BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 11057

SUBJECT: Performance of Low Cost Saturn SIVB with UA1207 Solid Rocket Motors as Interim Launch Vehicle - Case 237

DATE: November 27, 1970

FROM: J. J. Schoch

ABSTRACT

A low cost Saturn SIVB combined with clusters of United Technology Center UA1207 1,400,000 lb thrust solid rocket motors (SRM) could serve as an interim launch vehicle to be used before the space shuttle becomes operational. The payload such a vehicle could deliver into a 100 nm 28 degree easterly orbit was calculated for several launch configurations made up of four to eight SRM as the first stage, either one or two SRM as the second stage, and the SIVB as the third stage. The analysis took into account the aerodynamic load limitations of the SIVB but did not fully consider other aerodynamic effects that might result from the different configurations. Results indicated payloads ranging from 88,000 lb for a four SRM first stage and one SRM second stage to 121,000 lb for six and two. If the present SIVB aerodynamic load limits can be exceeded, payloads as high as 148,000 lb may be obtained with an eight and two SRM configuration.

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(NASA-CR-116079) PERFORMANCE OF LOW COST SATURN S-4B WITH UA1207 SOLID ROCKET MOTORS AS INTERIM LAUNCH VEHICLE (Bellcomm, Inc.) 10 p

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MEMORANDUM FOR FILE

INTRODUCTION

The United Technology Center (UTC) UA1205, a 120 inch diameter solid rocket motor (SRM) made up from five, ten foot diameter segments was developed for use in pairs as stage zero of the Titan IIIC launch vehicle and has been used successfully for over five years. UTC has recently completed the first phase of development, including four full scale tests, of an increased thrust version of the UA1205, designated the UA1207, which is made up from seven SRM segments and includes several improved components.

The McDonnell Douglas Astronautics Company (MDAC) has recently considered the possibility of combining their SIVB with either of these SRM to provide an interim launch vehicle that could be used before the Space Shuttle is ready. The SIVB stage in such a vehicle would only be used for sub-orbital boost and its engine would be required to execute only one burn. Total flight time would be ten minutes compared to six and a half hours for the Apollo mission. These lower flight requirements would permit simplifications in the propulsion system and replacement of the IU with a simplified electronics system which would reduce stage burnout weight by 4500 lb. Because of this reduced complexity and weight, it could be produced at less cost and is hence designated "low cost SIVB". MDAC claims that by eliminating a number of the more critical components of the present SIVB, the low cost SIVB would have a higher reliability.

The MDAC study showed that four UA1205 solid rocket motors with the low cost SIVB as a second stage could deliver about 50,000 lb into a 100 nm, 28° easterly orbit, and four UA1207 SRM could deliver 68,000 lbs. In the MDAC study the SRM cluster had one SRM located in the center with three others surrounding it. This arrangement was necessary so that ignition of the center rocket could be delayed to prevent incurring excessive maximum aerodynamic load (q_{max}).

The present study is an extension of this work and was undertaken to find out how much payload might be delivered by the low cost SIVB and clusters of UA1207 SRM.

CONFIGURATIONS STUDIED

Ten vehicle configurations were considered. All of them consist of three stages and the last stage is, in each case, the SIVB. The first stage has from four to eight UA1207 SRM; the second either one or two. The various configurations of the first two stages are illustrated in Figure 1 and are also shown in the left columns of Table 1. The combinations 4+1, 5+1, 5+2, 6+2, 7+2, and 8+2 were considered.

Some combinations had to be excluded because of either insufficient or excessive thrust to weight ratio. For instance since the MDAC study showed that, when using four SRM with the SIVB, ignition of the fourth SRM had to be delayed in order to keep the q_{max} value within allowable limits, the high initial thrust to weight ratio combinations 5+0, 6+0, etc were excluded a priori. The combination 4+2 was excluded because its initial thrust to weight ratio was so low that the payload was no better than that of the 4+1 combination. Most combinations are considered in more than one configuration. For instance, configurations 3 and 4 are both 5+2 combinations but the SRM's of the second stage are attached and staged differently. In configuration 3 it was assumed that one SRM would be attached to each side of the SIVB and in configuration 4, the two second stage SRM would be surrounded by the five first stage units.

