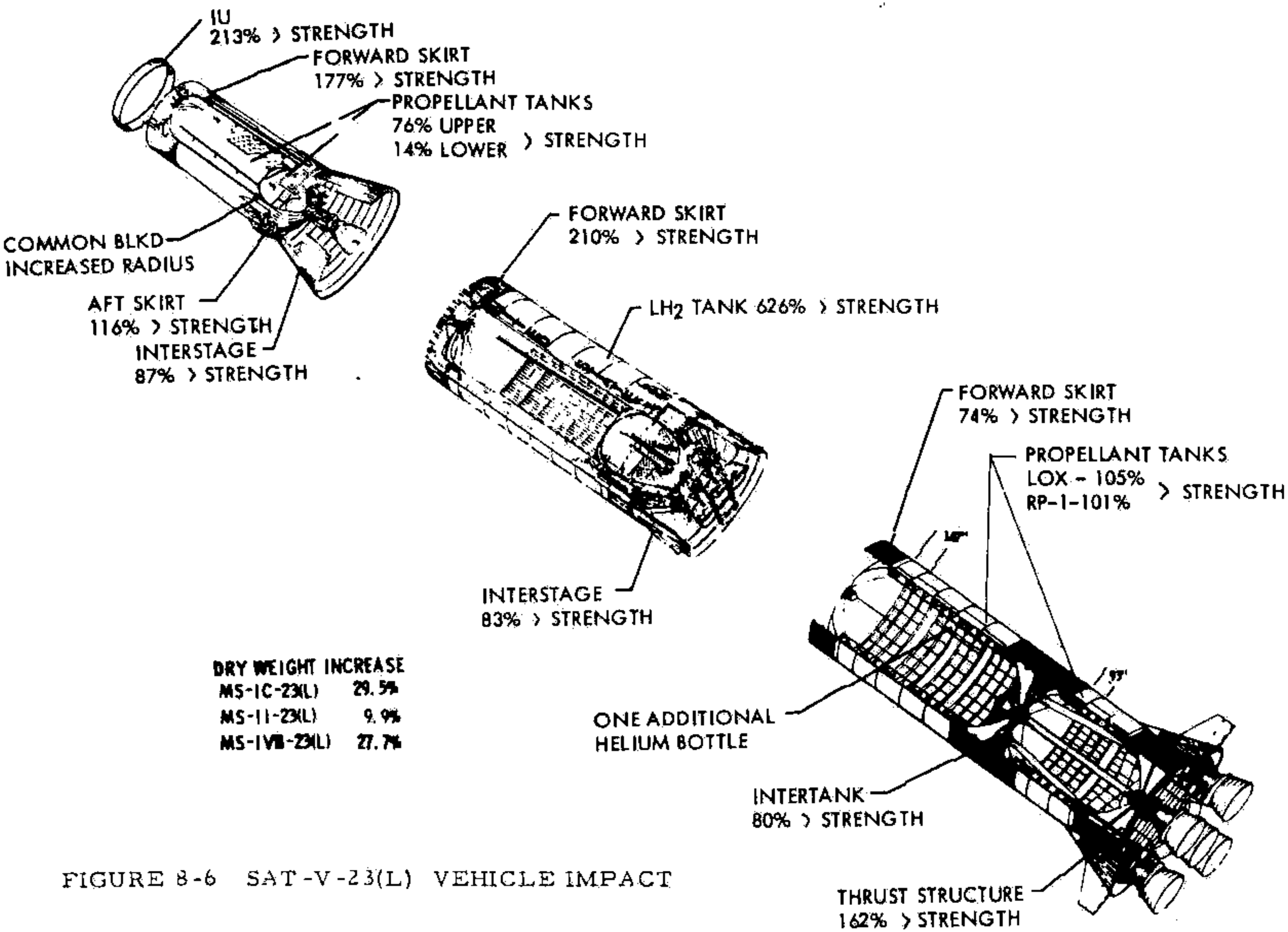


FIGURE 8-6 SAT-V-23(L) VEHICLE IMPACT

The manufacturing plan for the SAT-V-23(L) liquid pods is similar to the S-IC except for welding skins longitudinally rather than cylindrically and reducing bulkhead gores from sixteen to six.

A new manufacturing facility with approximately two million square feet of area is needed to produce 24 pods per year. The facility could be located at Michoud.

A scaled-down S-IC dual position test stand and storage facilities must be provided at MTF for pod acceptance firing.

