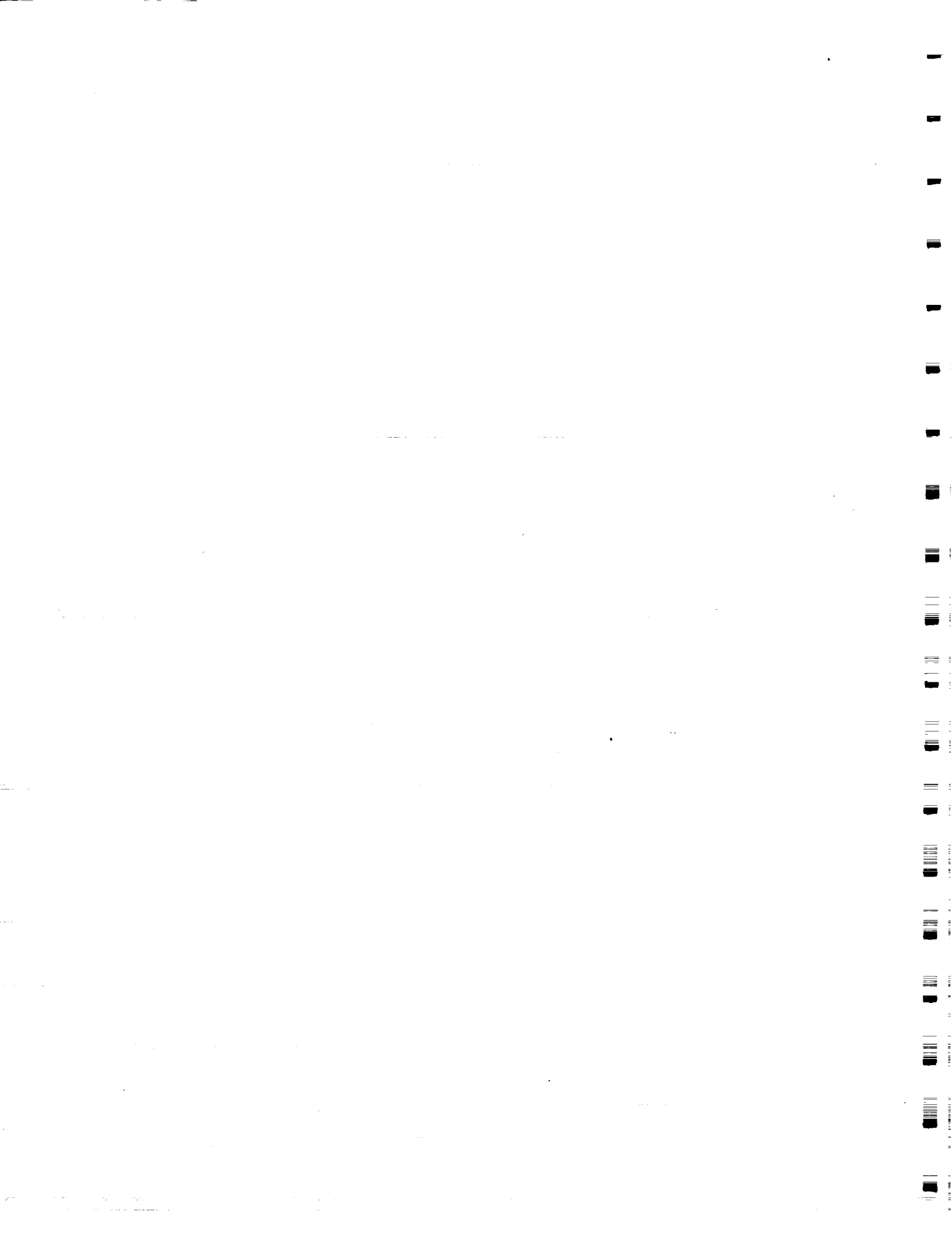


# **INDEPENDENT ORBITER ASSESSMENT**

## **ANALYSIS OF THE ASCENT THRUST VECTOR CONTROL ACTUATOR SUBSYSTEM**

**21 NOVEMBER 1986**



MCDONNELL DOUGLAS ASTRONAUTICS COMPANY  
HOUSTON DIVISION

SPACE TRANSPORTATION SYSTEM ENGINEERING AND OPERATIONS SUPPORT

WORKING PAPER NO. 1.0-WP-VA86001-06

INDEPENDENT ORBITER ASSESSMENT  
ANALYSIS OF THE ASCENT THRUST VECTOR CONTROL ACTUATOR SUBSYSTEM

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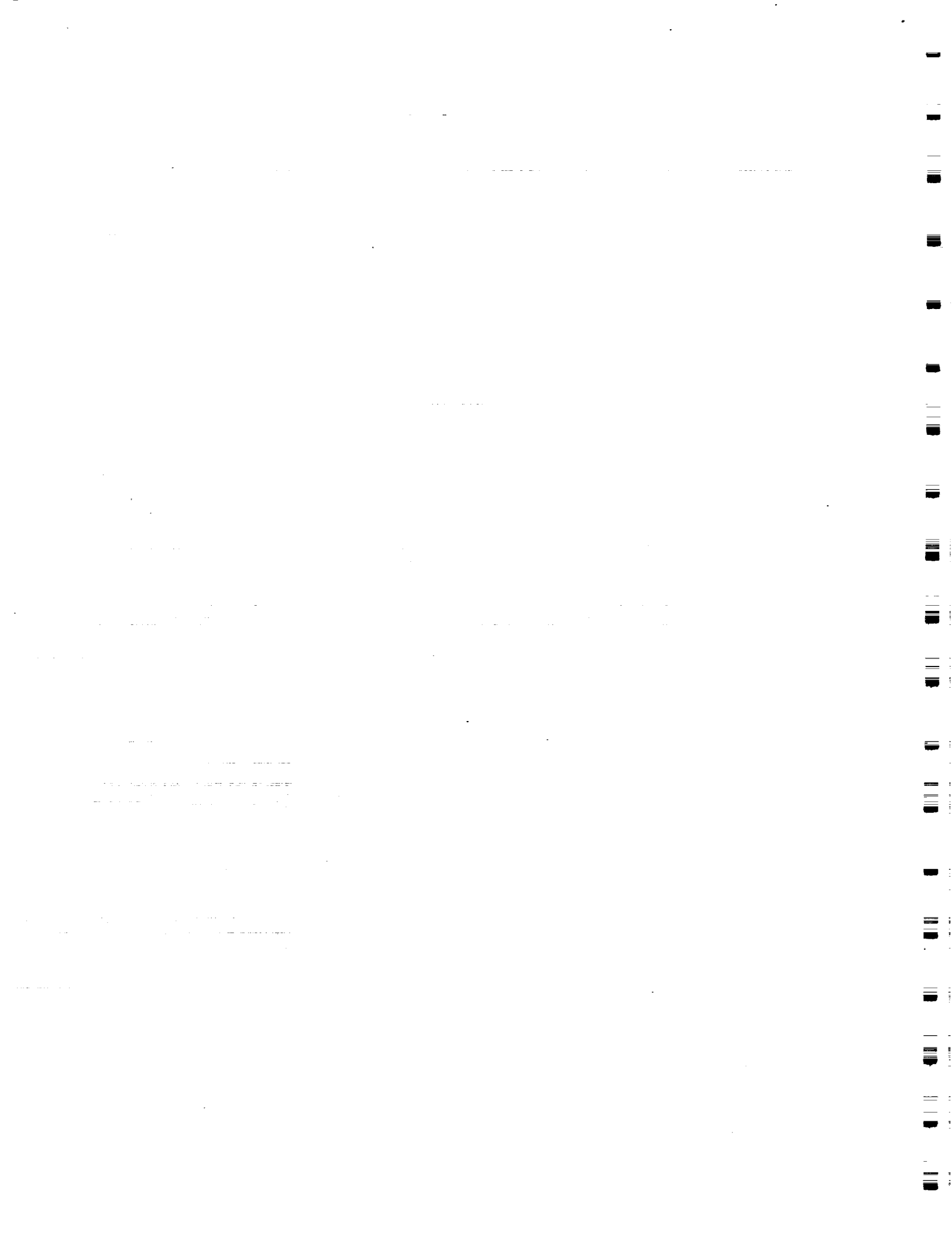
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Independent Orbiter Assessment  
Analysis of the Ascent Thrust Vector Control Actuator Subsystem

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 for the Ascent Thrust Vector Control (ATVC) Actuator hardware.

The function of the Ascent Thrust Vector Control Actuators (ATVC) is to gimbal the main engines to provide for attitude and flight path control during ascent. During first stage flight, the SRB nozzles provide nearly all the steering. After SRB separation, the Orbiter is steered by gimbaling of its main engines. There are six electrohydraulic servoactuators, one pitch and one yaw for each of the three main engines.

Each servoactuator is composed of four electrohydraulic servovalve assemblies, one second stage power spool valve assembly, one primary piston assembly and a switching valve.

The IOA analysis process utilized available 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.