Thrust vector control (TVC) for the solid rocket motors is achieved by fluid injection through groups of valves located in the four quadrants of the nozzle exit cone. For this reason, the first stage SRM clusters were arranged whenever possible symmetrically with respect to pitch and yaw directions. Configurations 2, 4, and 8 having five, five, and seven first stage SRM respectively, lack this symmetry and therefore a more complex TVC system may be required. However, for the present study it was assumed that such an arrangement would be feasible.

The different frontal areas resulting from these configurations are included in Table 1.

The next two columns show how the weight penalty for connecting the different SRM's between each other and to the SIVB were taken into account. It was assumed that an outer SRM would be fastened to an inner one by attachment weighing

225 lb, the same weight as is required to attach the zero stage SRM to the Titan III core.[1] Therefore in configuration 1 four such devices are required to connect the outer four SRM to the central one which is the second stage. In the more complex configurations, one such attachment was assumed whenever two SRM were in contact. Seven such devices are required for configuration 5 and 8, twelve for configurations 6, 7, and 10, and sixteen for configuration 9.

Structure for connecting the stages was considered to be of the form of a truncated skirt weighing about 8000 lb.[2] This weight value was used for the interstage between second and third stage for configurations 1 and 2 and the interstage between first and second stage for configurations 3 and 7. The interstage weight between first and second stage was increased to 12,000 lb to account for the more complex shape necessary to connect the SIVB to two SRM in configurations 5 and 10. Similarly the interstage between the second and third stage was increased to 12,000 lb in configurations 3, 5, 7, and 10 to allow for a possible need to stiffen the SIVB. This value was further increased to 16,000 lb in configurations 4, 6, 8, and 9 in which the interstage connects the SIVB to two SRM.

The following ground rules were observed.

a. Thrust-time shapes and weights for the SRM were taken as the nominal for the seven segment UA1207 SRM.

b. Upon firing, each SRM burns 477 lb of propellant before lift-off thrust is developed. For the trajectory calculations, this amount was subtracted from the propellant weight of all first stages.

c. The standard SRM has a separation system weighing 1238 lb. After burnout of the main rocket this system provides a lateral thrust that pushes the spent SRM outward. In those configurations where such a mode of separation is unnecessary, the weight of the separation system was subtracted from the SRM burnout weight. For instance, such a lateral separation is only necessary for the first stage SRM's of configurations number 1, 2, 4, 6, 8, and 9 for the second stage SRM's of configurations number 3, 5, 7, and 10.

TRAJECTORY

For all configurations the trajectories start with a short vertical rise for about five seconds. Then, after an appropriate tilting maneuver, which is determined by the computer in such a manner as to give maximum payload, the vehicle follows a gravity turn trajectory (zero angle of attack) for the rest of the first stage burn. At this point the altitude is still too low (the dynamic pressure too high) to depart from a gravity turn, but on the other hand, continuing the gravity turn for the complete burn of the second stage decreases the payload considerably. The following compromise was followed. During the first part of the second stage burn the vehicle follows a gravity turn trajectory, and then switches to a linear tangent steering mode when the drag is below one thousand pounds. Some gain in payload may also be obtained by changing the oxygen/hydrogen mixture ratio in the SIVB; therefore it is assumed that the J2 engine is operated to give a thrust of 235,000 lb at an Isp of 425 sec for the first 225 seconds of third stage flight, and the mixture ratio is then decreased to give 175,000 lb thrust at an Isp of 431 seconds for the remaining part of the burn.

The same drag coefficient was used for each configuration and was based upon available information for the Saturn V.

RESULTS

Table 1 shows the payloads and the values of q_{max} for a 100 nm easterly orbit of 28.5 degrees inclination. Arrangement of SRM clusters and the SIVB comprising the various vehicles is shown on Figure 1. The q_{max} limit of the SIVB is 740 lb/ft^2; therefore, if that limit could not be exceeded, configurations number 2, 7, 8, 9, and 10 would have to be excluded or the trajectories modified at the expense of payload. If a q_{max} limit up to 800 lb/ft^2 could be tolerated then configurations number 7 and 8 could be included.

