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MODIFIED LAUNCH VEHICLE (MLV) SATURN V IMPROVEMENT STUDY COMPOSITE SUMMARY REPORT

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George C. Marshall Space Flight Center, Huntsville, Alabama

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George C. Marshall Space Flight Center

Huntsville, Alabama

ABSTRACT

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This document is a composite summary of the contractor and MSFC in-house Saturn V Improvement Studies conducted during the period of June 29, 1964, to April 15, 1965. The purpose of the studies was to determine the requirements for modifying the S-IC, S-II, and S-IVB stages. Maximum use was to be made of existing facilities, hardware, and technology for configurations that could be obtained in the 1970 - 1975 time frame.

Presented are the summary results of the detailed definition, design, performance, and resource studies conducted by the contractors under eight study contracts for the Modified Launch Vehicle (MLV) Saturn V configurations. Major system and structural revisions to the stages along with the performance and schedules for each vehicle are included.

The evaluation of the problems associated with the design, development, and operation of the MLV-Saturn V vehicles disclosed that these vehicles are a practical means of uprating the Saturn V vehicle. No insurmountable problems were uncovered. Detailed design and manufacturing procedures are within present technology and tooling capability.

This report was compiled with the assistance of Advanced Projects Study Branch of Aero-Astrodynamics Laboratory, the Future Projects Office, and the Structures and Propulsion Divisions of the Propulsion and Vehicle Engineering Laboratory.

Author

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MODIFIED LAUNCH VEHICLE (MLV) SATURN V IMPROVEMENT STUDY COMPOSITE SUMMARY REPORT

Compiled By

Advanced Studies Office

PROPULSION AND VEHICLE ENGINEERING LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

FOREWORD

A series of Saturn V Improvement Studies is currently being conducted by Saturn stage and engine contractors, under sponsorship of NASA/Manned Space Flight and direction of the NASA/Marshall Space Flight Center. The objective of these studies is to determine growth potential of the Saturn V vehicles for potential future missions and to obtain comparisons of alternative uprating methods in terms of payload gains achievable, costs, lead times, impact on facilities, etc. This report is the composite summary of the contractor and complementary MSFC in-house Saturn V Improvement Studies conducted under FY-64 funding.

Vehicle configurations representative of several alternative uprating methods were specified by MSFC for initial studies. The methods of uprating considered in the contractor studies were the following:

1. Thrust uprating of F-1 engines and corresponding increases in propellant capacities.

2. Addition of sixth F-1 engine in the S-IC stage, as an alternative to engine uprating, plus increased propellant capacities.

3. Use of large solid motor boost assist.

4. Additional J-2 engines in the S-II stage, plus increased upper stage propellant capacities.

5. Improved or advanced upper stage engines, plus increased propellant capacities.

The Saturn V Improvement Studies conducted under FY-64 funding to investigate and define these concepts are given below:

	Contract No.	Company	Funding	Study
1.	NAS8-11339	The Boeing Company	$215K	MS-IC Stage for Modified Launch Vehicle (MLV) Saturn V

	Contract No.	Company	Funding	Study
2.	NAS8-11352	North American Aviation	$217K	Design Study of the S-II Stage for the Modified Launch Vehicle (MLV) Saturn V
3.	NAS8-11359	Douglas Aircraft Company	210K	Saturn V Improvement Study MS-IVB-1 and MS-IVB-2
4.	NAS8-11443	The Boeing Company	308K	Saturn V Improvement Study Liquid-solid System Integration
5.	NAS8-11478	The Boeing Company		Study of Resources Required for Liquid-solid System Integration
6.	NAS8-11428	The Boeing Company	246K	Saturn V Improvement Study Fluid and Flight Mechanics Studies (for all configurations)

The following engine studies directly supported the FY-64 Saturn V Improvement Studies:

7.	---	Rocketdyne Div., NAA	146K*	F-1 and J-2 Uprating
8.	NAS8-11427	Pratt and Whitney Aircraft	500K	Design Studies of Advanced Upper Stage Engines

* Saturn/Apollo funding.

Detailed information concerning the results of the study is published in the contractor reports listed in the bibliography.

The following personnel, representing their respective organizations, participated in directing and managing the contractor studies:

H.H. Koelle	R-FP	MSFC-Director of Future Projects
P.J. DeFries*	R-AERO-S	Technical Coordinator and Editor-in-Chief
A.G. Orillion	R-P&VE-AV	Deputy Editor-in-Chief and P&VE-Technical Coordinator
J.M. Schwartz/ L.B. Allen	R-P&VE-AVC	Alt. P&VE Technical Coordinator
L.T. Spears	R-FP	Future Projects Office Representative
R.J. Davies	R-FP	Resources Analysis for all Studies
H. Thomae	R-AERO-DP	AERO-Technical Coordinator and COR F&FM Contract
R.D. Scott	R-AERO-DP	Alt. COR F&FM Contract
W. Corcoran	R-P&VE-S	COR MS-IC Contract MS-II Contract MS-IVB Contract
J.M. Walters	R-P&VE-SAE	Alt. COR MS-IC Contract
G.B. Smith	R-P&VE-SA	Alt. COR MS-II Contract
H.L. Billmayer	R-P&VE-SS	Alt. COR MS-IVB Contract
A. Boyanton	R-P&VE-S	COR Liquid-Solid Integration Contract
J. Massey	R-P&VE-AAA	COR Liquid-Solid Integration Resources Analysis

*Participated in the initiation of the study but withdrew because of other assignments.

J. Lombardo	R-P&VE-PAA	COR Engine Contractor
D. DeMars	R-P&VE-PAA	Alt. COR F-1 and J-2 Engines Contracts
J. McCarty	R-P&VE-PAA	Alt. COR HG-3 Engine Contract

Various personnel from the Test, Manufacturing and Astrionics Laboratories of MSFC and Launch Operations of KSC participated in the studies in advisory capacities.

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MODIFIED LAUNCH VEHICLE (MLV) SATURN V IMPROVEMENT STUDY COMPOSITE SUMMARY REPORT

SECTION I. INTRODUCTION

Following the Apollo lunar mission, the national space program will expand from the Apollo Extension System concept to the utilization of large new payload systems. Improved Saturn V launch vehicles, utilizing improved propulsion systems, must be considered in establishing requirements for these future missions.

This document is a composite summary report of Saturn V Improvement Studies conducted from June 29, 1964, to April 15, 1965, under eight study contracts. The purpose of the study is to investigate potential modified stage designs for use in Modified Launch Vehicle (MLV) Saturn V. Presented are the summary results of the detailed definition, design, performance, and resource studies conducted by the contractors for the MLV-Saturn V configurations. Major system and structural revisions to the stages for each configuration are included. Performance and schedules are presented for each of the modified launch vehicles.

At the initiation of the study, no mission assignments had been made; therefore, no specific mission requirements existed for an improved launch vehicle system. As a result, the approach to this study was to establish the earliest practical vehicle configuration, followed by appropriate evolutionary steps to the "ultimate" practical configuration (within the study ground rules, e.g., using the expected engine improvements and remaining within facility restraints; if the ground rules are changed, the "ultimate" vehicle could change).

The stage designs considered were for use in launch vehicles operating in the 1970's, subsequent to the presently scheduled vehicle SA-515.

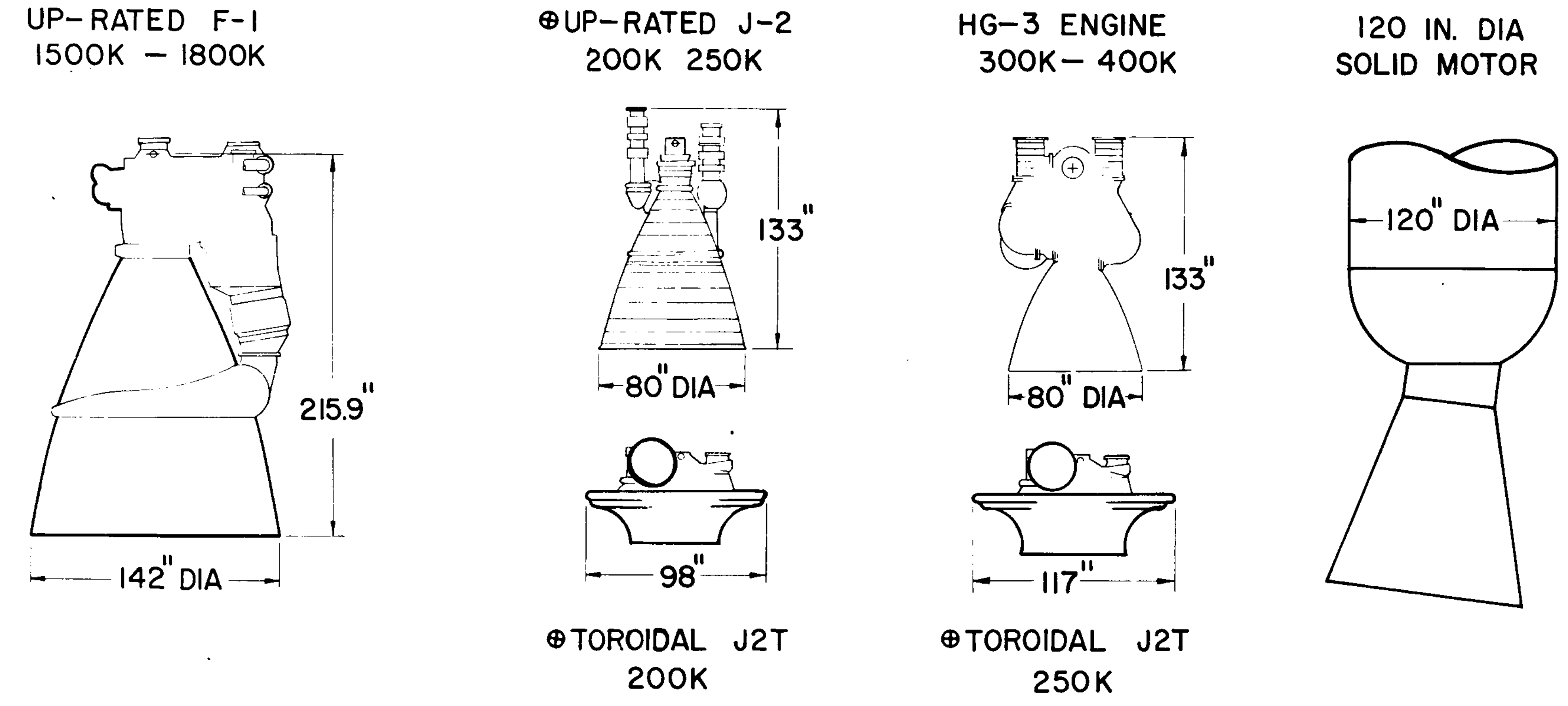
There are a number of changes that can be imposed on each stage and various modified stage combinations that can be arranged to increase the Saturn V launch vehicle performance. An outline of some potentials that may be considered is shown in Table 1.

TABLE 1. - PRINCIPAL TECHNIQUES FOR MAJOR VEHICLE UPRATING

	First Stage	Second Stage	Third Stage
Propulsion System	• Increase No. of Engines • F-1 Uprating • Toroidal F-1 • Floxing	• Increase No. of Engines • J-2 Uprating • High P_c Engine • Toroidal J-2 • Floxing	• J-2 Uprating • High P_c Engine • Toroidal J-2 • Floxing
Stage	• Increased Propellant Loading	• Increased Propellant Loading	• Increased Propellant Loading
Other	• Solid or Liquid Motor Assist		

Studies were conducted in the spring of 1964 at MSFC by R&DO on various configurations involving these techniques. In addition, improved vehicle systems studies by other sources, e.g., Industrial Operations, contractors, etc., were scrutinized for potential consideration. From this approach, configurations were selected that were considered the more practical and representative within the applied restraints for the contractor studies. Only those concepts realizing 10 percent or more in payload gain were considered.

To increase the payload capability of the launch vehicles, the stage propulsion was improved by uprating the present engines and/or introducing new engine or propulsion systems. For these studies, an uprated F-1, a new high-pressure upper-stage engine - the HG-3 - and the 120-inch-diameter solid motors (shown in Figure 1) were used. The uprated



⊕ Configurations using these engines were studied in-house for performance gains only.

FIGURE 1. - SATURN V IMPROVEMENT STUDIES CANDIDATE ENGINES

J-2 engine was not considered in the initial contractor studies as it was not apparent at that time how high its thrust could be increased. An assumed 10-percent increase in thrust only resulted in a 4-percent increase in payload which was considered insufficient to warrant further examination. MSFC decided to defer vehicle studies utilizing the uprated J-2 until the engine studies were complete. Although the engine studies later revealed that the J-2 could be uprated to 250 000 pounds of thrust, MSFC elected to increase the number of engines in the second stage rather than use the uprated J-2. (However, the use of the J-2 and J-2T engines was considered in the MSFC in-house performance studies.) The United Technology Corporation (UTC) 120-inch-diameter UA-1205 solid motor was used in the contractor liquid-solid integration studies.

Initially, the original configurations chosen for contractor studies (MLV-Saturn V-1, V-2, V-3, and MLV-Saturn V-4(S) shown in Figures 2 and 3) were scheduled to be studied for the duration of the contract. However, the results obtained at the midterm review were of such depth that the studies were considered to be near completion; the contractors were therefore directed to study two additional configurations: MLV-Saturn V-1A and MLV-Saturn V-4(S)A. Cost estimates from these studies will be summarized and discussed in a separate MSFC report. At the initiation of the study, the official payload capability of the baseline Saturn V LOR vehicle was 90 000 pounds. After the midterm review, the new payload capability of the Saturn V (95 000 pounds) was factored into the study.

Modifications to the Instrument Unit (IU) were not included in the all-liquid studies since it was agreed that the preferred improvement scheme should be selected prior to studying the IU.

In addition to the contractor studies, alternative configurational performance studies were conducted at MSFC. The in-house studies have attempted to place on a common ground the performance capabilities of a variety of vehicle configurations that can be generated by pursuing a particular method or philosophy of uprating. These studies, which are reported in Section VII, reflect only the performance of the vehicles and do not incorporate any detailed stage or vehicle designs.

Other in-house studies investigated the performance capability of the improved Saturn V system with a nuclear propulsion system in the third stage rather than the chemical MS-IVB. The nuclear stage study was introduced at the request of Office of Manned Space Flight, NASA Headquarters. These studies were performed in-house and do not reflect the same study effort as the contractor's studies. The results of these studies are discussed in Section VIII.

