

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

REPLY TO ATTN OF: FC54 (71-142)

AUG 1 3 1971

MEMORANDUM

TO: FC/Apollo 15 Flight Director

FROM: FC5/Retrofire Officers

SUBJECT: Apollo 15 Postflight Report

I. Problems/Resolutions.

A. Prelaunch - No major RFO problems.

B. Launch through LOX Dump - This portion of the flight was nominal, except for the SPS ignition circuit anomaly after docking that caused the SPS Thrust Light to illuminate.

C. SIVB Lunar Impact Targeting - Two SIVB APS MCC's were executed. APS, was delayed because of a vector problem.

D. Translunar Coast.

1. During LM housekeeping, the outer glass in the tape meter was found to be broken; however, no impact to LM status.

2. The EMS scroll and RSI lights and the status lights on the LEB DSKY were disabled by a circuit breaker which opened due to a short. The circuit breaker was not reset.

E. LOI/DOI - The only significant problem was that during DOI computation the DMT picked up an incorrect spacecraft weight. The RTCC weight was corrected and DOI computation proceeded smoothly. A DR was written against the RTCC.

F. Predescent Lunar Orbit - No major RFO problems.

G. LM Activation through T_2 - CSM/LM undocking was late because of a cable/plug problem in the funnel.

H. Lunar Stay - No significant RFO problems.

I. Ascent/Rendezvous - No RFO problems.

J. Post-docking Lunar Orbit.

1. Due to difficulty in the suit and hatch integrity checks, ascent stage jettison and subsequent deorbit were delayed one rev each. The ascent stage jettison was about 30° past the nominal inertial point. This placed the LM behind and above the CSM; thus, the CSM retrograde separation maneuver was in the general direction of the ascent stage. To avoid thrusting toward the ascent stage, a 2-fps posigrade separation burn was executed.

2. Due to the extra revolution prior to LM jettison, the Flight Director planned to allow the crew to sleep longer. This would leave the crew without any block data for about one rev; however, the Flight Director felt that this was acceptable. After wakeup, the crew was passed TEI_{62} since TEI_{60} would have expired shortly.

K. TEI - No major RFO problems.

L. Transearth Coast/Entry.

1. The CSM Sim Bay mapping camera extend/retract mechanism failed in the extended position. This had only a small effect on the CSM c.g. and corresponding SPS engine trims.

2. During the computation of the MCC-7 external ΔV command load, the routine that converts the decimal data to octal for uplink made a significant error in the ΔV conversion. The decimal value used in the trajectory prediction and all decimal displays was correct, i.e., zero, as MCC-7 required no out-of-plane ΔV . The only error was in the octal uplink value. Although the erroneous load was uplinked, the error was discovered almost immediately and a correct external ΔV load was generated from the MPT and uplinked. There was no danger that the incorrect maneuver would have been executed since P30 Vg's would have disagreed with the PAD values. Also the CM desired attitude would have disagreed with the PAD attitude.

II. Mission Narrative.

A. Prelaunch.

1. During the CDDT, the CMC clock was observed to have a drift rate. From KSC readouts, the drift rate for the CMC clock was determined to be .696 millisec/hr fast. The LGC was determined to be .195 millisec/ hr fast. On July 26, 1971, at 9:19 GMT, the CMC was biased +0.02 secs in order for the clock error to be zero at lift-off.

2. After the computations were done to establish the new dry weights, the lift-off (T-6) mass properties (weights, c.g.'s, and aerodynamics) were generated without incident and loaded into the RTCC by T-3:37 (h, m). 3. Recovery reported weather in all launch abort areas was acceptable.

4. All RFO console configurations and supporting displays functioned properly during FDO confidence runs.

B. Launch through LOX dump.

1. The GMT of first motion was 13:34:00.587. The CMC lift-off was 13:34:00.79, which was entered into the RTCC as GMTLO.

2. The launch phase was nominal, except that USB intermittent during powered flight.

3. The IU was updated with a MSFN vector prior to TLI due to the onboard vector being out-of-tolerance.

4. TLI was nominal with the CMC and IU navigation in agreement.

5. During TD and E the SPS Thrust Light on the EMS illuminated spontaneously.

C. SIVB Lunar Impact Targeting - Two SIVB MCC's were executed for a lunar target of $\phi = 3.65S$, $\lambda = 7.58W$. An APS, of 32.7 fps was executed at 5:48 and an APS, of 9.8 fps was executed at 10:01. The second APS MCC was delayed because of a problem with the vector. The predicted IP at 30 hrs GET was $\phi = 3:00S$, $\lambda = 9:59W$.

