MEMORANDUM FOR FILE

The attached viewgraphs were used in a presentation to Dr. G. E. Mueller and Lt. Gen. S. C. Phillips on October 23 at POB-10B. The purpose was to review how the capabilities of the CM computer program Colossus might affect the Lunar Orbital alternative of the C-Prime mission.

Also attached are responses generated by Department 2014 and 2013 to questions asked at the presentation.

W. G. Heffron

2014-WGH-bjh

Attachments
SUBJECT: Computer Problems on Mission C - Case 310

DATE: October 24, 1968

FROM: W. G. Heffron

This note concerns problems with the use of the guidance computer on Mission C, as requested on October 23, 1968 in a meeting at FOB-10B. The information is preliminary and was furnished by Mr. Jack Garman, the prime shift computer expert for the Mission.

1. Star code 00 was used with auto optics while in platform alignment determination. It is not valid for Sundisk and a restart occurred with no mission impact in any way. It had occurred in training. It occurred in flight three times. Code 00 is valid for Colossus.

2. Use of P-30 (external ΔV pre-thrust) with ΔV = 0 to obtain an accurate display of apogee and perigee is an AOH (workaround) procedure. The computer coding in P-30 is such that for the pathological case of the vector ΔV = 0, it gives unit (ΔV) = (2, 0, 0). If REFSMMAT (IMU attitude matrix) has element(1,2) greater than 0.5 then unit (ΔV) · REFSMMAT row 2 is greater than 1. The arc-cosine programming causes a restart for arc-cosine (1+). This occurred twice (first use and retry) in flight. Note, if the REFSMMAT value is less than 0.5 there is no problem, which apparently was the case in training, where the procedure was used. There was no mission effect. The arc-cosine error in Colossus causes a "go to P-00" abort.

3. The crew operated V37 within 20 seconds after a restart in violation of a Sundisk program note. This would cause PIPA fail to go undetected. It was noticed by the ground but the crew was not informed because the computer was going to standby. The flag was reset properly automatically when the computer came up later. No mission effect. Same note exists for Colossus.

4. Calculations for platform alignment for a burn were made more than one orbit before it. The position calculation routine gives a wrong answer in such a case (program note exists) and alignment was about 30° - 40° off in yaw. It was noticed, in good time, by the crew during P-30 pre-thrust (less than one orbit before the burn) and corrected. The burn could have been conducted with the FDAI 30° - 40° off 000, but probably would have been skipped if noticed too late.
5. The crew thought P-21 (ground track determination) was hung up one time. This was over a station with no computer downlink. Over the next station, with downlink, by the time the ground diagnosed the problem it had gone away -- the time inserted into P-21 was considerably later than "now" and P-21 simply took a long time to finish. No mission problem. Colossus has V96E to stop P-21 in such a case, but the same problem would exist otherwise.

6. The DTO inserted late in the mission called for the optics line of sight to be aimed above the horizon. The computer tried to solve the problem of distance to the earth's surface, for which there is no solution in this case, and gave a restart on "square root of a negative number." The procedure was wrong and must not have been tested prior to transmittal to the crew.

The restart was "perpetual," once every 0.5 seconds. A fresh start was required but V36E cannot be keyed in within 0.5 seconds. The crew was forced to simultaneous depression of Error Reset and Mark Reject to cause the fresh start. In Colossus this error causes a "go to P-00" abort, not a restart.

7. When flashing verb 51 requests an optics mark, the correct response is ENTER if no more marks will be taken, followed by V37E00E to go to P-00. The crew skipped the E -- this left a flag in the wrong state and the mark button did not work the next time it was used. A workaround procedure was devised by Steve Copps, MIT, sent to the crew and they used it successfully. When the problem was diagnosed by the ground, a procedure was devised to reset the flag and all became normal. The crew could also have reset the flags directly if they had known which ones. Mission effect was to delay optics use for some time.

This is a general problem in responding to flashing verbs and exists in Colossus also. Crew must observe correct procedures, with no short cuts. It would have occurred in training.

8. If the optics trunnion angle desired exceeds 38°, the trunnion drive simply stops where it is, without driving over to the maximum value possible. Optics shaft drive has no limits. This caused two problems.

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A. In post-rendezvous tracking of the SIVB, it suddenly went out of view and tracking was abandoned. The SCS was being used for attitude control and 38° was exceeded. The computer showed an alarm (over 38° commanded), but the crew had given up. If attitude had been under computer control, the CSM would have been rotated to reduce the command to less than 38° and track would have been maintained (except for a transient). But such sudden attitude changes had been experienced earlier by the crew and objected to by the crew, so they selected SCS.

With the eyes at the optics and the optics shaft drive running, it is difficult to notice either the DSKY alarm or the cessation of trunnion motor operation. Best procedure is to use the computer autopilot and endure the transient.

B. Before landmark tracking, the optics are zeroed. If the landmark requires over 38° trunnion, the optics stay at zero trunnion. This persists until the landmark trunnion is less than 38, but then the landmark is moving one way (decreasing trunnion) and the optics the other way (from 0 up towards the command) and lock on the landmark gets difficult.

