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IN REPLY REFER TO: 70-FM73-328

December 3, 1970

MEMORANDUM TO: FA/Director of Flight Operations

FROM : FM7/Chairman, Independent Software Review Panel for Apollo 14

SUBJECT : Final Report for the Apollo 14 Independent Software Review

References

1. MSC Memorandum 70-FM73-248, "Status of the Apollo 14 Independent Software Review," by R. O. Nobles, dated October 5, 1970.

2. MSC Memorandum 70-FM73-296, "Interim Status Report of the Apollo 14 Independent Software Review," by R. O. Nobles, dated November 5, 1970.

The review panel met at North American (NR) the week of November 9 and at Grumman (GAC) the week of November 16 to review the results of the test cases defined in reference 1 and other special tests. We also observed simulations at both facilities in which the onboard programs were exercised in the areas where most changes had been made, i.e., landmark tracking (P24) for COLOSSUS and descent (primarily R12) for LUMINARY. The results of each test are presented in Appendices A and B.

The assembly comparisons performed by Delco Electronics have been completed and all open items reported in enclosures 1 and 2 of reference 2 have been closed.

In summary, I am happy to report that we found no program deficiencies. However, during the course of the review we did find several abnormalities and they are documented in the attached appendices as "Special Notes". These "special notes", in addition to "special notes" reported in reference 1, should be considered as action items for the Flight Software Branch (FSB) and closed as specified in reference 1.

As chairman of the Independent Software Review Panel for Apollo 14, I would like to express my gratitude to NR, GAC, Delco Electronics and all panel members for their cooperation and diligent work in performing the software review. As a result of this effort, I have a better understanding of and increased confidence in both the COLOSSUS and LUMINARY programs.

Richard O. Nobles

Enclosures

cc:
(See list attached)

APPENDIX A

COLOSSUS SPECIAL NOTES

1. If the orbrate/PTC routine (V79) is called and a V49 (automatic attitude maneuver) is executed subsequent to loading N79, the VECPOINT and KALCMANU routines destroy the N79 (rate, deadband, and axis option) contents. While the GSOP Section #3 calls this out, the crew checklist passes over it lightly. Normally, the procedure used in this test will not occur in flight but if it does the crew will probably do what was done during the test, i.e., fail to reload N79 thereby getting an erratic maneuver for PCT/ORB RATE.

2. The RCS minimum impulse is supposed to be about 14 milliseconds long. However, because of other computer priorities and loading, the time is closer to 16 milliseconds. This 2 millisecond difference does not affect DAP performance or pilot handling qualities but the documentation should be changed to reflect the actual pulse width.

3. A 1520 alarm (V37 not permitted) will be issued if V37 is requested within 15 seconds of moving optics zero switch to "on" position. To avoid the alarm one should wait 15 seconds before requesting V37.

4. Several interesting things happened to the test cases that had hardware restarts. The most significant observation is that all output channels are set to zero when a restart occurs. This is done to protect from getting erroneous outputs resulting from the restart. The computer reinitializes the program within 20 milliseconds, however, vehicle transients will occur in P40 due to SPS engine commands being set to zero for 20 milliseconds. While in P24 a 120 alarm (optics not zeroed) was issued. After the alarm and subsequent to rezeroing the optics a flashing V51 appeared (please mark). Both these abnormalities were the result of channel 33 being zeroed by the restart. A restart just before the orbrate start time destroyed the orbrate set up in P24. The effect was significant in that the rate could not be reestablished before the landmark line of sight occured. The 60 x 8 tracking pass was thus lost.

APPENDIX A

COLOSSUS SPECIAL NOTES
Reference Memo 70-FM73-248

1. PCR 869, Test #15
   There is a potential problem in the rate aided OPTICS DRIVE ROUTINE (R52) with the mechanization of the shaft-stop-avoidance logic. An oscillatory motion of the optics could possibly occur when the optics reaches the 270° stop position. This could possibly occur if there is an interval of more than 0.24 sec between successive updates of the shaft rates.

2. PCR 869, 987
   There is a potential problem with the use of the P24 mark reject capability. For special timing conditions the receipt of the mark reject could cause the CSM position to be determined at a negative time (some fraction of the past revolution). If this occurred it would produce the incorrect rates and possibly could eliminate the remainder of the tracking pass.

3. No PCR
   Limitations of the noun scaling associated with DSKY displays should be well understood. In general, problems can arise due to the fact that the DSKY display is constrained to a dynamic range of 1:100,000. Barring rescaling, this represents a dynamic range of only about 17 bits, while many quantities in the program are double precision and hence expressed to 28 bits.

   Two different problems can arise, both of which could be cause for in-flight difficulty:

   a. The number shown on the DSKY can be zero to the precision indicated, but the number in the memory is not a "binary zero". This is particularly dangerous for those cells which serve as problem-solution flags, such as elevation angle in P34. This particular problem (a P12 residual value for a different parameter corresponding to less than 0.005°, giving a zero N55 display) was recognized in the LM, and was one of the 163/173 changes (PCN 1048). The similar situation in the CSM, however, still exists.

   b. The number shown on the DSKY can be zero modulo, the maximum value allowed, but of course not zero as processed by the program. This situation can also occur for other values (for example, 11,000 fps and 1,000 fps would both display the same value on a XXXX.X fps scale, and this display is desired in CSM P47, for example, as described on lines 100-110 of Section 4 Rev. 13 GSOP).

   In both cases, the "fix" is to encourage the crew to manually write over the information with their own zero input.

4. PCR 859, 860
   Two peculiarities exists which will affect the character of the FDAI error needles when in Mode 2.

   a. If R60 is entered from R61, N22 is loaded with meaningless information. This information is subsequently written over by the VECPOINT solution, but could cause a transient to appear on the FDAI error needles.

   b. In R61 (tracking attitude) the FDAI attitude error needles do not reflect what the DAP is doing. Each pass through R61, the "desired attitude about the pointing vector" is set equal to the "present attitude" for error needle purposes. RCS jet firings could be issued by the DAP about the pointing axis direction while the FDAI error needles continue to show errors well within the deadband.

APPENDIX A

COLOSSUS SUMMARY

The following changes were reviewed and speicfic tests were performed to test the logic associated with the change.

PCR 288, 289, 290, 292, 295, 302.1, 315.1, 859, 860, 867, 868, 869, 872.1, 874.1, 921, 970.1, 973, 974, 987, 991.1, 993 & 1020.

Anomalies COM 31, COM 34, & COM 37

The following changes were reviewed and no specific tests were defined. These changes, for the most part, were verified by visual inspection of the Comanche 108 assembly.

PCR 821.1, 822, 857, 916, 917, 978, 985, 986.1, 994, 995, 1041, & 1046.

Anomalies COM 32, COM 33, COM 35, & COM 36.

ACB 101, 102, 103, 104, 105, 106, 107, 110, 111, 112, 113, 114, 116, & 117.

APPENDIX A

Attendees at NR

FM7/R. Nobles
FM4/R. Savely
FC5/W. Presley
EG7/C. Hackler
FM4/R. Eckekkamp
Bellcomm/G. Heffron
GAC/C. Tillman
TRW/R. Manders
Delco Electronics/C. Clark
CB/V. Brand
CB/A. Worden
NR/B. Schoen & crew

APPENDIX A

COLOSSUS TEST RESULTS

1. PCR 288

Description: Current partials in the final phase reference table cause the entry guidance logic to conserve ranging potential early in P67. This conservation results in dumping of the potential late in P67 and consequently causes higher than necessary g loads.

Test: Nominal entry with 1285 nm range. Compare g-load to Apollo 13 g load time history.

Test Results: The Apollo 13 program reached a smaller value of "g" than does the Apollo 14 program. The maximum "g" in P67 was higher for the 13 program than for the 14 program. The roll command history for the Apollo 14 test case indicated proper operation during all phases of entry with proper convergence to 4 "g" during P64 and increased smoothness in P67. Non-zero roll commands during P67 occurred sooner for the Apollo 14 program. These characteristics indicate that the updated partials in the final phase Table were incorporated into the Apollo 14 program and works as expected.

2. PCR 859

Description: Modify rate drive in R-61. Vehicle rate in tracking mode is now being limited to 0.1 deg/sec plus LOS rate rather than 0.5 deg/sec whenever the attitude is outside the deadband but less than 10°.

Test: The nominal rendezvous run with preferred tracking attitude maneuver. Verify that the rate when the attitude is outside deadband and less than 10° is limited to 0.1 deg/sec using time history of attitude rates. Plot vehicle and LOS rates vs time. Difference should be less than 0.1 deg/sec.

Test Results: The vehicle and LOS rates were plotted for the three tracking intervals in the nominal rendezvous. In all cases the difference between the vehicle and LOS rates were within $.1^{\circ}$ sec.

3. PCR 860

Description: Modify VECPOINT during P20. The VECPOINT routine has been modified to prevent roll drift during preferred attitude tracking maneuvers.

Test: Nominal rendezvous run with preferred tracking attitude maneuvers. Verify initial roll angle is maintained throughout tracking maneuver sequence. Observe vehicle attitude, rates, and FDAI errors on downlist and environment.

Test Results: The IMU gimbal angle drift observed for the test case was less than one degree for both roll and yaw. The Apollo 13 program exhibited drifts of up to 20° in yaw and 50° in roll for comparable tracking periods. Thus it is concluded that the PCR was implemented correctly.

4. PCR 970.1

Description: Modify gyro torquing routine. Gyro torquing has been recoded to add a routine TWOPULSE. This routine has gyro torquing always end with the same polarity pulses. TWOPULSE puts out (at end of normal pulsing) two plus pulses and then two minus pulses. Purpose is to minimize gyro bias shifts caused by pulse torquing.