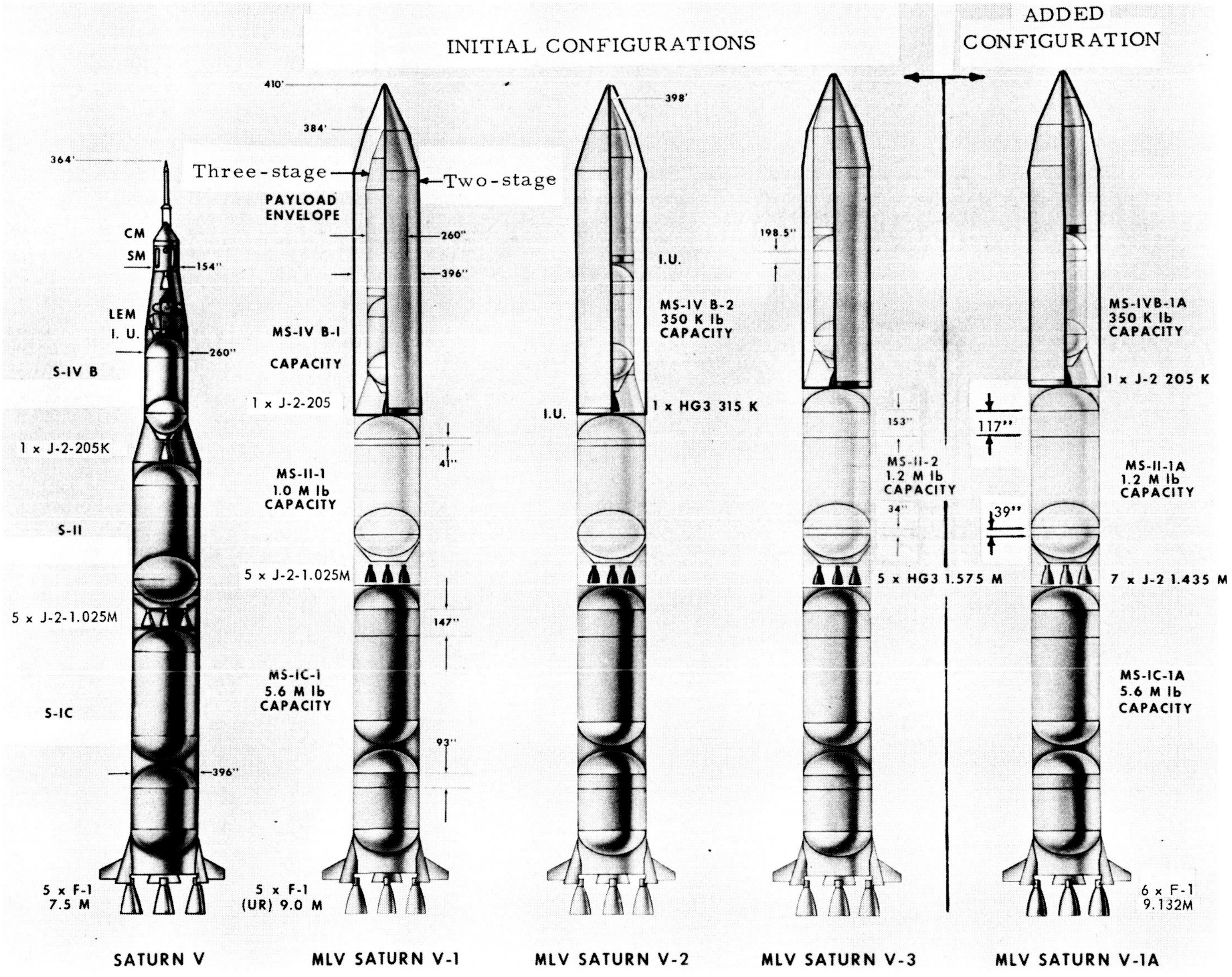


FIGURE 2. - SATURN V IMPROVEMENT STUDY, MLV-SATURN V ALL-LIQUID CONFIGURATIONS

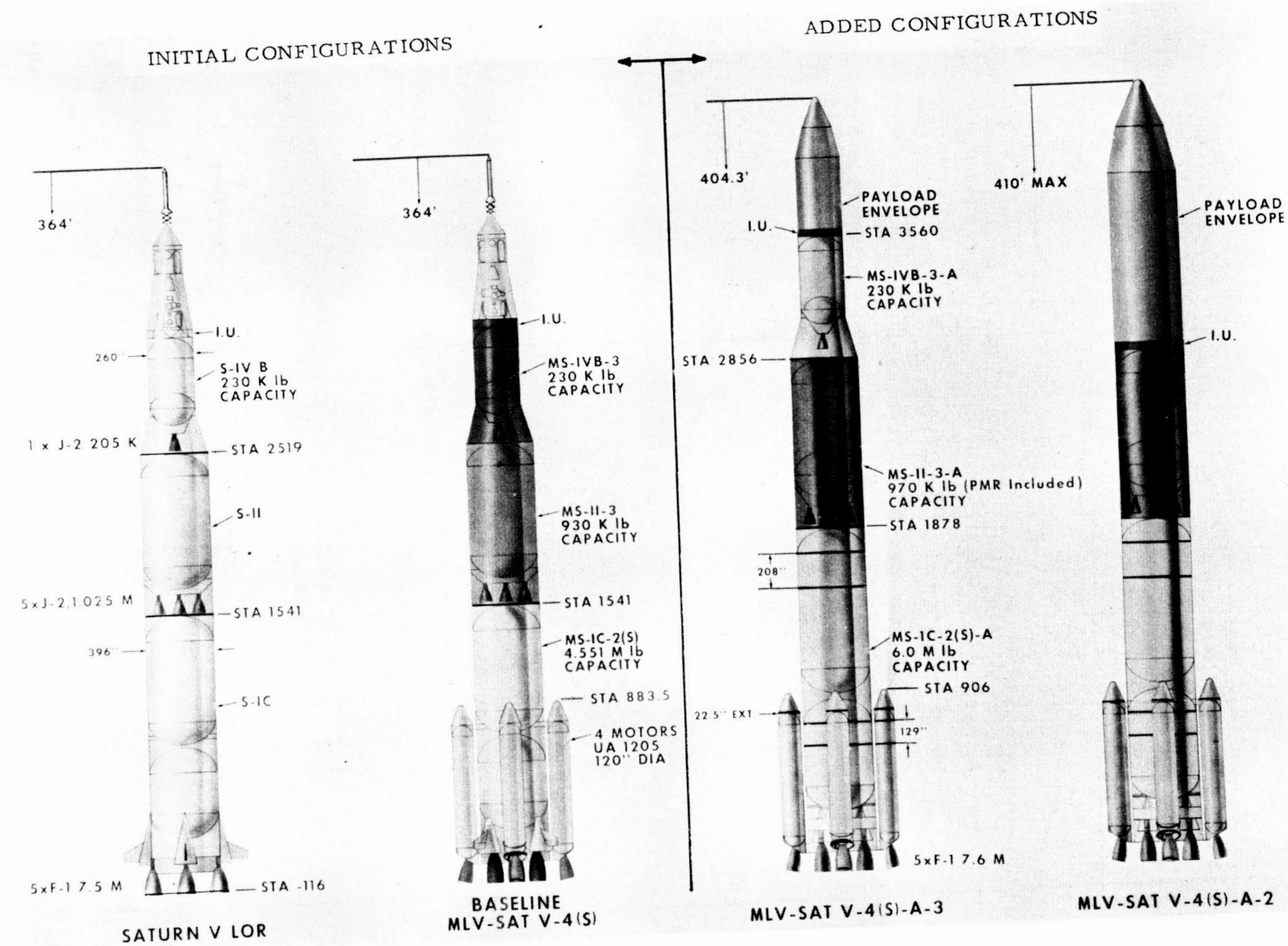


FIGURE 3. - SATURN V IMPROVEMENT STUDY, MLV-SATURN V LIQUID-SOLID INTEGRATION CONFIGURATIONS

SECTION II. TECHNICAL APPROACH

A. Configuration Selection

1. Pre-midterm Studies

a. All-liquid vehicles---In the initial phase of the study, the all-liquid vehicles were uprated by incorporating, in various combinations, two or more of the following schemes into the baseline vehicle:

(1) Increased thrust in F-1 engines on S-IC stage.

(2) Replacement of J-2 engines on the S-II and S-IVB stages with the high-pressure HG-3 engine.

(3) Appropriate increases in stage propellant capacities as required for the vehicle.

In all cases, the stages were either held at the same size or increased in capacity with each improvement method. If a later improvement required less propellant for a given stage, that stage would be off-loaded rather than resized for the smaller propellant loading. Product improvements, per se, were not considered as a part of this study; however, technology improvements were to be considered if a redesign was indicated. Where feasible, improvements made for earlier vehicles were incorporated into later vehicles. All applicable Saturn V design criteria were followed in the design of the MLV vehicles and,throughout the development of stage design, a major criterion was that maximum use be made of hardware and facilities available from the current Saturn V/Apollo program.

The stages were to be designed for the most critical load conditions to be experienced for any MLV vehicle in which they were used. The MS-IC-1 stage, for example, was designed so that it could be used without further modification in the MLV-Saturn V-1, V-2 and V-3 vehicles shown in Figure 2. (In addition, the two-stage configurations imposed critical loading conditions that structurally designed the first and second stages.) The payload envelope was chosen to give the maximum loading conditions possible for the vehicle and still remain within the facility limitations of 33 feet in diameter and 410 feet in height. Designing to these maximum loads resulted in off-optimum performance for some of the configurations.

The design of the MLV-Saturn V-2 vehicle, which was to be an intermediate step between the earliest and ultimate vehicles, was based on the following initial assumptions:

(1) A single HG-3 high-pressure engine could be obtained earlier than six of these engines.

(2) An S-IVB stage using only one engine could be manufactured more quickly than a multiple-engine stage.

As the study progressed, it was determined that the HG-3 engine was the pacing item and that a multiple-engine MS-II stage could be available sooner than the engines. From this consideration, it was concluded that the MLV-Saturn V-2 vehicle would not be necessary and study effort on this configuration was terminated after the midterm review.

b. Liquid-solid integration---The liquid-solid configuration, MLV-Saturn V-4(S), was chosen for study as a method of increasing the Saturn V LOR payload without requiring an engine development program.

This part of the study involved investigating the problems of integrating four 120-inch-diameter UA-1205 solid motors with a modified Saturn V launch vehicle. This study was not expected to produce an optimum liquid-solid vehicle but only to define and evaluate the problems and related changes associated with attaching the solids to the Saturn V launch vehicle and to establish the feasibility of such a concept. The vehicle studied in the first phase was the Saturn V LOR vehicle (strengthened to withstand the increased loads) with four 120-inch-diameter, 5-segment UA-1205 solid motors attached to the first stage and an Apollo-shaped payload (see Figure 3). The propellant loading and thrust levels were the same as the Saturn V LOR vehicle.

2. <u>Post-midterm Studies</u>

a. All-liquid vehicles---After midterm, the contractors were directed to study another vehicle that did not use the uprated engines but instead increased the number of engines in the first and second stages (the MLV-Saturn V-1A shown in Figure 2). This vehicle was chosen because it would be considered an "earlier" vehicle and would have the capability of being further improved by the incorporation of the uprated engines as an "ultimate" vehicle. The optimum propellant capacities for each of the stages were similar to the initial vehicles studied by the contractors, i.e., MLV-Saturn V-3.

The new ground rules were factored into the study at this time and the earlier configurations were updated to reflect these changes.

Since more than 60 percent of the study effort was complete prior to midterm, it was anticipated that less study effort would be put into the investigation of the MLV-Saturn V-1A vehicle. This portion of the study was to provide a configuration definition and to evaluate the implications of the concept along with an estimate of the resources, including costs and schedules.

b. Liquid-solid integration---After midterm, the liquid-solid vehicle configuration was changed to be more compatible with the all-liquid configurations. The configuration, MLV-Saturn V-4(S)A, is shown in Figure 3 . In order to reduce the high lift-off acceleration experienced by the V-4(S) vehicle and to increase the payload, the propellant capacity of the S-IC stage was increased. The second and third stage capacities were held constant. This study effort was to resolve the preliminary design of the attachment structure and support, to investigate the structural changes to the liquid stages, and to assess the changes in heating environments as compared to the initial configuration. It should be noted that because of the late introduction of this configuration the depth of the study was not as great as the vehicles prior to midterm. However, the results are of sufficient depth to be comparable.

The effects on launch facilities were not included in this investigation.

B. Ground Rules

Compatibility of the various MLV-Saturn V stage designs and performance cost analyses was possible through early establishment of the study ground rules. As the study progressed, minor variations to the original ground rules were introduced to improve overall study results.

The major ground rules and assumptions established at the initiation of the study program and after the midterm review are listed below.

1. <u>Pre-midterm Studies</u>

a. Development of the MLV configurations is to be conducted on a non-interference basis with the current Saturn V/Apollo program.

b. Operation of the launch vehicles using the first class of uprated stages (MLV-Saturn V-1) is to be considered for the early 1970's.

c. The second class of improvements is those modifications requiring long lead time development and/or major facilities changes. Such modifications would become operative in the later 1970's. For the purposes of this study, availability of the high-pressure propulsion system for the MS-IVB stage will follow MLV-Saturn V-1 availability.

d. Maximum utilization of existing facilities, system components, vehicle hardware, and items presently under development is to be a major consideration in design and development programs

e. The HG-3 engine thrust was selected at 315K vacuum thrust, based on the thrust limit of the Santa Susana S-II test stand.

f. The capacity of the stage must either remain constant or increase in size with each uprating, never increase and then decrease.

g. The maximum vehicle height will not exceed 410 feet (hook height of VAB) including payload.

h. The MS-IC stage is to be sized for a propellant loading capacity of 5.6×10^6 lb with a 3-percent ullage in the oxidizer tank and a 2-percent ullage in the fuel tank.

i. The baseline MLV-Saturn V vehicle T/W at lift-off is to be 1.25.

j. The F&FM contractor is to determine the performance of each MLV-Saturn V configuration with a fully tanked MS-IC stage to approach a lift-off T/W of 1.18.

k. The basic MS-II stage mixture ratio is fixed at 5.0.

l. Programmed mixture ratio (PMR) will not be used for the upper stages in the baseline configurations; however, it is to be used to determine the payload effect of PMR in the MS-II stage.

m. The development programs for each stage are to include delivery of structural dynamic test stages and two R&D flight-test stages.

n. A total of 12 operational man-rated launch vehicles is required on a bimonthly delivery rate.

o. MSFC manufacturing and test facilities will be available in a similar fashion as used in the standard Saturn V program.

p. Funds are available as required, with program start in July 1965.

q. Impact of launch facilities and operations is not to be included.

r. The cost estimates are to be based on 1965 dollars.

s. A three-month interval will precede and follow delivery of the two R&D flight-test articles.

t. The latest possible Saturn V LOR vehicle structural concepts in stage design are to be incorporated in the studies. Additional structural concept improvements, if available, may be used in contractor side-studies, provided a net gain is realized and the side-studies do not interfere with the mainstream effort.

u. All Saturn V LOR design criteria will apply to the design of the MLV-Saturn V vehicles.

2. Post-midterm Studies

After midterm, a better evaluation of the configurations being studied was possible. Therefore the ground rules were altered to comply with the newly aligned MSFC philosophy. The following were established or changed:

a. The reference vehicle is to be the Saturn V LOR vehicle that is capable of placing 95 000 pounds into a lunar transfer trajectory.

b. A programmed mixture ratio (PMR) shift is to be used in the MS-II stage for the vehicles using the J-2 engine.

c. Maximum payload density is 8.0 lb/ft^3 (previous range = 6-10 lb/ft^3).

d. The HG-3 thrust level is to be 375K vacuum for the in-house studies.

e. The earliest initiation of Program Definition Phase (PDP) is January 1966.

f. The resources analysis is to be based on earliest permissible hardware funding starting July 1966 (FY-67).

g. The cost analysis for implementing these improvements is to include the engineering expenditure, facility modification, and component development, where required.

SECTION III. FLUID AND FLIGHT MECHANICS (PERFORMANCE)

A. General

The objective of the Fluid and Flight Mechanics Study was to investigate the vehicle performance, aerodynamics and heating, stabilization and flight control, structural dynamics, general flight mechanics, and mission analysis.

B. Performance

All of the liquid vehicles have payload capabilities ranging from 12 to 50 percent above the current Saturn V and have no major problems in the area of fluid and flight mechanics.

The various stages, as defined in the study, were found to have acceptable propellant capacity compromises when optimized for both the three-stage LOR missions and the two-stage orbital missions. All of the stages, as defined at the initiation of the study, were found to have acceptable propellant capacities with the possible exception of the MS-II-1 stage. The MS-II-1, when optimized, requires a propellant loading near the current S-II capacity of 930 000 pounds instead of the 1 000 000-pound capacity. Since the 930 000-pound loading does not require a geometry change to the current S-II stage, use of this stage size is recommended rather than the MS-II-1.

The fixed stage capacities for all configurations resulted in a very small payload penalty as compared to the optimized vehicles shown in Figure 4 . It is noted that fully loading the stages to capacity or limiting the thrust-to-weight at lift-off to 1.18 results in a performance comparable to the fully optimized case.

The baseline strap-on solids configuration (MLV Saturn V-4(S)) has a payload capability approximately 25 percent higher than the current Saturn V. The high lift-off thrust-to-weight ratio (1.45) created higher structural loads and heating rates than the all-liquid configurations. There are no control problems associated with this configuration. The alternate solid strap-on configuration (MLV Saturn V-4(S)A) was investigated as a more comparable configuration to the all-liquid systems.

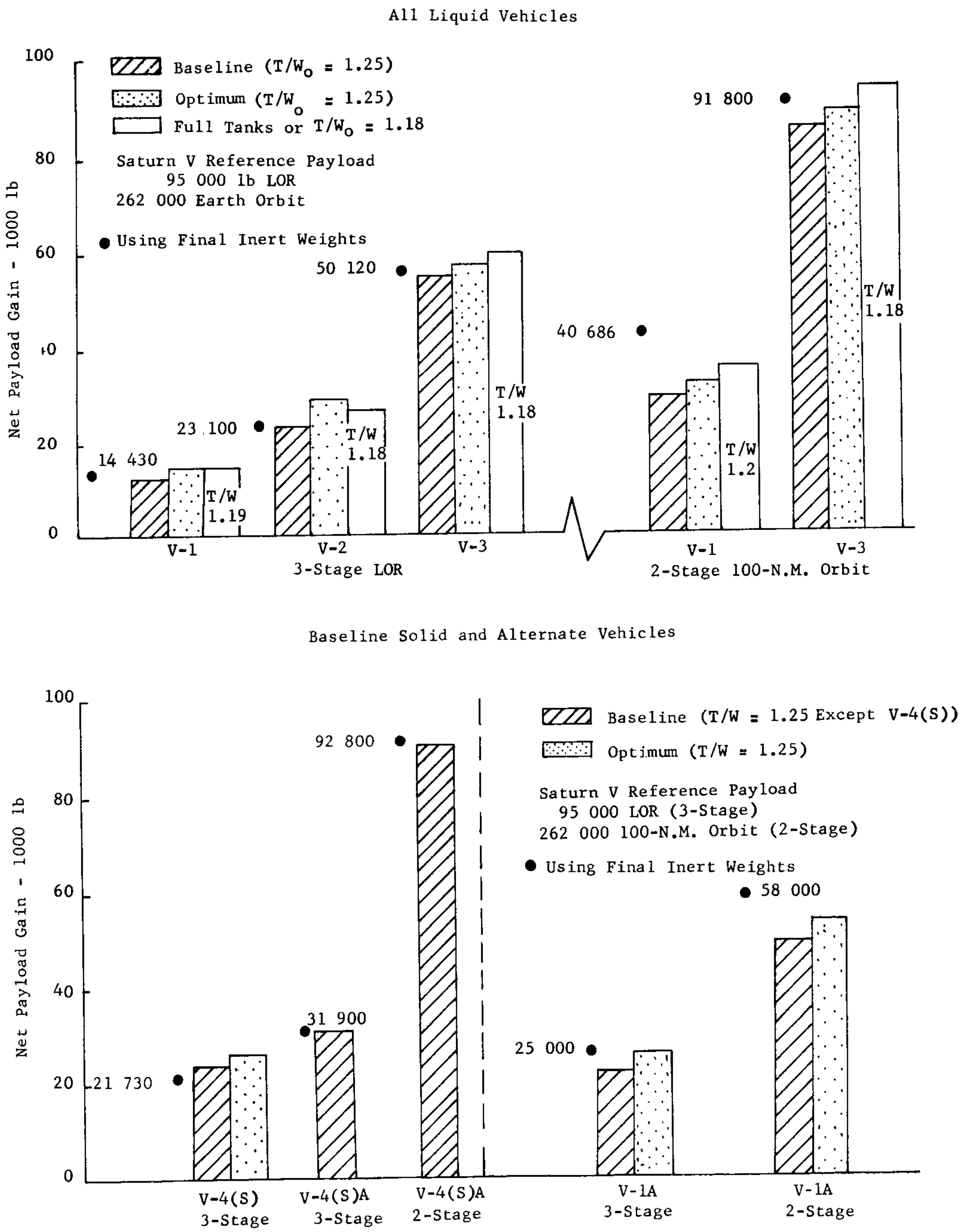


FIGURE 4. - PAYLOAD COMPARISON SUMMARY

By increasing the propellant capacity of the first stage, the T/W at lift-off was reduced, thus alleviating the in-flight loads and the aerodynamic heating This vehicle had an increased payload capability of approximately 32 percent above the current Saturn V capability.

The alternate liquid configuration, MLV-Saturn V-1A, which has six standard F-1 engines in the first stage and seven J-2 engines in the second stage, has an increased payload capability of approximately 25 percent above the current Saturn V.

