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MIT/IL PRESENTATION FOR THE
MISSION "H-2" APOLLO 13
FLIGHT SOFTWARE READINESS REVIEW

HELD AT NASA/MSC ON 16 MARCH 1970

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SECTION I

CSM PROGRAM

SUMMARY OF COLOSSUS 2D DEVELOPMENT

Establishment of a COLOSSUS 2D Assembly	18 July 1969
Release of COLOSSUS 2D for Rope Manufacture	
COMANCHE 72	20 Oct. 1969
MANCHE72 Rev 3	12 Dec. 1969
Completion of Mission "H-2" Level 6 Testing	12 March 1970*
Completion of Mission "H-2" RTCC Testing	11 March 1970
Total Number of PCR/PCNs Accomplished in the COLOSSUS 2D Release	11
Total Number of Anomalies Fixed in the COLOSSUS 2D Release	8

*Pending completion of Takeover and Normal Boost Cases.

COLOSSUS 2D PCR/PCNs IMPLEMENTED

806.1	Allow N07 to Address Output Channels.
863.1	Make P76 Set NODO Flag.
936.1	Initialize V90 Time to TIG.
962	Describe Error Check in P23. (GSOP)
963	R52-delete 407 Alarm and Drive Trunnion to 50^{o}.
965	Define POOFLAG. (GSOP)
966	Clear Preferred Orientation Flag in P40/41.
977	Alignment Star Aberration Alogorithm Change. (GSOP)
980	Termination of R60. (GSOP)
984	Avoid Coarse Align during Saturn. (MANCHE72 Rev 3)
992	T6JOB OPCODE Correction. (GSOP)

