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**FAILURE MODES EFFECTS ANALYSIS (FMEA) - CRITICAL HARDWARE  
NUMBER: M8-1MR-5M011-X**

SUBSYSTEM NAME: MECHANICAL - EDS

REVISION: 1 9/1/95

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

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**PART DATA**


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**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 CONTROL, DOCKING WITH CALIBRATING DOCKING MECHANISM.

**MAINTAINABILITY**

REPAIR METHOD - REPLACEMENT.

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



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

NUMBER: M8-1MR-BM011-01

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:**

LOSS OF ROTATION

**MISSION PHASE:**

OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

**CAUSE:**GEAR/SHAFT FAILURE DUE TO MECHANICAL/THERMAL SHOCK OR  
MANUFACTURE/MATERIAL DEFECT, DUAL MOTOR/CLUTCH FAILURE, JAMMING,  
FRICTIONAL BRAKE FAILURE

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/AB)  
N/AC)  
N/A**METHOD OF FAULT DETECTION:**VISUAL OBSERVATION - RING FAILS TO EXTEND/RETRACT OR EXTENDS & RETRACTS  
SLOWLY. APPROPRIATE INDICATORS ON THE DOCKING CONTROL PANEL WILL  
INDICATE POSITION OF RING AT TIME OF FAILURE. TELEMETRY SENSORS MONITOR  
POWER TO THE ACTUATOR MOTORS.**- FAILURE EFFECTS -****(A) SUBSYSTEM:**SINGLE MOTOR, CLUTCH, OR DRIVE CHAIN FAILURE WILL RESULT IN AN INCREASED  
OPERATING TIME OF THE ACTUATOR WITH RING MOVEMENT TAKING TWICE AS LONG  
TO COMPLETE. WORST CASE, FAILURE OF ENTIRE ACTUATOR WILL RESULT IN LOSS  
OF MOVEMENT IN THE KINEMATIC CHAIN. COMPLETE ACTUATOR FAILURE WILL LOSE  
ALL FUNCTIONS ASSOCIATED WITH RING EXTENSION/RETRACTION - LOSS OF**Proprietary Data**

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

NUMBER: M8-1MR-BM011-01

CAPABILITY TO CAPTURE (EXTENSION) AND INABILITY TO MATE ORBITER DOCKING MECHANISM WITH MIR DOCKING MECHANISM (RETRACTION).

**(B) INTERFACING SUBSYSTEM(S):**

NO EFFECT ON INTERFACING ORBITER SUBSYSTEMS.

**(C) MISSION:**

WORST CASE, DOCKING BETWEEN ORBITER AND MIR IS IMPOSSIBLE IF EXTEND/RETRACT ACTUATOR FAILS TO ROTATE RESULTING IN LOSS OF ORBITER/MIR MISSION OBJECTIVES.

**(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.)

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

ACTUATOR DESIGN PROVIDES FOR DUAL MOTOR CONTROL, EITHER OF WHICH IS SUFFICIENT TO EXTEND OR RETRACT THE DOCKING RING. REDUNDANT POWER IS SUPPLIED TO THESE MOTORS. TWO CLUTCHES AND A NO-BACK DEVICE PROVIDE ISOLATION BETWEEN EACH MOTOR/GEAR CHAIN AND THE OUTPUT OF THE ACTUATOR. A FAILURE OF THE ACTUATOR SHAFT OR FRICTIONAL BRAKE IS CONSIDERED VERY REMOTE.

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

1. ELECTRICAL SCHEMATIC CHECKOUT - CONTACT RESISTANCE ON EACH PIN OF THE CONNECTOR WHICH IS ELECTRICALLY TIED TO EACH EXTEND/RETRACT ACTUATOR MOTOR IS CHECKED. THIS TEST VERIFIES CONTINUITY THROUGH THE ACTUATOR MOTOR WINDINGS.
2. INSULATION ELECTRICAL RESISTANCE TEST - THE INSULATION RESISTANCE AND ELECTRICAL STRENGTH OF INSULATION CHECKOUT OF EACH PIN OF EACH EXTEND/RETRACT ACTUATOR CONNECTOR TO THE APDA HOUSING WILL VERIFY THAT THE EXTEND/RETRACT ACTUATOR MOTOR WINDINGS ARE NOT ELECTRICALLY SHORTED TO GROUND.
3. INSPECTION SERVICEABILITY TEST - DURING THE GUIDE RING FUNCTIONAL PERFORMANCE TEST THE DOCKING MECHANISM RING IS EXTENDED TO ITS INITIAL POSITION AND THEN ITS FORWARD POSITION AND THEN RETRACTED TO ITS FINAL POSITION. EXTEND/RETRACT ACTUATOR IS VERIFIED FOR PROPER OPERATION DURING RING EXTENSION AND RETRACTION.
4. VIBRORESISTENT TEST - APDS SUBJECTED TO THE FOLLOWING VIBRATION LEVELS FOR 2 MINUTES PER AXIS:



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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; AND AN ELECTRICAL CIRCUIT TEST, AN INSULATION RESISTANCE TEST, AND FUNCTIONAL CHECK ARE PERFORMED, PER ATP'S #1, #2, & #3 ABOVE, TO VERIFY PROPER OPERATION OF THE EXTEND/RETRACT ACTUATOR.

5. 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.

6. 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<sup>-4</sup> TO 10<sup>-5</sup> 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.