Figures 1 and 2 presents a summary of the failure criticalities for each of the major elements of the Main Engine Servoactuator. A summary of the number of failure modes, by criticality, is also presented below with Hardware (H) 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 :	9	7	-	1	-	9	26

ATVC ACTUATOR ANALYSIS SUMMARY			
CRIT.	#FM	#PCI	
1/1	9	9	
2/1R	7	7	
3/1R	1	0	
3/3	9	0	

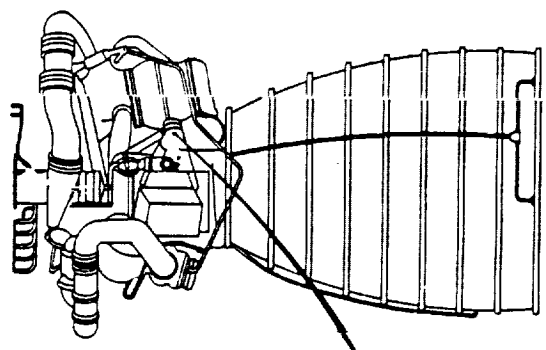
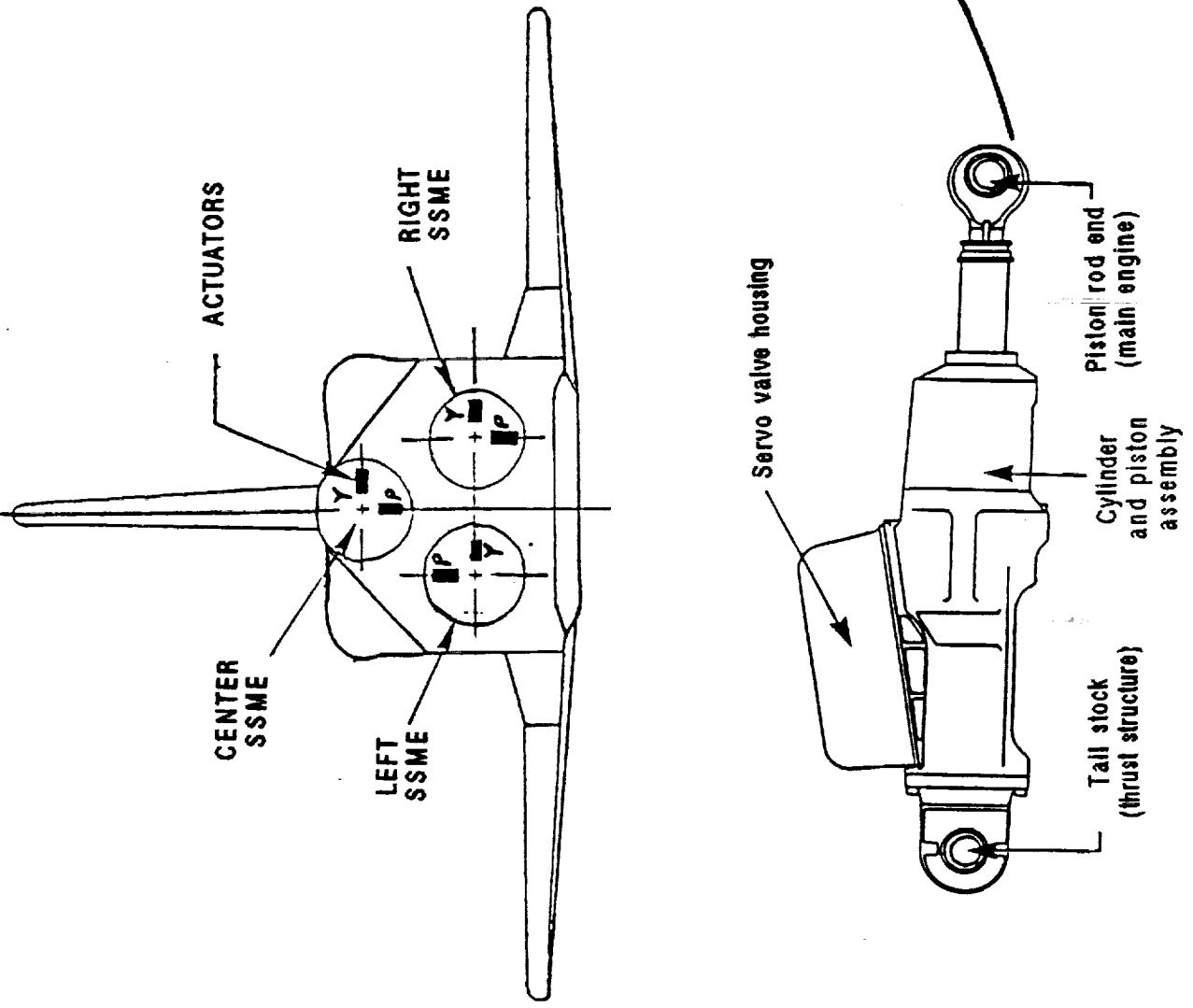


Figure 1 - ATVC ELECTROHYDRAULIC SERVOACTUATOR SUMMARY



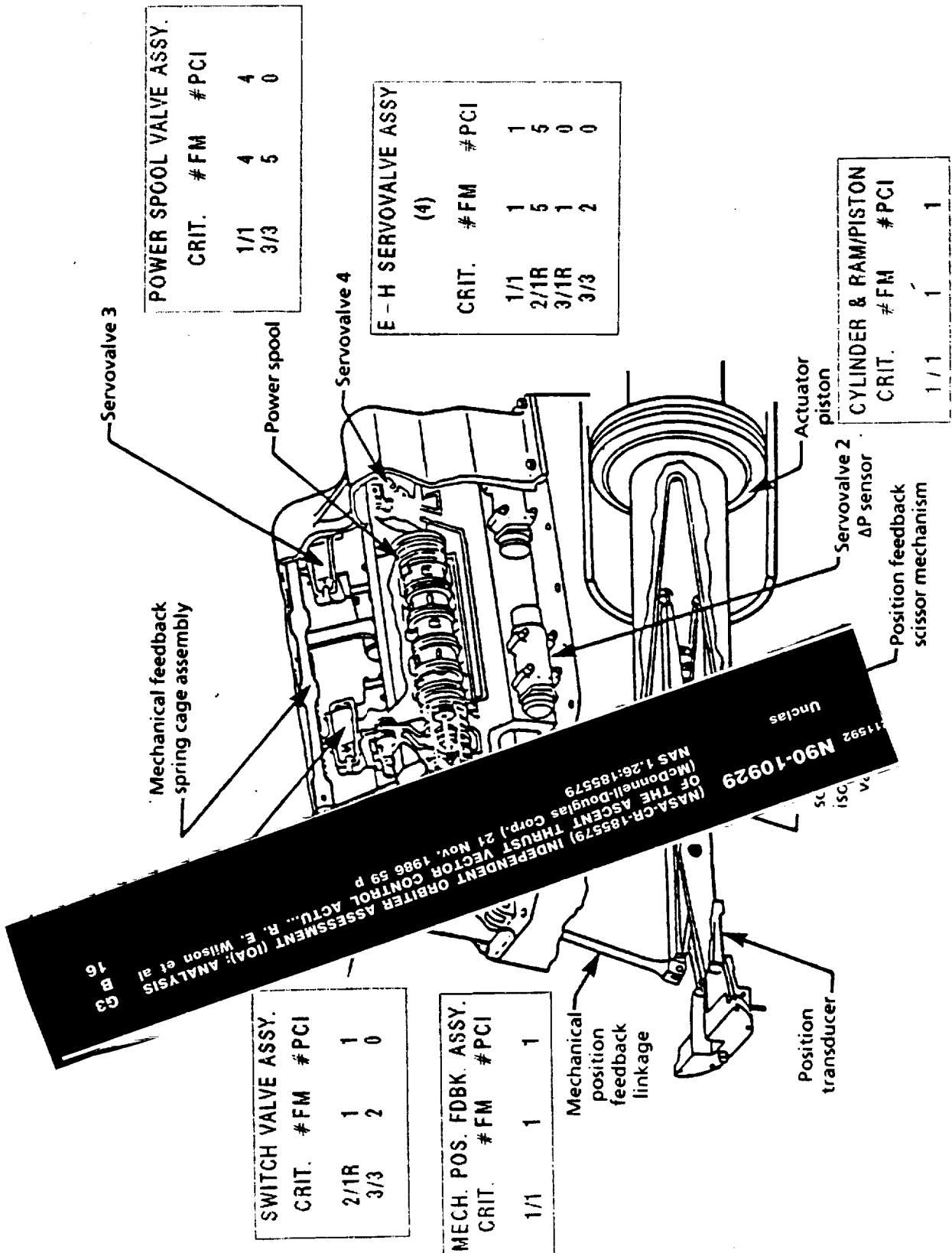


Figure 2 - TYPICAL ACTUATOR ASSEMBLY

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 :	9	7	-	-	-	16

Critical failures resulting in loss of ATVC were mainly due to loss of hydraulic fluid, fluid contamination and mechanical failures.

## 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 ATVC Actuator Ground Rules and Assumptions

The ATVC Actuator definitions, ground rules, and assumptions used in the IOA are defined in Appendix B.1 and B.2. There were no subsystem specific ground rules and assumptions used in the analysis.

### 3.0 SUBSYSTEM DESCRIPTION

#### 3.1 Design and Function

The ATVC servoactuators gimbal the main engines in pitch and yaw to provide for attitude and flight path control during ascent. There are two Ascent Thrust Vector Control (ATVC) actuators for each ME, one for pitch movement and one for yaw movement. Each actuator receives four command voltages, one from each ATVC driver electronics channel. Each actuator employs two of the three Orbiter hydraulic systems (one primary and one secondary). Each METVC servoactuator consists of the following components:

1. Switching valve. Two Orbiter hydraulic systems are connected to the valve. The output from the valve connects to four servovalves and to a power spool. The valve will shift position when the hydraulic pressure of the controlling system is less than 1200 to 1500 psi and will furnish standby pressure to the actuator.
2. Four electro-hydraulic servovalves. Each servovalve consists of a second-stage valve, a torque motor assembly with power valve feedback wire, a mechanical position feedback spring cage assembly, a bypass valve, a dynamic pressure feedback valve, and a secondary delta pressure transducer. The function of the servovalve is to generate secondary hydraulic pressure to drive a power spool valve in response to position commands from the ATVC electronic driver.
3. Torque motor assembly. The assembly consists of dual magnets, a flapper valve and two feedback wires attached to the flapper; one wire is linked to the servovalve and the other is linked to the power spool valve. The wires are used to control the spool velocity. When a command voltage generates a torque, it causes the flapper to rotate in a clockwise or counterclockwise direction causing a pressure buildup in either the right or left sections of the servovalve, thus moving the valve to the right or left. When the valve is displaced, the hydraulic pressure is transferred to the power spool which then transfers hydraulic pressure to the primary drive piston.
4. Mechanical position feedback assembly. The assembly links each of the four torque motor flappers to the primary piston. The assembly allows the flapper to rotate initially in response to a command voltage input, and then mechanically moves the flapper back to its neutral position as the primary piston reaches its commanded position.
5. Bypass valve. The bypass valve isolates a servovalve when a secondary delta pressure is determined to be bad by the ATVC electronics. When an isolation command is issued to a solenoid a piston shuttles against a spring. This allows

hydraulic pressure to shuttle a second piston which inhibits hydraulic flow from the servovalve to the power piston. This equalizes pressure on both sides of the hydraulic supply which allows the servovalve to float, thus isolating it from the system.

