INDEPENDENT ORBITER ASSESSMENT

ANALYSIS OF THE ELECTRICAL POWER GENERATION/FUEL CELL POWERPLANT SUBSYSTEM

5 DECEMBER 1986

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
HOUSTON DIVISION

SPACE TRANSPORTATION SYSTEM ENGINEERING AND OPERATIONS SUPPORT

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INDEPENDENT ORBITER ASSESSMENT ANALYSIS OF THE ELECTRICAL POWER GENERATION/FUEL CELL POWERPLANT SUBSYSTEM

5 December 1986

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1.0 EXECUTIVE SUMMARY

The McDonnell Douglas Astronautics Company (MDAC) was selected in June 1986 to perform an Independent Orbiter Assessment (IOA) of the Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL). Direction was given by the STS Orbiter and GFE Projects Office to perform the hardware analysis using the instructions and ground rules defined in NSTS 22206, Instructions for Preparation of FMEA and CIL, 10 October 1986. The IOA approach features a top-down analysis of the hardware to determine failure modes, criticality, and potential critical items. To preserve independence, this analysis was accomplished without reliance upon the results contained within the NASA FMEA/CIL documentation. This report documents (Appendix C) the independent analysis results corresponding to the Orbiter Electrical Power Generation (EPG)/Fuel Cell Powerplant (FCP) hardware.

The EPG/FCP hardware is required for performing functions of electrical power generation and product water distribution in the Orbiter. Specifically, the EPG/FCP hardware consists of the following divisions:

- o Power Section Assembly (PSA)
- o Reactant Control Subsystem (RCS)
- o Thermal Control Subsystem (TCS)
- o Water Removal Subsystem (WRS)

The IOA analysis process utilized available EPG/FCP hardware drawings and schematics for defining hardware assemblies, components, and hardware items. Each level of hardware was evaluated and analyzed for possible failure modes and effects. Criticality was assigned based upon the severity of the effect for each failure mode.

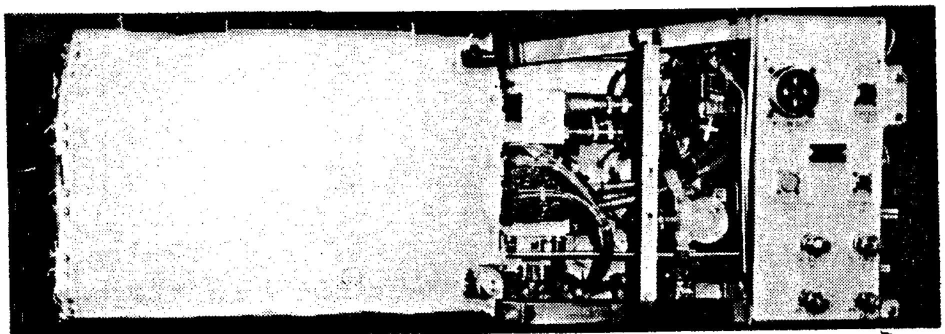
Figure 1 presents the failure criticalities for the four major divisions of the two FCP assemblies. A summary of the number of failure modes, by criticality, is also presented below with Hardware (HW) criticality first and Functional (F) criticality second.

Summary of IOA Failure Modes By Criticality (HW/F)							
Criticality:	1/1	2/1R	2/2	3/1R	3/2R	3/3	TOTAL
Number :	3	26	-	10	4	19	62

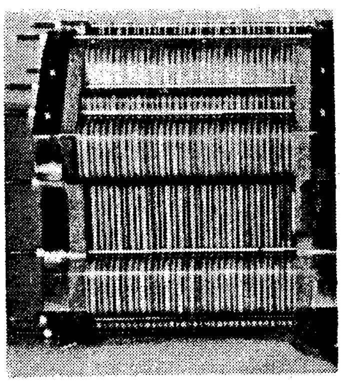
EPG/FCP OVERVIEW ANALYSIS SUMMARY

EPG/FCP ANALYSIS SUMMARY

CRIT	#FM	#PCI	CRIT	#FM	#PCI
1/1	3	3	3/2R	4	3
2/1R	26	26	3/3	19	NA
3/1R	10	0			



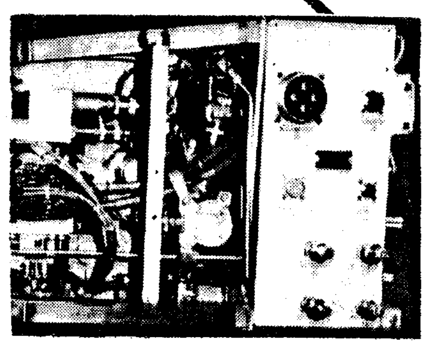
POWER SECTION



POWER SECTION ASSEMBLY

CRIT	#FM	#PCI
1/1	2	2
2/1R	5	5
3/3	1	NA

ASSESSORY SECTION



REACTANT CONTROL SUBSYSTEM

CRIT	#FM	#PCI
1/1	1	1
2/1R	7	7
3/1R	3	0
3/3	6	NA

THERMAL CONTROL SUBSYSTEM

CRIT	#FM	#PCI
2/1R	5	5
3/1R	2	0
3/3	4	NA

WATER REMOVAL SUBSYSTEM

CRIT	#FM	#PCI
2/1R	9	9
3/1R	4	0
3/2R	4	3
3/3	9	NA

CRIT - CRITICALITY
FM - FAILURE MODE
PCI - POTENTIAL CRITICAL ITEM
NA - NOT APPLICABLE

Figure 1 - EPG/FCP OVERVIEW ANALYSIS SUMMARY

For each failure mode identified, the criticality and redundancy screens were examined to identify critical items. A summary of Potential Critical Items (PCIs) is presented as follows:

Summary of IOA Potential Critical Items (HW/F)						
Criticality:	1/1	2/1R	2/2	3/1R	3/2R	TOTAL
Number :	3	26	-	-	3	32

2.0 INTRODUCTION

2.1 Purpose

The 51-L Challenger accident prompted the NASA to readdress safety policies, concepts, and rationale being used in the National Space Transportation System (NSTS). The NSTS Office has undertaken the task of reevaluating the FMEA/CIL for the Space Shuttle design. The MDAC is providing an independent assessment of the Orbiter FMEA/CIL for completeness and technical accuracy.

2.2 Scope

The scope of the independent FMEA/CIL assessment activity encompasses those Shuttle Orbiter subsystems and GFE hardware identified in the Space Shuttle Independent FMEA/CIL Assessment Contractor Statement of Work. Each subsystem analysis addresses hardware, functions, internal and external interfaces, and operational requirements for all mission phases.

2.3 Analysis Approach

The independent analysis approach is a top-down analysis utilizing as-built drawings to breakdown the respective subsystem into components and low-level hardware items. Each hardware item is evaluated for failure mode, effects, and criticality. These data are documented in the respective subsystem analysis report, and are used to assess the NASA and Prime Contractor FMEA/CIL reevaluation results. The IOA analysis approach is summarized in the following Steps 1.0 through 3.0. Step 4.0 summarizes the assessment of the NASA and Prime Contractor FMEAs/CILs that is performed and documented at a later date.

Step 1.0 Subsystem Familiarization
- 1.1 Define subsystem functions
- 1.2 Define subsystem components
- 1.3 Define subsystem specific ground rules and assumptions

Step 2.0 Define subsystem analysis diagram
- 2.1 Define subsystem
- 2.2 Define major assemblies
- 2.3 Develop detailed subsystem representations

Step 3.0 Failure events definition
- 3.1 Construct matrix of failure modes
- 3.2 Document IOA analysis results

Step 4.0 Compare IOA analysis data to NASA FMEA/CIL
- 4.1 Resolve differences
- 4.2 Review in-house
- 4.3 Document assessment issues
- 4.4 Forward findings to Project Manager

2.4 EPG/FCP Ground Rules and Assumptions

The EPG/FCP ground rules and assumptions used in the IOA are defined in Appendix B.

3.0 SUBSYSTEM DESCRIPTION

3.1 Design and Function

The EPG/FCP consists of hardware that is required for electrical power generation and Fuel Cell (FC) product water collection and distribution in the Orbiter. Reference Figures 2 and 3. The EPG/FCP consists of the following divisions:

1. The Power Section Assembly (PSA) which is also called Cell Stack Assembly (CSA) combines hydrogen and oxygen through an electrochemical conversion to produce electrical power, water, and heat. Each PSA cell stack consists of cell plates, pressure plates, end cell heater/insulator plates, tie rods, and individual cell voltage harness. Each cell plate is made up of Unitized Electrode Assembly (UEA) and separator plates. The cell stack consists of 96 cell plates grouped electrically into three substacks connected in parallel. The substack contains 32 cell plates connected electrically in series. The PSA also contains a cell performance monitor which provides continuous analog data outputs to the Orbiter. The outputs transmit individual cell performance problems or imminent failures. Reference Figure 4.

2. The Reactant Control Subsystem (RCS) consists of preheaters, coupled reactant regulator, hydrogen pump-separator, condenser, hydrogen/water purge/vent line and oxygen purge/vent line. The RCS heats cryogenic-temperature gaseous reactants (oxygen and hydrogen) from the Power Reactant Storage and Distribution System (PRSDS) to an acceptable temperature for delivery to the coupled reactant regulator. The RCS delivers reactant gases to the PSA on demand and controls the reactant pressure within the cell plates. The RCS provides for purging of inert gases from reactant lines. The RCS circulates hydrogen for water removal from the PSA and also prevents water from entering the PSA. Reference Figure 5.

3. The Thermal Control System (TCS) contains a coolant pump, thermal control valve, coolant accumulator, start/sustaining heater, and condenser. The TCS controls the FCP operating temperatures and electrolyte concentration. The TCS removes waste heat from the PSA and heat from the moist hydrogen recycle flow to condense water vapor. The TCS transfers heat to the inlet reactant gases passing through preheaters and rejects heat to the Orbiter vehicle cooling system. Reference Figure 6.

4. The Water Removal Subsytem (WRS) consists of a condenser, hydrogen pump-separator, water purity sensor,

water trap and water discharge line. The WRS removes water produced in the PSA during the FCP operation. The FCP produces water vapor which is converted to a liquid in the condenser. The hydrogen pump-separator centrifugally separates the water from the hydrogen. The WRS delivers the water to the Orbiter vehicle potable water storage system or to the water relief line. Reference Figure 7.

3.2 Interfaces and Locations

The three EPG/FCPs are installed in the mid-body of the Orbiter beneath the payload bay liner. Fuel Cell 1 (FC1) is located on the left-hand side of the payload bay. Whereas, FC2 and FC3 are located forward and aft respectively, on the right-hand side of the payload bay. Reference Figure 8. The FCPs PSA receives the hydrogen and oxygen reactants from the Power Reactants Stowage and Distribution System (PRSDS). The product water from the PSA is transported to the Environmental Control and Life Support System (ECLSS) for stowage. The waste heat produced by the PSA is rejected to the Orbiter vehicle cooling system through the FC40 coolant in the TCS. The FCP receives three phase AC electrical power from the Orbiter to power the coolant pump, hydrogen pump-separator, and the water purity sensor. The FCP generates DC electrical power which is distributed to the Orbiter electrical power system. Reference Figure 9.

3.3 Hierarchy

Figures 2 and 3 illustrate the hierarchy of the EPG and FCP systems, respectively. The FCP subsystems are depicted in Figures 4 through 7.

