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Mission Techniques Memo #41A

TO:DistributionFROM:Malcolm W. JohnstonDATE:December 13, 1969SUBJECT:"H2" Odds and Ends

- 1. Precautions on the use of V35 (light test) are reviewed in the attached memo by G. Silver.
- Enclosed Colossus Memo #232, by D. S. Reinke describes a work-a-round for P32 alarms resulting from pericenters < 35k. See also MTM #39A, item #19.
- 3. MIT would again like to call attention to the allowable G & N coolant temperature. In summary, the desirability of allowing G & N operation with coolant temperature varying between 45°F and 80°F must be traded off against reduced G & N reliability and performance. (i.e., Don't hesitatetoolong to boil water!) See AG Memo #473-69 by A. Laats, dated October 30, 1969 and EGM-69-232 by R. G. Chilton. (Already sent under separate cover).
- 4. What LM S/C attitude excursions (from nominal) during the ACA "feel" check will safely avoid non-nominal throttling etc. ?
 - Ans. Brief excursions up to 5[°] in magnitude should be safe. If more extensive excursions are planned, MIT would like to review them.
- 5. The software S/C (ICDU) rate limit of 2/3^o/sec, above which marks will not be accepted, was incorporated to protect against CDU transients. This rate limit was selected to provide a minimum platform alignment accuracy, not to protect against a CDU transient of some known magnitude. The limit can be increased

to about 3°/sec, with an associated loss of CDU transient protection, for low orbit tracking by changing an erasable constant! The limit will probably be eliminated from P22 if a "rate aided optics" program is incorporated.

- Pertaining to the cis-lunar DAP data load for rates $(0.2^{\circ}/\text{sec vs})$ 6. 0.5° /sec).... MIT is happy with either rate!
- 7. The enclosed Luminary Memos #118, #121 and #127 and Colossus Memo #226 describe software changes applicable to this flight.
- Some special DAP considerations concerning control of a LM 8. pushing CSM burn are outlined in the enclosed Luminary Memo #117 by G. Kalan.
- Do LM pipa scale factor errors affect the P57 alignment accuracy? 9.

No! (Neither do large pipa bias errors.) Ans.

The enclosed AG memo[#]513-69 by A. Laats outlines suggestions 10. for improving AOT alignment accuracy.

Malcolin V. Johnston

MEMO

To: M. Johnston
From: G. L. Silver
Date: 12 December 1969
Subject: Use of V35 and PIP Bias Changes With IMU Operate On.

A Verb 35 (Lamp Test) creates a LGC or CMC Warning which causes the PIP loops to be opened for approximately 10 seconds. The loops then close using the reduced current closure mode (PVR delay). One* uncertainty in bias can result when a different torquer is used to close the loop (and at a slightly different temperature) than the original** turn on sequence. The change at "one" Gravity can be in the .1 to .4 cm/sec² range. The change in 1/6 "G" is some proportion of the 1 "G" value, but no data presently exists to define that proportion.

Suggest that the V35 be done with the computer power on (LGC Dsky CB), but before the IMU operate power is applied.

In space CSM use of V35, with the IMU always on, might also be weighed as to information gained versus confidence in PIP data, although the opening of the loops in zero G should not cause the same magnitude changes as "one" G.

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George L. Silver System Test Group

GLS/df

^{*}Other significant bias error sources are "AC hysteresis" and "position memory" (See ISS Memo No. 517 and Memo Bukow to Silver dated 10 December 1969.)

^{**}Earth (Ground) operations in the S/C always turn on the IMU from a common position. i.e.: IMU parked with Y up and X & Z horizontal. Bias repeatability has been excellent. (See the Inertial Component history distributed by ACED.) All V35's are done in a IMU operate "Off" condition.

ME MO

To:George L. SilverFrom:George BukowDate:10 December 1969

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in.

AC Hysteresis is a term applied to bias variations caused by suspension fluxes coupling through fringe portions of the rotor when the float is allowed to rotate to an angular stop. Typical bias variations due to the effect are in the order of 0.2 cm/sec^2 . The bias change is not permanent, and the bias will slowly return to its original value in a period of 6 to 8 hours.

The AC Hysteresis effect is due to a phenomenon called disaccommodation. Disaccommodation is a time varying permeability due to cation migration within the metallic lattice. This cation migration is caused by a change in magnetic field linking with the magnetic material.

George Bukow

MASSACHUSETTS INSTITUTE OF TECHNOLOGY Instrumentation Laboratory Cambridge, Massachusetts

John Miller **TO:**

155 Memo #517

FRO'1: George Bukow

6 March 1968 DATE:

SUBJECT: Notes on Position Hemory

Position memory is an acceleration sensitive bias phenomenon obtained with electromagnetic torquers of the type used in the Apollo 16 PIP Med D. The exact cause of position memory is still under investigation.

Position memory causes a bias build-up within the PIP which is opposite to the direction of the applied acceleration input. The size of the bias variation obtained is dependent on both the magnitude and the duration of the input.

Typical position memory bias shifts for both LEM and Block II PIPA's are shown in Figs. 1 & 2. The shifts shown are relative to a normalized, or neutral, state and represent position memory effects in the absence of biasing or perturbing influences.

In general, position memory effects are characterized by both short term and long term phenomena. The short term phenomena are as indicated in Figs. 1 & 2. The long term phenomena are essentially non-reversible and can be removed only by degaussing. A long term bias build-up can apparently be "washed out" by applying to the PIPA the opposite polarity input. However, what really is happening is that the bias is building up on the opposite side in opposition to the original bias set.

