5.0 MLV-SAT-V-3B LAUNCH VEHICLES

The SAT-V-3B (see Figure 5-1) is a Saturn V with all stages lengthened and the thrust of each stage increased.

The vehicle, as defined in the trade study activity and studied in detail in the 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.

5.1 CONFIGURATION SELECTION (PHASE I)

Trade studies were directed towards deriving sufficient data to allow MSFC to determine the best compromise MS-II-3B stage thrust level which satisfied requirements for both the SAT-V-3B three-stage vehicle and the MLV-SAT-INT-17 two-stage vehicle. The INT-17 uses the SAT-V-3B upper stages (MS-II/MS-IVB) as a ground launch vehicle, and was studied concurrently by North American Aviation under separate contract.

5.1.1 Candidate Configurations

MS-IC-3B thrust was fixed at five 1.8 million-pound F-1 engines for all configurations. The second stage is an MS-II-3B using from four to seven advanced engines with 300,000 to 700,000 pounds of thrust. The three-stage vehicles have an MS-IVB-3B as the third stage using a single engine of the same type and thrust level as for the second stage. Maximum vehicle length was 410 feet.

Upper stage propulsion considered two advanced engine concepts, a toriodal aerospike engine and an advanced bell engine (see Figure 5-2).

The LOX/LH_2 aerospike engine has a toroidal combustor and truncated aerodynamic spike annular nozzle. This design results in a 64-inch reduction in engine length. The other engine considered was a high-pressure LOX/LH_2 concept with a bell nozzle. Bell nozzle engine length, from gimbal point to nozzle exit plane, was maintained at 116 inches because of upper stage interstage clearance requirements.

5.1.2 Trade Studies

Parametric data developed for the SAT-V-3B two- and three-stage vehicles included: (1) weight and mass characteristics, (2) trajectories and performance, (3) aerodynamics and heating, (4) design loads, and (5) separation. Trades were also made for the two types of advanced engines operating over a range of thrust levels.

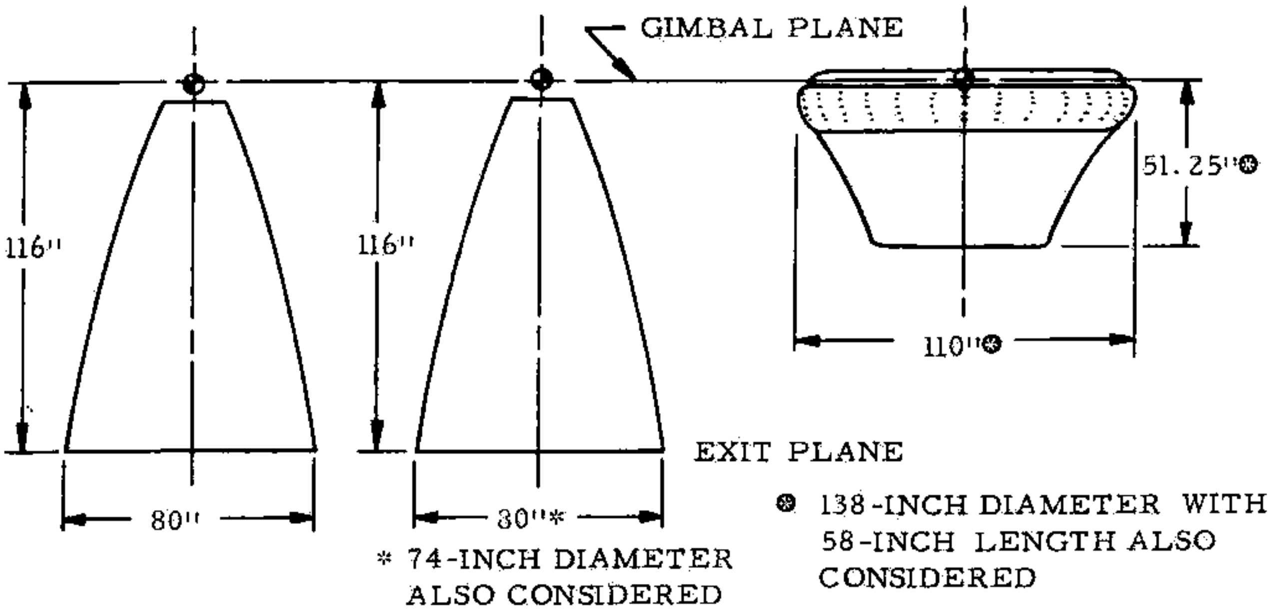


FIGURE 5-2 TRADE STUDY UPPER STAGE ENGINES

Data was prepared for vehicles whose stage lengths were optimized to yield maximum payload capability. Payload performance was also determined for vehicles whose upper stage length increases were fixed at 15.5 feet for the second stage and 16.5 feet for the third stage.

Net payloads for the three-stage vehicle with bell nozzles are shown on Figure 5-3. The data are typical of those prepared for the trade study. Dashed lines on Figure 5-3 refer to the number of engines on the MS-II-3B stage while the solid lines give thrust per engine. The lower group of curves shows payload with the upper stage sizes fixed. The upper set of curves covers the propellant-optimized stages. With optimized stages, the payload increases with increasing thrust in the upper stages. However, the vehicle height limit of 410 feet is quickly exceeded. The same type of data for the two-stage bell-nozzle configuration exhibit the same trends. With fixed upper stages, maximum payload is achieved with MS-II-3B thrust of around two million pounds for both the two- and three-stage vehicles.

Figure 5-4 summarizes performance for fixed upper stage configurations and propellant-optimized versions within the 410-foot limit. These data cover two- and three-stage vehicles with bell and toroidal upper stage engines. Use of toroidal engines gives a two to five percent increase in payload. Performance results for the SAT-V-3B favor a total MS-II

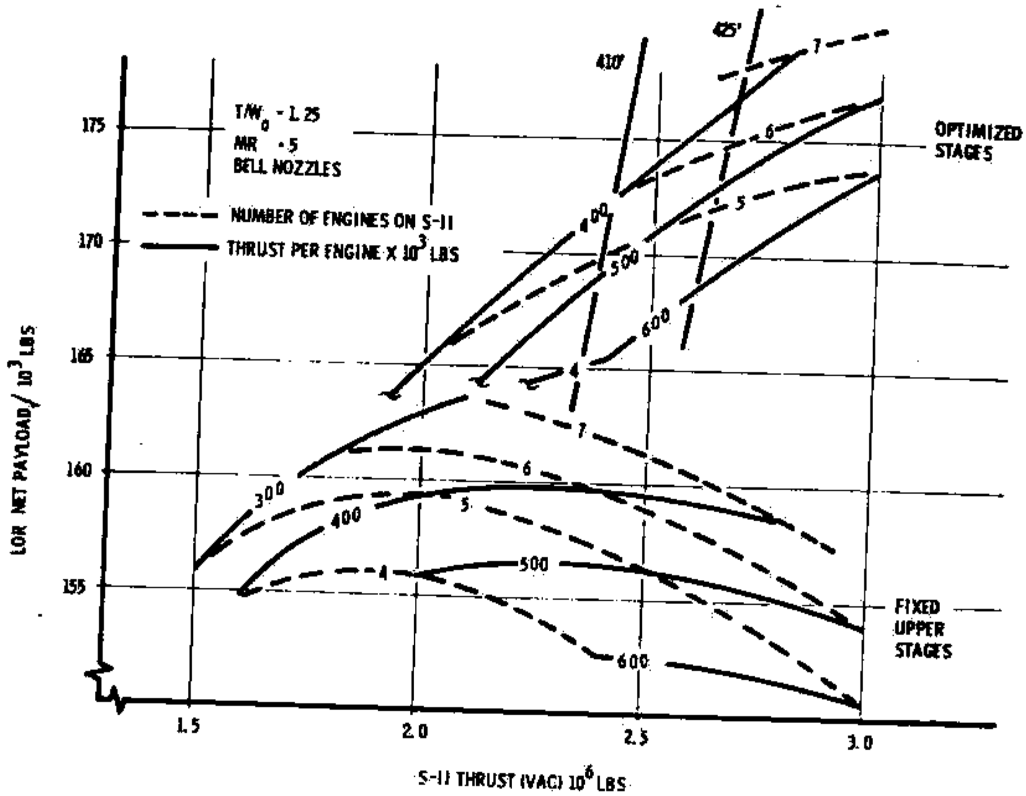


FIGURE 5-3 TRADE STUDY PERFORMANCE DATA

thrust of around two million pounds using 400, 000 to 500, 000 pounds of thrust per engine. Seven 300, 000 pound thrust second stage engines show a 2.6 percent increase over five 400, 000 pound thrust engines. The lower thrust engines exhibit better performance because engine length was held constant. To decrease engine thrust, the nozzle throat area was decreased thereby increasing engine area ratio and thus specific impulse. Higher mixture ratio (6:1) in upper stages showed a small payload improvement as indicated.