ELECTRICAL POWER GENERATION SUBSYTEM OVERVIEW

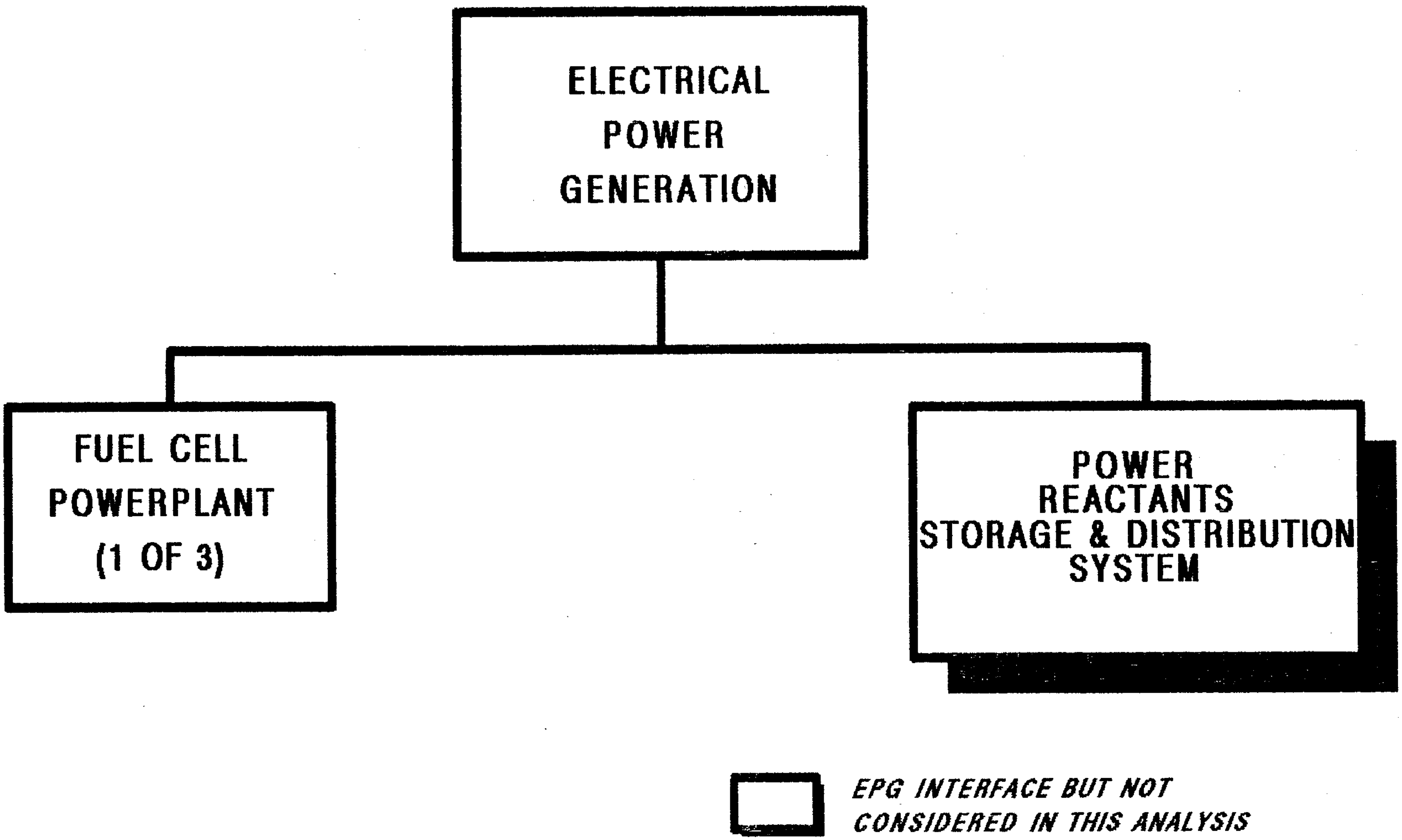


Figure 2 - EPG SUBSYSTEM OVERVIEW

FUEL CELL POWER PLANT SUBSYSTEM OVERVIEW

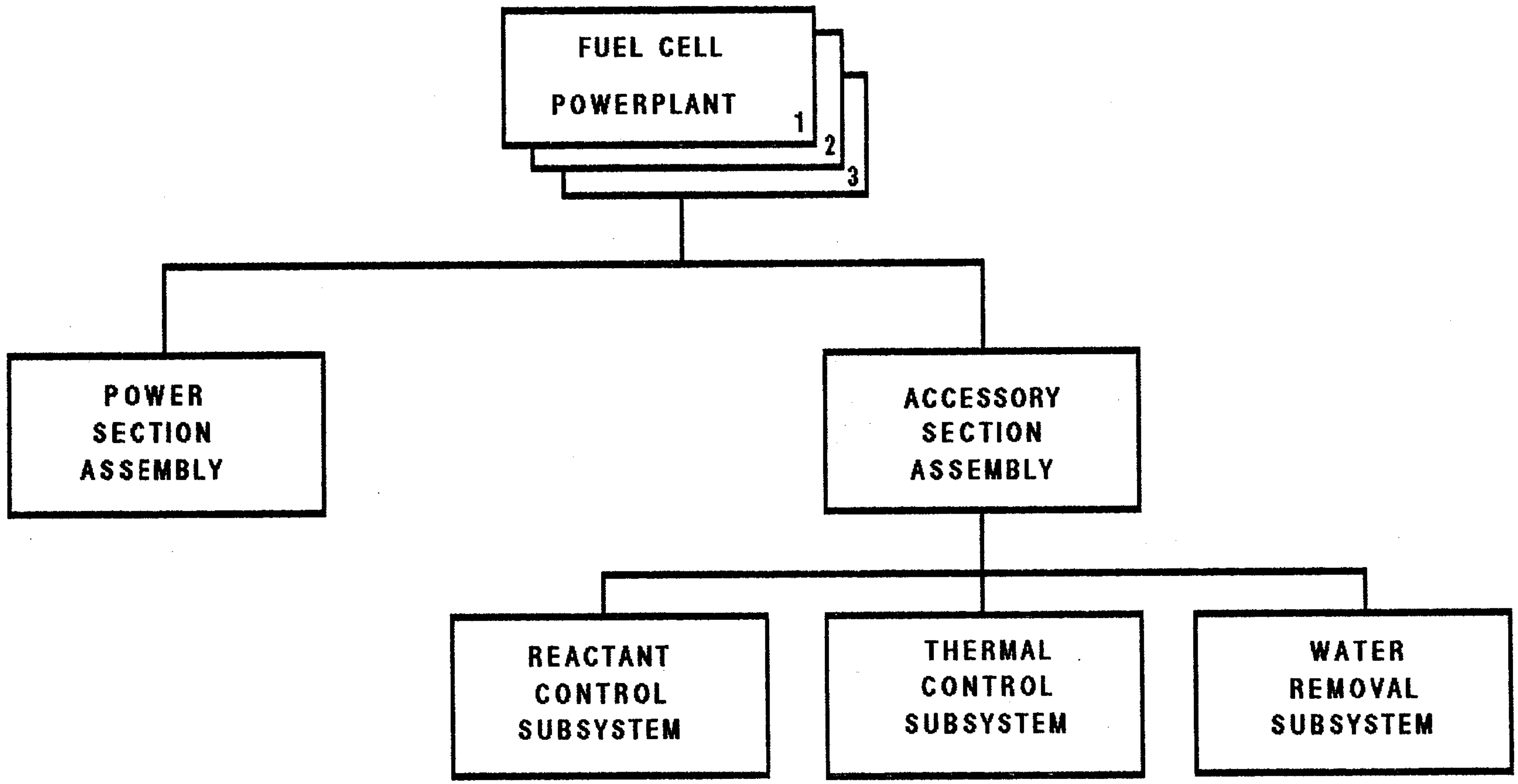


Figure 3 - FCP SUBSYSTEM OVERVIEW

FCP POWER SECTION ASSEMBLY

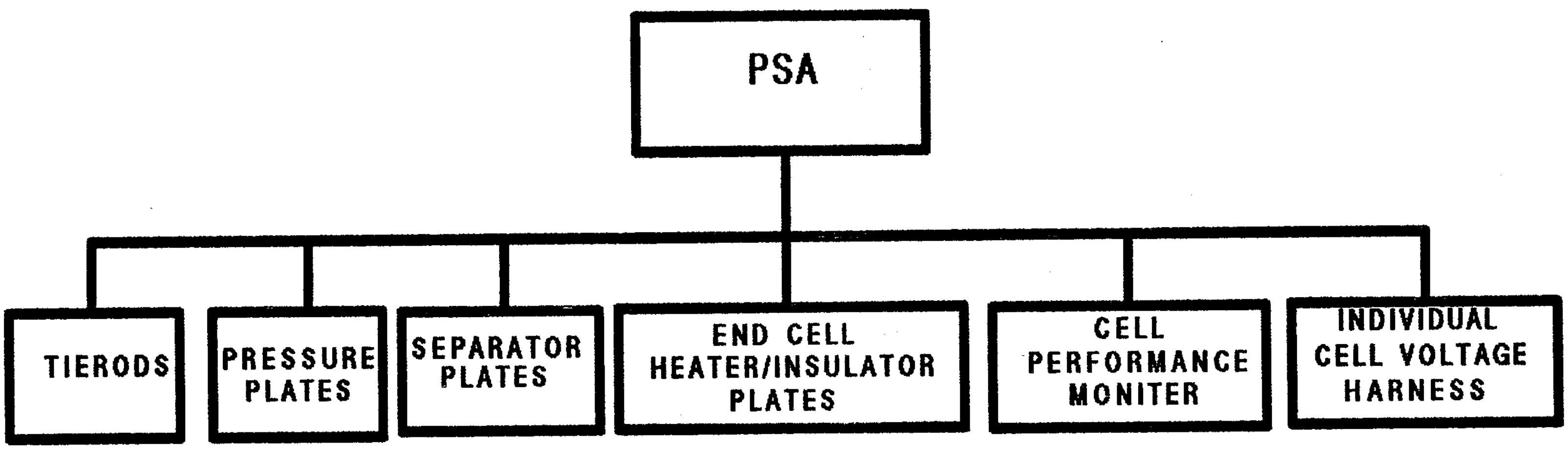


Figure 4 - FCP POWER SECTION ASSEMBLY (PSA)

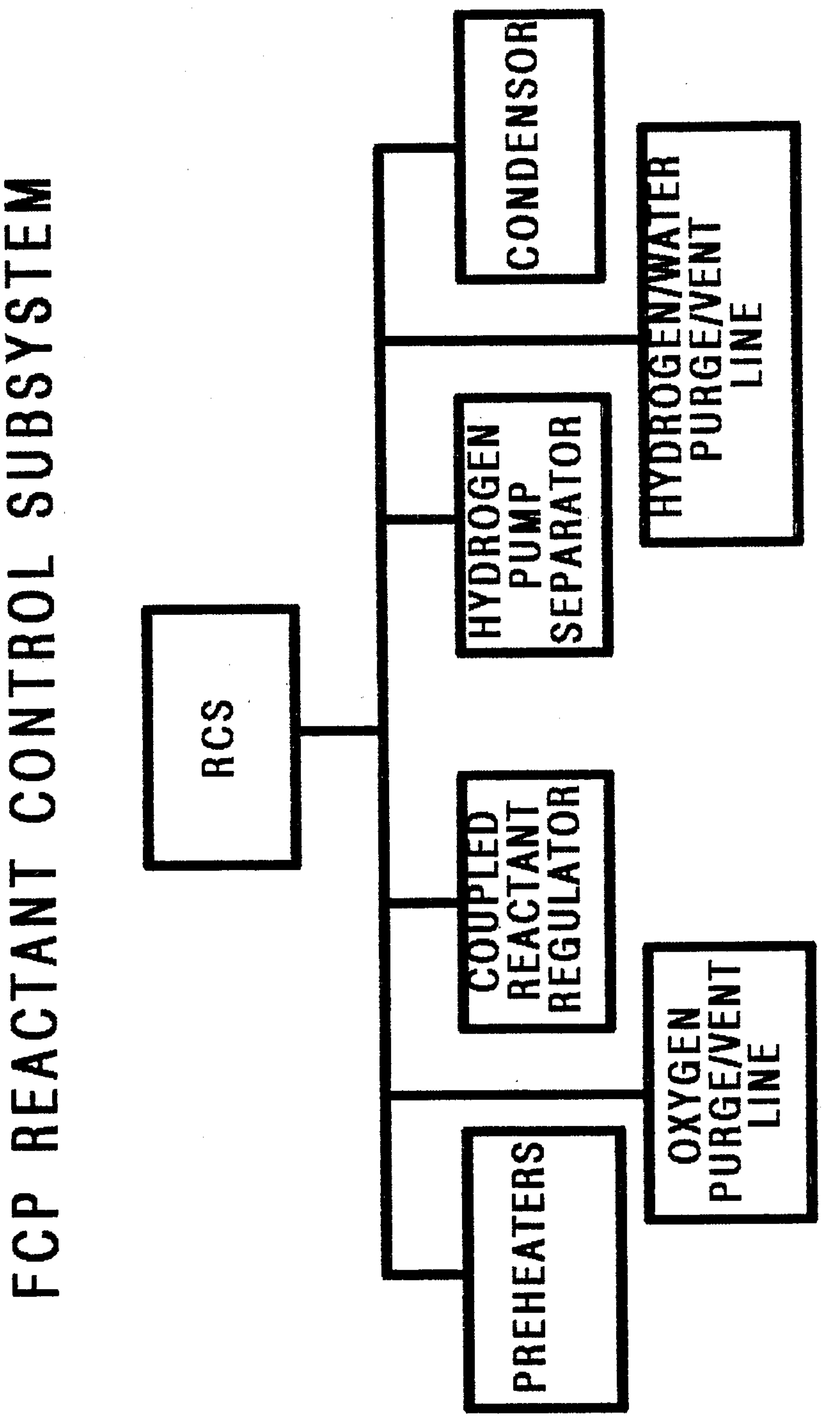


Figure 5 - FCP REACTANT CONTROL SUBSYSTEM (RCS)