D. Translunar Coast.

1. The crew executed a manual SPS burn to test the ignition circuitry. The burn was executed at 28:40:22.5 and in the direction desirable for MCC₂. The ΔV resulting was about 5.3 fps. The test resulted in operating ball valve bank A in a manual mode using a circuit breaker for LOI and TEI. All subsequent short burns were executed on bank B. Prior to this test consideration was given to using the DPS for TLC block data.

2. LOI Abort Charts.

a. Preliminary LOI Abort Chart Chart Update at 33 - 37 hrs.

(1) Docked DPS $\triangle V$ available:

LOI <u><u></u>M</u>	WT at LOI C/O	Docked DPS AV Avail
652	. 96254.3	2196
890	94020.6	2255
640	96368	2195

(2) GET LOI = 78:31:32.4.

(3) Premission CSM gimbal angles converted to LM gimbal angles on actual LOI REFSMMAT were R = 291.7, P = 181.9, Y = 157.1. These gimbal angles violated the h = 20 + 200 criteria at an LOI ΔV_m of 890; thus, a new abort attitude^P was computed. The computed LM gimbal angles were P = 181, Y = 157, R = 293. The LOI+30 min abort curve was then generated.

LOI <u><u></u>M</u>	Abort AV
640	2042
735	2150
900	2420

(4) Mode I (30 min) to Mode II crossover moved to LOI $\Delta V_m = 900$ fps because at the premission crossover value of 890 fps, the Mode II burns exceeded DPS ΔV available. The maneuvers were as follows:

Mode II burn l $ riangle V_{ m Z}$ =	$645 \qquad \Delta t_{b} = 204 \text{ sec}$	GETI	= 80:31:00
Mode II burn 2 $\Delta V =$	1606	GETI	= 103:52:00
Total $\Delta V = 22$	251	Coast Time	= 23:21:00
$\Delta V A vailable = 2255$		Allowable C	oast = 24:00:00

(5) Mode I (2 hr) to Mode I (30 min) crossover moved to LOI $\Delta V_m = 640$ fps because at the premission value of 652 fps, the Mode I 2-hr ΔV exceeded the DPS ΔV available. The resultant Mode I 2-hr ΔV at LOI $\Delta V_m = 640$ was 2192 fps. The ΔV available was 2195 fps.

- b. Final LOI Chart Update at 59 hrs GET.
 - (1) Docked DPS available:

TOI VA	WT at LOI C/O	Docked DPS Avail
640	96316	2197
652	96202	2200
735	95418	2219
890	93970	2259

No update was required on the DPS $\triangle V$ available curve.

(2) GET LOI = 78:31:34.2.

(3) Premission CSM gimbal angles converted to LM on LOI REFSMMAT were R = 292, P = 182, Y = 156. These gimbal angles violated the h 20 + 200 n.m. criteria at LOI $\Delta V_m = 890$ (h was 260); thus, a new abort^Pattitude was computed. The computed LM gimbal angles were R = 293, P = 181, Y = 157, and the equivalent CSM gimbal angles were R = 144, P = 358, Y = 68. The LOI+30 min abort curve was then generated.

LOI AV m	Abort ∆V at 30 min
640	2042
784	2231
900	2436

(4) Mode I (30 min) to Mode II crossover moved to $\Delta V = 900$ fps because the premission crossover value of 890 fps caused the Mode II burn to exceed the DPS ΔV available. The maneuvers were as follows:

Mode II burn $1 \Delta V_z = 645$ $\Delta t_b = 200 \text{ sec}$ GETI = 80:31Mode II burn $2 \Delta V = 1608$ GETI = 103:50Total $\Delta V =$ 2253Coast $\Delta t = 23:19$ ΔV Available = 2260Allowable Coast = 24:00

Coast time based on 1099 psi SHe pressure at LOI+2 hr.

