Massachusetts Institute of Technology
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LUMINARY Memo #222

To: Distribution

From: Luminary Test Group

Date: 15 June 1971

Subject: Summary of Level 6 Test Results for LUMINARY 1E

Reference: LUMINARY Memo #214 Rev. 1 "Level 6 Test Description for Luminary 1E" dated 6 April 1971

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

6.1.0 RENDEZVOUS
6.2.0 ABORTS FROM DESCENT
6.3.0 LUNAR SURFACE OPERATIONS, ALIGNMENTS, ASCENT
6.4.0 LANDING ON LUNAR SURFACE
6.5.0 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 15 Data File.
(3) Apollo 15 Operation Trajectory.
(4) Apollo 15 Erasable Load.
(5) 71/72 Ephemeris.
(6) 0 TLOSS.
(7) LM-10 Vehicle.

Typical values of 1σ initialization error are given on page 2.

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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	-116	-116

STATE VECTOR ERRORS AT PDI IGNITION

	ALTITUDE	CROSS-RANGE	DOWN-TRACK
POSITION (ft.)	-1410	1080	-4220
VELOCITY (fps.)	4.3	1.28	-1.38

RENDEZVOUS RADAR ERRORS

	BIAS	RANDOM
RANGE (ft.)	800 if $R > 50.8$ N.M. 80 if $R \leq 50.8$ N.M.	.3% R
RANGE-RATE (fps)	.3	.4% $\dot{R}$ (MINIMUM .0044 fps)
SHAFT/TRUNNION (Mr.)	15.0	1.0

LANDING RADAR ERRORS

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

TEST 6.1.1 RENDEZVOUS

I. Test Objective

This test is made to verify the nominal LM Active Short Rendezvous Program Sequence.

II. Test Description

Timeline

See Figure 1

Program Sequence

P00	LGC Idling
P20	Rendezvous Navigation
P34	Transfer Phase Initiation (TPI)
P42	APS
P35	Transfer Phase Midcourse (TPM)
P41	RCS
P35	Transfer Phase Midcourse (TPM)
P41	RCS
P00	LGC Idling
P47	Thrust Monitor
P00	LGC Idling

Extended Verbs

V47	Initialize AGS (R47)
V48	Start DAP Data Load (R03)
V63	Start RR/LR Self Test Routine (R04)
V64	S-Band Antenna Routine (R05)
V67	W Matrix RMS Error Display
V80	Enable LM State Vector Update
V82	Request Orbit Param Display (R30)
V83	Request Rendezvous Param Display (R31)
V93	Enable W Matrix Initialization
V95	No Update of Either State Vector

III. Test Initialization

1. 10% TLOSS during powered flights.

IV. Discussion of Results

The Navigation data from P20 is shown in Table I. The state errors before each targetting computation are as follows:

	Position (m)	Velocity (m/s)
TPI	334	0.215
MCC1	179	0.256
MCC2	88	0.185

These values are considered nominal.

The targetting data is shown in Tables II and III and is considered nominal.

This test had no downrupts lost and had seven N49s (listed in Table IV).

V. Conclusions and Special Comments

This test verified the nominal LM Active short rendezvous sequence with the closest point of approach computed as 82 meters and less than two FPS of burn uncertainty for each burn.

6.1.1 SHORT RENDEZVOUS

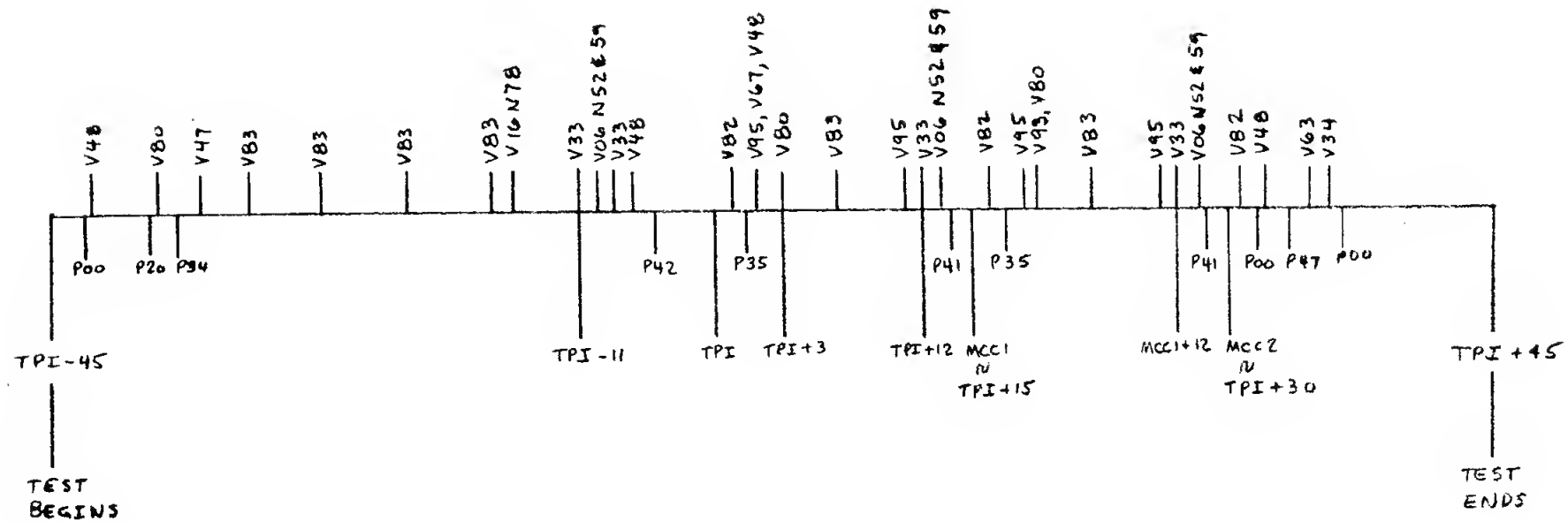

Figure 1

SUMMARY OF FIRST-LAST MARK DATA

TIME(SEC.)	MARKS	POSITION(METERS) X	Y	Z	MAG	VELOCITY(M/SEC) XDOT	YDOT	ZDOT	MAG
619000.239	0	225	- 2243	- 699	2361	-0.398	-3.421	0.140	3.447
620281.449	19	224	- 159	- 190	334	-0.037	-0.177	-0.116	0.215
621231.579	0	303	- 205	- 303	475	0.015	-0.303	-0.057	0.309
621606.469	6	126	21	- 126	179	0.162	0.094	0.173	0.256
621965.189	0	209	122	- 53	248	0.316	0.285	0.138	0.448
622488.369	8	75	47	0	88	0.175	0.005	0.059	0.185
0.000	0	0	0	0	0	0.000	0.000	0.000	0.000

TABLE I

NOMINAL TPI 620979.90

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	RANGE M
TPI		- 0.00		+ 70.7	- 0.2	+ 21.4	+ 73.9				623498.19	219.2
	620979.90	- 0.00		+ 70.6	+ 0.4	+ 21.9	+ 73.9	+ 0.1	- 0.1	+ 0.3		
MCC1				- 0.5	- 0.6	+ 0.1	+ 0.8				623421.13	579.3
	621887.01			- 0.5	+ 0.2	- 1.1	+ 1.2	- 0.0	- 0.0	+ 0.1		
MCC2				+ 2.5	- 1.1	+ 5.4	+ 6.1				623497.00	82.3
	622790.93			+ 2.4	- 0.7	+ 4.1	+ 4.8	+ 0.1	+ 0.2	+ 0.2		