<u>MS-II-23(L)</u>

The MS-II-23(L) stage RDT&E program was influenced by two factors - stage design modifications and schedule delivery dates for test hardware. The stage design includes a strengthened structure; therefore, a new structural static test will be required. Delivery of the dynamic test stage nine months before the flight test of the new stage requires acceleration of production to twelve stages per year for the standard S-II stage program. Storage has been assumed available for these stages at no additional cost. Two flight test stages are also included in the development program.

The current S-II program transport equipment and vehicles are compatible with the MS-II-23(L). No modification will be required to handle the additional stage weight.

The manufacturing requirements are also defined by schedule delivery dates and stage structural design. Scheduling of the MS-II-23(L) static/dynamic (S/D) test stage necessitates acceleration of the standard S-II production to accumulate sufficient stages to maintain delivery to KSC at two-month intervals. Manufacture of the first flight test stage is started four months after the S/D stage. The revised structural design requires modification of tools for fabrication and assembly of the forward and aft skirts, $LH_2$ tank walls, interstage, aft LOX bulkhead and aerodynamic fairings.

The Seal Beach facility requires only minor changes, principally modification to the structural test tower to take the increased test loads. Some handling equipment at Tulsa and Seal Beach will require modification. The Static Test Tower modification must be completed by September 1971. for test of the MS-II-23(L). After static test, the stage is modified for the dynamic test and shipped to MSFC in August 1972. Bi-monthly delivery of the 30 flight stages occurs after completion of the second flight test stage MS-II-36 (October 1973).

MS-IVB-23(L)

The greater length and weight necessitate major modification to the Stage Transporter and certain items of handling equipment, and minor changes to other items. Minor modifications of propulsion and electrical GSE are also required.

Complex arrangements are required to provide time for modification of tooling and facilities without affecting delivery of standard stages. The time for modification and expansion of the tooling and fabrication facilities is provided by a temporary acceleration of the assembly of the standard stage and then storage prior to delivery.

There are no major problems in the other resource areas. The design is within present fabrication technology. No new or unique testing procedure is required. Modifications will be required to transportation and handling equipment. The increased stage size precludes use of the Super Guppy and necessitates ocean shipment.

Launch Facility and Operational Impact

The modified core vehicle will be assembled according to standard procedures in the VAB on the Mobile Launcher. The pods assembled at Michoud will be shipped to MILA where they will be attached to the core vehicle in the VAB. After test and checkout, the vehicle will be moved to the launch pad.

Normal operations for the vehicle will be resumed and additional operations as required for the pod final checkout and arming will be accomplished.

The existing VAB with work platforms relocated and modified can be used. The launch pad and flame trench need modification to adapt to the MLV-SAT-V-23(L) configuration. The existing crawler transports will be replaced. One Saturn V mobile launcher will be modified to handle SAT-V-23(L). A new mobile launcher and mobile service structure are provided because of program timing.

Schedules

Within the study groundrules and after an analysis of the required design and development plans and manufacturing impact, a schedule for development and production of this vehicle was prepared. See Figure 8-7.

The vehicle timing is based on new manufacturing and test facilities for the pods, ground test pod manufacture and test before the first flight article reaches MILA in the second quarter of 1973.

## Costs

The vehicle cost summary is shown on Table 8-III.

