FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE
NUMBER: M8-1MR-BM008-X

SUBSYSTEM NAME: MECHANICAL - EDS

REVISION: 1 9/1/95

		PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	:	MECH. GUIDE RING BALLSCREW	33U.6365.011-05
		NPO-ENERGIA	33U.6365.011-05
SRU	:	FIXER	33Y.6662.003
		NPO-ENERGIA	33Y.6662.003

PART DATA

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

REFERENCE DESIGNATORS:

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

FUNCTION:
CONTAINED WITHIN EACH BALLSCREW INTERCONNECTING MECHANISM, THE FIXER LOCKS OR UNLOCKS BOTH RODS OF A SINGLE BALLSCREW PAIR. WHEN POWER IS APPLIED TO THE FIXER, A MAGNETIC FIELD IS CREATED THAT EXTENDS A LEVER TO ENGAGE A GEAR WHICH MECHANICALLY LOCKS BOTH BALLSCREW RODS OF A SINGLE PAIR BY LIMITING THEIR ROTATION. THIS ACTION PREVENTS ROLL AND TRANSLATION MOVEMENT OF THE DOCKING RING AT ONE OF THREE POINTS AROUND THE RING. WHEN POWER IS REMOVED FROM THE WINDINGS OF THE FIXER, A SPRING RETRACTS THE LEVER (THAT LOCKS THE MECHANICAL GEAR LINK BETWEEN THE RODS) AND ALLOWS BOTH RODS OF THE BALLSCREW PAIR TO ROTATE.

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

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

REFERENCE DOCUMENTS: 33U.6365.011-05
33U.6662.003

FAILURE MODES EFFECTS ANALYSIS (FMEA) – CIL FAILURE MODE
NUMBER: M8-1MR-BM008- 02

REVISION# 1 9/1/95

SUBSYSTEM NAME: MECHANICAL - EDS
LRU: BALLSCREW INTERCONNECTING MECHANISM CRITICALITY OF THIS
ITEM NAME: FIXER, RING FAILURE MODE: 2/2

FAILURE MODE:
FAILS TO UNLOCK

MISSION PHASE:
OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

CAUSE:
MULTIPLE SPRING FAILURES DUE TO MECHANICAL/THERMAL SHOCK OR MANUFACTURE/MATERIAL DEFECT, JAMMED ROD DUE TO 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 PRIOR TO CAPTURE. ANALYSIS OF TELEMETRY DATA TO EVALUATE A FAILURE TO CAPTURE MAY IDENTIFY A LOCKED FIXER AS THE CAUSE. SENSORS WILL MONITOR POWER TO ALL FIXERS AND PROVIDE THE INFORMATION FOR GROUND MONITORING THROUGH TELEMETRY DATA.

- FAILURE EFFECTS -

(A) SUBSYSTEM:
AFFECTED RODS OF ONE BALLSCREW PAIR ARE NOT PERMITTED TO ROTATE FREELY. ROLL AND TRANSLATION MOVEMENT IS RESTRICTED AT ONE POINT ON THE DOCKING RING. CAPTURE CAPABILITIES ARE IMPEDED SIGNIFICANTLY UPON A FAILURE TO UNLOCK A SINGLE FIXER PRIOR TO CAPTURE. NO EFFECT ON MATING OF THE TWO DOCKING MECHANISMS IF FAILURE OCCURS AFTER RING RETRACTION FOLLOWING CAPTURE.

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(B) INTERFACING SUBSYSTEM(S):
EXCESSIVE LOADS INCURRED DURING DOCKING, AS THE RESULT OF A SINGLE RING FIXER BEING LOCKED PRIOR CAPTURE, COULD PROPAGATE TO EXTERNAL AIRLOCK AND ORBITER STRUCTURE.

(C) MISSION:
WORST CASE, A SINGLE RING FIXER FAILS TO UNLOCK FOLLOWING RING EXTENSION TO THE INITIAL POSITION. SINCE A MECHANICAL FAILURE OF THE FIXER IS NOT DETECTABLE, DOCKING WITH A LOCKED RING FIXER COULD RESULT IN EXCESSIVE LOADS. THESE LOADS COULD PREVENT CAPTURE RESULTING IN LOSS OF DOCKING AND SUBSEQUENT LOSS OF MISSION OBJECTIVES.

(D) CREW, VEHICLE, AND ELEMENT(S):
NO EFFECT ON CREW AND ORBITER STRUCTURE. HOWEVER, EXCESSIVE LOADS COULD CAUSE DAMAGE TO BOTH ORBITER AND MIR DOCKING MECHANISMS.

(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:
THE BALLSCREW INTERCONNECTING MECHANISM FIXERS CONTROL ROLL AND TRANSLATION MOVEMENT OF THE RING ONLY. COIL SPRING IS PRELOADED TO 18 KG TO ALLOW FIXER TO UNLOCK ONCE POWER IS REMOVED. THREE OR MORE BREAKS IN THE COIL ARE REQUIRED BEFORE TOTAL FAILURE OF THE SPRING OCCURS. FIXER IS NORMALLY IN UNLOCKED POSITION. A RING FIXER FAILING TO UNLOCK CAN OCCUR MECHANICALLY DURING RING MOVEMENT TO IT'S INITIAL POSITION PRIOR TO CAPTURE. FIXERS ARE LOCKED WHENEVER THE RING IS MOVED.

