

Massachusetts Institute of Technology
C. S. Draper Laboratory
Cambridge, Massachusetts

LUMINARY Memo #229

To: Distribution
From: David Moore, Craig Work, Peter Weissman
Date: 15 July 1971
Subject: Post-FSRR (Luminary 1E) Docked DPS Burns

Summary

These tests were run on the MIT/CSDL All-Digital Simulator in the LM/CSM docked configuration. As a response to NASA/MSC inquiries concerning burn performance under certain conditions, this test package was assembled. Tabulated in this report are the initialization parameters (both for the LGC and the simulator environment) for each test, some DSKY displays of interest, and the burn parameters and results of each test. A statement, concerning the analysis of the control performance of the Digital Autopilot for each test, is included by the Digital Autopilot Group at MIT/CSDL.

Purpose

To verify performance of the DPS burn program in the Docked configurations as given by NASA/MSC.

Tests

The following test cases were then given by NASA/MSC to MIT/CSDL for Post-FSRR testing:

- I. Case 1 - Docked DPS - TEI (with CSM half full)
- II. Case 2 - Docked DPS TL Abort (with empty CSM)
- III. Case 3 - Docked DPS PCY +2 hr Abort (with full CSM).

Test Sequence

The following sequence was used in each test:

P00	LGC Idling Program
V48	DAP Data Load Routine (R03)
V62	Display Total Attitude Errors
V77	Rate Command
P30	LGC Targeting Program
P40	DPS Burn Program
P00	LGC Idling Program

Discussion

One can note from the tabulated data results that each of the Docked-DPS burns appeared to perform favorably. In particular, the Burn Parameters and Results table gives pertinent data in the form of ΔV , Burn time and ΔVG . Consider each test, now, with reference to these parameters as compared to NASA/MSC-derived data (tabulated under Test Facility Data Comparison).

All cases agree as to $\Delta VMAG$ because this was the parameter which would be common to both facilities. As to burn time, it is seen that there is little error (less than 1%) between the expected burn time and the actual burn time in each case. As for ΔVG it is seen that in each case, N85 displays are small.

Conclusion

From the above discussion and the DAP group statements at the end of this report, it can be concluded that the performance of the assigned tests was satisfactory. Therefore, the objective, verification of the Docked-DPS burn performance in the test cases included in this memo, has been achieved.

Case 1 - Docked DPS TE1 - Initialization Parameters

I. AGC Initialization

\underline{R} = (611565, -1362428, -1055578) meters

\underline{V} = (-1461, -164, -685) meters/second

Time = 88^h 7^m 0^s GET = 317219 seconds G. E. T.

(Selenocentric inertial coordinate system)

REFSMMAT = $\begin{bmatrix} -.88894521 & .44150806 & -.12184857 \\ -.40323516 & -.62826046 & .66534969 \\ .21720462 & .64059304 & .73652069 \end{bmatrix}$

Gimbal angles (I, M, O) = (0, 0, 0) degrees

II. Environment Initialization

Nonlinear slosh, bending, and a slow IMU were utilized in this test. The Mass and CG properties were as follows:

C. G. = (323.23, 2.53, 0.68) inches

Total Mass = 74811 lb.

APS fuel = 5191 lb.

DPS fuel = 19595 lb.

RCS fuel = 592.6 lb.

CSM fuel = 12058 lb.

IMU compensation errors = 1σ

Case 2 - Docked DPS TL Abort - Initialization Parameters

I. AGC Initialization

$\underline{R} = (-257580448, -108954046, -75236313)$ meters

$\underline{V} = (533, -21.7, 14.67)$ meters/second

Time = $46^{\text{h}} 54^{\text{m}} 0^{\text{s}}$ G. E. T. = 168840 seconds G. E. T.

