SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
485 Lexington Avenue, New York 17, N.Y.

Selected Methods for Uprating Saturn Vehicles

Alfred G. Orillion and Ronald D. Scott
Marshall Space Flight Center, NASA

SOCIETY OF AUTOMOTIVE ENGINEERS

Advanced Launch Vehicles and Propulsion Systems Conference
Huntsville, Ala.
June 14-16, 1966

660453

660453

Selected Methods for Uprating Saturn Vehicles

Alfred G. Orillion and Ronald D. Scott
Marshall Space Flight Center, NASA

ABSTRACT

This paper will discuss selected methods for increasing the Saturn launch vehicle payload capabilities. These methods involve system changes or additions that give large step performance increases over those which can be obtained by product improvements. The selected philosophy of approach and the established designed systems will be described, as well as anticipated system concepts that may be used to increase the Saturn vehicles' capabilities.

THE SATURN IB AND SATURN V vehicles have payload delivery capabilities that can be measured in tens of tons. These vehicles have an adequate capability for the tasks for which they are intended and at present there is no planned requirement for vehicles with greater delivery capability. However, eventually there may be new missions established requiring payloads in earth orbit, to lunar transit or higher mission energies, greater than those which can be delivered by the Saturn family. This requirement for increased capability may range from incremental payload gains to large quantum jumps. In consideration of this, the various avenues to accomplish increased payload capability must be examined.

Increased payload capability for orbital or high-energy missions can be accomplished either by the orbital rendezvous technique or by improving the performance of the basic launch vehicle. It is the latter approach that is of concern here; for if one is to assume that a large traffic of vehicles is to be employed in the future, then the use of a single improved vehicle seems to be the better approach. If an unrestricted uprating approach is considered, then there is a host of changes that can be made -- everything from component product improvement to completely new stage and propulsion concept design and substitution. Such a broad field is too encompassing to be covered in its entirety in this discussion. To narrow the field, it is necessary to cover concepts that involve incremental steps within the state-of-the-art. That is to say, the changes considered will be expected evolutionary steps which can produce payload gains about ten percent or greater than the ones expected from general product improvement, and yet not introduce radically new propulsion concepts. The upper limit of this field will be based on the restraint of using the basic core systems and employing available systems or reasonable expected evolutionary systems. It is well recognized that with continuing technological advancement it is very difficult to draw the line where expected propulsion evolution, within the state-of-the-art, ends and radically new propulsion concepts begin. To minimize this controversy, the propulsion advancements considered in this discussion will be those selected by the authors as the most logical and applicable within the next several years. With this philosophy, the field can be narrowed further to a specific series of concepts that will be covered. Therefore, by selection, the definition to be applied to uprating for this discussion will be those changes which will give significant vehicle performance increases while employing most of the basic systems or anticipated evolutions. Figure 1 pictorially displays the region to be discussed. Although, in any planned improvement program, a large number of factors, e.g., technical aspects, schedules, costs, facilities, manufacturing, and so forth, must be considered, for the purposes of this discourse, time will permit only an examination of the technical relationships for the growth concepts and a brief survey of possible vehicle configurations. This brings us to an examination of our survey of selected methods for uprating Saturn vehicles. Beyond this introduces the types of changes that may be classed as the more optimum for the level of performance increase desired. That is to say, the basic core stages and engine systems would be redesigned, developed, and produced to correspond to more efficient utilization. These types of changes would be more in the realm of new systems or technology development which

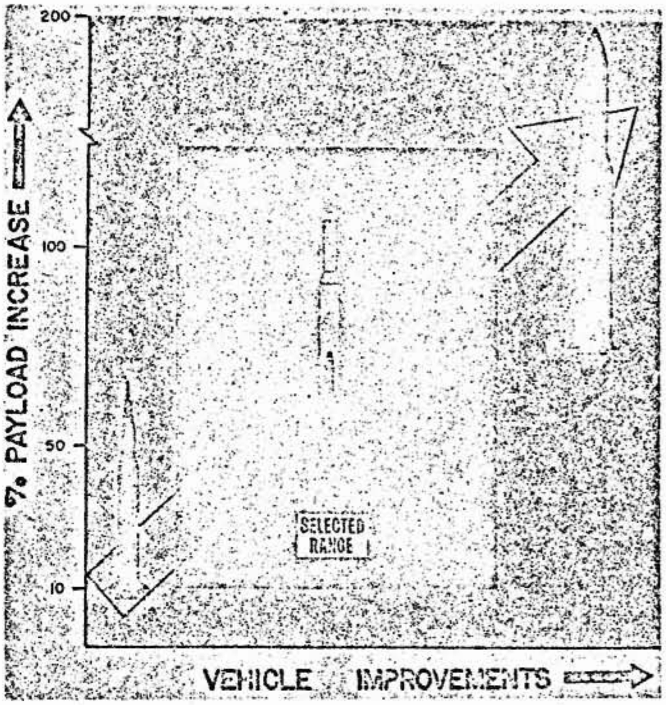


Fig. 1 - Improvement study range

are classified as beyond the scope of uprating techniques.

UPRATING APPROACH

Within these limits, the approach for uprating a vehicle may well be governed by (1) a specific mission which requires capabilities exceeding those of available launch vehicles, or (2) a requirement for flexible launch vehicles is established which increases the scope of capabilities, thereby giving a wide spectrum of potential missions. In the former case, the requirements, of course, dictate a need for a specific capability in which the vehicle modifications may be selected for the best approach. In the latter case, improvements and modifications must be effected and expanded over the total vehicle to assure the flexibility desired. The approach to the second governing factor will produce more freedom of design and flexibility.