After this happened in flight, the ground suggested a manual motion to 35° after optics zero. It worked very well.

I couldn't find a program note on this. The crew can readout the desired and actual angles and see if the optics are pointed properly. The error probably exists in Colossus also, and should have been observed in training.

9. Pre-retrofire the correct procedure involves V48E (DAP data load) followed by V46E (turn DAP on). Apparently the crew did V46E, V48E and the DAP was not on. The ground caught it from the flag words, requested V46E, the crew did it and the DAP went on.

If not observed by the ground, the crew would have observed lack of attitude control and switched to SCS. It applies for any burn and would have shown up in training. Will occur in Colossus, also.

10. The crew keyed in + xxx.xx for latitude of a landmark instead of - xxx.xx. Not seeing the landmark in the optics, they could have switched to "unknown landmark tracking."
Additionally, for your information, V36E (Fresh Start) does not zero the state vector.

Copy to
Messrs. G. H. Hage - NASA/MA
C. M. Lee - NASA/MA
A. P. Boysen, Jr.
D. A. Chisholm
D. A. Corey
B. G. Niedfelt
L. M. Ross
R. V. Sperry
R. L. Wagner
Central Files

W. G. Heffron
Dr. G. E. Mueller - NASA/M:
Lt. General S. C. Phillips - NASA/MA:

I believe the attached letter to Mr. C. C. Kraft, which has been sent, is the best way to settle the questions you asked on October 23, 1968 regarding possible problems with the computer during pre-thrust and thrusting operations on Mission C-Prime.

W. G. Heffron
Subject: Review of Colossus Program Notes - Case 310

October 25, 1968

Mr. C. C. Kraft
Director of Flight Operations
Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas 77058

Code: PA

Dear Chris:

Review of the Colossus Program Notes, particularly numbers 1.2.8, 1.79, 3.7.2, 3.7.4, 3.7.5 (see attachment), causes me some concern about the susceptibility of the pre-thrust and thrusting programs to restarts and aborts.

I would appreciate it if these problems receive special attention at the Colossus FSHR on November 5, 1968, addressing the following aspects:

1. Should crew procedures in P30, P40 and P41 be written to minimize computer activity (avoidance of special displays, for example)?

2. Should special crew training and procedures for overcoming possible problems be required?

3. A report at the FSHR regarding how often problems of this type have occurred during Colossus testing and use is also requested.

Best regards,

Original signed by

2014-WGH-bjh

W. G. Heffron
Department Head
Guidance and Navigation

Attachment

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Bellcomm, Inc.
1.2.8 Since some extended verbs (notably V82, V83, and V85) use several JOB areas, a software restart may be generated if these verbs are selected in periods of high activity due to VAC or Core Set overflow. In this case the Program Alarm light will be lit and alarm code 1201 or 1202 will be stored. Extended verb activity will be lost and the verb must be reselected. Typical periods of high activity when this might occur are (1) V83 in P3X or P7X with P20 in the background, and (2) V82 in P4X with Lambert.

1.7.9 An interpreter abort (codes 1301 and 1302) during average G will request a new program (flashing V37) and leave the permanent state vector at its value before average G was initiated. The result is that all subsequent onboard computations will not account for the ΔV added during average G. However, until the next permanent integration, the quantities on the downlist will have accounted for the ΔV. After the integration, this information is lost. This type of abort will most probably require a new uplink.

3.7.4 If a restart occurs between TIG + 0 and TIG + 0.4 seconds, the TVC gimbal actuator interface will not be re-established. Avoidance procedure: none. Recovery procedure: After a restart select P00 and then retarget via P3X. An alternative would be to exercise V69E immediately. This will force a hardware restart and re-establish proper TVC control.

3.7.5 If a POOD00 type of ABORT (aborts 1206, 1210, 1301, 1302, 1501, 1502) occurs during SERVICER, SERVICER is never finished. This means that the state vector is lost if a burn has occurred. Also, this means PIPA compensation information is left in an incorrect state with the results PIPA compensation will not take place after this type of abort. Avoidance procedure: none. Recovery procedure: Uplink new state vector. Select P47 in order to establish proper PIPA compensation. Select new desired program after the first display in P47.
SUBJECT: Use of NR Simulator for C-Prime Case 310

DATE: October 24, 1968

FROM: W. G. Heffron

Dr. G. E. Mueller - NASA/M:

This note concerns use of the NR Mission Evaluator for C-Prime mission validation, as requested on October 23, 1968 in a meeting at FOB-10B.

The NR simulations will be used for two weeks on C-Prime high speed entries with prime crew participation. Otherwise it will be used for the D mission (using Colossus I until IA becomes available).

The reason is that the facility does not have cislunar or lunar capability at present. It is under development and will be ready in early 1969 for the mission after D. Mr. Low decided it was too expensive to advance the date for this capability.

The CMS is therefore the only facility available for lunar operations training, and is being so used.

This information was furnished by Mr. D. Cheatham, GCD, MSC.

