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

SUBJECT: Comments on the J-2S Engine Impacting on the Saturn V Program - Case 103

DATE: December 4, 1968

FROM: C. Bendersky

ABSTRACT

The present trend of the J-2S engine as impacting on the Saturn V is discussed based primarily on source data obtained at the "J-2S Improvement Study Mid-Term Review" held at MSFC October 23 and 24, 1968. The following trends appear valid:

1. Retrofit of J-2S on available Saturn V's is not warranted.

2. The J-2S program might better be divorced from the Saturn V option and married to a future low cost booster concept.

The proceedings at the meeting are also reported.

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MEMORANDUM FOR FILE

The writer attended the mid-term review of the J-2S Improvement Studies held on the 23 and 24 of October, 1968 at MSFC, Huntsville, Alabama. The J-2S is a major supporting development activity designed to provide uprated, improved, and simplified propulsion for use in the Saturn V H_2/O_2 stages. The FY68 effort consists of continued experimental activity on the J-2S, plus "impact studies conducted by the Saturn V stage contractors." These impact studies will define the stage integration development requirements to implement installation of J-2S engines on follow-on buys of Saturn V (post SA-515) and possible retrofit on those existing vehicles available at the time of J-2S qualification.* The McDonnell Douglas Astronautics Division (MDA) is responsible for the impact study on the SIVB, North American Rockwell Space Division (NAR/SD) for the SII stage, and IBM for the Instrument Unit (IU). Boeing is responsible for the overall impact on the Saturn V, flight and payload calculations, and overall coordination (and reporting) of the studies much as in present Saturn V practice. The J-2S engine is under predevelopment by the North American Rockwell, Rocketdyne Division (Rocketdyne).

The mid-term briefing was concerned primarily with a summary of mission oriented trade studies by Boeing and descriptions of proposed engineering designs and modifications to the SII, SIVB, and IU stages. In addition Rocketdyne presented the latest J-2S test status. Cost and resources impacts were not discussed and are scheduled for a later meeting to be held in December.

The highlights of the presentations are described below.

1.0 Mission Profiles

1.1 It was concluded that a three burn J-2S greatly improves the mission flexibility of Saturn V. The restart and reduced chilldown requirements allow use of transfer orbits which can allow synchronous orbits at any longitude and eliminate the penalty for direct injection to "low earth orbits." (A two burn SII stage can inject 240,000 lbs payload to 300 n.m. by use of a Hohmann transfer from 100 n.mi. compared to 165,000 lbs payload single-burn direct injection mode.)

*Earliest retrofit was ground ruled at SA-508. A more realistic time span was considered to be SA-511.

1.2 Figure 1 lists the performance of a J-2S equipped Saturn V for three missions; (1) a basic lunar orbit rendezvous (LOR) Apollo trajectory, (2) a three burn synchronous, and (3) a 300 n.m. low earth orbit (LEO) using a 2 stage Saturn V (SIC/SII). Also shown is the LOR payload of a "baseline" SA-511 vehicle. As shown in Figure 1, the J-2S LOR improves the translunar injection capability by 10%.*

1.3 In a retrofit mode, it was judged that retrofit uprating of the thrust structure of the SIVB and SII was not practical in order to accept the full 265,000 lbs thrust of the J-2S. Therefore, the J-2S would be used in a "thrust limited mode" at the 235,000 lbs thrust J-2 level.

Preliminary results show that the retrofit LOR payload increase over the reference SA-511 is reduced to 5.7% from the previous 10%. (The increase is only due to the I_{sp} improvement of J-2S).

2.0 SIVB Impacts - Follow on Saturn V

MDA has defined the effects of the simplification aspects of the J-2S (Figure 2). As shown the list is impressive. Figure 3 shows the estimate of increased SIVB reliability for a J-2S SIVB in both an LOR and Synchronous mission mode. The reduction of failure modes, actual mission loss, and launch delay failure modes is impressive.