George Bukow

:ctc

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Distribution: R. McKern C.Lory J.Feldman R.Cooper H. Landey D. Svanson R.Crisp - -D. Brown · J.Harber 1.ifeaton J.Gilmore 1. Salamin J. Lawrence H.Biggs - MSC V.Shields - MSC-G.Silver - KSC T.Henker - NAA 1. Adams - GAUC R. Tasekel - GAEC W.Schiek - Sperry W.Blumenstock - Sperry D.Fischer - ACE H.Neuville - ACE





Massachusetts Institute of Technology

Inst rumentation Laboratory

Cambridge, Massachusetts

Colossus Memo # 232, Luminary Memo # 125

TO: Distribution

FROM: Donald S. Reinke

DATE: November 21, 1969

SUBJECT Work-around for P32 bomb-outs due to insufficient post-CSI or post-CDH pericenter (Alarm codes 601 and 602, respectively)

P32 was designed to give an alarm if post-CSI or post-CDH pericenters are computed to be less than 85 nm. or 35K ft. around the earth and moon, respectively. Some future rendezvous abort flight paths may necessarily cause pericenters less than the minimum specified, and yet, perhaps, still within safe limits.

Should a 601 or 602 alarm come up, it might be easier to try to stretch out the rendezvous by increasing t_{IG} (TPI), and N (R1 of N55), or have the other vehicle do the maneuver. Lengthening the duration of the rendezvous will usually raise a bad pericenter somewhat; if the other vehicle does the maneuver, no bad pericenter will result, although the logic of P32 might put the other vehicle too high at TPI, resulting in a 600 alarm. If these methods do not work, or are undesirable, a work-around does exist that will allow P32 to run to completion, despite the alarm. This work-around, however, has some problems associated with it.

First, the work-around:

- Conditions that might give rise to 601 or 602, among others, are not tested until <u>after</u> P32 has converged on a solution. This is the fact that allows the work-around to exist at all.
- 2. When alarm conditions are discovered, P32 is in interpretive coding which must, for all practical purposes, be bypassed.
- 3. The solution is an Executive Call at the next piece of basic coding, namely, at P32/P72F + 5, CAF V06N75. The Executive Call <u>must</u> be a FINDVAC job, as a restart will occur if NOVAC is tried. Problems:
- 1. More than likely, an alarm will be encountered in an initial pass, when it is still desirable to take marks. This Executive Call bypasses the interpretive coding that sets UPDATFLG. Therefore, if the astronaut wishes to have any marks incorporated

he must set said flag via V25 N07 (procedure, below) after each recycle, before any marks are taken.

- 2. The Executive Call also bypasses the interpretive coding that calculates the minutes portion of $\Delta T(CSI/CDH)$ and $\Delta T(CDH/TPI)$ mod 60. Therefore, if either of those quantities exceeds 60, PINBALL will display 59b59. This may be confusing.
 - Conceivably, it might be nice to know just how bad the offending pericenter really is. This is possible via a display request through the DSKY. (See example and table below.) The display can be compared with a table to determine approximately how small the pericenter is.
- 4. This work-around bypasses tests for alarm codes 603 and 604 (insufficient time between CSI and CDH, and between CDH and TPI), and, if 601 is the one that came up, then 602 is also bypassed. Therefore, if either pericenter is low, $\Delta T(CSI/CDH)$ and $\Delta T(CDH/TPI)$ will not be checked. If the post-CSI pericenter is low, the post-CDH pericenter is not checked. It is, then, the astronaut's responsibility to ensure that those 2 or 3 quantities fall within safe limits.
- EXAMPLES: Acknowledgements to P. Rye and J. Vella for developing procedures. (Absolute addresses below apply for Rev. 72 of COMANCHE)
 - 1. Procedure for setting UPDATFLG

3.

V25 N07 E 75E 100E 1E

2. Executive Call for work-around

V25 N26 E

13001 E

03414 E

V 30 E

3. Examine value of pericenter

a. Post-CSI value (Erasable location POSTCSI)

V07 N01 E

3457 E

b. Post-CDH value (Erasable location POSTCDH)

V07 N01 E

3471 E

¹⁰⁰⁰⁴ E

TABLE for determining approximate value of pericenters

The quantities in this table were determined by multiplying 35K, 34K, etc., by 0.3048, and dividing by 5368709^{12} (i.e., 2^{29})

ter	Displayed Value
feet	00001
	9870 7
feet	00001
	93030
feet	00001
	87352
feet	00001
	81675
feet	00001
	75998
feet	00001
	70320
feet	00001
	64643
feet	00001
	58966
feet	00001
	53288
	ter feet feet feet feet feet feet feet f

Massachusetts Institute of Technology Instrumentation Laboratory Cambridge, Massachusetts

LUMINARY Memo # 118

To:	• •	Distribution

From: D. Eyles.

Date: 27 October 1969

Subject: Landing Changes Put Into LUMINARY 1C

Four changes that affect the landing were made for LUMINARY 1C:

(1) After a restart STILBADH and STILBADV, if they contain zero, are incremented to prevent incorporation of the next landing radar altitude and velocity readings. This is because if a restart occurs during a (80 ms) radar read this read is stopped and the next read consists of its remaining portion - and thus is wrong.

