7.0 MLV-SAT-V-4(S)B

The SAT-V-4(S)B (See Figure 7-1) is a Saturn V vehicle with lengthened first stage, adapted to accept attachment of four 120-inch diameter solid motors.

The vehicle as defined in the trade study activity and studied in detail in the Phase II activity is a feasible and cost effective configuration and is, therefore, a logical candidate to provide payloads in excess of those currently available with the Saturn V vehicle. No major problem areas were identified for either development or production of this vehicle.

7.1 CONFIGURATION SELECTION (PHASE I)

By varying the number of solid rocket motor segments (and thus solid propellant weight), and considering both optimized length and fixed length core stages, a number of related SAT-V-4(S)B vehicles were evolved. Payload capability and costs were established for these vehicles in order to choose one arrangement for more detailed analysis.

7.1.1 Candidate Configurations

For the trade study both two and three stage operation was considered. The vehicle height was fixed at 410 feet for both the 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 120-inch solid propellant rocket motors were attached to the vehicle for thrust augmentation. The number of segments in the solid motors was varied between five and seven. The characteristics of each solid motor were specified by MSFC. Significant solid motor parameters are shown in Table 7-I. The vehicle liftoff weight was varied to maintain a liftoff thrust-to-weight of approximately 1.25.

7.1.2 Trade Studies

Figure 7-2 is typical of the parametric performance data prepared for the trade study. Figure 7-2 illustrates the net payload versus the number of segments in the 120-inch motors for the three-stage vehicle. This curve shows two conditions, optimized first-stage propellant weight with the upper stage propellant

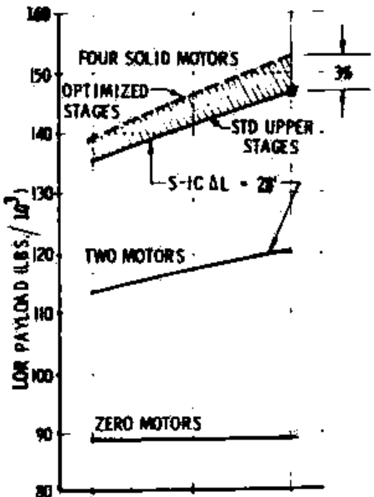


FIGURE 7-2 TRADE STUDY PERFORMANCE DATA

TABLE 7-I SOLID MOTOR CHARACTERISTICS

	UA-1205 (5-Segment)	UA-1206 (6-Segment)	UA-1207 (7-Segment)
Motor diameter	120 in	120 in	120 in
Average sea level I_{sp} (approximately)	230 sec	234 sec	232 sec
Sea level action time total impulse	97,132,000 lb-sec	116,080,000 lb-sec	116,080,000 lb-sec
Total propellant weight	421,480 lb	495,018 lb	571,324 lb
Total motor weight	489,519 lb	570,690 lb	655,108 lb
Characteristic velocity	5,170 ft/sec	5,170 ft/sec	5,170 ft/sec
Overall motor length	1,015.8 in	1,127 in	1,305 in
Maximum chamber pressure	690 psia	680 psia	760 psia
Initial nozzle throat area	1,116.3 sq in	1,301 sq in	1,301 sq in
Initial nozzle exit area	8,930 sq in	8,922 sq in	12,490 sq in
Initial expansion ratio	8.0	6.86	9.6
Nozzle length	114.0 in	111.6 in	175.4 in
Nozzle weight	7,705 lb	7,705 lb	9,574 lb
Burn action time	112.0 sec	107.8 sec	119.6 sec

weights fixed, and propellant weights for all stages optimized. For the optimized vehicles, the S-IVB stage would have to be lengthened aproximately 14 feet while the S-II stage remains at its standard length and the S-IC stage is increased in length by about 28 feet. A similar study of two-stage vehicles shows the optimum core vehicle to be basically a standard S-II stage and a 28-foot longer MS-IC stage.

The Figure 7-2 data demonstrates that:

a. Payload increases approximately 4.5 percent with each additional solid motor segment (increased solid propellant weight).

b. Payload gains of approximately 3 percent accrue by optimizing propellant weights in all stages.

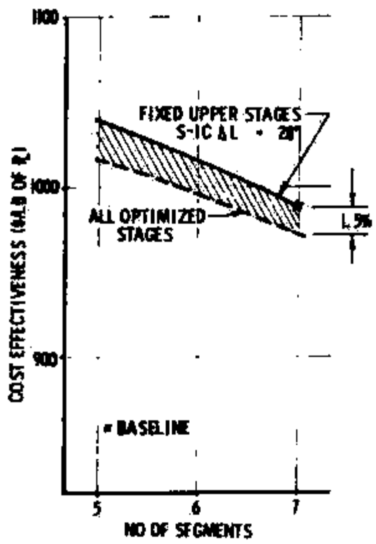


FIGURE 7-3 TRADE STUDY COST DATA

Figure 7-3 compares the payload cost efficiency of using various solid motor weights (numbers of segments) with either fixed or optimized core stages. It should be noted that the major difference between optimized vehicles and fixed upper stage vehicles is the transfer of 100,000 pounds of propellant from the S-IC to the S-IVB stage. The resultant increase in S-IVB cost only allows a 1.5 percent improvement in cost efficiency even though payload is improved 3 percent.

Since study ground rules specified that upper stage modifications be minimized, a fixed length upper stage vehicle was chosen for the next phase of study. The selected vehicle is indicated on Figures 7-2 and 7-3 as "Baseline."

7.2 DESIGN STUDY VEHICLE (PHASE II)

The single SAT-V-4(S)B selected during the Phase I activity was defined in detail, its capabilities and characteristics were determined and its resource requirements established.