(5) Mode I (2 hr) to Mode I (30 min) crossover moved to $\Delta V_m = 640$ fps because at the premission value of 652 fps, the Mode I 2-hr ΔV exceeded the DPS ΔV available. The resultant Mode I 2-hr ΔV at LOIAV_m = 640 was 2196 fps and the ΔV available was 2197.

c. The LOI abort chart changes were passed to the crew as follows:

(1) IOI ignition was changed to 78:31:34.2.

(2) LOI+30 min DPS abort was changed to 79:01:34.2.

(3) CSM IMU pitch was changed from 002° to 358°.

(4) Mode I DPS at 2 hrs was changed to 0:00 to 1:36 and 0 fps to 640 fps.

(5) Mode I DPS at 30 min was changed from 1:36 to 1:57 and 640 fps to 784 fps.

(6) Mode I DPS at 30 min + APS at 2.5 hrs was changed from 1:57 to 2:13 and 784 fps to 900 fps.

(7) Mode II was changed from 2:13 to 3:11 and 900 fps to

(8) The Mode I 30-min abort ΔV curve was not updated although the chart was in error by ~20 fps at the start of Mode I 30 min. The crew was advised that the curve was somewhat in error. During LOI, the RFO was prepared to pass the correct ΔV if required.

3. MCC-4 was executed with a ∆V of 5.4 fps at 73:31:14.02 GET.

4. All TLC data by RFO (including RTE block data and telescope pointing data) were passed as scheduled.

5. No GET update was required during TLC.

E. LOI/DOI.

1. LOI was executed at 78:31:46 as a 3000.1 fps burn. The residuals at SPS cutoff were zero; however, the burn was 3 secs shorter than predicted.

2. DOI was executed at 82:34:48 with about 0.6 fps underburn.

3. Engine trims for LOI were the CMC values from MCC-4 cutoff and the trims used for DOI were the CMC values from LOI cutoff.

4. The SPS undocked ΔV after DOI was computed to be 3795 by the GNC's, but was later refined to 3844. Thus to insure adequate TEC ΔV reserves, TET₁₂ block data was passed with a day longer TEC to honor the 3795 ΔV remaining.

F. Predescent Lunar Orbit.

1. Mass Properties - Final LM mass properties for PDI were computed and verified with the DMG support at 90:00 GET. The CSM 1 man mass properties for CIRC were also finalized at this time, and both sets of mass properties were made into permanent mass properties tables in the RTCC at 91:55 GET.

2. Derivation of SPS Redline For Rescue.

a. At approximately 112 hrs GET, Flight requested that RFO provide the absolute minimum ΔV to be reserved for a TEI in the event of a contingency rescue between rev's 18 and 61.

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1313.

b. Minimum $\triangle V$ solutions were examined assuming unconstrained return inclinations and late return days. From this study, it was determined that the following allowance should be made:

2710 fps	TEI (min solution)
+ 64 fps	36 Dispersions in SPS
2774 fps	Total to Reserve

c. It was pointed out that other high-priority items should be considered as $\bigtriangleup V$ would allow:

160 fps	*30 SCS TEI Allowance
150 fps	Constrain i to 40°
65 fps	Shaping Maneuver for Subsatellite
375 fps	

*It was noted that the EMS performance thus far on this mission has been considerably better than 3σ so that it would be reasonable to allow $l\sigma$ for SCS TEI if propellant usage were high during a rescue.

G. IM Activation through $\mathbb{T}_2.$

1. Undocking failed to occur at the first attempt. An electrical (cable/plug) problem in the tunnel was detected and undocking/SEP occurred approximately 26 mins late.

2. An LGC clock sync Δt update = +.66 sec was executed at 98:52. An AGS K-factor of 100:00:00.06 was uplinked at 101:21.

3. The LM DPS Thrust was 9920 during entry descent. Throttle down time 7:23 (m, s) was passed to the crew and the crew reported throttle-down ontime at 7:22/7:23.

4. Landing occurred with $\sim 9^{\circ}$ off vertical cant and we were "stay".

H. Lunar Stay.

1. TEI block data maneuvers were passed without difficulty. However, TEI 37 had to be updated shortly after it was passed as a vector change was such that a midcourse of about 120 fps would have been required.

