FAILURE MODES EFFECTS ANALYSIS (FMEA) – CIL HARDWARE
NUMBER: M8-1MR-8M002-X

SUBSYSTEM NAME: MECHANICAL - EDS
REVISION: 2 9/1/95

		PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU	:	STRUCTURAL LATCH MECHANISM NPO-ENERGIA	33U.6365.010-05 33U.6365.010-05
SRU	:	PYROTECHNIC BOLT NPO-ENERGIA	MC621-0067-0020 MC621-0067-0020

PART DATA

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
PYROTECHNIC BOLT

REFERENCE DESIGNATORS:

QUANTITY OF LIKE ITEMS: 24
TWENTY-FOUR (1 FOR EACH ACTIVE/PASSIVE HOOK ON 12 ORBITER DOCKING MECHANISM STRUCTURAL HOOK ASSEMBLIES)

FUNCTION:
UPON RECEIVING AN ELECTRICAL COMMAND FROM THE PPCU THE AFFECTED PYRO BOLTS DETONATE AND SEVER TO ALLOW THE RELEASE OF THEIR RESPECTIVE ACTIVE OR PASSIVE STRUCTURAL HOOKS. THE PYRO RELEASE OF 12 ORBITER ACTIVE HOOKS PROVIDES POSITIVE SEPARATION BETWEEN THE MIR AND THE ORBITER. (THE PYRO BOLTS ON THE 12 ORBITER PASSIVE HOOKS ARE USED DURING CONTINGENCIES ONLY.)

SERVICE IN BETWEEN FLIGHT AND MAINTENANCE CONTROL:
SERVICEABILITY CONTOL (ELECTRICAL CHECK).

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

REFERENCE DOCUMENTS: LD34.440.024
33U.4645.011-05
33U.6121.038-05
33U.6201.008-05
33U.6365.010-05
33U.6366.007-05
33U.6366.008-05
33U.6366.009-05
33U.6366.010-05

FAILURE MODES EFFECTS ANALYSIS (FMEA) – CIL FAILURE MODE
NUMBER: M8-1MR-BM002- 01

REVISION# 1 9/17/95

SUBSYSTEM NAME: MECHANICAL - EDS
LRU: STRUCTURAL LATCH MECHANISM
ITEM NAME: BOLT, PYROTECHNIC

CRITICALITY OF THIS FAILURE MODE: 1R3

FAILURE MODE:
PREMATURE FRACTURE

MISSION PHASE:
OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY: 104 ATLANTIS

CAUSE:
STRAY VOLTAGES, STATIC ELECTRICITY, RF RADIATION, EXTREME TEMPERATURES, IMPROPER MACHINING OF FRACTURE AREA, EXCESSIVE LOADS, MECHANICAL SHOCK

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) FAIL

PASS/FAIL RATIONALE:
A)
N/A - PYROTECHNIC DEVICES ARE NOT CHECKED DURING GROUND OPERATIONS.

B)
N/A - PYROTECHNIC DEVICES ARE NOT CHECKED IN-FLIGHT.

C)
FAILS REDUNDANCY SCREEN "C" SINCE AN INADVERTENT FIRE COMMAND, EXTREME TEMPERATURES, OR STRAY/STATIC ELECTRICITY/RF RADIATION CAN ACTUATE MORE THAN ONE PYROTECHNIC RELEASE DEVICE. ALL WORKAROUNDS WOULD ALSO BE LOST WITH THIS EVENT - PREMATURE FIRING OF PYRO BOLTS ON MIR MAY RENDER IT'S STRUCTURAL HOOKS UNUSABLE AND RAPID DECOMPRESSION DUE TO INADVERTENT FIRING OF ALL PYRO'S WOULD PRECLUDE CLOSING THE HATCHES TO ISOLATE LEAKAGE.

METHOD OF FAULT DETECTION:
PHYSICAL OBSERVATION - LEAKAGE THROUGH INTERFACE. CREW COULD POTENTIALLY HEAR A PREMATURE FIRING OF A PYRO.
IF PREMATURE FRACTURING OF PYRO BOLTS RESULTS IN SLOW PRESSURE LEAKAGE, GIVEN SUFFICIENT TIME, CREW COULD CLOSE THE APPROPRIATE HATCHES TO ISOLATE LEAKAGE.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: M8-1MR-BM002-01

- FAILURE EFFECTS -

(A) SUBSYSTEM:
INADVERTENT OPENING OF A CLOSED ACTIVE HOOK OR SEPARATION OF A PASSIVE HOOK.

(B) INTERFACING SUBSYSTEM(S):
NO EFFECT FIRST FAILURE. POSSIBLE LOSS OF PRESSURE IN ORBITER HABITABLE AREAS FOLLOWING PREMATURE FRACTURING OF SECOND PYRO BOLT.

