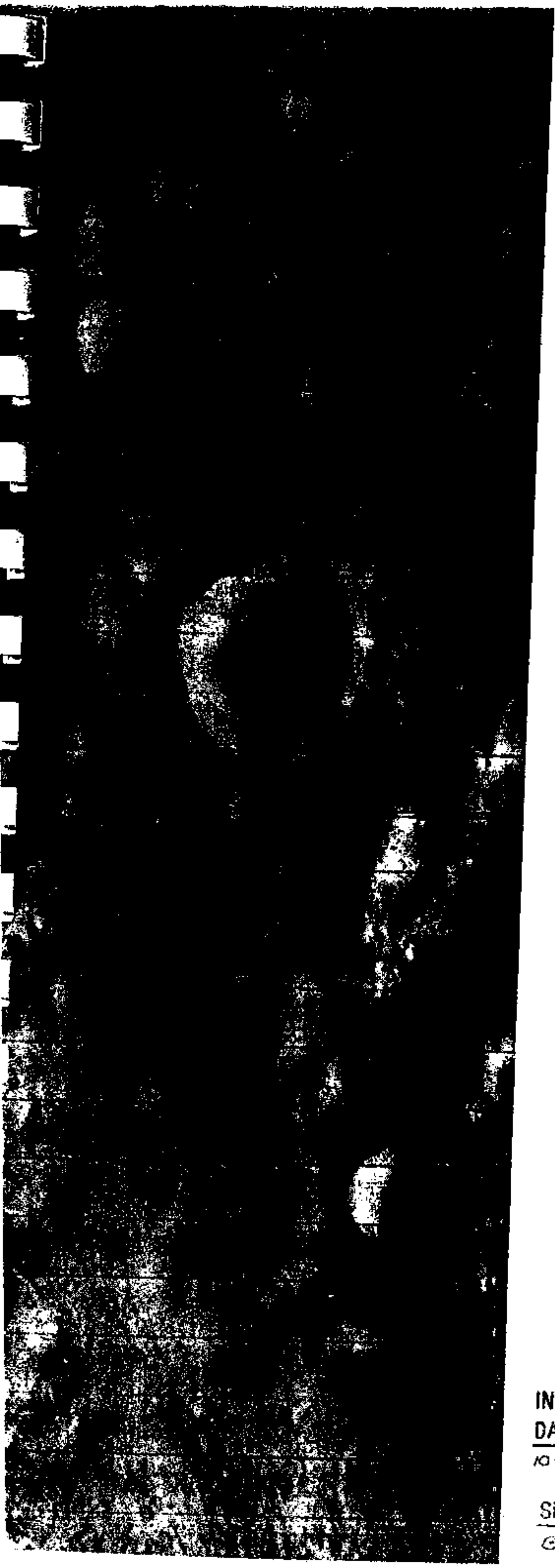

D5-13183

Final Report - Studies of Improved Saturn V Vehicles and Intermediate Payload Vehicles (P-115)

SUMMARY

Prepared for
NASA - George C. Marshall Space Flight Center under Contract NAS8-20266

October 7, 1966

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THE BOEING COMPANY — SPACE DIVISION

STUDIES OF IMPROVED SATURN V VEHICLES AND INTERMEDIATE PAYLOAD SATURN VEHICLES (P-115)

SUMMARY DOCUMENT
D5-13183

FINAL REPORT
PREPARED UNDER CONTRACT NUMBER NAS8-20266

SUBMITTED TO
GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OCTOBER 7, 1966

SUBMITTED BY
SYSTEMS ANALYSIS CONTRACTOR
THE BOEING COMPANY
SPACE DIVISION
LAUNCH SYSTEMS BRANCH
HUNTSVILLE, ALABAMA

FOREWORD

This volume summarizes five technical Vehicle Description Documents reporting a ten-month study to prepare technical and resource data on uprated payload Saturn V and intermediate payload Saturn vehicles. This study is part of a continuing effort by the National Aeronautics and Space Administration (NASA) to investigate the capability and flexibility of the Saturn V launch vehicle and to identify practical methods for diversified utilization of its payload capability. NASA Contract NAS8-20266 authorizes the work reported herein and was supervised and administered by the Marshall Space Flight Center (MSFC). S-II data was supplied by the Space and Information Division of North American Aviation. S-IVB data was supplied by the Missile and Space Systems Division of Douglas Aircraft Company. Launch system data was supplied by the Denver Division of The Martin Company. Solid motor data were supplied by United Technology Corporation. The Launch Systems Branch, Aerospace Group, Space Division of The Boeing Company was the Systems Analysis contractor for this study.

Program documentation includes a summary volume (this document), five volumes covering vehicle descriptions, research and technology implications report, and a cost document. Individual designations are as follows:

D5-13183	Summary Document
D5-13183-1	Vehicle Description MLV-SAT-INT-20, -21
D5-13183-2	Vehicle Description MLV-SAT-V-3B
D5-13183-3	Vehicle Description MLV-SAT-V-25(S)
D5-13183-4	Vehicle Description MLV-SAT-V-4(S)B
D5-13183-5	Vehicle Description MLV-SAT-V-23(L)
D5-13183-6	Research and Technology Implications Report
D5-13183-7	First Stage Cost Plan

ABSTRACT

This document summarizes a study conducted under NASA/MSFC Contract NAS8-20266, "Studies of Improved Saturn V Vehicles and Intermediate Payload Saturn Vehicles (P-115)", from December 6, 1965 to October 7, 1966. The details of this study are contained in five "Vehicle Description Documents" (D5-13183-1, -2, -3, -4, and -5). Phase I of the study was a parametric performance and resources analysis to select one baseline configuration for each of the six vehicles. Phase II of the study included a fluid and flight mechanics study, design impact on systems, and a resources analysis for each baseline vehicle. The uprated vehicles 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. The intermediate payload vehicle derivatives of Saturn V are a logical means of providing orbital payload capability between that of the Saturn IB and the two-stage Saturn V.

KEY WORDS

Contract NAS8-20266
D5-13183
Vehicle Description Document
Saturn V
NASA/MSFC
Uprating
Trade Studies
Payload to 72 Hour Lunar Injection
Fluid and Flight Mechanics
Impact
Resources
Cost
Payload to 100 NM orbit
MLV-INT
Baseline Configuration
MLV-SAT-V

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1.0 INTRODUCTION

This study is part of a continuing effort by NASA to identify a spectrum of practical launch vehicles to meet future payload and mission requirements as they become defined. The launch vehicles studied under Contract NAS8-20266 cover a payload range between the existing Saturn IB and the Saturn V (intermediate payload vehicles) and a payload range beyond the existing Saturn V capabilities (uprated Saturn V vehicles).

The vehicles studied were combinations of existing or modified Saturn V stages; some vehicles also included boost-assist components. A primary study requirement was to make maximum use of existing Saturn technology and support equipment.

In general, the NAS8-20266 study program objectives were to:

a. Select feasible and cost effective baseline vehicles from each of several categories.

b. Prepare sufficient technical data to define vehicle environments, design, capabilities, and characteristics.

c. Define support system requirements.

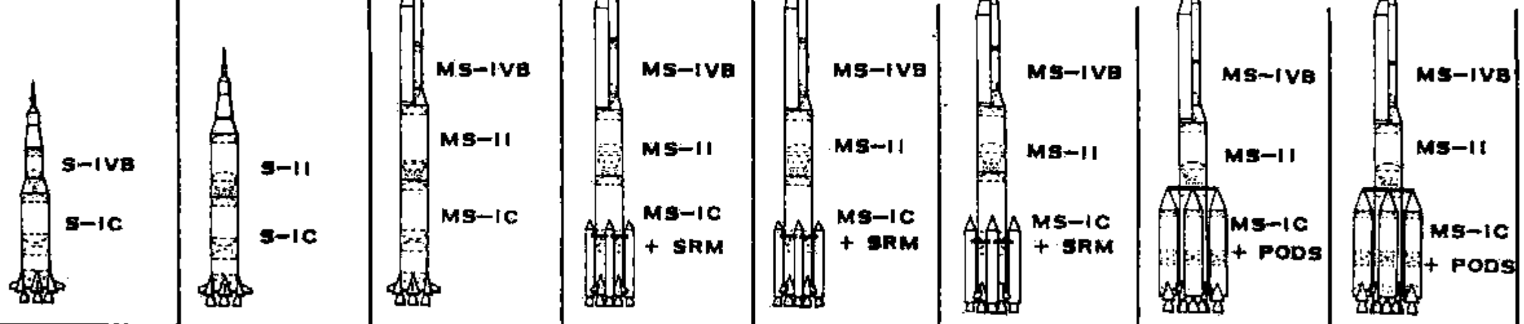
d. Determine the date that the first flight article could be available within study ground rules.

e. Estimate cost required for implementation of the system plus production of thirty flight articles in five years.

