FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE
NUMBER: M8-1MR-BM004-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-BM004- 03

REVISION# 1 9/1/95

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

CRITICALITY OF THIS FAILURE MODE: 2/2

FAILURE MODE:
FAILS TO DISENGAGE

MISSION PHASE:
OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

CAUSE:
STRUCTURAL FAILURE DUE TO MECHANICAL/THERMAL SHOCK, VIBRATION, OR MANUFACTURE/MATERIAL DEFECT; CONTAMINATION

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

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

REDUNDANCY SCREEN A) N/A
B) N/A
C) N/A

PASS/FAIL RATIONALE:
A)
N/A

B)
N/A

C)
N/A

METHOD OF FAULT DETECTION:
NONE

- FAILURE EFFECTS -

(A) SUBSYSTEM:
RESISTANCE TO MOVEMENT OF KINEMATIC CHAIN ELEMENTS BETWEEN AFFECTED BALLNUT PAIRS. ROTATIONAL VELOCITIES OF THE DOCKING RING ARE LIMITED IN THE PITCH AND YAW DIRECTIONS. POSSIBLE HIGH DOCKING LOADS.

(B) INTERFACING SUBSYSTEM(S):
POTENTIAL EXCESSIVE LOADS INCURRED DURING DOCKING, AS THE RESULT OF A SINGLE HIGH ENERGY DAMPER BEING ACTIVATED PRIOR CAPTURE, COULD PROPAGATE TO EXTERNAL AIRLOCK AND ORBITER STRUCTURE.

(C) MISSION:
NO EFFECT ON CURRENT DOCKING. ONLY SUBSEQUENT DOCKINGS ARE AFFECTED - A SINGLE HIGH ENERGY DAMPER BEING ACTIVATED PRIOR TO CAPTURE COULD DAMAGE ELEMENTS IN THE KINEMATIC CHAIN POTENTIALLY RESULTING IN POSSIBLE 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.

(D) CREW, VEHICLE, AND ELEMENT(S):
NO EFFECT ON CREW AND VEHICLE. POTENTIAL DAMAGE TO MIR AND ORBITER DOCKING MECHANISMS DURING SECOND DOCKING.

(E) FUNCTIONAL CRITICALITY EFFECTS:
N/A

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

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

-DISPOSITION RATIONALE-

(A) DESIGN:
DAMPING OCCURS BY ELECTRO-MAGNETIC MEANS AND IS ONLY ACTIVATED WHEN POWER IS APPLIED TO THE WINDINGS. AS SUCH, A FAILURE TO DISENGAGE A DAMPER IS MORE LIKELY TO OCCUR AS THE RESULT OF AN ELECTRICAL FAILURE RATHER THAN A MECHANICAL FAILURE. MECHANICAL FAILURES ARE ONLY POSTULATED BECAUSE A SECOND DOCKING MAY BE REQUIRED. ALL DAMPER PARTS HAVE A SAFETY FACTOR NO LESS THAN 1.4.

LOAD ANALYSES:
(1) LOADS ANALYSIS HAS INDICATED THAT A SINGLE HIGH ENERGY DAMPER BEING ACTIVATED PRIOR TO CAPTURE COULD RESULT IN MOMENTS OF 686 KGF-M WHICH EXCEEDS THE ODS LIMIT LOAD SPECIFICATION OF 500 KGF-M.
(2) ADDITIONAL ANALYSIS HAS SHOWN THAT THE MAXIMUM AXIAL LOADS INCURRED AS THE RESULT OF ALL THREE HIGH ENERGY DAMPERS BEING ACTIVATED PRIOR TO CAPTURE ARE 5097KGF (TENSION) AND 2906 KGF (COMPRESSION) IN THE Z-AXIS. ANALYSIS HAS INDICATED THAT THE CAPTURE LATCHES WILL DISENGAGE WHEN THE AXIAL LOAD ON THIS AXIS REACHES 3698 KGF. DAMAGE TO THE CAPTURE LATCH, THAT WOULD PREVENT IT FROM BEING ACTUATED OPEN, WILL NOT OCCUR PRIOR TO THE DISENGAGEMENT AXIAL LOAD OF 3698 KGF.
(3) THESE LOADS WILL NOT EXCEED EXT AIRLOCK/ORBITER STRUCTURAL LIMITS.

(B) TEST:
DOCKING MECHANISM ACCEPTANCE TESTS:

1. INSPECTION SERVICEABILITY TEST (SENSOR FUNCTIONAL TEST) - OPERATIONAL CHECKOUT OF THE ELECTROMAGNETIC DAMPERS IS PERFORMED THROUGH CAPTURE SENSOR PER STEP 13 OF INSTRUCTION 33U.6201.008-05 PM-3.

2. 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 ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE AND A FUNCTIONAL CHECK IS PERFORMED, PER ATP #1 ABOVE, TO VERIFY PROPER OPERATION OF THE ELECTROMAGNETIC DAMPERS.

3. 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 DAMPER FAILING TO DISENGAGE WOULD BE DETECTED.

4. 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 0.16M/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.

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

<u>DOCKING MECHANISM QUALIFICATION TESTS:</u>

1. 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	61	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

SUBSEQUENT TO THIS TEST AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE AT WHICH TIME A FAILED "ON" DAMPER WOULD BE DETECTED.

2. 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 AT WHICH TIME A FAILED "ON" DAMPER WOULD BE DETECTED.

3. 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. A FAILED "ON" DAMPER WOULD BE DETECTED AT THIS TIME.

4. 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 "ON" DAMPER. SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE.

5. 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 388 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.

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^{-6} 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 "ON" DAMPER WOULD BE DETECTED.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: M8-1MR-BM004- 03

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°	+60+/-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, & -6001 ONLY

AFTER COMPLETION AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE.

7. 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

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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.

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

- APPROVALS -

DESIGN ENGINEER	:	M. NIKOLAYEVA	: [signature]
DESIGN MANAGER	:	A. SOUBCHEV	: [signature]
NASA SS/MA	:		: [signature]
NASA SUBSYSTEM MANAGER	:		: [signature]