



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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IN REPLY REFER TO: 71-FC55-28

FEB 17 1971

MEMORANDUM TO: FC/Apollo 14 Flight Director
FROM : FC5/Guidance Officers
SUBJECT : Apollo 14 Postflight Report

I. Problems/Resolutions.

A. Prelaunch - A lift-off delay due to weather restrictions required that the CMC launch azimuth be updated.

B. Launch through Evasive - Slight navigational errors developed between the IU and CMC systems during powered flight. Subsequent orbital analysis verified the error as acceptable.

C. Translunar Coast.

1. The crew noted a difference between ground loaded P30 and pad values. The difference was due to procedural roundoff.

2. Onboard readout of the TEPHEM after lift-off time update disagreed with ground predicted value. The difference was due to CMC sign manipulation of the MSB in one component.

D. LOI/DOI - No significant problems.

E. LM Activation through T_3 - The abort command discrete, channel 30 bit 1, sensed by the LGC due to switch malfunction. This was alleviated by software workaround.

F. Ascent/Rendezvous.

1. A small, acceptable drift was detected in the IMU roll axis.

2. Procedural error during the final P57 required completely repeating the program.

3. CSM received only two VHF marks between insertion and LOS. An unusual number of N49's were observed and the w-matrix was reinitialized.

G. Transearth Coast/Entry.

1. The CMC issued a " T_{IGN} slip" alarm for MCC-5 due to the delay onboard in taking the action to allow pre "average G" integration to be

completed. The crew burned on time anyway with no subsequent problems since the burn was P41 RCS.

2. P23 marks performed on first star at 211:20:00 were degraded because the marks were taken on a wrong lunar horizon.

II. Mission Narrative.

A. Prelaunch - A hold was called at T-00:08:02 due to weather restrictions. Since this hold was outside of T-00:08:00, an azimuth update to realign the CSM IMU was mandatory. The hold lasted 00:40:02 adjusting the azimuth from a predicted value of 72.07° to 75.56° . It agreed with the IU firing azimuth of $75^{\circ} 33' 26''$. Due to a time limitation in executing the azimuth update, the IMU was freed at lift-off while in vertical erection rather than gyrocompassing mode, but with no consequences. Any azimuth change during gyrocompassing results in entering the vertical erection loop for 320 seconds.

B. Launch/Evasive.

1. At earth-orbit insertion, a slight navigational error had accumulated between the IU and CMC. The velocity residuals between the two at insertion were:

- a. $\Delta \dot{X}$ (IMU coordinates, IU-CMC) = +7.02.
- b. $\Delta \dot{Y}$ (IMU coordinates, IU-CMC) = +0.52.
- c. $\Delta \dot{Z}$ (IMU coordinates, IU-CMC) = -7.50.

2. A cursory look at the subsequent orbital characteristics of both systems indicates that CMC accelerometer bias probably contributed to the error.

3. Post-orbit insertion analysis of the IU navigational state against the best MSFN at 00:56:00 revealed an acceptable error. This error resulted primarily from incorrectly modeling the vent onboard, with the IU hardware contributing to the rest. Just prior to the mission, MSFC pointed out that an undervent could be expected, whereas the IU onboard was carrying the larger nominal vent profile. Orbital parameter analysis using the best MSFN (CROS012) at 00:56:00 gave the following:

- a. ΔRV (downrange position) = +22034 ft.
- b. Δa (semi-major axis) = ± 0.851 n.m.
- c. $\Delta \dot{w}_{MAX}$ (maximum nodal crossrange velocity) = 6-7 fps.

4. These errors are well within the 3.7σ tolerance requiring an IU navigational update to preserve a desirable MCC-1.

C. Translunar Coast.

1. The maneuver pad for MCC-2 was read to the crew with an error in N81 XAV target velocity Vgy. The error was in roundoff to the nearest 0.1 fps. In cycling through P30, the crew noted the difference between the pad and CMC stored value (previously uplinked). Upon crew query of the difference, the stored value was confirmed and the error was explained. The processor from which the pad data is obtained, the DMT, rounds the value to the nearest hundredth. The displayed value is then manually rounded to the nearest tenth for the pad. The command processor, however, accesses the value from the maneuver processor to a much greater accuracy and automatically rounds off to the nearest tenth. This presents a problem only under one given circumstance.

2. The DMT for MCC-2 displayed a Vgy of +4.35. This value was rounded up to +4.4 for the pad. The command target load, however, displayed +4.3 which the crew eventually read from the P30 DSKY. Evidently, the true value was between +4.345 and +4.349. When the value falls in this range, the roundoff problem can occur. No display changes are required because the pad values can be checked procedurally with the target load.