C. Flight Control

All configurations were controllable with the current fins and control system with the exception of the two-stage MLV-Saturn V-4(S)A configuration which will require additional control capability over the F-1 TVC system. Several methods were investigated to solve the problem, i.e., additional fin area to provide stability, increased gimbal angle, and different control laws. TVC by the 120-inch solids was not considered, as flight control could be maintained by other methods.

The lift-off dynamics study determined that the most critical MLV vehicles would clear the launch tower. The criteria used in these launch cone studies include three-sigma tolerances on the launch vehicle parameters and a 99-percent wind force blowing toward the tower.

There were no separation problems encountered with any of the vehicles.

D. Structural Dynamics

There were no major structural dynamics problems for any of the MLV series vehicles. Model data reflected slightly reduced first-bending frequencies; however, stability and control analyses have shown no significant coupling effects on vehicle response from this result when the control frequency is maintained at 0.2 cps.

SECTION IV. ENGINE STUDIES

The results of the engine studies performed by Rocketdyne on the F-1 and J-2 and by Pratt and Whitney on the HG-3 are discussed in the following paragraphs. Only the F-1 and HG-3 engines were used by the contractors in their stage and vehicle studies.

A. F-1 Engine Uprating Study

The F-1 engine uprating study was a six-month study effort by Rocketdyne. The primary purpose was to define reasonable engine uprating limits and furnish uprated engine performance data to the Saturn V Improvement Study.

Basic ground rules established to limit the field of investigation and to conform with the Saturn V Improvement Study design philosophy were (1) to make maximum use of and have minimum modification to existing hardware, and (2) to use the 1522K qualification engine configuration as the base from which the uprating process should begin.

Uprating beyond the 1522K qualification engine was limited by the 35-inch turbine horsepower. Therefore, uprated configurations used a 30-inch turbine design. Results of the analytical effort indicated that 1650 and 1800K were the intermediate and maximum thrust levels that the engine could be uprated to without major engine and component redesign.

The primary changes required for uprating to the 1650K level were the utilization of a 30-inch turbine, improved pump inducers, and strengthened gas generator (GG) operating at a lower LOX-to-fuel ratio. Further uprating was limited by the turbopump critical speed. The 1800K configuration required such additional major changes as increasing the diameter of the pump impellers, increasing the gas generator volume for temperature control, and reducing turbine exhaust back-pressure. Further uprating was again limited by turbopump critical speed and torque. Technical and performance characteristics are presented in Rocketdyne Report No. R-5910.

Development schedules based on the configurations mentioned above are as follows:

1. For the 1650K engine, flight rating tests would be completed 25 months after go-ahead with engine qualification tests completed 40 months after go-ahead.

2. Flight rating tests for the 1800K engine would be completed 33 months after go-ahead and first engine delivery 36 months after go-ahead. Engine qualification tests would be completed 51 months after go-ahead.

B. J-2 Engine Uprating Study

Uprated J-2 engine systems were defined in detail and the necessary hardware modifications were determined. Emphasis was placed on minimum component changes during uprating of the 200 000-pound-thrust J-2 qualification engine. Two thrust levels (225 000 and 250 000 pounds) were selected and engine designs for these levels were studied in detail.

The results of the study indicated that the 200 000-pound-thrust J-2 qualification engine can be uprated to the 225 000-pound-thrust level by component modifications to the turbopumps, gas generator control valve, thrust chamber bypass system, and the injector. Further modifications are required to permit uprating to 250 000 pounds of thrust. These changes would include the oxidizer turbopump assembly, the concentric gas generator control valve, the fuel turbopump, and new high-pressure ducts.

C. HG-3 Engine Study

The HG-3 engine system study is a program of analysis and design to investigate and evaluate advanced propulsion system components and system operating concepts for high-performance propulsion systems of the 300 to 400K thrust class. The purpose of this study is to systematically define logical advanced propulsion systems and to provide data on the characteristics, performance, and problem areas of the systems over the range of design constraints of interest (envelope, thrust, mixture ratio, and specific impulse). In addition, it is anticipated that this study will detect and define deficiencies (should any exist) in available technology data which require immediate remedial action before the definition and evaluation of advanced systems and components can proceed.

For this study, certain configuration constraints are assumed: propellants are oxygen/hydrogen; designs incorporate provisions for variable mixture ratio and thrust; and designs are based on pump-fed, single pump set/chamber units. Some of the major component and system concepts intended for study are these: centrifugal and axial fuel pumps; bell and aerodynamic nozzles; gimbal and secondary injection thrust vector control systems; and single and dual preburner power cycles and single, tandem, tapoff and dual gas generator (GG) power cycles, including afterburning.

For the thrust range studied, detailed analyses indicate that the centrifugal fuel pump is preferred over the axial fuel pump because the much broader head/flow operating region of the centrifugal pump provides greater flexibility for variable thrust and mixture ratio operation. Also, the broad operating region reduces start problems since it is unnecessary to as closely control the pump operating point for prevention of stall or instability. Other rating factors, such as efficiency, design complexity, weight, suction performance, temperature conditioning requirements, etc., for the two pumps are equal.

A comparative investigation to determine performance and characteristics of system configurations employing a bell nozzle, centrifugal fuel pump, and various power cycles revealed that, at consistent levels of specific impulse, thrust, and envelope, the single preburner power cycle is the logical choice for use with a bell nozzle. This selection is based on the following: lighter system weight at consistent performance levels and greater performance potential than with GG power cycle configurations; and, similar performance and characteristics to the dual preburner cycle configuration without such technological unknowns as main injector cooling and the generation and use of oxidizer-rich turbine working fluid.

Parametric data, generated for the selected bell nozzle configuration and published in Pratt and Whitney Report PWA FR-1182A, express the relationship of thrust, specific impulse, and weight in various engine envelopes. In addition, data on the trade-off between pump NPSH and engine weight and specific impulse over the mixture ratio range were established. The ranges over which the data were generated are: thrust - 315 000 to 400 000 pounds; specific impulse -

419 to 467 lb-sec/lb; engine diameter - 80 to 120 inches; engine length - 100 to 252 inches; fuel NPSH - 25 to 365 feet; oxidizer NPSH - 13 to 118 feet.

A review of available technology data and analytical techniques applicable to the aerodynamic nozzle was made prior to initiating system configuration studies. It was concluded that analytical techniques necessary to determine system characteristics (chamber pressure, area ratio, nozzle length, combustion chamber geometry, weight, etc.) associated with a set of design constraints (envelope, thrust, mixture ratio, specific impulse, etc.) are, at present, limited to an empirical method of scaling the cold flow data to values consistent with the gas properties associated with full-scale engine operation. Therefore, detailed definition of system characteristics over the wide range of design constraints of interest in this study does not appear possible; however, estimates of some system characteristics can be made.

Preliminary system evaluation based upon these approximate techniques indicates that system configurations utilizing an aerodynamic nozzle offer performance potential consistent with the level of interest in the HG-3 design study. As such they definitely warrant continued consideration, as data become available, and continued emphasis to correct the deficiency in technology data.

An estimate of the system characteristics for an advanced, high-performance engine of 315 000 pounds thrust was established for use in the Saturn Improvement Studies. This estimate was based on an assumed system configuration composed of a bell nozzle, centrifugal fuel pump and preburner cycle. The data generated to define this "best estimate" system were published in Pratt and Whitney Report PWA FR-1044A. This engine had a design constraint to be within the present J-2 envelope.

SECTION V. VEHICLE/STAGE DESCRIPTIONS

A. All-Liquid Configurations

1. MS-IC Stages

a. MS-IC-1 stage---The study resulted in a detailed preliminary design and analysis of the MS-IC-1 stage.

The structural loads imposed by the V-1 two-stage configurations have increased approximately 50 percent over the S-IC loads, as shown in Figure 5. The tank walls and bulkheads are strengthened to withstand the increased loads. The forward skirt is the same configuration as the S-IC. The intermediate frame spacing is the same as the S-IC. The skins, frames, and skin stiffeners are strengthened to accept the MLV loads. The intertank is an optimum-weight, corrugated-skin configuration which is similar to the S-IC; however, the corrugated skin is thicker, has a greater corrugation spacing, and is supported by four frames (S-IC has five).

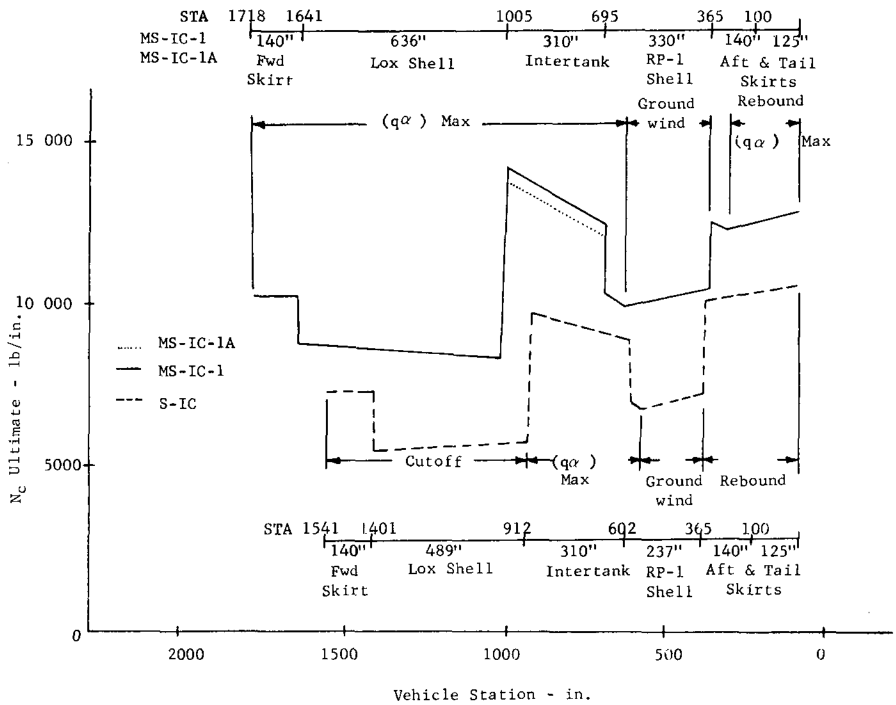


FIGURE 5. - MS-IC-1 AND MS-IC-1A COMPOSITE AXIAL LOADS

The thrust structure has the same structural arrangement as the S-IC. All structural components will increase in cross-sectional area over the S-IC except the holddown posts, holddown fittings, skin stiffeners, and engine actuator supports.

The MS-IC-1 propellant pressurization system will have design pressures comparable to the S-IC system; but the pressurant flow rates will increase approximately 15 percent for increased propellant expulsion rates to the UF-1 engines. Figure 6 shows the major MS-IC stage modifications. The dry weight of the MS-IC-1 has increased approximately 36 000 pounds.

b. MS-IC-1A stage---A configuration definition, control system requirements, and two iterations of loads and weights were generated for the MS-IC-1A stage. The feasibility of redesigning the thrust structure, while maintaining the four existing holddown post locations, for the relocation and addition of propellant ducts to accommodate the sixth engine was established.

The outboard engines are located radially outward 28 inches from the location of the MS-IC-1 and S-IC outboard engines (12 inches outside of thrust structure skin line). The two inboard engines are mounted 154 inches apart on a thrust structure cross beam similar to that used for the MS-IC-1 and S-IC. This arrangement for the six engines allows greater clearance between the MS-IC-1A and the LUT aspirator hole during the most critical position of the engines in the gimbal pattern than is available for the S-IC. The two inboard engines are oriented such that the LUT flame deflector is between the engines.

The axial loads imposed by the MS-IC-1A two-stage configuration are essentially the same as MS-IC-1 loads.

The location of the two center engines and the outboard engines on the MS-IC-1A restricts the inboard gimbal angle to 2.5 degrees with 7.8 degrees outboard. Preliminary results indicate no control problem with this gimbal pattern.

Review of propulsion/mechanical systems indicates no significant change between MS-IC-1, MS-IC-1A, and S-IC requirements. The primary change of the MS-IC-1A from the MS-IC-1 and S-IC will be extra supply lines for the sixth engine. The LOX and RP-1 delivery systems for the MS-IC-1A and MS-IC-1 lengthen because of the 20-foot increase in stage height over the S-IC.

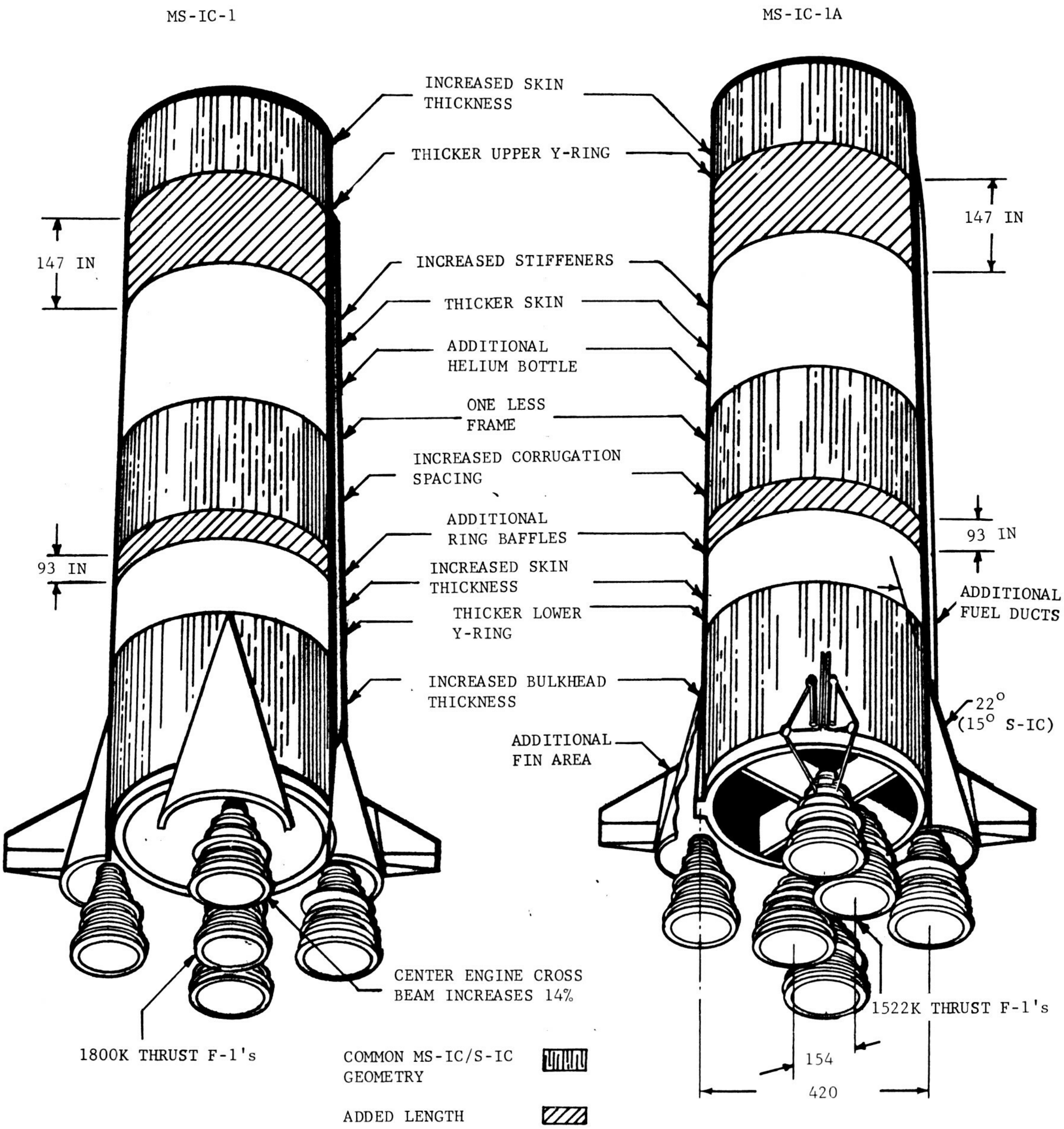


FIGURE 6.-MS-IC STAGE MAJOR MODIFICATIONS

The MS-IC-1A dry weight has increased approximately 56 000 pounds over the S-IC and 19 600 pounds over the MS-IC-1.

c. MS-IC-1 and MS-IC-1A manufacturing and facilities effects---The results of the resources analysis show that facility, manufacturing, and GSE/MSE support requirements for the MS-IC-1 and MS-IC-1A can be met with modifications that would be expected for a block change. The major facility modifications at Michoud are to the VAB and the stage test facility; at MTO and MSFC major changes are required to the static test stands.

The primary manufacturing requirements include modification of fixtures for age and bulge forming the heavier skins, the modification of handling tools for the larger, heavier containers, and the extensive rework of assembly fixtures to accommodate the increased thicknesses/cross sections of structural components and the larger fasteners. The GSE/MSE requirements are primarily rework of existing test, checkout, handling, and transportation equipment.

The dynamic test, the static test, and the structural test connect stages are recommended to be assembled at MSFC to prevent major facility duplication at Michoud.

Two significant restraints to S-IC growth were noted in the study: (1) the enclosed barge limits growth to an additional 40 feet in length, (2) vertical assembly of the booster within current assembly crane height restrains growth to an additional 46 feet.

2. <u>MS-II Stages</u>

a. MS-II-1 stage---The design of the MS-II-1 stage to accommodate 1 000 000 pounds of propellant at a tank mixture ratio (LO_2/LH_2) of 5.0:1 is achieved by filling the LO_2 tank to its maximum capacity and extending the LH_2 tank by 41 inches. In this configuration the compressive load intensities have increased, as shown in Figure 7, as a result of the first-stage (MS-IC-1) thrust uprating to 9 000 000 pounds, and the increased area of the vehicle payload. The major structural modifications to the stage skirts and interstage are increased skin and stringer gauges and revised frames. A summary of the structural and system changes to the S-II stage to provide the MS-II-1 configuration is provided in Figure 8.

The increase in dry weight of the MS-II-1 stage over that of the S-II is approximately 6 percent.

