NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

REPLY TO ATTN OF: FS66-72-155

NOV 28 1972

MEMORANDUM

TO: Distribution

FROM: FA/Chairman, Apollo Spacecraft Software Configuration Control Board

SUBJECT: Minutes of the Apollo 17 Flight Software Readiness Review (FSRR)

The Apollo 17 FSRR was held on October 26, 1972, at MSC in building 2, room 966, from 9 a.m. to 1 p.m. The review was chaired by the Software Control Board Chairman and attendees are listed (enclosure 1).

Presentations were provided for the AGS, LGC, and CMC Apollo 17 flight programs. In all cases these programs are the same as those flown on Apollo 15 and Apollo 16 with the exception of mission dependent constants. The programs and their original release dates are as follows:

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| Abort Guidance System (AGS) Flight Program (FP) 8 | April 28, 1971 |
| LM Guidance Computer (LGC) LUMINARY, revision 210 | March 22, 1971 |
| CM Guidance Computer (CMC) ARTEMIS, revision 72 | March 1, 1971 |

Presentations on the AGS program were provided by TRW and Grumman Aerospace Corporation (GAC), on the LGC program by MIT/SDL and GAC, and on the CMC program by MIT/SDL. In addition, the Guidance and Control Division (G&CD) provided a presentation on Apollo 16 problems related to software and their rectification. In all cases, the participants voiced an endorsement of the flight programs as being fully acceptable for performing their functions on the Apollo 17 mission, and thus was the resolution of the FSRR itself. In addition, the Flight Crew Operations Directorate provided statements expressing the flight crew's confidence in the programs. Copies of particular presentations are available from Mr. C. D. Sykes at MSC, extension 2308; they are not reproduced herein due to their bulk.

As planned, the total amount of verification performed on these programs since Apollo 16 proved to be substantially less than that done for previous missions. The rationale for this is in the fact that this is the third mission for which all three programs are being used; and, therefore, all verification activity leading up to the previous two missions can be substantially included in that done for Apollo 17. All parties carefully described how their Apollo 17 testing covered all areas changed since Apollo 16, and it might be noted that all critical phases of the mission were re-verified whether or not there was change. A large segment of the testing effort was placed on the new Erasable Memory Programs (EMP's) for Apollo 17. Almost all these have to do with operation of the CMC and LGC in light of Coupling Display Unit (CDU) malfunctions. It can safely be stated that more verification has been done on these flight programs and a higher degree of confidence on them has been reached than ever before. It can likewise be said that there has been more preparation of special procedures and programs to cover hardware and software malfunctions than ever before.

Between now and Apollo 17, the remaining software activity will center around continuing verification runs for late constants changes and contingency mission plans (e.g., earth orbit maneuvers and entry). In addition, the final program note and EMP review with the prime and backup crews is being scheduled to take place between 2 and 4 weeks before launch as usual. Finally, there are some special runs being scheduled to perform final operational verification on the new EMP's both at GAC, and during integrated simulations.

Some specific issues discussed are described below.

a. AGS

(1) GAC reported on one specific abort case in which AGS performance was questioned. For an abort at PDI+10 minutes, the nominal (from Operational Trajectory) insertion altitude is 73,000 ft.* An abort on AGS at PDI+10 at the Full Mission Engineering Simulator (FMES) produced an insertion altitude of 62,000 feet which, although is closer to the targeted value of 60,000 feet, does not follow the nominal value. TRW confirmed that the above is a true indication of AGS performance and offered the following explanation.

During an ascent, both Primary Guidance and Navigation Control System (PGNCS) and AGS are targeted to achieve specified values of altitude (H), altitude rate ($\dot{H}$), and horizontal velocity ($V_H$). (For aborts from powered descent, values for $\dot{H}$ and $V_H$ are computed based upon LM-CSM phase angle at the time of abort.) The targeted insertion altitude is a constant 60,000 feet. The guidance equations, of both PGNCS and AGS, are designed such that when it is impossible to achieve all three targeting conditions, control of insertion altitude is degraded to achieve the

*Altitude values rounded to nearest 1,000 feet targeted velocity conditions. Aborts in the region of PDI+10 require Descent Propulsion System plus Ascent Propulsion System (DPS+APS). At staging, the net acceleration on the LM is reduced to about one-half of the 100% DPS configuration. In order to achieve the desired end results, the LM is pitched up to account for the lower acceleration level. In order to gain the velocity end conditions, altitude control is reduced and typically the LM reaches a higher-than-targeted altitude prior to achieving the velocity conditions required for engine shutdown. TRW stated that this is indeed the case. Prior to FP8, this was even more pronounced because the AGS software explicitly accounted for the fact that the APS is canted and thrust is not exactly along the +X direction. After considerable testing, both by TRW and GAC, to insure that performance would be adequate, the APS cant compensation was removed from AGS software to make room for auto RR. TRW stated that the APS cant is in such a direction, that by not compensating for it, except in a closed loop control fashion, the AGS is now able to more closely achieve the targeted altitude for aborts in the region of PDI+10.

