

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE****NUMBER: 03-1-0454 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 1 08/08/00**PART DATA**

|     | <b>PART NAME</b>                           | <b>PART NUMBER</b>                             |
|-----|--|--|
|     | <b>VENDOR NAME</b>                         | <b>VENDOR NUMBER</b>                           |
| LRU | :17" DISC ASSY, ORB, LH2/LO2               | MC284-0389-1461 (LH2)<br>MC284-0389-1561 (LO2) |
|     | BOEING                                     |  |
| SRU | :17" DISC LATCH ASSY, LH2/LO2              | 5863431-101 (LH2)<br>5863431-102 (LO2)         |
|     | BOEING                                     |  |
| LRU | :17" DISCONNECT LATCH ACTUATOR,<br>LH2/LO2 | 5863450-102 (LH2)<br>5863450-103 (LO2)         |
|     | BOEING                                     |  |

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

VALVE LATCH ASSEMBLY, LH2/LO2 FEED DISCONNECT (PD1,PD2)  
ORBITER HALF ONLY.

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY PARKER-HANNIFIN. BOEING IS A CERTIFIED ALTERNATE PRODUCTION AGENCY.

**REFERENCE DESIGNATORS:** PD1  
PD2

**QUANTITY OF LIKE ITEMS:** 2  
ONE EACH LO2, LH2

**FUNCTION:**

A PNEUMATICALLY ACTUATED LATCH MECHANISM IS PROVIDED TO PREVENT THE VALVE FLAPPERS FROM CLOSING DURING FLOW CONDITIONS. THE LATCH IS BISTABLE AND IS CONTROLLED BY A SEPARATE PNEUMATIC ACTUATOR ASSEMBLY WITH REDUNDANT LOCK AND UNLOCK (TWO EACH) POSITION SWITCHES. LATCH IS PLACED IN UNLOCKED POSITION FOR ALL FLAPPER OPEN OR CLOSE OPERATIONS. LATCH MECHANISM INCORPORATES A TOGGLE PIVOT WHICH ALLOWS FLAPPER CLOSURE DURING BACKUP MECHANICAL SEPARATION IF LATCH IS IN LOCKED POSITION. SEE DISCONNECT FMEA/CIL 0407/0408 FOR ADDITIONAL INFORMATION.

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**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: 17" DISC ASSY, ORB LH2, LO2**

**ITEM NAME: 17" DISC LATCH ASSY LH2, LO2**

**CRITICALITY OF THIS**

**FAILURE MODE: 1R2**

**FAILURE MODE:**

ERRONEOUS INDICATION

**MISSION PHASE:**

PL PRE-LAUNCH

LO LIFT-OFF

**VEHICLE/PAYLOAD/KIT EFFECTIVITY:**

102 COLUMBIA

103 DISCOVERY

104 ATLANTIS

105 ENDEAVOUR

**CAUSE:**

PIECE PART STRUCTURAL FAILURE

**CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO**

**REDUNDANCY SCREEN**

A) PASS

B) FAIL

C) PASS

**PASS/FAIL RATIONALE:**

A)

B)

FAILS B SCREEN BECAUSE PIECE PART STRUCTURAL FAILURE OF THE LATCH DRIVE MECHANISM CANNOT BE DETECTED SINCE POSITION SWITCHES ARE LOCATED IN THE ACTUATOR.

C)

**- FAILURE EFFECTS -**

**(A) SUBSYSTEM:**

RESULTS IN LATCH EITHER FAILING TO LOCK OR UNLOCK BUT POSITION SWITCHES INDICATE ERRONEOUS LATCH SHAFT POSITION DUE TO PIECE PART STRUCTURAL FAILURE IN LATCH DRIVE MECHANISM.

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

SAME AS A.

**(C) MISSION:**

NO EFFECT.

