FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE
NUMBER: M8-1MR-BM010-X

SUBSYSTEM NAME: MECHANICAL - EDS

REVISION: 1 9/1/95

| | | PART NAME<br>VENDOR NAME | PART NUMBER<br>VENDOR NUMBER |
|---|---|---|---|
| LRU | : | DOCKING MECHANISM ASSEMBLY | 33U.6316.003-05 |
| | | NPO-ENERGIA | 33U.6316.003-05 |
| SRU | : | ASSEMBLY, DIFFERENTIAL | 33U.6321.004 |
| | | NPO-ENERGIA | 33U.6321.004 |

PART DATA

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**
DIFFERENTIAL ASSEMBLY

**REFERENCE DESIGNATORS:**

**QUANTITY OF LIKE ITEMS: 1**
ONE

**FUNCTION:**
THE DIFFERENTIAL ASSEMBLY IS THE PRIMARY COMPONENT IN THE KINEMATIC CHAIN AND PERFORMS THE FOLLOWING FUNCTIONS: (1) ENSURES DEPENDENT MOVEMENT OF EACH BALLNUT PAIR; (2) LOCKS BALLNUT PAIRS TO LIMIT THEIR MOVEMENT RELATIVE TO EACH OTHER (FIXATOR); (3) ENABLES EXTENSION AND RETRACTION OF THE DOCKING RING BY THE EXTEND/RETRACT ACTUATOR; (4) PROVIDES FORCED SUMMED INPUTS TO THE FRICTIONAL BRAKE; AND (5) PROVIDES CENTERING OF RING IN PITCH AND YAW DIRECTIONS (SPRING MECHANISMS). CONTAINED IN THE DIFFERENTIAL ASSEMBLY ARE THE "RING INITIAL POSITION" SENSOR AND "RING FORWARD POSITION" SENSOR. EACH IS DESCRIBED BELOW:

RING INITIAL POSITION SENSOR - ONCE THE DOCKING RING REACHES IT'S INITIAL POSITION, ABOUT 335 MM FROM ITS FULLY RETRACTED POSITION, A SENSOR DRIVEN FROM THE FINAL SUMMING GEAR STAGE OF THE DIFFERENTIAL ASSEMBLY SENDS REDUNDANT SIGNALS TO THE DSCU. THESE SIGNALS ARE USED TO AUTOMATICALLY TURN OFF THE EXTEND/RETRACT ACTUATOR AT THE POINT WHERE INITIAL POSITION OF THE RING IS ACHIEVED AND IS USED TO ILLUMINATE THE "RING INITIAL POSITION" INDICATOR LIGHT ON THE DOCKING CONTROL PANEL. RING INITIAL POSITION IS ALSO DOWNLINKED FOR GROUND CREW MONITORING.

RING FORWARD POSITION SENSOR - A SECOND SENSOR DRIVEN FROM THE FINAL SUMMING GEAR STAGE OF THE DIFFERENTIAL ASSEMBLY SENSES WHEN THE DOCKING RING IS FULLY EXTENDED AND SENDS REDUNDANT SIGNALS TO THE DSCU TO TURN OFF THE EXTEND/RETRACT ACTUATOR, CONTINUE AUTOMATIC DOCKING SEQUENCE (RETRACT RING), AND TO ILLUMINATE THE "RING FORWARD POSITION" INDICATOR LIGHT ON THE DOCKING CONTROL PANEL. RING FORWARD POSITION IS DOWNLINKED FOR GROUND MONITORING.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) – CRITICAL HARDWARE**
**NUMBER: M8-1MR-BM010-X**

**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.6321.004
33U.6916.003-05

FAILURE MODES EFFECTS ANALYSIS (FMEA) – CIL FAILURE MODE
NUMBER: M8-1MR-SM01D-02

REVISION# 1 9/1/95

SUBSYSTEM NAME: MECHANICAL - EDS
LRU: DOCKING MECHANISM ASSEMBLY
ITEM NAME: ASSEMBLY, DIFFERENTIAL

CRITICALITY OF THIS FAILURE MODE: 1R2

FAILURE MODE:
BROKEN

MISSION PHASE:
OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

CAUSE:
UNIVERSAL JOINT FAILURE, STRUCTURAL FAILURE DUE TO MECHANICAL/THERMAL SHOCK OR MANUFACTURE/MATERIAL DEFECT, BROKEN GEAR

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.