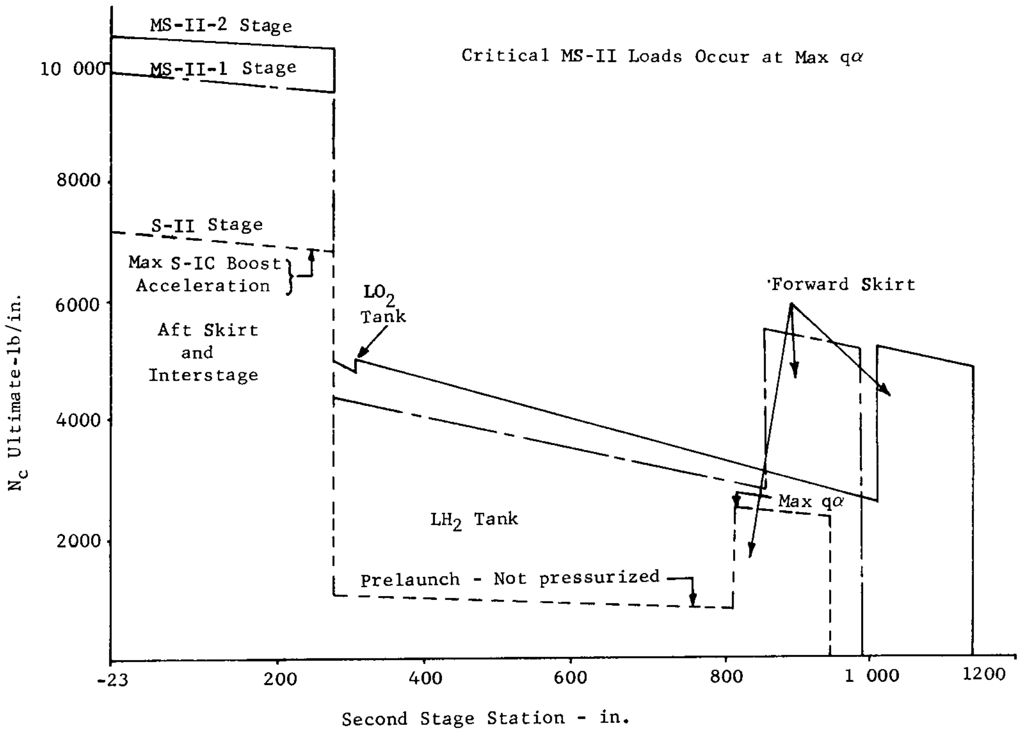


FIGURE 7. - MS-II-1 AND MS-II-2 ULTIMATE COMPRESSIVE LOADS

Investigations for the MS-II-1 stage show that the S-II control capability is adequate and that the present Saturn V S-IC/S-II separation sequence can be maintained. The current S-II tank wall insulation is satisfactory for the MS-II-1 and the present S-II base heat shield is also retained for the uprated design.

Studies have shown that reduction in the MS-II-1 stage propellant load to the present S-II loading of 970 000 pounds (W/PMR) and maintenance of the S-II stage tank configuration will have negligible effect on the MLV performance. This would result in the same configurational envelope as the present S-II and would eliminate modifications and additions to the stage except for strengthening due to increased loads. Therefore, this is the recommended stage for the MLV-Saturn V-1 configuration.

b. MS-II-1 manufacturing and facilities effects---The S-II stage manufacturing equipment will require revised subassembly and assembly jigs for production of the MS-II-1 skirt.

No significant new GSE requirements exist for the MS-II-1 design but if the length of the stage is increased this will necessitate extension of the transporter. Facilities for production and testing of the S-II stage are essentially adequate for construction and testing of the MS-II-1, except for the modifications to the structural static test facility at Seal Beach, California.

c. MS-II-2 stage---Installation of a new propulsion system on the MS-II-2 design necessitates redesign of the S-II stage thrust structure. The new thrust structure is a conical configuration similar to the current stage design. Attachment points for the engine actuators are relocated for compatibility with the new engine actuation system. Structural and systems revisions for the MS-II-2 stage are summarized in Figure 8, showing the included effects of increasing the propellant to 1 200 000 pounds.

As the HG-3 engine thrust does not vary with change in mixture ratio, the MS-II-2 propulsion system will operate at the nominal 5.0:1 mixture ratio except for deviations to minimize propellant residuals. The configuration of the HG-3 engine also results in changes to stage/engine interfaces. Revisions will also be necessary in the propellant management, electrical, and propellant dispersion systems. The increase in the dry weight of the MS-II-2 stage over that of the S-II is approximately 19 percent.

Preliminary analyses indicate that the S-II stage propellant tank insulation material and thickness will be adequate for the MS-II-2 design. The base heat shield insulation also will be acceptable.

d. MS-II-2 manufacturing and facilities effects---Evaluation of the manufacturing requirements associated with implementation of the MS-II-2 design shows that tools and jigs similar to those for the MS-II-1 design will be required. In addition, the increased diameter of feed lines for the HG-3 engine will necessitate modification of the weld fixture for installation of feed-line fittings on the LH_2 tank wall. The extension of the LO_2 tank will require modification of the bulkhead explosive form dies and check jigs and of the tank hydrostatic test fixture. The redesign of the thrust structure to accommodate the new propulsion system will necessitate modification of all subassembly and assembly jigs and new detail fabrication tools.

Ground support equipment (GSE) for the MS-II-2 stage will require revision for handling and transportation, and new equipment for the propulsion systems.

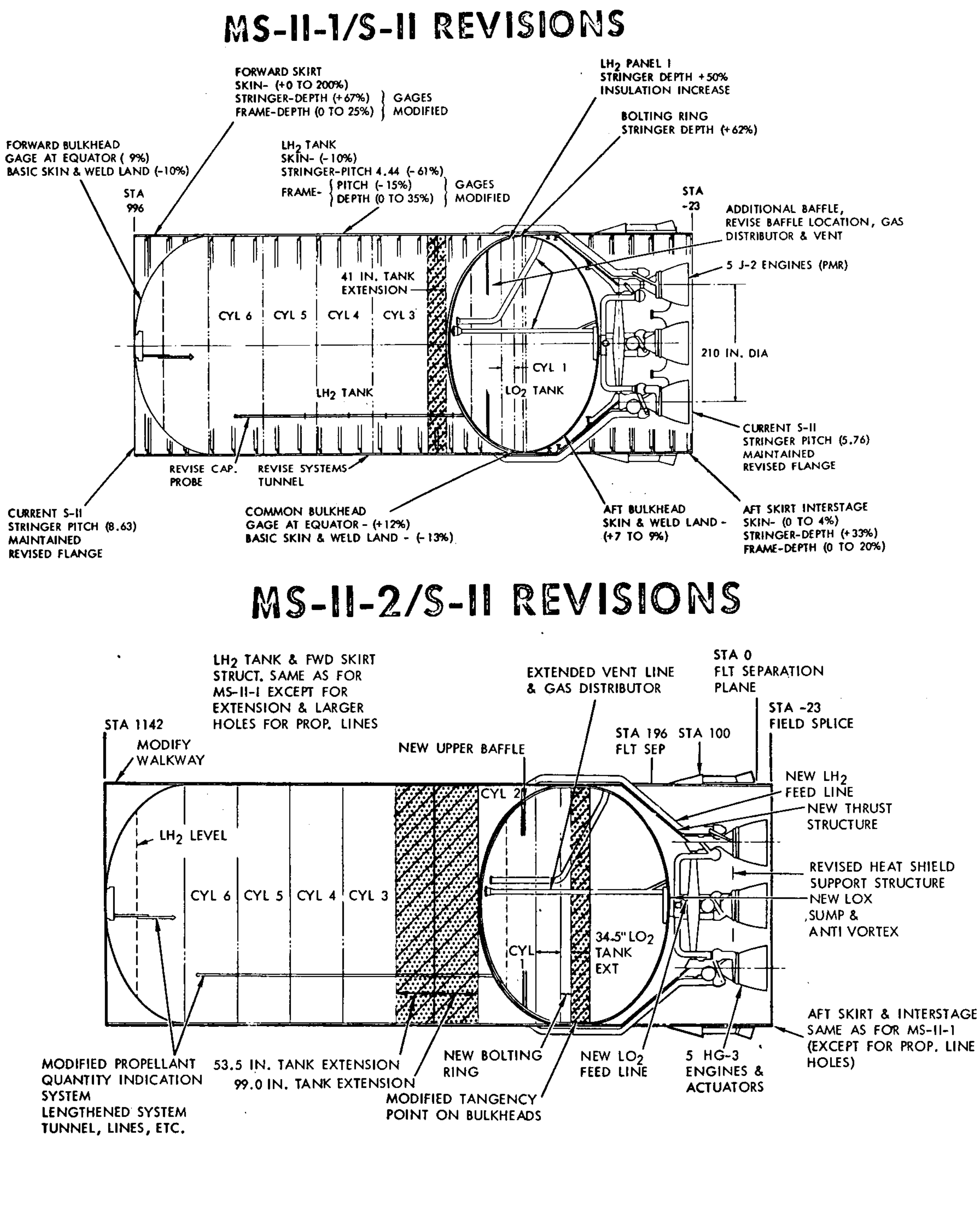


FIGURE 8.- MS-II STAGE MAJOR MODIFICATIONS

Production of the MS-II-2 stage will require cranes in the Seal Beach facility and additional facility space to accommodate duplicate toolings. A modification of transportation dollies and the hydrostatic cleaning boom system will be necessary. Provision for installation of the stage handling cone will be required at one of the assembly stations. Testing of the uprated design will require minor modifications to the structural static test facility at Seal Beach and modification of the Battleship facility at Santa Susana to accommodate the new propulsion system. Maximum S-II growth, without requiring major facility modifications, is 1 200 000 pounds of propellant (187-inch length increase).

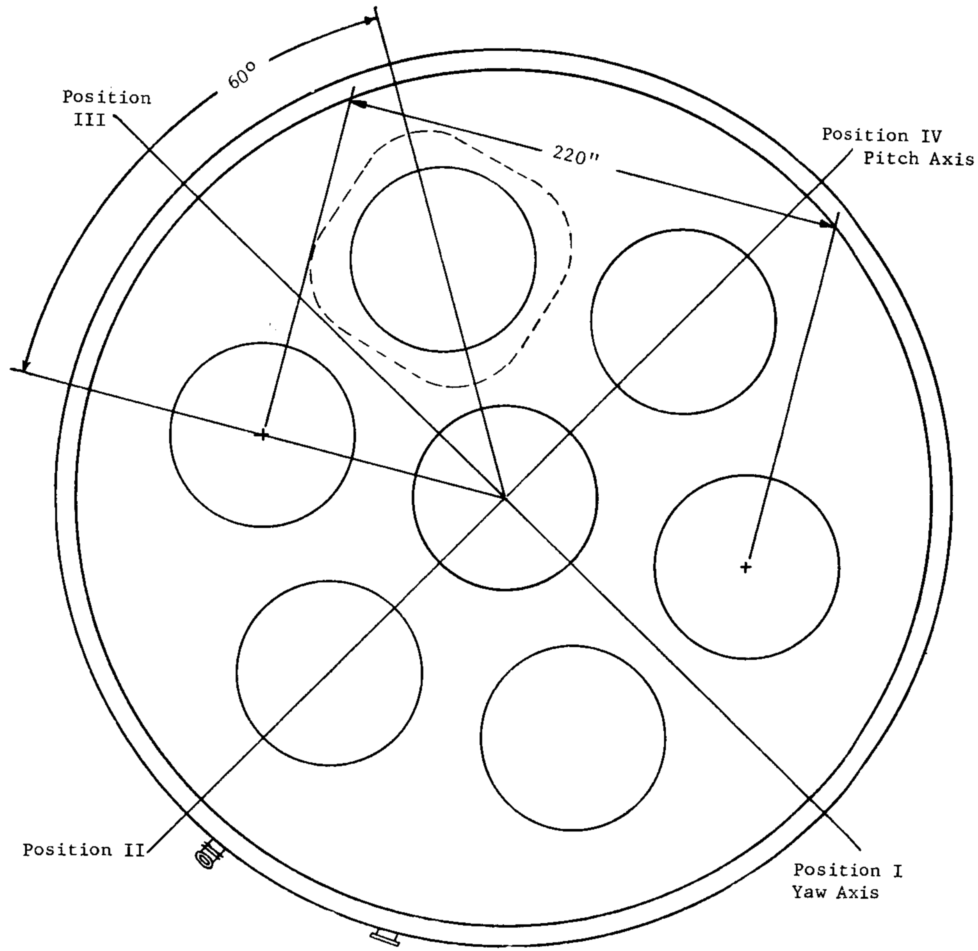
e. MS-II-1A stage---The major difference in the design of the seven-engine MS-II-1A stage is in the thrust structure and propulsion system. In addition to taking full advantage of the available stage thrust, the tanks are extended to accommodate a propellant load of 1 200 000 pounds. The aft end view of the MS-II-1A stage and the major stage design changes required to install seven J-2 engines and to accommodate an increased propellant load are defined in Figure 9 .

3. MS-IVB Stages

a. MS-IVB-1 stage---The MS-IVB-1 has the same geometry and dimensions as the S-IVB. The S-IVB/Saturn V stage design was found to be most adaptable to the V-1 vehicle configuration. The modification to this stage is predominately structural and is due to increased payload weights and envelope.

Modifications of the S-IVB to strengthen the forward and aft skirts and interstage are required. The propulsion repressurization system is changed by replacing the ambient helium bottles with cold helium bottles and a helium heater. The 200 000-pound-thrust J-2 engine was used; however, a liquid oxygen (LOX) pump inducer with a lower NPSH (18 feet versus 25 feet) was assumed which results in a LOX tank pressure of 40.5 psia. Figure 10 summarizes the major differences between the S-IVB and the MS-IVB-1. The weight increase of this stage is 1319 pounds over the present S-IVB.

b. MS-IVB-1 manufacturing and facilities effects---The present manufacturing facilities are adequate without modifications. Only minor revisions will be required to tooling and facilities due to the high degree of similarity to the present S-IVB. The primary tools for the S-IVB skirts and interstage will require minor rework and new detail tooling (templates,



- New 117-in. Panels
- New 39-in. LO_2 Tank Ring
- Seven J-2 Engines
- Added Feed Lines
- Revised Thrust Structure 220-in. PCD
- Revised Heat Shield

FIGURE 9.- END VIEW - SEVEN ENGINE MS-II-1-A STAGE

STRUCTURES

ASSEMBLIES STRENGTHENED

- FORWARD SKIRT
- AFT SKIRT
- AFT INTERSTAGE
- PROPELLANT TANKS

PROPULSION

ADDED

- THREE 3½ CUBIC FT COLD He BOTTLE (11 TOTAL)
- ONE HELIUM HEATER

DELETED

- NINE AMBIENT He BOTTLES AND ASSOCIATED COMPONENTS (1 LEFT)

MODIFIED

- J-2 LOX PUMP INDUCER TO REDUCE NPSH FROM 25 FT TO 18 FT

MS-IVB-1 PROFILE (SAME AS S-IV B)

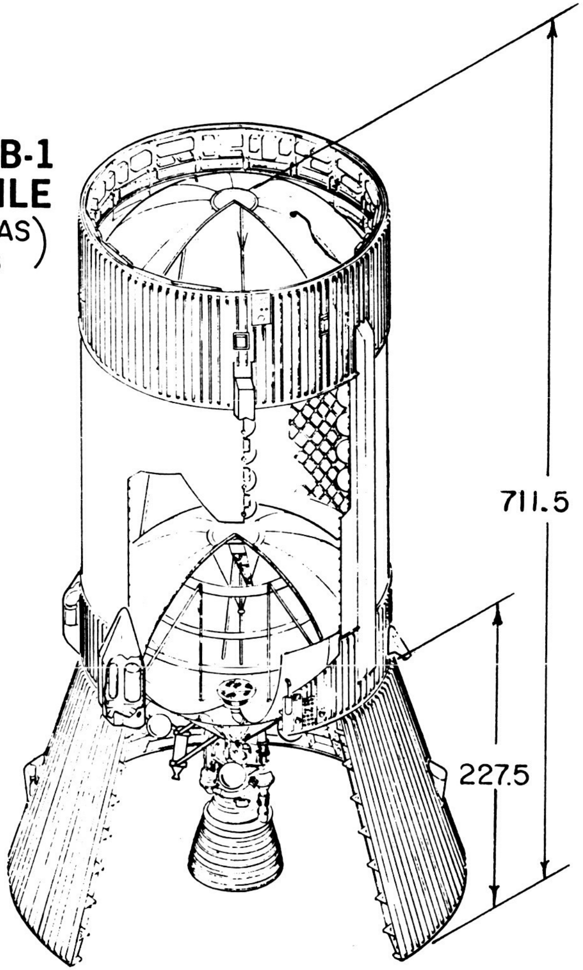


FIGURE 10.- MAJOR DIFFERENCES BETWEEN S-IVB AND MS-IVB-1

form blocks, etc.) will be required. The electrical, mechanical, propulsion, GSE, and test facilities used at Huntington Beach and Sacramento for the S-IVB were determined to be satisfactory with only minor modifications for use on the MS-IVB-1. A minimum component and vehicle test program is required.

c. MS-IVB-2---The MS-IVB-2 has the same diameter as the S-IVB but is longer and uses the HG-3 engine. The payload for the V-3 configuration has increased about 50 percent and the maximum in equivalent axial load in the interstage area is 95 percent in compression and 150 percent in tension over the present S-IVB, as shown in Figure 11. This required strengthening the forward and aft skirts, tank sidewalls and interstage. The common bulkhead is flatter and a 16-inch cylindrical section is added to the LOX tank. A new thrust structure was required due to the increased thrust of the engine. The interfaces with the Instrument Unit are unchanged. The propulsion system was modified by deleting ambient helium bottles, adding cold helium bottles and two helium hydrogen heaters, and using large propellant lines. The HG-3 concept requires a very short chilldown; therefore, the LOX and LH_2 chilldown pumps are deleted. With the reduced NPSH requirement of the HG-3 and the incorporation of larger propellant feed lines,both the LOX and LH_2 tank pressures are