(C) MISSION:
POSSIBLE CREW DECISION TO ABORT MISSION IF AN INADVERTENT FRACTURING OF A PYRO BOLT OCCURS PRIOR TO COMPLETION OF MISSION OBJECTIVES. PYRO BOLT FRACTURING MAY PRECLUDE SUBSEQUENT DOCKINGS.

(D) CREW, VEHICLE, AND ELEMENT(S):
NO EFFECT FIRST FAILURE. POSSIBLE LOSS OF CREW FOLLOWING SECOND INADVERTENT PRYO BOLT FRACTURE.

(E) FUNCTIONAL CRITICALITY EFFECTS:
FIRST PREMATURE PYRO BOLT FRACTURE - ONE ORBITER DOCKING MECHANISM STRUCTURAL HOOK IS NOT LATCHED. NO EFFECT, PRESSURE MAINTAINED WITH 11 HOOKS CLOSED.
SECOND PREMATURE PYRO BOLT FRACTURE - WORST CASE, TWO ADJACENT STRUCTURAL HOOKS ARE NOT LATCHED RESULTING IN ONLY 10 CLOSED HOOKS. DYNAMIC MOVEMENT BETWEEN ORBITER AND MIR COULD BREAK THE SEAL BETWEEN BOTH MECHANISMS RESULTING IN LOSS OF HABITABLE PRESSURE THROUGH THIS INTERFACE. DURING IVA, ORBITER AND MIR CREW SAFETY IS JEOPARDIZED WITH LOSS OF HABITABLE VOLUME.

DESIGN CRITICALITY (PRIOR TO OPERATIONAL DOWNGRADE, DESCRIBED IN F): 1R2

(F) RATIONALE FOR CRITICALITY CATEGORY DOWNGRADE:
THIRD FAILURE (FAILURE TO CLOSE TWELVE MIR STRUCTURAL HOOKS) - UNABLE TO SEAL INTERFACE. CONTINUOUS LOSS OF HABITABLE PRESSURE TO OUTSIDE ATMOSPHERE.
FOURTH FAILURE (UNABLE TO CLOSE APPROPRIATE HATCHES) - INABILITY TO ISOLATE LEAKAGE. POSSIBLE LOSS OF CREW AND VEHICLE WITH LOSS OF HABITABLE PRESSURE.

-DISPOSITION RATIONALE-

(A) DESIGN:
FIRING CIRCUITRY CONSISTS OF TWISTED SHIELDED CABLES FOR BOTH EMI AND RF PROTECTION. THE PFCU CONTAINS BLEED-OFF RESISTORS WHICH GROUND OUT ANY ELECTROSTATIC CHARGE BUILDUP WITHIN THE ADPA. SERIES SWITCHES, SWITCH GUARDS, AND PULLED CIRCUIT BREAKERS PROVIDE PROTECTION AGAINST AN ERRONEOUS PYRO FIRING COMMAND. SPRING RATE OF BELLEVILLE WASHERS ARE VERIFIED BEFORE BEING INSTALLED ON PASSIVE HOOK. THE PRYO BOLT MATERIAL USED HAS A SAFETY FACTOR GREATER THAN 1.4 TIMES THE LIMIT LOAD.

THERMAL ANALYSIS HAD INDICATED THAT THE TEMPERATURE AT THE DOCKING MECHANISM WILL NEVER BE HIGH ENOUGH TO CAUSE AUTO-IGNITION OF THE PYROS BECAUSE THE ATTITUDE OF THE ORBITER IS CONSTANTLY CHANGING, IN RESPECT TO THE MIR, DURING THE DOCKING PROCESS. (REFER TO SECTION 2.6 OF VOLUME III TO THE FMEA/CIL DOCUMENT FOR DETAILS.)

DEFLECTION ANALYSIS HAS INDICATED THAT THE ORBITER/MIR DOCKING MECHANISM INTERFACE CAN BE INITIALLY SEALED FOR PRESSURIZATION WITH 10 ADJACENT ORBITER HOOKS CLOSED. HOWEVER, WITH THESE 10 HOOKS CLOSED DYNAMIC MOVEMENT BETWEEN THE VEHICLES COULD CREATE A GAP BETWEEN THE DOCKING MECHANISM AND SEAL, RESULTING IN LOSS OF PRESSURE THROUGH THIS INTERFACE. LEAK ANALYSIS HAD INDICATED THAT UNDER WORST CASE CONDITIONS A LEAK RATE OF 262 SCFM COULD OCCUR WHICH EXCEEDS THE 43.3 SCFM AIR MAKEUP CAPABILITY OF THE ORBITER AIR REVITALIZATION SYSTEM. (REFER TO SECTIONS 2.3 AND 2.4 OF VOLUME III TO THE FMEA/CIL DOCUMENT FOR DETAILS.)