3. Another error was made on the maneuver pad in the comments for hi-gain antenna angles. The error was in the coordination between ENCO/COMM/FDO. The ENCO support room position, COMM, had given FDO the antenna data for the pad. As the pad was being read to the crew, ENCO corrected the antenna data over the loops. There was no problem, but the incident pointed out the coordination errors that can occur. The antenna data should be given directly to CAPCOM, not the FDO.

4. At approximately 54:53:30 true GET, the CMC was uplinked a -40:02.9 min:sec TEPHEM update. The uplink effectively increased the CMC clock and GET by an equivalent delta. After the uplink, the crew read from the CMC the new TEPHEM. The CMC second and third components differed numerically from the pad value updated before the uplink. The values were identical, however. The pad value contained the components with like positive signs. The CMC value, however, contained first and second components with positive signs but a third component with a negative sign.

PAD: 00006
35223
16020

CMC: 00006
35224
56017

5. The most significant bit of each component is the sign bit. A 0 indicates positive, a 1 indicates negative. The three components are summed. Summing the second and third components of the CMC value results in identical pad agreement:

35224	00000	=	35223	37777	Equivalent to LSB of second component
+ <u>56017</u>			+ 00001		
			- <u>21760</u>		2's complement to change sign
		or	35223	16020	

6. The difference in numbers was explained. No resolution is required, because the only problem was in understanding how the CMC handles multiple components. At the time, the crew asked which set of numbers should be stored. The Guidance position preferred the all positive sign values, but stated that it did not make any difference. The crew chose to leave the CMC values as read out. Later, around 76:39, a request came from MIT through SPAN to have the crew reload the TEPHEM with the all positive sign values before MCC-4. This was accomplished at 76:43. The reason for the change request was that all the program verification runs had been performed with TEPHEM having sign agreement. Even though MIT had no definite data point to suspect improper CMC operation, it was felt reloading would be preferred.

D. LOI/DOI - The DOI burn was nominal, but the ΔV_X body residual of 0.5 fps was larger than expected. Due to this, the crew was queried if they had shut down the SPS. They reported that it had been a CMC shutdown. Based on this information, the GNC personnel looked into the question and determined that the thrust decay number, carried by the CMC, did not match the actual thrust decay, therefore accounting for the slight underburn.

E. LM Activation through T_3 .*

1. With one exception, the LM activation was pretty nominal. The exception of course is the well known problem with the abort command discrete input to the LGC, channel 30 bit 1. After verifying the telemetry indication by DSKY readout of channel 30, several workaround procedures were developed and passed to the crew. The second procedure was decided on to preclude the possibility of having the bit set between ignition and setting the software to ignore the bit. The procedure exercised is briefly described below:

<u>ACTION</u>	<u>EFFECT</u>
After N62 display in P63, DSKY entered: V21N1E 1010E 107E	After P63 was sequenced to the final countdown to ignition, the cell MODREG was loaded to a value of 71. This effectively disabled the abort discrettes monitor routine, R11. In addition, auto throttle-up and guidance start was prevented.
After ignition and manual throttle-up on time, DSKY entered: V25N7E 101E 200E 1E	ZOOMFLAG, flagword 5 bit 8, was set to indicate throttle-up to enable start of guidance in P63.

*See addendum (page 10).

DSKY entered:

V25N7E
105E
400E
0E

Flagword 9 bit 9, LETABORT, was reset to disable the selection of the abort programs P70/P71.

DSKY entered:

V21N1E
1010E
77E

Loaded the cell MODREG to a value of 63. This was required to allow proper processing of landing radar (LR) data.

2. After ignition, the descent was smooth with no guidance problems until it became evident that LR lockon was late. Throttle occurred manually on time, guidance was enabled by 46 secs, aborts disabled by 1 min. 8 secs, MODREG loaded back to 63 by 1 min 21 secs, and a N69 of +2800 ft entered by 2 mins 24 secs. The late LR lockon was apparently due to the low scale selection after ignition. The cause for the low scale setting is currently under investigation. In recycling the LR circuit breakers, the scaling was reinitialized and good altitude data was achieved by 6 mins 50 secs. The initial Δh at lockon was 11,557 ft which prompted a hurried call to accept the data into the LGC. The initial Δh was obtained at an LGC altitude of 21,944 ft at which the maximum acceptable Δh is 12,400 ft. However, the Δh decreased to 1015 ft and was accepted into the LGC by 7 mins 8 secs at a PGNS altitude of 20,755 ft. The maximum acceptable Δh at this point was 11,600 ft. The LGC altitude converged very quickly and velocities incorporated right away since the total velocity at acceptance was 1285 fps.