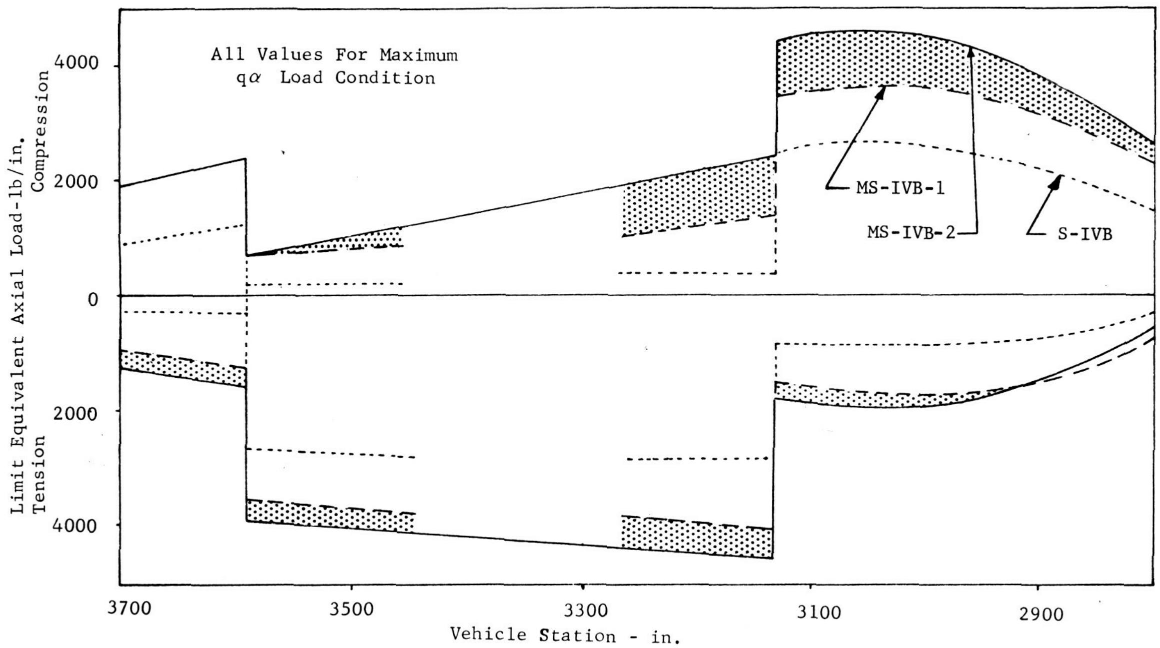


FIGURE 11. - MS-IVB-1 AND MS-IVB-2 MAXIMUM EQUIVALENT AXIAL LOADS

reduced 4 psia. The major structures and propulsion revisions are summarized in Figure 12. These modifications result in a dry weight increase of 9939 pounds.

d. MS-IVB-2 manufacturing and facilities effects---During the transition of production from S-IVB or MS-IVB-1 to MS-IVB-2, 6 of the 52 major tools have insufficient capacity on a 5-day, 2-shift, 8-hour day and must be scheduled for a 6-day, 2-shift, 8-hour day for a period of 20 weeks of the year. Detailed fabrication tooling will be 90 percent new. Of the 52 major tools, 22 can be used without change, 16 will have to be modified, and 14 will have to be new. Most of the new tools are required because of the change to the tankage. There is a total of 181 electrical, mechanical, and propulsion GSE models required for the MS-IVB-2 stage. Of these models, 72 remain unchanged, 103 require modification, and 6 are new.

e. MS-IVB-1A---The MS-IVB-1A stage configuration is the result of a limited study effort. Its objective was to define an uprated stage with an early availability date, minimum impact on facilities and cost, and having long-term growth potential. This stage differs from the MS-IVB-2 in that it has heavier tank walls, modified propellant feed system, higher tank pressures, a 205K J-2 engine and the J-2 thrust structure. The forward skirt, aft skirt, and interstage are the same as the MS-IVB-2. The revisions required to this stage, as compared to the S-IVB, are also summarized in Figure 12.

The tooling and manufacturing are similar to the MS-IVB-2; therefore, the same tools and facilities, with minor modifications, may be used.

B. Liquid-Solid System Integration Vehicles

1. <u>MLV-Saturn V-4(S)</u>. - The S-IC thrust structure can handle the solid motor aft attachment loads as presently designed. An increase in S-IC intertank frame capability is required to react the solid motor forward attachment loads. Increased aerodynamic heating loads are encountered and additional protective insulation is required to the MS-II-3, MS-IVB-3, and Instrument Unit.

STRUCTURES
- ASSEMBLIES STRENGTHENED
  - FORWARD SKIRT
  - AFT INTERSTAGE
  - TANK SIDEWALLS
  - THRUST STRUCTURE
  - AFT SKIRT
  - FWD & AFT DOMES
- TANKAGE LENGTHENED
- COMMON BULKHEAD REDESIGNED
- NEW ACTUATORS FOR HG-3 ENGINE

PROPULSION
- HIGHER THRUST & 50% MORE PROPELLANT
- ADDED 4 COLD H_e BOTTLES - SINGLE AMBIENT H_e BOTTLE, USES TWO HELIUM HEATERS AND LH_2 PUMP
- LOWER TANK DESIGN PRESSURES
- SHORT CHILLDOWN FEATURES
  - MINIMUM SYSTEM (RETURN LINE ONLY FROM LH_2 PUMP HOUSING)
  - LARGE LH_2 CHILL PUMP DELETED
  - LO_2 CHILL PUMP DELETED
- INCREASED 3400 LBF THRUST ULLAGE MOTORS FROM TWO TO THREE
- LARGER DIAMETER PROPELLANT LINES

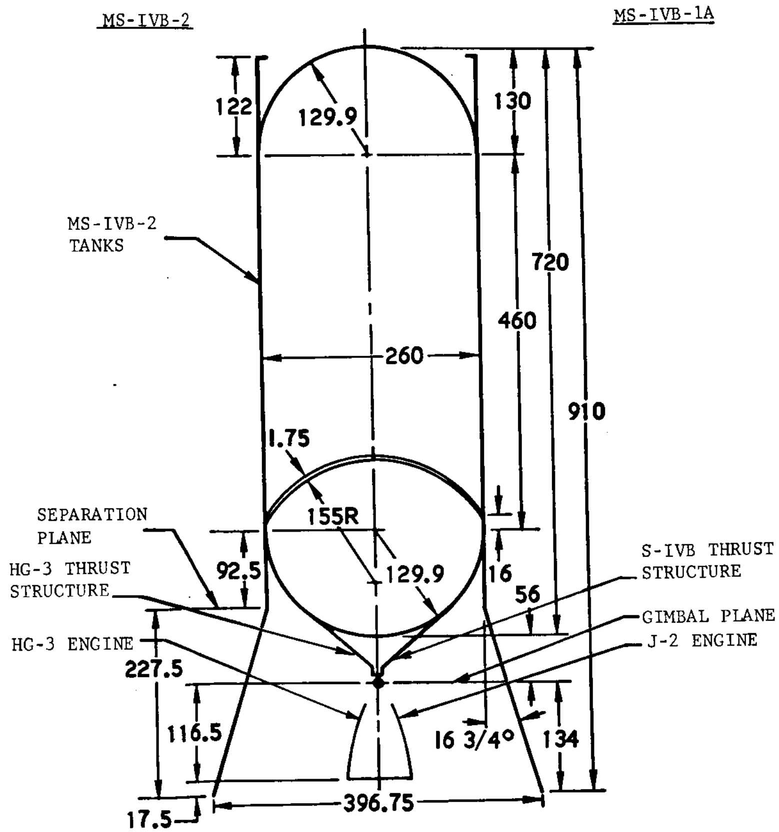


FIGURE 12.-MAJOR DIFFERENCES BETWEEN S-IVB AND MS-IVB-2

The present control capability of the MS-IC stage is sufficient without requiring thrust vector control (TVC) on the solid motors. Figure 13 summarizes the major structural changes. Extensive requalification of vibration-sensitive elements is required for the increased acoustic environment. Impacts on the design and use of major ground equipment elements at Launch Complex 39 have been created by the boost-assisted vehicle. The F-1 engine nozzles and solid motor nozzles can withstand the environments without change; however, heat protection is required for the aft solid motor attachment skirt.

The liquid-solid vehicles were evaluated for ground, flight, and crew safety. The results indicated that the solid motors must be installed at the launch pad and an evaluation must be made of the overpressure limits of the Saturn V vehicle from explosion to permit simultaneous occupation of both Saturn V pads. The flight termination systems of the present vehicle and solid-motor systems meet range safety requirements. The crew safety evaluation determined that no change in the required crew escape time interval is required for an intentional destruct action.

2. MLV-Saturn V-4(S)A. - Increased compressive loading of 50 to 300 percent, as shown in Figure 14, at max ($q\alpha$) flight conditions and the increased propellant loading capability to 6.0 million pounds require extensive strengthening of all-liquid stages and the Instrument Unit shell structures. Additional structural changes are required to the S-IC stage as a result of increased rebound loads and reaction of the forward solid motor attachment loads. The solid-motor nose-cone structure must be revised to move the attachment points forward in line with the MS-IC-2(S)A intertank frames. An increase in fin area is required to provide stability within the control capability of the F-1 engines. There are no requirements for TVC on the solid motors, if the fin size is increased or the flight profile altered to minimize vectorable thrust requirements for the two-stage configuration. The aerodynamic heating problem encountered in the MLV-Saturn V-4(S) trajectory is relieved in this configuration. The MS-IC-2(S)A base heating region requires an advancement in reflectory insulation properties for the base heat shield. Figure 15 summarizes the major structural changes. Extensive requalification of vibration-sensitive elements is required for the increased acoustic environment. Impacts on the design and use of major ground equipment elements at Launch Complex 39 have been created by the boost-assisted vehicle. The F-1 engine nozzles and solid-motor nozzles can withstand the environments without change; however, heat protection is required for the aft solid-motor attachment skirt.

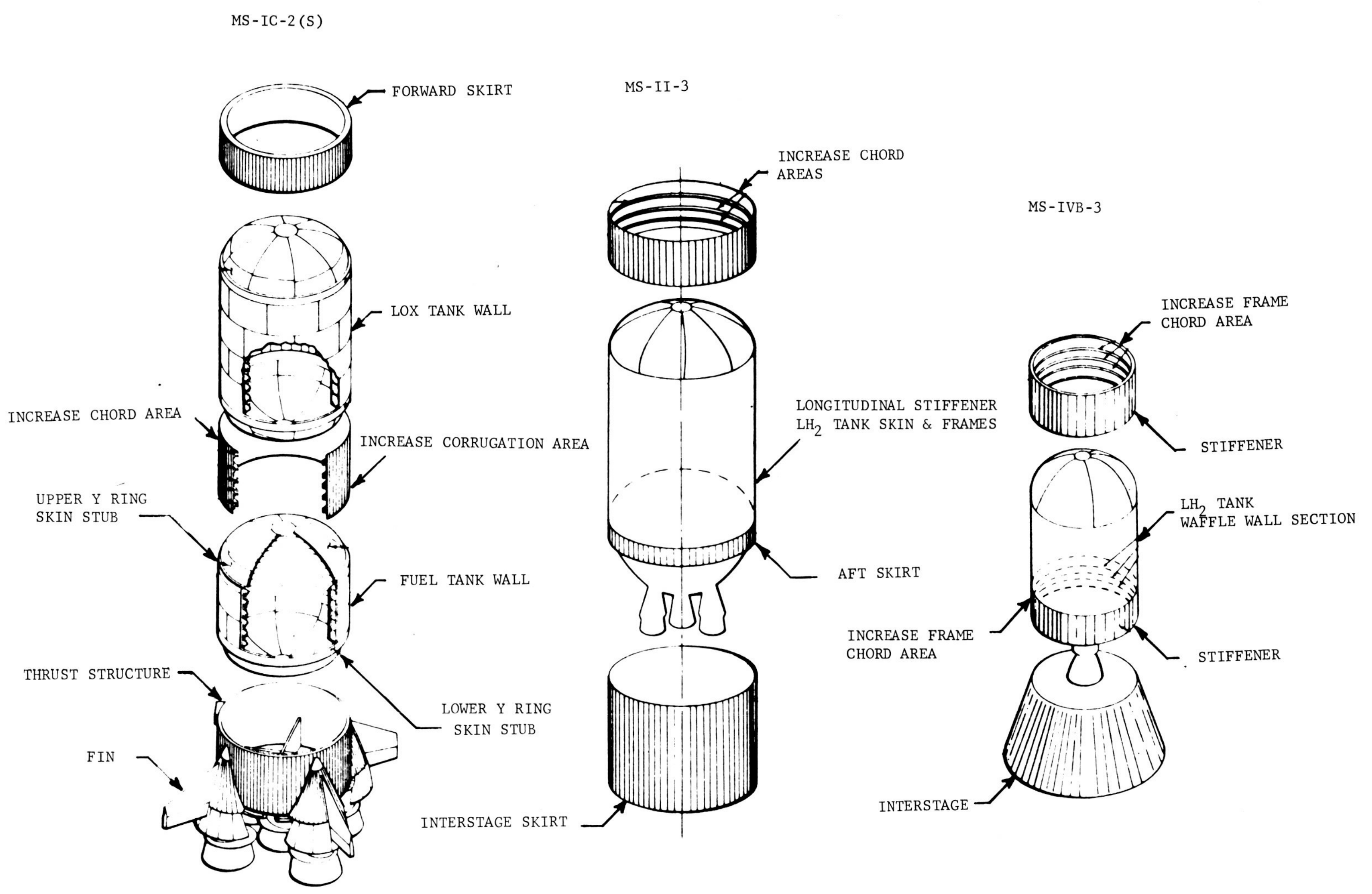


FIGURE 13. - STAGE STRUCTURAL MODIFICATIONS FOR MLV-SATURN V-4(S)

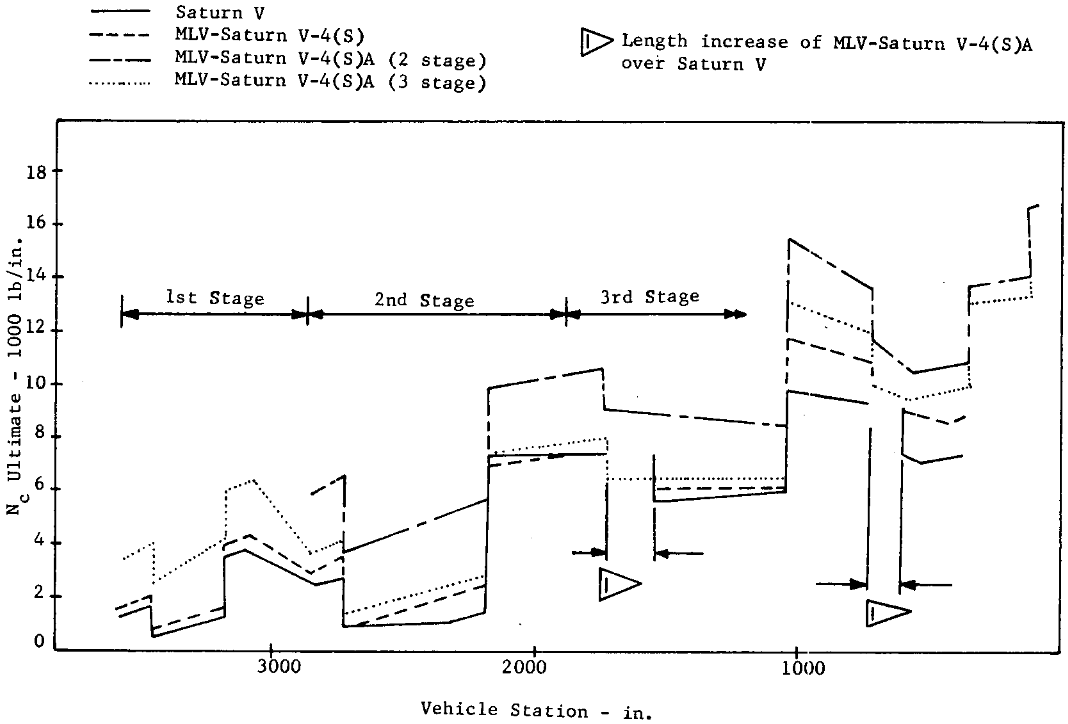


FIGURE 14. - MLV-SATURN V-4(S) AND MLV-SATURN V-4(S)A ULTIMATE COMPRESSIVE LOADS

3. Manufacturing and facilities effects. - The 28-foot longer MS-IC-2(S)A stage will impede the use of the 180-ton crane in the Vertical Assembly Building at Michoud. Many minor changes must be made to first-stage tank assembly fixtures and tooling. No major changes are required for the MLV-Saturn V-4(S) stages and the upper stages of the MLV-Saturn V-4(S)A vehicle. Facility changes for the MLV-Saturn V-4(S) are minimal and are required at Michoud to provide assembly stations for solid rocket motor attachment structure, at MTO and MSFC static test stands to match new first-stage umbilical locations, and at MSFC dynamic test stand to provide an additional hydrodynamic support system.

