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LUMINARY MEMO #240

To: Distribution

From: Luminary Test Group

Date: 2 March 1972

Subject: Luminary Level 6 Test Results for Mission 16

Reference: LUMINARY Memo #231 "Level 6 Test Description for Mission 16 (PRELIMINARY)" dated 8 November 1971

This memo summarizes the results of the LUMINARY Level 6 digital testing effort conducted at MIT. The tests fall into the following general categories:

6.1.0 ASCENT AND RENDEZVOUS
6.2.0 ABORT FROM DESCENT
6.3.0 LUNAR SURFACE OPERATION AND ALIGNMENTS
6.4.0 LUNAR LANDING
6.5.0 ERASABLE MEMORY PROGRAMS
6.6.0 SPECIAL TESTS.

The test initialization listed below apply to all the tests and any special initial conditions will be indicated in the particular test.

(1) 1σ IMU, Radar, State Vector Errors
(2) Normal Astronaut Interface from Apollo 16 Data File
(3) Apollo 16 Operation Trajectory
(4) Apollo 16 Erasable Load
(5) 71/72 Ephemeris
(6) 10% TLOSS
(7) LM-11 Vehicle
(8) Apollo 16 Terrain

Typical 1σ initialization errors are given on page 3. An index for the test results is provided on the following page.

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TYPICAL 1 SIGMA INITIALIZATION ERRORS

IMU ERRORS

	X	Y	Z
Misalignment (milliradians)	1.0	1.0	1.0
Bias Drift (MERU)	2.00	2.00	2.00
Input Axis Drift (MERU/G)	8.00	-8.00	8.00
Spin Axis Drift (MERU/G)	-5.00	5.00	-5.00
PIPA Bias (CM/SEC^2)	.20	.20	.20
PIPA Scale Factor (PPM)	-116.00	-116.00	-116.00

STATE VECTOR ERRORS WRT SM AT PDI - 10 MIN.

	ALTITUDE	CROSS-RANGE	DOWN-TR
POSITION (ft.)	-1030	4400	-9100
VELOCITY (fps.)	8.54	-4.66	-1.07

RENDEZVOUS RADAR ERRORS

	BIAS	RANDOM
RANGE (ft.)	800 if R > 50.8 N.M. 80 if R ≤ 50.8 N.M.	.3% R
RANGE-RATE (fps)	.3	.4% R (MINIMUM .004
SHAFT/TRUNNION (Mr.)	15.0	1.0

LANDING RADAR ERRORS

	RANDOM	MINIMU
ALTITUDE (ft.)	.5%	5
VX (fps)	.5%	.8
VY (fps)	.7%	.8
VZ (fps)	1.0%	.8

6.1.0 ASCENT AND RENDEZVOUS

6.1.1 ASCENT AND RENDEZVOUS

I. Test Objective

Demonstrate LM Ascent from the lunar surface and LM active short Rendezvous.

II. Test Description

The LM is tilted approximately 10^{o} on the Lunar Surface.

Program Sequence

P57	AT-3 to Landing Site
P00	
V48	DAP Data Load
V41N72	Position RR
P12	Ascent
V64	S-Band Antenna
V82	Orbital Parameter Display (R30)
P00	
V48	DAP Data Load
P20	Rendezvous Navigation
V80	Enable LM State Vector Update
P34	Transfer Phase Initiation (TPI)
V83	Rendezvous Parameter Display (R31)
N52	Display LM Central Angle
N59	Display Delta LOS Vel.
V48	DAP Data Load
P42	APS
V82	Orbital Parameter Display (R30)
P35	Transfer Phase Midcoarse (TPM)
V67	W-Matrix Display
V48	DAP Data Load
V83	Rendezvous Parameter Display (R31)

P41	RCS
V82	Orbital Parameter Display
P35	Transfer Phase Midcourse (TPM)
V93	Enable W-Matrix Initialization
P41	RCS
V82	Orbital Parameter Display
P00	
V48	DAP Data Load
P47	Thrust Monitor
P00	

TEST 6.1.1 DATA SUMMARY

P57 AT-3 to Landing Site

NOUN 04 = 9.89
(LM tilted approximately 10 degrees on Lunar Surface)
Sighting: Starcode = 104, Sighting err. = .00 (deg.)
NOUN 05 = -.01
NOUN 93 = -.081, .063, .040
True misalignment after torquing
OIM = -.015, .001, -.010 (deg.)

