AVIONICS SYSTEMS ENGINEERING DIVISION INTERNAL NOTE

(NASA-CR-134331) MAIN PROPULSION FUNCTIONAL PATH ANALYSIS FOR PERFORMANCE MONITORING FAULT DETECTION AND ANNUNCIATION (Lockheed Electronics Co.)

76 p HC $7.00

MAIN PROPULSION FUNCTIONAL PATH ANALYSIS FOR PERFORMANCE MONITORING FAULT DETECTION AND ANNUNCIATION

DISTRIBUTION AND REFERENCING

This paper is not suitable for general distribution or referencing. It may be referenced only in other working correspondence and documents by participating organizations.

National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas
April 1974

LEC-3193
AVIONICS SYSTEMS ENGINEERING DIVISION INTERNAL NOTE

MAIN PROPULSION FUNCTIONAL PATH ANALYSIS
FOR
PERFORMANCE MONITORING FAULT DETECTION
AND
ANNUNCIATION

PREPARED BY

E. L. Keesler, Principal Engineer
Lockheed Electronics Company, Inc.

APPROVED BY

Robert W. Moorehead
Chief, Communications, Power, and Data Systems Branch

William C. Bradford
Chief, Avionics Systems Engineering Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS
April 1974

LEC-3193
ACKNOWLEDGEMENTS

This document was prepared by Lockheed Electronics Company, Inc., Aerospace Systems Division, Houston, Texas, for the Avionics Systems Engineering Division at the Johnson Space Center, under contract NAS 9-12200, Job Order 22-10. It was written by E. L. Keesler, Principal Engineer, and approved by J. R. Thrasher, Project Manager, Avionics Systems Engineering Department, Lockheed Electronics Company, Inc.
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>SUMMARY</td>
</tr>
<tr>
<td>2.0</td>
<td>MAIN PROPULSION SYSTEM</td>
</tr>
<tr>
<td>2.1</td>
<td>Description</td>
</tr>
<tr>
<td>2.1.1</td>
<td>External Tank</td>
</tr>
<tr>
<td>2.1.2</td>
<td>Orbiter Plumbing</td>
</tr>
<tr>
<td>2.1.3</td>
<td>Main Engines</td>
</tr>
<tr>
<td>2.1.4</td>
<td>Main Engine Controller</td>
</tr>
<tr>
<td>2.1.5</td>
<td>Operational Flight Instrumentation (OFI)</td>
</tr>
<tr>
<td>3.0</td>
<td>FUNCTIONAL PATH ANALYSIS</td>
</tr>
<tr>
<td>3.1</td>
<td>Functional Paths</td>
</tr>
<tr>
<td>3.1.1</td>
<td>Main Engine No. 1</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Main Engine No. 2</td>
</tr>
<tr>
<td>3.1.3</td>
<td>Main Engine No. 3</td>
</tr>
<tr>
<td>3.2</td>
<td>Pneumatic Helium Supply</td>
</tr>
<tr>
<td>3.2.1</td>
<td>LO₂ Supply</td>
</tr>
<tr>
<td>3.2.2</td>
<td>LH₂ Supply</td>
</tr>
<tr>
<td>3.3</td>
<td>Engine Monitoring</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Environment</td>
</tr>
<tr>
<td>3.3.2</td>
<td>FDA Measurements</td>
</tr>
<tr>
<td>4.0</td>
<td>MEASUREMENT TO FUNCTIONAL PATH CORRELATION</td>
</tr>
<tr>
<td>5.0</td>
<td>MEASUREMENT LIMITS FOR FAULT DETECTION AND ANNUNCIATION</td>
</tr>
</tbody>
</table>
# FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Engine No. 1, He supply functional paths</td>
<td>3-2</td>
</tr>
<tr>
<td>2</td>
<td>Engine No. 2, He supply functional paths</td>
<td>3-3</td>
</tr>
<tr>
<td>3</td>
<td>Engine No. 3, He supply functional paths</td>
<td>3-4</td>
</tr>
<tr>
<td>4</td>
<td>Pneumatic He supply functional paths</td>
<td>3-6</td>
</tr>
<tr>
<td>5</td>
<td>Valve actuation supply B manifold functional paths</td>
<td>3-9</td>
</tr>
<tr>
<td>6</td>
<td>Valve actuation He supply A manifold functional paths</td>
<td>3-10</td>
</tr>
<tr>
<td>7</td>
<td>LO₂ monitoring functional paths</td>
<td>3-11</td>
</tr>
<tr>
<td>8</td>
<td>LH₂ monitoring functional paths</td>
<td>3-14</td>
</tr>
<tr>
<td>9</td>
<td>Typical preburn He monitor</td>
<td>6-2</td>
</tr>
<tr>
<td>10</td>
<td>Typical burn He monitor</td>
<td>6-3</td>
</tr>
<tr>
<td>11</td>
<td>He supply profile</td>
<td>6-4</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>1</td>
<td>ENGINE NO. 1 He SUPPLY</td>
<td>3-17</td>
</tr>
<tr>
<td>2</td>
<td>LO₂ MONITORING FDA</td>
<td>3-21</td>
</tr>
<tr>
<td>3</td>
<td>LH₂ MONITORING FDA</td>
<td>3-25</td>
</tr>
<tr>
<td>4</td>
<td>ENVIRONMENT ENGINE COMPARTMENT FDA</td>
<td>3-29</td>
</tr>
<tr>
<td>5</td>
<td>CONTROLLER DATA WORDS FOR FDA</td>
<td>3-30</td>
</tr>
<tr>
<td>6</td>
<td>MPS OFI INSTRUMENTATION LIST</td>
<td>3-33</td>
</tr>
<tr>
<td>7</td>
<td>PMS MEASUREMENT DATA</td>
<td>4-2</td>
</tr>
<tr>
<td>8</td>
<td>PMS MEASUREMENT REQUIREMENTS</td>
<td>5-2</td>
</tr>
</tbody>
</table>
ABBREVIATIONS

Disc  Disconnect
E     Engine
Eng   Engine
GH$_2$ Gaseous Hydrogen
GO$_2$ Gaseous Oxygen
He    Helium
HPFT  High Pressure Fuel Turbine
HPFTP High Pressure Fuel Turbo Pump
HPOT  High Pressure Oxidizer Turbine
HPOTP High Pressure Oxidizer Turbo Pump
LH$_2$ Liquid Hydrogen
LO$_2$ Liquid Oxygen
ME    Main Engine
OX    Oxidizer
PNEU  Pneumatic
Reg   Regulator
RPM   Revolutions Per Minute
RSV   Relief Shut-off Valve
SOV   Shut-off Valve
1.0 SUMMARY

A total of 48 operational flight instrumentation measurements have been identified for use in performance monitoring and fault detection. Thirty of these measurements are contained in Volume I of the Master Measurements List.

The Operational Flight Instrumentation List, from the main propulsion panel meeting, November 28, 1973, contains all measurements identified for fault detection and annunciation. It is recommended that these measurements be included in the next revision of the Master Measurements List.

In addition, 16 controller data words have been identified for use in fault detection and annunciation. Eight of these data words are not presently in the first 32 data words which will be available to performance monitoring. It is understood that the data word list is being revised to relocate these words.
2.0 MAIN PROPULSION SYSTEM

2.1 Description

The main propulsion system consists of the following:

- External Tank
- Orbiter Plumbing
- Main Engine (three each)
- Main Engine Controller (three each)
- Operational Flight Instrumentation

2.1.1 External tank. The external tank houses propellant for the main engine and provides the structural interface for the launch configuration.

2.1.2 Orbiter plumbing. The Orbiter plumbing provides flow paths and controls for propellant transfer from the external tank to the main engine.

2.1.3 Main engines. The three main engines are reusable hydrogen fuel cooled liquid propellant rocket engines with variable thrust and mixture ratio. Each engine operates at a mixture ratio (liquid oxygen/liquid hydrogen) of 6 to 1, and a chamber pressure of approximately 3000 psia to produce a sea-level thrust of 375,000 pounds and a vacuum thrust of 470,000 pounds. The engines are throttleable over a range of 50 to 109 percent of design thrust level. This provides for high-thrust level during liftoff and early ascent and allows limiting Orbiter acceleration to 3 G's during final ascent. The engines are gimbaled to provide Thrust Vector Control.
2.1.4 **Main engine controller.** Each main engine has a dedicated controller (DCU) which interfaces commands and data between the vehicle and the engine. Main engine fault detection is also provided by the controller.

The controller consists of two identical, independent, stored program, general-purpose, digital computers, each having a self-contained random access memory, arithmetic/control section, and power supply. Each computer has a 16K, 17 bit word, memory capacity.

One controller channel will be active for control. The second channel will be in a monitor mode ready to take the active role on controller command if the active channel fails.

2.1.5 **Operational Flight Instrumentation (OFI).** Volume I of the Shuttle Master Measurements List, dated November 16, 1973, defines the instrumentation presently baselined for the Main Propulsion System.
3.0 FUNCTIONAL PATH ANALYSIS

Figures 1 through 8 identify the functional paths of the external tank and Orbiter plumbing of the Main Propulsion System. They are identified to be consistent with the identification used by Rockwell International as defined in Rockwell International internal letter 392-RGM-73-037; dated August 31, 1973; subject, "Documentation of Subsystem Functional Path Analysis."

These functional paths are defined at the component level and identified MEXXX or METX. Various combinations of these functional paths are used together during different mission phases as operating functional paths. The operating functional paths used for performance monitoring during flight are identified OMEXX.

3.1 Functional Paths

3.1.1 Main Engine No. 1. Figure 1 defines the functional paths for Main Engine No. 1 helium supply. Figures 2 and 3 define the paths for Main Engines 2 and 3.

ME 1 is a quick-disconnect check valve used for connecting the helium fill manifold to a ground loading source. The check valve serves as a backup for the four source bottle valves.

ME 2 is a 4.5 cu. ft. helium holding source for Main Engine No. 1. The source pressure is maintained at a pressure of 4000 to 4200 psig and a temperature of 500 to 580° R by a ground source until liftoff minus 30 seconds.
Figure 1. - Engine No. 1 - He Supply Functional Paths.

