OPTIONAL PORM NO. 10 MAY 1982 EDITION GEA PPMR (SI CPR) 101-11.8 UNITED STATES GOVERNMENT

## Memorandum

TO : Flight Director, Apollo 11

DATE: AUG 4 1969

FROM : Guidance Officers

SUBJECT: Apollo 11 Postflight Report

1. Prelaunch - There were no noteworthy anomalies in prelaunch.

2. Launch phase through SPS evasive - The following comments and data were pertinent to the launch phase through TLI and the SPS evasive:

a. The GMT guidance reference release times observed were:

IU 16:13:31:43.02

CMC 16:13:32:00.78, resulting in a computed launch azimuth of 72.06°.

b. At EOI, the Guidance stripchart velocity traces were all Mode A, or GO for TLI with the following values:

	Uncorrected	Corrected for L/O Bias			
$ riangle v_T$	+4.17	Same			
∆x́	+1.62	Same			
ΔY	+26.33	See below			
∆z	+5.41	+9.61			

The  $\Delta Y$  reflected a zero value until approximately GET + 3 to GET + 5 secs, when a step function of approximately -5 fps (IU - CMC) was observed. There was a standard booster yaw maneuver to avoid tower contact scheduled at GET = 1.4 secs to end at 10.4 secs. A later delog indicated the IU received the above velocity, but the CMC apparently missed it. The delog had reflected effectively zero  $\Delta Y$  error to that point. The normal procedure is to compensate the EOI values by a bias determined from lift-off values. Had a lift-off compensation bias been added to the EOI  $\Delta Y$  value of +26.33 fps, the total error would have been approximately 75 fps, or at the Mode C limit.

c. At GET = 2.06, the final  $\triangle AZ$  computation was made, which was designed to remove crosstrack launch phase errors due to pad azimuth misalignments inherent in the CMC gyrocompassing scheme. The value was +.22°, larger than normally observed.



Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan

The normal orbital element checks were made at CRO/HSK and the states passes. The following results were observed:

	IU	CMC	
$\Delta R_V$ (downrange) ft	-26336	- 30044	•
∆a (semimajor axis) n.m.	.636	1.191	
∆W <sub>max</sub> (crosstrack) fps	7	37 fps	Using torque <b>∢s</b> 7 fps

The downrange and semimajor axis errors were well within limits, though the IU reflected a value larger than ever previously observed. The magnitude of the error was approximately 1/4 of the limit value for the IU errors. The error was again manifest in the MCC correction at TLI + 24 hrs. The crosstrack errors, including the gyrocompassing error, were larger than previously observed. Also the normal procedure has been to examine the CMC orbital parameters in the eventuality of a TLI manual guidance takeover for an IU reference failure. Using the normal procedure of correcting the orbital parameters for the AAZ (+.22) observed in launch phase, the value of 37 fps was noted. This was considered large, and an additional evaluation was made utilizing the IMU Z-axis torque angle (+.15°) to recompute the crosstrack value. The rationale for use of the torque angles was a satisfactory procedure. This was due to the observed step function in  $\Delta \dot{Y}$  on the launch phase recorders, which resulted in an erroneous input to the  $\triangle AZ$  computation. The  $\triangle AZ$ computation is designed to compensate strictly for gyrocompassing misalignments. Due to a procedural miscue, the crosstrack error was chased perhaps a little harder than it would have been, because it was being compared initially against a post-TLI limit rather than the larger pre-TLI value.

d. During TLI, several dropouts of CMC data occurred while IU remained solid. This was observed also on Apollo 10. The network and CM communications people should look into this area for an explanation, since it seems to be recurring.

e. TLI and the SPS evasive were executed with no problems. All data was confirmed by HOSC. A fairly larger P52 X-axis torque angle (.171°) was noted post-SPS evasive. The error was later determined to be a small drift and was ultimately compensated for.