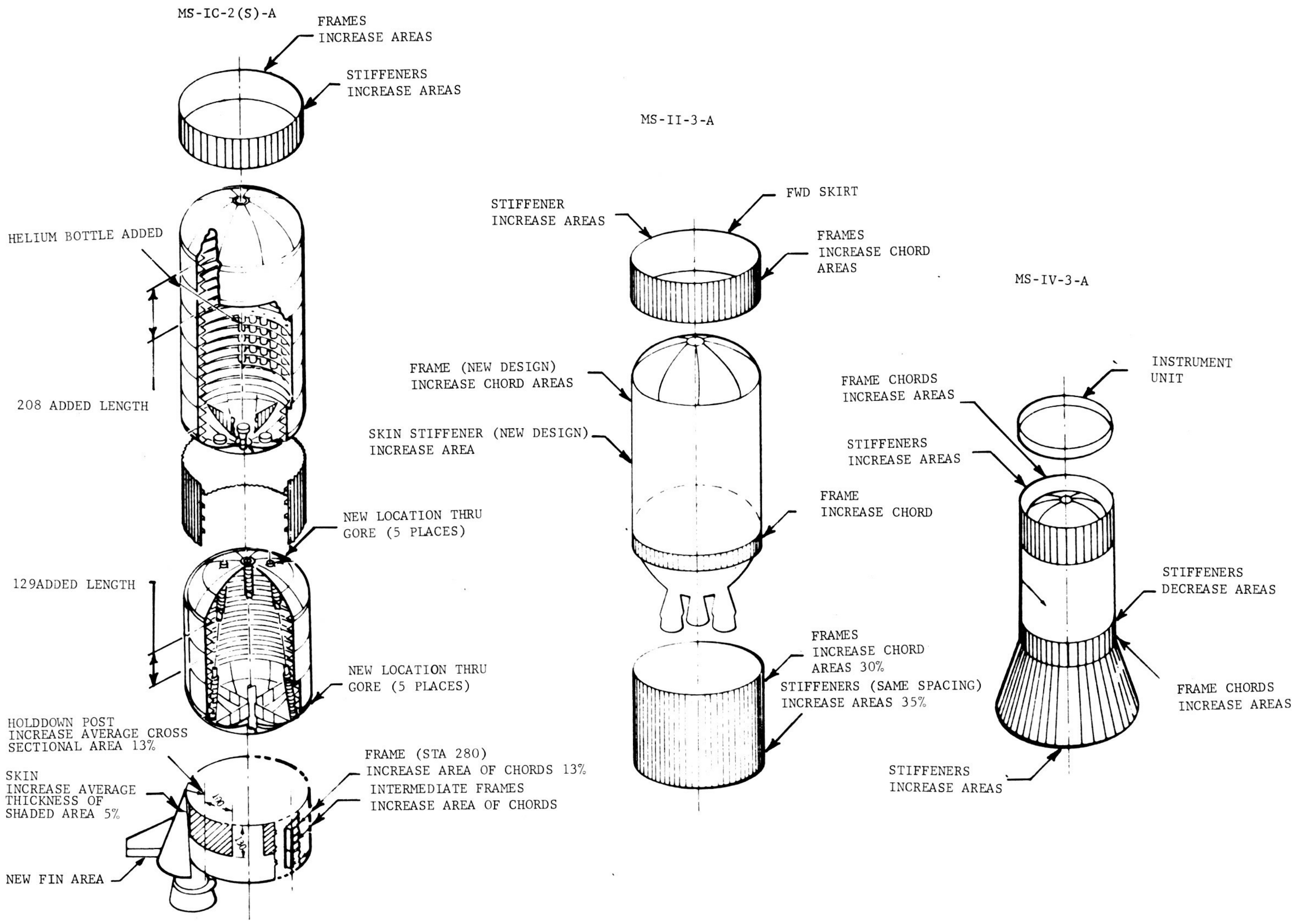


FIGURE 15. - STAGE STRUCTURAL MODIFICATIONS FOR MLV-SATURN V-4(S)A

SECTION VI. SCHEDULES

A. Vehicle Schedules

The schedules shown in Figure 16 depict a few of the major milestones in the development and delivery of the MLV-Saturn V configurations. The initiation dates of the various stage program definition phases and subsequent hardware go-ahead dates can be read directly from the charts. Additionally, delivery to Merritt Island Launch Area (MILA) of both the first R&D flight stage and the first operational stage for each configuration is identified. The engine development schedules for the uprated F-1 engine and the HG-3 engine have been included for those stages with which the engines are associated. Each configuration schedule plan, including stages and engines, is shown independently.

1. MLV-Saturn V-1A Configuration. - In the MLV-Saturn V-1A configuration the MS-IVB stage requires the longest development time of all the stages (four years), becoming the pacing item for this configuration. Although thrust structure redesign is not necessary in this stage as it is in the two lower stages, extensive stage modification is required to increase the tank capacity to 350 000 pounds of propellant.

North American Aviation requires a six-month interval in the changeover from delivery of standard to modified flight stages, due to their limited production facilities and the necessity for producing test items. To allow for this interval and to minimize the resulting impact on both the MS-IC and MS-IVB delivery schedules (in which this extensive period is not required), earlier delivery to MILA would be accepted for both the MS-IC and MS-IVB first R&D flight stages. Subsequent operational stage delivery (not indicated on this chart) would be on a three-month interval for these stages until the MS-II bimonthly operational stage delivery schedule is matched. Subsequent delivery for all stages would then proceed on a two-month interval (six per year).

Matching the stage delivery schedules in the manner cited would permit introduction of this configuration with vehicle SA-522. Initiation of the development schedules for the MS-IC and MS-IVB stages has been adjusted to meet this introduction date.

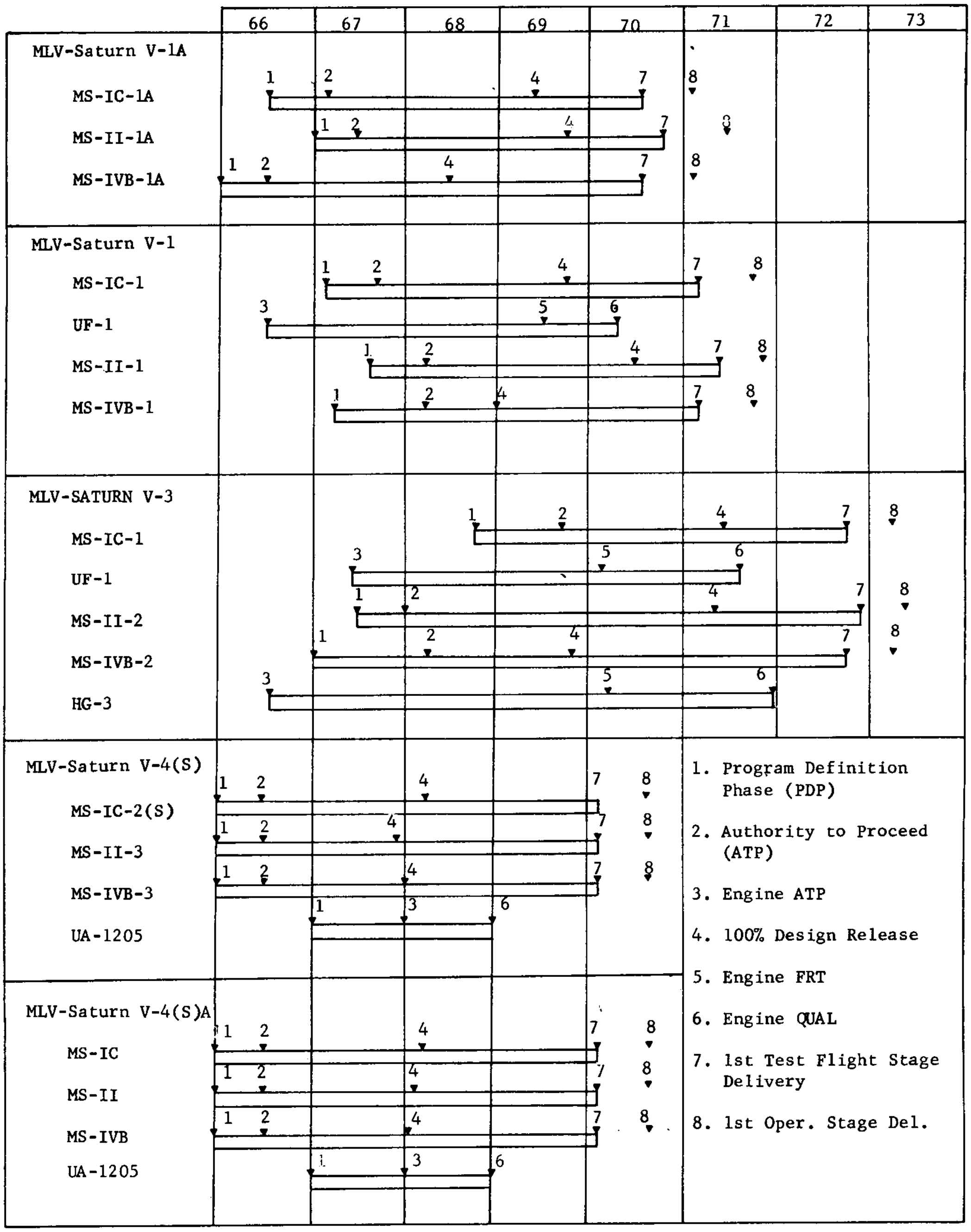


FIGURE 16. - MLV-SATURN V IMPROVEMENT STUDY CONFIGURATIONS, SUMMARY SCHEDULE

2. MLV-Saturn V-1 Configuration. - The development of the MLV-Saturn V-1 configuration is paced by the availability of the uprated F-1 engine to be used in the MS-IC stage. For this configuration schedule, the engine development program has been accelerated to minimize the time between engine Flight Rating Test (FRT) and Qualification Test (QUAL). In addition, a six-month delivery of flight engines prior to engine QUAL has been permitted with a subsequent two-week interval in the stage production schedule to allow for kit modification to the engine. In this manner, pre-QUAL engines delivered for operational stages may be updated to the QUAL configuration prior to stage test and delivery.

To change over from delivery of standard flight stages to the modified MS-II flight stages, NAA requires a six-month interval similar to that for the previously discussed configurations. As was done in the MLV-Saturn V-1A configuration schedule, early delivery of the MS-IC and MS-IVB stages to MILA was accepted with a trimonthly production rate until production of all stages matched. Subsequent production of all stages would be bimonthly. This would permit introduction of this vehicle configuration at SA-526.

3. MLV-Saturn V-3 Configuration. - The pacing item in the introduction of this configuration is the availability of QUAL HG-3 engines. The long period for HG-3 development and delivery, initiated in July 1966, delays introduction of this configuration to SA-536. In the scheduling of stage development and uprated F-1 engine development and delivery, full advantage has been taken of this long period available. Consequently, no acceleration of the uprated F-1 development program has been reflected and uprated F-1 QUAL engines are assumed to be delivered following engine QUAL.

NAA requires a 13-month interval between production of the last standard S-II stage and the first modified MS-II-2 flight stage. However, the production of standard S-II stages subsequent to SA-520 will not require a full two months (learning curve effect). Therefore, production of these standard stages is compressed slightly to permit early Seal Beach delivery. Storage of these early delivery stages is assumed at NAA until they are scheduled for test and subsequent bimonthly delivery to MILA. By freeing the NAA production facilities earlier than would be normally anticipated, the effective production changeover time required (reflected in MILA delivery interval) can be reduced to four months. Minimization of the impact of a four-month delivery interval on the other two stage contractors would be similar to the two preceeding configurations.

4. MLV-Saturn V-4(S) Configuration. - The schedule for the development and introduction of the MLV-Saturn V-4(S) configuration, as developed by The Boeing Company, essentially reflects the time necessary to introduce the MS-IC stage for this configuration. The 50-month development schedule, starting with the Program Definition Phase in January 1966, permits introduction of this configuration at SA-519. A four-month interval in production is required between standard stage and modified stage delivery to MILA. Procurement of man-rated UA-1205 solid rocket motors imposes no foreseeable problems. The schedules for the MS-II and MS-IVB stages were estimated on the basis that the necessary work to be performed for these stages was conducted in a manner similar to the Boeing effort, and the extent of change required could be performed in that time necessary for the MS-IC effort.

5. MLV-Saturn V-4(S)A Configuration. - The schedule for the development and introduction of the MLV-Saturn V-4(S)A configuration is similar in many respects to that of the previous liquid-solid integrated vehicle configuration. This schedule, as outlined by The Boeing Company, essentially reflects the time required for the development and introduction of the MS-IC stage, with the development and introduction of the other two stages being possible within a similar period. In accordance with the greater magnitude of effort required for this configuration (as compared to the previous liquid-solid configuration), additional steps have been taken in the determination of the development schedule to permit the earliest possible introduction of the configuration. The 50-month development time required for MLV-Saturn V-4(S)A introduction thus determined is, coincidentally, the same as that determined for the MLV-Saturn V-4(S) configuration.

B. Program Availability

Figure 17 shows the overall program availability of the selected improved Saturn V configurations. The MSFC "J-1" MILA delivery schedule, used in the determination of the configuration schedules, is shown at the top and has been extended beyond SA-515 on a bimonthly basis. The delivery of standard Saturn V vehicles and the subsequent introduction and delivery of the modified configuration is shown for each configuration. The time points indicate delivery of the complete vehicle (all stages) to MILA. Although operational use of the modified vehicles is assumed at the rate of six per year for an indefinite period, only the first two years of operational use are indicated on the chart (total of two R&D and twelve operational vehicles). However, it must be noted that the potential influence of the launch facility modifications on the vehicle availability is not included.

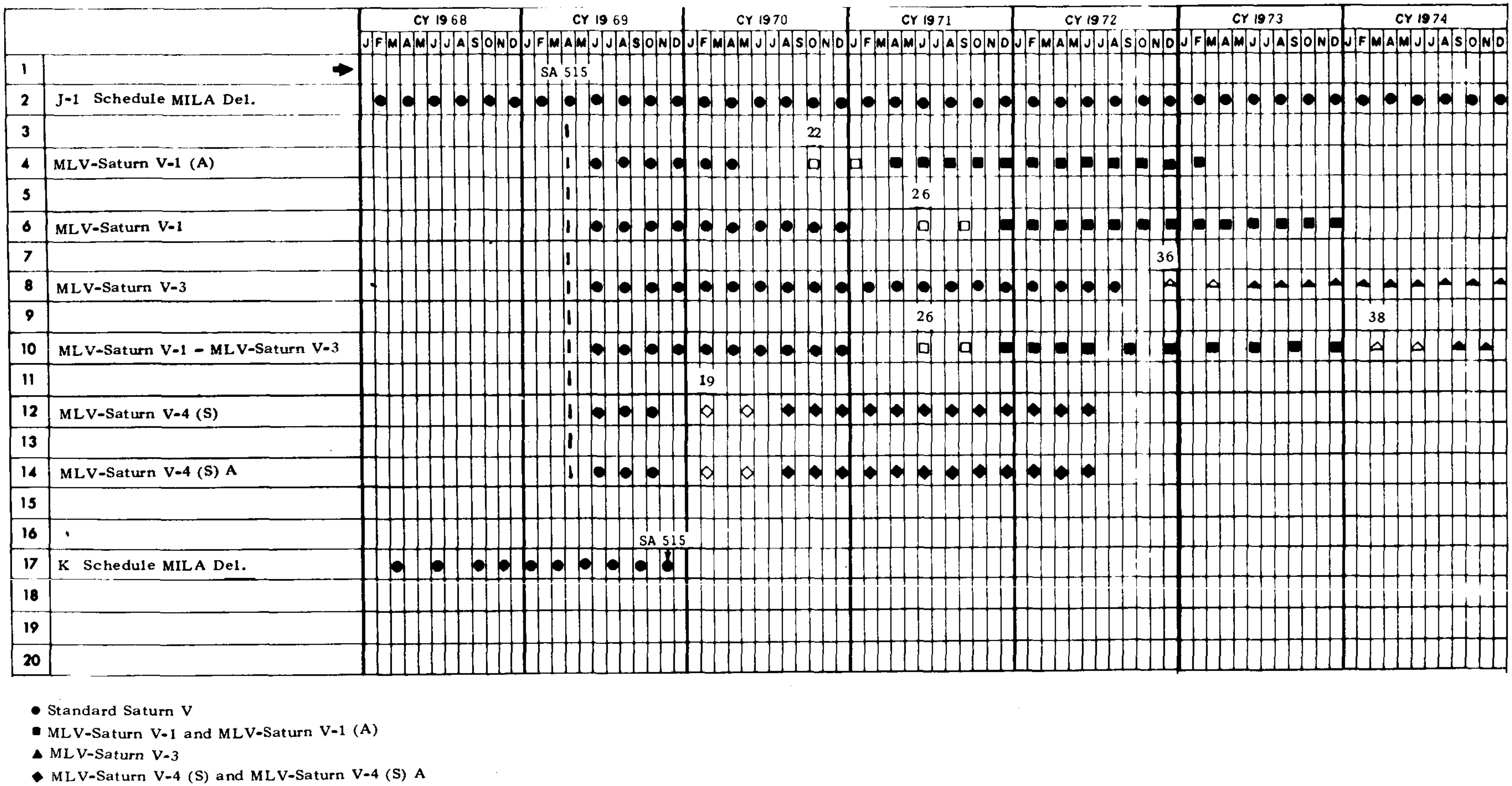


FIGURE 17. - PROGRAM AVAILABILITY MLV-SATURN V VEHICLES

Introduction of the MLV-Saturn V-1A configuration at SA-522 and the MLV-Saturn V-1 configuration at SA-526 is indicated following the six-month changeover period. The MLV-Saturn V-3 configuration is available for SA-536 following a four-month changeover period. Similarly, the MLV-Saturn V-4(S) and MLV-Saturn V-4(S)A configurations are introduced at SA-519 following a four-month changeover period.

Introduction of the MLV-Saturn V-1 prior to MLV-Saturn V-3 is at SA-522 and SA-538, respectively. However, the extensive changeover period required by NAA to introduce the MS-II stage for the MLV-Saturn V-3 configuration results in a lower production rate for the other stages and the consequently lower vehicle availability rate for the preceding configuration. A slightly earlier introduction of the MLV-Saturn V-3 would be possible, but only by accepting a much larger gap in vehicle availability between the two configurations.

For reference purposes only, the more recently released MSFC "K" MILA delivery schedule is shown.

C. Payload versus Time

Figure 18 indicates the amount of payload which could be available versus the time period of availability assuming funding for the configurations considered is available in FY '67. The effect on the MLV-Saturn V-1 and MLV-Saturn V-3 configurations of engine development time is clearly indicated in contrast to the more readily available solid rocket motors for the MLV-Saturn V-4(S) and MLV-Saturn V-4(S)A configurations.