There were two phases of study work. Phase I was a twelve-week effort in which candidate vehicle performance and preliminary cost trade studies were conducted to select a feasible and cost effective baseline vehicle from each of five categories (shown in Figure 1-1). An additional baseline vehicle was later added from Category 4.

For each of the six baseline vehicles selected (see Figure 1-2), Phase II directed the effort to defining ground and flight environments, defining system design and resource impact for each stage and the total vehicle, and determining vehicle mission capabilities and characteristics.

The launch vehicles in Categories 1 and 2 are Saturn V stage combinations for missions in the payload range between the current Saturn IB and Saturn V payload capability. The launch vehicles in



SIZE-410 FT MAX MS-II SIZE 1160 IN MAX MS-IVB SIZE 350K PROPELLANT AT MR 5 :1 MAX PAYLOAD 5 LB/FT³ (2 STG) 11 LB/FT³ (3 STG) STD: STANDARD ΔL: CHANGE IN STAGE LENGTH	S-IVB S-IC	S-II S-IC	MS-IVB MS-II MS-IC	MS-IVB MS-II MS-IC + SRM	MS-IVB MS-II MS-IC + SRM	MS-IVB MS-II MS-IC + SRM	MS-IVB MS-II MS-IC + PODS	MS-IVB MS-II MS-IC + PODS
LAUNCH VEHICLE	INT-20	INT-21	SAT-V-3B	SAT-V-4(S)B	SAT-V-22(S)	SAT-V-25(S)	SAT-V-23(L)	SAT-V-24(L)
CATEGORY	1	2	3	4			5	
THIRD STAGE			ADVANCED ENGINE ΔL VARIABLE	STD J-2 ΔL VARIABLE	ADVANCED ENGINE ΔL VARIABLE	STD J-2 ΔL VARIABLE	STD J-2 ΔL VARIABLE	ADVANCED ENGINE ΔL VARIABLE
SECOND STAGE	STD J-2's ΔL - 0	STD J-2's ΔL - 0	ADVANCED ENGINES ΔL VARIABLE	STD J-2's ΔL VARIABLE	ADVANCED ENGINES ΔL VARIABLE	STD J-2's ΔL VARIABLE	STD J-2's ΔL VARIABLE	ADVANCED ENGINES ΔL VARIABLE
FIRST STAGE	STD F-1's ΔL - 0	STD F-1's ΔL - 0	5 X 1.8M F-1 ENGINES ΔL VARIABLE	STD F-1's ΔL VARIABLE	STD F-1's ΔL VARIABLE	STD F-1's ΔL VARIABLE	STD F-1's ΔL VARIABLE	5 X 1.8M F-1 ENGINES ΔL VARIABLE
STRAP-ON COMPONENTS				4 X 120 IN DIA SOLID MOTORS	4 X 120 IN DIA SOLID MOTORS	4 X 156 IN DIA SOLID MOTORS	4 LIQUID PODS 2 X STD F-1 ENGINES	4 LIQUID PODS 2 X 1.8M F-1 ENGINES

FIGURE 1-1 PHASE I LAUNCH VEHICLE CANDIDATES

Categories 3, 4, and 5 are advanced Saturn V configurations with payload capabilities beyond that of the existing Saturn V.

The five categories of vehicles are:

Category 1 (MLV-SAT-INT-20) during Phase I was a family of two-stage launch vehicle candidates with standard size S-IC and S-IVB stages using standard F-1 engines (three, four, and five) and a standard J-2 engine. A single baseline launch vehicle (Figure 1-2) was selected for the Phase II study effort.

Category 2 (MLV-SAT-INT-21) during Phase I was a family of two-stage launch vehicle candidates with standard size S-IC and S-II stages using standard F-1 engines (three, four, and five) and J-2 engines (three, four, and five). A single baseline launch vehicle (Figure 1-2) was selected for the Phase II study effort.

Category 3 (MLV-SAT-V-3B) during Phase I was a family of two- and three-stage launch vehicle candidates with modified uprated Saturn V stages using various types, numbers, and thrust levels of advanced engines in the upper stages and uprated F-1 engines in the modified S-IC stage. A single baseline launch vehicle (Figure 1-2) was selected for the Phase II study effort.

Category 4 included modified Saturn V launch vehicles with strap-on solid boost-assist components. Three families of vehicles were studied as follows:

a. MLV-SAT-V-4(S)B during Phase I was a family of two- and three-stage launch vehicles with modified Saturn V stages, standard F-1 and J-2 engines with strap-on 120-inch diameter (five, six, and seven segment) solid motors. A single baseline launch vehicle (Figure 1-2) was selected for the Phase II study effort.

b. MLV-SAT-V-22(S) during Phase I was a family of two- and three-stage launch vehicles with modified Saturn V stages using various types, numbers, and thrust levels of advanced engines in the upper stages, a modified S-IC stage with standard F-1 engines in the first stage, and strap-on 120-inch diameter (five, six, and seven segment) solid motors. No launch vehicle in this family was studied beyond Phase I.

c. MLV-SAT-V-25(S) during Phase I was a family of two- and three-stage launch vehicles with modified Saturn V stages, standard F-1 and J-2 engines, and strap-on 156-inch diameter (two and three segment) solid motors. A single baseline launch vehicle (Figure 1-2) was selected for the Phase II study effort.