2014-WGH-bjh

Copy to
Messrs. G. H. Hage - NASA/MA
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I. M. Ross
R. V. Sperry
R. L. Wagner

Official File Copy
Bellcomm, Inc.
Date: October 25, 1968

From: W. G. Heffron

Dr. G. E. Mueller - NASA/M:

The spacecraft computer include circuits which warn of under--and over--voltage in the power supplies.

Although there have been demonstrations that the computer will work properly outside the assigned ranges, the present tolerances are considered by GCD as proper and judicious, and have been the subject of several reviews. GCD does not consider that there is sufficient evidence at the present to warrant broadening the range of acceptability voltages.

Changing the limit values would involve redesign of the modules involved, as well as the effort to determine the new values to be used.

This information was furnished by Mr. Holley, GCD, MSC.

W. G. Heffron

Copy to
Messrs. G. H. Hage - NASA/MA
C. M. Lee - NASA/MA
A. P. Boysen, Jr.
D. A. Chisholm
D. A. Corey
B. G. Niedfeldt
I. M. Ross
R. V. Sperry
R. L. Wagner

Central Files
Mr. W. G. Heffron:

The validation of the RTCC Orbit Determination Program (ODP) is being based upon reprocessing of tracking data collected during the Lunar Orbiter Missions. Tracking data arcs are selected so that they are identical to those previously processed at JPL. The resulting converged ODP solution and the residuals of the fit are then compared to those obtained by JPL. Discrepancies in the results are then checked out. RTCC ODP runs are being made using translunar and lunar parking orbit tracking data.

The Doppler tracking data, which is available for this validation effort, is from the DSN and MSFN. Only three-way Doppler tracking data from the MSFN is available during translunar coast. Range and two and three-way Doppler tracking data is available from the MSFN during lunar orbiting phases. Range and Doppler tracking data is available from the DSN during both phases.

During an Apollo lunar mission, three independent data types will be available for ODP processing; range, Doppler, and on-board sextant sightings. An RTCC ODP solution will be based only on Doppler data. This converged solution will then be passed through the other two data types and the quality of the fit will be determined in real time. This procedure will be carried out through the entire mission.

2014-BGN-bjh

B. G. Niedfeldt
SUBJECT: Some Trajectory and Abort Options for the C-Prime Mission - Case 310

DATE: October 30, 1968

FROM: R. A. Bass
T. B. Hoekstra

MEMORANDUM FOR FILE

The attached charts were prepared for use by Mr. A. P. Boysen, Jr. at the C-Prime Mission Planning Meeting, October 28, 1968 at MSC.

R. A. Bass
T. B. Hoekstra

Attachments

Copy to Messrs.
D. R. Anselmo
A. P. Boysen, Jr.
J. O. Cappellari, Jr.
D. A. Chisholm
D. R. Hagner
W. G. Heffron
B. T. Howard
D. B. James
J. L. Marshall, Jr.
J. Z. Menard
V. S. Mummert
P. E. Reynolds
I. M. Ross
R. V. Sperry
J. W. Timko
R. L. Wagner
All Members, Department 2013
Department 1024 Files
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SOME TRAJECTORY AND ABORT OPTIONS FOR C-PRIME

ALL DATA PRESENTED IS BASED ON PATCHED CONIC TRAJECTORIES DEVELOPED FOR A C-PRIME MISSION LAUNCHED ON DECEMBER 21, 1968 WITH PACIFIC INJECTION AND AT A LAUNCH AZIMUTH OF 72 DEGREES.

FIGURE 1

RCS CIRCUMLUNAR ABORTS

This figure shows the RCS ΔV costs for circumlunar aborts at 6 1/2 hours after TLI. Both underburn and overburn at TLI are considered. A 50 FPS error in TLI velocity corresponds to approximately a one second error in burn time. The three sigma variation in TLI velocity is expected to be fifteen FPS.

The RCS ΔV costs were determined allowing full optimization of both post abort perilune distance and return inclination.

FIGURE 2

The ΔV cost for targeting to increased perilune altitude.

This curve presents the ΔV penalty resulting from targeting the C-PRIME trajectory to higher perilune altitudes followed by a later transfer to the nominal 60 N.M. circular orbit. The ΔV penalty includes the transfer costs. This option would require an additional SPS burn plus a retargeted TLI.
FIGURE 3

- CURVE #1 SHOWS ΔV REQUIRED TO ABORT FROM HIGH APOGEE ELLIPSES RESULTING FROM TLI UNDERBURNS (ABORT CARRIED OUT AT APOGEE).

- CURVE #2 SHOWS TLI ΔV DEFICIENCY VS BURN TIME (AT END OF BURN, 1 SECOND IS EQUIVALENT TO ABOUT 50 FPS IN TLI ΔV).

- CURVE #3 SHOWS APPROXIMATE TIME FROM TLI TO REENTRY FOR HIGH ELLIPSE ABORTS.

NOTE: 3 BODY EFFECTS MAKE IT INVALID TO EXTRAPOLATE THE ABORT ΔV CURVE BEYOND ABOUT 305 SECONDS.
FIGURE 4

- SHOWS ΔV REQUIRED TO CORRECT TEI ΔV ERRORS FOR VARIOUS COAST TIMES FROM TEI TO CORRECTION.

