FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE
NUMBER: M8-1MR-8M004-X

SUBSYSTEM NAME: MECHANICAL - EDS

REVISION: 1 9/1/95

		PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	:	DOCKING MECHANISM ASSEMBLY NPO-ENERGIA	33U.5316.003-05 33U.5316.003-05
SRU	:	ASSY, ELECTRO-MAGNETIC DAMPER NPO-ENERGIA	33U.6661.006 33U.6661.006
SRU	:	ASSY, ELECTRO-MAGNETIC DAMPER NPO-ENERGIA	33U.6661.007 33U.6661.007

PART DATA

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
HIGH ENERGY ELECTRO-MAGNETIC DAMPER ASSEMBLY

REFERENCE DESIGNATORS:

QUANTITY OF LIKE ITEMS: 3
THREE (ONE PER BALLSCREW PAIR)

FUNCTION:
A HIGH ENERGY ELECTRO-MAGNETIC DAMPER IS LOCATED BETWEEN EACH ROD OF THE BALLSCREW PAIRS AND IS ENGAGED BY A SOLENOID DRIVEN MECHANICAL LOCK (CLUTCH) DEVICE. ALL THREE DAMPER ASSEMBLIES ARE INTERCONNECTED THROUGH THE KINEMATIC CHAIN TO DAMP OUT RELATIVE PITCH AND YAW ROTATIONAL VELOCITIES OF THE RING FOLLOWING CAPTURE.

SERVICE IN BETWEEN FLIGHT AND MAINTENANCE CONTROL:
VISUAL INSPECTION, SERVICEABILITY CONTOL, DOCKING WITH CALIBRATING DOCKING MECHANISM.

MAINTAINABILITY
REPAIR METHOD - REPLACEMENT.

REFERENCE DOCUMENTS: 33U.6661.006
33U.6661.007
33U.6316.003-05
33U.6321.004

FAILURE MODES EFFECTS ANALYSIS (FMEA) – CIL FAILURE MODE
NUMBER: M8-1MR-SM004- 02

REVISION# 1 9/1/95

SUBSYSTEM NAME: MECHANICAL - EDS
LRU: DOCKING MECHANISM ASSEMBLY
ITEM NAME: ASSEMBLY, HIGH ENERGY DAMPER

CRITICALITY OF THIS FAILURE MODE: 2R3

FAILURE MODE:
FAILS TO ENGAGE

MISSION PHASE:
OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

CAUSE:
CLUTCH/SHAFT FAILURE, BROKEN CLUTCH COIL WINDINGS OR WORN/BROKEN GEAR TEETH DUE TO MECHANICAL/THERMAL SHOCK, VIBRATION, OR MANUFACTURE/ MATERIAL DEFECT, JAMMED CLUTCH DUE TO CONTAMINATION

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

CRITICALITY 1R2 DURING INTACT ABORT ONLY (AVIONICS ONLY)? N/A

REDUNDANCY SCREEN
A) PASS
B) FAIL
C) PASS

PASS/FAIL RATIONALE:
A)

B)
FAILS REDUNDANCY SCREEN "B" SINCE A MECHANICAL FAILURE RESULTING IN A HIGH ENERGY DAMPER FAILING TO ENGAGE IS NOT DETECTABLE PRIOR TO CAPTURE. ELECTRICAL FAILURES THAT MAY RESULT IN THE SAME DAMPER FAILURE CAN BE DETECTED BY GROUND MONITORING OF ASSOCIATED TELEMETRY MEASUREMENTS. AFTER CAPTURE, GROUND EVALUATION OF TELEMETRY DATA RELATING TO BALLSCREW ALIGNMENT COULD IDENTIFY A DAMPER FAILING TO ENGAGE AS THE CAUSE OF THE PROBLEM.

C)

METHOD OF FAULT DETECTION:
FAILURE RESULTING IN A HIGH ENERGY DAMPER FAILING TO MECHANICALLY ENGAGE IS NOT DETECTABLE PRIOR TO CAPTURE. ELECTRICAL FAILURES THAT MAY RESULT IN THE SAME DAMPER FAILURE CAN BE DETECTED BY GROUND MONITORING OF ASSOCIATED TELEMETRY MEASUREMENTS. AFTER CAPTURE, GROUND EVALUATION OF TELEMETRY DATA RELATING TO BALLSCREW ALIGNMENT COULD IDENTIFY A DAMPER FAILING TO ENGAGE AS THE CAUSE OF THE PROBLEM.

