FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE
NUMBER: M8-1MR-BM003-X

SUBSYSTEM NAME: MECHANICAL - EDS

REVISION: 1 9/1/96

		PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	:	DOCKING MECHANISM ASSEMBLY NPO-ENERGIA	33U.6316.003-05 33U.6316.003-05
SRU	:	ASSY, RIGHT BALLSCREW/NUT NPO-ENERGIA	33U.6421.009 33U.6421.009
SRU	:	ASSY, LEFT BALLSCREW/NUT NPO-ENERGIA	33U.6421.010 33U.6421.010
SRU	:	ASSY, RIGHT BALLSCREW/NUT NPO-ENERGIA	33U.6421.011 33U.6421.011
SRU	:	ASSY, LEFT BALLSCREW/NUT NPO-ENERGIA	33U.6421.012 33U.6421.012
SRU	:	ASSY, RIGHT BALLSCREW/NUT NPO-ENERGIA	33U.6421.013 33U.6421.013
SRU	:	ASSY, LEFT BALLSCREW/NUT NPO-ENERGIA	33U.6421.014 33U.6421.014

PART DATA

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
LEFT/RIGHT BALLSCREW/NUT ASSEMBLY

REFERENCE DESIGNATORS:

QUANTITY OF LIKE ITEMS: 6
SIX (3 LEFT AND 3 RIGHT)

FUNCTION:
THE BALLSCREW ASSEMBLY IS A KINEMATIC ELEMENT WHICH TRANSFERS THE MOTION FROM THE ACTUATOR TO THE RING (ON EXTENSION OR RETRACTION) AND FROM THE RING TO ELEMENTS OF THE ATTENUATION SYSTEM DURING DOCKING. IT CONSISTS OF (1) ROD SCREW OF 475 MM IN LENGTH WITH LEFT-HAND (LEFT BALLSCREW/NUT ASSEMBLIES) AND RIGHT-HAND THREAD (RIGHT BALLSCREW/NUT ASSEMBLIES); (2) BALLSCREW/NUT ASSEMBLIES WHICH PROVIDES THE TRANSFORMATION OF THE ROTATIONAL MOTION OF THE NUT INTO THE LINEAR PROGRESSIVE MOTION OF THE SCREW AND VICE VERSA; AND (3) THREE DIMENSIONAL HINGE WITH CROSS AXIS GEARING TO TRANSFER THE ROTATION FROM THE SCREW NUT TO THE OUTPUT SHAFT.

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

MAINTAINABILITY
REPAIR METHOD - NONE (REPAIRING IN MANUFACTURING CONDITIONS ONLY).

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REFERENCE DOCUMENTS: 33U.6421.009
33U.6421.010
33U.6421.011
33U.6421.012
33U.6421.013
33U.6421.014
33U.6316.003-05

FAILURE MODES EFFECTS ANALYSIS (FMEA) – CIL FAILURE MODE
NUMBER: M8-1MR-BM003- 01

REVISION# 1 9/1/95

SUBSYSTEM NAME: MECHANICAL - EDS
LRU: DOCKING MECHANISM ASSEMBLY
ITEM NAME: ASSEMBLY, BALLSCREW/NUT

CRITICALITY OF THIS FAILURE MODE: 1R2

FAILURE MODE:
BROKEN (SHAFT/GEAR/TUBE BREAKAGE)

MISSION PHASE:
OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

CAUSE:
MATERIAL/MANUFACTURE DEFECT, EXCESSIVE EXTERNAL LOADS, VIBRATION, MECHANICAL SHOCK

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

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

REDUNDANCY SCREEN
A) PASS
B) PASS
C) PASS

PASS/FAIL RATIONALE:
A)

B)

C)

METHOD OF FAULT DETECTION:
INSTRUMENTATION - THE CORRESPONDING DOCKING RING INDICATORS ON THE DOCKING CONTROL PANEL WILL ILLUMINATE TO INDICATE RING POSITION AND ALIGNMENT. VISUAL OBSERVATION - INABILITY TO MOVE THE DOCKING RING; POTENTIAL MOMENT CREATED BETWEEN VEHICLES ABOUT ONE POINT ON THE RING.

- FAILURE EFFECTS -

(A) SUBSYSTEM:
INABILITY OF AFFECTED BALLSCREW/NUT ASSEMBLY TO CARRY A LOAD. LOSS OF CAPABILITY TO ALIGN, CAPTURE, RETRACT, AND EXTEND THE DOCKING RING. LOADS EXPERIENCED DURING CAPTURE WILL COLLAPSE THE DOCKING RING AT THE POINT ON THE RING WHERE FAILURE OF THE BALLSCREW OCCURRED.