Test: Do a V42E gyro fine align in all axes in both directions recording Channel 14 bit 9 activity. Pulse activity should be 00,11 at end.

Test Results: This particular test case required a special setup to record the gyro torquing bit train. A review of the test data indicates the PCR has been implemented correctly. We noted that the data reduction was improperly coded so that the actual data shows the final output activity to be 00,00. However, other data on the strip chart infers the true activity to be 00,11 which is correct.

5. PCR 302.1, 315.1

Description: PCR 302.1 adds Channel 77 to the computer and PCR 315.1 modifies the downlist location. Purpose of the channel is to provide information relative to hardware restart causes.

Test: Generate hardware stimuli to create specific restart indications that Channel 77 monitors. Verify the coding is correct. Do V36E (FRESH START) and verify Channel 77 is reset. Do a P27 state vector uplink and verify the final V33E resets Channel 77. Verify Channel 77 is in the appropriate word on all downlists.

Test Results: Test data shows that the two PCR's have been implemented correctly. A V36E sets the channel contents to zero as does the final V33E on a P27 state vector update. All restarts that were checked were coded correctly. However, voltage and scalar fail restarts can not be checked in the NA facility.

6. PCR 868, 993

<u>Description</u>: PCR 868 is related to P23 (cislunar navigation) changes. Originally, calibration was to be done on landmarks whereas the inflight calibration has been done on stars. The program has been changed to (1) allow maneuvering of the vehicle to star LOS or N88 input; (2) make horizon bias a function of range from the earth; and (3) improve the sextant LOS for a LM-on occulting problem; that is, when the V50N25, 00202 (please maneuver flash code) is displayed, a PRO response calculates a maneuver to give an optical shaft angle of 180 degrees. An ENTER response V50N25 does not restrict the optics shaft angle.

PCR 993 changes the P23 auto maneuver to use as an option the three-axis maneuver to avoid LM occultation and to make the MIC operation more predictable (pure roll will adjust the substellar point).

<u>Test</u>: Perform the following P23 cases:

a. P23 with LM on. Initialize at GET = 9:30

(1) Do R57 (optics CAL) with STAR ID 33

(2) Do three-axis star horizon maneuver then VECPOINT maneuver for star 30EF, Observe final gimbal angles for each maneuver are same.

(3) Do VECPOINT maneuver then three-axis star horizon maneuver for STAR 33EN.

(4) Check horizon bias with HORISLP = 0, 0.05, -0.05

b. P23 with LM off. Initialize at entry interface minus 8 hrs

(1) Same as above but with STAR ID 37

(2) Same as above but with STAR 45EN

(3) Same as above but with STAR 44EF

<u>Test Results:</u> The capability to maneuver the vehicle with R60 during R57 such that the landmark line of sight (LLOS) points continuously to a star was verified by comparing the LLOS resulting from the maneuver against the position of the star given by its unit vector. The comparison was within 0.01 deg. The three-axis and VECPOINT maneuvers were compared on both the trans-earth and trans-lunar coast. The LLOS direction for the 3-axis was compared with the LLOS direction for the VECPOINT and the results were within 0.07 deg. The horizon bias (as a function of range) was verified by loading 0.0, ±0.02, ±0.05 and observing the computed trunnion angle.

7. PCR 974, Anomaly COM 31

Description: Allows for resetting the RENDWFLG during the pointing vector routine which corrects anomaly COM 31 (flag not reset if state vector update not done between end of P20 and doing P23).

Test: Run with Case No. 6, part b. Set RENDWFLG = 1, ORBWFLG = 0. Record flagwords on downlist at V50N25 after first N89 in P23.

Test Results: A review of the test data shows that RENDWFLG is reset to zero following a N89 subsequent to V50N25 in P23. The referenced anomaly, therefore, has been corrected.

8. PCR 292, 867

Description: PCR 292 adds time to start maneuver as the first display in V79 (orbrate/PTC routine). This time to start orbrate capability permits the pilot to use the optics instead of watching the DSKY as he begins lankmark tracking. PCR 867 implements a provision to make V79 rotate about YCDU independent of XCDU.

Test: CM in 60 x 8 nm lunar orbit set NO. PASS = 100. Optics in CMC mode. Call P24 (rate aided optics). Use V79 to enter maneuver start time. Select maneuver such that CDUX $\neq 7.25^{\circ}$. Set PASSCNT = 0 at N89 display. Note N92 display of optics angles. Switch optics to manual. Mark greater than 6 times with one mark reject. Observe successful landmark tracking and marking.

Test Results: PASSCNT was successfully entered as zero and more than six unrejected marks were taken. The landmark tracking and marking appeared normal. The V79 was used to start the maneuver and the N92 display was verified.

9. PCR 292, 867

Description: See 8 above.

Test: Select P00. Key V79E and verify no N16 display. Enter maneuver information and verify no uplink activity light. Perform for 0°, 90°, and 180° CDUX angles.

Test Results: The calling of V79 through P00 deletes the N16 display and no activity light follows the entering of maneuver data in N22. It was verified that the rotation about the YCDU was independent of the XCDU angle.

Note of Interest: If V79 is called and a V49 (automatic attitude maneuver) is executed subsequent to loading N79, the VECPOINT and KALCMANU routines destroy the N79 (rate, deadband and axis option) contents. While GSOP Section 3 calls this out, the crew check list passes over it lightly. Normally, this does not occur in flight but if it does the crew will probably do what was done during the test, i.e., fail to reload N79 thereby getting somewhat of an erratic maneuver for PCT/ORB RATE.

10. PCR 869, 987

Description: PCR 869 adds rate aided optics drive (P24) to the program assembly to provide smoother performance and increased capability to the optics. The PCR also deletes alarm code 407 (trunnion angle >50°) and sets optics drive to 50° if the desired trunnion angle is greater than 50°. PCR 987 contains a number of revisions made necessary or desirable because of the addition of P24. Specifically, the PCR deletes the TRUNFLAG and bit 9 of OPTMODES (neither needed) and defines the new flags P24 FLAG, NEWLMFLG, and P24MKFLG (needed by P24). Finally V41N91 (optics coarse align) is restricted to P00 to assure optics will not be coarse aligned in P40.

Test: Repeat Case 8 with NO. PASS = 5 and do not alter PASSCNT. Observe optics behavior.

Test Results: NO. PASS = 5 was verified and no difference in optics behavior was noted. The program behaved normally.

11. PCR 869

Description: See 10 above.

Test: Place vehicle in 60 x 60 nm lunar orbit with optics control in CMC. Call P24 and set trunnion to greater than 90°. Input landmark through N89. Verify alarm 404 (trunnion >90°). Observe V16N91 = 49.775 and V16N92 = Set Value. Mark. Verify optics hand controller disabled.

Test Results: The basic flow of P24 was verified. Alarm 404 was generated as expected when required trunnion was greater than 90°. When desired trunnion became less than 90° but greater than 50° the optics was driven to about 50° as expected.

Note of Interest: After the 404 alarm is cleared, one should wait until the required trunnion angle is less than 90° before proceeding or the 404 alarm will occur again. This is as it should be but requires patience on the part of the program operator.

12. No PCR

Test: Call P22 in 60 x 60 n.m. lunar orbit with optics in CMC. Mark; place optics hand controller to manual and mark 5 times, reject last mark, mark 2 more times. Verify 114 alarm code (mark made but not desired).

Test Results: All displays were normal. Tests of alarms 404 and 114 were verified and use of optics hand controller was successful.

13. PCR 290

Description: Implements a modification to R21 (Rendezvous Tracking Sighting Mark) and R23 (Backup Sighting Mark) that makes a display of marks and time from ignition available to the crew in V57 (Call R21).

Test: Enter P20 anywhere in a nominal rendezvous sequence. Do V57 and verify the flashing V51N45. Mark three times and verify N49 priority display. Accept marks and do V87 (set VHF range flag). Again verify N49 display and accept mark. Verify number of marks in R1 of N45. Should read 01X03.

Test Results: Flashing V51 N45 was observed. Mark counts in R1 were correct. Update tolerances were set to zero and V06N49 (ΔR and ΔV) occurred each mark. Mark rejects (V32) were observed. The PCR implementation seems proper.

14. PCR 874.1

Description: An improvement to the decimal loading technique. Hitherto, it was necessary to load the sign plus all 5 digits of a decimal number. This PCR changes the technique such that only the significant digits need be loaded; i.e., to load 0, key +E; to load +50, key +50E.

Test: Enter P30 using TIG and delta V's to cover all possibilities of loading. Do following sequence:

V37E30E
FL V06N33
V25E
+XXX (1 hour later than present time)
+50E
+5000E
Verify DSKY R_1, R_2, R_3 display
R_1 = +00XXX, R_2 = +00050, R_3 = 05000
PRO, FL V06N81
V25E, +E, +50000E, +5E
Verify DSKY
R_1 = +00000, +50000, +00005

Verification by subject comment and DSKY downlist.

Test Results: The following loads were verified.

N81 Inputs	V06N33 Monitor
+82E	+00082
+38E	+00038
+1363E	+01363

N81 Inputs	V06N81 Monitor
-27847	-27847
-10759	-10759
+660	+00660

Two loading possibilities were not used. These were loading of all zeros by keying +E and loading one significant digit by keying +XE. However, the correct execution of above inputs seems adequate to verify the correct implementation of the PCR.

15. PCR 869

Description: See 10 above.

Test: Check rate aided optics shaft stop oscillation by having desired shaft angle greater than 270°. In manual mode, check optics rate drive for oscillatory behavior.

Test Results: The test results showed that the optics drive stopped at 270° with no oscillatory behavior. This is the desired results but not what was expected. Inspection of the coding leads one to believe that a minor oscillation will occur. The absence of the expected results could possibly be the result of a simulator deficiency, and this test is considered an open item.