7.2.1 Vehicle Description

The baseline SAT-V-4(S)B vehicle is shown in Figure 7-1. It incorporates standard length upper stages and a 28-foot longer first-stage augmented by four seven-segment 120-inch rocket motors. The solid motors, as designated by MSFC, conform to preliminary designs developed by United Technology Center for Titan III-C applications. Each motor has an initial sea level thrust of 1.4 million pounds and a propellant weight of 579,000 pounds. Each motor has a liquid injection (N_2O_4) thrust vector control system to augment the control capabilities of the gimbaled F-1 engines during flight through the max q regime. The liquid core stages of SAT-V-4(S)B are equipped with standard F-1 and J-2 engines. The first stage of the vehicle is rotated 45 degrees from its position in the standard Saturn V configuration to minimize the impact on launch facilities and operations. The second stage is standard S-II length with a propellant capacity of 930,000 pounds. The third stage (for three-stage applications) is standard S-IVB length with 230,000 pounds propellant capacity. Since study funds and timing were limited, the desirable increased length S-IVB was not studied and the S-II stage for MLV-SAT-V-25(S) was used directly on SAT-V-4(S)B.

7.2.2 Design Study Results

The SAT-V-4(S)B two-stage payload capability to 100 nautical miles orbit is 379 thousand pounds and its 72 hour lunar injection three-stage capability is 139 thousand pounds.

Use of this vehicle was also considered for application where the 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 as shown in Table 7-II.

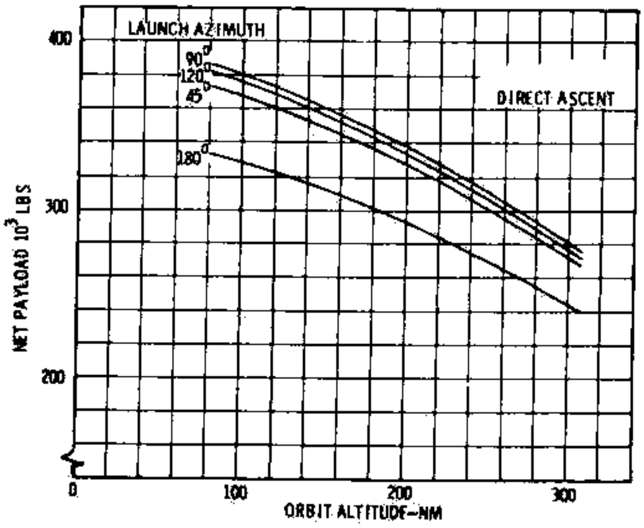


FIGURE 7-4 ORBIT ALTITUDE - AZIMUTH PAYLOAD CAPABILITY

Additional studies identified information useful for mission planning. Payloads available for various orbital altitudes between 80 and 300 nautical miles and launch azimuths between 45 degrees and 180 degrees are shown in Figure 7-4. Polar and near polar orbit payloads are shown

TABLE 7-II PAYLOAD CAPABILITY

	NET PAYLOAD (LB) TWO-STAGE 100 NM Orbit	NET PAYLOAD (LB) THREE-STAGE 72-hour Lunar Injection
Core Vehicle Without Solid Motors		
$T_o/W_o = 1.25$ $W_{P1} = 7,387,368$ lb	243, 512	89, 444
$T_o/W_o = 1.18$ $W_{P1} = 4,740,350$ lb	251, 683	92, 445
Core Vehicle With Two Solid Motors		
$T_o/W_o = 1.25$ $W_{P1} = 5,358,842$ lb	320, 725	117, 805
$T_o/W_o = 1.18$ $W_{P1} = 5,855,789$ lb	330, 920	121, 549
Core Vehicle with Four Solid Motors		
$T_o/W_o = 1.25$ $W_{P1} = 6,000,000$ lb	379, 300	139, 300

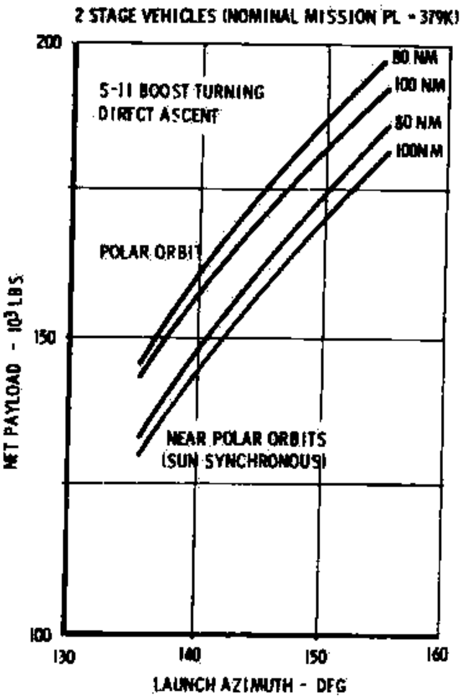


FIGURE 7-5 POLAR & SUN SYNCHRONOUS ORBIT PAYLOAD CAPABILITY

in Figure 7-5. Three-stage mission payload capability for a 24-hour sun synchronous orbit, and more generally, payload as a function of the specific energy parameter are shown on Figure 7-6.

Significant load criteria and other data pertinent to vehicle design are shown on Table 7-III with comparative Saturn V values. Although max dynamic pressure (q) and acceleration are reduced, compared to SAT V, the 410-foot vehicle height coupled with the 33-foot diameter two-stage payload shape has a large impact on structural design requirements.

The first stage control requirements of the SAT-V-4(S)B necessitate additional control beyond the present fins and gimbal capability of the F-1's using the current attitude, attitude rate control system. Alternate control mode studies showed that approximately a 5 percent reduction in maximum bending response could be expected if an angle of attack feedback control mode were employed. The use of the liquid injection thrust vector control on the solid motor is required for 30 seconds near maximum q time of flight, as shown in Table 7-III. Since the solid motor TVC requirements are less than the Titan III-C, the liquid injectant tanks will be off-loaded to carry only the required fluid. The use of enlarged fins in lieu of solid motor TVC was also considered. This analysis indicated that the fin size for the baseline SAT-V-4(S)B vehicle would have to be double that required for AS-516 (150 square feet

