R. Larson

Mission Techniques Memo #39B

TO: Distribution
FROM: Malcolm W. Johnston
DATE: November 6, 1969
SUBJECT: Final "H" Odds & Ends and Document Review

1. The present plans are to No Go DOI only if the platform misalignment at PDI is projected to be greater than 0.5° (memo #69-FM73-301 by D. Long). MIT feels that this limit is too loose (See MTM #39A, item #10), and that 0.35° would be better. Our analysis shows that aborts from hover require less than 0.42° PDI platform misalignment to achieve a clear pericynthion.

2. The LR data will not be used if a 523 alarm is triggered at hi gate. See the enclosed Mission Simulation Memo #29-69 by B. Kriegsman for information concerning this decision.

3. An error analysis of LM Navigation during the powered landing is enclosed as Mission Simulation Memo #31-69 by B. Kriegsman. Another, #32-69 has been sent separately.

4. It may be desirable to inhibit landing radar data from being incorporated in the LM state late in the descent via a V58, or a zeroing of the velocity weighting function (erasable load change). The latter is preferred by MIT. Zeroing would occur at lowgate or 500 ft.

5. The enclosed telephone record by J. Turnbull answers a crew question concerning the use of V94.

6. Conceivably some CSM rescue cases (and Apollo #13 nominal procedure) could bring the CSM down to an altitude below 35000 ft. What program restrictions should be observed? (See also MTM #39A, item #19).

Ans. The enclosed memo by P. Plender, dated October 10, 1969, outlines present restrictions.

7. An erasable program has been written that enables the astronaut to set the SIVB ignition bit. It is described in the enclosed Colossus Memo #222.

8. The use of Noun 93 during pulse torquing is described in the enclosed Colossus Memo #225.

9. For Apollo #12 the RTCC will have the new Lunar Potential model ("L1"), while the CMC and LGC have the old R2 model. Though this inconsistency will be acceptable for this mission, MIT would like to incorporate a "universal" technique for Apollo #14. The formulation of this technique has been coordinated between W. Robertson (MIT) and B. Cockrell (MPAD). If programming problems develop with this, addition of the new term to the present model is straightforward. (In fact, it has evidently been done already in an off-line assembly).

10. Enclosed STG memo #1384, by G. Edmonds, describes procedures for updating gyro compensation terms. (This may have to be done by the LM crew manually,prior to PDI).

11. The enclosed DG Memo #1405, by I. Johnson, presents some additional analysis of the manual ascent studies that were rather informally exercised prior to Apollo #11.

12. "Rate aided optics" techniques for landmark tracking from low orbital altitudes requires both hardware and software changes. Normal optics operation is not inhibited if one change is made without the other! (i.e., hardware fixed, but software not, or visa-versa).

13. The current status of Mission Techniques document review for the "H" mission is summarized below:

SV Launch Phase Aborts - (dated 3/31/69) - Not changed since "G".

EPO and TLI - (dated 7/14/69) - Not changed since "G".

TL (MCC) and LOI - (dated 2/17/69 and change pages dated 6/10/69) - Essentially no changes since "G".

Lunar Descent - (dated 10/17/69)

The comments noted by items #3 and #4 in MTM #28D are still applicable.

At the bottom of page 2-4, the LM altitude display times and magnitudes are, of course, only typical.

It should be noted, on page 4-8, that retargeting to take into account an ullage ΔV during a second PDI attempt is not necessary, providing the LM state properly reflects this ullage. The retargeting referred to was, it is assumed, a ground procedure to account for propagation errors etc.

On page 4-9, the 100 sec limit on DPS operation in the non-throttleable region is a hardware limit (we guess). The guidance equations are more restrictive!

The second line of page 4-10 should read "unexpected or prolonged attitude rates of 5 degrees per second."

On page 4-13 and figure 4-3, the apparent inconsistency of allowable ΔH at hi-gate (5000 ft just before, 1000 ft just after) is due to the software reasonability test. Perhaps a PCR should be written to alleviate this "sometimes overly constraining" test!

Also, on figure 4-3, the Apollo #12 landing site does'nt have the same terrain altitude uncertainty at 104 secs as Apollo #11 did .... does it?

On page 4-16, abort cues based on commanded thrust reversals are discussed, and reference made to Fig. 4-6. MIT (A. Klump) does not understand this figure! Who should we talk to at MSC for an explanation?

The first paragraph on page 4-20 should be changed to conclude as follows..." thrust becomes <u>nearly</u> zero. (approximately 40 secs after throttle down command)." Also, in the middle of the same page, TG-34 secs should read TG-10 secs.

The following summarizes the preferred post-landing RCS thruster firing avoidance scheme. <u>Pre-P68</u>.... if in P65, Mode Control in Att. Hold - engage ROD switch - Pro; if in P66 or P67, Mode Control in Att. Hold - Pro! <u>Post P68</u> .... Nothing is required except Mode Control in Att. Hold as P68 sets the "pulse" mode. Pages 4.26 and 5.24 of this descent document and page 4 of the October 15th Lunar Surface Phase technique document should be changed to reflect the above.

<u>Aborts From Descent</u> - (dated 10/?/69) - Update for Apollo #12 not received to date!

Lunar Surface Phase - (dated 10/15/69)

Pages 4, 27, and 38 should be changed to reflect the latest RCS thruster firing avoidance scheme. See previous description under Lunar Descent document discussion.

Pages 1, 9, 30, and 43 should be changed to reflect the fact that the LGC will be taken to standby not off! Enclosed STG memo #1416 (rev 1) discusses the reasons for this change. Also, it should be remembered that the LGC must be taken from standby to on every 23 + hours to maintain the clock!

The "CDU Zero" mentioned at the bottom of page 10 should be followed by a wait of about 15 secs before continuing.

Also on page 10, MIT would like to see an AOT/gravity vector separation of at least 40° rather than 20°. A forthcoming memo by R. White, MIT/IL, will explain this request.

Pages 32 and 33 indicate that there will be about 1 hr and 45 min between P57 alignments prior to liftoff. While this is adequate for gross drift determination and gyro compensation update (3-4 meru, 1σ), a longer period would be desirable.

Note E, on page 43, is correct if the initial pipa bias check in lunar orbit had been completed utilizing the lower 0.001 ft/sec^2 threshold.