3. The following comments were pertinent during the translunar phase:

a. P23 difficulties, first day, GET 006:00:00.

(1) The first exercise of the star/horizon sightings was degraded by improper measurements. The major error in the measurements was taking marks with the star aligned on the horizon at a point other than the substellar point. In basic terms, the substellar point is that point on the horizon nearest the star being sighted. When the star is superimposed on the horizon at the substellar point, the axis of trunnion rotation is perpendicular to the radius vector to that point. With this condition satisfied, the horizon appears parallel with the M-line of the sextant reticle (see figure 1). When the star is superimposed on the horizon at some other point, the reticle M-line is not parallel to the horizon and the trunnion angle required becomes larger.

(2) Additionally, the sextant trunnion calibration was performed twice but never accepted. For each calibration, the trunnion bias was determined as -0.003 degree. Although small, the failure to accept this bias introduced another error to the sightings. With the erroneous trunnion measurements, the CMC estimated the spacecraft state to be on a cone with a half angle larger than it actually was. Thus, the range and velocity adjustments,  $\Delta R$  and  $\Delta V$ , were quite large.

(3) The improper measurements were experienced through attitude control difficulties and bad advice from the ground controllers. The CMC state vector at the beginning of the navigation sightings was degraded. The last state vector update had been uplinked prior to the TLI maneuver. The resulting state vector errors degraded the preferred attitude computations for the sightings. As a result, the CMC maneuvered to an attitude which placed the horizon improperly in the sextant fieldof-view. In addition, the crew was observed to select CMC free mode during the sightings. This mode allows the attitude to drift unchecked. Under these conditions, the drive of the sextant shaft and trunnion becomes quite difficult to line up the reticle correctly. This difficulty led the crew to question the necessity of taking marks with the reticle M-line parallel to the horizon. As is well known by now, the crew was advised erroneously that there was no restriction.

(4) Although the advice did not come through the Guidance position, partial responsibility is accepted. It is recognized that the marking decision should have been overruled or challenged. As a result of the improper sightings, an improved value for the Earth horizon bias could not be determined.

b. P23 difficulties, second day, GET 024:00:00.

(1) The second exercise of the star/horizon sightings was preceded by a ground state vector update, a trunnion bias calibration, and a recommendation emphasizing the necessity for reticle/horizon alignment. The results of the sightings were very acceptable. The improvement in the exercise can be seen by comparing the  $\Delta R$ ,  $\Delta V$  results for the same star marked on each day:





DO = error in trummion



FIGURE 1

	Day 1	Day 2		Day 1	Day 2
Star 02			Star 45		
∆R (ft)			$\Delta R$ (ft)		
Mark 1	879.3	13.2	Mark 1	4786.7	2.7
2	1066.4	5.8	2	1014.3	2.9
3	111.1	0.1	3	76.7	0.0
riangle V (fps)			$\triangle V$ (fps)		
Mark 1	0.0	20.2	Mark 1	6464.8	5.3
2	1962.2	8.8	2	1237.1	5.4
3	836.6	0.2	3	95.4	0.3

(2) Two minor problems were experienced, however. The CMC computed attitude for the first sighting was such that the star was occulted by the LM. The spacecraft was maneuvered to the ground specified attitude and the problem went away. Secondly, at one point the crew commented the star was drifting out of the field-of-view like the CMC auto optics was not driving. A request for trunnion calibration, V59, was observed at the time which meant the auto optics was indeed not driving. Thus, the comment was explained. After the crew bypassed the calibrate request, the optics functioned properly. With the satisfactory sightings, MIT/MPAD determined a new horizon bias value of 35 KM. The new value was uplinked to the CMC at GET 57:36:00.

c. MCC<sub>2</sub>, GET 026:44:58 - Only one minor problem--the maneuver pad had to be updated after being voiced to the crew. The change affected ignition attitude and sextant star check. The change was required by INCO request to obtain high-gain antenna coverage. Burn was nominal-residuals in X and Z were +0.4 fps and +0.5 fps, respectively. These were not trimmed.

d. PTC difficulty, GET 035:00:00.