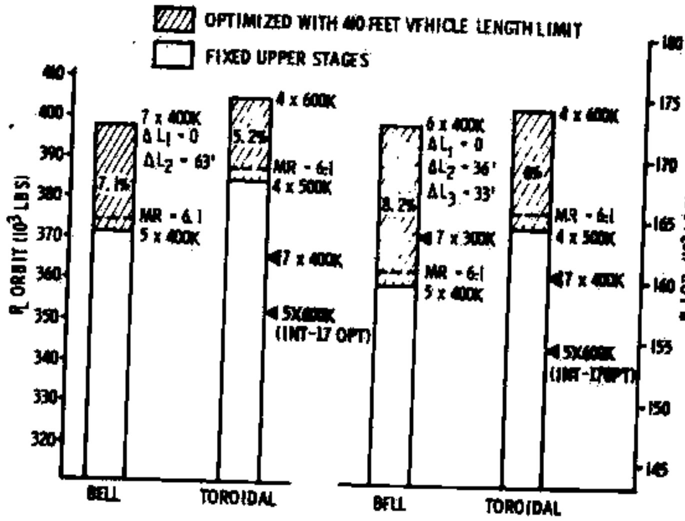


FIGURE 5-4 TRADE STUDY VEHICLE PAYLOAD COMPARISON

These trade study data, those prepared on MLV-SAT-INT-17 and their respective trade study resource analysis were compared by NASA/MSFC in order to reach a compromise on engine quantity, thrust, and type. It was found that the INT-17 vehicle would operate most efficiently at approximately 3. 0 million pounds of thrust. On the other hand, SAT-V-3B needs a second stage thrust closer to 2. 0 million pounds for most efficient operation. Further, the SAT-V-3B third stage requires not more than 180, 000 pounds of thrust for most efficient operation. NASA/MSFC selected a compromise second stage thrust of 2. 8 million pounds, seven 400 thousand pound engines, for further study. The compromised performance by this choice is indicated on Figure 5-5. Also indicated is the degradation to SAT-V-3B which would have resulted had NASA chosen a still higher thrust level (3. 0 million pounds). MSFC selected the toroidal aerospike engine rather than the bell nozzle engine since the bell was examined in detail in last year's studies.

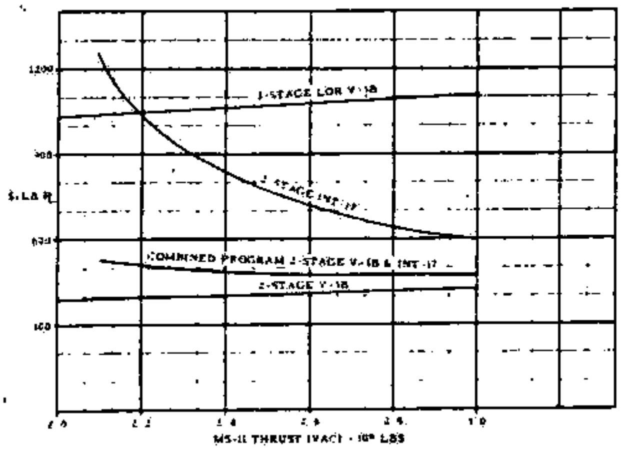


FIGURE 5-5 SAT-V-3B & INT-17 COST EFFICIENCY TRADE

	-3B	SAT V *
LOAD CRITERIA		
MAX. q (LBS/FT^2)	735	766
g's AT MAX q, α	1.92	1.954
HEIGHT (FT)	410	363
CONTROL		
MODE	GIMBALED F-1'S	GIMBALED F-1'S
MAX. DEFLECTION ANGLE IN FLIGHT	4.3 DEG.	3.5 DEG.
HEATING		
TYP. AERODYNAMIC (S-IC FWD SKT)	167°F	167°F
BASE MAX. TEMP.	1940°F	1900°F

* BASELINE 516 WITH T_0/W_0 = 1.25

TABLE 5-I SIGNIFICANT LOAD CRITERIA

5. 2 DESIGN STUDY VEHICLE (PHASE II)

Design and analyses were conducted for two-and three-stage SAT-V-3B vehicles using the propulsion systems chosen by MSFC. Complete resources were prepared for the three stage vehicle.

5. 2. 1 Vehicle Description

The MLV-SAT-V-3B baseline vehicle is shown in Figure 5-1. The MS-IC-3B stage uses five 1. 8 million pound thrust uprated F-1 engines. First stage length increase is 20 feet for a propellant capacity of 5. 6 million pounds with a propellant loading (T/Wo = 1. 25) of 4. 99 million pounds and 4. 8 million pounds for the two and three stage vehicles, respectively. The second stage has seven 400, 000 pound thrust toroidal aerospike engines. It has a length increase of 15. 5 feet for a propellant capacity of 1. 29 million pounds. The shorter toroidal engines allows a 62-inch reduction in interstage length thereby permitting a commensurate tankage increase. The third stage (for three stage application) uses a single 400,000 pound thrust toroidal aerospike engine, a 16.5 foot length increase for a propellant capacity of 350,000 pounds of propellant.

5.2.2 Design Study Results

Payload performance data for the SAT-V-3B for both nominal and alternate missions were determined. The nominal mission for the two stage version is direct ascent to a 100 nautical mile circular Earth orbit. Nominal mission for the three-stage vehicle is direct ascent to a 100 nautical mile circular parking orbit, followed by reignition of the third stage and boost into a 72 hour lunar transfer trajectory. Alternate missions considering a range of altitudes and launch azimuths were also considered.

Figure 5-6 summarizes the orbit/altitude capability for the two stage SAT-V-3B. Net payload for the nominal mission is 367,400 pounds. However, with the high thrust (2.8 million pounds) and short burn time of the MS-II-3B stage, a sizable performance loss occurs at the higher orbit altitudes. For example, more payload is obtained at a 300 nautical mile orbit with existing two stage Saturn V (INT-21) than is obtained with a SAT-V-3B. If engine throttling is used in the MS-II-3B second stage, the payload losses to the higher orbits are reduced considerably as shown in Figure 5-6.

High energy mission (C_3) performance of the three stage vehicle is illustrated on Figure 5-7. Net payload for the nominal 72 hour lunar injection mission is 160,000 pounds. Payloads for polar and sun synchronous orbits are shown on Figures 5-8 and 5-9. A boost turn is required to obtain these orbits from Cape Kennedy. This maneuver requires energy expenditure which is reflected in less payload capability.

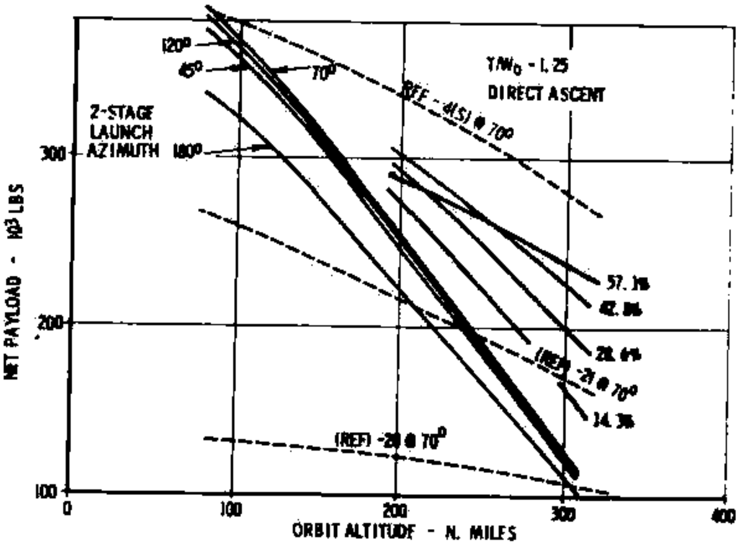


FIGURE 5-6 ORBIT ALTITUDE - AZIMUTH PAYLOAD CAPABILITY

Significant load criteria, and other data pertinent to vehicle design, are shown on Table 5-I, with comparative Saturn V values. Although maximum dynamic pressure (q) and acceleration are slightly less for the

SAT-V-3B the increase in vehicle height, the 33-foot diameter two-stage payload, and increased engines thrusts have significantly increased structural loads over the existing Saturn V.

Control maximum deflection angle in flight has increased from 3.5 degrees (on Saturn V) to 4.3 degrees using the current attitude, attitude rate control system. This is well within the current 5.15 degree gimbaling capability of F-1 engines. Alternate control mode studies showed that approximately 12 percent reduction in maximum bending response could be expected if an angle of attack feedback loop were added to the attitude, attitude rate control mode.

Both aerodynamic and base heating temperatures on the SAT-V-3B vehicle are comparable to Saturn V.

The reliability of the two and three stage configuration of SAT-V-3B vehicle is 0.975 and 0.965, respectively, as compared to 0.990 and 0.980 for the baseline AS-516.

The additional propellant in all stages increases the 0.4 psi on-pad explosive overpressure range 600/feet compared to Saturn V but not enough to impact the adjacent pad at MILA.

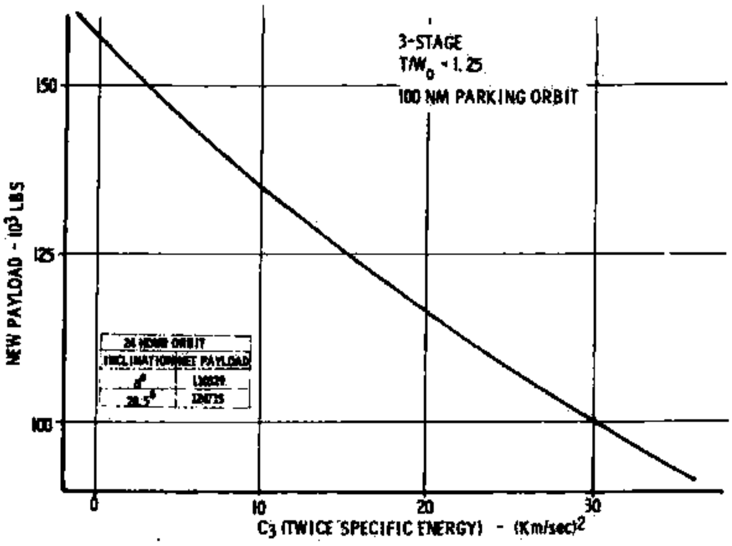


FIGURE 5-7 HIGH ENERGY PAYLOAD CAPABILITY

Saturn V flight and crew provisions are satisfactory for use with this vehicle. No problems were found with structural dynamics, RF attenuation or antenna look angle.