(Geocentric inertial coordinate system)

REFSMMAT = $\begin{bmatrix} .88748177 & .37944333 & .26153177 \\ -.04409626 & -.49498272 & .86778317 \\ .45872825 & -.78167432 & -.42255611 \end{bmatrix}$

Gimbal angles = (I, M, O) = (0, 0, 0) degrees

II. Environment Initialization

Nonlinear slosh and a slow IMU were utilized in this test.

The Mass and C. G. properties were as follows:

CG = (293.306, 1.692, -.903) inches

Total Mass = 62620 lb.

APS fuel = 5191 lb.

DPS fuel = 19462 lb.

RCS fuel = 592.6 lb.

CSM fuel = 0 lb.

IMU compensation errors = 1σ

Case 3 - Docked DPS PCY +2 hr Abort - Initialization Parameters

I. AGC Initialization

$\underline{R} = (-1122307.4, 5985033.9, 7889395)$ meters

$\underline{V} = (290.56, 846.72, 1096.67)$ meters/second

Time = $80^{\text{h}} 25^{\text{m}} 0^{\text{s}}$ G. E. T. = 289500 seconds G. E. T.

(Selenocentric inertial coordinate system)

REFSMAT =

.14992487	.88118554	-.44836882
.98033782	-.07364470	.18306887
.12829765	-.46699949	-.87490068

Gimbal angles = (I, M, O) = (0, 0, 0) degrees

II. Environment Initialization

Nonlinear slosh and a slow IMU was utilized in this test. Mass and C. G. properties were as follows:

CG = (378.27, 4.46, 1.01) inches

Total Mass = 102817 lb.

APS fuel = 5191 lb.

DPS fuel = 19465.2 lb.

RCS fuel = 592.7 lb.

CSM fuel = 40590 lb.

IMU compensation errors = 1σ

Displays of Interest

Case 1 - Docked DPS TEI

<u>V/N</u>	<u>R1</u>	<u>R2</u>	<u>R3</u>	<u>Mode</u>
04/46	31021			0
06/47	+36860	+37951		
06/33	+00088	+00013	+01747	30
06/81	+27935	-04248	-01031	
06/42	+99999	+00555	+28275	
16/45		-05X08		
50/18	+00003	+00041	+00045	40
06/40	-00X01	+28273	+00007	
16/40	-00X00	+00015	+28270	
16/85	+00015	-0	-0	

Case 2 - Docked DPS TL Abort

<u>V/N</u>	<u>R1</u>	<u>R2</u>	<u>R3</u>	<u>Mode</u>
04/46	31021			0
06/47	+36860	+25762		
06/33	+00047	+0	+0	30
06/81	-00072	0	+19572	
06/42	+99999	+01915	+19572	
16/45		-04X50		
50/18	+00002	+00001	+00011	40
06/40	-00X01	+19569	+00008	
16/40	-00X00	+00010	+19568	
16/85	+00010	-00001	+0	

Case 3 - Docked DPS PCY +2 hr Abort

<u>V/N</u>	<u>R1</u>	<u>R2</u>	<u>R3</u>	<u>Mode</u>
04/46	31021			0
06/47	+36860	+65954		
06/33	+00080	+00031	+02955	30
06/81	-00215	-13251	-00307	
06/42	+99999	+05229	+13604	
16/45		-05X22		
50/18	+34831	+00411	+35967	40
06/40	-00X01	+13602	+00006	
16/40	-00X01	+00008	+13603	
16/85	+00008	+0	+0	

Burn Parameters and Results

Parameter/Case	1	2	3
TIG (h:m:s)	88:13:17.47	47:00:00	80:31:29.5
ΔV_X (fps)	2793.5	-7.2	-21.53
ΔV_Y (fps)	-424.8	0	-1325.08
ΔV_Z (fps)	-103.1	1957.16	-307.03
ΔV_{MAG} (fps)	2827.5	1957.2	1360.3
Burn Time (sec)	590.75	363	425
ΔV_{GX} (fps)	1.5	1.0	.8
ΔV_{GY} (fps)	0	0	0
ΔV_{GZ} (fps)	0	0	0
DPS fuel used (lb.)	18774.24	11326.07	13375.07
RCS fuel used (lb.)	17.94	6.08	29.83