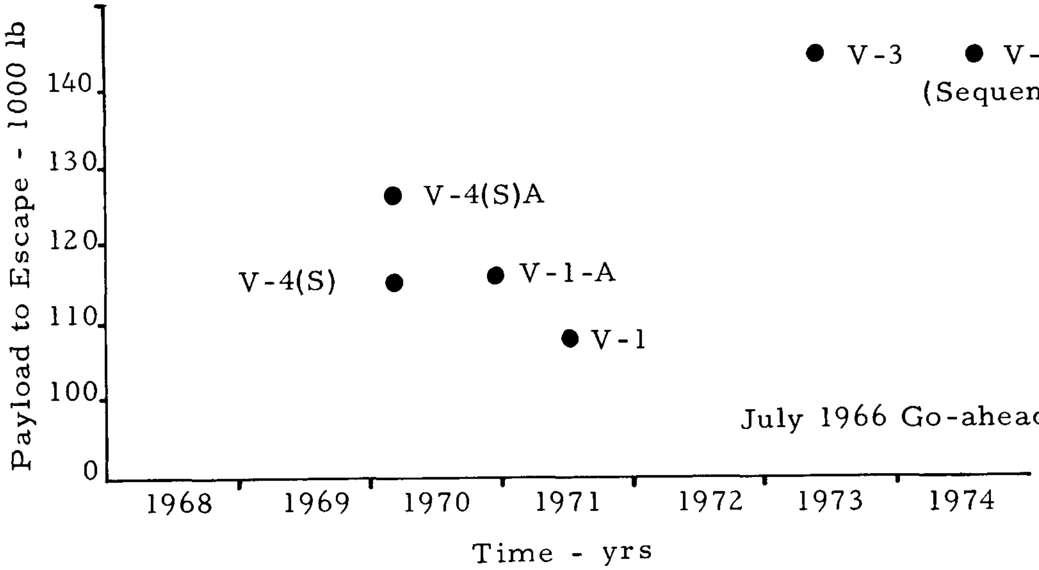


FIGURE 18. - MLV-SATURN V PAYLOAD VERSUS AVAILABILITY

SECTION VII. SATURN V IMPROVEMENT STUDIES IN-HOUSE EFFORTS

The in-house Saturn V Improvement Studies adopted similar ground rules and assumptions as the contracted study. The principal techniques for possible vehicle uprating are shown in Figure 19. The various techniques, when used separately or in combination, leave open a multitude of uprating methods resulting in numerous vehicle configurations.

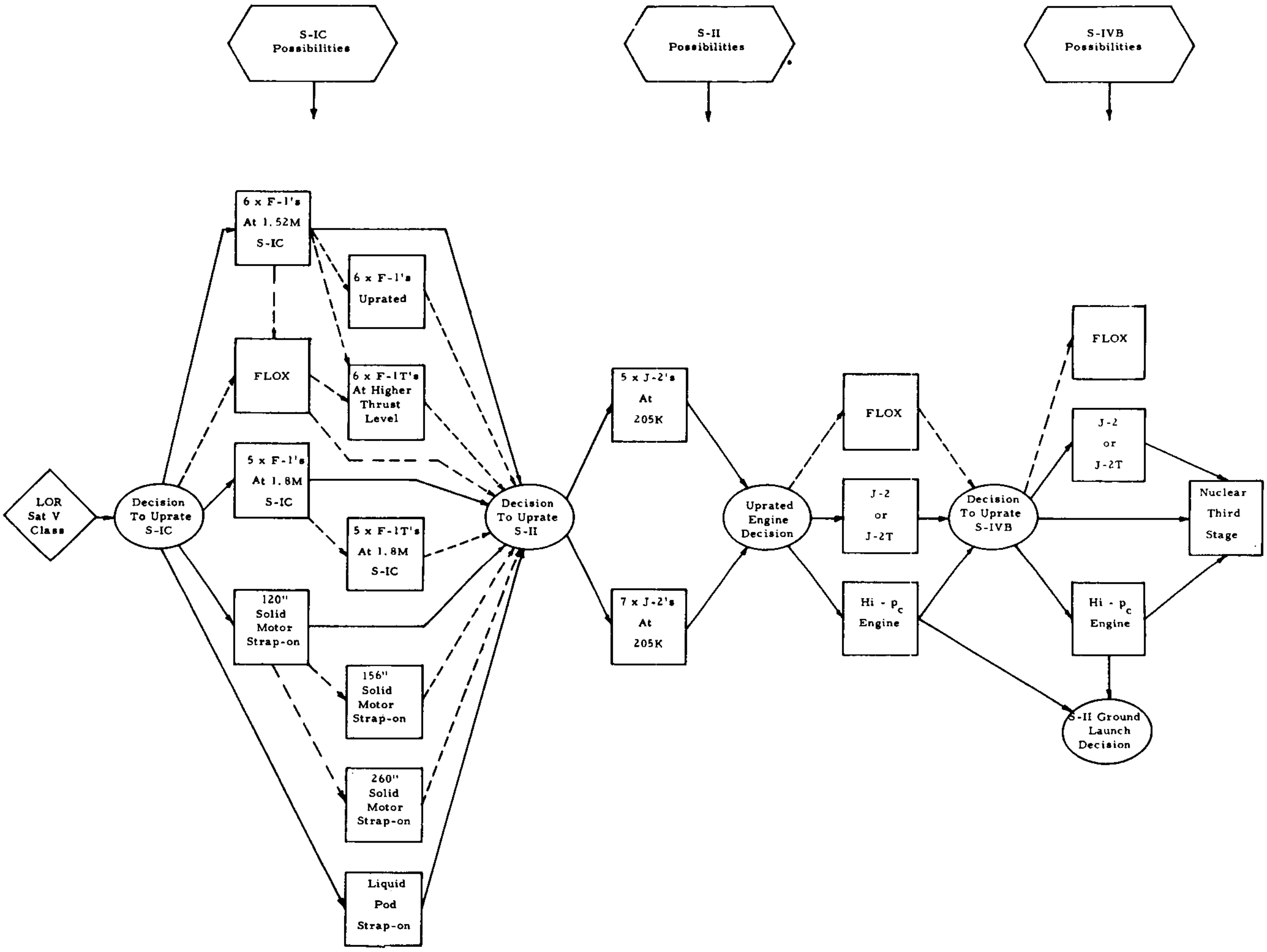


FIGURE 19. - SATURN V IMPROVEMENT STUDIES POSSIBLE UPRATING PATHS

To establish the philosophy to be pursued in uprating Saturn V, a diversified spectrum of approaches must be considered. Each alternate method will result in a moderate to large performance increase over the standard Saturn V. Each method, if properly analyzed, has an inherent time frame with respect to availability as well as a total program cost; however, the time frame and the costs were not considered, only the resulting performance. The in-house studies have attempted to place on a common ground the performance capability of a variety of vehicle configurations that can be generated by pursuing a particular philosophy of uprating.

Table 2 gives performance capability of configurations that can be generated by pursuing the 5 UF-1 engine path in the first stage and then combining 5, 6, and 7 J-2's, UJ-2's, and finally J-2T engines in the upper stages.

The first two columns in the tables list the second and third stage engine combinations, and the next column lists the optimum stage size for the two- and three-stage configurations for two-stage-to-100-N.M. orbit or three-stage-to-escape missions. The fixed vehicle column denotes the stage size upon which the compromised payload is based. The optimum payload column corresponds to the optimum stage sizes. The percent loss column is the percentage payload degradation of the compromised payload from the optimum payload. The two-stage numbers denote net orbital payload and the three-stage numbers denote the 72-hour lunar injected net payload capability.

Table 3 shows the performance results utilizing 6 F-1 engines in the first stage and a similar combination of 5, 6, and 7 J-2's, UJ-2's, and J-2T engines in the upper stages.

Table 4 portrays the performance results of 5 versus 7 HG-3 engines in the second stage with a single HG-3 engine in the third stage. It will be noted that two thrust levels of the HG-3 engine were investigated: 315K and 375K pounds thrust per engine. The first stage was also varied, i.e., 5 UF-1 engines, 5 F-1T engines, 6 standard F-1 engines, and 6 UF-1 engines.

Table 5 summarizes the payload capability of the liquid-solid integration combination for the various MLV-Saturn V core vehicles.

Figure 20 shows the performance capability of the more interesting configurations discussed above. In addition, a summary chart is given on the effects of floxing some stages. This represents the limited effort performed on floxing schemes.

The in-house study is a continuing effort. As new ideas or approaches to the problem arise, they are evaluated and used to increase the large information matrix of the Saturn V Improvement Studies.

Table 2. - CONFIGURATIONS WITH 5(UF-1) ENGINES IN MS-IC STAGE (IN-HOUSE STUDIES)

S-II Mods	S-IVB Mods	Optimum 3-Stage Vehicle		Optimum 2-Stage Vehicle		Fixed Vehicle	Optimum Payload		Compromised Payload		% Loss
6 x J-2 at 207 K	1 x J-2 at 207 K	S-IC S-II S-IVB	5.249 M 0.933 M 311 K	S-IC S-II	5.244 M 1.085 M	5.6 M 1.0 M 300 K	2-Stage 3-Stage	301.4 K 112.9 K	2-Stage 3-Stage	298.8 K 111.7 K	0.9 0.3
7 x J-2 at 207 K	1 x J-2 at 207 K	S-IC S-II S-IVB	5.121 M 1.024 M 335 K	S-IC S-II	5.111 M 1.205 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	305.2 K 116.4 K	2-Stage 3-Stage	302.9 K 113.1 K	0.8 2.8
5 x J-2 at 250 K	1 x J-2 at 250 K	S-IC S-II S-IVB	5.230 M 0.921 M 340 K	S-IC S-II	5.227 M 1.100 M	5.6 M 1.0 M 300 K	2-Stage 3-Stage	306.7 K 115.5 K	2-Stage 3-Stage	304.0 K 114.2 K	0.9 1.1
5 x J-2T at 250 K	1 x J-2T at 250 K	S-IC S-II S-IVB	5.205 M 0.935 M 340 K	S-IC S-II	5.202 M 1.105 M	5.6 M 1.0 M 300 K	2-Stage 3-Stage	326.0 K 127.6 K	2-Stage 3-Stage	322.9 K 126.2 K	0.95 1.1
6 x J-2T at 250 K	1 x J-2T at 250 K	S-IC S-II S-IVB	5.044 M 1.059 M 360 K	S-IC S-II	5.089 M 1.201 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	333.2 K 133.3 K	2-Stage 3-Stage	330.5 K 130.9 K	0.8 1.8
7 x J-2T at 250 K	1 x J-2T at 250 K	S-IC S-II S-IVB	4.903 M 1.165 M 376.5 K	S-IC S-II	4.982 M 1.295 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	335.6 K 137.9 K	2-Stage 3-Stage	331.8 K 136.1 K	1.1 1.3

Table 3. - CONFIGURATIONS WITH 6(F-1) ENGINES IN MS-IC STAGE (IN-HOUSE STUDIES)

S-II Mods	S-IVB Mods	Optimum 3-Stage Vehicle		Optimum 2-Stage Vehicle		Fixed Vehicle	Optimum Payload		Compromised Payload		% Loss
None	None	S-IC S-II S-IVB	5.364 M 0.822 M 300 K	S-IC S-II	5.357 M 0.969 M	5.6 M 1.0 M 230 K	2-Stage 3-Stage	29.14 K 106.5 K	2-Stage 3-Stage	289.6 K 103.1 K	0.6 3.2
6 x J-2 at 207 K	None	S-IC S-II S-IVB	5.224 M 0.938 M 309 K	S-IC S-II	5.220 M 1.090 M	5.6 M 1.0 M 300 K	2-Stage 3-Stage	297.7 K 111.4 K	2-Stage 3-Stage	295. K 110.2 K	0.9 1.1
7 x J-2 at 207 K	None	S-IC S-II S-IVB	5.094 M 1.038 M 326 K	S-IC S-II	5.110 M 1.186 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	301.6 K 115.2 K	2-Stage 3-Stage	299.5 K 111.6 K	0.7 3.1
5 x J-2T at 250 K	1 x J-2T at 250 K	S-IC S-II S-IVB	5.181 M 0.938 M 338 K	S-IC S-II	5.177 M 1.110 M	5.6 M 1.0 M 300 K	2-Stage 3-Stage	322.2 K 126.0 K	2-Stage 3-Stage	319.0 K 124.7 K	1.0 1.0
6 x J-2T at 250 K	1 x J-2T at 250 K	S-IC S-II S-IVB	5.018 M 1.065 M 356 K	S-IC S-II	5.059 M 1.202 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	329.4 K 131.7 K	2-Stage 3-Stage	326.9 K 129.3 K	0.8 1.8
7 x J-2T at 250 K	1 x J-2T at 250 K	S-IC S-II S-IVB	4.881 M 1.168 M 377.7 K	S-IC S-II	4.958 M 1.300 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	333.5 K 136.1 K	2-Stage 3-Stage	331.2 K 133.5 K	0.7 1.9

Table 4. - CONFIGURATIONS WITH 5 AND 7 HG-3 ENGINES IN MS-STAGE (IN-HOUSE STUDIES)

S-IC Mods	S-II Mods	S-IVB Mods	Optimum 3-Stage Vehicle		Optimum 2-Stage Vehicle		Fixed Vehicle	Optimum Payload		Compromised Payload		% Loss
5 x F-1 at 1.8 M	5 x HG-3 at 315 K	1 x HG-3 at 315 K	S-IC S-II S-IVB	4.976 M 1.103 M 367 K	S-IC S-II S-IVB	4.977 M 1.279 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	350.7 K 142.9 K	2-Stage 3-Stage	346.9 K 141.0 K	1.1 1.3
5 x F-1 at 1.8 M	5 x HG-3 at 375 K	1 x HG-3 at 375 K	S-IC S-II S-IVB	4.820 M 1.202 M 407.8 K	S-IC S-II S-IVB	4.914 M 1.344 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	351.6 K 144.8 K	2-Stage 3-Stage	345.9 K 142.3 K	1.6 1.7
5 x F-1 at 1.8 M	7 x HG-3 at 315 K	1 x HG-3 at 315 K	S-IC S-II S-IVB	4.680 M 1.301 M 425.1 K	S-IC S-II S-IVB	4.744 M 1.489 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	355.5 K 151.9 K	2-Stage 3-Stage	342.9 K 146.6 K	3.5 3.5
5 x F-1 at 1.8 M	7 x HG-3 at 375 K	1 x HG-3 at 375 K	S-IC S-II S-IVB	4.457 M 1.461 M 470.6 K	S-IC S-II S-IVB	4.581 M 1.647 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	348.2 K 153.6 K	2-Stage 3-Stage	329.7 K 144.8 K	5.3 5.7
5 x F-1T at 1.8 M	7 x HG-3 at 375 K	1 x HG-3 at 375 K	S-IC S-II S-IVB	4.517 M 1.366 M 475 K	S-IC S-II S-IVB	4.614 M 1.582 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	382.0 K 166.6 K	2-Stage 3-Stage	365.0 K 157.0 K	4.4 5.8
6 x F-1 at 1.5 M	5 x HG-3 at 315 K	1 x HG-3 at 315 K	S-IC S-II S-IVB	4.945 M 1.101 M 383 K	S-IC S-II	5.030 M 1.225 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	346.9 K 141.6 K	2-Stage 3-Stage	344.3 K 139.8 K	0.7 1.3
6 x F-1 at 1.8 M	7 x HG-3 at 375 K	1 x HG-3 at 375 K	S-IC S-II S-IVB	5.657 M 1.553 M 504.4 K	S-IC S-II S-IVB	5.741 M 1.768 M	6.8 M 1.2 M 350 K	2-Stage 3-Stage	427.6 K 185.9 K	2-Stage 3-Stage	394.0 K 169.7 K	7.9 8.7

Table 5. - CONFIGURATIONS WITH SOLID ASSIST (IN-HOUSE STUDIES)

S-IC Mods	S-II Mods	S-IV Mods	Optimum 3-Stage Vehicle		Optimum 2-Stage Vehicle		Fixed Vehicle	Optimum Payload		Compromised Payload		% Loss
2 x 156"	None	None	S-IC S-II S-IVB	4.699 M .829 M 307.5 K	S-IC S-II	4.690 M .977 M	4.556 M .930 M 230 K	2-Stage 3-Stage	310.3 K 114.1 K	2-Stage 3-Stage	306.5 K 111.3 K	1.2 1.5
4 x 120"	5 x HG-3 at 315 K	1 x HG-3 at 315 K	S-IC S-II S-IVB	5.437 M 1.152 M 404 K	S-IC S-II	5.524 M 1.260 M	5.6 M 1.2 M 350 K	2-Stage 3-Stage	408.3 K 168.1 K	2-Stage 3-Stage	403.1 K 165 K	1.3 1.8
2 x 156"	5 x HG-3 at 315 K	1 x HG-3 at 315 K	S-IC S-II S-IVB	4.266 M 1.121 M 390.6 K	S-IC S-II	4.353 M 1.238 M	4.556 M 1.2 M 350 K	2-Stage 3-Stage	368.5 K 151 K	2-Stage 3-Stage	369 K 150.5 K	.1 .3
5 x F-1 at 1.8 M 4 x 120"	5 x HG-3 at 315 K	1 x HG-3 at 315 K	S-IC S-II S-IVB	None	S-IC S-II	None	5.6 M 1.2 M 350 K	2-Stage 3-Stage	None	2-Stage 3-Stage	447.6 K 168.4 K	None