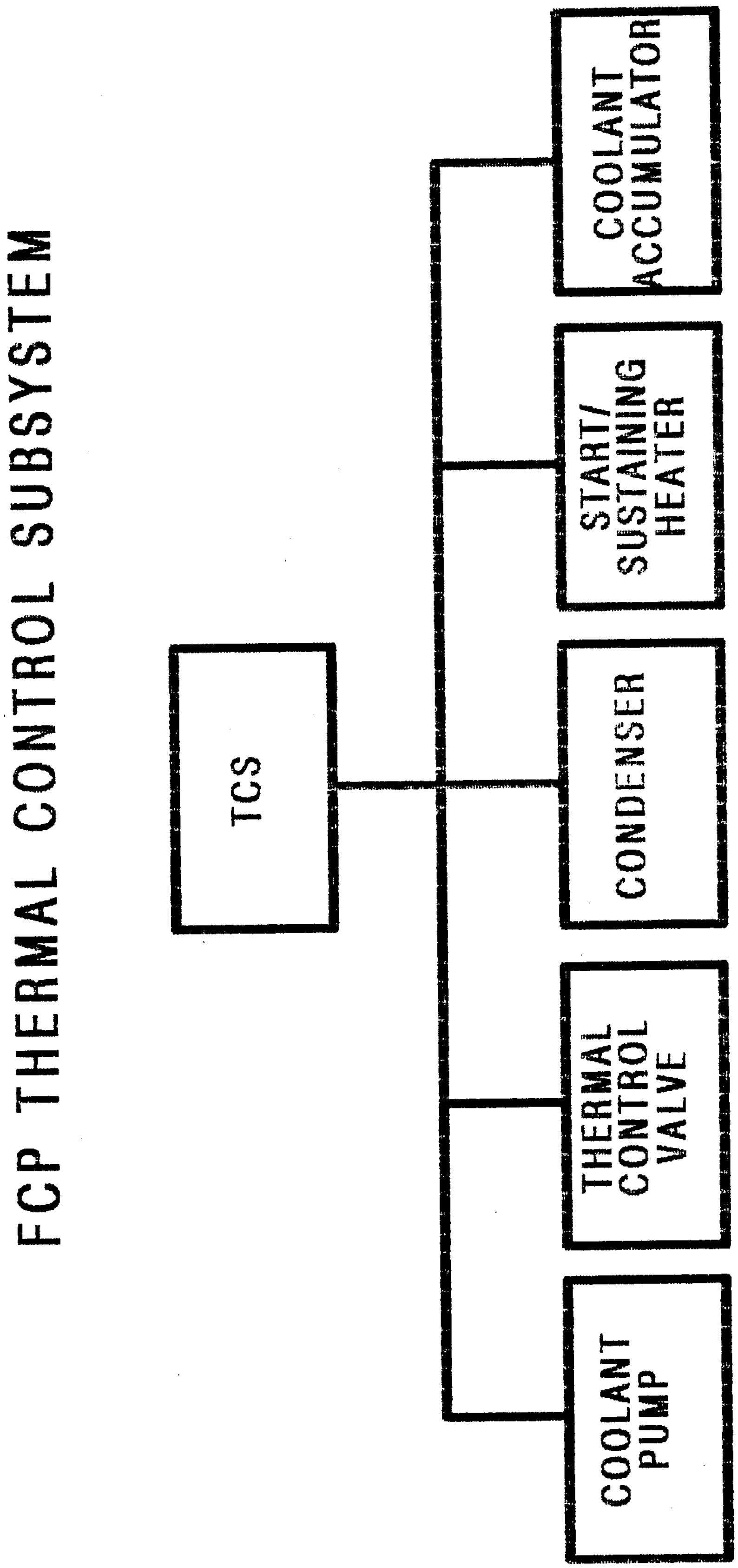


Figure 6 - FCP THERMAL CONTROL SUBSYSTEM (TCS)

FCP WATER REMOVAL SUBSYSTEM

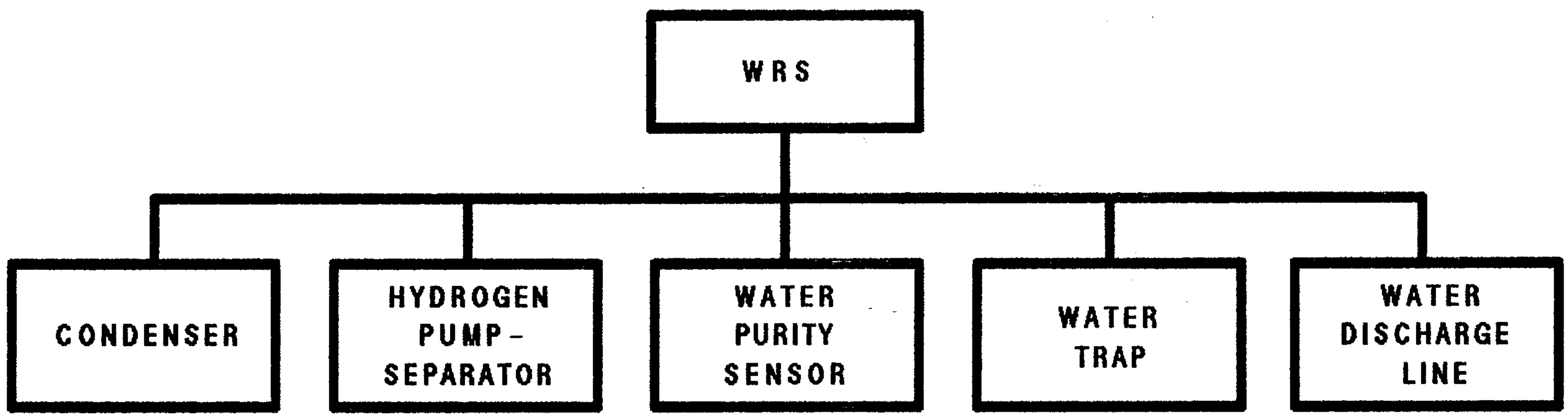
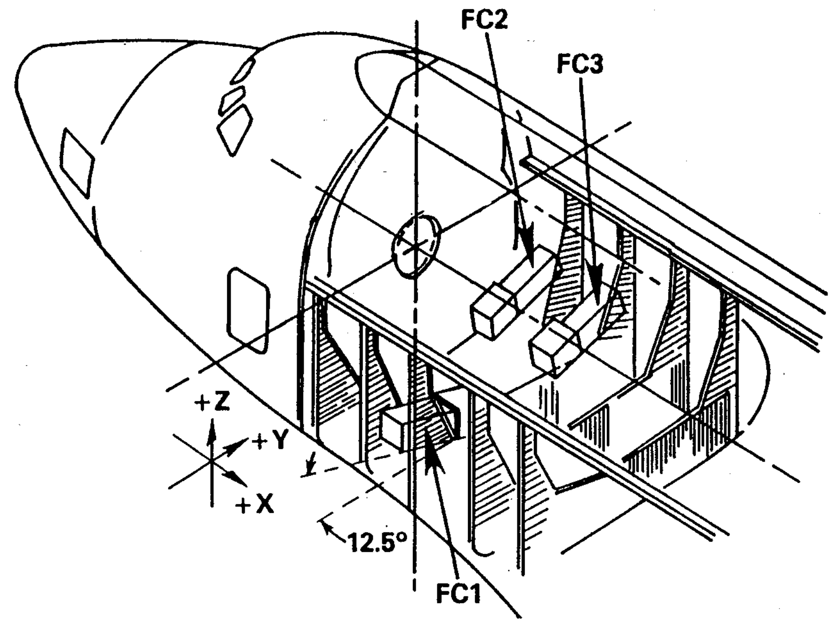


Figure 7 - FCP WATER REMOVAL SUBSYSTEM (WRS)

FUEL CELL POWERPLANT

LOCATION IN THE ORBITER VEHICLE



O Three Orbiter FCP's installed in the Orbiter vehicle mid-body beneath the payload liner

- FC1 installed on left-hand side
- FC2 installed forward on right-hand side
- FC3 installed aft on right-hand side

Figure 8 - FCP LOCATION IN THE ORBITER VEHICLE

FCP LOCATION AND INTERFACES

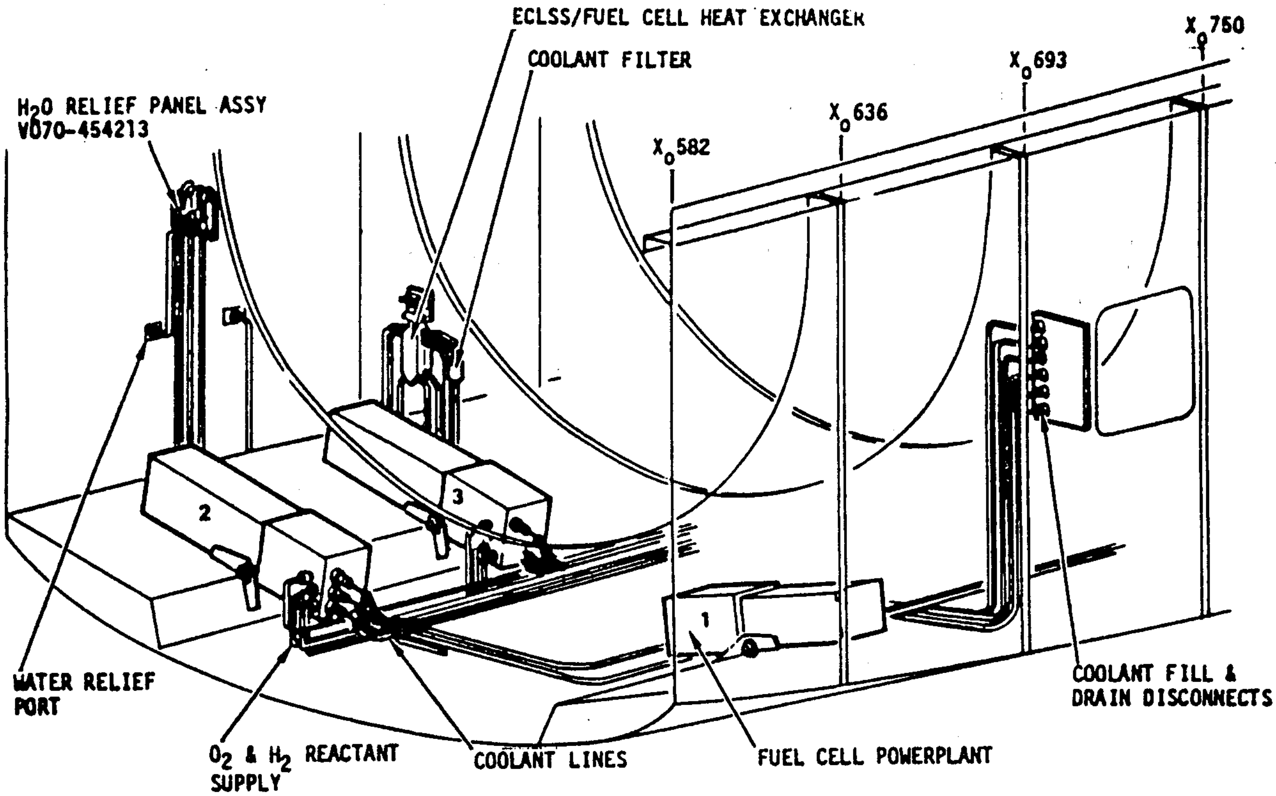


Figure 9 - FCP LOCATION AND INTERFACES

4.0 ANALYSIS RESULTS

Detailed analysis results for each of the identified failure modes are presented in Appendix C. Table I presents a summary of the failure criticalities for each of the four major subdivisions of the EPG/Fuel Cell. Further discussion of each of these subdivisions and the applicable failure modes is provided in subsequent paragraphs.