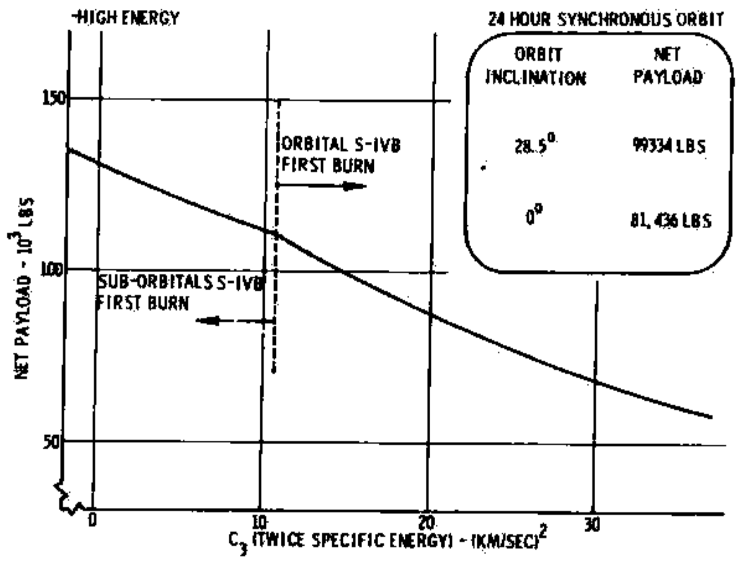


FIGURE 7-6 THREE-STAGE HIGH ENERGY MISSION CAPABILITY

per fin versus 75 square feet per fin). Wind tunnel tests will be required to substantiate this analysis. Because of the rotation of the first stage 45 degrees, the flight control signal must be modified to compensate for the rotation.

Control studies of vehicles defined in the special study on payload sensitivities below indicated that for reduced payload lengths for the two-stage vehicle (payload densities of 5 pounds/feet^3 and greater) and for nominal payload lengths for the three-stage vehicle, that no additional control capability beyond nominal for AS-516 is required for the SAT-V-4(S)B.

	-4(S)B	SAT V
LOAD CRITERIA		
MAX q (LBS/FT^2)	604	766
g's AT MAX q_α	1.83	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	2.3° PER MOTOR	N/A
SOLID TVC OPERATING	70-100 SEC	N/A
HEATING		
AERODYNAMIC (AHI) FT-LB/FT^2	653,000	792,000
BASE MAX. TEMP.	2200°F	1900°F
OTHERS	MS-IC-4(S)B ROTATED 45°	

BASELINE 516 WITH T_0/W_0 - 1.25

TABLE 7-III SIGNIFICANT LOAD CRITERIA

Studies were conducted to determine the payload envelope and corresponding wind limitations for the vehicle with: (1) no or minimum upper stage modifications; and (2) the full structural modifications as indicated for the MLV-SAT-V-4(S)A vehicle in the previous fiscal year 1964 contracted study effort. Typical results are summarized on Figures 7-7 and 7-8. This data shows that for the nominal payload lengths (i.e., 159 feet for the two-stage payload and 101 feet for the three-stage payload) that there is basically no possibility of flying either the two- or three-stage vehicle from December through March unless modifications are made to the upper stages. With minimal modifications, the availability for launch during these months is approximately 20 percent. This data further shows that, with no modifications to the upper stages, a 95 percent or better launch availability can be obtained for every month of the year by reducing the two-stage payload length to approximately 70 feet (payload density equals 12.5 pounds/foot^3). The data shows, however, that three-stage applications will not have 95 percent availability with any length payload during February and March unless the upper stages are modified. A 50 percent or better availability for a three-stage payload length of 50 feet is possible for every month of the year with no upper stage modifications.

The addition of more fuel in the first stage and the four solid motors increases the 0.4 psi overpressure distance to a value greater than the distances 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