3.0 SII Impacts - Follow on Saturn V

NAR(SD) has similarly defined the simplification aspects of the J-2S. The results are similar to that for the SIVB. Figure 4 shows the estimate of the increased SII reliability for the LOR mode. Again the improvements are impressive.

4.0 IU Impacts - Follow on Saturn V

The impacts of the J-2S installation in the SII and SIVB stages on the IU are truly minor and in context with "Product Improvement." It is noteworthy that as a result of the SA-502 flight, improved analysis and strengthening of the IU structure provides confidence that the present production IU is capable of a 110,000 lbs payload in an LOR mode.

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*This performance increase results primarily from SII stage operation at higher thrust and SIIB operation at higher I_{sp}.

5.0 J-2S Test Status

Testing on two complete engine builds have essentially demonstrated the preliminary model specification requirements of idle mode, childown time, high thrust, and I_{sp}. One engine build has been operated, twice, at longer than full J-2 duration requirements. This latter build had greater than 95% production type parts. A third build now in progress will have 99% production hardware. The test program is progressing on schedule with no unforeseen problem areas visible.

One point was uncomfortable. The J-2S as designed is a completely different engine than the J-2. As such no major components are interchangeable.

6.0 Retrofit

The retrofit study is less than 50% complete and it therefore may be premature to make judgments at the present time. Nevertheless the following comments appear valid.

The ground rules for the J-2S equipped Saturn V (J-2S/SAT V) specify no flight test for vehicle qualification. It is proposed that the first J-2S/SAT V be flown unmanned with payload. As stated previously in a retrofit mode the J-2S/SAT V would operate, derated, at the thrust level of the present J-2 and in an LOR mode might increase payload 5.7%. However, even in an unmanned mode the first flight of a new engine system on both the SII and SIVB stages should be heavily instrumented a'la a R&D vehicle. In addition the flight reserves and margins should be more conservative than say SA-511. In other words the potential payload increase may quickly evaporate in the real world application.

The ground rule of an unmanned flight of a retrofit J-2S/SAT V should be carefully reviewed. In the time span of flights up to SA-515 (for example mid 1974), the two main candidates for unmanned Saturn V flights are the orbital workshop and advanced lunar exploration. The cost of these payloads would be large and it is questionable that an untried J-2S/SAT V should be committed for these uses.

Another major impact on retrofit is the proposed J-2S qualification program (Figure 5). Full qualification is scheduled for January 1, 1972. As far as known no concurrent production of flight suitable engines is planned. Lead times for engine delivery are at least 18 months. If a series type program is approved, the earliest flight engines would not be available until mid 1974. A retrofit J-2S/SAT V would not be available until mid 1975. For earlier delivery, engine production must be initiated sooner with concomitant increased funding.

In summary, retrofitting J-2S engines on existing Saturn V vehicles does not appear a reasonable option.

7.0 General Comments

As in many cases, the ground rules established for the impact studies became less valid (or invalidated) due to unforeseen events. The high probability of the Saturn V production program being gapped during the 1972/1973 period severly impacts upon the J-2S program. The J-2S program still requires of the order of $60 $\bar{M}$ for qualification by January, 1972. None of the hardware of the proposed qual program, (6 complete engine assemblies and 15 engine builds*) is or should be proposed for use on flight vehicles. The production lead time of J-2S is one-to-two years less than that for reinstitution of Saturn V production. Therefore, the engine could be initiated at a later time. In any event the J-2S qualification program could probably be stretched out without impacting on the reactivation of Saturn V. Indeed a stretch-out could reduce the overall direct cost of the J-2S program.

On the other hand the J-2S <u>is not</u> required for the mission flexibility desired for the Saturn V. The J-2 engine can provide the multiple restarts desired for candidate synchronous and 200-300 mile low earth orbit missions. The restarts are presently limited by system helium supply and tank repressurization requirements. These can be satisfied by addition of supplementary helium pressure vessels.