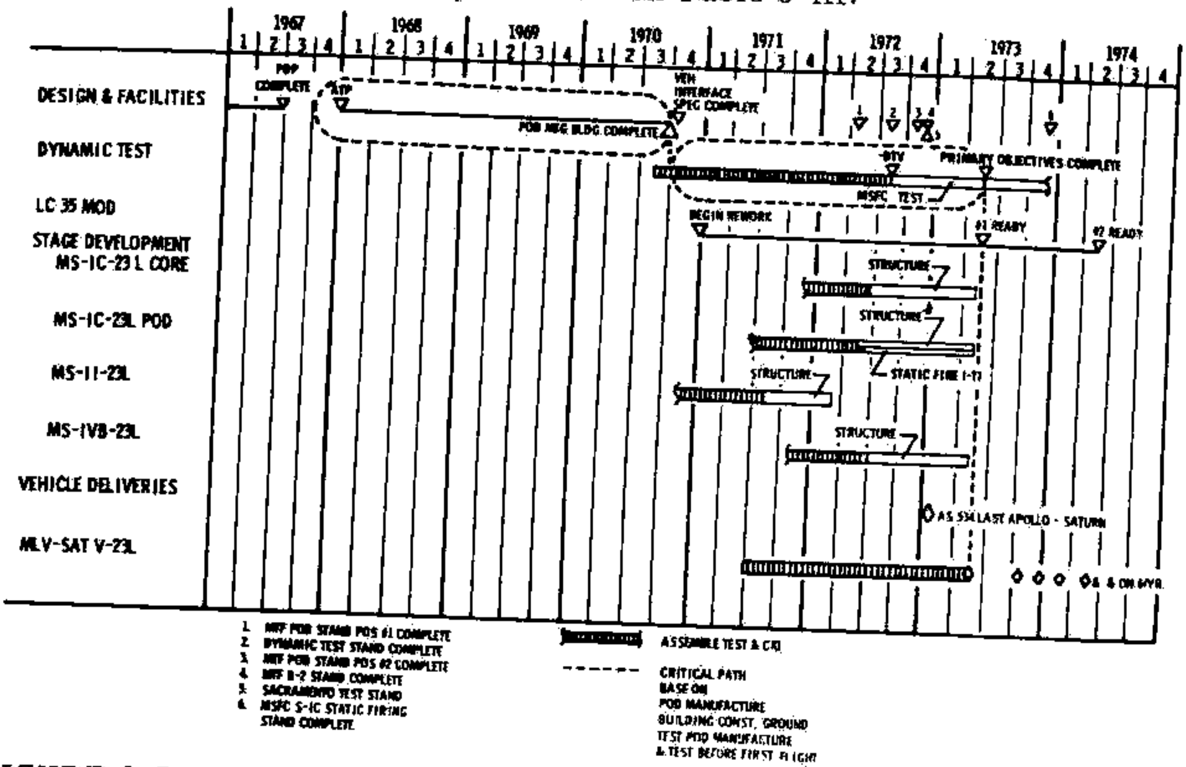


FIGURE 8-7 SAT-V-23(L) VEHICLE DEVELOPMENT AND DELIVERY PLAN

| COST - DOLLARS IN MILLIONS | DEVELOPMENT STAGE | DEVELOPMENT ENGINE | OPERATIONAL STAGE | OPERATIONAL ENGINE | TOTAL |
|---|---|---|---|---|---|
| **LAUNCH VEHICLE** | | | | | |
| Boost Assist - Pod | 132.7 | | 1023.8 | 398.4 | 1554.9 |
| S-IC Stage | 67.6 | | 595.7 | 249.0 | 912.3 |
| S-II Stage | 52.7 | | 517.6 | 181.3 | 757.6 |
| S-IVB Stage | 72.1 | | 559.3 | 36.4 | 467.8 |
| Instrument Unit | | | 131.5 | | 131.5 |
| LAUNCH VEHICLE TOTAL | 331.1 | | 2627.9 | 865.1 | 3824.1 |
| **GROUND SUPPORT EQUIPMENT** | | | | | |
| Boost Assist - Pod | 33.4 | | 43.2 | | 76.6 |
| S-IC Stage | 16.2 | | 27.0 | | 43.2 |
| S-II Stage | 11.5 | | 57.6 | | 69.1 |
| S-IVB Stage | 53.7 | | 48.5 | | 82.2 |
| GSE TOTAL | 94.8 | | 176.3 | | 371.1 |
| **FACILITIES** | | | | | |
| Boost Assist - Pod | 229.9 | | | | 229.9 |
| S-IC Stage | 56.5 | | | | 56.5 |
| S-II Stage | .7 | | | | .7 |
| S-IVB Stage | 6.0 | | 5.4 | | 11.4 |
| Instrument Unit | | | | | |
| Launch Vehicle - KSC | 213.2 | | 764.6 | | 977.8 |
| Launch Vehicle - Other | 10.0 | | | | 10.0 |
| FACILITIES TOTAL | 516.3 | | 770.0 | | 1276.3 |
| SYSTEMS ENGINEERING & INTEGRATION | 2.7 | | 475.8 | | 507.5 |
| LAUNCH SYSTEMS TOTAL | 944.9 | | 4050.0 | 865.1 | |
| | 944.9 | | 4915.1 | | 5860.0 |
| R&D FLIGHTS (2) | | | | | 413.0 |

TABLE 8-III SAT-V-23(L) COST SUMMARY

# 9.0 CONCLUSIONS AND RECOMMENDATIONS

All the launch vehicles studied under the NAS8-20266 study contract are feasible configurations and candidates for payloads ranging from 78,000 pounds to 960,000 pounds to a 100 nautical mile Earth orbit.

Specific baseline vehicles studied within facility limitation ground rules were limited to a maximum payload of 579,000 pounds to a 100 nautical mile Earth orbit.

