INDEPENDENT ORBITER ASSESSMENT

ASSESSMENT OF THE ELEVON ACTUATOR SUBSYSTEM

05 FEBRUARY 1988

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
HOUSTON DIVISION

SPACE TRANSPORTATION SYSTEM ENGINEERING AND OPERATIONS SUPPORT

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INDEPENDENT ORBITER ASSESSMENT
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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 effort first completed an analysis of the Elevon Subsystem hardware, generating draft failure modes, and potential critical items. To preserve independence, this analysis was accomplished without reliance upon the results contained within the NASA FMEA/CIL documentation. The IOA results were then compared to the NASA FMEA/CIL baseline with proposed Post 51-L updates included. A resolution of each discrepancy from the comparison is provided through additional analysis as required. This report documents the results of that comparison for the Orbiter Elevon hardware.

The IOA product for the Elevon analysis consisted of twenty-five failure mode "worksheets" that resulted in seventeen potential critical items being identified. Comparison was made to the NASA FMEA/CIL, (as of 7 December 87) which consisted of (Note 1) twenty-three FMEAs and thirteen CIL items. The comparison determined if there were any results which had been found by the IOA but were not in the NASA baseline. This comparison produced agreement on all CIL items. Based on the Pre 51-L baseline, all non-CIL FMEAs were also in agreement. Based on discussions with the NASA subsystem manager, no additional non-CIL FMEAs are anticipated for the post 51-L update. Figure 1 presents a comparison of the proposed Post 51-L NASA baseline, with the IOA recommended baseline, and any issues.

Note 1. The comparison and correlation of NASA FMEA Non-CIL items is based on the Pre 51-L baseline since all post 51-L FMEAs have not been received as the date of this report.

The initial issues which were resolved arose due to NASA combining failures which had the same effect in one FMEA whereas IOA wrote a separate analysis for each failure. Minor issues such as fail or pass of screens did not effect the number of CIL items agreed to.

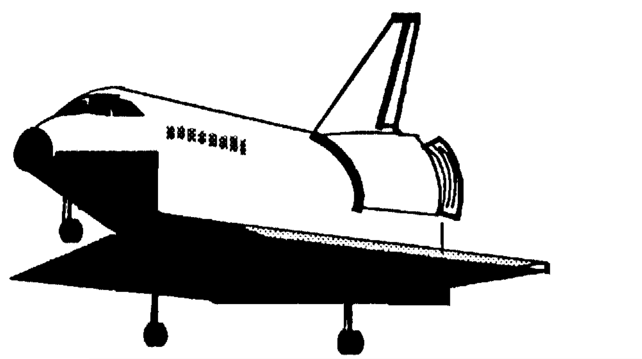
ELEVON ACTUATOR ASSESSMENT OVERVIEW

ELEVON ACTUATOR ASSESSMENT SUMMARY							
ORIGINAL ASSESSMENT*				FINAL RESOLUTION**			
	IOA	NASA	ISSUES		IOA	NASA	ISSUES
FMEA	25	23	4	FMEA	23	23	0
CIL	17	13	4	CIL	13	13	0

PRIMARY ACTUATOR	*IOA*	*NASA*	*ISSUES*
FMEA	11	11	1
CIL	6	5	1

SWITCH VALVE ASSY.	IOA	NASA	ISSUES
FMEA	7	6	2
CIL	5	3	2

E-H SERVOVALVE ASSY.	IOA	NASA	ISSUES
FMEA	7	6	1
CIL	6	5	1



* *NASA PROPOSED BASELINE AS OF 5 MAY 1987*

** *FINAL NASA CIL ITEMS BASELINE AS OF 7 DECEMBER 1987 AND NASA NON-CIL FMEAS – PRE 51-L BASELINE*

Figure 1 - ELEVON ACTUATOR ASSESSMENT SUMMARY

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 reevaluation results 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 Ground Rules and Assumptions

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

3.0 SUBSYSTEM DESCRIPTION

The following sections describe the elevon actuator system hardware. Each of the four elevon actuator systems (Figure 2) comprise the following components: a flow cutoff valve, switching valve, EH servoactuator, secondary pressure transducer, bypass valve, power valve, primary actuator, primary actuator delta pressure transducer, and primary actuator position transducer.

3.1 Design and Function

The elevon actuators are located at the trailing edge of the wing surface. The proper function of the elevons is essential during the dynamic flight phases of ascent and entry. During flight the Orbiter is controlled, in part, by four aerosurfaces called elevons. An elevon is a control surfact which performs the same functions as an elevator and an aileron on a conventional airplane. In the ascent phase of flight, the elevons are used for relieving high wing loads. For entry, the elevons are used to pitch and roll the vehicle.

Each elevon actuator is driven by one primary actuator. Control of the actuator is provided by four EH servovalves. These servovalves are used to create a secondary delta pressure which controls the flow of hydraulic fluid to one power valve. This power valve, when actuated, diverts fluid to the primary actuator (Figure 3).

The flow cutoff valve (or low-pressure bypass valve) is used to circulate hydraulic fluid during certain thermally cold periods. The flow cutoff valve should be opened during circulation pump operations only. The flow cutoff valve must be closed during high-pressure operations or degraded elevon performance will result.

The switching valve diverts pressure from one of the Orbiter's three hydraulic systems to supply adequate fluid and pressure to the primary and secondary elevon hydraulic system. The switching valve (Figure 4) contains two pistons, a primary and a secondary. If the pressure in the primary Orbiter hydraulic sytem drops below 1200 to 1500 psi, the switching valve primary piston will translate and allow the secondary hydraulic system to provide the required fluid and pressure to the downstream actuators. If the second hydraulic system is unable to provide pressure above 1200 to 1500 psi, the second switching valve piston will translate allowing the third hydraulic system to provide pressure to the actuator and servovalves. Linear Variable Differential Transformers (LVDTs) attached to the switching valve pistons indicate to the crew which hydraulic system is powering the elevon.