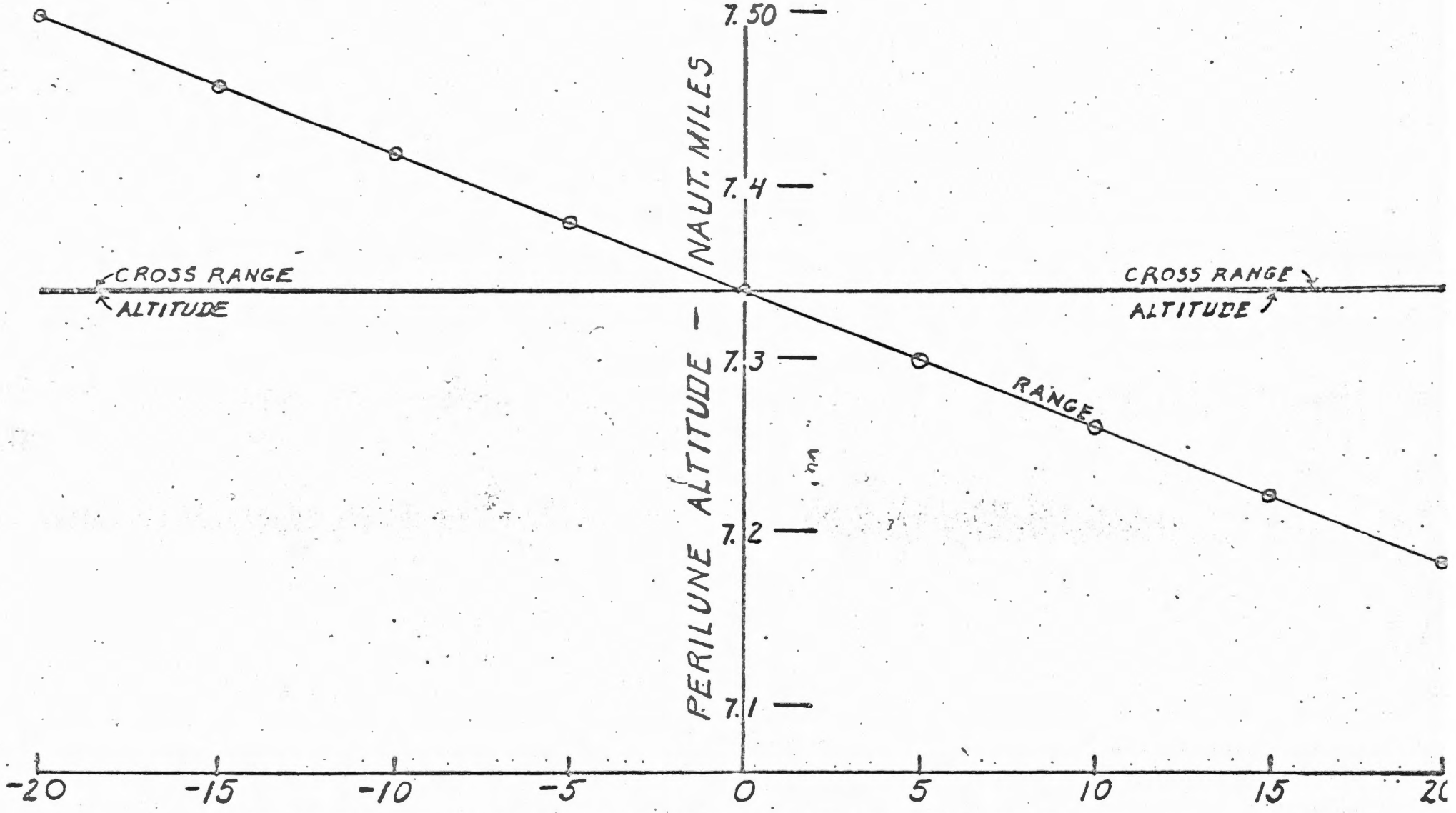
ANOMALIES FIXED IN COLOSSUS 2D

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 Flagword 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.

COLOSSUS 2D
PERFORMANCE TESTING

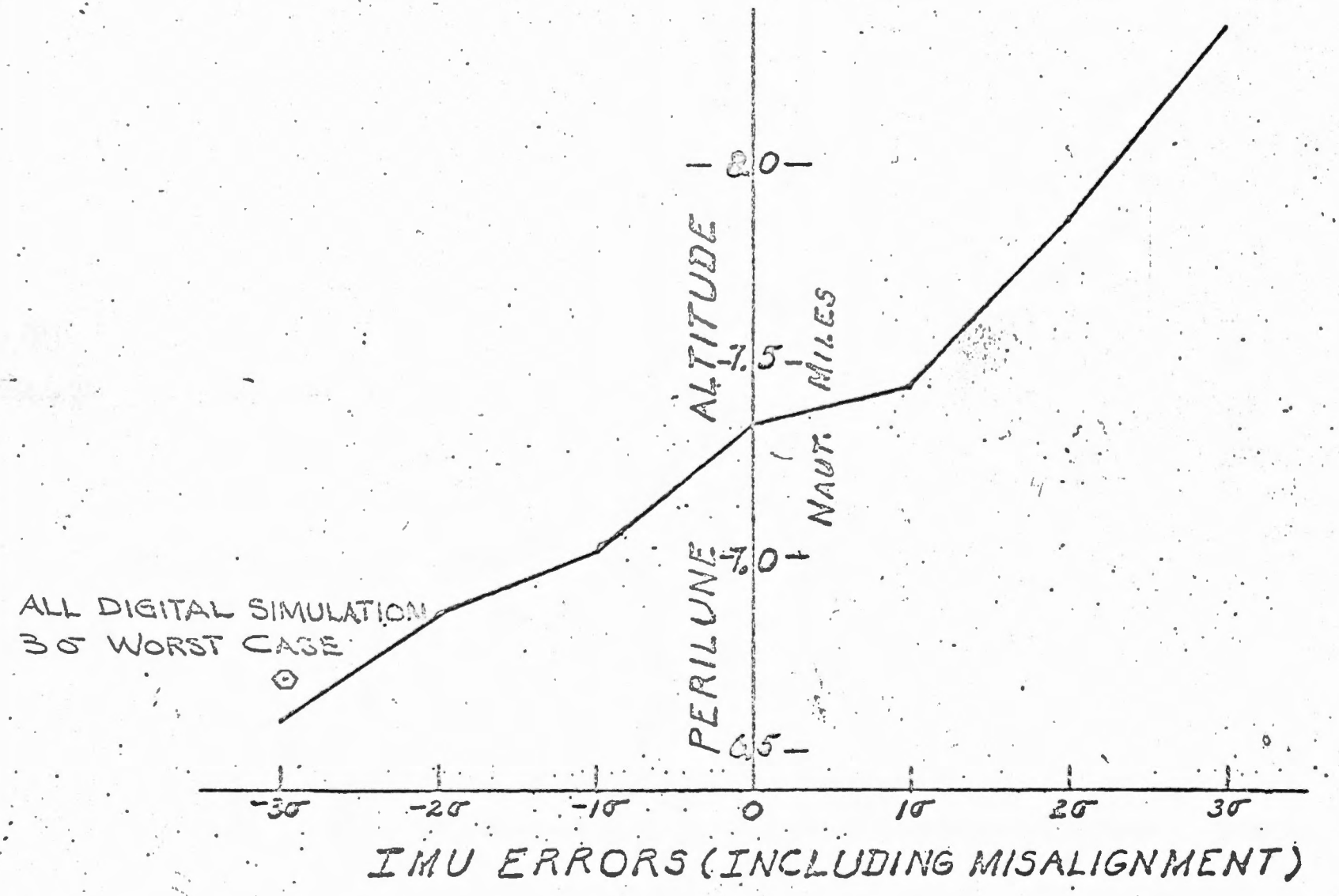
Boost Takeover during Polynomials.*
Normal Boost to Orbit, P52, R04.
DOI
CSM Active from Insertion (LM in 10 nm. x 45 nm. Orbit).
CSM Passive from Insertion (LM in 10 nm. x 45 nm. Orbit).
CSM Active from Insertion (LM in 10 nm. x 45 nm. Orbit) - Optics Only.
CSM Active from Insertion (LM in 10 nm. x 45 nm. Orbit) - VHF Only.
RTE (EI-30 Hours to Splash).
RTE (Post TEI-abort, No Comm., P23, P37/P40/P41 after Sphere Crossing to Splash).
Nominal Lunar Entry.