TABLE I Summary of IOA Failure Modes and Criticalities

Criticality:	1/1	2/1R	2/2	3/1R	3/2R	3/3	TOTAL
PSA	2	5	-	1	-	-	8
RCS	1	7	-	3	-	6	17
TCS	-	5	-	2	-	4	11
WRS	-	9	-	4	4	9	26
TOTAL	3	26	-	10	4	19	62

Of the 62 failure modes analyzed, 32 failures were determined to be PCIs. A summary of the PCIs is presented in Table II. Appendix D presents a cross reference between each PCI and a specific worksheet in Appendix C.

TABLE II Summary of IOA Potential Critical Items

Criticality:	1/1	2/1R	2/2	3/1R	3/2R	TOTAL
EPG/FPC	3	26	-	-	3	32

4.1 Analysis Results PSA

The Power Section Assembly consists of the end cell heater/insulator plates, pressure plates, tie rods, individual cell voltage harness, cell performance monitor, and separator plates. These components are illustrated in Figure 4. There were eight failure modes identified for this division. Of these eight, two are criticality 1/1, five are criticality 2/1R, and one is criticality 3/1R. Seven failures from the PSA are identified to be PCI's. These are listed in Appendix D.

4.2 Analysis Results RCS

The Reactant Control Subsystem consists of preheaters, coupled reactant regulator, hydrogen pump spearator, condenser, hydrogen/water purge vent line and oxygen purge/vent line. These components are illustrated in Figure 5. There were seventeen failure modes identified for the RCS division. Of these seventeen, one is criticality 1/1, seven are criticality 2/1R, three are criticality 3/1R, and six are criticality 3/3. Eight failures from the RCS are identified to be PCI's. These are listed in Appendix D.

4.3 Analysis Results TCS

The Thermal Control Subsystem contains a coolant pump, thermal control valve, coolant accumulator, start/sustaining heater and condenser. These components are illustrated in Figure 8. There were eleven failure modes identified for the TCS division. Of these eleven, five are criticality 2/1R, two are criticality 3/1R, and four are 3/3. Five failures from the TCS are identified to be PCI's. These are listed in Appendix D.

4.4 Analysis Results WRS

The Water Removal Subsystem consists of a condenser, hydrogen pump-separator, water trap and water discharge line. These components are illustrated in Figure 9. There were twenty-six failure modes identified for the WRS division. Of these twenty-six, nine are criticality 2/1R, four are criticality 3/1R, four are criticality 3/2R, and nine are criticality 3/3. Twelve failures from the WRS are identified to be PCI's. These are listed in Appendix D.

5.0 REFERENCES

Reference documentation available from NASA, Rockwell, International, International Fuel Cells, and Pratt and Whitney was used in the analysis. The documentation used included the following:

1. JSC-12820, PCN-1 STS Operational Flight Rules, 12-16-85

2. V45 File III, Operations and Maintenance Requirements and Specification Document - Orbiter OMRSD - Electrical Power Generation/Power Reactant Storage and Distribution, 5-29-86

3. TD268, Shuttle Flight Operations Manual, Vol 2, EPS, 11-84

4. JSC-12830, EGIL Console Procedure Handbook, Rev. C, 10-83

5. NSTS 22206, Instructions for Preparation of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL), 10 October 1986

6. 100-2G, Rockwell International Reliability Desk Instruction Flight Hardware FMEA and CIL, 1-31-84

7. Orbiter Fuel Cell Powerplant Review and Training Course, International Fuel Cells (IFC), 5-86

8. JSC-18691, Flight Data File Malfunction Procedures, Rev. B, 10-10-85

9. JSC-18540, Flight Data File Entry Checklist, Rev. B, 3-17-86

10. JSC-18547, Flight Data File Ascent checklist, Rev. B, 5-28-85

11. JSC-18541, Flight Data File Orbit Operations Checklist, Rev. B, 5-22-85

12. M4001002, JSC Orbiter Full Problem Record Report, EPG Subsystem, 7-22-86.

13. VS70-945099, Integrated System Schematic Electrical Power System (EPS) Orbiter Vehicles -099, 103, 104, 7-18-85

14. VS70-945102, Integrated System Schematic Orbiter OV-102 EPS, 9-19-84

15. Magnesium Plate Status Review and Proposed Investigations to Improve Reliability, IFC, 7-15-86

16. EPA Ban on Future Use of Asbestos Creates Serious Orbiter Fuel Cell Availability Problem, IFC, 7-16-86

17. Orbiter Fuel Cell Powerplant Improved Coolant Accumulator, IFC, 7-15-86

18. Orbiter Fuel Cell Powerplant Improved Cell Performance Monitoring, IFC, 7-15-86

19. Review of IFC Product Improvement Recommendations and Problems and Concerns, (Orbiter Operational Program), IFC, 7-16-86

20. N2 Diagnostic Test Data Review (Comparison of CPM Data to Single Cell Data), IFC, 7-16-86

21. Program Review Orbiter Operational Improvement Program, IFC, 7-15-86

22. Operational Program Powerplant(s) Failure Review, IFC, 7-15-86

23. Rockwell Specifications for Fuel Cells

a. MC 464-0115	Fuel Cell
b. ME 363-0042-0003	Water Nozzle & Heater Assembly
c. MC 284-0431-0001	Water Pressure Relief Valve
d. ME 284-0475-0001	Water Supply Check Valve
e. MC 363-0037-0001	Strip Heater EPG
f. MC 363-0038-0014	Line Heater H20 Relief Vent Line
g. MC 363-0038-0001-0004	Line Heater Oxygen Purge Line
h. MC 363-0038-0003-0004	Line Heater Hydrogen Purge Line
i. MC 363-0037-0002	Strip Heater Hydrogen Purge Port
j. MC 363-0038-0006	Line Heater, FCP Product Water Line
k. ME 449-0160-0003	Temperature Sensors for Product Water Line, Water Relief Valve, Coolant Return, Oxygen Vent Line, Hydrogen Vent Line and Water Relief Line

24. Rockwell International Drawings

a. VS70-450-102	Orbiter Fuel Cell Control Subsystem
b. VS70-450-109	Orbiter Fuel Cell Control Subsystem
c. VS70-450-112	Orbiter Fuel Cell Control Subsystem
d. VS70-450-119	Orbiter Fuel Cell Control Subsystem
e. V070-454-765	Panel - Water Relief Assembly

25. Pratt and Whitney Aircraft Drawings

a.	752153	Plate - Fuel Electrode
b.	752154	Plate - Oxidizer Electrode
c.	752158	Plate - Oxidizer Electrode
d.	754930	Electrode - Fuel Cell Assembly
e.	755422	Plate - Fuel Electrode Terminal
f.	768429	Heater Coolant Start-up
g.	769016	Regulator, Reactant
h.	769288	Accumulator and Strap Coolant Assembly
i.	769546	Filter Coolant (Ref Drawing 14336 501 Change B)
j.	770488	Transducer - Oxidizer Flow
k.	770489-91	Transducer - Fuel Flow
l.	770598-99	Components Assembly - Fuel Cell
m.	782900	Power Plant Assembly - Fuel Cell
n.	787900	Power Plant Assembly - Fuel Cell
o.	788400	Power Plant Assembly - Fuel Cell
p.	796798	Components Assembly - Fuel Cell
q.	800634	Cable - Fuel Cell Output Assembly
r.	800635	Wiring Harness, Fuel Cell Input
s.	800636	Wiring Harness, Fuel Cell
t.	822998	Cable Routing - Component Assembly
u.	823098	Component Assembly - Fuel Cell
v.	823100	Power Plant Assembly - Fuel Cell

APPENDIX A
ACRONYMS

AOA	-	Abort Once Around
ATO	-	Abort To Orbit
CIL	-	Critical Items List
CPM	-	Cell Performance Monitor
CRIT	-	Criticality
CSA	-	Cell Stack Assembly
C&W	-	Caution and Warning System
ECLSS	-	Environmental Control and Life Support System
EPA	-	Environmental Protection Agency
EPG	-	Electrical Power Generation
EPS	-	Electrical Power System
F	-	Functional
FC	-	Fuel Cell
FCP	-	Fuel Cell Powerplant
FMEA	-	Failure Mode and Effect Analysis
FSSR	-	Flight System Software Requirement
GFE	-	Government Furnished Equipment
HW	-	Hardware
IFC	-	International Fuel Cells
IOA	-	Independent Orbiter Assessment
MDAC	-	McDonnell Douglas Astronautics Company
NASA	-	National Aeronautics and Space Administration
NSTS	-	National Space Transportation System
NA	-	Not Applicable
OMRSD	-	Operations and Maintenance Requirements and Specification Document
PCI	-	Potential Critical Item
PRCB	-	Program Requirements Control Board
PRSDS	-	Power Reactant Storage & Distribution System
PSA	-	Power Section Assembly
RCS	-	Reactant Control Subsystem
RI	-	Rockwell International
RTLS	-	Return To Landing Site
SM	-	System Management
STS	-	Space Transportation System
TAL	-	Transatlantic Abort Landing
TCS	-	Thermal Control Subsystem
UEA	-	Unitized Electrode Assembly
WRS	-	Water Removal Subsystem

APPENDIX B

DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

APPENDIX B
DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

B.1 Definitions

Definitions contained in NSTS 22206, Instructions For Preparation of FMEA/CIL, 10 October 1986, were used with the following amplifications and additions.

INTACT ABORT DEFINITIONS:

RTLS - begins at transition to OPS 6 and ends at transition to OPS 9, post-flight

TAL - begins at declaration of the abort and ends at transition to OPS 9, post-flight

AOA - begins at declaration of the abort and ends at transition to OPS 9, post-flight

ATO - begins at declaration of the abort and ends at transition to OPS 9, post-flight

CREDIBLE (CAUSE) - an event that can be predicted or expected in anticipated operational environmental conditions. Excludes an event where multiple failures must first occur to result in environmental extremes

CONTINGENCY CREW PROCEDURES - procedures that are utilized beyond the standard malfunction procedures, pocket checklists, and cue cards

EARLY MISSION TERMINATION - termination of onorbit phase prior to planned end of mission

EFFECTS/RATIONALE - description of the case which generated the highest criticality

HIGHEST CRITICALITY - the highest functional criticality determined in the phase-by-phase analysis

MAJOR MODE (MM) - major sub-mode of software operational sequence (OPS)

MC - Memory Configuration of Primary Avionics Software System (PASS)

MISSION - assigned performance of a specific Orbiter flight with payload/objective accomplishments including orbit phasing and altitude (excludes secondary payloads such as GAS cans, middeck P/L, etc.)

MULTIPLE ORDER FAILURE - describes the failure due to a single cause or event of all units which perform a necessary (critical) function

OFF-NOMINAL CREW PROCEDURES - procedures that are utilized beyond the standard malfunction procedures, pocket checklists, and cue cards

OPS - software operational sequence

PRIMARY MISSION OBJECTIVES - worst case primary mission objectives are equal to mission objectives

PHASE DEFINITIONS:

PRELAUNCH PHASE - begins at launch count-down Orbiter power-up and ends at moding to OPS Major Mode 102 (liftoff)

LIFTOFF MISSION PHASE - begins at SRB ignition (MM 102) and ends at transition out of OPS 1 (Synonymous with ASCENT)

ONORBIT PHASE - begins at transition to OPS 2 or OPS 8 and ends at transition out of OPS 2 or OPS 8

DEORBIT PHASE - begins at transition to OPS Major Mode 301 and ends at first main landing gear touchdown

LANDING/SAFING PHASE - begins at first main gear touchdown and ends with the completion of post-landing safing operations

APPENDIX B
DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

B.2 IOA Project Level Ground Rules and Assumptions

The philosophy embodied in NSTS 22206, Instructions for Preparation of FMEA/CIL, 10 October 1986, was employed with the following amplifications and additions.

1. The operational flight software is an accurate implementation of the Flight System Software Requirements (FSSRs).

   RATIONALE: Software verification is out-of-scope of this task.

2. After liftoff, any parameter which is monitored by system management (SM) or which drives any part of the Caution and Warning System (C&W) will support passage of Redundancy Screen B for its corresponding hardware item.

   RATIONALE: Analysis of on-board parameter availability and/or the actual monitoring by the crew is beyond the scope of this task.

3. Any data employed with flight software is assumed to be functional for the specific vehicle and specific mission being flown.

   RATIONALE: Mission data verification is out-of-scope of this task.

4. All hardware (including firmware) is manufactured and assembled to the design specifications/drawings.

   RATIONALE: Acceptance and verification testing is designed to detect and identify problems before the item is approved for use.