The many small passages, orifices, and restrictions in the secondary side of the servovalve assembly are highly sensitive to contaminants which enter the hydraulic sytem. A 15 micron filter conditions the hydraulic fluid which supplies the secondary side of the actuation system.

The elevon bypass valve is used to isolate an erroneous servovalve output from influencing the power valve movement. If secondary delta pressure exceeds 2200 psi for 120 milliseconds, the bypass valve diverts fluid away from the power spool to the return, preventing the erroneous or failed channel from creating a potential force-flight or incorrectly influencing power spool and elevon motion.

The secondary delta pressure transducers are used to measure the instantaneous pressure differential between the hydraulic source (nominally 3000 psi) and the servovalve reduced pressure. The transducer comprises a dual-spring balanced piston and a LVDT which transmits a transducer piston position in the form of a voltage to the Aerosurface Servo Amplifier (ASA). The ASA can use this voltage to determine the delta pressure across the corresponding servovalve. This information is used to bias equalization of four servovalve channels and activate their corresponding bypass valves when a channel cutoff is required.

The power valve combines four servovalve induced secondary delta pressures into a translation representing the commanded elevon movement. As the power valve moves, it allows a primary pressure to translate the primary actuator and its corresponding elevon. When one of the four secondary pressures are bypassed or erroneous, the remaining three pressures will overdrive the power valve.

The primary actuator is responsible for the ultimate motion of the elevon. It is controlled by a secondary pressure power valve which diverts primary hydraulic fluid and pressure to the actuator (Figure 5).

The primary delta pressure transducer is used to measure the instantaneous pressure differential across the primary actuator. The transducer comprises a dual-spring balanced piston and a LVDT which transmits a transducer piston position in the form of a voltage to the ASA. The ASA uses this voltage to determine the delta pressure across the primary actuator.

The position feedback transducer feeds the instantaneous position of the elevon to the ASA and General Purpose Computers (GPCs). The transducer consists of a LVDT calibrated to feedback a position voltage to the ASA. This information is used by the ASA for servovalve biasing and to the GPCs for Flight Control System (FCS) and caution and warning inputs. The current elevon position is displayed to the crew on the surface position indicators on Panel F7.

3.2 Interfaces and Locations

The elevon system hardware is located at the trailing edge of the Orbiter's wings. The elevon system interfaces with the Orbiter's three hydraulic systems, each corresponding to one Auxiliary Power Unit (APU). The elevon system hardware interfaces with the ASAs which in turn interface with the FCS portion of the GPCs for system control, fault detection, actuation and feedback.

3.3 Hierarchy

Figure 2 illustrates the hierarchy of the Elevon hardware and the corresponding subcomponents. Figures 3 through 5 comprise the detailed system representations.