TO ENGINE # 1

TO MANIFOLD

TO COMMON

ENGINE # 1

HE SUPPLY

TO 4 HE SUPPLIES

HE MANIFOLD COMMON
He FILL MANIFOLD COMMON TO 4 He SUPPLIES

Figure 2. – Engine No. 2 – He supply functional path.
Figure 3. - Engine No. 3 - He supply functional paths.
ME 6 and ME 7 are helium shut-off valves used to isolate the helium source from the engine flow path. Both valves are commanded open by the engine controller just prior to engine start.

The regulator in ME 14 regulates the helium source pressure to engine purge pressure, 750 ± 35 psig. The check valve prevents back flow to the helium source in the event the engine is being supplied from a different source through ME 26.

ME 15 is a burst disc and poppet relief valve to protect the engine from excessive pressure in the event the regulator in ME 14 fails open.

ME 26 is a shut-off valve that connects engine 1 to a helium manifold normally supplied by the pneumatic helium supply, source bottle No. 4. In the event ME 26 is opened, ME 6 and ME 7 are closed.

Helium is used by the engine during burns to purge the cavity between the high-pressure oxidizer turbo pump turbine seals. Approximately 20 psig in the helium line is required to open the helium purge valve. It is assumed that some small blanket pressure will be loaded between the Shut-Off Valves (SOV's) and the engine for leak monitoring prior to liftoff.

P1150C, P1154C, and T1151A provide the required instrumentation for engine No. 1 helium monitoring. The operating functional paths for monitoring engine No. 1 helium are:

$$\text{OFM 1 = (ME 1) (ME 2)}$$

$$\text{OFM 7 = (OFM 1) (ME 6 + ME 7) (ME 14)}$$
The switchable functional path in the event of an OFM 7 failure is (OFM 5) (ME26) (see sec. 3.2, pneumatic supply). Loss of engine purge helium will cause engine shutdown. Source depletion may occur while attempting to isolate transducer failures; therefore, transducer failures should not be considered prior to switching sources during burns.

2.1.2 Main Engine No. 2. Engine No. 2 helium supply (fig. 2) has functional paths identical to those in the engine No. 1 helium supply. The operating functional paths used for performance monitoring FDA are:

OFM 2 = (ME 1) (ME 3)

OFM 8 = (OFM 2) (ME 8 + ME 9) (ME 17)

The switchable functional path in the event of an OFM 8 failure is (OFM 5) (ME 27) (see sec. 3.2).

2.1.3 Main Engine No. 3. Main Engine No. 3, helium supply (see fig. 3) has functional paths identical to those in the engine No. 1 helium supply. The operating functional paths used for performance monitoring FDA are:

OFM 3 = (ME 1) (ME 4)

OFM 9 = (OFM 3) (ME 10 + ME 11) (ME 20)

The switchable functional path in the event of an OFM 9 failure is (OFM 5) (ME 28) (see sec. 3.2).
Figure 4. - Pneumatic He supply functional paths.
3.2 Pneumatic Helium Supply

The pneumatic helium supply (fig. 4) has functional paths identical to those in the engine No. 1 helium supply. This fourth helium source supplies pressure to the valves shown in figures 5 and 6. The operating functionals used for performance monitoring FDA are:

$$\text{OPM 4} = (\text{ME 1}) (\text{ME 5})$$

$$\text{OPM 5} = (\text{OPM 4}) (\text{ME 12 + ME 13}) (\text{ME 23})$$

The switchable functional paths in the event of OPM 5 failure are:

$$(\text{OFM 3}) (\text{ME 28})$$

or

$$(\text{OFM 2}) (\text{ME 27})$$

or

$$(\text{OFM 1}) (\text{ME 26})$$

2.2.1 LO$_2$ supply. Three identical operating functional paths supply LO$_2$ to each engine and return GO$_2$ to the tank for pressurant. No redundant paths are available for switching. FDA is used to isolate failures in the path that may be corrected by the crew. The operating functional paths for LO$_2$ flow are (see fig. 7) the following:

Engine No. 1

$$\text{OFM-10} = (\text{MET 2}) (\text{ME 94}) (\text{ME 89}) (\text{ME 111})$$

$$(\text{ME 112 + ME 113}) (\text{ME 95}) (\text{MET 1})$$

Engine No. 2

$$\text{OFM-11} = (\text{MET 2}) (\text{ME 94}) (\text{ME 90}) (\text{ME 115})$$

$$(\text{ME 116 + ME 117}) (\text{ME 95}) (\text{MET 1})$$
Figure 5. - LO₂ monitoring functional paths.
Figure 6. - LH₂ monitoring functional paths.
Figure 7. – Valve actuation supply B manifold functional paths.
Engine No. 3

\[ \text{OEM-12} = (\text{MET 2}) \ (\text{ME 94}) \ (\text{ME 91}) \ (\text{ME 118}) \\
(\text{ME 119} + \text{ME 120}) \ (\text{ME 95}) \ (\text{MET 1}) \]

MET 2 is the LO$_2$ tank containing LO$_2$ and ullage volume for GO$_2$ tank pressurant. Tank pressure is maintained between 20 and 22 psia. Over pressurization protection is provided by vent valves in MET 5 and MET 6. ME-94 consist of two mutually helium activated shut-off valves at the external tank Orbiter interface. A momentary fail closed of these valves results in the loss of all main engines. ME 89 is a helium activated LO$_2$ prevalve. A fail closed condition results in loss of one engine. ME 111 consists of two check valves in the engine GO$_2$ outlet line. The check valves prevent GO$_2$ backflow through a failed engine. ME 112 is an orifice limiting flow of GO$_2$ tank pressurant. It is in parallel with ME 113, which is a second orifice and shut-off valve. The shut-off valve of ME 113 is normally open. As tank pressure approaches the upper limit a pressure switch closes the SOV. Tank pressurant flow is then limited to the orifice in ME 112. ME 95 consist of two Orbiter external tank interface shut-off valves for the GO$_2$ repress line. The tank valve is a close-on disconnect type. The Orbiter side is a helium-actuated shut-off valve. In the event of a fail closed condition, it can be commanded open from the crew panel.

MET 1 is an orifice that provides a final limit to pressurant flow to the tank. Components in the Engine 2 and 3 LO$_2$ functional paths provide identical functions.
3.2.2 LH\textsubscript{2} supply. Three identical operating functional paths supply LH\textsubscript{2} to each engine and return LH\textsubscript{2} to the tank for pressurant. No redundant paths are available for switching. FDA is used to isolate functional path failures which may be corrected by the crew (fig. 8). The operating functional paths for LH\textsubscript{2} are:

Engine No. 1
OFM 13 = (MET 4) (ME 96) (ME 86) (ME 121)
(ME 122 + ME 123) (ME 98) (MET 3)

Engine No. 2
OFM 14 = (MET 4) (ME 96) (ME 87) (ME 125)
(ME 126 + ME 127) (ME 98) (MET 3)

Engine No. 3
OFM 15 = (MET 4) (ME 96) (ME 88) (ME 128)
(ME 129 + ME 130) (ME 98) (MET 3)

MET 4 is the LH\textsubscript{2} tank containing LH\textsubscript{2} and an ullage volume for GH\textsubscript{2} pressurant. Tank pressure is maintained between 32 and 34 psia. Over pressurization protection is provided by vent valves in MET 7 and MET 8. ME 96 consists of two mutually helium activated shut-off valves, at the external tank Orbiter interface. A momentary fail closed of these valves results in the loss of all main engines. ME 86 is a helium activated LH\textsubscript{2} prevolve. A fail closed condition results in the loss of one engine.

ME 121 consists of two check valves in the engine GH\textsubscript{2} outlet line. The check valves prevent GH\textsubscript{2} back flow through a failed engine. ME 122 is an orifice limiting flow of GH\textsubscript{2} tank pressurant. It is in parallel with ME 123, a second
Figure 8. - Valve actuation He supply A manifold functional paths.
orifice and shut-off valve. The shut-off valve of ME 123 is normally open. As tank pressure approaches the upper limit a pressure switch closes the shut-off valve. Tank pressurant flow is then limited to the orifice in ME 122.

ME 98 consists of two Orbiter external tank interface shut-off valves for the GH₂ repress line. The tank valve is a close on disconnect type. The Orbiter side is a helium activated shut-off valve. In the event of a fail close condition, it can be commanded open from the crew panel.

MET 3 is an orifice that provides a final limit to GH₂ pressurant flow to the tank. Components in the engine 2 and 3 LH₂ functional paths provide identical functions.

3.3 Engine Monitoring

Each engine is monitored by its own dedicated controller during checkout and main engine burns. Failures are compiled in a fault data word. FDA will be used to annunciate these failures to the crew. In addition, seven controller parameters will shut down the engine if their limits are exceeded. In cases where it is desired to insure the engines do not shut down, these limit shut-downs will be inhibited by the crew. FDA will be used to monitor these parameters during the inhibit period. The first 32 data words from each controller are available to PMS. The data word list is presently being revised and it is anticipated that all data words in table 5 will be included in the first 32 data words.
3.3.1 Environment. Engine compartment environment will be monitored by two temperature sensors located in the engine compartment.

3.3.2 FDA measurements. Tables 1 through 5 define the measurements required and their justification for FDA. Those contained in Vol. 1, Part I, of the Master Measurement List (MML), are identified, also those presently assigned to performance monitoring are identified.