5. All Flight Data File crew procedures will be assumed performed as written, and will not include human error in their performance.

   RATIONALE: Failures caused by human operational error are out-of-scope of this task.

6. All hardware analyses will, as a minimum, be performed at the level of analysis existent within NASA/Prime Contractor Orbiter FMEA/CILs, and will be permitted to go to greater hardware detail levels but not lesser.

   RATIONALE: Comparison of IOA analysis results with other analyses requires that both analyses be performed to a comparable level of detail.

7. Verification that a telemetry parameter is actually monitored during AOS by ground-based personnel is not required.

   RATIONALE: Analysis of mission-dependent telemetry availability and/or the actual monitoring of applicable data by ground-based personnel is beyond the scope of this task.

8. The determination of criticalities per phase is based on the worst case effect of a failure for the phase being analyzed. The failure can occur in the phase being analyzed or in any previous phase, whichever produces the worst case effects for the phase of interest.

   RATIONALE: Assigning phase criticalities ensures a thorough and complete analysis.

9. Analysis of wire harnesses, cables, and electrical connectors to determine if FMEAs are warranted will not be performed nor FMEAs assessed.

   RATIONALE: Analysis was substantially complete prior to NSTS 22206 ground rule redirection.

10. Analysis of welds or brazed joints that cannot be inspected will not be performed nor FMEAs assessed.

    RATIONALE: Analysis was substantially complete prior to NSTS 22206 ground rule redirection.

11. Emergency system or hardware will include burst discs and will exclude the EMU Secondary Oxygen Pack (SOP), pressure relief valves and the landing gear pyrotechnics.

    RATIONALE: Clarify definition of emergency systems to ensure consistency throughout IOA project.

B.3 EPG-Specific Ground Rules and Assumptions

1. Component age life will not be considered in the analysis.

   RATIONALE: Component age life analysis is beyond the scope of this task.

2. Cryogenic system pressure to the fuel cell will be assumed lost if unable to maintain minimum supply conditions of 100 PSI for H2 and/or O2 tanks.

   RATIONALE: Minimum requirements definition. Flight rule definition.

3. An O2 cryo tank will be assumed lost if both of its heaters fail to function (i.e., neither heater will function with the delta current sensors enabled).

   RATIONALE: Systems failure definition. Flight rule definition.

4. An H2 cryo tank will be assumed lost if neither of its heaters will function.

   RATIONALE: Systems failure definition. Flight rule definition.

5. An impending loss of all cryo O2 or all cryo H2 tanks will be cause to exercise the highest-priority abort mode the loss/leak will allow.

   RATIONALE: Flight rule definition.

6. Continue nominal ascent if 2/3/4 O2 (H2) tanks fail when flying 3/4/5.

   Enter next PLS daily go/no-go if two O2 (H2) tanks fail during lift-off and on-orbit.

   RATIONALE: Flight rules go/no-go criteria.

7. Ascent abort decision will be needed for any EPG/PRSD/FCP problems that will not support four hours on-orbit plus entry time.

   RATIONALE: Flight operations rules.

8. A fuel cell will be considered failed if the following conditions exist.

   a. An abnormal or unexplained voltage versus current performance loss of ≥0.5 volts for a single FC based on predicted performance data.

   b. Coolant pump or H2 pump/H2O separator is lost.

   c. Fuel cell stack-coolant temperature >255 degrees (242.5) degrees F or <175 degrees (182.5) degrees F.

   d. Coolant pressure >75 (71.4) PSIA and increasing.

   e. Fuel cell unable to discharge water to the ECLSS H2O storage tanks or overboard via the fuel cell H2O relief system.

   f. Local KOH concentration >48 percent (45 percent) dry or <24 percent (29 percent) wet as indicated by fuel cell stack-coolant temperature, condenser exit temperature, and current relationship.

   g. Fuel cell reactant valve fails closed.

   h. Cannot be connected to a main bus.

   i. Fuel cell H2O pH high confirmed.

   j. Fuel cell O2 reaction chambers cannot be purged.

   k. Fuel cell end-cell heater failing on.

   l. Fuel cell substack delta volts >150 millivolts and increasing.

   RATIONALE: Systems failure definition.

9. Loss of one fuel cell is considered cause for priority flight and abort decision.

   RATIONALE: Mission flight rule definition.

10. Loss of two fuel cells is considered cause for abort mission.

   RATIONALE: Contingency action summary. Flight Rule definition.

11. Loss of three fuel cells is considered loss of life/vehicle in all mission phases.

    RATIONALE: Flight rule definition.

12. Loss of two fuel cells in the first stage of ascent is considered loss of life/vehicle.

    RATIONALE: SRB loads are too high for one fuel cell to support. Voltage may go <25v which will shut down the GPCs.

13. Although the ECLSS product-water storage is a separate system from EPG, it will be considered as a failable redundant product-water relief line for purposes of the EPG functional criticality scenarios.

    RATIONALE: This assumption violates general ground rule 3.1.1.6 but is essential for evaluating failures associated with the water relief line.

14. Filter failure will only be considered in the case of total flow blockage. Cases of improper/insufficient filtering will not be considered except where obvious.

    RATIONALE: The effect of 'poor' filter performance on downstream components is beyond the scope of our efforts.

15. The start/sustaining heater on the left-hand FCP (FCP #1) is assumed to be disconnected. Thus, this FCP cannot be maintained operational at no-load, and will be considered shutdown if the load cannot be maintained at greater than 2 KW.

    RATIONALE: Load needed to maintain operating temperature. Right hand FCP uses sustaining heater to maintain temperature at no-load.

16. For all "failed open" failure modes for valves which are normally open, redundancy screen B will be assumed failed.

    RATIONALE: The failure is not detectable until the valve is required to be closed.

17. Five 02 and H2 tanks are being used as the baseline configuration under study.

RATIONALE: The configuration for all redundant components is being considered for this analysis.

18. Inadvertant Fuel Cell shutdown during RTLS and TAL abort is considered loss of crew/vehicle.

RATIONALE: Loss of FCP 1/Bus A is loss of OMS Engine Purge Capability (required for TAL) and Aft Compartment MPS Helium Purge Capability (required for RTLS and TAL).

APPENDIX C
DETAILED ANALYSIS

This section contains the IOA analysis worksheets generated during the analysis of this subsystem. The information on these worksheets is intentionally similar to the NASA FMEAs. Each of these sheets identifies the hardware item being analyzed, and parent assembly, as well as the function. For each failure mode, the possible causes are outlined, and the assessed hardware and functional criticality for each mission phase is listed, as described in the NSTS 22206, Instructions for Preparation of FMEA and CIL, 10 October 1986. Finally, effects are entered at the bottom of each sheet, and the worst case criticality is entered at the top.

LEGEND FOR IOA ANALYSIS WORKSHEETS

Hardware Criticalities:
- 1 = Loss of life or vehicle
- 2 = Loss of mission or next failure of any redundant item (like or unlike) could cause loss of life/vehicle
- 3 = All others

Functional Criticalities:
- 1R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of life or vehicle.
- 2R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of mission.

Redundancy Screen A:
- 1 = Is Checked Out PreFlight
- 2 = Is Capable of Check Out PreFlight
- 3 = Not Capable of Check Out PreFlight
- NA = Not Applicable

Redundancy Screens B and C:
- P = Passed Screen
- F = Failed Screen
- NA = Not Applicable

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY		HDW/FUNC
SUBSYSTEM:	EPG		FLIGHT:	2/1R
MDAC ID:	101		ABORT:	1/1

ITEM: FUEL CELL
FAILURE MODE: LOSS ELECTRICAL CONTACT IN THE POWER SECTION

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) PSA
4)
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	1/1
LIFTOFF:	2/1R	TAL:	1/1
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, CORROSION, THERMAL STRESS, FATIGUE

EFFECTS/RATIONALE:
LOSS OF ELECTRICAL CONTACT CAUSES INADVERTANT FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 104

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	2/1R

ITEM: END CELL HEATER
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT   SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) PSA
4)
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: ELECTRICAL FAILURE

EFFECTS/RATIONALE:
LOSS OF FUEL CELL THERMAL INSULATION IS CAUSED BY THE FAILED OFF END CELL HEATERS. DURING LIGHT ELECTRICAL LOADING OF THE FUEL CELL, THE LOSS OF THE FUEL CELL HEATER MAY CAUSE CELL FLOODING WHICH REQUIRES FCP SHUTDOWN. ELECTRICAL END CELL HEATERS ARE BEING REPLACED WITH HEATERS CONTROLLED BY THE COOLANT SYSTEM.

REFERENCES:

C-3-
C-4

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 105

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	2/1R

ITEM: END CELL HEATER
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) PSA
4)
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: ELECTRICAL FAILURES

EFFECTS/RATIONALE:
ON ORBIT THE FUEL CELL WOULD HAVE TO BE SHUTDOWN WITH A FAILED ON END CELL HEATER. EXCESSIVE HEATING WILL DEGRADE CELL MATRIX OR SEALS AND ALLOW REACTANT CROSSOVER.
WITH THE END CELL HEATERS FAILED ON THE FUEL CELL CAN OPERATE FOR 51 MINUTES BEFORE THE CELL HAS TO BE SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 106

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	1/1
ABORT:	1/1

ITEM: SEPARATOR PLATES/UEA
FAILURE MODE: REACTANT LEAKAGE TO ORBITER (EXTERNAL LEAKAGE)

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) PSA
4)
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	1/1	RTLS:	1/1
LIFTOFF:	1/1	TAL:	1/1
ONORBIT:	1/1	AOA:	1/1
DEORBIT:	1/1	ATO:	1/1
LANDING/SAFING:	1/1		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: SEAL FAILURE

EFFECTS/RATIONALE:
AN EXTERNAL REACTANT LEAK IN THE SEPARATOR PLATES CAN CAUSE A POTENTIAL EXPLOSION/FIRE. THE LEAKAGE IS DETECTABLE WITH HIGH REACTANT FLOW RATES.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	1/1
MDAC ID:	107	ABORT:	1/1

ITEM: SEPARATOR PLATES/UEA
FAILURE MODE: INTERNAL LEAKAGE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) PSA
4)
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6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	1/1	RTLS:	1/1
LIFTOFF:	1/1	TAL:	1/1
ONORBIT:	1/1	AOA:	1/1
DEORBIT:	1/1	ATO:	1/1
LANDING/SAFING:	1/1		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: DEFECT IN ELECTROLYTE MATIRX; DEFECT IN SEAL/SEPARATOR PLATE; EXCESSIVE REACTANT PRESSURE

EFFECTS/RATIONALE:
REACTANT CROSSOVER WITHIN THE SEPARATOR PLATES CAN CAUSE POTENTIAL EXPLOSION/FIRE HAZARD. THE REACTANT CROSSOVER IS DETECTABLE BY CELL PERFORMANCE MONITOR AND HIGH REACTANT FLOW RATES.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	108	ABORT:	2/1R

ITEM: SEPARATOR PLATES
FAILURE MODE: COOLANT LEAKAGE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) PSA
4)
5)
6)
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8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: SEAL FAILURE

EFFECTS/RATIONALE:
COOLANT LEAK WITHIN THE SEPARATOR PLATES WILL CONTAMINATE THE ELECTROLYTE AND DEGRADE FCP PERFORMANCE. IT COULD ALSO CAUSE LOSS OF TEMPERATURE CONTROL. EITHER CONDITION WILL REQUIRE FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	109	ABORT:	2/1R

ITEM: SEPARATOR PLATES
FAILURE MODE: REACTANT BLOCKAGE (O2 INLET MANIFOLD)

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) PSA
4)
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: CORROSION, CONTAMINATION

EFFECTS/RATIONALE:
IF THE OXYGEN INLET TO THE SEPARATOR PLATE IS BLOCKED, THEN HIGH HYDROGEN CONCENTRATION FORCES ELECTROLYTE OUT OF THE CELL MATRIX RESULTING IN PRODUCT WATER CONTAMINATION AND FCP DEGRADATION. WATER CONTAMINATION IS GROUND RULE FOR FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 110

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/1R
ABORT:	3/1R

ITEM: CELL PERFORMANCE MONITOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) PSA
4)
5)
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CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	3/1R	TAL:	3/1R
ONORBIT:	3/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	3/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0015

CAUSES: ELECTRICAL FAILURE

EFFECTS/RATIONALE:
ERRONEOUS OUTPUT WOULD CAUSE LOSS OF ABILITY TO MONITOR CELL PERFORMANCE AND CELL FAILURE. IF THE CPM IS LOST FOR ONE FUEL CELL, THE AFFECTED CELL CAN BE BUS TIED FOR PERFORMANCE MONITORING. IF ALL CPM'S ARE LOST, IT COULD BE CATASTROPHIC. REACTANT CROSSOVER, WHICH COULD RESULT IN AN EXPLOSION, WOULD BE UNDETECTABLE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	10/01/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	111	ABORT:	1/1

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: GROSS VENTING

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	1/1
LIFTOFF:	2/1R	TAL:	1/1
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, FATIGUE, CORROSION, CONTAMINATION

EFFECTS/RATIONALE:
GROSS VENTING ALLOWS REACTANTS TO VENT THROUGH THE PURGE/VENT LINE AT A FLOW RATE THAT PREVENTS REACTANT FLOW TO THE PSA. THIS WOULD CAUSE INADVERTANT FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 112

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	2/1R

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: H2 OVERPRESSURE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECANICAL SHOCK, VIBRATION, CORROSION, CONTAMINATION, PIECE PART STRUCTURAL FAILURE.