Structural loads and acoustic environments are illustrated on Figure 5-10. The acoustic loads have increased slightly in the first stage but are within the existing specification limit. Some selective requalification of components may be required. The second stage acoustic level has increased sufficiently from the static firing of seven 4,000,000 pound thrust toroidal engines and inflight conditions to require a new spec limit for this stage. No problems exist in the third stage.

As shown in Figure 5-10, the combined loading condition has increased significantly compared to Saturn V, requiring a major structural beefup as

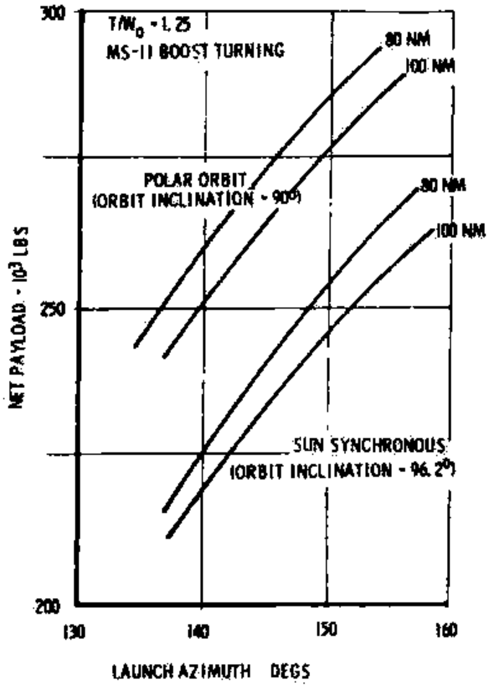


FIGURE 5-8 TWO-STAGE POLAR & SUN SYNCHRONOUS ORBIT PAYLOAD CAPABILITY

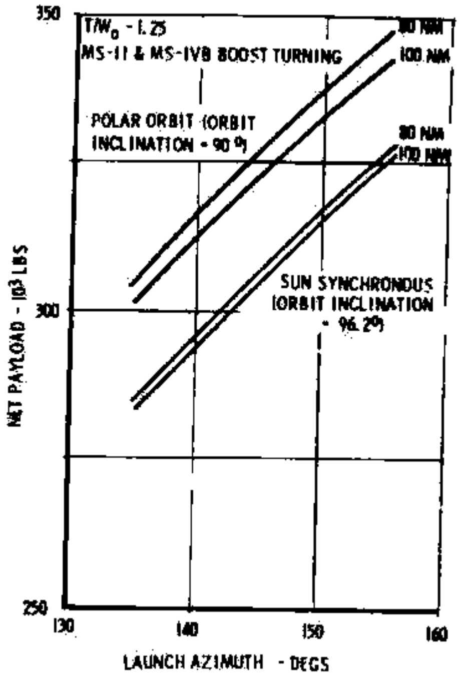


FIGURE 5-9 THREE-STAGE POLAR & SUN SYNCHRONOUS ORBIT PAYLOAD CAPABILITY

as shown in Figure 5-11. Percentage increases in dry weights of each SAT-V-3B stage are also tabulated in Figure 5-11.

5.3 RESOURCES

Increases in the length and thrust of the SAT-V-3B - stages compared to Saturn V impact production, test, transportation and launch facilities. Uprated F-1 engine and new toroidal upper stage engine developments are the most costly items required. Existing facilities will be employed to manufacture and test the MLV-SAT-V-3B. These facilities are to be used on a non-interference basis with normal Saturn V production schedules. The present stage and I. U. vendors were assumed to be contractors for the modified vehicle components.

A dynamic test vehicle, structural test components, and two man-rating R&D flights are required. Relocation of work platforms and increase in height is required at the MSFC Dynamic Test Stand to handle the new configuration. The first stage of the dynamic test vehicle will be refurbished after test and used as a flight stage. The second stage of the dynamic test vehicle will have undergone structural static test prior to -D testing.

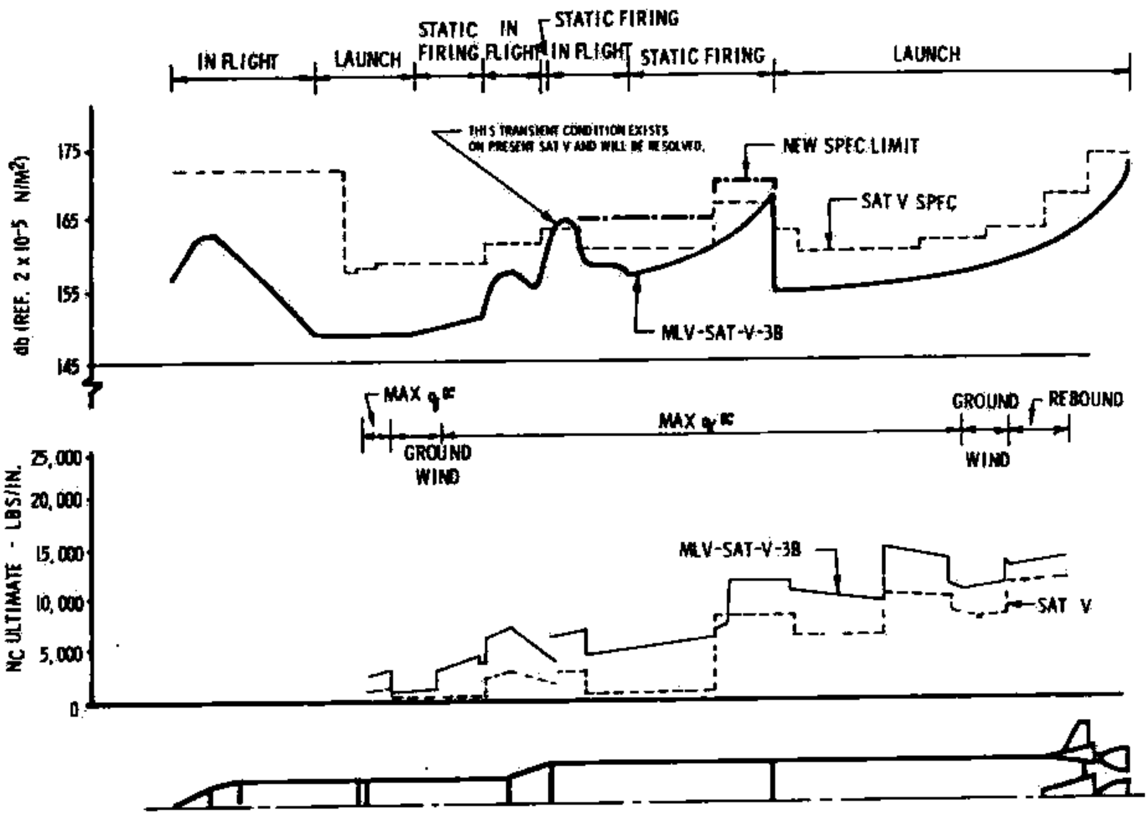


FIGURE 5-10 ACOUSTIC ENVIRONMENT AND STRUCTURAL LOADS

A production rate of six vehicles per year for a period of five years was used to assess production impact. A companion intermediate payload vehicle, also produced at six per year for five years, was the Saturn IB, making use of the MS-IVB-3B.

MS-IC-3B

The thrust increase from 7.5 to 9.0 million pounds necessitates increases in skin stiffener and ring frame gage throughout the MS-IC stage. These changes plus the increase in stage length require requalification of the entire structure.

Revisions are made to S-IC tooling to account for the new material thickness and stiffener locations or for length increases. An additional tank assembly position and new tank clean position are added to avoid long downtime while tooling up for the new configuration. The MTF and MSFC test stands require modification to accept the longer stage. Both stands, however, are capable of handling the greater thrust but more holes are needed in the flame deflectors.