*Also run with Apollo 12-type Glitches.



POSITION ERROR AT IGNITION - THOUSANDS OF FEET

EFFECT OF POSITION ERROR AT DOI ON PERILUNE



EFFECT OF IMU ERRORS ON PERILUNE DURING DOI

COLOSSUS 2D

MISSION "H-2" RTCC TESTING

Large Translunar Midcourse Correction (Earth Centered P30/P40).

Lunar Orbit Insertion (LOI, P30/P40).

Descent Orbit Injection (DOI, P30/P40).

Uplinks (All CMC Command Loads).

P11 Boost REFSMMAT, Nominal Liftoff.

P11 Boost REFSMMAT, 1-hour Late Liftoff.

P51 Alignment Determination #1.

P51 Alignment Determination #2.

Nominal Hi-speed Lunar Entry.

Lo-speed Deorbit Entry.

COLOSSUS 2D

SPECIAL MIT BOOST RUNS*

#0 Reference Run: Nominal Takeover and V46 during Polynomials.

#1 180° CDUZ Glitch at 45 sec; Takeover at 50-sec., V46 20 sec. later.

#2 Takeover at 50 sec., 180° CDUZ Glitch at 55 sec., V46 15 sec. later.

#3 -180° CDUX Glitch at 45 sec., Takeover 5 sec. later.

#4 Takeover and V46 at 20 sec., 180° CDUZ Glitch at 30 sec., 90° CDUZ Glitch at 70 sec.

#5 V48 for NODAP, 90° CDUZ Glitch at 70 sec., Takeover and V46.

*Documentation for these runs is presented in Colossus Memo #262: Special Boost Glitch Testing on Colossus 2D (MANCHE72 Rev 3), by O.S. Eliassen. Simulation and edit printouts and plot material are on file at MIT.

COLOSSUS 2D

SPECIAL ENTRY RUNS

MSC Requested Entry Runs (1575 nm, 1550 nm, 1600 nm Range).