THE ELECTROEXPLOSIVE SYSTEM IS DESIGNED TO LIMIT THE POWER PRODUCED AT EACH PYROTECHNIC BOLT BY THE ELECTROMAGNETIC ENVIRONMENT ACTING ON THE SUBSYSTEM TO A LEVEL AT LEAST 20 DB BELOW THE MAXIMUM PIN-TO-PIN DC NO FIRE LEVEL OF THE PYROTECHNIC BOLT.

(B) TEST:

ACCEPTANCE TESTS (PYRO): THE FOLLOWING ACCEPTANCE TESTS WERE PERFORMED ON 100% OF THE FLIGHT UNITS:

(1) X-RAY - TWO VIEWS OF EACH PYRO BOLT ARE TAKEN APPROXIMATELY 90° APART AND PERPENDICULAR TO THE LONGITUDINAL AXIS.

(2) BRIDGEWIRE RESISTANCE - RESISTANCE BETWEEN BRIDGEWIRE TERMINALS OF EACH PYRO BOLT IS MEASURED TO BE BETWEEN 1.0 AND 2.0 OHMS USING A MAXIMUM TEST CURRENT OF 50 MILLIAMPS APPLIED FOR A MAX TIME OF 1 MIN.

(3) ELECTROSTATIC DISCHARGE - EACH PYROTECHNIC BOLT SUBJECTED TO AN ELECTROSTATIC DISCHARGE FROM A 180-220 PICOFARAD CAPACITOR CHARGED UP TO 24,800 - 25,200 VOLTS AND WITH THE DISCHARGE APPLIED BETWEEN THE SHORTED PINS OF THE BRIDGEWIRES AND THE INITATOR BODY THROUGH A 4500 - 5500 OHM RESISTOR CONNECTED IN SERIES WITH THE SHORTED PINS.

(4) INSULATION RESISTANCE - RESISTANCE BETWEEN THE BODY AND BRIDGEWIRE TERMINALS AND BETWEEN BRIDGEWIRE TERMINALS THEMSELVES OF EACH PYRO BOLT IS A MINIMUM OF 2 MEGOHMS WHEN 250 +/- VOLTS OF DIRECT CURRENT IS APPLIED FOR 15 SECONDS MINIMUM.

QUALIFICATION TESTS (PYRO BOLT): THE FOLLOWING QUALIFICATION TESTS WERE PERFORMED ON UNITS TAKEN FROM THE SAME LOT AS THE FLIGHT UNITS:

(1) ELEVATED TEMPERATURES - THE PYROTECHNIC BOLTS OR LATCH ASSEMBLIES ARE EXPOSED TO ELEVATED TEMPERATURES UP TO 212°F. THE TEMPERATURE OF THE PYRO BOLT IS MONITORED AT ALL TIMES DURING THIS TEST. THE RATE OF TEMPERATURE CHANGE WITHIN THE CHAMBER IS LESS THAN 1°F PER MINUTE AND NOT MORE THAN 4°F PER MINUTE. TEMPERATURE OF THE PYRO BOLT IS STABILIZED AT 212°F FOR ONE HOUR.

(2) BREAKING STRENGTH - PRYO BOLT BREAKING STRENGTH TEST WAS PERFORMED ON LOT SAMPLES TO ENSURE THAT THE STRENGTH IS NOT LESS THAN 4,000 KGF.

(3) 6-FOOT DROP - TWO PRYO BOLTS (ONE DROP PER SPECIMEN) ARE DROPPED FROM A HEIGHT OF 6 FEET PLUS 6 INCHES MINUS ZERO ALONG TWO

PERPENDICULAR AXES, ONE OF WHICH IS THE LONGITUDINAL AXIS, IMPACT SURFACE SHALL BE A STEEL PLATE WITH A MINIMUM THICKNESS OF 1/4 INCH BACKED BY A MINIMUM OF 3/4 INCH THICK CONCRETE.
(4) DC SENSITIVITY - A DC SENSITIVITY TEST IS SCHEDULED TO BE PERFORMED TO DETERMINE MAXIMUM NO FIRE CURRENT. EACH PYRO BOLT WILL BE INITIATED USING A CONSTANT CURRENT PULSE APPLIED TO A SINGLE BRIDGEWIRE (PIN-TO-PIN) FOR 40 TO 50 MILLISECONDS.
(5) SHOCK - 20G'S FOR A NOMINAL DURATION OF 11 MILLISECONDS. TEST UNITS WERE SUBJECTED TO 18 IMPACT SHOCKS OF 20G'S (3 SHOCKS IN OPPOSITE DIRECTIONS ALONG EACH OF THE THREE MUTUALLY PERPENDICULAR AXES)
(6) BRIDGEWIRE RESISTANCE - RESISTANCE BETWEEN BRIDGEWIRE TERMINALS MEASURED TO BE BETWEEN 1.0 AND 2.0 OHMS USING A MAXIMUM TEST CURRENT OF 50 MILLIAMPS APPLIED FOR A MAXIMUM TIME OF 1 MINUTE.
(7) INSULATION RESISTANCE - RESISTANCE BETWEEN THE BODY AND BRIDGEWIRE TERMINALS AND BETWEEN BRIDGEWIRE TERMINALS THEMSELVES OF EACH PYRO BOLT IS A MINIMUM OF 2 MEGOHMS WHEN 250 +/- VOLTS OF DIRECT CURRENT IS APPLIED FOR 15 SECONDS MINIMUM.

