FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE
NUMBER: M8-1MR-SM011-X

SUBSYSTEM NAME: MECHANICAL - EDS
REVISION: 1 9/1/95

		PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	:	DIFFERENTIAL ASSEMBLY	33U.6321.004
		NPO-ENERGIA	33U.6321.004
SRU	:	ACTUATOR, EXTEND/RETRACT	33U.6121.035
		NPO-ENERGIA	33U.6121.035

PART DATA

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
EXTEND/RETRACT ACTUATOR

REFERENCE DESIGNATORS:

QUANTITY OF LIKE ITEMS: 1
ONE

FUNCTION:
PROVIDES THE ENERGY NECESSARY TO EXTEND AND RETRACT THE ORBITER DOCKING RING. CONTAINED IN THE ACTUATOR IS A FRICTIONAL BRAKE. THE FRICTIONAL BRAKE IS LOCATED ON THE SHAFT OF THE EXTEND/RETRACT ACTUATOR AND LIMITS DOCKING LOADS AND DISSIPATES ENERGY. DURING MATING WHEN LOADS ON THE ACTUATOR ARMATURE ARE HIGH, THE BRAKE ABSORBS THE AXIAL KINETIC ENERGY ASSOCIATED WITH THE RELATIVE CLOSING VELOCITY BY SLIPPING. BRAKE SLIPPAGE ALSO OCCURS DURING RING RETRACTION WHEN THE RING HAS BOTTOMED OUT.

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

MAINTAINABILITY
REPAIR METHOD - REPLACEMENT.

REFERENCE DOCUMENTS: 33U.6121.035
33U.6321.004
33U.6321.038-05

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: M8-1MR-BM011-02

REVISION# 1 9/1/96

SUBSYSTEM NAME: MECHANICAL - EDS
LRU: DIFFERENTIAL ASSEMBLY
ITEM NAME: ACTUATOR, EXTEND/RETRACT

CRITICALITY OF THIS FAILURE MODE: 2/2

FAILURE MODE:
FAILS TO TRANSFER TORQUE LOADS

MISSION PHASE:
OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

CAUSE:
ACTUATOR FAILURE - GEAR/SHAFT/KEY FAILURE BETWEEN NO-BACK & DIFFERENTIAL DUE TO MECHANICAL/THERMAL SHOCK, MANUFACTURE/MATERIAL DEFECT, OR STRESS CORROSION

LOW SLIP FORCE ON FRICTIONAL BRAKE - SHAFT/MULTIPLE RING FAILURES DUE TO MECHANICAL/ THERMAL SHOCK OR MANUFACTURE/MATERIAL DEFECT, EXCESSIVE LOADS, MULTIPLE BROKEN SPRINGS, LOOSE SHAFT NUT, OIL 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:
VISUAL OBSERVATION - RING FAILS TO EXTEND OR RETRACT. INSTRUMENTATION - APPROPRIATE INDICATORS ON THE DOCKING CONTROL PANEL WILL INDICATE POSITION OF RING AT TIME OF FAILURE. WITH ACTUATOR DISCONNECTED FROM THE KINEMATIC CHAIN THE ORBITER DOCKING RING CAN BE MANUALLY RETRACTED BY PUSHING ON THE RING.

FAILURE MODES EFFECTS ANALYSIS (FMEA) – CIL FAILURE MODE
NUMBER: M8-1MR-BM011-02

- FAILURE EFFECTS -

(A) SUBSYSTEM:
EXTEND/RETRACT ACTUATOR IS DISCONNECTED FROM THE REMAINING ELEMENTS IN THE KINEMATIC CHAIN. INABILITY OF DOCKING MECHANISM TO SUSTAIN A LOAD RESULTING IN A COLLAPSE OF THE DOCKING RING DURING CAPTURE. DOCKING LOADS ARE EXCESSIVE GIVEN THIS FAILURE. DAMAGE TO EXTEND/RETRACT ACTUATOR AS THE RESULT OF THESE EXCESSIVE LOADS COULD RESULT IN LOSS OF CAPABILITY TO EXTEND OR RETRACT THE RING TO COMPLETE DOCKING.

(B) INTERFACING SUBSYSTEM(S):
EXCESSIVE LOADS INCURRED DURING DOCKING AS THE RESULT OF THE EXTEND/ RETRACT ACTUATOR FAILING TO TRANSFER TORQUE LOADS COULD PROPAGATE TO EXTERNAL AIRLOCK AND ORBITER STRUCTURE.

(C) MISSION:
DOCKING BETWEEN ORBITER AND MIR IS IMPOSSIBLE IF RING CANNOT BE EXTENDED OR RETRACTED. EXTENSIVE DAMAGE TO EITHER DOCKING MECHANISM AS THE RESULT OF THIS FAILURE COULD FURTHER IMPEDE THE DOCKING PROCESS. WORST CASE, LOSS OF ORBITER/MIR MISSION OBJECTIVES.