P12 Ascent Insertion Data

	ENV	LGC	TARGETED
Ha (nm)	47.57	45.6	
Hp (nm)	9.01	9.00	
Y (ft)	729	282.4	281.5
H (ft)	61305	60416	60000
HDOT (fps)	36.2	32.4	32.0
FORVEL (fps)	5532.5	5530.8	5530.6
YAW (deg)	.31	-.24	
PITCH (deg)	-2.95	-5.33	
VGX (fps)		-.16	0
VGY (fps)		-.54	0
VGZ (fps)		.47	0

P20 Navigation Data Summary

State Vector errors.

	Time (sec)	No. Marks	Position(m)	Velocity(m/s
TPI	619726	0	1770	2.24
	621068	18	134	.15

	Time(sec)	No. Marks	Position(m)	Velocity(m/s
MCC1	621815	0	188	.27
	622264	7	139	.37
MCC2	622551	0	182	.16
	623148	9	65	.21

Noun 49 Summary

Marktime	RMAG (ft)	VMAG (ft/sec)	MEAS.
619726	2651	2.13	shaft
619726	7264	.09	trun.
619811	2158	6.08	trun.
619893	1542	4.14	trun.
619976	3550	4.43	shaft
619976	1108	3.39	trun.
620065	3917	4.55	shaft
620065	597	2.95	trun.

TARGETING AND BURN PERFORMANCE

The targeting and burn performance data summary is shown in Tables I and II.

TABLE I

NOMINAL TPI 621562.90

EVENT	TIG SEC	TPI SLIP SEC	DELTA ALT NM	DELTA V (LOCAL VERT)-FPS X	Y	Z	MAG	BURN RESIDUAL-FPS X	Y	Z	ENV CPA TIME SEC	ENV CPA RANGE M
TPI		- 0.00		+ 76.4	+ 4.3	+ 34.8	+ 84.1					
	621562.90	- 0.00		+ 76.7	+ 4.3	+ 32.7	+ 83.5					
TPI		+ 0.00		+ 76.4	+ 4.3	+ 34.8	+ 84.1				624153.74	339.4
	621562.90	- 0.00		+ 76.7	+ 4.6	+ 33.1	+ 83.7	+ 0.1	+ 0.3	+ 0.3		
MCC1				+ 0.8	+ 0.1	+ 0.2	+ 0.8				624153.93	244.2
	622473.47			+ 0.7	- 0.8	- 0.4	+ 1.1	- 0.1	+ 0.1	+ 0.2		
MCC2				+ 1.1	+ 1.0	- 0.8	+ 1.7				624115.98	185.1
	623377.39			+ 1.1	+ 1.0	- 2.0	+ 2.5	- 0.5	+ 0.2	- 0.0		

ENU
LGC

TABLE II

BURN PERFORMANCE

TEST	EVENT	BURN UNCERTAINTY(FPS) RANGE	TRACK	ALT	MAG	DELTA V MAG (FPS)	MISS (METERS)
	CSI	+ 0.0	+ 0.0	+ 0.0	+ 0.1	0.0	
	CDH	+ 0.0	+ 0.0	+ 0.0	+ 0.1	0.0	
	TPI	+ 0.3	+ 0.3	- 1.7	+ 1.8	83.7	339
	MCC1	- 0.2	- 1.0	- 0.7	+ 1.2	1.1	244
	MCC2	- 0.0	- 0.0	- 1.2	+ 1.3	2.5	185

TPI SLIPPAGE - 0.00 SECONDS

6.2.0 ABORTS FROM DESCENT

The following applies to all tests in this section unless indicated differently in test description.

a) The LM is yawed left 20 degrees at PDI-3 mins.
The 20 degrees yaw is removed at PDI +3 mins. This maneuver is done in the AUTO mode.

b) The AUTO throttle and ABORT back up discretes are set.

c) The abort switch is failed ON.

d) The SLOSH environment model is not simulated.

e) The environmental FAST IMU is used.

f) Abort sequence:
Switch to ATTHOLD
Full Throttle
ABORT or ABORT STAGE
V22N46 ENTER ENTER
Switch to AUTO

g) Terrain slope error of -1 degree.