- ASSUMES TEI VELOCITY ERROR IS COLLINEAR WITH TEI ΔV.

CONCLUSIONS
- ABOUT 3 FPS OF CORRECTION IS NEEDED FOR EVERY 1 FPS OF TEI ERROR IF THE CORRECTION OCCURS BETWEEN 3 AND 12 HOURS AFTER TEI (THE MSI IS PASSED ABOUT 12 HOURS AFTER TEI).
- CORRECTIONS OCCURRING LESS THAN 3 HOURS AFTER TEI HAVE A LOWER ΔV CORRECTION / ΔV ERROR - SEE FIGURE 5.
- THE RCS ΔV CAPABILITY WILL PROBABLY BE NEAR 100 FPS AT TEI WHICH PERMITS ABOUT A 35 FPS TEI ΔV ERROR (THIS WOULD BE ABOUT A 1 1/2 SECOND MAXIMUM OVERBURN OR UNDERBURN).

FIGURE 5

- SHOWS ΔV CORRECTION / ΔV ERROR FOR VARIOUS COAST TIMES FROM TEI TO CORRECTION.

- ASSUMPTIONS SAME AS FIGURE 4.

CONCLUSIONS
- DO CORRECTION AS SOON AS POSSIBLE.
- IF DELAY IS OVER 3 HOURS, IT DOES NOT HURT TO WAIT A FEW HOURS LONGER.
Figure 1
RC5 CIRCUMNAVIGATING ABOFT FROM TLI OVERBURN
WITH SPS ENGINE FAILURE

(160 Fps - Max. RCS
AV CAPABILITY ON 0°)

36°

70
-50

-100

-150

-200

-50
-40
-30
-20
-10
0
10
20
30
40
50

TLI ERROR - FPS

1. 50 FPS IS APPROXIMATELY ONE SECON TLI OVERBURN
2. ABORT TIME IS 6 1/2 HOURS PAST TLI
Figure 2. Cost of Targeting to Increased Recalling Altitude followed by Transfer to 60,000 ft. MSL, Cessna 210.
REVIEW

- COLOSSUS DEVELOPMENT AND VERIFICATION
- C-PRIME USE OF COLOSSUS
- PROGRAM NOTES AND ANOMALIES
- RESTARTS, FRESH STARTS, OPERATOR ERRORS
### Possible Schedules for S/C Rope Manufacture

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SOFTWARE TESTING - COLOSSUS - CM - AS-503 AND UP

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- G&CD/MSC SIMULATOR

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**MIT**

- **LEVEL 5 POST CARR**
- **C MISSION VERIFICATION (HYBRID AND ALL DIGITAL)**
- **INCLUDES RTCC COMPATABILITY (ALL DIGITAL)**
- **C MISSION HARDWARE/AUTOPILOT (HYBRID)**

**TRW/Houston (Sundisk)**

- **C MISSION EVALUATION (HYBRID) (PARTIALLY)**
- **29 DISCREPANCIES**

**NR**

- **C MISSION HARDWARE/AUTOPILOT (HYBRID)**
- **NO DISCREPANCIES**

**G & CD/MSC Simulator**

**Trainners**

- CMPS
- DCPS
- CMS 1 (MSC)
- CMS 2 (KSC)
- CMS 3 (KSC)

**SOFTWARE TESTING - SUNDISK AS-205**
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<tr>
<th>G&amp;C FUNCTIONS</th>
<th>PRELAUNCH</th>
<th>LAUNCH</th>
<th>EARTH PARKING ORBIT</th>
<th>TRANSLUNAR INJECTION</th>
<th>SEPARATION</th>
<th>TRANSPOSITION &amp; SIMULATED DOCKING</th>
<th>1st MCC</th>
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<th>3rd MCC</th>
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<th>CIRCULARIZATION BURN</th>
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</table>
RESTARTS

CAUSED BY:

1. 28 v SUPPLY BELOW 22.6 v, OR/4 v BELOW 12.5 v OR ABOVE 16 v, OR 4 v BELOW 3.65v OR ABOVE 4.4 v
2. COMPUTER OSCILLATOR FAILURE
3. "NIGHT WATCHMAN" - FAILURE TO ADDRESS CELL 0067 WITHIN 0.64 TO 1.92 SECONDS. (PROGRAM HANGUP)
4. "TC" (TRANSFER CONTROL TO ---) OR "TCF" (= "TC" BUT ONLY TO FIXED MEMORY) ORDER IN EFFECT FOR 5 TO 15 ms, OR NO "TC" OR "TCF" DONE IN THIS INTERVAL OR AFTER A COUNTER INTERRUPT. SOFTWARE USES "TC-SELF" TO CAUSE A RESTART
5. PARITY FAIL ON A WORD READ IN EITHER ERASABLE OR FIXED MEMORY
6. PROGRAM INTERRUPT FAILURE ("RUPT" LOCK) - PROGRAM INTERRUPT CONTINUOUS FOR 140 TO 300 ms, OR IF NO PROGRAM INTERRUPT IN THIS INTERVAL
7. RECOVERY FROM STANDBY OPERATION
8. V69E BY CREW ON DSKY
WHEN A RESTART OCCURS, COMPUTER