In a gross sense, the more effective means of improving the capability of a vehicle are to increase the engine thrust and efficiency along with the stage propellant. The paths to accomplish this are: (1) payload increase through "brute force" modifications, and (2) performance improvements through technological advances or advances in the state-of-the-art. Category (1) is primarily dictated by increased thrust and gross weight by STRAP-ON MODULES, LARGER STAGES, and MORE ENGINES. Category (2) is represented by INCREASED THRUST and SPECIFIC IMPULSE as a result of more EFFICIENT ENGINES and BETTER FUELS. Figure 2 lists the methods of improvement for the two categories. Certain concepts may, of course, involve a combination of both approaches.

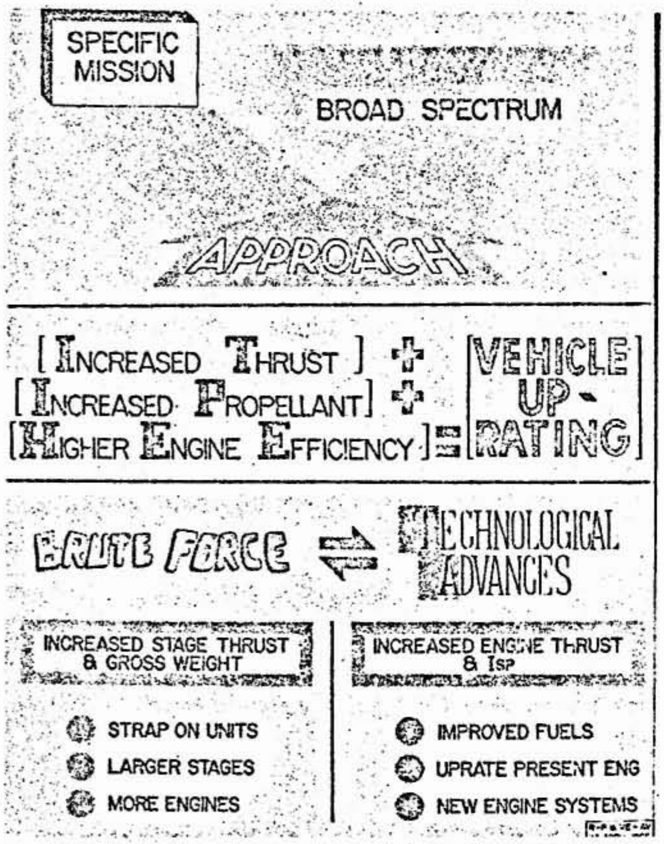


Fig. 2 - Uprating approach

GUIDELINES FOR SATURN IMPROVEMENT STUDIES

To identify particular configurations that may be available within the selected philosophy and approach it is first necessary to establish and outline some specific guidelines.

Although many of the guidelines and ground rules of Saturn Improvement Studies are arbitrary, others are more or less firmly dictated by the primary goals of NASA as they reflect the national commitment of a successful manned lunar landing. With the vast technological abilities being developed, it is only fitting that the improvement programs assume that hardware items and engineering techniques developed under present programs will be utilized to the maximum extent permissible. This philosophy extends to all technical and management areas including design, fabrication, assembly, transportation, launch, and utilization

GUIDELINES

- MAXIMUM USE OF AVAILABLE HARDWARE, FACILITIES AND TECHNIQUES, USING THE FOLLOWING LIMITS:

		FROM	TO
1. STAGE HEIGHTS:	S-IB	80.3'	100'
	S-IC	138'	182'
	S-II	82'	97'
	S-IVB	58.4'	74.3'
2. VEHICLE HEIGHTS:			
	SAT IB	223'	243'
	SAT V	363'	410'

- POST 1970 TIME FRAME, NON-INTERFERENCE WITH APOLLO
- ONLY LARGE PAYLOAD GAINS CONSIDERED (> 10 PERCENT)
- EMPHASIS ON MISSION FLEXIBILITY, MEETING APOLLO SPECIFICATIONS
- DO NOT REPRESENT OR REQUIRED TO MEET APPROVED PROGRAMS

Fig. 3 - Guidelines

of available manpower and funding resources. With this end in view, the first and most important guideline is the maximum use of available equipment and know-how, insuring compatibility of the old with the new (Figure 3). This philosophy in many cases limits the extent of possible launch vehicle modification by affecting the stage and vehicle lengths and levels of engine thrusts. Based on previous studies, a selection of stage and vehicle limits is as tabulated in Figure 3.

No improvement program can, in any manner, interfere with the timely execution of the top-priority Project Apollo within this decade. A direct result of this non-interference policy is the guideline of an assumed post-1970 timeframe for the improvement program.

As previously discussed, the improvement programs arbitrarily consider only those concepts which will produce a significant payload increase. Modifications of the "product improvement" nature would automatically be factored into the launch vehicle as the opportunity arises.

Another basic guideline is that maximum consideration be given to the potential flexibility of missions with the attendant requirement that all vehicles meet Apollo design specifications and reliability standards, thereby encompassing the spectrum with manned ability.

Finally, guidelines have been adopted that improvement programs are undertaken for planning purposes only and do not represent or require approved hardware programs. This allows a variety of concepts to be considered and evaluated as possible candidates for the next generation of Saturn launch vehicles.

SATURN ENGINE IMPROVEMENTS

With the basic paths and rules for vehicle improvement identified, it is now time to examine the available and new propulsion concepts that may be employed. Parameters of the aforementioned "brute force" and "technological" advances pertaining to uprating present Saturn engines, strap-on units, improved fuels and new engine systems will be identified. The various items are displayed in Figure 4.

The H-1 engine, a derivative of an earlier 150,000-pound-thrust Atlas rocket engine, is presently used on the Saturn IB first stage and is to operate at a thrust level of 205,000 pounds. Uprating studies conducted by the engine manufacturer have shown that the practical thrust limit of the H-1 is 250,000 pounds.

The 1520k-pound-thrust F-1 engine powers the Saturn V first stage. Studies conducted by the engine manufacturer have shown that this engine may be uprated to practical limits of 1800k pounds. The first step, 1650k, may be accomplished by installing a new, smaller-diameter, higher-speed turbine on the turbopump system and appropriately increasing the power input. To achieve the 1800k-pound level, a higher-capacity pump would be introduced with the new turbine and, of course, with corresponding increased power input.