TEST 6.2.1 ABORT AT 33 K. FT.

I. Test Objective

Demonstrate DPS Abort from descent.

II. Test Description

Manual yaw ± 5 degrees in P70 in AUTO mode.

Program Sequence

P00
V48 DAP Data Load
V64 S-Band Antenna Routine (R05)
P63 Braking Phase Program
V57 LR Update (R12)
ABORT sequence at 33 K ft. altitude.
P70 DPS Abort Program
N76 Monitor Desired HVEL, RVEL, Crossrange
N77 Monitor TTOGO, VGY, ABVEL
N85 Monitor VG
P00 LGC Idle Program
V64 S-Band Antenna Routine (R05)
V82 Orbital Parameter Display Routine (R30)
V83 Rendezvous Parameter Display Routine (R31)
P20 Rendezvous Navigation Program
P32 Coelliptic Sequence Initiation Program

TEST 6.2.1 DATA SUMMARY

	Environment	LGC	Target
Apolune (n. mi.)	105.4	114.7	114.3
Perilune (n. mi.)	7.9	9.8	9.15
Out of Plane distance (ft)	1380	1.0	0
Altitude (ft)	45387	60056	60000
Altitude rate (fps)	-3.3	19.5	19.5
Downrange Velocity (fps)	5620.5	5623.2	5623.1
Yaw Angle (deg)	-10.94	-10.76	
Pitch Angle (deg)	-0.68	+0.08	
VGX Body (fps)		-0.06	
VGY Body (fps)		-0.04	
VGZ Body (fps)		+0.09	
Theta (phase angle) (at cutoff)		-2.6°	

Discussion of Results:

All of the test data are within expected tolerances. The large discrepancy between the environment and AGC in altitude (almost 15,000 feet) and apolune (9.3 n. mi.) results from the large state vector errors. Since the abort is early in the descent trajectory (27,000 ft. true altitude), Landing Radar updating has not yet begun to reduce the state vector errors. Hence at the time the abort button was pushed, the error in altitude was about 5,000 ft., and in altitude rate, about 23 fps. These large initial errors plus the 1σ IMU errors result in the errors at cutoff as tabulated above. The LGC, of course, achieves the targeted insertion conditions nearly exactly. There was one downrupt lost in this test.

TEST 6.2.2 ABORT AT 7 K. FT.

I. Test Objectives

Demonstrate DPS and APS Abort from descent.

II. Test Description

The abort switch is failed OPEN requiring the astronaut to select P70 via DSKY. A manual yaw ± 5 degrees in P71 in ATTHOLD mode.

Program Sequence

P00	
V48	DAP data load
V64	S-Band Antenna Routine (R05)
P63	Braking Phase
V57	LR Update (R12)
P64	Approach Phase
	ATTHOLD at 7 K ft.
	Full throttle
	V22N46 EE
P70	DPS Abort select by Astronaut
	AUTO mode

ABORT STAGE at DPS depletion

P71	APS Abort
N76	Monitor Desired Horizontal, Radial Vel, Crossrange
N77	Monitor TTOGO, VGY, ABVEL
N85	Monitor VG
P00	
V64	S-Band Antenna Routine (R05)
V82	Orbital Parameter Display (R30)
V83	Rendezvous Parameter Display (R31)
P20	Rendezvous Navigation
P32	Coelliptic Sequence Initiation

TEST 6.2.2 DATA SUMMARY

	Environment	LGC	Target
Apolune (n.mi.)	51.5	56.1	56.5
Perilune (n.mi.)	10.6	10.7	9.15
Out of plane distance (ft)	-608	4.1	0
Altitude (ft)	65446	66647	60000
Altitude rate (fps)	24.4	20.9	19.5
Downrange velocity (fps)	5534.6	5541.3	5541.3
Yaw angle (deg)	-0.14	-1.92	
Pitch angle (deg)	-5.23	-6.77	
VGX Body (fps)		0.1	
VGY Body (fps)		-.8	
VGZ Body (fps)		1.4	
Theta (phase angle) (at cutoff)		13.96	

Discussion of Results:

The test data fall within expected tolerances and indicate that the program functioned properly during the abort. The discrepancy between AGC and environment Apolune (almost 4.5 n.mi.) is caused by a combination of factors. The insertion at a higher altitude than targeted, the slightly lower forward velocity, and the higher radial rate each contribute to the error in Apolune.