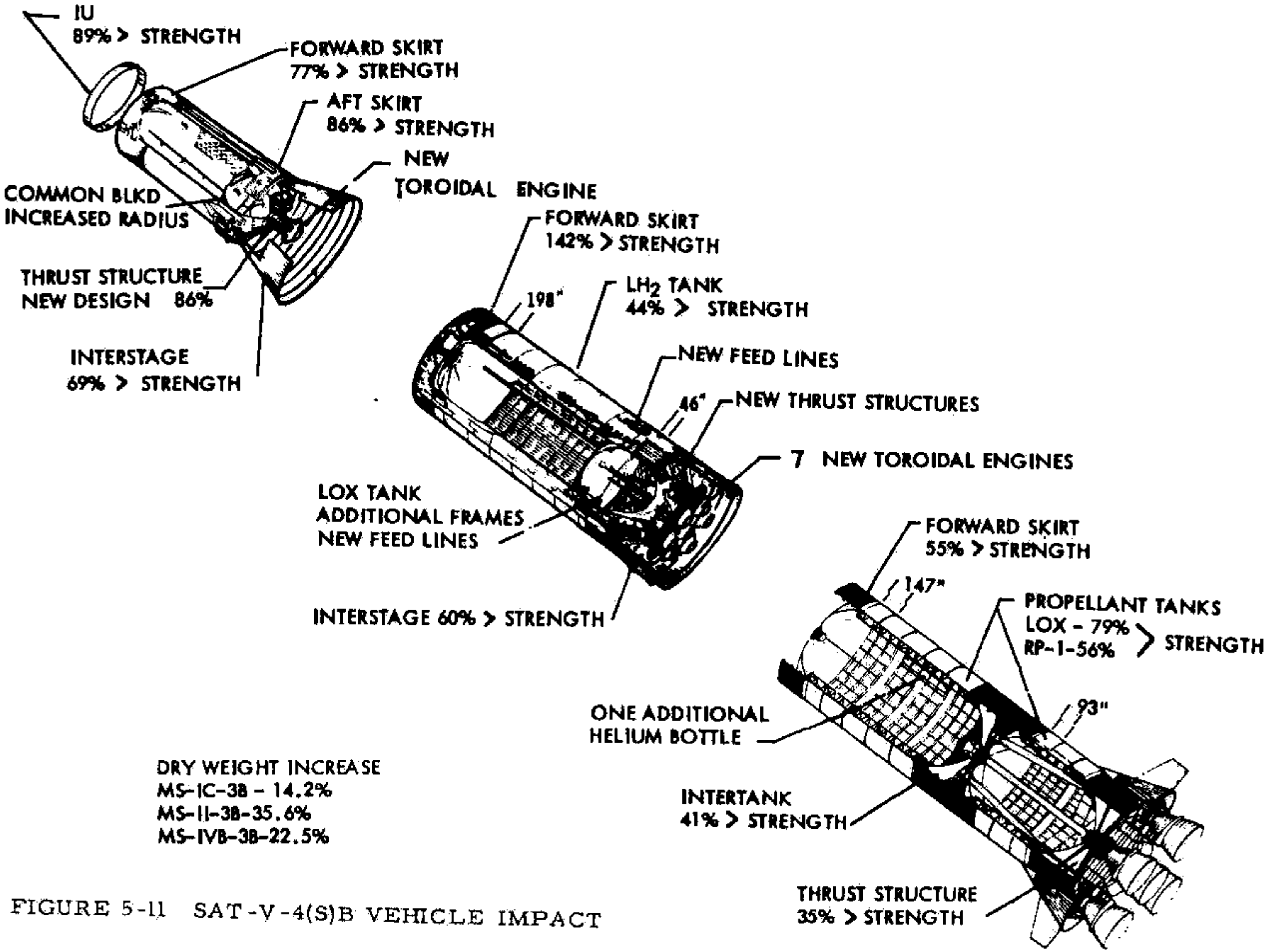


FIGURE 5-11 SAT-V-4(S)B VEHICLE IMPACT

Timing of the MS-IC-3B production is paced by upper stage requirements; therefore, Authority to Proceed is not required until 26 months after start of the upper stage programs. With this timing, the first flight article will be delivered to MILA 3.5 years after first stage ATP.

MS-II-3B

The structure and propulsion system changes to this stage will necessitate static and dynamic structural tests and a "battleship" test development program. To meet the required delivery date of the dynamic test stage, production of the standard S-II would be accelerated, starting with S-II-18. Two flight test stages are included in the development phase.

Standard transport equipment is generally compatible with the MS-II-3B, although lengthening of stage transporters would be necessary, as well as minor modifications such as relocation of tie downs on the Point Barrow. Both Type I and Type II transporters can handle the added weight, except that tire loads may be excessive on the Type II.

Delivery of the dynamic test stage, nine months prior to the first flight stage, determines the point at which production of the standard S-II would be phased out to allow phase-in of new tooling for the MS-II-3B. The structure and propulsion system revisions require modification of standard tools or design of new tools. Tooling mainly affected is that for manufacture of the LH_2 tank, forward and aft skirts, interstage, LOX tank extension and new thrust structure.

The Seal Beach facility requires some modifications, including minor building extensions and revised assembly sequences. New facilities are not necessary, but stage assembly and buildup tools will be modified. Handling equipment at all facilities will be modified for the increased stage weight. Modification and checkout of the Static Test Tower would be completed in December 1971, the dynamic test stage shipped to MSFC in December 1971, and the first operational flight stage completed in September 1973.

MS-IVB-3B

Engineering design or redesign effort is needed mainly in the structure and propulsion system areas because of the increased tank volume, higher flight loads and the installation of a new type higher thrust engine. Development and qualification effort involves a moderate amount of work associated with the same vehicle changes. A dynamic test stage will be furnished for test at NASA/MSFC to verify predicted vibration modes and frequencies.

To allow for modification to tooling and facilities without interfering with standard stage deliveries, a temporary speed-up of the standard stage assembly is planned. No new fabrication technology is proposed nor any new or unique testing procedures. Some expansion and/or modification of facilities is required, at the Santa Monica and Huntington Beach plants, and at the Sacramento Test Center.

The increased stage size precludes transportation by the Super Guppy and will mean dependence on ocean shipment to the Sacramento test site and to Kennedy Space Center. Major modification of the stage transporter is needed because of the added length, and lesser modifications to other items of handling equipment.

Launch Facility and Operation Impact

Changes at MILA for the SAT-V-3B vehicle are primarily due to increased vehicle length. Mobile launcher swing arms as well as VAB high and low bays access platforms are relocated. A new (taller) mobile service structure is needed since insufficient time is available between last Saturn V and first MLV-SAT-V-3B to rework the existing MSS.

No changes are required in the Saturn V operational plan for SAT-V-3B.

Schedule

An MLV-SAT-V3B vehicle development and delivery schedule is shown in Figure 5-12. The vehicle timing is based on almost four years required for upper stage engine development. Upper stage design is paced so that battleship stages are available when PFRT engines are ready. Completion of all critical stage ground development testing is completed before the first flight article reaches MILA in September of 1973.

Cost

A cost summary for the SAT-V-3B is shown in Table 5-II.

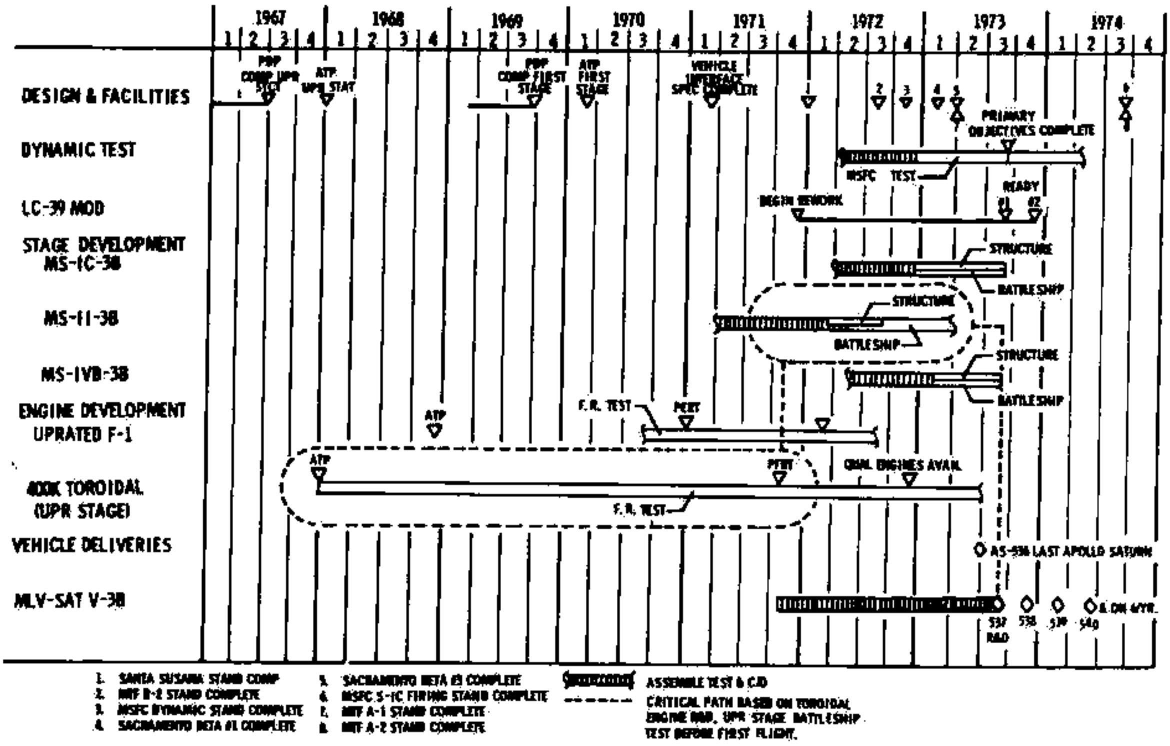


FIGURE 5-12 SAT-V-3B VEHICLE DEVELOPMENT AND DELIVERY PLAN

COST - DOLLARS IN MILLIONS	DEVELOPMENT STAGE	DEVELOPMENT ENGINE	OPERATIONAL STAGE	OPERATIONAL ENGINE	TOTAL
LAUNCH VEHICLE					
S-IC Stage	70.0	123.0	596.3	439.7	1214.0
S-II Stage	165.7	336.2	551.1	686.9	1774.2
S-IVB Stage	97.8	62.9	362.4	114.4	642.4
Instrument Unit			130.7		130.7
LAUNCH VEHICLE TOTAL	333.5	522.1	1640.5	1241.0	3761.3
GROUND SUPPORT EQUIPMENT					
S-IC Stage	10.0		21.9		31.9
S-II Stage	28.1		64.8		92.9
S-IVB Stage	33.7		48.5		82.2
GSE TOTAL	71.8		135.2		207.0
FACILITIES					
Toroidal Engines		39.2			39.2
S-IC Stage	13.3				13.3
S-II Stage	21.7				21.7
S-IVB Stage	7.2		5.4		12.6
Launch Vehicle - KSC	81.7		721.8		803.5
Launch Vehicle - Other	4.8				4.8
FACILITIES TOTAL	128.7	39.2	727.2		895.1
SYSTEMS ENGINEERING AND INTEGRATION	2.3		425.1		425.1
LAUNCH SYSTEMS TOTAL	536.3	561.3	2928.0	1241.0	
	1097.6		4169.0		5266.6
		R&D FLIGHTS (2)			325.6