TABLE II

BURN PERFORMANCE

TEST	EVENT	BURN UNCERTAINTY (FPS)				DELTA V MAG (FPS)	MISS (METERS)
		RANGE	TRACK	ALT	MAG		
	CSI	+ 0.0	+ 0.0	+ 0.0	+ 0.1	0.0	
	CDH	+ 0.0	+ 0.0	+ 0.0	+ 0.1	0.0	
	TPI	- 0.1	+ 0.7	+ 0.5	+ 0.9	73.9	219
	MCC1	+ 0.1	+ 1.0	- 1.4	+ 1.7	1.2	579
	MCC2	- 0.1	+ 0.4	- 1.4	+ 1.5	4.8	82

TPI SLIPPAGE - 0.00 SECONDS

TABLE III

SUMMARY OF EXCESSIVE STATE VECTOR UPDATE DATA

MARKTIME SECS.	RMAG FEET	VMAG FT/SEC
619000.2399	2047.34	2.497259
619000.2399	5689.25	4.590250
619000.2399	3504.10	0.000000
619085.8599	0.00	3.420002
619085.8599	1410.82	3.409990
619236.2499	3280.99	4.405952
619932.3299	1391.14	2.991016
0.0000	0.00	0.000000

TABLE IV

TEST 6.2.1 ABORT AT 33 K. FT.

I. Test Objective

Verify proper operation and ascertain performance of the DPS Abort Program P70 in Luminary revision 210.

II. Test Description

This test is run with ABORT discrete present

Program Sequence

P00	Idle Program
V48	DAP Data Load.
	Set Abort Backup
V64	S-Band Antenna Routine (R05)
P63	Braking Phase Program
V57	State Vector Update Routine; LR Update (R12)

Manual Throttle to 99% and ABORT at 33K ft.

ATTITUDE HOLD

P70	DPS Abort Program
	Switch to AUTO

P00	LGC Idling Program
V64	S-Band Antenna Routine (R05)
V82	Orbital Parameters Display Routine (R30)
V83	Rendezvous Parameter Display Routine (R31)
P20	Rendezvous Navigation Program
P32	Coelliptic Sequence Initiation Program

While in P70 the following exercises will be performed:

I. Manual yaw maneuver to observe vehicle attitude control response to ACA when mode control is AUTO.

II. Monitor N76, N77, N85 via V16.

III. Test Initialization

1. Environment initialization
   - A. Terrain profile with $+1^{\circ}$ errors.
   - B. 10% TLOSS
2. CHANBKUP abort discrete set in P00.

IV. Test Results

Examination of the on-line printout, guidance edits, and DAP performance edit and plots revealed that the LGC Abort Program behaved in a nominal fashion. The correct targets were selected and the TGO and the desired downrange velocities were computed correctly. The insertion parameters were as targetted, with small ΔV residuals in N85.

Throughout the simulation, Ascent nouns 76, 77, and 85 were monitored, and it was seen that the correct data was available through these nouns.

During this test, there were 1 lost downrupts. The analysis and report of these lost downrupts is included in LUMINARY Development Note #87 dated 14 June 1971.

V. Conclusion

The objective has been achieved.

Figures of Merit - 6.2.1

Data (insertion)	Environment Value	LGC Value	Target Value
Apolune (n.mi.)	137.04	132.4	132.5
Perilune (n.mi.)	10.27	9.8	
Out of Plane distance	.15 n.mi.	-1.2ft	0
Altitude (ft.)	59614	60051	60000
Altitude rate (fps)	25.6	19.88	19.5
Down range Velocity (fps)	5654	5651	5651
Yaw angle (deg)	+.19	.53	
Pitch angle (deg)	-11.24	-10.52	
VGX Body (fps)		+.118	
VGY Body (fps)		+.041	
VGZ Body (fps)		+.533	
Theta [phase angle]		-15.05	

Abort at 33 K Ft.

Displays of Interest

V/N	R1	R2	R3	Mode
04/46	21112	00001		00
06/47	+36703	+38643		
06/51	+16243	-04315		
06/61	-11x05	-3x44	-00002	63
50/18	+35993	+11006	+00023	
06/62	+55639	-01x00	+00000	
06/63	+99999	-00043	+49849	
06/63	-03670	-00768	+35750	
06/94	+30179	-00001	+30077	70
16/94	+00001	+00201	+60070	
16/85	+00004	-00008	+00009	
06/51	+17401	+01719		00
16/44	+01322	+00098		
16/54	+26517	+05350		

Timeline of Test 6.2.1
Abort at 33 K Ft.

Event	Time (G.E.T.)
Start Simulation	375834.8
P00	375849
V48 (R03) (CHANBKUP = 00001)	375870
V64 (R05)	375876
P63 initiation	375896
DPS engine ignition (PDI)	376137
Throttle up	376163
LR Data acceptance	376456
Abort Sequence initiation	376470
P70 Entry	376480
DPS engine cutoff	376727
P00	376749
V64 (R05)	376770
V82 (R30)	376783
V83 (R31)	376802
P20	376825
P32	376892
End Simulation	377818

TEST 6.2.2 ABORT AT 7K FT.

I. Test Objective

Verify operation and ascertain performance of the APS Abort Program (after DPS depletion in the DPS Abort Program) in Luminary revision 210.

II. Test Description

This test is run with the ABORT discrete present

Program Sequence

P00	Idle Program
V48	DAP Data Load
	Set Abort Backup
V64	S-Band Antenna Routine (R05)
P63	Braking Phase Program
V57	State Vector Update Routine; LR Update (R12)
P64	Approach Phase Program
P70	DPS Abort Program (at 7K ft)
Abort Stage	
P71	APS Abort Program (at DPS depletion)
P00	LGC Idling Program
V64	S-Band Antenna Routine (R05)
V82	Orbital Parameters Display Routine (R30)
V83	Rendezvous Parameters Display Routine (R31)
P20	Rendezvous Navigation Program
P32	Coelliptic Sequence Initiation Program

While in P70, the following exercise will be performed (until DPS depletion):

1. Monitor N76, N77, N85 via V16.

While in P71, the following exercises will be performed:

I. Manual yaw maneuver to observe vehicle attitude control response to ACA when mode control is ATTHOLD.

II. Monitor N76, N77, N85 via V16.

III. Test Initialization

1. Environment Initialization
   - A. LM-10 Vehicle
   - B. Terrain profile with $+1^{o}$ errors.
   - C. 10% TLOSS
2. CHANBKUP abort discrete set in P00.

IV. Test Results

Examination of the on-line printout, guidance edits, and DAP performance edit and plots revealed that the LGC Abort Program behaved in a nominal fashion. The correct targets were selected and the TGO and the desired downrange velocities were computed correctly. The insertion parameters were as targetted, with small ΔV residuals in N85.

Throughout the simulation, Ascent nouns 76, 77, and 85 were monitored, and it was seen that the correct data was available through these nouns.