3. The performance of the PGNS guidance system was practically flawless. The Lear-PGNS velocity residuals were essentially nulled all the way down. The initial LR Δh can be attributed to initial MSFN altitude uncertainty. The AGS, however, experienced several error sources. Going into PDI, the AGS/PGNS altitude difference was 568 ft, and the altitude rate difference was 1 fps. The AGS being the lower in each case. This difference is currently unexplained and under investigation. The possibility exists, however, that small errors after the -8 min AGS vector initialization may have grown to give the differences at PDI. Before ignition, AGS gyro drift was suspected. The powered flight AGS/PGNS velocity differences substantiated the drift. AGS velocity errors grew in all three axes. The radial residual of -9 fps and the downrange residual of -3 fps were caused by a y-axis drift of approximately $+0.17^\circ/\text{hr}$. In addition, a crossrange residual grew to -6 fps due to a Z-axis drift of approximately $-0.37^\circ/\text{hr}$.

4. After touchdown and a "stay" given for T_1 , the crew procedurally did an AGS 414+2. On query if the entry was taken, a confirmation was slow because of the delay in telemetry. The only problem experienced after touchdown was in performing the AT-2 P57 alignments. On the first alignment, some difficulty was experienced in taking or accepting star marks. A procedural error-type LGC program alarm was experienced, 00115, mark rejected when no marks were taken. Even though the crew had marked on a star, the

the mark reject was keyed before informing the LGC to accept the mark data. The crew was advised of this, and the alignments proceeded nominally.

5. Before LGC/IMU power down, the lunar gravity measurement exercise was executed without difficulty. The proper angles were received from the Bldg. 45 SPAN area and the desired data obtained in telemetry. The exercise was a complete success. The LGC/IMU was placed in standby/powered down at 111:42:50 GET.

F. Ascent/Rendezvous.

1. Between P57 alignments on the surface, continual computation of IM body attitude revealed a noticeable change in roll. Since this was a gradual divergence, it could only be diagnosed as drift of the IMU roll gimbal rather than a legitimate body attitude shift. The drift rate was estimated at 1-2 MERU (1 σ for this IMU was slightly over 1 MERU) and was confirmed as slightly over 2 MERU by the final P57.

a. Body attitude at 129:56:10:

(1) YH = 285.23.

(2) PH = 357.95.

(3) RH = 007.00.

b. Body attitude at 141:12:30:

(1) YH = 285.05.

(2) PH = 358.01.

(3) RH = 006.64.

2. During the final P57 alignment, after the gravity measurement and during the star sightings, a procedural error necessitated starting P57 completely over. The program was in R53 at the N79 display in preparation for input of the first cursor/spiral set. Normal sequence is to load data and "recycle" at this point for the other two cursor/spiral sets, however, a "proceed" was executed. (This stores the star line-of-sight vector, terminates R53, and displays NO5--difference between desired and measured LOS angles). Since no star sighting mark had been taken at R53 exit, the NO5 stored erroneous information. The only alternative was to reselect the program and start over. This was done with no consequence.

3. After ascent, the LGC continued to sense a valid abort signal via input channel 30 bit 1. This appeared to be a repeat of the switch input failure that required a software workaround for descent. It was acknowledged as not being a problem since the abort monitor routine is not used in ascent/rendezvous/lunar impact operations. The signal was still present at IM impact LOS.

4. During pre-TPI rendezvous operations, a problem with CSM VHF ranging was experienced. Ranging was enabled shortly after LM insertion, however, only two ranging points were received by the CMC prior to LOS. The first point exceeded the visual acceptance limits of 12,000 ft and 12 fps and was rejected. The second point was still outside the limits but was accepted. In addition, 11 optic marks were accepted by LOS, with the w-matrix being reinitialized prior to the last three optic marks. A N49 summary of all 13 marks is as follows:

ΔR (n.m.)	+7.3	
ΔV (fps)	0.0	
Code (1-optics, 2-VHF)	2	Rejected
	+0.9	
	+0.5	
	1	Accepted
	+8.8	
	+7.1	
	2	Accepted
	+0.0	
	+3.0	
	1	Accepted
	+1.8	
	+49.8	
	1	Accepted
	+5.6	
(Missing)	1	Accepted
	+0.7	
	+19.3	
	1	Accepted
	+0.3	
	+6.3	
	1	Accepted
	+0.5	
	+8.9	
	1	Accepted

5. The continual appearance of N49's created an uncertain idea to reinitialize the w-matrix. This was recommended but later retracted when the N49's appeared to be converging. It's not obvious at this time whether the actual reinitialization was done based on ground recommendation. It should be noted that it is an accepted procedure to reinitialize the matrix in this situation for VHF only. No where is it outlined to do so

for SXT only, especially when further VHF capability is a possibility. The ground recommendation given probably stems from the fact that there was not a central control point for making such recommendations. Rather, several areas contributed simultaneously hopefully converging on a like opinion.

