BELLCOMM, INC.

SUBJECT: Saturn Improvement Studies - A Summary - Case 330

DATE: October 28, 1966

FROM: G. W. Craft

ABSTRACT

The final presentations on the FY 66 Saturn Improvement Studies were made by Boeing, Chrysler, Douglas and North American at MSFC on October 3, 4, and 5. This paper reports on those presentations and comments very briefly on some of the more interesting points brought out in the studies. It is the opinion of the author that the selection of optimal configurations for uprated launch vehicles must also depend heavily on mission planning philosophy and on launch considerations, specifically, facility and operations costs as well as launch rate expectations.

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MEMORANDUM FOR FILE

Presentation of Study Results

Boeing, Douglas, Chrysler, and North American made their final presentations at MSFC on the Saturn Improvement Studies for FY 66 on October 3, 4, and 5. These studies have been conducted under contract with MSFC, represented by Mr. R. Davies for Saturn V derived vehicles and by Mr. M. Page for Saturn 1B based configurations. NASA Headquarters MSF/MTV was represented at these presentations by Messrs. D. Schnyer and J. Burke. MSF/MTV coordinates these studies and companion studies by KSC on corresponding facilities for launch of these vehicles. Bellcomm attendees of the final presentations were D. Valley and the author. Earlier phases of these studies have also been reported by C. Bendersky and A. W. Starkey. The speakers and supporting contractor personnel represented some nineteen companies.

Boeing led off the presentations with descriptions of S-1C boosted MLV Saturn INT (Intermediate, or derated versions of Saturn V) configurations and uprated MLV Saturn V configurations. The Systems Analysis Contractor for each configuration considered in these studies was the manufacturer of the first liquid stage. NAA's presentation which followed Boeing's therefore covered MLV Saturn INT assemblies that eliminate the S-1C from the Saturn V stack-up. Strap-on solids are regarded as either a "zero" stage or augmentation to the liquid "core" if the core is ignited at liftoff. The NAA presentation also covered second stage support for the Boeing-studied configurations. On the second day, Chrysler presented MLV Saturn 1B configurations which retain the S-1B basic stage. Douglas followed this with a description of a configuration which replaces the S-1B stage of Saturn 1B with a cluster of five 120" SRMs. Douglas' presentation also included their activities in support of the other contractors where derivatives of the S-IVB were planned for upper stages.*

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*Except as noted in the discussion, summary descriptions of these configurations have been included in earlier reports:
Mid Term Review of Saturn 1B Improvement Studies at MSFC May 18, 1966, A. W. Starkey, 5/20/66, and
Mid Term Review for Saturn V Improvement Studies at MSFC July 6, 1966, G. W. Craft, 7/12/66.

The presentations of each company generally included descriptions of each configuration with emphasis on special design features and variation on existing practice and hardware. Cost summaries were given and included estimates of R&D, manufacturing, testing, launch facility and operating costs to support a total program of 30 missions with the indicated configuration. Payload/mission capability was detailed for a broad range of orbits and trajectory. Operating constraints and strategy, implementation schedules, and phase-in were also discussed based on minimum modification of existing support elements and facilities and an early go-ahead. In each presentation, a relatively brief summary reviewed criteria for comparison and identified familial configurations of graduated capability and cost. Recommendations were related mainly to suggestions for further study of notably sticky problems and of potential mission requirements for the vehicles.

The morning of the third day was devoted to an Executive Summary of the presentations. In this session, the 260" SRM boosted MLV Saturn 1B-5a was included (this configuration has been the subject of a previous report by Douglas), and the Martin Company commented on the most significant aspects of launch facilities for each configuration.

Discussion

The direct approach to uprating vehicle capability is to add more of the same. Exemplary of this approach with the Saturn V is the MLV Saturn V-3B. In this configuration, the first stage is stretched to provide more propellant capacity. Higher thrust for lifting the heavier vehicle is obtained by uprating the F-1 engines which have a significant margin for further development. Six engine S-1C's were investigated during the studies and eliminated because of the extensive modifications they would necessitate to the boat-tail section of the stage and to ground facilities. By similar reasoning, the perfectly feasible approach of increasing stage diameters was eliminated at the outset.

The uprating approach for upper stages, aside from lengthening the tanks, is to replace the J-2 engines with a new generation of LOX/LH_2 burning engines. Two approaches are suggested: toroidal aerospike engines and high combustion chamber pressure bell engines. The toroidal aerospike engine has a significant advantage in its short axial length, and in its simplicity. This allows the stage tanks to be stretched probably some 10 ft or more before the effect results in an overall lengthening of the stage. Since the toroidal aerospike engine is gimballed in the plane of its maximum diameter, adjacent clustered engines can be located on very close centers with hot gas recirculation controlled by flexible heatshields similar to those presently in use on the S-II stage. Finally, this type of engine has an expansion ratio that is characteristically altitude compensating.