QUALIFICATION TESTS (ADPA): THE FOLLOWING TESTS WERE PERFORMED ON THE ADPA QUALIFICATION UNIT:
(1) RADIO FREQUENCY SAFETY - RADIATION TESTS PERFORMED ON THE MIR/SHUTTLE DOCKING QUALIFICATION UNIT. RADIATED RF POWER LEVELS WERE AS FOLLOWS: 11 VOLTS/M FOR FREQUENCY RANGE OF 1.5 TO ABOUT 11.5 MHZ; THEN INCREASES TO 13 VOLTS/M AT 11.5 MHZ; THEN INCREASES AT A CONSTANT RATE BETWEEN 13 AND 200 VOLTS/M BETWEEN 11.5 AND 1000 MHZ; AND REMAINS CONSTANT AT 200 VOLTS/M UNTIL A FREQUENCY OF 18,000 MHZ. THE RF RADIATION FIELD IS A CONTINUOUS WAVE SIGNAL. THIS TEST IS PERFORMED AT TWO WORST CASE POSITIONS WHERE EXPOSED PYRO BOLTS AND/OR WIRING ARE LOCATED. AT EACH TEST FREQUENCY THERE IS ABOUT 20 SECONDS OF DWELL TIME AND 20 SECONDS OF COOLING TIME.

(C) INSPECTION:
VISUAL INSPECTION
100% OF ALL PYRO BODIES ARE VISUALLY INSPECTED AND DOCUMENTEF FOR ABSENCE OF MECHANICAL DAMAGE AND CORROSION BY RSC-ENERGIA.

CRITICAL PROCESSES
HEAT TREATMENT PROPERTIES VERIFIED ON TEST SAMPLES ARE INSPECTED AND DOCUMENTED BY RSC-ENERGIA.

NON-DESTRUCTIVE EVALUATION
(1) X-RAY EVALUATION IS PERFORMED ON 100% OF THE FLIGHT UNITS AND COMPONENT QUAL TEST UNITS (SERIES II), BY RI. TO VERIFY CONSISTENCY OF PRODUCTION QUALITY BETWEEN UNITS TO ENSURE PROPER RELATIVE THICKNESS OF THE CROSS SECTION.
(2) SPECTROGRAPHY IS PERFORMED AND DOCUMENTED BY RSC-ENERGIA ON A 100% BASIS TO VERIFY PROPER MATERIAL GRADE COMPOSITION.
(3) MAGNETIC DETECTION METHOD IS PERFORMED AND DOCUMENTED BY RSC-ENERGIA ON A 100% BASIS TO VERIFY MATERIAL CONTINUITY (ABSENCE OF LATENT DEFECTS SUCH AS CRACKS).
(4) DIMENSIONAL CHECKS ARE PERFORMED BY RSC-ENERGIA ON A 100% BASIS TO VERIFY COMPLIANCE WITH DRAWING REQUIREMENTS.

FAILURE MODES EFFECTS ANALYSIS (FMEA) – CIL FAILURE MODE
NUMBER: M8-1MR-BM002- 01

ASSEMBLY/INSTALLATION
ASSEMBLY/INSTALLATION IS INSPECTED AND DOCUMENTED BY RSC-ENERGIA.

TESTING
QTP/ATP ARE INSPECTED AND DOCUMENTED BY RSC-ENERGIA WITH LIMITED PARTICIPATION FROM RI.

HANDLING/PACKAGING
HANDLING/PACKAGING PROCEDURES AND REQUIREMENT FOR SHIPMENT ARE INSPECTED AND DOCUMENTED BY RSC-ENERGIA.

(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:
IF PREMATURE FRACTURING OF PYRO BOLTS RESULTS IN SLOW PRESSURE LEAKAGE, GIVEN SUFFICIENT TIME, CREW COULD CLOSE THE APPROPRIATE HATCHES TO ISOLATE LEAKAGE. CREW COULD UTILIZE TWELVE MIR HOOKS TO SEAL INTERFACE.

- APPROVALS -

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