The J-2S particularly on the SIVB stage is apparently one of the keys in obtaining a new low cost booster. All NASA first stage prime contenders (260 in-solid, 156-in solid cluster, SIC, pressure fed liquid) could effectively use a flexible low cost SIVB second stage. The J-2S may assist in promoting economies in stage fabrication, checkout, launch operations; etc. and indeed may be the <u>key</u> to a cheap NASA vehicle. It therefore might be unwise to attach this program to that of a rejuvenated Saturn V.

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*An engine build is an engine assembly of new or reworked components which are estimated to cost the same as an engine constructed of brand new hardware.

The above judgements may be altered after the vehicle costing, scheduling and resources data become available. Nevertheless in this writers opinion the whole J-2S program cost schedule, overall aims etc. should be given brand new scrutiny and be reintegrated into today's environment.

C. Bendersky

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Attachments

BASIC VEHICLE CHARACTERISTICS

	BASELINE* SA-511	BASIC VEHICLE LOR	BASIC VEHICLE SYNCHRONOUS	BASIC VEHICLE LEO
PAYLOAD (LBS)	100,078	110,135	65,792	239,090
LOAD CRITERIA				
MAX Q (LBS/FT^2)	699	709	723	746
G'S AT MAX Q	2.08	2.09	2.1	2.13
MAX G	4.15	4.14	4.23	4.41
HEIGHT (FT)	363.5	363.5	363.5	363.5
CONTROL MODE	GIMBALED ENGS. & APS**DURING S-IVB COAST	GIMBALED ENGS. AND APS** DURING S-IVB COAST	GIMBALED ENGS. AND APS** DURING S-IVB COAST	GIMBALED ENGS. AND APS** DURING S-II COAST
HEATING				
AERODYNAMIC (AHI) ($FT - LBS/FT^2$)	46.43×10^6	+5.74%	+9.17%	+14.82%
PROPELLANT LOADING (LBS.)				
S-IC	4,577,113	4,577,113	4,577,113	4,577,113
S-II	970,441	970,441	970,441	970,122
S-IVB	227,991	229,097	219,330	
THRUST (LBS.) MAX				
S-IC	7,610,064	7,610,064	7,610,064	7,610,064
S-II	1,149,635	1,318,850	1,318,850	1,318,850
S-IVB	231,012	237,500	265,000	

* LOR FLIGHT

** AUXILIARY PROPULSION SYSTEM

FIGURE 1

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY	J-2S/S-IVB IMPROVEMENT STUDY S-IVB SIMPLIFICATION	CHART NO 6119 DATE: 10-23-68 SPEAKER: R.J.Cielnicky

NET DELETIONS

- 150 LEAK PATHS
- 33 MEASUREMENTS
- 15 VALVES
- 16 POSITION INDICATOR SWITCHES
- 2 ACTUATION CONTROL MODULES
- 1 DISCONNECT
- 1 PRESSURE SWITCH
- 7 REDLINES

FIGURE 2

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

J-2S/S-IVB IMPROVEMENT STUDY
S-IVB RELIABILITY

CHART NO 6110
DATE: 10-23-68
SPEAKER: R.J. Cielnicky

	STRD J-2 CONFIGURATION	J-2S EQUIPPED CONFIGURATION
LOR STAGE (LESS ENGINE) CRITICALITY	29,070	25,312
LOR TOTAL FAILURE MODES (F/M)	1,056	860
LOR "ACTUAL MISSION LOSS" F/M	180	126
LOR "LAUNCH DELAY" F/M	505	450
SYNCHRONOUS STAGE (LESS ENGINE) CRITICALITY	42,840	36,563
SYNCHRONOUS TOTAL FAILURE MODES	1,073	871
SYNCHRONOUS "ACTUAL MISSION LOSS" F/M	192	135
SYNCHRONOUS "LAUNCH DELAY" F/M	505	450
ENGINE CRITICALITY	14,000	14,000

FIGURE 3

J-2S IMPACT ON S-II RELIABILITY

(LOR MISSION)