Lunar Ascent - (dated 6/25/69 and change pages dated 9/23/69)

MIT assumes that the RR will be off during ascent, therefore, references to its use on pages 2-9, 2-12, and 3.12 should be deleted.

Presently, a 20° yaw will be executed 1 min after liftoff. Preliminary analysis indicates this may cause increased fuel consumption about that axis....both due to the yaw maneuver and slosh effects that may be initiated by it. Further analysis is being conducted (G. Kalan - MIT/IL).

What is meant by "balanced couple on" page 2-3, and "balanced couple off" page 2-4?

Manual Ascent - (dated 7/17/69) - Not changed since "G".

Lunar Orbit Activities - (dated 10/ ?/69) - Update for Apollo #12 not received to date!

TEI, TE(MCC), and Entry - (dated 10/ ? /69) - Update for Apollo #12 not received to date!

Contingency Procedures - (dated 10/ ? /69) - Update for Apollo #12 not received to date!

Data Select - (dated 10/?/69)-Update for Apollo #12 not received to date!

Malcolm W. Johnston

Malcolm W. Johnston

M. Johnson

Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge, Massachusetts

Mission Simulation Memo # 29-69

TO: Distribution
FROM: B.A. Kriegsman and D. E. Gustafson
DATE: October 14, 1969
SUBJECT: LR Position-2 Unit Vectors Are Put Into the LGC During P64 With the Antenna In Position-1 --- Apollo-12 Targets.

SUMMARY

The astronaut at present can PROCEED in P64 with the Position-2 LR unit vectors in the LGC, even though the antenna might be very close to (or in) Position-1. This could occur as a response to alarm #523 shortly after the start of P64. In Ref. (1) simulation results were presented for Apollo-11 targets. The present memo presents data for Apollo-12 targets.

With the present guidance and the incorrect LR unit vectors in the LGC during P64, the landing trajectories were unsuccessful for both the typical "vehicle-high" and "vehicle-low" simulated landings. A completely automatic system was assumed (P63, P64, P65), and LR dropout boundaries were modeled very conservatively (Ref. 2).

In the test cases studied, velocity estimation errors as large as 12 ft/sec were introduced by LR updatings in P64. Touchdown errors were about 10 ft/sec in the simulated landing runs.

For the particular situation studied in this memo, the accuracy of the LGC velocity information in P64 would have been better if LR updatings had <u>not</u> been used at all in P64, i.e., if IMU data alone were used here.

DISCUSSION

The same "vehicle-high" and "vehicle-low" test cases described in Ref. 1 have been repeated here using Apollo-12 aim conditions provided by A. Klumpp of MIT. These aim conditions are similar to those provided by J. Alphin of MSC in

69-FM22-248. Dropout boundaries were modeled according to data from K. Cox at MSC (Ref. 2). This model is supposed to be extremely conservative, i.e., the maximum permissible beam displacements (w.r.t. to local vertical) provided by the model tend to be small.

The important simulation results are shown in Figs. 1 and 2, where the velocity estimation errors presented as a function of time. As can be seen, peak velocity estimation errors of as much as 12 ft/sec are introduced by the LR updatings in P64. The terminal velocity estimation errors are seen to decrease as the end of the landing is approached and the vehicle's speed decreases. Nevertheless, in both test cases the terminal velocity errors were about 10 ft/sec.

At the start of P64 with the LR in Position-1, the LR dropped out in both test cases for about 60 seconds. This can be seen in Figs. 1 and 2 immediately after the start of P64 where the estimation-error profiles are relatively smooth. During this particular interval, only IMU measurements are used to update the state estimates.

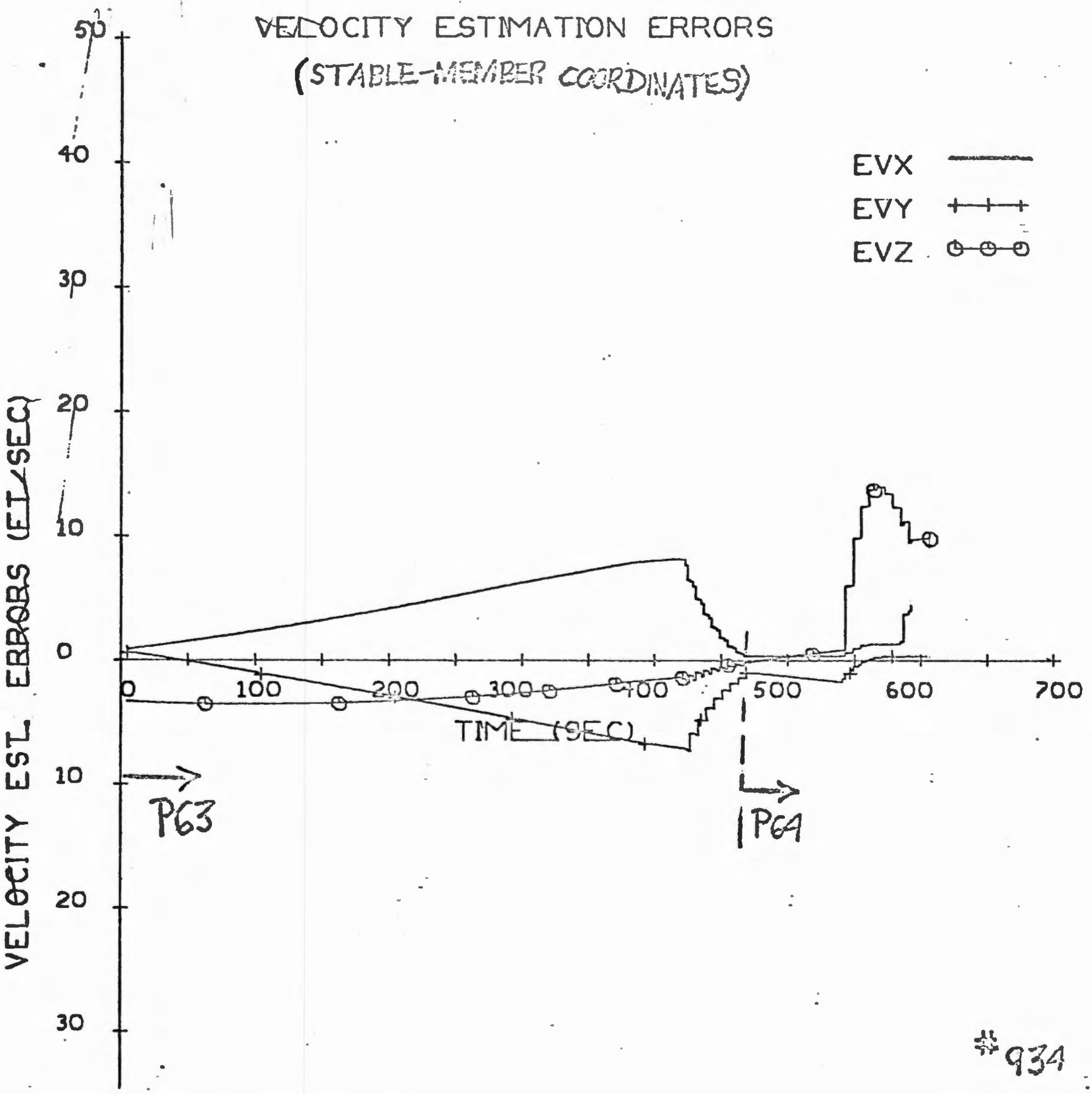
The important point to be seen in Figs. 1 and 2 is that if the velocity errors at the start of P64 were extrapolated forward to the end of the landing, assuming no LR updatings, then the entermediate and final velocity estimation errors would be smaller than if the LR updatings were incorporated. Under the conditions of interest in this memo, assuming that a reasonable interval of LR updatings has been obtained before P64 (e.g. at least 50-100 seconds), it is felt that better accuracy velocity data would be obtained by inhibiting the LR velocity updatings after P63.