16. PCR 295, 872.1

Description: PCR 295 places AK attitude error quantities and RCSFLAGS powered flight downlist in words 64 and 65. This doubles the AK sampling rate. PCR 872.1 implements the initiation of TFI clockjob in P40's so that N35 and N40 are available any time after the start of P40.

Test: Do any powered flight maneuver; verify from the downlist that word 14 = word 64 (AK0, AK1) and word 15 = word 65 (AK2/RCSFG). In addition, call N35 and N40 and monitor TFI. These can be compared against the event timer.

Test Results: While in P40, N40 then N35 were monitored at the point of request for maneuver to desired attitude. The N40 and N35 values were compared to the difference of DSKY printout GET and ignition GET. The comparisons agreed to within 0.36 sec for N40 and 0.23 sec for N35. These differences are attributed to the delay between the N40/35 computation and the downlink DSKY printout. The test is considered successful. The contents of words 64/65 were compared to words 14/15 in the octal downlink printout. The comparisons agreed out to the least significant digit. For words 14/64 and 15a/65a (AK attitude errors), the largest difference noticed was 00004 octal. Words 15b/65b (RCS flags) agreed exactly as expected. The differences in the AK comparisons is attributed to the approximate 1 sec computation delay between word 14 and 64. With this delay, differences would be expected from attitude rates within the deadband. The test for PCR 295 is considered successful.

While in P41, both N40 and N35 were monitored prior to maneuvering to desired attitude. Comparison of the N35/40 values with the DSKY printout/ignition GET difference was close. The ignition time stored internally had to be read from word 18 of the powered flight downlist, since the ignition time is not a nominal DSKY display in P41. The N35 value agreed to 0.65 sec and the N40 value to 0.45 sec. These differences are attributed to the delay between the time of DSKY printout and value computation. The test is considered successful.

17. PCR 921

Description: This PCR places the time of last integrated vector (TET) and N06 option codes in words 64 and 65 of all but the powered flight downlists.

Test: a. Coast/Align Downlist Check. Initialize with CSM in either earth or lunar orbit with IMU aligned. Select P52. At the V04N06 display, compare R1 and R2 of downlist DSPTAB words with word 64. R1 and R2 should equal word 64a & 64b respectively. Select the nominal option by keying V22E2E then proceed. At the V06N34 display, load a time one hour in the future via V25. After entering the N34 time, key a proceed then immediately select a N38 monitor via V16N38E. Compare R1, R2, and R3 of downlist DSPTAB words with word 65. After computer activity light extinguishes, key Key Release, then terminate program at next display.

b. Rendezvous/Prethrust Downlist Check. Select P21 via V37. At the V04N06 DSKY display, compare R1 and R2 of downlist DSPTAB words with word 64. R1 and R2 should equal word 64a dnd 64b respectively. Key a Proceed on the N06 display. At the V06N34 DSKY display, load a time two hours in the future via V25. After entering the N34 time, key a Proceed, then immediately select an N38 monitor via V16N38E. Compare R1, R2, R3 of downlist DSPTAB words with word 65. R1, R2, R3 (hr:min:sec) should equal word 65. After computer activity light extinguishes, terminate program.

c. P22 Downlist Check. Verify CSM permanent state vector time tag is different from present time by about two hours. Select P24 then immediately select an N38 monitor via V16N38E. Compare R1, R2, R3 of downlist DSPTAB words with word 65. R1, R2, R3 (hr:min:sec) should equal word 65. After computer activity light extinguishes, terminate the program.

Word 64, option codes, cannot be checked for this downlist. The programs which call this downlist do not utilize the N06 option. Thus, word 64 has no significance in this downlist.

d. Entry/Update Downlist Check. Verify CSM permanent state vector time tag is different from present time by about two hours. Select P62 by V37E62E, then immediately select an N38 monitor via V16N38E. Compare R1, R2, R3 of downlist DSPTAB words with word 65. R1, R2, R3 (hr:min:sec) should equal word 65. After computer activity light extinguishes, terminate program.

Word 64, option codes, cannot be checked for this downlist. The programs which call this downlist do not utilize the N06 option display. Thus, word 64 has no significance in this downlist.

Test Results:

a. P52 was selected. At the N06 DSKY display, word 64 was checked with DSKY R1 and R2. R2 was loaded with a different value. Word 64 was identical before and after the change. P00 was selected after loading special values of Time 1/Time 2. After computer activity light extinguished, the DSKY value of N38 was equal to word 65.

b. P21 was selected. At the N06 display, R2 was again loaded to a different value. Word 64 agreed to R1 and R2 before and after the change. The program was sequenced to cause integration. After the computer activity light extinguished, the N38 DSKY monitor value was equal to word 65.

c., d. The Entry downlist and P22 downlist were not exercised during the run. A special retest is not considered required since the telemetry pickup is similar for the various downlists. The successful check of the two downlists seems adequate. During the Apollo 14 flight control/crew mission simulations, the N38 TET quantity has been observed in the downlink. This serves as a check for the R22 downlist. This time can be observed for the Entry/Update downlist during upcoming Entry simulations.

18. PCR 289

Description: This PCR makes minimum impulse available to the crew through the rotational hand controller when the mode control switch is in the FREE position.

Test: Call P00 and place mode control to FREE. Verify minimum impulse DAP response (time history of RCS jets). Also do a translation maneuver, then move RHC out of detent and verify no erroneous acceleration commands from DAP (RCS jet time history).

Test Results: In a normal entry, in P62 (post SEP and pre .05g), the mode control was put to FREE and the stick deflected. Examination of the traces of stick position and RCS moments indicates the changes were made correctly: no moments occurred until the stick was moved out of center detent; only one pulse resulted per deflection.

Note of Interest: Time duration is, by T6 RUPT count, supposed to be 14.375 ms. However, because of other computer priorities and loading, the time is closer to 16 ms. Actually, this 2 ms difference affects neither DAP performance or pilot handling qualities, but we recommend the GSOP be changed for Apollo 15 and the Apollo 14 program notes reflect this discrepancy.

19. PCR 991.1

Description: Provides the summation of the UPRUPTS and $\overline{K}$KK codes entered during uplink. This is primarily for ground testing in P07.

Test: While in P00, set NODOP01 flag to zero. Send known uplink and check proper summation of UPRUPTS and K$\overline{K}$K codes.

Test Results: In addition to the above test case, a special test was performed as follows:

1. Zero UPSUM, UPSUM+1
2. Reset NODOP07
3. Perform V7 by UPLINK
4. Record UPSUM, UPSUM+1 via DSKY readout

A bit-by-bit generation of UPSUM and UPSUM+1 was then compared to these readouts and verified that the proper uplink sums were generated. UPSUM showed a sum of 623308 and UPSUM+1 showed that 2 uplink transmissions had occurred.

20. PCR 869, 987

Description: See 10 above.

Test: Conduct Case #8 again but with random restarts.

Test Results: Several nominal P24 runs were interrupted with parity-fail restarts at V06N84. Program alarm 120 (optics not zeroed) was generated in each case. After the program alarm was issued, the pilot re-zeroed the optics which resulted in a flashing V51. The flashing V51 should appear only after optics mode has been set to manual. Both these abnormalities occured because the computers knowledge of optics position (channel 33) had been altered during the restart. After the computer recovered from the restart the flashing V51 remained. The optics was not driven with rate commands during this anomalous behavior. The same type of event can occur in other programs while in R52 after a restart.

A restart just before the orbrate start time destroyed the orbrate set up. The effect was significant in that the rate could not be reestablished before the LLOS occurred. The 60 x 8 tracking pass was thus lost.

21. No PCR

Test: Perform nominal entry, LOI, DOI, TEI, and two short burns (Tgo = .75 sec, Tgo = 5.5 sec) with random restarts and TLOSS.

Test Results: These test cases were run to demonstrate the program integrity under stress conditions such as hardware restarts and significant time loss (T Loss). Under no circumstance is T Loss or restarts expected to occur and they are considered serious matters if they do. The following is a brief description of what was observed for the stress cases.

a. Hardware Restarts: The most significant observation is that all output channels are set to zero when a restart occurs. This is done to protect from erroneous outputs resulting from the restart. The computer reinitializes the program within 20 milliseconds, however, vehicle transients do occur in P40 due to SPS engine commands being set to zero for 20 milliseconds. The engine thrust is not lost as 20 milliseconds is insufficient time for all SPS relays to close. The test results for test #20 above is another example of the effects of restarts.

b. Time Loss: T Loss cases were run for powered flight, entry, landmark tracking, and rendezvous tracking for LM active rendezvous. The T Loss cases run were 7.5%, 15%, and 22.5%. The degredation of the performance of the computers problem solving was inconsequential and control appeared to get more sluggish as T Loss increased, as could be expected. The only significant observation was that DOWNRUPTS were lost with P40 runs with as low a T Loss as 7.5%. This case also had restarts but it is felt that the DOWNRUPT loss was a result of T Loss. This item is considered open until more information becomes available.

22. PCR 1020

Description: This PCR changes the initial delay of TVC EXEC from 0.5 sec to 0.51 sec. This increase in delay prevents loss of downlist processing because of adverse DOWNRUPT/T3/T5RUPT phasing.

Test: Do P30 and P40 runs during a nominal rendezvous sequence. Edit downlists for either too much or too little data.

Test Results: Several P30 and P40 downlist printouts were reviewed for loss or pickup of data. In all cases, except those cases having either a restart or time loss, it was observed that there was no anomalous behavior.

It was observed that data was lost during the following cases.

a. LOI run with RESTARTS and 22.5% T Loss.

b. TEI run with RESTARTS and 7.5% T Loss.

c. TEI run with Restarts and 22.5% T Loss.