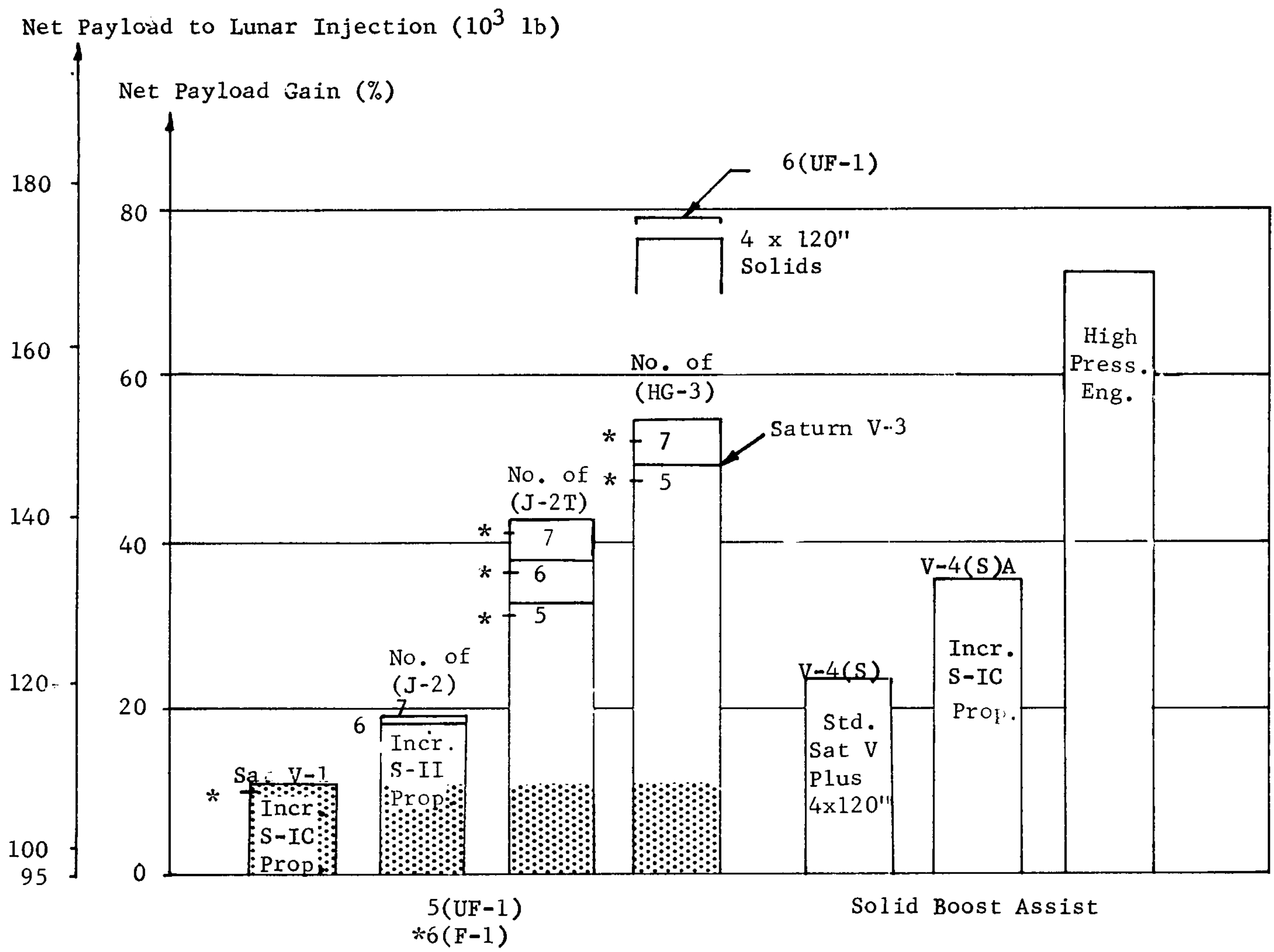


FIGURE 20a. - SATURN V IMPROVEMENT STUDIES PAYLOAD GAIN SUMMARY (IN-HOUSE STUDIES)

Base Configurations = MS-IC with 5 x UF-1 and 5.6 M prop. cap.
S-II with 5 x J-2 and 930 K prop. cap.
MS-IVB with 1 x J-2 and 300 K Prop. cap.

PERCENT OF MS-IC FLOXING	NET PAYLOAD (ORBITAL/LUNAR) (lb)
30	322/117
50	340/124
70	354/130
PERCENT OF FLOXING ALL STAGES	
30	330/123
50	354/135
70	373/144

FIGURE 20b. - IN-HOUSE SATURN V IMPROVEMENT STUDY OF FLOXING

SECTION VIII. SATURN V/NUCLEAR UPRATING STUDIES

The application of nuclear propulsion in the third stage of Saturn V launch vehicles for the purpose of uprating the escape performance capability of the Saturn V system is a desirable by-product of the modular nuclear vehicle concept.

Standard Saturn V and uprated Saturn V/nuclear vehicle performance data are shown in Table 6 for the lunar logistics mission utilizing a 72-hour transfer and cryogenic braking and landing stage. All configurations were constrained to a minimum lift-off acceleration of 1.24 g's and employ a third stage suborbital start in a 185-km waiting orbit. Propellant distribution was optimized, within the fixed loading capacities of the chemical launch stages, for maximum payload at lunar transfer injection. All-chemical vehicle performance is shown for comparison with nuclear vehicles employing both the NERVA 1 (56 000-pound-thrust) and the NERVA 2 (230 000-pound-thrust) nuclear engines. It is shown in Table 6 that the employment of nuclear stages provides 30 to 45 percent transfer payload improvement for each launch vehicle. By combining chemical

TABLE 6. - SATURN V/NUCLEAR AND CHEMICAL LUNAR LOGISTICS PERFORMANCE COMPARISON

	Lunar Transfer	Lunar Orbit*	Lunar Surface#
Saturn V Chemical	93 500	66 800	27 100
Saturn V/NERVA 1	122 760	88 600	40 200
Saturn V/NERVA 2	126 455	91 300	41 800
MLV-Saturn V-1 Chemical	107 500	77 100	33 000
MLV-Saturn V-1/NERVA 1	147 600	107 200	50 800
MLV-Saturn V-1/NERVA 2	155 400	113 100	54 100
MLV-Saturn V-3 Chemical	137 100	99 000	45 900
MLV-Saturn V-3/NERVA 1	179 000	130 800	64 100
MLV-Saturn V-3/NERVA 2	190 000	139 100	68 800

*O_2/H_2 Orbital Braking Stage (L-1). #O_2/H_2 Decent and Landing Stage(L-2).
Payloads include Instrument Unit.

and nuclear uprating of the basic Saturn V, represented by MLV-3/NERVA 2, a total transfer payload improvement of greater than 100 percent can be achieved. The corresponding performance improvements measured in terms of lunar surface payloads are 40 to 65 percent for nuclear uprating only and greater than 150 percent for combined chemical/nuclear uprating.

The employment of optimum sized nuclear stages with Saturn V launch vehicles necessitates longer vehicles (due to the lower LH_2 propellant density) which impose greater loads on the boost stages than they are required to carry in all-chemical configurations and, in many cases, exceed planned launch facility height limitations. Additional boost stage stiffening requirements were estimated where appropriate and all payloads were adjusted accordingly. It is believed that these additional stiffening requirements could, in general, be accomplished with minimum effect on tooling by increasing stiffener thickness (milling away less material). Optimum propellant distribution in the configurations of Table 6 resulted in both the V-3 vehicles (shown in Figure 21) and the V-1/NERVA 2 vehicle (shown in Figure 21) exceeding the ground rule 410-foot VAB hook height, with the longest being 470 feet. Propellant/payload tradeoff analyses were conducted to determine the best performance that could be obtained for these configurations when they are constrained to 410 feet by limiting nuclear stage propellant. This constraint is quite severe resulting in injected payload losses of up to 30 000 pounds. There are a number of means by which this facility/payload-loss problem could be alleviated, such as: (1) employment of 396-inch-diameter spacecraft stages, (2) shortening off-loaded chemical boost stage propellant tanks, (3) assembly of the uppermost vehicle components outside the VAB, (4) employment of hammerhead nuclear stages, and/or (5) modification of one cell of the VAB to increase the hook height. Other facility implications which result from long nuclear vehicles concern the effect of greater overturning moments upon the crawler and road surface load limit design and the relocation of service arm positions and checkout equipment.

A potential development sequence for nuclear vehicle systems, based on the modular concept approach, shows that an operational nuclear third stage for the Saturn V launch vehicle could be available in the mid to late 1970's.

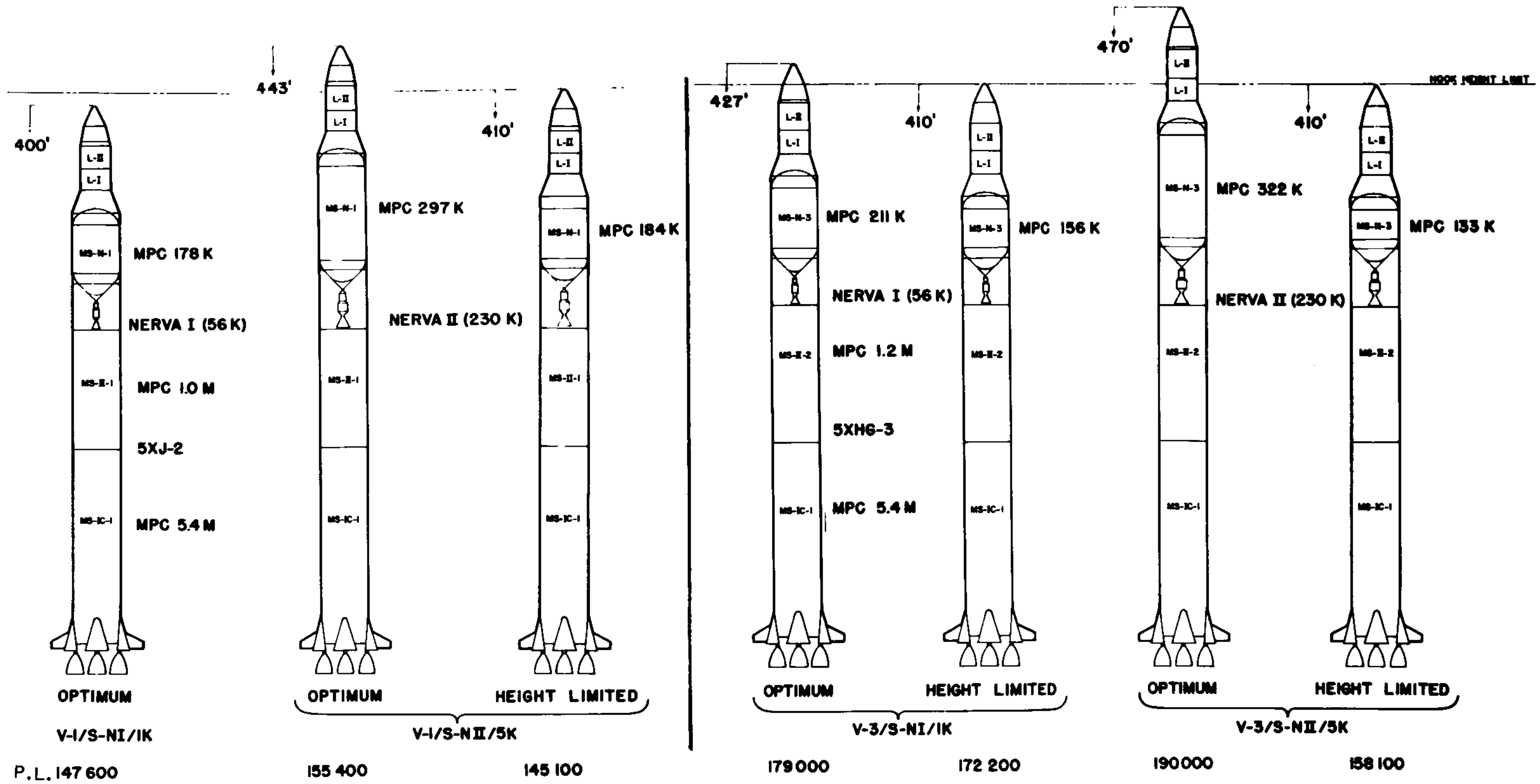


FIGURE 21. - MLV-SATURN V-1/NUCLEAR AND V-3/NUCLEAR IMPROVEMENT CONFIGURATIONS LUNAR LOGISTICS MISSION

SECTION IX. CONCLUSIONS

The evaluation of the problems associated with the design, development, and operation of the MLV-Saturn V vehicles disclosed that these vehicles are a practical means of uprating the Saturn V vehicle. No insurmountable engineering problems were uncovered. Detailed designs and manufacturing procedures are within present technology and tooling capability.

The MLV-Saturn V-1 offers the simplest stage and vehicle engineering but is dependent on uprated F-1 availability and expenditures for F-1 uprating.

The MLV-Saturn V-1A vehicle offers major stage and vehicle uprating without the potential schedule delay and major expenditures for engine uprating. It would allow greater long-range Saturn V growth with later incorporation of F-1 engine uprating and introduction of the HG-3 in the upper stages. A more complex engineering and development effort of the first two stages is involved because of the additional engines and the redesign of the thrust structure. The third stage is modified only to take the increased tankage.

The MLV-Saturn V-3 offers the largest payload capability of the vehicles studied, with the corresponding highest cost effectiveness of all the vehicles studied. Based on the performance studies, it was concluded that, if the 1 200 000-pound propellant load is maintained for the MS-II-2 stage, the stage engine thrust should be increased above the 315K value for optimum payload gains.

The evaluation of the problems associated with the design, development, and operation of the MLV-Saturn V-4(S) and MLV-Saturn V-4(S)A disclosed that these vehicles are a practical means of uprating the Saturn V vehicle. No insurmountable engineering problems pertaining to the configuration and stages are apparent; however, extensive requalification of vibration-sensitive elements is required for the increased acoustic environment.

In the in-house Saturn V Improvement Studies, performance capabilities of a variety of vehicle configurations and uprating methods were investigated. The information obtained from these studies is used to complete the matrix of the various Saturn V improvement methods.

The MLV studies have progressed sufficiently to define the performance capability, design problems, and manufacturing and facility limitations within the configuration restraints imposed. These studies, along with studies of lesser depth,conducted by MSFC have shown alternate approaches to Saturn V growth. Analysis will be necessary to assure proper configuration selection prior to a program definition phase for incorporation of major changes to the Saturn V system.

As a result of these studies, MSFC and the contractors obtained a detailed knowledge of the contractor manufacturing capabilities and facility limitations. Organization of preliminary design studies has been established which will result in greater confidence in future studies and improve the cost and schedules resulting from the studies. The past studies have established the performance increase, as a result of uprating the engines, and the time frame required to uprate the engines.

BIBLIOGRAPHY

1. NASA Contract NAS8-11339, "Design Study of the MS-IC Stage for the Modified Launch Vehicle (MLV) Saturn V."

   Reports by The Boeing Company, dated April 15, 1965:

   a. D5-11420-0, Summary Report.
   b. D5-11420-1, Preliminary Model Specification.
   c. D5-11420-2, Propulsion/Mechanical-Electrical/Electronics Analysis and Trade Studies.
   d. D5-11420-3, Structural Analysis and Trade Studies
   e. D5-11420-4, Program Plan.
   f. D5-11420-5, Manufacturing, GSE/MSE, and Facility Requirements.
   g. D5-11420-6, General Test Plan.
   h. D5-11420-7, Cost Analysis.

2. NASA Contract NAS8-11352, "Design Study of the MS-II Stage for the Modified Launch Vehicle (MLV) Saturn V."

   Reports by North American Aviation, dated April 29, 1965:

   a. SID65-244-1, Technical Summary Report.
   b. SID65-244-2, Design Data Manual, MS-II-1 Stage.
   c. SID65-244-3, Design Data Manual, MS-II-2 Stage.
   d. SID65-244-4, Cost Analysis Summary.
   e. SID65-244-5, Seven Engine MS-II-1A Stage.
   f. SID65-244-6, MS-II Design Study Summary Briefing.
   g. SID65-244-7, MS-II Cost Analysis Summary Briefing.

3. NASA Contract NAS8-11359, "Saturn V Improvement Study, MS-IVB-1 and MS-IVB-2."

   Report by Douglas Aircraft, dated April 15, 1965:

   a. SM-47090, Technical.
   b. SM-47090, Preliminary Model Specifications.
   c. SM-47090, Stress Analysis.
   d. SM-47090, Fiscal.
   e. SM-47090, Summary Report.

4. NASA Contract NAS8-11428, "Saturn V Improvement Study, Fluid and Flight Mechanics."

Reports by The Boeing Company, dated April 30, 1965:

a. D5-13109-1, Final Summary Report.
b. D5-13109-2, General Data.
c. D5-13109-2, MLV-Saturn V-1, Two-Stage Launch Vehicle.
d. D5-13109-2, MLV-Saturn V-1, Three-Stage Launch Vehicle.
e. D5-13109-2, MLV-Saturn V-2, Three-Stage Launch Vehicle.
f. D5-13109-2, MLV-Saturn V-3, Two-Stage Launch Vehicle.
g. D5-13109-2, MLV-Saturn V-3, Three-Stage Launch Vehicle.
h. D5-13109-2, MLV-Saturn V-4(S), Three-Stage Launch Vehicle.
i. D5-13109-2, Alternate Configurations.

5. NASA Contract NAS8-11443, "Saturn V Improvement Study Liquid-Solid System Integration."

Reports by The Boeing Company, Dated April 30, 1965:

a. D5-13087, Summary Report.
b. D5-13087, Technical Report.
c. D5-13087, Appendix.

6. NASA Contract NAS8-11478, "Study of Resources Required for MLV-Saturn V-4(S) and MLV-Saturn V-4(S)A, Liquid-Solid System Integration."

Reports by The Boeing Company, undated:

a. D5-13118, Summary.
b. D5-13118, MLV-Saturn V-4(S).
c. D5-13118, MLV-Saturn V-4(S)A.
d. D5-13118, Cost Plan.

7. NASA Contract NAS8-19, "J-2 Uprating Study Final Report," Rocketdyne Report R-5902, dated November 5, 1964.

8. NASA Contract NASw-16, "F-1 Uprating Study Final Report," Rocketdyne Report R-5910, dated January 26, 1965.

9. NASA Contract NAS8-11427, "HG-3 Liquid Rocket Engine Design Study Data Summary," Pratt and Whitney Aircraft Report 1044A, dated November 1964.

10. NASA Contract NAS8-11427, "HG-3 Liquid Rocket Engine Design Study Parametric Data Summary," Pratt and Whitney Aircraft Report 1182A, dated April 1965.

11. "A Catalog of Saturn V Improvement Configurations, 1965 Studies." Unpublished Memorandum by R-AERO-DP.

12. "Saturn V Improvement Studies Resources Analysis Summary Document." Unpublished Report, R-P&VE-AA.

July 2, 1965 APPROVAL TM X-53252

MODIFIED LAUNCH VEHICLE (MLV) SATURN V IMPROVEMENT STUDY COMPOSITE SUMMARY REPORT

Compiled By

Advanced Studies Office

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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