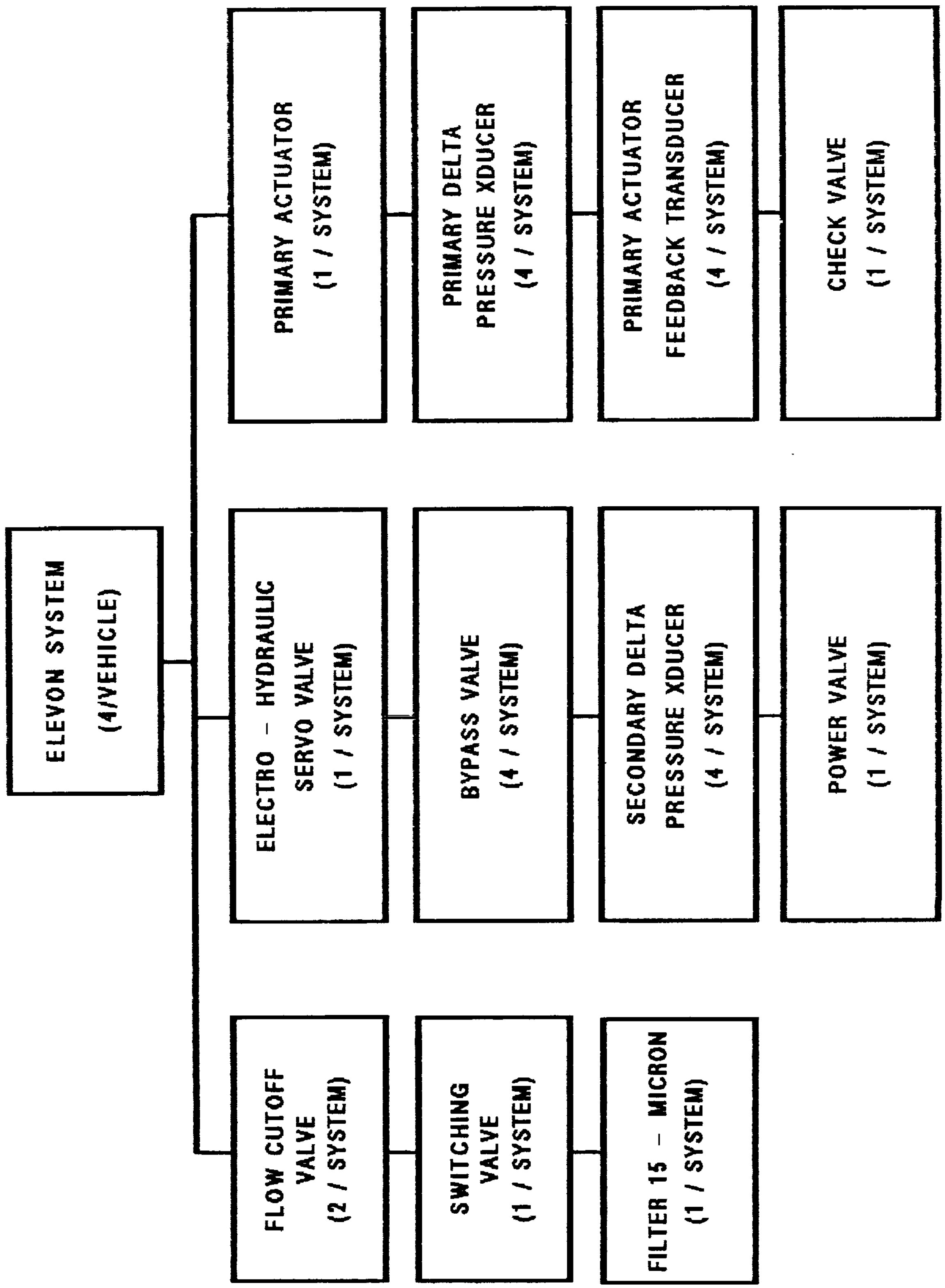


Figure 2 - ELEVON SUBSYSTEM OVERVIEW

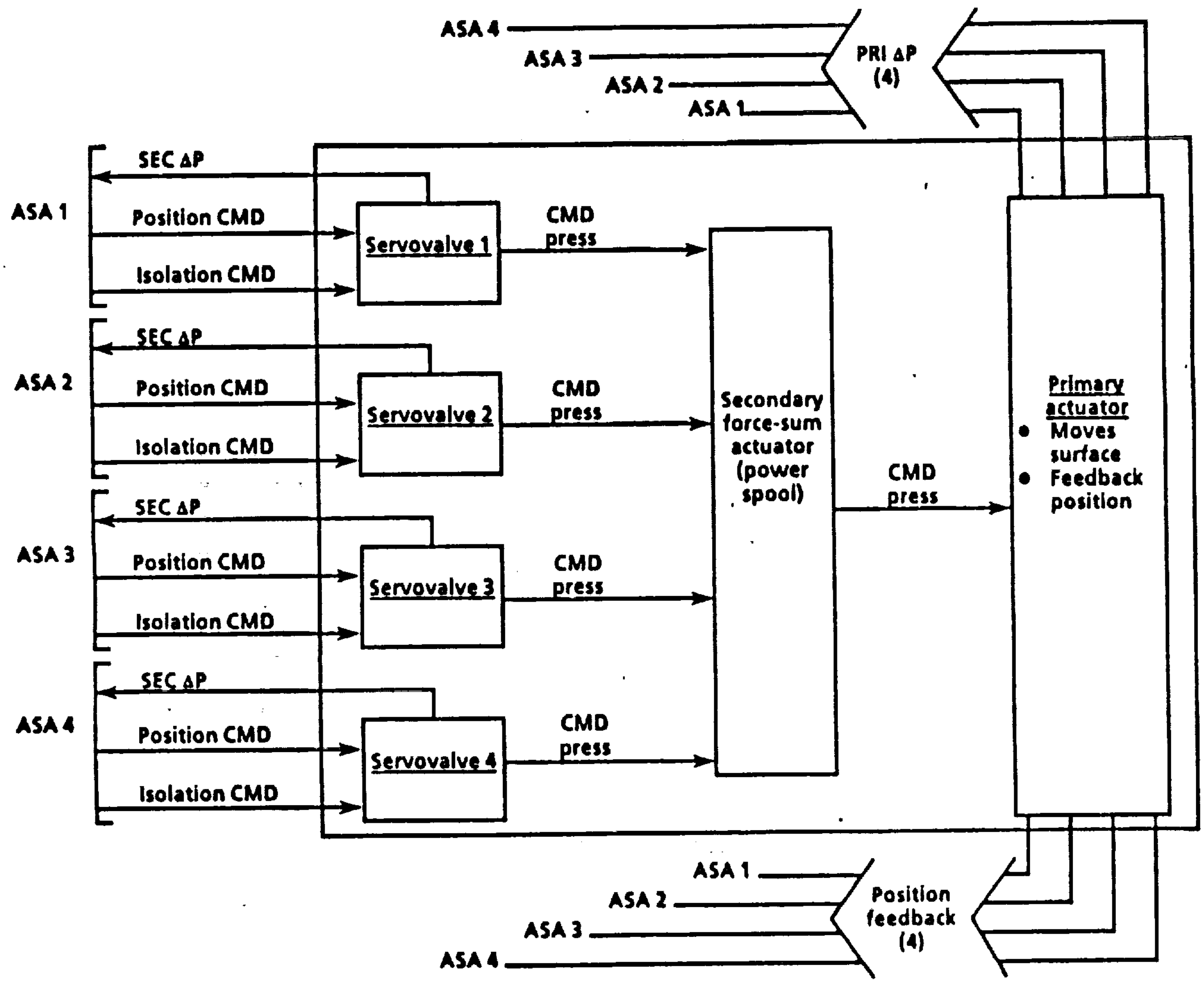


Figure 3 - TYPICAL ELEVON ACTUATION SYSTEM

P_P primary pressure
R_P primary return

P_{S1} standby one press
R_{S1} standby one return

P_{S2} standby two press
R_{S2} standby two return

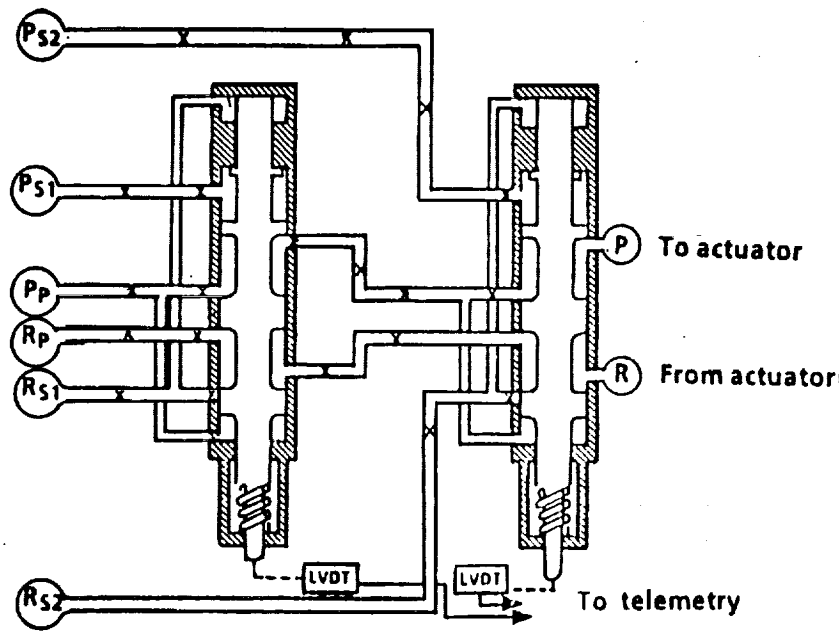


Figure 4 - SWITCHING VALVE

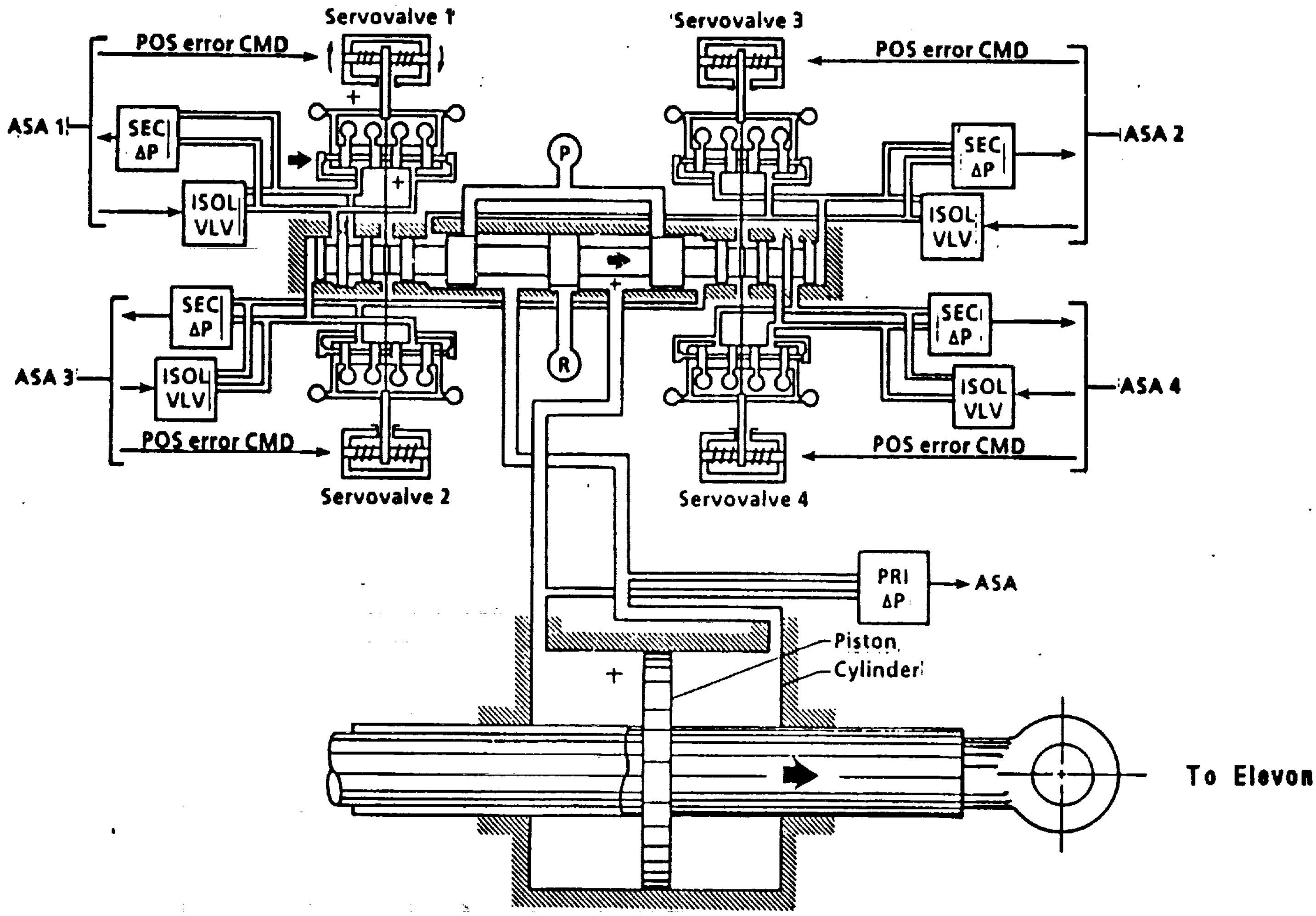


Figure 5 - ELEVON ACTUATOR SCHEMATIC

4.0 ASSESSMENT RESULTS

The IOA analysis of the elevon actuator hardware initially generated twenty-five failure modes worksheets and identified seventeen Potential Critical Items (PCIs) before starting the assessment process. No additional failure mode worksheets were generated during the comparison. The analysis results were compared to the proposed NASA Post 51-L baseline of (Note 1) twenty-three FMEAs and thirteen CIL items. Upon completion of the assessment all of the IOA and NASA failure modes were in agreement.

Note 1. Only Post 51-L NASA CIL items have been received; all Post 51-L NASA FMEAs were not received as of this report date. Non-CIL items comparison was based on review of NASA Pre 51-L baseline and the IOA analysis.