(1) After being in the PTC mode for a while, the crew terminated via V37EOOE to run some programs in the CMC. Upon completion of the computer exercise, the pitch/yaw attitude was observed to be close to desired. Thus, the V49 attitude maneuver was bypassed in reinitializing the PTC mode. After the rates, delta CDU, and holdflag were loaded, the roll rate took off at 0.7 deg/sec.

(2) The problem is explained as a procedural error. The error was the bypass of the V49 attitude maneuver. Although the pitch and yaw actual gimbal angles were close to desired, the roll angle differed considerably from the desired loaded during the previous initialization. As a result, the computer interpreted the difference as an attitude error and commanded a corrective rate, in addition to the desired PTC value.

(3) The crew attempted initialization a second time, only to run into another procedural error. After exercising the V49 attitude maneuver, the request for attitude trim was not given response. This left a V50 N18 display on the DSKY. The checklist calls for a loading sequence of V24E, address, data, data to load the desired delta CDU values. In the normal case, a NO1 would be remaining on the DSKY. In this case, however, the V24 was combined with the N18 which does not require an address to be specified. Thus, entering the address and first line of data satisfied the V24. The ENTER following the second line of data was interpreted by the computer as the response to the V50 N18 request. Upon the response, the computer blanks the DSKY. The crew tried to set holdflag with the blank verb/noun registers, thereby causing an operator error warning. A third attempt proved to be the winning charm.

e. Command load error, GET 052:00:00 - An error in the RTCC format for the LGC REFSMMAT command load was discovered by accident. A random discussion in the SSR MIT/AGS support area about discrepancies between the LGC program listing and other published documents led to a quick check of command load starting addresses. It seems that in switching from Luminary Rev 069 (Apollo 10) to Rev 099 (Apollo 11), several addresses changed. The MIT document, GSOP Section 2/Data Links, contains two erroneous addresses--for the External AV update and for the REFSMMAT update, "preferred" locations. After checking all formats, only the one error was found in the RTCC. All the CMC load formats checked out correct. The LGC format error had not been discovered in simulations, for normal use of the command load utilizes the "actual" REFSMMAT address which was correct. The uplink workaround procedure was developed and noted by all Guidance personnel.

f. LOI, GET 075:49:50.

(1) The maneuver pad and command loads were relayed to the spacecraft on the nominal timeline. The Guidance/MIT interface for the hybrid simulator prediction of the P3O  $H_A$ ,  $H_P$  values was executed smoothly. The resultant CMC values compared exactly in  $H_P$  and to with 0.3 n.m. in  $H_A$ . The slight disagreement is believed to be the result of a difference in state vectors at time of ignition. MIT was provided the state vector actually uplinked to the CMC, timetagged 4 50 prior to ignition. Whereas the MIT solution integrated the short interval forward to ignition, the CMC integrated over a much longer interval. During the command uplink activity, the CMC integrated the uplinked vector

backward to current time. When the P3O solution was executed, the CMC then integrated forward to time of ignition. Because of truncation and roundoff in the integration process, the increased integration interval experienced by the CMC could be expected to result in a difference in the state vector at ignition between the CMC/MIT solutions.