While the runs in which data was lost were combination stress runs with both T Loss and hardware restarts, it is believed that T Loss was the culprit.

23. PCR 973, Anomaly COM 34

Description: T6JOB, an erasable program used monitoring the Saturn time base six job, was moved to fixed memory by this PCR. Anomaly COM 34 on Apollo 13 states that LONGCALL should generate a 21204 (POODOO) abort any time a negative or zero delta t delay is requested. This has been implemented for Apollo 14.

Test: Load TIG less than TNOW. Call P15 and verify 21204 POODOO. Then load TIG greater than TNOW and reenter P15. During V16N35 monitor is going on, request N20, do Key Release. Observe the N35 does not return until N35 request keyed in. Also, test program with restarts.

Test Results: The time was set (by DSKY load) to earlier than current time. When P15 was entered, a 21204 alarm occurred immediately. When the time was changed to later than current time, P15 worked properly.

Also it was verified that, in P15, after V16N35 is established and then N20 requested, a key release does not establish N35 again. A new request for N35 is required and does establish N35 again.

One restart occurred too early in the run to matter. It was impossible to tell if other restarts occurred, but if they did, there was no noticeable effect on proper performance.

24. Anomaly COM 37

Description: In Colossus 2D, a wait list overflow caused a 31203 (BAILOUT) in the targeting programs if more than six V32E's were made in response to the flashing V16N45. This has been corrected for Apollo 14.

Test: Call P35 and V32E seven times on V16N45. Verify no 31203 alarms.

Test Results: During this run at least seven recycles were performed. None of these resulted in the 31203 alarm as determined by the DSKY printout.

APPENDIX B

LUMINARY SPECIAL NOTES

1. The RCS minimum impulse is supposed to be about 14 milliseconds long. However, because of other computer priorities and loading, the time is closer to 15.5 milliseconds. This difference does not affect the DAP performance or pilot handling qualities but the documentation should be changed to reflect the actual pulse width.

2. Several simulations were run with restarts. In general, no detremental affects were observed. A point of interest was that a restart at the entrance of P68 (while LM was on lunar surface) recycled the program back to the start of P63 where it failed the ignition algorithm (naturally). The general conclusion is a suspicion of the V37 restart protection.

APPENDIX B

LUMINARY SPECIAL NOTES

Reference Memo 70-FM73-248

1. PCR 983, Test #21

This PCR was implemented to allow N88 (celestial body 1/2 unit vector) to accept a unit vector. However, there are certain unit vectors that N88 will not accept. In particular, the unit vector individual component as input to the DSKY has a maximum value of only 0.99996. The limit is due to the single precision nature of the noun processing done for N88, which includes a "binary rounding" operation which rejects an input equal to $(1 - 2^{-15})$ or more. This is equivalent to 0.9999695 (approximately). Hence, attempts to load (plus or minus) 0.99997, 0.99998, or 0.99999 will result in a program "recycle" to the initiation of the display, together with the initiation of an operator error light.

2. ACB L-7

The order in which the program checks MARKRUPT and ROD was changed. For Apollo 12 the program checked MARKRUPT then ROD. In this case a mark failure would inhibit ROD bits in P66. For Apollo 13 the order was reversed to check ROD first. This is equally as serious in that if the ROD switch fails on there would be no way to do an undocked IMU alignment. This was documented in the program notes as "with a failed on ROD switch MARK X, MARK Y, or MARK REJECT functions are inhibited". It is the consensus of the review group that more emphasis should be directed at this situation for Apollo 14. It is also the consensus of the review group that the Apollo 15 program should be corrected such that a failure of either the MARK or ROD will not jeopardize the other function. This can be done by recognizing the ROD bits only when "average g" is running.

3. PCN 1048

Limitations of the noun scaling associated with DSKY displays should be well understood. In general, problems can arise due to the fact that the DSKY display is constrained to a dynamic range of 1:100,000. Barring rescaling, this represents a dynamic range of only about 17 bits, while many quantities in the program are double precision and hence expressed to 28 bits.

Two different problems can arise, both of which could be cause for in-flight difficulty:

a. The number shown on the DSKY can be zero to the precision indicated, but the number in the memory is not a "binary zero". This is particularly dangerous for those cells which serve as problem-solution flags, such as elevation angle in P34. This particular problem (a P12 residual value for a different parameter corresponding to less than 0.005°, giving a zero N55 display) was recognized in the LM, and was one of the 163/173 changes (PCN 1048).

b. The number shown on the DSKY can be zero modulo the maximum value allowed, but of course not zero as processed by the program. This situation can also occur for other values (for example, 11,000 fps and 1,000 fps would both display the same value on a XXXX.X fps scale, and this display is desired in CSM P47, for example, as described on lines 100-110 of Section 4, Rev. 13, GSOP).

In both cases, the "fix" is to encourage the crew manually to write over the information with their own zero input.

APPENDIX B

LUMINARY SUMMARY

The following changes were reviewed and specific tests were performed to test the logic associated with the change.

PCR 306, 1056, 287, 872.2, 1040, 874.2, 1038, 936.2, 298, 310, 1022, 1021, 302.2, 315.2, 942, 944, 945, 970.2, 990, 991.2, 996, 1036, 896, 895, 943, 296, 899, 314, 982, 307, 983, 294, 322, 1027, 1039, 1028, 1035, 863.2, 1013, 1037, 1052, 988, 1015, 285, 806.2, & 1058.

Anomalies L-1B-01, L-1C-04, L-1B-09, L-1B-10, L-1C-08, L-1C-01, LNY75 & LNY92.

The following changes were reviewed and no specific test was defined. These changes, for the most part, were verified by visual inspection of the Luminary 178 assembly.

PCR's 286, 821.2, 892, 897, 898, 979, 986.2, 1025, 1029, 1043, 1048, 846, 893, 968, 971, & 972.

Anomalies 1-1B-03, L-1B-05, L-1B-06, L-1C-02, L-1C-03, L-1C-05, L-1C-06 & L-1D-03.

ACB's L12, L13, L14, L16, L17, L18, L19, L20, L22, L23, L24, L25, L27, L5, L6, L7, L8, L9, & L21.

APPENDIX B

ATTENDEES AT GAC

FM7/R. Nobles
FM4/R. Savely
FC5/W. Presley
EG7/C. Hackler
FM2/J. Alphin
FS5/T. Price
Bellcom/G. Heffron
Delco Electronics/C. Clark
CB/F. Haise
GAC/C. Tillman
GAC/S. Greene & crew

APPENDIX B

LUMINARY TEST CASES

1. PCR 306

Description: Add ΔV_m to Ascent/descent downlist. Same ΔV_m as displayed on DSKY and used on ground for cue of fuel remaining ($\Delta V_m = \int F/M$).

Test: Standard descent, check T/M word #78 on descent downlist against environment.

Test Results: The comparison of downlink and environment delta V_m did not agree. At touchdown, the LGC word 78 showed 6543.0 fps whereas the environment had 6566.8 fps. On an ascent run the comparison at insertion was 6032.3 vice 6048.3 LGC and environment respectively. The disagreement had been discovered previously by the regular FMES activity and documented by GAC SDR LM-LUM-110, August 18, 1970. This software report explains the disagreement as a problem in scaling the delta V of the last PIPA sample before adding to the previous delta V_m total. The scaling should be done by double precision factor, but only the most significant half of the factor is actually used. As a result, the LGC accumulated during a burn will be approximately 0.3% less than actual. The difference will be reflected in DSKY displays N40 and N62 as well as in the downlink. The discrepancy has been documented in the software program notes as note 2.1.7.

2. PCR 1056

Description: Automatic ullage on at t_{ig} -6 sec (instead of -3.5 sec) for APS maneuver. T_{ig} -5 sec V_g update is compensated for 6.5 sec (instead of 4 sec) of expected 4 jet ullage. This eliminates V_g errors for manual ullage prior to T_{ig} -3.5 sec.

Test: Perform three APS short maneuvers (P30, P42) with worst case CG loading. Burn times of 0.75 sec and 1.5 sec with automatic ullage. Burn time of 5.5 sec with 9 sec manual ullage. Record N85 V_g residuals from DSKY or downlist. Record roll, pitch, yaw attitudes and rates from vehicle environment. Record DAPBOOLS bit 06 (ULLAGER).

Test Results: Burns for delta V's of 28.0, 41.8 and 125.1 fps were made in succession, with 4-jet ullage on 6.5, 6.5, and 9 sec before APS ignition. Residuals were (-1.1, -.2, -1.4), (+.6, -.6, -2) and (-.8, -1.9, -5.3). The low V_{GX} residuals indicate the constants have been fixed and the ullage is measured properly. (.65, 1.34, 5.5) = T_{burn}.

3. PCR 287, Anomaly L-1B-01

Description: While LM is on lunar surface and tracking CSM in P22 and when the LM-CSM LOS range is greater than 400 nm display N54 range and range rate with no 526 alarm.

Test:

a. LM on surface, CSM in approximate 60 nm circular orbit with LOS range > 400 nm. V95E, V37E22E, PRO on FL V04N06 with R_2 = 00001, verify subsequent display of V16N54 with no program alarm light illuminated nor a 526 alarm. When range is < 400 nm verify DSKY blanks and RR commences to track (via X-pntrs and/or monitor of V16N72). Simultaneously crossreference N54 values to environment range & Range Rate.

b. Continue track until LOS Range > 400 nm and range rate is positive. Verify a flashing V37 is displayed at this time.