MSC Requested Runs:

#1 Nominal Entry
#2 Steep Entry
#3 Deorbit Entry
#4 Long Range Entry
#5 Shallow High Speed Entry
#6 Initially Lift Down Short Range Entry
#7 Special UPCONTRL-Exit Entry
#8 Ultra High Speed Entry

COLOSSUS 2D
MISCELLANEOUS DOCUMENTATION

Colossus Memo #246	Apollo 12 Pre-CSI CSM Rendezvous Navigation. (E. Muller/P. Kachmar)
Colossus Memo #247	Procedures for Avoidance of Apollo 12 Pre-CSI CSM Rendezvous Navigation Problem. (E. Muller/P. Kachmar)
Colossus Memo #259	Apollo 13 DOI Level 6 Perturbation Analysis. (E. Hume/C. Beals)
Colossus Memo #262	Special Boost Glitch Testing on Colossus 2D (MANCHE72 Rev 3). (O.S. Eliassen)

COLOSSUS 2D
MISSION PROCEDURAL TESTING

P37 RTE

LOI

CSM DOI

LM Initiation, Undocking and Separation

P22 Landing Site Tracking

CSM Circularization

CSM Lunar Orbit Plane Change

Post-Insertion to TPF

Post-Insertion to TPF - Non-nominal

TEI

High Velocity Entry

COLOSSUS 2D

MISSION PROCEDURAL TESTING

P37 RTE: Longitude Control (Outbound)	Tests completed; no procedural problems.
LOI:	Tests completed; no procedural problems.
DOI:	Tests completed; no procedural problems.
P22 LM Tracking: (8 nm x 60 nm Orbit)	Tests completed; no procedural problems.
CSM Lunar Orbit Circularization:	Tests completed; no procedural problems.
CSM Plane Change #1	
Coarse & Fine Align:	Tests completed; no procedural problems.
Gyro Torquing:	Tests completed; no procedural problems.
Rendezvous, Insert to TPF	
Nominal, LM Active:	Tests completed; no procedural problems.
Nominal, CSM Active:	Tests completed; no procedural problems.
Non-nominal, CSM Active (10 fps Out-of-plane)	
CSI, PC, CDH Sequence:	Tests completed; no procedural problems.
Forced node at MCC2:	Tests completed; no procedural problems.
TEI:	Tests completed; no procedural problems.
High Velocity Entry:	Tests completed; no procedural problems.

REFERENCES FOR H2 MISSION
PROCEDURAL VERIFICATION TESTING

1. Apollo 13 Mission O.T. Simulator Data Package #69-FM13-611, 12 December 1969 (12 March 1970 Liftoff).

2. Revision 1 to Apollo 13 Mission O.T. Simulator Data Package #70-FM13-58, 17 February 1970 (11 April 1970 Liftoff).

3. CSM Rendezvous Procedures, H1 Mission, Final Rev A, 14 October 1969.

4. LM Rendezvous Procedures, H1 Mission, Final, 26 September 1970.

5. Apollo 13 Preliminary CMP Solo Book, 6 February 1970.

6. Apollo 13 CSM G&C Checklist, 5 January 1970.

7. Apollo 13 Preliminary Flight Plan, 6 February 1970.

8. Mission H2 Flight Readiness Test Prelaunch Erasable Load for MANCHE72 Rev 3, #70-FS55-12, 10 January 1970.

9. Apollo 13 LM Lunar Surface Checklist, 16 February 1970.

10. LM Descent/Ascent Procedures, Mission H, Final, 23 September 1969.

COLOSSUS 2D
SYSTEM TEST LAB TESTING

Extended Verbs

IMU Operational Programs

IMU Performance Test

IRIG Scale Factor

Prelaunch Alignment

Special P11/Gimbal Lock

COLOSSUS 2D

SYSTEM TEST LAB FINAL TEST

AREAS TESTED

1. Change in Gimbal Lock Protection Portion of T4RUPT to Prevent Coarse Align in P11.

2. IMU Performance and IRIG Scale Factor Test.

3. Prelaunch Alignment.

4. IMU Control Extended Verbs and Control Programs.

COLOSSUS 2D

DOCUMENT REVIEW CHRONOLOGY

1. CSM 109 Flight Data File

   Systems Checklist, dated 1/5/70, received 1/9/70.
   Malfunction Procedures, dated 1/5/70, received 1/9/70.
   CSM Systems Data, dated 1/12/70, received 1/23/70.
   Update, dated 2/9/70, received 2/17/70.
   CSM Cue Cards, dated 1/26/70, received 2/2/70.
   Update, dated 2/20/70, received 3/3/70.
   CSM Entry Checklist, dated 1/5/70, received 2/2/70.
   CSM Launch Checklist, dated 1/5/70, received 2/2/70.
   CSM G&C Checklist, dated 1/5/70, received 2/2/70.
   CMP Solo Book, dated 2/6/70, received 2/19/70.
   CSM Rescue Book, dated 2/16/70, received 2/27/70.