During this test, there were 19 lost downrupts. The analysis and report of these lost downrupts is included in LUMINARY Development Note #87 dated 14 June 1971.

V. Conclusion

The objective has been achieved.

Figures of Merit - 6.2.2

Data (insertion)	Environment Value	LGC Value	Taget Value
Apolune (n.mi.)	102.5	100.2	101
Perilune (n.mi.)	10.54	10.4	
Out of Plane distance	-.03 n.mi.	-1.64 ft	0
Altitude (ft.)	58491	64031	60000
Altitude rate (fps)	27.0	20.1	19.5
Down range Velocity (fps)	5609	5607.8	5607
Yaw angle (deg)	+1.17	+.91	
Pitch angle (deg)	-3.13	-5.5	
VGX Body (fps)		-.07	
VGY Body (fps)		+.08	
VGZ Body (fps)		+.93	
Theta [phase angle]		+1.39	

Abort - Abort Stage at 7 K Ft.

Displays of Interest

V/N	R1	R2	R3	Mode
04/46	21112	00001		00
06/47	+36703	+38643		
06/61	-11x05	-03x54	-00002	63
50/18	+35993	+11006	+00023	
06/62	+55639	-01x00	+00000	
06/63	+99999	-00043	+49849	
06/63	-03874	-00618	+40517	
06/64	+99x40	-1752	+06978	64
06/94	+07732	+00247	+05385	70
97/94	+41154	+02391	+21635	
06/94	+42403	+02009	+24221	71
16/94	-00004	+00205	+63902	
16/85	+00004	-00012	+00019	
06/51	+17327	+01455		00
16/44	+01000	+00104		
16/54	+04587	-02031	+30524	

Timeline of Test 6.2.2

Abort - Abort stage at 7 K Ft.

Event	Time (G.E.T.)
Start simulation	375834.8
P00	375849
V48 (R03) (CHANBKUP = 00001)	375869
P63 initiation	375885
Start attitude maneuver (R60)	375907
End attitude maneuver	375993
Abort button depress	376135
DPS engine ignition (PDI)	376137
Throttle up	376163
LR Data acceptance	376386
Throttle down	376583
P64 initiation	376698
Abort procedure initiation	376702
P70 entry	376712
DPS Engine fuel exhaustion	376803
Abort stage button depress	376812
P71 entry	376822
APS engine cutoff	377160
P00	377256
V64 (R05)	377285
V82 (R30)	377297
V83 (R31)	377316
P20	377339
P32	377436
End simulation	377784

TEST 6.2.3 ABORT AFTER TOUCHDOWN

I. Test Objective

Verify operation and ascertain performance of the APS Abort Program (after a nominal Lunar Landing) in Luminary revision 210.

II. Test Description

This test is run with the ABORT present

Program Sequence

P00	Idle Program
V48	DAP Data Load Routine (R03)
	Set abort channel backup
P63	Braking Phase Program
V57	State Vector Update Routine; LR Update (R12)
P64	Approach Phase Program
P66	Vertical Phase Program (R. O. D. -Auto)

Abort Stage

P71	APS Abort Program (after Touchdown)
P00	LGC Idling Program
V64	S-Band Antenna Program (R05)
V82	Orbital Parameters Display Routine (R30)
V83	Rendezvous Parameters Display Routine (R31)
P20	Rendezvous Navigation Program
P32	Coelliptic Sequence Initiation Program

While in P71, the following exercises will be performed:

1. Manual yaw maneuver to observe vehicle attitude control response to ACA when mode control is ATTHOLD.
11. Monitor N76, N77, N85 via V16.

III. Test Initialization

1. Environment Initialization
    A. LM-10 Vehicle
    B. Terrain profile with $+1^{o}$ errors
    C. 10% TLOSS
2. CHANBKUP abort discrete set in P00

IV. Test Results

Examination of the on-line printout, guidance edits, and DAP performance edit and plots revealed that the LGC Abort Program behaved in a nominal fashion. The correct targets were selected and the TGO and the desired downrange velocities were computed correctly. The insertion parameters were as targetted, with small ΔV residuals in N85.

Throughout the simulation, Ascent nouns 76, 77, and 85 were monitored, and it was seen that the correct data was available through these nouns.

During this test, there were 12 lost downrupts. The analysis and report of these lost downrupts is included in LUMINARY Development Note #87 dated 14 June 1971.

V. Conclusion

The objective has been achieved.

Figures of Merit - 6.2.3

Data (insertion)	Environment Value	LGC Value	Target Value
Apolune (n. mi.)	71.9	69.5	70.5
Perilune (n. mi.)	9.79	9.7	
Out of Plane distance	-.04 n. mi.	9 ft	0
Altitude (ft)	55750	60318	60000
Altitude rate (fps)	27.1	19.5	19.5
Down range Velocity (fps)	5572	5569	5578
Yaw angle (deg)	-4.02	-1.15	
Pitch angle (deg)	-5.47	-6.53	
VGX Body (fps)		+.25	
VGY Body (fps)		+.13	
VGZ Body (fps)		+.22	
Theta [phase angle]		+10.15	

Abort Stage from Touchdown - A

Displays of Interest

V/N	R1	R2	R3	Mode
04/46	21112	00001		00
06/47	+36703	+38643		
06/61	-11x05	-04x08	-00002	63
50/18	+35993	+11006	+00023	
06/62	+55639	-01x00		
06/63	+99999	-00045	+49856	
06/63	-02008	-00635	+37563	
16/68	-00752	-05x45	+30852	
16/92	+00103	-00715	+28741	
06/63	+00072	-01819	+10246	
06/64	+99x79	-01830	+07737	64
06/60	+00047	-00066	+00195	66
06/60	-00004	-00002	+00002	
06/60	+00015	+00169	+00034	
06/94	+27035	+00568	+00298	71
16/94	+00001	+00203	+60376	
16/85	+00003	-00000	+00009	
16/44	+00692	+00097		00
16/54	+17248	-04472	+30654	

Timeline of Test 6.2.3
Abort Stage from Touchdown - A

Event	Time (G.E.T.)
Start simulation	375834.8
P00	375850
V48 (R03) (CHANBKUP=00001)	375867
P63 initiation	375875
Start attitude maneuver (R60)	375895
Finish attitude maneuver	375982
Abort button depress	376135
DPS engine ignition (PDI)	376137
Throttle up	376163
LR data acceptance	376389
Throttle recovery	376583
P64 initiation	376698
P66 initiation	376822
Touchdown; DPS engine cutoff	376854
Abort Stage button depress	376857
P71 entry	376870
APS engine cutoff	377294
V64 (R05)	377345
V82 (R30)	377358
V83 (R31)	377378
P20	377401
P32	377472
End simulation	378395

TEST 6.3.1 LUNAR SURFACE OPERATIONS

I. Test Objective

This test is made to demonstrate the LM IMU alignment capability for a nominal program sequence during the lunar surface stay.