6. Secondary delta pressure transducer. Each servovalve has a transducer which measures the resistance its servovalve sees relative to the other three servovalves. It sends signals to the ATVC electronics which determines which, if any, delta pressure is outside allowable limits. If a delta pressure fails, the TVC sends an isolation command to the bypass valve.
7. Power spool valve assembly. Each actuator has one power spool which provides primary hydraulic pressure to the primary piston. The power spool consists of a cylinder that contains a linear power spool. The power spool has a central position whose motion is driven by the summation of the secondary delta pressure from the four servovalves. When the power spool is displaced, hydraulic fluid is directed through a lock valve to the primary piston. The lock valve hydraulically isolates the cylinder and primary piston from the hydraulic source to prevent further movement of the primary piston. If there is a hydraulic failure, the lock valve spool moves (due to spring pressure) to a closed position which locks the primary piston in its last commanded position. A force limiter valve limits internal cylinder pressure to 4050 psi. (The valve was used during the OFT program to determine side loads during main engine gimbaling.) The valve is functionally non-critical. Instrumentation has been removed from the Orbiter.
8. Cylinder and ram/piston assembly. The assembly produces linear motion (extend or retract) to move the SSME in pitch and mechanical position feedback cam and a feedback scissor assembly which connects to the mechanical position feedback spring cage assembly. The main cylinder reservoirs receive hydraulic pressure or return the Orbiter hydraulic supply through the feed/return lines leading to the power valve via the lock valve. As the ram moves, the scissor assembly contracts or expands, pushing the mechanical linkage (up or down) which moves the torque motor flapper. When the piston/cam reaches its commanded position, the feedback assembly removes secondary fluid pressures to the power valve.

### 3.2 Interfaces and Locations

The ATVC servoactuators interface with the four ATVC electronics drivers which receive commands via four MDMs from the four GPCs. Crew initiated command inputs are through the GPCs. The crew can

turn power on or off to any ATVC channel and place a FCS channel in ORIDE which bypasses the ATVC fault detection circuitry.

Each actuator is fastened to the Orbiter thrust structures and to the powerhead of one of the three SSMEs.

Crew inputs fall into three areas, rotational hand controller (RHC) commands, override commands and ATVC power.

The FA MDMS and the ATVC electronic drives are located in Avionics Bays 4, 5 and 6.

FCS channel monitor switches are located on Panel C3. The ATVC power switches are located on Panel 017.

The two displays relative to MPS ATVC are the caution and warning (C&W) matrix (Panel F7) and the GNC System Summary 1 display. The GNC System Summary 1 display (PASS and BFS) shows a down arrow for an FCS channel that has isolated a failed servovalve and a fault message.

### 3.3 Hierarchy

Figure 3 is a block diagram of the ATVC servo actuators. Figures 4 through 8 show components which were analyzed for failure modes.