There seems to be little difference between the payloads of the different configurations having the same number of SRM's. For instance there is practically no difference in payload between configuration number 3 and 4. It appears that the additional drag penalty of configuration 3 is almost compensated by the assumed structural penalty in configuration number 4. It should be noted that in configuration number 3 the combination of second and third stage is wider than the

first stage. This occurs also with configuration numbers 5, 7, and 10. Such a hammerhead configuration could result in serious aerodynamic instabilities. It is also noted that the SIVB stage is about half the length of the UA1207 which is about 112 ft long.

In configurations number 4, 6, 8, and 9 a similar though not quite as severe aerodynamic situation exists during second stage burn. The second stage with two SRM's has about the same diameter as the third stage in one plane but is only half as thick in the plane 90 deg perpendicular to it. This may require some fairing between the second and third stages. This fairing could be made an integral part of the structure connecting the two stages. The drag coefficient that was used in the trajectory computations does not take these changes in shape into account.

POSSIBLE IMPROVEMENTS FOR FUTURE STUDIES

Although not considered in this study, it is noted that the undesirable effects of hammerhead configurations and the asymmetrical arrangement of the first stage SRM could be eliminated by replacing the one or two SRM used as second stage with a larger number of shorter rockets, having an equivalent thrust on top of the first stage cluster. For instance, the one SRM used as second stage in configuration 2 could be substituted by three shorter ones and the two in configurations 4, 6, 8, and 9 by four or more shorter ones using less segments but having the same total thrust. The number and the length of these shorter SRM would depend both on the configuration of the first stage SRM and the thrust requirement.

It is also noted that q_{max} could be reduced by lowering the thrust level through use of a smaller number of segments in some or all of the SRM. In addition the burn could be shaped appropriately.

CONCLUSIONS

Attaching UA1207 SRM's to a low cost SIVB results in a series of launch vehicles having orbital payloads in the so-called intermediate category. Based on a 28 degree inclination 100 nm easterly orbit, payloads ranging from 88,000 lb for a 4+1 configuration to 121,000 lb for a 6+2 configuration may be obtained staying within the allowable q_{max} limits for the SIVB. If these limits can be exceeded, then payloads up to 148,000 lb are obtainable with a 8+2 configuration. There may be some aerodynamic problems because of the shape of the vehicle. The feasibility of using the present TVC system when the first stage cluster is unsymmetrical requires further study.

ACKNOWLEDGEMENT

The suggestions of Mr. A. S. Kiersarsky regarding the attachment of the SRM is gratefully acknowledged.

1013-JJS-klm

J. J. Schoch

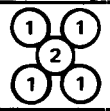
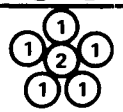
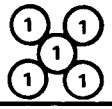
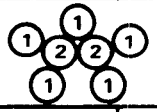
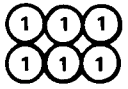
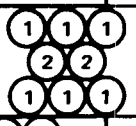
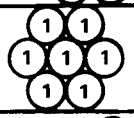
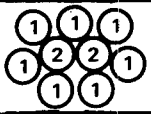
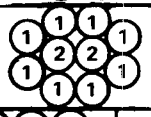
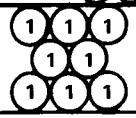
REFERENCES

1. Discussion between Mr. A. S. Kiersarsky, Bellcomm; and Mr. Schade of the Martin Co. in Denver, Colorado.

2. Discussion between Mr. A. S. Kiersarsky, Bellcomm; and Mr. Robert Cielnicky at Douglas, Huntington Beach, California.

TABLE I

PERFORMANCE OF LOW COST S-IVB WITH UA1207 SOLID ROCKET MOTORS

	DISPOSITION			DRAG AREA		CONNECT. STRUCTURE		PAYLOAD 100 N. MI. EASTERLY ORBIT	Q_{MAX} LB/FT^2
	STAGE 1	2	3	STAGE 1	STAGE 2	STAGE 1	STAGE 2		
1			S-IVB	706	370	4 x 225	8000	88,024	729
2			S-IVB	706	370	5 x 225	8000	103,722	882
3		2 S-IVB 2		840	530	4 x 225 + 8000	12000	104,608	547
4			S-IVB	706	370	5 x 225	16000	104,941	556
5		2 S-IVB 2		570	530	7 x 225 + 12000	12000	121,417	689
6			S-IVB	706	370	12 x 225	16000	120,647	680
7		2 S-IVB 2		706	530	12 x 225 + 8000	12000	135,519	790
8			S-IVB	706	370	7 x 225	16000	135,193	790
9			S-IVB	940	370	16 x 225	16000	147,353	866
10		2 S-IVB 2		780	530	12 x 225 + 12000	12000	148,447	880