There were 10 downrupts lost during this run. The basic reason for losing downrupts is a synchronization of the R10 and DAP interrupts. An analysis of the factors which lead to lost downrupts during powered descent and abort mission phases is presented in LUMINARY Development Note #87, dated 14 June 1971.

TEST 6.2.3 ABORT AFTER TOUCHDOWN - TEST I

I. Test Objective

Demonstrate APS (T1) Abort

II. Test Description

The Auto Throttle is failed off.

Program Sequence

P00	
V48	DAP Data Load
V64	S-Band Antenna Routine (R05)
P63	Braking Phase
V57	LR Update Enable
P64	Approach Phase
P66	Vertical Phase

ABORT Sequence at Lunar Surface Touchdown

P71	APS Abort
P00	
V64	S-Band Antenna Routine (R05)
V82	Orbital Parameter Display (R30)
V83	Rendezvous Parameter Display (R31)
P20	Rendezvous Navigation
P32	Coelliptic Sequence Initiation

TEST 6.2.3 DATA SUMMARY

Data	Environment	LGC	Target
Apolune (n.mi.)	54.5	58.8	57.5
Perilune (n.mi.)	9.7	9.7	9.15
Out of Plane Distance (ft)	-1200	-3.9	0
Altitude (ft)	59337	60335	60000
Altitude rate (fps)	24.7	19.9	19.5
Downrange velocity (fps)	5543.0	5549.6	5549.3
Yaw angle (deg)	1.97	1.29	
Pitch angle (deg)	-4.56	-5.63	
VGX Body (fps)		-0.2	
VGY Body (fps)		+0.7	
VGZ Body (fps)		+0.5	
Theta (phase angle) (at cutoff)		23.5°	

Discussion of Results:

The test data all indicate that the system functioned properly. The error in Apolune (4.3 n.mi.) is caused by the errors in altitude, radial rate, and downrange velocity, which in turn are caused by the 1σ IMU errors. Nine downrupts were lost in this test. The computer time required for this digital simulation was 66 mins.

TEST 6.2.4 ABORT AFTER TOUCHDOWN - TEST II

I. Test Objective

Demonstrate APS (T1) Abort

II. Test Description

The SLOSH and detailed IMU models of the environment simulators are used in this test. The ABORT and AUTO throttle backup discretes are not set.

Program Sequence

Same as TEST 6.2.3

TEST 6.2.4 DATA SUMMARY

Data	Environment	LGC	Target
Apolune (n.mi.)	54.3.	58.6	57.5
Perilune (n.mi.)	9.7	9.7	9.15
Out of Plane Distance (ft)	-1080	3.7	0
Altitude (ft)	59424	60346	60000
Altitude rate (fps)	24.7	19.5	19.5
Downrange Velocity (fps)	5542.7	5549.3	5549.3
Yaw Angle (deg)	0.53	0.48	
Pitch Angle (deg)	-4.05	-5.46	
VGX Body (fps)		0.06	
VGY Body (fps)		0.04	
VGZ Body (fps)		0.07	
Theta (phase angle) (at cutoff)		23.5^{o}	

Discussion of Results:

This test is exactly the same as test 6.2.3, with the exception that the SLOSH environment model is included. All test data points agree very closely with 6.2.3. There were 19 lost downrupts in this test. The computer time required for this digital simulation was 144 mins.

6.3.0 LUNAR SURFACE OPERATION AND ALIGNMENTS

TEST 6.3.1 LUNAR SURFACE OPERATIONS

I. Test Objective

Demonstrate LM IMU Lunar Surface alignments and operations.

II. Test Description

The LM is tilted approximately 10^{o} on the Lunar Surface.