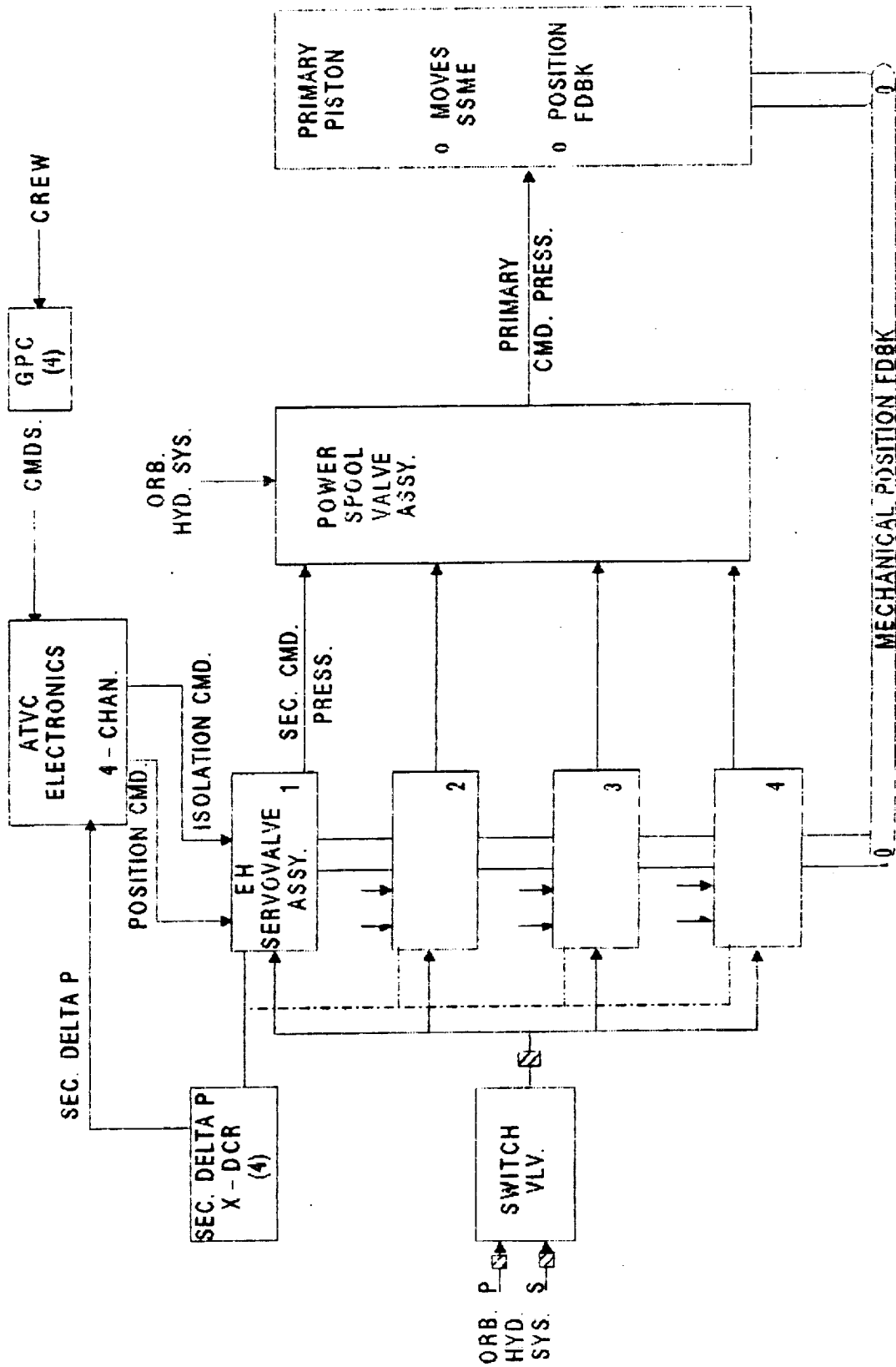


Figure 3 - ATVC SERVOACTUATOR BLOCK DIAGRAM



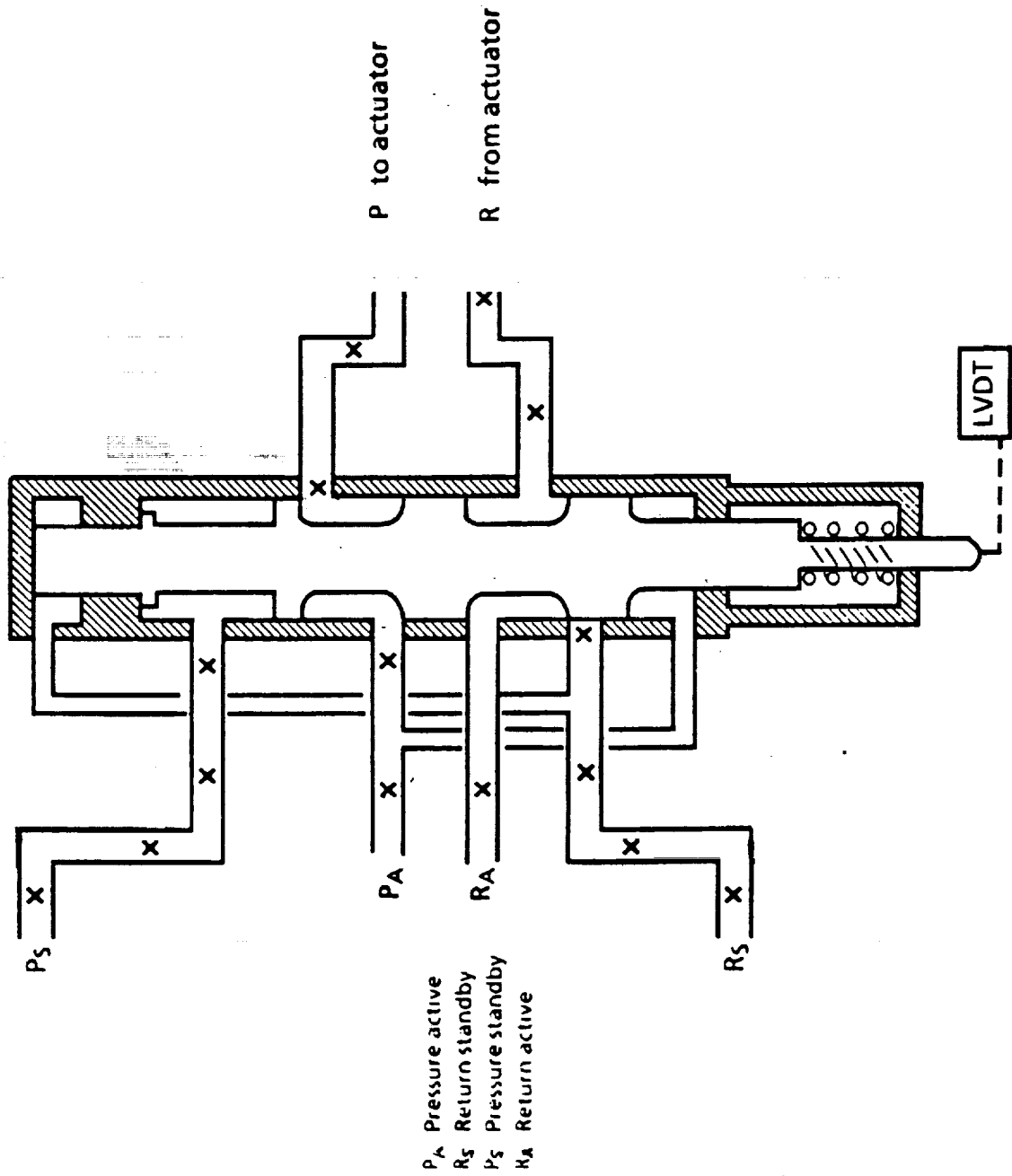


Figure 4 - SWITCHING VALVE

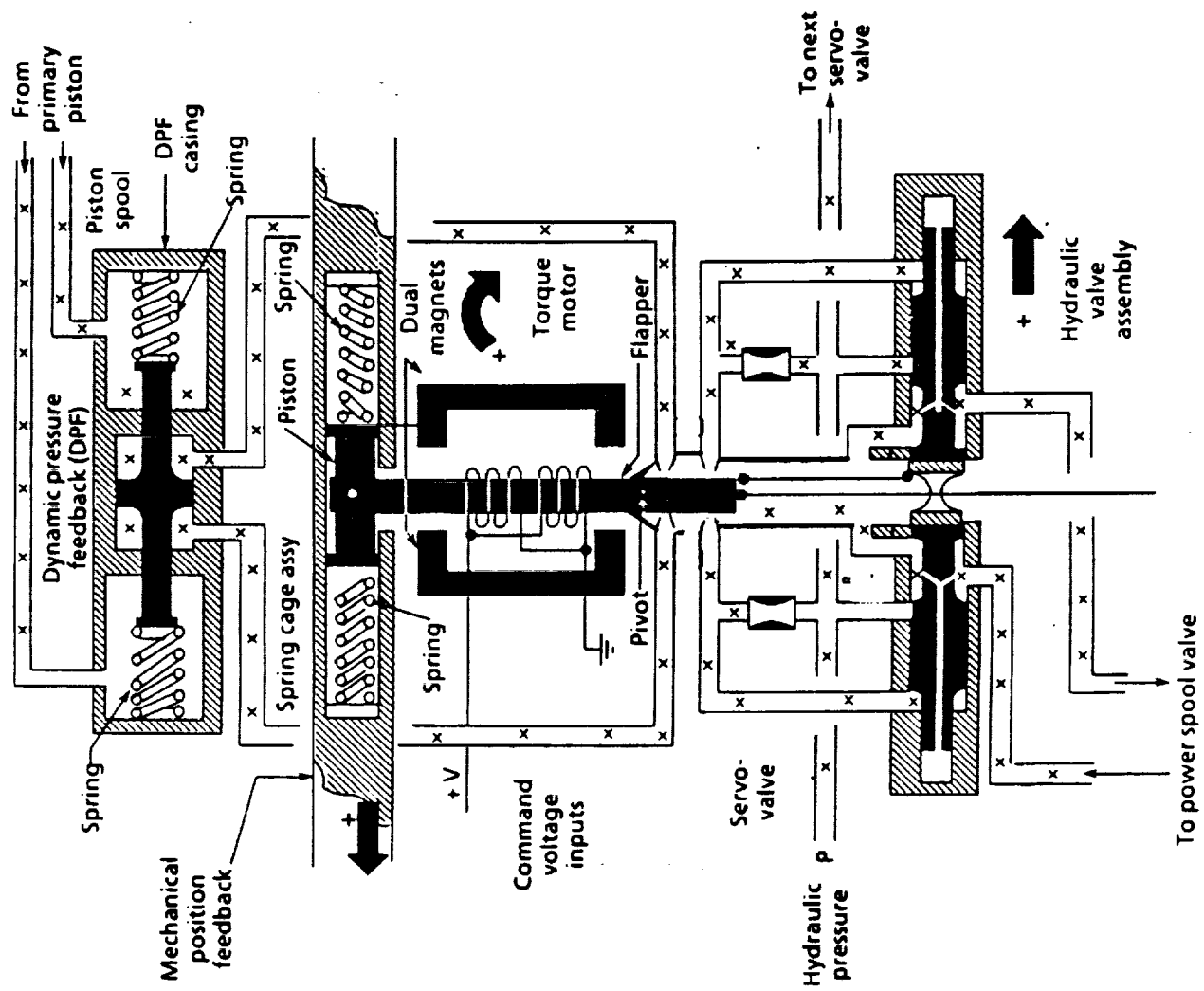


Figure 5 - ELECTROHYDRAULIC SERVOVALVE ASSEMBLY

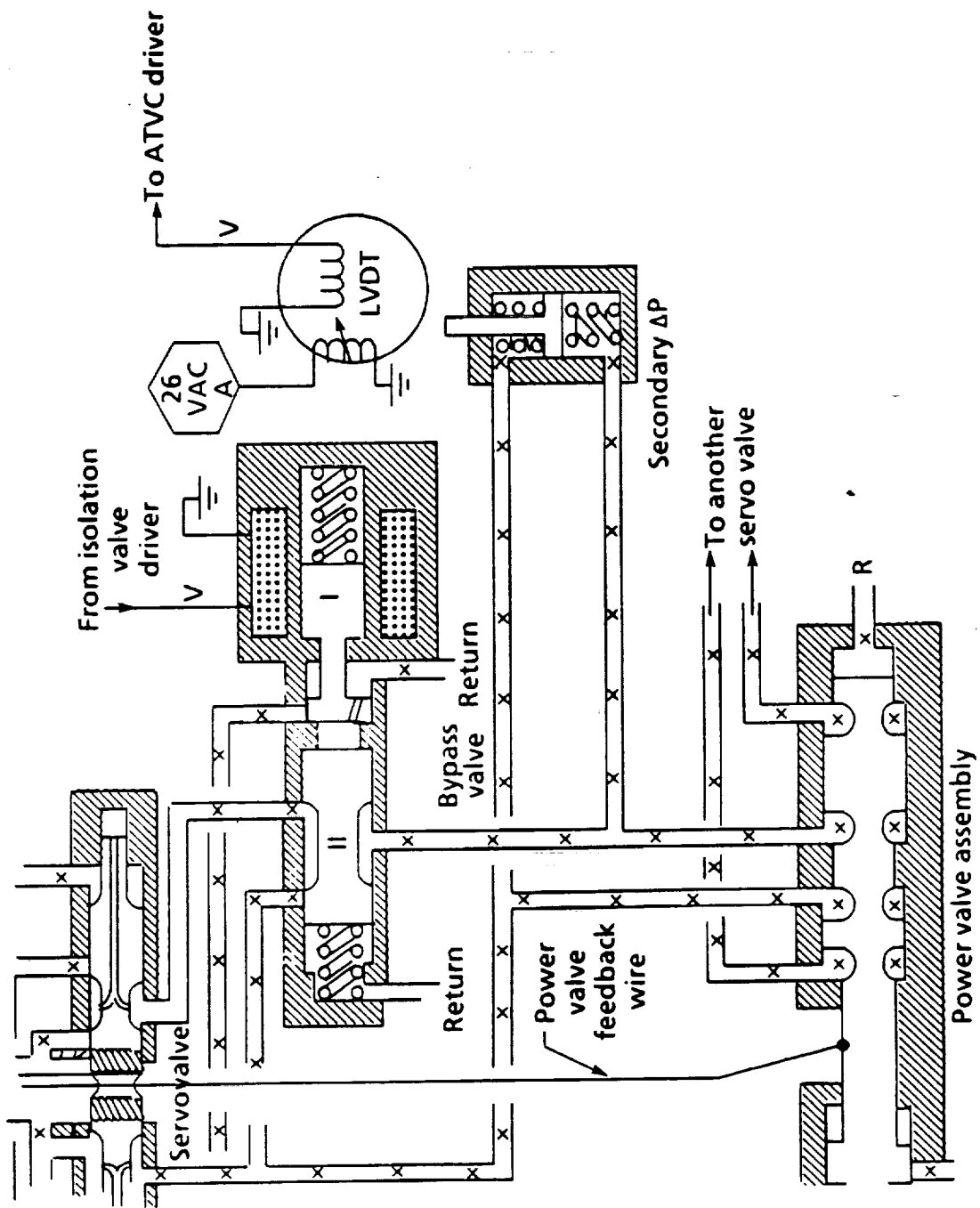


Figure 6 - BYPASS VALVE

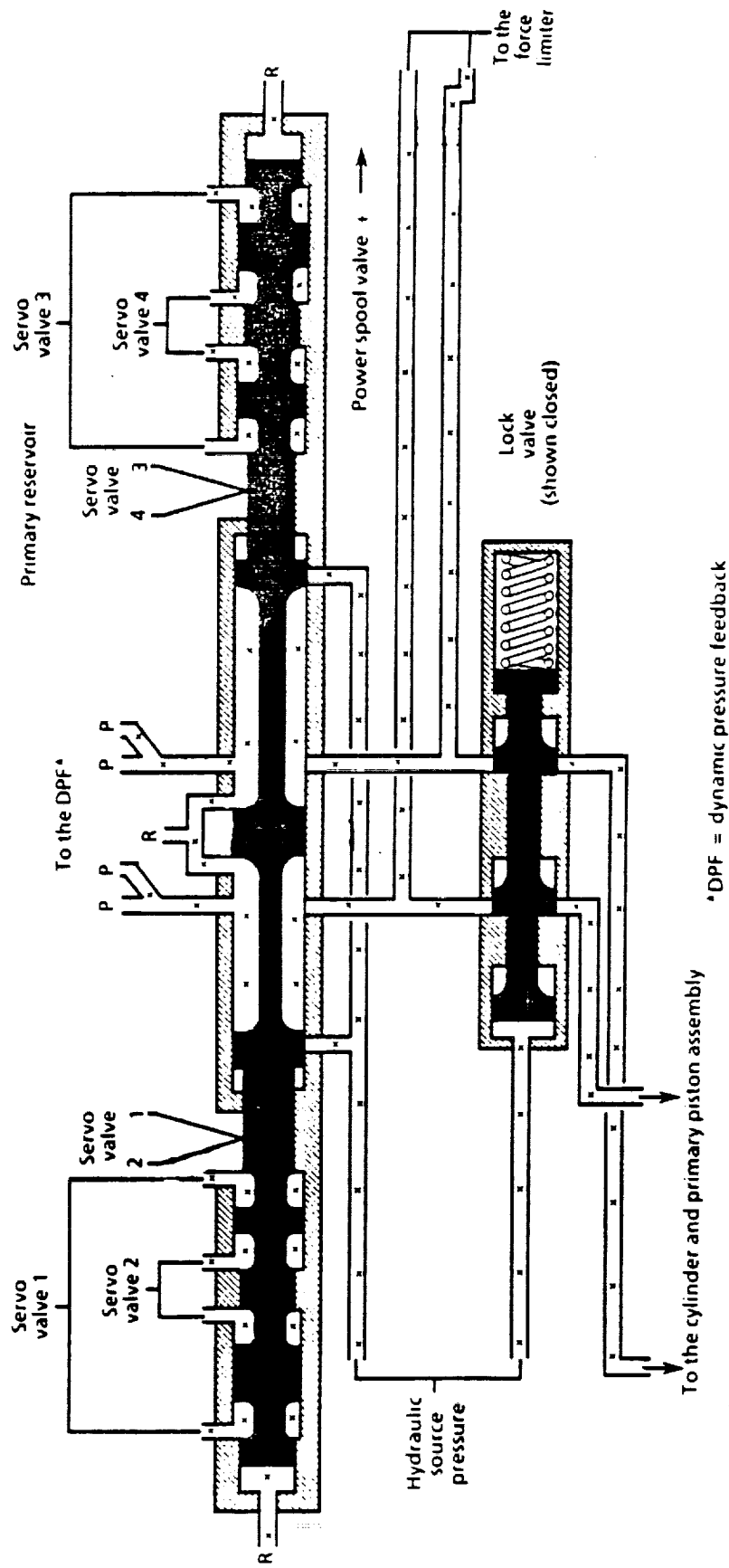


Figure 7 - POWER SPOOL VALVE ASSEMBLY

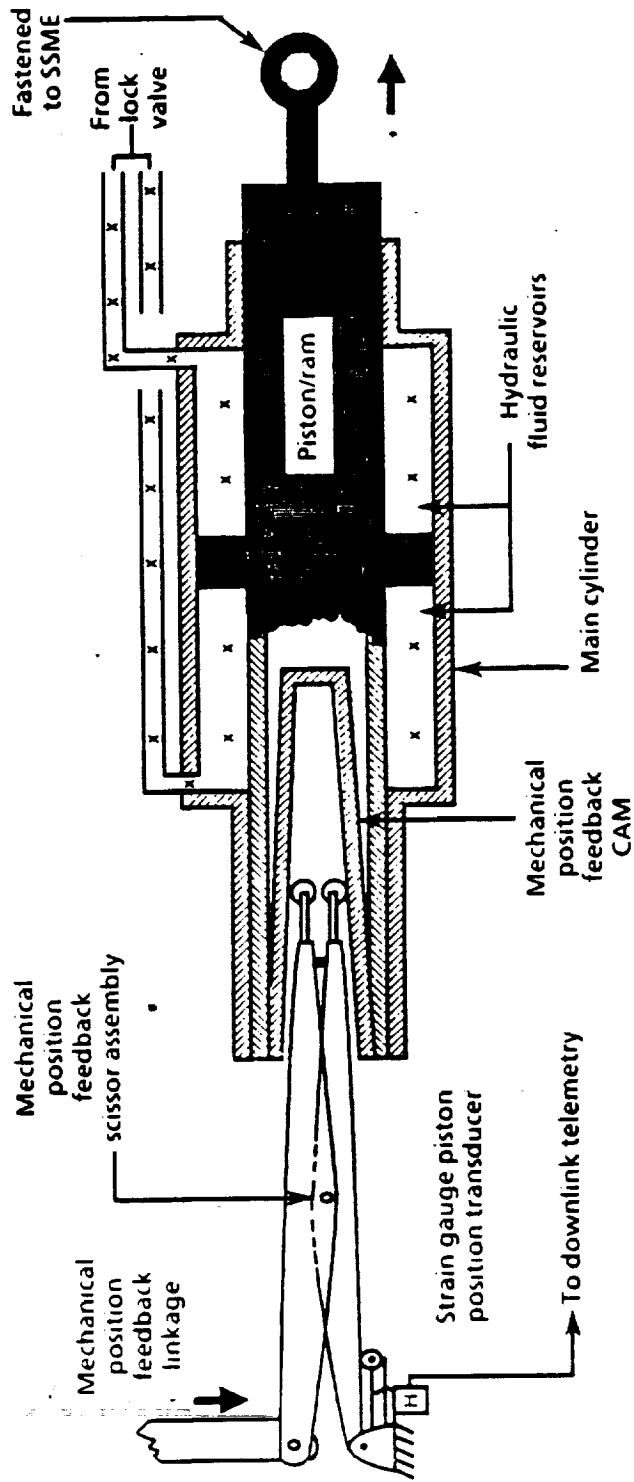


Figure 8 - CYLINDER AND PISTON/RAM ASSEMBLY

#### 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.

TABLE I Summary of IOA Failure Modes and Criticalities							
Criticality:	1/1	2/1R	2/2	3/1R	3/2R	3/3	TOTAL
O Servo-Actuator Hydraulic Valve Module	2	1	-	-	-	-	3
EH Servovalve Filter	-	4	-	-	-	-	4
Bypass Valve Secondary	1	-	-	-	-	1	2
Delta P Transducer	-	-	-	1	-	-	2
Power Spool Valve	-	1	-	-	-	-	1
Check Valve	1	-	-	-	-	-	1
Lock Valve	1	-	-	-	-	1	2
Force Limiter Valve	2	-	-	-	-	-	2
Dynamic Press. Feedback Valve	-	-	-	-	-	2	2
Switch Valve	-	1	-	-	-	-	1
Flow Cutoff Primary Piston Assembly	-	-	-	-	-	-	-
Valve Mechanical	-	-	-	-	-	2	2
Pos. Feedback Cylinder and Ram/Piston Assembly	1	-	-	-	-	-	1
Assembly	1	-	-	-	-	-	1
<b>TOTAL</b>	<b>9</b>	<b>7</b>	<b>-</b>	<b>1</b>	<b>-</b>	<b>9</b>	<b>26</b>