Appendix C presents the detailed assessment worksheets for each failure mode identified and assessed. Appendix D highlights the NASA critical items and corresponding IOA worksheet ID. Appendix E contains IOA analysis worksheets supplementing previous analysis results reported in STS Engineering and Operations Support (STSEOS) Working Paper 1.0-SP-VA86001-25, Analysis of the ELevon, 3 December 1986. No supplemental analysis worksheets were generated for the Elevon assessment. Appendix F provides a cross-reference between the NASA FMEA and corresponding IOA worksheets. IOA recommendations are also summarized.

A summary of the quantity of NASA FMEAs assessed, versus the recommended IOA baseline, and any issues identified is presented in Table I.

TABLE I Summary of IOA FMEA Assessment

Component	NASA	IOA	Issues
o Primary Actuator	6	6	0
o Check Valve	2	2	0
o Primary Delta P X-DCER	2	2	0
o Primary Feedback X-DCER	1	1	0
o Switch Valve Assembly			
o Switch Valve	2	2	0
o Flow Control Valve	2	2	0
o Filter	1	1	0
o Servovalve Assembly			
o E-H Servovalve	3	3	0
o Bypass Valve	2	2	0
o Sec. Delta P X-DCER	1	1	0
o Power Valve	1	1	0
TOTAL	23	23	0

A summary of the quantity of NASA CIL items assessed, versus the recommended IOA baseline, and any issues identified is presented in Table II.

TABLE II Summary of IOA CIL Assessment			
Component	NASA	IOA	ISSUES
o Primary Actuator	2	2	0
o Check Valve	2	2	0
o Primary Delta P X-DCER	1	1	0
o Primary Feedback X-DCER	1	1	0
o Switch Valve Assembly			
o Switch Valve	2	2	0
o Flow Control Valve			
o Filter	1	1	0
o Servovalve Assembly			
o E-H Servovalve	2	2	0
o Bypass Valve			
o Sec. Delta P X-DCER	1	1	0
o Power Valve	1	1	0
TOTAL	13	13	0

Table III presents a summary of the IOA recommended failure criticalities for the Post 51-L FMEA baseline. Further discussion of each of these subdivisions and the applicable failure modes is provided in subsequent paragraphs.

TABLE III Summary of IOA Recommended Failure Criticalities

Criticality:	1/1	2/1R	2/2	3/1R	3/2R	3/3	TOTAL
o Primary Actuator	2				1	3	6
o Check Valve	1	1					2
o Primary Delta P X-DCER				2			2
o Primary Feed-back X-DCER	1						1
o Switch Vlv Assy							
o Switch Valve	1	1					2
o Flow Cntrl Vlv						2	2
o Filter	1						1
o Servovalve Assy							
o E-H Servovalve		2				1	3
o Bypass Valve				2			2
o Sec. Delta P X-DCER		1					1
o Power Valve	1						1
TOTAL	7	5		4	1	6	23

Of the failure modes analyzed, 17 failures were determined to be critical items. A summary of the IOA recommended critical items is presented in Table IV.

TABLE IV Summary of IOA Recommended Failure Criticalities

Criticality:	1/1	2/1R	2/2	3/1R	3/2R	3/3	TOTAL
o Primary Actuator	2				1		3
o Check Valve	1	1					2
o Primary Delta P X-DCER							
o Primary Feed-back X-DCER	1						1
o Switch Vlv Assy							
o Switch Valve	1	1					2
o Flow Cntrl Vlv							
o Filter	1						1
o Servovalve Assy							
o E-H Servovalve		2					2
o Bypass Valve							
o Sec. Delta P X-DCER		1					1
o Power Valve	1						1
TOTAL	7	5			1		13

The scheme of assigning IOA assessment (Appendix C) and analysis (Appendix E) worksheet numbers is shown in Table V.

TABLE V IOA Worksheet Number

Component	IOA ID Number
Primary actuator	Elevon-106, 107, 117, 118, 119, 120, 121, 122, 123, 124, 125
Switch Valve Assembly	Elevon-101, 102, 103, 104, 105, 108
Servovalve Assembly	Elevon-109, 110, 111, 112, 113, 114, 115, 116

4.1 Primary Actuator

Failures which were related to the Elevon actuator as an entity were analyzed. Critical failures were the loss of hydraulic fluid due to gross and slow leaks. There failures were caused by component rupture, manifold leaks, cylinder and actuator body fractures and seal leaks. Other critical failures were associated with mechanical failures of the ram/piston assembly. The loss of the four primary feedback transducers due to mechanical failure of the gauged linkage also resulted in a critical failure.

4.2 Switch Valve Assembly

Components of the assembly were individually analyzed. The most critical failures were associated with contaminated hydraulic fluid which restricted fluid flow, clogged filters and jammed valves which resulted in failure to switch hydraulic sources and to prevent fluid flow through a check valve to the main drive piston.

4.3 Servovalve Assembly

The worst critical failures were caused by 1) hydraulic fluid contaminated which caused the main power alve to jam open or closed, and 2) rupture of the power valve housing due to fatigue which caused loss of all hydraulic fluid with associated loss of actuator control. Loss of command signal input, jammed valve and fractured flapper valve caused loss of a servovalve; however the three remaining servovalves overdrive the failed servovalve providing nominal control.

4.4 Failure Comparison

The reason for the IOA showing more CIL items than NASA was due to the fact that IOA wrote failure sheets for each item whereas NASA combined failures. Review of the NASA CIL items showed that all of IOA failures had been analyzed. Since the combined failures all resulted in the same effect it was concluded that there were no issues with the IOA failures. Minor differences such as pass or fail of screens were readily resolved. Frequent discussions with the subsystem manager resulted in a better understanding of the system and component operation. As a result of these discussions, several IOA criticalities were downgraded.