TABLE 5-II SAT-V-3B COST SUMMARY

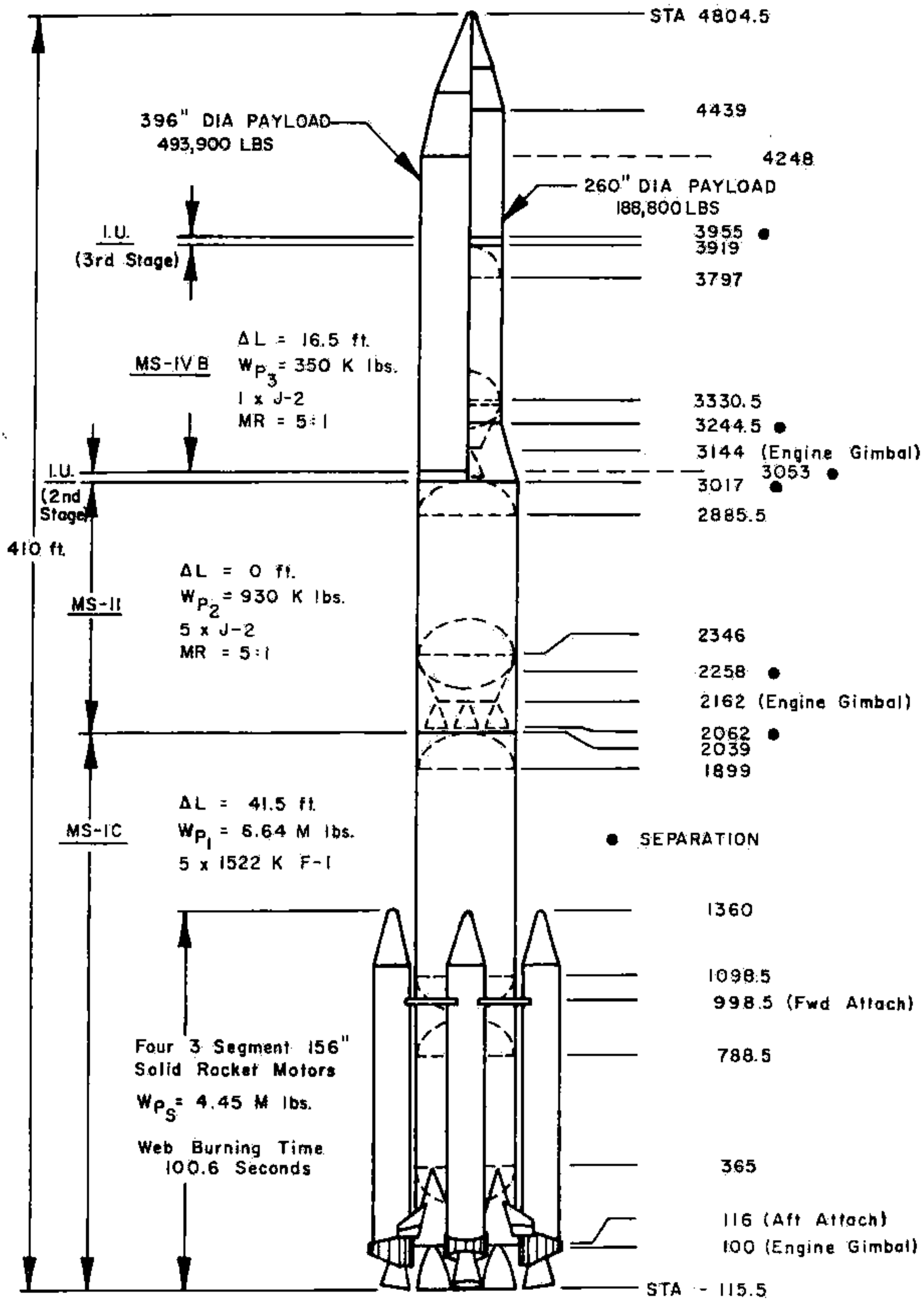


FIGURE 6-1 MLV-SAT-V-25(S) BASELINE VEHICLE

6.0 MLV-SAT-V-25(S) LAUNCH VEHICLE

The Saturn V-25(S) vehicle (see Figure 6-1) is a Saturn V with lengthened first and third stages, adapted for attachment of four 156-inch diameter solid propellant motors.

The vehicle as defined in the Phase I trade study activity and studied in detail in the 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.

6.1 CONFIGURATION SELECTION (PHASE I)

By varying the weight and thrust of the 156-inch solid rocket motors and the weight of propellant in the core stages, a number of related SAT-V-25(S) vehicles were evolved. Payload capability and vehicle costs were established for these vehicles in order to choose one arrangement for more detailed analysis.

6.1.1 Candidate Configurations

For the trade study, both two- and three-stage operation was considered. Vehicle height was fixed at 410 feet for both two- and three- stage configurations. Propulsion and engine type for all stages was fixed to correspond to the baseline AS-516 vehicle. Varying weights of propellant and corresponding stage lengths were studied for all stages. Four 156-inch solid propellant rocket motors were attached to the vehicle for thrust augmentation. The number of segments (and thus solid propellant weight) in the solid motors was varied between two and four. Solid motor thrust/time restraints were specified by MSFC. Burntimes and thrust levels of the various sized solid motors were varied also, within the restraints, to optimize vehicle liftoff thrust-to-weight.

6.1.2 Trade Studies

Figure 6-2 is typical of the parametric performance data prepared for the trade study. Figure 6-2 illustrates the net payload for the various number of segments in the 156-inch motors as a function of liftoff thrust-to-weight for the three-stage vehicle. This chart shows two conditions, i.e., (1) optimized first stage propellant weight with standard second stage propellant weight,

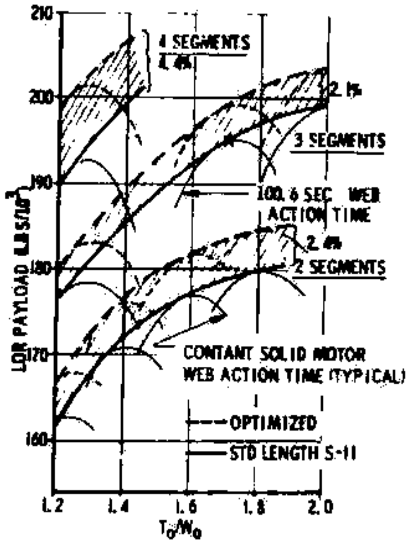


FIGURE 6-2 PERFORMANCE TRADE DATA

and (2) optimized propellant weights for the first and second stages. The MS-IVB in all cases was sized to maximize payload out of 100 nautical mile Earth orbit to lunar injection. Note that the curves are the loci of maximum payload resulting from considering different constant solid motor web action times combined with various core vehicle launch weights.

The data demonstrate that:

a. Payload increases approximately eight percent with each additional solid motor segment.

b. A payload increase of more than two percent accrues by optimizing second stage length. Typical optimized S-II stage length increases are on the order of an additional ten feet.

c. Significant payload increases are attributable to the shorter burn time solid rocket motors and the resulting higher values for liftoff thrust-to-weight ratio.

In developing these data, no structural penalties were assessed to the candidate vehicles for the liftoff thrust-to-weight variation. When structural weight penalties are considered, as they were in other similar studies, it is found that beyond 1.6 to 1.8 thrust-to-weight, payload increases are not as large as indicated on Figure 6-2.

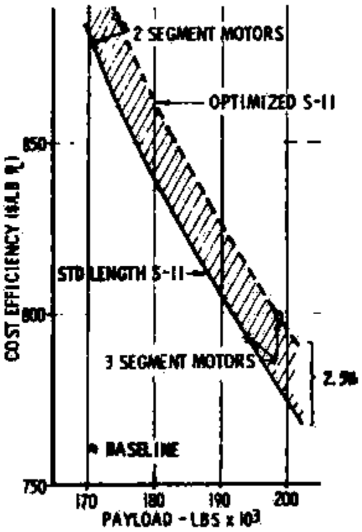


FIGURE 6-3 COST EFFICIENCY TRADE DATA

Figure 6-3 compares the payload cost efficiency of different solid motor weights for the optimized S-II stage and standard length S-II stage. The chart indicates that S-II stage optimization is not worthwhile but that larger solid motor weights can significantly improve vehicle cost efficiency. From these data, and because minimum solid motor burntime was ground ruled at 100.6 seconds, it was recommended to MSFC that the vehicle indicated as "baseline" on Figures 6-2 and 6-3 be chosen for the next phase of study. MSFC approved this selection.

6.2 DESIGN STUDY VEHICLE (PHASE II)

The single SAT-V-25(S) vehicle chosen during the Phase I activity was defined in detail, its capabilities and characteristics were determined, and its resource requirements were established.

6.2.1 Vehicle Description

The MLV-SAT-V-25(S) baseline vehicle is shown in Figure 6-1. It utilizes four three-segment 156-inch strap-on solid rocket motors each with 1.1 million pounds of propellant for thrust augmentation. Each solid motor has a launch thrust of 4.0 million pounds. They burn regressively so that at burnout thrust is reduced to about 65 percent of the liftoff value. Each of the solid motors has a liquid injection (N_2O_4) thrust vector control system to augment the capability of the gimbaled F-1 engines during flight through the max q regime. The liquid core stages of SAT V-25(S) are equipped with standard F-1 and J-2 engines. First stage propellant capacity has been increased to 6.64 million pounds by lengthening the stage 41.5 feet. The second stage is standard S-II length with a propellant capacity of 930,000 pounds. The third stage (for three-stage applications) is increased in length by 16-1/2 feet and has a propellant capacity of 350,000 pounds.

