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Memo

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SUBJECT: LM PGNCS Software Performance with a Failed Attitude Hold or Auto Mode Control Discrete

I. Summary

LM PGNCS software performance is evaluated with the mode control switch in the AUTO, ATT. HOLD and OFF positions for each of the four possible single bit failures of the auto and attitude hold mode control discretes. The evaluation is then repeated assuming that the DAP can not operate in the idling mode while "AVERAGE G" is running, as suggested in PCR 303. A comparison of these two preliminary evaluations indicates that the proposed DAP modification has several undesirable effects and does not warrant the extensive testing necessary to flight qualify it.

II. Nominal Operation

The nominal values of the attitude hold mode control discrete, bit 13 channel 31, and the auto mode control discrete, bit 14 channel 31, corresponding to the three mode control switch positions are displayed in Table 1.

MODE CONTROL SWITCH POSITION	BIT 13 CHANNEL 31	BIT 14 CHANNEL 31
AUTO	1	0
ATT. HOLD	0	1
OFF	1	1

TABLE 1 - Nominal Values of Bits 13 and 14 in Channel 31

Bits 13 and 14 are both checked in the DAP "CHEKBITS" subroutine and in the V43 coding. The "CHEKBITS" subroutine causes the DAP to idle if both bits are "1". The V43 coding prevents loading of the attitude error displays and causes the operator error light to go on if both bits are not "1".

After the "CHEKBITS" test, the DAP examines only bit 13 to determine if the mode control switch is in the AUTO or ATT. HOLD position. Bit 13 is also examined in the P64 redesignation logic and in the Landing Auto Modes Monitor, R13. The P64 redesignation logic does not process ACA deflections as redesignations during the P64 redesignation period if bit 13 is "0". The R13 logic does not permit early entry into P66 with ROD switch activation if bit 13 is "1".

Bit 14 is checked in "FINDCDUW" and in the "G + NAUTO" subroutine. "FINDCDUW" zeroes all commands to the DAP (desired rates, desired attitude increments and attitude error lag angles) when bit 14 is "1". If bit 14 is "1", the "G + N AUTO" subroutine results in a flashing V50 N25 at the beginning of the Master Ignition Routine (Burn Baby Burn) for any APS or DPS burn, prevents initiation of R60 attitude maneuvers (although the desired FDAI ball angles are displayed), terminates any R60 attitude maneuvers already in progress, and prevents automatic maneuvering in the Preferred Tracking Attitude Routine, R61, and in the Fine Preferred Tracking Attitude Routine, R65, (although the desired FDAI ball angles are displayed for both routines).

III. Current Performance with Discrete Failures

Since each of the two mode control discretes can fail to a "1" or to a "0", there are four distinct single bit failure modes. PGNCS software performance must be examined with the mode control switch in the AUTO, ATT. HOLD and OFF positions for each of these failure modes to provide an adequate system evaluation.

A. Failure Mode 1 - Bit 13 = 1.

The bit values corresponding to the three mode control switch positions with bit 13 failed to "1" are illustrated in Table 2.

		BIT 13 CHANNEL 31	BIT 14 CHANNEL 31
MODE CONTROL SWITCH POSITION	AUTO	1	0
	ATT. HOLD	1	1
	OFF	1	1

TABLE 2 - Values of Bits 13 and 14 of Channel 31 with Bit 13 Failed to "1"

For this failure mode, PGNCS performance would be nominal with the mode control switch in the AUTO and OFF positions. However, if the mode control switch were in the ATT. HOLD position, the DAP would operate only in the idling mode and would not control attitude, update the attitude error needle displays, or implement manual ACA commands. Consequently, P66 AUTO could not be selected prior to automatic entry at the end of the P64 Approach Phase and P66 MANUAL would be inoperative. If the failure occurred with the mode control switch in the ATT. HOLD position the vehicle would rotate freely until the mode control switch were moved to the AUTO position or AGS were selected.

B. Failure Mode 2 - bit 14 = 1

The bit values corresponding to the three mode control switch positions with bit 14 failed to "1" are illustrated in Table 3.