(2) P67 was eliminated. Putting the throttle control switch into manual in P63, P64, P65 or P66 no longer causes a program change. What it does do is cut off the LGC (i. e. auto) throttle signal, and thus engine thrust level will immediately drop to that commanded by whichever hand throttle is alive. This means that a transition from auto-throttle to manual throttle control cannot be smooth: if the switch is put in manual before the manual throttle is brought up, thrust will drop; if the manual throttle is brought up before the switch is switched, since the manual and auto-throttle signals are <u>added</u>, there will be irregular throttling as the LGC corrects for the excessive thrust. To assist the astronaut in following the LGC's thrust command once he has switched over to manual, as the FDAI error needles help him follow attitude command, noun 92 was created containing R1 THRCMD R2 HDOT R3 H

THRCMD is the percent throttle desired by the LGC, based on the DPS rated thrust of 10500 pounds. Half-throttle would look like this: +00050. Thrust and thrust desired for a nominal landing look like this (thrust desired is the dotted line):



During most of P63 more thrust is desired than can be delivered, so don't be surprised when noun 92 shows a THRCMD of 150% or so. HDOT and H occupy the remaining spaces so that when V16N92 is on the DSKY altitude and altitude-rate information is not lost. P67, by the way, is only gone in name: any of the other programs with mode in attitude-hold and throttle in manual is equivalent. Warning: be careful when flying with mode in auto and throttle in manual not to command more thrust than the LGC desires, as this might cause the guidance equations to ask the vehicle to thrust downwards to compensate. For the same reason be careful when switching mode from attitude-hold to auto when the throttle has been under manual control.

(3) VHORIZ, non-directional horizontal velocity, has been replaced in noun 60 (displayed during P65 and P66 and on call in P63 and P64) by forward velocity FORVEL. This minor change came as a result of Armstrong's comment at the debriefing that VHORIZ wasn't of much use.

(4) Finally, it was made possible to bias displayed LPD angles and vehicle yaw to make up for errors in the alignment of the LPD reticle and for window bending when the LM is pressurized. Pad-load erasables AZBIAS and ELBIAS were created overlaying RDOTM - which is okay because there is no P20 Nav prior to landing. Both are single precision and scaled in units of half a revolution, the same as CDUs. ELBIAS is added to LPD angle before it is displayed in noun 64: thus if the reticle points too high, ELBIAS should be positive. The value pad-loaded in AZBIAS is added to desired outer gimbal angle in FINDCDUW: if the reticle points too far to the right, AZBIAS should be negative to keep the vehicle yawed left a little. As usual when hardware bugs are corrected in the software, program elegance suffers. Sympathy is due Allan Klumpp whose subroutine FINDCDUW now has another input OGABIAS to accomodate an outer gimbal angle bias. OGABIAS is filled from AZBIAS during P64 only. OGABIAS is initialized zero in INITCDUW (called by BURNBABY before every burn) so other programs don't have to worry about it. Finally, I should point out that that part of window error which cannot be resolved into rotations about the body y and x axes will remain uncompensated, except at a chosen spot along the reticle, which for the information of the team at GAEC who will compute these numbers should be 42° , the mean LPD angle of the approach phase.

Massachusetts Institute of Technology Instrumentation Laboratory Cambridge, Massachusetts

LUMINARY Memo #121

To:	Distribution
From:	B. McCoy
Date:	5 November 1969
Subject:	What Is LUMINARY 1C

Now that 1C is out the door, maybe a discussion is needed to describe what 1C contains and some details on the fixes. The released revision number is 130.

Anomaly Fixes

L-1B-01 - The pre-designate routine in P22 uses a loop to determine when the CSM will pass inside the RR Mode II limits. An integration is made to a particular time and this time is incremented by 10 seconds every time around the loop. The anomaly was that the increment was never made; for each pass through the loop integration was done to the same time, thus never finding the CSM in the mode limits. The fix was to add this 10 seconds in on each loop pass.

L-1B-03 - Due to a coding error, the LM DAP in LUMINARY 1A and LUMINARY 1B does not control about the R axis whenever the computed jet control authorities about the Q and R axes are equal. Although these control authorities could not be equal unless the value of "HIDE -SCENT" or the scaling of "MASS" were changed, the logical flow was corrected to prevent the occurrance of the anomaly in future missions.

L-1B-04 - When the RR is cycled on and off, T4RUPT removes the RR ERROR COUNTER ENABLE bit, thus disabling the Forward and Lateral velocities sent to the X-pointers. The fix was to check for this bit every pass through the Landing Display Routines and reinitialize the X-pointers if the bit is missing. A note here: if this bit is being reset every second, this fix will inhibit data from being sent to the tape meter as well as the X-pointers. L-1B-05 - R60 attitude maneuvers were to have the newly computed Mode 2 attitude errors displayed on the attitude error needles. However, the coding automatically called the mode 2 error displays before actually computing the new desired attitude in VECPOINT, thus erroneously displaying an "old" attitude's error on the needles. The new coding does not automatically call for mode 2 attitude error displays until the new attitude errors have been computed in the initial pass through VECPOINT.

L-1B-9 - Concerning here only the Landing Radar, routine R12's setting the radar activity bit causes the LGC hardware to start an 80 ms. counter which issues strobe pulses to the radar. If a Restart (hard or soft) occurs during this 80 ms, the resetting of the activity bit will stop the counter and the strobe pulses. The Restart will keep the radar from being read and so the 80 ms counter will not be reset; now, when the radar is read again, the 80 ms counter will count from where it left off on up to 80 ms and the data read in during this shortened interval will be used to update the state vector if it passes the reasonability test. The fix was to increment STILLBADH, V during the Restart; R12 will see these values are not zero and will not use the data read after a Restart.

