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# *Memorandum*

TO : All Astronauts

DATE: OCT 17 1967

FROM : CB/C. Duke

SUBJECT: Status of the LM Descent and Ascent Propulsion Systems

1. Descent Propulsion Systems (DPS)

a. A meeting was held about two months ago to discuss the effects of the engine throttling constraints on the guidance schemes used by MIT for the lunar mission. Representatives from FOD, G&C, MIT, TRW, GAEC, and MSC propulsion were in attendance. MIT presented the nominal DPS profile which was

(1) Deorbit burn - start at 10% for 26 sec. and then fixed throttle position (FTP) for 7 sec.

(2) Shutdown

(3) Start up for powered descent - 10% for 26 sec.

(4) Full thrust burn for 307 sec.

(5) High gate phase - 52% to 58% for 120 sec.

(6) Low gate phase - 58% to 27% for 147 sec.

(7) Hover phase - 24% for 120 sec.

There are some potential engine problems associated with (1), (4), (5), (6), and (7) above. It was pointed out by GAEC that during the deorbit burn if the crew decided to override the throttle-up command and perform the entire burn at 10% thrust level, it was possible to overpressurize the supercritical helium (SHe) tank. The engine constraint here is that the maximum allowable burn time at 10% thrust is 92 sec. with the SHe tank pressurized to 1300 psig at start of burn. Don't think this is any real big deal.

In the full thrust phase of the powered descent, the engine is presently constrained to operate at a fixed throttle position. It would be extremely more efficient fuel wise and give the guidance people more flexibility in hitting the high gate, if the engine could be throttled about 5% around the FTP. TRW is presently engaged in a test program to determine if the shallow throttling scheme is feasible. After nine firings, there doesn't appear to be a problem.

In the high gate phase, MIT has abided by the engine constraint that no throttling is allowed between 60% and the FTP. Since they need a 6% thrust band, they have selected 52% to 58%. TRW says that the engine Isp performance is increased by 1% if the minimum thrust called for in the high gate phase is raised from 52% to 55%. So to allow MIT their 6% range with a minimum thrust of 55%, TRW will investigate raising the 60% throttle limit. Also during this phase, if the guidance commands a thrust greater than 58%, the engine goes to full thrust for a minimum of 2 seconds. This problem is also present during the low gate phase. Due to the thermal characteristics of the ablative thrust chamber, TRW has a hazy constraint on operation of the engine at the FTP level after the long FTP burn. TRW will undertake a program which will more precisely define the capability of FTP burns after the long FTP burn.

A similar problem arises if an abort is required during the powered descent. Assuming the DPS is working properly, MIT states that an abort during the first 150 seconds of the powered descent calls for shutdown of the DPS, reorientation of the s/c and restart of the DPS at the FTP. Between 150 seconds and touchdown the scheme calls for DPS throttle to FTP and burn to depletion. However, the present engine constraint during an abort calls for a maximum allowable burn at FTP of only 2 seconds. This figure is an "out of the air" one and in my opinion is next to worthless. TRW is to determine more realistically engine ablative chamber constraints for abort burns at FTP.

b. As far as I can determine, the DPS has had only one hardware problem in the past few months. A failure of a flight type fuel-helium heat exchanger occurred at White Sands. This failure was caused by a side panel letting go. The panel was apparently weakened during cold flow when water was allowed to freeze in the heat exchanger at GAEC. The cold flow process has been changed to prevent a recurrence.

Seal leakage problems, notably LM-1, continue to plague us. Lots of people working this one.

2. Ascent Propulsion System (APS)

After many months of wandering in the dark, a new day may be breaking for the APS. For nearly a year now, it has been apparent that the ascent engine injector had a stability problem, was not compatible with the thrust chamber and that the fabrication process was poor. BAC finally last June admitted troubles existed and embarked on a program to eliminate the problems. This program itself sort of wandered aimlessly until MSC decided to start a parallel development on the injector. The parallel contractor is Rocketdyne. A summary of our present status follows:

a. BAC has tried a number of different injector designs in a rather extensive bomb test program. Two designs appear to give good stability.

The first is an injector with a 3-legged $1\frac{1}{2}$ inch baffle with an acoustic cavity in the injector face. This acoustic cavity gives acoustic damping of the unstable mode. The second design also incorporates the 3-legged baffle with a $\frac{1}{2}$" deep circular hub 4" in diameter around the injector center. The baffle is cooled with fuel; however, the hub is uncooled. BAC wants to go with an injector incorporating both designs but no decision has been made yet. As far as performance goes, they'll meet the minimum Isp of 306.3. Compatability of either design has not been determined as yet. BAC still suffers from fabrication problems and schedule slippage. As an example, a schedule published September 1 was a month behind on October 1. It takes BAC at least 70 days to build up an injector, whereas Rocketdyne can do the job in 25 days. At the last program review, BAC top management finally appeared concerned and guarantees they'll stay on schedule.

b. Rocketdyne is going full blower on their program. They have three designs under consideration. These are called the triplet, mixed doublet and the unlike doublet, and the names relate to how the fuel and ox are injected. I am not an artist so if you want more detail on exactly what each looks like, come see me and I'll show you a picture.

The Rocketdyne test program is in full swing as is their manufacturing process. They are beginning to get some preliminary performance data on the triplet design Isp of 309 or so and on the unlike doublet about 313 Isp. In the compatability area, they are experiencing thrust chamber gouging on all three designs which is unacceptable. The mixed doublet design was so bad on the gouging that it has been dropped from consideration. A redesign effort is in work which is expected to cure the gouging. The redesign is not simply a fix like plugging holes but consists of hardware changes.

In the stability area, Rocketdyne has had no troubles at all. They have bombed both the triplet and the unlike doublet and both have recovered in milliseconds so I am confident they have a design which will give stable operation.

Rocketdyne appears hungry for the job and is impressive in their ability to stay close to an ambitious schedule. Which way we'll go on an injector hasn't been decided yet. Assurance has been given that we'll have a stable engine on LM-2 either BAC or Rocketdyne.

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