(2) The vector integration during the uplink activity was a chance of fate occurrence. While in Program 00, the CMC compares current time against the state vector timetag once every 10 minutes. If the vector is more than four integration time steps in the past, the vector is integrated forward to current time. In Program 27, the same 10-minute checks are performed, except the comparison against four-time steps is bypassed. If a vector check is called for during Program 27, integration is performed either backward or forward to current time. While the integration is in progress, the CMC is hung in Program 27. For the initiation of any command load, the CMC must be in Program 00. Thus, if the vector check is made during Program 27 for any but the last of a series of command loads, the uplink activity must be delayed until the integration is complete. The experience gained from the Program 27 integration prior to LOI proved to be beneficial, for it was to strike again in the LGC during the time

4. The following comments were pertinent during lunar orbit phase:

a. LOI, GET 080:11:36 - The maneuver pad and command loads were relayed to the spacecraft a little ahead of the nominal timeline. Again the MIT predicted P30 altitude values were obtained with no problems. Eventhough the P30/P40 altitude solutions differed by less than 1.0 n.m., the MIT predicted P30 values were passed under the guidelines of LOI. One restriction was placed on the maneuver pad related to the sextant star check. The available stars at the burn attitude were in the general vicinity of the sun. Thus to avoid sighting difficulty, the star check was advised to occur between the time the selected star became visible above to lunar horizon and the time the spacecraft came into sunlight. The nominal timeline placed the check in this period, so the maneuver preparation was not

b. Descent preparations.

(1) Rev ll - All activities scheduled on the first rev of LM activation were performed as per the flight plan with no problems. The gyro torque angles passed to the crew were: X = -0.060, Y = +0.620, and Z = +1.080. These angles were computed on a set of LM and CSM gimbal angles obtained at a GET of 97:14:00.

(2) Rev 12 - Two problems were encountered on the second pass.

(a) Problem 1 - Prior to AOS, the Guidance Officer was told by FIDO to go with the nominals for the LGC and AGS abort constants. The Guidance Officer understood that address 226 in the AGS (upper bound on the AGS semimajor axis) was to be loaded with a pos max value. However,

it was advised by AGS support specialists that TRW recommended going with a value of +70312, as any semimajor axis computation larger than 70313 would cause AGS overflow. After agreement with MPAD personnel, the value of +70312 was passed to the crew. Although this problem was solved, it points out the fact that the control of the AGS erasable load should be improved. Perhaps a review of the control procedures used by the LGC personnel would be in order.

(b) Problem 2 - While transmitting the initial LM state vector to the LGC, integration occurred between completion of P27 on the LM vector and the V66E for transfer of the LM vector to the CSM slots. There was a pos max time in the CSM shot loaded premission, and the integration was attempting to integrate the CSM state vector to present time. The integration would have taken hours to perform; therfore, V96E was executed to stop the integration. All other loads were executed, then the ground selected POO by V37EOOE in order to restart the POO integration logic. For the future, it is recommended that V96E be utilized procedurally when the initialization of the LGC is performed.

(c) The docked drift check was performed at a GET of 99:04:00. The torque angles computed were X (yaw) = -0.33 degrees, Y (pitch) = +0.05 degrees, and Z (roll) = +0.05 degrees. These angles gave a high degree of confidence that the drift rate in the LM platform was well within the required tolerances.

c. Powered descent.

(1) All activities up to T<sub>T</sub> minus 30 sec (AVE G ON) were as expected. T<sub>TC</sub> computed by the LGC was .05 sec earlier than the pad values. This was expected due to the very low DOI residuals after the trim. The only possible question to be cleared up is the AGS Z-dot residual of .7 fps.

(2) At AVE G ON ( $T_{T_{C}}$  minus 30 sec), the MSFN-LGC radial velocity difference was 20 fps. Since this error was confirmed by doppler residuals, and the behavior of the trace for the first minute of PDI was to hold this constant value, the difference was considered as a downrange position error in the LGC. It was pointed out that with this error, the landing radar altitude information was mandatory by an LGC altitude of 18,000 ft. In addition, any other LGC error that would have added another 15 fps error to the trace would have created an abort case.

(3) Landing radar altitude data was observed at an elapsed time of 4:45. The initial landing radar values indicated an altitude 2900 ft lower than the LGC state vector. The Guidance Officer advised the data as good and within the acceptable limits. The crew accepted the data with V57E, and the altitude converged in 30 secs. The velocity updating by the landing radar had corrected the initial LGC radial error by 8:30. (4) The following LGC alarms occurred during powered descent:

1202 alarm at 5:18. 1202 alarm at 5:58. 1201 alarm at 9:12. 1202 alarm at 9:38.