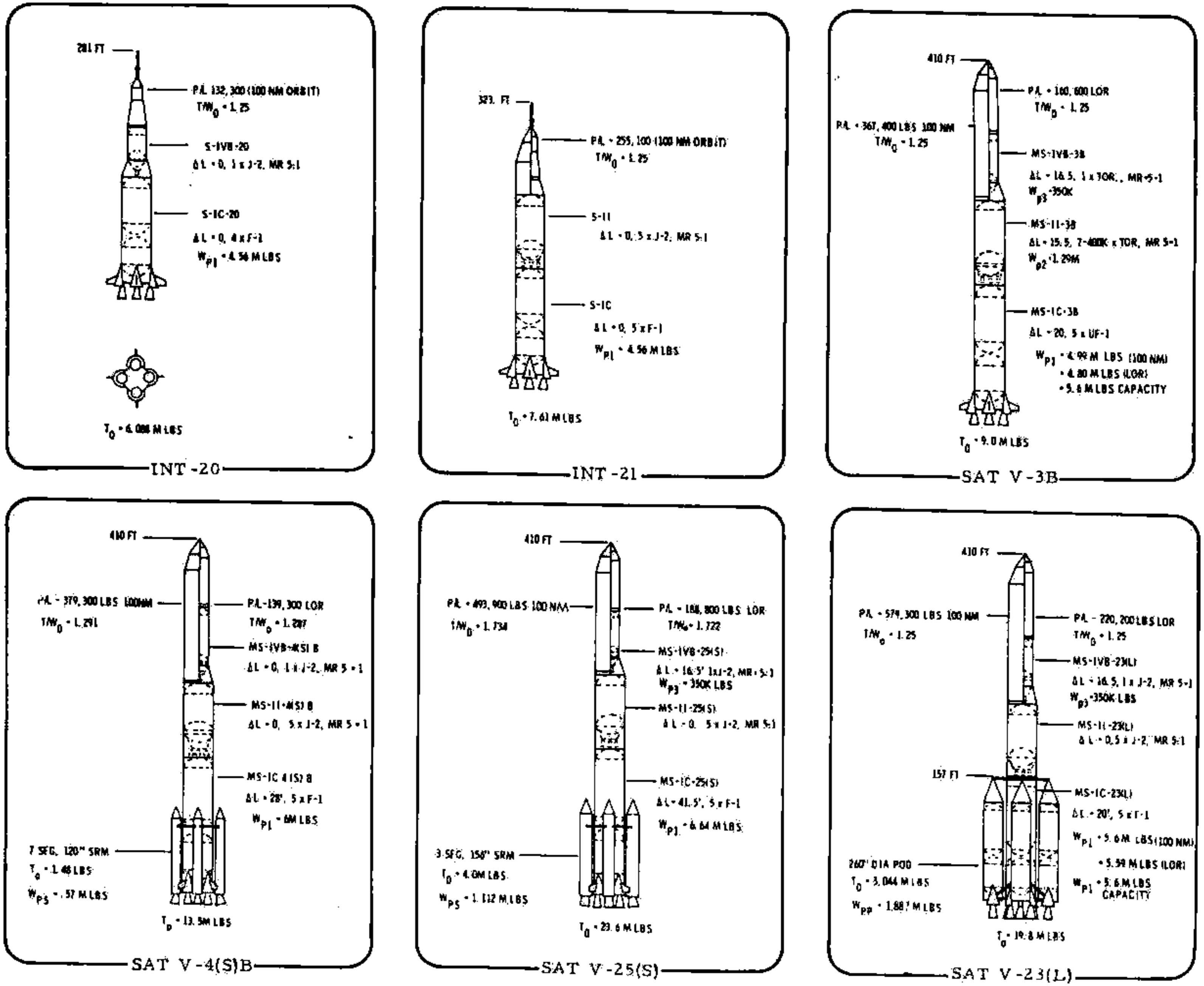


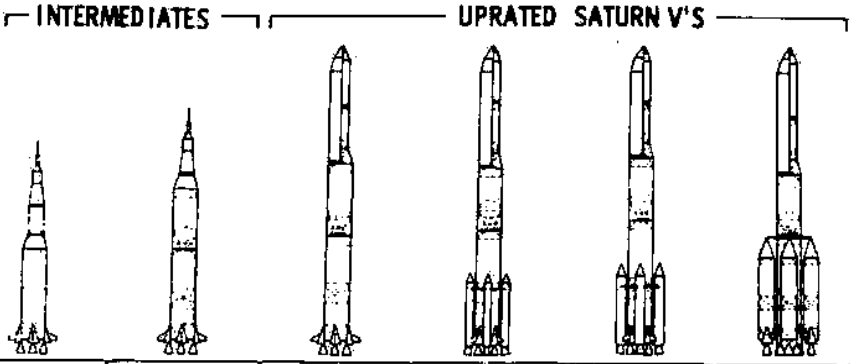
FIGURE 1-2 SELECTED BASELINE LAUNCH VEHICLES FOR PHASE II STUDY EFFORT

Category 5 included modified Saturn V launch vehicles with strap-on boost-assist liquid propellant pods. Two families of vehicles were studied as follows:

a. MLV-SAT-V-23(L) during Phase I was a family of two- and three-stage launch vehicles with modified Saturn V stages, standard F-1 and J-2 engines and four strap-on liquid propellant pods each using two standard F-1 engines. A single baseline launch vehicle (Figure 1-2) was selected for the Phase II study effort.

b. MLV-SAT-V-24(L) during Phase I was a family of two- and three-stage launch vehicles with modified Saturn V stages using various types, numbers, and thrust levels of advanced engines in the upper stages, a modified S-IC stage with 1,800,000 pound F-1 engines, and four liquid propellant pods each containing two 1,800,000 pound F-1 engines. No launch vehicles in this family were studied beyond Phase I.

2.0 SUMMARY



* $176.7M 12/YR. PRODUCTION
45M 8/YR. PRODUCTION
14.6M 6/YR. PRODUCTION
SINGLE COST FOR SYMULTANEOUS IMPLEMENTATION OF ALL 8 -20/-21 ENGINE/STAGE COMBINATIONS

	INT-20 (2 STG) F-1	INT-21 (2 STG) F-1/J-2	SAT V-3B 2 STG	SAT V-3B 3 STG	SAT V-4(S)B 2 STG	SAT V-4(S)B 3 STG	SAT V-25(S) 2 STG	SAT V-25(S) 3 STG	SAT V-23(L) 2 STG	SAT V-23(L) 3 STG
PAYLOAD - KLB	3: 78, 4: 132	43 44 45 53 54 55 / 167 186 196 222 246 259	367	161	380	139	494	189	579	220
DDT&E - $M	*	*		1097.6		431.6		603.1		944.9
R&D FLIGHT VEHICLES - $M	(1) 60.8	0		325.6		279.1		324.2		413.0
AVG. OPERATIONAL UNIT COST - $M	60.5	74.6	116.7	139.0	105.1	124.8	109.6	131.0	142.5	163.8
OPERATIONAL COST EFFICIENCY - $/LB	458	292	318	864	276	896	222	694	246	745
FIRST DELIVERY (ATP - JAN 68)	AS-516 FEB '70	AS-516 FEB '70	AS-537 SEPT '73		AS-524 JUNE '71		AS-524 JULY '71		AS-535 MAY '73	

FIGURE 2-1 VEHICLE COMPARISON

The Phase I study effort resulted in selection of six baseline launch vehicles. The Phase II study effort included detailed technical and resource analysis on these six baseline launch vehicles. Payload capabilities, costs, and availability data are compared on Figure 2-1. Operational costs shown are the averages for thirty launch vehicles. It should be noted that the total of $176.7 million for the SAT-INT-20 and SAT-INT-21 is proposed as a single R&D expenditure to implement all eight stage/engine combinations listed. This would allow NASA the flexibility of selecting the vehicle matching each of many different payloads expected in the range between present Saturn IB and Saturn V capabilities. The data required is very sensitive to launch rate as indicated by the reductions noted for eight per year and six per year launches.

Figure 2-2 illustrates the delta payload increase (from Saturn V) and compares the investment costs for developing the uprated Saturn V launch vehicles. The more favorable vehicles from an investment standpoint fall to the left, i.e., least cost for a given payload improvement. Figure 2-3 summarizes the total program cost efficiency for the six two-stage baseline launch vehicles and Figure 2-4 summarizes cost efficiency for the three-stage uprated Saturn V launch vehicles. All of these comparisons favor the solid strap-on method of uprating, usually by a relatively small margin.

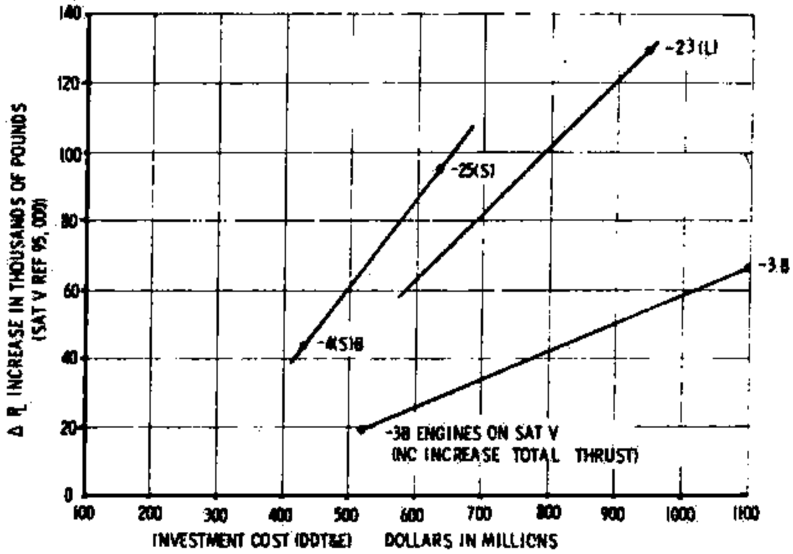


FIGURE 2-2 UPRATED VEHICLE INVESTMENT COST COMPARISON

Availability of the SAT-INT-20 and SAT-INT-21 intermediate vehicles exceeds the normal Saturn V procurement time by only one month. For uprating, the solid strap-on method requires the least lead time (3-1/2 years) which is comparable to the liquid pod strap-on (SAT-V-23(L)) method except a two-year delay has been included in the SAT-V-23(L) lead time to build an assembly facility. The five-year, nine-month lead time for the increased thrust liquid engine - larger tank uprating method (SAT-V-3B) is due to the new toroidal aerospike engine development for upper stage applications.

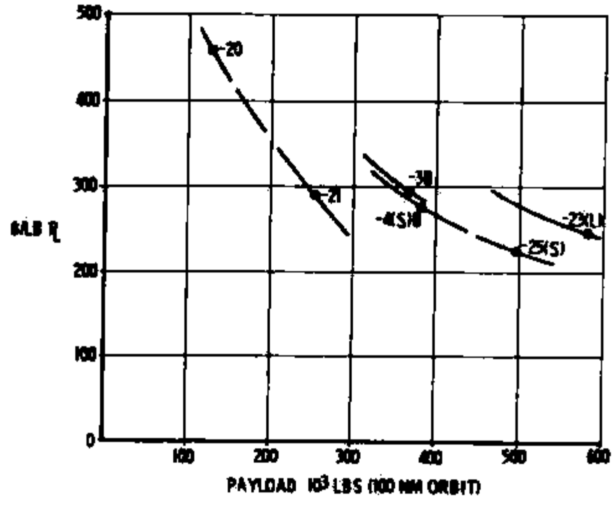


FIGURE 2-3 TWO-STAGE VEHICLE COST EFFICIENCY

All the baseline launch vehicles were feasible and logical configurations for their respective payload capabilities. Each was configured within restrictive existing facility limitation ground rules, limiting the maximum payload achieved to 579,000 pounds to 100 nautical mile Earth orbit (SAT-V-23(L)). The liquid pod strap-on concept, with uprated F-1s and advanced engines in the second stage (SAT-V-24(L)), achieved payloads to 960,000 pounds to 100 nautical mile Earth orbit when stage and total vehicle length restrictions were relaxed.