FAILURE MODES EFFECTS ANALYSIS (FMEA) – CIL FAILURE MODE
NUMBER: M8-1MR-6M004- 02

- FAILURE EFFECTS -

(A) SUBSYSTEM:
LOSS OF CAPABILITY TO DAMP OUT ROTATIONAL SPEED OF ONE BALLNUT PAIR. LIMITED DAMPING PROVIDED AT ONE OF THREE POINTS ON THE DOCKING RING. NO EFFECT ON CAPTURE SINCE DAMPING IS NOT REQUIRED UNTIL AFTER CONTACT. HOWEVER, LOSS OF DAMPING CAPABILITIES DUE TO ALL THREE DAMPERS FAILING TO ENGAGE COULD CAUSE DAMAGE TO ELEMENTS IN THE KINEMATIC CHAIN RESULTING IN THE LOSS OF CAPABILITY TO EXTEND OR RETRACT DOCKING RING.

(B) INTERFACING SUBSYSTEM(S):
EXCESSIVE LOADS INCURRED DURING DOCKING AS THE RESULT OF THREE HIGH ENERGY DAMPERS FAILING TO ENGAGE AFTER CAPTURE COULD PROPAGATE TO EXTERNAL AIRLOCK AND ORBITER STRUCTURE.

(C) MISSION:
NO EFFECT UNTIL THIRD DAMPER FAILS TO ENGAGE FOLLOWING CAPTURE. THEN EXCESSIVE LOADS INCURRED DURING CAPTURE COULD PRECLUDE DOCKING CAPABILITIES.

(D) CREW, VEHICLE, AND ELEMENT(S):
POTENTIAL DAMAGE TO ORBITER AND MIR DOCKING MECHANISM HARDWARE FOLLOWING CAPTURE. CREW AND ORBITER STRUCTURE ARE UNAFFECTED BY THESE LOADS.

(E) FUNCTIONAL CRITICALITY EFFECTS:
FIRST FAILURE - LIMITED DAMPING AT ONE POINT ON DOCKING RING.
SECOND FAILURE - LIMITED DAMPING AT TWO POINTS ON DOCKING RING.
THIRD FAILURE - LOSS OF ALL DAMPING CAPABILITIES COULD CAUSE DAMAGE TO THE ELEMENTS IN THE KINEMATIC CHAIN RESULTING IN LOSS OF CAPABILITY TO EXTEND OR RETRACT DOCKING RING. INABILITY TO MOVE RING TO MATE BOTH MECHANISMS WILL PRECLUDE DOCKING CAPABILITIES RESULTING IN LOSS OF ORBITER/MIR MISSION CAPABILITIES

DESIGN CRITICALITY (PRIOR TO OPERATIONAL DOWNGRADE, DESCRIBED IN F): 2R3

(F) RATIONALE FOR CRITICALITY CATEGORY DOWNGRADE:
N/A (THERE ARE NO WORKAROUNDS TO CIRCUMVENT THIS FAILURE.)

-DISPOSITION RATIONALE-

(A) DESIGN:
MATERIAL SELECTION FOR STRENGTH WILL HELP PRECLUDE STRUCTURAL FAILURES. ALL COMPONENTS HAVE A SAFETY FACTOR NO LESS THAN 1.4. REDUNDANT COIL WINDINGS ARE AVAILABLE AND REDUNDANT CONTROL POWER IS PROVIDED TO EACH DAMPER ASSEMBLY.

LOAD ANALYSIS HAS SHOWN THAT THE MAXIMUM DOCKING LOADS INCURRED AS THE RESULT OF THIS FAILURE WILL NOT EXCEED EXTERNAL AIRLOCK/ORBITER STRUCTURAL LIMITS.

(B) TEST:

DOCKING MECHANISM ACCEPTANCE TESTS:

1. ELECTRICAL SCHEMATIC CHECKOUT - CONTACT RESISTANCE ON EACH PIN OF THE CONNECTOR WHICH IS ELECTRICALLY TIED TO THE ELECTRO-MAGNETIC DAMPER WINDINGS IS CHECKED. THIS TEST VERIFIES CONTINUITY THROUGH THE E/M DAMPER WINDINGS.

2. INSULATION ELECTRICAL RESISTANCE TEST - THE INSULATION RESISTANCE AND ELECTRICAL STRENGTH OF INSULATION CHECKOUT OF EACH PIN OF EACH E/M DAMPER CONNECTOR TO THE APDA HOUSING WILL VERIFY THAT THE E/M DAMPER WINDINGS ARE NOT ELECTRICALLY SHORTED TO GROUND.