(B) INTERFACING SUBSYSTEM(S):
POTENTIAL DAMAGE TO ORBITER STRUCTURE IF ORBITER/MIR COLLIDE DUE TO THIS FAILURE AND WORKAROUND IS NOT IMPLEMENTED.

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(C) MISSION:
WORST CASE, LOSS OF ALL FUNCTIONS ASSOCIATED WITH THE DOCKING RING (ALIGNMENT, CAPTURE, RETRACTION, EXTENSION) WILL PRECLUDE DOCKING CAPABILITIES RESULTING IN LOSS OF ORBITER/MIR MISSION OBJECTIVES.

(D) CREW, VEHICLE, AND ELEMENT(S):
FIRST FAIURE (BROKEN BALLSCREW/NUT ASSEMBLY) COLLAPSE OF THE DOCKING RING AT ONE POINT ON THE RING DURING CAPTURE COULD CAUSE A MOMENT BETWEEN ORBITER AND MIR.

(E) FUNCTIONAL CRITICALITY EFFECTS:
N/A

DESIGN CRITICALITY (PRIOR TO OPERATIONAL DOWNGRADE, DESCRIBED IN F): 1/1

(F) RATIONALE FOR CRITICALITY CATEGORY DOWNGRADE:
SECOND FAILURE (INABILITY TO OPEN CAPTURE LATCHES OR PERFORM SEPARATION) - INABILITY TO CIRCUMVENT THE MOMENT CREATED BETWEEN ORBITER AND MIR. POTENTIAL COLLISION BETWEEN BOTH VEHICLES RESULTING IN POSSIBLE LOSS OF CREW AND VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:
A BROKEN BALLSCREW/NUT ASSEMBLY IS CONSIDERED VERY REMOTE BASED ON THE FOLLOWING: THE USE OF THE EXPERIENCE OF PREVIOUS DEVELOPMENTS; STRENGTH ANALYSIS OF STRUCTURAL ELEMENTS AND PARTS HAVING A SAFETY FACTOR NO LESS THAN 1.4; THE CHOICE OF MATERIALS THAT SHOWED A GOOD PERFORMANCE IN OPERATIONAL USE; THE CALCULATION OF TOLERANCES AND DIMENSIONAL CIRCUITS; AND THE CHOICE OF SPECIAL BEARINGS SUITABLE FOR OPERATIONAL CONDITIONS.

(B) TEST:
DOCKING MECHANISM ACCEPTANCE TESTS:

1. INSPECTION SERVICEABILITY TEST - DURING THE GUIDE RING FUNCTIONAL PERFORMANCE TEST THE DOCKING MECHANISM RING IS EXTENDED TO IT'S INITIAL POSITION AND THEN IT'S FORWARD POSITION AND THEN RETRACTED TO IT'S FINAL POSITION. BALLSCREW/NUT ASSEMBLY IS VERIFIED FOR PROPER OPERATION DURING RING EXTENSION AND RETRACTION.

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 BALLSCREW/NUT ASSEMBLY.

3. DOCKING MECHANISM CHECKOUT (STATIC) TEST - RING IS EXTENDED AND RETRACTED AS NECESSARY TO FULLY TEST ITS OPERATION DURING A SINGLE DOCKING. FORCE IS APPLIED TO THE RING TO SIMULATE LOADS THAT CAN OCCUR DURING RING CAPTURE AND MATING OF THE TWO MECHANISMS. ATTENUATION SYSTEM CHARACTERISTICS IS DETERMINED WHEN THE RING IS DEFLECTED AND ROTATED DURING THIS TEST. A CHECK OF RING RETRACTION FORCE AND FORCE GENERATED AND KEPT BY THE DOCKING MECHANISM IS PERFORMED. THIS TEST WILL VERIFY PROPER OPERATION OF THE BALLSCREW/NUT ASSEMBLY UNDER LOAD AND NO-LOAD CONDITIONS.

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 0.15M/SEC BETWEEN THE SIMULATOR AND MOVEABLE PLATFORM (CONTAINING THE DOCKING MECHANISM). PROPER OPERATION OF THE BALLSCREW/NUT ASSEMBLY IS VERIFIED DURING RING EXTENSION/RETRACTION AND DOCKING FOR A TEMPERATURE RANGE OF -50° C/-55°C TO 50°C/55°C.