Program Sequence

P68	Lunar Surface Confirmation Program
P00	
P12	Ascent Program
P57	AT-3 Lunar Surface Alignment to REFSMMAT
	Recycle Gravity Determination
V47	AGS Initialization
V41N20	Park IMU
	Coarse align IMU to parking gimbal angles
P06	LGC Power Down Program
	LGC Power Up
P57	AT-3 Lunar Surface Alignment to Landing Site
	4 Star sightings
V63	RR Self test
P22	Lunar Surface Navigation (No Update Mode)
P57	AT-3 Lunar Surface Alignment to Landing Site
V47	AGS Initialization
V48	DAP Data Load
V82	Orbital Parameter Display
P12	Ascent Program to TIG
P00	

TEST 6.3.1 DATA SUMMARY

P68

NOUN 43

Lat. = -9.00, Long. = 15.51

(This agrees within .00 degs. of actual landing site)

P57 AT-3 to REFSMMAT

NOUN 04 = .01

Recycle

NOUN 04 = .00

Sighting: starcode 233, sighting err. = .01

NOUN 05 = .00

NOUN 93 = -.030, .001, -.004

True misalignment after torquing

OIM = -.014, -.002, -.001

P57 AT-3 to Landing Site

NOUN 04 = .00

1st sighting: starcode 233, sighting err. = .00

NOUN 05 = .00

NOUN 93 = .011, .005, .001

Recycle

2nd sighting: starcode 340, sighting err. = .00

NOUN 05 = .00

NOUN 93 = .012, .005, .001

Recycle

3rd sighting: starcode 233, sighting err. = .00

NOUN 05 = .01

NOUN 93 = .003, .005, .013

Recycle

4th sighting: starcode 604, sighting err. = .00
NOUN 05 = .00
NOUN 93 = .012, .002, .013
True misalignment after torquing
OIM = .000, .003, .005

P57 AT-3 to Landing Site

NOUN 04 = .00
Sighting: starcode 604, sighting err. = .00
NOUN 05 = -.01
NOUN 93 = -.016, -.019, .006
True misalignment after torquing
OIM = -.008, .000, .000

Verb 82 (Orbital Parameter Display)

LGC NOUN 44	68.2,	51.8	(n.m.)
ENV	68.15,	51.74	(n.m.)

TEST 6.3.2 INFLIGHT ALIGNMENT

I. Test Objective

Demonstrate nominal LM IMU docked and inflight alignments.

II. Test Description

The docked coarse alignment technique and a P52 using the cursor/spiral sighting mark procedure is simulated.

Program Sequence

P00	
V48	DAP Data Load
V06N20	Gimbal Angles for Coarse Alignment
V41N20	Coarse Align IMU
V40N20	Set IMU Inertial
P51	Set drift flag
V06N20	Record Gimbal Angles
P52	IMU alignment to REFSMMAT
	Select cursor/spiral sighting technique
	(star-planet)
V06N20	Record Gimbal Angles
V48	DAP Data Load
	(Undocked Configuration)
V41N72	Coarse Align RR
P52	Alignment to REFSMMAT
	LPD calibration
	COAS calibration
P00	

TEST 6.3.2

V41N20 Docked Coarse Align

True misalignment after coarse alignment

OIM = .646, -.583, .159

P52 to REFSMMAT using Cursor/Spiral Sighting Technique

1st sighting: starcode 100 (Planet), sighting err. = .01

2nd sighting: starcode 344 sighting err. = .00

NOUN 05 = -.01

NOUN 93 = -.646, .570, -.152

True misalignment after torquing

OIM = -.001, -.011, .014

P52 to REFSMMAT

1st sighting: starcode 204, sighting err. = .00

2nd sighting: starcode 244, sighting err. = .01

NOUN 05 = -.01

NOUN 93 = .000, .004, -.008

True misalignment after torquing

OIM = -.005, -.011, .009

6.4.0 LUNAR LANDING

The following applies to all tests in this section unless indicated differently in test description.

a) The LM is yawed left 20 degrees at PDI -3 mins.
The 20 degree yaw is removed at PDI +3 mins. This maneuver is done in the AUTO mode.

b) The AUTO throttle and ABORT back up discretes are set.

c) The abort switch is failed ON and the auto throttle failed OFF.

d) The SLOSH mode is not simulated.

e) The environmental FAST IMU is simulated.

f) Terrain slope error -1 degree

TEST 6.4.1 LUNAR LANDING - AUTO (ERROR FREE)

I. Test Objective

Demonstrate LM automatic landing.