6.2.2 Design Study Results

As noted on Figure 6-1, the SAT-V-25(S) two stage payload capability to 100 nautical mile orbit is almost 494,000 pounds and its 72-hour lunar injection three-stage capability is almost 189,000 pounds.

Use of this vehicle was also considered for applications where the baseline core vehicle (liquid stages without solids) could be flown by itself or with only two strap-on solid motors. The payloads identified for these alternates are shown on Table 6-I.

To further improve payload, a special study was conducted to determine the effect of tailoring the solid motor thrust time trace. For this study, the thrust was made regressive until the vehicle has passed through the maximum dynamic pressure regime. The thrust level was then made progressive until solid motor burnout. The payload improvement for the optimum regressive-progressive thrust time trace over that available with the baseline vehicle was approximately one percent. This improvement was not considered significant enough to warrant complicating solid motor design for regressive-progressive burning.

Significant load criteria, and other data pertinent to vehicle design, are

TABLE 6-I PAYLOAD CAPABILITY

	NET PAYLOAD (LB) TWO-STAGE 100 NM Orbit	NET PAYLOAD (LB) THREE-STAGE 72-hour Lunar Traj.
Core Vehicle Without Solid Motors		
$T_o/W_o = 1.25$ $W_{Pl} = 4,343,423$ lb	231,466	88,475
$T_o/W_o = 1.18$ $W_{Pl} = 4,696,492$ lb	239,558	91,568
Core Vehicle With Two Solid Motors		
$T_o/W_o = 1.40$ $W_{Pl} = 6,000,000$	387,073	147,954
Core Vehicle With Four Solid Motors		
$T_o/W_o = 1.734$ $W_{Pl} = 6,640,000$ lb	493,900	188,800

shown on Table 6-II with comparative Saturn V values. Although max dynamic pressure (q) and acceleration are increased slightly, the 410 foot vehicle height coupled with the 33-foot diameter two-stage payload cause the largest impact on structural design requirements.

Control requirements necessitate additional capability beyond the present fin and F-1 engine gimbaling of the first stage. The use of the liquid injection thrust vector control on the solid motor is required for 26 seconds near max q time of flight. Also, because the first stage is rotated 45 degrees compared to Saturn V, the flight control signal must be modified to compensate for the rotation.

Aerodynamic heating is significantly lower than the Saturn V. The shock wave from the solid motor nose cap may impinge on the first stage LOX tank and local insulation may be required. No problems are anticipated as a result of aerodynamic heating.

	-25(S)	SAT V
LOAD CRITERIA		
MAX q (LBS/FT^2)	855	766
g'S AT MAX q α	1.99	1.954
HEIGHT (FT)	410	363
CONTROL		
MODE	GIMBALED F-1'S PLUS N_2O_4 LITVC ON SOLIDS	GIMBALED F-1'S
SOLID MAX. DEFLECTION ANGLE	1.8° PER MOTOR	N/A
SOLID TVC OPERATING	46-71 SEC	N/A
HEATING		
TYP AERODYNAMIC (S-IC FWD SKT) MAX TEMP	132°F	167°F
(MAX TEMP BASE)	2080°F	1900°F
OTHER	MS-IC-25 (S) ROTATED 45°	

BASELINE 516 WITH T_0/W_0 = 1.25

TABLE 6-II SIGNIFICANT LOAD CRITERIA

The base heating environment is more severe for the MLV-SAT-V-25(S) than for the Saturn V due to the solid motor exhaust plumes. Heat shield materials can withstand the anticipated 2080°F temperatures successfully. The aft solid motor attachment skirt will reach 1950°F. Insulation protection here will be required.

The reliability of the two- and three-stage configurations of Saturn V-25(S) are 0.986 and 0.964, respectively, as compared to 0.990 and 0.980 for the baseline AS-516. The lower values for reliability can be attributed to the addition of the strap-on solid motors and to longer first and third stage burntimes.

Separation of the 156-inch SRM's from the vehicle can be accomplished satisfactorily using explosive separation devices and small solid rockets for separation force.

The addition of more fuel in the first stage and the four solid motors increases the 0.4 psi over-pressure distance to a value 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 vehicle with the solid motors attached.

Saturn V flight and crew safety provisions are satisfactory for use with this vehicle. Communications for some stations will be "blacked out" due to the exhaust plume interference. Other stations, however, will have clear antenna access during these periods and continuous communications can be maintained

Structural loads and acoustic environment are illustrated in Figure 6-4. The design loads are higher than those for the standard Saturn V requiring an increase in vehicle structural weight. The present acoustic specification limits are exceeded at several locations on the first stage. Requalification of acoustically sensitive components on this stage will be required.

Major core vehicle changes including the impact of structural load increases is summarized in Figure 6-5. Dry weight increases are also tabulated.

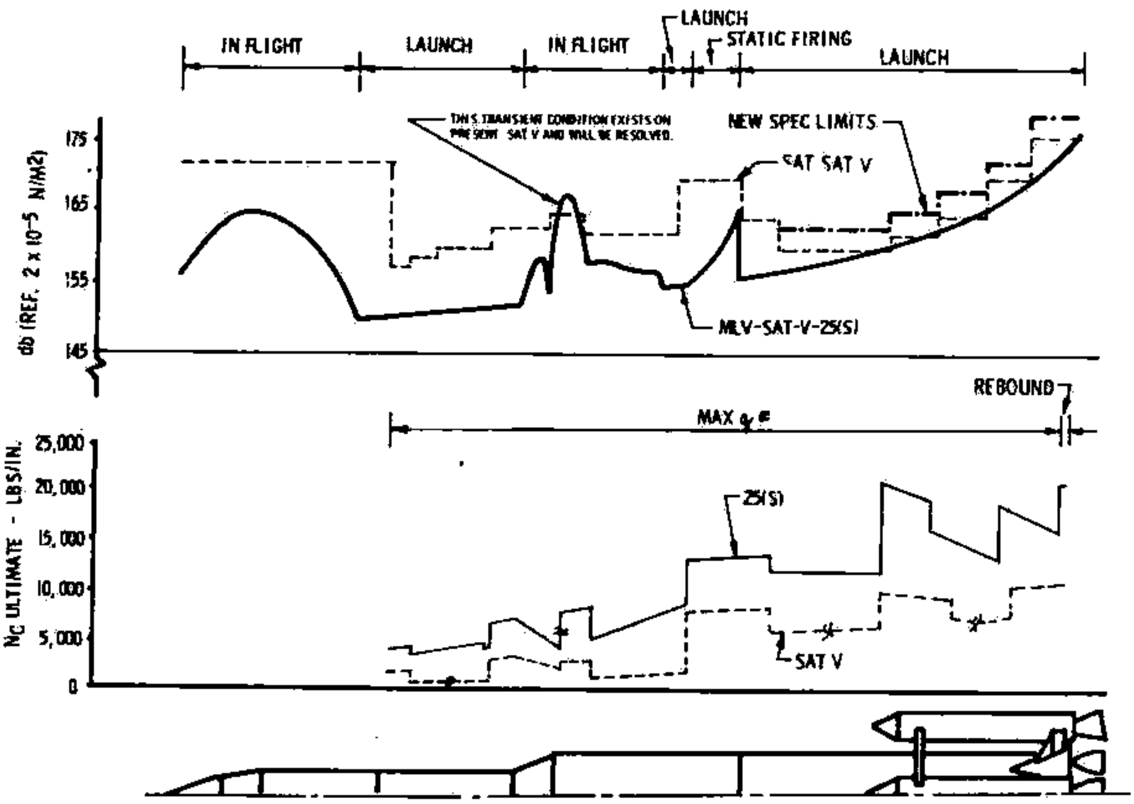
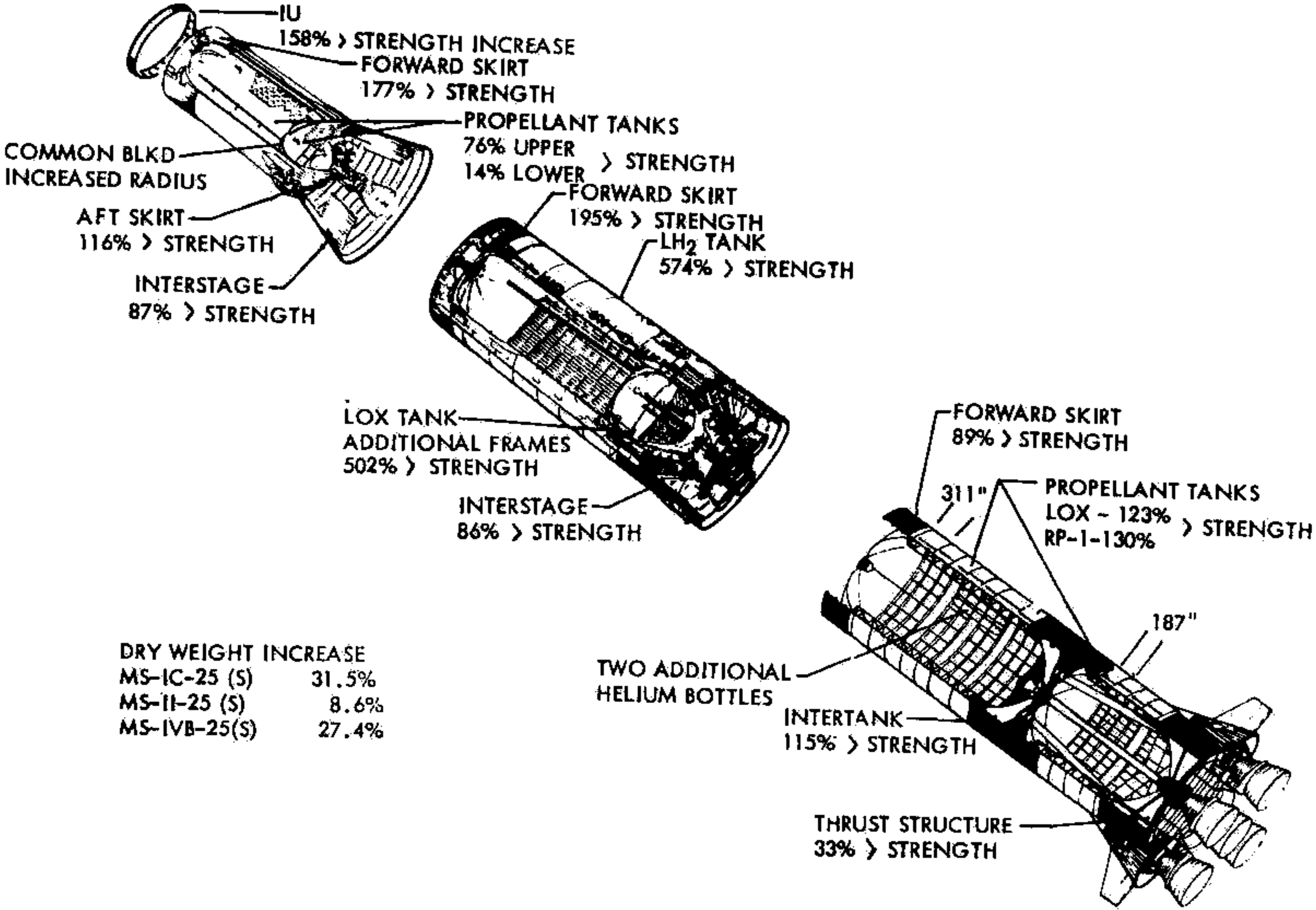