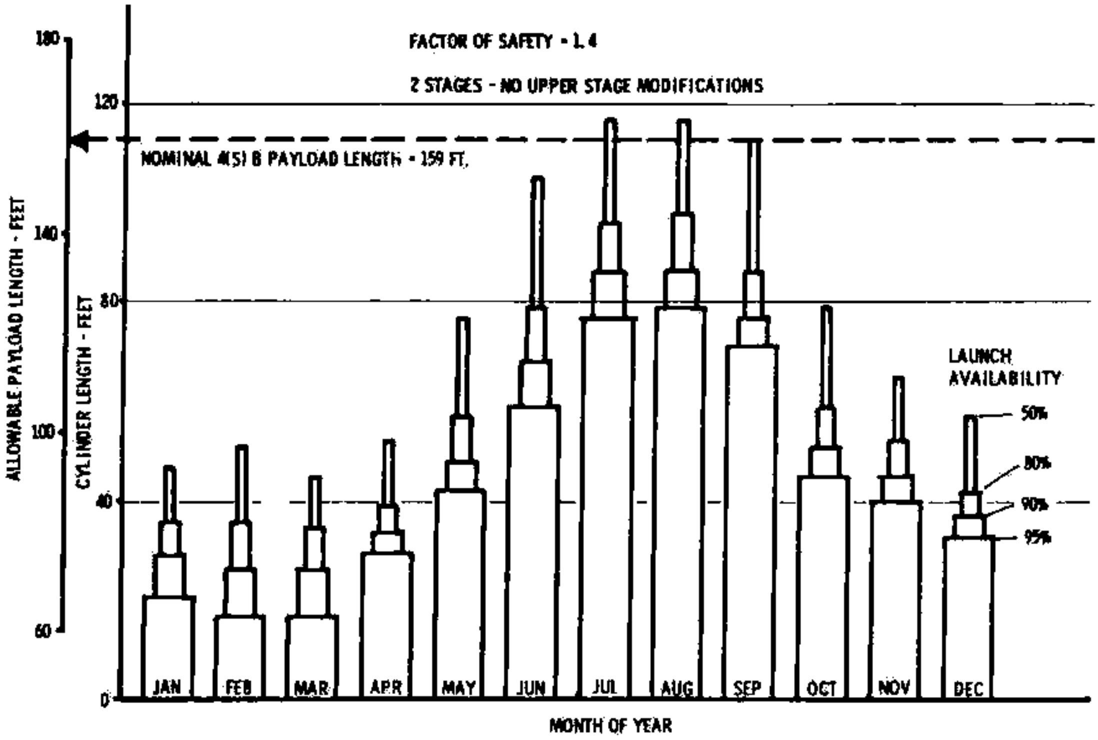


FIGURE 7-7 TWO-STAGE WIND/PAYLOAD SENSITIVITY

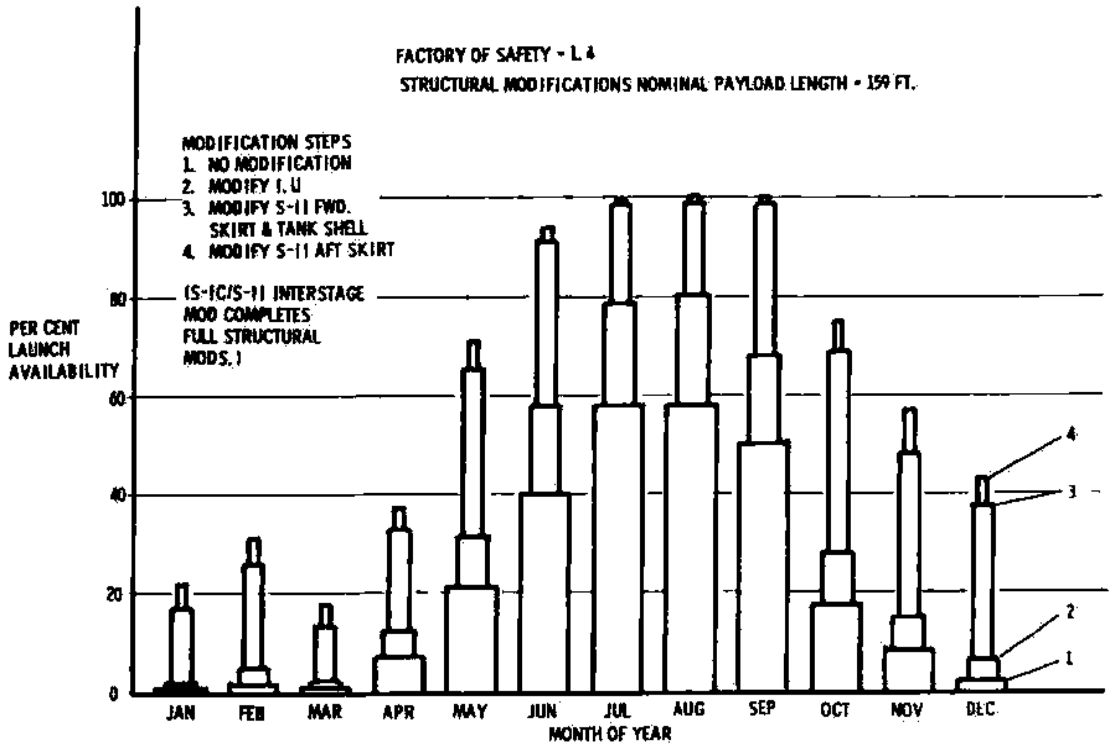


FIGURE 7-8 THREE-STAGE WIND/PAYLOAD SENSITIVITY

pad contains a fueled core vehicle with the solid motors attached. The acoustic level will require protection of personnel during launch.

Flight and crew safety are satisfactory for this vehicle. Communications for some stations may possibly be "blacked out" due to the exhaust plume interference. Other stations, however, will have clear communications during these periods and can provide continuous communications.

Assuming an Apollo payload and launch escape system, the abort lead time for this vehicle was developed for comparison with that of the Saturn V. Using a solid motor TNT equivalency of 100 percent, an abort lead time of 2.76 seconds is required for this vehicle versus 2.19 seconds for the Saturn V. Abort lead time is that time prior to explosion of the vehicle that the launch escape system firing pulse must be initiated. Other studies showed that no problems for abort are anticipated because of separation dynamics.

Aerodynamic heating for the MLV-SAT-V-4(S)B is significantly lower than the Saturn V. The aerodynamic heating indicator (AHI) at 653,000 foot-pounds per square foot for the SAT-V-4(S)B is 18 percent lower than the nominal SAT V AHI value of 792,000 foot-pounds per square foot and 30 percent below the maximum AHI value for the Saturn V of 924,000 foot-pounds per square foot. The shock wave from the solid motor nose cap may impinge on the first stage near the intertank and local insulation may be required.

The base heating environment is more severe for the MLV-SAT-V-4(S)B than for the Saturn V due to the solid motor exhaust plumes. However, heat shield materials can withstand the 2200 degree F temperatures anticipated successfully. The aft solid motor attachment skirt will reach 2480 degrees F. Insulation protection on the aft skirt will be required. A base heat shield will also be required for each of the solid motors.

The reliability of the two- and three-stage MLV-SAT-V-4(S)B vehicle is 0.984 and 0.967, respectively, as compared to .990 and .980 for the baseline AS-516. The lower reliability can be attributed to the modifications to the stages and the addition of the strap-on solid motors.

Separation of the solid motors from the core vehicle can be accomplished satisfactorily using explosive separation devices and the present Titan IIIC separation rocket motors.

Vehicle combined loads and acoustics are illustrated in Figure 7-9. The design loads are approximately 60 percent higher than those for the standard Saturn V. The acoustic specification limits are exceeded at several locations on the first stage. Acoustic requalification of approximately 70 percent of the acoustically sensitive components on this stage will be required.