1202 alarm at 9:54.

Since many of the official sources are currently writing the details of the cause of the problem, this report will confine itself to the rational used to give a GO on the LGC. Both the 1201 and 1202 alarms are symptoms of possible serious LGC overloading, but are not in themselves NO/GO alarms. Therefore, it had been decided by AGC support, MIT, and the Guidance Officer at a preflight meeting, that the bailout type alarm codes (which include 1201 and 1202) would not be a NO/GO case. However, at that time both AGC and MIT warned that continual bailout alarms could cause other G and N mission rules, such as velocity differences, to be violated. In real time, the AGC support verified with the FAIL REGS that the alarms were not continually occurring while GUIDO and YAW verified proper LGC navigation. Based on this information, a confident GO could be given on the alarms. In addition, Guidance recommended that the crew not use N68, and that the landing radar data would be monitored on the ground. This recommendation was made in order to save computer time, and therefore, help relieve the loading problem.

d. Touchdown to T<sub>2</sub>.

(1) At touchdown, LGC and AGS attitudes agreed such that no special AGS procedures were required for a T<sub>1</sub> lift-off. After the P57 AT-1, the gravity vector, the touchdown REFSMMAT and gimbal angles were used to determine a preliminary RLS. The results were latitude = 0.5543 North, longitude = 23.5705 East. The AGS and LGC gravity vectors at this time agreed to within .01 degrees. The RLS computed after the P57 AT-2 was latitude = 0.523 North, longitude = 23.42 East. Given these two RLS values, the sun check, and close examination of the stripcharts during descent, it <u>appears</u> that a gravity anomaly of about .1 degree existed in the North/South plane, and that the LGC had approximately .1 degree pitch misalignment error at PDI.

(2) The RLS and CSM state vector in the LGC was updated at T<sub>2</sub> minus 50 minutes. The RLS loaded at that time was obtained from FIDO. Values were latitude = 0.799 North, longitude = 23.461 East.

e. Ascent, GET 124:22:00.

(1) In revolution 24, one revolution prior to ascent, P22 tracking was executed in both the LGC and CMC. The purpose being to gain additional knowledge about the LM position on the lunar surface and the CSM orbit

plane, respectively. This knowledge is gained by RTCC processing of P22 marking data available at the appropriate time in each vehicles telemetry downlink. A problem was experienced with the LGC downlink data that negated its use for LM position determination.

(2) Once P22 is entered, the LGC output the applicable downlink that includes a set of "mark data" associated with P22 operation. However, until the marks become valid for the current RR inputs, the downlink reflects whatever remains from the last valid program output. This might be an earlier P20, P22, or RO4 because the data is common to each. The ground processing accepted this old invalid mark as the first point for computing the desired solution. This was realized, but it was also determined that the RTCC processor had a limitation that prevented editing out the first point of a set. Thus, the data set was completely unusable.

(3) In view of the unexpected overload experienced by the LGC during descent, some precautions were taken to relieve the computer workload for ascent. This relief was achieved by reconfiguring the RR to leave the circuit breakers open and mode switch in "slew", and taking the tape meter out of LGC mode. After this initial configuration, MIT recommended a change in RR configuration feeling that they had discovered the source of computer overload during the descent. The new recommendation was that the RR circuit breakers be left open, and that the RR mode switch be placed in the "IGC" position rather than left in the slew position. It was felt that there was an increased workload on the LGC in reading RR antenna position with the mode in "slew" or "auto" versus "LGC". This increased workload seems to stem out of the fact that when the "slew" or "auto" modes are selected, the radar position is controlled by a power source that is independent of the LGC power source. Therefore, the computer must spend extra time trying to "phase" its reading of radar position due to the difference in the power sources used in this configuration. When the "LGC" mode is selected, the "phasing" effort is no longer required due to the change in the power source configuration.