		BIT 13 CHANNEL 31	BIT 14 CHANNEL 31
MODE CONTROL SWITCH POSITIONS	AUTO	1	1
	ATT. HOLD	0	1
	OFF	1	1

TABLE 3 - Values of Bits 13 and 14 of Channel 31 with Bit 14 Failed to "1"

For this failure mode, PGNCS performance would be nominal with the mode control switch in the ATT. HOLD and OFF positions. If the mode control switch were in the AUTO position, the DAP would operate only in the idling mode and would not control attitude, update the attitude error needle displays or implement steering commands. Consequently, Kalcmanu

(R60) maneuvers, R61 and R65 Tracking Attitude Routine maneuvers, and all APS and DPS burns would require manual attitude control. Landing point redesignations could be made with the ACA in P64 only at the expense of relinquishing PGNCS attitude control during the time that the redesignations were being made. If the failure occurred with the mode control switch in the AUTO position the vehicle would rotate freely until the mode control switch were moved to the ATT. HOLD position or AGS were selected.

C. Failure Mode 3 - bit 13 = 0

The bit values corresponding to the three mode control switch positions with bit 13 failed to "0" are illustrated in Table 4.

		BIT 13 CHANNEL 31	BIT 14 CHANNEL 31
MODE CONTROL SWITCH POSITION	AUTO	0	0
	ATT. HOLD	0	1
	OFF	0	1

TABLE 4 - Values of Bits 13 and 14 of Channel 31 with Bit 13 Failed to "0"

For this failure mode, PGNCS performance would be nominal with the mode control switch in the ATT. HOLD position. Since performance with the mode control switch in the OFF position would be identical to that in ATT. HOLD, the DAP could not be turned off with the mode control switch and the attitude error displays could not be loaded with V43.

If the mode control switch were in the AUTO position, automatic steering or maneuver commands would be implemented as usual unless the ACA were moved out of the detent position. Moving the ACA out of detent about any axis would cause the DAP to enter the manual rate command mode, respond to ACA commanded rates and ignore automatic commands about all axes until the ACA had returned to detent and the rate damping was complete. During powered flight or automatic Kalcmanu maneuvers, the vehicle would then immediately begin maneuvering back to the attitude commanded by the program. Landing point redesignations with the ACA

would be ignored by the guidance and implemented by the DAP as manual rate commands.

D. Failure Mode 4 - Bit 14 = 0

The bit values corresponding to the three mode control switch positions with bit 14 failed to "0" are illustrated in Table 5.

MODE CONTROL SWITCH POSITION	BIT 13 CHANNEL 31	BIT 14 CHANNEL 31
AUTO	1	0
ATT. HOLD	0	0
OFF	1	0

TABLE 5 - Values of Bits 13 and 14 of Channel 31 with Bit 14 Failed to "0"

In this failure mode, PGNCS performance with the mode control switch in the AUTO position would be nominal. Since performance with the mode control switch in the OFF position would be identical to that in AUTO, the DAP could not be turned OFF with the mode control switch and the attitude error displays could not be loaded with V43.

In the ATT. HOLD mode control switch position, performance would be identical to that in AUTO unless the ACA were moved out of detent. If the ACA were moved out of detent about any axis at any time, the DAP would enter the manual rate command mode, respond to ACA commanded rates and ignore automatic commands about all axes until the ACA had returned to detent and the rate damping was complete. During powered flight or automatic Kalcmanu maneuvers, the vehicle would immediately begin maneuvering back to the attitude commanded by the program after completion of the rate damping.

IV. Performance with Discrete Failures if DAP is Prevented from Idling When "AVERAGEG" is Set

PCR 303 suggests that the DAP be modified to not idle if bits 13 and 14 are both 1 while the "AVERAGEG" flag is set. Since, after the "CHEKBITS" subroutine, the DAP examines only bit 13 to determine the mode control

switch position, the DAP would actually function as if AUTO had been selected in this case.

"AVERAGEG" is set at TIG-30 in all APS, DPS and RCS burn programs and is reset when a major mode change is requested via V37 or when a freshstart occurs. Performance in all other mission phases, including coasting flight periods with failure modes 1 through 4, would be unaffected by the modification. The effects of the proposed modification during periods when "AVERAGEG" is set are as follows:

A. Nominal Operation With "AVERAGEG" Set

During normal operation, PGNCS performance with the mode control switch in the AUTO or ATT. HOLD position would not be affected by the modification. However, if "AVERAGEG" were set, the DAP could not be turned OFF with the mode control switch.