II. Test Description

This test contains no initialization errors.

Program Sequence

P00	
V48	DAP data Load
V64	S-Band Antenna Routine (R05)
P63	Braking Phase
V57	LR Update Enable
N68	Monitor Range, TGO, Velocity
N92	Monitor THROTTLE CMD, HDOT, H
P64	Approach Phase
P66	Vertical Phase
P68	Lunar Surface Confirmation
P00	

Test data for this simulation is summarized on pages 31 and 32.

TEST 6.4.1. LUNAR LANDING - AUTO

I. Test Objective

Demonstrate LM automatic landing.

II Test Description

This is the same as TEST 6.4.1 (ERROR FREE) except that it contains a -1 degree terrain slope error.

Test data for this simulation is summarized on pages 31 and 32.

TEST 6.4.2 LUNAR LANDING - AUTO

I. Test Objection

Demonstrate LM automatic landing.

II. Test Description

This test exercises landing site redesignation option at PDI -10 mins. to correct propagated state vectors errors; at PDI +5 mins. to correct IMU errors and at PDI +8 mins. to correct altitude errors. Y and Z PIPA Bias errors = 1.6 cm/sec^2.

Test Sequence

P00	
N69	Landing Site Redesignation at PDI -10 mins.
	Downtrack = -9000 ft
	Crosstrack = +1000 ft
V48	DAP Data Load
V64	S-Band Antenna Routine (R05)
P63	Braking Phase
V57	LR Update Enable
N69	Landing Site Redesignation at PDI +5 mins.
	Downtrack = -10000 ft
	Crosstrack = -10000 ft
N69	Landing Site Redesignation at PDI +8 mins.
	Altitude = +3280 ft
P64	Approach Phase
P66	Vertical Phase
P68	Lunar Surface Confirmation
P00	

Test data for this simulation is summarized on pages 31 and 32.

IN P66 @ ALT of 167 ft, ALT RAT
-4.6 fps performed 3 descent-cli
ROD

TEST 6.4.3 LUNAR LANDING - NOMINAL

I. Test Objective

Demonstrate LM nominal landing to offset landing site.

II. Test Description

This test exercises the landing site redesignation option N69 at PDI +2 and LPD during P64. The N69 redesignation offsets the actual landing site.

Program Sequence

P00	
V48	DAP Data Load
P63	Braking Phase
N69	Landing Site Redesignation at PDI +2 mins.
	Downtrack 20 K ft.
	Crosstrack 20 K ft.
P64	Approach Phase
	LPD ACA: 2 (-EL), 2 (+AZ)
P66	Vertical Phase
	Entered manually at 700 ft.
P68	Lunar Surface Confirmation
P00	

Test data for this simulation is summarized on pages 31 and 32.

TEST 6.4.4 LUNAR LANDING - NOMINAL

I. Test Objective

Demonstrate LM nominal landing to corrected landing site.

II. Test Description

This test exercises the landing site redesignation option N69 at PDI +2 and LPD during P64. The N69 redesignation corrects an initial landing site error.

Program Sequence

P00	
V48	DAP Data Load
P63	Braking Phase
N69	Landing Site Redesignation at PDI +2 mins.
	Downtrack 20 K ft.
	Crosstrack 20 K ft.
P64	Approach Phase
	LPD ACA: 2(-EL), 2(+AZ)
P66	Vertical Phase
	Entered manually at 700 ft.
P68	Lunar Surface Confirmation
P00	

Test data for this simulation is summarized on pages 31 and 32.