The J-2 engine powers the S-IVB stage on the Saturn IB and the S-II and S-IVB stages on the Saturn V. Presently, these engines will have a thrust level of 205k. As a result of uprating studies conducted by the manufacturer, 225k and 250k thrust levels were selected as feasible uprating points. Either level requires extensive fuel pump modification.

Overall vehicle performance can be improved slightly by changing mixture ratio in flight (PMR), thereby increasing or decreasing engine thrust as desired for optimum stage performance. Varying the engine mixture ratio from 5.0 to 5.5 increases the thrust of the 205k engine to 230k, with a small reduction in specific impulse.

High-performance engine concepts envisioned for future Saturn propulsion applications include the high-pressure bell engine and the lower-pressure toroidal aerospike engine concepts. Both concepts have been studied by engine manufacturers. Engine thrust levels of 300k to 600k appear to be feasible for the new-engine concepts. With

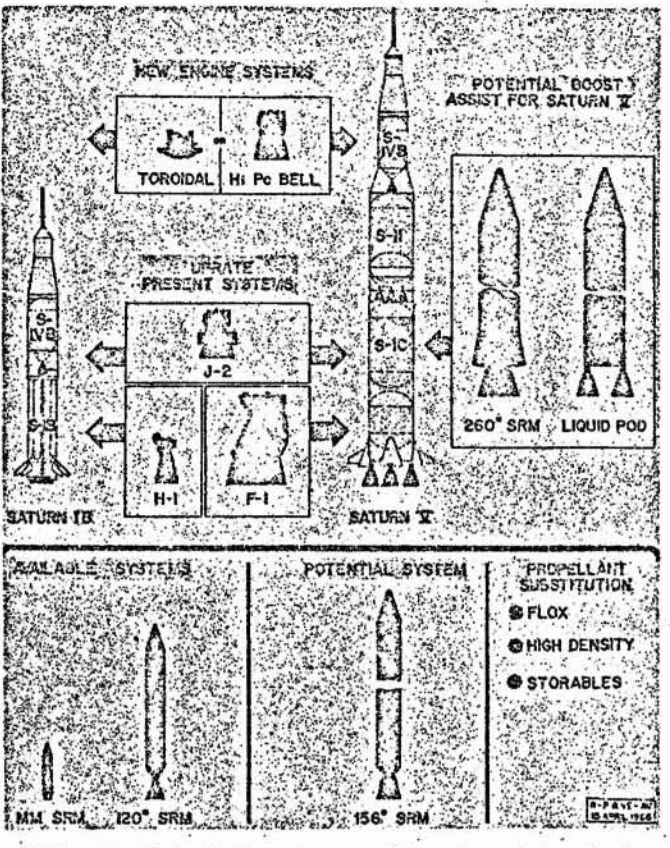


Fig. 4 - Selected engines and boost assist units

higher pressure and better effective expansion ratios, significant improvements in the specific impulse can be anticipated.

Unconventional rocket nozzle concepts have received considerable attention for some time. The toroidal engine concept uses moderately high chamber pressures (about half the pressure of the bell engine) but derives its greatest advantage from its pancake shape. Its torus-shaped combustion chamber and short truncated aerospike nozzle permit relatively high area ratios in a short envelope. This factor becomes important when constraints are placed on stage length. The most significant problems connected with this concept would be expected to occur in the development of the torus-shaped combustion chamber.

PROPELLANT SUBSTITUTION FOR SATURN VEHICLES

The liquid propellant combinations used on today's Saturn vehicles are LOX/RP-1 on the first stages and LOX/LH_2 on the upper stages.

Performance of the booster stages, S-IC and S-IB, can be significantly increased by the addition of fluorine to the oxidizer. From a performance standpoint, fluorine appears very attractive, but problems arise using it in the first stage because of the toxic and corrosive nature of the propellant; however, fluorine appears very attractive when considered for use in upper stages. The disadvantages of the propellant are somewhat reduced because of the smaller quantities involved and the fact that most of the exhaust products are discharged outside the atmosphere.

Other possibilities that have been considered are substitution of storable propellants, such as nitrogen tetroxide as oxidizer with a 50 percent unsymmetrical dimethylhydrazine and 50 percent hydrazine mixture as fuel for the LOX/RP-1 combination. However, in the S-IB or S-IC the gains realized from substitution of storables for LOX/RP-1 do not appear to warrant the expenditure of funds required.

Also under consideration are certain high density fuels that offer the advantage of increased propellant weight with a given stage.

BOOST-ASSIST SYSTEMS

Numerous boost-assist systems have been considered during the Saturn Improvement studies. These include solid rocket motor (SRM) systems and liquid propellant systems. Both basic types of systems have been analyzed sufficiently to determine the performance and relationship of one system versus another. Under consideration are available systems, i.e., systems that are developed, and potential systems, which are systems that are accepted as reasonable potentials.

Of the numerous available systems only two offer significant payload gains. The first of the accepted available systems is the Minuteman first stage motors, which when used on the Saturn IB or Saturn V first stages would be similar to a JATO-type system. This motor is approximately 25 feet in length and 5 1/2 feet in diameter; it develops approximately 200,000 pounds of thrust at sea level.

The second available system considered is the higher-thrust, 120-inch-diameter solid rocket motor. This system is applicable as a "zero stage" on the Saturn IB or boost assist for either the Saturn IB or Saturn V. When used in clusters of four or more, it could possibly be used to replace the first stage of the Saturn IB. The 120-inch motors come in 5- and 7-segment assemblies being 98 and 118 feet long, having thrusts of 1.16M and 1.22M pounds at sea level, respectively.