G. Transearth Coast/Entry.

1. The MCC-5 maneuver was performed on time, but due to a late "enter" on the V50N18 display in P41, desired ignition time slipped 8.47 seconds. The on-time maneuver was to be at 166:14:58.54 but was slipped by the CMC to 166:15:07.01 due to the late "enter". Since the maneuver was RCS via P41 and desired ignition was not slipped more than 30 secs, no problem resulted from burning on time. Had predicted ignition been slipped more than 30 secs the CMC would not have been in "average G", thus failing to measure the ΔV . The concern about a possible "slipped Tign" was pointed out in time to avoid what happened, however, ground advisement was delayed too long.

2. During the P23 mark sequence starting at 211:20:00, the CMC vector was degraded by the acceptance of three bad marks on the first star, #22. Due to the large V49 values, the ground asked the pilot if he had possibly marked on the wrong horizon on his first star. The pilot checked and confirmed that he had marked on the wrong horizon on star 22. The CMP repeated the three marks on star 22, but the damage had already been done and the additional three marks did not correct the input error. After completion of the remaining stars, the CMC vector still gave different entry conditions than exhibited prior to the marking sequence. The FAO recommended that the CMP take additional marks on star 22 to decrease the error in that plane that had occurred due to the three bad marks. After an additional nine marks, the perigee was at approximately 51 n.m. Due to the weighting of the w-matrix, the error created in the vector was only slightly corrected with each additional mark. The last set of sightings prior to entry still did not bring the vector back to the entry conditions that existed prior to the set of bad marks. In looking at the crew procedures, the proper procedure to follow in such a case would be to incorporate the vector in the IM slots and reinitialize the w-matrix prior to taking additional P23 sightings.

III. Recommendation.

A. Due to the large amount of interface between the FDO and IFTT (HOSC-MSFC) during post-TLI SIVB impact maneuvers, the IFTT loop should be placed on the FDO console. Discussions between the two positions developed to the extent that they interfered with support of CSM operations.

B. Since the first lunar mission, MPB-MPAD has been very active in providing support for various mission navigational efforts. Included are horizon bias determination for P23, P23 evaluation in real time, lunar orbit landmark tracking, RLS determination, and rendezvous navigation. It is obvious from the subjects mentioned that relevant inputs probably impact the onboard computer and trajectory operations more than flight plan scheduling,

etc. Why are these people not represented in the FDB SSR as part of the normal MPAD support? Relocating them would alleviate uncertain action or confusing inputs from areas questioned or influenced by their decisions. A prime example is the CSM w-matrix reinitialization because of the lack of VHF. Normally, two areas should provide a unified response to the problem: The OMAB dispersion analysis people and the MPB navigation people. They of course were located in different SSR's and appeared to have had different opinions. This is magnified by the fact that they reported through different MOCR positions. It is also important to note that almost all of the data flow control is handled for these people by FDB, i.e., backside P24 tracking, P57 star sighting data, etc.

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A D D E N D U M

LM Activation - Because of tracking attitudes, the low orbit P24 optics data has to be recorded then retrieved post-event. This data was not obtained at MCC on rev 12. Even though careful plans were made preflight to retrieve this data before LOS, high gain antenna problems prevented the playback. After completion of the P24, high gain/high bit rate data was obtained only briefly. A DSE tape dump was started but interrupted by loss of high gain before the P24 data. On rev 13, playback of the circularization maneuver data ranked higher in priority. By the time the maneuver data was obtained, the rev 13 high orbit P24 was in progress. As a result, the rev 12 landmark tracking data was retrieved on 14 (PDI rev), too late for useful processing.