II. Test Description

Program Sequence

P68	Lunar Surface Confirmation Program
P00	
P12	Ascent Program
P57	AT=1 Lunar Surface Alignment to REFSMMAT (Recycle Gravity Determination) (Reject Noun 93)
V41N72	Radar Designate
P57	AT-2 Lunar Surface Alignment to REFSMMAT (Star and Planet)
P57	AT-2 Lunar Surface Alignment to REFSMMAT (2 stars)
V47	AGS Initialization
P06	LGC Power Down Program
P00	
P57	AT-3 Lunar Surface Alignment to Landing Site (1 star, Spiral-Cursor marks)
V64	S-Band Antenna Routine
V63	Radar Selftest
P22	Lunar Surface Navigation (No Update Mode)
V48	DAP Data Load
P57	AT-3 Lunar Surface Alignment to Landing Site (1 star)
V47	AGS Initialization Routine
V48	DAP Data Load

V82	Orbital Parameter Display
P12	Ascent Program
	(Terminate at TIG -5)
P00	

Initialization

Landing Site Lat. = 26.073, Long. = 3.653

TEST DATA - ALIGNMENTS

P68

NOUN 43

Lat. = 26.07, Long. = 3.66

(This agrees within .01 degs. of actual landing site)

P57 AT-1 to REFSMMAT

NOUN 04 = .00

RECYCLE

NOUN 04 = .00

NOUN 05 = -.01

NOUN 93 = +.005, -.009, -.006

True misalignment after torquing

OG = .005, IG = .000, MG = .006

P57 AT-2 to REFSMMAT

1st sighting: detent 2, starcode 01, sighting err = .00

2nd sighting: detent 4, starcode 00, sighting err = .00

NOUN 05 = .00

NOUN 93 = -.008, .001, -.008

True misalignment after torquing

OG = .004, IG = .005, MG = -.004

NOUN 89 AGC computed Landing Site

Lat. = 26.078, Long. = 3.642

(This agrees within .01 degs. of actual landing site)

P57 AT-2 to REFSMMAT

1st sighting: detent 2, starcode 01, sighting err = .00

2nd sighting: detent 4, starcode 05, sighting err = .00

NOUN 05 = .00

NOUN 93 = -.003, -.006, .002

True misalignment after torquing

OG = .006, IG = .002, MG = -.005

NOUN 89 AGC Computed Landing Site

Lat. = 26.079, Long. = 3.652

(This agrees to within .01 degs. of actual landing site)

P57 AT-3 to Landing Site

NOUN 04 = .00

Sighting: detent 4, starcode 05, sighting err = .00

NOUN 05 = -.01

NOUN 93 = -.003, -.012, -.014

True misalignment after torquing

OG = -.000, IG = .001, MG = -.006

P57 AT-3 to Landing Site

NOUN 04 = .00

Sighting: detent 2, starcode 01, sighting err = .00

NOUN 05 = .00

NOUN 93 = +.005, +.000, +.017

True misalignment after torquing

OG = .011, IG = .000, MG = .004

TEST DATA - VERB 64 (S-Band Antenna Routine)

Pitch Angle = 71.578, err = .11 degrees

Yaw Angle = -63.09, err = -.19 degrees

VERB 82 (Orbital Parameter Display)

AGC NOUN 44	62.7	52.5 (nm)
ENV	62.64	52.48 (nm)

TEST 6.3.1.1 INFLIGHT ALIGNMENTS

I. Test Objective

This test is made to demonstrate the LM IMU alignment capability for a nominal program sequence using the P57 sighting mark procedure and normal inflight mark procedure.

II. Test Description

Program Sequence

P00	
V48	DAP Data Load
V41N72	RADAR Designate
P52	Alignment to REFSMMAT
	Select P57 Sighting Procedure
	(star-planet, Cursor-Spiral marks)
V48	DAP Data Load
P52	Alignment to REFSMMAT
	(2 stars, normal X-Y marks)
P52	Alignment to REFSMMAT
	(Sun-Planet, normal X-Y marks)
P00	

III. Test Initialization

1. IMU errors to reflect docked coarse aligned IMU.

TEST DATA - Inflight Alignments

P52 Alignment to REFSMMAT Using Cursor-Spiral Marking Technique

1st sighting: Detent 5, Starcode 00 (Planet), sighting err = .00

2nd sighting: Detent 1, Starcode 02, sighting err = .00

NOUN 05 = +.01

NOUN 93 = -.419, +.002, +.390

True misalignment after torquing

OG = .002, IG = -.007, MG = .011

P52 Alignment to REFSMMAT

1st Sighting: Detent 2, Starcode 40, sighting err = .00

2nd Sighting: Detent 2, Starcode 45, sighting err = .00

NOUN 05 = .00

NOUN 93 = -.001, +.013, -.008

True misalignment after torquing

OG = -.001, IG = .004, MG = .006

P52 Alignment to REFSMMAT

1st Sighting: Detent 2, Starcode 46 (Sun), sighting err = .01

2nd Sighting: Detent 2, Starcode 00 (Planet), sighting err = .00

NOUN 05 = .00

NOUN 93 = .001, .003, .001

True misalignment after torquing

OG = -.002, IG = .004, MG = .008

TEST 6.3.2 ASCENT FROM LUNAR SURFACE

I. Test Objective

This test is made to verify LM performance for a nominal program sequence for Ascent from the Lunar Surface.

II. Test Description

Program Sequence

P68	Lunar Surface Confirmation
P00	
V48	DAP Data Load
P12	Ascent
Target for 1 n.m. out-of-plane	
	Yaw LM 40^{o} after the nominal pitch over
V83	Request Rendezvous Parameter Display
V64	S-Band Antenna Routine
P00	
V48	DAP Data Load
V82	Request Orbital Parameter Display
V83	Request Rendezvous Parameter Display
P20	Rendezvous Navigation
	No state vector update
V83	Request Rendezvous Parameter Display
P34	TPI
P00	

III. Test Initialization

1. 10% TLOSS
2. 14.5 n.m. out of CSM plane

Ascent Insertion Data

	ENV	LGC	TARGETTED
H_A (nm)	52.24	54.2	
H_P (nm)	9.24	9.3	
Y (ft)	37.08	7191	7176
H (ft)	57739	60531	60000
HDOT (fps)	18.8	31.6	32.
Forvel (fps)	5542.3	5541.0	5541.0
Yaw (deg)	6.47	5.45	
Pitch (deg)	-2.74	-5.01	
V_{GX} (fps)		-.2	
V_{GY} (fps)		-1.0	
V_{GZ} (fps)		1.5	

IV. Discussion of Results

In P12 the orbit achieved had an apolune of 54.2 n.m. and a perilune of 9.3 n.m. Three seconds after cutoff, V94 display were as follows:

VGX (LM) = -.2 ft/sec.
altitude rate = 31.6 ft/sec.
computed altitude = 60531 ft.

The N85 display of residuals were 0, -.3 and 1.8 ft/sec. These are expected results.

In P34 the following values were computed:

	AGC	MAC	ENV	
Elevation angle	15.71	15.69	15.71	degrees
Perigee altitude (Post TPI)	47.8	48.2	48.2	n.m.
Delta V (TPI)	109.1	109.3	109.5	ft/sec.
Delta V (TPF)	48.7	48.8	48.6	ft/sec.
Delta VX (LV)	74.0	74.1	74.2	ft/sec.
Delta VY (LV)	-11.7	-11.8	-12.4	ft/sec.
Delta VZ (LV)	79.3	79.4	79.5	ft/sec.