The potential boost systems include the 156 and 260-inch SRM's and liquid pods. The 156-inch motor is segmented with a selected length and sea level thrust of 105 feet and 2.7 million pounds, respectively. The 260-inch motor is a non-segmented assembly having a peak length of 137 feet delivering 5.5 million pounds of thrust at sea level. Liquid strap-on pods powered by H-1 and F-1 engines have been studied by MSFC for boost assist on the Saturn IB and Saturn V vehicles, respectively. It should be noted that the 260-inch SRM or clusters of the 120-inch or 156-inch SRM's could be utilized as a replacement for the S-IB stage on the Saturn IB vehicle.

SATURN IB IMPROVEMENT

With the rules and the equipment to be used identified, the next step will be to investigate the performance of selected configurations resulting from the application of these methods. The payload quotations are based upon launch from KSC under an azimuth of 72 degrees with direct ascent into a 100-n. mi. circular orbit. The payload is defined as everything above the Instrument Unit which is forward of the S-IVB stage.

The presently configured Saturn IB with an orbit delivery capability of just under 40,000 pounds has an inherent growth capability that more than doubles that of the existing vehicle.

The smaller gains that can be achieved by engine improvements are tabulated in Figure 5, along with a configuration/performance display. These gains employed separately result in payload gains of less than ten percent; however, by increasing the propellant capacity of the first stage, some noteworthy improvements are possible.

From an overall growth point of view, the significant gains are achieved by attaching solid rocket motor boost-assist modules to the first stage. It is this path that the uprating most likely will pursue. A steady progression in delivery capability to earth orbit is seen by increasing the gross weight and/or total thrust of the system (Figure 5). This is readily achieved by utilizing the SRM in various boost-assist modes.

Application of the Minuteman SRM increases the orbital payload capability into the 50,000- to 60,000-pound range. The four Minuteman configurations can achieve 50,000 pounds to low earth orbit and by the addition of four more (8) 60,000 pounds becomes possible.

Progressing to the right of Figure 5, one enters the domain of the 120-inch SRM which has been used so successfully by the Titan III-C program.

The Saturn IB "zero-stage" concept increases the payload capability into the 90,000-pound range. By "staggering" the ignition time of four of the eight H-1 engines on the S-IB stage (4 early in flight and the last 4 near SRM burnout) payloads slightly over 100,000 pounds can be achieved. If only two 120-inch SRM's are used with an increase in first-stage tank capacity (20 feet in length), payloads in the range of 70,000-80,000 pounds are possible.

With flexibility of design, the option of launching with 0, 2, or 4 SRM's could become a reality and, therefore, span the payload spectrum of 35,000-100,000 pounds.

Next is shown the substitution of the S-IB stage with 260-inch full-length solid motor. Although, as mentioned, clusters of smaller motors (120-inch or 156-inch SRM's) could likewise be substituted for the S-IB. The amount of study effort performed on this configuration warrants its special recognition. This vehicle has an orbital payload capability in excess of 90,000 pounds and performs competitively with respect to the four 120-inch SRM "zero-stage" Saturn IB concept.

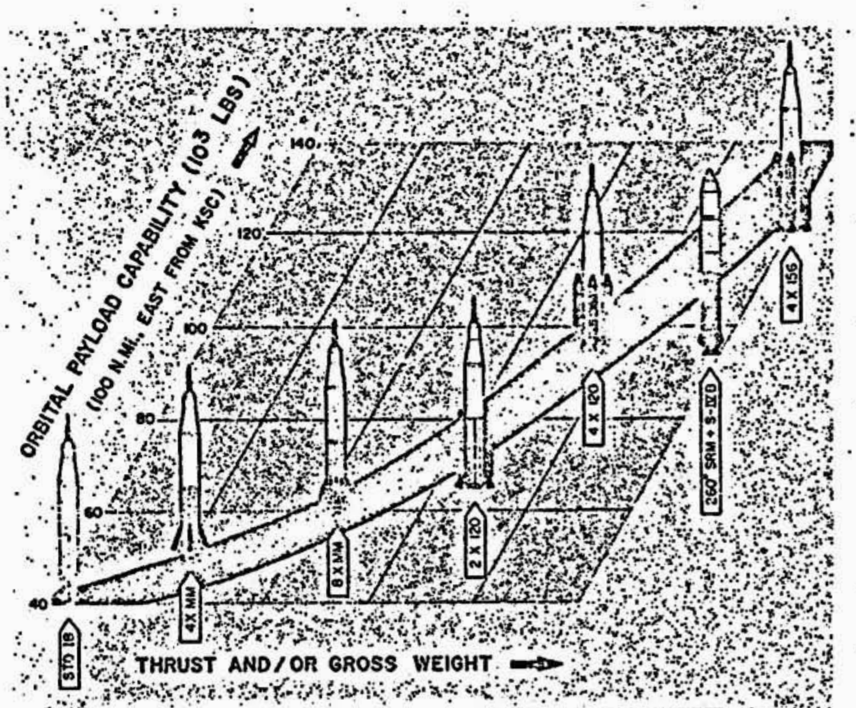
Still further improvement could be achieved by utilizing the 156-inch SRM's, increasing the upper payload range to 120,000 pounds to low earth orbit.

INTRODUCTION TO INTERMEDIATE RANGE

The present capability of the Saturn IB and its growth potential are indicated on Figure 6. Quite logically there is a limit to the increase in payload that may be achieved through reasonable improvement processes, and this limit is seen to fall far short of even the present orbital capability of the Saturn V. This gap between vehicle capabilities has been termed the "Intermediate Range" and a discussion of various methods of producing launch vehicles with payloads within this region is now in order.

INTERMEDIATE RANGE COVERAGE BY SELECTED VEHICLES

Figure 7 shows two possible paths into the Intermediate-range-payload region. The first possibility is trying to force the Saturn IB performance up by some means other than those previously discussed. More likely, however, would be the utilization of a launch vehicle derived from the present Saturn V. In this case the philosophy of the Intermediate launch vehicle would be using various combinations of the stages of the three-stage Saturn V vehicle. This offers several significant advantages. The expense of parallel vehicle development is eliminated as is the number of systems and subsystems. Greater utilization of developed stages and technology provides for minimum program costs.



