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QUARTERLY PROGRESS REPORT

OCTOBER - DECEMBER 1970

SPACE SHUTTLE PROPULSION SYSTEMS ON-BOARD CHECKOUT AND MONITORING SYSTEM DEVELOPMENT STUDY

Contract NAS8-25619
DRL No. 187 Rev. A
Line Item No. 2 (Issue 2)

Prepared for

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

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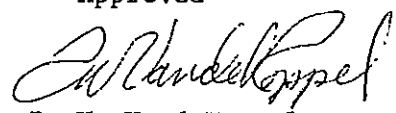
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Approved



R. W. VandeKoppel
Program Manager

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FOREWORD

This quarterly progress report, submitted in accordance with the requirements of Contract NAS8-25619, describes the work accomplished on the subject contract during the period of October through December 1970.

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SUMMARY

(Major Work Accomplished October-December 1970)

→ Checkout and Monitoring Requirements for the main, auxiliary and air-breathing propulsion systems have been defined and presented in a unified, phase-by-phase sequence (Section IV and Appendix D).

→ Requirements for 3028 Booster propulsion measurements and 1331 Orbiter propulsion measurements have been established (Section IV and Appendix E).

→ A maximum propulsion data rate of 430,000 bits per second occurs at main engine start, and the processing requires up to 75% of the computer's time during this phase. During other phases the data bus load peaks at 130,000 bits per second with 11% computer loading (Section V).

→ Digital Interface Unit allocation criteria was generated and resulted in the definition of 20 DIUs to accomodate the 823 orbiter propulsion measurements not associated with main engine or leak detection (Section V).

→ OCMS problem areas have been resolved primarily through use of procedures and existing instrumentation or recommended propulsion system changes. New sensor technology is recommended in some areas, such as leak detection, bearing incipient failure detection, and valve position monitoring (Section V).

→ Line Replaceable Units have been described, and procedures for removal, replacement and retest of the LRUs have been defined (Section III).

→ Further definition of the approach to the OCMS objectives and the rationale for selecting those directions has been developed during this reporting period, and the OCMS definition is being finalized.

NOMENCLATURE

I. Definitions

BIT: A single binary digit. The smallest informational element of a digital system.

BUILT-IN-TEST EQUIPMENT (BITE): An integral part of a functional unit which serves to test and/or provide status on that functional unit, but does not participate in performing the unit's principle function

BYTE: A specified number of BITS.

CHECKOUT: The process of determining whether or not specified physical quantities or operations meet their prescribed criteria. The process can include such functions as data acquisition, processing, storage, display, stimulus generation, etc.

CONTROL: The act or process of initiating, regulating and/or terminating the operation and performance of a functional element in a prescribed manner.

CONTROLLER: A device which governs the state or performance of a particular functional element in a prescribed manner, e.g. engine controller.

DATA BUS: The transmission line(s) along which the system computer(s) communicate with the various Digital Interface Units, controllers, peripheral equipment, and other computers.

DATA COMPRESSION: The process of screening and selecting data such that only desired information is retained for further processing and/or storage.

DESIGN REFERENCE MODEL: The baseline configuration.

DIAGNOSIS: The determination of the state or condition of an element or parameter through evaluation of available data.

DIGITAL INTERFACE UNIT: An intermediary unit between the computer(s) and another device which formats that device's output for communication to a computer, and accepts and translates a computer's transmissions to the device.

FAULT ISOLATION: The processing of analyzing a malfunction or abnormality to the extent of determining which functional element is defective, where the functional element is ordinarily a Line Replaceable Unit.

NOMENCLATURE (Continued)

FUNCTIONAL ELEMENT: A unit which performs a characteristic action. Parts, components, assemblies, and subsystems are functional elements of increasing complexity.

GAS PATH ANALYSIS: An assessment of engine performance that is made through evaluation of a set of measured values of pressures, temperatures and/or flow rates.

GROUND SUPPORT EQUIPMENT: (for checkout and monitoring) That equipment, in addition to the onboard equipment, which is needed to accomplish the functions of checkout and monitoring.

LINE REPLACEABLE UNIT: A component or group of components that can, as a unit, be removed and replaced in the normal vehicle maintenance area. Such criteria as allowable replacement time spans and degree of complesity of post-replacement calibration form a basis for Line Replaceable Unit selection.

MAINTENANCE: Those functions and activities associated with restoring the vehicle to a serviceable condition between flights.

MEASUREMENT: A physical quantity or event whose magnitude or time of occurence is of significance.

MONITORING: Repetitive acquisition and evaluation of needed data.

POGO: An oscillatory instability resulting from a dynamic coupling between the fluid and structural elements of the vehicle.

PROCESSING: The manipulations and operations performed on data from the time and place it is acquired to the time and place it is used in its final form.

SELF CHECK: The process by which a functional element assesses its own operational integrity and readiness.

SENSOR: A functional element which responds to a physical quantity or event and converts that response to transmissible data which is proportional to the magnitude of the quantity or indicates occurence of the event.

SINGLE POINT FAILURE: A functional element whose inability to operate within prescribed limits would cause loss of vehicle, crew, and/or mission objectives.

STIMULUS: An excitation or forcing function which is applied from an external source at a prescribed place and time.

NOMENCLATURE (Continued)

TIMELINE: A representation of a sequential series of events which depicts the time of occurence and duration of each event.

TRANSDUCER: Same as sensor.

TREND ANALYSIS: The process of evaluating successive samples of the same data to forecast end of useful life and/or incipient failure as an aid to maintenance operations and to mission or vehicle configuration decisions.

II. Abbreviations and Acronyms

Note: Measurement nomenclature is defined in the measurement section.

A/B	Airbreather or airbreathing
APS	Auxiliary Propulsion System
APU	Auxiliary Power Unit
BITE	Built-In Test Equipment
CC	Combustion Chamber
CCC	Central Computer Complex
CCU	Channel Control Unit
C_f	Thrust Coefficient
C*	Characteristic Exhaust Velocity
DIU	Digital Interface Unit
DRM	Design Reference Model
ΔV	Change in Velocity
EPL	Emergency Power Level
FMEA	Failure Modes and Effects Analysis
FPB	Fuel Preburner
FS_1	Fire Switch #1 (Engine Start Signal)
FS_2	Fire Switch #2 (Engine Shutdown Signal)
GHe	Gaseous Helium
GH_2	Gaseous Hydrogen
GN_2	Gaseous Nitrogen
GOX	Gaseous Oxygen
GSE	Ground Support Equipment
G & N	Guidance and Navigation
HPFTPA	High Pressure Fuel Turbopump Assembly

NOMENCLATURE (Continued)

HPOTPA	High Pressure Oxidizer Turbopump Assembly
Ign	Igniter or Ignition
KSC	Kennedy Space Center
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
LOX	Liquid Oxygen
LPFTPA	Low Pressure Fuel Turbopump Assembly
LPOTPA	Low Pressure Oxidizer Turbopump Assembly
LRU	Line Replaceable Unit
MPL	Minimum Power Level
MR	Mixture Ratio
MSFC	Marshall Space Flight Center
NPL	Normal Power Level
OCMS	Onboard Checkout and Monitoring System
OMS	Orbital Maneuvering System
OPB	Oxidizer Preburner
P/L	Payload
RCS	Reaction Control System
TCA	Thrust Chamber Assembly
TPF	Terminal Phase Finalization
TPI	Terminal Phase Initiation
TVC	Thrust Vector Control
VAB	Vertical Assembly Building
WTR	Western Test Range

I. INTRODUCTION

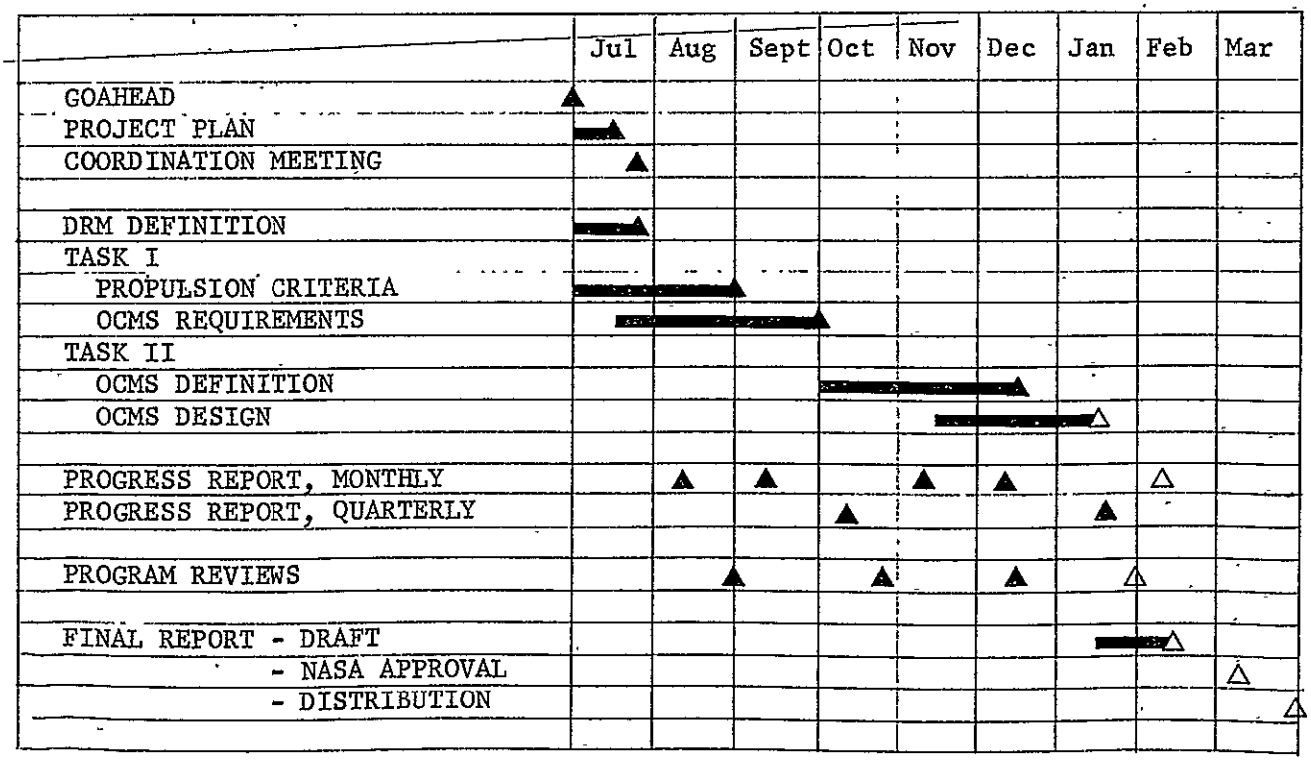
The Space Shuttle Program has the primary objective of providing an economical space transportation system. Inherent in this objective are such aspects of the Space Shuttle system as maximum reuse of components, facilities, ground equipment, labor and materials for maintenance and preflight activities. Previous launch vehicle experience has shown that extensive ground checkout systems are expensive to acquire and entail substantial time and manpower for such test activities as mating and detaching the test equipment to and from the vehicle. Recent technology has demonstrated the feasibility of alleviating this problem by maximizing the onboard checkout capability within the constraints of onboard weight and complexity to obtain an autonomous system. The capabilities of this onboard checkout system can be extended to include the related functions of performance monitoring, emergency detection and post-flight evaluation, thereby making a significant step towards realizing such other Space Shuttle objectives as rapid turnaround and low hazard operations.

This is the second quarterly progress report on a study contract to define an onboard checkout, performance monitoring, emergency detection and postflight evaluation system for the Space Shuttle propulsion systems. This study is being made of the Space Shuttle's main, auxiliary, and airbreathing propulsion systems' functional, performance and durability requirements to define the checkout, monitoring and evaluation criteria and to evolve an approach for performing the functions of preflight checkout, performance monitoring, fault isolation, diagnosis, emergency detection, display, data storage, postflight evaluation and maintenance. The timing of the study is such that the checkout and monitoring requirements, concepts and designs may be incorporated and utilized in the basic design and development of the propulsion systems.

The program schedule is presented in Figure I-1 and the study approach is illustrated in Figure I-2. As shown, the technical work is to be completed 6½ months after go-ahead. The initial element of the study consisted of the detailed definition of the Design Reference Model, (the Space Shuttle vehicle, mission, propulsion system configuration, and vehicle electronics) which comprises the baseline concept. The propulsion systems were defined to the component level and the functional requirements of the propulsion systems were established. Failure modes and effects analyses were conducted to the propulsion components level and, for critical components, to the parts level. Also, those propulsion system elements which could be replaced between flights without impacting the allowed 10-working day turnaround were defined (these elements are referred to as Line Replaceable Units.) The characterization of the propulsion system resulting from these definition studies formed the criteria from which the on-board checkout and monitoring requirements could be established, and was presented in detail in this study's first quarterly progress report.

The second quarter's work as presented herein has dealt with the evolution of the on-board checkout and monitoring requirements and the formulation of concepts for performing the required functions and operations. This effort has consisted primarily of defining what measurements must be made, when the measurements are to be made and with what sample rates; what data bus traffic and processing loads result; what sensors are required and what technology is needed to fulfill these requirements; and what onboard checkout and monitoring system design criteria must be followed in design concept finalization. The study will be completed during the next month in the form of design concept selection and definition.

Figure I-1 Program Schedule



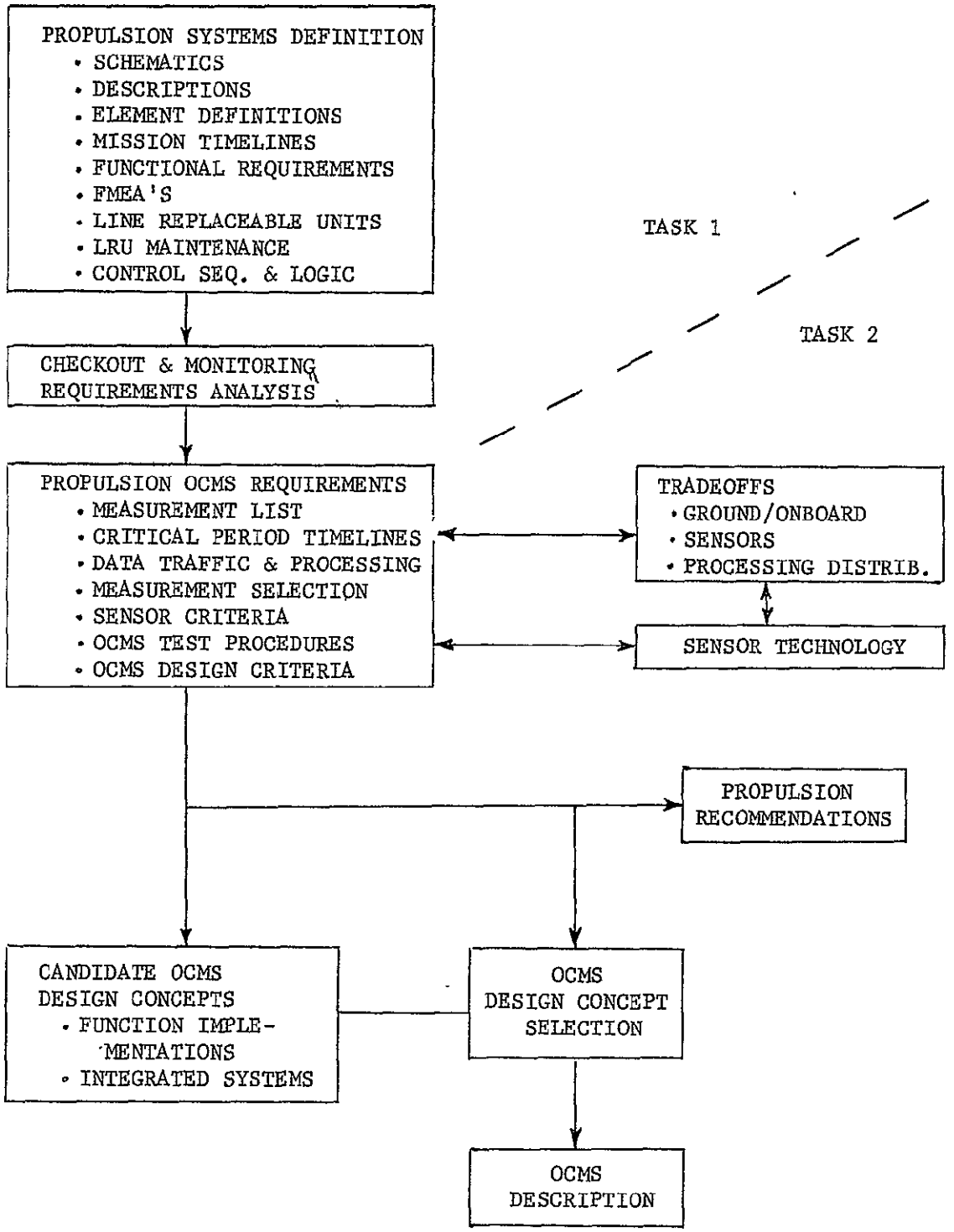


Figure I-2 STUDY APPROACH

II. DESIGN REFERENCE MODEL

The Space Shuttle vehicle, mission, propulsion systems and electronics Design Reference Models remain as presented in MCR-70-274 (Issue 1), Quarterly Progress Report for July - September, 1970.

III. PROPULSION CRITERIA

The Propulsion Subsystem Requirements and the Failure Modes and Effects Analysis data sheets were presented in MCR-70-274 (Issue 1), Quarterly Progress Report for July - September, 1970, and are not repeated herein. However, since this information will be presented in the final report, Sections A and B of this chapter are retained for continuity. Section C of this chapter defines and describes propulsion system Line Replaceable Units.

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C. LINE REPLACEABLE UNITS

Among the several functions to be performed by the on-board checkout and monitoring system are inflight fault isolation of line-replaceable-units (LRUs) for timely maintenance, and verification purposes after LRU replacement. Therefore, the definition of the checkout systems is in part determined by the requirement to isolate faulty LRUs and check them out after replacement, consistent with mission time lines. This portion of the report defines an LRU, presents the LRU selection ground rules, and identifies the LRUs.

The procedures for LRU removal, replacement and retest in the Maintenance Phase have been defined as a part of the LRU selection study and to establish LRU maintenance requirements pertinent to the OCMS definition. These procedures were previously published in MCR-70-306 (Issue 3), Monthly Progress Report for October, 1970; because of their bulk, examples only are republished in this report in Appendix C. The complete set will be included in the final report.

1. Definition

A line replaceable unit is defined as any component, series of components, assembly, or subsystem that can be replaced by a competent mechanic in the Space Shuttle maintenance area.

2. Ground Rules and Criteria

a. Replacement of an LRU shall not impact the Space Shuttle maintenance timeline. It is assumed that simultaneous replacement can be achieved;

b. Replacement shall not require removal of major operational hardware which is not a part of the LRU subsystem;

c. Connections for LRU removal shall be minimized;

d. Retest requirements shall necessitate only retest of the replaced LRU;

e. The functional status of each LRU shall be able to be verified and monitored, and shall not introduce uncertainty in calibration in excess of the specification performance limits;

f. An LRU may consist of a series or group of LRUs.

Interconnecting lines were not generally evaluated in this study. Only main engine interconnecting and attaching lines were considered.

Component groupings into modular packaged LRUs were used when possible. The approach used the following criteria:

a. Component grouping shall be used on redundant-like components. In general, complex components or components which are expected to operate at high cycle rates will not be grouped with simple components or components which are expected to operate at low cycle rates;

b. Component groupings which require hydraulic, pneumatic or electrical disassembly connections in excess of those required for a lower level of replacement will not be considered as LRU candidates;

c. Modules weighing more than 150 lb. will not be considered as LRU candidates unless:

   1) The module is located at an obvious access door,

   2) The module is external to the vehicle skinline,

   3) Replacement of lower level components, assemblies or subsystems would delay mission timelines.

The LRU identification resulting from these ground rules and criteria are presented in the following pages. For each propulsion system, all of the components are identified, and a criteria matrix resulting in LRU selection is presented. The top level LRUs are shown on schematics and have written descriptions; those LRUs which are contained within the top level LRUs are identified in the tabular listings.

An objective is to have all propulsion control sensors be LRUs. However, the control sensors are not defined in the LRU listings.

3. Booster Main Propulsion System

Table III-1 reflects all components within the Booster main propulsion system and presents the criteria matrix resulting in LRU selection. (Because of commonality, the orbiter main propulsion system components are also presented in this table). Top level LRU identification for the Booster main propulsion system is shown schematically in Figure III-1. These are followed by a brief description of the top-level LRUs. Those LRUs which are contained within the top-level LRUs are identified in the tabular listings.

Table III-1 Main Propulsion System LRUs

Ref. No.	Main Propulsion System Booster Item	Meets LRU Criteria				LRU	
		Time	Accessibility	Calibration	Verification	Yes	No
1.1	Engine Subsystem	X	X	X	X	X	
1.1.1.1	Low Pressure Fuel Turbopump	X	X	X	X	X	
1.1.1.2	High Pressure Fuel Turbopump	X	X	X	X	X	
1.1.1.3	Low Pressure Oxidizer Turbopump	X	X	X	X	X	
1.1.1.4	High Pressure Oxidizer Turbopump	X	X	X	X	X	
1.1.1.5	Fuel Preburner	X	X	X	X	X	
1.1.1.6	Oxidizer Preburner	X	X	X	X	X	
1.1.1.7	Hot Gas Manifold	NO	NO	X	X		X
1.1.1.8	Fuel Main Valve	X	X	X	X	X	
1.1.1.9	Oxidizer Main Valve	X	X	X	X	X	
1.1.1.10	Fuel Control Valve, Oxidizer Preburner	X	X	X	X	X	
1.1.1.11	Oxidizer Control Valve, Oxidizer Preburner	X	X	X	X	X	
1.1.1.12	Oxidizer Control Valve, Fuel Preburner	X	X	X	X	X	
1.1.1.14	Interconnect Artic. Lines	X	X	X	X	X	
1.1.1.15	Interconnect Lines	X	X	X	X	X	
1.1.1.16	Oxidizer Recirculation Select Valve	X	X	X	X	X	
1.1.1.17	Fuel Recirculation Select Valve	X	X	X	X	X	
1.1.1.18	Fuel Recirculation Control Valve	X	X	X	X	X	
1.1.1.19	Fuel Recirculation Regulator	X	X	X	X	X	
1.1.2.1	Main Injector	NO	NO	NO	X		X
1.1.2.2	Main Combustion Chamber	NO	NO	X	X		X
1.1.2.3	Booster Nozzle	X	X	X	X	X	
1.1.2.4	Gas Distribution Plate	NO	NO	X	X		X
1.1.2.5	Interconnect Lines	X	X	X	X	X	
1.1.3.1	Preburner and Main TCA Igniters	X	X	X	X	X	
1.1.3.2	Interconnect Lines	X	X	X	X	X	
1.1.4.1	Gimbal Block	NO	NO	X	X		X
1.1.4.2	Gimbal Actuator and Power Pack	X	X	X	X	X	
1.1.5.1	Engine Controller	X	X	X	X	X	
1.1.5.2	Ignition and Valve Control Harness	X	X	X	X	X	
1.1.5.3	Instrumentation Harness	X	X	X	X	X	
1.1.5.4	Sensors	X	X	X	X	X	
1.1.6.1	Fuel Tank Pressurant Check Valve	X	X	X	X	X	
1.1.6.2	Oxidizer Tank Pressurant Check Valve	X	X	X	X	X	
1.1.6.3	Oxidizer Heat Exchanger	X	X	X	X	X	
1.1.6.4	Interconnect Lines	X	X	X	X	X	
1.1.7.1	Purge Valves	X	X	X	X	X	
1.1.7.2	Interconnect Lines	X	X	X	X	X	

Table III-1 (Continued)

Ref. No.	Main Propulsion System Orbiter Item	Meets LRU Criteria				LRU	
		Time	Accessibility	Calibration	Verification	Yes	No
4.1	Engine Subsystem	X	X	X	X	X	
4.1.1.1	Low Pressure Fuel Turbopump	X	X	X	X	X	
4.1.1.2	High Pressure Fuel Turbopump	X	X	X	X	X	
4.1.1.3	Low Pressure Oxidizer Turbopump	X	X	X	X	X	
4.1.1.4	High Pressure Oxidizer Turbopump	X	X	X	X	X	
4.1.1.5	Fuel Preburner	X	X	X	X	X	
4.1.1.6	Oxidizer Preburner	X	X	X	X	X	
4.1.1.7	Hot Gas Manifold	NO	NO	X	X		X
4.1.1.8	Fuel Main Valve	X	X	X	X	X	
4.1.1.9	Oxidizer Main Valve	X	X	X	X	X	
4.1.1.10	Fuel Control Valve, Oxidizer Preburner	X	X	X	X	X	
4.1.1.11	Oxidizer Control Valve, Oxidizer Preburner	X	X	X	X	X	
4.1.1.12	Oxidizer Control Valve, Fuel Preburner	X	X	X	X	X	
4.1.1.14	Interconnect Artic. Lines	X	X	X	X	X	
4.1.1.15	Interconnect Lines	X	X	X	X	X	
4.1.1.16	Oxidizer Recirculation Select Valve	X	X	X	X	X	
4.1.1.17	Fuel Recirculation Select Valve	X	X	X	X	X	
4.1.1.18	Fuel Recirculation Control Valve	X	X	X	X	X	
4.1.1.19	Fuel Recirculation Regulator Valve	X	X	X	X	X	
4.1.2.1	Main Injector	NO	NO	NO	X		X
4.1.2.2	Main Combustion Chamber	NO	NO	X	X		X
4.1.2.3	Orbiter Nozzle	NO	NO	X	X		X
4.1.2.4	Gas Distribution Plate	NO	NO	X	X		X
4.1.2.5	Interconnect Lines	X	X	X	X	X	
4.1.3.1	Preburner and Main TCA Igniters	X	X	X	X	X	
4.1.3.2	Interconnect Lines	X	X	X	X	X	
4.1.4.1	Gimbal Block	NO	NO	X	X		X
4.1.4.2	Gimbal Actuator and Power Pack	X	X	X	X	X	
4.1.5.1	Engine Controller	X	X	X	X	X	
4.1.5.2	Ignition and Valve Control Harness	X	X	X	X	X	
4.1.5.3	Instrumentation Harness	X	X	X	X	X	
4.1.5.4	Sensors	X	X	X	X	X	
4.1.6.1	Fuel Tank Pressurant Check Valve	X	X	X	X	X	
4.1.6.2	Oxidizer Tank Pressurant Check Valve	X	X	X	X	X	
4.1.6.3	Oxidizer Heat Exchanger	X	X	X	X	X	
4.1.6.4	Interconnect Lines	X	X	X	X	X	
4.1.7.1	Purge Valves	X	X	X	X	X	
4.1.7.2	Interconnect Lines	X	X	X	X	X	
4.1.8.1	Extendible Nozzle	N/A	X	X	X	X	
4.1.8.2	Extendible Nozzle Coolant Valve	N/A	X	X	X	X	
4.1.8.3	Extendible Nozzle Deployment Kit	N/A	X	X	X	X	
4.1.8.4	Nozzle Coolant Line	N/A	X	X	X	X	

Table III-1 (Continued)

Ref. No.	Main Propulsion System - Booster & Orbiter Item	Meets LRU Criteria				LRU	
		Time	Accessibility	Calibration	Verification	Yes	No
I.0	Booster - Main Propulsion System						
1.2.1.1	Oxidizer Feed Line (L-1 through L-7)	X	X	X	X	X	
1.2.1.2	Oxidizer Prevalve (V-77 through V-83)	X	X	X	X	X	
1.2.2.2	Oxidizer Isolation Valve (V-1 and V-2)	X	X	X	X	X	
1.2.3.2	Oxidizer Vent Valve (V-3 through V-6)	X	X	X	X	X	
1.2.4.2	Oxidizer Fill Valve (V-7)	X	X	X	X	X	
1.2.4.3	Oxidizer Fill Coupling (C-1)	X	X	X	X	X	
1.2.5.1	Oxidizer Tank - Diffuser and Sump (T-1)	NO	NO	X	X		X
1.2.6.2	Helium Coupling (C-2)	X	X	X	X	X	
1.2.7.1	Fuel Feedline (L-13 through L-19)	X	X	X	X	X	
1.2.7.2	Fuel Isolation Valve (V-8 through V-14)	X	X	X	X	X	
1.2.8.2	Fuel Vent Coupling (V-15 through V-18)	X	X	X	X	X	
1.2.8.3	Fuel Vent Valve (V-15 through V-18)	X	X	X	X	X	
1.2.9.2	Fuel Fill Coupling (C-5)	X	X	X	X	X	
1.2.9.3	Fuel Fill Valve (V-19)	X	X	X	X	X	
1.2.10	Fuel Tank - Diffuser and Sump (T-2)	NO	NO	X	X		X
1.3.1.2	Oxidizer Pressure Control Orifice (O-1 and O-2)	X	X	X	X	X	
1.3.1.3	Oxidizer Pressure Control Valve (V-20 and V-21)	X	X	X	X	X	
1.3.1.4	Oxidizer Pressurant Filter (F-1)	X	X	X	X	X	
1.3.1.6	Fuel Pressure Control Orifice (O-3 and O-4)	X	X	X	X	X	
1.3.1.7	Fuel Pressure Control Valve (V-22 and V-23)	X	X	X	X	X	
1.3.1.8	Fuel Pressurant Filter (F-2)	X	X	X	X	X	
1.3.2.2	Helium Coupling - Oxidizer (C-6)	X	X	X	X	X	
1.3.2.4	Helium Coupling - Fuel (L-4)	X	X	X	X	X	
4.0	Orbiter - Main Propulsion System						
4.2.1.2	Oxidizer Isolation Valve (V-1 and V-2)	X	X	X	X	X	
4.2.2.2	Oxidizer Vent Valve (V-3 through V-6)	X	X	X	X	X	
4.2.3.2	Oxidizer Fill and Drain Valve (V-7)	X	X	X	X	X	
4.2.3.3	Oxidizer Fill and Drain Coupling (C-1)	X	X	X	X	X	
4.2.4.1	Oxidizer Tank (Diffuser & Sump) (T-1 & T-2)	NO	NO	X	X		X
4.2.5.2	Helium Coupling - Oxidizer (C-2)	X	X	X	X	X	
4.2.5.3	Helium Coupling - Fuel (C-8)	X	X	X	X	X	
4.2.6.2	Fuel Isolation Valve (V-8 and V-9)	X	X	X	X	X	
4.2.7.2	Fuel Tank Vent Coupling (C-3)	X	X	X	X	X	
4.2.7.3	Fuel Tank Vent Valve (V-10 through V-13)	X	X	X	X	X	
4.2.8.2	Fuel Fill and Drain Coupling (C-5)	X	X	X	X	X	
4.2.8.3	Fuel Fill and Drain Valve (V-14)	X	X	X	X	X	
4.2.9.1	Fuel Tank (Diffuser & Sumo) (T-3)	NO	NO	X	X		X
4.3.1.2	Oxidizer Pressure Control Valve (V-19 and V-20)	X	X	X	X	X	
4.3.1.3	Oxidizer Pressure Control Orifice (O-3 and O-4)	X	X	X	X	X	
4.3.1.4	Oxidizer Pressurization Line Filter (F-2)	X	X	X	X	X	
4.3.1.6	Fuel Pressure Control Valve (V-21 and V-22)	X	X	X	X	X	
4.3.1.7	Fuel Pressure Control Control Orifice (O-5 and O-6)	X	X	X	X	X	
4.3.1.8	Fuel Pressurization Line Filter (F-3)	X	X	X	X	X	
4.3.2.2	Helium Coupling - Oxidizer (C-6)	X	X	X	X	X	
4.3.2.4	Helium Coupling - Fuel (C-4)	X	X	X	X	X	

Table III-1 (Concluded)

Table III-1 (concl)

Ref. No.	Main Propulsion System - Booster & Orbiter Item	Meets LRU Criteria				LRU	
		Time	Accessibility	Calibration	Verification	Yes	No
4.4.1.2	Oxidizer Isolation Valve (V-23)	X	X	X	X	X	
4.4.2.2	Oxidizer Tank Vent Valve (V-24, V-25)	X	X	X	X	X	
4.4.2.3	Oxidizer Vent Heat Exchanger (H-1)	NO	X	X	X		X
4.4.3.1	Oxidizer Tank (Diffuser & Sump) (T-4)	NO	NO	X	X		X
4.4.4.2	Fuel Isolation Valve (V-26, V-27)	X	X	X	X	X	
4.4.5.2	Fuel Tank Vent Valve (V-28 through V-31)	X	X	X	X	X	
4.4.5.3	Fuel Vent Line Heat Exchanger (H-2, H-3)	NO	X	X	X		X
4.4.5.4	Fuel Vent Coupling (C-11)	X	X	X	X	X	
4.4.6.1	Fuel Tank (Diffuser & Sump) (T-5 & T-6)	NO	NO	X	X		X
4.5.1.2	Oxidizer Tank Pressurization Line Filter (F-4)	X	X	X	X	X	
4.5.1.3	Oxidizer Pressurization Regulator (R-5 & R-7, R-6 & R-8)	X	X	X	X	X	
4.5.1.4	Oxidizer Pressurization Valve (V-32, V-33)	X	X	X	X	X	
4.5.1.6	Fuel Tank Pressurization Line Filter (F-5)	X	X	X	X	X	
4.5.1.7	Fuel Pressurization Regulator (R-9 & R-11, R-10 & R-12)	X	X	X	X	X	
4.5.1.8	Fuel Pressurization Valve (V-34 and V-35)	X	X	X	X	X	

3. Booster Main Propulsion System (Continued)

LRU (1) LO_2 Tank Vent Package

Each vent valve package is composed of four series — parallel vent valves and is used in two places. Each valve, in addition to being a pressure relief valve, is a pneumatically controlled normally closed valve, which incorporates a positive opening and closing feature.

LRU (2) LO_2 Tank Isolation Valve

There are two of these valves per boom and they are connected at the oxidizer tank sump and to the engine distribution ducts. These valves are 18 inches in diameter and are attached by means of bolted flanges which contain sealing devices.

LRU (3) Fuel Isolation Valve

There are seven of these valves per boom and they are connected to the engine suction ducts. These valves are 14 inches in diameter and are attached by means of bolted flanges which contain sealing devices. The estimated weight of each valve is 70 lb.

LRU (4) LO_2 Prevalve

There are seven of these valves per boom and they are connected to the engine suction ducts. These valves are 10 inches in diameter and are attached by means of bolted flanges which contain sealing devices. The estimated weight of each valve is 60 lb.

LRU (5) Fuel Fill Valve

There are two of these valves in each boom and they are connected to the LH_2 fill and drain ducts. The valve functions as an emergency shutoff valve during captive firing tests and is also used to prevent backflow during engine chilldown.

3. Booster Main Propulsion System (Continued)

LRU (6) Fuel Autogenous Line Filter

There are two of these components on the booster and these gas filters are installed in the GH_2 autogenous pressurization line. They contain a diffuser and a removeable filter element which should be replaced after each flight.

LRU (7) Oxidizer Autogenous Line Filter

There are two of these components on the booster and these gas filters are installed in the GO_2 autogenous pressurization line. They contain a diffuser and a removeable filter element which should be replaced after each flight.

LRU (8) Fuel Pressurant Control Valve Package

These valves are used to control the pressurant flow rate of the autogenous gas to the propellant tanks in the event the primary orifice does not provide adequate control. These are solenoid operated valves.

LRU (9) Oxidizer Pressurant Control Valve Package

These valves are used to control the pressurant flow rate of the autogenous gas to the propellant tanks in the event the primary orifice does not provide adequate control. These are solenoid operated valves.

LRU (10) Oxidizer Pressurant Control Orifice

This fixed orifice controls the pressurant flow rate into the propellant tanks in each boom. It is enclosed in a flanged joint for easy removal or replacement.

LRU (11) Fuel Pressurant Control Orifice

This fixed orifice controls the pressurant flow rate into the propellant tanks in each boom. It is enclosed in a flanged joint for easy removal or replacement.

3. Booster Main Propulsion System (Continued)

LRU (12) Fuel Vent Valve Package

Each vent valve package is composed of four series-parallel vent valves and is used in two places. Each valve, in addition to being a pressure relief valve, is a pneumatically controlled normally closed valve, which incorporates a positive opening and closing feature.

LRU (13), (19) Fuel and Oxidizer Fill Line Coupling

The airborne half of this coupling consists of a mating ring with sealing surfaces. This component will require routine replacement of the mating parts.

LRU (14) Fuel Vent Line Coupling

This disconnect coupling is the airborne half of the GH_2 tank dump system coupling. It is attached to the airborne vent line by means of a mating ring with sealing surfaces.

LRU (15) Fuel Tank Prepressurization Coupling

This disconnect coupling is utilized to provide a helium connection for GSE prepressurization service. It is maintained like the other LRU couplings.

LRU (16) LO_2 Recirculation Line Coupling

This disconnect coupling is utilized to provide for ground recirculation of propellants just prior to launch. It is maintained like the other couplings.

LRU (17) LO_2 Tank Prepressurization Coupling

This disconnect coupling is utilized to provide a helium connection for GSE prepressurization service. It is maintained like the other LRU couplings.

3. Booster Main Propulsion System (Continued)

LRU (18) LO_2 Fill Valve

There are two of these valves in each boom and they are connected to the LO_2 fill and drain ducts. The valve functions as an emergency shut-off valve during captive firing tests and is also used to prevent backflow during engine chill-down.

LRU (20) Main Engine Subsystem

The high pressure, turbopump engine subsystem as defined in the DRM is composed of many assemblies, some of which are time sensitive and may require periodic maintenance. In the event that certain components in the engine that are not LRUs should fail or after the engine life cycle is passed, then a complete engine subsystem would be installed. Since there would be a base heat-shield and close-out boot that would isolate part of this engine, access panels in the rear area of each boom should be provided. The estimated weight of one complete engine is 5,370 lb. Therefore, special GSE would be required for engine removal.

LRU (21) LO_2 Feed Lines

There are seven of these 10-inch ducts that are connected at the tank sump end and at the inlet to the oxidizer prevalve at the engine end. They are vacuum jacketed ducts and contain an evacuation port, a thermocouple vacuum gauge connection and a burst disc.

LRU (22) LH_2 Feed Lines

There are seven of these 14-inch ducts that are connected at the tank sump end and at the inlet to the fuel prevalve at the engine end. They are vacuum jacketed ducts and contain an evacuation port, a thermocouple vacuum gauge connection, and a burst disc.

4. Orbiter Main Propulsion System

Table III- 1 reflects all components within this system and presents the criteria matrix resulting in LRU selection. Top level LRU identification for the main propulsion system is shown in Figure III-2.

The following is a brief description of the top-level LRUs. Those LRUs which are contained within the top-level LRUs are identified in the tabular listings.

LRU (1), (12) LO_2 and Fuel Tank Vent Package

Each vent valve package is composed of four series -- parallel vent valves and is used in one place for each propellant tank. Each valve in addition to being a pressure relief valve, is a pneumatically controlled normally closed valve, which incorporates a positive opening and closing feature.

LRU (2), (3) LO_2 and Fuel Isolation Valve

There are four of these valves for LH_2 and three valves for LO_2. They are connected at the tank sump and to the engine distribution ducts. These valves are 14 and 10 inches in diameter and are attached by means of bolted flanges which contain sealing devices.

LRU (4), (5) On-Orbit LO_2 and Fuel Tank Vent Package

These vent valve packages each contain two series valves. There are two of these packages on the LH_2 tankage and one package on the LO_2 tankage. The vent gases on ducted through special line heat exchanges to lower the heat leak into the on-orbit tankage.

4. Orbiter Main Propulsion System (Continued)

LRU (9), (6) On-Orbit LO_2 and Fuel Tank Pressurant Filters

There are two of these components on the orbiter, one each installed in the GH_2 and GO_2 pressurant lines. They contain a diffuser and a removeable filter element which should be replaced after each flight.

LRU (10), (7) On-Orbit LO_2 and Fuel Tank Pressurant Control Regulator Package

There are four of these regulators in series -- parallel for each propellant system. This component is a pressure regulator which incorporates a relief valve.

LRU (11), (8) On-Orbit LO_2 and Fuel Tank Pressurant Shutoff Valve

There are two of these valves in parallel for each propellant system. This solenoid actuated valve contains a set of orifices that permits slow passage of gas through the valve and acts to prevent overpressurization of the pressurization line upstream of the valve.

LRU (13), (21) LO_2 and Fuel Tank Prepressurization Coupling

These disconnect couplings are utilized to provide a helium connection for GSE prepressurization service. They are maintained like the other LRU couplings.

LRU (14) Fuel Tank Vent Coupling

This disconnect coupling is the airborne half of the GH_2 tank dump system coupling. It is attached to the airborne vent line by means of a mating ring with sealing surfaces.

LRU (15), (20) LO_2 and Fuel Fill Valve

There are two of these valves in the orbiter and they are connected to the LH_2 and LO_2 fill and drain ducts. The valve functions as an emergency shutoff valve during captive firing tests and is also used to prevent backflow during engine chilldown.

4. Orbiter Main Propulsion System (Continued)

LRU (16) , (19) LO_2 and Fuel Fill Coupling

The airborne half of these couplings consist of a mating ring with sealing surfaces. These components will require routine replacement of the mating parts.

LRU (17) , (18) LO_2 and Fuel Recirculation Line Coupling

These disconnect couplings are utilized to provide for ground recirculation of propellants just prior to launch. They are maintained like the other couplings.

LRU (22) , (25) LO_2 and Fuel Autogenous Line Filters

There are two of these components on the orbiter and these gas filters are installed in the GH_2 and GO_2 autogenous pressurization lines. They contain a diffuser and a removeable filter element which should be replaced after each flight.

LRU (23) , (26) Oxidizer and Fuel Pressurant Control Valve Package

These valves are used to control the pressurant flow rate of the autogenous gas to the propellant tanks in the event the primary orifice does not provide adequate control. These are solenoid operated valves.

LRU (24) , (27) Oxidizer and Fuel Pressurant Control Orifice

These fixed orifices control the pressurant flow rate into the propellant tanks. They are enclosed in a flanged joint for easy removal or replacement.

4. Orbiter Main Propulsion System (Continued)

LRU (28) Orbiter Main Engine

The high pressure, turbopump engine subsystem as defined in the DRM is composed of many assemblies, some of which are time sensitive and may require periodic maintenance. In the event that certain components in the engine that are not LRUs should fail or after the engine life cycle is passed, then a complete engine subsystem would be installed. Since there would be a base heat-shield and close-out boot that would isolate part of this engine, access panels in the rear area of each boom should be provided. The estimated weight of one complete engine is 5,370 lb. Therefore, special GSE would be required for engine removal. Additional ground equipment will be required for the extendable nozzle skirt on the orbiter engine.

5. Booster Auxiliary Propulsion System

Top level LRU identification for the APS is shown schematically in Figure III-3. Table III-2 reflects all components within this system and presents the criteria matrix resulting in LRU selection. The following is a brief description of the top-level LRUs. Those LRUs which are contained within the top-level LRUs are identified in the tabular listings.

LRU (1) RCS/Separation Engine Package

The RCS/Separation Engine Package consists of a thrust chamber assembly, ignition assembly and valve assembly. Under the ground rules established for determining a LRU, which states that the unit must be replaceable in the system with no change in system balance, and further, that the integrity of the replaced unit can be verified, the engine package will be removed as a single unit. The package includes the propellant valves, igniter assembly, and instrumentation, together with the thruster injector and chamber. The replacement of components on the package would be very difficult with the unit installed on the vehicle with the limitations of space and the inability to verify the component-to-vehicle-line-interface seal integrity once a component change had been made.

LRU (2)(3) GH_2 and GO_2 Filter

The oxygen and hydrogen gas filters are approximately eight inches long and are compatible with two to three inch lines and weigh approximately 3 pounds. The filter element is of the double weave wire cloth or etches disc type. The gas filters are brazed to the propellant distribution lines.

LRU (4)(5) GH_2 and GO_2 Solenoid Valve

The GH_2 solenoid valve is brazed to three inch propelland feed lines and weighs approximately 12 pounds. The GO_2 solenoid valve is brazed to three inch propelland feed lines and weighs approximately 10 pounds. Each solenoid valve has electrical connectors for electrical actuation and valve position instrumentation.

5. Booster Auxiliary Propulsion System (Continued)

LRU (6) GH_2 Check Valve Package

The GH_2 check valve package consists of two series redundant check valves welded to two inch propellant lines. The check valve package is brazed to two inch propellant lines in the Booster Hydrogen Conditioning Subsystem and Orbiter Propellant Conditioning Subsystem Gas Generator Assemblies. The check valve package is approximately 16 inches long and weighs approximately 1 pound.

LRU (7) Gas Generator GH_2 Propellant Valve Package

The gas generator GH_2 propellant valve package consists of two series redundant solenoid valves (main fuel valve and isolation valve) welded to two inch lines and weighs approximately 20 pounds. The valve package is brazed to two inch propellant lines in the Booster Hydrogen and Oxygen Conditioning Subsystems, Booster APU, and Orbiter Propellant Conditioning Subsystem Gas Generator Assemblies. Each solenoid valve has electrical actuation and valve position instrumentation connectors.

LRU (8) Gas Generator GO_2 Propellant Valve Package

The gas generator GO_2 propellant valve package consists of two series redundant solenoid valves (main oxidizer and isolation valve) welded to 1/2 inch lines and weighs approximately 15 pounds. The valve package is brazed to 1/2 inch propellant lines in the Booster Hydrogen and Oxygen Conditioning Subsystems, Booster APU, and Orbiter propellants conditioning subsystem gas generator assemblies. Each solenoid valve has electrical actuation and valve position instrumentation connectors.

LRU (9) LH_2 Check Valve Package

The LH_2 check valve package consists of two series redundant check valves welded to three inch propellant lines. The check valve package is brazed to three inch propellant lines in the Booster Hydrogen Conditioning Subsystem turbopump assembly. The check valve package is approximately 20 inches long and weighs approximately 2 pounds.

LRU (10) Turbopump

The booster turbopump consists of a LH_2 pump, turbine, gearbox, and lubrication system. The turbopump weighs approximately 250 pounds and flanges are provided on

5. Booster Auxiliary Propulsion System (Continued)

the turbine and pump for mounting to the vehicle structure. Three inch pump suction and discharge lines are brazed to the pump inlet and outlet. Electrical connectors are provided for pump and turbine speed and lubrication system temperature.

LRU (11) Turbopump Suction Valve Package

The turbopump suction valve package and LH_2 pump suction valve package consists of two series redundant solenoid valves (suction and isolation valves) welded to three inch and two inch lines respectively. The valve package weighs approximately 20 pounds. The valve package is brazed to pump suction lines in the Booster Hydrogen Conditioning and Orbiter Propellant Conditioning Subsystem turbopump assemblies. Each solenoid valve has electrical actuation and valve position instrumentation connectors.

LRU (12) Gas Generator/Heat Exchanger Package

The gas generator/heat exchanger package weighs approximately 50 pounds and has flanges for mounting to the turbine inlet duct. Mounting pads are also supplied for mounting to the vehicle structure. The heat exchanger inlet and outlet lines and gas generator propellant line connections are brazed. Electrical connectors are supplied for heat exchanger and gas generator pressure and temperature instrumentation and control.

LRU (13) LH_2 Solenoid Valve Package

The LH_2 Solenoid Valve Package consists of two series redundant solenoid valves (accumulator resupply valve and isolation valve) welded to three inch lines and weighs approximately 20 pounds. The valve package is brazed to three inch lines in the Booster Hydrogen Conditioning Subsystem turbopump assemblies. Each solenoid valve has electrical actuation and valve position instrumentation connectors.

LRU (14) Gas Generator

The gas generator weighs approximately 25 pounds and has flanges for mounting to the turbine inlet duct. Mounting pads are also supplied for mounting to the vehicle structure. The gas generator GO_2 propellant inlet is brazed to 1/2 inch line and the GH_2 propellant inlet is brazed to 2 inch line. Electrical connectors are supplied for igniter power, igniter valve control, and pressure and temperature control.

5. Booster Auxiliary Propulsion System (Continued)

LRU (15) Compressor GO_2 Inlet Valve Package

The compressor GO_2 inlet valve package consists of two series redundant solenoid valves (GO_2 propellant valve and isolation valve) welded to one inch lines and weighs approximately 15 pounds. The valve package is brazed to one inch propellant lines in the Booster Oxygen Conditioning Subsystem turbocompressor assemblies. Each solenoid valve has electrical actuation and valve position instrumentation connectors.

LRU (16) Turbocompressors

The booster turbocompressor weighs approximately 200 pounds and has flanged inlets and outlets to permit mounting to the gas generator, overboard ducting, and GO_2 inlet and outlet lines. Mounting pads are also supplied for mounting to the vehicle structure. An electrical connector is supplied for turbine and compressor instrumentation.

LRU (17) GO_2 Check Valve Package

The GO_2 check valve package consists of two series redundant check valves welded to one inch (booster) or two inch (orbiter) propellant lines. The check valve package is brazed to propellant lines in the Booster Oxygen Conditioning and Orbiter Propellant Conditioning Subsystems. The check valve package is approximately 12 inches long and weighs approximately 1 pound.

LRU (18) Turbine

The turbine weighs approximately 85 pounds and has a flanged inlet and outlet to permit mounting to the gas generator and overboard dump ducting. Mounting pads are also supplied for mounting to the vehicle structure. An electrical connector is supplied for turbine instrumentation.

LRU (19) GO_2 Manual Valve

The GO_2 manual valve is brazed to two inch propellant fill lines and weighs approximately 1 3/4 pounds.

LRU (20) GO_2 Relief Valve

The GO_2 relief valve is brazed to two inch propellant fill lines and weighs approximately 1 3/4 lbs.

5. Booster Auxiliary Propulsion System (Continued)

LRU (21) GO_2 Quick Disconnect/Solenoid Valve Package

The quick-disconnect/solenoid valve package consists of a quick-disconnect coupling in series with a solenoid valve. The components are welded to two inch lines and weighs approximately 12 pounds. The package is brazed to propellant fill lines in the propellant fill assemblies. Each solenoid valve has electrical connectors for electrical actuation. Mounting flanges are supplied on the quick-disconnect coupling for bolting to the vehicle structure.

LRU (22) GH_2 Manual Valve

The GH_2 Manual Valve is brazed to a three inch propellant fill line and weighs approximately 2 pounds.

LRU (23) GH_2 Relief Valve

The GH_2 Relief Valve is brazed to a three inch propellant fill line and weighs approximately 2 pounds.

LRU (24) GH_2 Quick Disconnect/Solenoid Valve Package

The LRU package is similar to LRU (21). The components are welded to three inch lines and the assembly weighs approximately 15 pounds.

LRU (25), (26) GO_2/GH_2 Regulator Package

The regulator package consists of two series redundant regulators. The regulators are welded to two to three inch connecting lines. Threaded connectors are provided downstream of each regulator for 1/4 inch sensing lines. The regulator package is brazed to two or three inch propellant lines in the Propellant Management Subsystem accumulator assemblies. Each regulator is supplied with electrical connectors for actuation and instrumentation. Each package weighs approximately 40 pounds and is supplied with mounting pads for bolting to the vehicle structure.

Table III-2 Auxiliary Propulsion System LRUs

Ref. No.	Auxiliary Propulsion System - Booster Item	Meet LRU Criteria				LRU	
		Time	Accessibility	Calibration	Verification	Yes	No
2.2.1.1	Accumulator Tank (T-4 through T-11)	NO	NO	X	X		X
2.2.1.2	Filter (F-4 through F-11)	X	X	X	X	X	
2.2.1.3	Regulator (R-5 through R-36)	X	X	X	X	X	
2.2.1.4	Solenoid Valve (V-29 through V-44)	X	X	X	X	X	
2.2.2.1	Quick Disconnect Coupling (C-8, C-9)	X	X	X	X	X	
2.2.2.2	Solenoid Valve (V-79, V-80)	X	X	X	X	X	
2.2.2.3	Relief Valve (V-25, V-27)	X	X	X	X	X	
2.2.2.4	Manual Valve (V-26, V-28)	X	X	X	X	X	
2.3.1.1	Turbine (U-1 through U-3)	X	X	X	X	X	
2.3.1.2	Power Train (PT-1 through PT-3)	X	X	X	X	X	
2.3.1.3	Pump (P-1 through P-3)	X	X	X	X	X	
2.3.1.4	LH_2 Solenoid Valve (V-90, V-91, V-92, V-93, V-94, V-63)	X	X	X	X	X	
2.3.1.5	LH_2 Check Valve (V-64 through V-69)	X	X	X	X	X	
2.3.1.6	GH_2 Accumulator Resupply Subassembly						
2.3.1.6.1	Heat Exchanger (H-1 through H-3)	X	NO	X	X		X
2.3.1.6.2	LH_2 Solenoid Valve (V-45 through V-50)	X	X	X	X	X	
2.3.2.1	Gas Generator (G-1 through G-3)	X	X	X	X	X	
2.3.2.2	Heat Exchanger (H-4 through H-6)	X	X	X	X	X	
2.3.2.3	GH_2 Solenoid Valve (GFV-1 through GFV-3)	X	X	X	X	X	
2.3.2.4	GO_2 Solenoid Valve (GOV-1 through GOV-3)	X	X	X	X	X	
2.3.2.5	GH_2 Check Valve (V-51 through V-53, V-95 through V-97)	X	X	X	X	X	
2.4.1.1	Turbine (U-4 through U-6)	X	X	X	X	X	
2.4.1.2	Power Train (PT-4 through PT-6)	X	X	X	X	X	
2.4.1.3	Compressor (CV-1 through CV-3)	X	X	X	X	X	
2.4.1.4	GO_2 Check Valve (V-54 through V-56, V-85 through V-87)	X	X	X	X	X	
2.4.1.5	GO_2 Solenoid Valve (V-57 through V-62)	X	X	X	X	X	
2.4.2.1	Gas Generator (G-4 through G-6)	X	X	X	X	X	
2.4.2.2	GO_2 Solenoid Valve (GOV-4 through GOV-6)	X	X	X	X	X	
2.4.2.3	GH_2 Solenoid Valve (GFV-4 through GFV-6)	X	X	X	X	X	
2.6.1.1	Gas Generator (G-7 through G-9)	X	X	X	X	X	
2.6.1.2	Turbine (X-1 through X-3)	X	X	X	X	X	
2.6.1.3	Power Train (PT-1 through PT-3)	X	X	X	X	X	
2.6.1.4	GH_2 Solenoid Valve (GFV-7 through GFV-9)	X	X	X	X	X	
2.6.1.5	GO_2 Solenoid Valve (GOV-7 through GOV-9)	X	X	X	X	X	

Table III-2 (Concluded)

Ref No.	Auxiliary Propulsion System - Booster and Orbiter Item	Meets LRU Criteria				LRU	
		Time	Accessibility	Calibration	Verification	Yes	No
2.1, 5.1	RCS Engine Subsystem	X	X	X	X	X	
2.1.1, 5.1.1	Thrust Chamber Assembly	X	NO*	X	NO		X
2.1.2, 5.1.2	Ignition Assembly	X	NO*	X	NO		X
2.1.3, 5.1.3	Valve Assembly	X	NO*	X	NO		X
2.5	APS Separation Engine Subsystem	X	X	X	X	X	
2.5.1	Thrust Chamber Assembly	X	NO*	X	X		X
2.5.2	Ignition Assembly	X	NO*	X	X		X
2.5.3	Valve Assembly	X	NO*	X	X		X
5.4	OMS Engine Subsystem	X	X	X	X	X	
5.4.1	Thrust Chamber Assembly	X	NO*	X	X		X
5.4.2	Ignition Assembly	X	NO*	X	X		X
5.4.3	Valve Assembly	X	NO*	X	X		X

*The components on the thrusters will, in all probability, be inaccessible; the thruster interfaces will be designed such that each thruster is readily replaceable, however.

Ref. No.	Auxiliary Propulsion System - Orbiter Item	Meets LRU Criteria				LRU	
		Time	Accessibility	Calibration	Verification	Yes	No
5.2.1.1	Accumulator Tank (T-8 through T-11)	NO	NO	X	X		X
5.2.1.2	Filter (F-6 through F-9)	X	X	X	X	X	
5.2.1.3	Regulator (R-13 through R-28)	X	X	X	X	X	
5.2.1.4	Solenoid Valve (V-36 through V-43)	X	X	X	X	X	
5.2.2.1	Quick Disconnect Coupling (C-9, C-10)	X	X	X	X	X	
5.2.2.2	Solenoid Valve (V-44, V-70)	X	X	X	X	X	
5.2.2.3	Relief Valve (V-45, V-71)	X	X	X	X	X	
5.2.2.4	Manual Valve (V-67, V-68)	X	X	X	X	X	
5.3.1.1	Gas Generator (G-1 through G-3)	X	X	X	X	X	
5.3.1.2	Heat Exchanger (H-4 through H-9)	X	X	X	X	X	
5.3.1.3	GO_2 Solenoid Valve (GOV-1 through GOV-3)	X	X	X	X	X	
5.3.1.4	GH_2 Solenoid Valve (GFV-1 through GFV-3)	X	X	X	X	X	
5.3.1.5	GO_2 Check Valve (V-46 through V-48)	X	X	X	X	X	
5.3.1.6	GH_2 Check Valve (V-49 through V-51, V-80 through V-85)	X	X	X	X	X	
5.3.2.1	Turbine (U-1 through U-3)	X	X	X	X	X	
5.3.2.2	Power Train (PT-1 through PT-3)	X	X	X	X	X	
5.3.2.3	Pump (P-1 through P-6)	X	X	X	X	X	
5.3.2.4	LO_2 Solenoid Valve (V-52 through V-54)	X	X	X	X	X	
5.3.2.5	LH_2 Solenoid Valve (V-55 through V-57)	X	X	X	X	X	

6. Orbiter Auxiliary Propulsion System

Table III-2 reflects all components within this system and presents the criteria matrix resulting in LRU selection. Top level LRU identification for the APS is shown schematically in Figure III-4.

The following is a brief description of the top-level LRUs. Those LRUs which are contained within the top-level LRUs are identified in the tabular listings.

LRU (1) RCS/OMS Engine Package

The definitions, removal, replacement and retest, procedures are similar to those defined for LRU (1) of the Booster Auxiliary Propulsion System.

LRU (2)(3) GH_2 and GO_2 Filter

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (2), (3) of the Booster Auxiliary Propulsion System.

LRU (4)(5) GH_2 and GO_2 Solenoid Valve

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (4), (5) of the Booster Auxiliary Propulsion System.

LRU (6) GH_2 Check Valve Package

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (6) of the Booster Auxiliary Propulsion System.

LRU (7) Gas Generator GH_2 Propellant Valve Package

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (7) of the Booster Auxiliary Propulsion System.

LRU (8) Gas Generator GO_2 Propellant Valve Package

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (8) of the Booster Auxiliary Propulsion System.