The OFI Measurement List, from the main propulsion panel meeting, November 28, 1973, is included as table 6. All measurements identified for FDA by this report are listed in table 6.
<table>
<thead>
<tr>
<th>Measurement Number</th>
<th>Measurement Identification</th>
<th>Justification for FDA</th>
<th>MML</th>
</tr>
</thead>
<tbody>
<tr>
<td>V41P1150C</td>
<td>E₁ He Supply Press</td>
<td>Leak detection (preburn)</td>
<td>Part I Software PM - Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leak detection (burn)</td>
<td></td>
</tr>
<tr>
<td>V41P1154C</td>
<td>E₁ He Reg. Outlet Press</td>
<td>Leak detection (preburn)</td>
<td>Part I Software PM - Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regulator/SOV Failures (burn)</td>
<td></td>
</tr>
<tr>
<td>*V41T1151A</td>
<td>E₁ He Supply Temp</td>
<td>Heat and cold soak preburn leak detection only</td>
<td>Part I Flight PM - Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*Needed for ground checkout only only.</td>
<td></td>
</tr>
</tbody>
</table>

Operating Functional Paths

\[
\text{OFM 1} = (\text{ME 1}) (\text{ME 2}) \\
\text{OFM 7} = (\text{OFM 1}) (\text{ME 6 + ME 7}) (\text{ME 14})
\]
## TABLE 1. – ENGINE NO. 2 He SUPPLY (Continued)

<table>
<thead>
<tr>
<th>Measurement Number</th>
<th>Measurement Identification</th>
<th>Justification for FDA</th>
<th>MML</th>
</tr>
</thead>
<tbody>
<tr>
<td>V41P1250C</td>
<td>E₂ He Supply Press</td>
<td>Leak detection (preburn)</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leak detection (burn)</td>
<td>Software</td>
</tr>
<tr>
<td>V41P1254C</td>
<td>E₂ He Reg. Outlet Press</td>
<td>Leak detection (preburn)</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regulators/SOV failures (burn)</td>
<td>Software</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PM - Yes</td>
</tr>
<tr>
<td>*V41T1251A</td>
<td>E₂ He Supply Temp.</td>
<td>Heat and cold soak (preburn)</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leak detection only</td>
<td>Flight</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*Needed for ground checkout only.</td>
<td>PM - Yes</td>
</tr>
</tbody>
</table>

**Operating Functional Paths**

- \( \text{OFM 2} = (\text{ME 1}) (\text{ME 3}) \)
- \( \text{OFM 8} = (\text{OFM 2}) (\text{ME 8 + ME 9}) (\text{ME 17}) \)
<table>
<thead>
<tr>
<th>Measurement Number</th>
<th>Measurement Identification</th>
<th>Justification for FDA</th>
<th>MML</th>
</tr>
</thead>
<tbody>
<tr>
<td>V41P1350C</td>
<td>E₃ He Supply Press</td>
<td>Leak detection (preburn)</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leak detection (burn)</td>
<td>Software</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PM - No</td>
</tr>
<tr>
<td>V41P1354C</td>
<td>E₃ He Reg. Outlet Press</td>
<td>Leak detection (preburn)</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regulator/SOV failures (burn)</td>
<td>Software</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PM - Yes</td>
</tr>
<tr>
<td>V41T1251A</td>
<td>E₃ He Supply Temp</td>
<td>Heat and cold soak (preburn)</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leak detection only</td>
<td>Flight</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PM - Yes</td>
</tr>
</tbody>
</table>

*Needed for ground checkout only.

Operational Functional Paths

\[
\text{OFM 3} = (\text{ME 1}) (\text{ME 4})
\]

\[
\text{OFM 9} = (\text{OFM 3}) (\text{ME 10 + ME 11}) (\text{ME 20})
\]
<table>
<thead>
<tr>
<th>Measurement Number</th>
<th>Measurement Identification</th>
<th>Justification for FDA</th>
<th>MML</th>
</tr>
</thead>
<tbody>
<tr>
<td>V41P1600A</td>
<td>Pneumatic Valve He Supply Press</td>
<td>Leak detection (preburn)</td>
<td>Part 1 Flight PM - Yes</td>
</tr>
<tr>
<td>V41P1605A</td>
<td>Pneumatic Valve He Reg Outlet Press</td>
<td>Leak detection (preburn)</td>
<td>Part 1 Flight PM - Yes</td>
</tr>
<tr>
<td>*V41T1601A</td>
<td>Pneumatic Valve He Supply Temp</td>
<td>Heat and cold soak leak detection</td>
<td>Part 1 Flight PM - Yes</td>
</tr>
</tbody>
</table>

*Needed for ground checkout only.

Operating Functional Paths

\[
\text{OFA 4} = (\text{ME 1}) (\text{ME 5}) \\
\text{OFA 5} = (\text{OFA 4}) (\text{ME 12 + ME 13}) \text{ ME 23}
\]
TABLE 2. – LO₂ MONITORING FDA

<table>
<thead>
<tr>
<th>Measurement Number</th>
<th>Measurement Identification</th>
<th>Justification for FDA</th>
<th>MML</th>
</tr>
</thead>
<tbody>
<tr>
<td>T41P1750A</td>
<td>LO₂ Ullage Press #1</td>
<td>Primary repress monitoring and leak detection</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flight PM No</td>
</tr>
<tr>
<td>T41P1751A</td>
<td>LO₂ Ullage Press #2</td>
<td>Primary repress monitoring and leak detection</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flight PM No</td>
</tr>
<tr>
<td>T41P1752A</td>
<td>LO₂ Ullage Press #3</td>
<td>Primary repress monitoring and leak detection</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flight PM No</td>
</tr>
<tr>
<td>V41P1130C</td>
<td>El LO₂ Inlet Press</td>
<td>Crew display backup primary inlet monitor</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Software PM No</td>
</tr>
<tr>
<td>V41P1230C</td>
<td>E₂ LO₂ Inlet Press</td>
<td>Crew display backup inlet monitor primary</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Software PM No</td>
</tr>
<tr>
<td>Measurement Number</td>
<td>Measurement Identification</td>
<td>Justification for FDA</td>
<td>MML</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------</td>
<td>----------------------</td>
<td>-----</td>
</tr>
<tr>
<td>V41P1330C</td>
<td>E&lt;sub&gt;3&lt;/sub&gt; LO&lt;sub&gt;2&lt;/sub&gt; Inlet Press</td>
<td>Primary Crew Display backup inlet monitor</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td>V41P1354C</td>
<td>LO&lt;sub&gt;2&lt;/sub&gt; Feed Manifold Press</td>
<td>Correlation Crew Display Backup inlet monitor</td>
<td>Part 1 Software PM Yes</td>
</tr>
<tr>
<td>V41P1590A</td>
<td>GO&lt;sub&gt;2&lt;/sub&gt; Press Disc.</td>
<td>Correlation Repress fault isolation</td>
<td>Part 1 Flight PM Yes</td>
</tr>
<tr>
<td>V41X1516X</td>
<td>GO&lt;sub&gt;2&lt;/sub&gt; Press Disc. Valve Open</td>
<td>Correlation Repress Fault isolation</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td>V41X1517X</td>
<td>GO&lt;sub&gt;2&lt;/sub&gt; Press Disc Valve Closed</td>
<td>Correlation Repress fault isolation</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td>Measurement Number</td>
<td>Measurement Identification</td>
<td>Justification for FDA</td>
<td>MML</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------</td>
<td>-----------------------</td>
<td>-----</td>
</tr>
<tr>
<td>V41X1774E</td>
<td>LO₂ Vent Valve</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Closed</td>
<td>Repress fault isolation</td>
<td></td>
</tr>
<tr>
<td>V41X1776E</td>
<td>LO₂ Vent Valve</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Open</td>
<td>Repress fault isolation</td>
<td></td>
</tr>
<tr>
<td>V41X1778E</td>
<td>LO₂ Vent Valve</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Closed</td>
<td>Repress fault isolation</td>
<td></td>
</tr>
<tr>
<td>V41T1161A</td>
<td>E₁ GH₂ Outlet Temperature</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repress fault isolation</td>
<td></td>
</tr>
<tr>
<td>V41T1261A</td>
<td>E₂ GH₂ Outlet Temperature</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repress fault isolation</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 2. — LO₂ MONITORING FDA (Concluded)