PERFORMANCE ATTAINABLE BY ENGINE UPRATING

ENGINE THRUST (LB)		PAYLOAD GAINS (LB) TO EARTH ORBIT
H-1	J-2	
STD	250K	2 800
250K	STD	11 800
250K	250K	15 400

Fig. 5 - Saturn IB growth spectrum

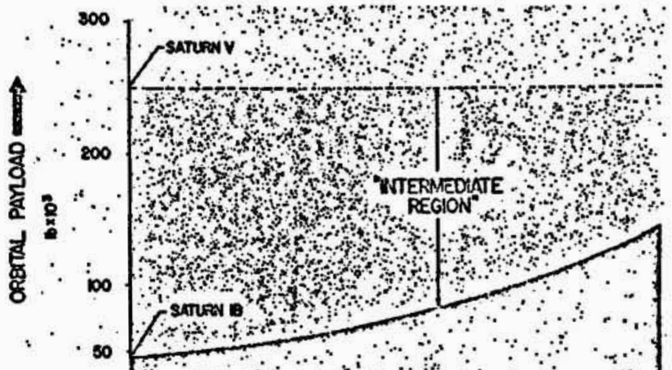


Fig. 6 - The intermediate payload region

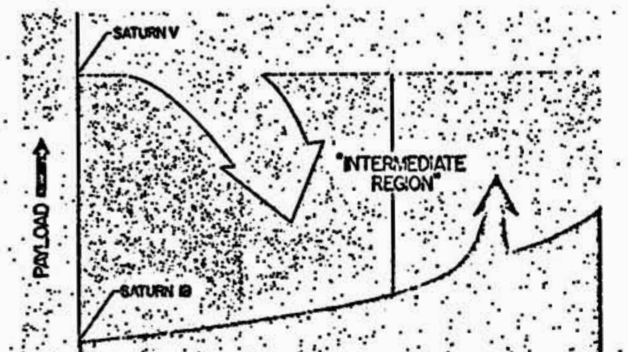


Fig. 7 - Spanning the intermediate payload region

The configurations shown on Figure 8 are potential vehicles utilizing stages from the Saturn V vehicle, which can fill the orbital payload gap between the Saturn IB and Saturn V launch vehicles. These vehicles are shown in order of descending payload capability.

The first and most logical vehicle, consisting of the first (S-IC) and second (S-II) stages of the Saturn V vehicle, has an orbital payload capability in excess of 250,000 pounds. One can simply remove engines from the stages in various combinations, i.e., 4 F-1's/3 J-2's, 4-4, 5-3, 5-4, 5-5, etc. This technique spans a payload range down to 165,000 pounds without

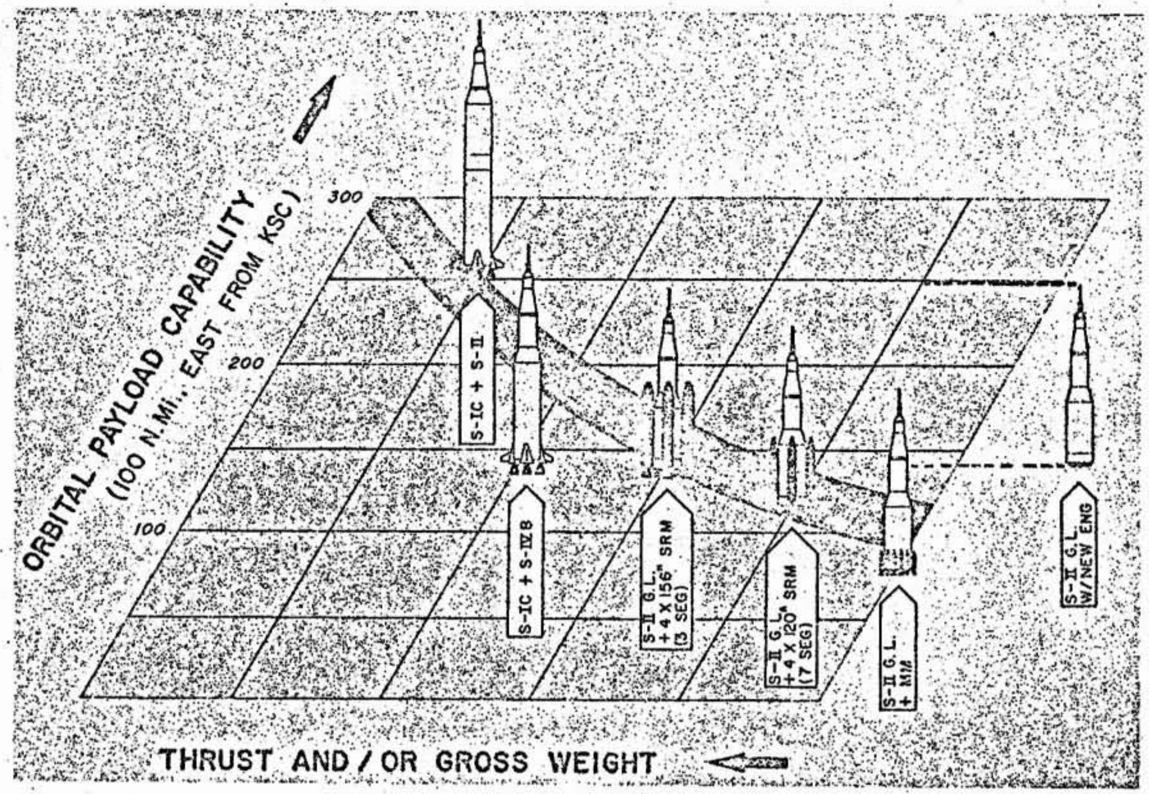


Fig. 8 - Selected intermediate vehicles

having to ballast the full payload that potentially could be delivered. Whether the cost of programming engine removal would exceed the cost of engines saved requires a close look.