L-1B-10 - When the ACA is returned to the detent position after being cycled in and out of detent in the manual rate command mode in a certain rapid timing sequence, the DAP may enter the attitude hold mode immediately instead of first damping the spacecraft rates as desired. The fix was to set the JUSTIN bit every time the ACA is deflected, thus always insuring Rate Damping mode when the ACA is returned to detent.

Additional Anomaly Fixes

75 - There was a 50% chance of R04 not cycling from the RR sample logic to the LR sample logic. The decision to go into the LR logic was based on the contents of RTSTDEX; now the decision is based on RTSTBASE in subroutine R04Y.

92 - Due to a certain type of extended verb (only V41 and V42 in LUMINARY) the display interface routine cannot perform these extended verb's displays if it is keyed into the DSKY during a nonflashing cyclical display, e.g. V06N40 in P40. These extended verbs did not perform a "CCS NEWJOB" before the first display. A coding change was done to add a CCS NEWJOB for every extended verb that asks whether another extended verb is going (SETXACT).

PCR's Implemented

936.2 Routine R36 used to load all zero's into the desired time of the computed out-of-plane parameters. Since these parameters are usually referenced to a particular ignition time it would be more convenient to have the routine load TIG into this desired time.

836.2 During P76's updating the CSM state vector for a burn, a V37EXXE could destroy the update if integration is still going on. P76 now sets the NODOFLAG just after the PRO to the ΔV display, thus giving a 1520 alarm if a V37 is attempted during the integration. Upon completion of the integration, the NODOFLAG is reset.

285 Selecting Manual Throttle during a descent would place the LGC in P67 with no way of returning to auto-guidance. This logic has been removed and the following logic takes its place in R13.



To provide the Astronaut with a display of what thrust the LGC would command if the throttle is in auto, the commanded thrust is computed as a percent every pass through the throttle equations, displayed in Register 1 of NOUN 92, XXXXX. % (R2 and R3 are HDOT and H). The erasable overlays ^kRDOTM which is used only in P20 when reading the Radar. This percent is what the LGC is commanding, so it is probably only valid for use after throttle-down.

D. Eyles expressed caution in mode switching in LUMINARY Memo #118.

943 The Landing Radar Velocity Reasonability Test limit was moved into erasable memory so that it may be tightened to a smaller number as post-flight data might indicate. It is DP and was placed in EBANK 6.1771, 1772 (PSEUDO address 3471, 3472); it is unshared, scaled 2(6) m/cs.

893 It was difficult for the ground flight controllers to determine which targets were used during Descent Aborts. Flagword 9 bit 7 is used to signify that the late abort targets are used (=1). It is set immediately after the decision is made to use the late targets. It is reset in V37 during DUMMYAD (just after MUNFLAG is reset).

895 Extended Verb 59 is designed to move the Landing Radar antenna from position 1 to position 2. Before LUMINARY 1C this was not allowed during PDI. The flow below shows the addition to the V59 logic.



882 NOUN 60 during P65, P66, and P67 has displayed omnidirectional horizontal velocity to the astronauts. No coding change was necessary to cause the forward velocity computed for the xpointer meter to be displayed in NOUN 60. The least significant bit is .5571 feet/second although the display in NOUN 60 is XXXX.X fps. This velocity will be the speed at which the spacecraft is moving with respect to the moon's surface along the +Z(spacecraft) direction.

968 Due to variations in the LM's geometry when it is pressurized in space, the LPD markings on the window may be in error. Two erasables were added (AZBIAS, ELBIAS) to compensate for these variations. AZBIAS is simply added to the OGA command to FINDCDUW; this bias will show up in the XCDU after entrance to P64. AZBIAS's erasable location is E7, 1773, unshared. ELBIAS is simply added to the 1/2 degree before storing in LOOKANGL. ELBIAS's erasable location is 1365, overlayed with WHCHREAD, which will not be used until Rendezvous during P20 navigation. See D. Eyles LUMINARY Memo #118 for further details. These biases are scaled in PI radians, single precision.

806.2 Before LUMINARY 1C there was no way to change a bit in an output channel without changing all bits in that channel. NOUN 07, which is used to change flagbits, is now capable of changing channel bits using the same keystrokes, e.g.

V25 N07 E 12 E 200 E 1 E

will set bit 8 of channel 12 to a "1".

971 P12, P71, and P42 use a tailoff constant to predict when the APS engine should be shut down. This tailoff is the time it takes for the thrust to reduce to zero after the engine off command is sent. The new value is -17.65cs although the actual number in memory is -18cs.

846 rev. 1 The DPS tailoff for P70 had been using a value based on 40% of FTP, 38cs. The new value is 23.68cs, although the actual number is 24 cs.

972 The sighting error displayed in N05 was found to give valuable assistance in determining the actual landing site if only the error had direction; Viz, after sighting on a star, the star angle difference displayed in N05, except for star sighting errors, represents that component of the angular difference between the gravity and landing site position vectors in essentially the plane of the star and landing site position vectors. Repeating this process on a second star in a different direction produces another component of the angular difference, thereby enabling one to obtain an estimate of the lat and long of the gravity vector (the true site). Thus, the absolute value instruction was removed from this sighting error display to retain its directional sign.

ACB's Implemented

#5 In the abort programs P70 and P71 the rotation control sequence is used to prevent the body x-axis from pitching through downward vertical $(-\overline{R})$ in achieving the desired thrust direction. The unit vector of this thrust direction is compared to a pad load erasable COSTHET1, and if it is greater (UNFC/2·XNBPIP \geq COSTHET1) the x-axis is prevented from pitching through $-\overline{R}$. Now, the COSTHET1 is pad loaded zero, so the decision is always passed, even though the equation is erroneous. The fix was to unitize the thrust direction vector. Also, see Luminary Memo #116 by L. Berman and TRW Software Anomaly report A-200-G-01.