EFFECTS/RATIONALE:
HYDROGEN OVERPRESSURE WILL CAUSE ELETROLYTE DEPLETION, WATER CONTAMINATION AND CELL SEAL FAILURE. HYDROGEN OVERPRESSURIZATION WOULD BE CAUSE FOR FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 113

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	1/1

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: H2 STARVATION

LEAD ANALYST: M. HIOTT   SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	1/1
LIFTOFF:	2/1R	TAL:	1/1
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, CORROSION, CONTAMINATION, PIECE PART STRUCTURAL FAILURE

EFFECTS/RATIONALE:
HYDROGEN STARVATION CAUSES INADVERTANT FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	10/01/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	114	ABORT:	2/1R

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: O2 OVERPRESSURE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, CONTAMINATION, CORROSION, PIECE PART STRUCTURAL FAILURE

EFFECTS/RATIONALE:
OXYGEN OVERPRESSURIZATION WILL CAUSE SEAL FAILURE AND OXYGEN LEAKAGE AND COOLANT OVERPRESSURE (THROUGH ACCUMULATOR). OXYGEN OVERPRESSURIZATION WOULD BE CAUSE FOR FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 115

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	1/1

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: O2 STARVATION

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	1/1
LIFTOFF:	2/1R	TAL:	1/1
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: MECHANICAL SHOCK, VIBRATION, CONTAMINATION, CORROSION, PIECE PART STRUCTURAL FAILURE

EFFECTS/RATIONALE:
OXYGEN STARVATION WILL CAUSE ELECTROLYTE DEPLETION WATER CONTAMINATION, AND SEAL FAILURE. REACTANT STARVATION CAUSES INADVERTANT FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 116

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 2/1R
ABORT: 2/1R

ITEM: INTEGRATED DUAL GAS REGULATOR
FAILURE MODE: PURGE FAILURE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: ELECTRICAL FAILURE, MECHANICAL SHOCK, VIBRATION, CONTAMINATION, CORROSION, PIECE PART STRUCTURAL FAILURE

EFFECTS/RATIONALE:
PURGE FAILURE OF THE INTEGRATED DUAL GAS REGULATOR WILL DEGRADE THE FUEL CELL PERFORMANCE. AN ADDITIONAL FAILURE RESULTING IN THE NEED TO VENT WOULD CAUSE REACTANT OVERPRESSURE, WHICH REQUIRES FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 117

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	1/1
ABORT:	1/1

ITEM: H2/O2 LINES AND FITTINGS AND ACCESSORY COMPONENTS
FAILURE MODE: REACTANT LEAKAGE TO THE ORBITER (EXTERNAL LEAKAGE)

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	1/1	RTLS:	1/1
LIFTOFF:	1/1	TAL:	1/1
ONORBIT:	1/1	AOA:	1/1
DEORBIT:	1/1	ATO:	1/1
LANDING/SAFING:	1/1		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, MECHANICAL SHOCK, CORROSION, CONTAMINATION, PIECE PART STRUCTURAL FAILURE

EFFECTS/RATIONALE:
AN EXTERNAL REACTANT LEAK AT THE COMPONENT CAN CAUSE A POTENTIAL EXPLOSION/FIRE. THE LEAKAGE IS DETECTABLE BY HIGH REACTANT FLOW RATES.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 118

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	2/1R

ITEM: O2/H2 PURGE-VENT LINES AND VENT NOZZLES
FAILURE MODE: RESTRICTED FLOW

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
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9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: V070-454720-003,V070-454720-004, V070-454210, V070-454211

CAUSES: CONTAMINATION, FREEZING

EFFECTS/RATIONALE:
RESTRICTED FLOW WITHIN THE VENT LINES AND NOZZLES PREVENTS THE PURGE OF THE FUEL CELL POWERPLANTS (FCP). THE INABILITY TO PURGE FCP'S WILL DEGRADE THEIR PERFORMANCE. AN ADDITIONAL FAILURE RESULTING IN THE NEED TO VENT COULD BE CATASTROPHIC.
THIS WOULD CAUSE REACTANT OVERPRESSURE. THIS FAILURE WOULD BE DETECTED DURING PURGE ATTEMPTS AND BY H2/O2 FLOWS AND PURGE LINE TEMPERATURE SENSORS.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 119

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/3
ABORT:	3/3

ITEM: O2 PURGE LINE TEMPERATURE SENSOR
FAILURE MODE: OPEN OR SHORT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-0003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
A FAILED TEMPERATURE SENSOR PREVENTS THE AUTO PURGE SEQUENCE BY INDICATING A CONSTANT LOW SCALE TEMPERATURE. MANUAL PURGE CAN BE PERFORMED.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 120

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/3
ABORT:	3/3

ITEM: O2 PURGE LINE TEMPERATURE SENSOR
FAILURE MODE: OUT OF TOLERANCE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-0003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
IF THE SENSOR INDICATES A HIGH TEMPERATURE, THEN THE PURGE VALVE COULD OPEN BEFORE THE OXYGEN LINE IS HEATED. THEREFORE, THE LINE COULD FREEZE WHICH COULD PREVENT PURGING. THE LOSS OF PURGING COULD CAUSE DEGRADED FUEL CELL PERFORMANCE. USE OF MANUAL HEATERS WOULD ALLEVIATE THE PROBLEM.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	10/01/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	121	ABORT:	3/3

ITEM: H2 PURGE LINE TEMPERATURE SENSORS 1 & 2
FAILURE MODE: OPEN OR SHORTED

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
A FAILED TEMPERATURE SENSOR PREVENTS THE AUTO PURGE SEQUENCE BY INDICATING A CONSTANT LOW SCALE TEMPERATURE. MANUAL PURGE CAN BE PERFORMED.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	10/01/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	122	ABORT:	3/3

ITEM: H2 PURGE LINE TEMP. SENSORS 1 & 2
FAILURE MODE: OUT OF TOLERANCE

LEAD ANALYST: M. HIOTT   SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
IF THE SENSOR INDICATES A HIGH TEMPERTURE, THEN THE PURGE VALVE COULD OPEN BEFORE THE LINE IS HEATED. THIS COULD CAUSE THE LINE TO FREEZE. A FROZEN LINE COULD PREVENT A PURGE WHICH WOULD CAUSE PERFORMANCE OF THE FUEL CELL TO BE DEGRADED. USE OF MANUAL HEATERS WOULD ALLEVIATE THE PROBLEM.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 123

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/1R
ABORT:	3/1R

ITEM: O2 PURGE LINE HEATERS (6)
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/1R	AOA:	3/3
DEORBIT:	3/3	ATO:	3/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0001, -0004

CAUSES: VIBRATION, SHOCK, HUMIDITY, SWITCH FAILURE, SHORT CIRCUIT

EFFECTS/RATIONALE:
THE FAILURE OF THE GPC HEATER CIRCUITS HAS NO EFFECT ON THE SYSTEM BECAUSE OF REDUNDANT HEATER CIRCUITS. IF BOTH HEATER CIRCUITS FAILED, THE LINE COULD FREEZE AND PURGE CAPABILITY WOULD BE LOST. A FAILURE RESULTING IN THE NEED TO VENT COULD CAUSE OVERPRESSURIZATION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 124

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/3
ABORT:	3/3

ITEM: O2 PURGE LINE HEATERS (6)
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0001, -0004

CAUSES: VIBRATION, SHOCK, HUMIDITY, SWITCH FAILURE, SHORT CIRCUIT

EFFECTS/RATIONALE:
A FAILED ON HEATER HAS NO MAJOR EFFECT ON THE FUEL CELL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 125

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 3/1R
ABORT: 3/1R

ITEM: H2 PURGE LINE HEATERS (6) AND NOZZLE HEATERS (2)
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/1R	AOA:	3/3
DEORBIT:	3/3	ATO:	3/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0003, -0004

CAUSES: VIBRATION, SHOCK, HUMIDITY, SWITCH FAILURE, SHORT CIRCUIT

EFFECTS/RATIONALE:
THE FAILURE OF THE GPC HEATER CIRCUITS HAS NO EFFECT ON THE FUEL CELL BECAUSE OF REDUNDANT HEATERS. IF BOTH HEATER CIRCUITS FAIL, THE LINE COULD FREEZE AND PURGE CAPABILITY WOULD BE LOST.
A FAILURE RESULTING IN THE NEED TO VENT COULD CAUSE OVERPRESSURIZATION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	10/01/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	126	ABORT:	3/3

ITEM: H2 PURGE LINE HEATERS (6) AND NOZZLE HEATERS (2)
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0003, -0004

CAUSES: VIBRATION, SHOCK, HUMIDITY, SWITCH FAILURE, SHORT CIRCUIT

EFFECTS/RATIONALE:
A FAILED ON HEATER HAS NO MAJOR EFFECT ON THE FUEL CELL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/01/86
SUBSYSTEM: EPG
MDAC ID: 127

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 3/1R
ABORT: 3/1R

ITEM: O2/H2 FLOWMETER
FAILURE MODE: ZERO OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) RCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	3/1R	TAL:	3/1R
ONORBIT:	3/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	3/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, CORROSION, ELETRICAL FAILURE

EFFECTS/RATIONALE:
IF A FLOWMETER MALFUNCTIONS, THEN LEAKING REACTANT WOULD BE UNDETECTABLE WHICH COULD POSSIBLY BE CATASTROPHIC.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	128	ABORT:	3/3

ITEM: START-UP HEATER
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
THE START/SUSTAINING HEATERS HAVE BEEN DISCONNECTED ON FCP1. FUEL CELL START-UP PROCESS WOULD TAKE LONGER AND WOULD POSSIBLY HAVE DEGRADED FUEL CELL PERFORMANCE DUE TO LOSS OF SUSTAINING HEATER THAT MAINTAINS COOLANT TEMPERATURE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	129	ABORT:	2/1R

ITEM: START-UP HEATER
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
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CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
IF THE HEATER FAILS ON, THE FUEL CELL WOULD OVERHEAT WHICH COULD CAUSE EXCESSIVE KOH RELEASE AND ELECTROLYTE DRYOUT. ELECTROLYTE DRYOUT CAN LEAD TO CROSSOVER AND REQUIRES FCP SHUTDOWN. THE HEAT COULD CAUSE COOLANT TO DRYOUT OR CHAR. THIS COULD POSSIBLY LEAD TO COOLANT PUMP FAILURE DUE TO PLUGGING FROM COOLANT CHARRING BY-PRODUCT. THIS WOULD ALSO REQUIRE FUEL CELL SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	130	ABORT:	2/1R

ITEM: H2/02 PREHEATER
FAILURE MODE: RESTRICTED COOLANT FLOW

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
5)
6)
7)
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9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, MECHANICAL SHOCK

EFFECTS/RATIONALE:
LOSS OF COOLANT FLOW TO THE FCP WOULD REQUIRE THE FUEL CELL TO BE SHUTDOWN. THIS WOULD BE DETECTED BY THE COOLANT DELTA PRESSURE SWITCH.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	131	ABORT:	2/1R

ITEM: H2/02 PREHEATER, PUMP, THERMAL CONTROL VALVE, CONDENSER, FILTERS, START/SUSTAIN HEATER, ACCUMULATOR, FLEXIBLE INTERFACES, ECLSS HEAT EXCHANGERS
FAILURE MODE: EXTERNAL LEAK OF TCS COOLANT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, MECHANICAL SHOCK