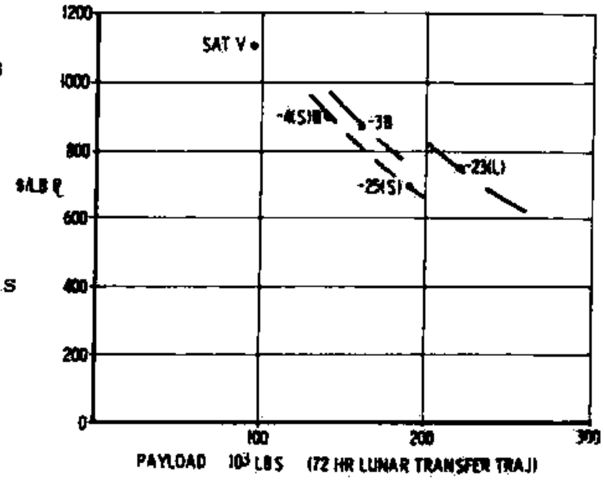


FIGURE 2-4 THREE-STAGE VEHICLE COST EFFICIENCY

3.0 GUIDE LINES AND ASSUMPTIONS

The following guide lines, ground rules, and assumptions were used in the study.

3.1 GENERAL

a. Applicable data from previous studies were utilized to the greatest extent possible.

b. The baseline vehicles were the AS-516 and the AS-213 as defined by MSFC. Apollo design criteria was used except where otherwise specified or approved by MSFC. Memorandum R-P&VE-DIR-65-143, "Saturn V Improvement Studies", dated November 5, 1965, was issued by MSFC to serve as the reference document for MSFC and contractor personnel directly involved in the Saturn V Improvement Studies. Memo R-P&VE-DIR-65-143 contains a description and definition of the projected launch vehicle AS-516 to be used as the baseline reference for the Saturn V Improvement Studies. One minor deviation to the AS-516 S-IC stage definition was made with MSFC concurrence. The redesign of the center engine crossbeam support was eliminated as a basic change because of a lack of definitive design data.

c. All propulsion data used by the stage contractors were approved by MSFC.

d. Both launch vehicle and launch facility modifications were considered. Exchange of information between the launch facility and launch vehicle study contractors was coordinated with MSFC and KSC.

e. Trajectory, propellant distribution, and stage size optimization procedures used were comparable to MSFC methods.

f. The nominal mission profiles used to size and establish the baseline vehicle design, to establish trajectories for heating and control analysis, and as a basis for performance comparison were:

1. Two-stage, direct ascent to 100 nautical mile circular orbit altitude.

2. Three-stage, with pre-orbital ignition of the third stage to 100 nautical mile circular parking orbit followed by a second burn out of orbit to 72-hour lunar injection. This is the planned Saturn V method.

Some vehicles used two-stage, direct ascent to a 100 nautical mile circular parking orbit followed by ignition of a third stage and boost to a 72-hour lunar transfer trajectory.

g. Launch azimuth from AMR was 70 degrees measured from north to south over east and flight profiles were optimized in the pitch plane.

h. Vehicle height, for both two- and three-stage vehicles, was limited to 410 feet.

i. Payload density was held at five pounds per cubic foot maximum for two stage operation and 11 pounds per cubic foot maximum for the three-stage vehicle.

3.2 FIRST STAGE

Thirty-three foot diameter and 2.29 propellant mixture ratio of the existing S-IC stage were to be maintained.

3.3 SECOND STAGE

a. Propellant mixture ratio of 5:1 and 33-foot diameter were to be maintained.

b. Maximum stage length for baseline selection was limited to 1,160 inches.

3.4 THIRD STAGE

a. Propellant mixture ratio of 5:1 and 260-inch diameter were to be maintained.

b. Maximum stage length equivalent to 350,000 pounds propellant capacity at a mixture ratio of 5:1 (about 16.5 foot increase) was to be maintained.

3.5 RESOURCES

a. Where two- and three-stage configurations of the same basic vehicle were exercised, the three-stage configuration was analyzed.

b. Uprated Saturn V stages were to be fabricated by the present contractors and cost data for the stages were obtained from the contractors.

c. The impact of study vehicles on test facilities at MSFC, test facilities at MTF, and launch facilities at KSC were considered with the assistance of those agencies or their designated contractors.

d. Two flight tests were specified to qualify uprated vehicles.

e. A production program of thirty operational uprated vehicles to be produced in five years was specified.

f. Uprated vehicles will be considered to be produced at six per year with Saturn IB a companion program at six per year.

g. Intermediate payload vehicles will be considered to be produced at six per year with Saturn V a companion program at six per year.

h. A dynamic test vehicle was required.

3.6 SCHEDULE

A program schedule was required subject to the following restrictions:

a. The uprated vehicle development program was to be parallel with the existing Saturn V program and not interfere with the existing Saturn V delivery schedule.

b. Vehicle development time to be a minimum, consistent with completion of a thorough test program.

c. A program definition phase (PDP) was required prior to beginning uprating vehicle design and development. Earliest allowed PDP start was January 1967.

d. Earliest allowed authority to proceed for hardware design and development was Janaury 1968.

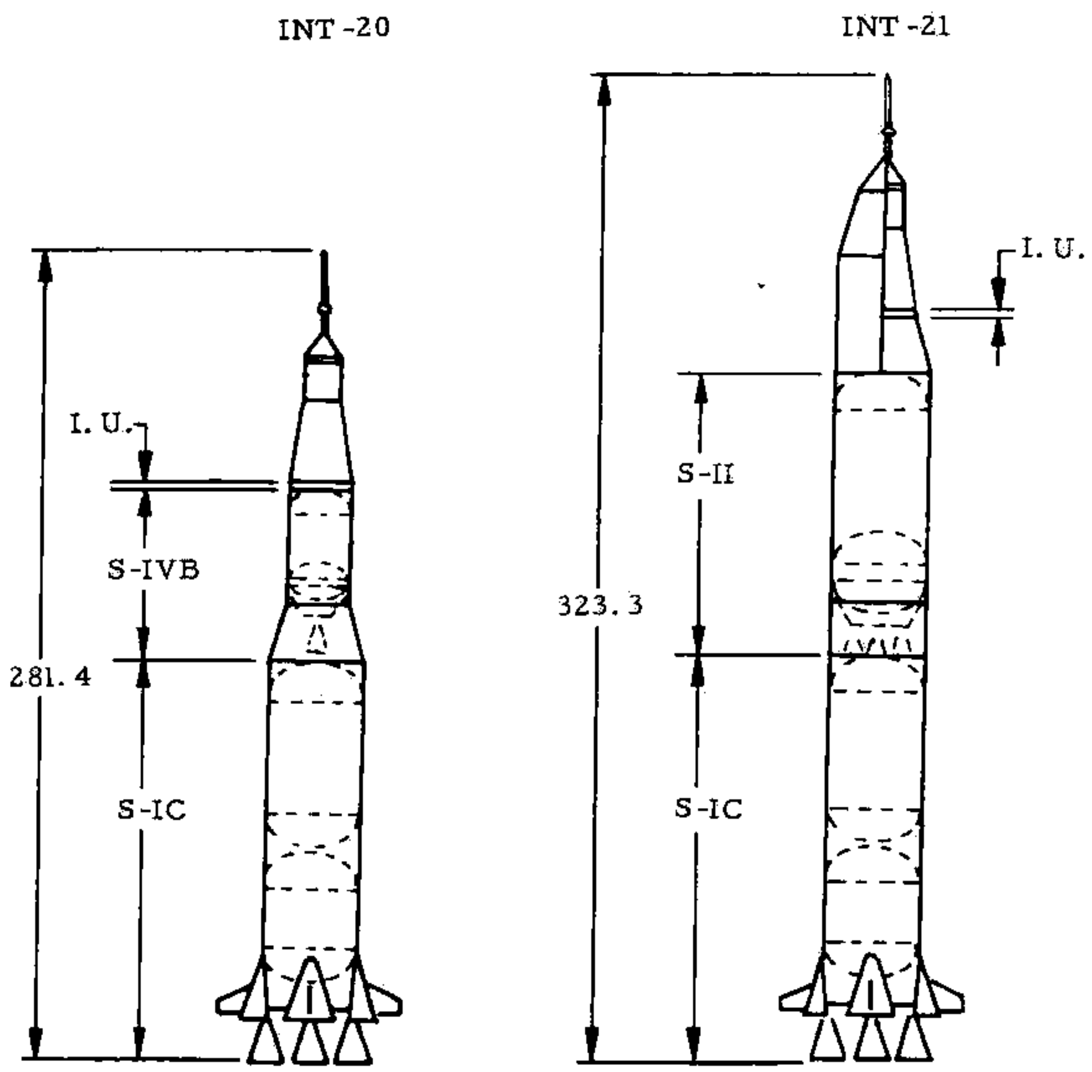
3.7 PRICING

It was also required in performing these resources analyses that the following pricing criteria be met:

a. Necessary funds are available as required.