Test Results: The test verified the display of the V16N54 with no program alarm light or 526 alarm when the range was greater than 400 n.m. At 400 n.m., the DSKY blanked and the V16N54 display froze at 400 n.m. A V83 was required to restore the N54 display. The no track light went out at an AOS of about 107 n.m. before time of closest approach. LOS occurred at a slant range of 90 n.m. after the time of closest approach. N78 and N54 as compared with the environment during track were valid. In addition the N54's were compared with the environment range before AOS with R greater than 400 n.m., less than 400 n.m., during track and after LOS with R less than 400 n.m. and R greater than 400 n.m. and verified in all cases. The flashing V37 (Test b) did not appear although the DSKY was monitored after LOS until the slant range exceeded 1000 n.m. The failure of the V37 appearance is an open item and is being investigated by GAC and MPAD. OPEN

4. PCR 872.2, 1040

Description: Initiate TFI clock in P41 for display in N35 and N40.

Test:

a. Load a P30 with TIG greater than one hour away. Any ΔV_x, y, z, numbers can be used. Set event timer counting down to TFI > one hour. PRO on the FL V16N45 display. Enter P41 and first display, FL V50N18, overwrite a V16N35 and V16N40. Compare the N35 time with event time and verify N40 is overflowed at 59 59. Enter by the V50N18 display to V16N85. Repeat the V16N35E and V16N40E looking for correlation as before.

b. Repeat same test as in a, except load in a TIG in P30 less than one hour from present time. In this case the N40 values of TFI should not be overflowed and can be compared against the event timer.

c. Load TIG as close to present time as possible in P30. On a P41 do a V16N35 on the V16N85 display and observe that after average-g the V16N85 display returns.

Test Results: 4a: P30 was entered and TIG set to 112:22:48 at G.E.T. 110:21:10; i.e., TIG was 2 hours in the future. N40 and N45 could show only 59:59 to go (they have no hours capability) but N35 showed (h, m, s) to TIG correctly.

4b: Couldn't find this one.

4c: Entered P41 with TFI = 2m 38.9 sec on N35. Counted down to TIG-35, DSKY blanked, resumed with V16N85 (VG in LM axes) and stayed N85 through an RCS burn. The PCR appears to have been installed correctly.

5. PCR 874.2

Description: Changes decimal load logic so operator is not required to enter preceding zeros. Prior to this PCR a sign and five digits had to enter. Of course, the prior option of loading is still available. For example, all zeros can now be loaded by + Enter or + 0E or + 00E or + 000E or + 0000E or + 00000E. A +750 can be inserted by +750E or +00750E.

Test: Load P30 TIG and ΔV's which are all decimal quantities to cover all possibilities of preceding zeros. Verify load correctly displays all five digits after entry in register three.

Test Results: The following decimal load logic was verified. In the process of loading N11 (TIG CSI) and N37 (TIG TPI) in P32 a +XXXXXE entry was made. In descent runs witnessed by the review board on 17 and 18 November, the remaining options: +XXXE, +XXE, +XE, and +E were verified in loading a K factor and the TIG for ascent in P12.

6. PCR 1038

Description: Retain the 526 alarm (Range >400 nm) in P20 to take care of the situation arising with P20 running in the background. This is to distinguish P20 from P22 where 526 alarm is deleted via PCR 287. This is accomplished by referencing the SURFFLAG after performing LPS 20.1 which computes LOS range to CSM. If the SURFFLAG is 0 you get the alarm, if it is a 1 as in P22 you don't.

Test: Set up I.C. with CSM LOS range greater than 400 nm. Enter P20, verify Prog. light on, V5N9E, verify 526 alarm.

Test Results: The test was initialized with the range DSPTAB 11 greater than 400 n.m. (R approximately 590 n.m.). The downlink word 50 was observed to change from 00000 in P00 to 40400 and then 00400 when P20 was called, thereby verifying that the program light was turned on. In addition, downlink word 62b FAILREG requested 00526 when P20 was called and 00526 was displayed with the V5N9E.

7. PCR 936.2

Description: This PCR incorporated in routine 36 of extended V90 (out of plane display) a step to make $DSPTEMX_{dp}$ = TIG. This value in turn is displayed to the crew with a flashing V06N16. Previously, it had been initialized to all zeros where a proceed would have solved the problem for present time.

Test: Set up with I.C. some point after insertion. Cycle through P32 to V16N45 display. Then V90E and verify the V06N16 display is the same as the N11, N13, N37 values loaded in P32, P33, P34.

Test Results: This test was a rendezvous abort case with TIG of CDH 110:52:48. The new logic to make $DSTEMX_{dp}$ = TIG was verified by a V90E at 110:06:08 in P00. The resulting V06N16 displayed read: +00110, +00052, +04800 matching correctly the TIG of CDH.

8. PCR 298, 310, 1022, & PCR 1021

Description: If the Landing Radar Antenna does not switch positions in 11 sec (instead of 21 sec) an alarm (511 in descent, 523 in other programs will be issued. The time to call the antenna positioning alarms was changed to 10 sec (instead of 2 sec) to prevent premature alarms. The program will accept landing radar data in either position as long as the data good discrete is present. PCR 1021 places the landing radar coordinate transformation matrix in fixed memory.

Test:

a. LM in lunar orbit. Call P00, Command Landing Radar to position 2 via V59. Configure environment channel 33 bit 7/6 to 1/0 (LR in position 1). Observe 523 alarm.

b. Powered descent. Nominal descent with state vector errors. Observe convergence of state vector to environment state vector. This will confirm use of proper LR antenna transformation matrix for position 1 and 2.

c. Nominal descent with no state vector errors but with LR in position 2 all the way to landing. Observe state vector behavior by comparing to environment.

d. Nominal descent, configure environment channel 33 bit 7/6 to 1/1 (LR not in position 1 or 2). Observe 511 alarm occurs in 10 seconds.

e. Same as d except configure environment channel 33 bit 7/6 to 0/0 at High Gate. Observe 511 alarm occurs in 20 seconds.

Test Results: In brief, the 511 alarm is called in 10 seconds except at high gate where it takes 20 seconds to occur. This alarm occurs only if neither or both discretes are present, otherwise data are used regardless of position if data are good. The test results show this occurs. The 523 alarm still exists, except that it will occur as specified by the relevant PCR's (V59 only).

9. PCR 302.2, 315.2

Description: Store hardware restart information on channel 77 (PCR 302.2) and put on downlink (PCR 315.2). This will allow identification of some sources of restarts.

Test: While in P00 configure environment to set as many restart bits as possible. Clear channel 77 with V36. Also clear channel 77 with V33 after P27 state vector update. Observe all data on downlist.

Test Results: Monitoring of channel 77 via the downlist printouts showed the following failures had occurred as planned.

1. RUPTLOK
2. TCTRAP
3. NIGHTWATCHMAN/COUNTER FAIL
4. SCALAR FAIL
5. SCALAR DOUBLE FREQ.
6. F. MEMORY PARITY FAIL
7. VOLTAGE FAIL/NIGHTWATCHMAN/RUPTLOK

In all cases channel 77 was cleared by a V36E. The only fail not demonstrated was an E MEMORY PARITY FAIL for which a test could not be made. Only the COAST/ALIGN downlist was downlinked but a review of the listing indicated channel 77 was on all downlists.

A special test was run and observed to demonstrate the V33E clearing of channel 77 following a P27 state vector update.

10. PCR 942

Description: Place a number in erasable memory so that the landing radar update can be automatically discontinued at a specified altitude. The 50 ft number was placed in fixed memory and is transferred to an erasable location after P63 is called.

Test: Nominal descent. LR Off is set at 50 ft in fixed memory.At 50 ft altitude observe no LR update via FLGWRD11 as bit #8 goes to zero. Also, change LR Off to 100 ft after entering P63 and repeat test.

Test Results: The test was made to demonstrate the shifting of HLROFFF from fixed memory to erasable memory and then a subsequent update of the parameter. This was done by using a V11 N1 to show that the HLROFFF value was shifted to the HLROFF location properly, then a V21 N1 to change the value of the HLROFF and then a V11 N1 monitor of the HLROFF location to show that the update of HLROFF was inserted into the proper location. This sequence is listed below.

V11 N1	R1 364 (octal equivalent of 50 ft)
	R2 AAAAA
	R3 3451
V21 N1	R1 750 (octal equivalent of 100 ft)
	R2 AAAAA
	R3 3451
V11 N1	R1 750
	R2 AAAAA
	R3 3451

11. PCR 944

Description: Put X-pointer input to CDU's (FORVMETR and LATVMETR) on ASCENT/DESCENT downlist.

Test: Nominal descent, compare downlist to cross pointers for FORVEL and LATVEL.

Test Results: Review of A/D downlist shows these are properly entered in Words 12b and 12a, respectively. Signs and magnitudes agree with strip charts of environment forward and lateral velocity. The PCR (944) has been correctly implemented.

12. PCR 945

Description: Landing radar altitude and velocity reasonableness test status put on downlink in Bit 13 and 14 of FLGWRD11.

Test: Nominal descent. Observe downlist flag word 11 Bit 13 (altitude) and bit 14 (velocity) contains proper status. Bits 13 and 14 show 1 for good data and 0 for failed test. Force large errors to fail reasonableness test and observe on downlist.

Test Results: The proper operation of these bits was demonstrated by the following error inputs:

Error	Result
20% in VX	Failed VX, passed VY, VZ and altitude
20% in VZ	Failed VZ, VX, passed VY and altitude
20% in VY	Failed VY, passed VX, VZ and altitude
20% in VY	
20% in altitude	Failed VY and altitude, passed, VX, VZ.

As the errors were incorporated, based on altitude it was observed that in one case the terrain changed by going over a crator, the error reverted back to the previous error. In all cases, bits 13 and 14 of FLAGWD 11 operated as expected or as explained by these terrain changes.