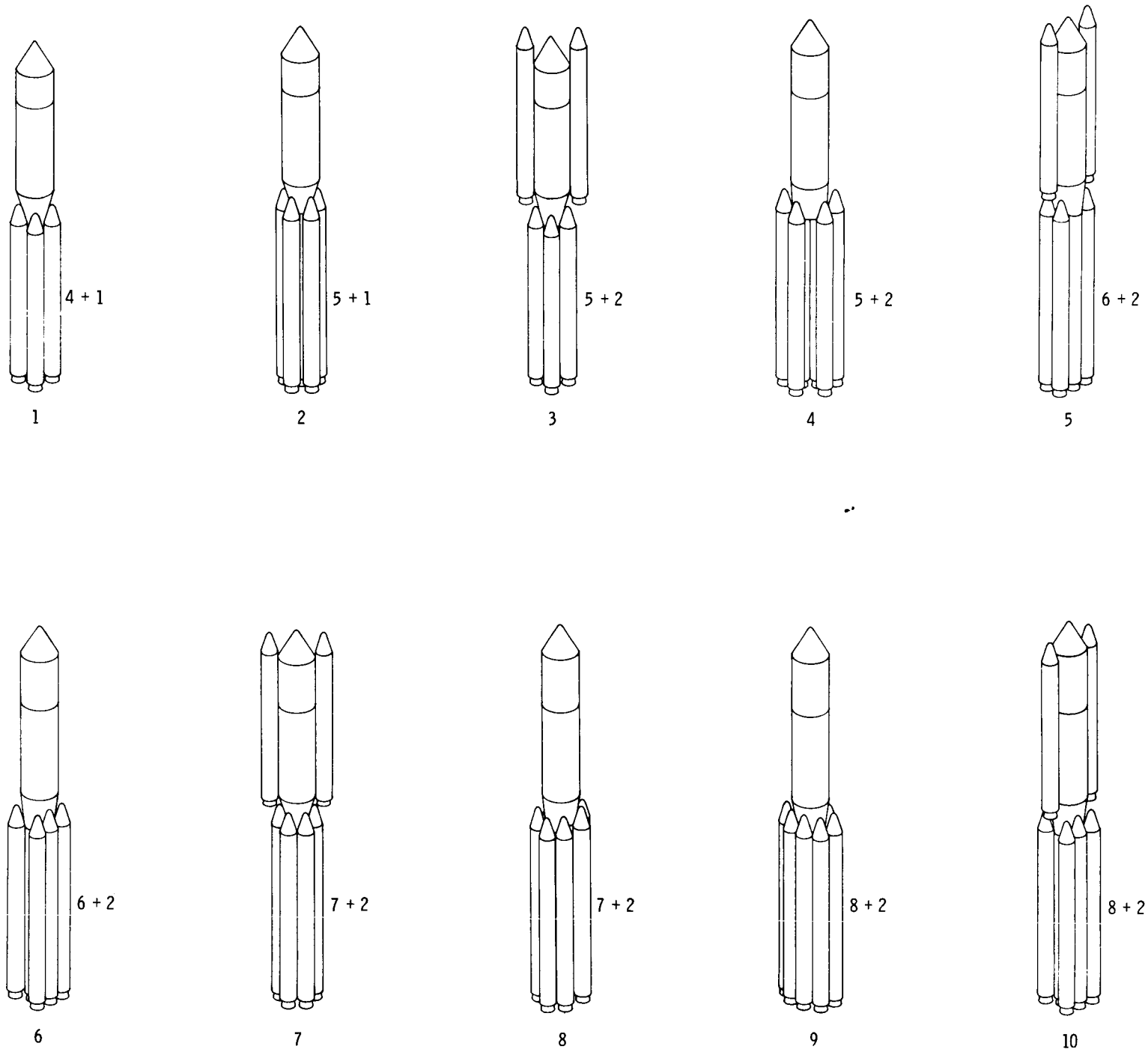


FIGURE 1 - LAUNCH VEHICLE CONFIGURATIONS FOR LOW COST S-IVB WITH UA 1207 SOLID ROCKET MOTORS