b. All costs were quoted in 1966 dollars with no inflationary factor or mid-point estimate.

c. All costs were based on two-shift, five-day week for manufacturing and one-shift, five-day week for engineering.



J-2/F-1	100 N Mi Orbit P_L - 10^3 LBS
3/1	78
4/1	132

F-1/J-2	100 N Mi P_L - 10^3 LBS
4/3	167
4/4	186
4/5	196
5/3	222
5/4	246
5/5	255

FIGURE 4-1 INT VEHICLES

4.0 MLV-SAT-INT-20/-21 LAUNCH VEHICLES

The MLV-SAT-INT-20 is a combination of the Saturn V S-IC and S-IVB stages. The MLV-SAT-INT-21 combines the Saturn V S-IC and S-II stages. All arrangements (see Figure 4-1) were found to be feasible. Each of eight stage/engine configurations could be used efficiently to launch a payload in increments between 78,000 pounds and 255,000 pounds to a 100 nautical mile Earth orbit.

Since future requirements will likely vary over a wide range of payloads and configurations, all INT-20/-21 vehicles should be implemented simultaneously. This would allow NASA planners to select the vehicle matching a specific payload requirement.

If an uprated vehicle is chosen for development, there are similar logical intermediate derivatives to be considered.

4.1 CONFIGURATION SELECTION (PHASE I)

Combinations of the three Saturn V stages and numbers of engines were studied during Phase I to establish the most promising configurations for detailed investigation.

4.1.1 Candidate Configurations

Three configurations were studied for INT-20, each having an S-IVB with a three-, four-, or five-engine S-IC. INT-21 arrangements included a three-, four-, or five-engine S-II combined with a four- or five-engine S-IC. This resulted in six INT-21 vehicles.

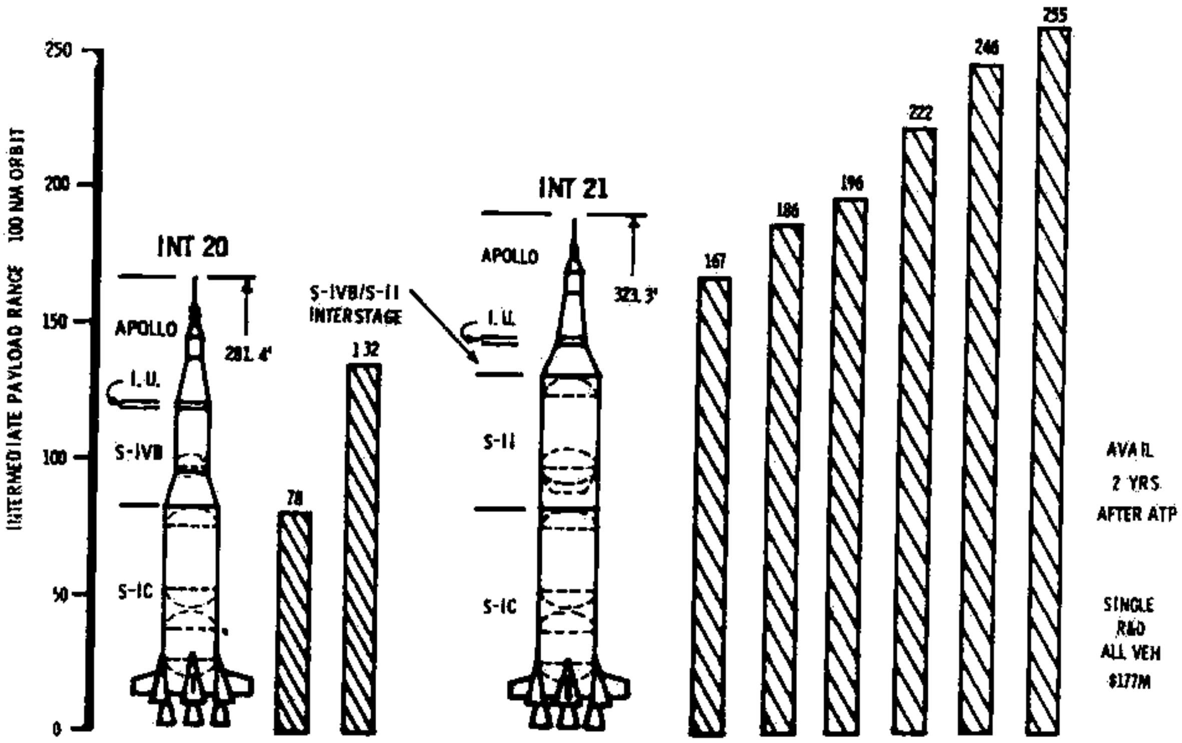
4.1.2 Trade Studies

Parametric data were generated for the candidate INT vehicles covering the following: (1) weight and mass characteristics, (2) trajectories and performance, (3) aerodynamics and heating, (4) vehicle control, (5) design loads, and (6) separation. A summary of INT-20 and INT-21 launch, propellant, and payload weights is shown in Table 4-I. The five-engine INT-20 vehicle, even though launched at a thrust-to-weight ratio of 1.25, depletes first-stage propellant rapidly. It therefore reaches a structural load limit at about 88 seconds after launch and three engines must be shut down. The resulting payload is not significantly better than the four-engine case (see Table 4-I) and therefore the five F-1 engine INT-20 was not considered further.

TABLE 4-I INTERMEDIATE VEHICLE PERFORMANCE SUMMARY

VEHICLE	STAGE ARRANGEMENT	NUMBER OF ENGINES	LAUNCH WEIGHT 10^6 LB	W_{P1} 10^6 LB	W_{P2} 10^6 LB	100 NM PAYLOAD 10^3 LB
SAT-INT-20	S-IC/S-IVB	3/1	3.65	3.0	0.23	78
		4/1	4.87	4.1	0.23	132
		5/1	5.07	4.3	0.23	133
SAT-INT-21	S-IC/S-II	4/3	4.87	3.56	0.71	167
		4/4	4.87	3.40	0.85	186
		4/5	4.87	3.30	0.93	196
		5/3	6.09	4.56	0.84	222
		5/4	6.09	4.47	0.91	246
		5/5	6.09	4.42	0.93	255

W_{P1} = First stage mainstage propellant
W_{P2} = Second stage mainstage propellant
Initial launch azimuth - 70 degrees



F1/J-2	3/1	4/1	4/3	4/4	4/5	5/3	5/4	5/5	SINGLE R&D
M$R&D 8/YR	42.3	42.3	37.8	37.8	35.8	35.5	35.5	33.5	NO PROD
M$R&D 12/YR	170.5	170.5	168.2	168.2	166.2	165.9	165.9	163.9	INC. 14.3M
$/LB	806	496	431	402	395	337	315	314	
S-IC BURNTIME	146	212	154	148	143	161	155	150	
	(3-146)	(2-146)	(2-146)	(2-146)	(4-143)	(1-146)	(1-146)	(1-146)	

FIGURE 4-2 INT-20/-21 VEHICLE COMPARISON

For the remaining baseline candidates (shown on Figure 4-2), it was necessary to shut down one or more F-1 engines during first stage flight to avoid the present 4.68 g longitudinal acceleration limit. The time of shutdown and number of engines shut down are shown with the first-stage burntime on Figure 4-2.