1. TESTS "TRUE" AND "COMPLEMENT" DATA IN RESTART
   PHASE TABLES TO SEE IF THEY ARE GOOD

2. IF NOT OK, CALLS FOR FRESH START

3. IF OK, RESTARTS JOBS AND TASKS WHICH APPEAR IN
   THE TABLES
SOFTWARE HAS SIX RESTART GROUPS

1. POWERED FLIGHT NAVIGATION
2. ORBITAL INTEGRATION
3. PRE-IGNITION, GENERAL
4. TIME DISPLAY ON DSKY
5. VELOCITY REQUIRED, LAMBERT
6. BURN TIME, PRE-IGNITION

MANY DISPLAYS ARE NOT RESTART PROTECTED

SOFTWARE ALARMS CAUSING RESTARTS (R), BAILOUTS (B), GO TO POO (P)

401 DESIRED GIMBAL ANGLES YIELD GIMBAL LOCK (P) 1210 TWO PROGRAMS USING IMU OR OPTICS
1103 UNPLANNED LOGIC BRANCH USED (B) 1211 ILLEGAL INTERRUPT OF EXTENDED VERB
(B) 1104 DELAY ROUTINE BUSY (P) 1301 ARCSIN-ARCCOS INPUT TOO LARGE
(B) 1201 NO VAC. AREAS AVAILABLE (P) 1302 \sqrt{} OF NEGATIVE NUMBER
(B) 1202 TOO MANY JOBS (P) 1501 INVALID DISPLAY DATA FROM INTERNAL PROGRAM
(B) 1203 TOO MANY TASKS (P) 1502 ILLEGAL FLASHING DISPLAY
(P) 1206 >1 PROGRAM USING DSKY 1601 BAD IMU TORQUE
(B) 1207 NO VAC. AREA FOR MARKS
APOLLO 7 HAS HAD RESTARTS
(SEE MEMO ATTACHED FOR DETAILS AND ADDITIONS)

1. WITH EVERY POWER UP/STANDBY (NORMAL)

2. INCORRECT USE OF P-30 (EXTERNAL \(\Delta V\) PRE-THRUST). TRYING TO GET \(H_A, H_P\) DISPLAYED, USED \(\Delta V = 0\) WHICH CAUSED ARCSIN ARGUMENT RESTART. CAUSED BY WRONG EARTH RADIUS IN NOUN 44 WHICH IS PROPER DISPLAY. (FIXED IN COLOSSUS)

3. INCORRECT USE OF STAR "PICK-A-PAIR" IN PLATFORM ALIGNMENT (2 ON 10/11/68, 1 ON 10/17/68) (WON'T HAPPEN IN COLOSSUS)
V69E

V09E  SPARE
V19E  SPARE
V29E  SPARE
V39E  SPARE
V49E  START CREW DEFINED MANEUVER
V59E  PLEASE MARK
V79E  START LUNAR LANDMARK SELECTION
V89E  RESET VHF RANGE FLAG
V99E  ENABLE ENGINE IGNITION
V68E  SET ATT. REF. TO NOW ATT.

V61E  MODE I ATT. ERROR
V62E  MODE II ATT. ERROR
V63E  MODE III ATT. ERROR
V64E  S-BAND ANT. CALCS.
V65E  START OPTICAL VERIFY OF PRELAUNCH
V66E  CSM STATE TO LM CELLS
V67E  W-MATRIX RMS DISPLAY
V68E  CSM STROKE TEST ON
V96E  STOP INTEGRATION, GO TO POO
N96E  X-AXIS ATTITUDE FDA1 ANGLES
FRESH STARTS

CAUSED BY:

1. V36E
2. RESTART DATA DESTROYED
3. MARK REJECT AND ERROR RESET BUTTONS PUSHED SIMULTANEOUSLY. MARK REJECT REQUIRES OPTICS POWER ON

- ESSENTIALLY PUTS THE COMPUTER INTO "IDLING" (POO)
- RESETS EARTH/MOON TO EARTH
- SETS REFERENCE ATTITUDE FLAG TO NOT GOOD
- MAY DESTROY STATE VECTOR IF INTEGRATION WAS IN PROCESS
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<td>V86E</td>
<td>REJECT REND BACKUP MARK</td>
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<td>V96E</td>
<td>STOP INTEGRATION, GO TO POO</td>
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<td>V30E</td>
<td>REQUEST EXECUTIVE</td>
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<td>REQUEST WAITLIST</td>
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COLOSSUS NOTES AND ANOMALIES

GENERAL

1.2.1  DON'T CALL V37 FOR 20 SEC AFTER "NO ATT" GOES OFF, OR PIPA FAIL WILL GO UNDETECTED

1.2.8, 9  HIGH COMPUTER ACTIVITY OCCURS, WITH RESTART LIKELY, IN P3X (PRE-THRUSTING) OR P7X (PRE-THRUSTING FOR LM) WITH P20 (RENEZVOUS NAVIGATION) RUNNING, PLUS EXTENDED VERB 83 (REND. PARAM. DISPLAY) - OR IN P4X (THRUSTING) WITH LAMBERT PLUS EXTENDED VERB 82 (ORB. PARAM. DISPLAY). RESTARTS WILL DUMP ALL EXTENDED VERBS.
COLOSSUS NOTES AND ANOMALIES

- AS OF OCT. 10, 1968, THERE ARE 73 NOTES, 59 OF WHICH APPLY FOR C-PRIME USES.