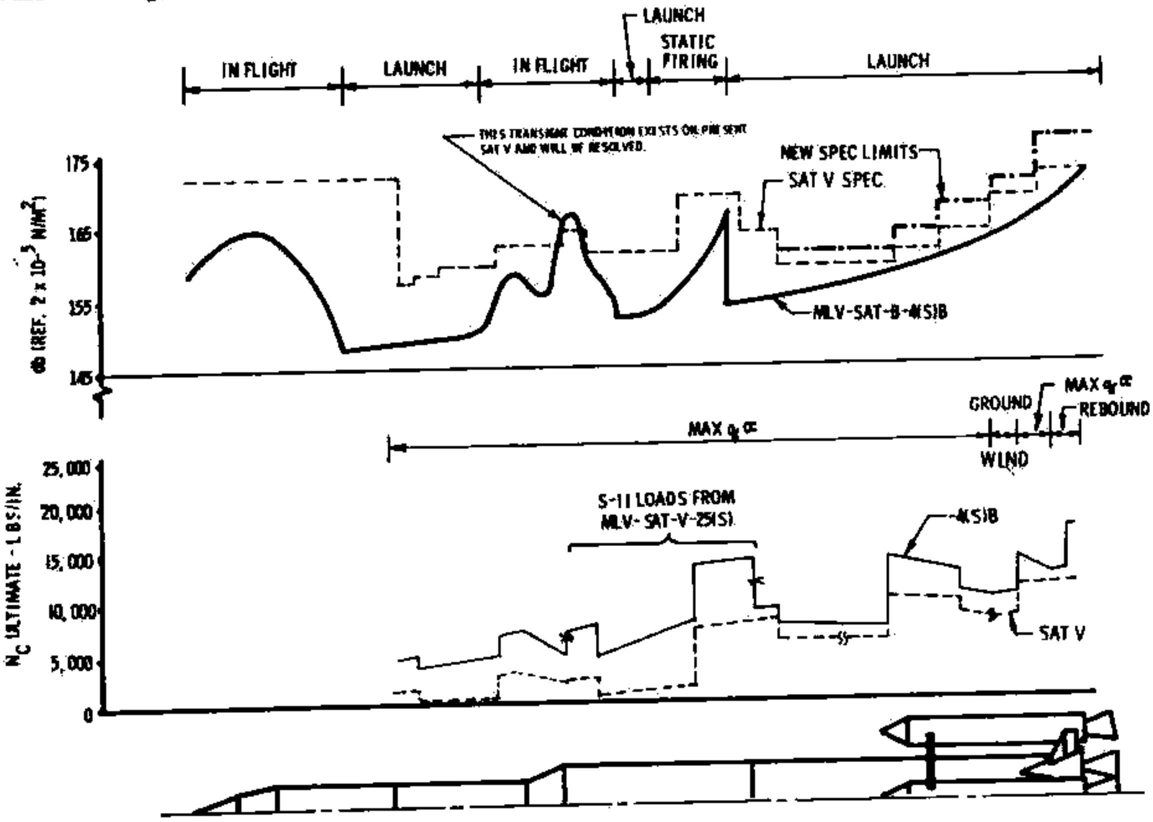


FIGURE 7-9 ACOUSTIC ENVIRONMENT AND STRUCTURAL LOADS

Major vehicle changes including the impact of structural load increases are summarized on Figure 7-10. Dry weight increases are also tabulated.

4.3 RESOURCES

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 R&D man-rating flight vehicles are required.

The existing Dynamic Test facility will be employed to test the MLV-SAT-V-4(S)B-D. Necessary modifications include relocation of platforms for increased vehicle length and an additional hydrodynamic support.

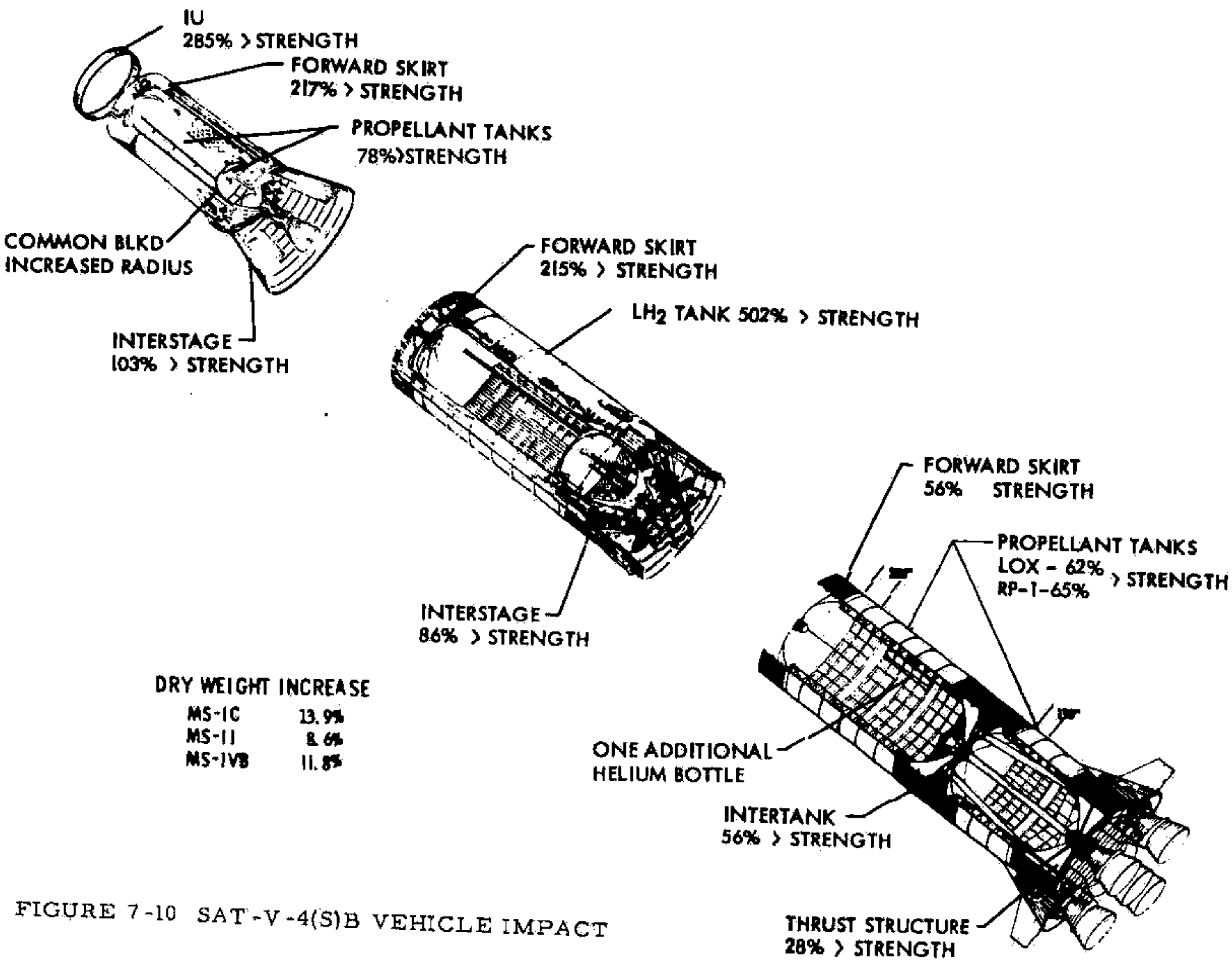


FIGURE 7-10 SAT-V-4(S)B VEHICLE IMPACT

The S-IC stage of the dynamic test vehicle will be refurbished after test and used as a flight article.