<table>
<thead>
<tr>
<th>Measurement Number</th>
<th>Measurement Identification</th>
<th>Justification for FDA</th>
<th>MML</th>
</tr>
</thead>
<tbody>
<tr>
<td>V41T1361A</td>
<td>E₃ GH₂ Outlet Temperature</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repress fault isolation</td>
<td></td>
</tr>
<tr>
<td>Measurement Number</td>
<td>Measurement Identification</td>
<td>Justification for FDA</td>
<td>MML</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------</td>
<td>-----------------------</td>
<td>-----</td>
</tr>
<tr>
<td>V41P1300C</td>
<td>E₃ LH₂ Eng Inlet Press</td>
<td>Primary</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Backup crew display</td>
<td>Software</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eng. inlet monitor</td>
<td>PM No</td>
</tr>
<tr>
<td>V41P1434C</td>
<td>LH₂ Feed Manifold Press</td>
<td>Correlation</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Backup crew display</td>
<td>Software</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inlet fault detection</td>
<td>PM Yes</td>
</tr>
<tr>
<td>V41P1160A</td>
<td>GH₂ Outlet Press E₁</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repress Failure isolation</td>
<td></td>
</tr>
<tr>
<td>V41P1260A</td>
<td>GH₂ Outlet Press E₂</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repress Failure isolation</td>
<td></td>
</tr>
<tr>
<td>V41P1360A</td>
<td>GH₂ Outlet Press E₃</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repress Failure isolation</td>
<td></td>
</tr>
<tr>
<td>Measurement Number</td>
<td>Measurement Identification</td>
<td>Justification for FDA</td>
<td>MML</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------</td>
<td>-----------------------</td>
<td>-----</td>
</tr>
<tr>
<td>T41P1700A</td>
<td>LH₂ Ullage</td>
<td>Primary</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td>Press #1</td>
<td>Repress Failure Isolation</td>
<td>Flight</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leak Detection</td>
<td>PM Yes</td>
</tr>
<tr>
<td>T41P1701A</td>
<td>LH₂ Ullage</td>
<td>Primary</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td>Press #2</td>
<td>Repress Failure Isolation</td>
<td>Flight</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leak Detection</td>
<td>PM Yes</td>
</tr>
<tr>
<td>T41P1702A</td>
<td>LH₂ Ullage</td>
<td>Primary</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td>Press #3</td>
<td>Repress Failure Isolation</td>
<td>Flight</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leak Detection</td>
<td></td>
</tr>
<tr>
<td>V41P1100C</td>
<td>E₁ LH₂ Eng.</td>
<td>Primary</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td>Inlet Press</td>
<td>Backup Crew Disposition</td>
<td>Software</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eng. Inlet Monitor</td>
<td>PM No</td>
</tr>
<tr>
<td>V41P1200C</td>
<td>E₂ LH₂ Eng.</td>
<td>Primary</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td>Inlet Press</td>
<td>Backup Crew Disposition</td>
<td>Software</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eng. Inlet Monitor</td>
<td>PM No</td>
</tr>
<tr>
<td>Measurement Number</td>
<td>Measurement Identification</td>
<td>Justification for FDA</td>
<td>MML</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------------</td>
<td>----------------------</td>
<td>-----</td>
</tr>
<tr>
<td>V41P1490A</td>
<td>GH₂ Press Disc.</td>
<td>Correlation</td>
<td>Part 1 Flight PM Yes</td>
</tr>
<tr>
<td>T41X1724E</td>
<td>LH₂ Vent Valve #1 Closed</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td>T41X1126E</td>
<td>LH₂ Vent Valve #1 Open</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td>T41X1744E</td>
<td>LH₂ Vent Valve #2 Closed</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td>T41X1746E</td>
<td>LH₂ Vent Valve #2 Open</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td>Measurement Number</td>
<td>Measurement Identification</td>
<td>Justification for FDA</td>
<td>MML</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------</td>
<td>-----------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>V41X1416E</td>
<td>GH₂ Press Disc. Valve Open</td>
<td>Correlation</td>
<td>Part 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repress Failure Isolation</td>
<td>Software PM No</td>
</tr>
<tr>
<td>V41X1417E</td>
<td>GH₂ Press Disc. Valve Closed</td>
<td>Correlation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repress Failure Isolation</td>
<td></td>
</tr>
<tr>
<td>Measurement Number</td>
<td>Measurement Identification</td>
<td>Justification for FDA</td>
<td>MML</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------------</td>
<td>------------------------</td>
<td>-----</td>
</tr>
<tr>
<td>T21 OFI List</td>
<td>Eng. Comp.</td>
<td>Over Temp. Monitoring</td>
<td></td>
</tr>
<tr>
<td>V41 None</td>
<td>Amb. Temp. 1</td>
<td>During burns</td>
<td></td>
</tr>
<tr>
<td>T22 OFI List</td>
<td>Eng. Comp.</td>
<td>Over Temp. Monitoring</td>
<td></td>
</tr>
<tr>
<td>V41 None</td>
<td>Amb. Temp. 2</td>
<td>During burns</td>
<td></td>
</tr>
<tr>
<td>Present Data Word Assignment</td>
<td>Measurement Identification</td>
<td>Justification for FDA</td>
<td>MML</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------------</td>
<td>----------------------</td>
<td>------</td>
</tr>
<tr>
<td>DW-1</td>
<td>Engine Identification</td>
<td>Primary Data Tag</td>
<td></td>
</tr>
<tr>
<td>DW-2</td>
<td>Engine Identification</td>
<td>Primary Data Tag</td>
<td></td>
</tr>
<tr>
<td>DW-3</td>
<td>ME Status</td>
<td>Precondition checks</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td>DW-5</td>
<td>Thrust</td>
<td>Correlation for Eng. Inlet Press</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td>DW-6</td>
<td>Failure ID</td>
<td>Primary Failure Annunciation</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td>DW-7</td>
<td>Test Data</td>
<td>Correlation Fault Annunciation</td>
<td>Part 1 Software PM No</td>
</tr>
</tbody>
</table>
TABLE 5. — CONTROLLER DATA WORDS FOR FDA (Continued)

<table>
<thead>
<tr>
<th>Present Data Word Assignment</th>
<th>Measurement Identification</th>
<th>Justification for FDA</th>
<th>MML</th>
</tr>
</thead>
<tbody>
<tr>
<td>DW-8</td>
<td>Parameter Value</td>
<td>Correlation Fault Annunciation</td>
<td></td>
</tr>
<tr>
<td>DW-40</td>
<td>HPFTP</td>
<td>Monitoring During</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td></td>
<td>Disc Temp</td>
<td>Limit Inhibit</td>
<td></td>
</tr>
<tr>
<td>DW-41</td>
<td>HPFT Shaft Speed</td>
<td>Monitoring During</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disc. Press</td>
<td>Limit Inhibit</td>
<td></td>
</tr>
<tr>
<td>DW-54</td>
<td>HPOTP</td>
<td>Monitoring During</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disc. Temp.</td>
<td>Limit Inhibit</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td>DW-55</td>
<td>HPOT Booster</td>
<td>Monitoring During</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stage Press Disc.</td>
<td>Limit Inhibit</td>
<td></td>
</tr>
<tr>
<td>DW-56</td>
<td>HPOT Booster</td>
<td>Monitoring During</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stage Press Disc.</td>
<td>Limit Inhibit</td>
<td></td>
</tr>
<tr>
<td>Present Word Data Word Assignment</td>
<td>Measurement Identification</td>
<td>Justification for FDA</td>
<td>MML</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------</td>
<td>-----------------------</td>
<td>-----</td>
</tr>
<tr>
<td>DW-57</td>
<td>HPOT Shaft Speed</td>
<td>Monitoring During Limit Inhibit</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td>DW-64</td>
<td>Ox - Tank Pressurant Press</td>
<td>Monitoring During Limit Inhibit</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td>DW-65</td>
<td>Ox - Tank Pressurant Press</td>
<td>Monitoring During Limit Inhibit</td>
<td>Part 1 Software PM No</td>
</tr>
<tr>
<td>DW-76</td>
<td>HPOT Intermediate Seal Purge Press</td>
<td>Monitoring During Limit Inhibit</td>
<td></td>
</tr>
<tr>
<td>CODE</td>
<td>MEASUREMENT #</td>
<td>NAME</td>
<td>RANGE</td>
</tr>
<tr>
<td>------</td>
<td>---------------</td>
<td>------------------</td>
<td>--------</td>
</tr>
<tr>
<td>P1T</td>
<td>T41P1750A</td>
<td>LO₂ Ullage Press #1</td>
<td>0-30 psia</td>
</tr>
<tr>
<td>P2T</td>
<td>T41P1751A</td>
<td>LO₂ Ullage Press #2</td>
<td>0-30 psia</td>
</tr>
<tr>
<td>P3T</td>
<td>T41P1752A</td>
<td>LO₂ Ullage Press #3</td>
<td>0-30 psia</td>
</tr>
<tr>
<td>P4T</td>
<td>T41P1700A</td>
<td>LH₂ Ullage Press #1</td>
<td>0-50 psia</td>
</tr>
<tr>
<td>P5T</td>
<td>T41P1701A</td>
<td>LH₂ Ullage Press #2</td>
<td>0-50 psia</td>
</tr>
<tr>
<td>P6T</td>
<td>T41P1702A</td>
<td>LH₂ Ullage Press #3</td>
<td>0-50 psia</td>
</tr>
<tr>
<td>T1T</td>
<td>T41T1755A</td>
<td>LO₂ Ullage Temp</td>
<td>-430 - 40° F</td>
</tr>
<tr>
<td>T2T</td>
<td>T41T1705A</td>
<td>LH₂ Ullage Temp</td>
<td>-430 - 40° F</td>
</tr>
</tbody>
</table>