5.0 REFERENCES

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

1.	NSTS 22206:	Instructions for Preparation of FMEA and CIL October 10, 1986
2.	FCS/EFF 2102:	The FCS/Effectors Trainig Manual February 1982
3.	JSC11174:	MOD Drawings - applicable pages
4.	VS70-580996:	Rockwell Drawings
5.	STS82-0039A:	Applicable CIL Sections
6.	NASA CP-2342:	Space Shuttle Technical Conference Part 2, pp. 861-871, June 28-30, 1983
7.	SD72-SH-0102-9:	Requirements/Definition Document Aero Flight Control Mechanisms Rockwell International, Volume 2-9, October 28, 1975
8.	SD72-SH-0102-6:	Requirements/Definition Document Hydraulic Subsystem Rockwell International, SDM Baseline, January 3, 1977

APPENDIX A
ACRONYMS

APU	- Auxiliary Power Unit
ASA	- Aerosurface Servo Amplifier
ASSY	- Assembly
CIL	- Critical Items List
EH	- Electro-Hydraulic
FCS	- Flight Control System
FM	- Failure Mode
FMEA	- Failure Modes and Effects Analysis
F	- Functional
GFE	- Government Furnished Equipment
GPC	- General Purpose Computer
HW	- Hardware
IOA	- Independent Orbiter Assessment
LVDT	- Linear Variable Differential Transformer
MDAC	- McDonnell Douglas Astronautics Company
NA	- Not Applicable
NASA	- National Aeronautics and Space Adminstration
NSTS	- National Space Transportation System
PCI	- Potential Critical Item
psi	- Pounds Per Square Inch
psid	- Pounds Per Square Inch Differential
RI	- Rockwell International
VLV	- Valve
xducer	- Transducer

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

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 Elevon-Specific Ground Rules and Assumptions

The IOA analysis was performed to the component or assembly level of the Elevon subsystem. The analysis considered the worst case effects of the hardware or functional failure on the subsystem, mission, and crew and vehicle safety.

APPENDIX C
DETAILED ASSESSMENT

This section contains the IOA assessment worksheets generated during the Assessment of the Elevon Actuator Subsystem. The information on these worksheets facilitates the comparison of the NASA FMEA/CIL (Pre and Post 51-L) to the IOA detailed analysis worksheets included in Appendix E. Each of these worksheets identifies the NASA FMEA being assessed, corresponding MDAC Analysis Worksheet ID (Appendix E), hardware item, criticality, redundancy screens, and recommendations. For each failure mode, the highest assessed hardware and functional criticality is compared and discrepancies noted as "N" in the compare row under the column where the discrepancy occurred.

LEGEND FOR IOA ASSESSMENT 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 Screens A, B and C:

- P = Passed Screen
- F = Failed Screen
- NA = Not Applicable

NASA Data :

- Baseline = NASA FMEA/CIL
- New = Baseline with Proposed Post 51-L Changes

CIL Item :

- X = Included in CIL

Compare Row :

- N = Non compare for that column (deviation)

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-101
NASA FMEA #: 02-6-C01-C11

NASA DATA:
BASELINE [X]
NEW [ ]

SUBSYSTEM: ELEVON
MDAC ID: 101
ITEM: FLOW CUTOFF VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /3]	[NA]	[NA]	[NA]	[ ] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-102
NASA FMEA #: 02-6-C01-C12

NASA DATA:
BASELINE [X]
NEW [ ]

SUBSYSTEM: ELEVON
MDAC ID: 102
ITEM: FLOW CUTOFF VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /3]	[NA]	[NA]	[NA]	[ ] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-103
NASA FMEA #: 02-6-C01-SW-C06

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 103
ITEM: SWITCHING VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[2 /1R]	[P]	[P]	[P]	[X] *
IOA	[2 /1R]	[P]	[P]	[P]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. THIS IOA FMEA WAS WRITTEN SPECIFICALLY FOR THE SWITCHING VALVE. NOTE: IOA FMEA NO. 125 COVERS THE SAME NASA FMEA BUT FOR THE SERVO ACTUATOR. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-104
NASA FMEA #: 02-6-C01-SW-C02

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 104
ITEM: SWITCHING VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[2 /1R]	[P]	[F]	[P]	[X] *
IOA	[2 /1R]	[P]	[P]	[P]	[X]
COMPARE	[/]	[ ]	[N]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-105
NASA FMEA #: 02-6-C01-A01

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 105
ITEM: SWITCHING VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. THIS IOA FMEA WAS WRITTEN FOR COMPONENT RUPTURES DOWNSTREAM OF THE SWITCHING VALVE. NOTE IOA FMEA NO. 115 COVERS THE SAME NASA FMEA BUT FOR THE POWER VALVE. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-106
NASA FMEA #: 02-6-C01-CV-C08

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 106
ITEM: CHECK VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-107
NASA FMEA #: 02-6-C01-CV-C09

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 107
ITEM: CHECK VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[2 /1R]	[F]	[F]	[P]	[X] *
IOA	[2 /1R]	[P]	[F]	[P]	[X]
COMPARE	[/]	[N]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. WOULD REQUIRE TWO FAILURES TO RESULT IN A LOSS OF LIFE/VEHICLE. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-108
NASA FMEA #: 02-6-C01-FE-B08

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 108
ITEM: FILTER - 15 MICRON

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-109
NASA FMEA #: 02-6-C01-SV-B01

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 109
ITEM: SERVO VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[2 /1R]	[P]	[F]	[P]	[X] *
IOA	[2 /1R]	[P]	[P]	[P]	[X]
COMPARE	[/]	[ ]	[N]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-110
NASA FMEA #: 02-6-C01-A03

NASA DATA:
BASELINE [X]
NEW [ ]