FIGURE 6-4 ACOUSTIC ENVIRONMENT AND STRUCTURAL LOADS



DRY WEIGHT INCREASE	
MS-IC-25 (S)	31.5%
MS-II-25 (S)	8.6%
MS-IVB-25(S)	27.4%

FIGURE 6-5 SAT-V-25(S) VEHICLE IMPACT

6.3 RESOURCES

The present stage, engine, and I.U. manufacturers were assumed to be contractors for the modified vehicle. A dynamic test vehicle, structural test components, and two R&D flights for man-rating are required. A new dynamic test stand will be required for test of this vehicle since its launch weight exceeds present Saturn V stand capability. The S-IC stage of the dynamic test vehicle will be refurbished after test and used as a flight article. The 156-inch solid rocket motors with their thrust vector control system must be developed and qualified for this application

A production rate of six vehicles per year for a period of five years was utilized to assess the production impact.

<u>MS-IC-25(S)</u>

First stage length increase coupled with the more severe structural loads require changes in skin gage, stiffener spacing, and frame chord area. These changes necessitate revisions in manufacturing tools. New tools are required for solid motor attachment structure manufacture. The addition of solid motor functions (ignition, separation, instrumentation) necessitates changes and additions to first stage electrical cable manufacturing boards.

The longer, heavier tanks of the MS-IC-25(S) cannot be hydrostatic tested in the present Michoud VAB position. A new stand will be needed and can be located in a presently unused position in that building. The final assembly and tank assembly stations also must be modified for increased stage length

To introduce the new configuration, without factory modification downtime, an additional tank assembly station and more storage space must be added in the Michoud factory.

The two presently unused stage test positions must be modified to accept the longer S-IC stages. Cables will be installed to the present test control stations and computers. Some new test equipment (solid motor simulators) and minor modification of existing equipment is required.

Modification of the S-IC test firing stands at MTF and MSFC are required only because of the increased stage length and associated propellant capacity.

A minor modification to the stage transporter cables and steering potentiometer will adapt it for the new stage length. However, the additional stage weight exceeds the forward (thrust structure) carriage capability. Two new wheel dollies must be added to the forward carriage.

Both shuttle and sea going barges must have their decks strengthened and supports and tie downs relocated for the longer heavier stage.

For the solid rocket motors, a development program of ten firings is assumed. Minor facilities are required but new tools, jigs and fixtures are a major item. New test and checkout and transportation equipment is also included. Rail transportation from manufacturer to KSC is assumed.

MS-II-25(S)

Manufacturing requirements for the MS-II-25(S) stage are defined by the schedule delivery dates and the stage structural modifications. A separate stage will be manufactured to be utilized for both static structures test and for stage dynamic test. Delivery of this static/dynamic (S/D) stage requires that the standard S-II production be accelerated to accumulate sufficient stages to maintain a constant delivery rate at one stage every two months.

The revised structural design will require modification of the fabrication and assembly tools for the forward and aft skirts, LH_2 tank walls, interstage and aero-fairings. The Seal Beach facilities require a minimum of modifications; the major work required is modification to the structural test tower for the increased test loads. Some handling equipment at Tulsa and Seal Beach will require modification as a result of the increased stage weight.

The current S-II program transport equipment and vehicles are compatible with the MS-II-25(S) stage design; no modifications would be required to handle the additional stage weight.

MS-IVB-25(S)

The elongated tank of the MS-IVB required by this vehicle has a significant impact on resources. The standard S-IVB facilities for manufacturing, assembly, test and checkout will need modification to accommodate this larger, heavier stage. Additional machine tools and space are required for the detail part manufacturing. The most significant area is the skin mills for machining the tanks. The 24 to 36 month delivery time for these machines make early delivery of modified stages difficult. The assembly and checkout towers must be reworked to increase their vertical capacity. Welding torches, platforms, and stage interfaces must be relocated and adapted to the new vehicle. A complicated scheduling problem exists to provide time to modify the facilities with minimum interference with delivery of standard stages. This requires accelerating the production rate of the standard stages and storing them for delivery on their normal shipping date. This could overload some of the checkout towers and require either extensive overtime or additional facilities and GSE. The static firing at Sacramento requires modifying the test stand. A streamlining of the test procedure is recommended as a means of significantly reducing the cost of these modifications. The streamlining would permit making the post-firing checkout in the test stand and eliminate modifying the vertical checkout laboratory cells.

The transporting equipment will require some redesign and all shipments will be by water since the present Super Guppy aircraft cannot carry the elongated stage.

Launch Facility and Launch Operations Impact

The impact of this vehicle on the launch facility and operations was studied by The Martin Company under separate contract to Kennedy Space Center. This study activity described the minimum impact launch sequences for this vehicle as shown below.

The modified core vehicle will be assembled according to standard procedures in the VAB on a modified mobile launcher (ML) and will subsequently be transported to the pad for attachment of the solid rocket motors. Concurrent with the core vehicle assembly and checkout, the solid rocket motors (SRM) segments and closure assemblies will undergo receiving inspection, component installation and individual checkout in a new mobile erection and processing structure (MEPS) at a remote site. After the liquid core vehicle on the mobile launcher has been secured to the launch pad, the MEPS with inspected segments and pre-assembly closures for all four of the solid rocket motors will move to the launch pad and will be mated with the mobile launcher and ground structure for transfer operations of the solid rocket motor segments (see Figure 6-6). Two cranes mounted on the MEPS will be used to lift and attach the aft solid rocket motor closure (with the pre-assembled aft attachment skirt) to the liquid core. Assembly of two SRMs will be accomplished concurrently. The three center segments and the forward closure will then be stacked on top of each of the aft closures. This procedure will be duplicated for assembly and mating of the remaining two solid rocket motors. After assembly is made and alignment of all four SRMs is completed, the MEPS will then be transported back to its parking position. From this point on, the launch operations proceed in a manner similar to those for the Saturn V vehicle with the exception of the added operations for integrated solid rocket motor checkout and for solid rocket motor arming.

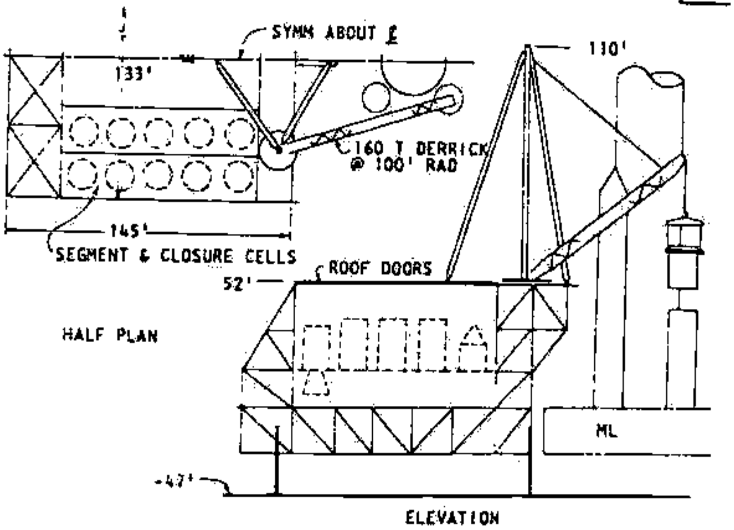


FIGURE 6-6 MOBILE ERECTION AND PROCESSING STRUCTURE

Introduction of the 156-inch solid rocket motors increases pad occupancy time from 58 to 70 days. However, emergency take-down can be accomplished in 39 hours, well within the 72-hour hurricane warning time.

The existing vertical assembly building with the work platform locations altered can be utilized.