APOLLO 14 ALIGNMENT SUMMARY

DATA SHEET

VEHICLE	OPTION	REFS/MIAT	STARS	NC5	X	N93 Y	Z	TORQUE GET	
CSM	3	LAUNCH	17, 14	+0.00	+0.127	-0.060	-0.011	6:40:35	
CSM	1	PTC	14, 17	+0.02		UNAVAILABLE		6:51:00	
CSM	3	PTC	31, 35	+0.01	+0.271	-0.127	-0.036	14:12:50	
CSM	3	PTC	20, 23	+0.02	+0.149	-0.130	+0.082	29:20:00	
CSM	3	PTC	10, 40	+0.00	-0.039	-0.221	+0.046	40:11:00	
CSM	3	PTC	20, 23		+0.006	-0.129	+0.052	53:11:30	
CSM	3	PTC	13, 03	+0.00	-0.073	-0.093	+0.033	59:41:10	
CSM	3	PTC	23, 32		+0.056	-0.262	+0.038	76:51:30	
CSM	3	PTC	27, 35	+0.00	-0.007	-0.045	+0.010	79:39:20	
CSM	1	LDG SITE	27, 35	+0.01	-0.021	-0.003	-0.032	79:47:35	
CSM	3	LDG SITE	30, 35	+0.01	+0.001	-0.055	+0.002	84:09:30	
CSM	3	LDG SITE	16, 17	+0.01	-0.050	-0.070	-0.045	86:10:15	
CSM	3	LDG SITE	16, 20		-0.031	+0.002	+0.027	88:05:00	
CSM	3	LDG SITE	17, 30	+0.00	+0.073	-0.229	+0.000	101:24:20	
CSM	1	LDG SITE	17, 30	+0.00	-0.150	+0.010	+0.003	101:28:30	
CSM	3	LDG SITE	42, 40		+0.030	-0.032	+0.022	105:02:10	
LM	3	LDG SITE	22, 26		+0.097	+0.062	-0.013	105:26:40	
LM	3	LDG SITE	22, 26	-0.02	+0.042	+0.052	-0.016	107:08:00	
CSM	3	LDG SITE	22, 24	+0.01	-0.002	-0.030	+0.029	107:13:20	
CSM	3	LDG SITE	34, 27	+0.01	-0.012	-0.013	+0.003	109:22:09	
LM	AT-1	LDG SITE		+0.03	-0.016	+0.015	-0.113	NO TORQUE	
LM	AT-2	LDG SITE	21, 00	+0.02	-0.041	+0.003	-0.054	109:46:43	
LM	AT-2	LDG SITE	26, 00	-0.07	+0.018	+0.047	-0.121	NO TORQUE	
CSM	3	LDG SITE	22, 27	+0.02	+0.021	-0.165	+0.055	117:02:30	

APOLLO 14 ALIGNMENT SUMMARY

DATA SHEET

VEHICLE	OPTION	REFSMAT	STARS	NO5	X	N93 Y	Z	TORQUE GET	
CSM	1	LOPC1	22, 27	+0.01	-0.199	+0.587	-0.124	117:11:30	
CSM	1	ASCENT				GYRO-TORQUED			
CSM	3	ASCENT	12, 21		-0.027	-0.065	+0.018	119:27:15	
LM	AT-3	ASCENT	26	+0.01	+0.044	+0.069	-0.046	129:56:10	
CSM	3	ASCENT	10, 13		-0.036	-0.157	+0.091	131:18:30	
CSM	3	ASCENT	6, 14	+0.00	-0.002	-0.166	-0.005	137:18:00	
CSM	3	ASCENT	30, 31	+0.00	-0.079	-0.006	-0.001	140:53:20	
LM	AT-3	ASCENT	26	+0.02	+0.119	+0.135	-0.349	141:53:01	
CSM	3	ASCENT		+0.00	+0.018	-0.091	+0.050	146:58:25	
CSM	1	TEI			UNAVAILABLE				
CSM	2	TEI	4, 31	+0.01	+0.037	-0.106	-0.043	150:17:00	
CSM	1	PTC	6, 34	+0.01	+0.002	+0.001	-0.074	150:29:55	
CSM	3	PTC	11, 6	+0.00	+0.046	-0.174	+0.017	163:42:37	
CSM	3	PTC	25, 42	+0.00	+0.040	-0.460	+0.076	183:21:24	
CSM	3	PTC	34, 41	+0.01	-0.038	-0.104	-0.003	192:14:25	
CSM	3	PTC	32, 10	+0.01	-0.009	-0.109	+0.038	196:58:15	
CSM	3	PTC	25, 23	+0.01	+0.071	-0.161	+0.026	208:11:05	
CSM	3	PTC	16, 23	+0.01	-0.049	-0.010	+0.041	212:52:54	
CSM	1	ENTRY	16, 23	+0.01	+0.021	+0.032	-0.036	218:10:50	
CSM	3	ENTRY	30, 37	+0.00	+0.029	-0.040	-0.069	241:22:45	