*Purpose code defined in Master Measurement List, Volume 1.
<table>
<thead>
<tr>
<th>CODE</th>
<th>MEASUREMENT #</th>
<th>NAME</th>
<th>RANGE</th>
<th>PURPOSE</th>
<th>S/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1T</td>
<td>T41X1730X</td>
<td>LH₂ Depletion Sensor #1</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X2T</td>
<td>T41X1731X</td>
<td>LH₂ Depletion Sensor #2</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X3T</td>
<td>T41X1732X</td>
<td>LH₂ Depletion Sensor #3</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X4T</td>
<td>T41X1733X</td>
<td>LH₂ Depletion Sensor #4</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X6T</td>
<td>T41X1760E</td>
<td>LO₂ Liquid Level 2% #1</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X7T</td>
<td>T41X1761E</td>
<td>LO₂ Liquid Level 2% #2</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X8T</td>
<td>T41X1762E</td>
<td>LO₂ Liquid Level 5%</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X9T</td>
<td>T41X1765E</td>
<td>LO₂ Liquid Level 98% #1</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X10T</td>
<td>T41X1766E</td>
<td>LO₂ Liquid Level 98% #2</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X11T</td>
<td>T41X1767E</td>
<td>LO₂ Liquid Level 99.85%</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X12T</td>
<td>T41X1768E</td>
<td>LO₂ Liquid Level 100% #1</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X13T</td>
<td>T41X1769E</td>
<td>LO₂ Liquid Level 100% #2</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X14T</td>
<td>T41X1770E</td>
<td>LO₂ Liquid Level 100.15%</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X15T</td>
<td>T41X1771E</td>
<td>LO₂ Liquid Level 102%</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X16T</td>
<td>T41X1710E</td>
<td>LH₂ Liq Level 2% #1</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X17T</td>
<td>T41X1711E</td>
<td>LH₂ Liq Level 2% #2</td>
<td>8</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X18T</td>
<td>T41X1712E</td>
<td>LH₂ Liq Level 5%</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X19T</td>
<td>T41X1715E</td>
<td>LH₂ Liq Level 98% #1</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CODE</td>
<td>MEASUREMENT #</td>
<td>NAME</td>
<td>RANGE</td>
<td>PURPOSE</td>
<td>S/S</td>
</tr>
<tr>
<td>-------</td>
<td>----------------</td>
<td>---------------------------</td>
<td>-------</td>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>X20T</td>
<td>T41X1716E</td>
<td>LH₂ Liq Level 98% #1</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X21T</td>
<td>T41X1717E</td>
<td>LH₂ Liq Level 99.7%</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X22T</td>
<td>T41X1718E</td>
<td>LH₂ Liq Level 100% #1</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X23T</td>
<td>T41X1719E</td>
<td>LH₂ Liq Level 100% #2</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X24T</td>
<td>T411720E</td>
<td>LH₂ Liq Level 100.3%</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X25T</td>
<td>T41X1721E</td>
<td>LH₂ Liq Level 102%</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X26T</td>
<td>T41X1776E</td>
<td>LO₂ Vent Valve #1 Open</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X27T</td>
<td>T41X1774E</td>
<td>LO₂ Vent Valve #1 Closed</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X28T</td>
<td>T41X1780E</td>
<td>LO₂ Vent Valve #2 Open</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X29T</td>
<td>T41X1778E</td>
<td>LO₂ Vent Valve #2 Closed</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X30T</td>
<td>T41X1726E</td>
<td>LH₂ Vent Valve #1 Open</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X31T</td>
<td>T41X1724E</td>
<td>LH₂ Vent Valve #1 Closed</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X32T</td>
<td>T41X1746E</td>
<td>LH₂ Vent Valve #2 Open</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>X33T</td>
<td>T41X1744E</td>
<td>LH₂ Vent Valve #2 Closed</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>CODE</td>
<td>MEASUREMENT #</td>
<td>NAME</td>
<td>RANGE</td>
<td>PURPOSE</td>
<td>S/S</td>
</tr>
<tr>
<td>------</td>
<td>---------------</td>
<td>-----------------------------</td>
<td>-------------</td>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>P1</td>
<td>V41P1130C</td>
<td>E₁ LO₂ Eng Inlet Press</td>
<td>0-400 psia</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>P2</td>
<td>V41P1230C</td>
<td>E₂ LO₂ Eng Inlet Press</td>
<td>0-400 psia</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>P3</td>
<td>V41P1330C</td>
<td>E₃ LO₂ Eng Inlet Press</td>
<td>0-400 psia</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>P4</td>
<td>V41P1534C</td>
<td>LO₂ Feed Manifold Press</td>
<td>0-400 psia</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>P5</td>
<td>V41P1100C</td>
<td>E₁ LH₂ Eng Inlet Press</td>
<td>0-200 psia</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>P6</td>
<td>V41P1200C</td>
<td>E₂ LH₂ Eng Inlet Press</td>
<td>0-200 psia</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>P7</td>
<td>V41P1300C</td>
<td>E₃ LH₂ Eng Inlet Press</td>
<td>0-200 psia</td>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>P8</td>
<td>V41P1434C</td>
<td>LH₂ Feed Manifold Press</td>
<td>0-200 psia</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>P9</td>
<td>V41P1160A</td>
<td>E₁ GH₂ Outlet Press</td>
<td>0-5000 psia</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>P10</td>
<td>V41P1260A</td>
<td>E₂ GH₂ Outlet Press</td>
<td>0-5000 psia</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>P11</td>
<td>V41P1360A</td>
<td>E₃ GH₂ Outlet Press</td>
<td>0-5000 psia</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>P12</td>
<td>V41P1150C</td>
<td>E₁ He Supply Press</td>
<td>0-5000 psia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>P13</td>
<td>V41P1250C</td>
<td>E₂ He Supply Press</td>
<td>0-5000 psia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>P14</td>
<td>V41P1350C</td>
<td>E₃ He Supply Press</td>
<td>0-5000 psia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>P15</td>
<td>V41P1600A</td>
<td>Pneu Valve He Supply Press</td>
<td>0-5000 psia</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>P16</td>
<td>V41P1154C</td>
<td>E₁ He Reg. Outlet Press</td>
<td>0-1000 psia</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>P17</td>
<td>V41P1254C</td>
<td>E₂ He Reg. Outlet Press</td>
<td>0-1000 psia</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>P18</td>
<td>V41P1354C</td>
<td>E₃ He Reg. Outlet Press</td>
<td>0-1000 psia</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>
### TABLE 6. — MPS OFI INSTRUMENTATION LIST (Continued)

**ORBITER PRESSURES**

<table>
<thead>
<tr>
<th>CODE</th>
<th>MEASUREMENT #</th>
<th>NAME</th>
<th>RANGE</th>
<th>PURPOSE</th>
<th>S/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>P19</td>
<td>V41P1605A</td>
<td>Pneu Valve H₂ Reg. Outlet Press</td>
<td>0-1000 psia</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>P20</td>
<td>V41P1590A</td>
<td>GO₂ Press Disc Press</td>
<td>0-1000 psia</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>P21</td>
<td>V41P1490A</td>
<td>GH₂ Press Disc Press</td>
<td>0-1000 psia</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>P22</td>
<td></td>
<td>LO₂ Tank ΔP</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>P23</td>
<td></td>
<td>LH₂ Tank ΔP</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>CODE</td>
<td>MEASUREMENT #</td>
<td>NAME</td>
<td>RANGE</td>
<td>PURPOSE</td>
<td>S/S</td>
</tr>
<tr>
<td>--------</td>
<td>---------------</td>
<td>------------------------------------</td>
<td>------------------</td>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>T1</td>
<td>V41T1131C</td>
<td>E1 LO₂ Eng Inlet Temp</td>
<td>-320 to -270° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T2</td>
<td>V41T1231C</td>
<td>E2 LO₂ Eng Inlet Temp</td>
<td>-320 to -270° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T3</td>
<td>V41T1331C</td>
<td>E3 LO₃ Eng Inlet Temp</td>
<td>-320 to -270° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>*T4</td>
<td>V41T1528A</td>
<td>LO₂ Feed Manifold Disc Temp</td>
<td>-325 to +125° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T5</td>
<td>V41T1101C</td>
<td>E1 LH₂ Eng Inlet Temp</td>
<td>-430 to -370° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T6</td>
<td>V41T1201C</td>
<td>E2 LH₂ Eng Inlet Temp</td>
<td>-430 to -370° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T7</td>
<td>V41T1301C</td>
<td>E3 LH₂ Eng Inlet Temp</td>
<td>-430 to -370° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T8</td>
<td>V41T1428A</td>
<td>LH₂ Feed Manifold Disc Temp</td>
<td>-430 to -379° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T9</td>
<td>V41T1171A</td>
<td>E1 GO₂ Outlet Temp</td>
<td>-250 to +1000° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T10</td>
<td>V41T1271A</td>
<td>E2 GO₂ Outlet Temp</td>
<td>-250 to +1000° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T11</td>
<td>V41T1371A</td>
<td>E3 GO₂ Outlet Temp</td>
<td>-250 to +1000° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T12</td>
<td>V41T1591A</td>
<td>GO₂ Press Disc Temp</td>
<td>-250 to +1000° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T13</td>
<td>V41T1161A</td>
<td>E1 GH₂ Outlet Temp</td>
<td>-65 to +500° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T14</td>
<td>V41T1261A</td>
<td>E2 GH₂ Outlet Temp</td>
<td>-65 to +500° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T15</td>
<td>V41T1361A</td>
<td>E3 GH₂ Outlet Temp</td>
<td>-65 to +500° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T16</td>
<td>V41T1491A</td>
<td>GH₂ Press Disc Temp</td>
<td>-65 to +500° F</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>T17</td>
<td>V41T1601A</td>
<td>Pneu Valve Hₑ Supply Temp</td>
<td>-65 to +500° F</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>T18</td>
<td>V41T1151A</td>
<td>E1 Hₑ Supply Temp</td>
<td>-65 to +500° F</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>CODE</td>
<td>MEASUREMENT #</td>
<td>NAME</td>
<td>RANGE</td>
<td>PURPOSE</td>
<td>S/S</td>
</tr>
<tr>
<td>------</td>
<td>---------------</td>
<td>-----------------------</td>
<td>---------------</td>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>T19</td>
<td>V41T1251A</td>
<td>E2 $H_e$ Supply Temp</td>
<td>-65 to +500° F</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>T20</td>
<td>V41T1351A</td>
<td>E3 $H_e$ Supply Temp</td>
<td>-65 to +500° F</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>T21</td>
<td></td>
<td>Eng Comp Amb Temp #1</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>T22</td>
<td></td>
<td>Eng Comp Amb Temp #2</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>T23</td>
<td>V41T1060A</td>
<td>E1 Controller H/W Temp</td>
<td>-200 to +400° F</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>T24</td>
<td>V41T1061A</td>
<td>E2 Controller H/W Temp</td>
<td>-200 to +400° F</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>T25</td>
<td>V41T1062A</td>
<td>E3 Controller H/W Temp</td>
<td>-200 to +400° F</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
### TABLE 6. MPS OFI INSTRUMENTATION LIST (Continued)