**(D) CREW, VEHICLE, AND ELEMENT(S):**

SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

CASE 1:

1R/2 2 SUCCESS PATHS. TIME FRAME -PROPELLANT LOADING/ENGINE OPERATION

- 1) LATCH ERRONEOUS INDICATION (LOCK INDICATION "ON"/LATCH UNLOCKED).
- 2) FLAPPER FAILS TO REMAIN OPEN

LH2/LO2 FLOW WILL BE TERMINATED. SURGE PRESSURE FROM VALVE CLOSURE MAY CAUSE DAMAGE OR RUPTURE TO THE MPS AND/OR ET SYSTEM, DEPENDING ON THE RATE OF CLOSURE. UNABLE TO PERFORM ET DRAIN. RUPTURE OF MPS LINES WILL LEAK LH2/LO2 INTO THE AFT COMPARTMENT. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL FUNCTIONS DUE TO CRYO EXPOSURE. LEAKAGE INTO AFT COMPARTMENT IS DETECTABLE ON GROUND USING HAZARDOUS GAS DETECTION SYSTEM (HGDS). RUPTURE OF ET FEEDLINE WILL LEAK LH2/LO2 OUTSIDE OF THE VEHICLE. FIRE/EXPLOSION HAZARD AND POSSIBLE DAMAGE TO VEHICLE EXTERIOR. DURING ENGINE OPERATION, SHUTDOWN OF ALL THREE ENGINES WITH UNCONTAINED DAMAGE DUE TO STARVATION CUTOFF. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

1R/2 2 SUCCESS PATHS. TIME FRAME - LOADING

- 1) LATCH ERRONEOUS INDICATION (UNLOCK INDICATION "ON"/LATCH LOCKED)
- 2) LEAKAGE/FIRE REQUIRING ISOLATION OF EXTERNAL TANK BY CLOSURE OF THE 17" DISCONNECT.

LATCH ERRONEOUS INDICATION WILL RESULT IN THE 17" DISCONNECT BEING COMMANDED CLOSED WITH THE LATCH IN THE LOCKED POSITION. POSSIBLE HARDWARE DAMAGE, FAILURE TO CLOSE FLAPPER AND/OR INTERNAL LEAKAGE. RESULTS IN FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 3:

1R/2 2 SUCCESS PATHS. TIME FRAME - PROPELLANT LOADING/ENGINE OPERATION.

- 1) LATCH ERRONEOUS INDICATION WHEN FLAPPERS COMMANDED OPEN FOR START OF PROPELLANT LOADING (UNLOCK INDICATION "ON"/LATCH LOCKED).
- 2) FLAPPER INDICATES OPEN ERRONEOUSLY (FLAPPERS RESTING ON TOP OF LATCH TOGGLE). THEN, LATCH IS COMMANDED LOCKED AND WILL INDICATE LOCKED.

FLAPPER CLOSURES DURING PROPELLANT LOADING OR ENGINE OPERATION. LH2/LO2 FLOW WILL BE TERMINATED. SURGE PRESSURE FROM VALVE CLOSURE MAY CAUSE DAMAGE

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OR RUPTURE TO THE MPS AND/OR ET SYSTEM, DEPENDING ON THE RATE OF CLOSURE. UNABLE TO PERFORM ET DRAIN. RUPTURE OF MPS LINES WILL LEAK LH2/LO2 INTO THE AFT COMPARTMENT. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL FUNCTIONS DUE TO CRYO EXPOSURE. LEAKAGE INTO THE AFT COMPARTMENT IS DETECTABLE ON GROUND USING HAZARDOUS GAS DETECTION SYSTEM (HGDS). RUPTURE OF ET FEEDLINE WILL LEAK LH2/LO2 OUTSIDE OF THE VEHICLE. FIRE/EXPLOSION HAZARD AND POSSIBLE DAMAGE TO VEHICLE EXTERIOR. DURING ENGINE OPERATION, SHUTDOWN OF ALL THREE ENGINES WITH UNCONTAINED DAMAGE DUE TO STARVATION CUTOFF. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

THE ACTUATOR SWING ARM (INCONEL 718) TRANSFERS LATERAL MOVEMENT OF THE ACTUATOR PISTON INTO CIRCULAR MOVEMENT OF THE LATCH ARM ASSEMBLY AND ROTATION OF THE POSITION SWITCH CAM. THE LATCH ARM AND TOGGLE ASSEMBLY IS SUPPORTED BY THE FLEXURE ASSEMBLY AND A BEARING INSERTED IN THE DISCONNECT HOUSING.

THE LATCH ARM ASSEMBLY CONSISTS OF THE LATCH, LATCH PIN, COVER SPRING, LATCH SPRING, RETAINER SPRING, AND ROLL PIN. THE LATCH IS CONSTRUCTED OF HEAT TREATED INCONEL 718 AND HAS DRY FILM LUBRICANT ON ALL SURFACES. THE LATCH PIN IS OF INCONEL 718 WITH A 32 MICROINCH SURFACE FINISH AND IS LUBRICATED WITH MICROSEAL. THE COVER SPRING IS OF 316 CRES PASSIVATED AND HAS MICROSEAL LUBRICANT ON ALL SURFACES. LATCH SPRING IS OF 302 CRES. THE SPRING IS STABLE WITH RESPECT TO BUCKLING. SPRING COIL PITCH AT INSTALLED HEIGHT IS LESS THAN WIRE SIZE, SO IF IT FRACTURES, ONLY ONE EFFECTIVE COIL IS LOST. THE RETAINER SPRING IS OF CRES 302 PASSIVATED. THE ROLL PIN IS OF CRES 302.