INT-20 and INT-21 vehicle costs were derived for six launches per year for five years. It was assumed that Saturn V was also launched at the same rate during this period. Bulk of the non-recurring cost (see Figure 4-2) is due to the increase in production and launch rates. Approximately 124 million dollars are required at KSC to build and equip for the new rate. The remainder covers mostly facilities, tools, and equipment. Note the marked reduction in R&D cost for eight per year and six per year INT production rates. The non-recurring cost for implementing all configurations simultaneously is estimated to be 13 million dollars (eight percent) more than the lowest-cost single arrangement at 12 per year.

Payload-cost-efficiencies (dollars per pound of payload, see Figure 4-2) vary uniformly, following the natural trend which is: smallest payload - largest cost per pound for delivery, and largest payload - least cost per pound for delivery.

Since all vehicles are shown to be cost efficient and NASA future requirements are more likely to be a number of different weight payloads, rather than one, it was recommended that all INT configurations be studied further. But, because funds, time, and manpower were limited, design analyses were restricted to the four-engine S-IC/S-IVB INT-20 and the five-engine S-IC/five-engine S-II INT-21. However, resources were prepared for all configurations.

4.2 DESIGN STUDY VEHICLE (PHASE II)

The baseline vehicles chosen during the Phase I activity were defined in detail, their complete characteristics determined, and their resource requirements established.

4.2.1 Vehicle Description

INT configurations chosen for further design study are shown on Figure 4-1. The INT-20 has a standard Saturn V S-IC first stage with the center F-1 engine and associated systems removed. The second stage is a standard S-IVB with its aft interface adapted to S-IC requirements. The INT-21 uses standard S-IC and S-II stages. An S-IVB/S-II interstage is used to adapt to the instrument unit and payload.

The manner in which a four-engine S-IC is achieved is illustrated on Figure 4-3. The baseline S-IC stage provided by NASA incorporates an insulated LOX duct rather than a duct-in-tunnel arrangement. With the duct removed, it is necessary to support the center duct spool to retain cross-feed capability. Cover plates and seals close the LOX and fuel bulkheads where lines are removed. Heat shield panels and supports from other locations replace those used where the engine is mounted. This installation can be made on any S-IC stage with insulated LOX ducts. Conversely, an S-IC INT-20 could readily be returned to the Saturn V configuration.

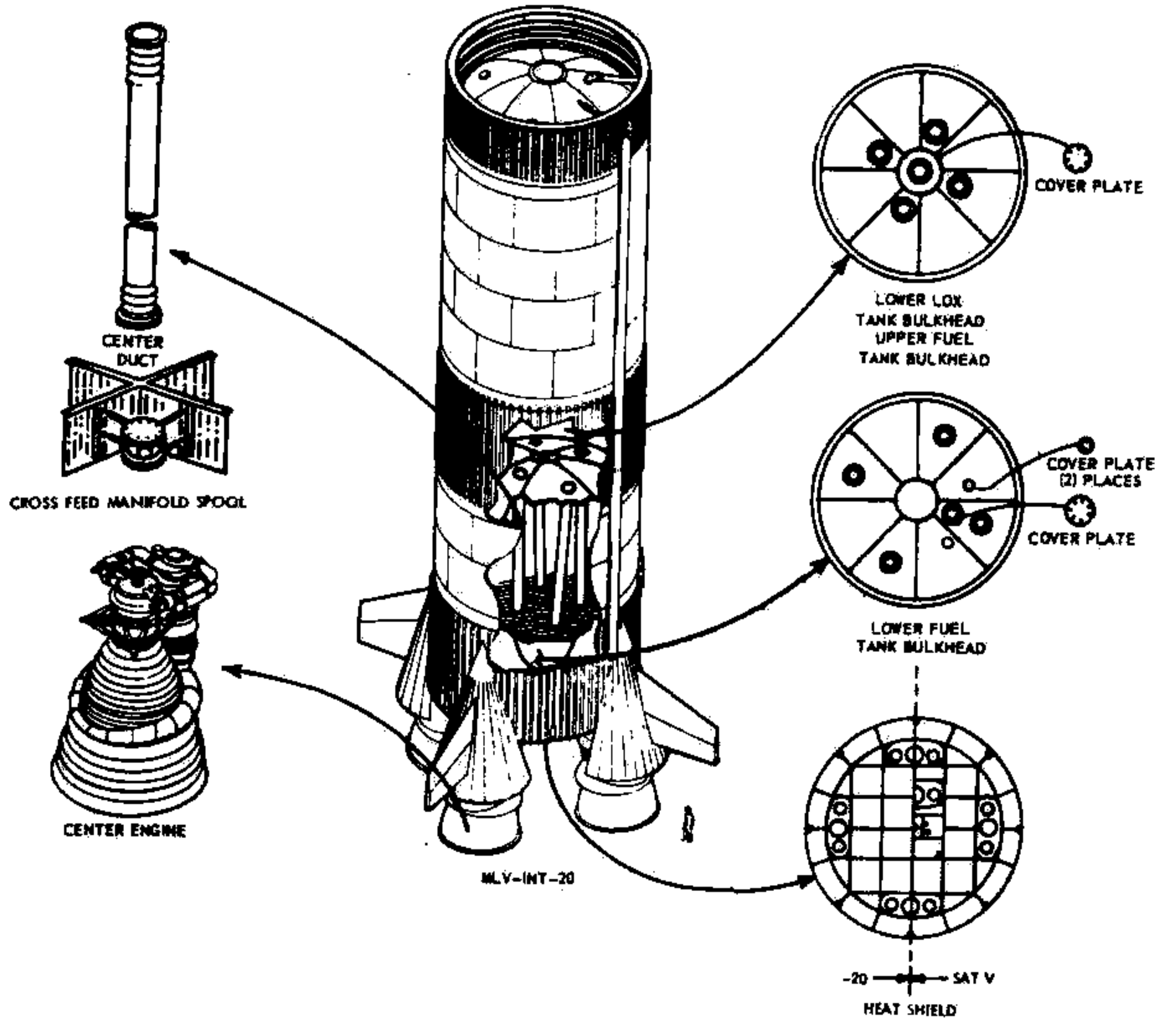


FIGURE 4-3 FOUR ENGINE S-IC-20 STAGE

4.2.2 Design Study Results

Significant load criteria and other data pertinent to vehicle design are shown on Table 4-II with comparative Saturn V values. As shown, load criteria is less than that for the existing Saturn V for both intermediate baseline configurations. Therefore, no structural modifications are required to the existing Saturn V stages.

Control requirements, as shown in Table 4-II, are below that of the existing Saturn V. Aerodynamic heating has increased slightly for both the INT-20 and INT-21 but is still within existing design criteria requiring no additional protection. Base heating on INT-20 is reduced compared with Saturn V and is identical to Saturn V on INT-21.

Detailed studies indicate that structural loads are less severe than for AS-516. No control or separation problems exist.

The reliability of the INT-20 is 0.999 and the INT-21 is the same as the baseline AS-516 reliability of 0.990.

Performance data were developed for the INTs for numerous missions. The nominal mission was direct ascent to a 100 nautical mile circular Earth orbit with a liftoff thrust-to-weight of 1.25 and a launch azimuth of 70 degrees. Alternate missions considered a range of orbit altitudes and launch azimuths.

	INT-20	INT-21	SAT V*
LOAD CRITERIA			
MAX q (LBS/FT^2)	758	760	766
g's AT MAX. q α	1.92	1.95	1.954
HEIGHT (FT)	281	323	363
CONTROL			
MODE	GIMBALED F-1'S	GIMBALED F-1'S	GIMBALED F-1'S
MAX. DEFLECTION ANGLE IN FLIGHT	2.3 DEG.	2.3 DEG.	3.5 DEG.
HEATING			
TYP AERODYNAMIC (S-IC FWD SKT) MAX. TEMP	197°F	176°F	167°F
BASE MAX. TEMP.	1720°F	1900°F	1900°F

* BASELINE 516 WITH $T_0/W_0 = 1.25$

TABLE 4-II SIGNIFICANT LOAD CRITERIA

Figure 4-4 summarizes the orbit/altitude capability for INT-20. Similar data are shown on Figure 4-5 for INT-21. Net payloads for the nominal mission are 132,000 pounds for INT-20 and 255,000 pounds for INT-21. Payloads for polar and sun synchronous orbits are shown on Figures 4-6 and 4-7. A boost turn is required to obtain these orbits from Cape Kennedy. This manuever requires energy expenditure which is reflected in less payload capability.