References

(1) Kriegsman, B., and Gustafson, D., "LR Position-2 Unit Vectors Are Put Into the LGC During P64 with the Antenna Remaining In Position-1", MIT Instrumentation Lab, Mission Simulation Memo #28-69, September 29, 1969.

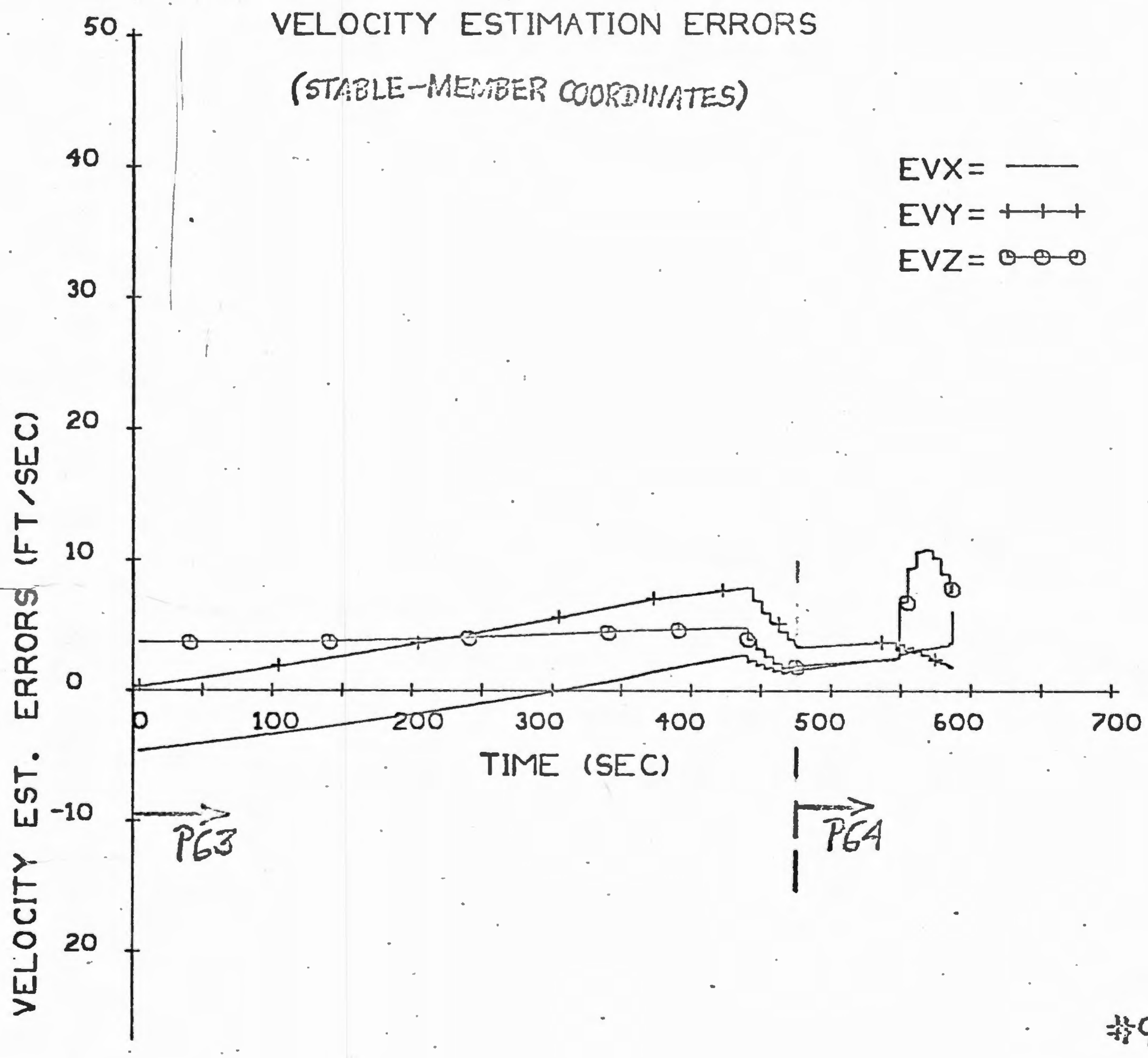
(2) Cox, K., "Preliminary Update of the Simplified LR Operating Boundary Model", MSC Memo EG 23-68-279, December 19, 1968.

Fig. 1: Velocity Estimation Errors --- Vehicle-Low Case



#934

Fig. 2: Velocity Estimation Errors---Vehicle-High Case



#941

Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge, Massachusetts

M. Johnson

Mission Simulation Memo 31-69

TO: Distribution
FROM: B. Kriegsman and D. Gustafson
DATE: October 20, 1969
SUBJECT: Error Analysis for LM Navigation System during Powered-Landing Maneuver --- Apollo-12 Trajectory

SUMMARY

The sensitivities of the estimation errors in LM position and velocity to various IMU measurement errors are presented for the Apollo-12 landing trajectory. Stable-member alinement, gyro drift-rate bias, accelerometer bias, and accelerometer scale-factor errors are considered. The data include errors accumulated during the DOI burn as well as those during the primary braking and approach phases.