	6.4.1 Error-free	6.4.1 1° slope error	6.4.2 Corrective N69's	6.4.3 N69 and ACA Redesignations	6.4.4 N69 with offset RLS
Mansrot Number	04409130	04408583	05605220	04416091	05905473
Ignition	354880.9	354880.9	354883.0	354881.9	354886.9
Attitude P	-175	-175	-172	-172	-173
Y	-21	-21	-21	-21	-30
R	1	1	1	1	3
V57 Time	355156	355218	355149	355155	355200
Alt	40155	35289	47289	45688	39820
ΔH	-1745	+5170	-12891	-9003	-7133
Throttledown	355324	355324	355339	355319	355376
	AGC/ENV	AGC/ENV	AGC/ENV	AGC/ENV	AGC/ENV
Alt	24494/24009	25192/24498	14445/14092	18895/18236	9859/9400
Alt-rate	-91.8/-91.3	-104.1/-103.1	-13.8/-28.9	-12.6/-36.4	-63.1/-65.2
Forvel	1160.0/1152.3	1153.8/1148.7	991.2/993.6	1286.7/1274.5	570.9/564.1
Range (nautical miles)	-16.9	-17.0	-13.0	-21.1	-5.3
Maxthrust after TDWN	5988	6012	6620	5817	None
Time	355431	355431	355366	355348	
Alt	9423	8804	13102	16479	
Highgate	355442	355444	355435	355461	355414
Alt	7858/7498	7070/6688	6632/6324	5913/5494	6112/5837
Alt-rate	-173.1/-174.5	-155.0/-156.7	-130.6/-132.6	-114.4/-117.1	-111.2/-114.
Forvel	294.1/290.0	284.3/280.5	295.9/293.5	278.4/274.6	288.1/284.0
Range	-2.6	-2.5	-2.6	-2.5	-2.5
Lowgate	355566	355568	355557	355531	355494
Alt	194/207	188/200	190/206	617/582	633/639
Alt-rate	-5.5/-5.7	-4.3/-4.6	-4.1/-4.3	-20.6/-20.6	-18.1/-18.0
Forvel	5.3/4.9	5.0/4.6	5.6/6.4	81.1/79.4	92.0/90.4

(Unless otherwise stated, all figures are in feet and feet/sec.)

	6.4.1 Error-free	6.4.1 1^{o} slope error	6.4.2 Corrective N69's	6.4.3 N69 and ACA Redesignations	6.4.4 N69 with offset RLS
Touchdown	355599	355608	355586	355601	355592
Alt-rate	-5.7/-5.9	-4.5/-4.6	-7.2/-7.6	-4.5/-5.0	-3.8/-5.4
Forvel	.1/.4	.1/.3	.4/2.0	.0/-.5	.1/-.5
Navigation Errors					
SM coords R_x	2.63	-.91	56.22	-286.24	+222.57
(meters) R_y	-43.3	-64.45	-3083.75	-881.58	-803.45
R_z	-.60	-23.26	-5250.1	-3034.36	-3137.29
V_x	.05	.06	.10	.13	.18
V_y	-.05	-.13	-.61	.15	.14
V_z	-.10	-.09	-.61	.16	.20
Fuel: (lbs.)					
RCS	50	47	49	66	87
DPS	18050	18138	17960	17965	18110
Landing Site errors:					
Cross-range	-151	-90	-1347	21182	104
Down-range	558	649	-3506	27479	9533
Altitude	-6	0	-59	1060	190
Downrupts lost:	3	3	7	8	6

TEST 6.4.5 LUNAR LANDING - N69 RED LINE - TEST I

I. Test Objective

Demonstrate LM landing wi th large Z-PIPA Bias error.

II. Test Description

This test uses the landing site redesignation option at PDI +6mins. to compensate for 7.0 cm/sec^2 Z-PIPA Bias error.

Test Sequence

P00	
V48	DAP Data Load
V64	S-Band Antenna Routine (R05)
P63	Braking Phase
V57	LR Update Enable
N69	Landing Site Redesignation at PDI +6 mins.
	Downtrack = +45000 ft
P64	Approach Phase
P66	Verticla Phase
P68	Lunar Surface Confirmation
P00	

6.4.5 Large IMU in Z axis: +7 cm/sec^2

Marsrot No. 06102522

Ignition		354880.9	1000' Time		355527
Attitude:	Pitch	-175	Altitude		1104/1037
(Deg)	Yaw	-19	Alt-rate		-36.4/-34.2
	Roll	1	Forvel		106.6/-37.6
			Latvel		/-13.8
V57 Time		355156	Range		-.4
DSKY	Altitude	39233	LAT/LONG		-9.01/15.59
	Deltah	-903			
Throttledown		355326	500' Time		355551
		AGC/ENV			
Altitude		23,664/23,295	Altitude		510/501
Alt-rate		-62.5/-64.1	Alt-rate		-15.8/-14.4
Forvel		1248.9/1137.4	Forvel		+53.3/-95.0
Range (nautical miles)		-19.8	Latvel		/-14.0
			Range		-.1
Max. thrust after Throttledown		5877	LAT/LONG		-9.01/15.61
Time		355429	(Targeted LAT/LONG is -9.00/15.52)		
Altitude		12036			
Highgate		355460			
Altitude		7457/7120			
Alt-rate		-164.1/-165.9			
Forvel		287.6/151.8			
Latvel		/-10.9			
Range		-2.5	Downrupts lost: 3		