EFFECTS/RATIONALE:
EXTERNAL LEAKAGE CAUSES A DECREASE IN COOLANT PRESSURE OF THE SYSTEM AND LOSS OF COOLANT FLOW TO THE FCP. THIS IS DETECTABLE BY THE COOLANT DELTA PRESSURE SWITCH. LOSS OF COOLANT WILL CAUSE FCP OVERHEATING AND POSSIBLE REACTANT CROSSOVER. THIS REQUIRES FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	132	ABORT:	2/1R

ITEM: COOLANT PUMP
FAILURE MODE: LOSS OF OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: CONTAMINATION, VIBRATION, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
COOLANT PUMP FAILURE WILL RESULT IN FCP OVERHEATING DUE TO INSUFFICIENT COOLANT FLOW. THIS MAY RESULT IN ELECTROLYTE DRYOUT WHICH COULD CAUSE REACTANT CROSSOVER. THIS REQUIRES FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 133

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 3/3
ABORT: 3/3

ITEM: COOLANT PRESSURE SWITCH
FAILURE MODE: FAIL OPEN

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: PIECE PART FAILURE, SHOCK, VIBRATION

EFFECTS/RATIONALE:
THE PRESSURE TAB WILL NOT GO GRAY WHEN FUEL CELL START-UP IS PERFORMED OR IT WILL GO TO BARBER POLE, IF THE FCP IS ALREADY RUNNING. RELAY K9 WILL NOT CLOSE, WHICH WILL PREVENT START-UP HEATER FROM ACTIVATING AND THE FLOW CONTROL BY-PASS VALVE FROM ACTIVATING. IF START BUTTON IS RELEASED THE FUEL CELL WILL DO AN AUTOMATIC SHUTDOWN. NOTE: FUEL CELL CAN STILL BE STARTED IF THE START BUTTON IS HELD DOWN FOR AT LEAST 32 SECONDS. THIS ALLOWS ENOUGH TIME FOR THE TIMER MODULE TO CLOSE RELAY K10.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	134	ABORT:	3/3

ITEM: STACK INLET TEMPERATURE SENSOR
FAILURE MODE: FULL OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
DETECTS STACK INLET TEMPERATURE USED BY START-UP HEATER ELECTRONICS. FAILURE HIGH WOULD PREVENT HEATER OPERATION WHICH WOULD SLOW THE START-UP PROCESS. NOTE THAT THE START-UP HEATER IS DISCONNECTED ON FCP#1.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 135

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/1R
ABORT:	3/1R

ITEM: STACK INLET TEMPERATURE SENSOR
FAILURE MODE: LOW OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
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9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	3/1R	TAL:	3/1R
ONORBIT:	3/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	3/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
MEASURES THE TEMPERATURE OF COOLANT ENTERING STACK USED BY THE START-UP HEATER ELECTRONICS. FAILURE LOW WOULD LOSE ONE PATH FOR START-UP HEATER SHUTDOWN. REMAINING PATH IS STACK OUTLET TEMPERATURE SENSOR AND ELECTRONICS AND MANUAL SWITCHES. FAILURE OF REDUNDANT PATHS COULD CAUSE START-UP HEATER TO FAIL ON WHICH COULD REQUIRE FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 136

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/3
ABORT:	3/3

ITEM: STACK OUTLET TEMPERATURE SENSOR
FAILURE MODE: FULL OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
MEASURES THE TEMPERATURE OF COOLANT EXITING THE STACK WHICH IS USED BY THE START-UP/SUSTAINING HEATER ELETRONICS. FAILURE HIGH COULD PREVENT START-UP OR SUSTAINING HEATER OPERATION. START-UP HEATER FAILURE COULD SLOW THE FCP START-UP PROCESS. SUSTAINING HEATER FAILURE COULD DEGRADE THE FCP PERFORMANCE. NOTE: START-UP HEATER IS DISCONNECTED ON FCP#1.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 137

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/1R
ABORT:	3/1R

ITEM: STACK OUTLET TEMPERATURE SENSOR
FAILURE MODE: LOW OUTPUT

LEAD ANALYST: M. HIOTT   SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
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6)
7)
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9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	3/1R	TAL:	3/1R
ONORBIT:	3/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	3/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
MEASURES THE TEMPERATURE OF THE COOLANT EXITING THE STACK WHICH IS USED BY THE START-UP/SUSTAINING HEATER ELECTRONICS. SENSOR FAILURE LOW COULD PREVENT START-UP OR SUSTAINING HEATER SHUTDOWN. THIS WOULD REQUIRE FCP SHUTDOWN. NOTE: START-UP HEATER IS DISCONNECTED ON FCP#1.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	138	ABORT:	2/1R

ITEM: WATER SEPARATOR PUMP
FAILURE MODE: DEGRADED PERFORMANCE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: CONTAMINATION, STRUCTURAL PART FAILURE, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
A FAILED OFF OR DEGRADED PERFORMANCE WATER SEPARATOR PUMP WILL FLOOD A FUEL CELL. THIS RESULTS IN DECREASED ELECTROLYTE CONCENTRATION AND REQUIRES FUEL CELL SHUTDOWN. AN ERRATIC PUMP MOTOR IS DETECTABLE BY ITS VOLTAGE AND CURRENT MEASUREMENTS, BECAUSE OF LIQUID GETTING INTO THE PUMP. A MOTOR FAILURE IS ALSO DETECTABLE BY A PH MEASUREMENT AND HIGH CONDENSER OUTLET TEMPERATURE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 139

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 2/1R
ABORT: 1/1

ITEM: WATER SEPARATOR PUMP/WATER CONDENSATE TRAP
FAILURE MODE: RESTRICTED FLOW

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	1/1
LIFTOFF:	2/1R	TAL:	1/1
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: CONTAMINATION

EFFECTS/RATIONALE:
RESTRICTED HYDROGEN FLOW FROM THE WATER SEPARATOR PUMP CAUSES REACTANT STARVATION AND INADVERTANT FUEL CELL SHUTDOWN. LOSS OF A SINGLE FUEL CELL REQUIRES PRIORITY MISSION AND/OR ABORT DECISION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 141

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	2/1R

ITEM: THERMAL CONTROL VALVE
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT   SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) TCS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: FATIGUE, MECHANICAL SHOCK, ELECTRICAL FAILURE, BINDING

EFFECTS/RATIONALE:
ERRONEOUS OUTPUT COULD CAUSE ELECTROLYTE DRY OUT. THE CONDENSER WOULD CONDENSE TOO MUCH WATER. THIS CONDITION CAN LEAD TO REACTANT CROSSOVER AND EXPLOSION. IF THE REVERSE FAILURE OCCURS, FUEL CELL FLOODING COULD OCCUR.
COOLANT TEMPERATURE WOULD NOT BE SUFFICIENT FOR CONDENSING WATER. EITHER FAILURE REQUIRES FUEL CELL SHUTDOWN.

REFERENCES:

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INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 142

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	2/1R

ITEM: WATER DISCHARGE VALVE
FAILURE MODE: FAIL CLOSED

LEAD ANALYST: M. HIOTT   SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, MECHANICAL SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
A FAILED CLOSED WATER DISCHARGE VALVE WILL CAUSE FUEL CELL FLOODING FROM WATER BUILD UP. FLOODING OF THE FUEL CELL REQUIRES SHUTDOWN.

REFERENCES:

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 143

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	2/1R

ITEM: H2O DISCHARGE LINE
FAILURE MODE: RESTRICTED FLOW

LEAD ANALYST: M. HIOTT   SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	2/1R	TAL:	3/1R
ONORBIT:	2/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0006

CAUSES: CONTAMINATION, CORROSION, FROZEN WATER

EFFECTS/RATIONALE:
RESTRICTED FLOW CAUSES FUEL CELL FLOODING AND SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	144	ABORT:	3/3

ITEM: PH WATER SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
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9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC464-0115

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
IF THE PH SENSOR FAILS TO WORK, THE PH CAN BE TESTED MANUALLY.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	145	ABORT:	3/3

ITEM: PRODUCT WATER LINE TEMPERATURE SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
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9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
A FAILED TEMPERATURE SENSOR CAUSES LOSS OF MEASUREMENT. A FAILED TEMPERATURE SENSOR CAN BE DETECTED BY SWITCHING TO THE STANDBY HEATERS AND CHECKING THE MEASUREMENT TO SEE IF IT STABILIZES. IF THE MEASUREMENT STABILIZES, THIS WOULD INDICATE THAT A FAILED HEATER WAS CAUSING THE PROBLEM.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	146	ABORT:	3/3

ITEM: PRODUCT WATER LINE HEATER (A&B)
FAILURE MODE: FAILED ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0006

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
FAILED ON LINE HEATERS HAVE NO EFFECT ON THE CREW OR MISSION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	147	ABORT:	3/3

ITEM: PRODUCT WATER LINE HEATER (A&B)
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
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7)
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9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0006

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
THE PRODUCT WATER LINE HEATERS ARE USED DURING START-UP. DURING NORMAL MISSIONS, THE HEATERS ARE NOT INITIATED, NOR IS THE FUEL CELL STOPPED AND RESTARTED.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	148	ABORT:	2/1R

ITEM: PRODUCT WATER LINE
FAILURE MODE: RESTRICTED FLOW (EXTERNAL LEAKAGE)

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
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CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	2/1R
LIFTOFF:	2/1R	TAL:	2/1R
ONORBIT:	2/1R	AOA:	2/1R
DEORBIT:	2/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: V070-454110-124

CAUSES: CONTAMINATION, FROZEN

EFFECTS/RATIONALE:
RESTRICTED FLOW WITHIN THE PRODUCT WATER LINE WOULD RESULT IN NO PRODUCT WATER TO THE ECLSS. IF THE WATER RELIEF LINE ALSO BECOMES BLOCKED, THEN ALL OF THE FUEL CELLS WOULD FLOOD. THIS MEANS YOU ARE ONE FAILURE AWAY FROM LOSS OF CREW/VEHICLE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 149

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 3/2R
ABORT: 3/2R

ITEM: WATER SUPPLY CHECK VALVE
FAILURE MODE: EXTERNAL LEAKAGE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
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7)
8)
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CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/2R	TAL:	3/3
ONORBIT:	3/2R	AOA:	3/3
DEORBIT:	3/3	ATO:	3/2R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [F]

LOCATION: MID-BODY
PART NUMBER: ME284-0475-0001

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
AN EXTERNAL LEAK AT THE WATER SUPPLY CHECK VALVE CAUSES LOSS OF PRODUCT WATER FROM THE FUEL CELL TO THE ECLSS. LOSS OF ALL PRODUCT WATER MEANS MISSION TERMINATION DUE TO INSUFFICIENT POTABLE WATER. LEAKAGE OF THE CHECK VALVE IN THE WATER RELIEF PANEL ASSEMBLY CAN CAUSE FREEZING OF ALL FUEL CELL WATER LINES. THIS WOULD RESULT IN FLOODING OF ALL FUEL CELLS.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 150

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 3/1R
ABORT: 3/1R

ITEM: WATER SUPPLY CHECK VALVE
FAILURE MODE: FAIL CLOSED

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
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7)
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9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	3/1R	TAL:	3/1R
ONORBIT:	3/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	3/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: ME284-0475-0001

CAUSES: VIBRATION, MECHANICAL SHOCK

EFFECTS/RATIONALE:
FAILURE OF THE CHECK VALVE WOULD NOT BE CRITICAL UNLESS THE RELIEF VALVE ALSO FAILED CLOSED. THIS WOULD CAUSE THE FUEL CELL TO OVERPRESSURE AND FLOOD.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 151

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 3/2R
ABORT: 3/2R

ITEM: WATER SUPPLY CHECK VALVE
FAILURE MODE: FAILS TO CHECK

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
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7)
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9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/2R	AOA:	3/3
DEORBIT:	3/3	ATO:	3/2R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [F] C [P]

LOCATION: MID-BODY
PART NUMBER: ME284-0475-0001

CAUSES: CONTAMINATION, FROZEN

EFFECTS/RATIONALE:
FAILURE OF A SINGLE CHECK VALVE TO CHECK PROPERLY MAY ALLOW ALL FUEL CELLS TO VENT WATER THROUGH A SINGLE WATER RELIEF VALVE. THE FIRST FAILURE WOULD BE A WATER RELIEF VALVE FAILED OPEN. THE SECOND FAILURE WOULD BE THE CHECK VALVE FOR THE SAME FUEL CELL FAILING TO CHECK. THIS COULD CAUSE MISSION TERMINATION DUE TO LOSS OF ALL POTABLE WATER.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 152