3. INSPECTION SERVICEABILITY TEST - PROPER E/M DAMPER OPERATIONS VERIFIED BY GUIDE RING FUNCTIONAL PERFORMANCE TEST AND SENSOR FUNCTIONAL TEST.

A. GUIDE RING FUNCTIONAL PERFORMANCE TEST - DOCKING MECH RING MOVEMENT IS ACCOMPLISHED WITH HIGH ENERGY DAMPERS ON.

B. SENSOR FUNCTIONAL TEST - OPERATIONAL CHECKOUT OF THE ELECTROMAGNETIC DAMPERS IS PERFORMED THROUGH CAPTURE SENSOR PER STEP 13 OF INSTRUCTION 33U.6201.006-05 PM-3.

4. VIBRORESISTENT TEST - APDS SUBJECTED TO THE FOLLOWING VIBRATION LEVELS FOR 2 MINUTES PER AXIS:

FREQUENCY (HZ)	SPECTORAL DENSITY ACCELERATION
FROM 20 TO 80	INCREASING, 3DB OCTAVE TO $0.04G^2/HZ$
FROM 80 TO 350	PERMANENT $0.04G^2/HZ$
FROM 350 TO 2000	DECREASING 3DB OCTAVE WITH $0.04G^2/HZ$

SUBSEQUENT TO THIS TEST AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT TEST, AN INSULATION RESISTANCE TEST, AND INSPECTION SERVICEABILITY TESTS ARE PERFORMED AS DEFINED IN ATP TESTS #1, #2, AND #3 ABOVE.

5. DOCKING MECHANISM CHECKOUT (STATIC) TEST - A HIGH ENERGY DAMPER FUNCTIONAL PERFORMANCE TEST IS PERFORMED AS PART OF THE CHECKOUT OF THE DOCKING MECHANISM. WITH THE GUIDE RING IN ITS INITIAL POSITION IT IS ROTATED ABOUT THE Y AND Z AXES AND THE MOMENT WAS MEASURED WITH AND WITHOUT HIGH ENERGY DAMPERS ENGAGED. THIS TEST VERIFIES THAT THE DOCKING RING RETURNS TO INITIAL POSITION WITH DAMPERS OFF AND DOES NOT RETURN TO INITIAL POSITION WITH DAMPERS ON. A FAILED DAMPER WOULD BE DETECTED AT THIS TIME.

6. THERMO VACUUM TEST - DOCKING OF THE MECHANISM IS THERMALLY CYCLED, UNDER LOAD CONDITIONS, FROM +20°C TO -50/+55°C TO +50/+55°C TO +20°C IN A VACUUM AT 10^{-4} TO 10^{-5} TORR. DWELL AT EACH TEMPERATURE AND BETWEEN OPERATIONS AT EACH TEMPERATURE IS A MINIMUM OF 60 MINUTES AFTER STABILIZATION. OPERATIONS INCLUDES PERFORMING DOCKING WHICH IS ACCOMPLISHED AT A SPEED OF 0.15M/SEC BETWEEN THE SIMULATOR AND MOVEABLE PLATFORM (CONTAINING THE DOCKING MECHANISM). AT EACH TEMPERATURE ELECTRO-MAGNETIC DAMPERS ARE TURNED ON FOLLOWING RING EXTENSION AND CURRENT TO EACH IS MEASURED. PROPER OPERATION

OF THESE DAMPERS IS VERIFIED FOR A TEMPERATURE RANGE OF -50°C/-55°C TO 50°C/55°C.

7. CONTROLLED DOCKING TEST - CONTROLLED DOCKING IS PERFORMED UNDER LOAD CONDITIONS. PROPER RING PERFORMANCE WILL VERIFY HIGH ENERGY DAMPING OPERATIONS.

DOCKING MECHANISM QUALIFICATION TESTS:

1. ELECTRICAL CIRCUIT TEST - CONTACT RESISTANCE ON EACH PIN OF THE CONNECTOR WHICH IS ELECTRICALLY TIED TO THE ELECTRO-MAGNETIC DAMPER WINDINGS IS CHECKED. THIS TEST VERIFIES CONTINUITY THROUGH THE E/M DAMPER WINDINGS.

2. INSULATION ELECTRICAL RESISTANCE TEST - THE INSULATION RESISTANCE AND ELECTRICAL STRENGTH OF INSULATION CHECKOUT OF EACH PIN OF EACH E/M DAMPER CONNECTOR TO THE APDA HOUSING WILL VERIFY THAT THE E/M DAMPER WINDINGS ARE NOT ELECTRICALLY SHORTED TO GROUND.