The 120-inch solid rocket motors with their thrust vector control system are assumed to be flight qualified in the Titan III-C vehicle systems.

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

MS-IC-4(S)B

The major impact of the first stage changes on Michoud facilities will be due to the added SRM functions and manufacture of the SRM aft skirt structure. Additional assembly equipment, checkout and handling, and transportation equipment will be required. The aft attachment structure is a maraging steel structure requiring boring machines, welding fixtures, and additional welding facility area. The heavier and longer first stage will require rework of much of the existing equipment.

Major tooling and assembly requirements at Michoud include an additional tank assembly station, an additional tank cleaning position, and some additional and modified tooling. Additional warehousing, quality assurance, and receiving inspection areas will be required. These additions provide the capability of introducing the new configuration with minimum downtime.

Modification of the S-IC test firing stands at MTF and MSFC are required only due to increased stage length and propellant capacity. Solid motors will not be fired in conjunction with the stage static test.

The stage transporter and the barges must be modified to accommodate the increased stage length. Additional solid motor handling and transportation equipment will be required.

MS-II-4(S)B

Manufacturing requirements for the MS-II-4(S)B 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 modification; 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-4(S)B stage design; no modifications would be required to handle the additional stage weight.

Due to study funding limitations, a separate MS-II-4(S)B resources study was not made. The MS-II-25(S) stage resource data was used without modification for SAT-V-4(S)B.

MS-IVB-4(S)B

The engineering redesign of the standard S-IVB to convert it to the MS-IVB-4(S)B presents no schedule or technical problems. Strengthening the basic structure of the stage will require a few development and qualification tests. The techniques and procedures required for these tests are similar to many tests conducted on the S-IVB stage. Tools and facilities for performing the tests are readily available and will not present any problem. The fabrication, assembly, checkout, and firing test facilities used for the standard S-IVB can be adapted to the MS-IVB-4(S)B. The machine tool capacity required to produce the standard S-IVB is adequate to produce the same rate of MS-IVB-4(S)B stages. The detail tooling will require numerous minor changes but these present no schedule problems. The assembly and checkout towers can be modified to accommodate the MS-IVB-4(S)B without any schedule complications. However, the 12 per year production rate (six for MLV-SAT-V-4(S)B and six for Saturn IB) taxes the capability of Towers 5 and 6. The Sacramento Test Center facilities are adequate and can be adapted to the MS-IVB-4(S)B without interference with the standard stage delivery rates. The present transportation equipment is adequate for the modified stage though some strengthening will be required on selected pieces of equipment.

Launch Facility and Operations Impact

The modified core vehicle will be assembled according to standard procedures in the VAB on the Mobile Launcher and will subsequently be transported to the pad where the solid rocket motors will be attached. The solid motor segments will be assembled in a Mobile Assembly and Handling Structure (MAHS), at a site to be provided, and transported by this MAHS to the launch pad for subsequent assembly of the solids to the

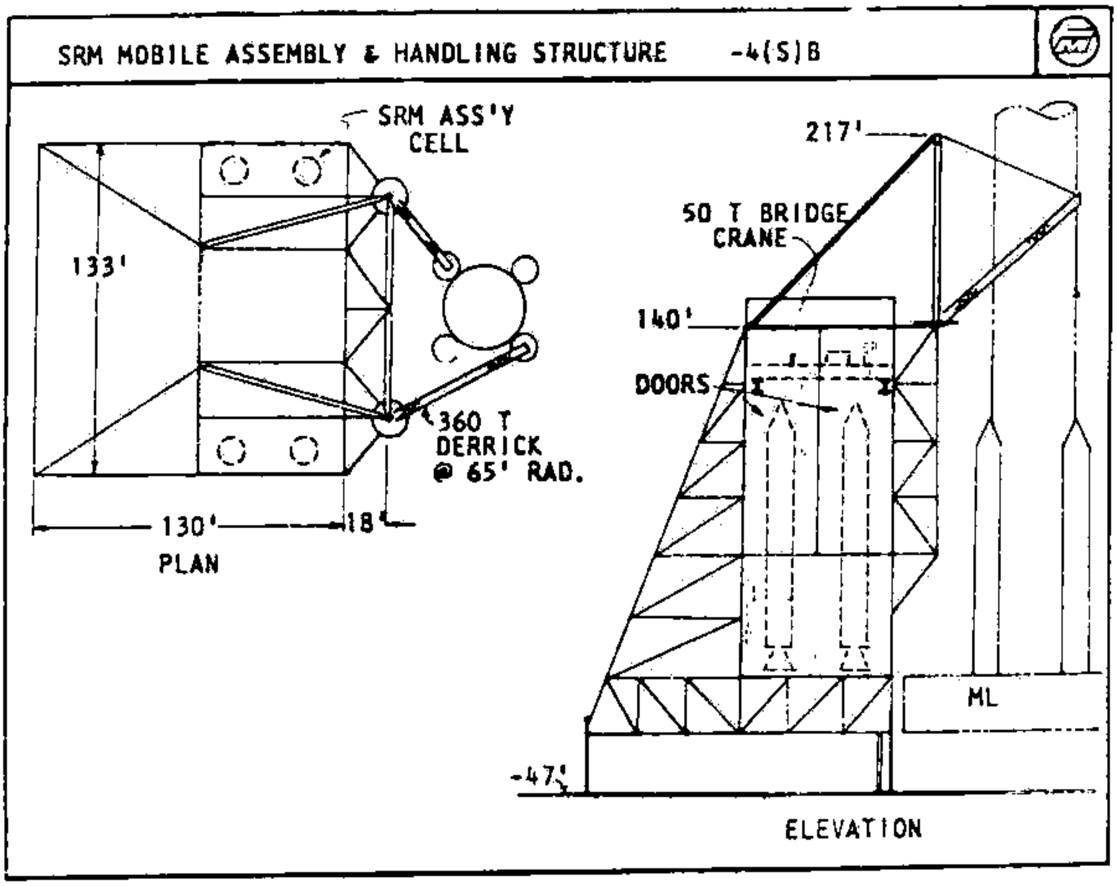


FIGURE 7-11 MOBILE ASSEMBLY AND HANDLING STRUCTURE

core vehicle. The MAHS will mate with the mobile launcher for this assembly operation and handling equipment within the MAHS will be utilized for placement of the solid motors against the core vehicle (see Figure 7-11). After assembly of the solid motors, the MAHS will be removed and replaced by the service tower. Normal operations for the core vehicle will be resumed and additional operations as required for solid motor final checkout and arming will be accomplished.