#7 There was a chance of being locked out of P66 if one of the channel bits associated with MARK X, Y or MKREJECT were stuck on, (Logic "0") A change was made to check for presence of an ROD bit rather than absence of a mark button bit in channel 16 at the entrance of MARKRUPT.

#6 In order to make room in fixing anomaly L-1B-03 an erasable was deleted as was the only instruction (Transfer to Storage) addressing this erasable (1JACCV). This erasable was a SP angular acceleration expected from a single jet fired about the V axis. In TJETLAW this acceleration is used as an average value computed from 1JACCU and 1JACCQ; thus this Transfer to Storage mentioned above is unnecessary as is the erasable itself.

Massachusetts Institute of Technology Instrumentation Laboratory Cambridge, Massachusetts

LUMINARY Memo #127

To: Distribution

From: Bruce McCoy

Date: · 3 December 1969

Subject: Re-release of LUMINARY 1C

A program bug was found in revision 130 of LUMINARY which could destroy some valuable erasable memory during an "early abort" from Descent. The severity of this bug caused MIT to recommend a release of LUMINARY revision 131 which has a fix to the problem. The problem was caused by adding one instruction to set a flagbit if the "late abort" targets are used.

As of today there is one known anomaly in Luminary which will probably not occur during Apollo 13. Extended Verb 59, which drives the LR to position 2 during coasting flight, works; but will leave the radar mode indicator (RADCADR) in an improper state. However, any V37 will clear up the state of RADCADR. It is to be fixed for Luminary 1D.

There are a couple of "other things" not quite right in Luminary 1C: to save words and recoding of the Landing Displays Routine, NOUN 60 was simply made to be FORVEL, already computed in this routine. However, it was overlooked that FORVEL is only computed when the MODE SELECT switch is in PGNCS position. To correct this oversight, FORVEL will be computed prior to checking the MODE SELECT switch position. Also, the conversion from bits to feet per second (0.5571) was typed wrong on the change card to be 0.5517. However, since by the time NOUN 60 is useful (500 ft. altitude) the forward velocity is too low to be affected, ~ 10 fps.

There are some corrections to Luminary Memo #121. For PCR 943, the pseudo addresses are 3371 and 3372; the erasable location for ELBIAS is 1356. A clarification for PCR 895; V59 during average G in P63 will assume the LR is stuck in position 2 and set up the matrix transformations accordingly; it does not actually position the antenna.

Massachusetts Institute of Technology Instrumentation Laboratory Cambridge, Massachusetts

COLOSSUS Memo #226

TO:	Distribution
FROM:	Stephen L. Copps
DATE:	October 27, 1969
SUBJECT:	Final Content and Testing of Colossus 2D
REFERENCE:	Colossus Memo #7, Rev. 1 Colossus 2D Development Plan, dated 10/17/69.

The Colossus 2D (COMANCHE. Rev. 72) program is a modification of Colossus 2C (COMANCHE, Rev. 67). The new coding is authorized in one of three ways:

- a) PCR/PCN's
- b) Colossus Anomalies (COLXX or COMXX) requiring no PCR; i.e., requiring no specification change.
- c) Assembly Control Board authorization (ACBXX), requiring no PCR;
 i.e., not an anomaly fix and not a specification change.

This memc records these changes:

Table A: List of PCR/PCN'S Table B: List of Anomalies Table C: List of ACB'S

All changes made to this assembly were unit tested (levels 2 and/or 3) and the following table lists the level 4 test performed on the released version of Colossus 2D (Rev. 72)

Carbon copies of all level 4 tests (computer printouts) will be sent to Stan Mann at NASA/MSC.

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TABLE A

PCR/PCN's Contained in the Colossus 2D Release

- PCR 806.1 Allow N07 to address output channels
- PCR 863.1 Make P76 Set NODO flag.
- PCR 936.1 Initialize V90 time to TIG
- PCR 963 R52 Delete 407 Alarm and drive trunnion to 50⁰
- PCR 966 Clear preferred Orientation Flag in P40/41

TABLE B

Anomalies fixed in the Colossus 2D Release

COM 21 Backwards Integration can occur in P27 uplink.

COM 22 V79, V41, V55, V42, do not perform CCS new job.

COM 24 Coding in iterator

COM 26 Extended Verb 92 Flg 6 is changed while job is not in INHINT

COM 27 V32E response to FLV16N45 in P37 results in indeterminate program transfer.

COM 29 N70 instead of N71 display in P23

TABLE C

ACB's in the Colossus 2D Release

ACB 91	V2X proceed response currently destroys content of R1,
	R2, R3 and returns to the V2l point of load.
ACB 97	Delete redundant line inadvertently inserted is implementation
	of PCR 810.
ACB 98	Delete INHINT before FINDVAC in V89.
ACB.99	Remove DSP2BIT in pinball game buttons and lights.