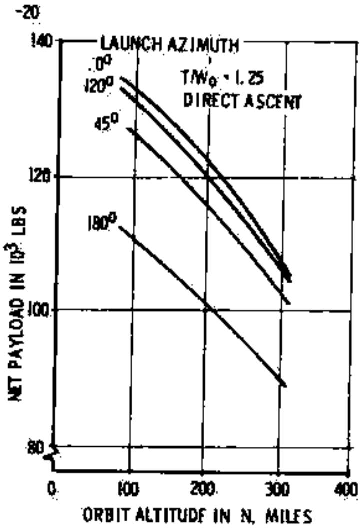


FIGURE 4-4 INT-20 ORBIT ALTITUDE - AZIMUTH PAYLOAD CAPABILITY

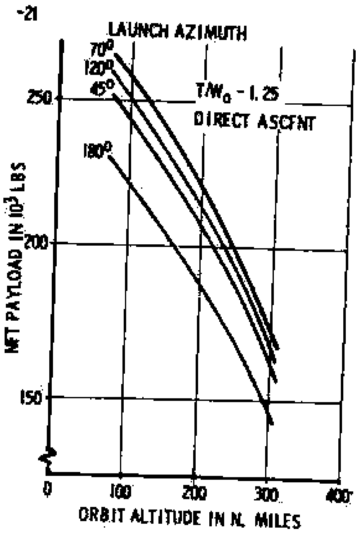


FIGURE 4-5 INT-21 ORBIT ALTITUDE AZIMUTH PAYLOAD CAPABILITY

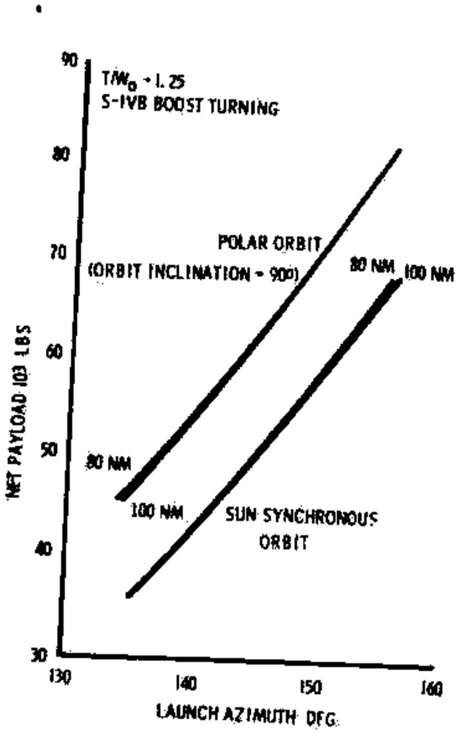


FIGURE 4-6 INT-20 POLAR & SUN SYNCHRONOUS PAYLOAD (DIRECT ASCENT)

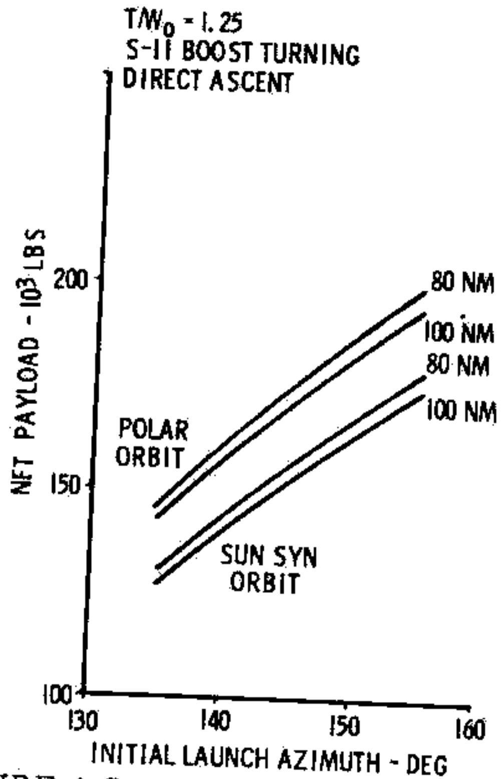
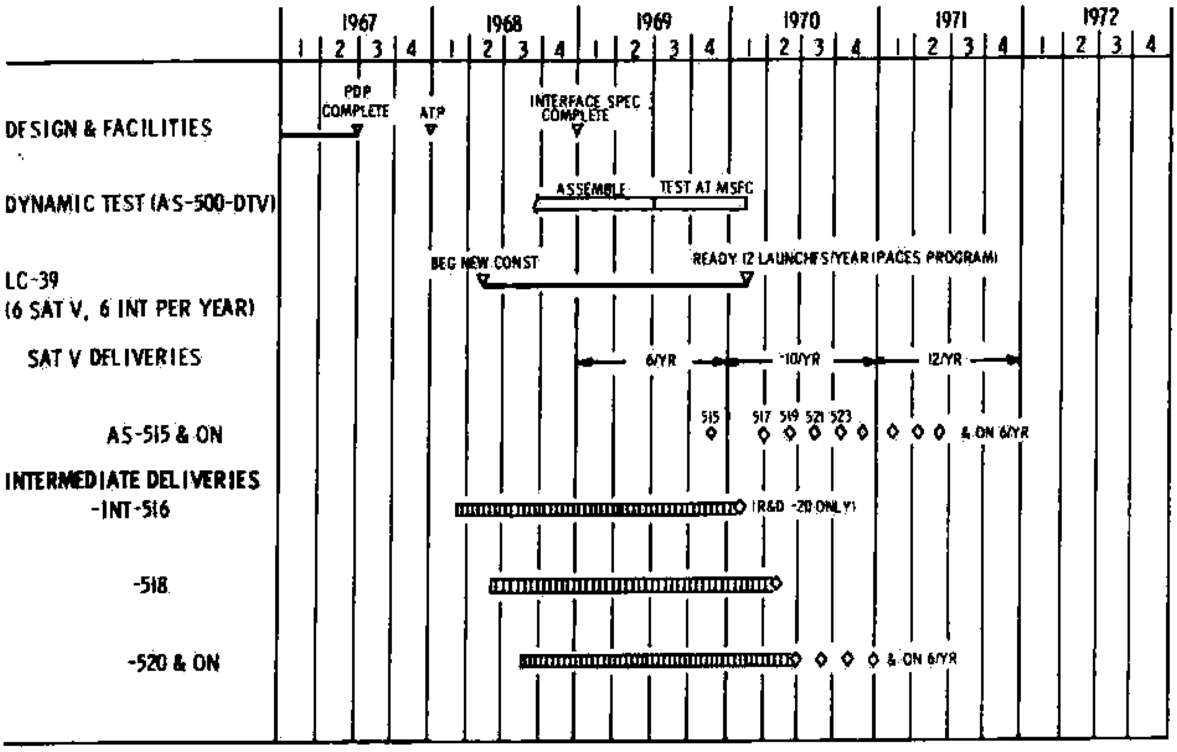


FIGURE 4-7 SYNCHRONOUS ORBIT PAYLOAD CAPABILITY

4.2.3 Resources

Study ground rules requiring six intermediate and six Saturn V vehicles per year have the strongest influence on resources. The greatest impact on facilities occurs at MILA. Here, 100 million dollars are required for an additional mobile launcher, a mobile service structure, and firing room equipment. Other launch system modifications and equipment are about 23 million dollars.



NOTE: MATERIAL PROCUREMENT FOR 12/YR PROD. AND LC-37 MOD
AND LC-39 MOD'S PACE PROGRAM
8/YR PROGRAM PACED BY PROCUREMENT AND MSS MOD
*AS REQUESTED BY KSC, PRODUCTION CAN REACH 12/YR IN 1970

FIGURE 4-8 INT-20/-21 VEHICLE DEVELOPMENT AND DELIVERY PLAN

A schedule for INT-20 or INT-21 development and delivery is shown on Figure 4-8. Study ground rules require a program definition phase (PDP) which may start as early as January 1967. Earliest authority to proceed (ATP) was ground-ruled to January 1968. With these controls, first intermediate vehicle delivery is February 1970. Since the INT-21 is a two-stage Saturn V vehicle, it will not require man-rating flights. The INT-20, even with previously man-rated stages, requires an R&D flight by MSFC ground rules.

Tables 4-III and 4-IV summarize the costs that would be incurred for implementing INT-20 and INT-21, respectively, plus the cost for 30 vehicles including launch.