V. Conclusions and Special Comments

This test verifies the nominal Ascent from Lunar Surface sequence.

TEST 6.4.1 LUNAR LANDING

I. Test Objective

This test is made to verify LM performance during an automatic landing program sequence.

II. Test Description

This test will exercise the landing site redesignation option prior to PDI to update targeted landing site. The abort discrete is failed throughout the landing. The LM is yawed left 50 degrees at PDI -3 min. The 50 degrees is removed at PDI +3 min.

Program Sequence

P00	
N69	Landing Site Redesignation at PDI -10 min.
	Down track -6865 ft.
	Cross track +417 ft.
	Altitude +380 ft.
V48	DAP Data Load
	Set ABORT Backup Discrete
P63	Braking Phase at PDI -5 min.
V57	LR Enable
N69	Landing Site Redesignation at PDI +5 min.
	Down track +653 ft.
	Cross track +662 ft.
N68	Monitor range, TGO, Velocity
N92	Monitor throttle CMD, HDOT, H
P64	Approach Phase
P66	Vertical Phase
P68	Lunar Surface confirmation
P00	

III. Test Initialization

1. Terrain profile ($+1^{o}$) error

6.4.1 Automatic Landing with N69 Corrections

Ignition	376134.4	Low gate	376821
Altitude: Yaw	-51	Altitude	AGC/ENV 189/208
Pitch	-178	Alt-rate	-5.7/-5.5
Roll	0	V-horiz	+4.7/ 5.5
V57: Time	376389	Touchdown	376856
Altitude	40,010	Altrate	-5.8
Deltah	-3531	V-horiz	+.2
Throttledown	376579	Navigation errors (SM coords.)	R_x 104 meters
TTF	-176		R_y -1940
Altitude	14201		R_z -986
Alt-rate	-85.5		V_x -0.4 m/sec
V-horiz	1149		V_y 0
Range	-168 n.m.		V_z -.14
Max thrust after throttledown	6527 lbs	Fuel: RCS	21.2 lbs
Time	376702	DPS	18208 lbs
Altitude	7469		
Highgate	376697	RLS-Actual site (MF coords.) X	72.7 meters
Altitude	AGC/ENV 8473/8239	Y	-350
Alt-rate	-198.5/-199.5	Z	-118
v-horiz.	283/283.4		
Range	-25		
500' : Time	376794	Ground-Track coords.	
Altitude	496	Crossrange	399'
Alt-rate	-17	Downrange	-1168'
v-horiz.	42.6		

TEST 6.4.2.1 LUNAR LANDING

I. Test Objective

This test is made to verify LM performance during a nominal landing program sequence.

II. Test Description

This test sequence exercises the landing site redesignation option in P63. The abort discrete is failed in P63, P64, P66.

LM is yawed left 50 degrees at TIG -3 min. The 50 degrees is removed at TIG +3 min.

Program Sequence

P00	
V48	DAP Data Load
	Set ABORT BACKUP
P63	Braking Phase
N69	Landing Site Redesignation at TIG +30 sec.
	Down range 10 K ft.
	Cross range 5 K ft.
P64	Approach Phase
P66	Vertical Phase
	Entered at 700 ft. - Attitude Hold and ± ROD switch
P00	

III. Test Initialization

1. Terrain profile ($+1^{o}$) error.

6.4.2.1 Landing with Redesignations (N69)

Ignition	376135.6	Lowgate	376788
Attitude: Yaw	-50	Altitude	AGC/ENV 614/602
Pitch	-176	Alt-rate	-23.2/-20.8
Roll	1	V-horiz.	+73.8/+73.7

V57: Time	376391	Touchdown	376874
Altitude	40,565	Alt-rate	-3.9
Deltah	-4349	V-horiz	-.1

Throttledown	376573	Navigation errors (SM coords)	R_x	+39 m
TTF	-192		R_y	-1981
Altitude	16,472		R_z	-1019
Alt-rate	-72.4		V_x	-.07 m/sec
V-horiz	1256.4		V_y	0
Range	-199		V_z	-.16

Max thrust after throttledown	6551	Fuel: RCS	23.75 lbs
Time	376678	DPS	18317 lbs
Altitude	12,291		

Highgate	376706
Altitude	AGC/ENV 7357/7224
Alt-rate	-162.6/-163.1
V-horiz	284/286.3
Range	-25 NM

RLS - Actual Site (MF coords)

X	477 m
Y	4624
Z	-1464

Ground-Track coords

Crossrange	5703'
Downrange	14,937'

TEST 6.4.2.2 LUNAR LANDING

I. Test Objective

This test is made to verify LM performance using nominal program procedures.

II. Test Description

This test sequence exercises the landing site redesignation options in P63 and P64. The abort discrete is failed prior to P63. LM is yawed left 50 degrees at TIG -3 min. The 50 degrees is removed at TIG +3.

Program Sequence

P00	
V48	DAP Data Load
	Set ABORT Backup
P63	Braking Phase
N69	Land Site Redesignation at TIG +30 sec.
	Downtrack 20 K ft
	Crosstrack 20 K ft
P64	Approach Phase
	ACA: 2(-EL), 2(+AZ)
P66	Vertical Phase
	Enter at 700 ft. manually
P00	

III. Test Initialization

1. 10% TLOSS
2. Terrain profile ($+1^{o}$) error.

6.4.2.2 Landing with Redesignations (N69 & ACA)

Ignition	376135.6	Lowgate	367802
Attitude: Yaw	-50	Altitude	AGC/ENV 560/570
Pitch	-178	Alt-rate	-20.6/-20.2
Roll	0	V-horiz	+51.8/+50.9

V57: Time	376420	Touchdown	376885
Altitude	39207	Alt-rate	-4.3
Deltah	-3150	V-horiz	-.1

Throttledown	376565	Navigation Errors (SM coords)	R_x	+23 m
TTF	-207		R_y	-2039
Altitude	18,190		R_z	-1059
Alt-rate	-58.5		V_x	-.02
V-horiz	1362.4		V_y	-.02
Range	-233		V_z	-.18

Max. thrust after throttledown	9990 lbs	Fuel: RCS	24.34 lbs.
Time	376684	DPS	18392 lbs.
Altitude	11,889		

Highgate	376716	RLS-Actual Site (MF coords)	X	2348 m
Altitude	AGC/ENV 7065/6960		Y	7575
Alt-rate	-148.3/-149.7		Z	-5110
V-horiz	272/273.9			
Range	-25 NM			

Ground Track coords.