A full size model of the toroidal aerospike engine (scaled for about 300K lbs thrust) was demonstrated for the Improvement Study attendees by Rocketdyne. It is about 12 feet in diameter and, with a greatly truncated center spike, only about four feet high. The hollow spike section contains propellant turbopumps, plumbing and gimbal bearings for the engine. The spike and combustion chamber are regeneratively cooled by hydrogen and turbine exhaust is bled into the low pressure volume aft of the spike truncation. Scale model firings have reportedly demonstrated the feasibility of most of the design features of this engine.

A new approach to the design of a high pressure bell engine was also demonstrated in full scale model form by Pratt & Whitney. Somewhat less exotic than Rocketdyne's approach, the P&W entry, nevertheless, exhibits some impressive innovations. Designated RL-20, it is a restartable LOX/Hydrogen engine similar in size and general appearance to the J-2. Aside from the high pressure combustion chamber, its main feature is a two position nozzle skirt extension. With the skirt in a retracted position, the engine takes up less axial length in the stacked vehicle. The engine can be operated in this configuration using the regeneratively cooled stub nozzle to provide expansion for low altitude operation. At high altitude, or after staging, the nozzle skirt would be extended (in 15 seconds) to increase its expansion ratio. Bleed hydrogen is used to cool the extended skirt and is expanded to local ambient pressure in miniature nozzles at the large nozzle's outlet plane. Nearly as much thrust results from this effect as would be obtained in burning the hydrogen. Pump turbines are mounted between a preburner and the film-cooled (hydrogen) main chamber where final O_2 is added. The preburner, main combustion chamber arrangement provides a progressive combustion effect which may reduce the possibility of combustion instability.

The INTermediate vehicles -17, -18.5(S), and -18.7(S) are of interest mainly as lesser members of an uprated Saturn V family. That is, given one of the uprated configurations, the corresponding INT configuration would be an obvious contender for concurrent development. Launching the INT vehicles, however, not only requires the use of a busy LC-39, but entails a considerable facilities cost over and above the cost of modifications for the parent configuration. In view of a foreseeable reduction in the continued need for Saturn 1B missions and depending, of course, on the relative launch rates in respective payload ranges, it may be more economical to use one of the MLV Saturn 1B configurations operating from LC-34 and/or 37 than an INT vehicle.

Among the Saturn 1B based vehicle configurations, the 260" boosted S-IVB (MLV Sat 1B-5a) was not emphasized in the main presentations, partly at least, because the 260" solid motor represents a relatively large departure from hardware that is currently available. An alternative, the MLV Saturn 1B-16, using five clustered 120" solids beneath an S-IVB, was reported on, but proved to be an inefficient weight lifter ($/lb) and a small one (52-62,000 lb to low earth orbit).

The Executive Summary did include the MLV Sat 1B-5a. It is nominally capable of carrying 95,500 pounds to low earth orbit: about the target for uprated versions of the Saturn 1B. In addition, it retains a significant margin for further uprating by stretching the S-IVB. However while 1B-5a is clearly the most economical vehicle over a thirty mission program, the initial investment cost associated with it is also higher than for any of the other 1B configurations. An important aspect of this cost is associated with the launch facilities and operations required for handling and launching so large a vehicle.* Follow-up on this aspect as well as continuing OART development of 260" solid technology may contribute to a revision of these comparisons.

Conclusions

The Saturn Improvement Studies have served the purpose of identifying a number of feasible vehicle configurations possible with only relatively minor excursions from current technology and hardware. The costs, extent of necessary modifications and mission capability, associated with these configurations provide only a part of the criteria for selecting among them. The unescapable factors still undefined are the mission requirements and launch rates. Nowhere is this more apparent than in a consideration of launch system modifications, particularly where it is desired to support a combination of existing and proposed vehicle configurations. While a launch vehicle "stable" can be defined and assembled, its appropriateness and efficiency remain dependent on the definition of a philosophy based on at least a general statement of long range objectives in space. In translating such objectives into mission hardware, a firm attitude will have to be taken on the relative advantages of a full spectrum of payload capability and the simplicity of uniform operations and equipment.

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*This is the subject of a recent Bellcomm TR 66-330-2, "A Concept For Handling and Launching Large Solid Rockets", dated September 30, 1966, by A. W. Starkey and the author.

It seems clear at this point that the development costs associated with any of the MLV configurations and with ground facilities for manufacturing, handling and launching demand their use for a large number of missions. A second perhaps obvious point is that the smaller that mission lead time is made for the sake of program flexibility, the greater is the need for vehicle standardization.

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