TABLE D

Level 4 Tests Run on Colossus 2D

TEST NO.	DESCRIPTION	MANCHE REV
C4.1	Nominal Boost With Saturn V, With IMU Realign-Digital	72
C4.2	Boost With Late Abort - Digital	72
C4.3	Boost With Early Abort - Digital	72
C4.7	Cis-Lunar Navigation With IMU Off - Digital	72
C4.8a	Lambert SPS Burn Sequence, CSM-LM Docked - Digital	72
C4.8b	Lambert SPS Burn Sequence, CSM-LM Docked - Digital	72
C4.9a	Lambert RCS Burn Sequence With Update - Digital	72
C4.9b	Lambert RCS Burn Sequence With Update - Digital	72
C4.10	RTE From Near-Earth Orbit, With SPS Burn	72
C4,11	Return To Earth From Far-Out Orbit, With RCS Burn	72
C4.12	Deorbit With SPS Ext. Burn, Update	72
C4.14	Backup IMU Alignment Sequence - Digital	72
C4.19a	CM Active Rendezvous and State Vector Update - Digital	1 72
C4.20a	LM Active Rendezvous With Update and Navigation-Digi	tal 72
C4.20b	LM Active Rendezvous With Update and Navigation-Digi	tal 72
C4.25a	SOR-SOM Sequence With Navigation - Digital	72
C4.25b	SOR-SOM Sequence With Navigation - Digital	72
C4.26a	CSI Back Up Sequence With SPS Burn - Digital	72
C4.26b	CSI Back Up Sequence With SPS Burn - Digital	72
C4.27a	CDH Back Up Sequence With RCS Burn - Digital	72
C4.27b	CDH Back Up Sequence With RCS Burn - Digital	72
C4.28a	IMU Power Up, TPI Targetting - Digital	72
C4.28b	IMU Power Up, TPI Targetting - Digital	72
C4.29a	TPI Search - CM Active - Digital	72
C4.29b	TPI Search - CM Active - Digital	72
C4.30a	TPI Search - CM Passive - Digital	72

C

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TEST NO.	DESCRIPTION	COMANCHE	REV
C4.30b	TPI Search - CM Passive - Digital	72	
C4.31a	LM Active SOR-SOM Sequence With Navigation - Digital	1 72	
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a = Test in Earth Sphere
b = Test in Moon Sphere

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Massachusetts Institute of Technology Instrumentation Laboratory Cambridge, Massachusetts

3

LUMINARY MEMO # 117

TO:	Distribution
FROM:	George R. Kalan
DATE:	October 24, 1969
SUBJECT:	Special Crew Procedures Necessary for Controlling the CSM-docked Configuration with the LM DAP

Due to the presence of jet plume deflectors on the LM descent stage, the use of +X thrusting LM jets for pitch or roll attitude control of the CSM-docked configuration will, for some mass loadings, cause a serious control instability if any -X thrusting jets have failed off or have been disabled. The problem can be explained with the aid of Fig. 1, which illustrates a typical jet pair firing about the U or V control axis to produce clockwise rotation about the center of gravity (CG). Because of impingement upon the jet plume deflector, the 100 lb +X thrusting jet produces a net force of 89 lb. in the +X direction acting on moment arm D₁ and a 59 lb. component perpendicular to the X axis acting on moment arm D₂. The net moment due to the firing of the +X thrusting jet, (M_{+X}), is expressed in Eq. 1.

 $M_{+X} = (89 \text{ lb}) D_1 - (59 \text{ lb}) D_2$ (Eq. 1)

For many mass loadings, D_2 is large enough to produce a negative M_{+X} , indicating that the net moment produced by the +X thrusting jet tends to rotate the vehicle in the counterclockwise direction. Fortunately, in this situation the proper clockwise rotation will always be obtained if both the +X thrusting jet and the -X thrusting jet are fired simultaneously. Since, in the absence of disabled jets, the CSM-docked DAP always utilizes jet pairs for U or V axis attitude control, the only penalties for a negative M_{+X} in nominal operation are slower rotation rates and higher RCS propellant consumption. However, if a -X thrusting jet has failed off undetected or has been disabled manually, a U or V axis rotation will eventually be attempted with a single +X thrusting jet. If M_{+X} is negative in this situation, a command for clockwise rotation will produce a counterclockwise rotation. Since the DAP will continue commanding the clockwise rotation with the +X thrusting jet, the vehicle will spin uncontrollably in the counterclockwise direction.

The approximate mass loadings for which M_{+X} is negative in the CSM-docked configuration are illustrated in Fig. 2. Whenever the LM DAP is used to control the CSM-docked configuration while mass loadings are in the shaded region of Fig. 2, the crew should manually disable all +X thrusting jets (jets 2, 6, 10, 14) to improve control authority and prevent the occurrence of the instability. The disabled jets may be enabled for +X translation or ullage only if the DAP is in the minimum impulse command mode. (The instability can not occur in this situation because the DAP does not attempt to control attitude in the minimum impulse command mode.) If, in addition to the disabled +X thrusting jets, some -X thrusting jets have been disabled, the DAP may not have enough jets available to control pitch, roll or yaw automatically. In such a situation, minimum impulse command mode should be entered and the +X thrusting jets should be enabled so that pitch and roll may be controlled manually with the Y and Z translational jets using the translational hand controller and yaw can be manually controlled with the rotational hand controller. *

Reference:

*

J. E. Jones, "Evaluation of the Effect of Jet Plume Deflectors Upon LM DAP Control of the CSM-docked Configuration - Simulation Results", Spacecraft Autopilot Development Memo #29-69, June 27, 1969.

It has been assumed that the panel switches (which also disable jets 4, 7, 11, 16 when the +X thrusting jets are disabled) are used to disable the +X thrusting jets.