   Informal transmittal of comments, 2/24/70 - 3/9/70. Review not completed on all documents.

2. CSM Procedures Documents

   CSM 109 AOH Vol. 2, dated 1/14/70, received 2/9/70.
   Informal transmittal of comments, 2/9/70 - 3/10/70.
   Formal Transmittal (POPC 505-511), dated 3/13/70.

   The inclusion of information related to software changes which updated COM 67 to COM 72 has been assured.

ANOMALIES EXISTING IN COLOSSUS 2D
(MANCHE72 Rev 3)

Anomaly	Description	Disposition
COM 31	RENDWFLG not reset correctly in P23.	Fix for 2E. Program note for 2D.
COM 32	Constant error in AUGEKUGL.	Fix for 2E.
COM 33	Coding error in KALCMANU steering.	Fix for 2E. Program note for 2D.
COM 34	LONGCALL POODOO exit errors.	Fix for 2E. Program note for 2D.
COM 35	Downlink state vector may be $\bar{0}$ after sphere crossing.	Fix for 2E. Program note for 2D.
COM 36	Erroneous state vector and W-matrix while in P00.	Fix for 2E. Program note for 2D.

CONCLUSION

BASED ON THE PRECEDING
DATA, MIT/CSD LABORATORY
RECOMMENDS THE USE OF
COLOSSUS 2D (MANCHE72 Rev 3)
FOR MISSION "H-2".

SECTION 2

LM PROGRAM

SUMMARY OF LUMINARY 1C DEVELOPMENT

Establishment of a LUMINARY 1C Assembly	15 Aug. 1969
Release of LUMINARY 1C for Rope Manufacture	
Rev 130	5 Nov. 1969
Rev 131	3 Dec. 1969
LUM131 Rev 9	14 Jan. 1970
LM131 Rev 1	4 Feb. 1970
Completion of Mission "H-2" Level 6 Testing	12 March 1970
Completion of Mission "H-2" RTCC Testing	13 March 1970
Total Number of PCR/PCNs Accomplished in the LUMINARY 1C Release	16
Total Number of Anomalies Fixed in the LUMINARY 1C (LM131 Rev 1) Release	9

LUMINARY 1C PCR/PCNs IMPLEMENTED

285	Remove Check of Auto Throttle Discrete.
806.2	Allow N07 to Address Output Channels.
846 (Rev 1)	More Accurate DELTA-T TAILOFF for P70.
863.2	P76 Set NODO Flag.
882	Replace VHORIZ with FORVEL.
893	Abort Targeting Flagbit.
895	V59E Allow Use of LR in Position #2 in P63.
936.2	Initialize V90 Time to TIG.
942	LR Update Cutoff (Accomplished as Part of PCR 988).
943	Velocity Reasonability Test.
968	LPD Bias.
971	Change Fixed Memory Constant (APS) DELTA-T TAILOFF
972	Display Polarity of Sighting Angle Difference in R54.
976	Erasable Program for LM Deorbit.
988	Auto P66 Implemented (LUM131 Rev 9).
1013	Multiply Servicers Avoidance in P66 (LM131 Rev 1).

ANOMALIES FIXED IN LUMINARY 1C

LNY 75	Radar Self Test Routine.
LNY 92	V41 and V42 do not Perform CCS New Job before Final Display.
L-1B-01	Selection of P22 before CSM is within RR Coverage.
L-1B-03	Quantity COEFFR Discrepancy when 1JACCQ and 1JACCR are Equal.
L-1B-04	During Descent Switching RR Mode into LGC and Out Disables Meter.
L-1B-05	R60 Mode II Attitude Errors Placed in FDAI Needles before Desired Attitude.
L-1B-09	If a Restart Occurs during a Radar Read, the following Radar Read may be Incorrect.
L-1B-10	Rate and Attitude Overshoot will be Observed after ACA is required.
L-1C-02	For Early Abort from PDI Locations of a VAC Area are Destroyed.