- AS OF OCT. 18, 1968, THERE HAVE BEEN 51 ANOMALIES DISCOVERED. 7 ARE TRIVIAL OR FALSE, 34 ARE ALREADY IN NOTES, 10 ARE OPEN.
## PRE-LAUNCH

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>P01</td>
<td>Initialize azimuth, pad and vehicle data, optical target date, IMU data. Coarse align platform</td>
</tr>
<tr>
<td>P02</td>
<td>Fine align</td>
</tr>
<tr>
<td>P03</td>
<td>Crew commands optical verification</td>
</tr>
<tr>
<td>P02</td>
<td>Crew commands new azimuth. 320 sec for torquing and re-leveling platform</td>
</tr>
</tbody>
</table>

Liftoff signal from S-IVB, backup V75 E (key V75 at T-2 min.). Go to P11
LAUNCH, TLI MONITOR

DISPLAY ATTITUDE ERRORS ON FDI FOR 163.8 SEC.
MONITOR VI, H DOT, H UNTIL SHUTDOWN

ALL SCS AUTO MODE

MONITOR VI, H DOT, H UNTIL SHUTDOWN, WHICH IS BACKED
UP BY CREW USING TIME AFTER PREDICTED SHUTDOWN

LAUNCH

ABORTS

TLI MONITOR

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COLOSSUS NOTES AND ANOMALIES

PRE-LAUNCH, LAUNCH, TLI MONITOR

NONE OF IMPORTANCE
RTE ABORT FROM TRANSLUNAR LEG

P27 CMC UPDATE AND TARGETING FOR EXTERNAL ΔV BURN

P30 PRE-THRUST, EXTERNAL ΔV

P40 SPS THRUSTING

P23 CISLUNAR NAVIGATION

BACKUP

P37 RETURN TO EARTH TARGETING FOR EXTERNAL ΔV BURN. GIVEN TIME, ΔV BURN MAGNITUDE, LANDING SITE, ENTRY FLIGHT PATH ANGLE, P37 FIND BURN ATTITUDE FIRST BY PATCHED CONICS, THEN BY PRECISION INTEGRATION.
UP DATA CAPABILITY AT LUNAR RANGE

- WITH FULL CSM COMMUNICATIONS CAPABILITY (HIGH GAIN ANTENNA AVAILABLE)
  (CSM IN HIGH BJT RATE TELEMETRY MODE)

  UP DATA STATE VECTOR IN APPROXIMATELY 60 SECONDS
  VERIFICATION BY REMOTE SITE COMMAND COMPUTER AUTOMATICALLY

- WITH REDUCED CSM COMMUNICATIONS CAPABILITY (NO HIGH GAIN ANTENNA)
  (CSM IN LOW BIT RATE TELEMETRY MODE)

  UP DATE CAN BE TRANSMITTED TO CSM AT NORMAL RATE
  VERIFICATION WILL HAVE TO BE ACCOMPLISHED MANUALLY

  • ASTRONAUT READ OUT VIA VOICE LINK
  • FLIGHT CONTROLLER VERIFICATION POSSIBLE BY MANUAL
    COMPARISON OF TELEMETRY DATA AND LOAD

  UPDATE CAN ALSO BE VOICED UP
IMU ON CONTINUALLY, PERIODICALLY REALIGNED

TELESCOPE - 4TH MAGNITUDE STARS REQUIRED FOR CONSTELLATION RECOGNITION

SEXTANT - 8TH MAGNITUDE STARS MAY BE VISIBLE AND FORM A PATTERN USED FOR STAR IDENTIFICATION IF TELESCOPE UNUSABLE

MAPS MAY BE CARRIED

SOFTWARE OPTIONS PERMIT USE OF SUN, EARTH, MOON, PLANETS (GROUND LOCATED) FOR ALIGNMENT. SUN FILTER FOR SXT AVAILABLE AND UP FOR CCB APPROVAL. 1/40 ACCURACY SATISFACTORY

COAS AS BACKUP TO SCT AND SXT FOR ALIGNMENT

BMAGS, FDAI AS BACKUP TO IMU (6°/HR, 3° DRIFT)
FIRST AND SECOND MAGNITUDE STARS
1-3 MAGNITUDE STARS
1 - 4 MAGNITUDE STARS
APOLLO 7
PRELIMINARY RESULTS

- Tests on number of stars seen in telescope (SCT) are in good agreement with Project MOSES data, lend validity to LM-docked results from MOSES.