LRU (9) LH_2 Pump

The orbiter LH_2 pump weighs approximately 40 pounds and is bolted to the gear box housing of the turbo-pump assembly on the Propellant Conditioning Subsystem and the vehicle structure. Two inch pump suction and discharge lines are brazed to the pump inlet and outlet. Electrical connectors are provided for pump speed instru-

6. Orbiter Auxiliary Propulsion System (Continued)

LRU (10) LO_2 Pump

The Orbiter LO_2 Pump weighs approximately 40 pounds and is bolted to the gearbox housing of the turbopump assembly on the Propellant Conditioning Subsystem and the vehicle structure. Two inch pump suction and discharge lines are brazed to the pump inlet and outlet. Electrical connectors are provided for pump speed instrumentation.

LRU (11) LO_2 Heat Exchanger

The LO_2 heat exchanger weighs approximately 23 pounds and has flanges for mounting to the turbine exhaust and overboard ducting. The heat exchanger inlet and outlet lines are brazed to 1/2 inch LO_2 lines. Electrical connectors are supplied for heat exchanger pressure and temperature instrumentation.

LRU (12) LH_2 Heat Exchanger

The LH_2 heat exchanger weighs approximately 23 pounds and has flanges for mounting to the turbine exhaust and overboard ducting. The heat exchanger inlet and outlet lines are brazed to two inch LH_2 lines. Electrical connectors are supplied for heat exchanger pressure and temperature instrumentation.

LRU (13) Power Train Unit

The power train unit weighs approximately 125 pounds and has flanges for mounting of LH_2 and LO_2 pumps. Mounting pads are supplied for bolting to structural members. The lubrication system and electrical harness connector are mounted to the gearbox housing. Spline connectors are used to connect the power shafts to the APU and turbine of the Orbiter Propellant Conditioning subsystem.

LRU (14) Gas Generator

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (14) of the Booster Auxiliary Propulsion System.

LRU (15) Turbine

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (18) of the Booster Auxiliary Propulsion System.

6. Orbiter Auxiliary Propulsion System (Continued)

LRU (16) LH_2 Pump Suction Valve Package

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (11) of the Booster Auxiliary Propulsion System.

LRU (17) LO_2 Pump Suction Valve Package

The LO_2 pump suction valve package consists of two series redundant solenoid valves (suction and isolation) welded to two inch lines. The valve package weighs approximately 20 pounds. The valve package is brazed to pump suction lines in the Orbiter Propellant Conditioning Subsystem turbopump assemblies. Each solenoid valve has electrical actuation and valve position instrumentation connectors.

LRU (18) GH_2 Manual Valve

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (22) of the Booster Auxiliary Propulsion System.

LRU (19) GH_2 Relief Valve

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (23) of the Booster Auxiliary Propulsion System.

LRU (20) GH_2 Quick Disconnect/Solenoid Valve Package

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (24) of the Booster Auxiliary Propulsion System.

LRU (21) GO_2 Manual Valve

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (19) of the Booster Auxiliary Propulsion System.

LRU (22) GO_2 Relief Valve

The definitions, removal, replacement, and retest procedures are similar to those defined for LRU (20) of the Booster Auxiliary Propulsion System.

6. Orbiter Auxiliary Propulsion System (Continued)

LRU (23) GO_2 Quick Disconnect/Solenoid Valve Package

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (21) of the Booster Auxiliary Propulsion System.

LRU (24) / (25) GO_2/GH_2 Regulator Package

The definitions, removal, replacement and retest procedures are similar to those defined for LRU (24) / (25) of the Booster Auxiliary Propulsion System.

7. Booster Airbreathing System

Table III-3 reflects all components within this system and presents the criteria matrix resulting in LRU selection. Top level LRU identification for the system is shown schematically in Figure III-5.

The following is a brief description of the top-level LRUs. Those LRUs which are contained within the top-level LRUs are identified in the tabular listings.

LRU (1) Turbofan Engine Subsystem

The turbofan engine subsystem as previously defined is composed on several assemblies (refer to Section IIC) some of which are time sensitive and may require periodic maintenance. Should a failure occur or periodic maintenance be required in the engine power assembly, it is probable that a complete new turbofan engine subsystem would be installed; however, turbofan engine LRUs are shown in Figure III-6. Since each of the seven turbofan engine subsystems is contained in its own wing compartment one subsystem can be removed with minimum effect on the other six subsystems. The estimated weight of one complete turbofan engine subsystem is 2200 lb. Therefore, ground support handling equipment would be required for engine removal.

LRU (2) Turbofan Inlet Valve Package

The valve package is composed of four series -- parallel solenoid valves and is used seven places. The package is fabricated with welded connections between the tubing and the solenoid valves. The welded assembly is installed into the vehicle with brazed sleeves. The tubing and valve inlet/outlet sizes are estimated at 0.5 in. O.D. The estimated weight of the package is 25 lb.

7. Booster Airbreathing System (Continued)

LRU (3) Cruise Tank Fuel Distribution Valve Package

The valve package consists of four series-parallel solenoid valves, joined with welded connections between the tubing and the solenoid valves. The welded assembly is installed into the vehicle with brazed sleeves. The tubing and valve inlet/outlet sizes are estimated at 4 in. O.D. The estimated weight of the package is 50 lb.

LRU (4) Cruise Tank Vent Valve Package

The valve package is composed of four series-parallel solenoid valves. The package is fabricated with welded connections between the tubing and the solenoid valves. The welded assembly is installed into the vehicle with brazed sleeves. The tubing and valve inlet/outlet sizes are estimated at 5 in. O.D. The estimated weight of the package is 60 lb.

LRU (5) Cruise Tank Vent Disconnect Coupling

This device is the airborne half of the GH_2 cruise tank GSE dumping system coupling. It is attached to the airborne vent transfer line by means of a bolted flange containing a sealing mechanism. The vent line tubing and corresponding attachment to the coupling are estimated at 5 in. O.D. The estimated airborne coupling weight is 20 lb.

LRU (6) Cruise Tank Fill Valve

This LRU has an estimated inlet/outlet size adaptable to 6-in. O.D. transfer lines. The valve is installed into the vehicle with bolted flanges which contain sealing devices. The estimated weight of the LRU is 30 lb.

LRU (7) Cruise Tank Fill Coupling

The coupling is the airborne half for the LH_2 cruise tanks GSE fill and drain system. The coupling is attached to the estimated 6-in. O.D. transfer lines by means of bolted flanges which contain sealing devices. The estimated weight of the airborne coupling is 25.

7. Booster Airbreathing System (Continued)

LRU (8) Cruise Tank Pressurization Regulator Package

The LRU package is composed of two regulators in series. The regulators and tubing are connected by welded joints. The regulator downstream sensing mechanism is connected to the downstream tubing with threaded plumbing tubing connections. The sensing line is estimated as ¼-in. O.D. tubing. The regulator inlet/outlet is sized for an estimated 2-in. O.D. tubing. The package is installed in the vehicle with brazed sleeves. The LRU estimated weight is 40 lb.

LRU (9) Cruise Tank Pressurization Valve Package

The LRU consists of two parallel mounted solenoid operated valves. The valves are installed in the vehicle with brazed sleeves. The valve inlet/outlet configuration is an estimated 2 in. O.D. tubing. The estimated LRU weight is 15 lb.

LRU (10) Pressurization Filter

The LRU is a single filter. The filter is installed into the vehicle with brazed sleeves. The inlet/outlet filter configuration is 2-in. O.D. tubing. The estimated LRU weight is 3 lb.

7. Booster Airbreathing System (Continued)

Turbofan Engine Subsystem

LRU (1) Engine Power Assembly

The Engine Power Assembly is composed of rotating machinery which is critical from an alignment and installation viewpoint. This criticality precludes in-place replacement of specific hardware. Replacement of failed hardware or periodic maintenance is best achieved through removal and replacement of the complete Turbofan Engine Subsystem. The removal, replacement and retest requirements for the Turbofan Engine Subsystem are as defined for LRU (1) of part a.

LRU (2) Fuel Control Assembly

The Fuel Control Assembly will be split into two modular packages which are mounted either directly on the Engine Power Assembly or on the engine compartment structure. One of the modular packages is the Electronic Controller, which will be mounted on the structure. The LRU description for the Electronic Controller is given below. The other modular package is composed of the fuel inlet valve, pump, and other hardware which supply GH_2 to the engine burner (refer to Figure III-6). These hardware will be modular mounted on the Engine Power Assembly. Because of the critical nature of the latter hardware and the dependence of proper operation of one component on the output of another component, it is assumed that failure of one component will necessitate "bench" recalibration of some other component at the time the failed component is replaced. Therefore, failure of any component in this modular package will require replacement of the entire package. Since the Electronic Controller depends upon component calibration data the Electronic Controller will be replaced anytime the modular component package is replaced. Thus, a totally "bench" calibrated Fuel Control System will be on board the vehicle at all times. The estimated weight of the modular component package is 150 lb.

7. Booster Airbreathing System (Continued)

LRU (3) Electronic Controller

As indicated above the Electronic Controller is structure-mounted in the engine compartment. The controller will be mounted in such a manner as to isolate it from the extraneous inputs that would impair or preclude function. An Electronic Controller failure will require that the replacement part be programmed with the acceptance test and calibration data that is unique to the Fuel Control Assembly and/or the Engine Power Assembly components. The estimated weight of the Electronic Controller is 80 lb.

LRU (4) Scavenge Pump

Five Scavenge Pumps are used. The pumps are modular mounted and when one pump fails the entire module is replaced. Six connections are broken for module replacement. The assembly is welded and the welded assembly is mounted to the Engine Power Assembly with brazed sleeves. The weight of the module is estimated at 40 lb.

LRU (5) Oil Boost Pump

The Oil Boost Pump is mounted to the Engine Power Assembly and plumbing connections are made with brazed sleeves. The estimated weight of the Oil Boost Pump is 10 lb.

LRU (6) Oil Pressure Pump

The Oil Pressure Boost Pump is mounted to the Engine Power Assembly and plumbing connections are made with brazed sleeves. The estimated weight of the Oil Pressure Pump is 10 lb.

LRU (7) Oil Strainer

Five Oil Strainers are used and are mounted external to the Engine Power Assembly. Each oil strainer has removal and replacement capability. The oil strainers are installed in the plumbing lines with threaded connectors. The estimated weight of each strainer is 1/2 lb.

7. Booster Airbreathing System (Continued)

LRU (8) Boost Pump Relief Valve

The Boost Pump Relief Valve is mounted on the Engine Power Assembly and plumbing connections are made with brazed sleeves. The estimated weight of the valve is 1 lb.

LRU (9) Boost Pump Regulating Valve

The Boost Pump Regulating Valve is mounted on the Engine Power Assembly and plumbing connections are made with brazed sleeves. The estimated weight of the valve is 1 lb.

LRU (10) Main Pressure Regulating Valve

The Main Pressure Regulating Valve is mounted on the Engine Power Assembly and plumbing connections are made with brazed sleeves. The estimated weight of the valve is 1 lb.

LRU (11) Zero "G" Tube Pressure System

This system does not exist on the Booster Turbofan Engine Subsystem.

LRU (12) Ignition Exciter

The Ignition Exciter is mounted on the Engine Power Assembly. Electrical connections are made with quick connect couplings. The estimated weight of the Exciter is 2 lb.

LRU (13) Ignition Compositor

The Ignition Compositor is mounted on the Ignition Exciter. Electrical connections are made with quick connect couplings. The estimated weight of the Compositor is 1/2 lb.

LRU (14) Ignition Plug

The Ignition Plug is mounted directly on the burner of the Engine Power Assembly. Electrical connections are made with quick connect couplings. The estimated weight of the Plug is 1/2 lb.

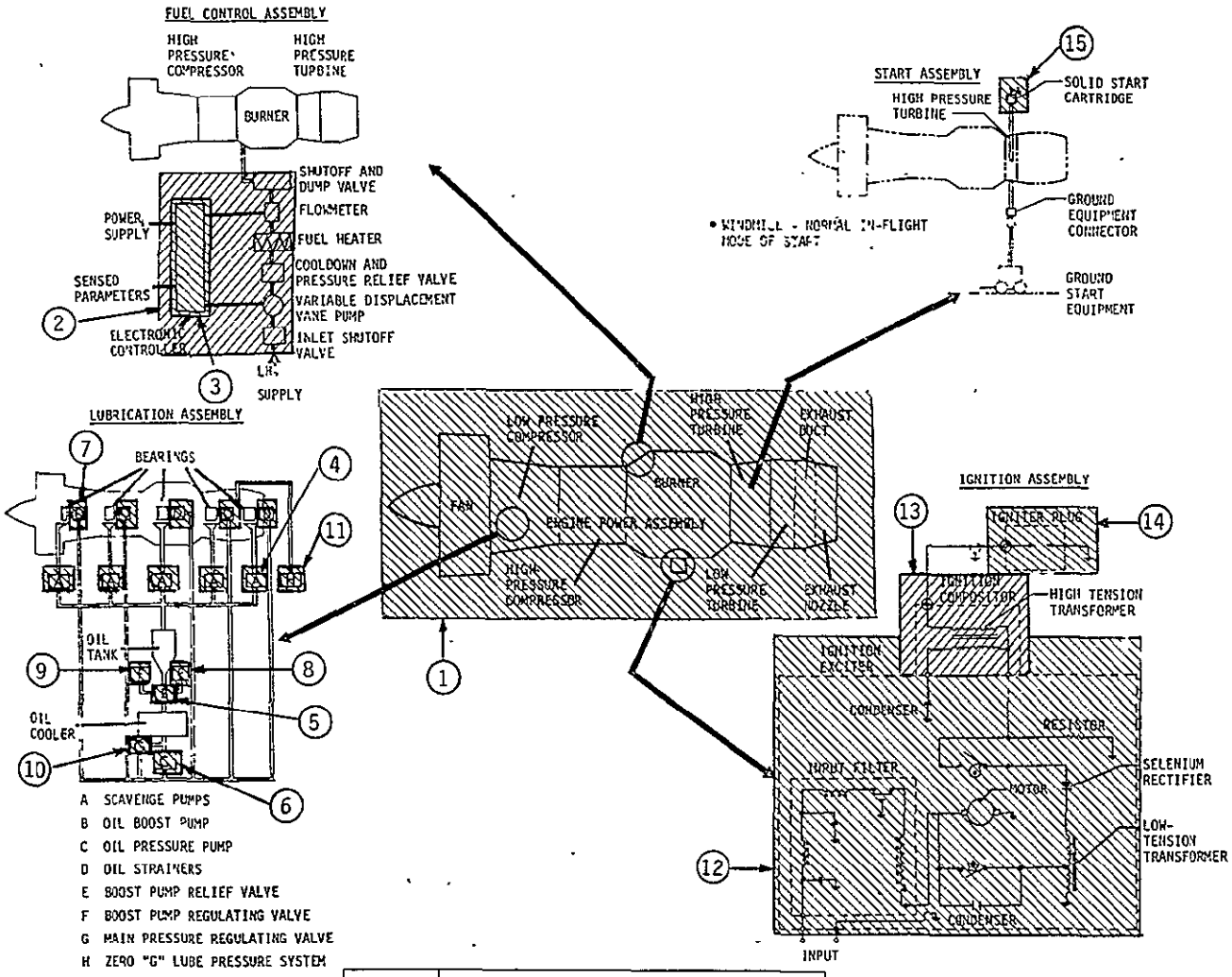
7. Booster Airbreathing System (Concluded)

LRU (15) Solid Start Cartridge

The Solid Start Cartridge is mounted in the Engine Power Assembly on the external structure of the high pressure turbine. Electrical connections are made with quick connect couplings. The estimated weight of the Cartridge is 2 lb.

Table III-3 Booster Airbreathing System LRUs

Ref. No.	Airbreatning Propulsion-Booster Item	Meets LRU Criteria				LRU	
		Time	Accessibility	Calibration	Verification	Yes	No
3.1	Engine Power Assembly	X	X	X	X	X	
3.1.1.1	Fan						X
3.1.1.2	Low Pressure Compressor	X	X	NO	NO		X
3.1.1.3	High Pressure Compressor	X	X	NO	NO		X
3.1.1.4	Burner	X	X	NO	NO		X
3.1.1.5	High Pressure Turbine	X	X	NO	NO		X
3.1.1.6	Low Pressure Turbine	X	X	NO	NO		X
3.1.2	Fuel Control Assembly	X	X	X	X	X	
3.1.2.1	Inlet Shutoff Valve						X
3.1.2.2	Variable Displacement Vane Pump	X	X	NO	NO		X
3.1.2.3	Cooldown and Pressure Relief Valve	X	X	NO	NO		X
3.1.2.4	Fuel Heater	X	X	NO	NO		X
3.1.2.5	Flowmeter	X	X	NO	NO		X
3.1.2.6	Shutoff and Dump Valve	X	X	NO	NO		X
3.1.2.7	Electronic Controller	X	X	X	X	X	
3.1.3.1	Scavenge Pumps	X	X	X	X	X	
3.1.3.2	Oil Boost Pumps	X	X	X	X	X	
3.1.3.3	Oil Strainers	X	X	X	X	X	
3.1.3.4	Boost Pumps Relief Valve	X	X	X	X	X	
3.1.3.5	Boost Pump Regulating Valve	X	X	X	X	X	
3.1.3.6	Main Pressure Regulating Valve	X	X	X	X	X	
3.1.4.1	Solid Start Cartridge	X	X	X	X	X	
3.1.5.1	Igniter Plug	X	X	X	X	X	
3.1.5.2	Ignition Compositer	X	X	X	X	X	
3.1.5.3	Ignition Exciter	X	X	X	X	X	
3.2.1.1	Inlet Pressurization Diffuser	NO	NO	NO	NO		X
3.2.1.2	Hemisphere Segments	NO	NO	NO	NO		X
3.2.1.5	Mounting Brackets	NO	NO	NO	NO		X
3.2.2.2	Series-Parallel Solenoid Valve Package	X	X	X	X	X	
3.2.3.2	Series-Parallel Solenoid Valve Package	X	X	X	X	X	
3.2.4.2	Series-Parallel Valve Package	X	X	X	X	X	
3.2.4.3	Quick Disconnect Coupling	X	X	X	X	X	
3.2.5.1	Quick Disconnect Coupling	X	X	X	X	X	
3.2.5.3	Solenoid Operated Valve with Integral Relief Provision	X	X	X	X	X	
3.3.1.2	Series-Parallel Regulator Package	X	X	X	X	X	
3.3.1.3	Parallel Solenoid Valve Package	X	X	X	X	X	
3.3.1.4	Filter	X	X	X	X	X	



LRU NUMBER	DESCRIPTION
(1)	Engine Power Assembly
(2)	Fuel Control Assembly
(3)	Electronic Controller
(4)	Scavenge Pump
(5)	Oil Boost Pump
(6)	Oil Pressure Pump
(7)	Oil Strainer
(8)	Boost Pump Relief Valve
(9)	Boost Pump Regulating Valve
(10)	Main Pressure Regulating Valve
(11)	Zero-g Lube Pressure System*
(12)	Ignition Exciter
(13)	Ignition Compositor
(14)	Igniter Plug
(15)	Solid Start Cartridge

*Applicable to orbiter only.

TURBOFAN ENGINE SUBSYSTEM LINE REPLACEABLE UNITS

Figure III-6

8. Orbiter Airbreathing System

Table III-4 reflects all components within this system and presents the criteria matrix resulting in LRU selection. Line Replaceable Unit (LRU) identification for the system is shown schematically in Figure III-7.

The following is a brief description of the top-level LRUs. Those LRUs which are contained within the top-level LRUs are identified in the tabular listings.

LRU (1) Turbofan Engine Subsystem

The removal, replacement and retest requirement description is the same as that described for the Booster Airbreathing System. Refer to paragraph a., LRU (1).

LRU (2) Fuel Feed Valve Package

The valve package is composed on four series -- parallel solenoid valves and is used seven places. The package is fabricated with welded connections between the tubing and the solenoid valves. The welded assembly is installed in the system with brazed sleeves. The tubing and valve inlet/outlet sizes are estimated at 1/2-inch O.D. The estimated weight of the valve package is 25 lb. The removal, replacement and retest requirements are similar to those described for the Booster Airbreathing System, LRU (2) Turbofan Engine Inlet Valve Package.

LRU (3) GH_2 Valve Package

The LRU package is composed of two solenoid valves in series. The valves and tubing are connected by welded joints. The valve inlet/outlet is sized for an estimated 1 inch O.D. tubing. The package is installed in the system with brazed sleeves. The LRU estimated weight is 20 lbs.

8. Orbiter Airbreathing System (Continued)

LRU (4) Gas Generator Assembly

The Gas Generator Assembly is assumed to be mounted to structure and attached by bolted flanges to the Turbopump inlet duct. The Gas Generator Assembly includes a spark type ignition system, as well as GH_2 and GO_2 inlet ports. An overboard vent system is assumed to be included as part of the Turbopump assembly. The inlet/outlet gas connections are tubing welded to the Gas Generator Assembly. The gas valves are installed on the tubing with brazed sleeves. The estimated weight of the Gas Generator Assembly is 23 lb.

LRU (5) GO_2 Valve Package

The LRU package is composed of two solenoid valves in series. The valves and tubing are connected by welded joints. The valve inlet/outlet is sized for an estimated 1 inch O.D. tubing. The package is installed in the system with brazed sleeves. The LRU estimated weight is 20 lb. The removal, replacement and retest requirements are similar to LRU (3) .

LRU (6) LH_2 Valve Package

The LH_2 Valve Package consists of two solenoid valves in series. The valves and tubing are connected by welded joints. The valve inlet/outlet is sized for an estimated 1/2 inch O.D. tubing. The package is installed in the system with brazed sleeves. The estimated weight is 13 lb.

LRU (7) Turbopump Assembly

The Turbopump Assembly is assumed to be mounted to structure and attached by bolted flanges to the Gas Generator Assembly outlet duct. The suction and discharge sides of the pump consist of tubing which is an integral part of the pump. The mating hardware is connected to the tubing with brazed sleeves. The estimated weight of the Turbopump Assembly is 30 lb.

8. Orbiter Airbreathing System (Continued)

LRU (8) Check Valve Package

The LRU is composed of two Check Valves in series. The valves and tubing are connected by welded joints. The valve inlet/outlet is sized for an estimated 1/2 inch O.D. tubing. The package is installed in the system with brazed sleeves. The estimated weight is 10 lb.

Turbofan Engine Subsystem

The LRUs for the Orbiter Turbofan Engine Subsystem are the same as those described for the Booster Turbofan Engine Subsystem except for the Zero-G lube oil pressure system which is described below. Refer to section b. of the Booster Airbreathing System for other Turbofan Engine Subsystem LRU descriptions and removal, replacement and retest requirements.

LRU (11) Zero-G Lube Pressure System

This LRU consists of a small gas storage vessel, a regulator which has vent capability, and a solenoid valve located at the tie-in point to the Lube Oil system. These components are modular mounted external to the Engine Power Assembly. A failure of any component requires replacement of the entire module. Modular mounted components are connected by welded tubing and the module is installed in the system with brazed sleeves. The estimated weight of the module is 25 lb.

Table III-4 Orbiter Airbreathing System LRUs

Ref. No.	Airbreathing Propulsion-Orbiter Item	Meets LRU Criteria				LRU	
		Time	Accessibility	Calibration	Verification	Yes	No
6.1.1.1	Fan	X	X	NO	NO		X
6.1.1.2	Low Pressure Compressor	X	X	NO	NO		X
6.1 1.3	High Pressure Compressor	X	X	NO	NO		X
6.1.1.4	Burner	X	X	NO	NO		X
6.1.1.5	High Pressure Turbine	X	X	NO	NO		X
6.1.1.6	Low Pressure Turbine	X	X	NO	NO		X
6.1 2.1	Inlet Shutoff Valve	X	X	NO	NO		X
6.1.2.2	Variable Displacement Vane Pump	X	X	NO	NO		X
6.1.2.3	Cooldown and Pressure Relief Valve	X	X	NO	NO		X
6.1.2.4	Fuel Heater	X	X	NO	NO		X
6.1.2.5	Flowmeter	X	X	NO	NO		X
6.1.2.6	Shutoff and Dump Valve	X	X	NO	NO		X
6.1.2.7	Electronic Controller	X	X	X	X	X	
6.1.3.1	Scavenge Pumps	X	X	X	X	X	
6.1.3.2	Oil Boost Pumps	X	X	X	X	X	
6.1.3.3	Oil Strainers	X	X	X	X	X	
6.1.3.4	Boost Pump Relief Valve	X	X	X	X	X	
6.1.3.5	Boost Pump Regulating Valve	X	X	X	X	X	
6.1.3.6	Main Pressure Regulating Valve	X	X	X	X	X	
6.1.3.7	Zero "G" Pressure Supply System	X	X	X	X	X	
6.1.4.1	Solid Start Cartridge	X	X	X	X	X	
6.1.5.1	Igniter Plug	X	X	X	X	X	
6.1.5.2	Ignition Compositor	X	X	X	X	X	
6.1.5.3	Ignition Exciter	X	X	X	X	X	
6.2.1.1	Series-Parallel Solenoid Operated Valve Package	X	X	X	X	X	
6.2.2.1	Pump	X					X
6.2.2.2	Series Solenoid Operated Valve Package	X	X	X	X	X	
6.2.2.3	Turbine	X					X
6.2.2.4	Series Check Valves	X	X	X	X	X	
6.2.3.1	Gas Generator	X	X	NO	NO		X
6.2.3.2	H_2 Series Solenoid Operated Valve Package	X	X	X	X	X	
6.2.3.3	O_2 Series Solenoid Operated Valve Package	X	X	X	X	X	
6.1.1	Engine Power Assembly	X	X	X	X	X	
6.1.2	Fuel Control Assembly	X	X	X	X	X	
6.2.2	Turbopump Assembly	X	X	X	X	X	
6.2.3	Gas Generator Assembly	X	X	X	X	X	

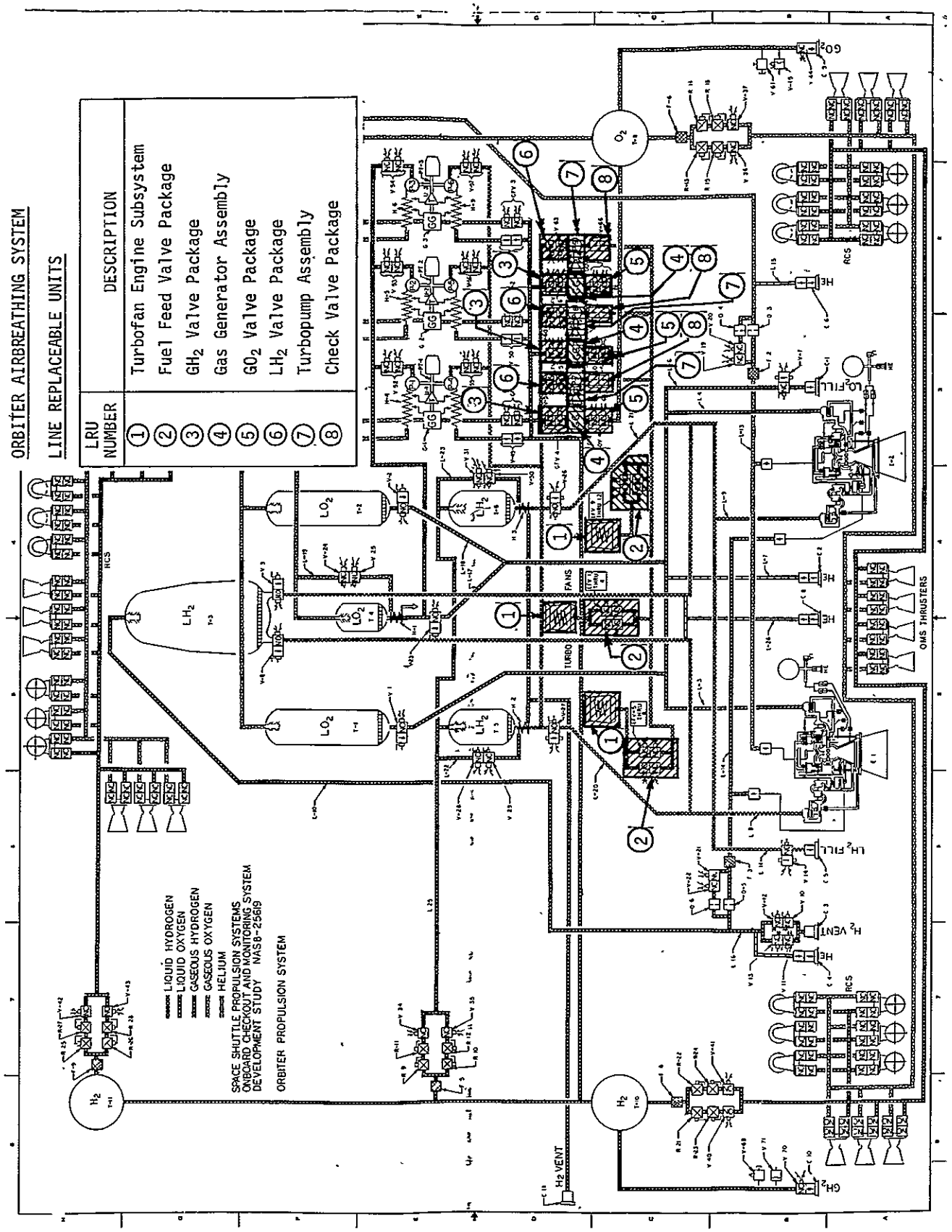

ORBITER AIRBREATHING SYSTEM
LINE REPLACEABLE UNITS
LRU NUMBER
DESCRIPTION
① Turbofan Engine Subsystem
② Fuel Feed Valve Package
③ GH2 Valve Package
④ Gas Generator Assembly
⑤ GO2 Valve Package
⑥ LH2 Valve Package
⑦ Turbopump Assembly
⑧ Check Valve Package
LIQUID HYDROGEN
LIQUID OXYGEN
GASEOUS HYDROGEN
GASEOUS OXYGEN
HELIUM
SPACE SHUTTLE PROPULSION SYSTEMS ONBOARD CHECKOUT AND MONITORING SYSTEM DEVELOPMENT STUDY NAS8-25619
ORBITER PROPULSION SYSTEM
RCS
OMS THRUSTERS
TURBO
TANK
H2 VENT
GO2 FILL
LH2 FILL
H2 VENT
GH2

Figure III-7

IV. PROPULSION OCMS REQUIREMENTS

A. REQUIREMENTS ANALYSIS

The OCMS Checkout and Monitoring Requirements Analysis was converted in this report period from a subsystem-by-subsystem analysis to a detailed phase-by-phase analysis. This documentation is discussed and presented in Appendix D.

B. MEASUREMENT REQUIREMENTS

A new measurement requirements list format was developed during this quarter. This format is designed to be used in conjunction with the OCMS Checkout and Monitoring Requirements Analysis (Appendix D) and the sensor criteria format. Together, these define the measurements and their usage to the extent that all necessary data is compiled for determining the following:

1. Availability of suitable sensors
2. Sensor development requirements
3. OCMS hardware functional requirements and distribution
4. Data Bus traffic

The measurement requirements have been updated and transcribed from preliminary listings to the new format and are included in Appendix E (Table E-I). A discussion of the column headings and codes used in the measurement requirements tabulation is included in the same appendix, as is a tabulation of measurement identity codes (Table E-II).

Table IV-I presents a tabulation of the measurement requirements grouped by measurement types. This table has been updated and expanded to include all measurements currently identified, with the exception of those for the main engine.

C. OCMS APPROACH

The following paragraphs provide an overview of the approach taken to perform the tasks required to meet the OCMS objectives.

1. Preflight Checkout - Preflight checks will be performed only for verification that completion of the last flight and the subsequent ground operations have left all equipment in the correct condition for propellant servicing and for start, and to establish an acceptable level of confidence in instrumentation. Functional tests to verify operating performance prior to start will not be conducted. This approach assumes that factory acceptance test, performance monitoring during flight, post-maintenance retest of replaced LRUs, and monitoring during ground servicing operations has

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TABLE IV-I

MEASUREMENT REQUIREMENTS
SUBSYSTEM: ALL
MEASUREMENT TYPES,

MEAS. TYPE NO.	PARAMETER DESCRIPTION	IDENTICAL MEAS. QUAN. BOOS.	IDENTICAL MEAS. QUAN. ORB.	RANGE AND UNITS	MEAS. TOL.	RESPONSE TIME	ENVIRONMENT	RQMTS. SOURCE REF. C/M ANAL. BOOS	C/M ANAL. ORB	FMEA BOOS	FMEA ORB
P-1	PRESSURE	13	11	0-60 PSIA	± 2 PSI	20 PSI/SEC	LO_2, LH_2, GH_2, 700°R, FLUSH MNT	1.2 3.2	4.2 4.4 6.2	1.2 3.2	4.2 4.4
P-1A	PRESSURE	8		0-50 PSIA	± 1 PSI	20 PSI/SEC	GO_2, GH_2, He, 750°R, FLUSH MNT, OVER PRES. 800 PSIA	2.2	5.2	2.2	5.2
P-1B	PRESSURE	8	4	0-50 PSIA	± 1 PSI	20 PSI/SEC	GO_2, GH_2, He, 750°R, FLUSH MNT, OVER PRES. 2000 PSIA	2.2	5.2	2.2	5.2
P-2	PRESSURE	26	11	0-100 PSIA	± 1 PSI	50 PSI/SEC	LO_2, GO_2, LH_2, He, 700°R, FLUSH MNT	1.1 1.2 2.4	4.1 6.2 4.2	1.2 2.3 2.4	4.2 6.2
P-2A	PRESSURE	9	6	0-100 PSIG	± 1 PSI	20 PSI/SEC	LUBE OIL, 700°R, FLUSH MNT	2.3 2.4 2.6	5.3 6.2	2.3 2.4 2.6	5.3
P-3	PRESSURE	16	3	0-200 PSIA	± 2 PSI	20 PSI/SEC	LO_2, 700°R, FLUSH MNT	1.1 1.2	4.1 4.2	1.2	4.2
P-4	PRESSURE	38	27	0-750 PSIA	± 2 PSI	50,000 PSI/SEC	GO_2, GH_2, COMBUST., 5000°R. FLUSH MNT	2.1 2.5	5.1 5.4	2.1 2.5	5.1 5.4
P-5	PRESSURE	9	6	0-1000 PSIA	± 5 PSI	50,000 PSI/SEC	GO_2, GH_2, COMBUST., 1800°R, FLUSH MNT	2.3 2.4 2.6	5.3 6.2	2.3 2.4 2.6	5.3 6.2
P-6	PRESSURE	8	4	0-800 PSIA	± 4 PSI	1,000 PSI/SEC	GO_2, GH_2, He, 750°R, FLUSH MNT	2.2	5.2	2.2	5.2
P-6A	PRESSURE	12	6	0-1200 PSIA	± 10 PSI	500 PSI/SEC	GO_2, GH_2, He, 900°R, FLUSH MNT	1.3	4.3	1.3	4.5
P-7	PRESSURE	21	12	0-2000 PSIA	± 10 PSI	1,500 PSI/SEC	GO_2, LH_2, 530°R, FLUSH MNT	2.3 2.4	5.3	2.3 2.4 2.6	5.3
P-7A	PRESSURE	16	8	0-2000 PSIA	± 10 PSI	1,000 PSI/SEC	GO_2, GH_2, He, 750°R, FLUSH MNT	2.2	5.2	2.2	5.2
P-7B	PRESSURE	2	2	0-2000 PSIA	± 10 PSI	500 PSI/SEC	GO_2, GH_2, 750°R, FLUSH MNT	3.3	4.5	3.3	4.5
P-1-TF	PRESSURE	7	3	0-60 PSIA	±0.5 PSI	20 PSI/SEC	GH_2, 600°R, FLUSH MNT	3.1	6.1		
P-1C-TF	PRESSURE	7	3	0-20 PSIA	±0.5 PSI	20 PSI/SEC	AMB. AIR, MNT ON INLET DUCT STRUCT.	3.1	6.1		
P-2A-TF	PRESSURE	28	12	0-100 PSIA	±0.5 PSI	20 PSI/SEC	LUBE OIL, 1000°F, FLUSH MNT.	3.1	6.1	3.1	6.1
P-3A-TF	PRESSURE	7	3	0-200 PSIA	±0.5 PSI	20 PSI/SEC	HOT GAS, 2500°R, FLUSH MNT.	3.1	6.1		
P-3B-TF	PRESSURE	7	3	0-150 PSIA	± 2 PSI	20 PSI/SEC	HOT GAS, 2500°R, MNT IN EXH. DUCT	3.1	6.1		
P-3C-TF	PRESSURE	7	3	0-200 PSID	± 4 PSI	20 PSI/SEC	LH_2, 530°R, MNT ON VANE PUMP	3.1	6.1		
V-1	VIBRATION	15	24	0-5 g	±0.5 g	0-5000 Hz	BEARING: COMPRES., TURB., PUMP, APU CLUTCH PWR. TRN.			2.3 2.4 2.6	5.3 6.2
V-1A-TF	VIBRATION	21	9	0-5 g, 3-AXIS	±0.5 g	0-3000 Ha	BEARING: FRONT FAN, CORE, LO-PRES.	3.1	6.1	3.1	6.1
AC-1-TF	ACOUSTIC	7	3	30-160 dB	± 3 dB	50-10,000 Hz	MNT ON ENG. PWR. ASSY.			3.1	6.1

NOTES: TF = TURBOFAN
MNT = MOUNT

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE IV-1 (Continued)

MEASUREMENT REQUIREMENTS
SUBSYSTEM: ALL
MEASUREMENT TYPES, GROUPED

MEAS. TYPE NO.	PARAMETER DESCRIPTION	IDENTICAL MEAS. QUAN.		RANGE AND UNITS	MEAS. TOL.	RESPONSE TIME	ENVIRONMENT	ROMTS. SOURCE REF. C/M ANAL.		FMEA	
		BOOS	ORB.					BOOS.	ORB.	BOOS	ORB.
T-1	TEMP.	9	3	0-100 °R	± 5°R	10°R/SEC	LH_2, 60 PSIA, MNT ON TK TOP, SUCT. LINE	3.2	6.2		
T-2	TEMP.	66	18	0-700 °R	± 5°R	20°R/SEC	LO_2, GO_2, LH_2, GH_2, 200 PSIA, MNT ON TK TOP, SUCT. LINE	1.1 1.2	4.1 4.2 4.4 4.5	1.2	4.2
T-3	TEMP.	8	4	0-750 °R	± 5°R	200°R/SEC	GO_2, GH_2, He, 1500 PSIA, MNT ON TK TOP	2.2	5.2 5.3		
T-4	TEMP.	--	6	0-1000°R	±10°R	20°R/SEC	1500 PSIA, MNT ON PUMP BRG.				5.3
T-5	TEMP.	9	9	0-1300°R	±10°R	20°R/SEC	LUBE OIL, 50 PSI, MNT ON TURB, FWR. TRN BRG	2.3 2.4 2.6	5.3	2.3 2.4 2.6	5.3
T-6	TEMP.	3	--	0-2000°R	±20°R	20°R/SEC	1500 PSIA, MNT ON COMPRES. BRG.			2.4	
T-7	TEMP.	9	6	0-2500°R	±20°R	200°R/SEC	GO_2 & GH_2 COMBUST. (~1800°R), 500 PSIA, MNT IN G.G. CHAMB.	2.3 2.4 2.6	5.3 6.2		
T-2A-TF	TEMP.	14	6	0-600 °R	±10°R	20°R/SEC	GH_2, 60 PSIA, MNT ON INLET ENG. & HEAT. OUTLET LINES	3.1	6.1		
T-4A-TF	TEMP.	7	3	0-1000°R	±20°R	20°R/SEC	INLET AIR, 20 PSIA, MNT ON DUCT	3.1	6.1		
T-5A-TF	TEMP.	7	3	0-1000°R	±20°R	20°R/SEC	LUBE OIL, 100 PSIA, MNT IN SCAV. PUMP	3.1	6.1	3.1	6.1
T-5B-TF	TEMP.	7	3	0-1500°R.	±20°R	20°R/SEC	200 PSIA, MNT IN TURB.	3.1	6.1	3.1	6.1
T-7A-TF	TEMP.	28	12	0-2500°R	±20°R	20°R/SEC	200 PSIA, MNT IN TURB, EXH. DUCT, BURNER	3.1	6.1		
FR-1	FLOW RATE	2	--	0-20 lb/SEC	±0.25 lb/SEC	100 lb/SEC^2	LH_2, MNT IN LINE FR. TK	3.2			
FR-1A-TF	FLOW RATE	7	3	0-20 lb/SEC	±0.5 lb/SEC	15 lb/SEC^2	GH_2, MNT IN FUEL FLOWMETER	3.1	6.1		
L-1	LEVEL	12	12	COV'D/UNCOV'D	±0.13 INCH	0.001 SEC	LO_2, LH_2, 700°R, 200 PSIA	1.2	4.2 4.4	1.2	4.2 4.4
L-2	LEVEL	9	6	0-6 INCH	±0.125 INCH	12 INCH/SEC	LUBE OIL, 100 PSIG, 700°R	2.3 2.4 2.6	5.3 6.2	2.3 2.4 2.6	5.3
L-3	LEVEL	4	--	0-20 FT	±0.07 FT	100 FT/SEC	LH_2, 100°R, MNT IN TK	3.2			
L-2A-TF	LEVEL	7	3	0-1 FT	±0.03 FT	20 FT/SEC	LUBE OIL, 1000°F, 100 PSIA	3.1	6.1	3.1	6.1
SP-1	SPEED	9	6	0-100,000 RPM	±500 RPM	10,000 RPM/SEC	TURB., 2400°R, 500 PSIA	2.3 2.4 2.6	5.3 6.2	2.3 2.4 2.6	5.3 6.2
SP-1A	SPEED	3	9	0-100,000 RPM	±500 RPM	10,000 RPM/SEC	PUMP, 41-530°R, 1500 PSIA			2.3	5.3
SP-2	SPEED	3	--	0-300,000 RPM	±1500RPM	10,000 RPM/SEC	COMPRES., 1000°R, 1500 PSIA			2.4	
SP-3-TF	SPEED	21	9	0-20,000 RPM	±50 RPM	1,000 RPM/SEC	SHAFT: HI-PRES, FAN, VANE PUMP IMPEL.	3.1	6.1	3.1	6.1

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE IV-I (Continued)

MEASUREMENT REQUIREMENTS

SUBSYSTEM: ALL

MEASUREMENT TYPES, GROUPED

MEAS. TYPE NO.	PARAMETER DESCRIPTION	IDENTICAL MEAS QUAN. BOOS	IDENTICAL MEAS QUAN. ORB.	RANGE AND UNITS	MEAS. TOL.	RESPONSE TIME	ENVIRONMENT	RQMTS. SOURCE REF. C/M ANAL. BOOS.	C/M ANAL. ORB	FMEA BOOS.	FMEA ORB
PN-2	POSITION, VALVE	36	14	Open or Closed	N/A	0.3 Sec.	MNT on Valve, GO_2, GH_2, LH_2, GHe	1.2 3.2 3.3	4.2 4.4 --	1.2 3.2 3.3	4.2 4.4 --
PN-2A	POSITION, VALVE	135	105	Open or Closed	N/A	0.5 Sec.	MNT on Valve, 25-900°R LH_2, LO_2, GO_2, GH_2, GHe	1.2 1.3 2.1 2.2 2.3 2.4 2.5 2.6 -- --	4.2 4.3 4.4 -- 4.5 5.1 5.2 5.3 5.4 6.2	1.2 1.3 2.1 2.2 2.3 2.4 2.5 2.6 -- --	4.2 4.3 -- 4.4 4.5 5.1 5.2 5.3 5.4 6.2
PN-2A-DR	POSITION, THERMAL DOOR	10	4	Open or Closed	N/A	0.5 Sec.	MNT on Door, Compartment Near Skin.	2.1 2.5	5.1 --	-- --	-- --
PN-3	POSITION, COUPLING	10	13	Open or Closed	N/A	0.3 Sec.	MNT on Coupling, NR Skin LO_2, LH_2, GH_2, GO_2	1.2 2.2 --	4.2 4.4 5.2	1.2 -- --	4.2 4.4 --
PN-3A	POSITION, COUPLING	4	0	Open or Closed	N/A	0.5 Sec.	MNT on Coupling, NR Skin GHe	1.3	4.3	1.3	4.3
PN-4	POSITION, VALVE	28	18	Open or Closed	N/A	0.2 Sec.	MNT on Valve, NR Skin LH_2	3.2	6.2	3.2	6.2
PN-5	POSITION, VALVE	3	--	Open or Closed	N/A	0.1 Sec.	MNT on Valve, GO_2	2.4	--	2.4	--
PN-5-TF	POSITION, VALVE	21	9	Open or Closed	N/A	0.1 Sec.	MNT on Valve, LA_2	3.1	6.1	--	--
PN-6	POSITION, VALVE	150	127	Open or Closed	N/A	0.01 Sec.	MNT on Valve, 1600 to 2400° R GO_2, GH_2	2.1 2.3 2.4 2.5 2.6	5.1 5.3 5.4 -- --	2.1 2.3 2.4 2.5 2.6	5.1 5.3 5.4 -- --

NOTES:

N/A= Not Applicable
DR = Door

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE IV-I (Continued)

MEASUREMENT REQUIREMENTS
SUBSYSTEM: ALL
MEASUREMENT TYPES, GROUPED (CONT'D)

MEAS. TYPE NO.	PARAMETER DESCRIPTION	IDENTICAL MEAS. QUAN. BOOS.	IDENTICAL MEAS. QUAN. ORB.	RANGE AND UNITS	MEAS. TOL.	RESPONSE TIME	ENVIRONMENT		RQMTS. SOURCE REF. C/M ANAL. BOOS.	RQMTS. SOURCE REF. C/M ANAL. ORB.	RQMTS. SOURCE REF. FMEA BOOS.	RQMTS. SOURCE REF. FMEA ORB.
EX-1-TF	EXCITATION (VOLTAGE), VALVE	14	6	TBD	TBD	TBD	Turbofan Valve		3.1	6.1	--	--
EX-1A-TF	EXCITATION (VOLTAGE), START CARTRIDGE	7	3	TBD	TBD	TBD	Turbofan		3.1	6.1	--	--
EX-1	EXCITATION (VOLTAGE), VALVE	352	237	28± 4VDC	±5%	TBD	Various Valves, Actuation		1.2 1.3 2.1 2.2 2.3 2.4 2.5 2.6 3.2 3.3	4.2 4.3 4.4 4.5 5.1 5.2 5.3 5.4 6.2 --	-- -- -- -- -- -- -- -- -- --	-- -- -- -- -- -- -- -- -- --
VO-1	VOLT; INPUT	47	40	28± 4VDC	±5%	TBD	RCS Eng., GG, Igniter		2.1 2.3 2.4 2.5 2.6	5.1 5.3 5.4 6.2 --	-- -- -- -- --	-- -- -- -- --
VO-1-TF	VOLT, INPUT	7	3	TBD	TBD	TBD	Turbofan Igniter		3.1	6.1	--	--
VO-2	VOLT, OUTPUT	9	3	TBD	TBD	TBD	GG Exciter		2.3 2.4	5.3 --	-- --	-- --
VO-2-TF	VOLT, OUTPUT	7	3	TBD	TBD	TBD	Ingition Exciter, Turbofan		3.1	6.1	--	--
VO-3-TF	VOLT, INPUT	7	3	TBD	TBD	TBD	Fuel Heater, Turbofan		3.1	6.1	--	--
CU-1	CURRENT, INPUT	38	40	TBD	TBD	TBD	RCS Eng., Igniter		2.1 2.5	5.1 5.4	-- --	-- --
CU-2	CURRENT, INPUT	9	3	TBD	TBD	TBD	GG Igniter		2.3 2.4 2.6	5.3 6.2 --	-- -- --	-- -- --
CU-3-TF	CURRENT, INPUT	7	3	TBD	TBD	TBD	Ignition, Turbofan		3.1	6.1	--	--
CU-4-TF	CURRENT, INPUT	7	3	TBD	TBD	TBD	Fuel Heater, Turbofan		3.1	6.1	--	--

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE IV-I (Concluded)

MEASUREMENT REQUIREMENTS
SUBSYSTEM: ALL

MEASUREMENT TYPES, GROUPED (CONT'D)

MEAS. TYPE NO.	PARAMETER DESCRIPTION	IDENTICAL MEAS. QUAN.		RANGE AND UNITS	MEAS. TOL.	RESPONSE TIME	ENVIRONMENT		RQMTS. SOURCE REF. C/M ANAL		FMEA	
		BOOS.	ORB.						BOOS.	ORB.	BOOS.	ORB.
GL-1	GAS LEAK	TBD	TBD	TBD	TBD	TBD	Various Compartments, GO_2, GH_2, GHe		1.2 1.3 2.1 2.2 2.3 2.4 2.5 2.6 3.2	4.2 4.3 4.4 5.1 5.2 5.3 5.4 -- 6.2	-- 1.3 2.2 2.4 -- -- -- -- --	-- -- -- -- -- -- -- -- --
FL-1-TF	FLAME DETECTOR	7	3	On or Off	N/A	0.1 Sec	Combustion Chamber, Turbofan Burner		3.1	6.1	3.1	6.1
FI-1-TF	FIRE DETECTOR	7	3	TBD	TBD	TBD	Compartment, Turbofan		3.1	6.1	--	--

FOLDOUT FRAME 1

FOLDOUT FRAME 2

verified performance capability, and instrumentation to acceptable confidence levels. The rationale for this assumption is that if equipment performed correctly throughout its last normal operating cycle (without evidence of failure, degradation, over-stress, or approach of end of normal lifetime) then no significantly greater confidence that it will again perform correctly can be obtained by testing. In fact, since the stresses on propulsion subsystems are primarily self-induced, tests requiring actual subsystem operation would decrease system life. Dry-system functional tests would require considerable simulation, would not be realistic in the absence of normal stresses, and would provide little additional confidence over that obtained by leakage checks, post flight inspections and by monitoring ground servicing operations such as purging and propellant loading.

Applicable condition indicators will be monitored and evaluated by onboard equipment during ground operations for purposes of emergency detection, fault detection and isolation, trend analysis, and operating-state history.

2. In-Flight Monitoring - Performance and condition indicating parameters will be monitored and evaluated during and after engine start and in flight by onboard equipment, with no vehicle-to-ground interface other than voice communication. The data acquired by monitoring will be processed in flight for the following purposes:

In-flight ready-to-start condition verification

Emergency detection

Fault detection and isolation

Real-time trend analysis

Operating-state history

Performance data recording

The extent to which each of these functions will be performed in flight is discussed in subsequent paragraphs.

3. Ready-to-Start Condition Verification - Appropriate on-board monitoring and evaluation will be provided to verify that all applicable equipment is in the correct condition for start whenever an abortive start might result in equipment damage, unsafe conditions, or need to off-load propellants. Monitoring parameters will include applicable valve positions, pressures, temperatures, etc.

4. Emergency Detection - Appropriate on-board monitoring and processing will be provided to detect and provide caution and warning indications for the following conditions:

Loss or impending loss of major functions (main engine, air-breathing engine, separation, etc.)

Flight Safety parameters exceeding safe limits

Redundancy reduced to "safe" level

Hazardous leakage

5. Fault Detection and Isolation - Fault detection and isolation will be accomplished through onboard monitoring and evaluation, to the extent that failures are identified and isolated to the LRU level; therefore, post-flight tests for isolation of faults occuring in flight will not normally need to be performed. Post-flight evaluation of in-flight recorded data, for fault isolation purposes, will be acceptable under certain conditions.

Fault isolation will be accomplished as soon after detection as is necessary to identify lost redundancy and to initiate corrective or safing action when applicable. In cases where no LUR-level redundancy exists and where corrective or safing action is taken in response to failure detection only, as in the case of ACPS engine emergency shut-down, diagnosis for fault isolation may be performed on stored data at a later time. Preferably, this type of diagnosis will be accomplished prior to landing, but may be delayed until after landing if necessary.

The rationale for taking all data for isolation of in-flight failures during or immediately after detection of the condition is that in many cases the operating conditions and actual sequence of events before, during and after the failure must be known in order to discriminate between cause and effect. Also, transient or intermittant faults may not be isolatable in later tests without resorting to highly realistic simulation of conditions and events.

6. Real Time Trend Analysis - Trend analysis will be performed on elements known to exhibit measurable symptoms of impending malfunction, profided they are not fail-operational redundant or where failure is likely to cause significant secondary damage. Analysis will be performed in real time if corrective action is available in flight or if caution and warning is necessary when a failure is probable.

This approach constrains the extent of trend analysis to a realizable and economically reasonable level. Without these constraints, the quantities of measurement channels, data storage capacities and processing loads became significantly more difficult to justify on the basis of improving the probability of mission success.

7. Operating-State History - Where correlation exists, or is likely, between an LRU's performance and its operating time, stresses, number of on/off cycles, number of revolutions or strokes, or combinations of these, a history of operation of the LRU will be maintained in computer

storage so that when an LRU's operating history exceeds the limit for that LRU, a post-flight printout will provide notification of required replacement.

These operating histories will not be continuous, but will be periodic or on-condition updated totals of accumulated time, cycles, etc., at discrete states (on, standby, NPL, MPL, etc.) or discrete stress levels (20% overtemperature for example).

Replacement based on statistical correlation of performance and operating history is a particularly valuable approach in cases of identical redundant LRUs having a strong correlation of performance with operating history. The stronger the correlation, the higher the probability that all of the identical units will fail during the same flight.

8. Performance Data Recording - Performance data will be acquired and recorded only during times of possible activity of interest. The use of various data compression techniques has been considered as a means to further reduce the quantity of recorded data. However, accomplishing any significant amount of compression either greatly overloads the computers during peak processing times, requires considerable additional data storage capability to temporarily hold data until it can be processed for compression, or requires an additional computer dedicated to data compression. The selected approach is to provide the necessary recording capacity to store the required data, uncompressed, in suitable format and suitably identified as to time and parameter to allow efficient post-flight processing for reduction and evaluation.

9. Post Flight Evaluation - In-flight type monitoring and evaluation will be continued until completion of shutdown operations. Immediately after shutdown and connection of ground power, data reduction and ground servicing programs will be loaded into the onboard computers, replacing the flight programs. Preferably, these programs will be loaded via the onboard mass storage device. Flight-recorded data will then be sorted, edited, and evaluated by the onboard computer complex to produce maintenance printouts, trend analysis results and performance data records, catagorized by suitable equipment groupings (such as main engines, air-breathing engines, APS thrusters, etc.).

10. Display - Types of information to be displayed are:

Operator or crew instructions, such as procedure steps for manual operations or checkoffs, both ground and flight.

System status, such as operating modes and redundancy levels.

Propellant quantities and consumption rates.

- Malfunction detection or prediction notification and identification, during ground operations when personnel are onboard and inflight when corrective action by the crew is possible.
- Caution and warning indications.
- Postflight printouts of maintenance data.

D. LEAK DETECTION AND MONITORING

1. Introduction

The leakage of propellants or pressurants aboard the Space Shuttle can result in hazardous conditions from fires or explosions, reduced stage performance, or functional losses of propulsion system elements. Although the level of redundancy in the propulsion systems is such that, in general, failures of single components do not adversely affect the operational capability of the stage, the failure modes and effects analyses show that leakage is the major potential cause of component failure. As a part of the definition of the propulsion system OCMS it was therefore necessary to define potential types of leaks and leakage sources and to identify an approach to leakage detection and monitoring which would accomplish the requisite functions of preflight checkout, readiness assessment and performance monitoring, hazard warning, etc. Leakage detection and monitoring considerations and recommendations resulting from this special study were presented in depth in the November Monthly Progress Report and are summarized herein.

The major conclusions and recommendations resulting from this study are as follows:

a. The functions of the leakage detection and monitoring system are two fold: first, the existence of external or internal leaks in the propulsion components in exceedance of component or subsystem design specifications must be detected, because such conditions can result in subnormal system performance, indicate that a redundant element no longer exists, or directly induce a hazardous condition. Secondly, the presence of hydrogen-air or hydrogen-oxygen mixtures at concentration levels and pressures in the combustible regime must be detected for hazard warning. A hybrid approach to accomplish these onboard functions is recommended. The approach consists of utilizing ultrasonic detectors for leakage detection, and a mass spectrometer/sampling probe system for concentration monitoring. The latter would also be used as the cabin gas analyzer.

b. A technology program to characterize the performance of the ultrasonic detectors with cryogenic hardware should be implemented.

c. Since the lower pressure limit for combustion of hydrogen with air or oxygen is approximately 0.15 psia, it should be a design goal to provide rapid venting of compartments to below this value during the boost phase.

d. Changes should be made to the Design Reference Model so that corrective action (such as purging, venting or abort) may be undertaken if a hazardous concentration or major leak is detected during ascent.

2. Ground Rules

a. The study encompasses detection and monitoring of leakage in the airborne vehicle systems. Launch facility items, such as propellant transfer equipment, are not included.

b. In general, large leakage resulting from a structural failure is excluded from the analysis.

c. The orbiter stage is used as the basis for the analysis because of its longer flight duration. The study results for the orbiter stage can also be applied to the booster stage.

d. The compartments are purged with an inert gas while hydrogen is being loaded and up to launch.

e. During main engine operation, any leakage from these engines into the base region downstrem of the base heat shield can constitute a special hazard problem. This problem is beyond the range of this study due to the interaction of recirculating gases from the external flow field and the complex nature of the total problem.

3. Leakage Sources and Consequences

To properly understand and classify the overall leakage problem it is necessary to define potential sources and consequences of leakage.

a. Sources - The leakage sources were evaluated for each of the three propulsion systems for the orbiter, as discussed in the following. The main engine is presented in Paragraph 4.

