FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE
NUMBER: M8-1MR-SM007-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

PART DATA

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 CONTOL, 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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SUBSYSTEM NAME: MECHANICAL - EDS
LRU: GUIDE RING ASSEMBLY
ITEM NAME: MECHANISM, BALLSCREW INTERCONNECTING

CRITICALITY OF THIS FAILURE MODE: 2/2

FAILURE MODE:
JAMMING, INCREASED RESISTANCE

MISSION PHASE:
OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

CAUSE:
MATERIAL DEFECT, MANUFACTURE DEFECT, EXCESSIVE EXTERNAL LOADS, 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:
THE CORRESPONDING DOCKING RING INDICATORS ON THE DOCKING CONTROL PANEL WILL ILLUMINATE TO INDICATE RING POSITION AND ALIGNMENT. ANALYSIS OF TELEMETRY DATA, ASSOCIATED WITH MOVEMENT OF THE RING (BALLSCREW MISALIGNMENT), TO EVALUATE A DIFFICULTY IN CAPTURING MAY IDENTIFY A FAULT WITHIN THE INTERCONNECTING MECHANISM AS THE CAUSE.

- FAILURE EFFECTS -

(A) SUBSYSTEM:
LITTLE OR NO MOVEMENT OF BOTH RODS OF ONE BALLSCREW PAIR. AT THE STAGE OF DOCKING, EXTERNAL FORCES COULD OVERCOME AN INCREASED MOMENT OF RESISTANCE IN WHICH CASE BALLSCREW INTERCONNECTING MECHANISM WILL FUNCTION PROPERLY. IN THE EVENT OF COMPLETE JAMMING, POTENTIAL EXISTS FOR FAILURE OF ORBITER DOCKING MECHANISM TO CAPTURE THE MIR DOCKING

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MECHANISM. NO EFFECT ON RING RETRACTION AND MATING OF THE DOCKING MECHANISMS IF FAILURE OCCURS AFTER CAPTURE.

(B) INTERFACING SUBSYSTEM(S):
NO EFFECT ON INTERFACING ORBITER SUBSYSTEMS.

(C) MISSION:
WORST CASE, INABILITY TO CAPTURE DUE TO JAMMING OF A SINGLE BALLSCREW INTERCONNECTING MECHANISM, RESULTING IN THE LOSS OF DOCKING CAPABILITIES. LOSS OF ORBITER/MIR MISSION OBJECTIVES WITH FAILURE TO PERFORM DOCKING.

(D) CREW, VEHICLE, AND ELEMENT(S):
NO EFFECT ON CREW OR VEHICLE.

(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:
JAMMING OF THE 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 HAVING A SAFETY FACTOR > 1.4); 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; THE ENTIRE BALLSCREW INTERCONNECT MECHANISM IS ENCASED TO REDUCE THE PROBABILITY OF JAMMING DUE TO CONTAMINATION; 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 $0.04G^2/HZ$
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.

2. DOCKING MECHANISM CHECKOUT (STATIC) TEST - AFTER CAPTURE SETTLING FORCES OF THE DOCKING RING ARE MEASURED FOLLOWING

APPLICATION OF VARIOUS LOAD FORCES. A JAMMED INTERCONNECTING MECHANISM COULD BE DETECTED AT THIS TIME.

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 DURING DOCKING FOR A TEMPERATURE RANGE OF -50°C/-55°C TO 50°C/55°C.

4. CONTROLLED DOCKING TEST - CONTROLLED DOCKING IS PERFORMED UNDER LOAD CONDITIONS. PROPER RING PERFORMANCE WILL VERIFY PROPER BALLSCREW INTERCONNECTING MECHANISM OPERATIONS.

DOCKING MECHANISM QUALIFICATION TESTS:

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 JAMMED BALLSCREW INTERCONNECTING MECHANISM 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 JAMMED BALLSCREW INTERCONNECTING MECHANISM WOULD BE DETECTED.

3. 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

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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 JAMMED BALLSCREW INTERCONNECTING MECHANISM 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°	60 +/-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

*MC621-0067-2001, -4001, & -5001 ONLY

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

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. A JAMMED BALLSCREW INTERCONNECTING MECHANISM WOULD BE DETECTED AT THIS TIME.

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

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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 JAMMED BALLSCREW INTERCONNECTING MECHANISM. SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE.

6. TARGET SERVICE LIFE TEST - TESTS ARE PERFORMED TO VERIFY PROPER DOCKING OPERATIONS OVER ITS LIFE OF 100 DOCKINGS. PROPER OPERATION OF THE BALLSCREW INTERCONNECTING MECHANISMS 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.

7. CONTROL DISASSEMBLY - UPON COMPLETION OF ALL QUAL TESTING THE DOCKING MECHANISM IS DISMANTLED AND BALLSCREW INTERCONNECTING MECHANISMS 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.

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.

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(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:
AN INCREASE IN RESISTANCE CAN BE OVERCOME WITH EXTERNAL FORCES. HOWEVER THERE IS NO WORKAROUND TO A COMPLETE JAMMING OF A BALLSCREW INTERCONNECTING MECHANISM.

- APPROVALS -

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DESIGN MANAGER	A. SOUBCHEV	
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