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/2R
ABORT:	3/2R

ITEM: WATER RELIEF VALVE
FAILURE MODE: EXTERNAL LEAKAGE

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/2R	TAL:	3/3
ONORBIT:	3/2R	AOA:	3/3
DEORBIT:	3/3	ATO:	3/2R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [F]

LOCATION: MID-BODY
PART NUMBER: MC284-0431-0001

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
AN EXTERNAL LEAK AT THE WATER RELIEF VALVE CAUSES LOSS OF PRODUCT WATER FROM THE FUEL CELL TO THE ECLSS. LOSS OF ALL PRODUCT WATER MEANS MISSION TERMINATION DUE TO INSUFFICIENT POTABLE WATER. LEAKAGE OF THE RELIEF VALVE IN THE WATER RELIEF PANEL ASSEMBLY CAN CAUSE FREEZING OF ALL FUEL CELL WATER LINES. THIS WOULD RESULT IN FLOODING OF ALL FUEL CELLS.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/2R
MDAC ID:	153	ABORT:	3/2R

ITEM: WATER RELIEF VALVE
FAILURE MODE: FAILS OPEN

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/2R	AOA:	3/3
DEORBIT:	3/3	ATO:	3/2R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC284-0431-0001

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
A FAILED OPEN WATER RELIEF VALVE CAUSES LOSS OF THE PRODUCT WATER FROM THE ONE FUEL CELL TO THE ECLSS. LOSS OF ALL PRODUCT WATER COULD OCCUR WITH A SECOND FAILURE: THE WATER RELIEF CHECK VALVE STUCK OPEN (FAILS TO CHECK) COULD ALLOW ALL PRODUCT WATER FROM ALL FCP'S TO VENT THROUGH THE SINGLE OPEN VALVE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 154

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/1R
ABORT:	3/1R

ITEM: WATER RELIEF VALVE
FAILURE MODE: FAILS CLOSED

LEAD ANALYST: M. HIOTT   SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/1R
LIFTOFF:	3/1R	TAL:	3/1R
ONORBIT:	3/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	3/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [NA] C [P]

LOCATION: MID-BODY
PART NUMBER: MC284-0431-0001

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
LOSS OF RELIEF VALVE CAUSES NO MAJOR IMPACT, BUT IF A BLOCKAGE OCCURS WITHIN THE ECLSS PRODUCT WATER LINE, THEN FUEL CELL WOULD FLOOD WHICH IS A GROUND RULE FOR FCP SHUTDOWN.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/1R
MDAC ID:	155	ABORT:	3/1R

ITEM: WATER RELIEF VALVE HEATER (A&B)
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/1R	TAL:	3/1R
ONORBIT:	3/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	3/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0014

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
FAILED OFF HEATERS COULD CAUSE WATER TO FREEZE IN VALVE AND BLOCK THE RELIEF LINE. THIS FAILURE COULD CAUSE LOSS OF A FCP, IF THE WATER NEEDS TO BE VENTED. REDUNDANT HEATERS MUST FAIL FOR THIS TO OCCUR.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 156

HIGHEST CRITICALITY HDW/FUNC
FLIGHT: 3/3
ABORT: 3/3

ITEM: WATER RELIEF VALVE HEATER A&B
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0014

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
FAILED ON HEATERS HAVE NO EFFECT ON THE FUEL CELL OR MISSION/CREW.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	157	ABORT:	3/3

ITEM: WATER RELIEF VALVE TEMPERATURE SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-0003

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
A FAILED TEMPERATURE SENSOR CAUSES LOSS OF MEASUREMENT. A FAILED TEMPERATURE SENSOR CAN BE DETECTED BY SWITCHING TO THE STANDBY HEATERS AND CHECKING THE MEASUREMENT TO SEE IF IT STABILIZES. IF THE MEASUREMENT STABILIZES, THIS WOULD INDICATE THAT A FAILED HEATER WAS CAUSING THE PROBLEM.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 158

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/3
ABORT:	3/3

ITEM: WATER RELIEF LINE TEMPERATURE SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME449-0160-0003

CAUSES: VIBRATION, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
A FAILED TEMPERATURE SENSOR IS LOSS OF MEASUREMENT ONLY. (THE LINE HEATERS ARE CONTROLLED BY THERMOSTATS.) INSTRUMENT LOSS CAN BE CHECKED BY SWITCHING TO A REDUNDANT HEATER TO SEE IF THAT STABILIZES THE LINE TEMPERATURE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 159

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	2/1R

ITEM: WATER RELIEF (VENT) LINE
FAILURE MODE: RESTRICTED FLOW

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	2/1R
LIFTOFF:	2/1R	TAL:	2/1R
ONORBIT:	2/1R	AOA:	2/1R
DEORBIT:	2/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [NA] C [P]

LOCATION: MID-BODY
PART NUMBER: V070-454110

CAUSES: CONTAMINATION, FREEZE-UP

EFFECTS/RATIONALE:
RESTRICTED FLOW WITHIN THE WATER RELIEF (VENT) LINE WOULD LOSE THE RELIEF FUNCTION FOR ALL CELLS. ADDITIONALLY, IF THE PRODUCT WATER LINE PLUGGED UP, THEN ALL THE FUEL CELLS WOULD FLOOD. THUS, WITH THE WATER RELIEF LINE PLUGGED, THERE IS ONLY ONE PATH (PRODUCT WATER LINE) REMAINING BEFORE LOSS OF LIFE/VEHICLE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/1R
MDAC ID:	160	ABORT:	3/1R

ITEM: WATER VENT LINE HEATER A&B AND BARREL HEATER A&B
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/1R	TAL:	3/1R
ONORBIT:	3/1R	AOA:	3/1R
DEORBIT:	3/1R	ATO:	3/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0014

CAUSES: VIBRATION, MECHANICAL SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
THE FIRST HEATER LOSS HAS NO EFFECT ON THE WATER VENT LINE BECAUSE OF REDUNDANT HEATERS. THE LOSS OF REDUNDANT HEATERS MAY CAUSE THE VENT LINE TO FREEZE. THIS FAILURE WOULD NOT BE A PROBLEM UNLESS THE ECLSS LINE IS ALSO BLOCKED, WHICH CAN CAUSE FUEL CELL FLOODING.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 161

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	3/3
ABORT:	3/3

ITEM: WATER VENT LINE HEATER A&B AND BARREL HEATER A&B
FAILURE MODE: FAILED ON

LEAD ANALYST: M. HIOTT   SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: MC363-0038-0014

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
FAILED ON HEATERS HAVE NO EFFECT ON THE CREW OR MISSION.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	3/3
MDAC ID:	162	ABORT:	3/3

ITEM: WATER NOZZLE HEATER (A&B)
FAILURE MODE: FAIL ON

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [NA] B [NA] C [NA]

LOCATION: MID-BODY
PART NUMBER: ME363-0042-0003

CAUSES: VIBRATION, SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
NOZZLE HEATER A IS DISCONNECTED, THEREFORE, THE HEATER ELEMENT IS NOT REDUNDANT. A FAILED ON NOZZLE HEATER HAS NO EFFECT ON THE FUEL CELL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 163

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	2/1R

ITEM: WATER NOZZLE HEATER (A&B)
FAILURE MODE: FAIL OFF

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	2/1R
LIFTOFF:	2/1R	TAL:	2/1R
ONORBIT:	2/1R	AOA:	2/1R
DEORBIT:	2/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: ME363-0042-0003

CAUSES: VIBRATION, MECHANICAL SHOCK, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
IF THE WATER IN THE NOZZLE FREEZES, THE WATER RELIEF FUNCTION IS LOST. ADDITIONALLY, IF THE PRODUCT WATER LINE IS BLOCKED, ALL THE FUEL CELLS WILL FLOOD. NOZZLE HEATER A IS DISCONNECTED; THEREFORE, THE HEATER ELEMENT IS NOT REDUNDANT. HOWEVER, FOR THE NEXT FLIGHT THE HEATER WILL BE FUNCTIONAL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	11/03/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	EPG	FLIGHT:	2/1R
MDAC ID:	164	ABORT:	2/1R

ITEM: WATER RELIEF NOZZLE TEMPERATURE SENSOR
FAILURE MODE: ERRONEOUS OUTPUT

LEAD ANALYST: M. HIOTT SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	3/3	TAL:	3/3
ONORBIT:	2/1R	AOA:	2/1R
DEORBIT:	2/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [P] C [P]

LOCATION: MID-BODY
PART NUMBER: K-SS4-U-T1-6CNX

CAUSES: VIBRATION, SHOCK, CORROSION, ELECTRICAL FAILURE

EFFECTS/RATIONALE:
AN ERRONEOUS OUTPUT FROM THE WATER RELIEF NOZZLE TEMPERATURE SENSOR COULD PREVENT THE NOZZLE HEATER FROM WORKING. IF THE HEATER IS NONFUNCTIONAL, THE NOZZLE WOULD FREEZE. IF THE PRODUCT WATER LINE IS BLOCKED, ALL THE FUEL CELLS WILL FLOOD.
WITH THE RELIEF NOZZLE BLOCKED, ONLY ONE PATH (PRODUCT WATER LINE) REMAINS OPEN BEFORE LOSS OF ALL FCP'S.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 11/03/86
SUBSYSTEM: EPG
MDAC ID: 165

HIGHEST CRITICALITY	HDW/FUNC
FLIGHT:	2/1R
ABORT:	2/1R

ITEM: WATER NOZZLE
FAILURE MODE: RESTRICTED FLOW

LEAD ANALYST: M. HIOTT   SUBSYS LEAD: M. HIOTT

BREAKDOWN HIERARCHY:
1) EPG
2) FCP
3) ASA
4) WRS
5)
6)
7)
8)
9)

CRITICALITIES

FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	2/1R	TAL:	3/3
ONORBIT:	2/1R	AOA:	2/1R
DEORBIT:	2/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [1] B [NA] C [P]

LOCATION: MID-BODY
PART NUMBER: ME363-0042-0003

CAUSES: CONTAMINATION

EFFECTS/RATIONALE:
IF THE WATER NOZZLE BECOMES BLOCKED, THE WATER RELIEF FUNCTION IS LOST. WITH THE WATER NOZZLE BLOCKED, ONLY THE WATER LINE REMAINS OPERATIONAL BEFORE LOSS OF ALL FCP'S DUE TO FLOODING.

REFERENCES:

C-2

APENDIX D
POTENTIAL CRITICAL ITEMS

MDAC-ID	ITEM	FAILURE MODE
101	Fuel Cell	Loss electrical contact in power section
104	End Cell Heater	Fail off
105	End Cell Heater	Fail on
106	Separator Plates/UEA	Reactant leakage to Orbiter (external leakage)
107	Separator Plates/UEA	Internal leakage
108	Separator Plates	Coolant leakage
109	Separator Plates	Reactant Blockage
111	Integrated Dual Gas Regulator	Gross Venting
112	Integrated Dual Gas Regulator	H2 overpressure
113	Integrated Dual Gas Regulator	H2 starvation
114	Integrated Dual Gas Regulator	02 overpressure
115	Integrated Dual Gas Regulator	02 starvation
116	Integrated Dual Gas Regulator	Purge failure
117	H2/O2 Lines and Fittings and Accessory Components	Reactant leakage to Orbiter (external leakage)
118	O2/H2 Purge-Vent Lines and Vent Nozzles	Restricted flow
129	Start-Up Heater	Fail on
130	H2/O2 Preheater	Restricted coolant flow
131	H2/O2 Preheater, Pump, Thermal Control Valve, Condenser, Filters, Start/Sustain Heater, Accumulator, Flexible Interface, ECLSS Heat Exchanger	External leak of TCS coolant
132	Coolant Pump	Loss of output
138	Water Separator Pump	Degraded performance
139	Water Separator Pump/ Water Condensate Trap	Restricted flow
141	Thermal Control Valve	Erroneous Output
142	Water Discharge Valve	Fail closed
143	H20 Discharge	Restricted flow
148	Product Water Line	Restricted flow
149	Water Supply Check Valve	External leakage
151	Water Supply Check Valve	Fails to check
152	Water Relief Valve	External leakage

MDAC-ID	ITEM	FAILURE MODE
159	Water Relief (Vent) Line	Restricted flow
163	Water Nozzle Heater (A&B)	Fail off
164	Water Relief Nozzle Temperature Output	Erroneous output
165	Water Nozzle	Restricted flow