(4) During the ascent phase, a minor AGS navigation error developed in the crossrange axis. It reached an accumulated magnitude of 9 fps at insertion, and is felt to have resulted from a misalignment of the yaw platform reference of about .08 degrees. The situation was not unexpected, having resulted from the planned ground support sequence of the onboard PGNCS and AGS platform alignments. In order to provide an AGS preferred lunar alignment totally independent of the PNGCS, the azimuth reference, which controls the yaw platform alignment, is passed from the ground for storing in the AGS. This value must be computed using the ground's best estimate of body attitude which is derived from the PGNCS alignment at the time of computation. The procedures are designed such that the PGNCS alignment at the time of computation is not the final preferred alignment for lift-off, but instead, is the orientation from the T-2 hr alignment. Thus, the final azimuth reference computed by the PGNCS for the preferred lift-off alignment using a star shot may differ slightly from an azimuth derived from downlink data using a prior alignment. For small differences (this mission had .08 degrees) between the two alignments, it is our opinion that either may be correct.

f. Docking - While the crew was maneuvering to docking attitude, the IM platform went into gimbal lock at GET of 127:56:36. The IM platform was course aligned to 0, 0, 0 and the AGS aligned to the PNGS. The CSM was not at jettison attitude in roll when the PNGCS was course aligned. After the CSM rolled to jettison attitude, the IM platform was course aligned to 0, 0, 0 and the AGS aligned to the PNGS again.

g. LM jettison - Since the crew had finished transfer to the CSM early and coolant to the PNGS had been stopped, it was decided to jettison the LM early. The LM was in AGS control, attitude hold, wide deadband, and the inertial attitude of the maneuver could not be changed. The decision was made to jettison the LM at their present attitudes, and the ground would pass the crew an evasive maneuver. An external  $\Delta V$  load was uplinked with targets 180 degrees out-of-phase, so that P30, P41 could be used to let the computer maneuver to the burn attitude appropriate for use of the -X translation thrusters. All future separation sequences should use this technique, because there is no question as to the attitude of the maneuver or the  $\Delta V$  imparted which makes it easy to confirm the maneuver in the MPT.

5. The following comments were pertinent during translunar phase:

PTC difficulties, GET 151:25.

(1) In setting up the CMC, the crew experienced sudden rates at the point of loading the desired delta CDU values. The basic cause of the problem was DSKY activity left running at the beginning of the PTC preparation. The crew had been monitoring, via the DSKY, the current gimbal angles. The DSKY was active with a V16 N20 combination. In loading the desired rates in the CMC, a V24 NOl is keyed in the DSKY which overrides the current V, N combination. On the data entry for the rates, the DSKY reverted back to the V16 N20 activity. In loading the desired delta CDU values, a V24 only was keyed as per the checklist. For the normal case, the NOL would have remained from the previous loading activity. In this case, however, the CDU data was loaded with a N2O active. The checklist contains one address and two lines of data to be entered after the V24. With the N2O, however, the address was interpreted as data. On entry of the address and first line of data, the V24 (load two components) was satisfied. The loaded numbers were stored as current gimbal angles in roll and pitch. Immediately the CMC recognized these angles as considerably different from the desired angles. As a result, rates were commanded to drive out the interpreted error.

(2) The crew was advised to perform a V4O N2O DSKY entry. This activity was to zero the current attitude registers then establish the attitudes from the gimbal resolvers. The DSKY monitor activity was then terminated, and PTC was accomplished nominally.

Willard S. Presley, Lead, Green team Stephen G. Bales, Descent/Ascer Granville E. Paules, Launch/Descent

Kenneth W. Russell Kenneth W. Russell, White team/Ascent

for William E. Fenner, Black team