1) Main Propulsion System

The orbiter main propulsion system is shown in Figure IV-1. The components, assemblies and subsystems that are potential leak sources are as follows:

Propellant tankage
Propellant lines
Isolation/prevalve
Vent and relief valves
Fill and drain valves
Pressure regulators
Shutoff valves
Check valves
Disconnects
Sealed joints
Main engine

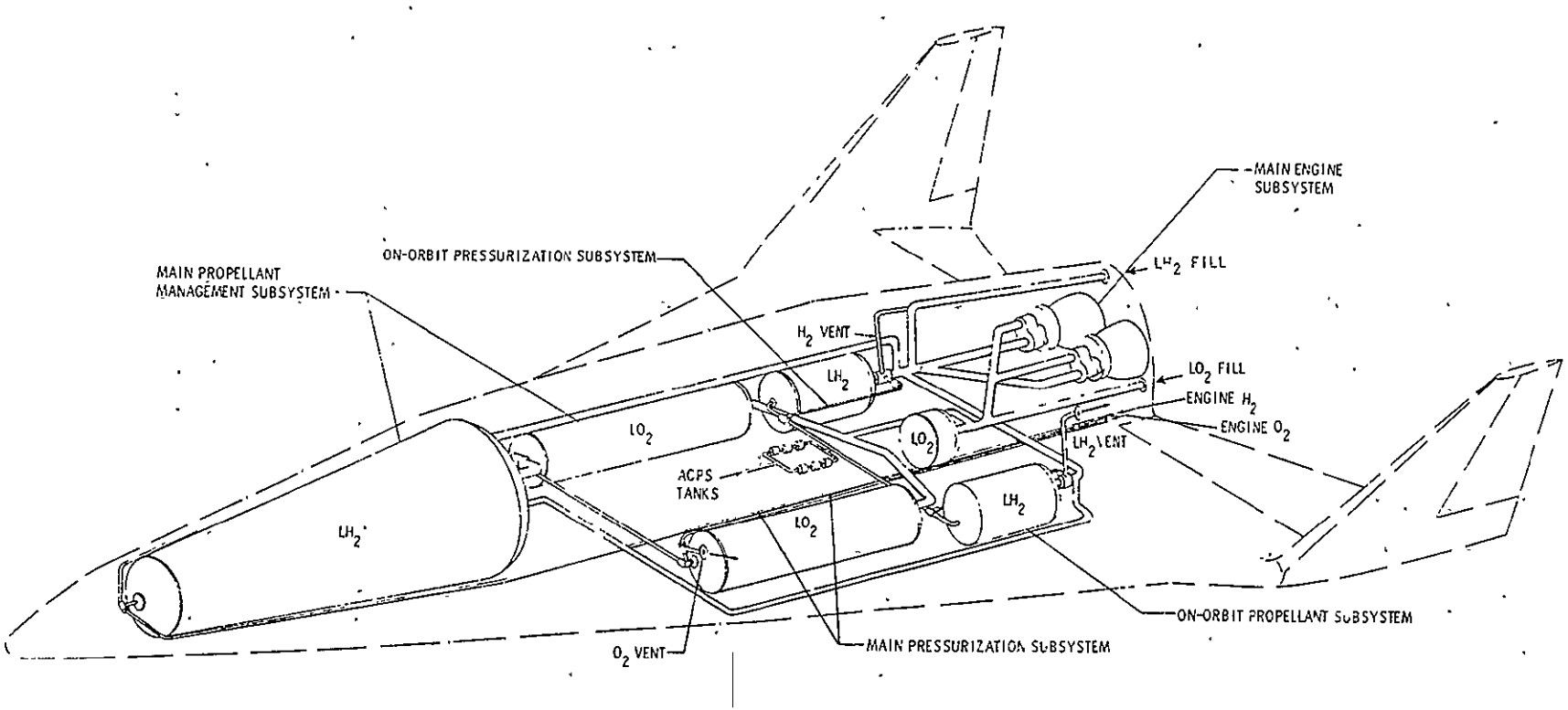


Figure 1. ORBITER MAIN PROPULSION SYSTEM

The propellant tankage includes both the main and on-orbit tankage. These tanks will be designed and tested for structural integrity at pressures greater than the normal operating pressure. Also, there will be design specifications which will determine the maximum allowable gas leakage from the tankage. Nevertheless, it is possible for leakage to occur at penetration points for lines and at seals for manhole covers. Repeated stage usage could also cause leakage at tank welds. In the horizontal or vertical position the leakage of any liquids would rapidly vaporize to the gaseous state. If the stage were in a horizontal attitude, leakage from the large main LH_2 tank would have a tendency to accumulate at the top of the stage in whatever compartment the leak occurred. If the stage were in a vertical attitude, leakage from large main LH_2 tank would have a tendency to rise toward the front of the stage.

The propellant and pressurant lines include both vacuum jacketed lines and regular single wall tubing. The single wall tubing and ducting can leak externally. The vacuum jacketed lines can leak and lose their vacuum. All of the larger lines contain flange joints. Leakage of the seals at these joints are another leakage source.

The propellant shutoff or isolation valves could leak both internally with leakage of liquid or gas into the position indicating switch, actuator, or closed position latch and externally at the flange joints. Leakage through the gate lip seal would allow propellant into the main engine.

The vent and relief valves can leak either internally or externally. The actuation solenoid valve and the step vent solenoid valve which are both part of this valve can also leak.

The fill and drain valves which are butterfly type valves can suffer leakage mainly through the valve seat lipseal. A relief valve which is located in the center of the butterfly is also a potential leak source.

The pressure regulators can leak both internally and externally. Leakage from the atmospheric sensing port and the regulator body is defined as external leakage. Internal leakage is that which occurs through the regulator outlet or from the integral relief valve.

The check valves can incur internal leakage after repeated usage.

The fill and drain disconnects consist of an airborne half which is essentially a mating ring with sealing surfaces and a ground half with a built in butterfly valve.

2) Auxiliary Propulsion System

The orbiter stage APS is shown in Figure IV-2. Those components, assemblies, and subsystems within this system that are potential leak sources are as follows:

Propellant accumulators
Propellant lines
Gas generators
Solenoid valves
Turbopumps
Turbocompressors
Heat exchangers
Check valves
APS engines

The propellant accumulators store the gaseous hydrogen and oxygen at 1500 psia. As with the main tankage, these high pressure bottles will be tested for structural integrity under pressures greater than the normal operating pressure.

The high pressure lines that connect the forward and rear accumulators are all brazed fittings which will be leak tested extensively during assembly and acceptance testing. In general they can be expected to have leak rates lower than 1×10^{-8} std cm^3/sec.

The bipropellant gas generators within the APS propellant conditioning subsystem could be a leak source for the GH_2 and GO_2 both internally and externally. Also they generate hot gases which could leak externally.

The heat exchangers which furnish the heat source to convert the LO_2 and LH_2 to GO_2 and GH_2 are devices with no moving parts. However, they are hard to inspect and do provide a potential leak path through the heat exchanger coils for hot fuel-rich combustion gases to contact liquid oxygen. This is a type of internal leakage with a potential for catastrophic failure.

The solenoid valves and check valves that control the flow of fuel and oxidizer into propellant conditioning subsystems and into the accumulator regulators can leak both internally and externally.

The APS rotating machinery which entails both turbine driven pumps and turbine driven compressors does require special consideration due to the dynamic sealing necessary to prevent leakage from such components. The principal dynamic seal types used in turbopumps and compressors are the labyrinth, face-riding, and shaft-

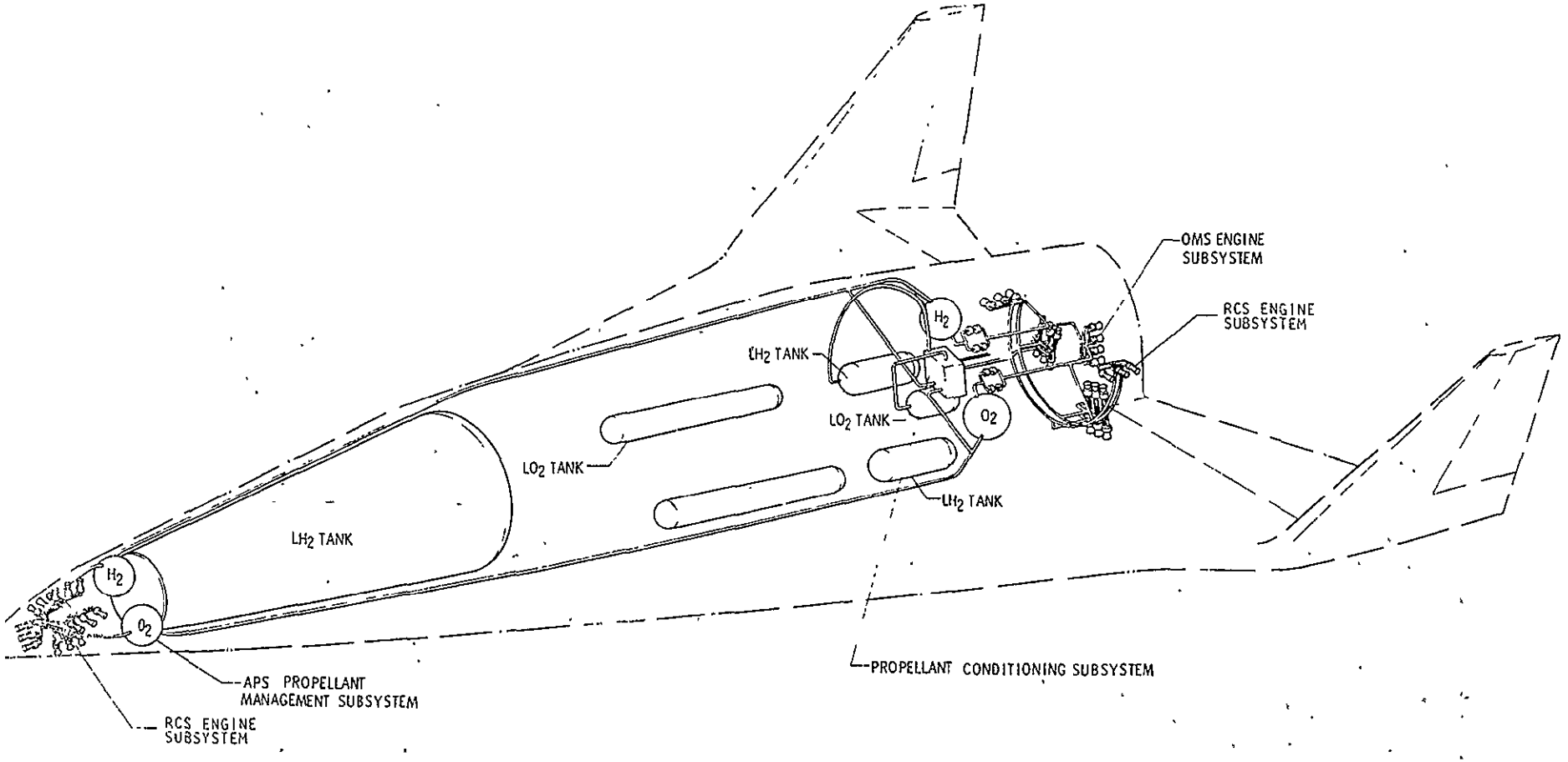


Figure 2. ORBITER AUXILIARY PROPULSION SYSTEM

riding seals. Since all of these dynamic seals can leak at a high rate, vent lines must be connected to the cavities between two or more dynamic seals which are installed in series. This is particularly important to assure positive sealing for critical applications such as propellant seals where fuel may be on one side and oxidizer on the other side of the seals. This vent line will be connected to GSE for ground testing and will be vented through the external skin in flight.

3) Air Breathing System

The orbiter stage A/B system is shown in Figure IV-3.. Those components, assemblies, and subsystems within this system that are potential leak sources are as follows:

Propellant lines
Solenoid and check valves
Gas generators
Turbopumps
Turbofan engines

Since leakage in all of these types of components has been discussed in the two previous sections they will not be repeated herein except for the engine.

In the engine power assembly both the low and high pressure compressors contain special air seals to limit interstage air recirculation and high leakage would decrease performance of the turbofan engines. This would be detected by trend data analysis of engine performance. In the high and low pressure turbines there are turbine blade tip seals and interstage labyrinth seals that could leak. Again this would result in a performance loss that can be detected.

In the fuel control assembly the variable displacement vane pump will utilize dynamic seals.

The scavenge pump which removes oil from the gearbox compartment for return to the oil tank would be the most likely source of an oil leak. The loss of oil may impair the lubrication of the engine bearings and result in bearing loss and subsequent engine shutdown. In the case of prolonged storage of a turbofan engine in space on the orbiter, three problems are of concern in the lubrication assembly: vaporization of the oil to the hard vacuum, cold welding of the contact surfaces, and freezing of the oil. Turbofan engine lubrication systems are usually vented to ambient through a breather valve.

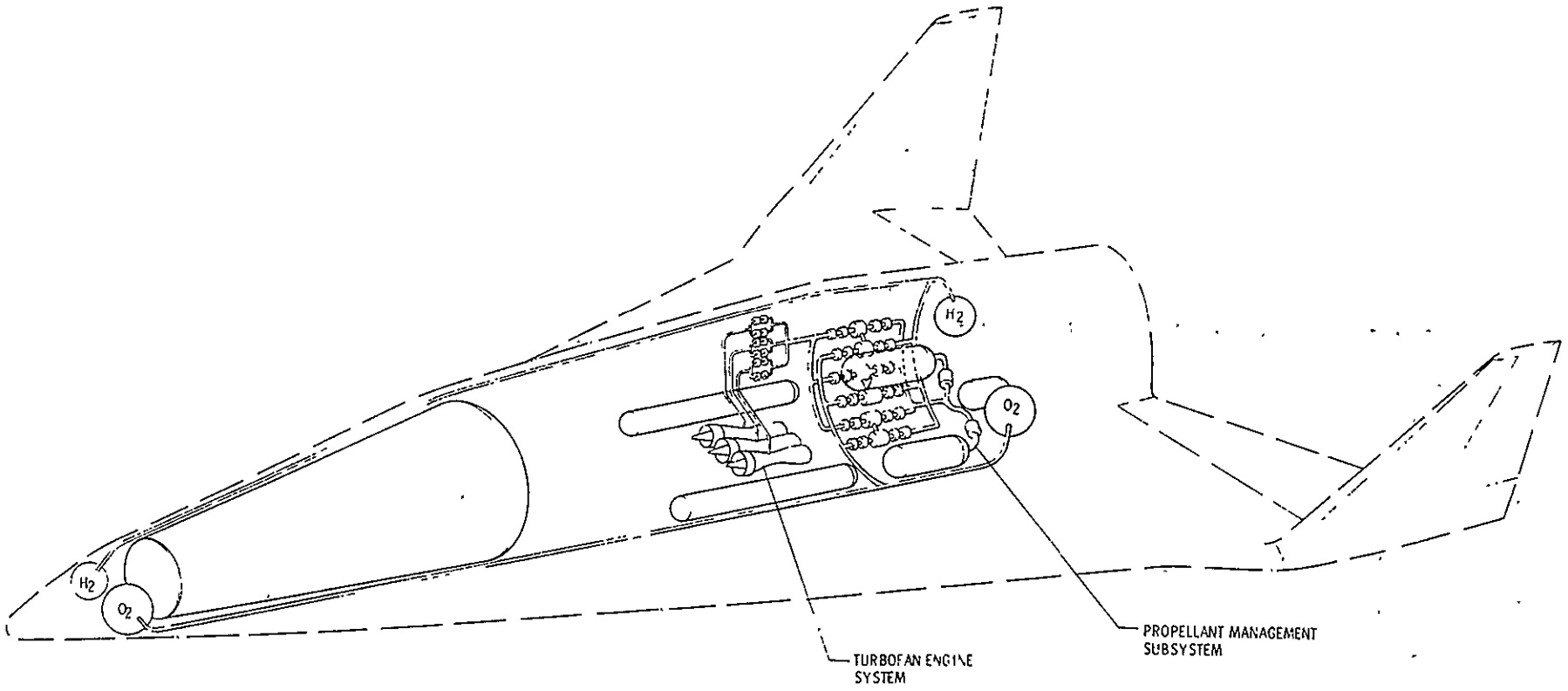


Figure 3. ORBITER AIRBREATHING PROPULSION SYSTEM

The bearing compartments and gearboxes have carbon face seals between the stationary housing and the rotating shaft for compartment sealing. While in orbit, the leakage through these seals would drop the system internal pressure to the vapor pressure of the oil. The oil residue from the vaporized oil would contaminate most of the lubrication system. This vaporization problem can be eliminated by maintaining a minimum internal lubrication system pressure which would be monitored by the OCMS.

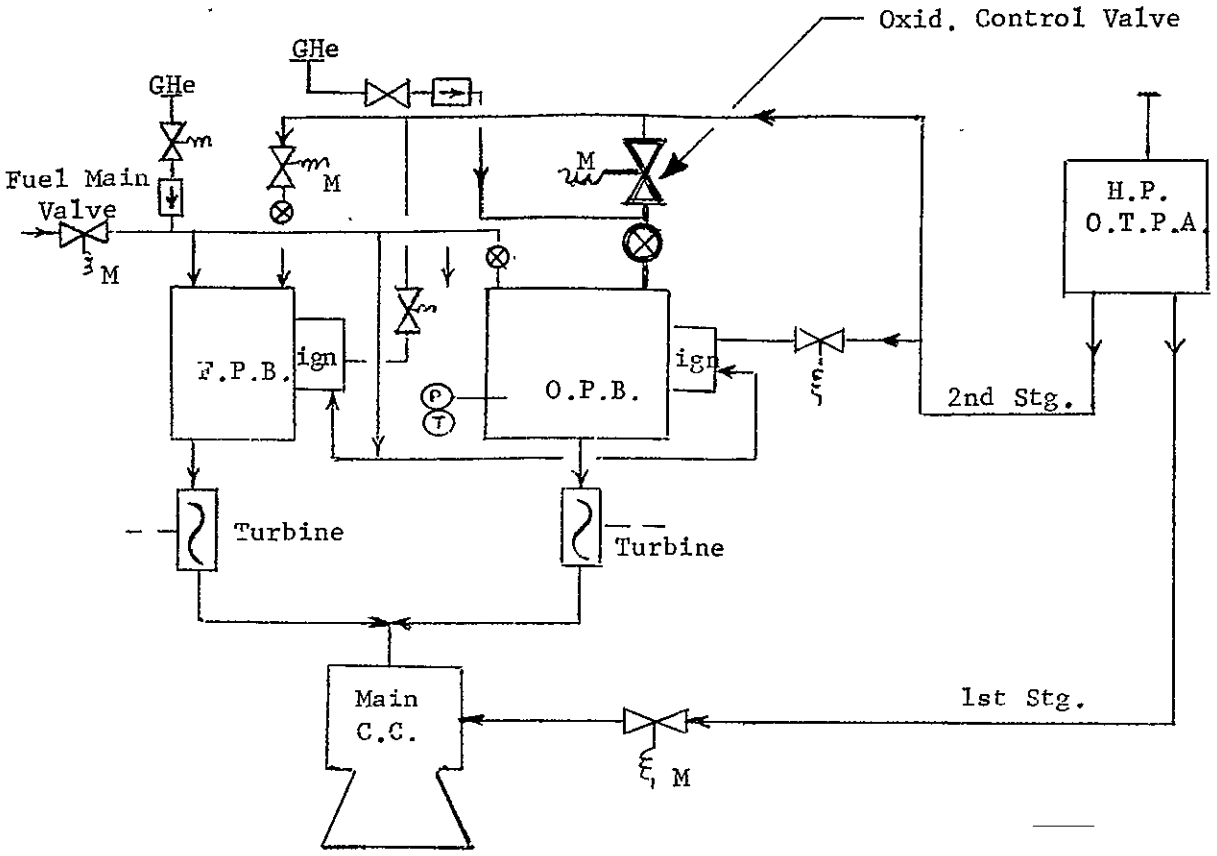
4) Main Engine and APS Engine Subsystems

In support of this study the Aerojet Liquid Rocket Company conducted a detailed leakage analysis to the component level on the Main and APS engines. Each engine component that could leak was analyzed to determine the consequences of the leak and how it could be detected. This first phase of the ALRC study resulted in an analysis sheet for each component. These analysis sheets are not presented in this report because of their bulk; an example is presented in Figure IV-4. These study results for the Main and APS engines are summarized in Figure IV-5. Each component that represented a leak source is identified and the type of leak, egress point for the leak, and effect of the leak is described. The detection test method is identified.

LEAK DETECTION ANALYSIS Sheet 19 of 39

OXIDIZER CONTROL VALVE, OX. PREBURNER (1.1.1.11)

FUNCTION: Provides on-off and modulating control of oxidizer to the oxidizer preburner.



CONSEQUENCES OF LEAKAGE:

1) At Start: "Small Leak" - GHE purge dilutes oxid; "Large Leak" - High press./temp. start with possible preburner and/or turbine damage.

2) Post FS-2: "Small Leak" - Minor increase in shutdown M.R.; "Large Leak": High pressure/temp. shutdown, possible turbine damage, extended shutdown (minor).

METHODS FOR DETECTION:

1) Preburner temperature/pressure at start and shutdown. Shutdown data will be more indicative, as a leak in the igniter oxidizer valve will cause a pressure peak at start.

2) It may be possible to use an external contact-type ultrasonic leak detector in conjunction with a 25-50 psig GHE or GN_2 pressurization in maint. shop. if flight data indicates an abnormality. The design of this valve may preclude incorporation of a leakage detector probe (i.e., thermocouple), so the ultrasonic technique should be pursued. Presence of igniter oxid. valve could make location of leak a difficult task.

Figure IV-4 Example of Engine Component Leak Detection Analysis

FIGURE IV-5

LEAKAGE DETECTION ANALYSIS SUMMARY

MAIN ENGINE

MISSION PHASE CODE:

A. FERRY
B. GROUND
C. FLIGHT

LEAKAGE SOURCE	TYPE OF LEAK AND EGRESS POINT	EFFECT OF LEAK	DETECTION TEST METHODS		
			ON-BOARD DETECTION IN CONJ. WITH FUNCTIONAL OUTPUTS	SHOP OR OTHER TEST IN CONJ. WITH ON-BOARD EQUIP.	SHOP OR OTHER TEST WITH NO ON-BOARD EQUIP.
1.1.1.2 - Lift -Off Seal, HPFTPA and 1.1.1.4 - Lift -Off Seal, OTPA	Fuel Leak. Face Seal, in Turbine Section of Pump. Exits Nozzle	A. None B. Fire Hazard C. Orbiter Only - Fire Hazard during Boost.	*None	* None	*Helium leak test but requires sensing at fuel main valve (parallel path), to differentiate. External ultrasonic contact probe at valve, and at pump.
1.1.1.2 - Ck. Valves for HPOTPA Turbine Bearing Coolant	Fuel Leak. Feed Line: Seat leaks in forward dir. Ret Line: Seat leaks in reverse dir. Both Exit Nozzle.	A. None B. Fire Hazard C. Orbiter Only - Fire Hazard during Boost.	Bearing Temperature.	None	Leak test with external ultrasonic contact probe
1.1.1.8 - Fuel Main Valve	Fuel Leak. Poppet Seal. Exits Nozzle	A. None B. Fire Hazard C. Orbiter Only - Fire Hazard during Boost.	Temp. Sensor downstream of Valve. Check temp. at Prop. loading, on-pad, and post-FS_2.	None	A helium leak test in shop can be performed with two types of sensors: 1) External ultrasonic probe at valve. 2) Mass. spec. probe inserted in main C.C. Igniter Tube, with a collar seal.
1.1.1.9 - Oxid. Main Valve	Oxid. Leak. Poppet Seal. Exits Nozzle	A. None B. Hard start, TCA damage. If large enough possible hazard on launch pad. C. Shutdown - high M.R. - Possible injector damage.	Temp. Sensor downstream of Valve. Check temp. at Prop. loading, on-pad, and post FS_2.	None	A GN_2 leak test with an external ultrasonic contact probe. The multiple paths for Oxid. leakage which exit the nozzle render a "sniff" test in the chamber useless.
1.1.1.11 - Oxid. Control Valve, O.P.B.	Oxid. Leak. Shutoff seal. Exits Nozzle	A. None B. Hard start. Possible preburner/turbine damage. Possible high M.R. at shutdown, with turbine damage. C. Orbiter - Hard start. Possible preburner/turbine damage. Possible high M.R. at shutdown with turbine damage.	1. Preburner pressure/temp. data at start and shutdown. Large leak would show up on pad on chamber temp. 2. Review valve design to determine whether or not a thermocouple could be incorporated in passage downstream of valve. The preferred method, however, is #1 above as it makes use of transducers already on engine for other purposes.	None	GN_2 leak test with external ultrasonic probe. Proximity of igniter oxidizer valves leaves some doubt about the specificity of this test.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

*FURTHER STUDY REQUIRED.

FIGURE IV-5 (Continued)

LEAKAGE DETECTION ANALYSIS SUMMARY

MAIN ENGINE

MISSION PHASE CODE:

A. FERRY
B. GROUND
C. FLIGHT

LEAKAGE SOURCE	TYPE OF LEAK AND EGRESS POINT	EFFECT OF LEAK	DETECTION TEST METHODS		
			ON-BOARD DETECTION IN CONJ. WITH FUNCTIONAL OUTPUTS	SHOP OR OTHER TEST IN CONJ. WITH ON-BOARD EQUIP.	SHOP OR OTHER TEST WITH NO ON-BOARD EQUIP.
1.1.1.12 - Oxid., Control Valve, F.P.B.	Oxid. Leak. Shutoff Seal. Exits Nozzle	A. None B. Hard start. Possible preburner/turbine damage. Possible high M.R. at shut-down, with turbine damage. C. Orbiter – Hard start. Possible preburner/ turbine damage. Possible high M.R. at shutdown with turbine damage.	1. Preburner pressure/temp. data Large leak would show up on pad on chamber temp. 2. Review valve design to determine whether or not a thermocouple could be incorporated in passage down-stream of valve. The preferred method, however, is #1 above as it makes use of transducers already on engine for other purposes.	None	GN_2 leak test with external ultrasonic probe. Proximity of igniter oxidizer valve leaves some doubt about the specificity of this test.
1.1.3.1-1 Ign. Oxid. Valve, O.P.B.	Oxid. Leak Poppet seal. Exits nozzle	A. None B. A large leak could result in igniter/ preburner/turbine damage at start. C. Orbiter - A large leak could result in igniter/ preburner/turbine damage at start.	1. Preburner chamber press/temp. 2. Review igniter design to deter-mine if a thermocouple could be incorporated downstream of valve. Preferred method is #1 above as it would make use of existing transducers.	None	GN_2 leak check, with external ultrasonic probe. Possible confusion with leakage in oxid. control valve exists. On-board device probably the best technique.
1.1.3.1-2 Ign. Oxid. Valve, F.P.B.	Oxid. Leak Poppet Seal. Exits nozzle	A. None B. A large leak could result in igniter/ preburner/turbine damage at start. C. Orbiter - A large leak could result in igniter/ preburner/turbine damage at start.	1. Preburner chamber press/temp. 2. Review igniter design to deter-mine if a thermocouple could be incorporated downstream of valve. Preferred method is #1 above as it would make use of existing transducers.	None	GN_2 leak check, with external ultrasonic probe. Possible confusion with leakage in oxid. control valve exists. On-board device probably the best technique.
1.1.3.1-3 Ign. Oxid. Valve, Main TCA	Oxid. Leak Poppet Seal. Exits nozzle FOLDOUT FRAME 1	A. None B. A large leak could result in igniter/main C.C. damage pre-mature shutdown. C. Orbiter - A large leak could result in igniter/ main C.C. damage premature shutdown.	1. Main Comb. Ch. Press. 2. Igniter design should be reviewed to determine if a thermocouple probe could be incorporated down-stream of valve.	None	GN_2 or GHe leak check, with probe inserted in igniter tube. This test can be successful, as the igniter chamber would be accessible. If external ultrasonic probes are proven, it could be used as there is no valve in the immediate vicinity as on the preburners. FOLDOUT FRAME 2

FIGURE IV-5 (Continued)
LEAKAGE DETECTION ANALYSIS SUMMARY

MAIN ENGINE

MISSION PHASE CODE:

A. FERRY
B. GROUND
C. FLIGHT

LEAKAGE SOURCE	TYPE OF LEAK AND EGRESS POINT	EFFECT OF LEAK	DETECTION TEST METHODS		
			ON-BOARD DETECTION IN CONJ. WITH FUNCTIONAL OUTPUTS	SHOP OR OTHER TEST IN CONJ. WITH ON-BOARD EQUIP.	SHOP OR OTHER TEST WITH NO ON-BOARD EQUIP.
1.1.6.1 - LH_2 Tank Press. Check Valve	Fuel Leak. Check valve seat. Exits Nozzle. This valve is redundant to vehicle check valve.	(Leakage Statement assumes Level 1 Redundancy is already leaking) A. None B. Loss of pre-pressurization gas on pad. C. Booster: No hazard unless a premature engine shutdown occurs, then it would exit the nozzle of dead engine with possible fire hazard up to some altitude. Orbiter: Loss of pre-pressurization gas.	Pressure sensor between the two check valves. Record data at pre-pressurization and post FS_2. The sensor also provides pressurization system information.	Observe pressure sensor via engine or vehicle data system with tank pressurized.	Tank pressurization with all other valves shut off; helium mass spec. test at main TCA (not considered a practical approach, but is feasible). By installation of several shutoff valves and pressurization ports, complete shop checkout is possible, but is not recommended.
1.1.6.2 - LOX Tank Press. Check Valve	Oxid. Leak. Check valve seat, exits nozzle. This valve is redundant to vehicle check valve.	(Leakage Statement assumes Level 1 is already leaking) A. None B. Loss of pre-pressurization gas on pad. C. Loss of tank pressurant gas IF premature shutdown occurs. Probably no hazard.	Pressure sensor between the two valves would give pressurization system data as well as data on check valves.	Observe pressure sensor via engine or vehicle data system with tank pressurized.	Tank pressurization with all other valves shut off; helium mass spec. test at main TCA (not considered a practical approach, but is feasible). By installation of several shutoff valves and pressurization ports, complete shop checkout is possible, but is not recommended.
1.1.7.1-1.a Preburners Oxid. Purge Solenoid Valve	GN_2 or GHe. Exits nozzle.	Loss of oxid. backflow shut-off redundancy excessive use of GHE. If check valve AND this valve leak, possible over-pressure of GHe or GN_2 system occurs; damage to fine(s), tank; premature shutdown of entire propulsion if common purge system used for all engines.	Pressure sensor at juncture of 1.1.7.1-1.a, -2.a, -2.b.	Pressure sensor in conjunction with purge system gas.	None. (See 1.1.6.1 also)

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE IV-5 (Continued)

LEAKAGE DETECTION ANALYSIS SUMMARY

MAIN ENGINE

MISSION PHASE CODE:

A. FERRY
B. GROUND
C. FLIGHT

LEAKAGE SOURCE	TYPE OF LEAK AND EGRESS POINT	EFFECT OF LEAK	DETECTION TEST METHODS. ON-BOARD DETECTION IN CONJ. WITH FUNCTIONAL OUTPUTS	SHOP OR OTHER TEST IN CONJ. WITH ON-BOARD EQUIP.	SHOP OR OTHER TEST WITH NO ON-BOARD EQUIP.
1.1.7.1-1.b Main TCA Fuel Purge Solenoid Valve	GHe. Exits nozzle.	Loss of fuel backflow shut-off redundancy excessive use of GHe. If check valve AND this valve leak, possible over-pressure of GHe or GN_2 system occurs; damage to line(s), tank; premature shutdown of entire propulsion if common purge system used for all engines.	Pressure sensor at juncture of 1.1.7.1-1.b and 2.c (check valve).	If cracking pressure of check valve is high enough, use of the pressure sensor in conjunction with the purge system gas could detect leakage.	None. (See 1.1.6.1 also)
1.1.7.1-1.c Main TCA Oxid. Purge Solenoid Valve	GHe/GN_2 Exits nozzle.	Loss of oxid. backflow shut-off redundancy excessive use of GHe. If check valve AND this valve leak, possible over-pressure of GHe or GN_2 system occurs; damage to line(s), tank; premature shutdown of entire propulsion if common purge system used for all engines.	Pressure sensor at juncture of solenoid valve and check valve (1.1.7.1-2.d	If cracking pressure of check valve is high enough, use of the pressure sensor in conjunction with the purge system gas could detect leakage.	None. (See 1.1.6.1 also)
1.1.7.1-1.d HPOTPA Seal Cavity Purge Solenoid Valve	GHe Exits overboard lines from HPOTPA.	Excessive use of GHe is possible.	None	Helium sniff test with purge system pressurized.	None
1.1.7.1-1.e Engine System Purge Solenoid Valve	GHe/GN_2. Exits nozzle.	A. None B. Possible excessive use of purge gas. C. None	None	None	Periodic check with gas decay test and/ or external ultrasonic probe.
1.1.7.1-2.a Oxid. Preburner Oxid. Inlet Purge Check Valve	GHe/GN_2 Exits nozzle.	See 1.1.7.1-1.a Also may result in minor mixture ratio control problem.	See 1.1.7.1-1.a	See 1.1.7.1-1.a	See 1.1.7.1-1.a
1.1.7.1-2.b Fuel Preburner Oxid. Inlet Purge Check Valve	GHe/GN2 Exits nozzle.	See 1.1.7.1-1.a Also may result in minor mixture ratio control	See 1.1.7.1-1.a	See 1.1.7.1-1.a	See 1.1.7.1-1.a

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE IV-5 (Continued)
LEAKAGE DETECTION ANALYSIS SUMMARY

MAIN ENGINE

MISSION PHASE CODE:

A. FERRY
B. GROUND
C. FLIGHT

LEAKAGE SOURCE	TYPE OF LEAK AND EGRESS POINT	EFFECT OF LEAK	DETECTION TEST METHODS		
			ON-BOARD DETECTION IN CONJ. WITH FUNCTIONAL OUTPUTS	SHOP OR OTHER TEST IN CONJ. WITH ON-BOARD EQUIP.	SHOP OR OTHER TEST WITH NO ON-BOARD EQUIP.
1.1.7.1-2.c Main TCA Fuel Inlet Purge Check Valve	GHe. Exits nozzle.	Same as 1.1.7.1-1.b	Same as 1.1.7.1-1.b	Same as 1.1.7.1-1.b	Same as 1.1.7.1-1.b
1.1.7.1-2.d Main TCA Oxid. Inlet Purge Check Valve	GHe. Exits nozzle	Loss of oxid. backflow shut-off redundancy. Excessive use of GHe. If solenoid valve and this valve leak, possible over-pressure of GHe or GN_2 system occurs; damage to line(s), tank may occur, with premature shut-down of entire propulsion system if common purge system used for all engines.	Pressure sensor at juncture of check valve and solenoid valve. 1.1.7.1-1.c	Same as 1.1.7.1-1.c	Same as 1.1.7.1-1.c
1.1.7.1-2.f Fuel Suction Line Purge Check Valve	No leak if GHe system pressure is up.	None	Function in forward direction is most significant. Can be accomplished with existing suction pressure meas.	----	----
1.1.7.1-2.g Oxid. Suction Line Purge Check Valve	No leak if GHe system pressure is up.	None	Function in forward direction is most significant. Can be accomplished with existing suction pressure meas.	-----	-----
1.1.8.1 Extendible Nozzle Coolant Valve (Orbiter Only)	Fuel. Exits nozzle.	A. None B. Fire Hazard. C. Fire Hazard up to some altitude.	1. Temp. probe downstream of valve.	None	Helium leak test using external ultrasonic probe (contact).

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE IV-5 (Continued)
LEAKAGE DETECTION ANALYSIS SUMMARY

MAIN ENGINE

MISSION PHASE CODE:

A. FERRY
B. GROUND
C. FLIGHT

LEAKAGE SOURCE	TYPE OF LEAK AND EGRESS POINT	EFFECT OF LEAK	DETECTION TEST METHODS		
			ON-BOARD DETECTION IN CONJ. WITH FUNCTIONAL OUTPUTS	SHOP OR OTHER TEST IN CONJ. WITH ON-BOARD EQUIP.	SHOP OR OTHER TEST WITH NO ON-BOARD EQUIP.
All Unshrouded joints (no carry-off ducts). These will by definition be 10^{-4} scc/sec or better, normally	Fuel. Joint seals to engine comp. area.	A. None B. Fire hazard. C. Fire hazard up to some altitude.	On-board GH_2 sensors in engine area. Then shop tests to localize source.	-----	Leak test with portable ultrasonic detector to locate leaks. Then helium mass spectrometer for leakage rate.
	Oxidizer. Joint seals to engine comp. area.	A. None B, C. None (Neglecting gross leakage due to seal failure).	None. If engine compartment is enclosed, an O_2 concentration analyzer is recommended.	-----	Periodic checks with an ultrasonic probe with system pressurized with GN_2 is recommended. (Microphone type probe)
All shrouded joints with carry-off ducts and inerting gas.	Fuel. Joint seals, to point of over-board dump.	A. None B. Fire hazard if above inerting capability. C. Fire hazard up to some altitude.	GH_2 sensor on duct near point of egress. If excessive concentration appears, shop test would be required to isolate joint.	-----	Helium press. test with external ultrasonic probe to localize leakage source.
	Oxidizer. Joint seals, to point of over-board dump.	A. None B., C. None (Neglecting gross leakage due to seal failure)	None	-----	Periodic checks with ultrasonic probe with system pressurized with GN2.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE IV-5 (Continued)

LEAKAGE DETECTION ANALYSIS SUMMARY

ACPS

MISSION PHASE CODE:

A. FERRY
B. GROUND
C. FLIGHT

LEAKAGE SOURCE	TYPE OF LEAK AND EGRESS POINT	EFFECT OF LEAK	DETECTION TEST METHODS		
			ON-BOARD DETECTION IN CONJ. WITH FUNCTIONAL OUTPUTS	SHOP OR OTHER TEST IN CONJ. WITH ON-BOARD EQUIP.	SHOP OR OTHER TEST WITH NO ON-BOARD EQUIP.
2.1.4 - Bi-Propellant Control Valve	Fuel. Seat Seal Leak. Exits Nozzle.	A. None B. Fire Hazard C. Fire Hazard to some Altitude.	1. GH_2 sensor in RCS compartment. 2. Ultrasonic contact probe on each thruster	Helium (or other gas) pressurization in conjunction with ultrasonic contact probe.	Helium leak test, with helium mass spectrometer.
	Oxid. Seat Seal Leak. Exits Nozzle.	A. None B. None, unless gross leak occurs, and fuel leak also occurs. C. None - Some possibility of a "hard start"	1. Ultrasonic contact probe on each thruster.	Helium (or other gas) pressurization in conjunction with ultrasonic contact probe.	Helium leak test, with helium mass spectrometer.
2.1.2 - Igniter Valves	Fuel. Seat Seal Leaks. Exits Nozzle.	A. None B. Possible Fire Hazard. C. Possible fire hazard up to some altitude.	Same as 2.1.4 (Fuel)	Helium (or other gas) pressurization in conjunction with ultrasonic contact probe.	Helium leak test, with helium mass spectrometer.
	Oxid. Seat Seal Leaks. Exits Nozzle.	A. None B. None C. None Above excludes gross failure.	Same as 2.1.4 (Oxid)	Helium (or other gas) pressurization in conjunction with ultrasonic contact probe.	Helium leak test, with helium mass spectrometer.
2.1.3 - Isolation Valve	Fuel, Oxid. No Egress, unless one of above valves leaks	A., B., C. - None without failure (leakage) of 2.1.2 or 2.1.4.	1. Pressure transducers in each circuit at juncture of this valve and 2.1.4, observe with pressure upstream. 2. Test in conjunction with 2.1.2, 2.1.4 (recommended approach)	Helium (or other gas) pressurization in conjunction with ultrasonic contact probe. Open control valve to permit flow.	Helium leak test, with helium mass spectrometer. Open control valve to permit flow.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

4. Consequences of Leakage

The first consideration in specifying the total allowable leakage of a system is that the system must not leak sufficient commodities to cause system failure during its mission duration. The orbiter stage has a mission duration considerably greater than that of the booster stage, and is, therefore, the limiting case.

The total allowable orbiter component leak rates will be governed for each propulsion system by the following requirements:

Main Propulsion System - Maintain internal tank pressure and propellants in the on-orbit tanks during the orbital mission phase.

APS - Maintain a sufficient supply of propellants in the accumulators to meet the RCS thruster demands during reentry operation, and to meet the APU requirements.

A/B System - Maintain a sufficient flow rate of fuel to allow proper operation of the turbofan engines for the approach and landing phase of the mission.

The second consideration in specifying the allowable leakage is that of the functional loss of a component, assembly or subsystem from leakage either directly or indirectly. The direct effect of leakage from a component that effects it alone can be seen in the FMEA's that were presented in the first quarterly progress report. In general, due to the level of redundancy in the propulsion systems, failure of a single component will not have a major impact on the stage. However, from a close examination of the failure mode and effects analysis performed to the parts level on the critical components, leakage (aside from failure due to normal wear) is the major cause of a component failure.

The third consideration in specifying the allowable leakage is the hazard presented to both ground personnel and the flight crew resulting from H_2/O_2 or H_2/air mistures.

The internal orbiter structural arrangement will consist of conventional skin/stringer/frame aircraft construction as shown in Figure IV-6. The propulsion tankage and equipment will be enclosed in bulkhead sections which in turn result in a series of compartments.

Ground support equipment would be used to purge all compartments with dry nitrogen prior to launch and with dry helium just before (30 min.) loading propellants. During flight all of these compartments would be vented to ambient conditions. A mixture of gaseous hydrogen and gaseous oxygen will combust if both constituents are present in a concentration level above 4%, an ignition source of 5 millijoules or greater is present, and the pressure is above 0.15 psia.

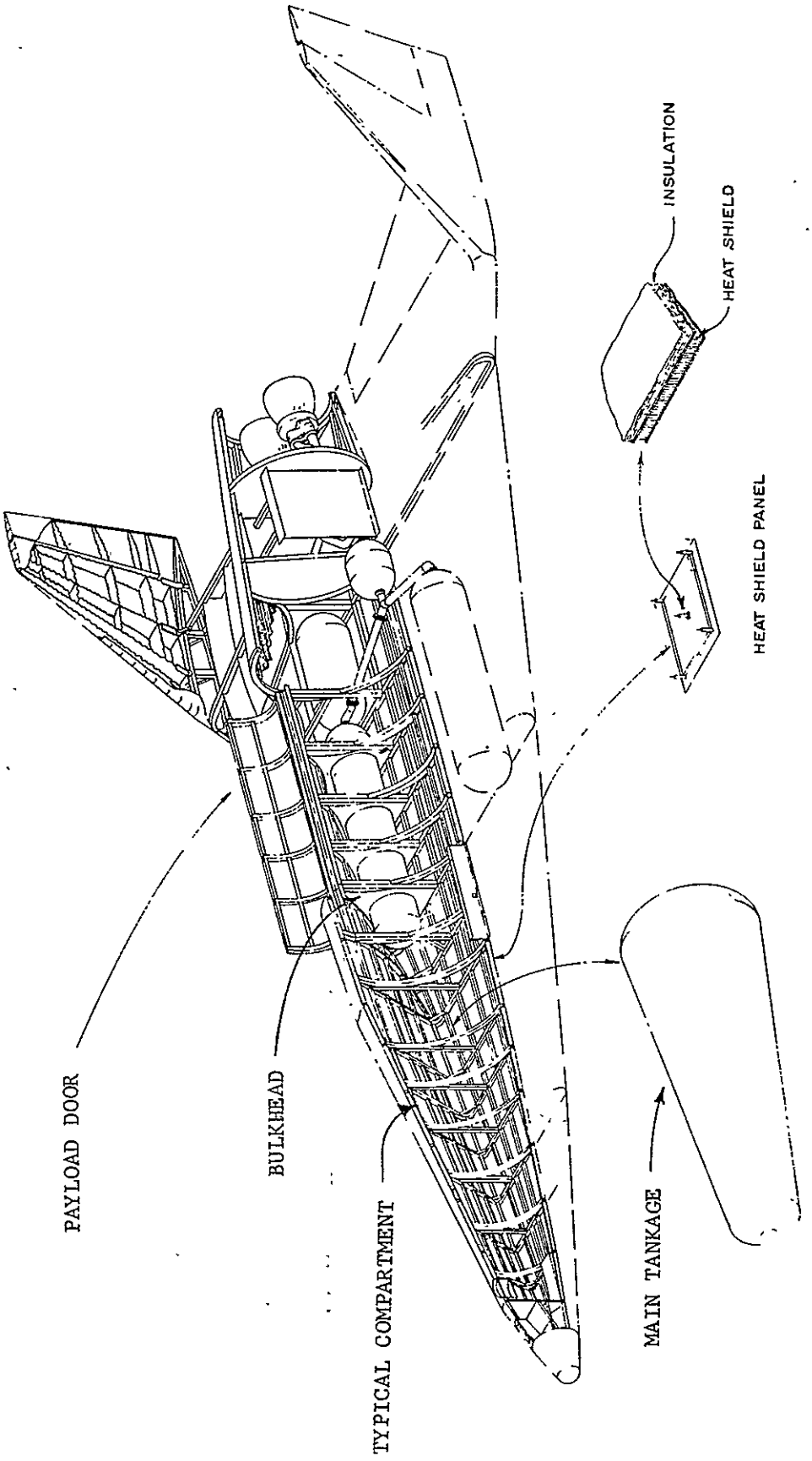


FIGURE IV-6 ORBITER STRUCTURAL DETAILS

5. Mission Phase Critical Leakage Testing

The leak testing and associated safety operations necessary for the orbiter propulsion systems has been divided into four major phases. These phases are as follows:

Factory acceptance leak testing
Pre-flight testing and purge operations
In-flight monitoring
Post-flight safing

The rationale for this division is due to the OCMS requirements, GSE requirements, and allocation of time to conduct certain tests and operations. The factory acceptance testing is included to allow a baseline total allowable leakage estimate and to identify those tests necessary to insure low leakage for safe pad operations.

The onboard systems, flight hardware and ground hardware necessary to accomplish all of the above mentioned tests and operations is identified in this section, and the details on such hardware are discussed in Section 7.

a. Factory Acceptance Leak Testing - These leak checks are comprehensive survey and build-up type of testing to detect leaks in all potential problem areas. Design deficiencies, manufacturing problems and equipment malfunctions will be detected and corrected at this time. Components will first be tested, then built up into assemblies after which assembly leak checks will be performed. Finally, subsystems and systems as installed will be leak checked. This phase of leak testing will employ the airborne leak detection system (as it becomes available during system buildup) for those tests for which it can provide sufficient sensitivity. Normal ground test methods will also be employed.

b. Pre-Flight Leak Testing - The Pre-flight leak testing of the orbiter stage is that testing which takes place after either factory acceptance leak testing for a new stage or after maintenance for a stage returning from a flight. These tests would take place during the Prelaunch and Launch Mission Phases.

The system integrity (leakage) checks are performed on each propulsion system in a separate operation. All purge systems are off at this time. The hydrogen side of the main propulsion system boost LH_2 tankage will be pressurized with dry Helium at a pressure of 40 psia. All of the compartments forward of the full bulkhead (designated in Figure IV-6) will be monitored by the on-board mass spectrometer and ultrasonic detectors through the OCMS. The on-orbit LH_2 tankage will then be leak checked in a like manner. The oxygen side of the main propulsion system boost LOX tankage will be pressurized with dry helium at a pressure of 25 psia. Those compartments behind the full bulkhead will now be monitored by the

on-board systems. During these sequential tests and before the valves at the tank outlets are activated, all instrumentation downstream of these compartments are monitored for any pressure build-ups. Following this series of tests the valving is operated to allow helium to flow into the propellant lines, and the ultrasonic leak detectors are monitored. Next, valves are opened to permit accumulators pressurization. The compartment located in fromt of the LH_2 tank and the aft compartment are monitored during this test phase. All OCMS systems are left in an active state to monitor leakage until the next major cycle.

Prior to hazardous servicing operations at T-17 hours the system compartment purge GSE is connected to the vehicle and purging with dry N_2 is begun. Loading of the APS-GH_2 and GO_2 is the next operation to be performed. During such loading the compartments containing these tanks are monitored for the presence of leakage of GH_2 or GO_2 at 1500 psia.

During LH_2 and LO_2 pre-chill, slow-fill, fast-fill, topping and replenishment operations, the vehicle will be in a vertical position. All compartments are being purged and the on-board mass spectrometers are monitored on a continuous basis. Since the crew is not yet on-board the orbiter, the on-board display will be monitored by TV camera.

The helium purge system must be operating prior to the LH_2 tanking for thirty minutes. If tanking has begun, and the He purge system fails, the compartments would probably contain 99.9% He. O_2 would begin entering the interstage through the exhaust ports and leakage areas from the outside atmosphere. Also, leakage from the propulsion system components would begin to build up within the volume.

c. <u>In-Flight Monitoring, Detection, and Safing</u> - The in-flight leak monitoring system must provide for detection from fire-switch #1 to GSE connection for post-flight tankage purging. The on-board systems must be operational during the boost phase when the compartment pressures will be rapidly changing and the docked phase which can last up to seven days in duration.

As the mated stages leave the ground, mixing through the leakage areas is increased due to the movement of the shuttle. As the atmospheric pressure decreases with altitude, the compartment pressures will correspondingly decrease. Normal leakage from the propulsion system components would be expected to vary only slightly upon increasing altitude. Constant H_2 leakage into a compartment with decreasing pressure would cause an increasing percentage of H_2.

The ambient pressure drops below 0.15 psia (the combustion limit for hydrogen/oxygen mixtures) before separation of the booster and orbiter stages and at approximately 120 seconds from liftoff. The compartment pressures will reach this same pressures level at some increment after

this time based on the venting rate out of the compartment into the ambient. The most critical inflight time period from a leakage standpoint are these 2 + Δt minutes from shuttle liftoff, since this is the time period inflight in which leakage could result in a compartment fire or explosion.

d. Post-Flight Safing - Post-flight leak testing is accomplished by ground crews who will first unload any propellants in the tankage and purge all the systems with dry helium. The compartment purge GSE will also be connected for a series of compartment purges with dry GN_2.

7. Flight System Hardware Approach

a. Mass Spectrometers - Two mass spectrometers are used redundantly and are both located in the crew compartment. Each utilizes a sampling line which extends the full length of the stage, with branch lines running off this main sampling line for compartment sampling (Figure IV-7).

The spectrometer operates by sampling a gas through a small orifice, the size of which is determined by the ambient pressure surrounding the equipment. When the equipment is to be used over a wide range of ambient pressures, the orifice size must be varied to be small for high pressures and large for low pressures. To utilize both spectrometers redundantly, a set of valves will be activated to switch the orifice size for atmosphere or in-space operation.

At the end of each branch line is a solenoid valve which is controlled by an electronic scanning or timing device which opens one valve at a time. A vacuum pump will be necessary to evacuate the main sampling line and to bring compartment samples past the sampling port of the mass spectrometer. This is necessary for the atmospheric operation; for vacuum operation, the sampling line will be evacuated to space by utilizing valving.

The mass spectrometers would be an instrument such as the Perkin-Elmer unit utilized on the Metabolic Activity Experiment for the Skylab Program, and would occupy approximately 500 cubic inches and which weighs 26 lbs. per instrument. The Perkin-Elmer unit is qualified for a Saturn 1-B launch environment and operating life of 30 days (720 hours). It utilizes 28 Volts - D.C. and provides a 0-5 Volt output. It contains a six detector unit which would be set-up for CO_2, O_2, N_2, H_2, H_2O, and He. This instrument would have to be calibrated after each flight with a calibration sample taken from a gas bottle.

The one limitation anticipated with the mass spectrometer system is the time required to cycle through from the aft compartment into the instrument. Based on an assumed velocity in a sampling line of 40 feet per second, it would require 4 seconds for a gas sample to be introduced into the mass spectrometer from the aft compartment. If the response, clean-up, pump, valve signals and valve actuation times are added to this sampling time, then the total time between compartment readings could be in the range of 10 seconds.

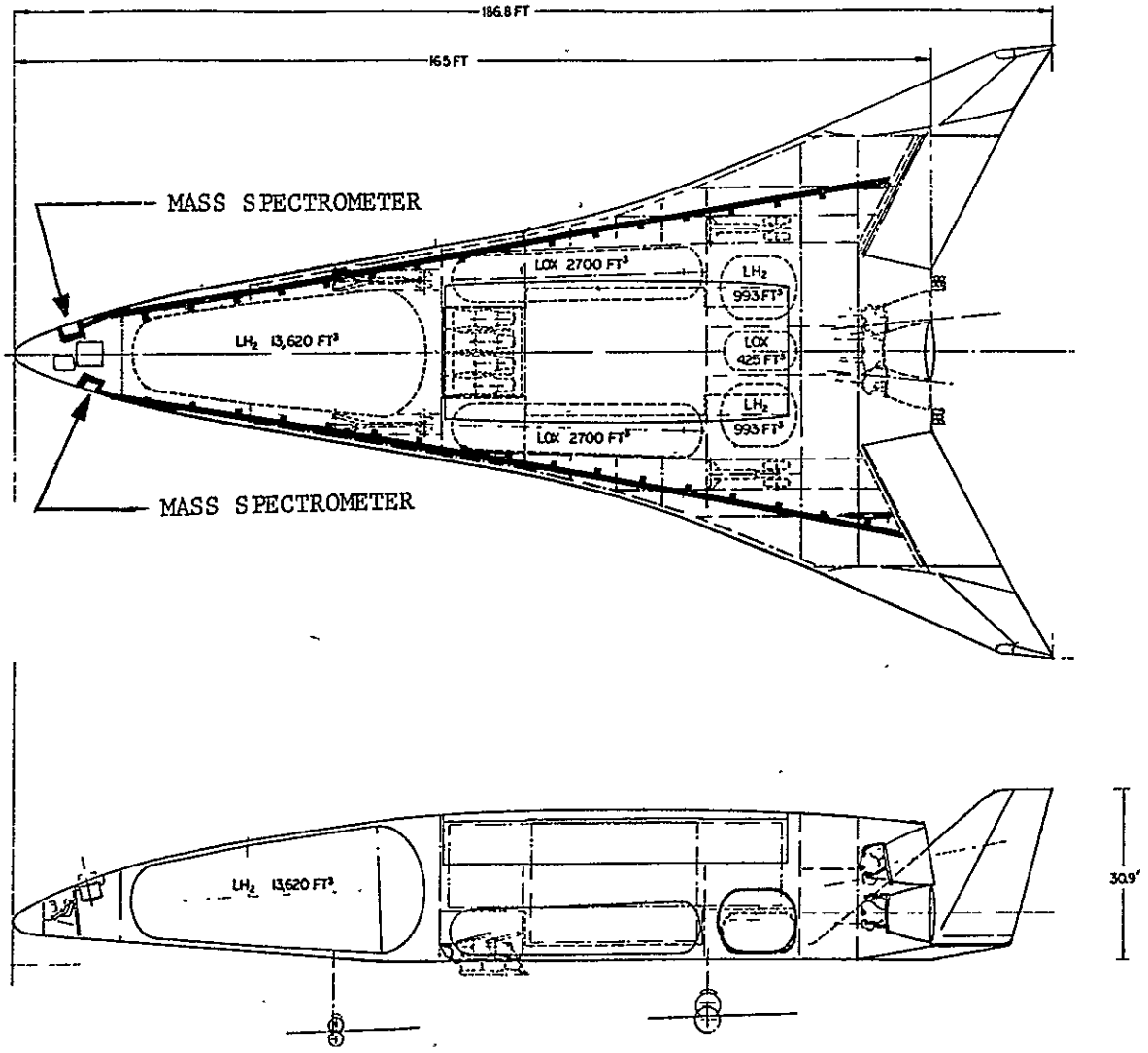


Figure IV-7 Mass Spectrometer/Sampling System

b. Ultrasonic System - The on-board ultrasonic leak detection system would consist of contact sensors mounted directly to the propellant ducting and pressurant tubing, probably together with directional microphones of the scanning type to provide a broad coverage of those components located in each compartment.

Leakage in pressurized systems may be detected by means of the sound energy generated in a fluid vortices which can accompany leakage. The frequency of the leakage noise ranges from the audible to the ultrasonic. The ultrasonic component of the leakage noise is broadly peaked at a frequency of 30 to 50 Kilohertz. A sensitivity of approximately 10^{-3} std $cm^3/sec.$ is anticipated, with the sensors bonded directly to the component to be monitored for leakage, or directly to the ducting near the component.

Based on an assumed location of a sensor for every 5 to 10 feet of ducting, the following number would be required:

- Main propulsion - 44 sensors
- APS - 64 sensors
- Air breathing propulsion - 18 sensors

All of the transducers for the same diameter line or same size component could probably be alike; however, different types or calibrations may be necessary for unlike components. Also, it would be important to determine the characteristic noise signal for each component without leakage under nominal operating conditions. The interference noise can also be generated by a component upstream or downstream of that component under observation and therefore, this noise must be properly identified to distinguish such interference from actual leakage.

The output of these 126 sensors will be monitored by a selector switch controlled and monitored by the on-board computer.

Prior to implementation of the onboard ultrasonic leak detection system, a technology program would be required to characterize the performance of the system with cryogenic hardware with high background acoustic levels.

V. OCMS DESIGN CONCEPTS AND CRITERIA

The study approach for refining propulsion OCMS requirements and developing the OCMS design concept was defined in October and presented in the October Monthly Progress Report. Figure V-1 depicts this approach in flow chart form. The defined approach has been followed, with some exceptions, during the remainder of this period. Results of the trade-off studies and analyses performed to date are presented in the following paragraphs.

A. PROCESSING LOADS AND DATA BUS TRAFFIC

1. Critical Period Traffic and Processing

From the Checkout and Monitoring Analyses, estimates have been made of the basic processing loads and data bus traffic for the most critical periods in the mission. These periods are during booster main engine start and during booster main engine shutdown and vehicle separation. To make the estimates, the following data bus system was hypothesized.

a) The basic data bus transmission formats are shown in Table V-1.

b) To command a DIU to some action (such as closing a valve) a four byte command is sent and recirculated back to the CCC.

c) To obtain a measurement from a DIU (such as a line pressure) a four byte command is sent to the DIU and recirculated. After an appropriate time delay to allow the DIU to make the measurement, a three byte data request is sent to the DIU which returns data rather than recirculating the command (typically in a four byte format).

d) To obtain the regularly scheduled engine controller information, a three byte command is sent to the engine controller DIU and the information is returned using as many bytes as necessary to return that particular set of information. The information sent from the engine controller is grouped by the frequency at which it is sent (for example, all data sent at a rate of 10 times per second is sent in one transmission).

e) Where a grouping of information is possible this information will be available in one transmission rather than requiring separate transmissions. An example is the chamber pressure of the separation thrusters. One data request can obtain the chamber pressures of all separation thrusters controlled by any single DIU.

The computer processing requirements were analyzed and it was determined that for data bus control, 37 CCC instructions are required to send a command to a DIU and 31 instructions are required to obtain information from a DIU. Thus, to obtain a measurement from a DIU, a total of 68 instructions must be executed to send and receive the commands and data, and verify the correctness of all transmissions. The make-up of the 68 instructions is:

- 5 instructions to initiate a measure command
- 5 instructions to initiate the data retrieval command
- 12 instructions to handle the command Input/Output request
- 13 instructions to handle the data request Input/Output
- 20 instructions to receive the recirculated command and verify its correctness
- 13 instructions to receive the data and verify it was obtained from the correct source

The actual checkout programs are assumed to consist of, on the averag 20 instructions for each command given, or measurement taken. This is based on having straight forward assembly language programs doing the checkout function. It does not take into account any system overhead which may be required by the CCC.

The data bus loading and processing requirements thus obtained are shown in Figures V-2 through V-5.