2. Mass property updates were made without any problems and ground computed engine trims agreed well with onboard trims during lunar orbit/TEI.

3. No GET updates were required.

4. LOPC = 330.9 fps was executed at 165:11:32.

I. Ascent/Rendezvous.

1. LM ascent stage lunar lift-off weight was within allowed limits at 10936 lbs.

2. AGS K-factor was computed, passed, and loaded as 170:00:00.80.

3. Lunar ascent was initiated at 171:37:22.36 under PGNS control and the burn time was nominal (7:12 m, s).

4. LGC clock was normal, with no time update required.

5. A LM "tweak" maneuver was building during ascent; however, none was required post insertion.

6. Post-insertion LM rendezvous radar R and R agreed very closely with ground-computed relative motion digitals.

7. LM rendezvous and docking was completed satisfactorily with a good capture and "hard-dock" by 172:30.

J. Post-docking Lunar Orbit.

1. The ascent stage was deorbited at 181:04:19. Predicted impact was 181:29:23; however, telemetry was lost about 181:29:35.

2. The Pan camera and Mapping camera were supported by RFO in that ground track data were generated and passed to OSO.

3. The Institute of Space Research for Observation, Bochum, W. Germany, under the direction of Heinz Kaminski, requested telescope pointing data for TEC. The data was generated several times during the remainder of the mission and passed through Madrid.

K. TEI.

1. New LM and CM "weight transfers" and c.g.'s were generated for TEI SPS engine trims and CM entry aerodynamics.

2. EOM TEI 74 and backup rev TEI 75 were computed with CROX 762. The pads were ready and passed on rev 74 at 222+49 GET.

3. The shape maneuver was performed normally as planned. The satellite was launched with low rates reported.

4. The TEI burn was executed on time, with 2:21 (m, s) burn time. No trim was required.

5. The confirmation of TEI using IMU Vg's and the last frontside pass of radar data had a resultant flight path angle at entry of -6.85°. The TEI target conditions were V_{EI} = 36907, $\gamma_{\rm EI}$ = -6.50°, landing lat = 26:07 N, and landing long = 157:58 W.

L. Transearth Coast/Entry.

1. MCC-5 was computed to be .3 fps on CDC 816 which was the vector solution just prior to MCC-5. A corresponding MCC-7 with no MCC-5 was computed to be 1.8 fps. Thus with the current $\gamma_{\rm ET}$ = -6.69°, MCC-5 was actually less than the vector uncertainty. Due to the small size of the maneuver and the vector uncertainty, MCC-5 was not executed.

 \sim 2. The CSM EVA proceeded smoothly and the film cassettes retrieved were used in the calculation of the final L/D for entry.

3. MCC-6 was not executed as there was no need for weather avoidance and the predicted $\gamma_{\rm ET}$ was -6.5°, which was the targeted $\gamma_{\rm ET}$.

4. At 272 GET, a preliminary entry PAD was passed to the crew to provide entry data for any future communication loss.

5. Two items on the entry cue card were updated. The comment about positive H dot in P67 was deleted and the point where steering commands start in P67 was changed from DRE = -6 to DRE = -24.

6. The waste water dump scheduled about 273 bars was dumped to allow alwost a full tank at entry to optimize the L/D. Using a predicted value of 52 lbs (actual at entry was 50.6 lbs) the computed L/D was .287.

7. MCC-7 was computed to be 5.6 fps to correct a $\gamma_{\rm EI}$ = -5.82 to $\gamma_{\rm EI}$ = -6.9°. During the command load generation, an error occurred but was subsequently corrected with a second uplink.

8. A safe entry could have been executed without MCC-7; however, the landing point would have to have been moved about 60 miles downrange.

9. A 5.6 fps MCC-7 was executed at 291:56:47.90 exactly as planned.

10. The entry was nominal and the DSKY agreed well with predicted data both prior to and after blackout. The crew reported that the G&N and the EMS agreed to within 10 n.m. during entry.

ll. At drogue chute deploy, which was very close to nominal, the G&N lat = +26.13 and long = -158.13 (the target was 26.13N and 158.13W) with a miss distance of .1 n.m. Recovery reports a preliminary landing point of 26.125 N and 158.15 W.