- Need 4th magnitude star visibility in SCT for constellation/star verification, seems achievable except for a few minutes after urine dump (can be scheduled or water dump (maybe not scheduleable))

- Reinforces trend toward star-earth horizon sightings replacing star-earth landmark sightings
COLOSSUS NOTES AND ANOMALIES

NAVIGATION

1.4.5 MOON ROTATION IN 2 HOURS IS STORED AS 6.7°, NOT 1.07°. GROUND TRACK PREDICTIONS 2 HOURS OR MORE AHEAD WILL HAVE OUT-OF-PLANE ERROR. LESS TIME AHEAD - NO ERROR.

1.6.9 SXT AND CDU ANGLES ARE NOT DOWNLINKED FOR STAR MARKS WHILE DOING ALIGNMENT DETERMINATION OR FINE ALIGN (P50, 51, 52, 53). ALIGNMENT MATRIX IS ON DOWNLINK. SLOW WORKAROUNDS EXIST.

3.6.2 A RESTART IN ONE PART OF R51 (FINE ALIGN) REQUIRES A RECYCLE, KEY STROKES, NEW STAR SIGHTINGS
FIGURE 4-1 - DISPLAY AND KEYBOARD ASSEMBLY
P-30 - EXTERNAL \( \Delta V \), PRE-THRUST

V37 E 30 E

F V06 N33 TIG

\( \text{PROCEED} \)

V25 E TO CHANGE TIG
LOAD DSKY

F V06 N81
\( \Delta V \) IN LOCAL VERTICAL AT TIG

\( \text{PROCEED} \)

V25 E TO CHANGE \( \Delta V \)
LOAD DSKY

SET EXT \( \Delta V \) FLAG

\( \text{CONFIRM BY GROUND} \)

F V06 N42
\( H_A, H_P, \Delta V \)

\( \text{PROCEED} \)

CONFIRM BY GROUND

RESELECT P30 IF UNHAPPY & CHANGE \( \Delta V \)

F V16 N45
#MARKS T TO TIG MIDDLE GIMBAL ANGLE AT TIG

\( \text{PROCEED} \)

ASSESS, RECYCLE AS REQUIRED

ROO

SET DEADBAND

F V37

REQUEST FOR NEW PROGRAM, KEY
V37 E 40 E - P40/SPS, OR
V37 E 41 E - P41/RCS
P-40 (SPS THRUST)

V37 E 40E

IMU STATUS CHECK,
C=0 IN CROSS PRODUCT,
THRUST DIRECTION,
ENGINE GIMBAL ANGLES,
SET 0.5° DEADBAND,

R60 ATTITUDE MANEUVER ROUTINE

F V50 N18
ROLL PITCH YAW
THRUST ATTITUDE

EXIT. ATTITUDE NOW OK ENTER

DO MANEUVER,
FLASH DISPLAY
UNTIL COMPLETE
RETURN TO P-40

F V50 N25
REQUEST ENGINE
GIMBAL TEST DRIVE

ENTER (NO) PROCEED

DO TEST

SET GIMBAL TO TRIM

V06 N40
T TO TIG
VG
ΔV MEASURED

UPDATE STATE VECTOR TO TIG-30
VG STILL COMPUTED

F V16 N40
T TO GO
VG
ΔV MEASURED

PROCEED

MINIMUM DEADBAND

F V16 N85
VG IN BODY AXES

PROCEED

DO ROO

SELECT POO (IDLE)
OR AS DESIRED

MANUALLY CONTROL RCS TO NULL, IF DESIRED
COLOSSUS NOTES AND ANOMALIES

PRE-THRUST & THRUSTING

1.5.7 \( V_G \) OR \( \Delta V \) DISPLAYS IN BODY AXES HAVE TIME DELAYS OF 0.5 - 1.5 SEC.

3.7.2 RESTART IN ONE PART OF AVERAGE-G NAVIGATION CAUSES PARTIAL OR COMPLETE LOSS OF PIPA COMPENSATION. RESELECT PROGRAM

3.7.4 RESTART BETWEEN T1G AND T1G + 0.4 SECONDS STALLS TVC. DO V69E, OR GO TO POO, THEN RETARGET BURN.

3.7.5 A 1206, 1210, 1301, 1302, 1501, 1502 ALARM ABORT DURING AVERAGE-G NAVIGATION CAUSES THE THRUST OR DRAG EFFECT ON THE STATE VECTOR TO BE LOST, PLUS PIPA COMPENSATION STOPS. RESELECT P47 TO RENEW PIPA COMPENSATION, UPLINK NEW STATE VECTOR

COL 45 ALARMS 1104, 1201, 1203, 1206, 1207, 1210, 1211, 1301, 1302, 1501, 1502 MAY CAUSE ENGINE SHUTDOWN.
TRANSLUNAR LEG

P23 Cislunar Navigation. Onboard and MSFN state vectors are both carried, with MSFN used if available.

P27 CMC update, MCC external ΔV targeting.

P30 Pre-thrust, external ΔV.