(D) CREW, VEHICLE, AND ELEMENT(S):
THE INABILITY OF THE DOCKING RING TO SUSTAIN LOADS AS THE RESULT OF THIS FAILURE COULD ALLOW THE RING TO COLLAPSE DURING CAPTURE, POTENTIALLY CAUSING EXTENSIVE DAMAGE TO 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:
STRUCTURAL FAILURE OF EXTEND/RETRACT ACTUATOR ARMATURE/SHAFT IS CONSIDERED VERY REMOTE. FRICTIONAL BRAKE IS MADE UP OF TWENTY SOLID RINGS. EACH RING IS MADE OF STEEL WITH A THICKNESS OF 1.5 MM AND IMPREGNATED WITH A SUBSTANCE THAT PROVIDES HIGH FRICTION. TEN RINGS ARE ATTACHED TO THE HOUSING WHICH IS MOUNTED TO THE SHAFT THAT DRIVES THE KINEMATIC CHAIN AND TEN ARE ATTACHED TO THE ARMATURE OF THE ACTUATOR. THESE RINGS ARE POSITIONED SIDE BY SIDE WITH EVERY OTHER RING ATTACHED TO THE SAME POINT (KINEMATIC SHAFT AND ACTUATOR ARMATURE). SIX SPRINGS FORCE THESE RINGS TOGETHER TO PROVIDE MAXIMUM FRICTION BETWEEN THEM. A SINGLE NUT IS SAFETY WIRED AT THE END OF THE ARMATURE TO HOLD ALL SIX COMPRESSED SPRINGS INTO PLACE.

LOAD ANALYSIS HAS SHOWN THAT THE MAXIMUM AXIAL TENSION LOAD INCURRED AS THE RESULT OF THE EXTEND/RETRACT ACTUATOR FAILING TO TRANSFER TORQUE LOADS (BROKEN CLUTCH/BRAKE) DURING CAPTURE IS 3559 KGF ALONG THE Z-AXIS WHICH IS NOT HIGH ENOUGH TO CAUSE A CAPTURE LATCH TO DISENGAGE. (ANALYSIS

HAS SHOWN THAT AN AXIAL LOAD OF 3698 KGF IS REQUIRED TO DISENGAGE A CAPTURE LATCH.) STRESS ANALYSIS HAS INDICATED THAT THE CAPTURE LATCH WILL NOT BE DAMAGED IN SUCH A WAY AS TO TO PREVENT IT FROM BEING ACTUATED OPEN DUE TO THIS 3559 KGF TENSION AXIAL LOAD. THIS AXIAL LOAD WILL NOT EXCEED EXTERNAL AIRLOCK /ORBITER STRUCTURAL LIMITS.

(B) TEST:
THE FRICTIONAL BRAKE IS PART OF THE EXTEND/RETRACT ACTUATOR DRIVE CHAIN. SINCE THIS FAILURE MODE WOULD CREATE A BREAK IN THAT DRIVE CHAIN, VERIFICATION OF PROPER FRICTIONAL BRAKE AND ACTUATOR OPERATION (IN RESPECT TO THIS FAILURE MODE) IS PROVIDED BY THE FOLLOWING ACCEPTANCE AND QUAL TESTING OF THE ACTUATOR:

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. EXTEND/RETRACT ACTUATOR IS VERIFIED FOR PROPER OPERATION DURING RING EXTENSION AND RETRACTION.

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. 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 EXTEND/RETRACT ACTUATOR UNDER LOAD AND NO-LOAD CONDITIONS.

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 AND A FUNCTIONAL CHECK IS PERFORMED, PER ATP #1 ABOVE, TO VERIFY PROPER OPERATION OF THE EXTEND/RETRACT ACTUATOR.

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 EXT/RET ACTUATOR 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 UNDER LOAD CONDITIONS AND WILL 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 EXTEND/RETRACT ACTUATOR.

DOCKING MECHANISM QUALIFICATION TESTS:

1. OPERATIONAL CAPABILITY TEST - EXTEND/RETRACT ACTUATOR 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 TESTS #1 ABOVE, IS PERFORMED TO VERIFY PROPER EXTEND/RETRACT ACTUATOR 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 TESTS #1 ABOVE, IS PERFORMED TO VERIFY PROPER EXTEND/RETRACT ACTUATOR 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, AS DEFINED IN QTP TESTS #1 ABOVE, IS PERFORMED TO VERIFY PROPER EXTEND/RETRACT ACTUATOR OPERATIONS DURING RING MOVEMENT.

5. 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 EXTEND/RETRACT ACTUATOR 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

*MC821-0087-2001, -4001, & -5001 ONLY

AFTER COMPLETION AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE AND AN OPERATIONAL CAPABILITY TEST, AS DEFINED IN OTP TESTS #1 ABOVE, IS PERFORMED TO VERIFY PROPER FUNCTIONING OF EXTEND/RETRACT ACTUATOR DURING RING MOVEMENT AND DOCKING OPERATIONS.

6. 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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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. CREW WOULD OPEN CAPTURE LATCHES AND FIRE ORBITER RCS JETS TO ENABLE SEPARATION.

- APPROVALS -

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