THE FLEXURE ASSEMBLY ABSORBS THE ENERGY FROM AN ABNORMAL OPERATION. FLEXURE ASSEMBLY CONSISTS OF ONE INSIDE FLEXURE AND ONE OUTSIDE FLEXURE. THE FLEXURE IS OF INCONEL 718, HEAT TREATED AND PASSIVATED.

THE LATCH ASSEMBLY IS DESIGNED FOR 2500 CYCLES (LOCKED TO UNLOCKED TO LOCKED) AT AMBIENT AND 1000 CYCLES AT -423 DEG F. FOR MECHANICAL LATCH LOADS, THE PROOF FACTOR OF SAFETY IS 1.1 AND THE ULTIMATE FACTOR OF SAFETY IS 2.0. STRUCTURAL ANALYSIS INDICATES POSITIVE MARGINS OF SAFETY FOR ALL CONDITIONS OF LATCH OPERATION; FRACTURE/FATIGUE ANALYSES SHOW THAT ALL CRITICAL PARTS ARE SATISFACTORY FOR FOUR TIMES EXPECTED LIFE.

**(B) TEST:**

ATP

LATCH ACTUATOR PROOF, AMBIENT 1275 PSIG

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LATCH/SHAFT ASSEMBLY PROOF LOAD TEST:

- ORBITER FLAPPER/ET FLAPPER CLOSURE LOAD, 750 LBF
- ET FLAPPER CLOSURE LOAD, 596 LBF
- ET OVER TRAVEL RESTRAINT LOAD, 596 LBF

OPERATIONAL CYCLE: AMBIENT: 400 PSIG, 1 CYCLE; 740 PSIG, 5 CYCLES

OPERATIONAL: LN2 TEMPERATURE, 450 PSIG, 5 CYCLES; 740 PSIG, 5 CYCLES

LATCH SHAFT SEAL LEAKAGE: AMBIENT AND LN2 TEMPERATURES, 10 AND 50 PSIG, 80 SCIM OF GHE

LATCH ACTUATOR EXTERNAL LEAKAGE: AMBIENT AND LN2 (BODY TEMPERATURES) 740 PSIG, STATIC SEAL, 150 SCIM OF GHE, PISTON SHAFT SEAL, 1000 SCIM OF GHE

LATCH ACTUATOR INTERNAL LEAKAGE: AMBIENT AND LN2 TEMPERATURES, 740 PSIG, 400 SCIM OF GHE

LH2 UNIT ADDITIONAL TESTS:

OPERATIONAL CYCLES: AMBIENT TEMPS, 10 CYCLES AT 740 PSIG AND 10 CYCLES AT 400 PSIG

OPERATIONAL CYCLES: LH2 TEMPS, 10 CYCLES AT 740 PSIG AND 10 CYCLES AT 450 PSIG

LATCH SHAFT SEAL LEAKAGE: LH2 TEMPS, 0 TO 50 PSIG, 80 SCIM OF GH2

LATCH ACTUATOR EXTERNAL LEAKAGE: LH2 TEMPS (BODY), 740 PSIG, STATIC SEAL, 150 SCIM OF GHE, PISTON SHAFT SEAL, 1000 SCIM OF GHE

LATCH ACTUATOR INTERNAL LEAKAGE: LH2 TEMPS (BODY), 740 PSIG, 400 SCIM OF GHE

ELECTRICAL CHARACTERISTICS: INSULATION RESISTANCE, VOLTAGE DROP, AND DIELECTRIC STRENGTH

EXAMINATION OF PRODUCT:

VERIFY THE CLEARANCE BETWEEN TOE OF THE LATCH TO EDGE OF FLAPPER FAIRING DOME.

VERIFY THE DEMATED VALVE FLAPPER MOVEMENT PAST LATCH TOGGLE.

MEASURE EDGE CLEARANCE FROM FULL OVER TOGGLE TO THE FLAPPER.