The existing VAB with work platform locations altered and the existing launch pad and its existing flame tranch can be utilized. The crawler transporter roadways are sufficient for this vehicle with the exception of the requirement for some additional crawler transporter roadways as required for access to the solid motor assembly site. Major impact areas include the development and construction of the MAHS and modifications to the mobile launcher (ML) to increase its deck load capacity, to relocate the swing arms, to relocate the tail service masts and holddown structure, and to enlarge the aspirator hole to allow additional space for the solid rocket motor nozzles. Insulation in selected areas will be required to protect the ML during launch.

The total cost for the modification and additions described is 177.3 million dollars. Of significance is the fact that a major portion of this cost is due to the requirements for a new as well as a modified mobile launcher (ML) and a new as well as a modified mobile service structure (MSS). These new items are forced because of the ground rule which limits the time between the last standard SAT V launch and the first MLV-SAT-V-4(S)B launch to five months. If this time could be extended to preclude these new items, the above cost could be reduced by approximately 80 million dollars.

Schedule

Within the study ground rules 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 7-12). This schedule shows that the MLV-SAT-V-4(S)B first flight vehicle for mission applications can be available 41 months after hardware Authority to Proceed (ATP).

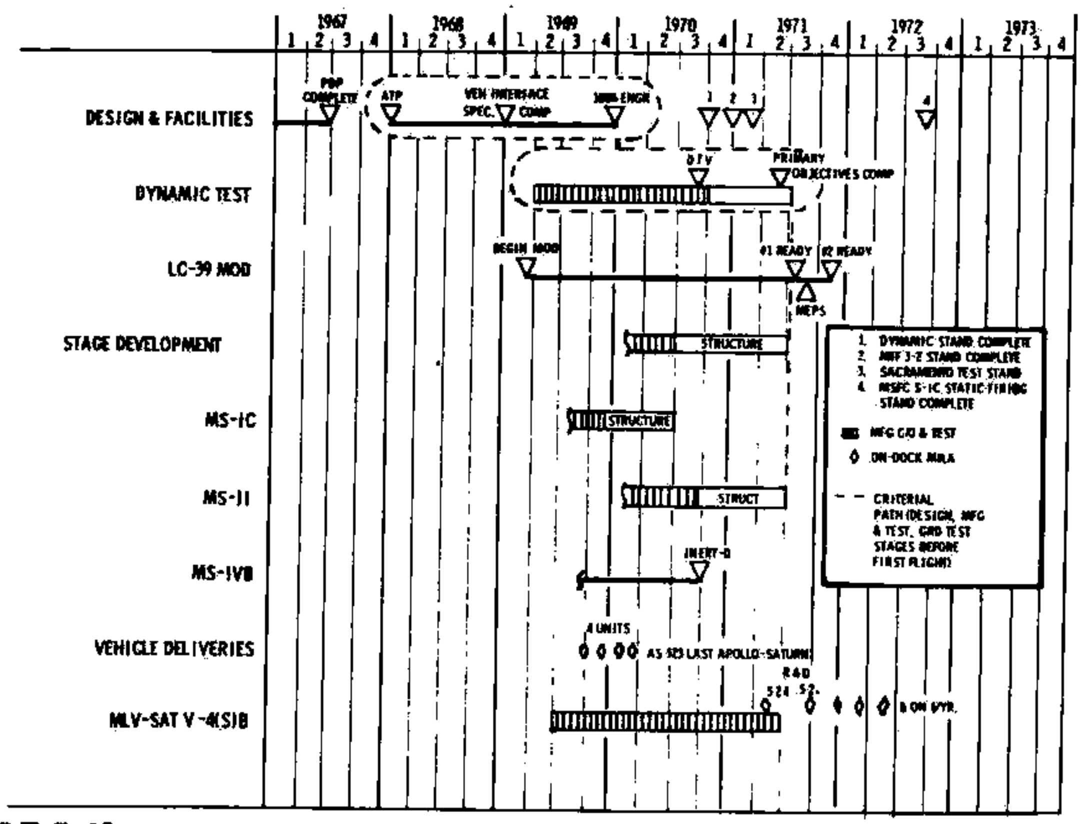


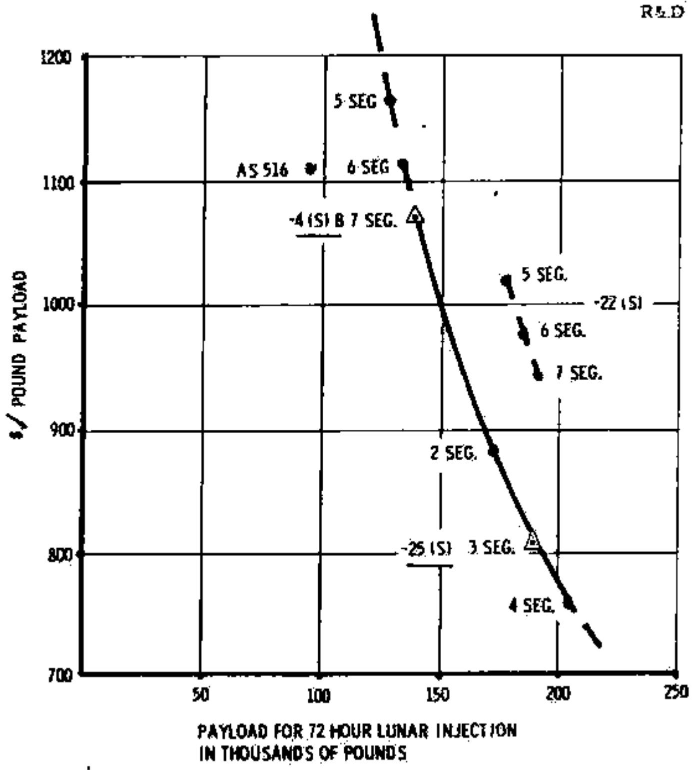
FIGURE 7-12 SAT-V-4(S)B VEHICLE DEVELOPMENT AND DELIVERY PLAN

Costs

A vehicle cost summary is shown in Table 7-IV.