LUMINARY 1C

PERFORMANCE TESTING

LM131 Rev 1 Level 4 TLOSS		5% TLOSS Level 6		
		LUMINARY 131	LUM131 Rev 9	LM131 Rev 1
	Rendezvous			
5%	Nominal LM Active w/P52 Alignment	X	X	X
	Aborts from Descent			
	Abort at 30K ft-Insertion to CSI Solution w/P20 Navigation	X	X	X
5%	Abort at 7K ft-Insertion to CSI Solution w/P20 Navigation	X	X	X
	Abort after Touchdown - Insertion to CSI Solution w/P20 Navigation	X	X	X
9.5%	Abort at 46K-ft			X
	Abort Stage at 46K-ft			X
	Lunar Surface Operation and Ascent			
	(Offset RLS to Show Effect of Gravity Vector Updates to RLS)			
	(Initialized with 5° Pitch, 15° Yaw)			
5%	P68, P00, P12, P57 (2 Stars), P06, P57 (Gravity/Star)			
	P57 (Gravity/REFSMMAT), P22, P12, P20, P32	X	X	X
	Landing (Prime Site)			
	Automatic Landing - V59 just Prior to HIGATE	X	X	X
5%	P66 Landing with Following Redesignations			
	N69: 10K/5K ft; ACA: None	X	X	X
9.5%	N69: 20K/20K ft; ACA: 2 + AZ/2 - EL	X	X	X
	N69: None; ACA: 2 - AZ/2 + EL	X	X	X

LUMINARY 1C

MISSION "H-2" RTCC TESTING

	LUMINARY 131	LUM131 Rev 9	LM131 Rev 1
APS Abort (P30/P42).	0	0	X
DPS Abort (P30/P40).	0	0	X
Uplink Test (All LGC Command Loads).	0	0	X
NOM CSI (P32).	0	0	X
Preturbed CDH (P33).	0	0	X
Preturbed TPI (P34).	0	0	X
Preturbed TPI (P34).	0	0	X
Two Star Alignment (P57).	0	0	X
Star/g -vector Alignment (P57).	0	0	X

LUMINARY 1C

MISSION PROCEDURAL TESTING

	LUMINARY 131	LUM131 Rev 9	LM131 Rev 1
Docked DPS DOI ABORT	0	0	0
Docked APS DOI ABORT	0	0	0
PDI (50, 000') to Landing - Auto	0	1	2
PDI (50, 000') to Landing - ROD	0	2	1
PDI (50, 000') to Landing - Redesignate	0	4	1
PDI (30, 000') to Landing - Auto	0	2	2
PCI (30, 000') to Landing - ROD	0	3	2
PDI (30, 000') to Landing - Redesignate	0	1	1
PDI (70, 000') to Landing - Auto	0	2	0
PDI (70, 000') to Landing - ROD	0	3	1
PDI (70, 000') to Landing - Redesignate	0	4	1
DPS Abort from Descent (PDI at 50, 000)	0	0	2
DPS-APS Abort from Descent (PDI at 50, 000')	0	1	2
DPS Abort from Descent (PDI at 30, 000')	0	2	1
DPS-APS Abort from Descent (PDI at 30, 000')	0	3	2
DPS Abort from Descent (PDI at 70, 000')	0	2	2
DPS-APS Abort from Descent (PDI at 70, 000')	0	1	1
DPS Abort from 2nd Pass Descent (PDI at 30, 000')	0	0	0
DPS-APS Abort from 2nd Pass Descent (PDI at 30,000')	0	0	0
Abort State from Surface	0	0	2

continued...

LUMINARY 1C
Mission Procedural Testing, cont'd.

	LUMINARY 131	LUM131 Rev 9	LM131 Rev 1
DPS Abort from 2nd Pass Descent (PDI at 30,000')	0	0	0
DPS Abort from 2nd Pass Descent (PDI at 70,000')	0	0	0
Surface Alignments (P57)	0	0	1
Surface Tracking (P22)	0	0	2
Pre-liftoff to Rendezvous	0	1	0
Ascent Liftoff to Insertion	4*	0	1
Post-insertion to Rendezvous	0	0	2**
Post-insertion to Rendezvous Non-nominal	0	0	0
Pre-TPI to Rendezvous	0	0	0
LM Deorbit	0	0	1

NOTES:

*3 on LUM131 Rev 2; 1 on LUM131 Rev 1.
**1 Linked.