Another interesting configuration is the first and third stages of the Saturn V. Again engine combinations of 3, 4, and 5 F-1's in the first stage span the spectrum of 75,000-135,000 pounds. Certain advantages of this configuration are the common 260-inch-diameter IU with respect to the S-IVB stage and the unmodified interface with the Apollo spacecraft, should it be the payload to be delivered to earth orbit.

The remaining configurations are the most intriguing of the potential Intermediate vehicles. These involve the concept of "ground launched S-II" employing the S-IVB as an upper stage. To utilize the present S-II stage with the J-2 engine, boost-assist modules are required to achieve the desired payload ranges. By "strapping-on" from 6 to 12 Minuteman SRM's the payload range achievable is 60,000-75,000 pounds.

More attractive are the 120-inch SRM's utilized either in a boost-assist or "zero-stage" mode (J-2's igniting later in flight). By varying the number of "strap-on's" from 2 to 4, a payload range of 90,000-115,000 pounds appears feasible. The "zero stage" would probably be more desirable in that the J-2 could then operate in a more desirable altitude range.

A potential extension of this configuration would be the utilization of 156-inch SRM's, thereby increasing the orbital payload capability into the 110,000-140,000-pound range.

The eventual evolution of the ground launched S-II concept would consist of the S-II and S-IVB stages with increased propellant capacities utilizing advanced engines. These advanced engines could either be toroidal or bell delivering a total thrust in the S-II compatible with utilization as upper stages on an advanced Saturn V configuration to be discussed presently. This configuration could deliver payloads in the range of 100,000-150,000 pounds to earth orbit depending on thrust per engine and the number of engines elected for the dual application.

AN INNOVATION

Considering the many inherent advantages of the ground launched S-II, this unique configuration deserves a closer look. By placing the two-stage Intermediate vehicle atop a truss structure platform, as a substitute for the first stage, both this configuration and the Saturn V may be fired from a single launch complex.

As shown in Figure 9, both of the stages are elevated to their normal height and oriented to their normal position relative to the Service Tower and umbilicals by use of the truss structure platform. With this arrangement, no relocation of the umbilical systems on the

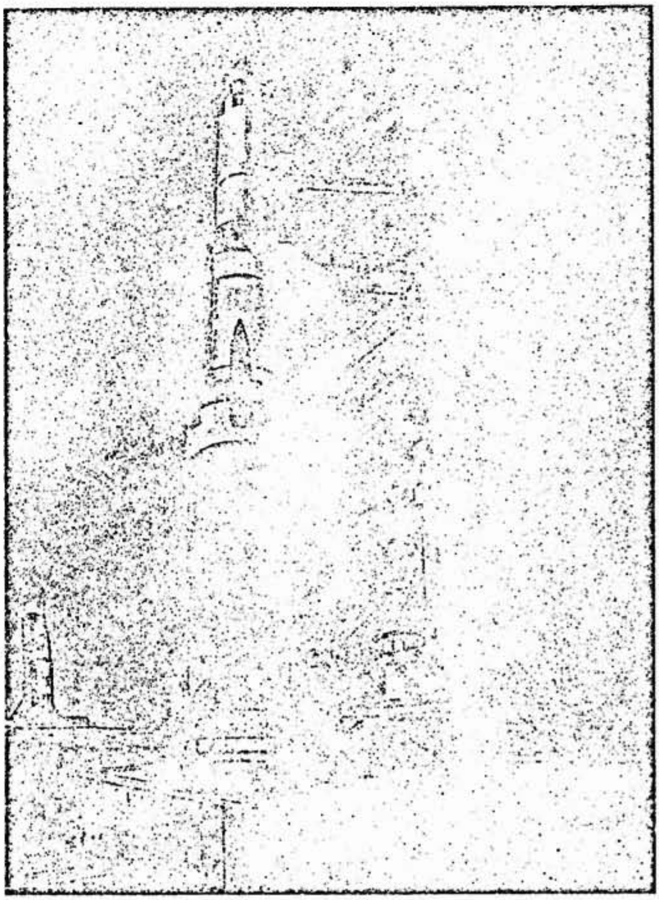


Fig. 9 - The new innovation

Mobile Launcher Tower is required and no change would be required of the hundreds of lines on the tower.

A further advantage of this system is that no additional technology or stage hardware development would be required beyond that requested for an uprated Saturn V vehicle. No additional manufacturing facilities, equipment for stage assembly, checkout systems compatibility, or launch facilities would be required. Also noteworthy is the fact that the launch vehicle can be assembled in the Vertical Assembly Building at the same levels as the present Saturn V.

A suggested variation of this innovation is shown in Figure 10. In this instance, four 7-segment 120-inch-diameter SRM's have been attached to the S-II stage and the S-IVB stage has been eliminated. Operating as a "zero-stage" vehicle, this configuration can place on the order of 90,000 pounds in low earth orbit.

SATURN V GROWTH POTENTIAL

Since we have seen by utilizing Saturn V stages that the lower and intermediate payload ranges can be spanned, it is now time to examine the upper reaches obtainable with the largest of the Saturn family. The Saturn V with its lunar injection capability of 95,000 pounds has an earth orbital payload capability in excess of a quarter of a million pounds. The tremendous industrial complex assembled to accomplish the lunar mission has an inherent growth capacity that lends itself well to improving the performance capability of the Saturn V vehicle.