TABLE 7-IV SAT-V-4(S)B COST SUMMARY

COST - DOLLARS IN MILLIONS	DEVELOPMENT STAGE	DEVELOPMENT ENGINE	OPERATIONAL STAGE	OPERATIONAL ENGINE	TOTAL
LAUNCH VEHICLE					
Boost Assist	3.0			319.4	322.4
S-IC Stage	74.0		634.5	273.4	[illegible]
S-II Stage	58.7		513.8	138.5	761.0
S-IVB Stage	47.[illegible]		314.2	37.8	[illegible]
Instrument Unit			136.1		136.1
LAUNCH VEHICLE TOTAL	183.5		1598.6	819.5	2601.6
GROUND SUPPORT EQUIPMENT					
Boost Assist		5.5			[illegible]
S-IC Stage	15.9		26.4		[illegible]
S-II Stage	11.5		57.6		[illegible]
S-IVB Stage	16.8		43.5		60.3
GSE TOTAL	43.3	5.[illegible]	127.5		176.[illegible]
FACILITIES					
S-IC Stage	18.0				18.0
S-II Stage	.7				.7
S-IVB Stage	2.0		4.9		6.[illegible]
Launch Vehicle - KSC	177.3		718.0		[illegible]
Launch Vehicle - Other	1.1				1.1
FACILITIES TOTAL	199.1		722.9		922.0
SYSTEMS ENGINEERING AND INTEGRATION	2.7		475.8		478.[illegible]
LAUNCH SYSTEMS TOTAL	429.1	5.5	29[illegible]4.8	819.5	
	434.6		[illegible]44.[illegible]		4178.[illegible]
R&D FLIGHT (2)					307.8



A comparison of the relative values of cost effectiveness for the MLV-SAT-V-4 (S)B; -22(S) and -25(S), shows that the most cost effective method for further improvement of performance is through the use of larger solid motors rather than through the use of uprated upper stage engines. This comparison is shown in Figure 7-13.

FIGURE 7-13 COST EFFICIENCY COMPARISON

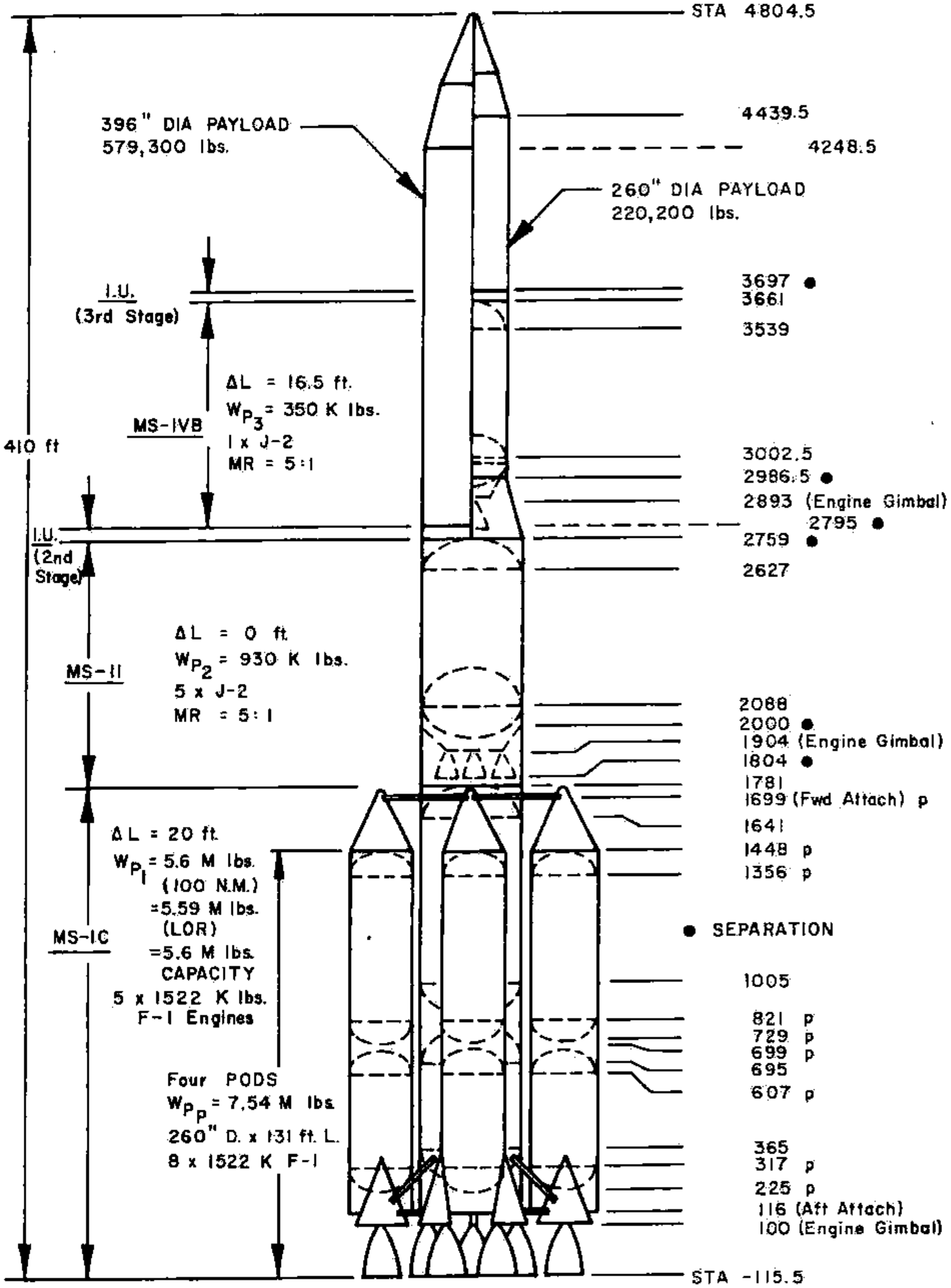


FIGURE 8-1 SAT-V-23(L) BASELINE VEHICLE