TRW presented the following case to verify the above explanation. For an abort at PDI+9 minutes, the LM time line shows nominal insertion altitude to be 74,000* feet. A nominal AGS insertion from an abort at PDI+9 yields an insertion altitude of 66,000 feet. With the APS cant removed from the vehicle simulation, AGS insertion altitude is 72,000 feet.

(2) TRW presented a review of AGS performance on Apollo 16 and, in particular, the X gyro problem that caused a large out-of-plane velocity error during descent. The problem cause has not been definitely fixed but the two "best suspect" reasons are: (a) large bubble and/or contamination; or (b) intermittent failure in the pulse torque servo amp. The instrument showed no abnormalities prior to flight. Special considerations taken for Apollo 17 include: (a) reviewing all test data on all Abort Sensor Assemblies (ASA's), particularly those in contention for the Apollo 17 flight; (b) special settling tests to detect any bubbles; (c) special failure tests; and (d) additional calibrations prior to flight.

(3) One open question remained in AGS testing for Apollo 17. In a run to verify AGS lunar surface operations, an unexplained error resulted from a lunar align. The unexplained error is about 0.4 arc min (~25 arc sec) in the pitch and roll axes. TRW stated that their analysis shows the error to be bounded and small enough to cause no problems. However, TRW considers it to be an open question until the error is accounted for. TRW is continuing their analysis of this run and will report results as obtained. TRW stated that the magnitude of the unexplained error is not large enough to cause undue concern and recommended the use of FP8 for Apollo 17.

b. LGC

(1) EMP to work around failure of certain LR transistors - The rationale for ceasing work on an EMP that would work around most of the problems associated with failure of one of the two suspect transistors in the Apollo 17 Landing Radar (LR) is documented in memorandum FS66-72-146, entitled "Software Workarounds for Possible Landing Radar (LR) Transistor Failures." The FSRR concurred with this rationale based on the current situation and there are, therefore, no plans to use such an EMP. The primary reason is that the failure cannot be detected until well into PDI, but the EMP would have to be loaded well before PDI. This is in direct conflict with an established EMP groundrule against altering the CMC or LGC configuration in any way simply in anticipation of a low probability failure.

(2) Difference between LGC and AGS computation of perilune leading up to PDI. Simulator runs have verified the existence of a large difference in perilune display between the AGS and LGC between DOI2 and PDI. However, the reason for the difference has been determined and is not due to any software anomalies in either flight program. The difference is due entirely to the difference between the lunar gravitational models used in the LGC and the AGS. The differences are not precisely repeatable because the AGS state vector is normally initialized by the LGC via astronaut keyboard commands at times not constrained to orbital position.

(3) A priori terrain model in the LGC - Because of limitations in the number of slopes provided in the LGC to model the lunar terrain, the analysis performed by the Mission Planning and Analysis Division to come up with the optimum set of constants resulted in a short but substantial mismatch between the true and LGC terrain. This is due to a large valley before the landing site and will result in about 20 seconds of 3- to 4-thousand foot differences between the LGC vector and LR measurement of altitude. In that time period, the LGC vector will be pulled off by something less than 2,000 feet.

c. CMC - CDU transients and failure indications during Apollo 16 - G&CD reported that the hardware analysis performed on the Apollo 16 Inertial Measurement Unit (IMU) CDU's isolated the CDU transients to the suspected inductance from the Thrust Vector Control (TVC) enable relay. A filter has been added to the Apollo 17 CDU's to prevent this problem in the future. The CDU failure indication is thought to be due to the failure of a zenier diode in the failure detection circuitry. As there are numerous of these diodes used through the Guidance and Navigation (G&N), and since there has never before been a failure suspected in them, no hardware action has been taken. As mentioned earlier, several special programs and procedures have been written and verified to workaround a large number of CDU malfunctions on the software side.

In summary then, there are no critical issues or problems associated with the Apollo 17 flight programs. Everyone involved with the review gave his respective endorsements to the programs, and the programs' long lifetime and use on two previous missions underline these statements of flight software readiness for Apollo 17.

Howard W. Tindall, Jr.

Enclosure

FS66/JRGarman:jvm:11/14/72:2308

LIST OF ATTENDEES

| | |
|---|---|
| S. Greene | GAC |
| J. Marino | GAC |
| C. Tillman | GAC |
| R. Larson | MIT/SDL |
| D. Millard | MIT/SDL |
| K. Greene | MIT/SDL |
| S. Copps | MIT/SDL |
| B. McCoy | MIT/SDL |
| G. Shook | TRW |
| K. Baker | TRW |
| K. Goodwin | MIT/EG |
| W. Sullivan | NASA |
| H. Miles | NASA |
| L. Gonzales | NASA |
| P. Shaffer | NASA |
| C. Kurten | NASA |
| B. Tindall | NASA |
| C. Hackler | NASA |
| G. Carman | NASA |
| B. Taylor | NASA |
| R. Carl | NASA |
| J. Garman | NASA |
| J. Williams | NASA |
| J. Mil. | NASA |
| W. Ankney | NASA |
| C. Finch | NASA |
| J. Roach | NASA |
| J. DeAtkine | NASA |

Enclosure