#### ORBITER DISCRETES

<table>
<thead>
<tr>
<th>CODE</th>
<th>MEASUREMENT #</th>
<th>NAME</th>
<th>LOW</th>
<th>HIGH</th>
<th>PURPOSE</th>
<th>S/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>V41X1580X</td>
<td>LO₂ Depletion Sensor #1 Wet</td>
<td>Dry</td>
<td></td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>X2</td>
<td>V41X1582X</td>
<td>LO₂ Depletion Sensor #2 Wet</td>
<td>Dry</td>
<td></td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>X3</td>
<td>V41X1584X</td>
<td>LO₂ Depletion Sensor #3 Wet</td>
<td>Dry</td>
<td></td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>X4</td>
<td>V41X1586X</td>
<td>LO₂ Depletion Sensor #4 Wet</td>
<td>Dry</td>
<td></td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>X6</td>
<td>V41X1510E</td>
<td>LO₂ InB Fill Valve Open</td>
<td></td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X7</td>
<td>V41X1509X</td>
<td>LO₂ InB Fill Valve Closed On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X8</td>
<td>V41X1413E</td>
<td>LO₂ OutB Fill Valve Open</td>
<td></td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X9</td>
<td>V41X1514X</td>
<td>LO₂ OutB Fill Valve Closed On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X10</td>
<td>V41X1409E</td>
<td>LH₂ InB Fill Valve Open</td>
<td></td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X11</td>
<td>V41X1410X</td>
<td>LH₂ InB Fill Valve Closed On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X12</td>
<td>V41X1413E</td>
<td>LH₂ OutB Fill Valve Open</td>
<td></td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X13</td>
<td>V41X1414X</td>
<td>LH₂ OutB Fill Valve Closed On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>X14</td>
<td>V41X1553E</td>
<td>LH₂ Topping Fill Valve Open</td>
<td></td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X15</td>
<td>V41X1456X</td>
<td>LH₂ Topping Fill Valve Closed</td>
<td></td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X16</td>
<td>V41X1134X</td>
<td>E1 LO₂ Pre Valve Open</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X17</td>
<td>V41X1234X</td>
<td>E2 LO₂ Pre Valve Open</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>CODE</td>
<td>MEASUREMENT #</td>
<td>NAME</td>
<td>LOW</td>
<td>HIGH</td>
<td>PURPOSE</td>
<td>S/S</td>
</tr>
<tr>
<td>------</td>
<td>----------------</td>
<td>---------------------</td>
<td>-----</td>
<td>------</td>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>X18</td>
<td>V41X1334E</td>
<td>E3 LO\textsubscript{2} Pre Valve Open</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X19</td>
<td>V41X1135E</td>
<td>E1 LO\textsubscript{2} Pre Valve Closed</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X20</td>
<td>V41X1235E</td>
<td>E2 LO\textsubscript{2} Pre Valve Closed</td>
<td></td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>X21</td>
<td>V41X1335E</td>
<td>E3 LO\textsubscript{2} Pre Valve Closed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X22</td>
<td>V41X1104E</td>
<td>E1 LH\textsubscript{2} Pre Valve Open</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X23</td>
<td>V41X1204X</td>
<td>E2 LH\textsubscript{2} Pre Valve Open</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X24</td>
<td>V41X1304E</td>
<td>E3 LH\textsubscript{2} Pre Valve Open</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X25</td>
<td>V41X1105E</td>
<td>E1 LH\textsubscript{2} Pre Valve Closed</td>
<td></td>
<td></td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X26</td>
<td>V41X1205E</td>
<td>E2 LH\textsubscript{2} Pre Valve Closed</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X27</td>
<td>V41X1305E</td>
<td>E3 LH\textsubscript{2} Pre Valve Closed</td>
<td></td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>X28</td>
<td>V41X1109E</td>
<td>E1 LH\textsubscript{2} Recirc Valve Open</td>
<td>On</td>
<td>Off</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>X29</td>
<td>V41X1209E</td>
<td>E2 LH\textsubscript{2} Recirc Valve Open</td>
<td>On</td>
<td>Off</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>X30</td>
<td>V41X1309E</td>
<td>E3 LH\textsubscript{2} Recirc Valve Open</td>
<td>On</td>
<td>Off</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>X31</td>
<td>V41X1110E</td>
<td>E1 LH\textsubscript{2} Recirc Valve Closed</td>
<td>On</td>
<td>Off</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>X32</td>
<td>V41X1210E</td>
<td>E2 LH\textsubscript{2} Recirc Valve Closed</td>
<td>On</td>
<td>Off</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>X33</td>
<td>V41X1310E</td>
<td>E3 LH\textsubscript{2} Recirc Valve Closed</td>
<td>On</td>
<td>Off</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>CODE</td>
<td>MEASUREMENT #</td>
<td>NAME</td>
<td>LOW</td>
<td>HIGH</td>
<td>PURPOSE</td>
<td>S/S</td>
</tr>
<tr>
<td>------</td>
<td>---------------</td>
<td>------</td>
<td>-----</td>
<td>------</td>
<td>---------</td>
<td>-----</td>
</tr>
<tr>
<td>*X34</td>
<td>V41X1545E</td>
<td>LO₂ RSV Open</td>
<td>9</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X35</td>
<td>V41X1546X</td>
<td>LO₂ RSV Closed</td>
<td>9</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X36</td>
<td>V41X1445E</td>
<td>LH₂ RSV Open</td>
<td>9</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X37</td>
<td>V41X1446E</td>
<td>LH₂ RSV Closed</td>
<td>9</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X38</td>
<td>V41X1529X</td>
<td>LO₂ F/L Disc Valve Open</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X39</td>
<td>V41X1530E</td>
<td>LO₂ F/L Disc Valve Closed</td>
<td>9</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X40</td>
<td>V41X1429X</td>
<td>LH₂ F/L Disc Valve Open</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X41</td>
<td>V41X1430E</td>
<td>LH₂ F/L Disc Valve Closed</td>
<td>9</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X42</td>
<td>V41X1419E</td>
<td>LH₂ Recirc Disc Valve Open</td>
<td>On</td>
<td>Off</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>X43</td>
<td>V41X1420E</td>
<td>LH₂ Recirc Disc Valve Closed</td>
<td>4</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X44</td>
<td>V41X1516X</td>
<td>GO₂ Press Disc Valve Open</td>
<td>On</td>
<td>Off</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>X45</td>
<td>V41X1517E</td>
<td>GO₂ Press Disc Valve Closed</td>
<td>9</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X46</td>
<td>V41X1415E</td>
<td>GH₂ Press Disc Valve Open</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X47</td>
<td>V41X1417E</td>
<td>GH₂ Press Disc Valve Closed</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### ORBITER SPEEDS

<table>
<thead>
<tr>
<th>CODE</th>
<th>MEASUREMENT #</th>
<th>NAME</th>
<th>UNITS</th>
<th>PURPOSE</th>
<th>S/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>V41R1115A</td>
<td>E1 LH₂ Recirc Pump Speed</td>
<td>RPM</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>R2</td>
<td>V41R1215A</td>
<td>E2 LH₂ Recirc Pump Speed</td>
<td>RPM</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>R3</td>
<td>V41R1315A</td>
<td>E3 LH₂ Recirc Pump Speed</td>
<td>RPM</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>
4.0 MEASUREMENT TO FUNCTIONAL PATH CORRELATION

The operational instrumentation measurements required for FDA are compiled in table 7. The normal operating range, functional path correlation, and mission phases to be monitored are also tabulated.
<table>
<thead>
<tr>
<th>MEASUREMENT</th>
<th>TYPE*</th>
<th>RANGE</th>
<th>FUNCTIONAL PATH</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1151A</td>
<td>P*</td>
<td>500 - 580°</td>
<td>ME 2</td>
<td>Preburn only</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1150C</td>
<td>P</td>
<td>(See fig. 9)</td>
<td>OFM 7</td>
<td>Curve fit for burns</td>
</tr>
<tr>
<td>P1154C</td>
<td>P</td>
<td>715 - 785</td>
<td>OFM 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSIA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1251A</td>
<td>P</td>
<td>500 - 580°</td>
<td>ME 3</td>
<td>Preburn only</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1250C</td>
<td>P</td>
<td>(See fig. 9)</td>
<td>OFM 8</td>
<td>Curve fit for burns</td>
</tr>
<tr>
<td>P1254C</td>
<td>P</td>
<td>715 - 785</td>
<td>OFM 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSIA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1351A</td>
<td>P</td>
<td>500 - 580°</td>
<td>ME 4</td>
<td>Preburn only</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1350C</td>
<td>P</td>
<td>(See fig. 9)</td>
<td>OFM 9</td>
<td>Curve fit for burns</td>
</tr>
<tr>
<td>P1354C</td>
<td>P</td>
<td>715 - 785</td>
<td>OFM 9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSIA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1601A</td>
<td>P</td>
<td>500 - 580°</td>
<td>ME 5</td>
<td>Preburn only</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1600C</td>
<td>P</td>
<td>(See fig. 9)</td>
<td>OFM 5</td>
<td>Profile fit</td>
</tr>
<tr>
<td>P1605C</td>
<td>P</td>
<td>715 - 785</td>
<td>OFM 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSIA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controller DW 5</td>
<td></td>
<td></td>
<td></td>
<td>See Table 5</td>
</tr>
</tbody>
</table>

*P = Primary
### TABLE 7. – PMS MEASUREMENT DATA
#### MAIN PROPULSION SUBSYSTEM (Continued)

<table>
<thead>
<tr>
<th>MEASUREMENT</th>
<th>TYPE</th>
<th>RANGE</th>
<th>FUNCTIONAL PATH</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T41P1750A</td>
<td>P</td>
<td>20-27 psia</td>
<td>OFM 10-11-12</td>
<td>Vote 2 of 3 = good.</td>
</tr>
<tr>
<td>T41P1751A</td>
<td>P</td>
<td>20-27 psia</td>
<td>OFM 10-11-12</td>
<td>Vote 2 of 3 = good.</td>
</tr>
<tr>
<td>T41P1752A</td>
<td>P</td>
<td>20-27 psia</td>
<td>OFM 10-11-12</td>
<td>Vote 2 of 3 = good.</td>
</tr>
<tr>
<td>V41P1590A*</td>
<td>S*</td>
<td>1000 – 5500 psia</td>
<td>OFM 10-11-12</td>
<td>Max. Min. limit PM limit may be different.</td>
</tr>
<tr>
<td>V41X1516X</td>
<td>S</td>
<td>Event</td>
<td>OFM 10-11-12</td>
<td></td>
</tr>
<tr>
<td>V41X1517X</td>
<td>S</td>
<td>Event</td>
<td>OFM 10-11-12</td>
<td></td>
</tr>
<tr>
<td>V41X1774E</td>
<td>S</td>
<td>Event</td>
<td>OFM 10-11-12</td>
<td></td>
</tr>
<tr>
<td>V41X1776E</td>
<td>S</td>
<td>Event</td>
<td>OFM 10-11-12</td>
<td></td>
</tr>
<tr>
<td>V41X1778E</td>
<td>S</td>
<td>Event</td>
<td>OFM 10-11-12</td>
<td></td>
</tr>
<tr>
<td>V41X1780E</td>
<td>S</td>
<td>Event</td>
<td>OFM 10-11-12</td>
<td></td>
</tr>
<tr>
<td>V41P1130C</td>
<td>P</td>
<td>23.3 - 375 psia</td>
<td>OFM 10</td>
<td>Max. Min. limits may be difficult.</td>
</tr>
<tr>
<td>V41P1230C</td>
<td>P</td>
<td>23.3 - 375 psia</td>
<td>OFM 11</td>
<td>Max. Min. limits may be difficult.</td>
</tr>
<tr>
<td>V41P1330C</td>
<td>P</td>
<td>23.3 - 375 psia</td>
<td>OFM 12</td>
<td>Max. Min. limits may be difficult.</td>
</tr>
<tr>
<td>V41P1534C</td>
<td>S</td>
<td>23.3 - 375 psia</td>
<td>OFM 10-11-12</td>
<td>Max. Min. limits may be difficult.</td>
</tr>
<tr>
<td>V41P1100C</td>
<td>P</td>
<td>20-130 psia</td>
<td>OFM 13</td>
<td>Limits are Min. and Max. spike. Require further refinement.</td>
</tr>
</tbody>
</table>