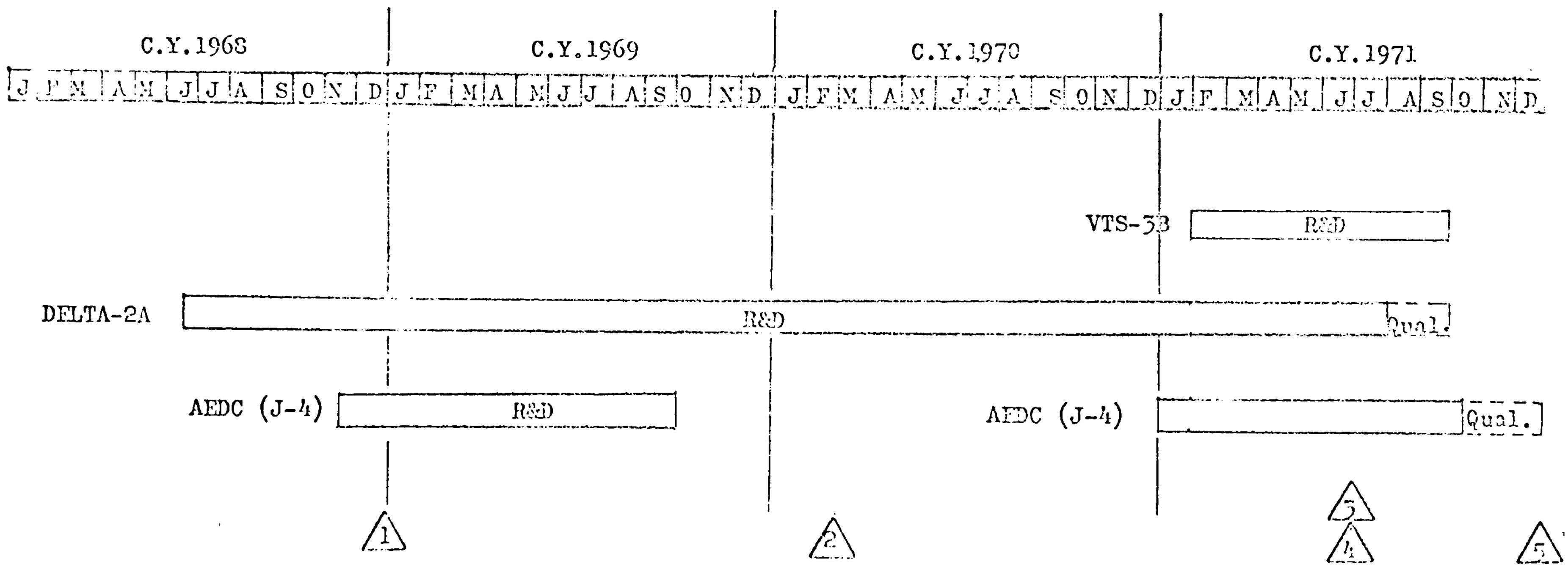
- REDUCED FAILURE MODES
  - 144 SINGLE POINT FAILURE MODES ELIMINATED THAT COULD CAUSE MISSION LOSS.
  - 201 SINGLE POINT FAILURE MODES ELIMINATED THAT COULD CAUSE A MISSION ABORT

- RELIABILITY BENEFITS
  - THE PREDICTED MISSION RELIABILITY WOULD INCREASE FROM .95 TO .96
  - OF RELIABILITY VERIFICATION TEST REQUIREMENTS COULD BE REDUCED IF SYSTEM/COMPONENT RELIABILITY WERE REAPPORTIONED (COST SAVINGS)
  - FAILURE ANALYSIS EFFORT REDUCED BECAUSE OF SYSTEM SIMPLIFICATIONS OR DELETIONS

FIGURE 4

FIGURE 5

J-2S ENGINE TEST PLAN



MAJOR MILESTONES

1. INITIAL DEMONSTRATION OF J-2S FEATURES AT SEA LEVEL AND SIMULATED ALTITUDE.
2. COMPLETE ENGINE DEMONSTRATION TEST SERIES.
3. COMPLETE COMPONENT QUALIFICATION.
4. COMPLETE RELIABILITY DEMONSTRATION.
5. COMPLETE ENGINE QUALIFICATION.