The major sources of cross-range position estimation error in order of decreasing importance are X-axis gyro drift-rate bias, X-axis IMU alinement, and Y-axis accelerometer bias. Three-sigma touchdown errors from these sources are 2800, 2200, and 500 feet respectively.

The major sources of down-range position estimation error, assuming no N69 landing-site position update in P63, are Z-axis and X-axis accelerometer bias. The three-sigma touchdown errors from these sources are 6500 and 3600 feet, respectively.

GENERAL INFORMATION

The sensitivity of PGNCS navigation errors during the powered landing maneuver to IMU errors has been studied for the Apollo-11 trajectory. The key results are presented in Ref. 1. The r. m. s errors in the estimates of LM position and velocity were also determined for Apollo-11, including IMU, LR, and orbit-navigation initial-condition errors. The propagation of errors through the DOI burn for Apollo-11 is given in Ref. 2; the propagation of errors through the landing-maneuver braking and visibility phases is shown in Refs. 3 and 4.

From the error-analysis viewpoint the most important differences between the Apollo-12 and Apollo-11 landing maneuvers are the following:

(1) Because of the westerly location of the Apollo-12 landing site, it will be possible to use MSFN and landmark-tracking data one orbit younger than in Apollo-11. The last pass of MSFN data, moreover, will be on the undocked LM. The actual updating will take place before PDI (more details in Ref. 5).

(2) MSFN tracking measurements will be made on the LM prior to PDI (Ref. 5). Based on these data, on "effective" update of the LGC down-range component of LM position will be made by changing the landing-site position vector by N69.

In analyzing Apollo-12 performance, it should be noted that the current estimates of accelerometer bias and stable-member alinement errors are somewhat better than for Apollo-11. The relevant 1-sigma numbers are .002 ft/s^2 for accelerometer bias (previously .0067 ft/s^2) and .67 mr/axis for alinement (previously 1 mr/axis). Also, the assumption of a 30-second period in the Average -G Routine after DOI (which was used in Ref. 2 to allow for nulling residuals) is probably unrealistic. It will be desirable to exit the routine as soon as possible after DOI to avoid the bad effects of PIPA bias.

ERROR SENSITIVITY DATA

The sensitivities of the errors in the LGC estimates of LM position and velocity to various IMU errors are presented in Tables 1-11 for the nominal Apollo-12 landing trajectory used in MIT Level-6 tests.

The various errors referred to in these tables are expressed in the stable-member XP, YP, ZP coordinate system. The XP-axis is along the local vertical at the landing site at the nominal landing time. The ZP-axis is normal to the CSM angular-momentum vector and the XP-axis, and is directed down-range. The YP-axis forms a right-handed system.

The values of time shown in the tables are all relative to the time at which the initial throttle-up command is issued to the DPS. As such, the start of ullage for the landing maneuver is denoted by -33.5 seconds.

In computing the sensitivities of Tables 1-11, small perturbations were made about a nominal trajectory. Only one perturbation was made in a given test run. No LR measurement errors or orbit-navigation initial-condition errors were assumed to be present. LR dropout boundaries were included, using a very conservative model (Ref. 6) which provided acquisition altitudes of about 30,000 feet for LR range (Beams 1, 2, and 4) and 16,000 feet for velocity (Beams 1, 2, and 3). A smooth terrain with no terrain-altitude variations or slopes was assumed.

It should be noted that the velocity-error sensitivity data in the various tables are stopped 400 seconds after initial throttle-up time. The reason for this is that LR velocity updatings commence shortly thereafter. Under these conditions the estimation errors no longer depend on the IMU alone, but rather on the LR-IMU combination. IMU error sensitivities have no meaning thereafter. For similar reasons, the RXP sensitivity data are terminated at 300 seconds after initial throttle-up time when LR range updating commences with the assumed LR dropout-boundary modeling. The down-range and cross-range position error sensitivities (RYP and RZP), on the other hand, were carried through to touchdown, which nominally was 650 seconds after initial throttle-up time.

Some general comments on the sensitivity data follow next. It should be kept in mind that the assumed IMU 3-sigma errors were 2 mr/axis for alinement, .09 deg/hr/axis drift-rate bias, .006 f/s^2 for accelerometer bias, and .045 percent for accelerometer scale-factor errors.

Under these assumed conditions it can be seen that:

(1.) The largest source of cross-track estimation errors in LM position (RYP) is X-axis gyro drift-rate bias. The 3-sigma touchdown error from Table 7 is seen to be about 2800 feet.

(2.) The next most important source of cross-track estimation error in LM position is X-axis IMU alinement. The 3-sigma touchdown error from Table 1 is seen to be about 2200 ft.

(3.) The third most important source of cross-track estimation error in LM position is Y-axis accelerometer bias. The 3-sigma touchdown error from Table 5 is seen to be about 500 feet

(4.) The largest source of down-range estimation error in LM position (RZP) is Z-axis accelerometer bias. The 3-sigma touchdown error from Table 6 is seen to be about 6500 feet (assuming no N69 landing-site position update in P63).

(5.) The next most important source of down-range estimation error in LM position is X-axis accelerometer bias. The 3-sigma touchdown error from Table 4 is seen to be about 3600 feet (assuming no N69 landing-site position update in P63).

(6.) The predominant down-range estimation errors in LM position are the result of errors from the DOI burn propagated one-half orbit ahead.

(7.) The predominant cross-range estimation errors, on the other hand, are accrued during the braking and visibility phases of the landing maneuver.