5. CONTROLLED DOCKING TEST - CONTROLLED DOCKING IS PERFORMED TO VERIFY PROPER RETRACTION OF THE DOCKING MECHANISM. A PULL TEST OF ASSEMBLIES WITH THE DOCKING MECHANISM ASSEMBLY IS PERFORMED DURING THIS TEST. THESE TESTS WILL VERIFY PROPER OPERATION OF THE BALLSCREW/NUT ASSEMBLY.

DOCKING MECHANISM QUALIFICATION TESTS:

1. OPERATIONAL CAPABILITY TEST - BALLSCREW/NUT ASSEMBLY MOVEMENT VERIFIED BY RING EXTENSION AND RETRACTION FROM THE END POSITION TO THE INITIAL POSITION THEN TO THE FORWARD POSITION AND FROM THE FORWARD POSITION TO THE END POSITION.

2. 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 AND AN OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP #1 ABOVE, IS PERFORMED TO VERIFY PROPER BALLSCREW/NUT ASSEMBLY OPERATIONS DURING RING MOVEMENT.

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 OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP #1 ABOVE, IS PERFORMED TO VERIFY PROPER BALLSCREW/NUT ASSEMBLY OPERATIONS DURING RING MOVEMENT.

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 OPERATIONAL CAPABILITY TEST IS CONDUCTED, AS DEFINED IN QTP #1 ABOVE, TO VERIFY PROPER BALLSCREW/NUT ASSEMBLY OPERATIONS DURING RING MOVEMENT.

5. 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. BALLSCREW/NUT ASSEMBLY MOVEMENT VERIFIED BY EXTENSION OF DOCKING RING TO INITIAL POSITION AND ABSORPTION OF ENERGY OF RELATIVE MOVEMENT DURING EACH DOCKING WILL DETECT A BROKEN BALLSCREW/NUT ASSEMBLY. SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE AND AN OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP #1 ABOVE, IS PERFORMED TO VERIFY PROPER BALLSCREW/NUT ASSEMBLY FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

6. TARGET SERVICE LIFE TEST - TESTS ARE PERFORMED TO VERIFY PROPER DOCKING AND UNDOCKING OPERATIONS OVER ITS LIFE OF 100 DOCKINGS. PROPER OPERATION OF THE BALLSCREW/NUT ASSEMBLY VERIFIED DURING 100 DOCKING AND UNMATING 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). THESE TESTS INCLUDE RING EXTENSION AND RETRACTION. SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE AND AN OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP #1 ABOVE, IS PERFORMED TO VERIFY PROPER BALLSCREW/NUT ASSEMBLY FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

7. 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 BROKEN BALLSCREW/NUT ASSEMBLY 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 OPERATIONAL CAPABILITY TEST, AS DEFINED IN OTP #1 ABOVE, IS PERFORMED TO VERIFY PROPER BALLSCREW/NUT ASSEMBLY FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

8. BACKUP UNDOCKING MEANS CHECK - PROPER OPERATION OF THE BALLSCREW/NUT ASSEMBLY IS VERIFIED DURING COUPLING OF THE APDA ASSEMBLY WITH THE SIMULATOR.

9. CONTROL DISASSEMBLY - UPON COMPLETION OF ALL QUAL TESTING THE DOCKING MECHANISM IS DISMANTLED AND ALL BALLSCREW/NUT ASSEMBLY OPERATING SURFACES ARE CHECKED FOR EVIDENCE OF WEAR OR FAILURE.

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

(C) INSPECTION:
RECEIVING INSPECTION
RAW MATERIAL IS VERIFIED BY INSPECTION TO ASSURE COMPLIANCE WITH THEIR SPECIFICATIONS ON A CERTAIN % OF THE BATCH AT THE INPUT CONTROL.

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, AND CHEMICAL PLATING VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
ADJUSTMENTS AND TUNING ACCORDING TO TECHNICAL REQUIREMENTS OF THE DRAWINGS ARE VERIFIED BY INSPECTION. QUALITY CONTROL OF COATINGS AND FABRICATION OF BALLSCREW/NUT ASSEMBLY (INCLUDING GEAR/BEARING MATING) IS 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:
CREW COULD OPEN CAPTURE LATCHES AND FIRE APPROPRIATE ORBITER RCS JETS TO PERFORM SEPARATION IN THE EVENT A BROKEN BALLSCREW/NUT ASSEMBLY RESULTS IN A MOMENT BETWEEN ORBITER AND MIR.

- APPROVALS -

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