Critical failures which cause loss of the servoactuator were due to loss of hydraulic fluid, gross and slow leaks, valve failures due to contamination, clogged filters, loss of hydraulic pressure, mechanical failures in servovalves and its mechanical feedback mechanism and inability to detect failures by the ATVC fault detection circuitry.

Of the 26 failure modes analyzed, 16 failures were determined to be Potential Critical Items (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
O Servo-Actuator	2	1	-	-	-	3
Hydraulic Valve Module	-	4	-	-	-	4
EH Servovalve	1	-	-	-	-	1
Filter	-	1	-	-	-	1
Secondary Delta P Transducer	-	1	-	-	-	1
Power Spool Valve	1	-	-	-	-	1
Check Valve	1	-	-	-	-	1
Lock Valve	2	-	-	-	-	2
Switch Valve	-	1	-	-	-	1
Primary Piston Assembly	-	-	-	-	-	-
Mechanical Pos. Feedback Cylinder and Ram/Piston Assembly	1	-	-	-	-	1
Assembly	1	-	-	-	-	1
TOTAL	9	7	-	-	-	16

#### 4.1 Analysis Results - Servoactuator

Failures which were related to the Servoactuators as an entity were first analyzed. Critical failures were due to loss of hydraulic fluid, gross and slow leaks.

#### 4.2 Analysis Results - Hydraulic Valve Module

Components were individually analyzed. Most critical failures of these components included loss of command signal input, valve failure due to contamination, clogged filters and loss of hydraulic pressure.

### 4.3 Analysis Results - Primary Piston Assembly

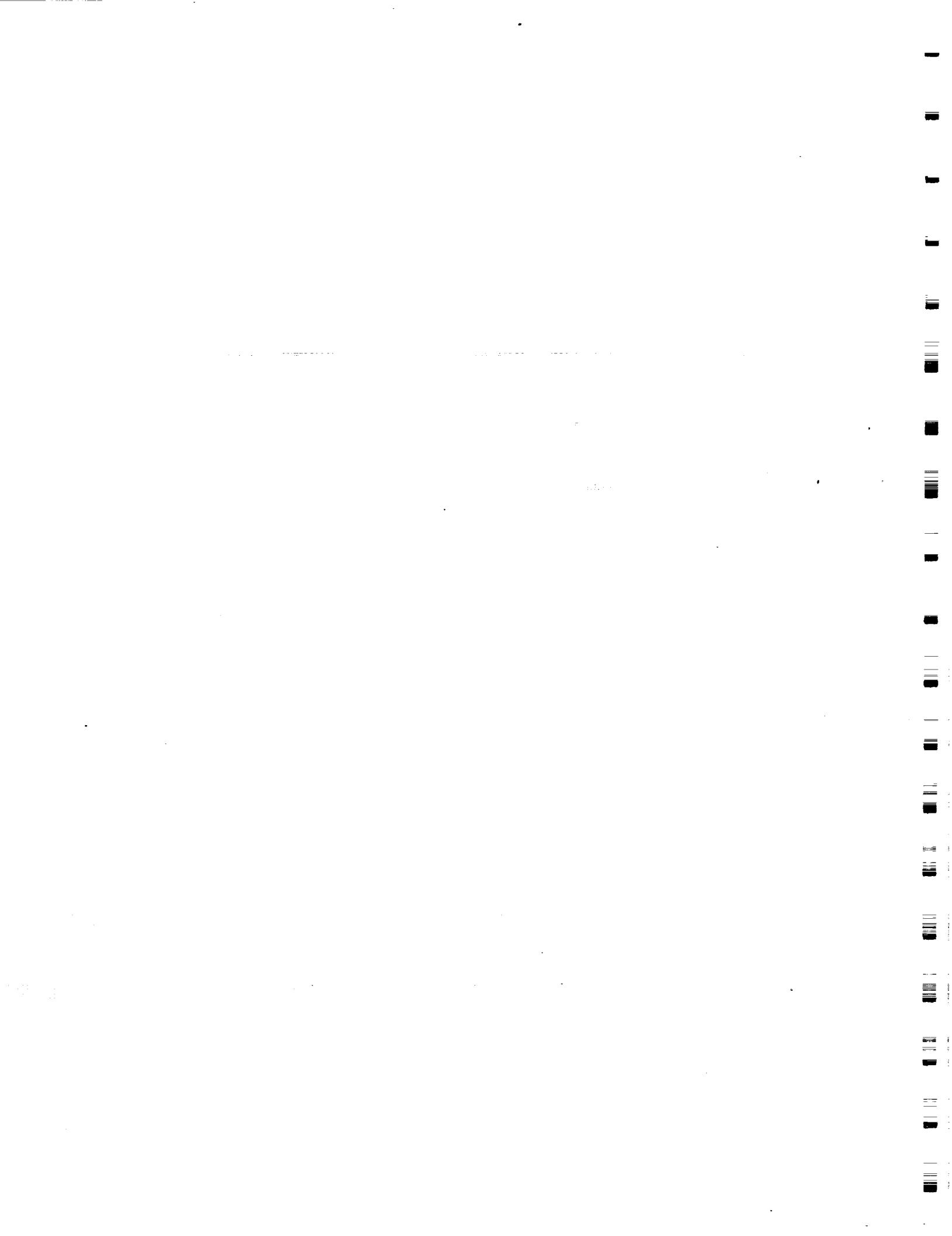
Critical failures were due to mechanical failures (fractures and jammed components).