REFERENCES

1.) Kriegsman, B. "Effect of IMU Errors During DOI and PD on Powered Landing PGNCS Performance", M. I. T. Inst. Lab Mission Simulation Memo #11-69, May 12, 1969

2.) Kriegsman, B. and Wells, J., "State Vector Estimation Errors at the Start of the Powered Landing Maneuver", M. I. T. Inst. Lab Mission Simulation Memo #15-69, May 27, 1969

3.) Kriegsman, B., Gustafson, D., and Wells, J., "FSRR for Powered Landing Programs P63, P64, and P65", M. I. T. Instrumentation Lab Mission Simulation Memo #21-69, July 8, 1969

4.) Kriegsman B. and Gustafson D., "Crew Training Talk on State-Vector Update Routine R-12", M. I. T. Inst. Lab Mission Simulation Memo #25-69, September 15, 1969

5.) Tindall, H. W. Jr., "How to Land Next to a Surveyor - a Short Novel for Do-It-Yourselfers", NASA/MSC Memo 69-PA-114A, August 1, 1969

6.) Cox, K., "Preliminary Update of the Simplified LR Operating Boundary Model" MSC Memo EG23-68-279

Landing Maneuver Error Sensitivities

Table 1: SM X-Axis Alinement:

Time	RXP	RYP	RZP	VXP	VYP	VZP
-33.5 s	≈0	≈0	≈0	≈0	≈0	≈0
0	↓	≈0	↓	↓	≈0	↓
100		-62			-1.2	
200		-237			-2.3	
300		-528			-3.5	
400		-950			-4.7	
650		-1100				

Units for Errors

Position -- Ft/mr.

Velocity -- f.p.s./mr.

Landing Maneuver Error Sensitivities

Table 2: SM Y-Axis Alinement:

Time	RXP	RYP	RZP	VXP	VYP	VZP
-33.5s	-86	≈0	-300	.21	≈ 0	-.06
0	-80	↓	-300	.30	↓	-.06
100	-5	↓	-315	1.3	↓	-.18
200	173	↓	-330	2.4	↓	-.10
300	460	↓	-327	3.6	↓	.19
400		↓	-260	-5.0	↓	.65
650			-185			

Units for Errors

Position--ft/mr.

Velocity-f.p.s/mr.

Landing Maneuver Error Sensitivities

Table3: SM Z-Axis Alinement

Time	RXP	RYP	RZP	VXP	VYP	VZP
-33.5s.	≈0	≈0	≈0	≈0	≈0	≈0
0	↓	≈0	↓	↓	≈ 0	↓
100	↓	13	↓	↓	.19	↓
200	↓	30	↓	↓	.10	↓
300	↓	30	↓	↓	−.16	↓
400	↓	−10	↓	↓	−.58	↓
650		−80				

Units for Errors

Position---Ft/mr

Velocity--Fps/mr

Landing Maneuver Error Sensitivities

Table 4: X-Axis Accelerometer Bias

Time	RXP	RYP	RZP	VXP	VYP	VZP
-33.5s.	75	0	593	-.44	0	.19
0	61	↓	600	-.42	↓	.18
100	23		615	-.34		.13
200	-5		625	-.27		.07
300	-21		630	-.17		.01
400			627	-.06		.05
650			620			

Units for Errors

Position---Ft/Fps²(.001)

Velocity--Fps/Fps²(.001)

Landing Maneuver Error Sensitivities

Table 5: Y-Axis Accelerometer Bias

Time	RXP	RYP	RZP	VXP	VYP	VZP
-33.5s	0	0	0	0	-.10	0
0	↓	0	↓	↓	-.06	↓
100	↓	1	↓	↓	.03	↓
200	↓	8	↓	↓	.12	↓
300	↓	26	↓	↓	.22	↓
400	↓	55	↓	↓	.32	↓
650		84				

Units for Errors

Position---Ft./f.p.s^2(.001)

Velocity---f.p.s/f.p.s^2(.001)

Landing Maneuver Error Sensitivities

Table 6: Z-Axis Accelerometer Bias

Time	RXP	RYP	RZP	VXP	VYP	VZP
-33.5s.	-139	0	836	-.64	↓	.45
0	-160	↓	850	-.67		.46
100	-232		902	-.75		.51
200	-310		950	-.83		.53
300	-398		1008	-.91		.55
400			1050	-.93		.56
650			1084			

Units for Errors

Position---Ft/F.p.s.^{2}(.001)

Velocity--F.p.s/F.p.s.^{2}(.001)

Time--seconds

Landing Maneuver Error Sensitivities

Table 7: X-Axis Drift Rate

Time	RXP	RYP	RZP	VXP	VYP	VZP
-33.5	0	0	0	0	0	0
0	↓	0	↓	↓	-.01	↓
100	↓	-13	↓	↓	-.26	↓
200	↓	-54	↓	↓	-.48	↓
300	↓	-125	↓	↓	-.87	↓
400	↓	-232	↓	↓	-1.18	↓
650		-309				

Units for Errors

Position---Ft/(deg/hr)(.01)

Velocity---F.p.s/(deg/hr)(.01)

Landing Maneuver Error Sensitivities

Table8: Y-Axis Drift Rate

Time	RXP	RYP	RZP	VXP ✓	VYP	VZP
-33.5	-7	0	-26	.01	0	0
0	-6	↓	-26	.02	↓	0
100	8		-29	.27		-.04
200	52		-34	.57		-.02
300	125		-32	.91		.04
400			-15	1.24		.16
650						

Units for Errors

Position---Ft/(deg/hr)(.01)

Velocity--Fps/(deg/hr)(.01)

Landing Maneuver Error Sensitivities

Table 9: Z-Axis Drift Rate

Time	RXP	RYP	RZP	VXP	VYP	VZP
-33.5	0	0	0	0	0	0
0	0	0	↓	↓	0	↓
100	1	3			.04	
200	1	7			.03	
300	2	6			-.04	
400		-4			-.16	
650		-23				

Units for Errors

Position---Ft/(deg/hr)(.01)

Velocity--Fps/(deg/hr)(.01)

Landing Maneuver Error Sensitivities

Table 10: X-Accelerometer Scale Factor

Time	RXP	RYP	RZP	VXP	VYP	VZP
-33.5	1.4	0	11	-.001	0	0
0	1.2	↓	12	-.001	↓	↓
100	-.7		12	-.02		
200	-3		12	-.02		
300	-4		12	.007		
400			12	.05		
650			12			

Units for Errors

Position---Ft/(percent)(.01)

Velocity--Fps/(percent)(.01)

Landing Maneuver Error Sensitivities

Table 11: Z-Accelerometer Scale Factor

Time	RXP	RYP	RZP	VXP	VYP	VZP
-33.5	-11	0	65	-.05	0	.04
0	-12	↓	66	-.05	↓	.03
100	-18		65	-.05		-.06
200	-24		54	-.06		-.16
300	-30		27	-.07		-.30
400			-13	-.07		-.43
650			-44			

Units for Errors

Position---Ft/(percent)(.01)

Velocity---Fps/(percent)(.01)

Distribution:
Dan Bland
Frank Hughes
ack Garman
Phyllis Rye
Jim Nevins
Mal Johnston
Russ Larson
Jack Dunbar
Steve Copps

TELEPHONE or CONFERENCE RECORD

DATE 10/17 | TIME 2:15 | PAGE 1 OF 1

THIS FORM PREPARED BY: Joseph F. Turnbull

CONTACT INITIATED BY: Dan Bland

COMPANY CONTACTED: KSC

INDIVIDUALS CONTACTED:

Original to be retained by Originator.