*S = Correlation
<table>
<thead>
<tr>
<th>MEASUREMENT</th>
<th>TYPE</th>
<th>RANGE</th>
<th>FUNCTIONAL PATH</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>V41P1200C</td>
<td>P</td>
<td>20-130 psia</td>
<td>OFM 14</td>
<td>Limits are Min. and Max. spike. Require further refinement.</td>
</tr>
<tr>
<td>V41P1300C</td>
<td>P</td>
<td>20-130 psia</td>
<td>OFM 15</td>
<td>Limits are Min. and Max. spike. Require further refinement.</td>
</tr>
<tr>
<td>V41P1434C</td>
<td>S</td>
<td>20-130 psia</td>
<td>OFM 13-14-15</td>
<td></td>
</tr>
<tr>
<td>V41X1726E</td>
<td>S</td>
<td></td>
<td>OFM 13-14-15</td>
<td></td>
</tr>
<tr>
<td>V41X1724E</td>
<td>S</td>
<td></td>
<td>OFM 13-14-15</td>
<td></td>
</tr>
<tr>
<td>V41X1746E</td>
<td>S</td>
<td></td>
<td>OFM 13-14-15</td>
<td></td>
</tr>
<tr>
<td>V411744E</td>
<td>S</td>
<td></td>
<td>OFM 13-14-15</td>
<td></td>
</tr>
<tr>
<td>V41X1516E</td>
<td>S</td>
<td></td>
<td>OFM 13-14-15</td>
<td></td>
</tr>
<tr>
<td>V41X1517E</td>
<td>S</td>
<td></td>
<td>OFM 13-14-15</td>
<td></td>
</tr>
<tr>
<td>V41X1490A</td>
<td>S</td>
<td>1500-4500 psia</td>
<td>OFM 13-14-15</td>
<td>Max. Min. limit PM limit may be different</td>
</tr>
<tr>
<td>V41P1160A</td>
<td>S</td>
<td>TBD</td>
<td>OFM 13</td>
<td></td>
</tr>
<tr>
<td>V41P1260A</td>
<td>S</td>
<td>TBD</td>
<td>OFM 14</td>
<td></td>
</tr>
<tr>
<td>V41P1360A</td>
<td>S</td>
<td>TBD</td>
<td>OFM 15</td>
<td></td>
</tr>
<tr>
<td>V41S1611E</td>
<td>Precond.</td>
<td>On - Off</td>
<td>OFM 13</td>
<td>Precondition check</td>
</tr>
<tr>
<td>V41S1613E</td>
<td>Precond.</td>
<td>On - Off</td>
<td>Precondition check</td>
<td></td>
</tr>
<tr>
<td>V411616E</td>
<td>Precond.</td>
<td>On - Off</td>
<td>Precondition check</td>
<td></td>
</tr>
<tr>
<td>V41S1613E</td>
<td>Precond.</td>
<td>On - Off</td>
<td>Precondition check</td>
<td></td>
</tr>
<tr>
<td>V41S1616E</td>
<td>Precond.</td>
<td>On - Off</td>
<td>Precondition check</td>
<td></td>
</tr>
<tr>
<td>T21 (OFI List)</td>
<td></td>
<td></td>
<td>Environment</td>
<td></td>
</tr>
<tr>
<td>T22 (OFI List)</td>
<td></td>
<td></td>
<td>Environment</td>
<td></td>
</tr>
</tbody>
</table>
5.0 MEASUREMENT LIMITS FOR FAULT DETECTION AND ANNUNCIATION

Table 8 defines the hard limits to be used for FDA, and the correlation checks required in the event a primary measurement fails the hard limit check.

Soft limits have not been included since they are not yet defined.
<table>
<thead>
<tr>
<th>PMS ACTIVITY</th>
<th>PRE-CONDITION TEST</th>
<th>SOFT LIMIT CHECK</th>
<th>HARD LIMIT CHECK</th>
<th>BACKUP CAUTION &amp; WARNING</th>
<th>CORRELATION CHECK</th>
<th>SYSTEM STATUS LIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>V41P1350C (P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E3 He Supply P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41P1354C (P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E3 He Reg Outlet P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1601A (S)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneu Valve He</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41P1600A (P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneu Valve He Supply Press</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SUBSYSTEM:** Main Propulsion

**TABLE 8. — PMS MEASUREMENT REQUIREMENTS**

*Fig. 11*

<table>
<thead>
<tr>
<th>SYSTEM DATA:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• MEASUREMENT NO.</td>
</tr>
<tr>
<td>• MEASUREMENT ID</td>
</tr>
<tr>
<td>• FUNCTIONAL PATH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEASUREMENT ID</th>
<th>FUNCTIONAL PATH</th>
</tr>
</thead>
<tbody>
<tr>
<td>* V41P1350C (P)</td>
<td></td>
</tr>
<tr>
<td>E3 He Supply P</td>
<td></td>
</tr>
<tr>
<td>OFM 9</td>
<td></td>
</tr>
<tr>
<td>* V41P1354C (P)</td>
<td></td>
</tr>
<tr>
<td>E3 He Reg Outlet P</td>
<td></td>
</tr>
<tr>
<td>OFM 9</td>
<td></td>
</tr>
<tr>
<td>T1601A (S)</td>
<td></td>
</tr>
<tr>
<td>Pneu Valve He</td>
<td></td>
</tr>
<tr>
<td>ME 5</td>
<td></td>
</tr>
<tr>
<td>* V41P1600A (P)</td>
<td></td>
</tr>
<tr>
<td>Pneu Valve He Supply Press</td>
<td></td>
</tr>
<tr>
<td>OFM 5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HARDWARE STATUS</th>
<th>CONFIGURATION CHECK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONFIGURATION CHECK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HIGH</th>
<th>LOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>715</td>
<td>785</td>
</tr>
</tbody>
</table>

| psia | psia |

| psia | psia |

| 500°R | 580°R |

| 500°R | 580°R |

| 1601 | 1605 |

| 1351 | 1354 |

| 1351 | 1354 |

| 1601 | 1605 |

| 1601 | 1605 |
### Table 8: PMS Measurement Requirements (Continued)

**Subsystem:** Main Propulsion

<table>
<thead>
<tr>
<th>PMS Activity</th>
<th>Pre-Condition Test</th>
<th>Hardware Status</th>
<th>Configuration Check</th>
<th>Soft Limit Check</th>
<th>Trend Check</th>
<th>Hard Limit Check</th>
<th>Backup Caution &amp; Warning</th>
<th>Correlation Check</th>
<th>System Status Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>V41P1605A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>715</td>
<td>785</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneu Valve He Outlet Reg Press</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>psia</td>
<td>psia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controller (Pre-cond)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Word 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eng Status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41T1151A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500°F</td>
<td>580°F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>El He Supply Temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41P1150C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fig. 11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El He Reg. Outlet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41P1154C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>715</td>
<td>785</td>
<td></td>
<td></td>
</tr>
<tr>
<td>El He Reg. Outlet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>psia</td>
<td>psia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYSTEM DATA:</td>
<td>FUNCTIONAL PATH</td>
<td>PRE-CONDITION TEST</td>
<td>HARDWARE STATUS</td>
<td>CONFIGURATION CHECK</td>
<td>SOFT LIMIT CHECK</td>
<td>HARD LIMIT CHECK</td>
<td>BACKUP CAUTION &amp; WARNING</td>
<td>CORRELATION CHECK</td>
<td>SYSTEM STATUS LIGHT</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------</td>
<td>---------------------</td>
<td>-----------------</td>
<td>---------------------</td>
<td>----------------</td>
<td>----------------</td>
<td>--------------------------</td>
<td>-----------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>V41T1251A</td>
<td>(S)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>580°F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E2 He Supply Temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41P1250C</td>
<td>(P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E1 He Supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41P1254C</td>
<td>(P)</td>
<td></td>
<td></td>
<td></td>
<td>715</td>
<td>785</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E2 He Reg Outlet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41T1351A</td>
<td>(S)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E3 He Supply Temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41S1611E</td>
<td>(S)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneu 1 Cross</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over Open Cmd.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMS ACTIVITY</td>
<td>PRE-CONDITION TEST</td>
<td>HARDWARE STATUS</td>
<td>CONFIGURATION CHECK</td>
<td>SOFT LIMIT CHECK</td>
<td>TRENDS CHECK</td>
<td>HARD LIMIT CHECK</td>
<td>BACKUP CAUTION &amp; WARNING</td>
<td>CORRELATION CHECK</td>
<td>SYSTEM STATUS</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------</td>
<td>-----------------</td>
<td>---------------------</td>
<td>------------------</td>
<td>--------------</td>
<td>-----------------</td>
<td>--------------------------</td>
<td>-------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>SYSTEM DATA: • MEASUREMENT NO. • MEASUREMENT ID • FUNCTIONAL PATH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• V41S1613E (S) Pneu 2 Cross Over Open Cmd.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• V41S1616E (S) Pneu 3 Cross Over Open Cmd.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• V41X1776E (S) LO₂ Vent Valve 1 Open OFM 10-11-12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• V41X1778E (S) LO₂ Vent Valve 2 Closed OFM 10-11-12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMS ACTIVITY</td>
<td>PRE-CONDITION TEST</td>
<td>HARDWARE STATUS</td>
<td>CONFIGURATION CHECK</td>
<td>SOFT LIMIT CHECK</td>
<td>HARD LIMIT CHECK</td>
<td>BACKUP CAUTION &amp; WARNING</td>
<td>CORRELATION CHECK</td>
<td>SYSTEM STATUS LIGHT</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------</td>
<td>-----------------</td>
<td>---------------------</td>
<td>-----------------</td>
<td>-----------------</td>
<td>------------------------</td>
<td>-------------------</td>
<td>--------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* V41X1780E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(S) LO₂ Vent Valve</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Open</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 10-11-12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* V41P1130C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(P) E1 LO₂ Eng</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlet Press</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* V41P1230C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(P) E2 LO₂ Eng</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlet Press</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* V41P1330C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(P) E3 LO₂ Eng</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlet Press</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFM 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMS ACTIVITY</td>
<td>PRE-CONDITION TEST</td>
<td>F D A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------</td>
<td>------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HARD LIMIT CHECK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BACKUP CAUTION &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WARNING</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CORRELATION CHECK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SYSTEM STATUS LIGHT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SUBSYSTEM: Main Propulsion**