## 5.0 REFERENCES

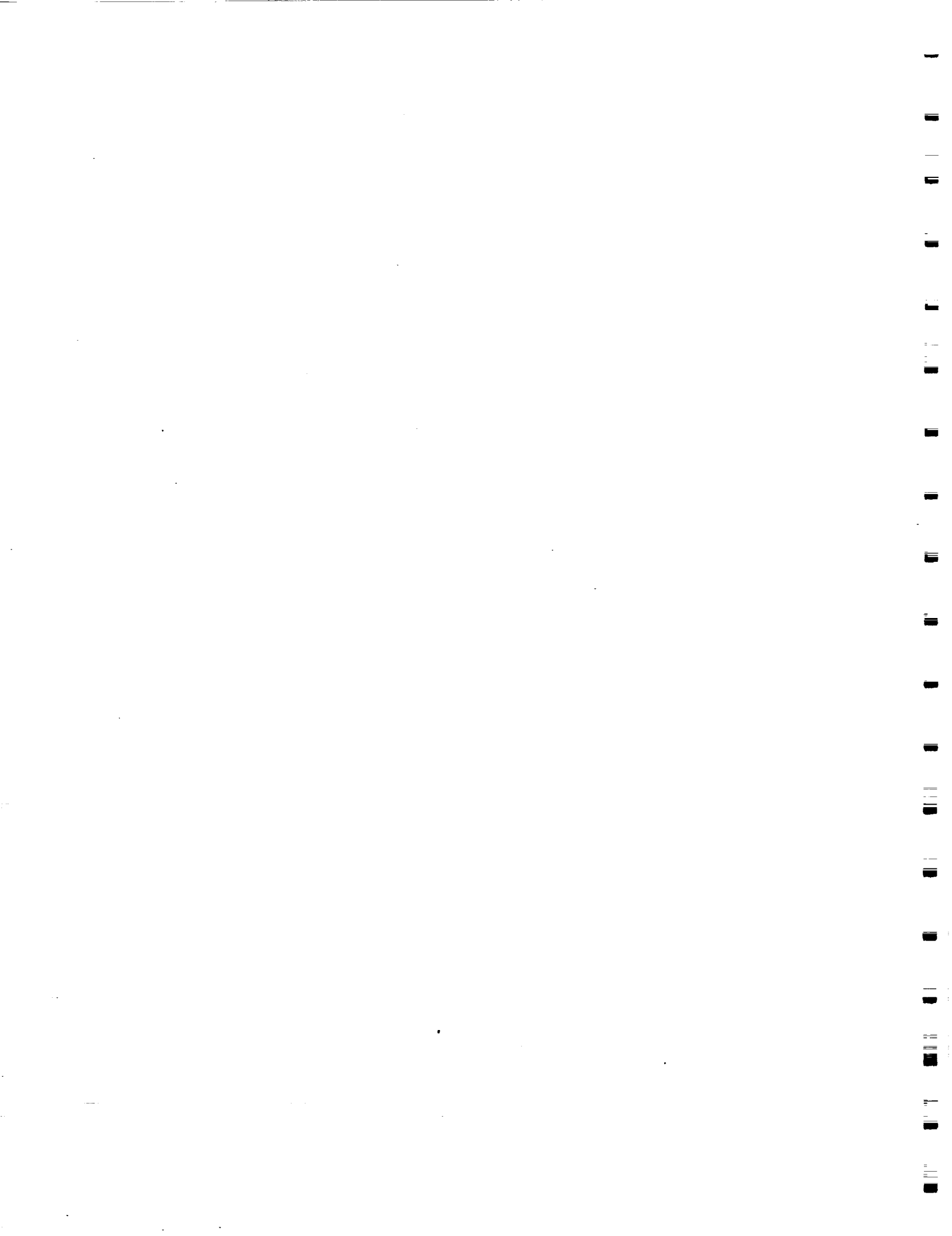
Reference documentation available from NASA and Rockwell was used in the analysis. The documentation used included the following:

1. Thrust Vector Control Training Manual, MPS TV 2102, 10/19/85
2. Space Shuttle Systems Handbook, JSC 11174, 09/13/86
3. SD72-SH-0102 Definition Manual Mechanical System Hydraulics, 10/28/75
4. RI Integrated Schematics (V570-580998, -58099)
5. Shuttle MML
6. FDF (Ascent)
7. OMRSD U58AGO, V79ATO, V58A00
8. GN&C Console Handbook JSC12843
9. Discussions with S/S Manager
10. Sketches, Drawings, Etc. Reviewed with S/S Manager
11. Instructions for Preparation of FMEA and CIL, NSTS 22206, 10 October 1986



APPENDIX A  
ACRONYMS

ATVC - Ascent Thrust Vector Control  
BFS - Backup Flight System  
C&W - Caution and Warning  
CIL - Critical Items List  
CRT - Cathode Ray Tube  
delta P - Differential Pressure  
E-H Servo VLV - Electro-Hydraulic Servovalve  
F - Functional  
FCS - Flight Control System  
FMEA - Failure Modes Effect Analysis  
GNC - Guidance Navigation and Control  
GPC - General Purpose Computer  
HW - Hardware  
IOA - Independent Orbiter Assessment  
MDAC - McDonnell Douglas Astronautics Company  
MDM - Multiplexer/Demultiplexer  
METVC - Main Engine Thrust Vector Control  
ORIDE - Override  
PASS - Primary Avionics Software System  
RI - Rockwell International  
RHC - Rotational Hand Controller  
SSME - Space Shuttle Main Engine  
SRB - Solid Rocket Booster



## APPENDIX B

### DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

- B.1 Definitions
- B.2 Project Level Ground Rules and Assumptions
- B.3 Subsystem-Specific 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.

APPENDIX B  
DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

B.3 ATVC Actuator - Specific Ground Rules and Assumptions

None.

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: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 1/1  
MDAC ID: 101 ABORT: 1/1

ITEM: METVC SERVO ACTUATOR (6)  
FAILURE MODE: COMPONENT RUPTURE DOWNSTREAM OF SWITCH VALVE

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACTUATOR (2EA. ENGINE)
- 2)
- 3)
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

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

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

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: MATERIAL DEFECT, SERVO VALVE, DYNAMIC PRESSURE FEEDBACK  
ASS'Y, MANIFOLDS, FORCE LIMITER, CYLINDER ACTUATOR BODY

EFFECTS/RATIONALE:

ASCENT - THERE IS A LOSS OF TWO HYDRAULIC POWER SYSTEMS WHICH  
RESULTS IN LOSS OF CONTROL. THIS IS A SINGLE FAILURE POINT WHERE  
THERE IS NO REDUNDANCY FOR CYLINDER RUPTURE.  
ENTRY - ENGINES CAN NOT BE POSITIONED, WHICH RESULTS IN POSSIBLE  
ENGINE COLLISION, INTERFERENCES WITH BODY FLAP, OR CENTER ENGINE  
PROJECTS INTO AIRSTREAM - LOSS OF VEHICLE/CREW.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 1/1  
MDAC ID: 102 ABORT: 1/1

ITEM: METVC SERVO ACTUATOR (6)  
FAILURE MODE: EXTERNAL LEAKAGE

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACTUATOR (2EA. ENGINE)
- 2)
- 3)
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

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

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

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: LOSS OF PISTON ROD GLAND RETENTION IN BODY - LOSS OF 1  
OR 3 DYNAMIC PRESSURE FEEDBACK ASSEMBLY RETENTION SCREWS.

EFFECTS/RATIONALE:

ASCENT - POSSIBLE LOSS OF TWO HYDRAULIC SYSTEMS RESULTS IN LOSS  
OF CONTROL.

DEORBIT - POSSIBLE LOSS OF TWO HYDRAULIC SYSTEMS TO ACTUATOR WHEN  
ISO VALVE OPENED FOR ENGINE REPOSITIONING PRIOR TO ENTRY WHICH  
MAY RESULT IN POSSIBLE ENGINE COLLISION AND POSSIBLE LOSS OF  
VEHICLE/CREW.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 2/1R  
MDAC ID: 103 ABORT: 2/1R

ITEM: METVC SERVO ACTUATOR (6)  
FAILURE MODE: LEAKAGE

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACTUATOR (2EA. ENGINE)
- 2)
- 3)
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

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

REDUNDANCY SCREENS: A [ 3 ] B [ P ] C [ P ]

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: SEAL FAILURE IN AND DOWNSTREAM OF SWITCH VALVE

EFFECTS/RATIONALE:

ASCENT - LOSS OF SOME HYDRAULIC FLUID, HOWEVER THERE IS INSUFFICIENT TIME TO DEplete A POWER SYSTEM - FULL CONTROL CAPABILITY IS PROVIDED.

ENTRY - THERE IS A POSSIBLE LOSS OF AN HYDRAULIC SYSTEM, HOWEVER THE REDUNDANT SYSTEM PROVIDES ADEQUATE CONTROL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 2/1R  
MDAC ID: 104 ABORT: 2/1R

ITEM: SWITCH VALVE (6)  
FAILURE MODE: FAILS TO TRANSFER SUBSEQUENT TO LOSS OF ACTIVE  
HYDRAULIC SYSTEM

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) MAIN ENGINE TVC SERVO ACTUATOR
- 2) SWITCH VALVE
- 3)
- 4)
- 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:	3/3	AOA:	2/1R
DEORBIT:	2/1R	ATO:	2/1R
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [ 2 ] B [ P ] C [ P ]

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: JAMMED, CONTAMINATION

EFFECTS/RATIONALE:

LOSS OF USE OF STANDBY SYSTEM TO GIMBAL ENGINE AND ENGINE WILL  
LOCK-UP IN LAST POSITION WITH A POSSIBLE ENGINE COLLISION AND  
POSSIBLE LOSS OF MISSION, VEHICLE/CREW (REQUIRES 2 FAILURES, LOSS  
OF ACTIVE HYD. SYS. & FAIL TO TRANSFER,  
ALSO CONDITIONS MUST EXIST FOR ENGINE COLLISION).