M. Johnston

Massachusetts Institute of Technology Instrumentation Laboratory Cambridge, Massachusetts

AG # 513-69 11 December 1969

Through:

To:

NASA Resident Apollo Project Office at M.I.T. Massachusetts Institute of Technology Instrumentation Laboratory 75 Cambridge Parkway Cambridge, Massachusetts

Mr. W. Kelly, PP 7 National Aeronautics and Space Administration Manned Spacecraft Center Houston, Texas Attention: Mr. J. Hanaway, EG 412 Mr. M. Holley, EG 44 Mr. R. Parker, EG 43

Subject:

Review of AOT utilization for inflight alignment of the IMU

Reference:

NASA Memorandum 69-PA-T-129A
 MIT System Test Group Memo #1426

Gentlemen:

Prior to the successful pinpoint landing of Apollo 12, there was considerable concern over the limitations imposed by the AOT on achieving IMU alignment accuracy satisfactory for pinpoint landing (ref. 1).

Review of AOT error sources indicated that the major errors could be reduced by the astronauts through proper use of the instrument. Apollo 12 astronauts showed it could be done.

This letter will summarize the accuracy limitations of the AOT and the possible changes which would minimize such limitations.

Table 1 summarizes the error sources that can be minimized by crew training and procedural changes. The inflight crew task can be simplified by re-adjustment of all AOTs (at the factory), so that the image and the reticle vacuum-focus point would coincide at the center of the reticle rather than the present 15° off-axis point. However, such a readjustment would be

at the cost of significantly less accurate IMU realignments on the lunar surface. The procedural changes for inflight utilization of the present AOT are presented in Reference 2. These changes could be instituted without mechanical readjustment of the AOT.

There exists a potentially large error that improved training and procedures cannot reduce. This error is due to the mechanical misalignment between the AOT and the IMU. Present ground tests roughly measure the quality of this mechanical installation about two axes. The test results are summarized in Figure 1. The present test specification allows 600 arc-second errors in the total alignment measurement. The mechanical misalignment error contribution can be reduced by devising more adequate techniques for measurement of the misalignment and then compensating in the computer for the measured error. This measurement probably would be made very late in the launch preparation sequence, due to the expected frequency of IMU replacements. I am confident a technique could be devised for calibrating the mechanical assembly in the SLA.

Very truly yours,

Ain Laats, Technical Director Apollo Guidance and Navigation

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TABLE 1.

SUMMARY OF AOT-RELATED ERROR SOURCES DURING

INFLIGHT LM IMU ALIGNMENT

rate

Error Source

Expected Magnitude

of apparent target

± 15 min/deg/sec

 Lag error due to astronaut reaction time in dynamic environment

2) Parallax error due to not centering eye in-exit pupil

3) Occultation of star image by reticle line

4) Focussing

63 sec (1 \sim) per mark maximum possible error $\sim .3$ min.

Supporting Evidence

Measurement made in one degree of freedom test fixture at MSC

Parallax measurements taken at KSC in February, 1967

N30 sec

For cases where the out of focus is not very readily obvious; error 30 sec. Deduced from sizes: of reticle lines and star images

Deduced from blur sizes of reticle and star FIGURE 1

AOT ALIGNMENT GROUND TEST RESULT SUMMARY LM 3, 4, 5, 6, 7, 8, 9



MIT/IL

Apollo Guidance and Navigation System Test Group Memo No. 1426

To:	Ain Laats
From:	James Hand, Kenneth Goodwin
Date:	13 November 1969
Subject:	Improved Inertial Platform Realignment with the LM
	Alignment Optical Telescope

References:

- MSC Memorandum 69 PA-T 129A, from H. W. Tindall, Jr. 20 October 1969
- 2. AOT Tests at MSC, 5 November 1969
- 3. Telcons: a) with J. Hanaway and E. Dickenson (MSC);b) with K. Goodwin (MIT at MSC)
- 4. MIT/IL AG Letter 472-67, from G. W. Karthas AOT Error Analysis, April 1967
- 5. MIT/IL Memorandum from G. Karthas, 6 November 1969

ABSTRACT

Optimal usage of the alignment optical telescope (AOT) could enhance the probability of precision landings of the LM through increased accuracy of the prerequisite IMU realignment (ref. 1).

Preliminary findings from dynamic star-sighting tests with the AOT at MSC indicate that the combined observer-response and parallax errors can increase significantly as a result of an undetectable increase in angular vehicle rate (ref. 2, 3). That is, the X and Y reticle-crossing marks are performed late - "lag error" is committed - as a result of excessive vehicle motion which is not apparent to the observer.

This memorandum reviews the test results to date, outlines further tests for confirming the findings, and describes guidelines for optimal inflight usage of the AOT. MIT/IL SIG Memo No. 1426 Page 2.

DISCUSSION

Test Results

A series of five tests with the AOT were conducted at MSC by sighting on real stars and executing a mark as the target appeared to cross the X or Y reticle lines. The observer was astronaut John Young; the AOT was a trainer model focused for use in air; the test mount afforded a single degree of base motion at a known rate superimposed on the sidereal rate. Instrumentation provided for the measurement of the angle at which each mark was executed, compared to the statically calibrated angle when the star and reticle were superimposed.

Figure 1 illustrates the five star-crossing tests performed as denoted by the dashed lines numbered Tl through T5. Base motion was always in the vertical plane - the AOT reticle was rotated about its center to obtain the desired angle of the star-crossing with respect to the X and Y reticle lines. Marks were executed as the star moved back and forth across the lines at the preselected rate of six \widehat{min}/\sec for Tl through T4 and at 12 \widehat{min}/\sec for T5.