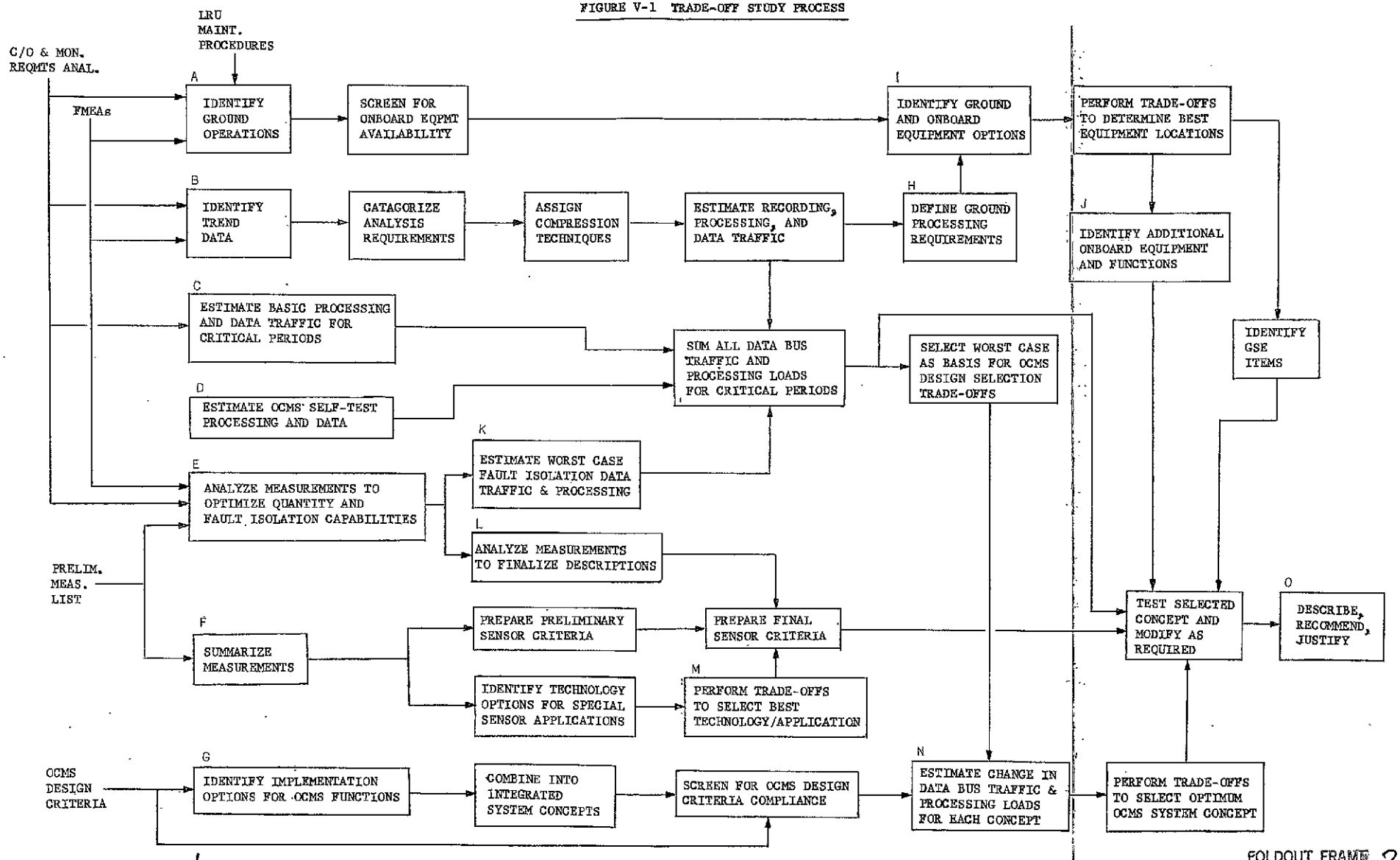
The approach given above imposes the highest load on the data bus of any system evaluated. This is because each logical data transfer requires 4 transmissions, i.e.,

CCC ⟶ DIU setup for measurement
DIU ⟶ CCC recirculation for verification
CCC ⟶ DIU ask for data
DIU ⟶ CCC send data

Also, since there is no set scheme of transmission, the processing load is heavy as each message must be formatted each time it is sent.

Note, however, that this system gives complete overall flexibility as any DIU can be contacted at any time. Also, it is the simplest in terms of hardware required as the DIU need only respond to its address and requires no data buffer. The CCC Data Bus Control is simply an Input/Output device - not a timing or multiplex device. Also, since the address is checked on every transmission, the error detection techniques will be the simplest possible. Thus, it is summarized:

FIGURE V-1 TRADE-OFF STUDY PROCESS



FOLDOUT FRAME 1

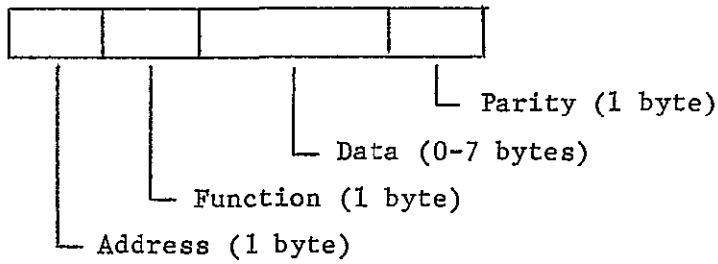
FOLDOUT FRAME 2

(3)

TABLE V-1

DATA BUS FORMATS

CCC to DIU

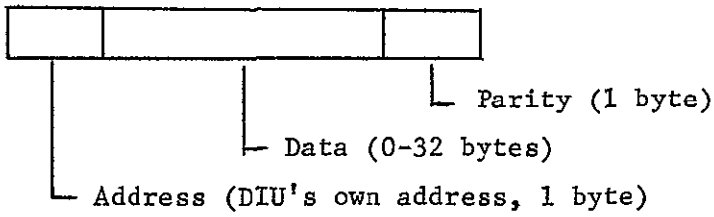


This format is sent to the DIU's for two reasons:

1) Command the DIU to some action (stimulate, perform a measurement, self check, etc.); in this case the message is recirculated back to the CCC in its entirity.

2) Request data (sent after a DIU has had time to make a measurement per a command); in this case the DIU returns a data message as shown below.

DIU to CCC



This is the format used by the DIU's to send measurement data to the CCC, and is also the format used to send information from an engine controller via a DIU.

NOTES: Each byte is nine bits long; 8 bits data, 1 bit parity.

A DIU cannot initiate a transmission. It must receive a message from the CCC (of the top format above) which it will respond to with the data it has to transmit.

- Highest Data Bus Load
- High CPU Usage
- Good System Utilization
- Very Flexible Approach
- Least Hardware

2. Alternate Data Bus Approaches

Another approach is comprised of two data busses, a send bus and a receive bus. The send bus transmits commands to the DIUs as before. The receive bus is a multiplexed approach where each DIU has a time slot during which it may transmit. This requires a clock line between the computer and the DIUs. Each DIU transmits in turn at the appropriate time and for some predetermined length of time. The processing would be scheduled to work on new data as it comes in during the appropriate time slot. The software would be the same for commands as before, but would require less than half as much to receive a measurement. For measurements, the overall processing and data bus load would be about 80% for that shown in the previous case. For commands, the loads would be the same.

This system is summarized:

- Low Measurement Data Bus Load
- Medium CPU Usage
- Fixed System Schedule
- Restricted Flexibility
- Medium Hardware

A third alternative consists of providing the DIUs with interrupt capability. The interrupt would be a separate line from the data bus and would give each DIU a unique interrupt into the CCC. Combining the interrupt with a comparator within the DIU would give a system with very low data bus traffic on a simple data bus such as the one used in obtaining the data rates given in Figures V-2 through V-5. This system would work with the CCC sending a command to the DIU, requesting a measurement and issuing limits and/or expected value to the DIU, in cases where expected values are variables or are adaptive. The DIU would respond by interrupting when the data was obtained and would respond with its address unless the measured value differed from that expected or exceeded the limit value, in which case the measured value would be transmitted to the CCC.

The data bus load for measurements would be almost zero as compared with the first technique shown. The command load would be the same.

In summary:

- Lowest Data Bus Load
- Medium CPU Usage
- Best System Utilization
- Very Flexible Approach
- Most Hardware

3. Trend Data

Using the basic approach to trend data acquisition, recording and processing presented in Section IV.C as a criteria, trend data requirements are being identified and catagorized as to whether or not real-time trend analysis is required. Estimates will then be made of the recording requirements for trend data to be recorded for post-flight analysis and of the processing loads for real-time analysis. Data compression will not be employed, for reasons presented in Section IV.C.

B. MEASUREMENT ANALYSIS

A matrix analysis technique, described in the October Monthly Progress Report, was tried as a means of determining the adequacy of measurements, and to uncover unnecessary measurements. This technique appeared to work well when applied to a fairly simple test case (Booster Hydrogen Conditioning Subsystem), but became increasingly difficult to apply to subsystems of greater complexity.

A similar technique, applied on a component basis for the main engines, also showed merit and resulted in some reduction in main engine measurement requirements. Results to date of the effort to reduce the quantity of measurements indicate that the current criteria on degree of redundancy verification, fault detection and isolation, trend detection and performance monitoring, prohibit any further significant reduction. Therefore, it is concluded that the present estimates of measurement quantities are reasonable for the assumed baseline configuration. A relaxation in any of the above criteria would allow a significant reduction in the number of measurements.

From the preliminary Measurement List, measurement requirements were summarized and used to prepare preliminary sensor criteria and to identify applications requiring new sensor technology. Table V- 2 presents the current summary of quantities of measurements, itemized by measured parameter. Some preliminary sensor criteria were developed and presented in the November Monthly Progress Report. These are presently being modified to comply with later study results, reported in paragraph C. below, and to incorporate additional criteria.

TABLE V-2

MEASUREMENT SUMMARY*

	BOOSTER					ORBITER				
	MAIN ENG	A/B ENG	LEAK DET'N	ALL OTHER	TOTAL	MAIN ENG	A/B ENG	LEAK DET'N	ALL OTHER	TOTAL
PRESSURE	476	63		156	695	68	27		115	210
TEMPERATURE	140	63	32	48	283	20	27	6	53	106
DISCR. POSIT'N	238	21	64	382	705	52	9	12	263	336
ANALOG. POSIT'N	140			9	149	22				22
QUAN. GAGING	14	7		16	37	2	3		18	23
FLOW RATE	28	7		2	37	4	3			7
FLAME DET'N	42	14			56	6	6			12
VIBRATION	56	28	252	15	351	8	12	126	24	170
CURRENT	42	14		47	103	6	6		43	55
SPEED	56	21		15	92	8	9		15	32
VOLTAGE		42		446	488		18		292	310
GAS ANAL.			32		32			48		48
TOTALS	1,232	280	380	1,136	3,028	196	120	192	823	1,331

*Does not include redundancy

C. SENSOR TECHNOLOGY

Analysis of the checkout and monitoring requirements of the propulsion systems has resulted in the identification of some checkout, monitoring and testing requirements which are not readily met by application of existing sensors or developed sensor concepts with onboard equipment. The options available in these problem areas are as follows:

1. Modify the Design Reference Model to eliminate the problem areas;

2. Accomplish the required function by a technique other than generating new sensor technology, for example, by utilizing other types of measurements in conjunction with additional processing and/or operating procedures;

3. Develop the required technology;

4. Eliminate the requirement on the basis that the disadvantages of any other approach outweigh the penalties incurred by not accomplishing the function;

5. Accomplish the function through ground testing with ground support equipment, rather than with onboard equipment.

In general it is difficult to identify the appropriate option for each problem area. This results from the fact that a full evaluation of the impacts of appropriate changes to the Design Reference Model is beyond the intent of this study, and because in some cases, initial elements of the sensor technology programs would have to be conducted to show that the concepts were feasible. We have, therefore, emphasized Option #2, where possible, in resolving the problem areas. If this option is not applicable, and if a sensor technology concept has been shown to be feasible, that concept has been selected as a recommended approach. In the case of the main engine, the design evaluation from the baseline during the course of the Phase B program will probably eliminate at least one of the problem areas.

Our finalized recommendations in this area will be presented in the January Monthly Progress Report. The problem areas and corresponding interim recommendations are presented in Table V-3.

TABLE V-3

SENSOR TECHNOLOGY RECOMMENDATIONS

Problem Areas	Comments and Recommendations
1. Flowmeter Calibration Check	
Main engine oxidizer flowmeters - may drift with repeated use because of bearing wear, etc. Physical installation problems plus additional components makes use of onboard pneumatic flowmeter spinup system undesirable. Use of GSE with ground calibration tests may impact maintenance timelines.	a. During inflight start and shutdown transients, compare flowmeter output with nominal reference signature. Also, compare flowmeter data with flowrate derived from LPOTPA inlet and discharge pressures, RPM and inlet temperature. If disagreement, use chamber pressure as referee. b. Change DRM to eliminate flowmeters; use pump parameters instead.
2. Solenoid Valve Position	
Valve closed or valve open indications; possible requirement for opening and closing traces for trend data.	a. Approach is influenced by valve design, usage and operating characteristics and, therefore, must be evaluated for each specific valve design in conjunction with its required function; evaluations must include impacts on data management system. Recommend technology program to evaluate sensing schemes such as signature coils, microswitches, proximity probes, etc.
3. Small Differential Pressure at High System Pressure	
Used in conjunction with other parameters for fuel flowrate measurement in main engine.	a. Use pump parameters as alternative approach for flowrate measurement. b. Conduct transducer technology program.
4. Lube Oil Condition Sensing	
Detect contaminant and residue build-up in lube oil; also, metal particles indicative of bearing deteriation (airbreathing engines).	a. Operations will probably require drain, flush and purge of lubrication system after each flight to preclude build-up of oil residue on lubricated surfaces during exposure to low pressures during next flight.

TABLE V-3 Continued

Problem Areas	Comments and Recommendations
5. Check Valve Failure Detection Detect failure of check valve either to open or to reclose, or detect internal leakage.	a. Utilize pressure measures in conjunction with operating procedures to determine open or closed status; use ultrasonic leak detectors for internal leakage monitoring.
6. Ignition Detection Gas generator and preburner ignition detection.	a. Recommend technology program to evaluate such approaches as infrared detector with view window.
7. Detection of Incipient Failures in Bearings	a. Recommend technology program to assess such approaches as acoustic emission, deflection measurements, etc.
8. Onboard Leak Detection	a. Use procedures with available sensors where possible. b. Recommend technology program to establish operating characteristics of ultrasonic detectors with cryogenic hardware at high acoustic levels.
9. Onboard Gas Concentration Monitoring	a. Recommend use of cabin gas analyzer (mass spectrometers) for H_2 - O_2 concentration monitoring. Development required to incorporate appropriate detector, to provide EMI shielding (if required) and possibly to modify emitter to enable operation in ascent environment.

D. GSE REQUIREMENTS

From the Checkout and Monitoring Requirements Analysis, the LRU Maintenance Procedures, and the FMEAs, all ground operations were identified. Those operations were then analyzed to determine equipment requirements, considering servicing as well as checkout requirements. Equipment requirements not suitable for onboard implementation, because of being used solely for operations on equipment removed from the vehicle or because of cost, weight, or technology considerations, were then tabulated. Where these requirements were associated with specific LRUs, matrices were prepared to show this relationship. These matrices are presented in Table V-4, which starts on page V-29.

The large majority of identified GSE is required solely for handling and ground servicing functions, having no relationship to checkout or performance evaluation. The list of GSE associated with checkout and performance evaluation is relatively short and is as follows:

Leak Test Equipment (for test of fluid line connections after LRU replacement - required only if onboard leak detection system does not provide sufficient accuracy for this function)

Optical Test Equipment (for damage inspection and airbreathing engine ignition plug spark inspection)

Vacuum Test Equipment (for vacuum check of replaced propellant lines)

Data Processing System, with tape drive compatible with onboard tape (for generation of computer program source tapes, for conversion of digital data tapes to analog recording, and for processing of data tapes for statistical data)

Oil Sampling and Contamination Analysis Equipment (for analysis of lubricants and hydraulic fluids)

LRU/DIU/Sensor Simulation Equipment (for substitution in place of electrical output or input elements to simulate interface signals in tests to verify or extend fault isolation)

E. OCMS CONCEPT DEVELOPMENT

In attempting to combine implementation options for individual OCMS functions (sensing, signal conditioning, signal conversion, signal routing, etc.) it became apparent that the number of possible combinations of implementation techniques and distributions (in sensor, in DIU, in engine controller, etc.) would reach unmanageable proportions. Eleven different ways of handling simple off/on sensor output signals alone were identified. Options for handling more complex sensor outputs are much more numerous since more functions (demodulation, A/D conversion, reference modeling, etc.) become involved.

An alternate approach is to define a baseline integrated OCMS concept and iterate that baseline to evolve the best configuration with respect to cost, weight, reliability, data bus traffic, processing loads, etc. To this end, a baseline allocation of measurements to DIUs was established for the Orbiter and a baseline DIU configuration was defined. The baseline measurement/DIU allocation is based on the following premises:

1) Physical location of DIUs near associated LRU of the propulsion system.

2) The same degree and type of redundancy in DIUs as provided for associated LRUs of the propulsion system, where redundancy exists.

3) Utilization of economical combinations of already identified DIUs to redundantly service non-redundant LRUs.

On this basis, 20 DIUs (in addition to engine controllers) were identified for the orbiter propulsion system as follows:

Equipment Serviced	DIU Numbers	Redundancy Arrangement
Forward RCS engines and forward APS Propellant Management	1, 2, 3	Each DIU services one RCS engine per engine module for a total of 5 engines per DIU. In addition, each DIU services all of the forward APS Propellant Management equipment in a triply-redundant arrangement.
Aft RCS engines and APS Propellant Management	4, 5, 6	Same as for DIUs 1, 2, and 3 for aft equipment.
OMS engines	7, 8	Each DIU services all 4 of the OMS engines on a primary/backup basis.
APS Propellant Conditioning	9, 10, 11	Each DIU services one section of the triply redundant subsystem.
Airbreathing engine propellant management.	12, 13, 14	Each DIU services one section of the triply redundant subsystem. All three service the quad feedline valves to the engines on a primary/backup basis.
Aft main propulsion	15, 16, 17	Each DIU services the same parameter in a triply redundant arrangement.
Forward main propulsion	18, 19, 20	Same as for DIUs 15, 16, and 17 for aft equipment.

This baseline Orbiter DIU allocation is shown in diagram form in Figure V-6. The quantities of measurements of different types serviced by each DIU are shown within the blocks representing the DIUs. "L" indicates position measurements; "P" pressure; "T" temperature; "V" voltage; "I" current; "O" other, and "Q" quantity.

Detailed measurement allocations to DIUs are included in the measurement requirements tabulation, Appendix E.

The baseline DIU configuration contains all functions necessary for conditioning, converting, and routing the sensor outputs (as defined by the sensor criteria) to the data bus and for converting commands received over the data bus to excitation signals for control functions. A simplified block diagram, representing the baseline configuration of DIUs 1, 2, and 3 is presented in Figure V-7.

The electronic engine controllers are considered to be the DIUs for the main and airbreathing engines. Figure V-8 depicts the baseline functional requirements for the airbreathing engine controller.

The OCMS approach to self-test is to perform self-test during readiness verification except when necessary to isolate a fault between a DIU and an LRU being serviced by that DIU. The DIU design is such that very little data transfer over the data bus and negligible computer processing will be required to initiate the self-test or recognize the test result. With this approach, the processing loads and data bus traffic added by OCMS self-test are negligible.

F. OCMS CONCEPT FINALIZATION

During the next reporting period, the OCMS system design concepts will be finalized. The principle areas of discussion and the objectives to be pursued in those areas are as follows:

1. Data Bus and Processing Definition

The selected data bus concept will be defined. That definition will include a description of operation, basic bit rate, redundancy requirements, interrupt structure, data formats, and maximum traffic. The final processing requirements will be defined, reflecting the selected data bus and the recommended solutions to the principle hardware-software tradeoffs; eg, hardware comparators vs software evaluation of reported data.

2. Sensor Criteria

The final sensor criteria format will be presented with a number of examples of recommended sensors for selected classes of measurements. Further definition and direction will be supplied for the sensor problem areas defined in paragraph C. above.

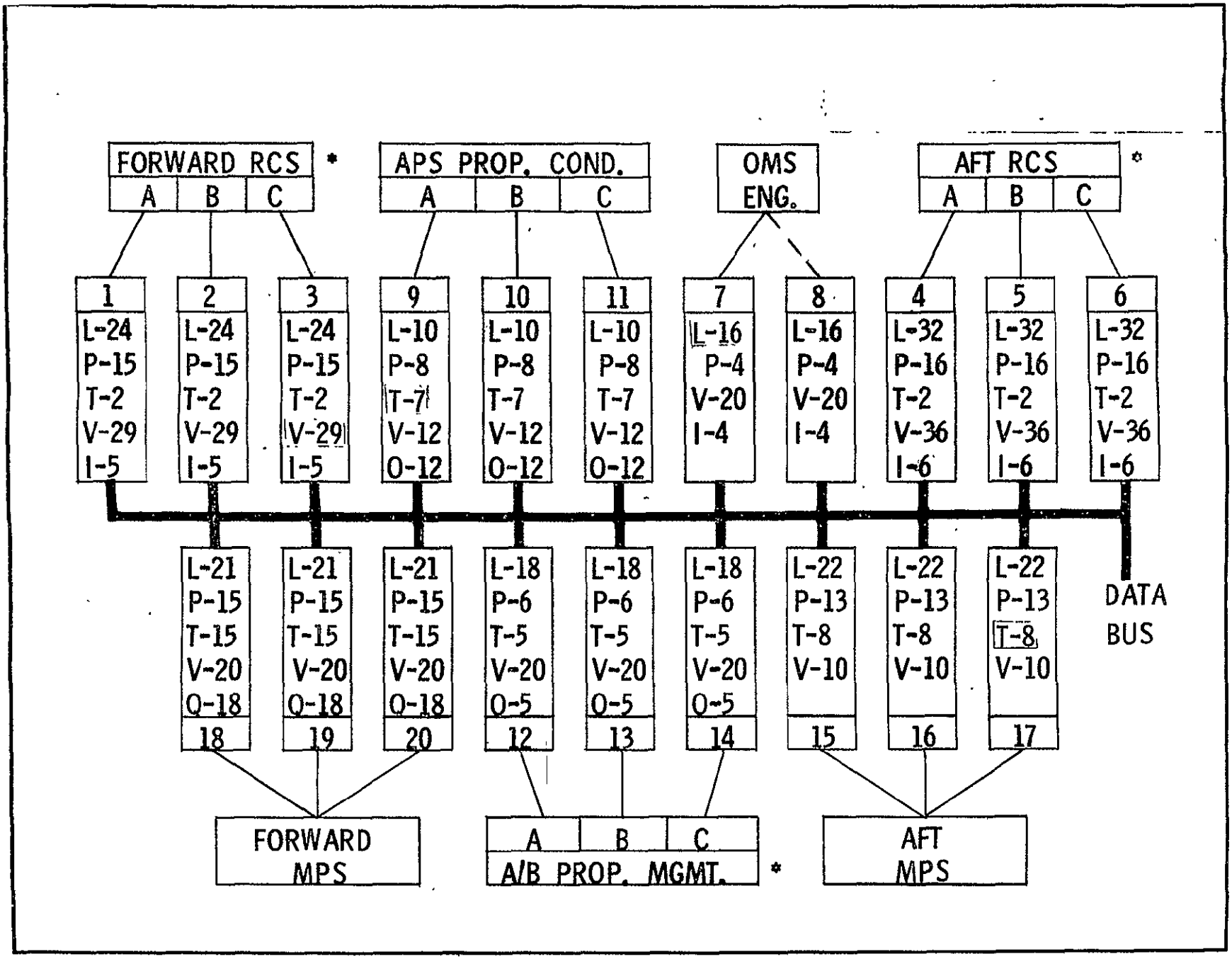


Figure V-6 ORBITER DIU ALLOCATION (W/O ENGINES)

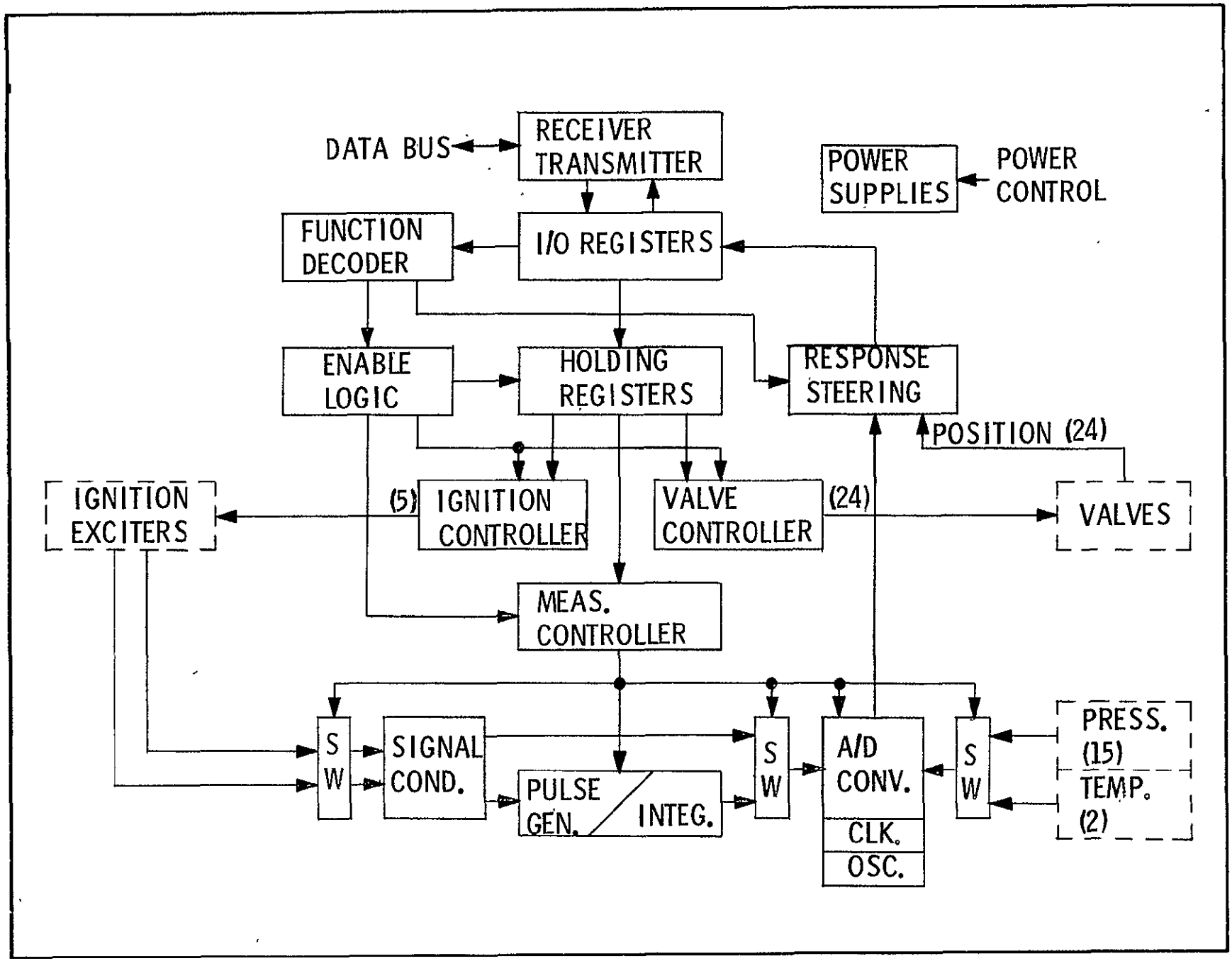


Figure V-7 SAMPLE DIU, SIMPLIFIED BLOCK DIAGRAM

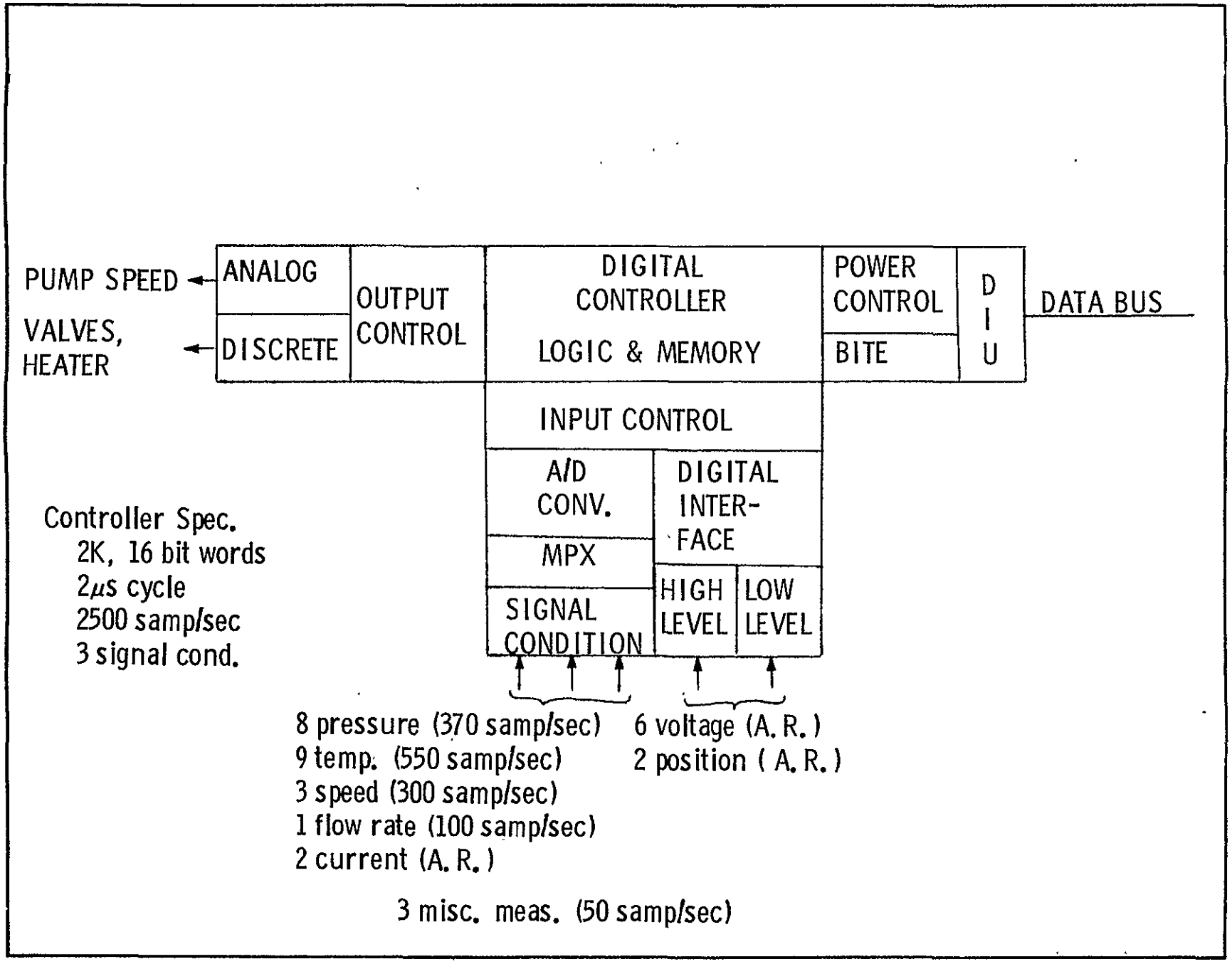


Figure V-8 AIRBREATHING ENGINE CONTROLLER

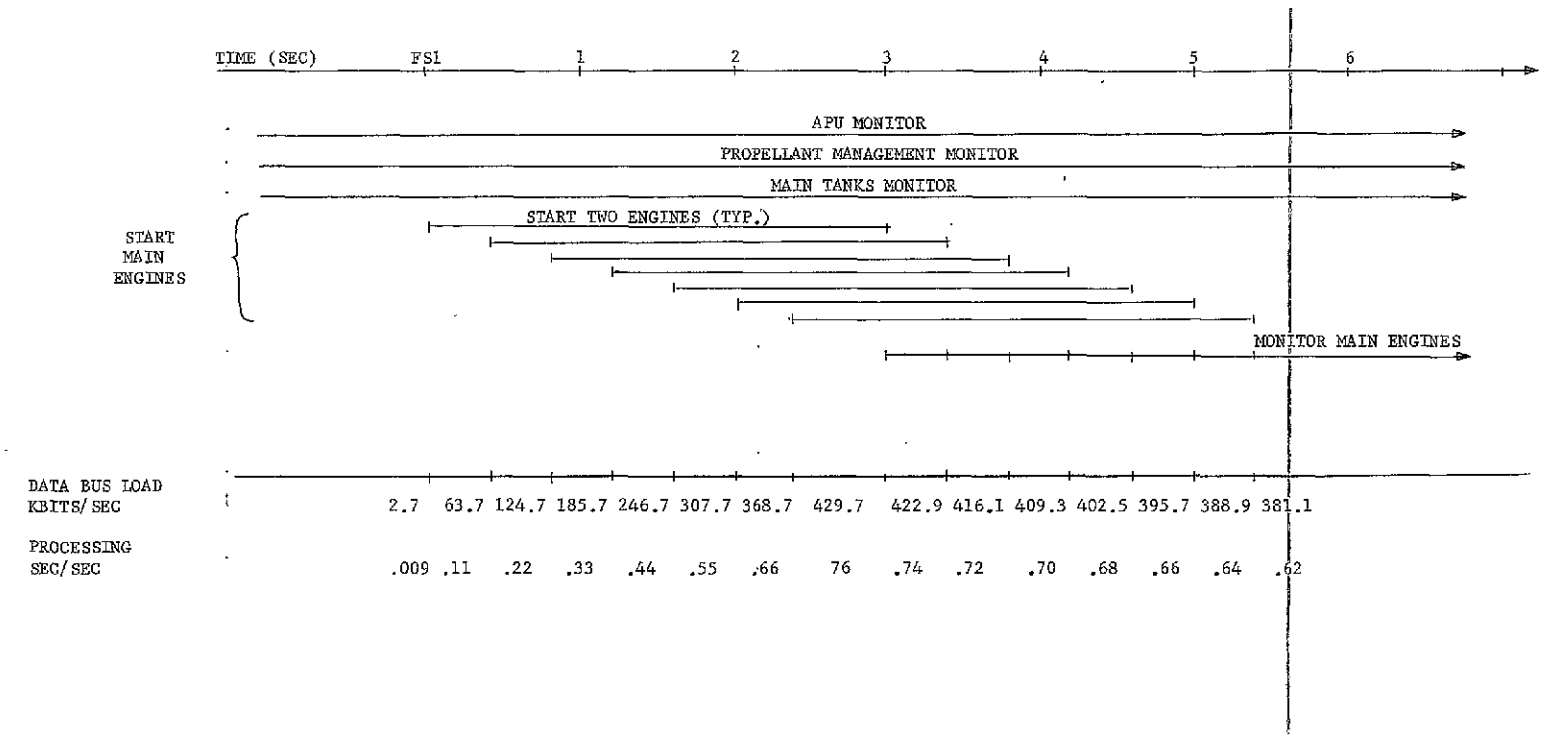
3. Measurement Requirements and Analysis

Finalization will consist of identifying the trend data requirements and procedures, updating sample rates as required, and providing additional clarity in the area of data usage.

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FIGURE V-2

BOOSTER MAIN ENGINE START

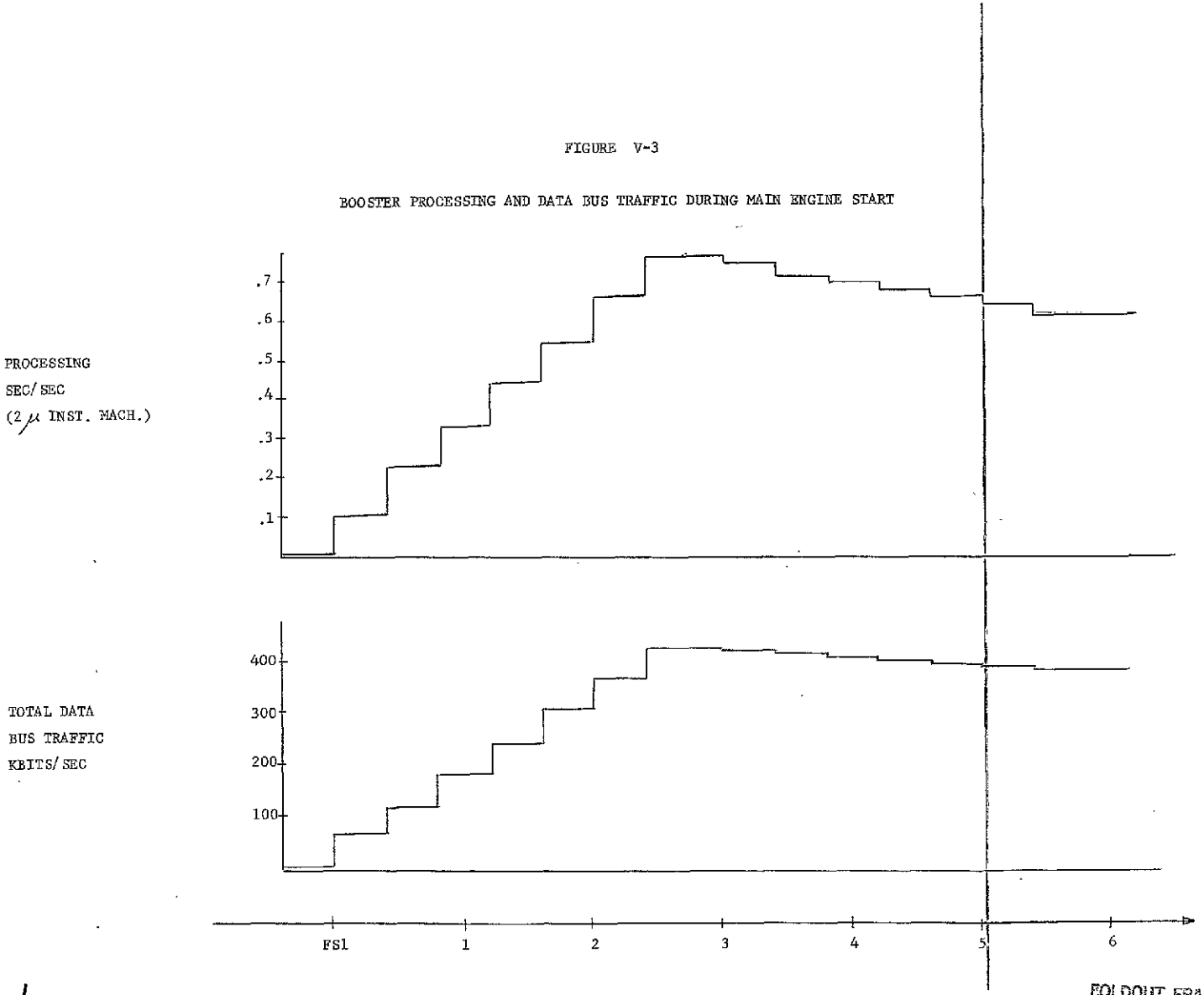


FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE V-3

BOOSTER PROCESSING AND DATA BUS TRAFFIC DURING MAIN ENGINE START

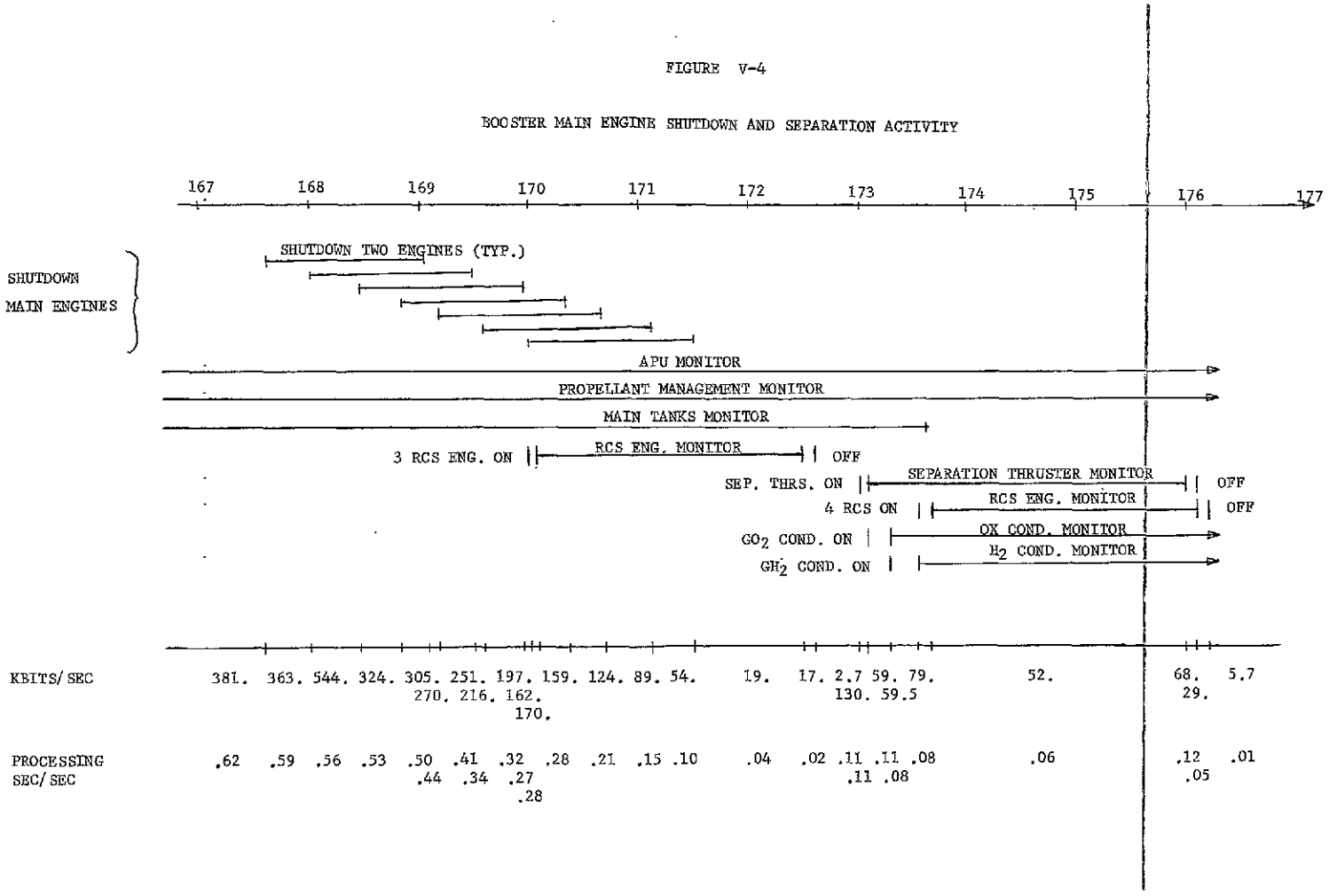


FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE V-4

BOOSTER MAIN ENGINE SHUTDOWN AND SEPARATION ACTIVITY

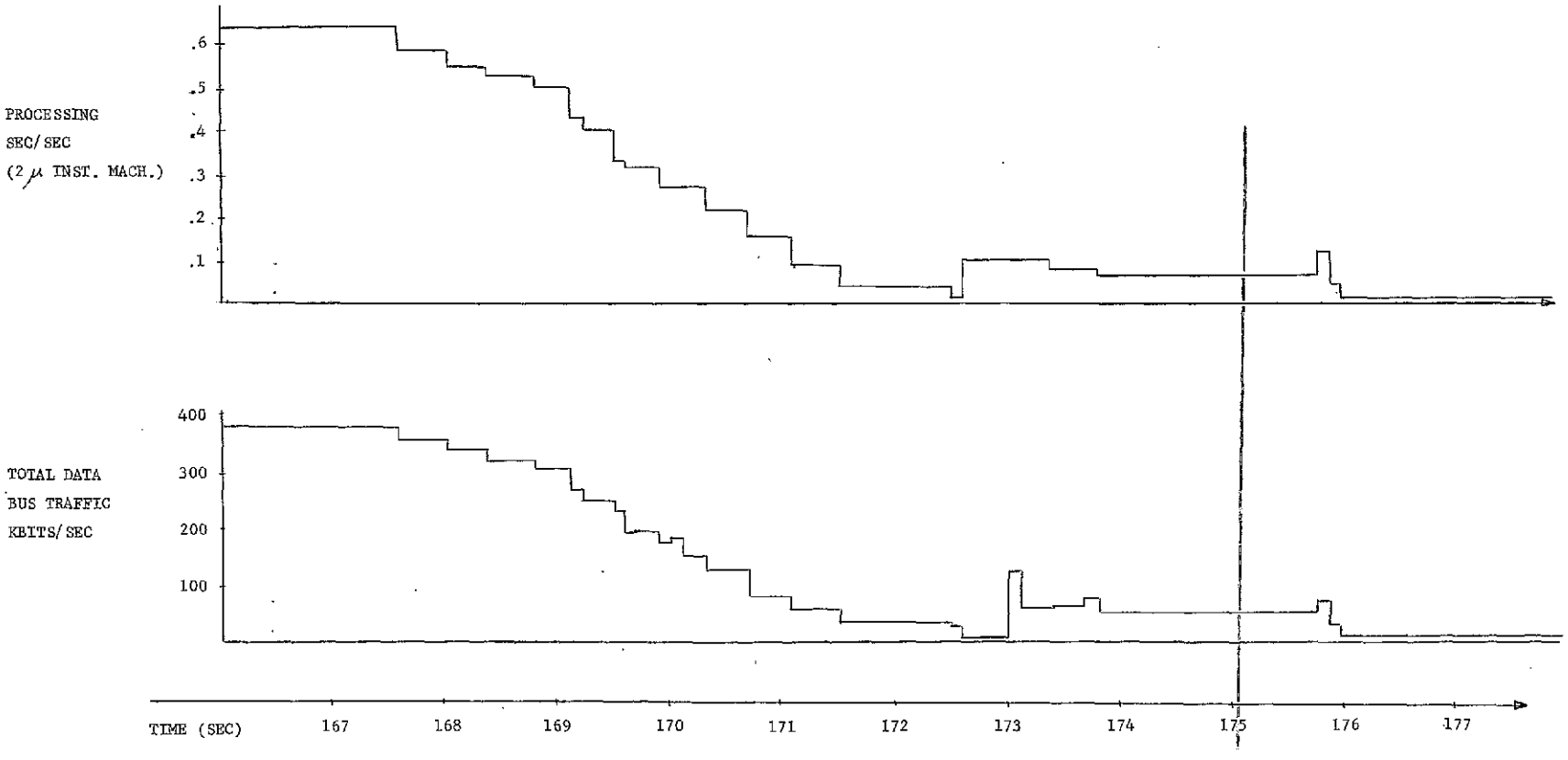


FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIGURE V-5

BOOSTER PROCESSING AND DATA BUS TRAFFIC DURING MAIN ENGINE SHUTDOWN AND SEPARATION



FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE V-4

GROUND SUPPORT EQUIPMENT MATRIX

for

A. MAIN PROPULSION SYSTEM

LRU NUMBER	LRU SUBS.	LRU DESCRIPTION	REQUIRED GSE: Contamination Protection Equip.	Valve Removal Eqmt.	Swab Sample Eqmt.	Caps	Leak Test Eqmt.	Removal&Duct Supporting Fixture	Engine Handling Fixture	Gimbal Support Fixture	Covers or Closures	Optical Test Eqmt.	Cut and Braze Eqmt.	Nozzle Protect & Support Fixt.	L.P.T.P.A. Handling Eqmt.	H.P.T.P.A. Tooling	TPA Handling Eqmt.	Hi-Press.Ox.Turbopump Hand.Eqmt.	Fuel Preburner Hand. Eqmt.	Ox. Preburner Hand. Eqmt.	Propellant Line Hand. Eqmt.	Vacuum Test Eqmt.	Bellows Compressor	Nozzle Support Eqmt.	Nozzle Positioning Eqmt.	Actuator Handling Eqmt.	Controller Handling Eqmt.	Nozzle Handling Eqmt.	Helium Serv. & Press.Meas.Eqmt.	Engine Removal Fixture	Turbopump Removal Fixture	Turbopump Mounting Fixture	Cold-Gas Turbine Drive Eqmt.	Turbocompressor Removal Fixt.	A/B Engine Removal Eqmt.				
1-B/O	MPMS	LO2 Tank Vent Pkg.	X	X	X	X	X																					X										
12-B/O	MPMS	LH2 Tank Vent Pkg.	X	X	X	X																						X										
2-B/O	MPMS	LO2 Tank Isol. Valve	X		X	X	X		X																			X										
3-B/O	MPMS	LH2 Tank Isol. Valve	X		X	X	X		X																			X										
4-B	MPMS	LO2 Prevalve	X	X	X	X	X																					X										
5/20-B/O	MPMS	LH2 Fill Valve	X	X	X	X	X																					X										
18/15-B/O	MPMS	LO2 Fill Valve	X	X	X	X	X																					X										
6/25-B/O	MPS	Fuel Autog. Filter					X																					X										
7/22-B/O	MPS	Ox. Autog. Filter					X																					X										
8/26-B/O	MPS	Fuel Press. Cont. Valve	X				X						X															X										
9/23-B/O	MPS	Ox. Press. Cont. Valve	X				X						X															X										
10/24-B/O	MPS	Ox. Press. Cont. Orifice					X																					X										
11/27-B/O	MPS	Fuel Press. Cont. Orifice					X																					X										
13/19-B/O	MPMS	Fuel Fill Coupling					X																					X										
16-O	MPMS	Ox. Fill Coupling					X																					X										
14-B/O	MPMS	Fuel Tank Vent Coup.					X																					X										
15/21-B/O	MPS	Fuel Tank Prepress. Coup.					X																					X										
17/13-B/O	MPS	LO2 Tank Prepress. Coup.					X																					X										
16/17-B/O	MPMS	LO2 Recirc. Coup.					X																					X										
18-B/O	MPMS	LH2 Recirc. Coup.					X																					X										
19-B	MPMS	LO2 Fill Coup.					X																					X										
20-B	MES	Main Engine	X		X	X	X		X	X	X	X																X										
4-O	OPRO	On-Orb. LO2 Vent Pkg.					X						X															X										
5-O	OPRO	On-Orb. LH2 Vent Pkg.					X						X															X										
6-O	OPRE	On-Orb. Fuel Tank Press. Filt.					X																					X										
9-O	OPRE	On-Orb. LO2 Tank Press. Filt.					X																					X										

LEGEND: B=Booster O=Orbiter MPMS=Main Propellant Management Subsystem MPS=Main Pressurization Subsystem OPRO=On-Orbit Propellant Management Subsystem OPRE=On-Orbit Pressurization Subsystem

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE V-4 (Cont'd)

GROUND SUPPORT EQUIPMENT MATRIX

for

A. MAIN PROPULSION SYSTEM

LRU NUMBER	SUBS.	DESCRIPTION	REQUIRED GSE	Contamination Protection Eqmt.	Valve Removal Eqmt.	Swab Sample Eqmt.	Caps	Leak Test Eqmt.	Removal & Duct Supporting Fixture	Engine Handling Fixture	Gimbal Support Fixture	Covers or Closures	Optical Test Eqmt.	Cut and Braze Eqmt.	Nozzle Protect & Support Fixt.	L.P.T.P.A. Handling Eqmt.	H.P.T.P.A. Tooling	TPA Handling Eqmt.	Hi-Press.Ox.Turbopump Hand.Eqmt.	Fuel Preburner Hand. Eqmt.	Ox. Preburner Hand. Eqmt.	Propellant Line Hand. Eqmt.	Vacuum Test Eqmt.	Bellows Compressor	Nozzle Support Eqmt.	Nozzle Positioning Eqmt.	Actuator Handling Eqmt.	Controller Handling Eqmt.	Nozzle Handling Eqmt.	Helium Serv. & Press.Meas.Eqmt.	Torque Meas. Device	Engine Removal Fixture	Turbopump-Removal-Fixture	Turbopump Mounting Fixture	Cold-Gas Turbine Drive Eqmt.	Turbocompressor Removal Fixt.	A/B Engine Removal Eqmt.				
7-0	OPRE	On-Orb. Fuel Tank Press. Reg.						X						X															X											
10-0	OPRE	On-Orb. LO2 Tank Press. Reg.						X						X															X											
8-0	OPRE	Fuel Tank Press. Shutoff Valve						X						X															X											
11-0	OPRE	Ox. Tank Press. Shutoff Valve						X						X															X											
28-0	MES	Main Engine		X		X	X	X		X	X	X	X																X											
1-B/O	MES	Low Press. Turbopump		X			X	X								X													X	X										
2-B/O	MES	High Press. Turbopump		X			X	X									X												X											
3-B/O	MES	Low Press. Turbopump		X		X	X	X				X						X											X	X										
4-B/O	MES	High Press. Turbopump		X			X	X											X										X											
5-B/O	MES	Fuel Preburner		X			X	X												X									X											
6-B/O	MES	Oxidizer Preburner		X			X	X													X								X											
7-B/O	MES	Fuel Main Valve						X																					X											
8-B/O	MES	Ox. Main Valve		X		X	X	X																					X											
9-B/O	MES	Fuel Control Valve						X																					X											
10-B/O	MES	Ox. Control Valve				X	X	X																					X											
11-B/O	MES	Ox. Control Valve				X	X	X																					X											
12-B/O	MES	Propellant Lines					X	X															X						X											
13-B/O	MES	Interconnect Lines		X			X	X				X												X					X											
14-B/O	MES	Select Valve		X			X	X																					X											
15-B/O	MES	Select Valve		X			X	X																					X											
16-B/O	MES	Control Valve		X			X	X																					X											

LEGEND: B=Booster OPRE=On-Orbit Pressurization Subsystem
O=Orbiter MES=Main Engine Subsystem

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE V-4 (Cont'd)

GROUND SUPPORT EQUIPMENT MATRIX

for

A. MAIN PROPULSION SYSTEM

LRU NUMBER	SUBS.	DESCRIPTION	Contamination Protection Eqmt.	Valve Removal Eqmt.	Swab Sample Eqmt.	Caps	Leak Test Eqmt.	Removal & Duct Supporting Fixt.	Engine Handling Fixture	Gimbal Support Fixture	Covers or Closures	Optical Test Eqmt.	Cut and Braze Eqmt.	Nozzle Protect & Support Fixt.	L.P.T.P.A. Handling Eqmt.	H.P.T.P.A. Tooling	TPA Handling Eqmt.	Hi-Press.Ox.Turbopump Hand. Eqmt	Fuel Preburner Handling Eqmt.	Ox. Preburner Handling Eqmt,	Propellant Line Handling Eqmt.	Vacuum Test Eqmt.	Bellows Compressor	Nozzle Support Eqmt.	Nozzle Positioning Eqmt.	Actuator Handling Eqmt.	Controller Handling Eqmt.	Nozzle Handling Eqmt.	Helium Serv.& Press.Meas.Eqmt.	Torque Meas. Device	Engine Removal Fixture	Turbopump Removal Fixture	Turbopump Mounting Fixture	Cold-Gas Turbine Drive Eqmt.	Turbocompressor Removal Fixt.	A/B Engine Removal Eqmt.				
REQUIRED GSE																																									
17-B/0	MES	Recirc. Regulator	X			X	X																						X											
18-B	MES	Booster Nozzle	X				X			X	X													X					X											
19-B/0	MES	Coolant Control Valve				X	X																						X											
20-B/0	MES	Interconnect Lines	X			X	X																						X											
21-B/0	MES	TCA Igniters					X				X																		X											
22-B/0	MES	Interconnect Lines					X																						X											
23-B/0	MES	Gimbal Actuators	X			X	X																						X											
24-B/0	MES	Engine Controller																							X	X			X											
25-B/0	MES	Wire Harness																									X													
26-B/0	MES	Instrumentation Harness																																						
27-B/0	MES	Check Valve				X	X																						X											
28-B/0	MES	Check Valve			X	X	X																						X											
29-B/0	MES	Heat Exchanger				X	X																						X											
30-B/0	MES	Purge Valves				X	X																						X											
31-0	MES	Extendible Nozzle																										X												
32-0	MES	Nozzle Deployment Kit																						X																

LEGEND: B = Booster; 0 = Orbiter; MES = Main Engine Subsystem

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE V-4 (Cont'd)

GROUND SUPPORT EQUIPMENT MATRIX

for

B. AUXILIARY PROPULSION SYSTEM

LRU NUMBER	LRU SUBS.	LRU DESCRIPTION	REQUIRED GSE	Contamination Protection Eqmt.	Valve Removal Eqmt.	Swab Sample Eqmt.	Caps	Leak Test Eqmt.	Removal & Duct Supporting Fixture	Engine Handling Fixture	Gimbal Support Fixture	Covers or Closures	Optical Test Eqmt.	Cut and Braze Eqmt.	Nozzle Protect & Support Fixt.	L.P.T.P.A. Handling Eqmt	H.P.T.P.A. Tooling	TPA Handling Eqmt.	Hi-Press.Ox.Turbopump Hand.Eqmt.	Fuel Preburner Handling Eqmt.	Ox. Preburner Handling Eqmt.	Propellant Line Handling Eqmt.	Vacuum Test Eqmt.	Bellows Compressor	Nozzle Support Eqmt.	Nozzle Positioning Eqmt.	Actuator Handling Eqmt.	Controller Handling Eqmt.	Nozzle Handling Eqmt.	Helium Serv.& Press.Meas.Equt.	Torque Meas. Device	Engine Removal Fixt.	Turbopump Removal Fixt.	Turbopump Mounting Fixture	Cold-Gas Turbine Drive Eqmt,	Turbocompressor Removal Fixt.	A/B Engine Removal Eqmt.
1-B	RCS	Engine Package						X					X																X		X						
1-B	SEP	Engine Package						X					X																X		X						
1-0	RCS	Engine Package						X					X																X		X						
1-0	OMS	Engine Package						X					X																X		X						
2-B/0	PMS	GO_2 Filter						X						X															X								
3-B/0	PMS	GH_2 Filter						X						X															X								
4-B/0	PMS	GH_2 Solenoid Valve						X						X															X								
5-B/0	PMS	GO_2 Solenoid Valve						X						X															X								
6-B	HCS	GH_2 Check Valve Package						X						X															X								
6-0	PCS	GH_2 Check Valve Package						X						X															X								
7-B	HCS	GG GH_2 Propellant Valve Pkg.						X						X															X								
7-B	OCS	GG GH_2 Propellant Valve Pkg.						X						X															X								
7-B	APU	GG GH_2 Propellant Valve Pkg.						X						X															X								
7-0	PCS	GG GH_2 Propellant Valve Pkg.						X						X															X								
8-B	HCS	GG GO_2 Propellant Valve Pkg.						X						X															X								
8-B	OCS	GG GO_2 Propellant Valve Pkg.						X						X															X								
8-B	APU	GG GO_2 Propellant Valve Pkg.						X						X															X								
8-0	PCS	GG GO_2 Propellant Valve Pkg.						X						X															X								
9-B	HCS	LH_2 Check Valve Pkg.						X						X															X								
10-B	HCS	Turbopumps						X						X																	X	X	X				
11-B	HCS	Turbopump Suction Valve Pkg.						X						X															X								
16-0	PCS	LH_2 Pump Suction Valve Pkg.						X						X															X								
12-B	HCS	GG Heat Exchanger Package						X						X															X								
13-B	HCS	LH_2 Solenoid Valve Package						X						X															X								
14-B	HCS	Gas Generator						X						X															X								

LEGEND:
RCS = Reaction Control Engine Subsystem
SEP = Separation Engine Subsystem
OMS = Orbital Maneuvering Engine Subsystem
PMS = Propellant Management Subsystem
HCS = Hydrogen Conditioning Subsystem
OCS = Oxygen Conditioning Subsystem
APU = Auxiliary Power Unit
PCS = Propellant Conditioning Subsystem
B = Booster
0 = Orbiter