LOAD ANALYSIS HAS SHOWN THAT THE MAXIMUM MOMENT IN THE Z DIRECTION AND A MAXIMUM LOAD IN THE X DIRECTION IS EXCEEDED GIVEN A SINGLE RING FIXER IS LOCKED PRIOR TO CAPTURE. HOWEVER THIS LOAD AND MOMENT WOULD NOT EXCEED THE LIMITS ON THE EXTERNAL AIRLOCK OR ORBITER STRUCTURE. IN TWO OF THE FIFTEEN DOCKING CASES MODELED, THE RING DID NOT CAPTURE GIVEN A SINGLE LOCKED RING FIXER PRIOR TO CAPTURE.

(B) TEST:
DOCKING MECHANISM ACCEPTANCE TESTS:

1. DOCKING MECHANISM CHECKOUT (STATIC) TEST - RING IS EXTENDED AND RETRACTED AS NECESSARY TO FULLY TEST ITS OPERATION DURING A SINGLE DOCKING. FIXERS ARE TURNED OFF WHEN THE RING REACHES IT'S INITIAL POSITION AND A FORCE IS APPLIED TO THE RING TO SIMULATE LOADS THAT CAN OCCUR DURING RING CAPTURE AND MATING OF THE TWO MECHANISMS. THIS TEST WILL VERIFY THAT THE FIXERS ARE NOT LOCKED UNDER LOAD CONDITIONS.

2. 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). A LOCKED FIXER WOULD BE DETECTED AT TIME OF CAPTURE.

3. 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.

4. CONTROLLED DOCKING TEST - CONTROLLED DOCKING IS PERFORMED UNDER LOAD CONDITIONS. THIS TESTS WILL DETECT A LOCKED FIXER DURING THE CAPTURE PROCESS.

DOCKING MECHANISM QUALIFICATION TESTS:

1. OPERATIONAL CAPABILITY TEST - FIXER OPERATION VERIFIED BY THE ULTIMATE TRANSLATIONAL LOAD TEST. WITH RING IN ITS INITIAL POSITION FIXERS ARE TURNED OFF AND A 700 KGF LOAD IS APPLIED PARALLEL TO THE SEAL INTERFACE. A LOCKED FIXER WOULD BE DETECTED AT THIS TIME. THE SYSTEM IS THEN INSPECTED FOR EVIDENCE OF DAMAGE OR DEGRADATION.

2. 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, AS DEFINED IN QTP TEST #1 ABOVE, IS PERFORMED. A LOCKED FIXER WOULD BE DETECTED AT THIS TIME.

3. 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 TEST #1 ABOVE, IS PERFORMED. A LOCKED FIXER WOULD BE DETECTED AT THIS TIME.

4. VIBRATION STRENGTH TEST - APDS SUBJECTED TO THE FOLLOWING VIBRATION LEVELS IN EACH AXIS FOR A 400 SECOND DURATION.SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TEST #1 ABOVE, IS PERFORMED. A LOCKED FIXER WOULD BE DETECTED AT THIS TIME.

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 $0.067G^2/HZ$

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. A LOCKED FIXER WOULD BE DETECTED DURING ABSORPTION OF ENERGY OF RELATIVE MOVEMENT ASSOCIATED WITH 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 TEST #1 ABOVE, IS PERFORMED. A LOCKED FIXER WOULD BE DETECTED AT THIS TIME.

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 FIXERS VERIFIED DURING 100 DOCKING AND UNMATING CYCLES (FOR MC621-0067-1001/-3001 UNITS ONLY). FOR MC621-0067-2001, -4001, & -5001 UNITS PROPER OPERATION VERIFIED DURING 388 CYCLES (44 VACUUM/LOAD CYCLES, 16 LOAD CYCLES, & 324 NO-LOAD CYCLES). A LOCKED FIXER WOULD BE DETECTED DURING CAPTURE. SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TEST #1 ABOVE, IS PERFORMED. A LOCKED FIXER WOULD BE DETECTED AT THIS TIME.

7. COLD AND HEAT RESISTANCE 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. FIVE CYCLES WERE PERFORMED AGAINST THE GUIDE RING EXTEND AND FINAL POSITION MECHANICAL STOPS FOR 10 SECONDS EACH. DOCKING PARAMETERS ARE SHOWN IN THE FOLLOWING TABLE.

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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*	—	—	—	+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

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

AFTER COMPLETION AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TEST #1 ABOVE, IS PERFORMED. A LOCKED FIXER WOULD BE DETECTED AT THIS TIME.

8. CONTROL DISASSEMBLY - UPON COMPLETION OF ALL QUAL TESTING THE DOCKING MECHANISM IS DISMANTLED AND ALL FIXER OPERATING SURFACES 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.

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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, SOLDERING, CHEMICAL PLATING, 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	
DESIGN MANAGER	A. SOUBCHEV	
NASA SS/MA		
NASA SUBSYSTEM MANAGER		