P40/41 SPS/RCS burns

Lacking the DPS as backup, MCC burns keep trajectory within RCS reach of free return. MCC's at TLI + 6 hours and at TLI + 25 hours use free return best adaptive path for mission success with a minimum fuel free return backup. Change time if required to keep backup within RCS capability. MCC's at LO1 -22 hours and LO1 -8 hours will target XYZT but if 10 FPS, change MCC time until >10 FPS. If this fails, then target minimum ΔV free return (with water landing).
LUNAR ORBIT INSERTION

LOI-1 & 2  
(60 x 170, 60 x 60 ORBITS)

P27  
CMC UPDATE, TARGETING DATA FOR EXTERNAL ΔV

P30  
PRE-THRUST, EXTERNAL ΔV (3000 FPS (1), 138 FPS (2))

P40  
SCS THRUSTING

P30  
ORBIT PARAMETER DISPLAY (\(H_A\), \(H_P\), TFF TO 300,000 FT (EARTH) OR 35,000 FT (MOON))

BACKUP  
SCS

60 x 170 LOI-1 PERMITS CREW SHUTDOWN USING EMS ΔV COUNTER SAFELY, OVERBURN DUE TO ΔV COUNTER ERRORS (0.15 FT/SEC², 1.5%) STILL GIVES SAFE PERILUNE
Figure 15 - Lunar orbit SC navigation for C1 alternate 1.

- LANDMARK TRACKING FOR LM DESCENT TARGETING
- ★ UNKNOWN LANDMARK TRACKING
- ◇◇◇◇ LIGHTING EVALUATION
- ---- PHOTOGRAPHY
TRANS-EARTH LEG

PROGRAMS AS IN TRANSLUNAR LEG WITH EMPHASIS ON BACKUP ON-BOARD NAVIGATION, (TEI + 1/2 HOUR ON), TWENTY EIGHT STAR/LUNAR HORIZON SETS OF MARKS, 23 STAR/EARTH HORIZON SETS, AND 3 STAR/EARTH LANDMARK SETS.

BASIC MCC PHILOSOPHY IS ACCEPT SPLASH POINT AND USE MCC'S TO CONTROL ENTRY FLIGHT PATH ANGLE.

BURNS ARE MADE IF OVER 1 FPS IS REQUIRED, AND THEY WILL BE MADE AS OFTEN AS REQUIRED. LAST BURN IS AT ENTRY-2 HOURS. SENSITIVITY IS 0.09°/FPS AT THIS LAST BURN.
RETURN TO EARTH

1.2.10 TFF - TIME TO ENTRY - MAY BE INACCURATE IN HYPERBOLIC ORBITS FOR CERTAIN RANGES OF TRUE ANOMALY

1.5.5 FOR PRE-APOGEE, LONG TIME ABORTS CONIC SOLUTIONS MAY YIELD BAD LANDING POINTS. PRECISION TRAJECTORIES MAY TAKE 10-30 MINUTES, WILL SHOW LANDING POINTS ACCURATELY. (PRECISION TRAJECTORIES ARE DONE AFTER CREW APPROVES CONIC SOLUTIONS)

3.5.1 P37 (RTE TARGETING) IS NOT RESTART PROTECTED. IF A RESTART OCCURS, RESELECT P37.
STAR-EARTH HORIZON FIELD OF VIEW
RETURN TO EARTH - LATE DECEMBER LAUNCH

5° BAND DUE TO ABLATIVE MATERIAL

50° FIELD

15° AROUND SUN UNUSABLE
(SUN OUTSIDE FOV FOR EARLY LAUNCH)

UNUSABLE BECAUSE OF POOR HORIZON LIGHTING

DARK HORIZON UNUSABLE

STARS MUST BE 1.6 MAGNITUDE OR BETTER

RESULT: FOR 8 HOURS DURING RTE FROM LAST PART OF WINDOW, ONLY 1 STAR IS AVAILABLE. BUT NAV ACCURACY IS STILL ±1/4° IN ENTRY FLIGHT PATH ANGLE, AND CORRIDOR IS ±1° WIDE.
ENTRY

- Nominal range 1200 NM, flight path angle -6.48°. Backup range 1800 NM. Corridor ±1° at 36500 FPS.
- 10% land area at 165°W, south of equator, but guidance accuracy good at 1200 NM range.
- Entry splash point resulting from TE1 burn will be accepted if fleet can reach it. MCC's then for flight path angle control. Otherwise MCC at MSI corrects splash point.
- 1200 NM range has 6.1 G max and no skip (0.8 G min)

Alternative modes for entry
- Completely automatic
- CMC guidance + manual attitude control
- Entry monitor system - range control
- G-meter-constant G-bank reversal timed
- Seat of pants
COLOSSUS NOTES AND ANOMALIES

ENTRY

1.2.2 IN ENTRY PROGRAM SEQUENCE (P 62 - SEP, TO P 67 - FINAL), V37 CAUSES A 1520 ALARM AND ENTRY KEEPS RUNNING, EXCEPT FOR V37NOO-GO TO POO.

1.7.17 TRIM ATTITUDE YAW AND ROLL GIMBAL ANGLES DISPLAYED TO CREW WHEN EXOATMOSPHERIC MAY BE WRONG.
SUBJECT: Colossus on C-Prime Case 310

FROM: W. G. Heffron

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