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE V-4 (Cont'd)

GROUND SUPPORT EQUIPMENT MATRIX

for

B. AUXILIARY PROPULSION SYSTEM

LRU NUMBER	LRU SUBS.	LRU DESCRIPTION	REQUIRED GSE: Contamination Protection Eqmt. Valve Removal Eqmt. Swab Sample Eqmt. Caps	Leak Test Eqmt.	Removal & Duct Supporting Fixt.	Engine Handling Fixture Gimbal Support Fixture Covers or Closures	Optical Test Equipment	Cut & Braze Eqmt.	Nozzle Protect. & Support Fixt.	L.P.T.P.A. Handling Eqmt.	H.P.T.P.A. Tooling	TPA Handling Eqmt.	Hi-Press.Ox.Turbopump Hand. Eqmt	Fuel Preburner Handling Eqmt.	Ox. Preburner Handling Eqmt.	Propellant Line Handling Eqmt.	Vacuum Test Eqmt.	Bellows Compressor	Nozzle Support Eqmt.	Nozzle Positioning Eqmt.	Actuator Handling Eqmt.	Controller Handling Eqmt.	Nozzle Handling Eqmt.	Helium Serv.& Press. Meas. Eqmt.	Torque Meas. Device	Engine Removal Fixture	Turbopump Removal Fixture	Turbopump Mounting Fixture	Cold-Gas Turbine Drive Eqmt.	Turbocompressor Removal Fixt.	A/B Engine Removal Eqmt.			
14-B	OCS	Gas Generator		X				X																											
14-B	APU	Gas Generator		X				X																											
14-0	PCS	Gas Generator		X				X																											
15-B	OCS	Compressor Inlet Valve Pkg.		X				X																											
16-B	OCS	Turbocompressor		X																										X	X				
17-B	OCS	GO_2 Check Valve Package		X				X																											
18-0	PCS	GO_2 Check Valve Package		X				X																											
18-B	HCS	Turbine		X																										X					
18-B	OCS	Turbine		X																										X					
18-B	APU	Turbine		X																										X					
15-0	PCS	Turbine		X																										X					
18/22-0/B	PMS	GH_2 Manual Valve		X				X																											
21/19-0/B	PMS	GO_2 Manual Valve		X				X																											
19/23-0/B	PMS	GH_2 Relief Valve		X				X																											
22/20-0/B	PMS	GO_2 Relief Valve		X				X																											
20/24-0/B	PMS	GH_2 QD/Solenoid Valve Pkg.		X				X																											
23/21-0/B	PMS	GO_2 QD/Solenoid Valve Pkg.		X				X																											
25-B/0	PMS	GO_2 Regulator Pkg.		X				X																											
26-B/0	PMS	GH_2 Regulator Pkg.		X				X																											
9-0	PCS	LH_2 Pump		X				X																								X			
10-0	PCS	LO_2 Pump		X				X																								X			
11-0	PCS	LO_2 Heat Exchanger		X				X																											
12-0	PCS	LH_2 Heat Exchanger		X				X																											
13-0	PCS	Power Train Unit																														X			
17-0	PCS	LO_2 Pump Suction Valve Pkg.		X				X																											

LEGEND:
RCS = Reaction Control Engine Subsystem
SEP = Separation Engine Subsystem
OMS = Orbital Maneuvering Engine Subsystem
PMS = Propellant Management Subsystem
HCS = Hydrogen Conditioning Subsystem
OCS = Oxygen Conditioning Subsystem
APU = Auxiliary Power Unit
PCS = Propellant Conditioning Subsystem
B = Booster
O = Orbiter

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE V-4 (Cont'd)

GROUND SUPPORT EQUIPMENT MATRIX

for

C. AIRBREATHING PROPULSION SYSTEM

LRU NUMBER	LRU SUBS.	LRU DESCRIPTION	REQUIRED GSE: Contamination Protection Eqmt. Valve Removal Eqmt. Swab Sample Eqmt.	Caps Leak Test Eqmt. Removal & Duct Supporting Fixt.	Engine Handling Fixture Gimbal Support Fixture Covers or Closures	Optical Test Eqmt. Cut and Braze Eqmt. Nozzle Protect & Support Fixt.	L.P.T.P.A. Handling Eqmt. H.P.T.P.A. Tooling TPA Handling Eqmt.	Hi-Press.Ox.Turbopump Hand. Eqmt Fuel Preburner Hand. Eqmt. Ox. Preburner Hand. Eqmt.	Propellant Line Hand.Eqmt. Vacuum Test Eqmt. Bellows Compressor	Nozzle Support Eqmt. Nozzle Positioning Eqmt. Actuator Handling Eqmt.	Controller Handling Eqmt. Nozzle Handling Eqmt. Helium Serv.& Press.Meas.Eqmt.	Boroscope, Pyro Engine Removal Fixture Turbopump Removal Fixture	Turbopump-Mounting-Fixture Cold-Gas Turbine Drive Eqmt. Turbocompressor Removal Fixt.	A/B Engine Removal Eqmt. Nitrogen Serv. & Press. Eqmt.			
1-B	TFE	Turbofan Engine		X							X			X			
2-B	APM	Inlet Valve Pkg.				X											
3-B	APM	Fuel Dist. Valve Pkg.				X					X						
4-B	APM	Vent Valve Pkg.				X					X						
5-B	APM	Vent Disconnect Coupling		X							X						
6-B	APM	Fill Valve									X						
7-B	APM	Fill Coupling		X							X						
8-B	APR	Pressure Regulator Package		X		X											
9-B	APR	Pressurization Valve Package		X		X											
10-B	APR	Pressurization Filter				X											
3-O	APM	GH2 Valve Package				X					X						
5-O	APM	GO2 Valve Package				X					X						
4-O	APM	Gas Generator				X					X						
6-O	APM	LH2 Valve Package				X					X						
7-O	APM	Turbopump Assembly				X					X						
8-O	APM	Check Valve Package				X					X						
2-B/O	TFE	Fuel Control Assembly		X							X						
3-B/O	TFE	Electronic Controller															

LEGEND: B=Booster TFE=Turbofan Engine Subsystem
O=Orbiter APM=Airbreathing Propellant Management Subsystem
APR=Airbreathing Pressurization Subsystem

FOLDOUT FRAME 1

FOLDOUT FRAME 2

TABLE V-4 (Cont'd)

GROUND SUPPORT EQUIPMENT MATRIX

for

C. AIRBREATHING PROPULSION SYSTEM

LRU NUMBER	SUBS.	DESCRIPTION	REQUIRED GSE	Contamination Protection Eqmt.	Valve Removal Eqmt.	Swab Sample Eqmt.	Caps	Leak Test Eqmt.	Removal & Duct Supporting Fixt.	Engine Handling Fixture	Gimbal Support Fixture	Covers or Closures	Optical Test Eqmt.	Cut and Braze Eqmt.	Nozzle Protect & Support Fixt.	L.P.T.P.A. Handling Eqmt.	H.P.T.P.A. Tooling	TPA Handling Eqmt.	HI-Press.,Ox.Turbopump Hand. Eqmt.	Fuel Preburner Hand. Eqmt.	Ox. Preburner Hand. Eqmt.	Propellant Line Hand. Eqmt.	Vacuum Test Eqmt.	Bellows Compressor	Nozzle Support Eqmt.	Nozzle Positioning Eqmt.	Actuator Handling Eqmt.	Controller Handling Eqmt.	Nozzle Handling Eqmt.	Helium Serv.& Press.Meas.Eqmt.	Boroscope, Pyro	Engine Removal Fixture	Turbopump Removal Fixture	Turbopump-Mounting-Fixture	Cold-Gas Turbine Drive Eqmt.	Turbocompressor Removal Fixt.	A/B Engine Removal Eqmt.	Nitrogen Serv. & Press. Eqmt.			
4-B/O	TFE	Scavenge Pump												X															X												
5-B/O	TFE	Oil Boost Pump												X															X												
6-B/O	TFE	Oil Pressure Pump												X															X												
7-B/O	TFE	Oil Strainer																											X												
8-B/O	TFE	Boost Pump Relief Valve												X															X												
9-B/O	TFE	Boost Pump Regulator Valve												X															X												
10-B/O	TFE	Pressurant Regulator Valve												X															X												
11-O	TFE	Zero-G Pressurization System						X						X																							X				
12-B/O	TFE	Ignition Exciter											X																												
13-B/O	TFE	Ignition Compositor											X																												
14-B/O	TFE	Ignition Plug											X																												
15-B/O	TFE	Solid Start Cartridge																																							
N/A-B/O	TFE	Fan																													X										
N/A-B/O	TFE	Low Pressure Compressor																													X										
N/A-B/O	TFE	High Pressure Compressor																													X										
N/A-B/O	TFE	Low Pressure Turbine																													X										

LEGEND: B=Booster
O=Orbiter
TFE=Turbofan Engine Subsystem

FOLDOUT FRAME 1

FOLDOUT FRAME 2

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APPENDIX B

FAILURE MODES AND EFFECTS

ANALYSIS DATA SHEETS

This appendix is reserved for the Failure Modes and Effects Analysis Data Sheets, formerly published in MCR-70-274 (Issue 1), Quarterly Progress Report for July - September, 1970. The data sheets will be included in the final report.

APPENDIX C

MAINTENANCE PROCEDURES
FOR THE MAIN, AUXILIARY
AND AIRBREATHING PROPULSION SYSTEMS

The maintenance procedures for the propulsion systems' Line Replaceable Units (LRUs) were published in MCR-70-306 (Issue 3), Monthly Progress Report for October, 1970. Typical examples are presented herein, and the complete set will be republished in the final report.

MAINTENANCE PROCEDURE

LRU (1) LO_2 Tank Vent Package

LRU (12) LH_2 Tank Vent Package

SYSTEM - Booster and Orbiter Main Propulsion

SUBSYSTEM - Propellant Management

ASSEMBLY - Tank Vent

COMPONENT - N/A

TASK TIME - 3 hours

SPECIAL CONSIDERATIONS - Vent Subsystem to Ambient Pressure

PROCEDURE

1. REMOVAL

   a. Remove access panels to forward region.
   b. Install contamination protection equipment around valve.
   c. Install valve removal equipment.
   d. Disconnect electrical cables; sensors, valve flange retaining bolts to vent line; valve flange bolts to LOX and LH_2 tank.
   e. Remove valve, and all seals.
   f. Take swab samples per contamination procedure.
   g. Cap all line openings and valve openings.

2. REPLACEMENT

   a. Remove all protective caps.
   b. Take swab samples.
   c. Install valve seals; valves and bolt-up both ducts.
   d. Connect electrical cables and sensors.
   e. Remove all GSE.
   f. Install safety wire and perform visual inspection of area.

3. RETEST

   a. Perform electrical checks.
   b. Perform valve leak check.
   c. Perform valve functional check through main system computer.
   d. Checkout of sensors.

MAINTENANCE PROCEDURE

LRU (2) LO_2 Tank Isolation Valve

LRU (3) LH_2 Tank Isolation Valve

SYSTEM - Booster and Orbiter Main Propulsion

SUBSYSTEM - Main Propellant Management

ASSEMBLY - Distribution and Feed

COMPONENT - 1.2.2.2 and 1.2.7.2

TASK TIME - 4 hours

SPECIAL CONSIDERATIONS - Insure system is purged and vent to ambient.

PROCEDURE

1. REMOVAL

   a. Remove access doors.
   b. Install contamination protection equipment around valve.
   c. Install valve removal GSE and duct supporting fixture.
   d. Disconnect electrical cables, sensors, valve flange retaining bolts to LOX engine distribution duct; valve flange bolts to tank sump.
   e. Remove valve and all seals.
   f. Take swap samples.
   g. Cap duct opening and sump opening.

2. REPLACEMENT

   a. Remove all protective caps.
   b. Take swap samples.
   c. Install valve seals; valve and secure both flange ends.
   d. Connect electrical cables and sensors.
   e. Remove all GSE.
   f. Install safety wire and perform visual inspection.

3. RETEST

   a. Perform electrical checkout.
   b. Perform valve leak check.
   c. Perform valve functional checkout through main system computer.
   d. Checkout of all sensors.
   e. Checkout of built-in relief valve.

MAINTENANCE PROCEDURE

LRU (4) LO_2 Prevalve

SYSTEM - Booster Main Propulsion

SUBSYSTEM - Main Propellant Management

ASSEMBLY - Oxidizer Feed

COMPONENT - 1.2.1.2

TASK TIME - 3 hours

SPECIAL CONSIDERATIONS - Insure system is purged and vented.

PROCEDURE

1. REMOVAL

   a. Remove access panels to rear base region.
   b. Install contamination protection equipment around valve.
   c. Install valve removal equipment.
   d. Disconnect electrical cables; sensors; valve flange retaining bolts to engine suction duct; valve flange bolts to oxidizer feed ducting.
   e. Remove valve, and all seals.
   f. Take swab samples per contamination procedure.
   g. Cap all duct openings.

2. REPLACEMENT

   a. Remove all protective caps.
   b. Take swab samples.
   c. Install valve seals; valves and bolt-up both ducts.
   d. Connect electrical cables and sensors.
   e. Removal all GSE.
   f. Install safety wire and perform visual inspection of area.

3. RETEST

   a. Perform electrical checks.
   b. Perform valve leak check.
   c. Perform valve functional check through main system computer.
   d. Checkout of sensors.

MAINTENANCE PROCEDURE

LRU (5) , (20) Booster/Orbiter LH_2 Fill Valve

LRU (18) , (15) Booster/Orbiter LO_2 Fill Valve

SYSTEM - Booster and Orbiter Propulsion

SUBSYSTEM - Main Propellant Management

ASSEMBLY - Fill and Drain

COMPONENT - N/A

TASK TIME - 3 hours.

SPECIAL CONSIDERATIONS - Insure valve is purged.

PROCEDURE

1. REMOVAL

   a. Remove access panels to lower aft region.
   b. Install contamination protection equipment around valve.
   c. Install valve removal equipment.
   d. Disconnect electrical cables; sensors; valve flange retaining bolts to fill and drain lines.
   e. Remove valve, and all seals.
   f. Take swab samples per contamination procedure.
   g. Cap all line openings and valve openings.

2. REPLACEMENT

   a. Remove all protective caps.
   b. Take swab samples.
   c. Install valve seals; valves and bolt-up both ducts.
   d. Connect electrical cables and sensors.
   e. Remove all GSE.
   f. Install safety wire and perform visual inspection of area.

3. RETEST

   a. Perform electrical checks.
   b. Perform valve leak check.
   c. Perform valve function check through main system computer.
   d. Checkout of sensors.

APPENDIX D

CHECKOUT AND MONITORING

REQUIREMENTS ANALYSIS

This appendix replaces the Checkout and Monitoring Requirements Analysis, Appendix D of MCR-70-274 (Issue 1), and MCR-70-306 (Issue 3). A conversion has been made from a subsystem-by-subsystem analysis of the orbiter stage to a detailed phase-by-phase analysis to improve the continuity of the previous analysis and to include GSE requirements and the detailed measurement requirements. The result is a step-by-step sequence for a nominal mission, including the values expected for a given measurement at a given time, and justification for the required measurements.

This task was accomplished by taking the previous analysis and molding the activities of each subsystem during a given phase into a cohesive phase analysis. This phase analysis was then evaluated against the subsystems requirements documentation. This procedure was followed through each mission phase. Finally, the detailed operations of the tasks that were indicated in the phase-by-phase analysis were added.

Glossary of Symbols:

ELEMENTS

V = valve
L = line
E.C. = engine controller
T.F. = turbofan
T.R. = thruster
T.C. = thrust chamber
FCA = fuel control assembly
LA = lube assembly
G = gas generator
PT = power train
TP = turbopump
FM = flowmeter
FH = fuel heater
H = heat exchanger
C = coupling
T = tank
GOV = LO_2 valve
GFV = LH_2 valve
EFV = engine fuel valve
IGN = ignition
U = turbine
SC = start cartridge
CL = clutch
P = pump
FD = flame detector
COMP = compartment

USES

R = readiness
S = status
M = monitor
C = control
C/O = checkout

ORBITER

I. FERRY PREFLIGHT

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1. Connect the Ground Power GSE.

2. Power up OCMS.

3. Perform an OCMS self-check, including engine controllers.

4. Power up all propulsion systems.

   a) Make the following MPS readiness checks.

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
F.P.	4	V-1	LOIV-1	1	R	Closed
		V-2	LOIV-2			
		V-3	LOVV-1			
		V-4	LOVV-2			
		V-5	LOVV-3			
		V-6	LOVV-4			
		V-7	LOFV-1			
		V-8	LFIV-1			
		V-9	LFIV-2			
		V-10	LFTVV-1			
		V-11	LFTVV-2			
		V-12	LFTVV-3			
		V-13	LFTVV-4			
		V-14	LFFV-1			
		V-19	LOPCV-1			
		V-20	LOPCV-2			
		V-21	LFPCV-1			
		V-22	LFPCV-2			
		V-23	LOIV-3			
		V-24	LOTVV-1			
		V-25	LOTVV-2			
		V-26	LFIV-3			
		V-27	LFIV-4			
		V-28	LFTVV-5			
		V-29	LFTVV-6			
		V-30	LFTVV-7			
		V-31	LFTVV-8			
		V-32	LOPV-1			
		V-33	LOPV-2			
		V-34	LFPV-1			
		V-35	LFPV-2			
		C-1	LOFC-1			
		C-2	LHC-1,2			
		C-3	LFTVC-1			
		C-4	LHC-3,4			
		C-5	LFFC-1			
F.P.	4	C-6	LHC-5,6	1	R	Closed

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTE VALUE
F.P.	4	C-8	LHC-7,8	1	R	Closed
		C-11	LFVC-1			Closed
		T-3	PFT-1			19 PSIA
		T-5	PfT-2			
		T-6	PfT-3			
		T-1	PoT-1			
		T-2	PoT-2			
		T-4	PoT-3			
		L-17	PoL-2			
		L-20	PfL-1			
		L-21	PfL-4			
		C-5/V-14	PfF-1			
		C-1/V-7	PoF-1			
		L-8	PfS-1			
		L-9	PfS-2			
		L-3	PoS-1			
		L-4	PoS-2			19 PSIA
		T-4	QoT-7			UNC
		T-4	QoT-8			
		T-4	QoT-9			
		T-5	QfT-4			
		T-5	QfT-5			
		T-5	QfT-6			
		T-6	QfT-7			
		T-6	QfT-8			
		T-6	QfT-9			UNC
		T-5	TfT-2			AMBIENT
		T-6	TfT-3			
		T-4	ToT-3			
		L-20	TfL-1			
		L-21	TfL-4			
			TfL-5			
		L-17	ToL-2			
F.P.	4		ToL-4	1	R	AMBIENT

b) Perform main engine readiness checks. (Include Gimbal Locks & Ig

c) Verify all main engine covers installed.

Make the following APS readiness checks.

F.P.	5		PoL-8	1	R	19 PSIA
			PoL-9			
			PfL-9			
			PfL-10			19 PSIA
		T.C.-(1-37)	LBIV-(1-37)	1/valve=37		Closed
		T.C.-(1-37)	LMBV-(1-37)			
		T.C.-(1-37)	LIOV-(1-37)	1/valve=37		Closed
F.P.	5	T.C.-(1-37)	VII-(1-37)	1/T.C.=37	R	OV
F.P.	5	T.C.-(1-37)	LIFV-(1-37)	1/valve=37		Closed

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
F.P.	5	V-36	LOPV-3	1	R	Closed
		V-37	LOPV-4			
		V-38	LOPV-5			
		V-39	LOPV-6			
		V-40	LFPV-3			
		V-41	LFPV-4			
		V-42	LFPV-5			
		V-43	LFPV-6			
		C-9	LOFC-2			
		C-10	LFFC-2			
		V-44	LOFV-2			
		V-70	LFFV-2			Closed
		T-8	PoT-4			19 PSIA
		T-9	PoT-5			
		T-10	PfT-4			
		T-11	PfT-5			19 PSIA
		T-8	ToT-4			AMBIENT
		T-9	ToT-5			
		T-10	TfT-4			
		T-11	TfT-5			AMBIENT
		GOV-1	LGOV-1			Closed
		GOV-1	LGOV-1I			
		GOV-2	LGOV-2			
		GOV-2	LGOV-2I			
		GOV-3	LGOV-3			
		GOV-3	LGOV-3I			
		GFV-1	LGFV-1			
		GFV-1	LGFV-1I			
		GFV-2	LGFV-2			
		GFV-2	LGFV-2I			
		GFV-3	LGFV-3			
		GFV-3	LGFV-3I			
		V-52	LLIV-1			
		V-52	LPSV-1			
		V-53	LLIV-2			
		V-53	LPSV-2			
		V-54	LLIV-3			
		V-54	LPSV-3			
		V-55	LFIV-1			
		V-55	LPSV-4			
		V-56	LFIV-2			
		V-56	LPSV-5			
		V-57	LFIV-3			
		V-57	LPSV-6			Closed
		G-1	VII-38			OV
		G-2	VII-39			OV
F.P.	5	G-3	VII-40	1	R	OV

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTE VALUE
F.P.	5	G-1	LIOV-38	1	R	Closed
		G-1	LIFV-38			
		G-2	LIOV-39			
		G-2	LIFV-39			
		G-3	LIOV-40			
F.P.	5	G-3	LIFV-40	1	R	Closed

Visually verify that all RCS and OMS protective covers are installed.

Request vehicle to close all RCS thermal protective doors and confirm.

Perform the following A/B readiness checks.

F.P.	6	GFV-4	LGFV-4I	1	R	Closed
		GFV-4	LGFV-4			
		GFV-5	LGFV-5I			
		GFV-5	LGFV-5			
		GFV-6	LGFV-6I			
		GFV-6	LGFV-6			
		GOV-4	LGOV-4I			
		GOV-4	LGOV-4			
		GOV-5	LGOV-5I			
		GOV-5	LGOV-5			
		GOV-6	LGOV-6I			
		GOV-6	LGOV-6			
		V-58	LFIV-4			
		V-59	LPSV-7			
		V-60	LFIV-5			
		V-61	LPSV-8			
		V-62	LFIV-6			
		V-63	LPSV-9			
		EFV-1	LEFV-1			
		EFV-2	LEFV-2			
		EFV-3	LEFV-3			
		EFV-4	LEFV-4			
		EFV-5	LEFV-5			
		EFV-6	LEFV-6			
		EFV-7	LEFV-7			
		EFV-8	LEFV-8			
		EFV-9	LEFV-9			
		EFV-10	LEFV-10			
		EFV-11	LEFV-11			
		EFV-12	LEFV-12			Closed
			PfL-11			19 PSIA
			PfL-12			
F.P.	6		PfL-13	1	R	19 PSIA

A/B E.C. - 1,2,3 perform the following readiness checks.

F.P.	7	FCA-1	LFIVA/B-1	1	R	Closed
F.P.	7	FCA-1	LCPRV-1	1	R	Closed

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
F.P.	7	FCA-1	LSPV-1	1	R	Closed
		IGN-1	VIIA/B-1			OVDC
		FCA-2	LFIVA/B-2			Closed
		FCA-2	LCPRV-2			↓
		FCA-2	LSPV-2			Closed
		IGN-2	VIIA/B-2			OVDC
		FCA-3	LFIVA/B-3			Closed
		FCA-3	LCPRV-3			↓
		FCA-3	LSPV-3			Closed
F.P.	7	IGN-3	VIIA/B-3	1	R	OVDC

Verify that the turbofan engine cradles are lowered and locked.

Verify that all turbofan engine covers have been removed.

LOAD

Connect the Propellant Servicing and Pressurization GSE to the appropriate couplings and perform the following status checks:

F.P.	7	C-1	LOFC-1	1	S	Open
		C-2	LHC-1			
		C-2	LHC-2			
		C-5	LFFC-1			
		C-8	LHC-7			
		C-8	LHC-8			
		C-9	LOFC-2			
		C-10	LFFC-2			
F.P.	7	C-11	LFVC-1	1	S	Open

Open the following valves and verify position.

F.P.	8	V-7	LOFV-1	1	S	Open
		V-23	LOIV-3			
		V-24	LOTVV-1			
F.P.	8	V-25	LOTVV-2	1	S	Open

Command LOX to slow transfer mode.

Verify operation by checking;

F.P.	9	L-17	ToL-2	1	S	$<200^{\circ}R$

When

F.P.	10	T-4	QoT-7	10/Sec	C	Covered

Command LOX helium recirculation on and LOX transfer to fast fill.

When

F.P.	11	T-4	QoT-8	10/Sec	C	Covered

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
			Command LOX transfer to slow fill, and terminate helium recirculation.			
			When			
F.P.	12	T-4	QoT-9	10/Sec	C	Covered
			Command LOX transfer to mode hold.			
			Verify the following:			
F.P.	13	T-4	ToT-3	1	S	164±3°R
		L-17	ToL-2			164±3°R
		L-17	PoL-2			
		L-3	ToS-1			164±3°R
		L-4	ToS-2			164±3°R
		L-3	PoS-1			
		L-4	PoS-2			
F.P.	13	L-7	PgRL-1	1	S	
			Check for leakage with scan cameras.			
			Open V-44; check			
F.P.	14	V-44	LOFV-2	1	S	Open
			Off-Load the stored helium in T-8 and T-9			
F.P.	15	T-8	PoT-4	1/Sec	S	14.7 PSIA
F.P.	15	T-9	PoT-5	1/Sec	S	14.7 PSIA
			Open V-70; check			
F.P.	16	V-70	LFFV-2	1	S	Open
			Off-Load the stored helium in T-10 and T-11			
F.P.	17	T-10	PfT-4	1/Sec	S	14.7 PSIA
F.P.	17	T-11	PfT-5	1/Sec	S	14.7 PSIA
			Load T-8 and T-9 with GO2.			
F.P.	18	T-8	PoT-6	1/Sec	C	1500 PSIA
		T-8	ToT-4			
		T-9	PoT-7			1500 PSIA
F.P.	18	T-9	ToT-5	1/Sec	C	
			Compute accumulator quantity and send stop signal to the GSE at full load			
			Close V-44; check			
F.P.	19	V-44	LOFV-2	1	S	Closed

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Monitor						
F.P.	20	T-8	PoT-6	1/Sec	M	1500 PSIA
↓	↓	T-8	ToT-4	↓	↓	
↓	↓	T-9	PoT-7	↓	↓	1500 PSIA
F.P.	20	T-9	ToT-5	1/Sec	M	
for decay.						
Load T-10 and T-11 with GH2.						
F.P.	21	T-10	PfT-6	1/Sec	C	1500 PSIA
↓	↓	T-10	TfT-4	↓	↓	
↓	↓	T-11	PfT-7	↓	↓	1500 PSIA
F.P.	21	T-11	TfT-5	1/Sec	C	
Compute accumulator quantity and send stop signal to GSE at full load.						
Close V-70; check						
F.P.	22	V-70	LFFV-2	1	S	Closed
Monitor						
F.P.	23	T-10	PfT-6	1/Sec	M	1500 PSIA
↓	↓	T-10	TfT-4	↓	↓	
↓	↓	T-11	PfT-7	↓	↓	1500 PSIA
F.P.	23	T-11	TfT-5	1/Sec	M	
for decay.						
Reverify						
F.P.	24		PoL-8	1	S	19 PSIA
↓	↓		PoL-9	↓	↓	↓
↓	↓		PfL-9	↓	↓	
F.P.	24		PfL-10	1	S	19 PSIA
Command open; verify						
F.P.	25	V-28	LFTVV-5	1	S	Open
↓	↓	V-29	LFTVV-6	↓	↓	↓
↓	↓	V-30	LFTVV-7	↓	↓	
F.P.	25	V-31	LFTVV-8	1	S	Open
Command open; verify						
F.P.	26	V-27	LFIV-4	1	S	Open
↓	↓	V-14	LFFV-1	↓	↓	↓
F.P.	26	V-26	LFIV-3	1	S	Open

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Commence slow fuel transfer to T-5 and T-6.				
		Verify operation by checking;				
F.P.	27	L-20	TfL-1	1	S	<50°R
↓	↓	L-21	TfL-4	↓	↓	<50°R
F.P.	27		TfL-5	1	S	<50°R
		When both				
F.P.	28	T-5	QfT-4	10/Sec	C	Covered
F.P.	28	T-6	QfT-7	10/Sec	C	Covered
		Command fuel transfer to fast fill				
		When				
F.P.	29	T-5	QfT-5	10/Sec	C	Covered
		or,				
F.P.	30	T-6	QfT-8	10/Sec	C	Covered
		Command fuel transfer to slow fill.				
		When				
F.P.	31	T-5	QfT-6	10/Sec	C	Covered
		Or,				
F.P.	32	T-6	QfT-9	10/Sec	C	Covered
		Command fuel transfer to mode hold when the other one covers,				
		or TBD seconds after the first one covers.				
		Verify no leakage with compartment detectors.				
		Verify safe condition with compartment fire detectors.				
		Verify;				
F.P.	33	T-5	TfT-2	1	S	36-40°R
↓	↓	T-6	TfT-3	↓	↓	↓
		L-20	TfL-1			
		L-21	TfL-4			
		L-8	TfS-1			
		L-9	TfS-2			36-40°R
↓	↓	L-8	PfS-1	↓	↓	
F.P.	33	L-9	PfS-2	1	S	

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Command and verify:						
F.P.	34	V-14	LFFV-1	1	S	Closed
If						
F.P.	35	T-4	QoT-9	1	S	Uncovered
Command LOX transfer to slow fill.						
When						
F.P.	36	T-4	QoT-9	10/sec	C	Covered
Command LOX transfer to stop.						
Command and verify;						
F.P.	37	V-7	LOFV-1	1	S	Closed
If						
F.P.	38	T-5	QfT-6	1	S	Uncovered
and/or						
F.P.	39	T-6	QfT-9	1	S	Uncovered
Command and verify						
F.P.	40	V-14	LFFV-1	1	R	Open
Command fuel transfer to slow fill.						
When						
F.P.	41	T-5	QfT-6	10/sec	C	Covered
or						
F.P.	42	T-6	QfT-9	10/sec	C	covered
Command fuel transfer to stop when the other covers, or TBD seconds after the first one covers.						
Command and verify:						
F.P.	43	V-14	LFFV-1	1	S	Closed

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Command and verify;						
F.P.	44	V-24	LOTVV-1	1	S	Closed
		V-25	LOTVV-2			
		V-28	LFTVV-5			
		V-29	LFTVV-6			
		V-30	LFTVV-7			
F.P.	44	V-31	LFTVV-8	1	S	Closed
Pressurization						
Verify						
F.P.	45	T-8	PoT-6	1	R	1500 PSIA
		T-9	PoT-7			1500 PSIA
F.P.	45	T-4	PoT-3	1	R	<30 PSIA
Command and verify;						
F.P.	46	V-33	LOPV-2	1	S	Open
Verify						
F.P.	47	T-4	PoT-3	1	S	35-40 PSI
Command and verify;						
F.P.	48	V-33	LOPV-2	1	S	Closed
Command and verify;						
F.P.	49	V-24	LOTVV-1	1	S	Open
F.P.	49	V-25	LOTVV-2	1	S	Open
Verify;						
F.P.	50	T-4	PoT-3	1	S	Ambient
Command and verify;						
F.P.	51	V-24	LOTVV-1	1	S	Closed
F.P.	51	V-25	LOTVV-2	1	S	Closed
Command and verify;						
F.P.	52	V-32	LOPV-1	1	S	Open
verify;						
F.P.	53	T-4	PoT-3	1	S	35-40 PSI

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify;					
F.P.	54	V-32	LOPV-1	1	S	Closed
	Verify;					
F.P.	55	T-10	PfT-6	1	S	1500 PSIA
↓	↓	T-11	PfT-7	↓	↓	1500 PSIA
↓	↓	T-5	PfT-2	↓	↓	<30 PSIA
F.P.	55	T-6	PfT-3	1	S	<30 PSIA
	Command and verify;					
F.P.	56	V-35	LFPV-2	1	S	Open
	Verify:					
F.P.	57	T-5	PfT-2	1	S	35-40 PSIA
F.P.	57	T-6	PfT-3	1	S	35-40 PSIA
	Command and verify;					
F.P.	58	V-35	LFPV-2	1	S	Closed
	Command and verify;					
F.P.	59	V-28	LFTVV-5	1	S	Open
↓	↓	V-29	LFTVV-6	↓	↓	↓
↓	↓	V-30	LFTVV-7	↓	↓	↓
F.P.	59	V-31	LFTVV-8	1	S	Open
	Verify:					
F.P.	60	T-5	PfT-2	1	S	Ambient
F.P.	60	T-6	PfT-3	1	S	Ambient
	Command and verify;					
F.P.	61	V-28	LFTVV-5	1	S	Closed
↓	↓	V-29	LFTVV-6	↓	↓	↓
↓	↓	V-30	LFTVV-7	↓	↓	↓
F.P.	61	V-31	LFTVV-8	1	S	Closed
	Command & verify;					
F.P.	62	V-34	LFPV-1	1	S	Open
	Verify;					
F.P.	63	T-5	PfT-2	1	S	35-40 PSIA
F.P.	63	T-6	PfT-3	1	S	35-40 PSIA

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify;					
F.P.	64	V-34	LFPV-1	1	S	Closed
	Monitor:					
F.P.	65	T-4	PoT-3	1/Sec	S	35-40 PSIA
↓	↓	T-5	PfT-2	↓	↓	↓
F.P.	65	T-6	PfT-3	1/Sec	S	35-40 PSIA
	For ____ minutes for decay					
	Command and Verify;					
F.P.	66	V-32	LOPV-1	1	S	Open
↓	↓	V-33	LOPV-2	↓	↓	↓
↓	↓	V-34	LFPV-1	↓	↓	↓
F.P.	66	V-35	LFPV-2	1	S	Open
	Retract and verify;					
F.P.	67	C-1	LOFC-1	1	S	Closed
↓	↓	C-2	LHC-1	↓	↓	↓
↓	↓	C-2	LHC-2	↓	↓	↓
↓	↓	C-5	LFFC-1	↓	↓	↓
↓	↓	C-8	LHC-7	↓	↓	↓
↓	↓	C-8	LHC-8	↓	↓	↓
↓	↓	C-9	LOFC-2	↓	↓	↓
↓	↓	C-10	LFFC-2	↓	↓	↓
F.P.	67	C-11	LFVC-1	1	S	Closed
	Commence;					
F.P.	68	T-8	PoT-6	1/Sec	M,C	1500 PSIA
↓	↓	T-8	ToT-4	↓	↓	
↓	↓	T-9	PoT-7	↓	↓	1500 PSIA
↓	↓	T-9	ToT-5	↓	↓	
↓	↓	T-10	PfT-6	↓	↓	1500 PSIA
↓	↓	T-10	TfT-4	↓	↓	
↓	↓	T-11	PfT-7	↓	↓	1500 PSIA
F.P.	68	T-11	TfT-5	1/Sec	M,C	
	Compute and display quantity on request.					
	Command and verify;					
F.P.	69	GOV-1	LGOV-1I	1	S	Open
↓	↓	GOV-2	LGOV-2I	↓	↓	↓
↓	↓	GOV-3	LGOV-3I	↓	↓	↓
↓	↓	GFV-1	LGFV-1I	↓	↓	↓
↓	↓	GFV-2	LGFV-2I	↓	↓	↓
↓	↓	GFV-3	LGFV-3I	↓	↓	↓
F.P.	69	V-52	LLIV-1	1	S	Open

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
F.P.	69	V-53	LLIV-2	1	S	Open
↓	↓	V-54	LLIV-3	↓	↓	↓
↓	↓	V-55	LFIV-1	↓	↓	↓
↓	↓	V-56	LFIV-2	↓	↓	↓
F.P.	69	V-57	LFIV-3	1	S	Open
		Command the APU shaft clutches to engage on all three sections.				
		Command and verify;				
F.P.	70	G-1	VII-38	1	S	28 VDC
↓	↓	G-2	VII-39	↓	↓	↓
F.P.	70	G-3	VII-40	1	S	28 VDC
		Command & verify;				
F.P.	70	G-1	LIOV-38	1	S	Open
		Initiate igniter spark, verify;				
F.P.	71	G-1	IIE-38	1	S	Pulses
F.P.	71	G-1	PC-38	1	S	
		Command and verify;				
F.P.	71	G-1	LIFV-38	1	S	Open
F.P.	71	G-1	PC-38	1	S	
		Command and verify;				
F.P.	72	GOV-1	LGOV-1	1	S	Open
F.P.	72	G-1	PC-38	1	S	
		Command and verify:				
F.P.	73	GFV-1	LGFV-1	1	S	Open
F.P.	73	G-1	PC-38	1	S	
		Check;				
F.P.	74	G-1	TC-1	1	S	
↓	↓	U-1	NT-1	2/Sec	C	
↓	↓	PT-1	NS-1	1	S	
↓	↓	PT-1	QPTL-1	↓	S	
↓	↓	PT-1	PPTL-1	↓	S	
F.P.	74	PT-1	TPTL-1	1	S	
		When NT-1 reaches steady-state, command igniter spark off and verify;				
F.P.	75	G-1	IIE-38	1	S	0

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify;					
F.P.	76	G-2	LIOV-39	1	S	Open
	Initiate igniter spark, verify					
F.P.	77	G-2	IIE-39	1	S	Pulses
F.P.	77	G-2	PC-39	1	S	
	Command and verify;					
F.P.	78	G-2	LIFV-39	1	S	Open
F.P.	78	G-2	PC-39	1	S	
	Command and verify;					
F.P.	79	GOV-2	LGOV-2	1	S	Open
F.P.	79	G-2	PC-39	1	S	
	Command and verify;					
F.P.	80	GFV-2	LGFV-2	1	S	Open
F.P.	80	G-2	PC-39	1	S	
	Check;					
F.P.	81	G-2	TC-2	1	S	
↓	↓	U-2	NT-2	2/sec	C	
		PT-2	NS-2	1	S	
		PT-2	QPTL-2	↓	↓	
↓	↓	PT-2	PPTL-2			
F.P.	81	PT-2	TPTL-2	1	S	
	When NT-2 reaches steady-state, command igniter spark off, verify;					
F.P.	82	G-2	IIE-39	1	S	0
	Command and verify;					
F.P.	83	G-3	LIOV-40	1	S	Open
	Initiate Igniter Spark, verify;					
F.P.	84	G-3	IIE-40	1	S	Pulses
F.P.	84	G-3	PC-40	1	S	
	Command and verify;					
F.P.	85	G-3	LIFV-40	1	S	Open
F.P.	85	G-3	PC-40	1	S	

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Command and verify;						
F.P.	86	GOV-3	LGOV-3	1	S	Open
F.P.	86	G-3	PC-40	1	S	
Command and verify;						
F.P.	87	GFV-3	LGFV-3	1	S	Open
F.P.	87	G-3	PC-40	1	S	
Check;						
F.P.	88	G-3	TC-3	1	S	
		U-3	NT-3	2/Sec	C	
		PT-3	NS-3	1	S	
		PT-3	QPTL-3			
		PT-3	PPTL-3			
F.P.	88	PT-3	TPTL-3	1	S	
When NT-3 reaches steady-state, command igniter spark off, verify;						
F.P.	89	G-3	IIE-40	1	S	0
Commence monitoring:						
F.P.	90	G-1	PC-38	1/Sec	M	
		G-1	TC-1	1/Sec		
		U-1	NT-1	2/Sec		
		PT-1	QPTL-1	1/2 sec		
		PT-1	PPTL-1	1/2 sec		
		PT-1	TPTL-1	1/2 sec		
		PT-1	NS-1	1/2 sec		
		G-2	PC-39	1/Sec		
		G-2	TC-2	1/Sec		
		U-2	NT-2	2/Sec		
		PT-2	QPTL-2	1/2 sec		
		PT-2	PPTL-2	1/2 sec		
		PT-2	TPTL-2	1/2 sec		
		PT-2	NS-2	1/2 sec		
		G-3	PC-40	1/Sec		
		G-3	TC-3	1/Sec		
		U-3	NT-3	2/Sec		
		PT-3	QPTL-3	1/2 sec		
		PT-3	PPTL-3	1/2 sec		
		PT-3	TPTL-3	1/2 sec		
F.P.	90	PT-3	NS-3	1/2 sec	M	
	91	Connect A/B Ground Start GSE				

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify;					
F.P.	92	V-58	LFIV-4	1	S	Open
		V-60	LFIV-5			
		V-62	LFIV-6			
		V-59	LPSV-7			
		V-61	LPSV-8			
F.P.	92	V-63	LPSV-9	1	S	Open
	Command and verify;					
F.P.	93	G-4	IIE-41	1	S	Pulses
	Command and verify;					
F.P.	94	GFV-4	LGFV-4I	1	S	Open
F.P.	94	GFV-4	LGFV-4	1	S	Open
	Command and verify;					
F.P.	95	GOV-4	LGOV-4I	1	S	Open
F.P.	95	GOV-4	LGOV-4	1	S	Open
	After TBD seconds, check;					
F.P.	96	U-4	NT-4	1	C,S	S.S.
		PT-4	PTPL-1		S	
		PT-4	QTPL-1			
		PT-4	TTPL-1			
F.P.	96	P-7	PPD-7	1	S	
	Terminate spark, verify;					
F.P.	97	G-4	IIE-41	1	S	0
	Check;					
F.P.	98	P-8	PPD-8	1	S	$<$TBD PSIA
F.P.	98	P-9	PPD-9	1	S	$<$TBD PSIA
	Command and verify;					
F.P.	99	G-5	IIE-42	1	S	Pulses
	Command and verify;					
F.P.	100	GFV-5	LGFV-5I	1	S	Open
F.P.	100	GFV-5	LGFV-5	1	S	Open
	Command and verify;					
F.P.	101	GOV-5	LGOV-5I	1	S	Open
F.P.	101	GOV-5	LGOV-5	1	S	Open

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
After TBD seconds, check:						
F.P.	102	U-5	NT-5	1	C,S	S.S.
↓	↓	PT-5	PTPL-2	↓	S	
		PT-5	QTPL-2		↓	
↓	↓	PT-5	TTPL-2	↓		
F.P.	102	P-8	PPD-8	1	S	
Terminate spark, verify;						
F.P.	103	G-5	IIE-42	1	S	0
Command and verify;						
F.P.	104	G-6	IIE-43	1	S	Pulses
Command and verify;						
F.P.	105	GFV-6	LGFV-6I	1	S	Open
F.P.	105	GFV-6	LGFV-6	1	S	Open
Command and verify;						
F.P.	106	GOV-6	LGOV-6I	1	S	Open
F.P.	106	GOV-6	LGOV-6	1	S	Open
After TBD seconds, check:						
F.P.	107	U-6	NT-6	1	C,S	S.S.
↓	↓	PT-6	PTPL-3	↓	S	
		PT-6	QTPL-3		↓	
↓	↓	PT-6	TTPL-3	↓		
F.P.	107	P-9	PPD-9	1	S	
Terminate spark, verify;						
F.P.	108	G-6	IIE-43	1	S	0
Command and verify;						
F.P.	109	EFV-1	LEFV-1	1	S	Open
↓	↓	EFV-2	LEFV-2	↓	↓	↓
		EFV-3	LEFV-3			
F.P.	109	EFV-4	LEFV-4	1	S	Open
Check:						
F.P.	110		PfL-11	1	S,C	
F.P.	110		TfL-6	1	S,C	

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Command and verify:						
F.P.	111	EFV-5	LEFV-5	1	S	Open
↓	↓	EFV-6	LEFV-6	↓	↓	↓
▼	▼	EFV-7	LEFV-7	▼	▼	▼
F.P.	111	EFV-8	LEFV-8	1	S	Open
Check:						
F.P.	112		PfL-12	1	S,C	
F.P.	112		TfL-7	1	S,C	
Command and verify;						
F.P.	113	EFV-9	LEFV-9	1	S	Open
↓	↓	EFV-10	LEFV-10	↓	↓	↓
▼	▼	EFV-11	LEFV-11	▼	▼	▼
F.P.	113	EFV-12	LEFV-12	1	S	Open
Check:						
F.P.	114		PfL-13	1	S,C	
F.P.	114		TfL-8	1	S,C	
Commence monitoring:						
F.P.	115	G-4	PC-41	10/Sec	M	
↓	↓	G-4	TC-4	1/Sec	↓	
		U-4	NT-4	5/Sec		
		P-7	PPD-7	5/Sec		
		G-5	PC-42	10/Sec		
		G-5	TC-5	1/Sec		
		U-5	NT-5	5/Sec		
		P-8	PPD-8	5/Sec		
		G-6	PC-43	10/Sec		
		G-6	TC-6	1/Sec		
		U-6	NT-6	5/Sec		
		P-9	PPD-9	5/Sec		
			PfL-11	5/Sec		
			PfL-12	5/Sec		
			PfL-13	5/Sec		
		PT-4	QTPL-1	1/2 Sec		
		PT-4	PTPL-1	1/2 Sec		
		PT-4	TTPL-1	1/2 Sec		
		PT-5	QTPL-2	1/2 Sec		
		PT-5	PTPL-2	1/2 Sec		
		PT-5	TTPL-2	1/2 Sec		
		PT-6	QTPL-3	1/2 Sec		
▼	▼	PT-6	PTPL-3	1/2 Sec	▼	
F.P.	115	PT-6	TTPL-3	1/2 Sec	M	

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Command turbofan #1 to start.				
		Activate turbofan Ground Start GSE.				
		The engine controller commands and verifies:				
F.P.	116	FCA-1	LFIVA/B-1	1	S	Open
		FCA-1	NVDVP-1			
		FCA-1	PDVDVP-1			
		FCA-1	LCPRV-1			Open
		FH-1	VFH-1			28 VDC
		FH-1	IFH-1			
		IGN-1	VIIA/B-1			28 VDC
		IGN-1	III-1			Pulses
		LA-1	PLPD-1			
		LA-1	PSPD-1			
		LA-1	TSPD-1			
		LA-1	QLO-1			
F.P.	116	FM-1	FfF-1	1	S	
		When:				
F.P.	117	TF-1	NHPT-1	100/Sec	C	Nx
		The engine controller commands and verifies:				
F.P.	118	FCA-1	LSPV-1	1	S	Open
		A/B E.C.-1 verifies combustion by checking:				
F.P.	119	FD-1	FLB-1	A.R.	S	On
		E.C.-1 commences to monitor the following for gas path analysis:				
F.P.	120	TF-1	PFI-1	100/Sec	C	
			TIA-1			
			NF-1			
			NHPT-1			
			FfF-1			
			PHPT-1			
			THPT-1			
			PED-1			
			TED-1			
			TLPTD-1			
			TCI-1			
F.P.	120	TF-1	PDVDVP-1	100/Sec	C	
		At steady-state thrust, the engine controller commands and verifies:				
F.P.	121	IGN #1	III-1	1	S	0

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
E.C.-1 commences to monitor:						
F.P.	122	LA-1	QLO-1	5/Sec	M	
		LA-1	PLPD-1	5/Sec		
		LA-1	PSPD-1	5/Sec		
		LA-1	TSPD-1	5/Sec		
		LA-1	PG-1	5/Sec		
		FCA-1	IFH-1	1/Sec		
		COMP-1	FIC-1	1/Sec		
Command turbofan 2 to start. Activate the turbofan Ground Start GSE						
E.C. -2 commands and verifies:						
F.P.	123	FCA-2	LFIVA/B-2	1	S	Open
		FCA-2	NVDVP-2			
		FCA-2	PDVDVP-2			
		FCA-2	LCPRV-2			Open
		FH-2	VFH-2			28 VDC
		FH-2	IFH-2			
		IGN #2	VIIA/B-2			28 VDC
		IGN #2	III-2			Pulses
		LA-2	PLPD-2			
		LA-2	PSPD-2			
		LA-2	TSPD-2			
		LA-2	QLO-2			
F.P.	123	FM-2	FfF-2	1	S	
When:						
F.P.	124	TF-2	NHPT-2	100/Sec	C	Nx
The engine controller commands and verifies:						
F.P.	125	FCA-2	LSPV-2	1	S	Open
E.C.-2 verifies combustion by checking:						
F.P.	126	FD-2	FLB-2	A.R.	S	On
E.C.-2 commences to monitor the following for gas path analysis:						
F.P.	127	TF-2	PFI-2	100/Sec	C	
			TIA-2			
			NF-2			
			NHPT-2			
			FfF-2			
			PHPT-2			
			THPT-2			
			PED-2			
			TED-2			
			TLPTD-2			
			TCI-2			
F.P.	127	TF-2	PDVDVP-2	100/Sec	C	

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
At steady-state thrust, E.C.-2 commands and verifies:						
F.P.	128	IGN. #2	III-2	1	S	0
E.C.-2 Commences to monitor:						
F.P.	129	LA-2	QLO-2	5/Sec	M	
		LA-2	PLPD-2			
		LA-2	PSPD-2			
		LA-2	TSPD-2			
		LA-2	PG-2	5/Sec		
		ECA-2	IFH-2	1/Sec		
F.P.	129	COMP-2	FIC-2	1/Sec	M	Off
Command Turbofan 3 to start, activate Ground Start GSE.						
E.C.-3 commands and verifies:						
F.P.	130	FCA-3	LFIVA/B-3	1	S	Open
		FCA-3	NVDVP-3			
		FCA-3	PDVDVP-3			
		FCA-3	LCPRV-3			Open
		FH-3	VFH-3			28 VDC
		FH-3	IFH-3			
		IGN. #3	VIIA/B-3			28 VDC
		IGN. #3	III-3			Pulses
		LA-3	PLPD-3			
		LA-3	PSPD-3			
		LA-3	TSPD-3			
		LA-3	QLO-3			
F.P.	130	FM-3	FfF-3	1	S	
When:						
F.P.	131	TF-3	NHPT-3	100/Sec	C	Nx
E.C.-3 commands and verifies						
F.P.	132	FCA-2	LSPV-3	1	S	Open
E.C.-3 verifies combustion by checking:						
F.P.	133	FD-1	FLB-3	A.R.	S	On
E.C.-3 commences to monitor the following for gas path analysis:						
F.P.	134	TF-3	PFI-3	100/Sec	C	
			TIA-3			
			NF-3			
			NHPT-3			
			FfF-3			
			PHPT-3			
			THPT-3			
			PED-3			
F.P.	134	TF-3	TED-3	100/Sec	C	

FERRY PREFLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
F.P.	134	TF-3	TLPTD-3	100/Sec	C	
↓	↓		TCI-3	↓	↓	
F.P.	134	TF-3	PDVDVP-3	100/Sec	C	
	At steady-state thrust, E.C.#3 commands and verifies:					
F.P.	135	IGN. #3	III-3	1	S	0
	E.C. #3 commences to monitor:					
F.P.	136	LA-3	QLO-3	5/Sec	M	
↓	↓	LA-3	PLPD-3	↓	↓	
		LA-3	PSPD-3			
		LA-3	TSPD-3			
		LA-3	PG-3			
↓	↓	FCA-3	IFH-3	1/Sec	↓	
F.P.	136	COMP-3	FIC-3	1/Sec	M	Off

137 Stop and retract Ground Start GSE

138 Verify vehicle power buses.

Execute power transfer.

139 Disconnect Ground Power GSE.

FERRY FLIGHT

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Make the following checks while at cruise altitude:						
F.F.	1	V-1	LOIV-1	1	S	Closed
		V-2	LOIV-2			
		V-3	LOVV-1			
		V-4	LOVV-2			
		V-5	LOVV-3			
		V-6	LOVV-4			
		V-7	LOFV-1			
		V-8	LFIV-1			
		V-9	LFIV-2			
		V-10	LFTVV-1			
		V-11	LFTVV-2			
		V-12	LFTVV-3			
		V-13	LFTVV-4			
		V-14	LFFV-1			
		V-19	LOPCV-1			
		V-20	LOPCV-2			
		V-21	LFPCV-1			
		V-22	LFPCV-2			
		V-23	LOIV-3			
		V-24	LOTVV-1			
		V-25	LOTVV-2			
		V-26	LFIV-3			
		V-27	LFIV-4			
		V-28	LFTVV-5			
		V-29	LFTVV-6			
		V-30	LFTVV-7			Closed
		V-31	LFTVV-8			Closed
		V-32	LOPV-1			Open
		V-33	LOPV-2			
		V-34	LFPV-1			
		V-35	LFPV-2			Open
		C-1	LOFC-1			Closed
		C-2	LHC-1,2			
		C-3	LFTVC-1			
		C-4	LHC-3,4			
		C-5	LFFC-1			
		C-6	LHC-5,6			
		C-8	LHC-7,8			
F.F.	1	C-11	LFVC-1	1	S	Closed
Monitor:						
F.F.	2	T-1	PoT-1	1/min	M	19 PSIA
		T-2	PoT-2	1/min		19 PSIA
		T-3	PfT-1	1/min		19 PSIA
		L-17	PoL-2	1/min		
		L-20	PfL-1	1/min		
		L-21	PfL-4	1/min		
		L-17	ToL-2	1/min		
F.F.	2	L-20	TfL-1	1/min	M	

FERRY FLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
F.F.	2	L-21	TfL-4	1/min.	M	
		T-4	ToT-3	1/10 sec.		
		T-5	TfT-2	1/10 sec.		
		T-6	TfT-3	1/10 sec.		
		T-4	QoT-7	1/sec.		Until Uncover
		T-4	QoT-8			
		T-4	QoT-9			
		T-5	QfT-4			
		T-5	QfT-5			
		T-5	QfT-6			
		T-6	QfT-7			
		T-6	QfT-8			
F.F.	2	T-6	QfT-9	1/sec.	M	Until Uncover

Monitor:

F.F.	3	T-8	PoT-6	1/sec	M,C	1500 PSIA
		T-8	ToT-4		M	
		T-9	PoT-7		M,C	1500 PSIA
		T-9	ToT-5		M	
		T-10	PfT-6		M,C	1500 PSIA
		T-10	TfT-4		M	
		T-11	PfT-7		M,C	1500 PSIA
F.F.	3	T-11	TfT-5	1/sec	M	

Compute and display accumulator quantity on request.

Continue to monitor:

F.F.	4	G-1	PC-38	1/sec	M
		G-1	TC-1	1/sec	
		U-1	NT-1	2/sec	
		PT-1	QPTL-1	1/2 sec	
		PT-1	PPTL-1	1/2 sec	
		PT-1	TPTL-1	1/2 sec	
		PT-1	NS-1	1/2 sec	
		G-2	PC-39	1/sec	
		G-2	TC-2	1/sec	
		U-2	NT-2	2/sec	
		PT-2	QPTL-2	1/2 sec	
		PT-2	PPTL-2	1/2 sec	
		PT-2	TPTL-2	1/2 sec	
		PT-2	NS-2	1/2 sec	
		G-3	PC-40	1/sec	
		G-3	TC-3	1/sec	
		U-3	NT-3	2/sec	
		PT-3	QPTL-3	1/2 sec	
		PT-3	PPTL-3	1/2 sec	
		PT-3	TPTL-3	1/2 sec	
F.F.	4	PT-3	NS-3	1/2 sec	M

FERRY FLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
When:						
F.F.	5	T-8	PoT-6	1/sec	C	1500-X PSIA
Or:						
F.F.	6	T-9	PoT-7	1/sec	C	1500-X PSIA
Verify:						
F.F.	7	V-52	LLIV-1	1	S	Open
↓	↓	V-53	LLIV-2	↓	↓	↓
F.F.	7	V-54	LLIV-3	1	S	Open
Command and verify:						
F.F.	8	V-52	LPSV-1	1	S	Open
↓	↓	V-53	LPSV-2	↓	↓	↓
F.F.	8	V-54	LPSV-3	1	S	Open
Engage the clutches to P-1, P-2, P-3.						
During GO2 resupply monitor the following additional parameters:						
F.F.	9	P-1	PPD-1	2/sec	M	1500 PSIA
↓	↓	H-4	THE-1	1/2 sec	↓	
		H-4	PHEO-1	1/2 sec		1500 PSIA
		P-2	PPD-2	2/sec		1500 PSIA
		H-5	THE-2	1/2 sec		
		H-5	PHEO-2	1/2 sec		1500 PSIA
		P-3	PPD-3	2/sec		1500 PSIA
↓	↓	H-6	THE-3	1/2 sec	↓	
F.F.	9	H-6	PHEO-3	1/2 sec	M	1500 PSIA
When:						
F.F.	10	T-8	PoT-6	1/sec	C	1500 PSIA
F.F.	10	T-9	PoT-7	1/sec	C	1500 PSIA
Disengage clutches to P-1, P-2, and P-3.						
Discontinue Resupply monitors.						
Command and verify:						
F.F.	11	V-52	LPSV-1	1	S	Closed
↓	↓	V-53	LPSV-2	↓	↓	↓
F.F.	11	V-54	LPSV-3	1	S	Closed

FERRY FLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
When:						
F.F.	12	T-10	PfT-6	1/sec	C	1500-Z-PSIA
Or:						
F.F.	13	T-11	PfT-7	1/sec	C	1500-Z-PSIA
Verify:						
F.F.	14	V-55	LFIV-1	1	S	Open
↓	↓	V-56	LFIV-2	↓	↓	↓
F.F.	14	V-57	LFIV-3	1	S	Open
Command and verify:						
F.F	15	V-55	LPSV-4	1	S	Open
↓	↓	V-56	LPSV-5	↓	↓	↓
F.F.	15	V-57	LPSV-6	1	S	Open
Engage clutches to P-4, P-5, and P-6.						
During GH2 resupply monitor the following additional parameters:						
F.F.	16	P-4	PPD-4	2/sec	M	1500 PSI
↓	↓	H-7	THE-4	1/2 sec	↓	
		H-7	PHEO-4	1/2 sec		1500 PSI
		P-5	PPD-5	2/sec		1500 PSI
		H-8	THE-5	1/2 sec		
		H-8	PHEO-5	1/2 sec		1500 PSI
		P-6	PPD-6	2/sec		1500 PSI
↓	↓	H-9	THE-6	1/2 sec	↓	
F.F.	16	H-9	PHEO-6	1/2 sec	M	1500 PSI
When:						
F.F.	17	T-10	PfT-6	1/sec	C	1500 PSI
F.F.	17	T-11	PfT-7	1/sec	C	1500 PSI
Disengage clutches to P-4, P-5, and P-6.						
Discontinue resupply monitors.						
Command and verify:						
F.F.	18	V-55	LPSV-4	1	S	Closed
↓	↓	V-56	LPSV-5	↓	↓	↓
F.F.	18	V-57	LPSV-6	1	S	Closed

FERRY FLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Continue to monitor:						
F.F.	19	G-4	PC-41	10/sec	M	
		G-4	TC-4	1/sec		
		U-4	NT-4	5/sec		
		P-7	PPD-7	5/sec		
		G-5	PC-42	10/sec		
		G-5	TC-5	1/sec		
		U-5	NT-5	5/sec		
		P-8	PPD-8	5/sec		
		G-6	PC-43	10/sec		
		G-6	TC-6	1/sec		
		U-6	NT-6	5/sec		
		P-9	PPD-9	5/sec		
			PfL-11	5/sec		
			PfL-12	5/sec		
			PfL-13	5/sec		
		PT-4	QTPL-1	1/2 sec		
		PT-4	PTPL-1			
		PT-4	TTPL-1			
		PT-5	QTPL-2			
		PT-5	PTPL-2			
		PT-5	TTPL-2			
		PT-6	QTPL-3			
		PT-6	PTPL-3			
F.F.	19	PT-6	TTPL-3	1/2 sec	M	
E.C. #1 continues to perform gas path analysis:						
F.F.	20	TF-1	PFI-1	100/sec	C	
			TIA-1			
			NF-1			
			NHPT-1			
			FfF-1			
			PHPT-1			
			THPT-1			
			PED-1			
			TED-1			
			TLPTD-1			
			TCI-1			
F.F.	20	TF-1	PDVDVP-1	100/sec	C	
E.C. #1 continues to monitor:						
F.F.	21	LA-1	QLO-1	5/sec	M	
			PLPD-1			
			PSPD-1			
			TSPD-1			
		LA-1	PG-1	5/sec		
		FCA-1	IFH-1	1/sec		
F.F.	21	COMP-1	FIC-1	1/sec	M	OFF

FERRY FLIGHT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTE VALUE
E.C. #2 continues to perform gas path analysis:						
F.F.	22	TF-2	PFI-2	100/sec	C	
			TIA-2			
			NF-2			
			NHPT-2			
			FfF-2			
			PHPT-2			
			THPT-2			
			PED-2			
			TED-2			
			TLPTD-2			
			TCI-2			
F.F.	22	TF-2	PDVDVP-2	100/sec	C	
E.C. #2 continues to monitor:						
F.F.	23	LA-2	QLO-2	5/sec	M	
			PLPD-2			
			PSPD-2			
			TSPD-2			
		LA-2	PG-2	5/sec		
		FCA-2	IFH-2	1/sec		
F.F.	23	COMP-2	FIC-2	1/sec	M	off
E.C. #3 continues to perform gas path analysis:						
F.F.	24	TF-3	PFI-3	100/sec	C	
			TIA-3			
			NF-3			
			NHPT-3			
			FfF-3			
			PHPT-3			
			THPT-3			
			PED-3			
			TED-3			
			TLPTD-3			
			TCI-3			
F.F.	24	TF-3	PDVDVP-3	100/sec	C	
E.C. #3 continues to monitor:						
F.F.	25	LA-3	QLO-3	5/sec	M	
			PLPD-3			
			PSPD-3			
			TSPD-3			
		LA-3	PG-3	5/sec		
		FCA-3	IFH-3	1/sec		
F.F.	25	COMP-2	FIC-3	1/sec	M	OFF

FERRY APPROACH & LANDING

1. Continue to monitor as in steps 2, 3, 4, 19, 20, 21, 22, 23, 24, and 25 of Ferry Flight.

2. After landing, taxi to revetment area.

Command & verify:

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
FAL	3	V-59	LPSV-7	1	S	Closed
		V-58	LFIV-4			
		V-61	LPSV-8			
		V-60	LFIV-5			
		V-63	LPSV-9			
FAL	3	V-62	LFIV-6	1	S	Closed

Command and verify:

FAL	4	G-4	VII-41	1	S	OVDC
		G-5	VII-42			
FAL	4	G-6	VII-43	1	S	OVDC

Command and verify:

FAL	5	GOV-4	LGOV-4	1	S	Closed
		GOV-4	LGOV-4I			
		GFV-4	LGFV-4			
		GFV-4	LGFV-4I			
		GOV-5	LGOV-5			
		GOV-5	LGOV-5I			
		GFV-5	LGFV-5			
		GFV-5	LGFV-5I			
		GOV-6	LGOV-6			
		GOV-6	LGOV-6I			
		GFV-6	LGFV-6			
FAL	5	GFV-6	LGFV-6I	1	S	Closed

Discontinue monitoring steps 2, 3, and 19 of Ferry Flight.
E.C.-1 commences monitoring.