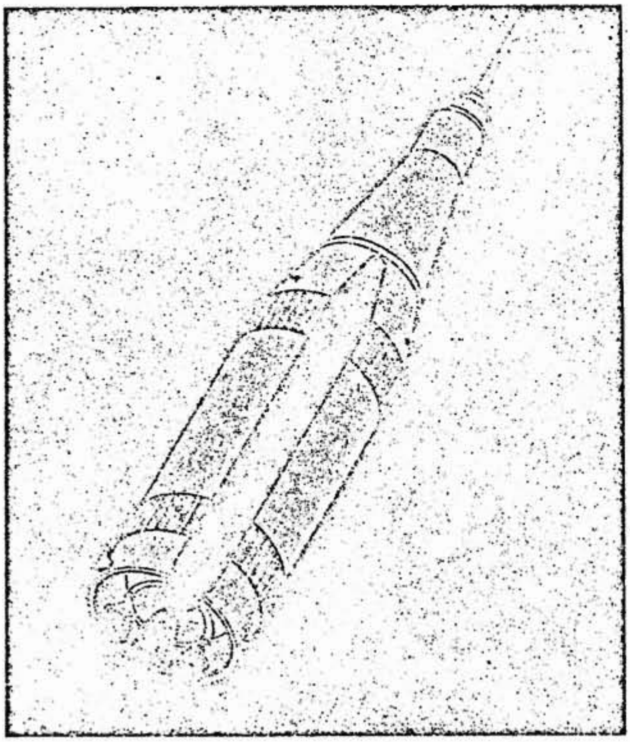


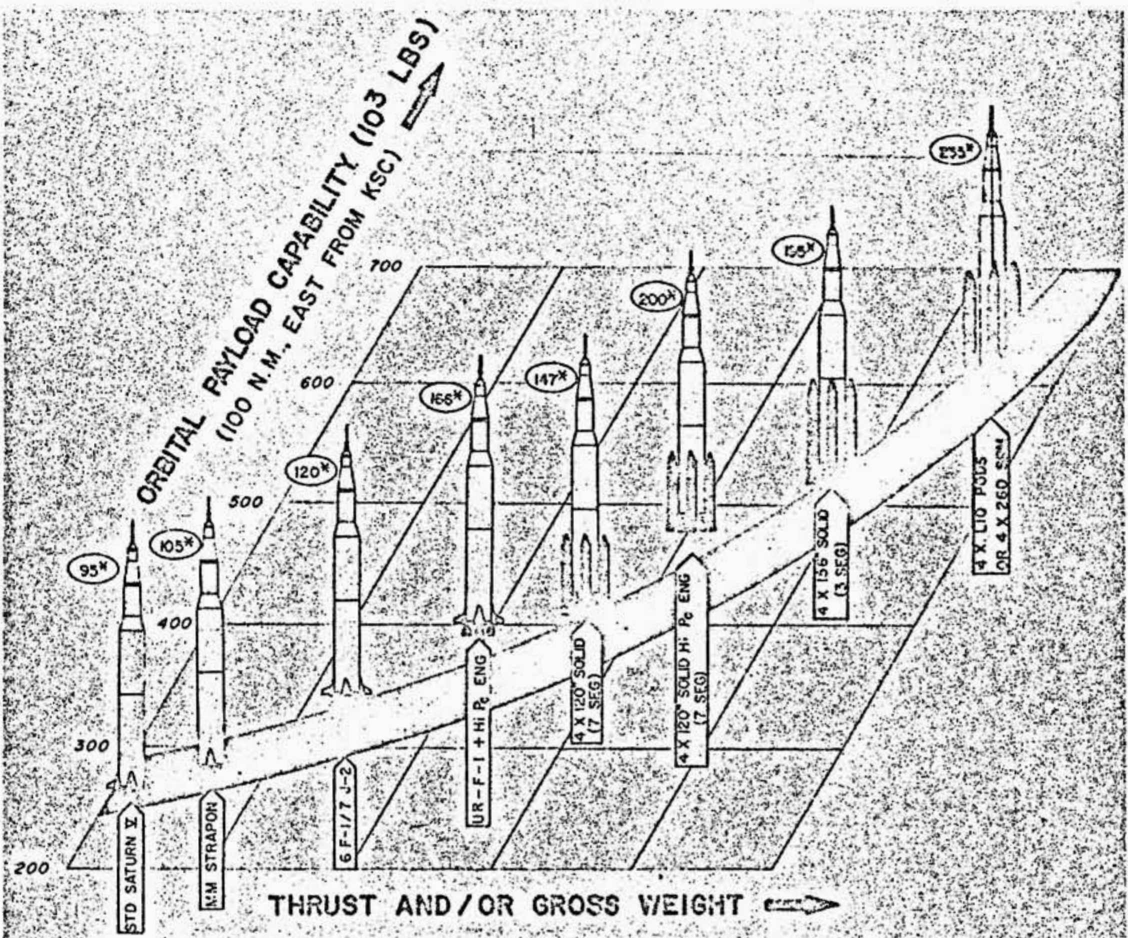
Fig. 10 - S-II ground launched zero single stage

As in the case of the Saturn IB, there are numerous growth paths that can be undertaken to improve the performance capability of this vehicle system. In a broad sense, these involve increased thrust and gross weight which is reflected in larger propellant capacity; Figure 11 demonstrates this.

By uprating the thrust and efficiency of the existing F-1 and J-2 engines, separately or in combination, performance gains from 16,000-25,000 pounds can be realized, as illustrated in the table of this figure. However, as shown above in the configuration-performance display it is evident the major growth potential comes about by utilizing boost-assist modules.

Progressing up the chart (Figure 11) from the referenced standard Saturn V vehicle, the first uprated configuration is that using first-stage Minuteman motors. As discussed with the Saturn IB, these are more of the JATO nature, the gains being relatively small and hardly within the ten percent ground rule.