12. During the descent on the three main chutes, one of the chutes partially collapsed. Prior research into the problem, due to the heaviest entry weight for an Apollo mission of 12955 lbs, revealed no problems with either three or two chutes.

M. General.

1. Summary of clock updates:

GET of Update	AT CMC of Update	Reason for Update
53:00	06 secs	Drift compensation for LOI/landmark tracking.
97:20	02 sec	Drift compensation for descent/landmark tracking.
150:00	05 sec	Drift compensation for ascent.
202:50	04 sec	Drift compensation for TEI.
272:30	05 sec	Drift compensation for entry.
	LGC	
98:52	+.66 sec	To Sync LGC clock to GET for descent.
	AGS K-Factor	
101:21	100:00:00.06	To sync AGS to LGC for descent.
170:57	170:00:00.80	To sync AGS to LGC for ascent.

*NOTE: No GET updates during entire mission.

2. Summary of TEC P23 vectors:

Sighting Time	$\chi_{\rm EI} = \frac{h}{r}$	(routine 30)	RTCC Designation
236:30	-7.26	11.1	CCHU057
251:50	-7.22	11.6	ссниоб 3
263:20	-6.54	21.6	CCHU091
273:10	-6.55	21.5	CCHU098
277:27	-6.61	20.6	CCHU007
289:33	-6.26	25.4	CCHUOL 3
After MCC-7	-6.93	15.8	•
292:30	-6.80	17.8	CCHUO19

3. Summary of TEC MSFN vectors:

Vector ID	$\mathcal{X}_{\mathrm{ET}}$	Purpose
CDC 816	-6.69	MCC-5 determination
BDAX 850	-6.54	Evaluation
GDSX 874	-6.12	Evaluation
GDSX 881	-6.45	Evaluation
GDSX 888	-6.40	Evaluation
CROX 895	-6.503	MCC-6 determination
MILX 954	-6.20	Evaluation
MILX 959 (SSI)	-5.84	Evaluation
CROX 967	-5.82	Evaluation
GWMX 970	-5.82	Evaluation
CROX 987	-5.82	MCC-7 determination
CROX 020	-6.51	Final entry pad

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Vector ID	$\gamma_{\rm ET}$	Purpose
*GWMS 026	-6.53	Evaluation
*GWMS 029	-6.50	Evaluation
*GWMS 032	-6.45	Evaluation
*GWMS 035	-6.44	Evaluation
*GWMS 039	-6.48	Evaluation

*These vectors have very short data arcs and are intended to show gross errors only. The small variation in the $\gamma_{\rm EI}$ indicates that CROX 020 was a good vector.

4. During the post EVA activity, there has always been some disagreement from various quarters on the stowage and weight of on-loaded equipment and rocks. However, during Apollo 15, members of ASPO and MPAD worked in the Flight Dynamics SSR and as a result of working together, the post EVA activities including CM stowage for entry went very smoothly. It is our wish that this procedure be utilized for future missions.

5. Support from MPAD, FCD, FSD, and SPAN personnel was excellent, and we wish to thank those who aided us during Apollo 15.

III. Recommendations.

A. The LOI chart update criteria for Apollo 16 should be derived premission with separate values for each of the crossover point updates and the 30-min abort ΔV curve. Agreement should be obtained from the Lead Flight Director on these update criteria and they should be strictly observed in real time.

B. The ascent stage jettison and subsequent CSM separation sequence as planned for Apollo 15 was very intolerant to delays. In the future if a posigrade separation maneuver is planned, large delays in the sequence will have small impact on the trajectory and crew procedures. Any possible recontact problem for TEI if the impact burn fails can be alleviated by proper TEI targeting.

C. The procedure that caused the command load problem at MCC-7 was never fully simulated. During all four entry simulations, one thing or another prevented full verification of the procedure which may have brought out the command load problem of MCC-7. In the future, all procedures not fully exercised during simulations with the crew should be verified with the RTCC, a simulated crew, and the CMS.

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Jerry C. Elliott

0 Janus 6. a Dames E. I'Anson

Edward L. Pavelka, Jr.

Bobby T. Spen poncer