Crossrange	21,370'
Downrange	23,900'

6.4.2.2B Landing with Redesignations (N69 and ACA) and reverse sign S.V. errors

Ignition	376133.9
Altitude: Yaw	-52
Pitch	-178
Roll	-1

V57: Time	376420
Altitude	38,993
Deltah	-2725

Throttledown	376563
TTF	-208
Altitude	18,635
Alt-rate	-55.5
V-horiz	1362.8
Range	-233

Max thrust after throttledown	6452
Time	376684
Altitude	12,710

Highgate	376712
Altitude	AGC/ENV 7618/7457
Alt-rate	-174.2/-174.4
V-horiz	281/284.7
Range	-25 NM

Lowgate	376799
Altitude	AGC/ENV 550/558
Alt-rate	-21.0/-20.8
V-horiz	+49.5/48.8

Touchdown	376870
Alt-rate	-4.9
V-horiz	-.2

Navigation errors (SM coords)		
	R_x	+26 m
	R_y	-2992
	R_z	+1586
	V_x	-.01
	V_y	0
	V_z	-.34

Fuel: RCS	24.41
DPS	18,248

RLS-Actual Site
(MF coords)

X	+2330 m
Y	+6089 m
Z	-5537 m

Ground Track coords

Crossrange	24,478'
Downrange	15,240'

TEST 6.4.2.3 LUNAR LANDING

I. Test Objective

This test is made to verify LM performance using nominal program procedures.

II. Test Description

This test sequence exercises the landing site redesignation option in P64. LM is yawed left 50 degrees at TIG -3 min. The 50 degrees is removed at TIG +3.

Program Sequence

P00	
V48	DAP Data Load
	Set ABORT BACKUP
P63	Braking Phase
V57	LR Enable
N68	Monitor Range, TGO, VI
N92	Thrust Monitor
P64	Approach Phase
	Redesignate ACA: 2(+EL), 2(-AZ)
P66	Vertical Phase
	Entered at 700 ft. Attitude Hold and ± ROD increments
P00	

III. Test Initialization

1. Terrain profile ($+1^{\circ}$) error.

6.4.2.3 Landing with Redesignations (ACA)

Ignition		376135.6	Lowgate	376786
Attitude:	Yaw	-50	Altitude	AGC/ENV 619/653
	Pitch	-177	Alt-rate	-19.4/-17.9
	Roll	-1	V-horiz.	+70.2/70.4

V57: Time	376378	Touchdown	376968
Altitude	40,921	Alt-rate	-3.0
Deltah	-4228	V-horiz	0

Throttledown	376581	Navigation errors (SM coords)	R_x	+59 m
TTF	-174		R_y	-1931
Altitude	12,965		R_z	-969
Alt-rate	-87.3		V_x	-.07
V-horiz	1148.7		V_y	-.14
Range	-167		V_z	-.14

Max. thrust after throttledown	6321	Fuel:	RCS	22.22
Time	376704		DPS	19318
Altitude	6812'			

Highgate	376698
Altitude	AGC/ENV 7740/7543
Alt-rate	-183.8/-184
V-horiz	277/278.2
Range	-25 NM

RLS-Actual Site (MF coords)

X	-155 m
Y	+1894 m
Z	+29 m

Ground Track coords.

Crossrange	122'
Downrange	6211'

	6.4.1	6.4.2.1	6.4.2.2	6.4.2.2B	6.4.2.3	6.5.4
Ignition	376134.4	376135.6	376135.6	376133.9	376135.6	376133.9
Attitude Yaw	-51°	-50°	-50	-52	-50	-52
Pitch	-178°	176°	-178	-178	-177	-178
Roll	0°	1°	0	-1	-1	-1
V57: Time	376389	376391	376420	376420	376378	376391
Altitude	40,010'	40,565'	39207	38,993	40,921	39963
Deltah	-3531'	-4349'	-3150	-2725	-4228	-3753
Throttledown	376579	376573	376565	376563	376581	376571
TTF	-176	-192	-207	-208	-174	-192
Alt.	14201'	16472	18190	18,635	12965	17111
Alt rate	-85.5'	-72.4	-58.5	-55.5	-87.3	-66.1
V-horiz	1149'	1256.4	1362.4	1362.8	1148.7	1258.3
Range	-168	-199	-233	-233	-167	-199
Max thrust after TDOWN	6527	6551	9990	6452	6321	6273
Time	376702	376678	376684	376684	376704	376710
Altitude	7469	12,291'	11,889'	12,710'	6812'	6938'
Highgate	376697	376706	376716	376712	376698	376705
Alt	8473	7357	7065	7618	7740	7878
Altrate	-198.5	-162.6	-148.3	-174.2	-183.8	-184.4
V-horiz	251	252	241	250	246	249
range	-25	-25	-25	-25	-25	-25
Lowgate	376821	376788	376802	3376799	376786	376801
Alt	189'	614'	560'	550'	619	429
Alt-rate	-5.7	-23.2	-20.6	-21.0	-19.4	-23.3
V-horiz	+4.7	+73.8	+51.8	+49.5	+70.2	43.3
Touchdown	376856	376874	376885	376870	376968	376822
Altrate	-5.8	-3.9	-4.3	-4.9	-3.0	-2.2
V-horiz	+.2	-.1	-.1	-.2	0	+5.9

	6.4.1	6.4.2.1	6.4.2.2	6.4.2.2B	6.4.2.3	6.5.4
Navigation errors (SM coords)						
R_x	104m	+39 m	+23 m	+26 m	+59 m	+150 m
R_y	-1940	-1981	-2039	-2992	-1931	-2918
R_z	-986	-1019	-1059	+1586	-969	+1657
V_x	-.04	-.07	-.02	-.01	-.07	-.01
V_y	0	0	-.02	0	-.14	0
V_z	-.14	-.16	-.18	-.34	-.14	-.25
Fuel: RCS	21.2	23.75	24.34	24.41	22.22	23.98
DPS	18208	18317	18392	18248	19318	17810
RLS-Actual Site (moon-fixed coords)						
X	72.7m	477	2348	2330	-155	1164
Y	-350	4624	7575	6089	1894	2013
Z	-118	-1464	-5110	-5537	29	-2300
Ground-Track coords						
Crossrange		5703'	21, 370'	24, 478'	122'	8758'
Downrange		14937'	23, 900'	15, 240'	6211'	6186'

	All nominal Auto landing No N69's	Nominal auto landing w/-3K downrange error No N69's	6.4.1 w/1σ errors No N69's	6.4.1 w/1σ errors & N69's	same, w slosh & IMU
Ignition	376134.8	376135.3	376135.6	376134.4	376134
Altitude P	-178°	-177	-177	-178	-178
Y	-50°	-50	-51	-51	-50
R	-1°	0	0	0	-1
V57: Time	376432	376420	376385	376389	376377
Altitude	37416'	38563	40617	40010	40270
Deltah	+1833'	-1952	-4101	-3531	-3846
Throttle down	376582	376582	376581	376579	376579
TTF	-174	-174	-175	-176	-176
Alt.	12266	11600	12974	14201	14254
Alt-rate	-87.6	-86.8	-87.8	-85.5	-85.9
V-horiz	1125	1125	1148.2	1148.9	1148.6
range	-163	-163	-167	-168	-168
Max thrust after TDOWN	6030	5952	6312	6527	6494
Time	376703		376704	376702	376702
Altitude	6753		6812	7469	7460
Highgate	376697	376698	376698	376697	376697
Alt	7606	7339	7766	8473	8432
Alt-rate	-169.1	-162.1	-184.6	-1985	-198.6
V-horiz	252	250	278	251	283
Range	-25	-25	-25	-25	-25
500' time	376789	376789	376792	376794	376794
Alt	500'	485	485	496	495
Alt-rate	-15.9'	-14.8	-16.2	-17.0	-17.1
V-horiz	52.6	52.8	48.5	42.6	42.3