3. VIBRATION STRENGTH TEST - APDS SUBJECTED TO THE FOLLOWING VIBRATION LEVELS IN EACH AXIS FOR A 400 SECOND DURATION.

FREQUENCY (HZ)	SPECTORAL DENSITY ACCELERATION
FROM 20 TO 80	INCREASING, 3DB OCTAVE TO 0.067G^2/HZ
FROM 80 TO 350	CONSTANT 0.067G^2/HZ
FROM 350 TO 2000	DECREASING 3DB OCTAVE WITH 0.067G^2/HZ

SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT TEST AND AN INSULATION RESISTANCE TEST ARE PERFORMED AS DEFINED IN QTP TESTS #1, AND #2 ABOVE.

4. SHOCK AND SAWTOOTH LOADING STRENGTH TEST - DOCKING MECHANISM IS SUBJECTED TO 20G TERMINAL SAWTOOTH SHOCK PULSES IN EACH AXIS, 3 PULSES IN EACH DIRECTION FOR A TOTAL OF 6 PULSES/AXIS. AFTER COMPLETION AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT TEST AND AN INSULATION RESISTANCE TEST ARE PERFORMED AS DEFINED IN QTP TESTS #1, AND #2 ABOVE.

5. TRANSPORTABILITY STRENGTH TEST - SHIPPING LOADS ARE SIMULATED ON A VIBRATING TABLE TO VERIFY THAT THE DOCKING MECHANISM WILL NOT BE DAMAGED DURING SHIPMENT. THIS TEST IS CONDUCTED UNDER THE CONDITIONS CONTAINED IN THE FOLLOWING TABLE.

VIBRATION ACCELER DIRECTION	VIBRATION ACCELER AMPLITUDE	FREQUENCY SUBBAND, HZ					TOTAL TEST DURATION	
		5-7	7-15	15-30	30-40	40-60		
		TEST DURATION, MIN					HR	MIN
ALONG X-AXIS	1.4	–	4	–	–	–	–	4
	1.2	76	93	32	81	39	5	7
ALONG Y-AXIS	1.1	–	4	–	–	–	–	4
	1.0	13	16	7	10	7	–	53
ALONG Z-AXIS	1.1	–	4	–	–	–	–	4
	1.0	32	40	16	26	16	2	10

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SUBSEQUENT TO THIS TEST AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT TEST AND AN INSULATION RESISTANCE TEST ARE PERFORMED AS DEFINED IN QTP TESTS #1, AND #2 ABOVE.

6. COLD AND HEAT RESISTANCE TEST - DOCKING OF THE MECHANISM IS THERMALLY CYCLED FROM +20°C TO -50/-55°C TO +50/+55°C TO +20°C IN A VACUUM AT 10^{-4} TO 10^{-5} TORR. DWELL AT EACH TEMPERATURE AND BETWEEN OPERATIONS AT EACH TEMPERATURE IS A MINIMUM OF 60 MINUTES AFTER STABILIZATION. FIVE CYCLES WERE PERFORMED AGAINST THE GUIDE RING EXTEND AND FINAL POSITION MECHANICAL STOPS FOR 10 SECONDS EACH. DURING EACH DOCKING, AS SHOWN IN THE FOLLOWING TABLE, A FAILED DAMPER WOULD BE DETECTED.

SEQ NO.	DOCKING RATE, M/S	SIMULATOR ROTATIONAL ANGLE		TEMP °C	VOLTAGE VOLTS	PRESS INTEGRITY CHECKOUT
		PITCH	ROLL			
1	0.10	0°	0°	25 +/-10	23	YES
2	0.10	0°	4°	25 +/-10	34	NO
3	0.12	4°	4°	25 +/-10	27	NO
4*	—	—	—	+60+/-5	—	YES
4	0.10	4°	0°	+50+/-5	27	YES
5*	—	—	—	-(60+/-5)	—	YES
5	0.10	4°	0°	-(30+/-5)	27	YES
6*	—	—	—	+60+/-5	—	YES
6	0.12	0°	4°	+50+/-5	23	YES
7*	—	—	—	-(60+/-5)	—	YES
7	0.10	0°	4°	-(30 +/-5)	23	YES
8*	—	—	—	+60+/-5	—	YES
8	0.12	4°	4°	50 +/-5	34	YES
9*	—	—	—	-(60+/-5)	—	YES
9	0.12	4°	4°	-(30 +/-5)	34	YES
10*	—	—	—	+60+/-5	—	YES
10	0.10	4°	0°	+50+/-5	27	YES
11*	—	—	—	-(60+/-5)	—	YES
11	0.10	0°	4°	-(30 +/-5)	27	YES
12*	—	—	—	+60+/-5	—	YES
12*	0.10	0°	4°	+50+/-5	27	YES
13*	—	—	—	-(60+/-5)	—	YES
13*	0.12	4°	4°	-(30 +/-5)	27	YES
14*	—	—	—	+60+/-5	—	YES
14*	0.12	4°	4°	+50+/-5	27	YES
15*	0.12	4°	4°	+25+/-10	23	YES