SUBJECT: A question regarding using V94 in P23 was raised by Stu Roosa and forwarded to me by Dan Bland.

Question: Does V94E recenter the DAP deadband or is it the PROCEED on V50 N18 that does the recentering?

Answer: All V94E does is to recycle you to a point in P23 where the attitude for pointing the LLOS axis is computed.

If one PROCEEDS on the resulting V50 N18 the DAP will maneuver the S/C to the newly computed attitude. Without PROCEEDing on V50 N18 the operation of the DAP will not be affected by having done V94E.

FILE NUMBER:

SIGNED:

M. Johnston

Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge, Massachusetts

MEMO

TO: S. Copps
FROM: P. Plender
DATE: October 10, 1969
SUBJECT: Behavior of COLOSSUS Programs in Low-Periapsis Lunar Orbit.

You have asked for a survey to identify COLOSSUS programs which might exhibit new or unusual behavior if the CSM were to be placed in a low-periapsis lunar orbit. I have reviewed the COLOSSUS mission programs and found that a low periapsis altitude is a factor in the three following cases:

a. The Pre-CSI targeting program (P32/P72) contains tests which cause alarms to be displayed if predicted periapsis altitude following the computed CSI or CDH maneuver is less than 35000 feet. The CSI targeting solution depends on many variables, including the CSM state vector, the LM state vector, and five pieces of data entered by the astronaut. The solution is not directly affected by the present CSM periapsis altitude, however, and the low-periapsis alarms are not guaranteed simply because present periapsis altitude is less than 35000 feet. The likelihood of the low-periapsis alarm is increased as the orbital altitude of either CSM or LM is reduced. As CSM periapsis altitude is reduced below 35000 feet while apoapsis altitude remains higher than that amount, the likelihood of the alarm continues to increase, but there is no abrupt change in the difficulty of targeting at the 35000-foot periapsis level.

b. The TPI Search Program (P17/P77) causes an alarm to be displayed when predicted periapsis altitude in the computed TPI or direct-transfer rendezvous maneuver is less than 35000 feet. The predicted transfer trajectory in this case depends upon the CSM state vector, the LM state vector, and an ignition time entered by the astronaut. As in the case of the Pre-CSI targeting, the current CSM periapsis altitude per se does not govern the solution for the maneuver. If apoapsis remains above 35000 feet, alarm-free solutions are still possible. It is true, however, that the likelihood of the alarm increases as the orbital altitudes of either vehicle are reduced.

c. When CSM periapsis is below the 35000-foot altitude while apoapsis remains above that level, the display of t_{ff} (time from a 35000-foot altitude) in the Orbit Parameter Display Routine (R30) exhibits a special kind of behavior. While the computed position of the CSM is below 35000 feet but periapsis has not been reached, t_{ff} is computed as the elapsed time from the recent downward crossing of the 35000-foot sphere. After the periapsis point is passed, the computed t_{ff} becomes the predicted length of time to the next <u>downward</u> crossing of that sphere; i. e., a time greater than half an orbital period but probably close to a whole period, or nearly two hours. Since t_{ff} is displayed in minutes and seconds, with a maximum reading of -59B59, the value -59B59 will appear on the display instead of the computed t_{ff}. The t_{ff} display is thus of no value in the time interval between periapsis and the next upward penetration of the 35000-foot altitude. The display may in fact cause confusion in this case because t_{ff} is normally set equal to -59B59 when periapsis altitude is <u>greater</u> than 35000 feet and t_{ff} is therefore not computable.

Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge, Massachusetts

COLOSSUS MEMO # 222

TO: Distribution
FROM: J. Stoppelman, N. Barnert, R. Covelli
DATE: October 8, 1969
SUBJECT: T6JOB for COLOSSUS 2C

A new erasable memory program has been designed to enable the astronaut to set the SIVB Injection Sequence bit from the CMC at T6 base time as a backup to the Saturn IU. T6JOB, as this program has been temporarily named, will be loaded into EBANK 7 as part of the E-Memory Kstart LOAD. It should be noted that the code is not restart protected and can not be repeated after a successful completion.

The program can be started from the ground by uplink, or by the astronaut. The way to start the program is as follows:

V 96 E to stop integration

V 25 N33 E + XXXXXE + XXXXXE + XXXXXE

Load three components of T6 base time in hours, minutes, and centi-seconds.

V 25 N 26 E 26000 E 01513E 10067E

Load the priority and address of T6JOB

V 30 E (Initiate T6JOB)

The T6 base time can be uplinked by the ground into the double precision register TIG, and the priority and address (2CADR) of T6JOB can be uplinked into the three registers of DSPTEM1.

After the V30E, V06N34 will appear on the DSKY, displaying the time to go until T6 base time (negative). This display will be updated once per second, counting down to the selected T6 base time.

At T6 base time, the SIVB Injection Sequence Start bit will be set in the CMC, and the Uplink Activity light on the DSKY will be set to notify the astronaut that this has happened. The V06N34 display will continue, now displaying the positive time since T6 base time.

The SIVB start bit and the uplink activity light will remain on for 10 seconds,(unless KR button pressed). At this time, the bit will be reset, the light turned off, and a flashing V37 will appear on the DSKY. The astronaut then must select a new program and continue with his other activities.

(1) V96 must be selected and the mode lights must show 00.

(2) The following programs cannot be called prior to T6JOB: P17, P20, P22, P23, P30's, P40's, P60's, P70's.