FAL	6	FD-1	FLB-1	10/sec	M,C	On

E.C.-1 Checks

FAL	7	TF-1	TTB-1	25/sec	M	

For TBD Seconds

When

FAL	8		PfL-11	5/sec	C	<TBD

FERRY APPROACH & LANDING (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		E.C.-1 commands and verifies T.F.-1 shutdown				
FAL	9	FCA-1	LFIV A/B-1	1	S	Closed
↓	↓	FCA-1	LCPRV-1	↓	↓	Closed
↓	↓	FH-1	VFH-1	↓	↓	OVDC
FAL	9	FCA-1	LSPV-1	1	S	Closed
		All engine assemblies are stopped.				
		When				
FAL	10	FD-1	FLB-1	10/sec	C	Off
		Command and verify:				
FAL	11	EFV-1	LEFV-1	1	S	Closed
↓	↓	EFV-2	LEFV-2	↓	↓	↓
↓	↓	EFV-3	LEFV-3	↓	↓	↓
FAL	11	EFV-4	LEFV-4	1	S	Closed
		E.G.-1 discontinues monitoring steps 20 and 21 of Ferry Flight and step 6 of Ferry Approach and Landing.				
		E.C.-2 commences monitoring				
FAL	12	FD-2	FLB-2	10/sec	—M,C	On
		E.C.-2 checks				
FAL	13	TF-2	TTB-2	25/sec	M	
		For TBD seconds.				
		When				
FAL	14		PfL-12	5/sec	C	<TBD
		E.C.-2 commands and verifies T.F.-2 shutdown				
FAL	15	FCA-2	LFIV A/B-2	1	S	Closed
↓	↓	FCA-2	LCPRV-2	↓	↓	Closed
↓	↓	FH-2	VFH-2	↓	↓	OVDC
FAL	15	FCA-2	LSPV-2	1	S	Closed
		All engine assemblies are stopped.				
		When				
FAL	16	FD-2	FLB-2	10/sec	C	Off

FERRY APPROACH & LANDING (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify:					
FAL	17	EFV-5	LEFV-5	1	S	Closed
↓	↓	EFV-6	LEFV-6	↓	↓	↓
		EFV-7	LEFV-7			
FAL	17	EFV-8	LEFV-8	1	S	Closed
	E.C.-2 discontinues monitoring steps 22 and 23 or Ferry Flight and 12 of Ferry Approach and Landing.					
	E.C.-3 commences monitoring					
FAL	18	FD-3	FLB-3	10/sec	M,C	On
	E.C.-3 checks					
FAL	19	FT-3	TTB-3	25/sec	M	
	for TBD seconds					
	When					
FAL	20		PfL-13	5/sec	C	<TBD
	E.C.-3 commands and verifies T.F.-3 shutdown.					
FAL	21	FCA-3	LFIV A/B-3	1	S	Closed
↓	↓	FCA-3	LCPRV-3	↓	↓	Closed
		FH-3	VFH-3			OVDC
FAL	21	FCA-3	LSPV-3	1	S	Closed
	All engine assemblies are stopped.					
	When					
FAL	22	FD-3	FLB-3	10/sec	C	Off
	Command and verify:					
FAL	23	EFV-9	LEFV-9	1	S	Closed
↓	↓	EFV-10	LEFV-10	↓	↓	↓
		EFV-11	LEFV-11			
FAL	23	EFV-12	LEFV-12	1	S	Closed
	E.C.-3 discontinues monitoring steps 24 and 25 of Ferry Flight and 18 of Ferry Approach and Landing.					

POSTFLIGHT-FERRY

1. Tow the Orbiter into revetment. Chock and tie-down.
2. Connect Ground Power GSE.
3. Execute power transfer to Ground Power GSE.
4. Continue to monitor step 4 of Ferry Flight until the APU shutdown command is received.

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Upon receipt of APU shutdown command					
	Command and verify:					
P-F	5	G-1	VII-38	1	S	OVDC
	Command and verify:					
P-F	6	GOV-1	LGOV-1	1	S	Closed
P-F	6	G-1	PC-38	1	S	
	Command and verify:					
P-F	7	GFV-1	LGFV-1	1	S	Closed
P-F	7	G-1	PC-38	1	S	
	Command and verify:					
P-F	8	G-1	LIOV-38	1	S	Closed
P-F	8	G-1	PC-38	1	S	
	Command and verify:					
P-F	9	G-1	LIFV-38	1	S	Closed
P-F	9	G-1	PC-38	1	S	
	Disengage the clutch to APU-1.					
	Command and verify:					
P-F	10	GOV-1	LGOV-1I	1	S	Closed
↓	↓	GFV-1	LGFV-1I	↓	↓	↓
↓	↓	V-52	LLIV-1	↓	↓	↓
P-F	10	V-55	LFIV-1	1	S	Closed
	Command and verify:					
P-F	11	G-2	VII-39	1	S	OVDC

POSTFLIGHT-FERRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify:					
P-F	12	GOV-2	LGOV-2	1	S	Closed
P-F	12	G-2	PC-39	1	S	
	Command and verify:					
P-F	13	GFV-2	LGFV-2	1	S	Closed
P-F	13	G-2	PC-39	1	S	
	Command and verify:					
P-F	14	G-2	LIOV-39	1	S	Closed
P-F	14	G-2	PC-39	1	S	
	Command and verify:					
P-F	15	G-2	LIFV-39	1	S	Closed
P-F	15	G-2	PC-39	1	S	
	Disengage the clutch to APU-2.					
	Command and verify:					
P-F	16	GOV-2	LGOV-2I	1	S	Closed
↓	↓	GFV-2	LGFV-2I	↓	↓	↓
↓	↓	V-53	LLIV-2	↓	↓	↓
P-F	16	V-56	LFIV-2	1	S	Closed
	Command and verify:					
P-F	17	G-3	VII-40	1	S	OVDC
	Command and verify:					
P-F	18	GOV-3	LGOV-3	1	S	Closed
P-F	18	G-3	PC-40	1	S	
	Command and verify:					
P-F	19	GFV-3	LGFV-3	1	S	Closed
P-F	19	G-3	PC-40	1	S	
	Command and verify:					
P-F	20	G-3	LIOV-40	1	S	Closed
P-F	20	G-3	PC-40	1	S	

POSTFLIGHT-FERRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Command and verify:				
P-F	21	G-3	LIFV-40	1	S	Closed
P-F	21	G-3	PC-40	1	S	
		Disengage the clutch to APU-3.				
		Command and verify:				
P-F	22	GOV-3	LGOV-3I	1	S	Closed
↓	↓	GFV-3	LGFV-3I	↓	↓	↓
↓	↓	V-54	LLIV-3	↓	↓	↓
P-F	22	V-57	LFIV-3	1	S	Closed
		23. Perform the checks of step 1a of Ferry Flight.				
		24. Take a status sample of the parameters of step 1b of Ferry Flight				
		Check:				
P-F	25		PoL-8	1	S	19 PSIA
↓	↓		PoL-9	↓	↓	↓
↓	↓		PfL-9	↓	↓	↓
P-F	25		PfL-10	1	S	19 PSIA
		26. Remove tape and hard copy, if any. Debrief crew as required. Review in-flight data and fault-isolation output.				
		27. Inspect all subsystems for mechanical disorders.				
		PURGE				
		Connect Drain and Purge GSE and verify status of the following couplings:				
P-F	28	C-1	LOFC-1	1	S	Open
↓	↓	C-2	LHC-1,2	↓	↓	↓
↓	↓	C-3	LFTVC-1	↓	↓	↓
↓	↓	C-4	LHC-3,4	↓	↓	↓
↓	↓	C-5	LFFC-1	↓	↓	↓
↓	↓	C-6	LHC-5,6	↓	↓	↓
↓	↓	C-8	LHC-7,8	↓	↓	↓
↓	↓	C-9	LOFC-2	↓	↓	↓
↓	↓	C-10	LFFC-2	↓	↓	↓
P-F	28	C-11	LFVC-1	1	S	Open
		Also connect purge GSE to the main oxidizer and on-orbit oxidizer tank vents.				

POSTFLIGHT-FERRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Command and verify:				
P-F	29	V-32	LOPV-1	1	S	Closed
		V-33	LOPV-2			
		V-34	LFPV-1			
P-F	29	V-35	LFPV-2	1	S	Closed
		Command and verify:				
P-F	30	V-70	LFFV-2	1	S	Open
		When GSE indicates P = ambient at C-10, repressure with helium thru C-10 until				
P-F	31	T-10	PfT-6	1/sec	M,C	1500 PSIA
P-F	31	T-11	PfT-7	1/sec	M,C	1500 PSIA
		Command GSE to hold.				
		Command and verify:				
P-F	31a	V-70	LFFV-2	1	S	Closed
		Command and verify:				
P-F	32	V-14	LFFV-1	1	S	Open
		Pressurize T-3 with helium thru C-4.				
		When:				
P-F	33	T-3	PfT-1	1/sec	M,C	35 PSIA
		Command and verify:				
P-F	34	V-8	LFIV-1	1	S	Open
		V-9	LFIV-2			
		V-26	LFIV-3			
		V-27	LFIV-4			
		V-34	LFPV-1			
P-F	34	V-35	LFPV-2	1	S	Open
		After 9 minutes, command GSE to open vent on C-8 for 1 minute. Command purge of L-8,9 through main engines for 3 minutes.				
		Command and verify:				
P-F	35	V-28	LFTVV-5	1	S	Open
		V-29	LFTVV-6			
		V-30	LFTVV-7			
P-F	35	V-31	LFTVV-8	1	S	Open

POSTFLIGHT-FERRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Purge out through C-11 for 1 minute.				
		Command and verify:				
P-F	36	V-34	LFPV-1	1	S	Closed
P-F	36	V-35	LFPV-2	1	S	Closed
		Stop helium purge from C-3.				
		Command and verify:				
P-F	37	V-10	LFTVV-1	1	S	Open
↓	↓	V-11	LFTVV-2	↓	↓	↓
↓	↓	V-12	LFTVV-3	↓	↓	↓
P-F	37	V-13	LFTVV-4	1	S	Open
		Reverse purge from C-5 out through C-3 and C-11 for 10 minutes. During this time configure the main engines and command and verify:				
P-F	38	V-21	LFPCV-1	1	S	Open
P-F	38	V-22	LFPCV-2	1	S	Open
		To purge the H_2 autogenous lines out through C-3.				
		Return the main engines to initial conditions and command and verify:				
P-F	39	V-21	LFPCV-1	1	S	Closed
P-F	39	V-22	LFPCV-2	1	S	Closed
		Reduce helium pressure to 20 PSIA and command and verify, in sequence:				
P-F	40	V-10	LFTVV-1	1	S	Closed
↓	↓	V-11	LFTVV-2	↓	↓	↓
↓	↓	V-12	LFTVV-3	↓	↓	↓
↓	↓	V-13	LFTVV-4	↓	↓	↓
↓	↓	V-8	LFIV-1	↓	↓	↓
↓	↓	V-9	LFIV-2	↓	↓	↓
↓	↓	V-26	LFIV-3	↓	↓	↓
↓	↓	V-27	LFIV-4	↓	↓	↓
↓	↓	V-14	LFFV-1	↓	↓	Closed
↓	↓	T-3	PfT-1	↓	↓	20 PSIA
P-F	40		PfL-2	1	S	20 PSIA
		Command and verify:				
P-F	41	V-44	LOFV-2	1	S	Open
		When GSE at C-9 indicates P = ambient, repressurize the C-9 with helium u				
P-F	42	T-8	PoT-6	1/sec	M,C	1500 PSL
P-F	42	T-9	PoT-7	1/sec	M,C	1500 PSL

POSTFLIGHT-FERRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify:					
P-F	43	V-44	LOFV-2	1	S	Closed
	Command and verify:					
P-F	44	V-7	LOFV-1	1	S	Open
	Pressurize T-1 & T-2 through C-6 with helium.					
	When:					
P-F	45	T-1	PoT-1	1/sec	M,C	35 PSIA
P-F	45	T-2	PoT-2	1/sec	M,C	35 PSIA
	Command and verify:					
P-F	46	V-1	LOIV-1	1	S	Open
		V-2	LOIV-2			
		V-23	LOIV-3			
		V-32	LOPV-1			
P-F	46	V-33	LOPV-2	1	S	Open
	Purge for 10 minutes. After 5 minutes configure the main engines to purge L-3,4 down through the engines for 3 minutes, then return the engines to initial conditions.					
	After 9 minutes Command and verify:					
P-F	47	V-24	LOTVV-1	1	S	Open
P-F	47	V-25	LOTVV-2	1	S	Open
	And open the vent on C-2 for 1 minute.					
	Command and verify:					
P-F	48	V-32	LOPV-1	1	S	Closed
P-F	48	V-33	LOPV-2	1	S	Closed
	Terminate purge from C-6.					
	Command and verify:					
P-F	49	V-3	LOVV-1	1	S	Open
		V-4	LOVV-2			
		V-5	LOVV-3			
P-F	49	V-6	LOVV-4	1	S	Open

POSTFLIGHT-FERRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Reverse purge at 35 PSIA from C-1 out through the main oxidizer vent.						
Command and verify:						
P-F	50	V-19	LOPCV-1	1	S	Open
P-F	50	V-20	LOPCV-2	1	S	Open
And configure the main engines to purge the oxidizer autogenous lines.						
Command and verify:						
P-F	51	V-19	LOPCV-1	1	S	Closed
P-F	51	V-20	LOPCV-2	1	S	Closed
And return the main engines to initial conditions.						
Reduce the helium pressure to 20 PSIA and command and verify in sequence:						
P-F	52	V-3	LOVV-1	1	S	Closed
		V-4	LOVV-2			
		V-5	LOVV-3			
		V-6	LOVV-4			
		V-1	LOIV-1			
		V-2	LOIV-2			
		V-23	LOIV-3			
		V-7	LOFV-1			Closed
		T-1	PoT-1			20 PSIA
P-F	52		PoL-1	1	S	20 PSIA
Command GSE to hold.						
Command and verify:						
P-F	53	GOV-1	LGOV-1I	1	S	Open
		GOV-1	LGOV-1			
		GFV-1	LGFV-1I			
		GFV-1	LGFV-1			
		G-1	LIOV-38			
		G-1	LIFV-38			
		GOV-2	LGOV-2I			
		GOV-2	LGOV-2			
		GFV-2	LGFV-2I			
		GFV-2	LGFV-2			
		G-2	LIOV-39			
		G-2	LIFV-39			
		GOV-3	LGOV-3I			
		GOV-3	LGOV-3			
		GFV-3	LGFV-3I			
		GFV-3	LGFV-3			
		G-3	LIOV-40			
P-F	53	G-3	LIFV-40	1	S	Open

POSTFLIGHT-FERRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
54. After 2 seconds command and verify all the valves of the previous step closed.						
Command and verify:						
P-F	55	GOV-4	LGOV-4I	1	S	Open
		GOV-4	LGOV-4			
		GFV-4	LGFV-4I			
		GFV-4	LGFV-4			
		GOV-5	LGOV-5I			
		GOV-5	LGOV-5			
		GFV-5	LGFV-5I			
		GFV-5	LGFV-5			
		GOV-6	LGOV-6I			
		GOV-6	LGOV-6			
		GFV-6	LGFV-6I			
P-F	55	GFV-6	LGFV-6	1	S	Open
56. After 2 seconds command and verify all the valves of the previous step closed.						
Command and verify:						
P-F	57	V-70	LFFV-2	1	S	Open
When GSE at C-10 indicates P = ambient,						
Command and verify:						
P-F	58	V-55	LFIV-1	1	S	Open
		V-55	LPSV-4			
		V-56	LFIV-2			
		V-56	LPSV-5			
		V-57	LFIV-3			
P-F	58	V-57	LPSV-6	1	S	Open
Purge for 2 minutes from C-11 out through C-10.						
Reduce the purge pressure to 19 PSIA and command and verify in sequence:						
P-F	59	V-70	LFFV-2	1	S	Closed
		V-55	LFIV-1			
		V-55	LPSV-4			
		V-56	LFIV-2			
		V-56	LPSV-5			
		V-57	LFIV-3			
		V-57	LPSV-6			Closed
		T-10	PfT-4			19 PSIA
P-F	59	T-11	PfT-5	1	S	19 PSIA

POSTFLIGHT-FERRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Increase purge pressure at C-11 to 35 PSIA.				
		Command and verify:				
P-F	60	V-58	LFIV-4	1	S	Open
		V-59	LPSV-7			
		V-60	LFIV-5			
		V-61	LPSV-8			
		V-62	LFIV-6			
		V-63	LPSV-9			
		EFV-1	LEFV-1			
		EFV-2	LEFV-2			
		EFV-3	LEFV-3			
		EFV-4	LEFV-4			
		EFV-5	LEFV-5			
		EFV-6	LEFV-6			
		EFV-7	LEFV-7			
		EFV-8	LEFV-8			
		EFV-9	LEFV-9			
		EFV-10	LEFV-10			
		EFV-11	LEFV-11			
P-F	60	EFV-12	LEFV-12	1	S	Open
		The turbofan engine controllers command and verify:				
P-F	61	FCA-1	LFIV A/B-1	1	S	Open
		FCA-1	LCPRV-1			
		FCA-1	LSPV-1			
		FCA-2	LFIV A/B-2			
		FCA-2	LCPRV-2			
		FCA-2	LSPV-2			
		FCA-3	LFIV A/B-3			
		FCA-3	LCPRV-3			
P-F	61	FCA-3	LSPV-3	1	S	Open
		Purge for 5 minutes.				
		Reduce the purge pressure to 19 PSIA.				
		62. The A/B engine controllers command and verify closed the valves of step 61 in reverse order to which they were opened.				
		63. Command and verify the valves of step 60 closed in reverse order to which they were opened.				
		Command and verify:				
P-F	64	V-28	LFTVV-5	1	S	Closed
		V-29	LFTVV-6			
		V-30	LFTVV-7			
P-F	64	V-31	LFTVV-8	1	S	Closed

POSTFLIGHT-FERRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Terminate purge from C-11.				
		Verify:				
P-F	65	T-5	PfT-2	1	S	19 PSIA
P-F	65	T-6	PfT-3	1	S	19 PSIA
		Attach A/B engine covers.				
		Command and verify:				
P-F	66	V-44	LOFV-2	1	S	Open
		When GSE indicates P - ambient at C-9.				
		Command and verify:				
P-F	67	V-52	LLIV-1	1	S	Open
		V-52	LPSV-1			
		V-53	LLIV-2			
		V-53	LPSV-2			
		V-54	LLIV-3			
P-F	67	V-54	LPSV-3	1	S	Open
		Purge for 2 minutes from the on-orbit oxidizer vent out through C-9. Reduce the purge pressure to 19 PSIA.				
		Command and verify in sequence:				
P-F	68	V-44	LOFV-2	1	S	Closed
		V-52	LLIV-1			
		V-52	LPSV-1			
		V-53	LLIV-2			
		V-53	LPSV-2			
		V-54	LLIV-3			
		V-54	LPSV-3			
		V-24	LOTVV-1			
P-F	68	V-25	LOTVV-2	1	S	Closed
		Terminate purge from on-orbit oxidizer vent.				
		Verify:				
P-F	69	T-4	PoT-3	1	S	19 PSIA

70. Complete main engine purge.

Secure and disconnect the Drain and Purge GSE.

POSTFLIGHT-FERRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
P-F	71	C-1	LOFC-1	1	S	Closed
		C-2	LHC-1,2			
		C-3	LFTVC-1			
		C-4	LHC-3,4			
		C-5	LFFC-1			
		C-6	LHC-5,6			
		C-8	LHC-7,8			
		C-9	LOFC-2			
		C-10	LFFC-2			
P-F	71	C-11	LFVC-1	1	S	Closed

Purge complete.

Mechanically lock V-1, 2, 8, 9, 23, 26, 27.
Power down the MPS.

Verify:

P-F	72	V-1	LOIV-1	1	S	Closed
		V-2	LOIV-2			
		V-8	LFIV-1			
		V-9	LFIV-2			
		V-23	LOIV-3			
		V-26	LFIV-3			
P-F	72	V-27	LFIV-4	1	S	Closed

Input flight data to processing system for trend analysis, performance evaluation, and/or maintenance report.

Power down OCMS.

MAINTENANCE

1. Tow the orbiter to the maintenance area.

2. Perform maintenance as required per maintenance procedures of Appendix C, MCR-70-306, Issue 3.

OCMS is powered up, self-checked, and used for retest.

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	Verify; EXPECTED VALUE
M	3	V-1	LOIV-1	1	S	Closed
		V-2	LOIV-2			
		V-3	LOVV-1			
		V-4	LOVV-2			
		V-5	LOVV-3			
		V-6	LOVV-4			
		V-7	LOFV-1			
		V-8	LFIV-1			
		V-9	LFIV-2			
		V-10	LFTVV-1			
		V-11	LFTVV-2			
		V-12	LFTVV-3			
		V-13	LFTVV-4			
		V-14	LFFV-1			
		V-19	LOPCV-1			
		V-20	LOPCV-2			
		V-21	LFPCV-1			
		V-22	LFPCV-2			
		V-23	LOIV-3			
		V-24	LOTVV-1			
		V-25	LOTVV-2			
		V-26	LFIV-3			
		V-27	LFIV-4			
		V-28	LFTVV-5			
		V-29	LFTVV-6			
		V-30	LFTVV-7			
		V-31	LFTVV-8			
		V-32	LOPV-1			
		V-33	LOPV-2			
		V-34	LFPV-1			
		V-35	LFPV-2			
		C-1	LOFC-1			
		C-2	LHC-1, 2			
		C-3	LFTVC-1			
		C-4	LHC-3, 4			
		C-5	LFFC-1			
		C-6	LHC-5, 6			
		C-8	LHC-7, 8			
		C-11	LFVC-1			Closed
		T-3	PfT-1			19 PSIA
		T-5	PfT-2			
M	3	T-6	PfT-3	1	S	19 PSIA

MAINTENANCE (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
M	3	T-1	PoT-1	1	S	19 PSIA
		T-2	PoT-2			
		T-4	PoT-3			
		L-20	PfL-1			
		L-21	PfL-4			
M	3	L-17	PoL-2	1	S	19 PSIA
	Verify:					
M	4		PoL-8	1	S	19 PSIA
			PoL-9			
			PfL-9			
M	4		PfL-10	1	S	19 PSIA
	Verify:					
M	5	V-36	LOPV-3	1	S	Closed
		V-37	LOPV-4			
		V-38	LOPV-5			
		V-39	LOPV-6			
		V-40	LFPV-3			
		V-41	LFPV-4			
		V-42	LFPV-5			
		V-43	LFPV-6			
		V-44	LOFV-2			
		V-70	LFFV-2			
		C-9	LOFC-2			
		C-10	LFFC-2			Closed
		T-8	PoT-4			19 PSIA
		T-9	PoT-5			
		T-10	PfT-4			
M	5	T-11	PfT-5	1	S	19 PSIA
	Verify:					
M	6	GOV-1	LGOV-1I	1	S	Closed
		GOV-1	LGOV-1			
		GOV-2	LGOV-2			
		GOV-2	LGOV-2I			
		GOV-3	LGOV-3			
		GOV-3	LGOV-3I			
		GFV-1	LGFV-1			
		GFV-1	LGFV-1I			
		GFV-2	LGFV-2			
		GFV-2	LGFV-2I			
		GFV-3	LGFV-3			
		GFV-3	LGFV-3I			
		V-52	LLIV-1			
M	6	V-52	LPSV-1	1	S	Closed

MAINTENANCE (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
M	6	V-53	LPSV-2	1	S	Closed
		V-53	LLIV-1			
		V-54	LLIV-3			
		V-54	LPSV-3			
		V-55	LFIV-1			
		V-55	LPSV-4			
		V-56	LFIV-2			
		V-56	LPSV-5			
		V-57	LFIV-3			
		V-57	LPSV-6			
		G-1	LIOV-38			
		G-1	LIFV-38			
		G-2	LIOV-39			
		G-2	LIFV-39			
		G-3	LIOV-40			
M	6	G-3	LIFV-40	1	S	Closed
	Verify:					
M	7	GFV-4	LGFV-4I	1	S	Closed
		GFV-4	LGFV-4			
		GFV-5	LGFV-5I			
		GFV-5	LGFV-5			
		GFV-6	LGFV-6I			
		GFV-6	LGFV-6			
		GOV-4	LGOV-4I			
		GOV-4	LGOV-4			
		GOV-5	LGOV-5I			
		GOV-5	LGOV-5			
		GOV-6	LGOV-6I			
		GOV-6	LGOV-6			
		V-58	LFIV-4			
		V-59	LPSV-7			
		V-60	LFIV-5			
		V-61	LPSV-8			
		V-62	LFIV-6			
		V-63	LPSV-9			
		EFV-1	LEFV-1			
		EFV-2	LEFV-2			
		EFV-3	LEFV-3			
		EFV-4	LEFV-4			
		EFV-5	LEFV-5			
		EFV-6	LEFV-6			
		EFV-7	LEFV-7			
		EFV-8	LEFV-8			
		EFV-9	LEFV-9			
		EFV-10	LEFV-10			
		EFV-11	LEFV-11			
		EFV-12	LEFV-12			Closed
			PfL-11			19 PSIA
			PfL-12			19 PSIA
M	7		PfL-13	1	S	19 PSIA

MAINTENANCE (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
The A/B engine controllers shall verify the following:						
M	8	FCA-1	LFIVAB-1	1	S	Closed
		FCA-1	LCPRV-1			
		FCA-1	LSPV-1			
		FCA-2	LFIVA/B-2			
		FCA-2	LCPRV-2			
		FCA-2	LSPV-2			
		FCA-3	LFIVA/B-3			
		FCA-3	LCPRV-3			
M	8	FCA-3	LSPV-3	1	S	Closed
Retract the engine cradles.						

V.A.B. MATE

1. Repeat step M-3.

2. Verify the following:

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
V.A.B.	2	T-3	TfT-1	1	S	Ambient
		T-5	TfT-2			
		T-6	TfT-3			
		T-1	ToT-1			
		T-2	ToT-2			
		T-4	ToT-3			Ambient
		T-3	QfT-1			uncovere
		T-3	QfT-2			
		T-3	QfT-3			
		T-5	QfT-4			
		T-5	QfT-5			
		T-5	QfT-6			
		T-6	QfT-7			
		T-6	QfT-8			
		T-6	QfT-9			
		T-1	QoT-1			
		T-1	QoT-2			
		T-1	QoT-3			
		T-2	QoT-4			
		T-2	QoT-5			
		T-2	QoT-6			
		T-4	QoT-7			
		T-4	QoT-8			
		T-4	QoT-9			Uncovere
			PfL-2			19 PSIA
			PfL-3			19 PSIA
		L-20	TfL-1			Ambient
			TfL-2			Ambient

V.A.B. MATE (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
V.A.B	2	L-21	TfL-4	1	S	Ambient
			TfL-5			Ambient
			PoL-1			19 PSIA
		L-18	PoL-3			19 PSIA
			ToL-1			Ambient
		L-17	ToL-2			↓
		L-18	ToL-3			
			ToL-4			Ambient
		L-14	PgF-1			19 PSIA
		0-5	PgF-2			↓
		L-16	PgF-3			
		C-5	PfF-1			
		L-13	PgO-1			19 PSIA
		0-3	PgO-2			19 PSIA
		L-15	PgO-3			19 PSIA
		L-14	TgF-1			Ambient
		L-14	TgF-2			Ambient
		L-13	TgO-1			Ambient
		L-13	TgO-2			Ambient
		L-8	PfS-1			19 PSIA
		L-9	PfS-2			19 PSIA
		L-8	TfS-1			Ambient
		L-9	TfS-2			Ambient
		L-3	PoS-1			19 PSIA
		L-4	PoS-2			19 PSIA
		L-3	ToS-1			Ambient
		L-4	ToS-2			Ambient
		L-7	PgRL-1			19 PSIA
V.A.B.	2	C-1	PoF-1	1	S	19 PSIA

PAYLOAD INSTALLATION

1.. Repeat steps V.A.B. - 1, 2.

PRELAUNCH

Connect electronics coolant GSE and Ground Power GSE.

Power up OCMS and all propulsion systems.

Perform OCMS self-check.

1. Remove the mechanical stops from V-1, 2, 8, 9, 25, 26, 27.
   Verify:

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
PL	1	V-1	LOIV-1	1	S	Closed
		V-2	LOIV-2			
		V-8	LFIV-1			
		V-9	LFIV-2			
		V-23	LOIV-3			
		V-26	LFIV-3			
PL	1	V-27	LFIV-4	1	S	Closed

Verify leak integrity:

PL	2	T-3	PfT-1	1	S	15-20 PS
		T-5	PfT-2			
		T-6	PfT-3			
		T-1	PoT-1			
		T-2	PoT-2			
		T-4	PoT-3			
			PoL-1			
		L-17	PoL-2			
		L-18	PoL-3			
		L-20	PfL-1			
			PfL-2			
			PfL-3			
		L-21	PfL-4			
		L-3	PoS-1			
		L-4	PoS-2			
		L-8	PfS-1			
		L-9	PfS-2			
		L-14	PgF-1			
		O-5	PgF-2			
		L-16	PgF-3			
		L-13	PgO-1			
		O-3	PgO-2			
		L-15	PgO-3			
		C-5	PfF-1			
		C-1	PoF-1			
		L-7	PgRL-1			
		F-4	PoL-10			
PL	2	F-5	PfL-14	1	S	15-20 PS

PRELAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify:					
PL	3	MEC-1		1	S	On
PL	3	MEC-2		1	S	On
PL	3	MEC-3		1	S	On
	Command and verify:					
PL	4	V-1	LOIV-1	1	S	Open
		V-2	LOIV-2			
		V-8	LFIV-1			
		V-9	LFIV-2			
		V-23	LOIV-3			
		V-26	LFIV-3			
PL	4	V-27	LFIV-4	1	S	Open
	Verify:					
PL	5	V-3	LOVV-1	1	S	Closed
		V-4	LOVV-2			
		V-5	LOVV-3			
		V-6	LOVV-4			
		V-7	LOFV-1			
		V-10	LFTVV-1			
		V-11	LFTVV-2			
		V-12	LFTVV-3			
		V-13	LFTVV-4			
		V-14	LFFV-1			
		V-19	LOPCV-1			
		V-21	LFPCV-1			
		V-22	LFPCV-2			
		V-23	LOIV-3			
		V-24	LOTVV-1			
		V-25	LOTVV-2			
		V-28	LFTVV-5			
		V-29	LFTVV-6			
		V-30	LFTVV-7			
		V-31	LFTVV-8			
		V-32	LOPV-1			
		V-33	LOPV-2			
		V-34	LFPV-1			
		V-35	LFPV-2			
		C-1	LOFC-1			
		C-2	LHC-1, 2			
		C-3	LFTVC-1			
		C-4	LHC-3, 4			
		C-5	LFFC-1			
		C-6	LHC-5, 6			
		C-8	LHC-7,8			
		C-11	LFVC-1			
PL	5	V-20	LOPCV-2	1	S	Closed

PRELAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	6. (a) Connect hydraulic GSE. (b) Connect GN2 purge GSE. (c) M.E.C-1, 2 conduct dry main engine start and shutdown sequence. Status is reported to CCC.					
	Verify:					
PL	7	TR-(1-37)	LBIV-(1-37)	1	S	Closed
		TR(1-37)	LMBV-(1-37)			
		TR(1-37)	LIOV-(1-37)			
		TR(1-37)	LIFV-(1-37)			Closed
		TR(1-37)	VII-(1-37)			0 VDC
PL	7	TR(1-37)	IIE-(1-37)	1	S	0
	Simulate:					
PL	7	TC-(1-37)	PC-(1-37)	1	C/O	300 PSI
	Verify:					
PL	8	V-36	LOPV-3	1	S	Closed
		V-37	LOPV-4			
		V-38	LOPV-5			
		V-39	LOPV-6			
		V-40	LFPV-3			
		V-41	LFPV-4			
		V-42	LFPV-5			
		V-43	LFPV-6			
		V-44	LOFV-2			
		V-70	LFFV-2			
		C-9	LOFC-2			
		C-10	LFFC-2			Closed
		T-8	PoT-4			19 PSIA
		T-9	PoT-5			
		T-10	PfT-4			
		T-11	PfT-5			
			PoL-8			
			PoL-9			
PL	8		PfL-10,9	1	S	19 PSIA
	And simulate:					
PL	8		PoL-6	1	C/O	400 PSI
		F-6	PoL-4			1500 PS
		T-8	PoT-6			1500 PS
		T-8	ToT-4			
		T-9	ToT-5			
		T-9	PoT-7			1500 PS
		F-7	PoL-5			1500 PS
			PoL-7			400 PSI
PL	8		PfL-7	1	C/O	400 PSI

PRELAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
PL	8	F-8	PfL-5	1	C/O	1500 PSIA
		T-10	PfT-6			1500 PSIA
		T-10	TfT-4			
		T-11	TfT-5			
		T-11	PfT-7			1500 PSIA
		F-9	PfL-6			1500 PSIA
PL	8		PfL-8	1	C/O	400 PSIA
	Verify:					
PL	9	GOV-1	LGOV-1	1	S	Closed
		GOV-1	LGOV-1I			
		GOV-2	LGOV-2			
		GOV-2	LGOV-2I			
		GOV-3	LGOV-3			
		GOV-3	LGOV-3I			
		GFV-1	LGFV-1			
		GFV-1	LGFV-1I			
		GFV-2	LGFV-2			
		GFV-2	LGFV-2I			
		GFV-3	LGFV-3			
		GFV-3	LGFV-3I			
		V-52	LLIV-1			
		V-52	LPSV-1			
		V-53	LLIV-2			
		V-53	LPSV-2			
		V-54	LLIV-3			
		V-54	LPSV-3			
		V-55	LFIV-1			
		V-55	LPSV-4			
		V-56	LFIV-2			
		V-56	LPSV-5			
		V-57	LFIV-3			
PL	9	V-57	LPSV-6	1	S	Closed
	and:					
PL	9	G-1	LIOV-38	1	S	Closed
		G-1	LIFV-38			
		G-2	LIOV-39			
		G-2	LIFV-39			
		G-3	LIOV-40			
		G-3	LIFV-40			Closed
		G-1	VII-38			OV
		G-2	VII-39			OV
		G-3	VII-40			OV
		G-1	VIEO-1			OVDC
		G-2	VIEO-2			OVDC
		G-3	VIEO-3			OVDC
		G-1	IIE-38			0
		G-2	IIE-39			0
PL	9	G-3	IIE-40	1	S	0

PRELAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
PL	9	PT-1	QPTL-1	1	S	
PL	9	PT-2	QPTL-2	1	S	
PL	9	PT-3	QPTL-3	1	S	
	and simulate:					
PL	9	G-1	PC-38	1	C/O	
		G-2	PC-39			
		G-3	PC-40			
		G-1	TC-1			
		G-2	TC-2			
		G-3	TC-3			
		V-46	PCV-1			1500 PSI
		V-49	PCV-4			↓
		H-4	PHEO-1			1500 PSI
		H-7	PHEO-4			
		H-4	THE-1			
		H-7	THE-4			
		P-1	PPD-1			1500 PSI
		P-4	PPD-4			↓
		V-47	PCV-2			
		V-50	PCV-5			
		H-5	PHEO-2			1500 PSI
		H-8	PHEO-5			
		H-5	THE-2			
PL	9	H-8	THE-5	1	C/O	
	and:					
PL	9	P-2	PPD-2	1	C/O	1500 PSI
		P-5	PPD-5			↓
		V-48	PCV-3			
		V-51	PCV-6			1500 PSI
		H-6	PHEO-3			
		H-9	PHEO-6			
		H-6	THE-3			
		H-9	THE-6			
		P-3	PPD-3			1500 PSI
		P-6	PPD-6			1500 PSI
		U-1	NT-1			
		U-1	AT-1			
		U-2	NT-2			
		U-2	AT-2			
		U-3	NT-3			
		U-3	AT-3			
		P-1	NP-1			
		P-1	AP-1			
PL	9	P-2	NP-2	1	C/O	

PRELAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
PL	9	P-2	AP-2	1	C/O	
		P-3	NP-3			
		P-3	AP-3			
		P-4	NP-4			
		P-4	AP-4			
		P-5	NP-5			
		P-5	AP-5			
		P-6	NP-6			
		P-6	AP-6			
		PT-1	NS-1			
		PT-2	NS-2			
		PT-3	NS-3			
		CL-1	AC-1			
		CL-2	AC-2			
		CL-3	AC-3			
		CL-4	AC-4			
		CL-5	AC-5			
		CL-6	AC-6			
		CL-7	AC-7			
		CL-8	AC-8			
		CL-9	AC-9			
PL	9	P-1	TPB-1	1	C/O	

And:

PL	9	P-2	TPB-2	1	C/O	
		P-3	TPB-3			
		P-4	TPB-4			
		P-5	TPB-5			
		P-6	TPB-6			
		PT-1	TPTB-1			
		PT-2	TPTB-2			
		PT-3	TPTB-3			
		PT-1	TPTL-1			
		PT-2	TPTL-2			
		PT-3	TPTL-3			
		PT-1	PPTL-1			
		PT-2	PPTL-2			
PL	9	PT-3	PPTL-3	1	C/O	

OCMS will conduct a dry A/B start

Verify:

PL	10	V-58	LFIV-4	1	S	Closed
		V-60	LFIV-5			
		V-62	LFIV-6			
		V-59	LPSV-7			
		V-61	LPSV-8			
PL	10	V-63	LPSV-9	1	S	Closed

PRELAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTEI VALUE
PL	10	G-4	VII-41	1	S	OVDC
		G-4	IIE-41			O
		G-4	VIEO-4			OVDC
		GFV-4	LGFV-4I			Closed
		GFV-4	LGFV-4			
		GOV-4	LGOV-4I			
		GOV-4	LGOV-4			Closed
PL	10	PT-4	QTPL-1	1	S	
	Simulate:					
PL	10	U-4	NT-4	1	C/O	
		PT-4	AT-4			
		PT-4	PTPL-1			
		PT-4	TTPL-1			
		P-7	PPD-7			50 PSIA
PL	10	P-7	AP-7	1	C/O	
	Verify:					
PL	11	G-5	VII-42	1	S	OVDC
		G-5	IIE-42			O
		G-5	VIEO-5			OVDC
		GFV-5	LGFV-5I			Closed
		GFV-5	LGFV-5			
		GOV-5	LGOV-5I			
		GOV-5	LGOV-5			Closed
PL	11	PT-5	QTPL-2	1	S	
	Simulate:					
PL	11	U-5	NT-5	1	C/O	
		U-5	AT-5			
		PT-5	PTPL-2			
		PT-5	TTPL-2			
		P-8	PPD-8			50 PSIA
PL	11	P-8	AP-8	1	C/O	
	Verify:					
PL	12	G-6	VII-43	1	S	OVDC
		G-6	IIE-43			O
		G-6	VIEO-6			OVDC
		GFV-6	LGFV-6I			Closed
		GFV-6	LGFV-6			
		GOV-6	LGOV-6I			
		GOV-6	LGOV-6			Closed
PL	12	PT-6	QTPL-3	1	S	

PRELAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Simulate:					
PL	12	U-6	NT-6	1	C/O	
		U-6	AT-6			
		PT-6	PTPL-3			
		PT-6	TTPL-3			
		P-9	PPD-9			50 PSIA
PL	12	P-9	AP-9	1	C/O	
	Verify:					
PL	13	EFV-1	LEFV-1	1	S	Closed
		EFV-2	LEFV-2			
		EFV-3	LEFV-3			
		EFV-4	LEFV-4			
		EFV-5	LEFV-5			
		EFV-6	LEFV-6			
		EFV-7	LEFV-7			
		EFV-8	LEFV-8			
		EFV-9	LEFV-9			
		EFV-10	LEFV-10			
		EFV-11	LEFV-11			
		EFV-12	LEFV-12			Closed
			PfL-11			19 PSIA
			PfL-12			19 PSIA
PL	13		PfL-13	1	S	19 PSIA
	Simulate:					
PL	13		TfL-6	1	C/O	
PL	13		TfL-7	1	C/O	
PL	13		TfL-8	1	C/O	
	A/B E.C.-1 will conduct a dry start of T.F.-1 by verifying:					
PL	14	FCA-1	LFIVA/B-1	1	S	Closed
		FCA-1	LCPRV-1			Closed
		FH-1	VFH-1			OVDC
		FH-1	IFH-1			OADC
		IGN-1	VIIA/B-1			OVDC
		IGN-1	III-1			O
		IGN-1	VIEO-1			OVDC
		LA-1	QLO-1			
PL	14	FCA-1	LSPV-1	1	S	Closed

PRELAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTE VALUE
and simulating:						
PL	14	FCA-1	NVDVP-1	1	C/O	
		FCA-1	PDVDVP-1			
		LA-1	PSPD-1			
		LA-1	TSPD-1			
		FM-1	FfF-1			
		TF-1	NHPT-1			
		FD-1	FLB-1			
		TF-1	PFI-1			
		TF-1	TIA-1			
		TF-1	NF-1			
		TF-1	PHPT-1			
		TF-1	THPT-1			
		TF-1	PED-1			
		TF-1	TED-1			
		TF-1	TLPTD-1			
		TF-1	TCI-1			
PL	14	LA-1	PG-1	1	C/O	
PL	14	LA-1	PLPD-1	1	C/O	
As well as:						
PL	14	TF-1	PfCCI-1	1	C/O	
		TF-1	TfCCI-1			
		TF-1	TTB-1			
		FCA-1	TFH-1			
		FCA-1	NVDVP-1			
		TF-1	AFFB-1			
		TF-1	AFCB-1			
		TF-1	ALPRB-1			
		COMP-1	FIC-1			
PL	14	COMP-1	ACEC-1	1	C/O	
A/B E.C.-2 will conduct a dry start of T.F.-2 by verifying:						
PL	15	FCA-2	LFIVA/B-2	1	S	Closed
		FCA-2	LCPRV-2			Closed
		FH-2	VFH-2			OVDC
		FH-2	IFH-2			OADC
		IGN-2	VIIA/B-2			OVDC
		IGN-2	III-2			0
		IGN-2	VIEO-2			OVDC
		LA-2	QLO-2			
PL	15	FCA-2	LSPV-2	1	S	Closed
And simulating:						
PL	15	FCA-2	NVDVP-2	1	C/O	
		FCA-2	PDVDVP-2			
		LA-2	PLPD-2			
		LA-2	PSPD-2			
		LA-2	TSPD-2			
		FM-2	FfF-2			
PL	15	TF-2	NHPT-2	1	C/O	

PRELAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
PL	15	FD-2	FLB-2	1	C/O	
		TF-2	PFI-2			
		TF-2	TIA-2			
		TF-2	NF-2			
		TF-2	PHPT-2			
		TF-2	THPT-2			
		TF-2	PED-2			
		TF-2	TED-2			
		TF-2	TLPTD-2			
		TF-2	TCI-2			
PL	15	LA-2	PG-2	1	C/O	

As well as:

PL	15	TF-2	PfCCI-2	1	C/O	
		TF-2	TfCCI-2			
		TF-2	TTB-2			
		FCA-2	TFH-2			
		FCA-2	NVDVP-2			
		TF-2	AFFB-2			
		TF-2	AFCB-2			
		TF-2	ALPRB-2			
		COMP-2	FIC-2			
PL	15	COMP-2	ACEC-2	1	C/O	

A/B E.C.-3 will conduct a dry start of T.F.-3 by verifying:

PL	16	FCA-3	LFIVA/B-3	1	S	Closed
		FCA-3	LCPRV-3			Closed
		FH-3	VFH-3			OVDC
		FH-3	IFH-3			OADC
		IGN-3	VIIA/B-3			OVDC
		IGN-3	III-3			O
		IGN-3	VIEO-3			OVDC
		LA-3	QLO-3			
PL	16	FCA-3	LSPV-3	1	S	Closed

And simulating:

PL	16	FCA-3	NVDVP-3	1	C/O	
		FCA-3	PDVDVP-3			
		LA-3	PLPD-3			
		LA-3	PSPD-3			
		LA-3	TSPD-3			
		FM-3	FfF-3			
		TF-3	NHPT-3			
		FD-3	FLB-3			
		TF-3	PFI-3			
		TF-3	TIA-3			
		TF-3	NF-3			
		TF-3	PHPT-3			
PL	16	TF-3	THPT-3	1	C/O	

PRELAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
PL	16	TF-3	PED-3	1	C/O	
		TF-3	TED-3			
		TF-3	TLPTD-3			
		TF-3	TCI-3			
PL	16	LA-3	PG-3	1	C/O	

As well as:

PL	16	TF-3	PfCCI-3	1	C/O	
		TF-3	TfCCI-3			
		TF-3	TTB-3			
		FCA-3	TFH-3			
		FCA-3	NVDVP-3			
		TF-3	AFFB-3			
		TF-3	AFCB-3			
		TF-3	ALPRB-3			
		COMP-3	FIC-3			
PL	16	COMP-3	ACEC-3	1	C/O	

Remove all solid start cartridges.

A/B E.C.-1, 2, 3 will command and verify:

PL	17	SC-1	VC-1	1	C/O	28 VDC
PL	17	SC-2	VC-2	1	C/O	28 VDC
PL	17	SC-3	VC-3	1	C/O	28 VDC

Then command and verify:

PL	17	SC-1	VC-1	1	C/O	OVDC
PL	17	SC-2	VC-2	1	C/O	OVDC
PL	17	SC-3	VC-3	1	C/O	OVDC

Connect Zero-G lube pressurization GSE

A/B E.C.- 1, 2, 3 will verify:

PL	18	LA-1	PZGL-1	1	C/O	
PL	18	LA-2	PZGL-2	1	C/O	
PL	18	LA-3	PZGL-3	1	C/O	

Stop and disconnect Zero-G lube GSE.
Replace all solid start cartridges.
Command all propulsion systems off.

Command all engine controllers off.

Power down OCMS.

Disconnect all GSE.

Tow orbiter to pad.

LAUNCH

1. Connect orbiter to pad electrical interfaces.
   Connect Electronic collant GSE.

2. Power up OCMS. Command OCMS self-check.
   Power up all engine controllers. Command controller self-checks.
   Power up all propulsion systems.

3. Verify:

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
L	3	V-1	LOIV-1	1	S	Open
		V-2	LOIV-2			Open
		V-3	LOVV-1			Closed
		V-4	LOVV-2			↓
		V-5	LOVV-3			
		V-6	LOVV-4			
		V-7	LOFV-1			Closed
		V-8	LFIV-1			Open
		V-9	LFIV-2			Open
		V-10	LFTVV-1			Closed
		V-11	LFTVV-2			↓
		V-12	LFTVV-3			
		V-13	LFTVV-4			
		V-14	LFFV-1			
		V-19	LOPCV-1			
		V-20	LOPCV-2			
		V-21	LFPCV-1			↓
		V-22	LFPCV-2			Closed
		V-23	LOIV-3			Open
		V-24	LOTVV-1			Closed
		V-25	LOTVV-2			Closed
		V-26	LFIV-3			Open
		V-27	LFIV-4			Open
		V-28	LFTVV-5			Closed
		V-29	LFTVV-6			↓
		V-30	LFTVV-7			
		V-31	LFTVV-8			
		V-32	LOPV-1			
		V-33	LOPV-2			
		V-34	LFPV-1			
		V-35	LFPV-2			
		C-1	LOFC-1			
		C-2	LHC-1,2			
		C-3	LFTVC-1			
		C-4	LHC-3,4			
		C-5	LFFC-1			
		C-6	LHC-5,6			
		C-8	LHC-7,8			
		C-11	LFVC-1			Closed
		T-3	PfT-1			15-20 PSIA
		T-5	PfT-2			↓
L	3	T-6	PfT-3	1	S	15-20 PSIA

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
L	3	T-1	PoT-1	1	S	15-20 PSIA
		T-2	PoT-2			
		T-4	PoT-3			
			PoL-1			
		L-17	PoL -2			
		L-18	PoL -3			
		L-20	PfL-1			
			PfL -2			
			PfL-3			
		L-21	PfL -4			
		L-3	POS-1			
		L-4	POS -2			
		L-8	PfS-1			
		L-9	PfS-2			
		C-5	PfF-1			
		C-1	PoF-1			
		L-7	PgRL-1			
		F-4	PoL-10			
		F-5	PfL-14			
		L-14	PgF-1			
		O-5	PgF -2			
		L-16	PgF -3			
		L-13	PgO-1			
		O-3	PgO -2			
L	3	L-15	PgO -3	1	S	15-20 PSIA

M.E.C.-1,2,3 will verify actuators locked, and igniters de-energized.