13. PCR 970.2

Description: Minimize gyro bias shifts when the polarity on gyro compensation was changed. The gyro torqueing routine was modified to terminate by pulsing 2 positive and 2 negative.

Test: Torque gyros via V42 a known positive angle. Record Bit stream of gyros to verify proper torquing.

Test Results: Routine TWOPULSE added by PCR to cause final pulse torque activity to be 00,11. No data were examined because GAC could not record activity. However, the 178 listing was inspected and the coding is correct. The coding is the same as Colossus program which was checked at NR. Because of the difficulty in obtaining data, we see no reason to check the routine at this time. GAC will be requested to do the test at a later date and forward data to MSC.

GAEC OPEN

14. PCR 990, Anomaly L-1C-04

Description: Prevent the disabling of RR antenna CDU error counters until remoding is complete. V44 (terminate RR designate) checks for remoding before termination of RR designate.

Test: While in free flight in P00, command RR antenna to 0° trunnion, 0° shaft via V41N72. Then command antenna to 180° trunnion, -90° shaft and do V44. Observe antenna should continue to mode 2 center and then stop.

Test Results: PCR 990 fixes anomaly L-1C-04 which allowed the RR CDU error counters to be disabled until remoding was complete. Test data show that keying V44 during a remode does not stop the CDU's from driving until the specified angles are attained. Thus, the original anomaly has been corrected even though another has been made. Unfortunately, in recoding for correcting the anomaly, the REPOSFLG is not reset correctly causing a tight loop sequence during V41N20 under certain conditions. This has been reported in anomaly L-1D-12.

15. PCR 991.2

Description: Provides for the summation of the uprupts and kk̄k codes entered during uplink. This is primarily for ground testing in P07.

Test: While in P00, set NODOP07 flag to zero. Send known uplink and check proper summation of uprupts and kk̄k codes.

Test Results: The test cleared erasable addresses 1245/1246, upsum +0/+1. The NODOP07 flag was reset then a verb keycode was uplinked. The addresses 1245/1246 were monitored and displayed 42721 and 00001, respectively. Address 1245 showed the octal equivalent of the Verb KK̄K bit configuration and address 1246 reflected the one uprupt. A digit 3 keycode was then uplinked. Again addresses 1245/1246 were reviewed and 52524 and 00002 respectively. Address 1245 showed the octal equivalent of the binary sum of the verb and 3 KK̄K bit configuration. Address 1246 showed the two uprupts. The test verifies the correct implementation of the PCR.

16. PCR 996, 1036

Description: A flag (NODOP07) is set and will issue an operator error if P07 is called. This is protection from calling a ground test program in flight.

Test: Nominal ascent. While in P00 call V92 and observe an operator error light. Also request fresh start (V36) and verify NODOP07 not reset to zero.

Test Results: The PCR has been implemented correctly. The operator error light is actuated when attempting to call programs P07 (V92) in flight. A fresh start (V36) will not reset the flagword but data are recorded in downlist hard copy edit.

17. PCR 896, 895, 943, Anomaly L-1B-09

Description: Modification to landing radar read routine (R12). Prior to Luminary 1D, the LR altitude and velocity reads were independent of one another. R12 now reads two samples of velocity, one sample of altitude and then three samples of velocity. With LR read sequenced in this fashion the state vector does not have to be extrapolated to incorporate LR data.

Tests: Nominal descent, put in state vector error, after LR data good call V57, PRO and see altitude converge and FLGWRD11 Bit 8 go to 1 on downlist. PRO again for normal N63 display (V, Ḣ, H). Now call V57, PRO set Bit 8 to 1. Call V32 and see Bit 8 go to 0 and flashing V06N68. Call V34 to return to nominal N63 and see Bit 8 remain 0. While in P66 go through zero doppler. Observe on downlist channel 33 Bit 8 and 5 = 1 (LR Bad). When LR data good (Bit 8 and 5 = 0) observe bits 7 and 4 of FLGWRD11 are delayed 4 sec. Nominal descent with no state vector errors, verify velocity update at 2500 ft/sec by watching state vector velocity convergence. Do random restarts.

Test Results: Modification to landing radar read routine (R12). This test consisted of three parts. The first part concerned the accepting landing radar. The following data shows the results of this test.

Input	Display	Flagword 11 Bit 8 1 means data accepted 0 means data inhibited
V57E	06 68	0
Pro	50 68	1
V32E	06 68	0
V34E	06 63	0
V57E	06 68	0
Pro	50 68	1
Pro	06 63	1

The results verify the correct action is taken to each input.

The second part concerned zero doppler dropout. After dropout of landing radar, channel 33 Bit 8 and Bit 5 are 1, Flagword 11 Bits 7 and 4 are 0. For 4 seconds after Channel 33 Bit 8 and Bit 5 are 0, Flagword 11 Bits 7 and 4 are 1, and 0 thereafter. This result is correct.

Radar velocity started converging at velocity of 2500 fps. Random restarts were included during these tests with no noticeable effect on program operation.

18. PCR 296

Description: After landing and in P68 set initial lunar gravity vector parallel to the landing site radius vector (instead of the X body axis).

Test: Initialize LGC state vector equal to environment state vector in P68. Call P00, call P57 and do IMU alignment with technique 1 option 3. Record N04 display of torqueing angles equal to zero.

Test Results: The resultant N04 display was +52.45. This unexpected value is the result of the referencing of PIPA data by the FMES in lunar stay phase. In effect, the FMES cannot perform a realistic gravity vector measurement in P57. During the gravity measurement, the IMU is physically driven to the proper offset angles, however, the sampled PIPA data is valid for a 0,0, 0 or body axis reference. As a result, the measured gravity vector is offset, and the test could not be verified as written.

The PCR may be verified during a flight control descent simulation with the LMS. The simulation activity usually terminates shortly after T_2 in those cases where touchdown is achieved. It may be possible to make a special extension to quickly cycle into P57 for a technique 1 alignment up to the N04 display. Will Presley will pursue this matter with the Apollo 14 descent flight director.

19. PCR 899

Description: Put N38 (state vector integration time tag) on downlink. Coast/align - wd 76, rendezvous/prethrust wd 95, lunar surface align - wd 28.

Test:

a. LM in lunar orbit in P00. Input CSM state vector with time six hours in past. Call N38 and monitor integration on DSKY. Verify downlist word 76 equals DSPTAB + 0 → + 7 during integration.

b. LM in lunar orbit. Call P21 and select either vehicle option (V04N06). Load a N34 desired time 3 hours in future. Call N38 and monitor integration on DSKY. Verify downlist word 95 equals DSPTAB + 0 → + 7 during integration.

c. Nominal descent, after touchdown update via P27 CSM state vector within 400 nm LOS range but time tag 2 hrs in future. Select P22 with CSM orbit option 1. Verify rendezvous radar in auto. Request N38 and monitor DSKY. Verify downlist word 28 equals DSPTAB + 0 → + 7 during integration.

Test Results: The respective downlist words are verified by comparison with N38 values monitored by the DSKY.

a. Coast and Align - Word 76, test for this downlist was not executed. The verification of the word 76 can be done during a flight control simulation with the LMS (Will Presley Action). The LM state vector time tag after P00 integration can be compared with Word 76. They should agree.

b. Rendezvous/Prethrust - Word 95, P21 was called and a time in the future loaded in N34. After integration was complete, Word 95 value compared exactly with the N38 DSKY value.

c. Lunar Surface/Align - Word 28, P22 was called after a CSM state vector update with a future time tag. After integration complete, Word 28 value compared exactly with the N38 DSKY value.

20. PCR 314

Description: Place descent Guidance Thrust Command (GTC) on word 5a of descent/ascent downlist. Time tag GTC with piptime and place on word 6 of downlist, snapshot buffer words 5 and 6 on downlist. This change was implemented to assist the ground in determining throttle modulations for a proposed descent fuel saving technique.

Test: Nominal descent. No sooner than four minutes after PDI call N92. Monitor N92 for about one minute and verify word 5a corresponds to R1 of DSKY.

Test Results: A check of the descent/ascent downlist shows that GTC is in Word 5a and piptime is Word 6a & 6b. This verifies the test.

21. PCR 982, 307, 983

Description: PCR 982 - Provide lunar surface sighting mark routine (R59) with capability to compute the cursor and spiral angles of celestial bodies entered via N88. PCR 307 - Put P57 marking data (mark time, cursor and spiral angles) on downlink. PCR 983 - Remove constraint in N88 for input planet or star vector to be less than unit vector in magnitude.

Tests: LM on lunar surface. Call P57, select technique 2. Call N88 and input 0.99999,0,0 then load 0.99997,0,0. If operator error occurs on either of these loads, PCR 983 was not properly implemented. Load 0.99996,0,0. Then load 0.99996, 0,99996, 0.99996. Note operator error on either of these loads. Load -0.37795, -0.31050, -0.87222 and note operator error. Call P57, select technique 2, load star ID 031, detent 3, record computed spiral and cursor angles, reload star ID 031 via N88, -0.78610, -0.52197, 0.33105, record computed spiral and cursor angles, mark, load star ID 054, detent 6, via N88, -0.37794, -0.31049, -0.87221. Complete marks, record data (spiral, cursor, mark time) and downlink during marking. Check downlink against mark data.

Test Results: The test showed that operator errors occurred when N88's were loaded with 99999, 0, 0 and 99998, 0, 0. This illustrates that PCR 983 was not properly implemented. N88 loads of 99996 were successful and the 99996 constraint is not believed to be significant. PCR 982 which permits computing the cursor and spiral angles (auto optics) for N88 loads was verified by loading star 31 via the star code and N88 and observing that the N79's were within .01° for cursor and .15° spiral. PCR 307 which places the mark data on the downlink was verified by comparing the mark data with the downlink. A possible problem was noted in that the downlink data changes throughout the program as well as the mark time.