SUBSYSTEM: ELEVON
MDAC ID: 110
ITEM: SERVO VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /3]	[NA]	[NA]	[NA]	[ ] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. THIS IOA FMEA COVERS THE ELEVON SERVO VALVE. IOA FMEA NO. 120 COVERS THE SAME FAILURE MODE (INTERNAL LEAKAGE) BUT FOR THE PRIMARY ACTUATOR. IOA ANALYSIS BROKE THE ELEVON HARDWARE TO A LOWER LEVEL THAN THE NASA ANALYSIS.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-111
NASA FMEA #: 02-6-C01-SV-B02

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 111
ITEM: SERVO VALVE RESTRICTOR

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[2 /1R]	[P]	[F]	[P]	[X] *
IOA	[2 /1R]	[P]	[F]	[P]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
SERVO VALVE RESTRICTOR PLUGS AND CAUSES AN IMBALANCE IN THE SERVO VALVE. THREE REMAINING SERVO VALVES OPERATE THE POWER SPOOL. CONCUR WITH NASA.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-112
NASA FMEA #: 02-6-C01-B03

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 112
ITEM: BYPASS VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[P]	[P]	[P]	[X] *
IOA	[2 /1R]	[P]	[P]	[P]	[X]
COMPARE	[N /]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE. TAKES 3 FAILURES; SERVO-VALVE THEN BYPASS VALVE AND ANOTHER SERVO-VALVE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-113
NASA FMEA #: 02-6-C01-B03

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 113
ITEM: BYPASS VALVE FILTER-100 MICRON

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[P]	[P]	[P]	[ ] *
IOA	[2 /1R]	[P]	[F]	[P]	[X]
COMPARE	[N /]	[ ]	[N]	[ ]	[N]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
A PLUGGED FILTER WOULD PREVENT THE BYPASS VALVE FROM BYPASSING AN ERRONEOUS CHANNEL. THE REMAINING THREE CHANNELS WOULD OVERDRIVE THE BAD CHANNEL. THIS ASSESSMENT IS COVERED BY NASA FMEA/CIL 02-6-C01-B03 (INCLUDES OTHER FAILURES MODES). SAME EFFECT AS MDAC ID 112. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-114
NASA FMEA #: 02-6-C01-PP-A06

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 114
ITEM: SECONDARY DELTA PRESSURE TRANSDUCER

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[2 /1R]	[P]	[F]	[P]	[X] *
IOA	[2 /1R]	[P]	[P]	[P]	[X]
COMPARE	[/]	[ ]	[N]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-115
NASA FMEA #: 02-6-C01-A01

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 115
ITEM: POWER VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. THIS IOA FMEA WAS WRITTEN FOR THE RUPTURE OF THE POWER VALVE. NOTE - IOA FMEA NO. 105 COVERS THE SAME NASA FMEA FOR OTHER COMPONENTS DOWNSTREAM OF THE SWITCHING VALVE. NO ISSUE. AGREE TO INCORPORATE UNDER ONE FMEA.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-116
NASA FMEA #: 02-6-C01-PV-B05

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 116
ITEM: POWER VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-117
NASA FMEA #: 02-6-C01-C06

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 117
ITEM: PRIMARY ACTUATOR

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /2R]	[P]	[F]	[P]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[N /N]	[N]	[N]	[N]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE. BUILT IN BARRIER SEAL PREVENTS RAPID LOSS OF HYDRAULIC FLUID. CAN STILL MAINTAIN ACTUATOR CONTROL.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-118
NASA FMEA #: 02-6-C01-PP-A07

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 118
ITEM: LVDT

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-119
NASA FMEA #: 02-6-C01-A02

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 119
ITEM: PRIMARY ACTUATOR

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-120
NASA FMEA #: 02-6-C01-A03

NASA DATA:
BASELINE [X]
NEW [ ]

SUBSYSTEM: ELEVON
MDAC ID: 120
ITEM: PRIMARY ACTUATOR

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /3]	[NA]	[NA]	[NA]	[ ] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. THIS IOA FMEA COVERS THE ELEVON PRIMARY ACTUATOR. IOA FMEA NO. 110 COVERS THE SAME FAILURE MODE (INTERNAL LEAKAGE) BUT FOR THE SERVO VALVE. IOA ANALYSIS BROKE THE ELEVON HARDWARE TO A LOWER LEVEL THAN THE NASA ANALYSIS.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-121
NASA FMEA #: 02-6-C01-A04

NASA DATA:
BASELINE [X]
NEW [ ]

SUBSYSTEM: ELEVON
MDAC ID: 121
ITEM: PRIMARY DELTA PRESSURE TRANSDUCER

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[P]	[P]	[P]	[ ] *
IOA	[3 /1R]	[P]	[P]	[P]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. REQUIRES TWO OF FOUR TRANSDUCER OUTPUTS FOR FAULT DETECTION DURING NULL FLIGHT PERIODS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-122
NASA FMEA #: 02-6-C01-B07

NASA DATA:
BASELINE [X]
NEW [ ]

SUBSYSTEM: ELEVON
MDAC ID: 122
ITEM: PRIMARY ACTUATOR DELTA PRESSURE TRANSDUCER

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[P]	[P]	[P]	[ ] *
IOA	[3 /1R]	[P]	[P]	[P]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. REQUIRES TWO OF FOUR TRANSDUCER OUTPUTS FOR FAULT DETECTION DURING NULL FLIGHT PERIODS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-123
NASA FMEA #: 02-6-C01-A08

NASA DATA:
BASELINE [X]
NEW [ ]

SUBSYSTEM: ELEVON
MDAC ID: 123
ITEM: HEATER

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /3]	[NA]	[NA]	[NA]	[ ] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-124
NASA FMEA #: 02-6-C01-A09

NASA DATA:
BASELINE [X]
NEW [ ]