The above procedural testing was conducted with no T-LOSS.

LUMINARY 1C

MISSION PROCEDURAL TESTING

Docked DPS burns (LOI & DOI Aborts):	Low priority run.
Auto P66 Landings:	Run from PDI Altitudes of 30,000, 50,000, and 70,000 feet, all nominal.
ROD P66 Landings:	Run from PDI Altitudes of 30,000, 50,000, and 70,000 feet, all nominal.
Redesignation Landings:	Run from PDI Altitudes of 30,000, 50,000, and 70,000 feet, all nominal.
N69 Landing Site Revision:	Combined with P66 and redesignation landings.
Aborts from Powered Descent:	Initiated from landings with PDI at 30,000, 50,000, and 70,000 feet, both DPS and DPS-APS aborts, all nominal.
Abort from Surface:	Nominal run.
Surface Activities:	Nominal runs using P57 and P22.
Ascent:	Nominal run.
Rendezvous from Post-Insertion:	Nominal run, also linked run done with off-nominal burns but good rendezvous.
LM Deorbit:	Nominal run.

NOTES:

(1) All runs listed are without TLOSS. TLOSS testing (approximately 30 runs)
(2) For references (Documents), refer to page C-13.

LUMINARY 1C
SYSTEM TEST LAB TESTING

IMU Performance Test

IRIG SF Test

AGS Align Test

Radar Test

LUMINARY 1C

SYSTEM TEST LAB FINAL TEST

AREAS TESTED

1. Several Radar Program Portions where Changes were made.

2. IMU Performance Test and IRIG Scale Factor Test.

3. AGS Align Test.

LUMINARY 1C
DOCUMENT REVIEW CHRONOLOGY

1. LM Flight Data File

Rendezvous Charts, dated 12/24/69, received 1/9/70.
Update, dated 2/16/70, received 2/20/70.
Data Card Book, dated 1/12/70, received 1/19/70.
Update, dated 2/20/70, received 3/2/70.
G&N Dictionary, dated 1/5/70, received 1/19/70.
Update, dated 2/13/70, received 2/20/70.
Cue Cards, dated 1/19/70, received 1/23/70.
Update, dated 2/4/70, received 2/17/70.
Systems Data, dated 1/12/70, received 1/23/70.
Contingency Checklist, dated 1/6/70, received 1/29/70.
Update, dated 2/13/70, received 2/25/70.
LM Time Line Book, dated 2/16/70, received 2/25/70.
Malfunction Procedures, dated 2/6/70, received 2/17/70.
Activation Checklist, dated 2/16/70, received 2/19/70.
Lunar Surface, dated 2/16/70, received 2/20/70.

Informal transmittal of comments, 3/11/70. Review not completed on all documents.

(continued...)

LUMINARY 1C
Document Review Chronology, cont'd.

2. LM7 Procedures Documents

AOH Vol. 2, dated 1/14/70, received 2/4/70, reviewed 2/28/70.

Informal transmittal of comments; No new comments.

Comments based on LUM 1C (Rev 131) were submitted for LM6 AOH on 1/19/70. With these comments, the inclusion of information in the LM7 AOH related to software changes which updated LUM116 to LUM131 has been assured.

ANOMALIES EXISTING IN LUMINARY 1C

(LM131 Rev 1)

Anomaly	Description	Disposition
L-1B-11	Terminal mass error.	Fix for 1D.
L-1C-01	Delta-V increment may be subtracted twice from V_G, following a restart.	Fix for 1D. Program note for 1C.
L-1C-03	Routine LRPOS2 is called by a TC, but it returns via SWRETURN.	Fix for 1D. V59 IN P00 DOESN'S WORK
L-1C-04	Two REMODE tasks operating simultaneously.	Fix for 1D (PCR 990). Work around for 1C. V41-V44-V41
L-1C-05	Sign disagreement when HCALC is calculated with RVBOTH.	Fix for 1D. Program note for 1C. X AXIS -26K
L-1C-06	P40, P42 or P63 commanding ullage, with average-g off.	Fix for 1D. Program note for 1C.
L-1C-07	Erroneous state vector and W-matrix while in P00.	Fix for 1D. Program note for 1C.