22. PCR 294

Description: Change the maximum LM weight to 16,700 KG (36817 lbs) to reflect current configuration.

Test: In lunar orbit call P00, V48, enter 40,000 lbs in N47, PRO, and observe LM weight of 36817 lbs.

Test Results: While in P63, DAP data load was requested (V48) and 40,000 lbs was entered into N47. After PRO the LM weight changed to 36,817 exactly as it should have.

23. PCR 322

Description: Change THROTLAG from 0.2 to 0.08 sec to improve the throttle stability in P66.

Test: Nominal descent

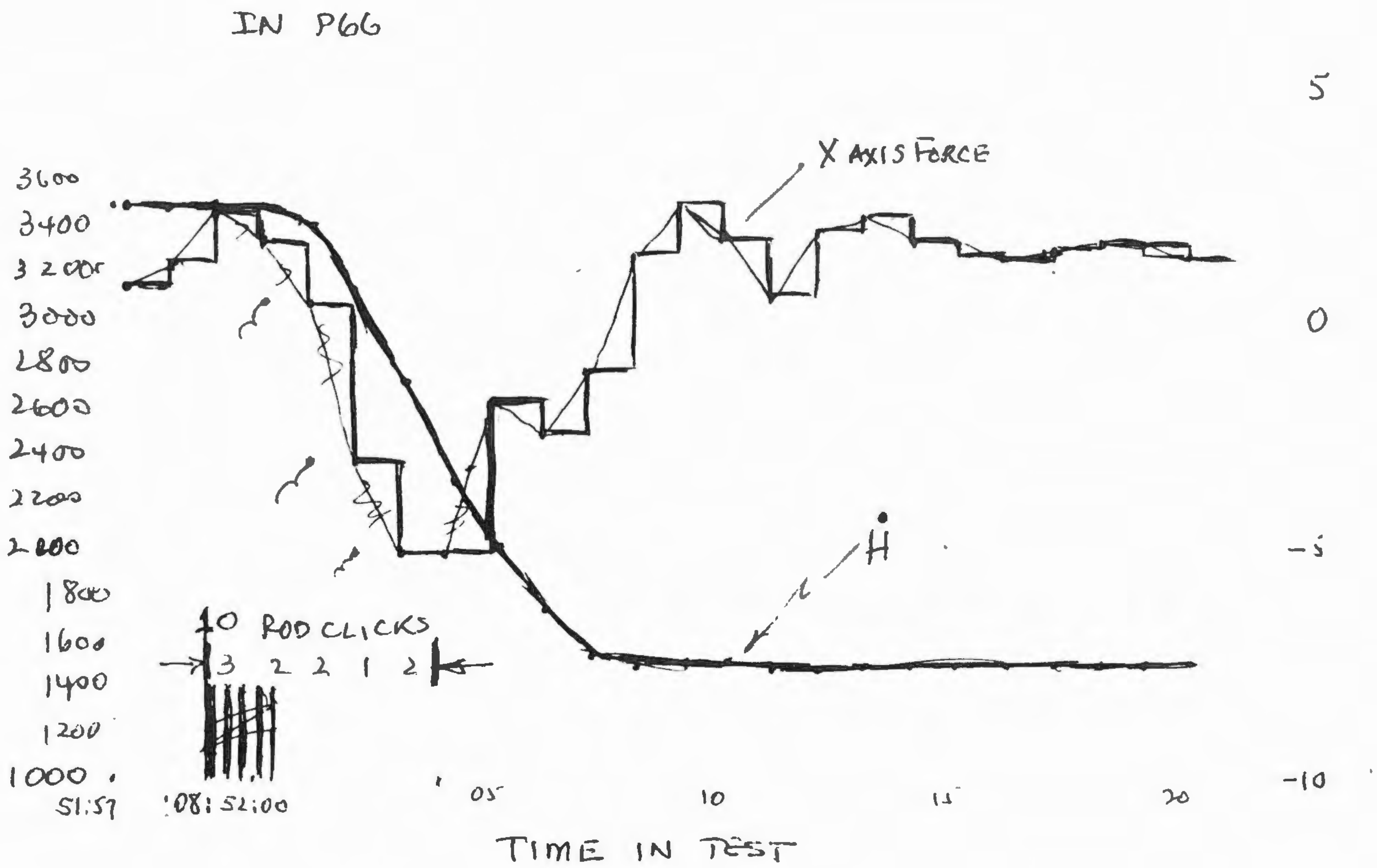
a. In P66 rapidly enter 2 or 3 ROD clicks. Observe $\dot{H}$ and throttle on downlist for 6 seconds for smooth response.

b. Change simulator ENVIRONMENT to EQUIVALENT THROTLAG of 0.12 sec and repeat test (a).

c. Change simulator to 0.04 sec repeat test (a).

d. Nominal descent. Within 1 second of touchdown enter 1 or 2 up ROD clicks. Observe throttle pulse.

Test Results: The graph plots thrust and $\dot{H}$ vs time in a period in P66 (manual) when 10 ROD clicks were injected in 5 seconds. The thrust response shows a slight oscillation, the $\dot{H}$ response is dead beat. This is very good and indicates the change was properly implemented. Later at 108:54:09 5 ROD clicks were injected of opposite sign in P66 auto. Results were similarly good.


IN P66
X AXIS FORCE
Ḣ
10 ROD CLICKS
3 2 2 1 2
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
51:57
108:52:00
05
10
15
20
5
0
-5
-10
TIME IN TEST

B16a

24. PCR 1027, 1039

Description: Addition of A-Priori lunar terrain model corresponding to path followed by intersection of the LR altitude beam with lunar surface.

Test: Nominal Descent: Patch Δh with and without terrain model compensation on to descent downlist. Plot the difference between the two Δh's and the intended terrain model.

Test Results: The A-Priori lunar terrain model was patched into word 2a and 2b of the descent/ascent downlist. Portions of the terrain model were plotted against the nominal and very good agreement was found. Therefore, the test demonstrates that the model is available.

25. PCR 1028

Description: Provide a two segmented LR altitude weighting function. Landing maneuvers over rough terrain with large hills and craters require relatively low weighting functions in the braking phase and relatively higher weighting functions in the approach phase.

Test: Nominal descent. Patch LRWH onto descent downlist. Watch quantity change when program goes to P64.

Test Results: The LRWH was patched into Word 2a of descent/ascent downlist. LRWH was 13146 and LRWH1 was 13140. Upon changing for Program 63 to Program 64, LRWH was changed from 13146 to 13140; thereby proving that the two-segmented weighting function was provided.

26. PCR 1035

Description: Entrance into P66 and execution of V68 will terminate use of lunar terrain model in descent.

Tests: Nominal descent into LITROW or COPERNICUS

a. Call V68 about 4 to 6 sec before P64. Observe vehicle attitude and rate response. Also observe Δh as outlined in test #24.

b. Same as (a) but call V68 about 4 to 6 sec before throttle recovery.

c. Observe information outlined in (a) when program enters P66.

Test Results: The following results indicate V68 was properly implemented.

a. V68 was entered prior to P64 and the following resulted:

Action	Result in Flagword 1 Bit 11
Before V68E	0 Terrain model used
V68E	1 Terrain not used

The attitude and rate showed small responses after V68E.

b. Upon entering P66, Flagword 1 Bit 11 was set to 1.

27. PCR 863.2

Description: Set NODO flag in P76 to complete incorporation of inputted ΔV into CSM state vector prior to exiting. This keeps CSM state vector from being destroyed when V37 (change program) is called prior to incorporation of complete vector.

Test: LM in coasting flight. Input ΔV into P76 with time to go 10 hrs off. While computer activity light is on, enter 337E00E and observe no response. Enter V96 (interrupt integration) and observe computer activity stops. Watch downlist state vector to see it doesn't get destroyed.

Test Results: Analysis of the data verified that during P76 the proper actions occurred. The NODOFLAG was set and subsequently locked out a V37E00E. Contrary to the test description which states that no response should be observed to the V37 entry, a program caution (01520) appeared indicating a V37 request not permitted at this time. While still in P76 a V96E caused an exit to P00 with the loss of the computer activity lamp. Throughout the test the CSM state did not change.

28. PCR 1013, 1037

Description: Addition of constants 2LATE466 and TOOFEW and counter CNTTHROT to allow P66 to continue despite TLOSS. Specifically, the changes are:

a. At the beginning of P66, check the elapsed time since reading the PIPAs for the current state vector (TIME 2 - PIPTIME). If the elapsed time is within the padloaded erasable margin 2LATE466, continue the P66 guidance. Otherwise, omit P66 and exit to the vertical displays.

b. If the number of throttlings between any omission is not greater than the padloaded erasable TOOFEW, issue the alarm 01466. This avoids locking out P66 completely without notice.

c. Raise the priority of the servicer job to 21 shortly after the preceding checks. This prevents a subsequent servicer job from starting until P66 finishes.

d. Request the independent ROD job at priority 22. This allows the independent ROD job to bump the servicer job at any point except in the ROD equations.

e. Raise the priority of the servicer job and the independent ROD job to 23 at the start of the ROD equations. This locks all subsequent jobs out of the ROD equations until the current job finishes.

f. Better overflow protection associated with TLOSS and 1466 alarm.

Test: Nominal descent with significant TLOSS. Patch CNTTHROT to downlist on spare and observe skipping of computer program when TLOSS is great. Increase TLOSS to force a 1466 alarm. It may be necessary to reduce 2LATE466 or TOOFEW to get the alarm if the simulator can't increase sufficient TLOSS. Observe guidance outputs state vectors, steering commands, throttle commands, and observe vehicle response, ie, attitudes and rates in environment.

