

**FAILURE MODES EFFECTS ANALYSIS (FMEA) - CRITICAL HARDWARE**  
**NUMBER: M8-1MR-BM007-X**

SUBSYSTEM NAME: MECHANICAL - EDS

REVISION: 1 9/1/95

	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	: GUIDE RING ASSEMBLY NPO-ENERGIA	33U.6271.011-05 33U.6271.011-05
SRU	: MECH, GUIDE RING BALLSCREW NPO-ENERGIA	33U.6365.011-05 33U.6365.011-05

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**PART DATA**


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**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**  
 GUIDE RING BALLSCREW INTERCONNECTING MECHANISM

**REFERENCE DESIGNATORS:**

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

**FUNCTION:**

LOCATED AT THE APEX OF EACH BALLSCREW PAIR, THE BALLSCREW INTERCONNECTING MECHANISM PROVIDES A KINEMATIC CONNECTION BETWEEN THE GUIDE RING AND THE REMAINING ELEMENTS OF THE DOCKING MECHANISM. THE MECHANISM PROVIDES LOCKING OF BOTH BALLSCREW RODS TO PREVENT THEM FROM ROTATING AND UNLOCKING OF BOTH BALLSCREW RODS TO ALLOW THEM TO OPERATE TOGETHER.

**SERVICE IN BETWEEN FLIGHT AND MAINTENANCE CONTROL:**

VISUAL INSPECTION, SERVICEABILITY CONTROL, DOCKING WITH CALIBRATING DOCKING MECHANISM.

**MAINTAINABILITY**

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

**REFERENCE DOCUMENTS:** 33U.6365.011-05  
 33U.6271.011-05



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**FAILURE MODES EFFECTS ANALYSIS (FMEA) - CIL FAILURE MODE**

NUMBER: MS-1MR-BM007-02

REVISION# 1 9/1/95

SUBSYSTEM NAME: MECHANICAL - EDS

LRU: GUIDE RING ASSEMBLY

CRITICALITY OF THIS

ITEM NAME: MECHANISM, BALLSCREW INTERCONNECTING

FAILURE MODE: 1R2

**FAILURE MODE:**

BROKEN

**MISSION PHASE:**

OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

**CAUSE:**

GEAR/SHAFT FAILURE DUE TO MATERIAL DEFECT, 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:**

ONE BALLSCREW OF THE PAIR IS ALLOWED TO ROTATE INDEPENDENTLY OF THE OTHER AND WILL NOT BE ABLE TO RESTRAIN AXIAL LOADS. LOSS OF CAPABILITY TO ALIGN THE DOCKING RING. LOADS EXPERIENCED DURING CAPTURE WILL COLLAPSE THE DOCKING RING AT THE POINT ON THE RING WHERE FAILURE OF THE BALLSCREW INTERCONNECTING MECHANISM 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:**

LOSS OF DOCKING RING ALIGNMENT WILL PRECLUDE DOCKING CAPABILITIES RESULTING IN LOSS OF ORBITER/MIR MISSION OBJECTIVES.

**(D) CREW, VEHICLE, AND ELEMENT(S):**

FIRST FAILURE (BROKEN BALLSCREW INTERCONNECTING MECHANISM) 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 INTERCONNECTING MECHANISM IS CONSIDERED TO BE VERY REMOTE BASED ON THE FOLLOWING: THE USE AND EXPERIENCE OF THIS MECHANISM ON PREVIOUS DEVELOPMENTS; PRELIMINARY STRENGTH ANALYSIS OF STRUCTURAL ELEMENTS AND PARTS; THE CHOICE OF STAINLESS STEELS AS THE MATERIAL HAD PERFORMED WELL IN OPERATIONAL USE; THE CALCULATION OF TOLERANCES AND DIMENSIONAL CIRCUITS; THE CHOICE OF SPECIAL BEARINGS SUITABLE FOR OPERATIONAL CONDITIONS; AND THE USE OF A SPRING MECHANISM TO REDUCE SPACING BETWEEN GEARS TO REDUCE THE POSSIBILITY OF GEAR TEETH DAMAGE OR BREAKAGE DUE TO EXCESSIVE LOADS.

**(B) TEST:****DOCKING MECHANISM ACCEPTANCE TESTS:**

1. 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 <sup>2</sup> /HZ
FROM 80 TO 350	PERMANENT 0.04G <sup>2</sup> /HZ
FROM 350 TO 2000	DECREASING 3DB OCTAVE WITH 0.04G <sup>2</sup> /HZ

SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE.

2. 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. THIS TEST WILL VERIFY

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**PROPER OPERATION OF THE BALLSCREW INTERCONNECTING MECHANISMS UNDER LOAD AND NO-LOAD CONDITIONS.**

3. 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 INTERCONNECTING MECHANISMS IS VERIFIED FOR A TEMP RANGE OF -50°C/-55°C TO 50°C/55°C.