In Test 1 the star crossed the reticles at an angle of approximately 45 degrees, near the center. The crossing angle for T2 was 90 degrees to the X reticle; for T3 the marks were executed as the target tracked up and down through the center of the reticle. In Test 4 the target tracked on the Y reticle through the precise 15 degrees off-axis intersection of the spiral and Y lines. This is the point of optimal focus minimum parallax - for vacuum-focused AOT's used inflight. Test 5 was at the same point in the field and at a rate of 12 min/sec instead of six min/second.

Table 1 summarizes the test results of 24 mark pairs for T1 and seven pairs each for T2 through T5. The sign convention is minus for observer lag and plus for lead with respect to the calibrated reticle crossings.

As shown in the table, the first test results in an average observer response lag of 1.3 arc minutes. These data agree closely with the MIT/IL STG Memo No. 1426 Page 3.

original error analysis by MIT/IL where observer response and parallax error is estimated at 1.45 arc minutes (ref. 4).

The response lag is tests 2 through 4 is of the same approximate magnitude: an average total (\overline{X}_T) at -1.5, -2.2 and -1.4 min.respectively. The imbalalance in average response lag (star moving up vs down) is probably due to the bias caused by operation in the one-g environment.

It is notable that average total lag doubled from about -1.5 to -3.0 min. as the apparent target rate was doubled from 6 to 12 min/second. The observer reported inability to discern the difference in rates. This leads to the idea that excessive inflight sighting errors may be due to undetectable excessive vehicle rate during marking (one RCS pulse imparts about 3 min/sec delta angular rate for the heavy - LM case). The computer-contained Star Data Test does not necessarily reflect all of the error from this source, due to geometrical considerations.

Additional Testing

The data from tests 2 through 5 are considered inconclusive because of the small number of marks for each test and because only one observer conducted the tests.

A repeat of tests 1 through 5 with two observers and at least 48 marks per test, per observer, should increase the reliability of the results. considerably.

Optimal Inflight Sightings

Assuming that further tests confirm the findings outlined above, i.e., the linear sensitivity of observer response and parallax error to base motion rate, an optimal inflight sighting technique can be considered.

All instrument factors considered, the most accurace place in the field of view to execute an inflight sighting mark with the AOT is at the center of the reticle, not on the X-Y reticles near the center as is the

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present method. Such factors include:

- a. Parallax is minimized when the eye is properly centered in the eyecup.
- b. The separation between the reticle lines at the center is matched to the image diameter (1 min.). Off-axis the image is distorted up to approximately nine times the line-width and thus it is not possible to accurately bisect the image with the line.
- c. The AOT is calibrated precisely at the center of the field. The computer-contained coordinates of the center of the field (detent calibration) are known to within 17 sec., one sigma.
- d. The double cursor can be used as in aid in "moving the star" to the center of the field.
- e. Response errors can be minimized.

One inflight sighting method, from the point of view of using the 'AOT accurately, would be:

- a. Perform the auto-optics maneuver (R52).
- b. Focus the eyepiece with the reticle lighting off for the best star image near the center of the field.
- c. Bring the reticle up in brightness only to the minimum required to see it 100% of the time.
- d. Use the eyecup and move the eye around so as to observe the extent of parallax and attempt to center the eye.
- e. Maneuver to bring the star approximately within the vertical cursor lines near the center of the field (approx. 1 degree off-axis).
- f. Maneuver in pitch slowly such that the star tracks along the vertical and mark at the crossing of the center.
- g. Perform an even number (preferably four pairs) of marks to negate response error, e.g. mark X-down, Y-up, Y-down, X-up...

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A study is needed to determine whether a sighting procedure such as that outlined above is practicable with regard to spacecraft control and RCS fuel expenditure.

James A. Hand System Test Group

Kenneth R. Goodwin System Test Group

cc: R. Ragan D. Hoag L. Larson N. Sears J. Nevins R. Larson G. Ogletree G. Karthas T. Lawton P. Felleman R. White M. Johnston I. Johnson MIT at KSC/MSC D. Dolan A. Laats J. Hand G. Silver

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G. Edmonds

MSC J. Hanaway E. Dickenson C. Manry J. Lovell J. Young H. W. Tindall, Jr. MIT/IL STG Memo No. 1426 Page 6.

TABLE I

Summary of AOT Test Results

				*
Test No.		Error (min)	Base Motion Ra	te
		(minus=lag; plus=lead)	(min/sec)	
				· · ·
1,		$X_{T} = -1.33$	6	
		(one sigma: 1.56 min)	•	
		(,	1	
2.		$\overline{X}_{rr} = +.57 \widehat{\min}$	6	
		$\overline{X} = -3.6$ (1)		
•			•	
*		$X_{T} = -1.5$		· •
. 3		♥ +-0.5	C	4
-		$\mathbf{X}_{\mathbf{D}} = -3.9$		
	l,	$X_{T} = -2.2$, · · ·	
	À,			
4.	•	$\mathbf{X}_{\mathbf{U}} = +1.5$	6	
~		$X_{D} = -4.1$		
	-	$X_{rr} = -1.4$		
۲ - ^{ال} م الم			•	-
5.		$X_{II} = -1.0$	12	
		$\overline{X}_{2} = -4.8$	18 ⁻¹	
		ע ⊽ - 20 ¹		-
	•	$^{X}T - 2.9$		
		· · · · · · · · · · · · · · · · · · ·	<u> </u>	
$\overline{\mathbf{X}}$	= aver	age	•	7
X .,	= aver	age; target moves upward		20
3	= aver	age; target moves downward	•	194 19 10
$\mathbf{x}_{\mathbf{T}}^{D}$	= aver	age of total		•
-		,		

1