7. CONTROLLED DOCKING TEST - CONTROLLED DOCKING IS PERFORMED UNDER LOAD CONDITIONS AND WILL VERIFY PROPER RETRACTION OF THE DOCKING MECHANISM. A FULL 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. ELECTRICAL CIRCUIT TEST - CONTACT RESISTANCE ON EACH PIN OF THE CONNECTOR WHICH IS ELECTRICALLY TIED TO EACH EXTEND/RETRACT ACTUATOR MOTOR IS CHECKED. THIS TEST VERIFIES CONTINUITY THROUGH THE ACTUATOR MOTOR WINDINGS.
2. INSULATION ELECTRICAL RESISTANCE TEST - THE INSULATION RESISTANCE AND ELECTRICAL STRENGTH OF INSULATION CHECKOUT OF EACH PIN OF EACH EXTEND/RETRACT ACTUATOR CONNECTOR TO THE APDA HOUSING WILL VERIFY THAT THE EXTEND/RETRACT ACTUATOR MOTOR WINDINGS ARE NOT ELECTRICALLY SHORTED TO GROUND.
3. OPERATIONAL CAPABILITY TEST - EXTEND/RETRACT ACTUATOR MOVEMENT VERIFIED BY RING EXTENSION AND RETRACTION FROM THE END POSITION TO

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THE INITIAL POSITION THEN TO THE FORWARD POSITION AND FROM THE FORWARD POSITION TO THE END POSITION.

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 ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, ARE PERFORMED TO VERIFY PROPER EXTEND/RETRACT ACTUATOR OPERATIONS DURING RING MOVEMENT.

5. 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 SHOWN BELOW.

VIBRATION ACCELER DIRECTION	VIBRATION ACCELER AMPLITUDE	FREQUENCY SUBBAND, HZ					TOTAL TEST DURATION	
		5-7	7-15	15-30	30-40	40-80	HR	MIN
		TEST DURATION, MIN						
ALONG X-AXIS	1.4	--	4	--	--	--	--	4
	1.2	75	93	32	61	38	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 ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, ARE PERFORMED TO VERIFY PROPER EXTEND/RETRACT ACTUATOR OPERATIONS DURING RING MOVEMENT.

6. 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 <sup>2</sup> /HZ
FROM 80 TO 350	CONSTANT 0.067G <sup>2</sup> /HZ
FROM 350 TO 2000	DECREASING 3DB OCTAVE WITH 0.067G <sup>2</sup> /HZ

SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, ARE PERFORMED TO VERIFY PROPER EXTEND/RETRACT ACTUATOR OPERATIONS DURING RING MOVEMENT.

7. 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. EXTEND/RETRACT ACTUATOR MOVEMENT VERIFIED BY EXTENSION OF



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DOCKING RING TO INITIAL POSITION AND ABSORPTION OF ENERGY OF RELATIVE MOVEMENT DURING EACH DOCKING WILL DETECT A FAILED EXTEND/RETRACT ACTUATOR. SUBSEQUENT TO THIS TEST AN ENGINEERING INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST ARE PERFORMED, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, TO VERIFY PROPER EXTEND/RETRACT ACTUATOR FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

B. COLD AND HEAT RESISTANCE TEST - DOCKING OF THE MECHANISM IS THERMALLY CYCLED FROM +20°C TO -50/-55°C TO +50/+65°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 +/-6)	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

\*MC821-0087-2001, -4001, &amp; -5001 ONLY

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AFTER COMPLETION AN INSPECTION IS PERFORMED TO IDENTIFY BROKEN OR LOOSE HARDWARE; AND AN ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, ARE PERFORMED TO VERIFY PROPER EXTEND/RETRACT ACTUATOR FUNCTIONING DURING RING MOVEMENT.

9. TARGET SERVICE LIFE TEST - TESTS ARE PERFORMED TO VERIFY PROPER DOCKING AND UNDOCKING OPERATIONS OVER ITS LIFE OF 100 DOCKINGS. PROPER OPERATION OF THE EXTEND/RETRACT ACTUATOR 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 ELECTRICAL CIRCUIT CHECK TEST, INSULATION RESISTANCE TEST, AND OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP TESTS #1, #2, AND #3 ABOVE, ARE PERFORMED TO VERIFY PROPER EXTEND/RETRACT ACTUATOR FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

10. BACKUP UNDOCKING MEANS CHECK - PROPER OPERATION OF THE EXTEND/RETRACT ACTUATOR IS VERIFIED DURING COUPLING OF THE APDA ASSEMBLY WITH THE SIMULATOR.

11. CONTROL DISASSEMBLY - UPON COMPLETION OF ALL QUAL TESTING THE DOCKING MECHANISM IS DISMANTLED AND ALL EXTEND/RETRACT ACTUATOR 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.

**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.



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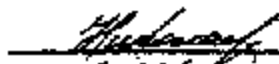
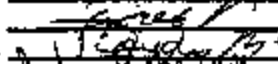
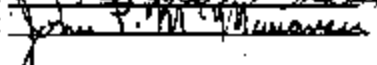

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**HANDLING/PACKAGING**  
HANDLING/PACKAGING PROCEDURES AND REQUIREMENT FOR SHIPMENT VERIFIED BY INSPECTION.

**(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:**  
NO WORKAROUND TO RESTORE A FAILED EXTEND/RETRACT ACTUATOR. CREW WOULD OPEN CAPTURE LATCHES AND FIRE ORBITER RCS JETS TO ENABLE SEPARATION.

**- APPROVALS -**

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



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