SUBSYSTEM: ELEVON
MDAC ID: 124
ITEM: HEATER

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[P]	[P]	[P]	[ ] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/N]	[N]	[N]	[N]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. EXERCISING ACTUATORS OR CHANGING TO A THERMALLY-WARM ATTITUDE MAY NOT BE FEASIBLE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/20/87
ASSESSMENT ID: ELEVON-125
NASA FMEA #: 02-6-C01-SW-C06

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ELEVON
MDAC ID: 125
ITEM: SERVO ACTUATOR

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[2 /1R]	[P]	[P]	[P]	[X] *
IOA	[2 /1R]	[P]	[F]	[P]	[X]
COMPARE	[/]	[ ]	[N]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA ANALYSIS. NO ISSUE. THIS IOA FMEA WAS WRITTEN FOR THE SERVO ACTUATOR. NOTE: IOA FMEA NO. 103 COVERS THE SAME NASA FMEA BUT FOR THE SWITCHING VALVE.

APPENDIX D
CRITICAL ITEMS

NASA FMEA	MDAC ID	ITEM	FAILURE MODE
02-6-C01-SW-C06	103 125	Switch valve	Leakage, gross external
02-6-C01-SW-C02	104	Switch valve	Fail to transfer
02-6-C01-A01	105 115	Servo actuator	External leakage/ component rupture downstream of switch valve
02-6-C01-CV-C08	106	Check valve	Fail closed
02-6-C01-CV-C09	107	Check valve	Fail open
02-6-C01-FE-B08	108	Filter	Clogged
02-6-C01-SV-B01	109	Servo valve	Fails at null
02-6-C01-SV-B02	111	Servo valve	Fail hardover, on channel
02-6-C01-PP-A06	114	Secondary Delta P	Loss of output
02-6-C01-PV-B05	116	Power valve	Jammed
02-6-C01-C06	117	Servo actuator	Leaks external- complete elastomeric seal failure
02-6-C01-PP-A07	118	Transducer- Piston position	Loss of output of all four transducers
02-6-C01-A02	119	Servo actuator	Fracture - tailstock, rod end etc.

APPENDIX E
DETAILED ANALYSIS

This appendix contains the IOA analysis worksheets supplementing previous results reported in STSEOS Working Paper 1.0-SP-VA86001-07, Analysis of the Elevon Subsystem, (21 November 1986). Prior results were obtained independently and documented before starting the FMEA/CIL assessment activity. Supplemental analysis was performed to address failure modes not previously considered by the IOA. Each sheet identifies the hardware item being analyzed, parent assembly and function performed. For each failure mode possible causes are identified, and hardware and functional criticality for each mission phase are determined as described in the NSTS 22206, Instructions for Preparation of FMEA and CIL, 10 October 1986. Failure mode effects are described at the bottom of each sheet and worst case criticality is identified at the top. There were no supplemental analysis worksheets prepared for the Elevon actuator subsystem.

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

APPENDIX F

NASA FMEA TO IOA WORKSHEET CROSS REFERENCE/RECOMMENDATION

This section provides a cross reference between the NASA FMEA and corresponding IOA analysis worksheet(s) included in Appendix E. The Appendix F identifies: NASA FMEA Number, IOA Assessment Number, NASA criticality and redundancy screen data, and IOA recommendations.

Appendix F Legend

<u>Code Definition</u>

All initial IOA criticality and redundancy screen differences were agreed to with the NASA subsystem manager. In addition, the combining of like failures under one FMEA were agreed to.

APPENDIX F

NASA FMEA TO IOA WORKSHEET CROSS REFERENCE / RECOMMENDATIONS

IDENTIFIERS		NASA		IOA RECOMMENDATIONS *			
NASA FMEA NUMBER	IOA ASSESSMENT NO.	CRIT HW/F	SCREENS A B C	CRIT HW/F	SCREENS A B C	OTHER (SEE LEGEND CODE)	ISSUE
02-6-C01-A01	ELEVON-105	1/1	NA NA NA	/			
	ELEVON-115	1/1	NA NA NA	/			
02-6-C01-A02	ELEVON-119	1/1	NA NA NA	/			
02-6-C01-A03	ELEVON-110	3/3	NA NA NA	/			
	ELEVON-120	3/3	NA NA NA	/			
02-6-C01-A04	ELEVON-121	3/1R	P P P	/			
02-6-C01-A08	ELEVON-123	3/3	NA NA NA	/			
02-6-C01-A09	ELEVON-124	3/1R	P P P	/			
02-6-C01-B03	ELEVON-112	3/1R	P P P	/			
	ELEVON-113	3/1R	P P P	/			
02-6-C01-B07	ELEVON-122	3/1R	P P P	/			
02-6-C01-C06	ELEVON-117	3/2R	P F P	/			
02-6-C01-C11	ELEVON-101	3/3	NA NA NA	/			
02-6-C01-C12	ELEVON-102	3/3	NA NA NA	/			
02-6-C01-CV-C08	ELEVON-106	1/1	NA NA NA	/			
02-6-C01-CV-C09	ELEVON-107	2/1R	F F P	/			
02-6-C01-FE-B08	ELEVON-108	1/1	NA NA NA	/			
02-6-C01-PP-A06	ELEVON-114	2/1R	P F P	/			
02-6-C01-PP-A07	ELEVON-118	1/1	NA NA NA	/			
02-6-C01-PV-B05	ELEVON-116	1/1	NA NA NA	/			
02-6-C01-SV-B01	ELEVON-109	2/1R	P F P	/			
02-6-C01-SV-B02	ELEVON-111	2/1R	P F P	/			
02-6-C01-SW-C02	ELEVON-104	2/1R	P F P	/			
02-6-C01-SW-C06	ELEVON-103	2/1R	P P P	/			
02-6-C01-SW-C06	ELEVON-125	2/1R	P P P	/			