COST DOLLARS IN MILLIONS	DEVELOPMENT STAGE	DEVELOPMENT ENGINE	OPERATIONAL STAGE	OPERATIONAL ENGINE	TOTAL
	$	$	$	$	$
LAUNCH VEHICLE					
S-IC STAGE	6.2		494.5	207.0	707.7
S-IVB STAGE	7.1		285.1	36.3	328.5
INSTRUMENT UNIT			128.2		128.2
LAUNCH VEHICLE TOTAL	13.3		907.8	243.3	1164.4
GROUND SUPPORT EQUIPMENT					
S-IC STAGE	9.1		21.5		30.6
S-IVB STAGE	.2		38.7		38.9
GSE TOTAL	9.3		60.2		69.5
FACILITIES					
S-IC STAGE	13.2				13.2
S-IVB STAGE			4.9		4.9
LAUNCH VEHICLE - KSC	121.7		364.2		485.9
FACILITIES TOTAL	134.9		369.1		504.0
SYSTEMS ENGINEERING AND INTEGRATION			234.0		234.0
LAUNCH SYSTEMS TOTAL	$157.5		$1571.1	$243.3	
	$157.5		$1814.4		$1979.7

R&D FLIGHTS (1) 60.4

TABLE 4-III INT-20 COST SUMMARY

COST DOLLARS IN MILLIONS	DEVELOPMENT STAGE	DEVELOPMENT ENGINE	OPERATIONAL STAGE	OPERATIONAL ENGINE	TOTAL
LAUNCH VEHICLE					
S-IC STAGE	3.9		508.3	256.9	769.1
S-II STAGE	13.6		449.4	176.8	639.8
S-IVB STAGE (INTERSTAGE)*			43.3		43.3
INSTRUMENT UNIT			128.2		128.2
LAUNCH VEHICLE TOTAL	17.5		1129.2	433.7	1580.4
GROUND SUPPORT EQUIPMENT					
S-IC STAGE	9.1		27.0		36.1
S-II STAGE			21.1		21.1
GSE TOTAL	9.1		48.1		57.2
FACILITIES					
S-IC STAGE	13.2				13.2
S-II STAGE	.6				.6
LAUNCH VEHICLE - KSC	123.5		393.2		516.7
FACILITIES TOTAL	137.3		393.2		530.5
SYSTEMS ENGINEERING & INTEGRATION			234.0		234.0
LAUNCH SYSTEMS TOTAL	163.9		1804.5	433.7	
	163.9		2238.2		2402.1

*ADAPT S-II TO IU

TABLE 4-IV INT-21 COST SUMMARY

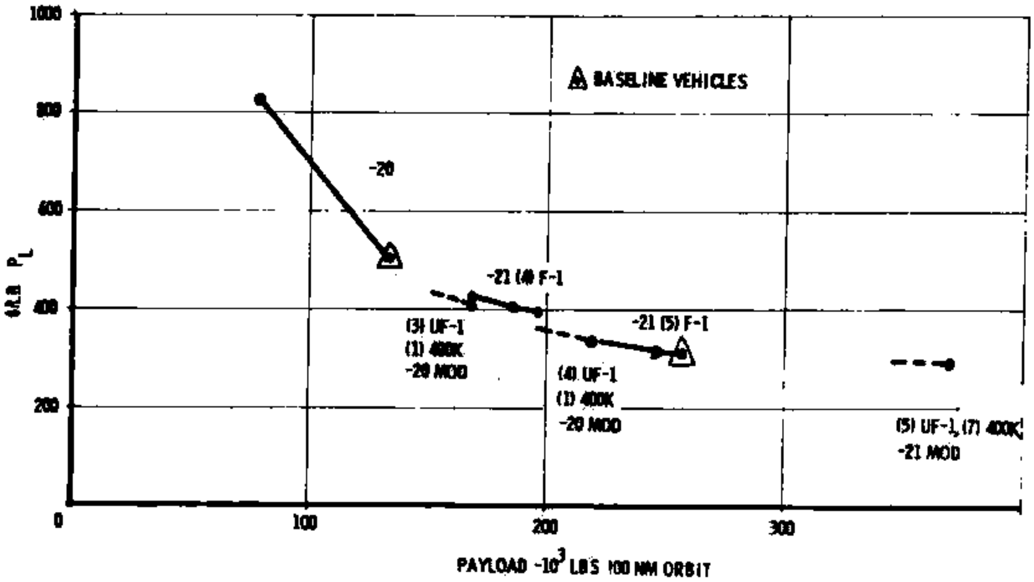


FIGURE 4-9 INT VEHICLE COST EFFICIENCY COMPARISON

Figure 4-9 summarizes the payload cost efficiency of the eight INT vehicles (solid lines) not including R&D flights. The dotted lines are vehicles similar to INT-20 and INT-21 but using the MLV-SAT-V-3B stages (see Section 5.0 of this document). These data demonstrate that INT vehicles could be derived from any of the uprated configurations studied. The strap-on systems, in addition to first and third or first and second stage combinations, can also be assembled with zero, two, or four boost-assist units.

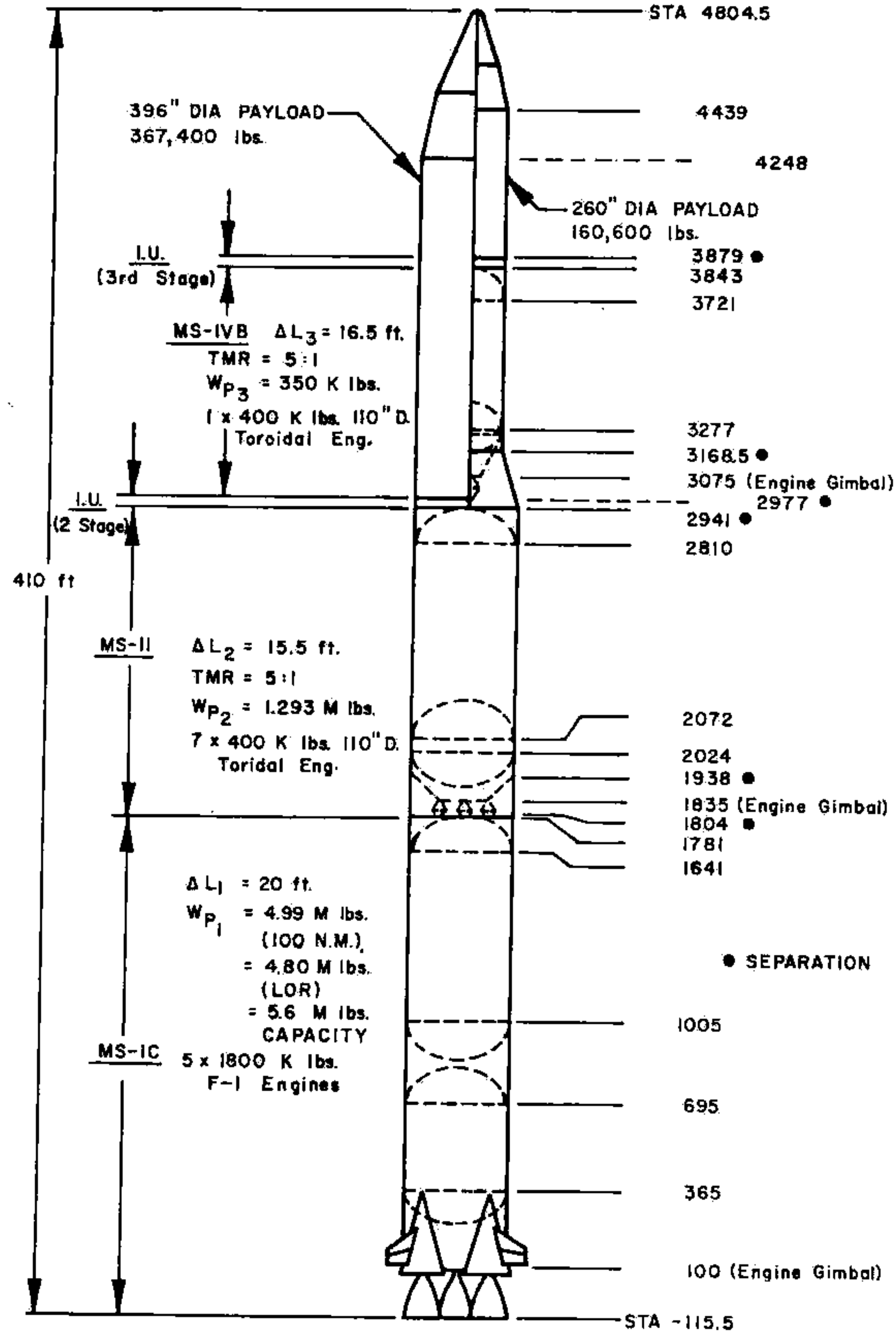


FIGURE 5-1 MLV-SAT-V-3B BASELINE LAUNCH VEHICLE