Test Facility Data Comparison

Case/Parameter	$\Delta VMAG$		Burn Time	
	MIT/CSDL	NASA/MSC	MIT/CSDL	NASA/MSC
1	2827.5	2827.5	590.75	595.95
2	1957.2	1957.17	363	366.8
3	1360.3	1360.3	425	428.3

Apollo 15, LM 10, Luminary 1E (Rev 210)
JOB A145342 07/09/71 13:12 (edit)
MARSROT 18719445 MOORE.D SPECDOCKDPS-1

Special Docked DPS test: FULL DPS, FULL APS, 30% CSM
P40 External Delta-V Burn, 2800 fps.

Simulation model used slosh, bending, and accurate IMU. This edit covers the period 317575-318193 sec.

POSTBURN N 85: (0, 0, 0)

317597 IGNITION in P40
317602 LEMTHROT to 40%
317623 FTP (ZOOM)
318188 ENGINOFF

Initial thrust vector mistrim with pitch $\left\{ \begin{array}{l} +0.43^\circ \\ -1.06^\circ \end{array} \right.$
compliance at 4200 lb. thrust was roll

RCS fuel used: ULLAGE 5.9 lb, In-burn 5.2 lb, Pre-burn 6.8 lb.

Roll ignition peak transient attitude error of 4.2° is due to initial thrust vector mistrim. DAP control was normal and satisfactory.

Craig Work

Apollo 15, LM 10, Luminary 1E (Rev 210)
JOB A145787 07/15/71 14:54
MARSROT 19100152 MOORE.D SPECDOCKDPS-4
DOCKED DPS BURN, CASE 4

Special Docked DPS test: FULL DPS, FULL APS, EMPTY CSM
P40 External Delta-V Burn, 1960 fps.

POSTBURN N 85: (1.0, -0.1, +0)

This edit covers period 169170-169572

169200	IGNITION in P40
169205	LEMTIROT to 40%
169226	FTP (ZOOM)
169565	ENGINOFF

The initial thrust vector mistrim produced a roll transient error of 2.6° . Otherwise the run was extremely calm, with errors less than 0.5° and rates less than $0.4^\circ/\text{sec}$.

Extended V 65 was in effect and no yaw jets were fired.

RCS fuel used: ULLAGE 5.7 lb, In-burn 0.0, Pre-burn 0.3lb.

DAP control was normal and satisfactory.

Craig Work

Apollo 15, LM 10, Luminary 1E (Rev 210)
JOB A143525 07/16/71 0:53
MARSROT 19100254 MOORE, D SPECDOCKDPS-5
DOCKED DPS BURN, CASE 5

Special Docked DPS test: FULL DPS, FULL APS, FULL CSM
P40 External Delta-V Burn, 1361 fps.

POSTBURN N 85: (+0.8, 0, 0)

This edit covers the period 289855-290485 seconds.

Initial thrust vector mistrim with
compliance at 4200 lb. thrust: $\left\{ \begin{array}{l} \text{pitch } -0.46^\circ \\ \text{roll } +1.32^\circ \end{array} \right.$

289889.6	IGNITION in P40
289894	LEMTHROT to 40 %
289916	FTP (ZOOM)
290316	ENGINOFF

RCS fuel used: ULLAGE 5.9 lb., In-burn 10.1 lb., Pre-burn 13.8 lb.

P-axis: Limit eyeled throughout the run, with period varying between 15 and 35 seconds.

Q-axis: Attitude error exceeded the deadband by 0.25° at FTP, control was otherwise uneventful.

R-axis: The initial thrust vector mistrim produced a $- .91^\circ / \text{sec}$ rate and a 7.9° attitude error. Otherwise, the attitude error stayed inside the deadband.

DAP control was normal and satisfactory.

Craig Work