## 9.1 INTERMEDIATE PAYLOAD LAUNCH VEHICLES

From these studies, it was concluded that all the intermediate launch vehicles were feasible using existing Saturn V stages with minimum modifications. These eight launch vehicles will cover an incremental payload range from 78,000 pounds to 255,000 pounds in low Earth orbit. No major structural or other system changes are required to the existing Saturn V stages to obtain this family of flexible launch vehicles.

Therefore, it is recommended that in the selection of the intermediate payload vehicles that both cost effectiveness and flexibility be considered. In the utilization of existing Saturn V stages for intermediate payload application, all possible arrangements should be implemented simultaneously to obtain this flexibility. It is further concluded that all uprated Saturn V vehicles also have intermediate derivatives. In other words, when an uprated vehicle is chosen for development, consideration should be given to developing simultaneously its intermediate payload capabilities.

## 9.2 UPRATED SATURN V LAUNCH VEHICLES

The uprated vehicles defined in the trade study and studied in detail in Phase II are feasible configurations and logical candidates for payloads in excess of the current Saturn V capability. No major problem areas were identified for either development or production. No significant adverse flight environmental characteristics were identified.

Major vehicle modifications to adapt the Saturn V vehicle to these new uprated configurations were defined as follows.

a. Structural modification of all stages to enable the vehicle to withstand the higher loads imposed due to the larger payload capability and increased payload envelope (increased payload diameter and 410 foot vehicle height).

b. Structural modification of some stages for increased tank lengths and increased engine thrust.

c. Selective requalification of the acoustically sensitive components to qualify these components for the increased acoustical environment.

General comparative conclusions arrived at from the NAS8-20266 studies are as follows.

The SAT-V-3B launch vehicle has the best payload to launch weight of all the uprated vehicles studied. The SAT-V-3B has the minimum launch impact of all the uprated launch vehicles studied. On the other hand, this vehicle requires the most research and development cost per pound of payload, and requires the most lead time of all uprated launch vehicles studied.

The SAT-V-4(S)B launch vehicle has the best payload per research and development dollar with a nominal launch impact. However, as shown on Figures 2-3 and 2-4, when operation costs are included, the SAT-V-4(S)B does not become the most cost effective launch vehicle. It requires the least lead time and development cost of all the uprated launch vehicles.

Of all the uprated launch vehicles studied under the NAS8-20266 contract, the SAT-V-25(S) launch vehicle is the most cost effective (slightly ahead of SAT-V-23(L)). The SAT-V-25(S) vehicle, when compared to the SAT-V-4(S)B vehicle, does cost more to develop and has a greater impact at the launch facility.

The SAT-V-23(L) launch vehicle has the greatest payload capability of all the launch vehicles studied and is almost as cost effective as the SAT-V-25(S). It also has the advantage of using existing standard Saturn V engines, propellants, and systems. It does, however, have the greatest impact on the launch facility.

As shown in Figures 2-3 and 2-4, the cost efficiency of the SAT-V-23(L) launch vehicle is directly competitive with the modified Saturn Vs with strap-on solid motors (SAT-V-4(S)B and SAT-V-25(S)). The development of a low cost liquid stage for strap-on boost-assist purposes would further reduce the cost efficiency of the SAT-V-23(L) launch vehicle. Another factor restraining the potential payload capability of the SAT-V-23(L) vehicle is the 410-foot height limitation established as a ground rule for the NAS8-20266 study. Further work should be done to consider overcoming the 410-foot height limitation such as installing the payload outside VAB, modification to VAB, etc.

Further studies should be directed toward future refinements of the vehicle designs and specifically toward possible future applications. The increased payload capability and improved cost effectiveness over that of the existing Saturn V could be used to reduce significantly overall mission costs by allowing the payloads for these missions to increase in weight to provide payload design simplification. For example, a direct lunar shot for Apollo-type missions could greatly reduce the cost of the payload package from those required for the current LOR hardware.

Assuming manned interplanetary exploration is an ultimate NASA goal, it is further recommended that:

a. A study be conducted on a modified uprated Saturn V core with 260-inch diameter solid motor strap-ons as an "ultimate" Saturn V uprating step, which, e.g., could eliminate rendezvous as a requirement for manned fly-by missions and minimize rendezvous for more ambitious missions. This method of uprating should be compared both with the SAT-V-23(L) and -24(L) vehicles described in this study and "low-cost" pressure-fed storable liquid pod strap-on alternatives; and

b. The feasibility of a stepped uprating program utilizing a common core be explored which would minimize facilities impact. In other words, size a modified Saturn V liquid core that could efficiently accept as strap-on boost-assist components several different sizes of solid rocket motors and/or several different sizes of liquid pods. Also develop a complementary flexible launch support equipment concept.