4. CONTROLLED DOCKING TEST - CONTROLLED DOCKING IS PERFORMED TO VERIFY PROPER DOCKING CAPABILITIES UNDER LOAD CONDITIONS. A PULL TEST OF ASSEMBLIES WITH THE DOCKING MECHANISM ASSEMBLY IS PERFORMED DURING THIS TEST. THESE TESTS WILL VERIFY PROPER OPERATION OF THE BALLSCREW INTERCONNECTING MECHANISMS.

**DOCKING MECHANISM QUALIFICATION TESTS:**

1. OPERATIONAL CAPABILITY TEST - WITH DOCKING RING IN ITS INITIAL POSITION 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. THIS TEST WILL VERIFY PROPER OPERATION OF THE BALLSCREW INTERCONNECTING MECHANISMS UNDER LOAD CONDITIONS.

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	HR	MIN
		TEST DURATION, 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 INTERCONNECTING MECHANISM OPERATIONS DURING RING MOVEMENT.

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 AND AN OPERATIONAL CAPABILITY TEST IS CONDUCTED, AS



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DEFINED IN QTP #1 ABOVE, TO VERIFY PROPER BALLSCREW INTERCONNECTING MECHANISM OPERATIONS DURING RING MOVEMENT.

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

FREQUENCY (HZ)	SPECTRAL 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 INTERCONNECTING MECHANISM 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 DOCKINGS. A TOTAL OF 20 DOCKINGS IS PERFORMED. BALLSCREW INTERCONNECTING MECHANISM OPERATION VERIFIED BY EXTENSION OF DOCKING RING TO INITIAL POSITION AND ABSORPTION OF ENERGY OF RELATIVE MOVEMENT DURING EACH DOCKING. 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 INTERCONNECTING MECHANISM 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 INTERCONNECTING MECHANISMS VERIFIED DURING 100 DOCKING AND UNMATING CYCLES (FOR MCG21-0087-1001/-3001 UNITS ONLY). FOR MCG21-0087-2001, -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, RETRACTION, AND ALIGNMENT. 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 INTERCONNECTING MECHANISM 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 FAILED BALLSCREW INTERCONNECTING MECHANISM WOULD BE DETECTED.

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## FAILURE MODES EFFECTS ANALYSIS (FMEA) - CIL FAILURE MODE

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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*	---	---	---	+80+/-5	---	YES
4	0.10	4°	0°	+50+/-5	27	YES
5*	---	---	---	-(80+/-5)	---	YES
5	0.10	4°	0°	-(30+/-5)	27	YES
6*	---	---	---	+80+/-5	---	YES
6	0.12	0°	4°	+50+/-5	23	YES
7*	---	---	---	-(80+/-5)	---	YES
7	0.10	0°	4°	-(30 +/-5)	23	YES
8*	---	---	---	+80+/-5	---	YES
8	0.12	4°	4°	50 +/-5	34	YES
9*	---	---	---	-(80+/-5)	---	YES
9	0.12	4°	4°	-(30 +/-5)	34	YES
10*	---	---	---	+80+/-5	---	YES
10	0.10	4°	0°	+50+/-5	27	YES
11*	---	---	---	-(80+/-5)	---	YES
11	0.10	0°	4°	-(30 +/-5)	27	YES
12*	---	---	---	+80+/-5	---	YES
12	0.10	0°	4°	+50+/-5	27	YES
13*	---	---	---	-(80+/-5)	---	YES
13	0.12	4°	4°	-(30 +/-5)	27	YES
14*	---	---	---	+80+/-5	---	YES
14	0.12	4°	4°	+50+/-5	27	YES
15*	---	---	---	+25+/-10	23	YES

\*M0821-0067-2001, -4001, &amp; -5001 ONLY

AFTER COMPLETION 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 INTERCONNECTING MECHANISM FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

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

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.



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**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, AND SOLDERING 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 INTERCONNECTING MECHANISM (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:**

CENTERING SPRING MECHANISM WILL LIMIT ROTATION OF ONE BALLSCREW, PROVIDING SOME RESTRAINT AGAINST RING COLLAPSE. HOWEVER, IF A BROKEN BALLSCREW INTERCONNECTING MECHANISM RESULTS IN A MOMENT BETWEEN BOTH VEHICLES, DURING DOCKING, CREW COULD OPEN CAPTURE LATCHES AND FIRE APPROPRIATE ORBITER RCS JETS TO PERFORM SEPARATION.

**- APPROVALS -**

DESIGN ENGINEER  
DESIGN MANAGER  
NASA SS/MA  
NASA SUBSYSTEM MANAGER

M. NIKOLAYEVA  
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*[Handwritten signatures and initials over approval lines]*



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