**SYSTEM DATA:**
- MEASUREMENT NO.
- MEASUREMENT ID
- FUNCTIONAL PATH

<table>
<thead>
<tr>
<th>HARDWARE STATUS</th>
<th>CONFIGURATION CHECK</th>
<th>SOFT LIMIT CHECK</th>
<th>HARD LIMIT CHECK</th>
<th>BACKUP CAUTION &amp; WARNING</th>
<th>CORRELATION CHECK</th>
<th>SYSTEM STATUS LIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HIGH</td>
<td>LOW</td>
<td>HIGH</td>
<td>LOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41P1534C (S)</td>
<td>LO₂ Feed Manifold</td>
<td>Press</td>
<td>OFM 10-11-12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T41P1750A (P)</td>
<td>LO₂ Ullage P1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T41P1751A (P)</td>
<td>LO₂ Ullage P2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T41P1752A (P)</td>
<td>LO₂ Ullage P3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 27 psia psia 1590 1774 1776 1778 1780
- 20 psia psia 1590 1774 1776 1778 1780
<table>
<thead>
<tr>
<th>PMS ACTIVITY</th>
<th>PRE-CONDITION TEST</th>
<th>SOFT LIMIT CHECK</th>
<th>HARD LIMIT CHECK</th>
<th>BACKUP CAUTION &amp; WARNING</th>
<th>CORRELATION CHECK</th>
<th>SYSTEM STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSTEM DATA:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- MEASUREMENT NO.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- MEASUREMENT ID</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- FUNCTIONAL PATH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUBSYSTEM: Main Propulsion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **V41P1590A (S)**
  - GO₂ Disc Press
  - OFM 10-11-12
  - Configuration Check: HIGH 5500 psia, LOW 1000 psia
  - System Status: 1516, 1517

- **V41X1516X (S)**
  - GO₂ Press Disc Valve Open
  - OFM 10-11-12
  - System Status:

- **V41X1517X (S)**
  - GO₂ Press Disc Valve Closed
  - OFM 10-11-12
  - System Status:

- **V41X1774E (S)**
  - LO₂ Vent Valve
  - 1 Closed
  - OFM 10-11-12
  - System Status:
**TABLE 8. - PMS MEASUREMENT REQUIREMENTS**

(Continued)

**SUBSYSTEM:** Main Propulsion

<table>
<thead>
<tr>
<th>PMS ACTIVITY</th>
<th>PRE-CONDITION TEST</th>
<th>F D A</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSTEM DATA:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• MEASUREMENT NO.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• MEASUREMENT ID</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• FUNCTIONAL PATH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HARDWARE STATUS</td>
<td>CONFIGURATION CHECK</td>
<td>HARD LIMIT CHECK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HIGH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HIGH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HIGH</td>
</tr>
</tbody>
</table>

- **T41X1746E (S)**
  - LH₂ Vent Valve
  - 2 Open
  - OFM 13-14-15

- **V41P1160A (S)**
  - GH₂ Outlet
  - Press E1
  - OFM 13

- **V41P1761A (S)**
  - GH₂ Outlet
  - Press E2
  - OFM 14

- **V41P1361A (S)**
  - GH₂ Outlet
  - Press E3
  - OFM 15

- **V41P1746E (S)**
  - Vent Valve
  - OFM 13-14-15

- **V41P1160A (S)**
  - Outlet Press E1
  - OFM 13

- **V41P1761A (S)**
  - Outlet Press E2
  - OFM 14

- **V41P1361A (S)**
  - Outlet Press E3
  - OFM 15
<table>
<thead>
<tr>
<th>Measurement</th>
<th>Description</th>
<th>Pre-Condition Test</th>
<th>Soft Limit Check</th>
<th>Trend Check</th>
<th>Hard Limit Check</th>
<th>Backup Caution &amp; Warning</th>
<th>Correlation Check</th>
<th>System Status Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>V41X1416E</td>
<td>GH₂ Press Disc Valve Open</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41X1417E</td>
<td>GH₂ Press Disc Valve Closed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41P1434C</td>
<td>LN₂ Feed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>130 psia</td>
<td>20 psia</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V41P1700A</td>
<td>LH₂ Ullage P1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39 psia</td>
<td>32 psia</td>
<td>1490</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1724</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1726</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1744</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1746</td>
</tr>
<tr>
<td>PMS ACTIVITY</td>
<td>HARDWARE STATUS</td>
<td>CONFIGURATION CHECK</td>
<td>SOFT LIMIT CHECK</td>
<td>TREND CHECK</td>
<td>HARD LIMIT CHECK</td>
<td>BACKUP CAUTION &amp; WARNING</td>
<td>CORRELATION CHECK</td>
<td>SYSTEM STATUS LIGHT</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------</td>
<td>---------------------</td>
<td>------------------</td>
<td>-------------</td>
<td>------------------</td>
<td>--------------------------</td>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>V41P1701A (P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39 psia</td>
<td>1746</td>
</tr>
<tr>
<td>LH₂ Ullage P2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39 psia</td>
<td>1744</td>
</tr>
<tr>
<td>OFM 13-14-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39 psia</td>
<td>1746</td>
</tr>
<tr>
<td>V41P1702A (P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39 psia</td>
<td>1746</td>
</tr>
<tr>
<td>LH₂ Ullage P3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39 psia</td>
<td>1746</td>
</tr>
<tr>
<td>OFM 13-14-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39 psia</td>
<td>1746</td>
</tr>
<tr>
<td>V41P1490A (S)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4500 psia</td>
<td>1360</td>
</tr>
<tr>
<td>GH₂ Press Disc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4500 psia</td>
<td>1360</td>
</tr>
<tr>
<td>OFM 13-14-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4500 psia</td>
<td>1360</td>
</tr>
<tr>
<td>T41X1724E (S)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4500 psia</td>
<td>1360</td>
</tr>
<tr>
<td>LH₂ Vent Valve</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4500 psia</td>
<td>1360</td>
</tr>
<tr>
<td>1 Open</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4500 psia</td>
<td>1360</td>
</tr>
<tr>
<td>OFM 13-14-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4500 psia</td>
<td>1360</td>
</tr>
</tbody>
</table>
### TABLE 8. — PMS MEASUREMENT REQUIREMENTS (Concluded)

**SUBSYSTEM:** Main Propulsion

<table>
<thead>
<tr>
<th>PMS ACTIVITY</th>
<th>PRE-CONDITION TEST</th>
<th>HARD LIMIT</th>
<th>SOFT LIMIT</th>
<th>TEND CHECK</th>
<th>BACKUP CAUTION &amp; WARNING</th>
<th>CORRELATION CHECK</th>
<th>SYSTEM STATUS LIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SYSTEM DATA:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Measurement No.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Measurement ID</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Functional Path</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HARDWARE STATUS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CONFIGURATION CHECK</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HIGH</strong></td>
<td>130 psia</td>
<td>20 psia</td>
<td>1434</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LOW</strong></td>
<td>130 psia</td>
<td>20 psia</td>
<td>1434</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **T41X1726E (S)**
  - LH<sub>2</sub> Vent Valve
  - 1 Open
  - OFM 13-14-15

- **T41X1744E (S)**
  - LH<sub>2</sub> Vent Valve
  - 2 Closed
  - OFM 13-14-15

- **V41P1100C (P)**
  - E1 LH<sub>2</sub> Eng.
  - Inlet Press

- **V41P1200C (P)**
  - E2 LH<sub>2</sub> Eng.
  - Inlet Press

- **V41P1300C (P)**
  - E3 LH<sub>2</sub> Eng.
  - Inlet Press

- **OFM 14**

- **OFM 15**
6.0 TYPICAL MONITORING SEQUENCE

Figures 9 and 10 show a typical type of monitoring sequence required for different mission phases.

Figure 11 demonstrates the type of parameter versus time monitoring that will be required.
Figure 9. - Typical preburn He monitor enter from precondition.
Figure 10. – Typical burn He monitor enter from precondition.
Figure 11. - Typical pneumatic system storage bottle pressure histories.
7.0 CONCLUSIONS AND RECOMMENDATIONS

The Master Measurements List, dated November 16, 1973, is not adequate for Main Propulsion Fault Detection and Annunciation.

The following measurements from the Operational Flight Instrumentation List, presented at the November 28 main propulsion panel meeting, should be added to the Master Measurements List, for the fault detection and annunciation:

V41X1517X  GO₂ Press Disc Valve Closed
V41X1774E  LO₂ Vent Valve 1 Closed
V41X1776E  LO₂ Vent Valve 1 Open
V41X1778E  LO₂ Vent Valve 2 Closed
V41X1780E  LO₂ Vent Valve 2 Open
V41T1161A  E₁ GH₂ Outlet Temp.
V41T1261A  E₂ GH₂ Outlet Temp.
V41T1361A  E₃ GH₂ Outlet Temp.
V41P1160A  E₁ GH₂ Outlet Press
V41P1260A  E₂ GH₂ Outlet Press
V41P1360A  E₃ GH₂ Outlet Press
T41X1724E  LH₂ Vent Valve 1 Closed
T41X1126E  LH₂ Vent Valve 1 Open
T41X1744E  LH₂ Vent Valve 2 Closed
T41X1746E  LH₂ Vent Valve 2 Open
V41X1417E  GH₂ Press Disc Valve Closed
No Assign Number  Eng. Comp. Amb. Temp. 1
No Assign Number  Eng. Comp. Amb. Temp. 2
All Measurements identified for fault detection and annunciation, in this document, should be made available to Performance Monitor.

In addition it is recommended that the controller data word list be revised. The 16 data words identified in table 5 should be included in the first 32 controller data words since only the first 32 words are available to Performance Monitor.