- FAILURE EFFECTS -

(A) SUBSYSTEM:
ELEMENTS OF THE KINEMATIC CHAIN ARE DISCONNECTED RESULTING IN THE INABILITY OF DOCKING MECHANISM TO SUSTAIN A LOAD. LOSS OF CAPABILITY TO EXTEND OR RETRACT DOCKING RING.

(B) INTERFACING SUBSYSTEM(S):
POTENTIAL DAMAGE TO ORBITER STRUCTURE IF ORBITER/MIR COLLIDE DUE TO THIS FAILURE AND WORKAROUND IS NOT IMPLEMENTED.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
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(C) MISSION:
LOSS OF ORBITER/MIR DOCKING CAPABILITIES FOLLOWING BREAK IN DIFFERENTIAL CHAIN. THE INABILITY TO DOCK WILL RESULT IN LOSS OF ORBITER/MIR MISSION OBJECTIVES.

(D) CREW, VEHICLE, AND ELEMENT(S):
A BROKEN DIFFERENTIAL WILL ALLOW THE DOCKING RING TO COLLAPSE DURING CAPTURE POTENTIALLY CAUSING 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 DIFFERENTIAL IS CONSIDERED VERY REMOTE. COMPONENTS OF THE DIFFERENTIAL CHAIN ARE MADE OF STAINLESS STEEL. SPRING MECHANISMS ARE USED TO REDUCE SPACING BETWEEN GEARS TO PREVENT TEETH BREAKAGE DURING PERIODS OF HIGH LOADS. THE DIFFERENTIAL IS ENCLOSED TO REDUCE THE POTENTIAL FOR STRUCTURAL IMPACT DAMAGE.

(B) TEST:
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. DIFFERENTIAL IS VERIFIED FOR PROPER OPERATION DURING RING EXTENSION AND RETRACTION.

2. 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 DIFFERENTIAL.

3. 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 DIFFERENTIAL UNDER LOAD AND NO-LOAD CONDITIONS.

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 DIFFERENTIAL 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. A PULL TEST OF ASSEMBLIES WITH THE DOCKING MECHANISM ASSEMBLY IS PERFORMED DURING THIS TEST. THESE TESTS WILL VERIFY PROPER OPERATION OF THE DIFFERENTIAL.

DOCKING MECHANISM QUALIFICATION TESTS:

1. OPERATIONAL CAPABILITY TEST - DIFFERENTIAL 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 | 78 | 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 DIFFERENTIAL OPERATIONS DURING RING MOVEMENT.

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 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 BROKEN DIFFERENTIAL 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* | — | — | — | -(50+/-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 #1 ABOVE, IS PERFORMED TO VERIFY PROPER DIFFERENTIAL FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

4. 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 #1 ABOVE, IS PERFORMED TO VERIFY PROPER DIFFERENTIAL OPERATIONS DURING RING MOVEMENT.

5. 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 DEFINED IN QTP #1 ABOVE, TO VERIFY PROPER DIFFERENTIAL OPERATIONS DURING RING MOVEMENT.

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 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. DIFFERENTIAL MOVEMENT VERIFIED BY EXTENSION OF DOCKING RING TO INITIAL POSITION AND ABSORPTION OF ENERGY OF RELATIVE MOVEMENT DURING EACH DOCKING WILL DETECT A BROKEN DIFFERENTIAL. 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 DIFFERENTIAL FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

7. TARGET SERVICE LIFE TEST - TESTS ARE PERFORMED TO VERIFY PROPER DOCKING AND UNDOCKING OPERATIONS OVER ITS LIFE OF 100 DOCKINGS. PROPER OPERATION OF THE DIFFERENTIAL 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 OPERATIONAL CAPABILITY TEST, AS DEFINED IN QTP #1 ABOVE, IS PERFORMED TO VERIFY PROPER DIFFERENTIAL FUNCTIONING DURING RING MOVEMENT AND DOCKING OPERATIONS.

8. BACKUP UNDOCKING MEANS CHECK - PROPER OPERATION OF THE DIFFERENTIAL IS VERIFIED DURING COUPLING OF THE APDA ASSEMBLY WITH THE SIMULATOR.

9. CONTROL DISASSEMBLY - UPON COMPLETION OF ALL QUAL TESTING THE DOCKING MECHANISM IS DISMANTLED AND ALL DIFFERENTIAL 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, AND CHEMICAL PLATING 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:**
CREW COULD OPEN CAPTURE LATCHES AND FIRE APPROPRIATE ORBITER RCS JETS TO PERFORM SEPARATION IN THE EVENT A BROKEN DIFFERENTIAL RESULTS IN A MOMENT BETWEEN ORBITER AND MIR.

**- APPROVALS -**

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