REFERENCES:





INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 2/1R  
MDAC ID: 106 ABORT: 3/3

ITEM: EH SERVOVALVE ASSY  
FAILURE MODE: SERVOVALVE FAILURE

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) MAIN ENGINE TVC SERVO ACTUATOR
- 2) EH SERVOVALVE ASSY (4EA. ACT)
- 3)
- 4)
- 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:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [ 2 ] B [ F ] C [ P ]

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: LOSS OF SIGNAL, ELECTRICAL OPEN (ATVC DRIVER FAIL OR  
ERRONEOUS ATVC OUTPUT) DEFECTIVE TORQUE MOTOR, JAMMED SPOOL

EFFECTS/RATIONALE:

THERE IS A POSSIBLE LOSS OF CONTROL, HOWEVER TWO FAILURES ARE  
REQUIRED BEFORE A CONTROL PROBLEM EXISTS. IF FAILURE OCCURS  
DURING NULL COMMANDING OR DURING A LOW VARYING RATE, THE ATVC  
DRIVER CANNOT DETECT THE FIRST FAILURE.  
FAILURES DURING DYNAMIC CONDITIONS ARE DETECTABLE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 1/1  
MDAC ID: 107 ABORT: 1/1

ITEM: FILTER  
FAILURE MODE: NO FLOW TO SERVOVALVE

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) MAIN ENGINE TVC SERVO ACTUATOR (6)
- 2) EH SERVOVALVE ASSY (4EA. ACT)
- 3) FILTER (1EA ACT.)
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

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

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

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: FILTER CLOGGED, EXCESSIVE CONTAMINATION

EFFECTS/RATIONALE:

THE ACTUATOR FAILS HARDOVER WITH A POSSIBLE ENGINE COLLISION WHICH RESULTS IN LOSS OF CONTROL AND LOSS OF VEHICLE CREW.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 3/3  
MDAC ID: 108 ABORT: 3/3

ITEM: FILTER  
FAILURE MODE: FAILS TO FILTER

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) MAIN ENGINE TVC SERVO ACTUATOR (6)
- 2) EH SERVOVALVE ASSY (4EA. ACT)
- 3) FILTER (1EA ACT.)
- 4)
- 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 [ 2 ] B [ F ] C [ P ]

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: RUPTURED FILTER

EFFECTS/RATIONALE:

NONE - 15 MICRON FILTER SIZED FOR VEHICLE LIFE - UPSTREAM 5 MICRON FILTER POP-UP INDICATOR (GROUND) - WOULD HAVE TO ALLOW CONTAMINATION TO JAM ALL 4 SERVO VALVE SPOOLS. FAILURE HIGHLY UNLIKELY.

NO KNOWN CONDITIONS COULD CAUSE THE 15 MICRON FILTER TO RUPTURE. NON-CREDIBLE FAILURE.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 2/1R  
MDAC ID: 109 ABORT: 3/3

ITEM: TORQUE MOTOR ASSY  
FAILURE MODE: MOTOR FAILS

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) MAIN ENGINE TVC SERVO ACTUATOR (6)
- 2) EH SERVOVALVE ASSY (4EA. ACT)
- 3) TORQUE MOTAR ASSY
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

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

REDUNDANCY SCREENS: A [ 2 ] B [ F ] C [ P ]

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: OPEN, SHORT IN MOTOR WINDINGS, LOSS OF SIGNAL FROM ATVC.

EFFECTS/RATIONALE:

LOSS OF 1 OF 4 CHANNELS. FAILURE IS 3/1R, HOWEVER, 2ND ATVC FAILURE CAN CAUSE LOSS OF CONTROL IF UNDETECTED THEREFORE ATVC FAILURE MODE IS 2/1R. (SEE MDAC ID 105 & 106)

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 2/1R  
MDAC ID: 110 ABORT: 3/3

ITEM: TORQUE MOTAR ASSY  
FAILURE MODE: FLAPPER FAILS TO CLOSE OFF ORIFICE TO DIRECT HYD.  
PRESS. TO SERVOVALVE

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) MAIN ENGINE TVC SERVO ACTUATOR (6)
- 2) EH SERVOVALVE ASSY (4EA. ACT)
- 3) TORQUE MOTAR ASSY
- 4)
- 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:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [ 2 ] B [ F ] C [ P ]

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: FLAPPER JAMMED, BROKEN (FATIGUE)

EFFECTS/RATIONALE:

LOSS OF 1 OF 4 CHANNELS. (SEE MDAC ID 106)

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 1/1  
MDAC ID: 111 ABORT: 3/3

ITEM: MECHANICAL POSITION FEEDBACK SPRING CAGE ASSY  
FAILURE MODE: NO POSITION FEEDBACK

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACTUATOR
- 2) EH SERVOVALVE ASSY
- 3) MECH. POS. FDBK - SPRING CAGE ASSY
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES			
FLIGHT PHASE	HDW/FUNC	ABORT	HDW/FUNC
PRELAUNCH:	3/3	RTLS:	3/3
LIFTOFF:	1/1	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: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: FEEDBACK MECHANISM JAMMED OR SEPARATED

EFFECTS/RATIONALE:

ASCENT - ACTUATOR FAILS HARD OVER WITH A POSSIBLE ENGINE COLLISION AND LOSS OF CONTROL. ORBIT - NO EFFECT, SYSTEM IS ISOLATED, REMAINING SYSTEM PROVIDES ENGINE POSITIONING CAPABILITY.

ENTRY - NONE, ADEQUATE ENGINE POSITIONING.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 3/1R  
MDAC ID: 112 ABORT: 3/3

ITEM: BYPASS VALVE  
FAILURE MODE: VALVE FAILS TO ISOLATE FAILED SERVOVALVE

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACTUATOR
- 2) EH SERVOVALVE ASSY (4EA ACT)
- 3) BYPASS VALVE (4EA ACT)
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

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

REDUNDANCY SCREENS: A [ 2 ] B [ P ] C [ P ]

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: JAMMED SPOOL, ELECTRICAL OPEN TO SOLENOID, LOSS OF ATVC DRIVE, ERRONEOUS ATVC OUTPUT

EFFECTS/RATIONALE:

LOSS OF ISOLATION OF DEFECTIVE CHANNEL - 4 FAILURES ARE REQUIRED BEFORE A CONTROL PROBLEM EXISTS (2 SERVOVALVES HARD OVER AND 2 RELATED ISO VLV OPEN).

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 2/1R  
MDAC ID: 113 ABORT: 3/3

ITEM: SECONDARY DELTA-P TRANSDUCER  
FAILURE MODE: FAILS TO SENSE DELTA-P

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO VALVE
- 2) EH SERVOVALVE ASSY
- 3) SEC. DELTA-P X-DUCER
- 4)
- 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:	3/3	AOA:	3/3
DEORBIT:	3/3	ATO:	3/3
LANDING/SAFING:	3/3		

REDUNDANCY SCREENS: A [ 2 ] B [ F ] C [ P ]

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: DEFECTIVE LVDT, ELECTRICAL OPEN, LOSS OR ERRONEOUS  
OUTPUT ATVC, JAMMED PISTON

EFFECTS/RATIONALE:

LOSS OF ISOLATION OF DEFECTIVE CHANNEL. LOSS OF CONTROL WITH  
LOSS OF VEHICLE/CREW REQUIRES FOUR FAILURES (2 SERVOVALVES  
HARDOVER PLUS 2 DELTA-P TRANSDUCERS FAIL).

IF A FAILURE OCCURS DURING NULL COMMANDS OR AT A LOW VARYING  
RATE, THE ATVC DRIVER CANNOT DETECT FAILURE, THEREFORE A  
SUBSEQUENT FAILURE DURING DYNAMIC CONDITIONS WOULD LEAVE 2  
CHANNELS OPERATIONAL.

HOWEVER, THE ASA CANNOT ISOLATE WHICH OF THE LAST TWO CHANNELS  
FAILED. THIS WOULD RESULT IN LOSS OF CONTROL.

REFERENCES:



INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 1/1  
MDAC ID: 114 ABORT: 1/1

ITEM: POWER SPOOL VALVE ASSY  
FAILURE MODE: POWER VALVE SPOOL JAMMED

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO VALVE
- 2) POWER SPOOL VALVE ASSY (1EA ACT)
- 3)
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

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

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

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: CONTAMINATION

EFFECTS/RATIONALE:

ACTUATOR FAILS HARDOVER RESULTING IN A POSSIBLE ENGINE COLLISION  
AND LOSS OF CONTROL WHICH RESULTS IN LOSS OF VEHICLE/CREW.  
ASCENT - ABORT DECISION

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 1/1  
MDAC ID: 115 ABORT: 1/1

ITEM: CHECK VALVE  
FAILURE MODE: FAILS CLOSED

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACT (6)
- 2) POWER SPOOL VALVE ASSY (1EA ACT)
- 3) CHECK VALVE
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

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

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

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: JAMMED, CONTAMINATION

EFFECTS/RATIONALE:

LOSS OF PRESSURE TO POWER SPOOL VALVE RESULTS IN LOSS OF CONTROL OF ONE ENGINE WITH A POSSIBLE ENGINE COLLISION RESULTING. THIS RESULTS IN LOSS OF CONTROL AND POSSIBLE INTERFERENCE WITH BODY FLAP DURING ENTRY.  
ASCENT - ABORT UNLESS ORBIT CAN BE ACHIEVED.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 3/3  
MDAC ID: 116 ABORT: 3/3

ITEM: CHECK VALVE  
FAILURE MODE: FAILS OPEN

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACT (6)
- 2) POWER SPOOL VALVE ASSY (1EA ACT)
- 3) CHECK VALVE
- 4)
- 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: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: JAMMED, CONTAMINATION

EFFECTS/RATIONALE:

NONE. WITH A NORMAL SYSTEM THERE IS ONLY A SLOWLY DECREASING PRESSURE LOSS. C&W LIGHT IS ACTIVATED AT 2750 +100 PSI WHICH IS SUFFICIENT TO MAINTAIN ACTUATOR POSITION C&W LIGHT ON. PILOT ACTION/DECISION TO DEACTIVATE FAILING SYSTEM. AUTO-SWITCH TO REDUNDANT SYSTEM. THIS FAILURE MODE IS NON FUNCTIONALLY CRITICAL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 1/1  
MDAC ID: 117 ABORT: 1/1