(3) To re-enter T6JOB (e.g., to change T6 base time) while T6JOB is running, do V96, then reselect T6JOB.

```
T6JOB     INHINT                        E7,1513     00004
          EXTEND                        E7,1514     00006
          DCA       TIG                 E7,1515     31413
          DXCH      LONGTIME            E7,1516     53140
          EXTEND                        E7,1517     00006
          DCS       TIME2               E7,1520     40025
          DAS       LONGTIME            E7,1521     21140
          TC        LONGCALL +1         E7,1522     05357
          ADRES     T6SET               E7,1523     01550
          BBCON     T6SET               E7,1524     10067
TGODSP    CCS       T6FLG               E7,1525     11573
          TC        GOTOPOOH            E7,1526     04106
          CA        1SEC                E7,1527     35055
          TC        TWIDDLE             E7,1530     05251
          ADRES     T6CNTDN             E7,1531     01543
          EXTEND                        E7,1532     00006
          DCS       TIG                 E7,1533     41413
          DXCH      DSPTEM1             E7,1534     53046
          TC        PATCH               E7,1535     01574    (see note)
ENDPATCH  DAS       DSPTEM1             E7,1537     21046
          CA        V06N34SR            E7,1540     33300
          TC        BANKCALL            E7,1541     04676
          CADR      REGODSP             E7,1542     20707
T6CNTDN   CA        PRIO26              E7,1543     37663
          TC        NOVAC               E7,1544     05150
          ADRES     TGODSP              E7,1545     01525
          BBCON     TGODSP              E7,1546     10067
          TC        TASKOVER            E7,1547     05340
T6SET     CA        BIT13               E7,1550     35017
          EXTEND                        E7,1551     00006
          WOR       CHAN12              E7,1552     05012
          CA        BIT3                E7,1553     35031
          EXTEND                        E7,1554     00006
          WOR       CHAN11              E7,1555     05011
          EXTEND                        E7,1556     00006
          DCA       TIME2               E7,1557     30025
          DXCH      TEVENT              E7,1560     21337
          TC        FIXDELAY            E7,1561     05303
T6DT      DEC       1000                E7,1562     01750
T6RESET   CS        BIT13               E7,1563     45017
```

TABLE 1

TABLE 1 continued -

```
             EXTEND                              E7,1564        00006
             WAND           CHAN12               E7,1565        03012
             CS             BIT3                 E7,1566        45031
EXTEND                                           E7,1567        00006
             WAND           CHAN11               E7,1570        03011
             INCR           T6FLG                E7,1571        25573
             TC             TASKOVER             E7,1572        05340
T6FLG        OCT            0                    E7,1573        00000
PATCH        EXTEND                              E7,1574        00006
             DCA            TIME2                E7,1575        30025
             TC             ENDPATCH             E7,1576        01537
```

NOTE: E7,1536 is skipped since this erasable is not available for the erasable program.

Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge, Massachusetts

COLOSSUS MEMO #225

TO: Distribution
FROM: Ed Olsson
DATE: October 22, 1969
SUBJECT: Noun 93 during Pulse Torquing

Although the crew procedure documents do not call out the use of V16 N93 during pulse-torquing operations in P52, the crews often use this display during extensive (plane change) pulse torquing as a clue to how nearly complete the operation is. The crew should be made aware that scaling of N93 under these circumstances does not remain XX.XXX degrees.

Pulse torquing is applied successively to the Y, Z and X-axis gyros. As each gyro axis is torqued, the scaling of angle-to-be torqued is changed in order to be of use to the torquing program. Pinball continues to display N93 as if the scaling were unchanged. Approximately each 2 1/2 seconds, the angle in the axis being torqued appears to have been decremented by 0.022°; actually it has been decremented by approximately 1.4°. (8192 pulses at 3200 pulses per second, approximately 0.55°/sec.)

Consequently, during pulse torquing, N93 will initially display proper numbers in R_1, R_2 and R_3. Thereafter the R_2 number will diminish to a fractional degree number and decrement to zero while R_1 and R_3 remains unchanged. Then R_3 will be similarly diminished and decremented. Finally R_1 is similarly treated.

It is suggested that N20 represents a more useful display during pulse torquing. If N93 is called up, the change in scaling should be kept in mind.

MIT/IL
Apollo Guidance and Navigation
System Test Group Memo No. 1384

To: George Silver
From: George P. Edmonds, Jr.
Date: 7 August 1969
Subject: Equations for Gyro Drift Measurement in Flight by Successive P52's and the Subsequent NBD Updates

Confusion still seems to exist on the proper signs for the in flight gyro drift measurement and NBD updates. I will try and clear this up.

In order to understand the signs there are three (3) facts that need to be noted:

1. The gyro compensation programs in the AGC expect gyro drifts to be loaded (i.e., rate SM will move with no compensation about gyro IA's).
2. The Z gyro is mounted on the SM such that its IA is along $-Z_{SM}$. (The X and Y gyros have their IA's along the respective +SM axis.)
3. N93 in P52 displays torquing angles about SM to correct the misalignment.

The following equations can now be written.

For the X and Y gyros:

$$N93 = (-GD + LC)\,\Delta t \times 0.015 \qquad (1)$$

For the Z gyro:

$$N93 = (+GD - LC)\,\Delta t \times 0.015 \qquad (2)$$

where N93 is the gyro torquing angle in degrees, GD is the existing gyro drift about the gyro IA before compensation in meru, LC is the loaded compensation in meru, Δt is the time in hours since the last P52 and 0.015 is the conversion factor between meru and degrees/hr.

These equations can be rearranged to show how to update the compensation and we get:

For X and Y

$$\text{New Load} = GD = \frac{1}{\Delta t \times 0.015} (-N93) + LC \qquad (3)$$

For Z

$$\text{New Load} = GD = \frac{1}{\Delta t \times 0.15} (N93) + LC \qquad (4)$$

Use of these equations shows that the correct updating was done in Apollo 11. It should be noted that for simplicity in the SCAMA room, the equations used compute the gyro drifts remaining after compensation as the first term on the right hand side in equations 3 and 4.

George P. Edmonds, Jr.
George P. Edmonds, Jr.
System Test Group

GPE/df
Distribution:
D. Dolan
MIT at KSC/MSC
G. Silver
G. Edmonds
G. Cox
D. Estabrook
E. Grace
K. Kido
R. Lones
V. Megna
W. Prince
J. Reedy
J. St. Amand
G. Schmidt
R. Sheridan
K. Goodwin
G. Reasor
A. Laats

Johnston

MIT Instrumentation Laboratory

DG Memo No. 1405

TO: M. Johnston
FROM: I. Johnson
DATE: 11 August 1969
SUBJECT: Manual Ascent With Z Pipa Failures (Saturated)

In DG 1390 (10 July), several hybrid simulator manual ascent tests were reported upon. In Table 2, two interesting things were evident which were not directly commented upon in that note:

(1) Rather large dispersions of H_A and H_P at cutoff

(2) Rather sizable difference in AGC and SDS (environment) versions of H_A (for those cases of no pipa failure).