	All nominal	Nominal auto	6.4.1 No N69's	6.4.1 N69's	same
Lowgate	376821	376822	376820	376821	376821
Alt	183	182	205	189	187
Alt-rate	-3.6	-3.5	-6.6	-5.7	-5.3
V-horiz	5.4	5.5	+7.0	4.7	4.6
Touchdown	376868	376869	376853	376856	376858
Altrate	-3.8	-3.7	-6.7	-5.8	-5.6
V-horiz	+.1	0	+.1	+.2	+.1
Navigation errors					
R_x	-9.29m	-21.36 m	-7.96 m	+103.9m	+102.32 m
R_y	-73.87	-67.14	-1938.5	-1935.4	-1944.8
R_z	+13.65	-803.54	-980.46	-982.9	-976.5
V_x	+.04	+.02	-.07	-.04	-.05
V_y	-.09	-.07	0	-.01	0
V_z	-.1	-.04	-.14	-.15	-.13
Fuel: RCS	46.35	31.25	53.23	55.83	64.6
DPS	18307	18314	18162	18208	18229
RLS-Actual Site (moon-fixed coords)					
X	35.6 m	-35 m	-37 m	104 m	245 m
Y	78.2 m	892 m	1538	-1940	-341
Z	-99.5 m	-90 m	-139	-986	-471
Ground-Track coords					
Cross range	356'	350'	590'	399'	1687'
Downrange	242'	2920'	5033'	-1168'	-1200'

TEST 6.5.1 LM RCS DEORBIT BURN

I. Test Objective

Verify proper operation and ascertain performance of the Erasable Memory RCS Guided Burn for LM Deorbit (P99) in Luminary revision 210.

II. Test Description

The procedure followed is that enumerated in Luminary Memo #211. The following sequence is used in the test:

P00	LGC Idling Program
V82	Orbital Parameters Display Routine (R30)
V48	DAP Data Load Routine (R03)
P30	External ΔV Targetting Program
V96	Extended Verb to Interrupt Integration and GOTOPOOH
V71	Universal Update - Block Address
V71	Universal Update - Block Address
V71	Universal Update - Block Address
V71	Universal Update - Block Address
V72	Universal Update - Single Address
V5N26	Verification of P99 address
V30	Request executive; call P99
V82	Orbital Parameters Displays Routine (R30)
P00	LGC Idling Program

In the above sequence, the astronaut egresses from the LM after V96; so that the ground continues at the uplink sequence, V71.

III. Test Initialization

1. Verified procedure and uplink for P99 as enumerated in Luminary Memo #211. Rev 1
2. Environment Initialization
   A. LM-10 Vehicle.
   B. CG and mass (fuel loadings, etc.) as agreed upon with MPAD; Guidance and Performance Division.

IV. Test Results

The test was performed according to the verified procedure in Luminary Memo #211 Revision 1. The data obtained from the on-line printout and DAP performance edit and plots gave evidence that the program and the procedure may be used with a reasonable assurance that the LM Deorbit will be successful in terms of the targetted impact parameters. A table of data comparison is included in this report.

The data is enumerated and the test is further explored and reported upon in Luminary Memo #218.

V. Test Conclusion

The objective has been achieved.

Timeline for Test 6.5.1
LM RCS Deorbit Burn

Event	Time (G.E.T.)
Start simulation	644180
P00	644186
V82 (R30)	644190
V48 (R03)	644202
P30	644219
V96	644250
V71 (Uplink Erasable Program)	644252
V30 (P99 entry)	644325
RCS ignition	644783
RCS cutoff	644865
V82 (R30)	644870
P00	644880
Lunar Impact	646265
End of Simulation	646265

Tabulated Displays

DSKY(VN)	R1	R2	R3	Mode
V37E00E				00
V82E				
V04N12	00002	00001		
V16N44	+60.5	+58.2		
V48E				
V21N46	12021			
V21N47	+5345			
V37E30E				30
V6N33	+179	+6	+22.70	
V6N81	-161.1	+57.3	+94.6	
V6N42	+60.9	-53.1	+195.4	
V16N45	0	-8x50	+16.93	
V96E				00
V71				27
V71				
V71				
V71				
V72				
V5N26E	13001	1420	12067	00
V62E				
V30E				99
V50N18	+162.52	+21.58	+13.91	
V6N40	-01x00	+195.4	0	
V6N40	-00x20	+195.4	+.1	
V6N40	-00x01	+195.4	+.3	
V16N40	-00X01	+.1	+195.9	
V16N85	-.1	-0	+0	
V82E				
V16N44	+60.9	-53.2	-21x30	
V16N85	-.2	-0	+0	
V37E00E				00

Test Facility Data Comparison

Data	MIT/CSDL Value	NASA Value
TIG	179:6:22.7 G.E.T.	179:6:22.7 G.E.T.
ΔV	195.4 fps	195.4 fps
B.T.	81.79 sec	82.3 sec
RCS fuel used	117.16 lb	115 lb
Impact Velocity	5527.3 fps	5527.9 fps
Impact Latitude	26.25^{o} N	26.3^{o} N
Impact Longitude	1.782^{o} E	1.7^{o} E
Impact Time	1:79:31:7 G.E.T.	179:31:7.9 G.E.T.

TEST 6.5.3 ABORT STAGE AFTER TOUCHDOWN

I. Test Objective

Verify operation and ascertain performance of the APS Abort Program (after a nominal Lunar Landing) in Luminary revision 210.

II. Test Description

Program Sequence

P00	LGC Idling Program
V48	DAP Data Load Routine (R03)
P63	Braking Phase Program
V57	State Vector Update Routine; LR Update (R12)
P64	Approach Phase Program
P66	Vertical Phase Program (R. O. D. - Auto)

Abort Stage

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

While in P71, the following sequences will be performed:

I. Manual yaw maneuver to observe vehicle attitude control response to ACA when mode control is ATTHOLD.

II. Monitor N76, N77, N85 via V16.

III. Test Initialization

1. Environment Initialization

A. LM-10 Vehicle

B. Terrain Profile with $+1^{o}$ errors.

C. 10% TLOSS

2. CHANBKUP abort discrete not set (abort discrete not present)

IV. Test Results

Examination of the on-line printout, guidance edits, and DAP performance edit and plots revealed that the LGC Abort Program behaved in a nominal fashion. The correct targets were selected and the TGO and the desired downrange velocities were computed correctly. The insertion parameters were as targetted, with small ΔV residuals in N85.

Throughout the simulation, Ascent nouns 76, 77, and 85 were monitored, and it was seen that the correct data was available through these nouns.

During this test, there were 25 lost downrupts. The analysis and report of these lost downrupts is included in LUMINARY Development Note #87 dated 14 June 1971.

V. Conclusion

The objective has been achieved.

