THE CHARLES STARK DRAPER LABORATORY
A DIVISION OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY
68 ALBANY STREET
CAMBRIDGE, MASSACHUSETTS 02139

LUMINARY Memo #231

To: Distribution
From: D. Millard
Date: 8 November 1971
Subject: Level 6 Test Description for Mission 16 (PRELIMINARY)

This memo provides a description of the LUMINARY Level 6 Performance Testing currently planned for Mission 16. Included are comments on test initialization and a detailed description of the digital simulation tests which fall into the following general categories.

During Level 6 performance testing for Mission 15 an investigation was made to determine whether the quality of the descent, abort and ascent digital test results would be compromised by removing the environment slosh mode from the tests. This investigation was part of an effort to reduce computer usage time for the Level 6 digital testing effort. It was found that by removing the slosh mode and using the FAST IMU model that the computer time required to simulate a nominal descent could be reduced by half, from 90 mins. to 45 mins. Investigation by the Digital Autopilot group of simulations of descents, aborts and ascents revealed essentially comparable performances for the fully simulated

environment tests and the tests with no slosh and the FAST IMU.

Based on this investigation, one fully simulated environment test of descent and T1 abort will be made to ensure that Mission 16 parameters in no way negate the conclusions of the Mission 15 investigation. The Mission 16 performance test plan included in this memo assumes that the simulated environment will use the FAST IMU and will not contain the slosh mode.

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

Typical 1σ initialization errors are given on page 3.

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

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° on the Lunar Surface.

Program Sequence

P57	AT-3 to Landing Site
P00	
V48	DAP Data Load
V42N72	Position RR
P12	Ascent
V83	Rendezvous Parameter Display (R31)
V64	S-Band Antenna
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
V83	Rendezvous Parameter Display (R31)

P41	RCS
V82	Orbital Parameter Display
P35	Transfer Phase Midcourse (TPM)
V93	Enable W-Matrix Initialization
P41	RCS
V83	Rendezvous Parameter Display
P00	
P47	Thrust Monitor
P00	

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 and the auto throttle failed OFF.

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 6.2.2 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 6.2.3 ABORT AFTER TOUCHDOWN - TEST I

I. Test Objective

Demonstrate APS (T1) Abort

II. Test Description

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 6.2.4 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

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
V42N20	Park IMU
	Coarse align IMU to parking gimbal angles
P06	LGC Power Down Program
	LGC Power Up
P57	AT-2 Lunar Surface Alignment to REFSMMAT
	4 star sighting - no torquing
P57	AT-3 Lunar Surface Alignment to Landing Site
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 6.3.2 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	
V06N20	Gimbal Angles for Coarse Alignment
V42N20	Coarse Align IMU
V41N20	
P51	Set drift
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)
P52	Alignment to REFSMMAT
P00	

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 6.4.2 LUNAR LANDING - AUTO

I. Test Objective

Demonstrate LM automatic landing.

II. Test Description

This test exercises landing site redesignation option at PDI -10 mins. to correct propagated state vector errors; at PDI +5 mins. to correct IMU errors and at PDI +8 mins. to correct altitude errors.

Program Sequence

P00	
N69	Landing Site Redesignation at PDI -10 mins.
	Downtrack
	Crosstrack
	Altitude
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
	Crosstrack
N69	Landing Site Redesignation at PDI +8 mins.
	Altitude
P64	Approach Phase
P66	Vertical Phase
P68	Lunar Surface Confirmation
P00	

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 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 6.4.5 LUNAR LANDING - N69 RED LINE

I. Test Objective

Demonstrate LM automatic landing with large IMU errors.

II. Test Description

The test usesthe landing site redesignation option at PDI +5 to compensate for red line IMU errors.

Test Sequence

P00	
V48	DAP Data Load
V64	S-Band Antenna Routine (R05)
P63	Braking Phase
P57	LR Update Enable
N69	Landing Site Redesignation at PDI +5 mins.
	Downtrack -
	Crosstrack
P64	Approach Phase
P66	Vertical Phase
P68	Lunar Surface Confirmation
P00	

6.5.0 ERASABLE MEMORY PROGRAMS

The testing of LUMINARY EMP's is indicated below.

	TEST STATUS 11/8/71
EMP 99 -LM DEORBIT	Digital TEST 6.5.1
EMP 100 -DSKY BACKUP	Digital TEST 6.5.2
EMP 101 -THRUST MONITOR BACKUP	Digital TEST 6.5.3
EMP 102 -SOFTWARE RESTART	Tested - STL/MIT
EMP 103 -DESCENT WITH FAILED CDU's	Tested - LMS KSC
EMP 104 -P20 OPERATION WITH IMU OFF	Digital TEST 6.5.4
EMP 106 -N79 DETENT ADVANCE	Tested - STL/MIT
EMP 108 -INHIBIT T4RUPT IMU COARSE ALIGN	STL/MIT

TEST 6.5.1 LM DEORBIT

Test Objective

Demonstrate LM deorbit using erasable memory program 99.

Test Description

Ref: LUMINARY Memo #218

TEST 6.5.2 LUNAR LANDING-DSKY BACKUP

Test Objective

Demonstrate LM nominal landing using erasable memory program 100.

Test Description

Same as TEST 6.4.4 except the DSKY BACKUP Erasable Program is loaded and the trim gimbal switch is activated to cause DSKY ENTER throughout the simulation.

TEST 6.5.3 THRUST MONITOR BACKUP

Test Objective

Demonstrate Thrust Monitor Backup Program - EMP 101.

TEST 6.5.4 P20 OPERATION WITH IMU OFF

Test Objective

Demonstrate P20 operation with IMU OFF - EMP 104

6.6.0 SPECIAL TESTS

Special tests planned as of 11/8/71.

Tests in addition to TEST 6.4.5 are planned to further verify LM automatic landing with very large IMU errors.