ITEM: LOCK VALVE  
FAILURE MODE: FAILS IN CLOSED POSITION

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACT (6)
- 2) POWER SPOOL VALVE ASSY (1EA ACT)
- 3) LOCK VALVE
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

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

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

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: JAMMED, SPOOL CONTAMINATION, BROKEN SPRING

EFFECTS/RATIONALE:

ASCENT - NO EFFECT-VLV IS VERIFIED OPEN IN PRE-LAUNCH BY PROPER SYSTEM FUNCTION. DO-POSSIBLE LOSS OF MISSION, CREW, VEHICLE DUE TO RESULTING CONTROL PROBLEM DEPENDING ON ENGINE POSITION. THERE IS A POSSIBLE LOSS OF CAPABILITY TO POSITION ENGINE FOR ENTRY.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 1/1  
MDAC ID: 118 ABORT: 1/1

ITEM: LOCK VALVE  
FAILURE MODE: FAILS IN OPEN POSITION

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACT (6)
- 2) POWER SPOOL VALVE ASSY (1EA ACT)
- 3) LOCK VALVE
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

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

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

LOCATION: - ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: JAMMED SPOOL, BROKEN SPRING SEAL FAILURE. INTERNAL LEAKAGE (PAST PISTON SEAL) EXTERNAL LEAKAGE (PAST PISTON ROD SEAL)

EFFECTS/RATIONALE:

ASCENT - NOT APPLICABLE, VALVE IS NORMALLY OPEN AND ACTUATOR IS IN A DYNAMIC MODE WHICH COMPENSATES FOR LEAKAGE.  
DEORBIT - POSSIBLE LOSS OF MISSION, VEHICLE, CREW. FAILURE COULD POSSIBLY LEAVE ENGINE IN POSITION TO INTERFERE WITH BODY FLAP. UPPER ENGINE WOULD PROJECT INTO AIR STREAM RESULTING IN A POSSIBLE CONTROL PROBLEM.

REFERENCES:



INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 3/3  
MDAC ID: 120 ABORT: 3/3

ITEM: FORCE LIMITER VALVE  
FAILURE MODE: VALVE FAILS TO OPEN

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACT (6)
- 2) POWER SPOOL VALVE ASSY (1EA ACT)
- 3) FORCE LIMITER VALVE
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

FLIGHT PHASE	CRITICALITIES		HDW/FUNC
	HDW/FUNC	ABORT	
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: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: JAMMED, CONTAMINATION, EXCESSIVE SPOOL SLEEVE FRICTION,  
BROKEN SPRING

EFFECTS/RATIONALE:

ASCENT - NONE, VALVE IS NOT REQUIRED TO FUNCTION DURING MAIN  
ENGINE BURNS. OPT FLIGHT DATA SHOWED ACTUATOR SIDE LOADS ARE  
WELL BELOW ATTACH POINT LIMITS AND LOAD RELIEF VALVE IS NOT  
ACTIVATED UNDER THESE CONDITIONS.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 1/1  
MDAC ID: 121 ABORT: 1/1

ITEM: CYLINDER AND RAM/PISTON ASS'Y  
FAILURE MODE: FRACTURE OF TAIL STOCK (THRUST, STRUCTURE), PISTON  
ROD END (ENGINE), PISTON HEAD, PISTON ROD

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACT (6)
- 2) CYLINDER AND RAM/PISTON ASSY. (LEA. ACT.)
- 3)
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

CRITICALITIES

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

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

LOCATION: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: MATERIAL DEFECT, FATIGUE

EFFECTS/RATIONALE:

ASCENT - LOSS OF ENGINE GIMBAL CONTROL.  
ENTRY - LOSS OF ABILITY TO MAINTAIN ENGINE POSITION CAN RESULT IN  
POSSIBLE ENGINE COLLISION. ENGINE CAN PROJECT INTO AIRSTREAM OR  
INTERFERE WITH BODY FLAP WHICH RESULTS IN POSSIBLE LOSS OF  
CONTROL.

REFERENCES:



INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 3/3  
MDAC ID: 122 ABORT: 3/3

ITEM: DYNAMIC PRESSURE FEEDBACK VALVE  
FAILURE MODE: SPOOL FAILS TO SHUTTLE

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACT (6
- 2) EH SERVO VALVE ASSY. (4 EA. ACT.)
- 3) DYNAMIC PRESSURE FDBK. VLV. (4 EA. ACT.)
- 4)
- 5)
- 6)
- 7)
- 8)
- 9)

FLIGHT PHASE	CRITICALITIES		HDW/FUNC
	HDW/FUNC	ABORT	
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: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: CONTAMINATION, BROKEN SPRING JAMS SPOOL

EFFECTS/RATIONALE:

NO EFFECT-OTHER 3 VALVES WOULD RESPOND TO PRESSURE FLUCTUATIONS RESULTING FROM ME VIBRATIONS CAUSING ACTUATOR MAIN PISTON/RAM TO SLIGHTLY EXTEND TO RETRACT  
LOSS OF 1 OR ALL IF THE DYNAMIC FEEDBACK VALVES HAS NO EFFECT ON CONTROLLABILITY OF THE ME SERVO ACTUATORS. THIS FAILURE IS FUNCTIONALLY NON-CRITICAL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE:	10/02/86	HIGHEST CRITICALITY	HDW/FUNC
SUBSYSTEM:	ATVC	FLIGHT:	3/3
MDAC ID:	123	ABORT:	3/3

ITEM: DYNAMIC PRESSURE FEEDBACK VALVE  
FAILURE MODE: SPOOL FAILS TO RETURN TO NULL

LEAD ANALYST: R. WILSON                      SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACT (6)
- 2) EH SERVO VALVE ASSY. (4 EA. ACT.)
- 3) DYNAMIC PRESSURE FDBK. VLV. (4 EA. ACT.)
- 4)
- 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:            ORBITER THRUST STRUCTURE  
PART NUMBER:    MC621-0015

CAUSES:    CONTAMINATION, BROKEN SPRING JAMS SPOOL

EFFECTS/RATIONALE:

NO EFFECT-OTHER 3 VALVES WOULD PREVENT UNWANTED MOVEMENT OF POWER SPOOL DUE TO PRESSURE FROM FAILED DYNAMIC FEEDBACK VALVE. LOSS OF 1 OR ALL OF THE VALVES HAS NO EFFECT ON CONTROLABILITY OF THE ACTUATORS. THIS FAILURE IS FUNCTIONALLY NON-CRITICAL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 3/3  
MDAC ID: 124 ABORT: 3/3

ITEM: FLOW CUTOFF VALVE  
FAILURE MODE: FAILS OPEN

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACT (6)
- 2) FLOWCUTOFF VALVES (1 EA. ACT.)
- 3)
- 4)
- 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: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: CONTAMINATION POPPET JAMMED

EFFECTS/RATIONALE:

VALVE IS UPSTREAM OF STANDBY HYDRAULIC LINE TO SWITCHING VALVE.  
VALVE IS CLOSED WITH PRESSURE ABOVE 350-PSIG AND IS USED TO  
CIRCULATE (WARM) HYD. FLUID IN STANDBY LINE. ASCENT - MINOR LOSS  
OF SYSTEM POWER AVAILABLE DUE TO BYPASSING  
FLUID. HAS ESSENTIALLY NO EFFECT ON SYSTEM OPERATION. DEORBIT -  
NO EFFECT. TVC ISO VALVES ARE CLOSED EXCEPT FOR PERIOD OF ENGINE  
REPOSITIONING. THIS FAILURE IS FUNCTIONALLY NON-CRITICAL.

REFERENCES:

INDEPENDENT ORBITER ASSESSMENT  
ORBITER SUBSYSTEM ANALYSIS WORKSHEET

DATE: 10/02/86 HIGHEST CRITICALITY HDW/FUNC  
SUBSYSTEM: ATVC FLIGHT: 3/3  
MDAC ID: 125 ABORT: 3/3

ITEM: FLOW CUTOFF VALVE  
FAILURE MODE: FAILS CLOSED

LEAD ANALYST: R. WILSON SUBSYS LEAD: J. RICCIO

BREAKDOWN HIERARCHY:

- 1) METVC SERVO ACT (6)
- 2) FLOWCUTOFF VALVES (1 EA. ACT.)
- 3)
- 4)
- 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: ORBITER THRUST STRUCTURE  
PART NUMBER: MC621-0015

CAUSES: CONTAMINATION POPPED JAMMED FRACTURES SPRING

EFFECTS/RATIONALE:

THE VALVE IS OPEN DURING LOW PRESSURE OPERATION ONLY. THERE IS A LOSS OF SYSTEM CAPABILITY TO THERMALLY CONDITION STANDBY HYD. SYSTEM AT AFFECTED ACTUATOR. THERE IS NO EFFECT SINCE STDBY SYSTEM WILL FUNCTION NORMALLY ONCE IT IS FUNCTIONING AS THE PRIMARY SOURCE. THE FAILURE EFFECT IS TEMPORARY AND NON-CRITICAL. DEORBIT - NO EFFECT. TVC ISO VALVES ARE CLOSED EXCEPT DURING ENGINE REPOSITIONING. NOTE: VALVE OPERATES ONLY WHEN 2 CIRCULATION PUMPS ARE RUNNING IN PRE-LAUNCH AND POST-LANDING.

REFERENCES:

APPENDIX D  
POTENTIAL CRITICAL ITEMS

<u>MDAC ID</u>	<u>ITEM</u>	<u>FAILURE MODE</u>
101	METVC Servoactuator	Component rupture downstream of switch valve
102	METVC Servoactuator	External leakage
103	METVC Servoactuator	Internal leakage
104	Switch Valve	Fails to transfer
105	E-H Servovalve	Fail one channel hardover
106	E-H Servovalve	One channel fail
107	Filter	No flow to servovalve
109	Torque Motor Ass'y.	Motor fails
110	Torque Motor Ass'y.	Flapper fails
111	Mechanical Position Feedback Spring Cage Assembly	No position feedback
113	Secondary Delta P Transducer	Fail to service Delta P
114	Power Spool	Jammed
115	Check Valve	Fails closed
117	Lock Valve	Fails closed
118	Lock Valve	Fails open
121	Cylinder and Ram/Piston Assembly	Fracture