Figures of Merit - 6.5.3

Data (insertion)	Environment Value	LGC Value	Target Value
Apolune (n.mi.)	72.4	70.0	70.5
Perilune (n.mi.)	9.77	9.7	
Out of Plane distance	-.03 n.mi.	9 ft.	0
Altitude (ft)	55770	60327	60000
Altitude rate (fps)	26.8	20.5	19.5
Down range Velocity (fps)	5571	5570	5571
Yaw angle (deg)	-3.24	-1.76	
Pitch angle (deg)	-5.29	-7.15	
VGX Body (fps)		+.15	
VGY Body (fps)		-.6	
VGZ Body (fps)		+.81	
Theta [phase angle]		+10.06	

Abort Stage from Touchdown - B

Displays of Interest

V/N	R1	R2	R3	Mode
04/46	21112	00010		00
06/47	+36702	+38643		
06/61	-11x05	-04x09	-00002	63
50/18	+35993	+11006	+00023	
06/62	+55639	-01x00	+00000	
06/63	+99999	-00046	+49855	
06/63	-03838	-00604	+40533	
06/64	+99x37	-01770	+06659	64
06/60	+00033	-00065	+00187	66
06/94	+07461	+00230	+00044	71
16/94	-00001	+00206	+60289	
16/85	+00002	-00013	+00021	00
16/44	+00697	+00097		
16/54	+17163	-04480	+30624	

Timeline of Test 6.5.3

Abort Stage from Touchdown - B

Event	Time (G.E.T.)
Start simulation	375834.8
P00	375848
V48 (R03) (CHANBKUP = 00010)	375867
P63 initiation	375874
Start attitude maneuver (R60)	375395
End attitude maneuver	375982
DPS engine ignition (PDI)	376137
Throttle up	376163
LR Data acceptance	376377
Throttle down	376583
P64 initiation	376698
P66 initiation	376822
Touchdown (DPS engine off)	376854
Abort stage button depress	376857
P71 entry	376863
APS engine cutoff	377294
P00	
V64 (R05)	
V82 (R30)	
V83 (R31)	
P20	
End simulation	

TEST 6.5.4 LUNAR LANDING

I. Test Objective

Verify operation and ascertain performance of a lunar landing sequence in which P66 is entered at 700 ft. altitude and the landing proceeds from there.

II. Test Description

The Auto Throttle backup discrete is set.

Program Sequence

P00	LGC Idling Program
V48	DAP Data Load Routine (R03) Set Auto Throttle Backup discrete
P63	Braking Phase Program
V57	State Vector Update Routine (LR Update; R12)
N69	Downtrack 10k ft, crosstrack 5k ft at TIG +5 min.
P64	Approach Phase Program
P66	Vertical Descent Program (R. O. D. -ATTHOLD)
P68	Landing Confirmation Program
P00	LGC Idling Program

III. Test Initialization

1. Environment Initialization

   A. Terrain profile with $+1^{o}$ error
   B. 10% TLOSS

2. CHANBKUP abort discrete not set (abort discrete not present)

TEST 6.5.5 DOCKED DPS PLANE CHANGE BURN

I. Test Objective

Verify operation and ascertain performance of the plane-change burn while in the Docked Configuration.

II. Test Description

Program Sequence

P00	LGC Idling Programs
V48	R03, DAP Data Load Routine; Load DAP for docked configuration
V62	Display Total Attitude Error
V77	Rate Command and Attitude Hold
P30	External Delta-V Targetting Program
P40	DPS Burn Program
V82	Orbital Parameter Display Routine (R30)
P00	LGC Idling Program

III. Test Initialization

1. State Vectors, TIG, ΔV required was supplied by MPAD at NASA/MSC.
2. Environment Initialization:
   CG and Mass (fuel loadings, etc.) as given by MPAD at NASA/MSC.

IV. Test Results

The Docked-DPS Plane Change burn was performed as indicated in the description. The on-line printout and DAP performance edit and plots indicated that the control of the CSM-LM docked configuration was excellent. The fact that the LM-10 vehicle is heavier, by about a ton, than the LM-8 vehicle is possibly responsible for the better control performance in this test than in the Apollo 14 Level 6 Plane Change test.

V. Conclusion

The objective has been achieved.

Timeline for Test 6.5.5
Docked-DPS Plane Change

Event	Time (G.E.T.)
Start simulation	594350.6
P00	549364
V48 (R03)	594378
V62	594389
V77	594391
P30 entry	594393
P40 entry	594423
Start attitude maneuver (R60)	594426
End attitude maneuver	594611
DPS ignition	594772
DPS cutoff	594858
P00	594865
End simulation	594868

Docked-DPS Plane Change
Displays of Interest

V/N	R1	R2	R3	Mode
04/46	31021	00011		00
06/47	+36860	+37277		
06/33	+00165	+00012	+5059	30
06/81	-00088	+03085	+00000	
06/42	+00596	+00596	+03086	
50/18	+00214	+35929	+33817	40
06/40	-01x00	+3086	+00000	
06/40	-00x01	+3084	+00007	
16/40	-00x00	+00008	+03086	
16/85	+00007	+00000	-00001	

TEST 6.5.6 DOCKED DPS TEI BURN

I. Test Objective

Verify operation and ascertain performance of the TEI burn while in the Docked Configuration.

II. Test Description

Program Sequence

P00	LGC Idling Program
V48	R03, DAP Data Load Routine; Load DAP for docked configuration
V62	Display Total Attitude Errors
V77	Rate Command and Attitude Hold
P30	External Delta-V Targetting Program
P40	DPS Burn Program
V82	Orbital Parameter Display Routine (R30)
P00	LGC Idling Program

III. Test Initialization

1. State vectors, TIG, ΔV as supplied by MPAD at NASA/MSC.
2. Environment Initialization:
   CG and Mass (fuel loadings, etc.) as given by MPAD at NASA/MSC.

IV. Test Results

The Docked-DPS TEI burn was performed as indicated in the description. The on-line printout and DAP performance edit and plots indicated that the control of the CSM-LM docked configuration was satisfactory. The LM-10 vehicle is heavier by about a ton, that the LM-8 vehicle. For this reason the control performance in this test is better than that experienced in the test performed for Apollo 14 Level 6.

In this test, it was noted that DPS fuel depletion occurred 2.9 seconds before nominal DPS cutoff. The Guidance and Performance division of MPAD at NASA/MSC was consulted on the matter of whether the data seen was to be expected from the initialization parameters. MIT/CSDL was informed that the DPS ΔV capability at the TEI time used in this test was not sufficient to complete the TEI burn by approximately 3 seconds. Since this statement is compatible with the observed data, and the test was made primarily to test the performance of DAP control, the test was not rerun with new initialization parameters. This was the only off-nominal occurrence.

V. Conclusion

The objective has been achieved.

Timeline for Test 6.5.6
Docked-DPS TEI

Event	Time (G.E.T.)
Start simulation	805008
P00	805021
V48	805027
V62	805045
V77	805048
P30	805051
P40	805082
DPS ignition	805429
DPS cutoff (depletion)	806040
V82	806047
P00	806051
End simulation	806055

Docked-DPS TEI

Displays of Interest

V/N	R1	R2	R3	Mode
04/46	31021	00011		00
06/47	+36860	+36281		
06/33	+00223	+00043	+04762	30
06/81	+29335	-08163	-01035	
06/42	+99999	+00585	+30467	
50/18	+17751	+19166	+35845	40
06/40	-01x00	+30467	+00000	
06/40	-00x01	+30464	+00007	
16/40	-00001	+00173	+30302	
16/85	+00173	+00004	+00001	
16/44	+99999	+00572		