Modifications at the launch pad include reinforcement of the mobile launcher support piers and pad structure and the provision of heat shields for pad mounted equipment and structure, new flame deflectors and improved flame deflector anchorage, flame protection for flame trench walls, auxiliary exhaust deflector shields and increased high pressure gas and propellant storage capabilities. Additional quantity and flow rates of industrial water will be required with increased pumping capacity and upgrading of the hydromatic systems. The water mains serving the pad area are adequate without modification. Existing electrical power and communications are satisfactory.

A solid rocket motor inert components building must be provided. A mobile erection and processing structure (MEPS) must be provided with parking position and additional crawler transporter road way for access.

The mobile service structure (MSS) will require a height extension to a level of 396 feet to permit work platforms to be raised to the required service levels. This will require increased structural reinforcement and increased elevator runs. The cantilever framing which supports the platforms in the vicinity of the solids must be reworked to increase the lateral clearance. It is not possible to accomplish these required modifications in the five-month time span between the last Saturn V launch and the first MLV-SAT-V-25(S) R&D launch; therefore, a new MSS incorporating the above changes must be built.

One new and one modified mobile launcher (ML) are required to satisfy the launch rate and program phase-in requirements for this vehicle. The principal modifications involve relocation to higher levels of all umbilical arms, shielding of the front umbilical face, increased elevator runs, an enlargement of the aspirator hole, from 45 feet to 55 feet, strengthening of the ML platform structure, replacement of the existing vehicle support arms and relocation of equipment in the umbilical tower and mobile launcher platform. Protection from exhaust impingement on the bottom of the ML will be required because of the exhaust plume spillover from the flame trench.

The crawler transporter which will be used to transport the mobile launcher and MEPS will require uprating by approximately 11 percent to handle the increased loads caused by the heavier MSS. These modifications will include structural beefup and a new, more powerful steering system.

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 6-7. This schedule shows that the MLV-SAT-V-25(S) first flight vehicle can be available 42 months after hardware authority to proceed (ATP).

Costs

A vehicle cost summary is shown in Table 6-III.

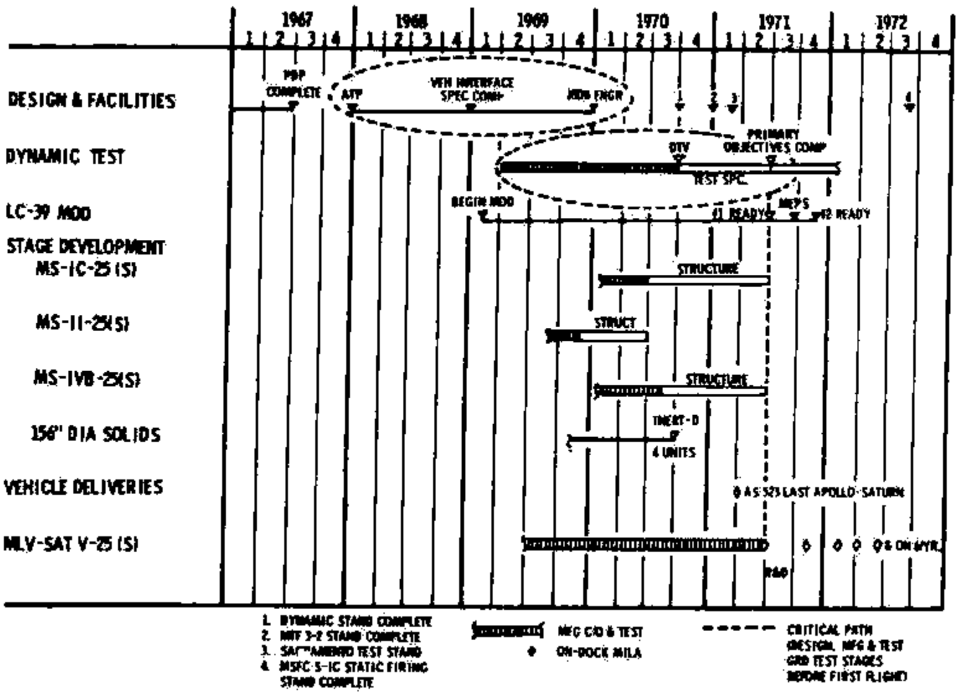


FIGURE 6-7 SAT-V-25(S) LAUNCH VEHICLE DEVELOPMENT AND DELIVERY PLAN

COST - DOLLARS IN MILLIONS	DEVELOPMENT STAGE	DEVELOPMENT ENGINE	OPERATIONAL STAGE	OPERATIONAL ENGINE	TOTAL
LAUNCH VEHICLE					
Boost Assist		96.7		440.5	537.2
S-IC Stage	77.1		640.1	273.8	991.0
S-II Stage	58.7		513.8	188.5	761.0
S-IVB Stage	72.0		359.3	37.7	469.0
Instrument Unit			136.1		136.1
LAUNCH VEHICLE TOTAL	207.8	96.7	1649.3	940.5	2894.3
GROUND SUPPORT EQUIPMENT					
Boost Assist		5.5			5.5
S-IC Stage	17.0		26.4		43.4
S-II Stage	11.5		57.6		69.1
S-IVB Stage	33.7		48.5		82.2
GSE TOTAL	62.2	5.5	132.5		200.2
FACILITIES					
S-IC Stage	19.6				19.6
S-II Stage	.7				.7
S-IVB Stage	5.4		5.7		11.1
Launch Vehicle - KSC	192.5		727.2		919.7
Launch Vehicle - Other	10.0				10.0
FACILITIES TOTAL	228.2		732.9		961.1
SYSTEMS ENGINEERING & INTEGRATION	2.7		475.8		478.5
LAUNCH SYSTEMS TOTAL	500.9	102.2	2990.5	940.5	
	603.1		3931.0		4534.1
R&D FLIGHTS (2)					324.2

TABLE 6-III SAT-V-25(S) COST SUMMARY

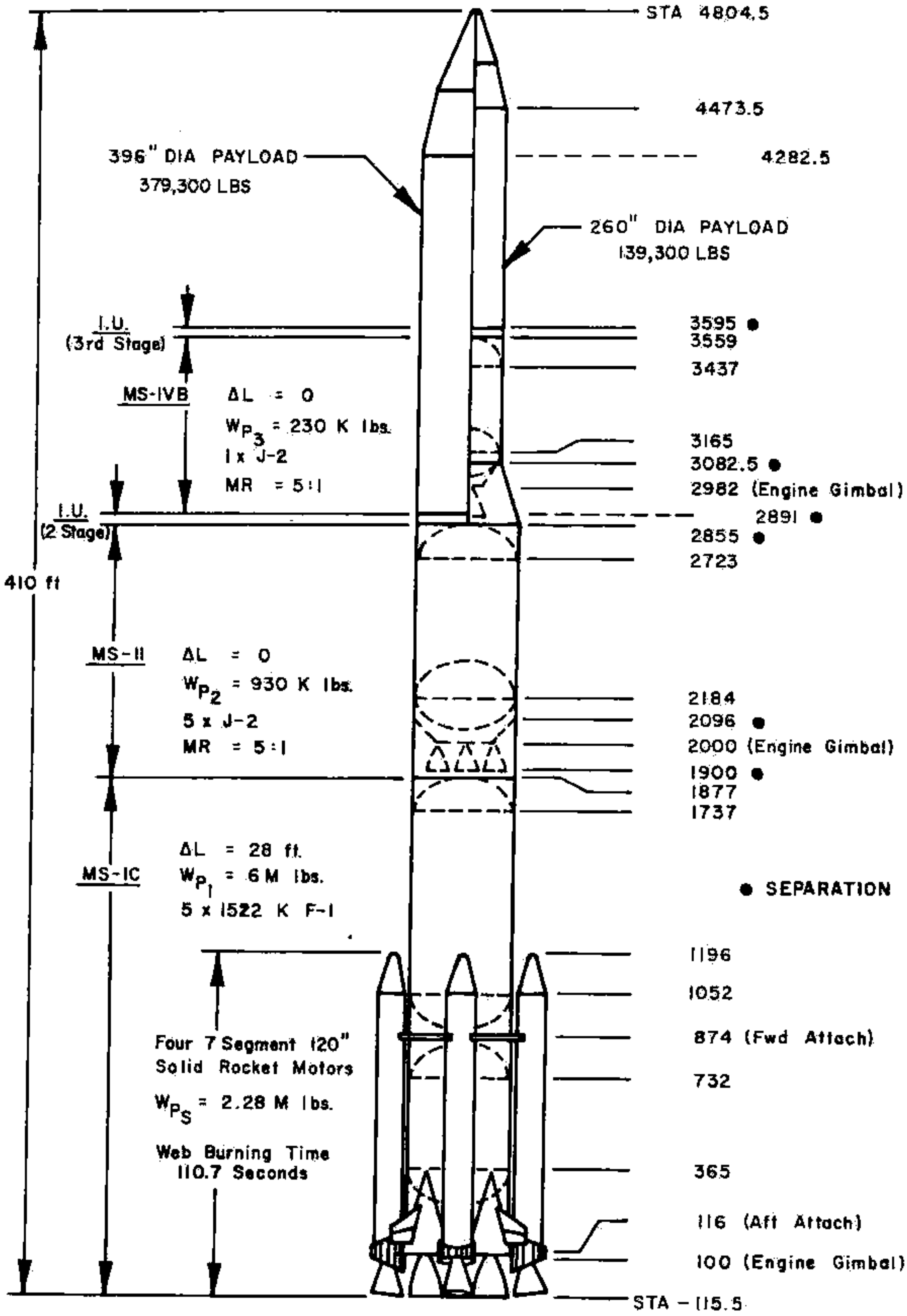


FIGURE 7-1 MLV-SAT-V-4(S)B BASELINE VEHICLE