B Failure Mode 1 - Bit 13 = 1 - with "AVERAGEG" Set

In this failure mode, PGNCS performance with the mode control switch in the AUTO position would be nominal. If the mode control switch were in the ATT. HOLD or OFF position, the DAP would hold attitude about the latest desired gimbal angles (CDUDs) but would not implement manual rate commands from the ACA (except about the P axis if X-axis override were allowed). Attempts to use the ACA for commanding pitch or roll rates during the P64 redesignation period would be ignored by the DAP and interpreted as landing point redesignations by the guidance program. P66 could not be selected prior to automatic entry at the end of the P64 approach phase. Since the manual rate command mode would be inoperative, P66 MANUAL would be useless.

C. Failure Mode 2 - Bit 14 = 1 - With "AVERAGEG" Set

In this failure mode, performance would be nominal with the mode control switch in the ATT. HOLD position. If the mode control switch were in the AUTO or OFF position, the DAP would hold attitude about the latest desired gimbal angles (CDUDs). FINDCDUW would not issue guidance commands to the DAP during any APS or DPS burn programs, although the attitude error needle displays would be updated properly.

D. Failure Mode 3 - Bit 13 = 0 - And Failure Mode 4 - Bit 14 = 0 - With "AVERAGEG" Set

PGNCS performance in these failure modes with the mode control switch in the AUTO or ATT. HOLD position would be identical to that described in Section III.

V. Discussion

The DAP modification suggested in PCR 303 can be evaluated by comparing the descriptions of performance in Section III and Section IV. The modification provides three features not available in the current system. First, if either bit fails to "1" while the mode select switch is in the position which should make it a "0", the vehicle rates will be damped and the DAP will hold attitude. Although this automatic rate damping capability is advantageous if the failure occurs when vehicle rates or offset accelerations are large, it could have the disadvantage of concealing potentially dangerous failures from the crew. For example, if bit 13 failed to "1" with the mode control switch in the ATT. HOLD position, the crew would have no immediate indication of the failure. Consequently, subsequent manual pitch and roll maneuvers commanded by the crew with the ACA would be ignored by the DAP and if commanded during the P64 redesignation period, would be processed as landing site redesignations by the guidance program. The loss of manual PANCS control capability without crew recognition could be extremely dangerous during the final phases of landing. If bit 14 failed to "1" with the mode control switch in the AUTO position, FINDCDUW would stop sending guidance commands to the DAP. The crew would not be aware of the failure until they noticed the drift in the attitude error displays. With the current system, the failure could quickly be detected by noting that the attitude error needles had frozen and with visual indications of the unchecked rotation through the LM windows. The crew could then switch to AGS or move the mode control switch to the remaining (not OFF) position to damp the rates and regain control.

The second feature provided by the modification is an attitude error display whenever "AVERAGEG" is set for all mode control switch positions and all failure modes. Since the freezing of the needles currently provides

a cue that the selected mode is not functioning and since switching to the remaining, functioning mode will cause the needles to work again, this characteristic may be undesirable and unnecessary. However, if this feature is wanted, the same effect can be obtained with an extremely simple, local change to the DAP "CHEKBITS" routine.

The third feature provided by the modification allows the use of the ACA for landing site redesignations in P64 with bit 14 failed to "1" and the mode control switch in the AUTO position. Since attitude control would have to be entirely manual during a landing with bit 14 failed to "1", the ACA redesignation capability is not essential.

The proposed modification would also preclude the use of the mode control switch for turning off the DAP while "AVERAGEG" is set during nominal operation as well as in the failure modes. Although the DAP could still be turned off by switching to AGS control, there may be situations in which using the mode control switch would be preferable -- for example, to terminate jet firings after touchdown if the standard procedure should fail.

Due to the number of routines which examine bits 13 and 14 of channel 31, and the complexity of the interactions between those routines, a rough analysis such as this is insufficient to determine the effects of implementing the proposed modification. Even extensive testing with the digital simulator may not uncover all the ramifications of the change. Previous experience has shown that modifications involving the interface between modes tend to be subject to insidious errors. Since several objectionable effects of the proposed modification have already been determined in this preliminary study and the few advantages apply to only half of the powered flight failure modes of bits 13 and 14, I feel that PCR 303 does not warrant further study.