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 $\Delta V$, Burn time and $\Delta VG$. 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 $\Delta VG$ 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 TEI - Initialization Parameters

1. AGC Initialization

\[ \mathbf{R} = (611565, -1362428, -1055578) \text{ meters} \]
\[ \mathbf{V} = (-1461, -164, -685) \text{ meters/second} \]
Time = 88h \( t^\text{m} \) 0s GET = 317219 seconds G. E. T.

(Selenocentric inertial coordinate system)

\[
\text{REFSMMAT} = \begin{bmatrix}
-0.88894521 & 0.44150806 & -0.12184857 \\
-0.40323516 & -0.62826046 & 0.66534969 \\
0.21720462 & 0.64059304 & 0.73652069
\end{bmatrix}
\]

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 = 1\sigma
Case 2 - Docked DPS TL Abort - Initialization Parameters

I. AGC Initialization

\[ R = (-257580448, -108954046, -75236313) \text{ meters} \]

\[ V = (533, -21.7, 14.67) \text{ meters/second} \]

Time = 46 h 54 m 0 s G. E. T. = 168840 seconds G. E. T.

(Geocentric inertial coordinate system)

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

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:

\[ \text{CG} = (293.306, 1.692, -903) \text{ inches} \]

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

\[
\begin{align*}
R &= (-1122307.4, 5985033.9, 7889395) \text{ meters} \\
V &= (290.56, 846.72, 1096.67) \text{ meters/second} \\
\text{Time} &= 80^\text{h} 25^\text{m} 0^\text{s} \text{ G.E.T.} = 289500 \text{ seconds G.E.T.} \\
\text{(Selenocentric inertial coordinate system)}
\end{align*}
\]

\[
\text{REFSMMAT} = \begin{bmatrix}
1.4992487 & 0.88118554 & -0.44836882 \\
0.98033782 & -0.07364470 & 0.18306887 \\
0.12829765 & -0.46699949 & -0.87490068
\end{bmatrix}
\]

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:

\[
\begin{align*}
\text{CG} &= (378.27, 4.46, 1.01) \text{ inches} \\
\text{Total Mass} &= 102817 \text{ lb.} \\
\text{APS fuel} &= 5191 \text{ lb.} \\
\text{DPS fuel} &= 19465.2 \text{ lb.} \\
\text{RCS fuel} &= 592.7 \text{ lb.} \\
\text{CSM fuel} &= 40590 \text{ lb.} \\
\text{IMU compensation errors} &= 1^\sigma
\end{align*}
\]
### Displays of Interest

#### Case 1 - Docked DPS TEI

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<tr>
<th>V/N</th>
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<th>R3</th>
<th>Mode</th>
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#### Case 2 - Docked DPS TL Abort

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Case 3 - Docked DPS PCY +2 hr Abort

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## Burn Parameters and Results

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<tr>
<th>Parameter/Case</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
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</thead>
<tbody>
<tr>
<td>TIG (h:m:s)</td>
<td>88:13:17.47</td>
<td>47:00:00</td>
<td>80:31:29.5</td>
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<tr>
<td>ΔVX (fps)</td>
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<td>ΔVY (fps)</td>
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<td>-1325.08</td>
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<td>ΔVZ (fps)</td>
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<td>1957.16</td>
<td>-307.03</td>
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<td>ΔVMAG (fps)</td>
<td>2827.5</td>
<td>1957.2</td>
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<td>Burn Time (sec)</td>
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<td>425</td>
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<tr>
<td>ΔVGX (fps)</td>
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<td>ΔVGY (fps)</td>
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<td>ΔVGZ (fps)</td>
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<td>DPS fuel used (lb.)</td>
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<td>RCS fuel used (lb.)</td>
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## Test Facility Data Comparison

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<tr>
<th>Case/Parameter</th>
<th>ΔVMAG</th>
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<tr>
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<td>3</td>
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Apollo 15, LM 10, Luminary 1E (Rev 210)
JOB A145342  07/09/71  13:12  (edit)
MARSROT 13719445  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 (Z00M)
318188  ENGINOFF

Initial thrust vector mistrim with pitch \( \pm 0.43^\circ \)
compliance at 4200 lb. thrust was roll \( -1.06^\circ \)

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

Case 1.  DAP Group Statement
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 LEMTHROT to 40%
169226 FTP (Z00M)
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°/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 0.3 lb.
DAP control was normal and satisfactory.

Craig Work

Case 2: DAP Group Statement
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 \{ pitch -0.46°
compliance at 4200 lb. thrust:
roll +1.32°

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 eyedled 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 -0.91°/sec
rate and a 7.9° attitude error. Otherwise, the attitude
error stayed inside the deadband.

DAP control was normal and satisfactory.

Craig Work

Case 3. DAP Group Statement