4. Remove all protective covers.

5. Verify RCS doors closed

Verify:

L	6	TR-(1-37)	LBIV-(1-37)	1	S	Closed
		TR-(1-37)	LMBV-(1-37)			
		TR-(1-37)	LIOV-(1-37)			
		TR-(1-37)	LIFV-(1-37)			Closed
		TR-(1-37)	VII-(1-37)			OVDC
		V-36	LOPV-3			Closed
		V-37	LOPV-4			
		V-38	LOPV-5			
		V-39	LOPV-6			
		V-40	LFPV-3			
		V-41	LFPV-4			
		V-42	LFPV-5			
		V-43	LFPV-6			
		V-44	LOFV-2			
		V-70	LFFV-2			
		C-9	LOFC-2			
		C-10	LFFC-2			Closed
		T-8	PoT-4			19 PSIA
L	6	T-9	PoT-5	1	S	19 PSIA

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
L	6	T-10	PfT-4	1	S	19 PSIA
		T-11	PfT-5			
			PoL-8			
			PoL-9			
			PfL-9			
L	6		PfL-10	1	S	19 PSIA
	Verify:					
L	7	GOV-1	LGOV-1	1	S	Closed
		GOV-1	LGOV-1I			
		GOV-2	LGOV-2			
		GOV-2	LGOV-2I			
		GOV-3	LGOV-3			
		GOV-3	LGOV-3I			
		GFV-1	LGFV-1			
		GFV-1	LGFV-1I			
		GFV-2	LGFV-2			
		GFV-2	LGFV-2I			
		GFV-3	LGFV-3			
		GFV-3	LGFV-3I			
		V-52	LLIV-1			
		V-52	LPSV-1			
		V-53	LLIV-2			
		V-53	LPSV-2			
		V-54	LLIV-3			
		V-54	LPSV-3			
		V-55	LFIV-1			
		V-55	LPSV-4			
		V-56	LFIV-2			
		V-56	LPSV-5			
		V-57	LFIV-3			
		V-57	LPSV-6			
		G-1	LIOV-38			
		G-2	LIOV-39			
		G-3	LIOV-40			
		G-1	LIFV-38			
		G-2	LIFV-39			
		G-3	LIFV-40			Closed
		G-1	VII-38			OV
		G-2	VII-39			OV
L	7	G-3	VII-40	1	S	OV
	Verify:					
L	8	GFV-4	LGFV-4I	1	S	Closed
		GFV-4	LGFV-4			
		GOV-4	LGOV-4I			
		GOV-4	LGOV-4			
		GFV-5	LGFV-5I			
L	8	GFV-5	LGFV-5	1	S	Closed

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
L	8	GOV-5	LGOV-5I	1	S	Closed
		GOV-5	LGOV-5			
		GFV-6	LGFV-6I			
		GFV-6	LGFV-6			
		GOV-6	LGOV-6I			
		GOV-6	LGOV-6			
		V-58	LFIV-4			
		V-59	LPSV-7			
		V-60	LFIV-5			
		V-61	LPSV-8			
		V-62	LFIV-6			
		V-63	LPSV-9			Closed
		G-1	VII-41			OVDC
		G-2	VII-42			
		G-3	VII-43			OVDC
		EFV-1	LEFV-1			Closed
		EFV-2	LEFV-2			
		EFV-3	LEFV-3			
		EFV-4	LEFV-4			
		EFV-5	LEFV-5			
		EFV-6	LEFV-6			
		EFV-7	LEFV-7			
		EFV-8	LEFV-8			
		EFV-9	LEFV-9			
		EFV-10	LEFV-10			
		EFV-11	LEFV-11			
		EFV-12	LEFV-12			Closed
			PfL-11			19 PSIA
			PfL-12			
L	8		PfL-13	1	S	19 PSIA

A/B E.C.-1,2,3 will verify:

L	9	FCA-1	LFIVA/B-1	1	S	Closed
		FCA-1	LCPRV-1			
		FCA-1	LSPV-1			Closed
		IGN-1	VIIA/B-1			OVDC
		FCA-2	LFIVA/B-2			Closed
		FCA-2	LCPRV-2			
		FCA-2	LSPV-2			Closed
		IGN-2	VIIA/B-2			OVDC
		FCA-3	LFIVA/B-3			Closed
		FCA-3	LCPRV-3			
		FCA-3	LSPV-3			Closed
		IGN-3	VIIA/B-3			OVDC

10 Connect helium servicing GSE to each main engine purge accumulator and service with 2000 Psia dry helium.

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LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Connect the Propellant Servicing and Pressurization GSE to the following couplings and verify:				
L	11	C-1	LOFC-1	1	S	Open
		C-2	LHC-1,2			
		C-3	LFTVC-1			
		C-4	LHC-3,4			
		C-5	LFFC-1			
		C-6	LHC-5,6			
		C-8	LHC-7,8			
		C-9	LOFC-2			
		C-10	LFFC-2			
L	11	C-11	LFVC-1	1	S	Open
		Command pre-propellant loading purge sequence of the main engines. When the main engine controllers indicate "ready for propellants", command and verify:				
L	12	V-1	LOIV-1	1	S	Closed
		V-2	LOIV-2			Closed
		V-7	LOFV-1			Open
		V-24	LOTVV-1			
L	12	V-25	LOTVV-2	1	S	Open
		Command LOX transfer to slow mode. Verify operations by checking:				
L	13	L-17	ToL-2	1	S	$<200^{\circ}R$
		When:				
L	14	T-4	QoT-7	10/sec	C	Covered
		Command LOX recirculation helium on at C-2, and command LOX transfer to fast fill. When:				
L	15	T-4	QoT-8	10/sec	C	Covered
		Command LOX transfer to slow fill and command termination of helium recirculation. When:				
L	16	T-4	QoT-9	10/sec	C	Covered

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Command LOX to mode hold.				
		Verify:				
L	17	T-4	ToT-3	1	S	164±3°R
		L-17	ToL-2			
		L-3	ToS-1			
		L-4	ToS-2			
		L-17	PoL-2			
		L-3	PoS-1			
		L-4	PoS-2			
L	17	L-7	PgRL-1	1	S	
		Visually check for leakage with scan cameras.				
		Commence monitoring for leakage with compartment gas analyzers.				
		Command and verify:				
L	18	V-3	LOVV-1	1	S	Open
		V-4	LOVV-2			
		V-5	LOVV-3			
		V-6	LOVV-4			
		V-1	LOIV-1			Open
L	18	V-23	LOIV-3	1	S	Closed
		Command LOX transfer to slow mode.				
		Verify operation by checking:				
L	19		ToL-1	1	S	$<200^{\circ}R$
		When:				
L	20	T-1	QoT-1	10/sec	C	Covered
		Command LOX Recirculation helium on at C-2, and command LOX transfer to fast fill.				
		When:				
L	21	T-1	QoT-2	10/sec	C	Covered
		Command LOX transfer to slow fill and command termination of helium recirculation.				
		When:				
L	22	T-1	QoT-3	10/sec	C	Covered

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Command LOX to mode hold.				
		Verify:				
L	23	T-1	ToT-1	1	S	164±3°R
↓	↓		ToL-1	↓	↓	164±3°R
L	23	T-1	PoL-1	1	S	
		Command and verify:				
L	24	V-1	LOIV-1	1	S	Closed
L	24	V-2	LOIV-2	1	S	Open
		Command LOX transfer to slow mode.				
		Verify operation by checking:				
L	25	L-18	ToL-3	1	S	$<200^{\circ}R$
		When				
L	26	T-2	QoT-4	10/sec	C	Covered
		Command LOX recirculation helium on at C-2, and command LOX transfer to fast fill.				
		When:				
L	27	T-2	QoT-5	10/sec	C	Covered
		Command LOX transfer to slow fill and command termination of helium recirculation.				
		When:				
L	28	T-2	QoT-6	10/sec	C	Covered
		Command LOX to mode hold.				
		Verify:				
L	29	T-2	ToT-2	1	S	164±3°R
↓	↓	L-18	ToL-3	↓	↓	164±3°R
L	29	L-18	PoL-3	1	S	
		Command and verify:				
L	30	V-2	LOIV-2	1	S	Closed
L	30	V-7	LOFV-1	1	S	Closed

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify:					
L	31	V-44	LOFV-2	1	S	Open
	When:					
L	32	T-8	PoT-4	1/sec	S	14.7 PSIA
L	32	T-9	PoT-5	1/sec	S	14.7 PSIA
	Commence servicing T-8, 9 with GO2.					
	Monitor:					
L	33	T-8	PoT-6	1/sec	C	1500 PSIA
↓	↓	T-8	ToT-4	↓	↓	
↓	↓	T-9	PoT-7	↓	↓	1500 PSIA
L	33	T-9	ToT-5	1/sec	C	
	Compute accumulator quantity, and send hold command to GSE at full load.					
	Command and verify:					
L	34	V-44	LOFV-2	1	S	Closed
	Monitor:					
L	35	T-8	PoT-6	1	M	1500 PSIA
↓	↓	T-8	ToT-4	↓	↓	
↓	↓	T-9	PoT-7	↓	↓	1500 PSIA
L	35	T-9	ToT-5	1	M	
	For decay.					
	Command and verify:					
L	36	V-70	LFFV-2	1	S	Open
	When:					
L	37	T-10	PfT-4	1/sec	S	14.7 PSIA
L	37	T-11	PfT-5	1/sec	S	14.7 PSIA
	Commence servicing T-10, 11 with GH2.					
	Monitor:					
L	38	T-10	PfT-6	1/sec	C	1500 PSIA
↓	↓	T-10	TfT-4	↓	↓	
↓	↓	T-11	PfT-7	↓	↓	1500 PSIA
L	38	T-11	TfT-5	1/sec	C	

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Compute accumulator quantity, and send hold command to GSE at full load.				
		Command and verify:				
L	39	V-70	LFFV-2	1	S	Closed
		Monitor:				
L	40	T-10	PfT-6	1/sec	M	1500 PSIA
↓	↓	T-10	TfT-4	↓	↓	
↓	↓	T-11	PfT-7	↓	↓	1500 PSIA
L	40	T-11	TfT-5	1/sec	M	
		For decay.				
		Reverify:				
L	41		PoL- 8	1	S	19 PSIA
↓	↓		PoL-9	↓	↓	↓
↓	↓		PfL-9	↓	↓	
L	41		PfL-10	1	S	19 PSIA
		Connect vents to TR-15 and TR-9.				
		Connect vents to TR-2 and TR-3.				
		Verify:				
L	42	F-6	PoL-4	1	S	1500 PSIA
↓	↓	F-7	PoL-5	↓	↓	↓
↓	↓	F-8	PfL-5	↓	↓	
L	42	F-9	PfL-6	1	S	1500 PSIA
		Command and verify:				
L	43	TR-2	LBIV-2	1	S	Open
↓	↓	TR-2	LMBV-2	↓	↓	↓
↓	↓	TR-2	LIFV-2	↓	↓	↓
↓	↓	TR-2	LIOV-2	↓	↓	↓
↓	↓	TR-3	LBIV-3	↓	↓	↓
↓	↓	TR-3	LMBV-3	↓	↓	↓
↓	↓	TR-3	LIFV-3	↓	↓	↓
↓	↓	TR-3	LIOV-3	↓	↓	↓
↓	↓	TR-9	LBIV-9	↓	↓	↓
↓	↓	TR-9	LMBV-9	↓	↓	↓
↓	↓	TR-9	LIFV-9	↓	↓	↓
↓	↓	TR-9	LIOV-9	↓	↓	↓
↓	↓	TR-15	LBIV-15	↓	↓	↓
↓	↓	TR-15	LMBV-15	↓	↓	↓
↓	↓	TR-15	LIFV-15	↓	↓	↓
L	43	TR-15	LIOV-15	1	S	Open

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
L	44		PoL-8	1/sec A.R.	C	Ambient
↓	↓		PoL-9	↓	↓	↓
			PfL-9			
L	44		PfL-10	1/sec A.R.	C	Ambient
	Command and verify:					
L	45	TR-2	LBIV-2	1	S	Closed
↓	↓	TR-2	LMBV-2	↓	↓	↓
		TR-2	LIFV-2			
		TR-2	LIOV-2			
		TR-3	LBIV-3			
		TR-3	LMBV-3			
		TR-3	LIFV-3			
		TR-3	LIOV-3			
		TR-9	LBIV-9			
		TR-9	LMBV-9			
		TR-9	LIFV-9			
		TR-9	LIOV-9			
		TR-15	LBIV-15			
		TR-15	LMBV-15			
		TR-15	LIFV-15			
L	45	TR-15	LIOV-15	1	S	Closed
	Command and verify:					
L	46	V-36	LOPV-3	1	S	Open
↓	↓	V-38	LOPV-5	↓	↓	↓
		V-40	LFPV-3			
L	46	V-42	LFPV-5	1	S	Open
	Verify:					
L	47		PoL-6	1	S	375-400 PSIA
↓	↓		PoL-7	↓	↓	↓
			PfL-7			
L	47		PfL-8	1	S	375-400 PSIA
	Command and verify:					
L	48	V-36	LOPV-3	1	S	Closed
↓	↓	V-38	LOPV-5	↓	↓	↓
		V-40	LFPV-3			
L	48	V-42	LFPV-5	1	S	Closed
	Repeat steps L-43, 44, 45.					
	Command and verify:					
L	49	V-37	LOPV-4	1	S	Open
↓	↓	V-39	LOPV-6	↓	↓	↓
		V-41	LFPV-4			
L	49	V-43	LFPV-6	1	S	Open

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Repeat step L-47.					
	Command and verify:					
L	50	V-37	LOPV-4	1	S	Closed
↓	↓	V-39	LOPV-6	↓	↓	↓
↓	↓	V-41	LFPV-4	↓	↓	↓
L	50	V-43	LFPV-6	1	S	Closed
	Monitor:					
L	51		PoL-6	5/sec	M	375-400 PSIA
↓	↓		PoL-7	↓	↓	↓
↓	↓		PfL-7	↓	↓	↓
L	51		PfL-8	5/sec	M	375-400 PSIA
	For decay.					
	Command and verify:					
L	52	V-36	LOPV-3	1	S	Open
↓	↓	V-37	LOPV-4	↓	↓	↓
↓	↓	V-38	LOPV-5	↓	↓	↓
↓	↓	V-39	LOPV-6	↓	↓	↓
↓	↓	V-40	LFPV-3	↓	↓	↓
↓	↓	V-41	LFPV-4	↓	↓	↓
↓	↓	V-42	LFPV-5	↓	↓	↓
L	52	V-43	LFPV-6	1	S	Open
	Command and verify:					
L	53	TR-1	LBIV-1	1	S	Open
	Through:					
L	53	TR-37	LBIV-1	1	S	Open
	Verifying:					
L	53		PoL-6	1 samp/step	S	375-400 PSIA
↓	↓		PoL-7	↓	↓	↓
↓	↓		PfL-7	↓	↓	↓
L	53		PfL-8	1 samp/step	S	375-400 PSIA
	Between each valve opening.					
	54. Commence monitoring the pressures of step L-53 at 5 samples/sec.					
	Command and verify:					
L	55	V-44	LOFV-2	1	S	Open

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Top T-8, 9 with GO2 from C-9, until					
L	56	T-8	PoT-6	1/sec	C	1500 PSIA
L	56	T-9	PoT-7	1/sec	C	1500 PSIA
	Command GSE to Hold, and					
L	57	V-44	LOFV-2	1	S	Closed
L	57	V-70	LFFV-2	1	S	Open
	Top T-10, 11 with GH2 from C-10 until					
L	58	T-10	PfT-6	1/sec	C	1500 PSIA
L	58	T-11	PfT-7	1/sec	C	1500 PSIA
	Command GSE to hold, and					
L	59	V-70	LFFV-2	1	S	Closed
	Disconnect the GSE vents from TR-2, 3, 9, 15.					
	Command and verify:					
L	60	V-8	LFIV-1	1	S	Closed
		V-9	LFIV-2			Closed
		V-28	LFTVV-5			Open
		V-29	LFTVV-6			
		V-30	LFTVV-7			
		V-31	LFTVV-8			
L	60	V-14	LFFV-1	1	S	Open
	Command fuel transfer to slow fill.					
	Verify operation by checking:					
L	61	L-20	TfL-1	1	S	$<50^{\circ}R$
		L-21	TfL-4			
L	61		TfL-5	1	S	$<50^{\circ}R$
	When both:					
L	62	T-5	QfT-4	10/sec	C	Covered
L	62	T-6	QfT-7	10/sec	C	Covered
	Command helium recirculation from C-8 on, and LH2 transfer to fast fill.					
	When:					
L	63	T-5	QfT-5	10/sec	C	Covered
	Or					
L	63	T-6	QfT-8	10/sec	C	Covered

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Terminate helium recirculation, and command transfer to slow fill.				
		When:				
L	64	T-5	QfT-6	10/sec	C	Covered
		Or:				
L	64	T-6	QfT-9	10/sec	C	Covered
		Command fuel transfer to mode hold when the other one covers, or TBD seconds after the first one covers.				
	65.	Monitor compartment analyzers for leakage. Monitor compartment fire detectors.				
		Verify:				
L	66	T-5	TfT-2	1	S	36-40°R
		T-6	TfT-3			
		L-20	TfL-1			
		L-21	TfL-4			
		L-8	TfS-1			
		L-9	TfS-2			
		L-8	PfS-1			
L	66	L-9	PfS-2	1	S	
		Command and verify:				
L	67	V-26	LFIV-3	1	S	Closed
		V-27	LFIV-4			Closed
		V-8	LFIV-1			Open
		V-9	LFIV-2			
L	67	V-(10-13)	LFTVV-(1-4)	1	S	Open
		Command fuel transfer to slow fill.				
		Verify operation by checking:				
L	68		TfL-2	1	S	< 50°R
L	68		TfL-3	1	S	<50°R
		When:				
L	69	T-3	QfT-1	1	S	Covered
		Command helium recirculation on from C-8 and command fuel transfer to fast fill.				
		When:				
	70	T-3	QfT-2	1	S	Covered

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Terminate helium recirculation, and command fuel transfer to slow fill.					
	When:					
L	71	T-3	QfT-3	1	S	Covered
	Command fuel transfer to mode hold.					
	Verify:					
L	72	T-3	TfT-1	1	S	36-40°R
↓	↓		TfL-2	↓	↓	↓
L	72		TfL-3	1	S	36-40°R
	Command and verify:					
L	73	V-14	LFFV-1	1	S	Closed
	Command and verify:					
L	74	V-1	LOIV-1	1	S	Open
L	74	V-7	LOFV-1	1	S	Open
	Top T-1 until:					
L	75	T-1	QoT-3	10/sec	C	Covered
	Terminate topping.					
	Command and verify:					
L	76	V-1	LOIV-1	1	S	Closed
L	76	V-2	LOIV-2	1	S	Open
	Top T-2 until					
L	77	T-2	QoT-6	10/sec	C	Covered
	Terminate topping.					
	Command and verify:					
L	78	V-2	LOIV-2	1	S	Closed
L	78	V-23	LOIV-3	1	S	Open
	Top T-4 until:					
L	79	T-4	QoT-9	10/sec	C	Covered

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Terminate topping.					
	Command and verify:					
L	80	V-23	LOIV-3	1	S	Closed
↓	↓	V-7	LOFV-1	↓	↓	Closed
↓	↓	V-1	LOIV-1	↓	↓	Open
L	80	V-2	LOIV-2	1	S	Open
	Command and verify:					
L	81	V-14	LFFV-1	1	S	Open
	Top T-3 until:					
L	82	T-3	QfT-3	10/sec	C	Covered
	Terminate topping.					
	Command and verify:					
L	82	V-8	LFIV-1	1	S	Closed
↓	↓	V-9	LFIV-2	↓	↓	Closed
↓	↓	V-26	LFIV-3	↓	↓	Open
L	82	V-27	LFIV-4	1	S	Open
	Top T-5, 6 until:					
L	83	T-5	QfT-6	10/sec	C	Covered
L	83	T-6	QfT-9	10/sec	C	Covered
	Terminate topping.					
	Command and verify:					
L	84	V-26	LFIV-3	1	S	Closed
↓	↓	V-27	LFIV-4	↓	↓	Closed
↓	↓	V-8	LFIV-1	↓	↓	Open
↓	↓	V-9	LFIV-2	↓	↓	Open
L	84	V-14	LFFV-1	1	S	Closed
	Command and verify:					
L	85	V-3	LOVV-1	1	S	Closed
↓	↓	V-4	LOVV-2	↓	↓	↓
↓	↓	V-5	LOVV-3	↓	↓	↓
↓	↓	V-6	LOVV-4	↓	↓	↓
↓	↓	V-10	LFTVV-1	↓	↓	↓
↓	↓	V-11	LFTVV-2	↓	↓	↓
↓	↓	V-12	LFTVV-3	↓	↓	↓
↓	↓	V-13	LFTVV-4	↓	↓	↓
L	85	V-24	LOTVV-1	1	S	Closed

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
L	85	V-25	LOTVV-2	1	S	Closed
↓	↓	V-28	LFTVV-5	↓	↓	↓
		V-29	LFTVV-6			
↓	↓	V-30	LFTVV-7	↓	↓	↓
L	85	V-31	LFTVV-8	1	S	Closed
	Verify:					
L	86	T-8	PoT-6	1	S	1500 PSIA
↓	↓	T-9	PoT-7	↓	↓	1500 PSIA
L	86	T-4	PoT-3	1	S	<30 PSIA
	Command and verify:					
L	87	V-33	LOPV-2	1	S	Open
	Verify:					
L	88	T-4	PoT-3	1	S	35-40 PSIA
	Command and verity:					
L	89	V-33	LOPV-2	1	S	Closed
	Command and verify:					
L	90	V-24	LOTVV-1	1	S	Open
L	90	V-25	LOTVV-2	1	S	Open
	Verify:					
L	91	T-4	PoT-3	1	S	Ambient
	Comma nd and verify:					
L	92	V-24	LOTVV-1	1	S	Closed
L	92	V-25	LOTVV-2	1	S	Closed
	Command and verify:					
L	93	V-32	LOPV-1	1	S	Open
	Check:					
L	94	T-4	PoT-3	1	S	35-40 PSIA
	Command and verify:					
L	95	V-32	LOPV-1	1	S	Closed

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Monitor:					
L	96	T-4	PoT-3	1/sec	M	35-40 PSIA
	For decay.					
	Verify:					
L	97	T-10	PfT-6	1	S	1500 PSIA
↓	↓	T-11	PfT-7	↓	↓	1500 PSIA
↓	↓	T-5	PfT-2	↓	↓	< 30 PSIA
L	97	T-6	PfT-3	1	S	<30 PSIA
	Command and verify:					
L	98	V-34	LFPV-1	1	S	Open
	Verify:					
L	99	T-5	PfT-2	1	S	35-40 PSIA
L	99	T-6	PfT-3	1	S	35-40 PSIA
	Command and verify					
L	100	V-34	LFPV-1	1	S	Closed
	Command and verify:					
L	101	V-28	LFTVV-5	1	S	Open
↓	↓	V-29	LFTVV-6	↓	↓	↓
↓	↓	V-30	LFTVV-7	↓	↓	↓
L	101	V-31	LFTVV-8	1	S	Open
	Verify:					
L	102	T-5	PfT-2	1	S	Ambient
L	102	T-6	PfT-3	1	S	Ambient
	Command and verify:					
L	103	V-28	LFTVV-5	1	S	Closed
↓	↓	V-29	LFTVV-6	↓	↓	↓
↓	↓	V-30	LFTVV-7	↓	↓	↓
L	103	V-31	LFTVV-8	1	S	Closed
	Command and verify:					
L	104	V-35	LFPV-2	1	S	Open
	Verify:					
L	105	T-5	PfT-2	1	S	35-40 PSIA
L	105	T-6	PfT-3	1	S	35-40 PSIA

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify:					
L	106	V-35	LFPV-2	1	S	Closed
	Monitor:					
L	107	T-5	PfT-2	1/sec	M	35-40 PSIA
L	107	T-6	PfT-3	1/sed	M	35-40 PSIA
	For decay. If none,					
	command and verify:					
L	108	V-32	LOPV-1	1	S	Open
↓	↓	V-33	LOPV-2	↓	↓	↓
↓	↓	V-34	LFPV-1	↓	↓	↓
L	108	V-35	LFPV-2	1	S	Open
	Command Pressurization of T-1 and T-2 with helium from C-6					
	until:					
L	109	T-1	PoT-1	10/sec	C	35-40 PSIA
L	109	T-2	PoT-2	10/sec	C	35-40 PSIA
	Terminate pressurization from C-6.					
	Continue Monitoring:					
L	110	T-1	PoT-1	10/sec	M	35-40 PSIA
L	110	T-2	PoT-2	10/sec	M	35-40 PSIA
	For decay.					
	Command pressurization T-3 with helium from C-4, until					
L	111	T-3	PfT-1	10/sec	C	35-40 PSIA
	Terminate pressurization from C-4.					
	Continue monitoring:					
L	112	T-3	PfT-1	10/sec	M	35-40 PSIA
	for decay.					

113. Repeat steps L-55 through L-59. (Top gas accumulators, T-8,9,10 11.)

Load and pressurization complete.

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Commence monitoring:				
L	114	T-8	PoT-6	1/sec	S	1500 PSIA
		T-8	ToT-4			
		T-9	PoT-7			1500 PSIA
		T-9	ToT-5			
		T-10	PfT-6			1500 PSIA
		T-10	TfT-4			
		T-11	PfT-7			1500 PSIA
L	114	T-11	TfT-5	1/sec	S	
		Compute and display accumulator quantity on request.				
		Command and verify:				
L	115	GOV-1	LGOV-1I	1	S	Open
		GOV-2	LGOV-2I			
		GOV-3	LGOV-3I			
		GFV-1	LGFV-1I			
		GFV-2	LGFV-2I			
		GFV-3	LGFV-3I			
		V-52	LLIV-1			
		V-53	LLIV-2			
		V-54	LLIV-3			
		V-55	LFIV-1			
		V-56	LFIV-2			
L	115	V-57	LFIV-3	1	S	Open
		Command the APU shaft clutches to engage on all three sections.				
		Command and verify:				
L	116	G-1	VII-38	1	S	28 VDC
		G-2	VII-39			
L	116	G-3	VII-40	1	S	28 VDC
		Command and verify:				
L	117	G-1	LIOV-38	1	S	Open
		Initiate igniter spark, verify:				
L	118	G-1	IIE-38	1	S	Pulses
L	118	G-1	PC-38	1	S	
		Command and verify:				
L	119	G-1	LIFV-38	1	S	Open
L	119	G-1	PC-38	1	S	

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify:					
L	120	GOV-1	LGOV-1	1	S	Open
L	120	G-1	PC-38	1	S	
	Command and verify:					
L	121	GFV-1	LGFV-1	1	S	Open
L	121	G-1	PC-38	1	S	
	Check:					
L	122	G-1	TC-1	1	S	
↓	↓	U-1	NT-1	2/sec	C	
		PT-1	QPTL-1	1	S	
↓	↓	PT-1	QPTL-1	↓	↓	
L	122	PT-1	TPTL-1	1	S	
L	122	PT-1	NS-1	1	S	
	When NT-1 reaches steady-state, command igniter sparkoff, and verify:					
L	123	G-1	IIE-38	1	S	OADC
	Command and verify:					
L	124	G-2	LIOV-39	1	S	Open
	Initiate igniter spark, verify:					
L	125	G-2	IIE-39	1	S	Pulses
L	125	G-2	PC-39	1	S	
	Command and verify:					
L	126	G-2	LIFV-39	1	S	Open
L	126	G-2	PC-39	1	S	
	Command and verify:					
L	127	GOV-2	LGOV-2	1	S	Open
L	127	G-2	PC-39	1	S	
	Command and verify:					
L	128	GFV-2	LGFV-2	1	S	Open
L	128	G-2	PC-39	1	S	
	Check:					
L	129	G-2	TC-2	1	S	
↓	↓	U-2	NT-2	2/sec	C	
		PT-2	NS-2	1	S	
		PT-2	QPTL-2	↓	↓	
↓	↓	PT-2	PPTL-2			
L	129	PT-2	TPTL-2	1	S	

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	When NT-2 reaches steady-state, command igniter spark off, and verify:					
L	130	G-2	IIE-39	1	S	OADC
	Command and verify:					
L	131	G-3	LIOV-40	1	S	Open
	Initiate igniter spark; verify:					
L	132	G-3	IIE-40	1	S	Pulses
L	132	G-3	PC-40	1	S	
	Command and verify:					
L	133	G-3	LIFV-40	1	S	Open
L	133	G-3	PC-40	1	S	
	Command and verify:					
L	134	GOV-3	LGOV-3	1	S	Open
L	134	G-3	PC-40	1	S	
	Command and verify:					
L	135	GFV-3	LGFV-3	1	S	Open
L	135	G-3	PC-40	1	S	
	Check:					
L	136	G-3	TC-3	1	S	
		U-3	NT-3	2/sec	C	
		PT-3	NS-3	1	S	
		PT-3	QPTL-3			
		PT-3	PPTL-3			
L	136	PT-3	TPTL-3	1	S	
	When NT-3 reaches steady-state, command igniter spark off, verify:					
L	137	G-3	IIE-40	1	S	OADC
	Commence monitoring:					
L	138	G-1	PC-38	1/sec	M	
		G-1	TC-1	1/sec		
		U-1	NT-1	2/sec		
		PT-1	QPTL-1	1/2 sec		
		PT-1	PPTL-1	1/2 sec		
		PT-1	TPTL-1	1/2 sec		
		PT-1	NS-1	1/2 sec		
		G-2	PC-39	1/sec		
		G-2	TC-2	1/sec		
L	138	U-2	NT-2	2/sec	M	
L	138	PT-2	TPTL-2	1/2 sec	M	

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
L	138	PT-2	QPTL-2	1/2sec	M	
		PT-2	PPTL-2	1/2sec		
		PT-2	NS-2	1/2sec		
		G-3	PC-40	1/sec		
		G-3	TC-3	1/sec		
		U-3	NT-3	2/sec		
		PT-3	QPTL-3	1/2sec		
		PT-3	PPTL-3	1/2sec		
		PT-3	TPTL-3	1/2sec		
L	138	PT-3	NS-3	1/2sec	M	

139 Verify vehicle power.

140 Execute power transfer.

141 Disconnect all remaining GSE.

Take final status.

Verify:

L	142	V-1	LOIV-1	1	S	Open
		V-2	LOIV-2			Open
		V-3	LOVV-1			Closed
		V-4	LOVV-2			
		V-5	LOVV-3			
		V-6	LOVV-4			
		V-7	LOFV-1			Closed
		V-8	LFIV-1			Open
		V-9	LFIV-2			Open
		V-10	LFTVV-1			Closed
		V-11	LFTVV-2			
		V-12	LFTVV-3			
		V-13	LFTVV-4			
		V-14	LFFV-1			
		V-19	LOPCV-1			
		V-20	LOPCV-2			
		V-21	LFPCV-1			
		V-22	LFPCV-2			
		V-23	LOIV-3			
		V-24	LOTVV-1			
		V-25	LOTVV-2			
		V-26	LFIV-3			
		V-27	LFIV-4			
		V-28	LFTVV-5			
		V-29	LFTVV-6			
		V-30	LFTVV-7			Closed
		V-31	LFTVV-8			Closed
		V-32	LOPV-1			Open
		V-33	LOPV-2			
		V-34	LFPV-1			
L	142	V-35	LFPV-2	1	S	Open

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
L	142	C-1	LOFC-1	1	S	Closed
		C-2	LHC-1,2			
		C-3	LFTVC-1			
		C-4	LHC-3,4			
		C-5	LFFC-1			
		C-6	LHC-5,6			
		C-8	LHC-7,8			
		C-11	LFVC-1			Closed
		T-3	PfT-1			35-40 PSIA
		T-3	QfT-2			
		T-3	QfT-3			
		T-1	PoT-1			35-40 PSIA
		T-1	ToT-1			164±3°R
		T-1	QoT-1			Covered
		T-1	QoT-2			
		T-1	QoT-3			Covered
		T-2	PoT-2			35-40 PSIA
		T-2	ToT-2			164±3°R
		T-2	QoT-4			Covered
		T-2	QoT-5			
		T-2	QoT-6			Covered
		T-4	PoT-3			35-40 PSIA
		T-4	ToT-3			164±3°R
		T-4	QoT-7			Covered
		T-4	QoT-8			
		T-4	QoT-9			Covered
		T-5	PfT-2			35-40 PSIA
		T-5	TfT-2			36-40°R
		T-5	QfT-4			Covered
		T-5	QfT-5			
		T-5	QfT-6			Covered
		T-6	PfT-3			35-40 PSIA
		T-6	TfT-3			36-40°R
		T-6	QfT-7			Covered
		T-6	QfT-8			
		T-6	QfT-9			
			PoL-1			
		L-17	PoL-2			
		L-18	PoL-3			
			ToL-1			164±3°R
		L-17	ToL-2			
		L-18	ToL-3			
			ToL-4			
		L-20	PfL-1			
			PfL-2			
			PfL-3			
		L-21	PfL-4			
		L-20	TfL-1			36-40°R
			TfL-2			
L	142		TfL-3	1	S	36-40°R
L	142	T-3	TfT-1	1	S	36-40°R
L	142	T-3	QfT-1	1	S	Covered

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
L	142	L-21	TfL-4	1	S	36-40°R
			TfL-5			36-40°R
		L-3	PoS-1			
		L-4	PoS-2			
		L-3	ToS-1			164±3°R
		L-4	ToS-2			164±3°R
		L-8	PfS-1			
		L-9	PfS-2			
		L-8	TfS-1			36-40°R
		L-9	TfS-2			36-40°R
		C-5	PfF-1			
		C-1	PoF-1			
		L-14	PgF-1			
		0-5	PgF-2			
		L-16	PgF-3			
		L-13	PgO-1			
		0-3	PgO-2			
		L-15	PgO-3			
		L-7	PgRL-1			
		L-14	TgF-1			
		L-14	TgF-2			
		L-13	TgO-1			
L	142	L-13	TgO-2	1	S	
and:						
L	143	C-9	LOFC-2	1	S	Closed
		C-10	LFFC-2			
		V-44	LOFV-2			
L	143	V-70	LFFV-2	1	S	Closed
and:						
L	144	GOV-4	LGOV-4I	1	S	Closed
		GOV-4	LGOV-4			
		GOV-5	LGOV-5I			
		GOV-5	LGOV-5			
		GOV-6	LGOV-6I			
		GOV-6	LGOV-6			
		GFV-4	LGFV-4I			
		GFV-4	LGFV-4			
		GFV-5	LGFV-5I			
		GFV-5	LGFV-5			
		GFV-6	LGFV-6I			
		GFV-6	LGFV-6			
		V-58	LFIV-4			
		V-59	LPSV-7			
		V-60	LFIV-5			
		V-61	LPSV-8			
L	144	V-62	LFIV-6	1	S	Closed

LAUNCH (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
L	144	V-63	LPSV-9	1	S	Closed
		EFV-1	LEFV-1			
		EFV-2	LEFV-2			
		EFV-3	LEFV-3			
		EFV-4	LEFV-4			
		EFV-5	LEFV-5			
		EFV-6	LEFV-6			
		EFV-7	LEFV-7			
		EFV-8	LEFV-8			
		EFV-9	LEFV-9			
		EFV-10	LEFV-10			
		EFV-11	LEFV-11			
		EFV-12	LEFV-12			Closed
			PfL-11			20 PSIA
			PfL-12			
L	144		PfL-13	1	S	20 PSIA

145 Command the main and turbofan engine controllers to take final status.

BOOST

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Verify readiness:						
B	1	V-1	LOIV-1	1	S	Open
		V-2	LOIV-2			Open
		V-3	LOVV-1			Closed
		V-4	LOVV-2			↓
		V-5	LOVV-3			
		V-6	LOVV-4			
		V-7	LOFV-1			Closed
		V-8	LFIV-1			Open
		V-9	LFIV-2			Open
		V-10	LFTVV-1			Closed
		V-11	LFTVV-2			↓
		V-12	LFTVV-3			
		V-13	LFTVV-4			
		V-14	LFFV-1			
		V-19	LOPCV-1			
		V-20	LOPCV-2			
		V-21	LFPCV-1			
		V-22	LFPCV-2			
		V-23	LOIV-3			
		V-24	LOTVV-1			
		V-25	LOTVV-2			
		V-26	LFIV-3			
		V-27	LFIV-4			
		V-28	LFTVV-5			
		V-29	LFTVV-6			
		V-30	LFTVV-7			
		V-31	LFTVV-8			Closed
		V-32	LOPV-1			Open
		V-33	LOPV-2			↓
		V-34	LFPV-1			
		V-35	LFPV-2			Open
		C-1	LOFC-1			Closed
		C-2	LHC-1,2			↓
		C-3	LFTVC-1			
		C-4	LHC-3,4			
		C-5	LFFC-1			
		C-6	LHC-5,6			
		C-8	LHC-7,8			
		C-11	LFVC-1			Closed
		T-3	PfT-1			35-40 PSIA
		T-3	TfT-1			36-40°R
		T-3	QfT-1			Covered
		T-3	QfT-2			↓
		T-3	QfT-3			Covered
		T-1	PoT-1			35-40 PSIA
		T-1	ToT-1			164±3°R
		T-1	QoT-1			Covered
		T-1	QoT-2			↓
B	1	T-1	QoT-3	1	S	Covered

BOOST (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
B	1	T-2	PoT-2	1	S	35-40 PSIA
		T-2	ToT-2			164±3°R
		T-2	QoT-4			Covered
		T-2	QoT-5			↓
		T-2	QoT-6			Covered
		T-4	PoT-3			35-40 PSIA
		T-4	ToT-3			164±3°R
		T-4	QoT-7			Covered
		T-4	QoT-8			↓
		T-4	QoT-9			Covered
		T-5	PfT-2			35-40 PSIA
		T-5	TfT-2			36-40°R
		T-5	QfT-4			Covered
		T-5	QfT-5			↓
		T-5	QfT-6			Covered
		T-6	PfT-3			35-40 PSIA
		T-6	TfT-3			36-40°R
		T-6	QfT-7			Covered
		T-6	QfT-8			↓
		T-6	QfT-9			Covered
			PoL-1			
		L-17	PoL-2			
		L-18	PoL-3			
			ToL-1			164±3°R
		L-17	ToL-2			↓
		L-18	ToL-3			
			ToL-4			164±3°R
		L-20	PfL-1			
			PfL-2			
			PfL-3			
		L-21	PfL-4			
		L-20	TfL-1			36-40°R
		L-21	TfL-4			↓
			TfL-5			36-40°R
		L-3	PoS-1			
		L-4	PoS-2			
		L-3	ToS-1			164±3°R
		L-4	ToS-2			164±3°R
		L-8	PfS-1			
		L-9	PfS-2			
		L-8	TfS-1			36-40°R
		L-9	TfS-2			36-40°R
		C-5	PfF-1			
		C-1	PoF-1			
		L-14	PgF-1			
		O-5	PgF-2			
		L-16	PgF-3			
		L-13	PgO-1			
		O-3	PgO-2			
B	1	L-15	PgO-3	1	S	

BOOST (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
B	1	L-7	PgRL-1	1	S	
		L-14	TgF-1			
		L-14	TgF-2			
		L-13	TgO-1			
B	1	L-13	TgO-2	1	S	
	Continue to monitor:					
B	2		PoL-6	5/sec	M	375-400 PSI
			PoL-7			
			PfL-7			
B	2		PfL-8	5/sec	M	375-400 PSI
	Continue to monitor:					
B	3	T-8	PoT-6	1/sec	S	1500 PSIA
		T-8	ToT-4			
		T-9	PoT-7			1500 PSIA
		T-9	ToT-5			
		T-10	PfT-6			1500 PSIA
		T-10	TfT-4			
		T-11	PfT-7			1500 PSIA
B	3	T-11	TfT-5	1/sec	S	
	Continue to monitor:					
B	4	G-1	PC-38	1/sec	M	
		G-1	TC-1	1/sec		
		U-1	NT-1	2/sec		
		PT-1	QPTL-1	1/2 sec		
		PT-1	PPTL-1	1/2 sec		
		PT-1	TPTL-1	1/2 sec		
		PT-1	NS-1	1/2 sec		
		G-2	PC-39	1/sec		
		G-2	TC-2	1/sec		
		U-2	NT-2	2/sec		
		PT-2	QPTL-2	1/2 sec		
		PT-2	PPTL-2	1/2 sec		
		PT-2	TPTL-2	1/2 sec		
		PT-2	NS-2	1/2 sec		
		G-3	PC-40	1/sec		
		G-3	TC-3	1/sec		
		U-3	NT-3	2/sec		
		PT-3	QPTL-3	1/2 sec		
		PT-3	PPTL-3	1/2 sec		
		PT-3	TPTL-3	1/2 sec		
B	4	PT-3	NS-3	1/2 sec	M	

5. At T+153 seconds, command extension of main engine nozzles.

SEPARATION (T+173 sec)

1. The CCC commands main engine start.

   At FS + 0.9 seconds, the main engine igniters are turned off.

   At Pc = 90%, the main engine gimbal actuators are unlocked.

   At TBD , command and verify.

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
S	2	V-19	LOPCV-1	1	S	Open
↓	↓	V-20	LOPCV-2	↓	↓	↓
↓	↓	V-21	LFPCV-1	↓	↓	↓
S	2	V-22	LFPCV-2	1	S	Open

In addition to the main engine data, monitor.

S	3	T-3	PfT-1	10/sec	M	35-40 PSIA
↓	↓	T-3	TfT-1	1/sec	M	36-40°R
↓	↓	T-3	QfT-2	10/sec	S	C/U
↓	↓	T-3	QfT-1	10/sec	C	C/U
↓	↓	T-1	PoT-1	10/sec	M	35-40 PSIA
↓	↓	T-1	ToT-1	1/sec	M	164±3°R
↓	↓	T-1	QoT-2	10/sec	S	C/U
↓	↓	T-1	QoT-1	10/sec	C	C/U
↓	↓	T-2	PoT-2	10/sec	M	35-40 PSIA
↓	↓	T-2	ToT-2	1/sec	M	164±3°R
↓	↓	T-2	QoT-5	10/sec	S	C/U
↓	↓	T-2	QoT-4	10/sec	C	C/U
↓	↓	L-8	PfS-1	20/sec	M	
↓	↓	L-9	PfS-2	20/sec	↓	
↓	↓	L-8	TfS-1	1/sec	↓	36-40°R
↓	↓	L-9	TfS-2	1/sec	↓	36-40°R
↓	↓	L-3	PoS-1	20/sec	↓	
↓	↓	L-4	PoS-2	20/sec	↓	
↓	↓	L-3	ToS-1	1/sec	↓	164±3°R
S	3	L-4	ToS-2	1/sec	M	164±3°R

Continue to monitor:

S	4		PoL-6	5/sec	M	375-400 PSIA
↓	↓		PoL-7	↓	↓	↓
↓	↓		PfL-7	↓	↓	↓
S	4		PfL-8	5/sec	M	375-400 PSIA

Continue to monitor:

S	5	T-8	PoT-6	1/sec	S	1500 PSIA
↓	↓	T-8	ToT-4	↓	↓	
↓	↓	T-9	PoT-7	↓	↓	1500 PSIA
↓	↓	T-9	ToT-5	↓	↓	
↓	↓	T-10	PfT-6	↓	↓	1500 PSIA
↓	↓	T-10	TfT-4	↓	↓	
↓	↓	T-11	PfT-7	↓	↓	1500 PSIA
S	5	T-11	TfT-5	1/sec	S	

SEPARATION (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		Continue to monitor:				
S	6	G-1	PC-38	1/sec	M	
		G-1	TC-1	1/sec		
		U-1	NT-1	2/sec		
		PT-1	QPTL-1	1/2 sec		
		PT-1	PPTL-1	1/2 sec		
		PT-1	TPTL-1	1/2 sec		
		PT-1	NS-1	1/2 sec		
		G-2	PC-39	1/sec		
		G-2	TC-2	1/sec		
		U-2	NT-2	2/sec		
		PT-2	QPTL-2	1/2 sec		
		PT-2	PPTL-2	1/2 sec		
		PT-2	TPTL-2	1/2 sec		
		PT-2	NS-2	1/2 sec		
		G-3	PC-40	1/sec		
		G-3	TC-3	1/sec		
		U-3	NT-3	2/sec		
		PT-3	QPTL-3	1/2 sec		
		PT-3	PPTL-3	1/2 sec		
		PT-3	TPTL-3	1/2 sec		
S	6	PT-3	NS-3	1/2 sec	M	

ASCENT

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	When:					
A	1	T-1	QoT-2	10/sec	S	UNC
A	1	T-2	QoT-5	10/sec	S	UNC
A	1	T-3	QfT-2	10/sec	S	UNC
	The central computer makes an update of the engine cutoff prediction.					
	In addition to the main engine data, continue to monitor:					
A	2	T-3	PfT-1	10/sec	M	35-40 PSIA
		T-3	TfT-1	1/sec	M	36-40°R
		T-3	QfT-2	10/sec	S	C/U
		T-3	QfT-1	10/sec	C	C/U
		T-1	PoT-1	10/sec	M	35-40 PSIA
		T-1	ToT-1	1/sec	M	164±3°R
		T-1	QoT-2	10/sec	S	C/U
		T-1	QoT-1	10/sec	C	C/U
		T-2	PoT-2	10/sec	M	35-40 PSIA
		T-2	ToT-2	1/sec	M	164±3°R
		T-2	QoT-5	10/sec	S	C/U
		T-2	QoT-4	10/sec	C	C/U
		L-8	PfS-1	20/sec	M	
		L-9	PfS-2	20/sec		
		L-8	TfS-1	1/sec		36-40°R
		L-9	TfS-2	1/sec		36-40°R
		L-3	PoS-1	20/sec		
		L-4	PoS-2	20/sec		
		L-3	ToS-1	1/sec		164±3°R
A	2	L-4	ToS-2	1/sec	M	164±3°R
	3. When the 4g limit is reached, command the main engines to MPL.					
	4. At T + 200 seconds, command the RCS thermal protective doors open.					
	Command and verify:					
A	5	TR-(1-37)	VII-(1-37)	1	S	28 VDC
A	5	TR-(1-37)	IIE-(1-37)	1	S	0 ADC
	Continue to monitor:					
A	6		PoL-6	5/sec	M	375-400 PSIA
			PoL-7			
			PfL-7			
A	6		PfL-8	5/sec	M	375-400 PSIA

ASCENT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Continue to monitor:						
A	7	T-8	PoT-6	1/sec	S	1500 PSIA
		T-8	ToT-4			
		T-9	PoT-7			1500 PSIA
		T-9	ToT-5			
		T-10	PfT-6			1500 PSIA
		T-10	TfT-4			
		T-11	PfT-7			1500 PSIA
A	7	T-11	TfT-5	1/sec	S	
Continue to monitor:						
A	8	G-1	PC-38	1/sec	M	
		G-1	TC-1	1/sec		
		U-1	NT-1	2/sec		
		PT-1	QPTL-1	1/2 sec		
		PT-1	PPTL-1	1/2 sec		
		PT-1	TPTL-1	1/2 sec		
		PT-1	NS-1	1/2 sec		
		G-2	PC-39	1/sec		
		G-2	TC-2	1/sec		
		U-2	NT-2	2/sec		
		PT-2	QPTL-2	1/2 sec		
		PT-2	PPTL-2	1/2 sec		
		PT-2	TPTL-2	1/2 sec		
		PT-2	NS-2	1/2 sec		
		G-3	PC-40	1/sec		
		G-3	TC-3	1/sec		
		U-3	NT-3	2/sec		
		PT-3	QPTL-3	1/2 sec		
		PT-3	PPTL-3	1/2 sec		
		PT-3	TPTL-3	1/2 sec	M	
A	8	PT-3	NS-3	1/2 sec		
When:						
A	9	T-1	QoT-1	10/sec	S	UNC
A	9	T-2	QoT-4	10/sec	S	UNC
A shutdown command is sent to the main engine controllers. (nominally T + 357 sec.)						
Conduct Post-Shutdown monitoring checks on the main engines and verify:						
A	10	V-1	LOIV-1	1	S	Open
		V-2	LOIV-2			Open
		V-3	LOVV-1			Closed
		V-4	LOVV-2			
		V-5	LOVV-3			
		V-6	LOVV-4			
A	10	V-7	LOFV-1	1	S	Closed

ASCENT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
A	10	V-8	LFIV-1	1	S	Open
		V-9	LFIV-2			Open
		V-10	LFTVV-1			Closed
		V-11	LFTVV-2			
		V-12	LFTVV-3			
		V-13	LFTVV-4			
		V-14	LFFV-1			Closed
		V-19	LOPCV-1			Open
		V-20	LOPCV-2			
		V-21	LFPCV-1			
		V-22	LFPCV-2			Open
		V-23	LOIV-3			Closed
		V-24	LOTVV-1			
		V-25	LOTVV-2			
		V-26	LFIV-3			
		V-27	LFIV-4			
		V-28	LFTVV-5			
		V-29	LFTVV-6			
		V-30	LFTVV-7			
		V-31	LFTVV-8			Closed
		V-32	LOPV-1			Open
		V-33	LOPV-2			
		V-34	LFPV-1			
		V-35	LFPV-2			Open
		C-1	LOFC-1			Closed
		C-2	LHC-1, 2			
		C-3	LFTVC-1			
		C-4	LHC-3, 4			
		C-5	LFFC-1			
		C-6	LHC-5, 6			
		C-8	LHC-7, 8			
A	10	C-11	LFVC-1	1	S	Closed

ON-ORBIT

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
0-0	1	V-1	LOIV-1	1	S	Closed
		V-2	LOIV-2			
		V-8	LFIV-1			
0-0	1	V-9	LFIV-2	1	S	Closed

2. Retract the main engine nozzles.

3. Command the main engines secure.

Commence monitoring:

0-0	4	V-1	LOIV-1	1/hr	S	Closed
		V-2	LOIV-2			
		V-3	LOVV-1			
		V-4	LOVV-2			
		V-5	LOVV-3			
		V-6	LOVV-4			
		V-7	LOFV-1			
		V-8	LFIV-1			
		V-9	LFIV-2			
		V-10	LFTVV-1			
		V-11	LFTVV-2			
		V-12	LFTVV-3			
		V-13	LFTVV-4			
		V-14	LFFV-1			
		V-19	LOPCV-1			
		V-20	LOPCV-2			
		V-21	LFPCV-1			
		V-22	LFPCV-2			
		V-23	LOIV-3			
		V-24	LOTVV-1			
		V-25	LOTVV-2			
		V-26	LFIV-3			
		V-27	LFIV-4			
		V-28	LFTVV-5			
		V-29	LFTVV-6			
		V-30	LFTVV-7			
		V-31	LFTVV-8			Closed
		V-32	LOPV-1			Open
		V-33	LOPV-2			
		V-34	LFPV-1			
		V-35	LFPV-2			Open
		C-1	LOFC-1			Closed
		C-2	LHC-1, 2			
		C-3	LFTVC-1			
		C-4	LHC-3, 4			
		C-5	LFFC-1			
		C-6	LHC-5, 6			
		C-8	LHC-7, 8			
0-0	4	C-11	LFVC-1	1/hr	S	Closed

ON-ORBIT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
0-0	4	T-1	PoT-1	1/hr	S	19 PSIA
		T-2	PoT-2			19 PSIA
		T-3	PfT-1			19 PSIA
		L-8	PfS-1			< X
		L-9	PfS-2			
		L-3	PoS-1			
		L-4	PoS-2			
		C-5	PfF-1			
0-0	4	C-1	PoF-1	1/hr	S	<X
	Commence monitoring:					
0-0	5	T-4	PoT-3	1/sec	S	35-40 PSIA
		T-4	ToT-3	1/sec A.R.		164±3°R
		T-4	QoT-7 *	10/sec A.R.		C/U
		T-4	QoT-8 *	10/sec A.R.		C/U
		T-4	QoT-9 *	10/sec A.R.		C/U
		T-5	PfT-2	1/sec		35-40 PSIA
		T-5	TfT-2	1/sec A.R.		36-40°R
		T-5	QfT-4 *	10/sec A.R.		C/U
		T-5	QfT-5 *	10/sec A.R.		C/U
		T-5	QfT-6 *	10/sec A.R.		C/U
		T-6	PfT-3	1/sec		35-40 PSIA
		T-6	TfT-3	1/sec A.R.		36-40°R
		T-6	QfT-7 *	10/sec A.R.		C/U
		T-6	QfT-8 *	10/sec A.R.		C/U
0-0	5	T-6	QfT-9 *	10/sec A.R.	S	C/U
	* While accelerating in the proper attitude.					
	When required to perform an RCS burn, verify:					
0-0	6	TR-X	LBIV-X	1	S	Open
	Initiate igniter spark, verify:					
0-0	7	TR-X	VII-X	1	S	28 VDC
0-0	7	TR-X	IIE-X	1	S	Pulses
	Command and verify:					
0-0	8	TR-X	LIOV-X	1	S	Open
0-0	8	TR-X	PC-X	1	S	
	Command and verify:					
0-0	9	TR-X	LIFV-X	1	S	Open
0-0	9	TR-X	PC-X	1	S	

ON-ORBIT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		For small bit impulses, this would be the end of the thruster start sequence. For larger burns, command and verify:				
O-O	10	TR-X	LMBV-X	1	S	Open
O-O	10	TR-X	PC-X	A.R.	S	
		At steady-state terminate igniter spark, verify:				
O-O	11	TR-X	IIE-X	1	S	0 ADC
		During burn, monitor:				
O-O	12	TR-X	PC-X	10/sec	S	300 PSIA
		To shutdown, command and verify:				
O-O	13	TR-X	LMBV-X	1	S	Closed
↓	↓	TR-X	LIOV-X	↓	↓	Closed
↓	↓	TR-X	LIFV-X	↓	↓	Closed
O-O	13	TR-X	PC-X	1	S	Ambient
		Continue to monitor:				
O-O	14		PoL-6	5/sec	S	375-400 PSIA
↓	↓		PoL-7	↓	↓	↓
↓	↓		PfL-7	↓	↓	↓
O-O	14		PfL-8	5/sec	S	375-400 PSIA
		Continue to monitor:				
O-O	15	T-8	PoT-6	1/sec	C	1500 PSIA
↓	↓	T-8	ToT-4	↓	S	
↓	↓	T-9	PoT-7	↓	C	1500 PSIA
↓	↓	T-9	ToT-5	↓	S	
↓	↓	T-10	PfT-6	↓	C	1500 PSIA
↓	↓	T-10	TfT-4	↓	S	
↓	↓	T-11	PfT-7	↓	C	1500 PSIA
O-O	15	T-11	TfT-5	1/sec	S	
		When:				
O-O	16	T-8	PoT-6	1/sec	C	1500-X PSIA
		Or:				
O-O	17	T-9	PoT-7	1/sec	C	1500-X PSIA
		Verify:				
O-O	18	V-52	LLIV-1	1	S	Open
O-O	18	V-53	LLIV-2	1	S	Open
O-O	18	V-54	LLIV-3	1	S	Open

ON-ORBIT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify:					
O-O	19	V-52	LPSV-1	1	S	Open
O-O	19	V-53	LPSV-2	1	S	Open
O-O	19	V-54	LPSV-3	1	S	Open
	Engage the clutches to P-1, 2, 3.					
	During GO2 resupply, monitor the following additional parameters:					
O-O	20	P-1	PPD-1	2/sec	S	1500 PSIA
		H-4	THE-1	1/2 sec		
		H-4	PHEO-1	1/2 sec		1500 PSIA
		P-2	PPD-2	2/sec		1500 PSIA
		H-5	THE-2	1/2 sec		
		H-5	PHEO-2	1/2 sec		1500 PSIA
		P-3	PPD-3	2/sec		1500 PSIA
		H-6	THE-3	1/2 sec		
O-O	20	H-6	PHEO-3	1/2 sec	S	1500 PSIA
	When:					
O-O	21	T-8	PoT-6	1/sec	C	1500 PSIA
O-O	21	T-9	PoT-7	1/sec	C	1500 PSIA
	Disengage the clutches to P-1, 2, 3.					
	Discontinue resupply monitors.					
	Command and verify:					
O-O	22	V-52	LPSV-1	1	S	Closed
O-O	22	V-53	LPSV-2	1	S	Closed
O-O	22	V-54	LPSV-3	1	S	Closed
	When:					
O-O	23	T-10	PfT-6	1/sec	C	1500-X PSIA
	Or:					
O-O	24	T-11	PfT-7	1/sec	C	1500-X PSIA
	Verify:					
O-O	25	V-55	LFIV-1	1	S	Open
O-O	25	V-56	LFIV-2	1	S	Open
O-O	25	V-57	LFIV-3	1	S	Open

ON-ORBIT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify:					
O-O	26	V-55	LPSV-4	1	S	Open
O-O	26	V-56	LPSV-5	1	S	Open
O-O	26	V-57	LPSV-6	1	S	Open
	Engage the clutches to P-4, 5, 6.					
	During GH2 resupply, monitor the following additional parameters:					
O-O	27	P-4	PPD-4	2/sec	S	1500 PSIA
		H-7	THE-4	1/2 sec		
		H-7	PHEO-4	1/2 sec		1500 PSIA
		P-5	PPD-5	2/sec		1500 PSIA
		H-8	THE-5	1/2 sec		
		H-8	PHEO-5	1/2 sec		1500 PSIA
		P-6	PPD-6	2/sec		1500 PSIA
		H-9	THE-6	1/2 sec		
O-O	27	H-9	PHEO-6	1/2 sec	S	1500 PSIA
	When:					
O-O	28	T-10	PfT-6	1/sec	C	1500 PSIA
O-O	28	T-11	PfT-7	1/sec	C	1500 PSIA
	Disengage clutches to P-4, 5, 6.					
	Discontinue resupply monitors.					
	Command and verify:					
O-O	29	V-55	LPSV-4	1	S	Closed
O-O	29	V-56	LPSV-5	1	S	Closed
O-O	29	V-57	LPSV-6	1	S	Closed
	Continue to monitor:					
O-O	30	G-1	PC-38	1/sec	M	
		G-1	TC-1	1/sec		
		U-1	NT-1	2/sec		
		PT-1	QPTL-1	1/2 sec		
		PT-1	PPTL-1	1/2 sec		
		PT-1	TPTL-1	1/2 sec		
		PT-1	NS-1	1/2 sec		
		G-2	PC-39	1/sec		
		G-2	TC-2	1/sec		
		U-2	NT-2	2/sec		
		PT-2	QPTL-2	1/2 sec		
		PT-2	PPTL-2	1/2 sec		
		PT-2	TPTL-2	1/2 sec		
		PT-2	NS-2	1/2 sec		
O-O	30	G-3	PC-40	1/sec	M	

ON-ORBIT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
0-0	30	G-3	TC-3	1/sec	M	
↓	↓	U-3	NT-3	2/sec	↓	
↓	↓	PT-3	QPTL-3	1/2 sec	↓	
↓	↓	PT-3	PPTL-3	1/2 sec	↓	
↓	↓	PT-3	TPTL-3	1/2 sec	↓	
0-0	30	PT-3	NS-3	1/2 sec	M	
When required to perform an OMS burn, verify:						
0-0	31	TR-1	LBIV-1	1	S	Open
↓	↓	TR-2	LBIV-2	↓	↓	↓
↓	↓	TR-3	LBIV-3	↓	↓	↓
0-0	31	TR-4	LBIV-4	1	S	Open
Initiate igniter spark, verify:						
0-0	32	TR-1	IIE-1	1	S	Pulses
↓	↓	TR-2	IIE-2	↓	↓	↓
↓	↓	TR-3	IIE-3	↓	↓	↓
0-0	32	TR-4	IIE-4	1	S	Pulses
Command and verify:						
0-0	33	TR-1	LIOV-1	1	S	Open
↓	↓	TR-1	PC-1	↓	↓	
↓	↓	TR-2	LIOV-2	↓	↓	Open
↓	↓	TR-2	PC-2	↓	↓	
↓	↓	TR-3	LIOV-3	↓	↓	Open
↓	↓	TR-3	PC-3	↓	↓	
↓	↓	TR-4	LIOV-4	↓	↓	Open
0-0	33	TR-4	PC-4	1	S	
Command and verify:						
0-0	34	TR-1	LIFV-1	1	S	Open
↓	↓	TR-1	PC-1	↓	↓	
↓	↓	TR-2	LIFV-2	↓	↓	Open
↓	↓	TR-2	PC-2	↓	↓	
↓	↓	TR-3	LIFV-3	↓	↓	Open
↓	↓	TR-3	PC-3	↓	↓	
↓	↓	TR-4	LIFV-4	↓	↓	Open
0-0	34	TR-4	PC-4	1	S	
Command and verify:						
0-0	35	TR-1	LMBV-1	1	S	Open
↓	↓	TR-1	PC-1	A.R.	↓	
↓	↓	TR-2	LMBV-2	1	↓	Open
↓	↓	TR-2	PC-2	A.R.	↓	
↓	↓	TR-3	LMBV-3	1	↓	Open
↓	↓	TR-3	PC-3	A.R.	↓	
↓	↓	TR-4	LMBV-4	1	↓	Open
0-0	35	TR-4	PC-4	A.R.	S	

ON-ORBIT (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
		At steady-state Pc, terminate spark, verify:				
0-0	36	TR-1	IIE-1	1	S	OADC
		TR-2	IIE-2			
		TR-3	IIE-3			
0-0	36	TR-4	IIE-4	1	S	OADC
		During burn, monitor:				
0-0	37	TR-1	PC-1	10/sec	S	300 PSIA
		TR-2	PC-2			
		TR-3	PC-3			
0-0	37	TR-4	PC-4	10/sec	S	300 PSIA
		To shutdown, command and verify:				
0-0	38	TR-1	LMBV-1	1	S	Closed
		TR-2	LMBV-2			
		TR-3	LMBV-3			
0-0	38	TR-4	LMBV-4	1	S	Closed
		Command and verify:				
0-0	39	TR-1	LIOV-1	1	S	Closed
		TR-2	LIOV-2			
		TR-3	LIOV-3			
0-0	39	TR-4	LIOV-4	1	S	Closed
		Command and verify:				
0-0	40	TR-1	LIFV-1	1	S	Closed
		TR-2	LIFV-2			
		TR-3	LIFV-3			
		TR-4	LIFV-4			Closed
		TR-1	PC-1			Ambient
		TR-2	PC-2			
		TR-3	PC-3			
0-0	40	TR-4	PC-4	1	S	Ambient
		Commence monitoring:				
0-0	41	LA-1	PZGL-1	1/hr	S	
		LA-2	PZGL-2			
		LA-3	PZGL-3			
		PT-4	QTPL-1			
		PT-5	QTPL-2			
		PT-6	QTPL-3			
		PT-4	PTPL-1			
		PT-5	PTPL-2			
0-0	41	PT-6	PTPL-3	1/hr	S	

DOCKING

1. Continue monitoring the Main Propulsion System as in steps On-Orbit 4, 5.

2. To execute and RCS or OMS burn
   repeat steps On-Orbit (6-13) or (31-40) respectively.

3. Continue to monitor APS gas pressures and temperatures as in steps On-Orbit - 14, 15.

4. To execute resupply of the APS accumulators, perform steps On-Orbit - (16-29).

5. Continue to monitor Propellant Conditioning System operation as in step On-Orbit - 30.

6. Continue to monitor A/B lube pressurization systems as in step On-Orbit - 41.

DOCKED

1. Continue monitoring the Main Propulsion System as in Docking step 1.

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
	Command and verify:					
DD	2	TR-(1-37)	VII-(1-37)	1	S	OVDC
	Command and verify:					
DD	3	TR-(1-37)	LBIV-(1-37)	1	S	Closed

Command the RCS doors closed.

4. Continue to monitor as APS gas pressures and temperatures as in steps On-Orbit - 14, 15.

5. Continue to monitor A/B lube systems as in step On-Orbit -41.

6. Continue operation of the Propellant Conditioning Subsystem until command is received for APU shutdown. Continue monitoring as in Docking step 30 until shutdown. Upon command to shutdown, perform steps P-F-(5-22).

7. The Propellant Conditioning Subsystem will be operated 10 minutes per day while on orbit for hydraulic system conditioning. To perform this operation,or to restart the subsystem prior to undocking, perform steps L-115 through L-138

DOCKED

8. Before undocking, open the RCS doors, and command and verify:

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
DD	9	TR-(1-37)	VII-(1-37)	1	S	28 VDC
and,						
DD	10	TR-(1-37)	LBIV-(1-37)	1	S	Open

DESCENT - Same as Docking

REENTRY

1. Continue monitoring the Main Propulsion System as in steps on-orbit- 4, 5.

2. Secure the RCS and OMS subsystems as in steps Docked - 2, 3.

3. Continue monitoring APS pressures and temperatures as in steps on-orbit - 14, 15.

4. Operate the Propellant Conditioning Subsystem in the resupply mode as in steps on-orbit - (16-29) as required, otherwise monitor as in step on-orbit - 30

Terminate zero-g pressurization of the turbofan lube systems and command readiness checks on the turbofan engines:

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
R	5	FCA-1	LFIV A/B-1	1	R	Closed
		FCA-1	LCPRV-1			Closed
		FCA-1	LSPV-1			Closed
		LA-1	QLO-1			
		FCA-2	LFIV A/B-2			Closed
		FCA-2	LCPRV-2			Closed
		FCA-2	LSPV-2			Closed
		LA-2	QLO-2			
		FCA-3	LFIV A/B-3			Closed
		FCA-3	LCPRV-3			Closed
		FCA-3	LSPV-3			Closed
R	5	LA-3	QLO-3	1	R	

Terminate zero-g pressurization of the A/B Propellant Management Power Train Lube Systems and verify:

R	6	GFV-4	LGFV-4I	1	S	Closed
		GFV-4	LGFV-4			
		GOV-4	LGOV-4I			
		GOV-4	LGOV-4			
		GFV-5	LGFV-5I			
		GFV-5	LGFV-5			
		GOV-5	LGOV-5I			
		GOV-5	LGOV-5			
		GFV-6	LGFV-6I			
		GFV-6	LGFV-6			
		GOV-6	LGOV-6I			
		GOV-6	LGOV-6			
		V-58	LFIV-4			
		V-59	LPSV-7			
		V-60	LFIV-5			
		V-61	LPSV-8			
		V-62	LFIV-6			
R	6	V-63	LPSV-9	1	S	Closed

REENTRY (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
R	6	G-1	VII-41	1	S	OVDC
		G-2	VII-42			↓
		G-3	VII-43			OVDC
		EFV-1	LEFV-1			Closed
		EFV-2	LEFV-2			
		EFV-3	LEFV-3			
		EFV-4	LEFV-4			
		EFV-5	LEFV-5			
		EFV-6	LEFV-6			
		EFV-7	LEFV-7			
		EFV-8	LEFV-8			
		EFV-9	LEFV-9			
		EFV-10	LEFV-10			
		EFV-11	LEFV-11			
		EFV-12	LEFV-12			Closed
			PfL-11			
			PfL-12			
			PfL-13			
		PT-4	QTPL-1			
		PT-5	QTPL-2			
R	6	PT-6	QTPL-3	1	S	

APPROACH & LANDING - (Orbital)

1. Continue to monitor the Main Propulsion System as in steps on-orbit- 4, 5.

2. Continue to monitor APS gas parameters as in step on-orbit - 15.

3. To resupply the APS gas accumulators execute steps on-orbit - (16-29), otherwise monitor the Propellant Conditioning Subsystem parameters as in step on-orbit - 30.