*MC621-0087-2001, -4001, & -5001 ONLY

AFTER COMPLETION AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT TEST AND AN INSULATION RESISTANCE TEST ARE PERFORMED AS DEFINED IN QTP TESTS #1, AND #2 ABOVE.

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7. APDS SERVICEABILITY TEST IN A SIX-DEGREE-OF-FREEDOM DYNAMIC TEST - THE SIX-DEGREE-OF-FREEDOM DYNAMIC TEST VERIFIES APDS DOCKING AND UNDOCKING OPERATIONS UNDER CLOSE-TO-FULL-SCALE CONDITIONS. STATIC MOTION OF ENTITIES IS SIMULATED UNDER SPECIFIC INERTIAL AND GEOMETRICAL PARAMETERS FOR VARIOUS INITIAL CONDITIONS FOR MIR/SHUTTLE DOCKING. A TOTAL OF 20 DOCKINGS IS PERFORMED. ABSORPTION OF ENERGY OF RELATIVE MOVEMENT DURING EACH DOCKING WILL DETECT A FAILED DAMPER. SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT TEST AND AN INSULATION RESISTANCE TEST ARE PERFORMED AS DEFINED IN QTP TESTS #1, AND #2 ABOVE.

8. TARGET SERVICE LIFE TEST - TESTS ARE PERFORMED TO VERIFY PROPER DOCKING OPERATIONS OVER ITS LIFE OF 100 DOCKINGS. PROPER OPERATION OF THE DAMPERS VERIFIED DURING 100 DOCKING CYCLES (FOR MC621-0087-1001/-3001 UNITS ONLY). FOR MC621-0087-2001, -4001, & -5001 UNITS PROPER OPERATION VERIFIED DURING 368 CYCLES (44 VACUUM/LOAD CYCLES, 16 LOAD CYCLES, & 324 NO-LOAD CYCLES). SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT TEST AND AN INSULATION RESISTANCE TEST ARE PERFORMED AS DEFINED IN QTP TESTS #1, AND #2 ABOVE.

9. CONTROL DISASSEMBLY - UPON COMPLETION OF ALL QUAL TESTING THE DOCKING MECHANISM IS DISMANTLED AND ELECTRO-MAGNETIC DAMPER ASSEMBLIES ARE CHECKED FOR EVIDENCE OF WEAR OR FAILURE.

OMRSD - TURNAROUND CHECKOUT TESTING IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:
RECEIVING INSPECTION
COMPONENTS ARE SUBJECTED TO A 100% RECEIVING INSPECTION PRIOR TO INSTALLATION.

CONTAMINATION CONTROL
CORROSION PROTECTION PROVISIONS AND CONTAMINATION CONTROL VERIFIED BY INSPECTION. CHECK OF ROOM CLEANLINESS; PARTS WASHING AND OTHER OPERATIONS OF THE TECHNOLOGICAL PROCESS WHICH PROVIDES CLEANLINESS ARE VERIFIED BY INSPECTION.

CRITICAL PROCESSES
ANODIZING, HEAT TREATING, CHEMICAL PLATING, SOLDERING, AND CURING VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
TORQUE, ADJUSTMENTS AND TOLERANCES ACCORDING TO TECHNICAL REQUIREMENTS OF THE DRAWINGS ARE VERIFIED BY INSPECTION.

TESTING
ATP/QTP/OMRSD TESTING VERIFIED BY INSPECTION.

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HANDLING/PACKAGING
HANDLING/PACKAGING PROCEDURES AND REQUIREMENT FOR SHIPMENT VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:
DATA ON TEST FAILURES, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING OF ODS DOCKING MECHANISMS CAN BE FOUND IN PRACA DATA BASE.

(E) OPERATIONAL USE:
NONE. LIMITED DAMPING IS PROVIDED BY THE SPRING MECHANISMS GIVEN A FAILURE OF ALL THREE HIGH ENERGY DAMPERS.

- APPROVALS -

DESIGN ENGINEER	M. NIKOLAYEVA	
DESIGN MANAGER	A. SOUBCHEV	
NASA SS/MA		
NASA SUBSYSTEM MANAGER		