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R. A. LARSON

REPLY TO
ATTN OF

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FROM : FM2/Landing Analysis Branch

SUBJECT : DPS throttle oscillations during descent

References:

1. Memorandum 70-FA-T-29 by Howard W. Tindall, Jr., "DPS throttle oscillations during descent," dated June 10, 1970.

2. Bellcomm memorandum by John A. Sorenson, "Linear Stability Analysis of LM Rate-of-Descent Guidance Equations Case 310," dated June 25, 1970.

Reference 1 gives a good review of the early discussions held to determine the cause of the DPS throttle oscillations during the rate-of-descent portion of the Apollo 11 and 12 lunar landings. As pointed out in the reference, several items were considered, including modifying the onboard computer program to remove the spacecraft rotational effects from the LM accelerometers.

In reference 2, John Sorenson of Bellcomm presents the results of a "Z-transform" analysis which further describes the causes of the oscillations. During the same time period, the Guidance and Control Division, the Mission Planning and Analysis Division (MPAD), and MIT have been actively pursuing this problem. MPAD has programmed the computer logic in an off-line closed-loop simulation so that individual parameters could be varied and the results analyzed. Typical results are presented in figures 1 and 2. Figure 1 compares the response of the throttle for the present value of Lag/Tau for throttle lags of 0.2 and 0. The throttle lag of 0 is considerably more stable. Figure 2 compares the effect of Lag/Tau for throttle lag of 0.2. The Lag/Tau of 0.17 provides a stable system. As results became available, the Flight Crew Support Division made the IMS available to check out the conclusions with a more accurate simulation. The correlation between the MPAD results and the IMS was good. As the data was received, discussions were held with Allan Klumpp of MIT. He ran similar cases on the all digital simulation at MIT. He confirmed the conclusions reached by MPAD and the IMS.

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Results from various simulations have been in general agreement, so conclusions arrived from the simulation data should sustain a reasonable level of confidence. The simulation results can be used to select program constants which will assure the most stable condition. There are two erasable constants and one fixed constant which may be varied to effect the stability of the system. One of the erasable constants, Taurod, determines the magnitude of guidance commands required to change the altitude rate of the vehicle.

Since the response time is of great importance, this number should be as small as practical. Therefore, this constant should remain at 1.5 sec. The second erasable constant, Lag/Tau, adjusts the guidance commands for the time delays required to execute the commands. This number was .41333 for Apollo 11 and 12; however, a value of .17 provides a much better response, minimum overshoot, and stabilizes the system. The fixed constant, throttle lag, represents the time constant for the engine response to commands. From engine ground test and flight data, the engine time constant has been approximately .05 to .08 sec. The Apollo 11 and 12 flights used a .2 for this constant. If the Lag/Tau and throttle lag are both too large, this leads to a system which is only marginally stable. Flight data indicates lightly damped oscillations which were probably excited by rotational effects. Removing the forcing function by compensating for the rotational effects makes the system less likely to be excited. However, by choosing the proper Lag/Tau and throttle lag, the inherent stability will be greatly enhanced. Since throttle lag is a fixed memory constant and the system can be made stable with the current value (0.2), it is not mandatory that this number be changed. For Apollo 15, the throttle lag should be removed from the program. Therefore, the only change recommended for Apollo 14 is to reduce the Lag/Tau to 0.17. With this change, the Apollo 14 rate-of-descent program will be adequate for the landing.

Wells m/Bolt
for James H. Alphin

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(See attached list)