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TEST 6.4.5 LUNAR LANDING - N69 RED LINE - TEST II

I. Test Objective

Demonstrate LM landing with large Y-PIPA Bias error.

II. Test Description

This test uses the landing site redesignation option at PDI +5 mins to compensate for 7.3 cm/sec^2 Y-PIPA Bias error.

Y/W SLOSH

Test Sequence

P00	
V48	DAP Data Load
V64	S-Band Antenna Routine
P63	Braking Phase
V57	LR Update Enable
N69	Landing Site Redesignation at PDI +5 mins
	Crosstrack = -52000 ft
P64	Approach Phase
P66	Vertical Phase
P68	Lunar Surface Confirmation
P00	

6.4.5 Large IMU error in Y axis: -7.3 cm/sec^2

Marsrot No. 04616222

Ignition		354880.9	1000' Time		355499
Attitude:	Pitch	-174	Altitude		1279/1052
(Deg)	Yaw	-20	Alt-rate		-45.2/-48.4
	Roll	0	Forvel		134.0/125.3
			Latvel		/138.6
V57 Time		355156	Range		-.7
DSKY	Altitude	40,152	LAT/LONG		-9.02/15.53
	Deltah	-1760			
Throttledown		355334	500' Time		355513
		AGC/ENV			
Altitude		22,775/22,120	Altitude		624/506
Alt-rate		-94.4/-94.5	Alt-rate		-24.2/-28.5
Forvel		1065.2/1052.0	Forvel		106.6/93.5
Range (nautical miles)		-15.1	Latvel		/141.5
Max. thrust after Throttledown		5924	Range		-.4
			LAT/LONG		-9.01/15.51
Time		355451			
Altitude		6096	(Targeted LAT/LONG is -9.00/15.52)		
Highgate		355446			
Altitude		7183/6764			
Alt-rate		-164.0/-174.5			
Forvel		267.9/265.4			
Latvel		103.6			
Range		-2.4	Downrupts lost: 0		

6.5.0 ERASABLE MEMORY PROGRAMS

Only those EMPs specified in the flight plan for a nominal mission will be reported on.

EMP 99 LM DEORBIT TEST 6.5.1

TEST 6.5.1 LM DEORBIT

I Test Objective

Demonstrate LM deorbit using Erasable Memory Program 99.

II Test Description

Test Sequence

P00

Load EMP 99

V48 DAP Data Load

V47 AGS Initialization

P30 External Delta-V

Verify Noun 26

V62 Display Total Attitude Errors

V30 Activate EMP 99

Test 6.5.1 Data Summary

	MIT/CSDL	NASA/MSC
TIG (hr:min:sec)	179:16:29.20	179:16:29.20
ΔV X	-134.5	-134.5
(fps) Y	-80.0	-80.0
Z	168.0	168.0
Magnitude	229.6	229.6
Ha (from P30)	67.7	---
Hp (n.mi.)	-40.8	---
Burn Time (min:sec)	1:39.16	1:36
Impact time (hr:min:sec)	179:39:27	179:39:28.6
	-9.49	15.01 MSC IMPACT TIME
Impact point		
Latitude	-9.48	-9.49
Longitude	15.10	14.98
	-9.51	14.83 SITE RADIUS
Ha (after burn)	68.0	68.2
Hp	-40.4	-40.6

Discussion of results:

The test results agree closely with the NASA/MSC results for the deorbit burn. The differences that do exist are attributable to differences in simulation models and computational accuracy.

6.6.0 SPECIAL TESTS

The only test processed in this category was for RTCC and involved V71 and V72 uplink. The results of this digital test were forwarded to MSC 2/29/72.