The next configuration incorporates one additional standard F-1 engine in the first stage with two additional standard J-2 engines in the



PERFORMANCE ATTAINABLE BY ENGINE UPRATING

ENGINE THRUST (LB)		PAYLOAD GAINS (LB) TO LUNAR INJECTION
F-1	J-2	
STD	250 K	7,200
1.8 M	STD	16,700
1.8 M	250 K	25,000

* LUNAR INJECTION PAYLOAD CAPABILITY (10^3 LBS)

Fig. 11 - Saturn V growth spectrum

second stage. A lunar injection payload gain over the standard vehicle of approximately 25,000 pounds can be achieved. However, by uprating the thrust and efficiency of the standard number of F-1 and J-2 engines, either separately or in combination, sizeable payload gains can be realized as reflected in the table at the bottom of Figure 11.

The remaining "non-boost-assist" system (fourth configuration) is a highly efficient one. This concept utilizes uprated F-1 engines in the first stage and advanced high-pressure engines (bell or toroidal) in the upper stages resulting in an attractive gross weight at lift-off and payloads of 165,000 pounds and 385,000 pounds to lunar transfer and earth orbit, respectively. An interesting fall-out of this configuration is the previously discussed ground launched vehicle, whereby the second and third stages become an intermediate payload delivery system.

Moving on to the right of Figure 11, it becomes evident that the major growth potential comes about by utilizing boost-assist modules, beginning with four of the 120-inch SRM's, progressing to four 156-inch SRM's and finally to a system utilizing either four 260-inch liquid propellant pods with two standard F-1 engines per pod or four 260-inch SRM's. The payload spectrum progresses to payloads exceeding 600,000 pounds to low earth orbit with corresponding lunar injection capabilities approaching a quarter of a million pounds. If one trys to maintain a total vehicle height of 410 feet and stays within realistic payload densities, the trend is to force a growth in the first-stage propellant (core and boost-assist modules) and corresponding thrust increases to maintain a minimum thrust-to-weight ratio at lift-off of 1.25. At the same time, one finds that the upper stages (LOX/H_2) prefer to retain the same stage sizes as the current vehicle if the thrust levels are fixed. Therefore, under the guidelines and assumptions, a constrained optimum does exist. With the proper foresight in design, versatility could be achieved by being able to launch a given vehicle with 0, 2, or 4 of the strap-on systems. Whether or not "modularity" could be achieved, utilizing a specific or family of boost-assist systems, would require detailed analysis along with cost evaluations. It can be seen that the payload capability of the Saturn V can be increased considerably by ingenuity and manipulation of state-of-the-art hardware and techniques.

THE EVER-INCREASING IMPROVED SATURN V

A closer examination of the liquid or solid :ocket motor strap-on Saturn V concept is interesting. The method of increasing the first, or S-IC, stage capability by adding propellant and engines in the form of strap-on pods has introduced a configuration whose potential can be a subject of considerable discourse, indeed far too much to cover within the limits of this paper. However, a quick view of some potentials is revealing. It has been seen that within the established guidelines the solid rocket motor or the liquid strap-on pod concept is a vehicle that can deliver payloads to low earth orbit in excess of a half-million pounds. If the guideline restricting the vehicle length is relaxed, it is found that, with the introduction of the new high-pressure engines in the upper stages and uprated F-1 engines in the first and liquid pod stages, the payload capability may well approach or exceed one million pounds to earth orbit. If selected third stages are coupled to these vehicles, there results a number of high payload mission capabilities out of earth orbit. The three configuration concepts of Figure 12 illustrate the potentials of new third stages. The first utilizes a 33-foot-diameter hird stage that takes advantage of the increased ehicle capability in the form of greater propellant without becoming unduly long. The second in the series is the introduction and utilization of a nuclear stage. The high performance of the nuclear stage can further increase the injection capability of the improved Saturn vehicle. The third configuration carries the liquid pod concept to the second stage and now introduces the possibility of a larger diameter third stage. This two-stage-pod-utilization design would bring the orbit payload capability to an excess of one million pounds. By taking advantage of a larger diameter third stage, without getting into "hammerhead" design problems, the overall vehicle length would become more manageable. In this design the upper loads would be carried through the strap-on-pod systems. Maintaining this continued strap-on philosophy permits the basic core stages still to be built within the present manufacturing facilities, except for the third stage. If the new third stage is to be a nuclear stage, then new manufacturing facilities would be required regardless.

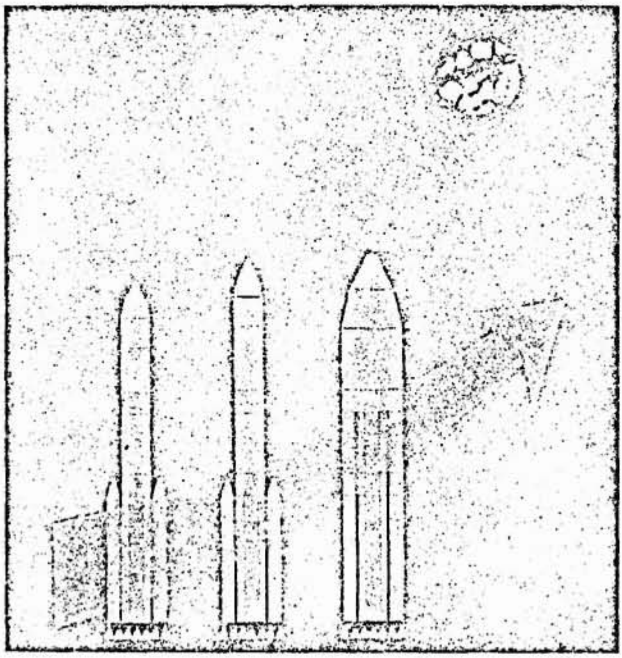


Fig. 12 - The ever increasing Saturn V

It should be emphasized that these concepts are only projections of the configurations discussed in this paper, but do indicate that, with imagination, this growing, ever-increasing uprated Saturn V has potentials that time and study efforts to date have not fully explored. Already it has been found that the next generation of vehicles to follow the Saturn V will have to be much greater than previously examined. The ever-increasing Saturn V can be uprated, within the system's state-of-the-art, to capabilities that were considered but a couple of years ago the goal of the next generation of launch vehicles.