In an effort to clarify these factors, further manual ascent tests were executed using the same pitch profile used in the tests reported in DG 1390. Two differences in test conditions exist between the runs reported in these two memos:

(1) Earlier tests run with LMY99 (Rev 1) Later tests run with LUM 111

(2) Z Pipa saturated positive in earlier tests
Z Pipa saturated negative in later tests

Table I is a summary of the manual ascents tests performed since 10 July. All DAP masses were loaded to 10,500#; N76 with 5515.0 (V_I at insertion, 32.0 (H), 0 (X Range). These are the same N76 loads used in tests reported in DG 1390.

Fuel depletion occurred very repeatably at 7:22 into the ascent. In one case where automatic shutdown due to fuel depletion did not occur at that time, the engine was shut down about 1/2 sec later.

Observations:

(1) Sizable dispersions of H_A, H_P at cutoff exist and are apparently caused primarily by slight differences in manual pitch attitude profile control; the facts that engine cutoff occurs regularly at 7:22 and smaller H_A and larger H_P are highly correlated form the basis of this conclusion.

(2) Run 4 shows the same SDS/LGC H_A, H_P differences seen in Table 2, DG 1390. This may be a hybrid/SDS peculiarity and should be investigated.

(3) Changing the sign of the Z pipa saturation and/or using LUM 111 appears to be the cause of three other new symptoms of interest:

  (a) Multiple 402 alarms rather than one or three (See DG 1390)

  (b) 21302 alarm (POODOO) when perform V82E (no such behavior resulted in earlier runs).

  (c) PGNCS engine off signal detected in digital runs was not detected in these hybrid runs.

TABLE I

RUN	PIPA FAILURE	Resultant Orbits		Comments
		LGC	ENVIRONMENT	
1	NONE	242 x -8.9		N85 at engine shutdown: -238/-117/455 fps Good attitude hold entire burn & after cutoff
2	NONE	224 x 6.7		Manual shutdown at 7:22 N85 Good att hold at shutdown: -222.7/28/269.
3	NONE	273.9/-0.3		N85 at shutdown: -317/121/365 Good att hold
4	NONE	229 x -8.5	270 x -10.6	N85 at shutdown: -110/-11/472 Good att hold entire burn and after cutoff
5	Z Saturated "Negative"		220 x 20.4	402 Alarm @ 0:51; nearly continuous 402 alarms thereafter Roll excursion up to ± 10° PGNCS on cmd still present at 5:25 V82E resulted in 21302 Alm (after cutoff)
6	Z Saturated "Negative"		292 x -3.1	402 Alarm at 0:51; nearly continuous 402 alarm until ~5:30; 402 at 6:30, 7:10 V82E resulted in 21302 Alm (after cutoff)

MIT/IL
Apollo Guidance and Navigation
System Test Group Memo No. 1416 Rev. 1

Malcolm Johnston
M.S. 23

To: Malcolm Johnston

From: George P. Edmonds, Jr.

Date: 30 October 1969

Subject: Shutdown of the PGNCS on the Lunar Surface

References:
(1) Apollo 12 Flight Plan 8 September 1969
(2) Apollo Mission Techniques H-1 Lunar Surface 15 October 1969
(3) E-1142 Rev. 56

Introduction

The LM PGNCS may be shut down on the lunar surface. Ref. 1 calls for placing the IMU in STANDBY and the LGC in STANDBY. Ref. 2 calls for IMU STANDBY but LGC OFF. This memo will point out considerations applicable to both procedures and give special information for LGC STANDBY and OFF. Significant changes from the original are indicated in this revision by a line in the margin.

Information Applicable to Any PGNCS Power Down

1. Turning IMU operate OFF saves about 200 watts. Ref. 3
2. The IMU should be in operate for at least 1 hour before use for precise measurements. Ref. 2 calls for 15 minutes between IMU operate ON and the first P57. $0.5\ \text{cm/sec}^2$ PIPA bias could exist at this time.
3. A Hardware restart occurs when the LGC is brought from STANDBY or OFF to OPERATE. The restart light may or may not light in either case.

Information Applicable Only to Power Down With the LGC in STANDBY

1. Turning computer operate OFF saves 56 watts, but 34 watts of power will still be used by the LGC. (Ref. 3)
2. The LGC clock will update properly after 23 hours or less in STANDBY. Ref. 1 calls for a longer time than this in STANDBY. Therefore a brief turn on to operate is required.
3. In LGC STANDBY, the STANDBY light is ON*.
4. The LGC warning light is not normally ON in STANDBY.

---

*The lights will go OFF if S/C power is removed from the DSKY.

Information Applicable to Power Down With the LGC to OFF

1. 34 additional watts are saved. (Ref. 3)
2. The LGC clock will stop and updating will be required at turn ON.
3. The LGC warning light will be ON while the LGC is OFF. (An OFF-ON-OFF sequence is possible during turn ON.)
4. To preserve instrument calibration, the IMU should be "parked" at turn OFF in the same attitude used on the earth to OG = 0, IG = 0 MG = 90°, (Modest vehicle tilt will not be harmful).
5. When the IMU is "parked" the No "Attitude" and "Gimbal Lock" light will come ON and stay ON*. (Special procedures are available to turn the lights OFF.)
6. If the LGC is powered down to OFF and the IMU is parked as in 4 above, 15 minutes with LGC STANDBY or OPERATE is required before IMU OPERATE power is applied. If the IMU is not parked 2 hours is required.

Conclusions

Turning the IMU OFF and the LGC to STANDBY provide considerable power savings without unreasonable operational constraints. However, the additional savings achieved by turning the LGC to OFF do not seem to compensate for the requirements for parking and the associated delays and updates after turn ON.

George P. Edmonds Jr.
George P. Edmonds, Jr.
System Test Group

GPE/df
Distribution:
G. Silver
B. Lones
A. Laats
R. Sheridan
E. Grace
V. Megna
G. Edmonds
P. Felleman
D. Dolan
MIT at KSC/MSC
R. Larson
A. Harano