4. Command the A/B engine cradles to be lowered.

5. The A/B Propulsion System is activated and monitored as in Ferry Pre-flight, steps 92 through 136 except that windmilling is the primary mode of start, with solid start cartridges as back-up, instead of ground start GSE.

6. After landing, taxi to the revetment area.

7. Shutdown the A/B Propulsion System as in steps 3 through 23 of Ferry Approach and Landing.

POSTFLIGHT - (Orbital)

1. Tow the Orbiter into the revetment. Chock and tie down.

2. Connect ground power GSE.

3. Execute power transfer.

4. Continue monitoring Propellant Conditioning Subsystem operation as in step on-orbit - 30, until the APU shutdown command is received. Upon receipt of the APU shutdown command, execute steps 5 - 22 of Postflight-Ferry.

5. Take a final status sample of the Main Propulsion System parameters of steps on-orbit - 4, 5.

6. Remove tape and hard copy, if any.
   Debrief crew as required.
   Review in-flight data and fault-isolation output.

7. Connect Drain and Purge GSE and verify as in step 28, Postflight-Ferry, (P-F).

8. Command and verify:

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
P-0	8	V-32	LOPV-1	1	S	Closed
↓	↓	V-33	LOPV-2	↓	↓	↓
↓	↓	V-34	LFPV-1	↓	↓	↓
P-0	8	V-35	LFPV-2	1	S	Closed

Command and verify:

P-0	9	V-36	LOPV-3	1	S	Closed
↓	↓	V-37	LOPV-4	↓	↓	↓
↓	↓	V-38	LOPV-5	↓	↓	↓
↓	↓	V-39	LOPV-6	↓	↓	↓
↓	↓	V-40	LFPV-3	↓	↓	↓
↓	↓	V-41	LFPV-4	↓	↓	↓
↓	↓	V-42	LFPV-5	↓	↓	↓
P-0	9	V-43	LFPV-6	1	S	Closed

10. Perform a purge of the main LH_2 system by executing steps 30 through 40 of Postflight-Ferry.

11. Perform a purge of the main LOX system by executing steps 41 through 52 of Postflight-Ferry.

Command and verify:

P-0	12	V-36	LOPV-3	1	S	Open
↓	↓	V-37	LOPV-4	↓	↓	↓
P-0	12	V-38	LPOV-5	1	S	Open

POSTFLIGHT - (Orbital) (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
P-O	12	V-38	LOPV-5	1	S	Open
		V-39	LOPV-6			
		V-40	LFPV-3			
		V-41	LFPV-4			
		V-42	LFPV-5			
P-O	12	V-43	LFPV-6	1	S	Open
	Command and verify:					
P-O	13	TR-(14-28)	LBIV-(14-28)	1	S	Open
	Command and verify:					
P-O	14	TR-(14-28)	LMBV-(14-28)	1	S	Open
		TR-(14-28)	LIOV-(14-28)			
P-O	14	TR-(14-28)	LIFV-(14-28)	1	S	Open
	After two seconds, command and verify:					
P-O	15	TR-(14-28)	LMBV-(14-28)	1	S	Closed
		TR-(14-28)	LIOV-(14-28)			
P-O	15	TR-(14-28)	LIFV-(14-28)	1	S	Closed
	Command and verify:					
P-O	16	V-38	LOPV-5	1	S	Closed
		V-39	LOPV-6			
		V-42	LFPV-5			
P-O	16	V-43	LFPV-6	1	S	Closed
	Command and verify:					
P-O	17	TR-21	LIOV-21	1	S	Open
P-O	17	TR-21	LIFV-21	1	S	Open
	Until:					
P-O	18		PoL-9	A.R.	C	19PSIA
P-O	18		PfL-10	A.R.	C	19PSIA
	Then, command and verify:					
P-O	19	TR-21	LIOV-21	1	S	Closed
		TR-21	LIFV-21			
P-O	19	TR-(14-28)	LBIV-(14-28)	1	S	Closed
	Command and verify:					
P-O	20	TR-(1-13)	LBIV-(1-13)	1	S	Open
P-O	20	TR-(29-37)	LBIV-(29-37)	1	S	Open

POSTFLIGHT - (Orbital) (Continued)

PHASE	STEP	ELEMENT	MEASUREMENT	SAMPLES	USE	EXPECTED VALUE
Command and verify:						
P-O	21	TR-(1-13)	LMBV-(1-13)	1	S	Open
		TR-(1-13)	LIOV-(1-13)			
		TR-(1-13)	LIFV-(1-13)			
		TR-(29-37)	LMBV-(29-37)			
		TR-(29-37)	LIOV-(29-37)			
P-O	21	TR-(29-37)	LIFV-(29-37)	1	S	Open
After two seconds, command and verify:						
P-O	22	TR-(1-13)	LMBV-(1-13)	1	S	Closed
		TR-(1-13)	LIOV-(1-13)			
		TR-(1-13)	LIFV-(1-13)			
		TR-(29-37)	LMBV-(29-37)			
		TR-(29-37)	LIOV-(29-37)			
P-O	22	TR-(29-37)	LIFV-(29-37)	1	S	Closed
Command and verify:						
P-O	23	V-36	LOPV-3	1	S	Closed
		V-37	LOPV-4			
		V-40	LFPV-3			
P-O	23	V-41	LFPV-4	1	S	Closed
Command and verify:						
P-O	24	TR-1	LIOV-1	1	S	Open
P-O	24	TR-1	LIFV-1	1	S	Open
Until:						
P-O	25		PoL-8	A.R.	C	19PSIA
P-O	25		PfL-9	A.R.	C	19PSIA
Then command and verify:						
P-O	26	TR-1	LIOV-1	1	S	Closed
		TR-1	LIFV-1			
		TR-(1-13)	LBIV-(1-13)			
P-O	26	TR-(29-37)	LBIV-(29-37)	1	S	Closed

27. Purge the gas lines of the Propellant Conditioning Subsystem and A/B Propellant Management Subsystem by executing steps 53-56 of Postflight-Ferry.

28. Purge remaining LH_2 system, less main engines, by executing steps 57-65 of Postflight-Ferry.

POSTFLIGHT - (Orbital) (Continued)

29. Purge remaining LOX system, less main engines, by executing steps 66-69 of Postflight-Ferry.

30. Complete main engine purge.

31. Secure and disconnect the Drain and Purge GSE. Verify propellant coupling status as in step 71 or Postflight-Ferry. Purge complete.

32. Inspect all subsystems for mechanical disorders.

33. Attach covers and install desicants where required.

34. Command RCS doors closed.

35. Secure and verify the MPS isolation valves as in step 72 of Postflight-Ferry.

36. Power down all propulsion systems and OCMS.

37. Input flight data to processing system for trend analysis, performance evaluation, and/or maintenance report.

APPENDIX E

MEASUREMENTS AND SENSORS

TABLE E-I

OCMS MEASUREMENT REQUIREMENTS

EXPLANATION OF COLUMN HEADINGS AND CODES

COLUMN HEADING	DESCRIPTION
1. IDENTITY CODE	The codes in this column relate to the measurement description given in Table E-II.
2. QTY.	The quantity of identical measurements (having identical description and requirements). Quantities indicated are per vehicle stage, except for engine measurements. Quantities for engine measurements are per engine.
3. RANGE & UNITS	The range of measurement and units of measure of the parameter to be measured.
4. ALLOW. ERROR	The allowable overall error between the actual parameter value and the processed data representing that value.
5. RESPONSE RATE	The maximum expected rate of change, time to change state, or frequency of variation of the parameter.
6. MTG.	Mounting of the sensor, or how the sensor is exposed to the forcing function. Codes used are: D - Direct mount. Sensing element directly exposed to the forcing function. CE - Component external. Sensor mounted on the component, with the sensing element indirectly exposed to the forcing function.
7. FLUID MEDIA	Denotes the fluid media, if any, to which the sensing element is exposed.
8. MEAS. TYPE	Relates to the sensor criteria of Table E-III. The sensor criteria associated with each measurement type defines the environment, output signal characteristics, and other requirements related to the physical equipment for transducing the measured parameter to an electrical signal.
9. DATA USE	Designates the end use of the data resulting from the measurement. Where data has more than one use and the time of data activity or sample rate is different for each use, a separate line is used for each. Codes used are: M - Monitor (for failure detection). C - Control

TABLE E-I (con't)

OCMS MEASUREMENT REQUIREMENTS

EXPLANATION OF COLUMN HEADINGS AND CODES

COLUMN HEADING	DESCRIPTION
9. (con't)	R - Readiness or status check. T - Trend data. FI - Fault isolation test. W - Warning of impending failure.
10. TIME OF DATA ACTIVITY	Operation or condition during which the data is meaningful.
11. SAMPLE RATE	The required rate of sampling the measurement during the time of data activity. Sampling rate is based on allowable error, response rate, and use of the data. Codes used are: AR - As required. Indicating one or several samples to be taken whenever the noted condition occurs under "time of data activity". E.O. - Each operation. Indicating one or several samples to be taken each time an operation occurs that would cause the measured parameter to change to a new value and remain at that value. Negl. - Negligibly low sampling rate. Not important to data bus traffic or processing loads. TBD - Sample Rate to be determined by further study.
12. CMPR. MTHD.	Compression Method. This column will contain codes designating the technique to be used for compressing the sampled data. These have not been assigned at this time.
13. DATA RATE	The rate at which data from each measurement will be placed on the data bus during the time of data activity. Data rate will be dependent on sample rate, compression technique, and method of organizing the data in the DIV prior to placing it on the data bus. Data rates have not been assigned at this time.
14. BLANK COLUMN	This column has been reserved for an additional column heading if one is determined to be necessary.

TABLE E-I (con't)

OCMS MEASUREMENT REQUIREMENTS

EXPLANATION OF COLUMN HEADINGS AND CODES

COLUMN HEADING	DESCRIPTION
15. DIU NO.	Indicates the numerical identifications of the DIUs to which the measurement is routed. Present assignments of DIUs in this column are baseline assignments.
16. REMARKS	An asterisk in this column indicates that the remark expands on information contained in another asterisked column on the same line.

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OCMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 4.2, ORB. MAIN PROP. MGMT.

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
PoT-1,2	2	0-50 psia	± 2 psi	20 psi/sec	D	GO_2,GH*	P-1	C	LO_2 Load Pressurization	10/sec				18,19,20	*LO_2 Tank Ullage
								C	Main Engine Burn	1/sec					
								R	Load & Purge	A.R.					
								M	Purge & Blanket Press.	Negl.					
PoL-1,3	2	0-100 psia	± 5 psi	20 psi/sec	D	LO_2	P-2	FI	Low Main Engine Thrust	A.R.				18,19,20	
								R	Load & Purge	A.R.					
PoF-1	1	0-100 psia	± 5 psi	20 psi/sec	D	LO_2	P-2	R	LO_2 Load, Start	A.R.				15,16,17	
								FI	Slow LO_2 Tank Fill	A.R.					
PfT-1	1	0-50 psia	± 2 psi	20 psi/sec	D	LH_2, HE*	P-1	C	LH_2 Load Pressurization	10/sec				18,19,20	*LH_2 Tank Ullage
								C	Main Engine Burn	1/sec					
								M	Purge & Blanket Press.	Negl.					
								R	Load & Purge	A.R.					
PfL-2,3	2	0-100 psia	± 5 psi	20 psi/sec	D	LH_2	P-2	R	Load & Purge	A.R.				18,19,20	
								FI	Low Main Engine Thrust	A.R.					
PfF-1	1	0-100 psia	± 5 psi	20 psi/sec	D	LH_2	P-2	R	LH_2 Load, Start	A.R.				18,19,20	
								FI	Slow LH_2 Tank Fill	A.R.					
ToT-1,2	2	2-700°R	± 5°R	20°/sec	D	GO_2,HE*	T-2	R	Load & Purge	A.R.				18,19,20	*LO_2 Tank Ullage
								FI	PoT-1, or 2 out of limit	A.R.					
								M	System Active	1/sec					
ToL-1,3	2	0-700°R	± 5°R	20°/sec	D	LO_2	T-2	R	Load & Purge	A.R.				18,19,20	
								FI	PoL-1 or 3 out of limit	A.R.					
TfT-1	1	0-700°R	± 5°R	20°/sec	D	GH_2*	T-2	M	System in use	1/sec				18,19,20	*LH_2 Tank Ullage
								FI	PfT-1 out of limit	A.R.					
								R	Load	A.R.					
TfL-2,3	2	0-700°R	± 5°R	20°/sec	D	LH_2	T-2	FI	PfL-2 or 3 out of limit	A.R.				18,19,20	
								R	Load & Purge	A.R.					
QoT-1,4	2	C/U	± .13"	.001 sec	D	LO_2	L-1	C	LO_2 Load	10/sec				18,19,20	
								C	Main Engine Burn*	10/sec					*After QoT-2,5 Uncover
QoT-2,5	2	C/U	± .13"	.001 sec	D	LO_2	L-1	C	LO_2 Load*	10/sec				18,19,20	*After QoT-1,4 Covered
								C	Main Engine Burn	10/sec					
								R	Load	A.R.					
QoT-3,6	2	C/U	± .13"	.001 sec	D	LO_2	L-1	C	LO_2 Load*	10/sec				18,19,20	*After QoT-2,5 Covered
								C	Main Engine Burn	10/sec					
								R	Load	A.R.					
QfT-1	1	C/U	± .13:	.001 sec	D	LH_2	L-1	C	LH_2 Load	10/sec				18,19,20	
								C	Main Engine Burn*	10/sec					*After QfT-2 Uncover
								R	Load	A.R.					

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OCMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 4.2, ORB. MAIN PROP. MGMT.

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
QfT-2	1	C/U	± .13"	.001 sec	D	LH_2	L-1	C	LH_2 Load*	10/sec				18,19,20	*After QfT-1 Covered
								C	Main Engine Burn	10/sec					
								R	Load	A.R.					
QfT-3	1	C/U	± .13:	.001 sec	D	LH_2	L-1	C	LH_2 Load*	10/sec				18,19,20	*After QfT-2 Covered
								C	Main Engine Burn	10/sec					
								R	Load	A.R.					
LOIV-1,2	2	O/C	-	0.5 sec	CE	-	PN-2A	R	Per POS. Status List	A.R.				18,19,20	
								FI	Low Main Eng. Thrust	A.R.					
								T	In-Flight Secure	50/sec					
LOVV-(1-4)	4	O/C	-	0.3 sec	CE	-	PN-2	R	LO_2 Load & Purge	E.O.				18,19,20	
								FI	PoT-1 or 2 out of limit	A.R.					
LOFV-1	1	O/C	-	0.5 sec	CE	-	PN-2A	R	LO_2 Load & Purge	A.R.				15,16,17	
LFIV-1,2	2	O/C	-	0.5 sec	CE	-	PN-2A	R	Per POS. Status List	A.R.				18,19,20	
								FI	Low Main Eng. Thrust	A.R.					
								T	In-Flight Secure	50/sec					
LFTVV-(1-4)	4	O/C	-	0.3 sec	CE	-	PN-2	R	LH_2 Load & Purge	A.R.				15,16,17	
								FI	PfT-1 out of limit	A.R.					
LFFV-1	1	O/C	-	0.5 sec	CE	-	PN-2A	R	LH_2 Load & Purge	A.R.				15,16,17	
LOFC-1	1	O/C	-	-	CE	-	PN-3	R	LO_2 Load & Purge	A.R.				15,16,17	
LHC-1,2	2	O/C	-	-	CE	-	PN-3	R	LH_2 Load & Purge	A.R.				15,16,17	
LFTVC-1	1	O/C	-	-	CE	-	PN-3	R	LH_2 Load & Purge	A.R.				15,16,17	
LFFC-1	1	O/C	-	-	CE	-	PN-3	R	LH_2 Load & Purge	A.R.				15,16,17	
LHC-7,8	2	O/C	-	-	CE	-	PN-3	R	LH_2 Load & Purge	A.R.				15,16,17	
VOIV-1,2	2	0/28 VDC	± 20%	-	-	-	EX-1	FI	LOIV-1 or 2 no-go	A.R.				18,19,20	
VOVV-(1-4)	4	0/28 VDC	± 20%	-	-	-	EX-1	FI	LOVV-(1-4) no-go	A.R.				18,19,20	
VOFV-1	1	0/28 VDC	± 20%	-	-	-	EX-1	FI	LOFV-1 no-go	A.R.				15,16,17	
VFIV-1,2	2	0/28 VDC	± 20%	-	-	-	EX-1	FI	LFIV-1,2 no-go	A.R.				18,19,20	
VFTVV-(1-4)	4	0/28 VDC	± 20%	-	-	-	EX-1	FI	LFTVV-(1-4) no-go	A.R.				15,16,17	
VFFV-1	1	0/28 VDC	± 20%	-	-	-	EX-1	FI	LFFV-1 no-go	A.R.				15,16,17	
PgRL-1	1	0-200 psia	± 2psi	20 psi/sec	D	LO_2,HE	P-3	M	LO_2 Load	1/sec				15,16,17	
								R	Load & Purge	A.R.					
PoS-1,2	2	0-2000 psia	± 2 psi	20 psi/sec	D	LO_2	P-3	M	Boost	20/sec				Eng. Cont.	
								R	Load & Purge	A.R.					
								FI	Low LO2 Pres.	A.R.					
PfS-1,2	2	0-100 psia	± 2 psi	20 psi/sec	D	LH_2	P-2	M	Boost	20/sec				Eng. Cont	
								R	Load & Purge	A.R.					
FOLDOUT FRAME 1								FI	Low LH_2	A.R.				FOLDOUT FRAME 2	

OCMS MEASUREMENT REQUIREMENTS

(Continued)

SUBSYSTEM: 4.2, ORB. MAIN PROP. MGMT.

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
ToS-1,2	2	0-600°R	± 5°	20°/sec	D	LO_2	T-2	R	Load & Purge	A.R.				Eng. Cont.	
								M	Engine Active	1/sec					
								FI	Engine Supply Wrong	A.R.					
TfS-1,2	2	0-600°R	± 5°	20°/sec	D	LH_2	T-2	R	Load & Purge	A.R.				Eng. Cont.	
								FI	Engine Supply Wrong	A.R.					
								M	Engine Active	1/sec					

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OGMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 4.3, Main Pressurization Subsystem

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
PgO-1,2,3	3	0-1200 psia	± 10 psi	500 psi/sec	D	GO_2	P-6A	R	Main Eng. Start/Burn,Ready	A.R.				15,16,17	Autogenous System
								FI	Ullage Pres. Low	A.R.					
PgF-1,2,3,	3	0-1200 psia	± 10 psi	500 psi/sec	D	GH_2	P-6A	R	Main Eng. Start/Burn,Ready	A.R.				15,16,17	Autogenous System
								FI	Ullage Pres. Low	A.R.					
LOPCV-1,2	2	O/C		0.5 sec	CE	GO_2	PN-2A	R	Main Tank Pressurization	E.O.				15,16,17	
								FI	Ullage Pres. Low	A.R.					
LFPCV-1,2	2	O/C		0.5 sec	CE	GH_2	PN-2A	R	Main Tank Pres.	E.O.				15,16,17	
								FI	Ullage Press. Low	A.R.					
LHC-3,4	2	O/C		0.5 sec	CE	HE	PN-2A	R	Load LH	E.O.				15,16,17	
LHC-5,6	2	O/C		0.5 sec	CE	HE	PN-2A	R	Load LO_2	E.O.				15,16,17	
VOPCV-1,2	2	O/28 V	± 20%				EX-1	FI	LOPCV-1,2 Apparent Fail.	A.R.				15,16,17	
VFPCV-1,2	2	O/28 V	± 20%				EX-1	FI	LFPCV-1,2 Apparent Fail.	A.R.				15,16,17	

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OCMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 4.4 On Orbit Propellant Subsystem

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
PoT-3	1	0-50 psia	± 2 psi	20 psi/sec	D	GO_2	P-1	M	Ferry, On-Orbit, Boost	1/sec				18,19,20	
								C	Off-Orbit Vent	E.O.					
								M	Load LO_2	10/sec					
								R	Load & Purge	A.R.					
								FI	Reg. or Filter Fail.	A.R.					Verify Upstream Press.
PfT-2,3	2	0-50 psia	± 2 psi	20 psi/sec	D	GM_2	P-1	M	Ferry, On-orbit, Boost	1/sec				18,19,20	
								C	Off-orbit Vent	E.O.					
								R	Load & Purg	A.R.					
								M	Load LH_2	10/sec					
								FI	Reg. or Filter Fail.	A.R.					Verify Upstream Press.
ToT-3	1	0-700°R	± 5°R	20°R/sec	D	GO_2	T-2	R	Load & Purge	A.R.				18,19,20	
								M	(See PoT-3)						
TfT-2,3	2	0-700°R	± 5°R	20°R/sec	D	GH_2	T-2	M	(See PfT-2,3)					18,19,20	
								R	Load & Purge	A.R.					
QoT-(7-9)	1	C/U	± .13"	.001"/sec	D	LO_2	L-1	C	Load and Boost	10/sec				18,19,20	
								R	Load & Purge	A.R.					
QfT-(4-9)	2	C/U	± .13"	.001"/sec	D	LH_2	L-1	C	Load and Boost	10/sec				18,19,20	
								R	Load & Purge	A.R.					
LOTVV-1,2	2	O/C	-	0.3 sec	CE	GO_2	PN-2	R	Load, Boost, Purge	A.R.				18,19,20	
LFTVV-(5,8)	4	O/C	-	0.3 sec	CE	GH_2	PN-2	R	Load, Boost, Purge	A.R.				18,19,20	
LOIV-3	1	O/C	-	0.5 sec	CE	LO_2	PN-2A	R	Ferry, On-Orbit, Boost	E.O.				18,19,20	
								FI	Low O_2 Supply Press.	A.R.					
LFIV-3,4	2	O/C	-	0.5 sec	CE	LH_2	PN-2A	R	Ferry, On-orbit, Boost	E.O.				18,19,20	
								FI	Low H_2 Supply Press.	A.R.					
LFVC-1	1	O/C	-	0.3 sec	CE	GH_2		R	Load	A.R.				15,16,17	
VOTVV-1,2	2	0/28 V	± 20%				EX-1	FI	LOTVV-1,2 Apparent Fail.	A.R.				18,19,20	
VFTVV-(5,8)	4	0/28 V	± 20%				EX-1	FI	LFTVV-(5,8) Apparent Fail.	A.R.				18,19,20	
VOIV-3	1	0/28 V	± 20%				EX-1	FI	LOIV-3 Apparent Fail.	A.R.				18,19,20	
VFIV-3,4	2	0/28 V	± 20%				EX-1	FI	LFIV-3,4 Apparent Fail.	A.R.				15,16,17	
ToL-2	1	0-700°R	± 5°R	20°R/sec	D	LO_2	T-s	M	Load, Boost	2/sec				18,19,20	
								R	Load & Purge	A.R.					
PoL-2	1	0-50 psia	± 2 psi	20 psi/sec	D	LO_2	P-1	M	Load, Boost	2/sec				18,19,20	
								R	Load & Purge	A.R.					
TfL-1,-4	2	0-700°R	± 5°R	20°R/sec	D	LH_2	T-2	M	Load, Boost	2/sec				18,19,20	
								R	Load & Purge	A.R.					
PfL-1,4	2	0-50 psia	± 2 psi	20 psi/sec		LH_2	P-1	M	Load, Boost	2/sec				18,19,20	FOLDOUT FRAME 2
								R	Load & Purge	A.R.					

FOLDOUT FRAME 1

OCMS MEASUREMENT REQUIREMENTS

(Continued)

SUBSYSTEM: 4.4 On Orbit Propellant Subsystem

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
ToL-4	1	0-700°R	± 5°R	20°R/sec	D	LO_2	T-2	M	Ferry, On-orbit, Boost	1/sec				18,19,20	
								R	Load & Purge	A.R.					
Pol-10	1	0-200 psia	± 10 psi	500 psi/sec	D	GO_2	P-7B	FI	Low O_2 Pressure	A.R.				18,19,20	
								R	Load & Purge	A.R.					
PfL-14	1	0-200 psia	± 10 psi	500 psi/sec	D	GH_2	P-7B	FI	Low H_2 Pressure	A.R.				18,19,20	
								R	Load & Purge	A.R.					
VFPV-(1,4)	4	O/28 V	± 20%				EX-1	FI	LFPV-(1,4)Apparent Fail.	A.R.				18,19,20	
TfL-5	1	0-700°R	± 5°R	20°R/sec	D	GH_2	T-2	FI	LH_2 Supply Failure	A.R.				18,19,20	
								R	Load & Purge	A.R.					
LOPV-1,2	2	O/C		0.5 sec	CE	GO_2	FN-2A	R	Load, Boost, Purge	A.R.				18,19,20	
LFPV-1,2	2	O/C		0.5 sec	CE	GH_2	FN-2A	R	Load, Boost, Purge	A.R.				18,19,20	

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OCMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 5.1 RCS Engine Subsystem

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
PC-(5-13)	9	0-450 psia	± 2 psi	50000 psi/sec	D	Hot Gas	P-4	C	RCS Engine Start	A.R.				4,5,6	
								M	RCS Engine On	20/sec					
PC-(14-28)	15	0-450 psia	± 2 psi	50000 psi/sec	D	Hot Gas	P-4	C	RCS Engine Start	A.R.				1,2,3,	
								M	RCS Engine On	20/sec					
PC-(29-37)	9	0-450 psia	± 2 psi	50000 psi/sec	D	Hot Gas	P-4	C	RCS Engine Start	A.R.				4,5,6,	
								M	RCS Engine On	20/sec					
LBIV-(5-13)	9	O/C	-	0.5 sec	CE	-	PN-2A	R	Load & Purge	A.R.				4,5,6	
								R	Prior to RCS Start-up	E.O.					
LBIV-(14-28)	15	O/C	-	0.5 sec	CE	-	PN-2A	R	Load & Purge	A.R.				1,2,3,	
								R	Prior to RCS Start-up	E.O.					
LBIV-(29-37)	9	O/C	-	0.5 sec	CE	-	PN-2A	R	Load & Purge	A.R.				4,5,6	
								R	Prior to RCS Start-up	E.O					
LMBV-(5-13)	9	O/C	-	0.01 sec	CE	-	PN-6	R	Load & Purge	A.R.				4,5,6	
								R	RCS Full Thrust	E.O.					
LBMV-(14-28)	15	O/C	-	0.01 sec	CE	-	PN-6	R	Load & Purge	A.R.				1,2,3	
								R	RCS Full Thrust	E.O.					
LMBV-(29-37)	9	O/C	-	0.01 sec	CE	-	PN-6	R	Load & Purge	A.R.				4,5,6	
								R	RCS Full Thrust	E.O.					
LIOV-(5-13)	9	O/C	-	0.01 sec	CE	-	PN-6	R	Load & Purge	A.R.				4,5,6	
								R	RCS O_2 Ignition	E.O.					
LIOV-(14-28)	15	O/C	-	0.01 sec	CE	-	PN-6	R	Load & Purge	A.R.				1,2,3	
								R	RCS O_2 Ignition	E.O.					
LIOV-(29-37)	9	O/C	-	0.01 sec	CE	-	PN-6	R	Load & Purge	A.R.				4,5,6	
								R	RCS O_2 Ignition	E.O.					
LIFV-(5-13)	9	O/C	-	0.01 sec	CE	-	PN-6	R	Load & Purge	A.R.				4,5,6	
								R	RCS H_2 Ignition	E.O.					
LIFV-(14-28)	15	O/C	-	0.01 sec	CE	-	PN-6	R	Load & Purge	A.R.				1,2,3	
								R	RCS H_2 Ignition	E.O.					
LIFV-(29-37)	9	O/C	-	0.01 sec	CE	-	PN-6	R	Load & Purge	A.R.				4,5,6	
								R	RCS H_2 Ignition	E.O.					
VBIV-(5-37)	33	0/28 V	± 20%	-			EX-1	FI	LBIV Apparent Failure	A.R.					Diu Same as P.C.
VMBV-(5-37)	33	0/28 V	± 20%	-			EX-1	FI	LMBV Apparent Failure	A.R.					Diu Same as P.C.
VIOV-(5-37)	33	0/28 V	± 20%	-			EX-1	FI	LIOV Apparent Failure	A.R.					Diu Same as P.C.
VIFV-(5-37)	33	0/28 V	± 20%	-			EX-1	FI	LIFV Apparent Failure	A.R.					Diu Same as P.C.
VII-(5-37)	33	0/28 V	± 20%	-			VO-1	R	Load & Purge	A.R.					
								FI	Ignition Failure	A.R.			FOLDOUT FRAME 3		Diu Same as P.C.
FOLDOUT FRAME 4 IIE-(5-37)	33	Pulse		-			CU-1	FI	Ignition Failure	A.R.					Diu Same as P.C.

OCMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 5.2, Propellant Management

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
PoT-4,5	2	0-50 psia	± 1.0psi	20 psi/sec	D	GO_2	P-1B	M	APU Blanket Pressure	1/sec				1,2,3,	For PoT-5
								R	Load & Purge	A.R.					
								FI	Low HE Pressure	A.R.				4,5,6	For PoT-4
PoT-6,7	2	0-2000 psia	±10 psi	1000 psi/sec	D	GO_2	P-7A	M	APU System Loaded	1/sec				1,2,3	For PoT-7
								R	Load & Purge	A.R.					
								FI	Low GO_2 Pressure	A.R.				4,5,6	For PoT-6
PfT-4,5	2	0-50 psia	±1.0 psi	20 psi/sec	D	GH_2	P-1B	M	APU Blanket Pressure	1/sec				1,2,3	For PfT-5
								R	Load & Purge	A.R.					
								FI	Low HE Pressure	A.R.				4,5,6	For PfT-4
PfT-6,7	2	0-2000 psia	±10 psi	1000 psi/sec	D	GH_2	P-7A	M	APU System Loaded	1/sec				1,2,3	For PfT-7
								R	Load & Purge	A.R.					
								FI	Low GH_2 Pressure	A.R.				4,5,6	For PfT-6
PoL-4,5	2	0-2000 psia	±10 psi	1000 psi/sec	D	GO_2	P-7A	FI	Low GO_2 Pressure	A.R.					Diu's as PoT-4,5
PfL-5,6	2	0-2000 psia	±10 psi	1000 psi/sec	D	GH_2	P-7A	FI	Low GH_2 Pressure	A.R.					Diu's as PfT-4,5
PoL-6,7	2	0-600 psia	± 4 psi	1000 psi/sec	D	GO_2	P-6	M	RCS or OMS Active	5/sec				1,2,3	For PoL-7
								R	Load & Purge	A.R.					
								FI	Thruster Supply Low	A.R.				4,5,6	For PoL-6
PfL-7,8	2	0-600 psia	± 4 psi	1000 psi/sec	D	GH_2	P-6	M	RCS or OMS Active	5/sec				1,2,3	For PfL-8
								R	Load & Purge	A.R.					
								FI	Thruster Supply Low	A.R.				4,5,6	For PfL-7
ToT-4,5	2	0-750°R	± 5°	200°/sec	D	GO_2	T-3	M	APU System Loaded	1/sec					Diu's as PoT-4,5
								R	Load & Purge	A.R.					
TfT-4,5	2	0-750°R	± 5°	200°/sec	D	GH_2	T-3	M	APU System Loaded	1/sed					Diu's as PfT-4,5
								R	Load & Purge	A.R.					
LOPV-(3-6)	4	O/C		0.5 sec	CE	GO_2	PN-2A	R	Prior to Thruster Firing	E.O.				1,2,3	For LOPV-(5-6)
								R	Load & Purge	A.R.					
								C	Regulator Failure	A.R.				4,5,6	For LOPV-(3,4)
LFPV-(3-6)	4	O/C		0.5 sec	CE	GH_2	PN-2A	R	Prior to Thruster Firing	E.O.				1,2,3	For LFPV-(5,6)
								R	Load & Purge	A.R.					
								C	Regulator Failure	A.R.				4,5,6	For LFPV-(3,4)
LOFV-2	1	O/C		0.5 sec	CE	GO_2	PN-2A	R	GO_2 Fill	A.R.				15,16,17	
LOFC-2	1	O/C		-	CE	GO_2	PN-3	R	GO_2 Fill	A.R.				15,16,17	
LFFV-2	1	O/C		0.5 sec	CE	GH_2	PN-2A	R	GH_2 Fill	A.R.				15,16,17	
LFFC-2	1	O/C		-	CE	GH_2	PN-3	R	GH_2 Fill	A.R.				15,16,17	
PoL-8,9	2	0-50 psia		20 psi/sec	D	GO_2	PN-3	M	APU Blanket Pressure	1/sec			FOLDOUT FRAME 2	1,2,3	For PoL-9
		FOLDOUT FRAME 1						R	Load & Purge	A.R.					
								FI	Low HE Pressure	A.R.				4,5,6	For PoL-8

OCMS MEASUREMENT REQUIREMENTS

(Continued)

SUBSYSTEM: 5.2. Propellant Management

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
PfL-9,10	2	0-50 psia		20 psi/sec	D	GH_2	PN-3	M'	APU Blanket Pressure	1/sec				1,2,3	For PfL-10
								R	Load & Purge	A.R.					
								FI	Low HE Pressure	A.R.				4,5,6	For PfL-9
VFPV-(3-6)	4	0/28 V	20%				EX-1	FI	Apparent Valve Failure	A.R.					See Valve For Diu
VOPV-(3-6)	4	0/28 V	20%				EX-1	FI	Apparent Valve Failure	A.R.					See Valve For Diu
VOFV-2	1	0/28 V	20%				EX-1	FI	Apparent Valve Failure	A.R.					See Valve For Diu
VFFV-2	1	0/28 V	20%				EX-1	FI	Apparent Valve Failure	A.R.					See Valve For Diu

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OCMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 5.3 ORB. A.P.S. Propel. Conditioning

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
PC-(38-40)	3	0-1000 psia	±5 psi	50K psi/sec	D	Hot Gas	P-5	C	Subsystem Start & Shutdown	A.R.				9,10,11	Each to Separate Diu
								M	Susystem Operation	1/sec					
PPTL-(1-3)	3	0-100 psig	± 1 psi	20 psi/sec	D	Oil	P-2A	M	Subsystem Operation	1/2 sec				9,10,11	Each to Separate Diu
								R	G.G. Startup	A.R.					
PPD-(1-3)	3	0-2000 psia	±10 psi	1500 psi/sec	D	LO_2	P-7	M	GO_2 Accum Resupply	2/sec				9,10,11	Each to Separate Diu
PPD-(4-6)	3	0-2000 psia	±10 psi	1500 psi/sec	D	LH_2	P-7	M	GH_2 Accum Resupply	2/sec				9,10,11	Each to Separate Diu
TC-(1-3)	3	0-2500°R	± 20°	200°/sec	D	Hot Gas	T-7	M	Subsystem Operation	1/sec				9,10,11	Each to Separate Diu
								R	G.G. Startup	A.R.					
TPTL-(1-3)	3	0-1300°R	± 10°	20 °/sec	D	Oil	T-5	M	Subsystem Operation	1/2 sec				9,10,11	Each to Separate Diu
								R	G.G. Startup	A.R.					
QPTL-(1-3)	3	0-6 inches	± .125"	12 in/sec	D	Oil	L-2	M	Subsystem Operation	1/2 sec				9,10,11	Each to Separate Diu
								R	G.G. Startup	A.R.					
NT-(1-3)	3	0-100K RPM	± 500	10K RPM/sec	D	-	SP-1	C	Subsystem Start-up	A.R.				9,10,11	Each to Separate Diu
								M	Subsystem Operation	2/sec					
LGOV-(1I-3I)	3	O/C	-	0.5 sec	CE	-	PN-2A	R	Subsystem Readiness	E.O.				9,10,11	Each to Separate Diu
								R	Load & Purge	A.R.					
								FI	PC-(38-40) Out of Limit	A.R.					
LGFV-(1I-3I)	3	O/C	-	0.5 sec	CE	-	PN-2A	R	Subsystem Readiness	E.O.				9,10,11	Each to Separate Diu
								R	Load & Purge	A.R.					
								FI	PC-(38-40) Out of Limit	A.R.					
LGOV-(1-3)	3	O/C	-	0.1 sec	CE	-	PN-6	C	Subsystem Start & Shutdown	E.O.				9,10,11	Each to Separate Diu
								R	Load & Purge	A.R.					
								FI	PC-(38-40) Out of Limit	A.R.					
LGFV-(1-3)	3	O/C	-	0.1 sec	CE	-	PN-6	C	Subsystem Start & Shutdown	E.O.				9,10,11	Each to Separate Diu
								R	Load & Purge	A.R.					
								FI	PC-(38-40) Out of Limit	A.R.					
LIOV-(38-40)	3	O/C	-	0.1 sec	CE	-	PN-6	C	Subsystem Start & Shutdown	E.O				9,10,11	Each to Separate Diu
								FI	PC-(38-40) Out of Limit	A.R.					
LIFV-(38-40)	4	O/C	-	0.1 sec	CE	-	PN-6	C	Subsystem Start & Shutdown	E.O.				9,10,11	Each to Separate Diu
								FI	PC-(38-40) Out of Limit	A.R.					
LLIV-(1-3)	3	O/C	-	0.5 sec	CE	-	PN-2A	R	Purge & GO_2 Resupply&Load	A.R.				9,10,11	Each to Separate Diu
								FI	PPD-(1-3) Out of limit	A.R.					
LFIV-(1-3)	3	O/C	-	0.5 sec	CE	-	PN-2A	R	Purge & GH_2 Resupply	A.R.				9,10,11	Each to Separate Diu
								FI	PPD-(4-6) Out of Limit	A.R.					
LPSV-(1-3)	3	O/C	-	0.5 sec	CE	-	PN-2A	R	Purge & Resupply & Load	A.R.				9,10,11	Each to Separate Diu
								C	GO_2 Resupply	E.O.					
								FI	PPD-(1-3) Out of Limit	A.R.					

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OCMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 5.3 ORB. A.P.S. Propel. Conditioning

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MFG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE			DIU NO.	REMARKS
LPSV-(4-6)	3	O/C	-	0.5 sec	CE	-	PN-2A	R	Purge & Load	A.R.					9,10,11	Each to Separate Diu
								C	GH_2 Resupply	E.O.						
								FI	PPD-(4-6) Out of Limit	A.R.						
VGOV-(1I-3I)	3	0/28 VDC	± 20%	-	-	-	EX-1	FI	LGOV-(1I-3I) No-go	A.R.					9,10,11	Each to Separate Diu
VGFV-(1I-3I)	3	0/28 VDC	± 20%	-	-	-	EX-1	FI	LGFV-(1I-3I) no-go	A.R.					9,10,11	Each to Separate Diu
VGOV-(1-3)	3	0/28 VDC	± 20%	-	-	-	EX-1	FI	LGOV-(1-3) no-go	A.R.					9,10,11	Each to Separate Diu
VII-(38,40)	3	0/28 VDC	± 20%	-	-	-	EX-1	R	Load & Purge	A.R.					9,10,11	Each to Separate Diu
IIE-(38,40)	3	Pulse	-	-	-	-	CU-1	R	G.G. Start	A.R.					9,10,11	Each to Separate Diu
VIOV-(38-40)	3	0/28 VDC	± 20%	-	-	-	EX-1	FI	LIOV-(38-40) no-go	A.R.					9,10,11	Each to Separate Diu
VIFV-(38-40)	3	0/28 VDC	± 20%	-	-	-	EX-1	FI	LIFV-(38-40) no-go	A.R.					9,10,11	Each to Separate Diu
VLIV-(1-3)	3	0/28 VDC	± 20%	-	-	-	EX-1	FI	LLIV-(1-3) no-go	A.R.					9,10,11	Each to Separate Diu
VFIV-(1-3)	3	0/28 VDC	± 20%	-	-	-	EX-1	FI	LFIV-(1-3) no-go	A.R.					9,10,11	Each to Separate Diu
VOSV-(1-3)	3	0/28 VDC	± 20%	-	-	-	EX-1	FI	LPSV-(1-3) no-go	A.R.					9,10,11	Each to Separate Diu
VPSV-(4-6)	3	0/28 VDC	± 20%	-	-	-	EX-1	FI	LPSV-(1-4) no-go	A.R.					9,10,11	Each to Separate Diu
NP-(1-3)	3	0-100K RPM	± 500	10K RPM/sec	D	-	SP-1A	FI	PPD-(1-3) Out of Limit	A.R.					9,10,11	Each to Separate Diu
AT-(1-3)	3	0-5g	± .05g	0-5000 Hz	CE	-	V-1	T	Subsystem Operation	*					9,10,11	*Analog Recording
AP-(1-3)	3	0-5g	± .05g	0-5000 Hz	CE	-	V-1	T	GO_2 Resupply	*					9,10,11	*Analog Recording
AP-(4-6)	3	0-5g	± .05g	0-5000 Hz	CE	-	V-1	T	GH_2 Resupply	*					9,10,11	*Analog Recording
TPB-(1-3)	3	30-1000°R	± 10°	20 deg/sec	D	LO_2,GO_2	T-4	T	GO_2 Resupply	1/2 sec					9,10,11	Each to Separate Diu
TPB-(4-6)	3	30-1000°R	± 10°	20 deg/sec	D	LH_2,GH_2	T-4	T	GH_2 Resupply	1/2 sec					9,10,11	Each to Separate Diu
TPTB-(1-3)	3	400-1000°R	± 10°	20 deg/sec	D	Oil	T-5	T	Subsystem Operation	1/2 sec					9,10,11	Each to Separate Diu
NS-(1-3)	3	0-100K RPM	± 500	10K RPM/sec	CE	-	SP-1A	M	APU Operation	1/2 sec					9,10,11	Each to Separate Diu
AC-(1-3)	3	0-5g	± 0.5g	0-5000 Hz	CE	-	V-1	T	GO_2 Resupply	*					9,10,11	*Analog Recording
AC-(4-6)	3	0-5g	± 0.5g	0-5000 Hz	CE	-	V-1	T	GH_2 Resupply	*					9,10,11	*Analog Recording
AC-(7-9)	3	0-5g	± 0.5g	0-5000 Hz	CE	-	V-1	T	APU Operation	*					9,10,11	*Analog Recording
THE-(1-3)	3	400-750°R	± 5°	200 Deg/sec	D	GO_2	T-3	M	GO_2 Resupply	1/2 sec					9,10,11	Each to Separate Diu
THE-(4-6)	3	400-750°R	± 5°	200 deg/sec	D	GH_2	T-3	M	GH_2 Resupply	1/2 sec					9,10,11	Each to Separate Diu
NP-(4-6)	3	0-100K RPM	± 500	10K RPM/sec	D	-	SP-1A	FI	PPD-(4-6) Out of Limit	A.R.					9,10,11	Each to Separate Diu
PHEO-(1-3)	3	0-1500 psia	±10 psi	1500 psi/sec	D	GO_2	P-7	M	GO_2 Resupply	1/2 sec					9,10,11	Each to Separate Diu
PHEO-(4-6)	3	0-1500 psia	±10 psi	1500 psi/sec	D	GH_2	P-7	M	GH_2 Resupply	1/2 sec					9,10,11	Each to Separate Diu
	FOLDOUT FRAME 1														FOLDOUT FRAME 2	

OCMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 5.4, OMS Engine

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
PC-(1-4)	4	0-450 psia	± 2 psi	50,000 psi/sec	D	Hot Gas	P-4	C	OMS Engine Start	A.R.				7, 8	
								M	OMS Engine On	20/sec					
LBIV-(1-4)	4	O/C	-	0.5 sec	CE	-	PN-2A	R	Load & Pruges, Prior to	A.R.				7, 8	
									RCS Start up						
LMBV-(1-4)	4	O/C	-	0.01 sec	CE	-	PN-6	R	OMS Full Thrust,Load&Purge	A.R.				7,8	
LIOV-(1-4)	4	O/C	-	0.01 sec	CE	-	PN-6	R	OMS Ignition, Load & Purge	A.R.				7, 8	
LIFV-(1-4)	4	O/C	-	0.01 sec	CE	-	PN-6	R	OMS Ignition, Load & Purge	A.R.				7, 8	
VBIV-(1-4)	4	0/28 V	20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				7, 8	
VMBV-(1-4)	4	0/28 V	20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				7, 8	
VIOV-(1-4)	4	0/28 V	20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				7, 8	
VIFV-(1-4)	4	0/28 V	20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				7, 8	
VII-(1-4)	4	0/28 V	20%	-	-	-	VO-1	FI	Ignition Failure	A.R.				7, 8	
								R	Load & Purge	A.R.					
IIE-(1-4)	4	Pulse		-	-	-	CU-1	FI	Ignition Failure	A.R.				7, 8	

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OCMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 3.1, 6.1, Airbreathing Engine

IDENTITY CODE	* QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE			DIU NO.	REMARKS
PfCCI	1	0-60 psia	±.5 psi	20 psi/sec	D	GH_2	P-1-TF	FI	Engine Malfunction	A.R.					Eng. Cont.	
PLPD	1	0-100 psia	±.5 psi	20 psi/sec	D	Lube	P-2A-TF	M	Engine Active	5/sec					Eng. Cont.	
								R	Engine Startup	A.R.						
								FI	Engine Malfunction	A.R.						
PSPD	1	0-100 psia	±.5 psi	20 psi/sec	D	Lube	P-2A-TF	M	Engine Active	5/sec					Eng. Cont.	
								R	Engine Startup	A.R.						
								FI	Engine Malfunction	A.R.						
PG	1	0-100 psia	±.5 psi	20 psi/sec	D	Lube	P-2A-TF	M	Engine Active	5/sec					Eng. Cont.	
								FI	Engine Malfunction	A.R.						
PFI	1	0-20 psia	±.5 psi	20 psi/sec	D	Air	P-1C-TF	C*	Engine Active	100/sec					Eng. Cont.	*Gas Path Analysis
PHPT	1	0-200 psia	± 5 psi	20 psi/sec	D	Hot Gas	P-3A-TF	C*	Engine Active	100/sec					Eng. Cont.	*Gas Path Analysis
PED	1	0-150 psia	± 2 psi	20 psi/sec	D	Hot Gas	P-3B-TF	C*	Engine Active	100/sec					Eng. Cont.	*Gas Path Analysis
PDVDVP	1	0-200 psia	± 4 psi	20 psi/sec	D	LH_2	P-3C-TF	C*	Engine Active	100/sec					Eng. Cont	*Gas Path Analysis
								R	Engine Startup	A.R.						
								FI	Engine Malfunction	A.R.						
TfCCI	1	0-600°R	± 10°R	20°/sec	D	GH_2	T-2-TF	FI	Engine Malfunction	A.R.					Eng. Cont.	
TSPD	1	0-1000°F	± 20°F	20°/sec	D	Lube	T-5A-TF	M	Engine Active	5/sec					Eng. Cont.	
								R	Engine Startup	A.R.						
								FI	Engine Malfunction	A.R.						
TIA	1	0-1000°R	± 20°R	20°/sec	D	Air	T-4A-TF	C*	Engine Active	100/sec					Eng. Cont.	*Gas Path Analysis
THPT	1	0-2500°R	± 40°R	20°/sec	D	Hot Gas	T-7A-TF	C*	Engine Active	100/sec					Eng. Cont.	*Gas Path Analysis
TLPTD	1	0-2500°R	± 40°R	20°/sec	D	Hot Gas	T-7A-TF	C*	Engine Active	100/sec					Eng. Cont.	*Gas Path Analysis
TED	1	0-2500°R	± 40°R	20°/sec	D	Hot Gas	T-7A-TF	C*	Engine Active	100/sec					Eng. Cont.	*Gas Path Analysis
TCI	1	0-2500°R	± 20°R	20°/sec	D	Hot Gas	T-7A-TF	C*	Engine Active	100/sec					Eng. Cont.	*Gas Path Analysis
TTB	1	0-1500°R	± 20°R	20°/sec	D	Hot Gas	T-5B-TF	M	Engine Active	25/sec					Eng. Cont.	
								R	Engine Start/Shutdown	A.R.						
TFH	1	0-600°R	± 10°R	20°/sec	D	GH_2	T-2-TF	FI	Engine Active	A.R.					Eng. Cont.	
FfF	1	0-20 lb/sec	±.5 lb/s	15 lb/sec^2	D	GH_2	FR-1A-TF	C*	Engine Active	100/sec					Eng. Cont.	*Gas Path Analysis
								R	Engine Start-Stop	A.R.						
QLO	1	0-1 ft	±.03 ft	20 ft/sec	D	Oil	L-2A-TF	M	Engine Active	5/sec					Eng. Cont.	
								R	Engine Start-Stop	A.R.						
NHPT	1	0-15000 rpm	± 50 rpm	5000 rpm/sec	CE	-	SP-3-TF	C*	Engine Active	100/sec					Eng. Cont	*Gas Path Analysis
NF	1	0-15000 rpm	± 50 rpm	1000 rpm/sec	CE	-	SP-3TF	C*	Engine Active	100/sec					Eng. Cont.	*Gas Path Analysis
NVDVP	1	0-20000 rpm	± 50 rpm	1000 rpm/sec	CE	-	SP-3-TF	M	Engine Active	10/sec					Eng. Cont.	
								R	Engine Start-Stop							
AFFB	1	0-5 g	±0.5 g	0-3000 HZ	CE	-	V-1A-TF	T	Engine Active	*					Eng. Cont.	*Analog Recording
AFCB	1	0-5 g	±0.5 g	0-3000 HZ	CE	-	V-1A-TF	T	Engine Active	*					Eng. Cont.	*Analog Recording

*Per Engine

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OCMS MEASUREMENT REQUIREMENTS

(Continued)

SUBSYSTEM: 3.1, 6.1, Airbreathing Engine

IDENTITY CODE	* QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
ALPRB	1	0-5 g	±0.5 g	0-3000 HZ	CE	-	V-1A-TF	T	Engine Active	*				Eng. Cont.	*Analog Recording
LFIVA/B	1	O/C	-	0.1 sec	CE	-	PN-5-TF	C	Engine Start/Shutdown	A.R.				Eng. Cont.	
LSPV	1	O/C	-	0.1 sec	CE	-	PN-5-TF	C	Engine Start/Shutdown	A.R.				Eng. Cont.	
VFIVA/B	1	0/28 V	-	-	-	-	EX-1-TF	FI	Apparent Valve Failure	A.R.				Eng. Cont.	
VSPV	1	0/28 V	-	-	-	-	EX-1-TF	FI	Apparent Valve Failure	A.R.				Eng. Cont.	
VC	1	0/28 V	-	-	-	-	EX-1A-TF	FI	Engine Malfunction	A.R.				Eng. Cont.	
VIIA/B	1	0/28 V	-	-	-	-	VO-1-TF	FI	Ignition Failure	A.R.				Eng. Cont.	
								R	Engine Start	A.R.				Eng. Cont.	
VIEO	1	TBD	-	-	-	-	VO-2-TF	FI	Ignition Failure	A.R.				Eng. Cont.	
VFH	1	0/28 V	-	-	-	-	VO-3-TF	M	Engine Active	10/sec				Eng. Cont.	
								R	Engine Start-Stop						
								FI	Engine Malfunction	A.R.					
III	1	TBD	-	-	-	-	CU-3-TF	FI	Ignition Failure	A.R.				Eng. Cont.	
								R	Engine Start	A.R.					
IFH	1	TBD	-	-	-	-	CU-4-TF	M	Engine Active	1/sec				Eng. Cont.	
								FI	Heater Malfunction	A.R.					
								R	Engine Start	A.R.					
FLB	1	on/off	-	0.1 sec	D	Hot Gas	FL-1-TF	C	Engine Start	A.R.					
								M	Engine Shutdown	10/sec					
FIC	1	TBD	-	-	D		FL-1-TF	FI	Engine Malfunction	A.R.				Eng. Cont.	
ACEC	1	30 to 160 db	± 2 db	50 HZ to 10KHZ	D		AC-1-TF	T	Engine Active	*				Eng. Cont.	*Analog Recording
LCPRV	1	O/C	-	0.1 sec	CE		PN-5-TF	R	Engine Start	A.R.				Eng. Cont.	
PZGL	1	0-100 psia	±.5 psi	20 psi/sec	D	Lube	P-2A-TF	R	Zero G Engine Lube P	A.R.				Eng. Cont.	

*Per Engine

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OCMS MEASUREMENT REQUIREMENTS

SUBSYSTEM: 6.2, A/B Prop. Management

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
PPD-(7-9)	3	0-100 psia	± 2 psi	20 psi/sec	D	LH_2	P-2	M	A/B System Active	5/sec				12,13,14	
								R	Engine Start	A.R.					
								FI	Low LH_2 Supply Pres.	A.R.					
PC-(41-43)	3	0-1000 psia	± 5 psi	5000 psi/sec	D	Hot Gas	P-5	C	Gas Gen. Start-up	A.R.				12,13,14	
								M	A/B System Active	10/sec					
								FI	Low LH_2 Supply Pres.	A.R.					
PfL-(11-13)	3	0-60 psia	± 2 psi	20 psi/sec	D	LH_2	P-1	C	A/B Eng. Start OK	A.R.				12,13,14	
								R	Load & Purge	A.R.					
								M	A/B System Active	5/sec					Also Input to Eng. Controller
								FI	A/B Engine Failure	A.R.					
PTPL-(1-3)	3	0-100 psig	± 1 psi	20 psi/sec	D	Lube	P-2A	M	G.G. Running	1/2 sec				12,13,14	
								R	Engine Start	A.R.					
								FI	G.G. Failure	A.R.					
TC-(4-6)	3	0-2500°R	± 20°	200°/sec	D	Hot Gas	T-7	M	G.G. Running	1/sec				12,13,14	
								FI	G.G. Failure	A.R.					
TfL-(6-8)	3	0-100°R	± 5°	10°/sec	D	LH_2	T-1	C	A/B Eng. Start OK	A.R.				12,13,14	
								R	A/B Eng. Start	A.R.					Also Input to Eng. Controller
								M	A/B System Active	5/sec					
								FI	A/B Eng. Failure	A.R.					
TTPL-(1-3)	3	0-1300°R	± 10°	20°/sec	D	Lube	T-5	M	G.G. Running	1/2 sec				12,13,14	
								R	Engine Start	A.R.					
								FI	G.G. Failure						
QTPL-(1-3)	3	0-6 inches	± 1/8"	-	D	Lube	L-2	M	G.G. Running	1/2 sec				12,13,14	
								R	Engine Start	A.R.					
								FI	G.G. Failure	A.R.					
NT-(4-6)	3	0-100,000rpm	± 500	1000/sec	CE	-	SP-1	M	G.G. Running	5/sec				12,13,14	
								R	Engine Start	A.R.					
								FI	G.G. or Turbine Failure	A.R.					
LGFV-(4I-6I)	3	O/C	-	0.5 sec	CE	-	PN-2A	R	A/B System Start-up & Load	A.R.				12,13,14	
LGFV-(4-6)	3	O/C	-	0.5 sec	CE	-	PN2A	R	A/B System Start-up & Load	A.R.				12,13,14	
LGOV-(4I-6I)	3	O/C	-	0.5 sec	CE	-	PN-2A	R	A/B System Start-up & Load	A.R.				12,13,14	
LGOV-(4-6)	3	O/C	-	0.5 sec	CE	-	PN-2A	R	A/B System Start-up & Load	A.R.				12,13,14	
LFIV-(4-6)	3	O/C	-	0.2 sec	CE	-	PN-4	R	A/B System Start-up & Load	A.R.				12,13,14	
LPSV-(7-9)	3	O/C	-	0.2 sec	CE	-	PN-4	R	A/B System Start-up & Load	A.R.				12,13,14	
LEFV-(1-12)	12	O/C	-	0.2 sec	CE	-	PN-4	R	A/B System Start-up & Load	A.R.				12,13,14	
VGFV-(4I-6I	3	O/28 V	± 20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				12,13,14	
VGFV-(4-6)	3	O/28 V	± 20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				12,13,14	

FOLDOUT FRAME 1

FOLDOUT FRAME 2

OCMS MEASUREMENT REQUIREMENTS

(Continued)

SUBSYSTEM: 6.2, A/B Prop. Management

IDENTITY CODE	QTY.	RANGE & UNITS	ALLOW. ERROR	RESPONSE RATE	MTG.	FLUID MEDIA	MEAS. TYPE	DATA USE	TIME OF DATA ACTIVITY	SAMPLE RATE	CMPR. MTHD.	DATA RATE		DIU NO.	REMARKS
VGOV-(4I-6I)	3	0/28 V	± 20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				12,13,14	
VGOV-(4-6)	3	0/28 V	± 20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				12,13,14	
VFIV-(4-6)	3	0/28 V	± 20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				12,13,14	
VPSV-(7-9)	3	0/28 V	± 20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				12,13,14	
VEFV-(1-12)	12	0/28 V	± 20%	-	-	-	EX-1	FI	Apparent Valve Failure	A.R.				12,13,14	
VII-(41-43)	3	0/28 V	± 20%	-	-	-	VO-1	R	G.G. Start-up	E.O.				12,13,14	
VIEO-(4-6)	3	TED		-	-	-	VO-2	FI	G.G. Start-up	A.R.				12,13,14	
IIE-(41-43)	3	TED	-	-	-	-	CU-2	R	Engine Start	A.R.				12,13,14	
								FI	Igniter Failure	A.F.					
AT-(4-6)	3	0.5 g	± 0.5 g	0-5000 HZ	CE	-	V-1	M*	Turbine Running						*Analog Recording
AP-(7-9)	3	0.5 g	± 0.5 g	0-5000 HZ	CE	-	V-1	M*	Pump Running						*Analog Recording

FOLDOUT FRAME 1

FOLDOUT FRAME 2