Test Results: In descents with TLOSS = 13.3%, no problems were observed although occasionally skips of certain routines were observed (skipping guidance is the way TLOSS problems are avoided). A second run was made with TLOSS = 13.3% and with V16N42 added to increase TLOSS by 8% additionally. Further, the number 2LATE466 was decreased from 1.5 sec to 1.3 sec (i.e., if the primary routine servicer takes more than 1.3 sec, guidance will be skipped. In this run, five alarms (31201) occurred in P63 and three in P64 indicating 13.3 + 8 = 21.3% TLOSS is a marginally high value while 13.3% is tolerable. Guidance was not affected. In P66 the effect was to cause two 1466 alarms indicating that guidance was skipped more often than one in three passes (for each alarm). With 2LATE466 = 1.3 not 1.5 (indicating 27% effective TLOSS during servicer) plus the actual 13.3 + 8 = 21.3% true TLOSS, this indicates that an effective loss of 48% will produce 1466 alarms occasionally, while earlier runs show 13.3% will not.

29. PCR 1052, 988

Description: General improvement in the implementation of P66 rate of descent program. Specifically the changes are:

a. Remove effects of IMU offset accelerations. The IMU is located 1 1/2 meters from the C.G, therefore X-translational accelerations were induced by vehicle rates.

b. Automatic nulling of horizontal velocity components.

Tests: Nominal descent. After entry into P66 pitch vehicle violently. Observe vehicle response, i.e. attitude and rates. Observe guidance performance, i.e., steering commands, throttle commands for smoothness. Repeat violent maneuver in roll and yaw channel independently.

Test Results: The first run showed the LM pitched about 15° while in P66 manual. No significant change was noted in H. At the beginning of P66 auto, with considerable LATVEL and the LM yawed 20°, H was again observed and it showed no significant change. In another run, P66 auto was begun with LATVEL = 4.4, FORVEL = 64.0 and pitch + 80.5°, pilot roll (CDUZ) = 4.8 and CDUX = 15.3. The attitude went to a pitch of -20° (P66 auto is limited to ±20° pitch and roll). FORVEL increased to -143 fps because of the bad pitch angle at P66 auto initiations and the velocity nulling was correct. Unfortunately P66 auto was turned off (to P66 manual) before the velocities were zero: the general trend in P66 auto was correct, although the whole operation of P66 was not observed.

Note of Interest: In both runs a partial freeze of the downlist, when the displays were switched to use raw LR data (DIDFLAG = 1) was observed. It becomes extremely difficult to use the downlist: FORVEL and LATVEL values freeze. One could (and the RTCC should) use the state vector to calculate the quantities if the MCC-H needs them. The DSKY display of FORVEL shows a noticeable time lag.

30. PCR 1015

Description: If V90 (rendezvous out of plane display) is called while "Average g" is running, an operator error will be issues instead of program alarm.

Tests: Nominal ascent, after insertion into orbit but prior to "average g" off, call V90 and verify operator error light goes on.

Test Results: V90 was tested in P47, P12, P70, P32, P40, and P63 when average "g" was on. In all cases an operator error was issued when V90 was entered.

31. PCR 285

Description: Remove P67 and all descent program checks of the auto-throttle discrete. Even in the event of auto-throttle failure the crew would use P63, 64, or 66 with manual throttle control. Make available on call display of GTC.

Test: Nominal descent. In P63 put manual throttle to ftp and switch throttle mode from auto to manual and back to auto. Program should remain in P63.

Test Results: Test was executed in P64. Throttle was manually put to FTP and throttle mode was switched from auto to manual and back to manual. Program stayed in P64 which verifies proper implementation of PCR.

32. PCR 806.2

Description: Allow N7 (flagword operator) to address output channels. Allows any R1 (erasable modification) entry of 30 or less to be accepted as a channel address.

Tests: Call P00, Call V25 N07 and load

a. R1 = 6, R2 = 00377, R3 = 1 Note channel 6 = 00377
b. T1 = 6, R2 = 00377, R3 = 0 Note channel 6 = 00000
c. R1 = 7, R2 = 37777, R3 = 1 Note no change to channel 7
d. R1 = 11, R2 = 77777, R3 = 0 Note channel 11 = 00000
e. R1 = 11, R2 = 00004, R3 = 1 Note channel 11 = 00004

NOTE: Test (a) and (b) may be difficult to observe because of DAP interface. Try V21 N01E30E to give about 2 1/2 minutes without DAP interface.

Test Results: Verify N7 will address output channels and allows any R1 entry of less than 30 to be accepted as a channel address. A review of the downlist edit shows the test cases requested were performed without error. The PCR, then, has been implemented correctly.

33. Anomaly LNY 75

Description: In the Rendezvous Radar/Landing radar self test routine a change has been made to allow this routine to cycle between the RR and LR. This is done by testing RTSTBASE as the flag to switch from RR to LR or LR to RR.

Test: Call P00, call V63 (sample radar once per second) for R04 (RR/LR Self test). Observe the proper cycling of displays for RR and LR.

Test Results: A review of the downlist printout showed the proper cycling of displays. The sequence was as follows:

1. V16N72 RR Trunnion and shaft angle
2. V16N78 RR Range, RR range rate, TFI
3. V16N66 LR slant range and position
4. V16N67 LR VX, LR VY, LR VZ
5. V16N72 See 1 above.

34. Anomaly LNY 92

Description: A change has been added to extended verbs to check NEWJOB to allow the extended verb display to come up whenever a normal non-flashing cyclical display is in process.

Test: Coasting flight: Call P40 and verify V06N40 display is non-flashing. Perform a V41N20 and observe the V21N22 request.

Test Results: P40 was called and a V06N40 nonflash display appeared. A V41N20 was entered and the V21N22 request was displayed. This was verified from the downlist data printout.

35. Anomaly L-1B-10

Description: When the ACA is returned to the detent position after being re-cycled in and out of detent in the manual rate command mode, the DAP may enter the attitude hold mode immediately, rather than first damping the spacecraft rates as desired.

Test: Execute the following manual rate command sequence

a. start in detent

b. move ACA out of detent to soft stop

c. remain on the soft stops until the pseudo-automatic mode is entered

d. return ACA to detent

e. quickly return ACA back to soft stops (before pseudo-automatic mode can be established in detent position)

f. remain on the soft stops until the pseudo-automatic mode is entered

g. return ACA to detent

When the ACA is returned to detent for the final time, rate and attitude overshooting should not occur.

Test Results: The tests performed indicate rates are damped prior to return to the attitude hold mode (strip charts of body attitude rates). It appears that the anomaly has been fixed.

36. Anomaly L-1C-01

Description: If a restart occurs during P40 the ΔV increment accumulated over last two seconds may be subtracted from Vg twice.

Tests: Call P30, P40 for DPS TEI maneuver. Do random restarts during preburn, burn and post burn. If irregular displays are noted do V74 (erasable dump). Observe incremental ΔV and Vg history on downlist.

Test Results: The test shows that the Vg did not increment twice under restart conditions. The accumulated delta V (DSKY display only) however, may increment twice under these same conditions. This anomaly is reported in anomaly L-1D-06 and in program note 2.1.7. Also, the delta V displayed will be in error by 0.34%.

37. Anomaly L-1C-08

Description: A hardware or software restart while the DAP is in the manual rate command may cause: a. temporary nulling of Q or R axis manually commanded rate while rotational hand controller is out of detent. b. Yaw to another attitude if restart occurs during 0.25 millisec period of the manual rate command mode initialization pass.

Test: Call P00, configure DAP to manual rate command. Move RHC out of detent to initiate vehicle rates. While RHC is out of detent, do restarts. Observe vehicle rates are not nulled.

Test Results: Inspection of the strip charts for attitude rates during manual maneuvers failed to disclose any anomalous results. However, the test is extremely difficult to perform as a restart has to occur within 0.25 milliseconds of initialization. This test does not necessarily confirm the anomaly has been corrected; on the other hand, the program listings show the coding has been changed correctly and we thus must assume a total fix to the anomaly.

38. PCR 1058

Description: Incorporate new landing analog displays to:

a. Minimize errors in forward and lateral velocity displayed on the cross-pointers.

b. Eliminate the periodic "lurch" in the altitude-rate displayed on the tape meter.

c. Correct error and exessive granularity of the forward velocity displayed in R1 of noun 60 (during P66).

d. Speed up display of altitude and altitude-rate (display each every 1/4 second as at present).

e. Begin displaying analog data when average G is turned on instead of waiting for ignition.

f. During ascent and aborts, display stable member Y-axis velocity as "lateral velocity" and zero forward velocity.

Tests: Perform following tests.

a. Nominal descent, in P66 go manual and fly needles, go back to P66 auto and check needles zero. Compare needle information with state vector. Switch mode from PGNS to AGS then back to PGNS. Observe PGNS continuity during switching. Call N69, change landing site and observe needle transients corresponding to new landing site. Perform random restarts throughout descent.

b. Nominal ascent, P12, manually roll vehicle and observe tape meter and needles follow. Perform randon restarts throughout ascent.

c. same as (b) except abort from descent using P70.

d. Same as (c) except use P71.

Test Results: A review of strip chart data of forward and lateral velocity to the crosspointers and the cross pointers in the cockpit indicate excellent performance. Except for two isolated cases, now under investigation, the erratic behaviour of the altitude/altitude rate tape meter has been corrected. Examination of ascent data (strip charts, cockpit) shows that stable member lateral velocity on the crosspointer performs as advertised. The PCR has been implemented correctly. (GAC will give us a final disposition of the glitch in altitude referred to above when they have had time to review the matter further).