TOGGLE SHALL MOVE FREELY AT AMBIENT AND CRYOGENIC CONDITIONS.

POSITION INDICATOR SWITCH REDUNDANCY SWITCH PICKUP WITHIN THE LIMITS BAND.

LATCH ACTUATOR SWITCH HOUSING VENT CHECK VALVE RELIEF SET PRESSURE.

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CLEANLINESS: MOISTURE FREE AND CLEANED TO LEVEL 400A OF MA 0110-301

MEASURE GAP BETWEEN BOTTOM OF LATCH AND TOP OF FLAPPER SEAL  
RETAINER RINGS.

MEASURE OVERLAP BETWEEN END OF LATCH AND END OF ET FLAPPER SEAL  
RETAINER RING.

CERTIFICATION

COMPONENT QUALIFICATION

THERMAL CYCLE; 3 CYCLES, AMBIENT TO -400 DEG F TO AMBIENT

VIBRATION:     RANDOM 20 TO 2000 HZ  
                  5.0 GRMS FOR Z-AXIS  
                  5.2 GRMS FOR X AND Y-AXIS  
                  48 MINUTES PER AXIS

CONDITIONS: MATED, NO FLOW, FLAPPERS OPEN, LATCH LOCKED, PRESSURIZED  
TO 10 PSIG, AND FILLED WITH LN2 (DONE PRIOR TO LH2 LEAKAGE  
TEST). DURING THE LAST TWO MINUTES OF RANDOM VIBRATION IN  
EACH AXIS, LATCH ACTUATOR PNEUMATIC SUPPLY PRESSURE IS  
RELIEVED.

ELECTRICAL CHARACTERISTICS: INSULATION RESISTANCE AND VOLTAGE DROP

BONDING; ELECTRICAL BONDING PER MIL-B-5087

ULTIMATE LOADS; LATCH ASSEMBLY, TOGGLE LOAD, ET SIDE AND FLAPPER OVER TRAVEL  
RESTRAINT, ET SIDE

ACTUATOR BURST PRESSURE: 1700 PSIG

SEQUENCE ERROR/RIGGING ERROR:

DOWNSTRIKE IMPACT: 8 CYCLES, FLAPPERS CLOSED, ACTUATE LATCH TO LOCKED  
POSITION, ACTUATE FLAPPERS OPEN, THEN CLOSE

FLAPPERS CLOSED AGAINST LATCH: 8 CYCLES, FLAPPER OPEN AND LATCHED,  
COMMAND FLAPPER CLOSED, THEN OPEN

MISRIGGING: 4 CYCLES, ACTUATE FLAPPERS OPEN, COMMAND LATCH TO  
ENGAGED POSITION, COMMAND LATCH TO DISENGAGE

ORBITER ANGLE LOW:  
ORB: 1.46 DEG  
ET: 4.5 DEG

ET ANGLE LOW:  
ORB: 3.0 DEG

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ET: 2.85 DEG

ET ANGLE HIGH:  
ORB: 3.0 DEG  
ET: 8.16 DEG

MECHANICAL CLOSURE (LO2, ORBITER, DEMATED): MANUALLY OPEN FLAPPER, ENGAGE LATCH, MANUALLY CLOSE FLAPPER. AT POINT WHERE LATCH BEGINS TO RELEASE FLAPPER, HOLD FLAPPER IN PLACE WHILE ROTATING TOGGLE TO EXTREME POSITION. MEASURE TOGGLE/FLAPPER CLEARANCE AT POINT OF RELEASE.

LIFE CYCLE,  
AMBIENT: 2400 CYCLES (UNLOCK TO LOCK TO UNLOCK)  
CRYOGENIC: 1000 CYCLES, -400 DEG F BODY TEMPERATURE

ACTUATOR AND LATCH SHAFT SEAL LEAKAGE: AMBIENT AND CRYO (LN2 AND LH2)

UMBILICAL SEPARATION TEST: (WITH LATCH)

FLAPPER PNEUMATICS/LATCH PNEUMATICS/PYROS/RETRACTOR HYDRAULICS

- (1) PNEUMATIC CLOSURE (NORMAL) - 4 CYCLES
- (2) MECHANICAL CLOSURE (BACKUP) - 5 CYCLES

BOTH PERFORMED AT AMBIENT, LN2 AND LH2 CONDITIONS.

LATCH WATER FLOW TESTS: (LH2 CONFIGURATION)

ELEVEN (11) EXPLORATORY TEST SERIES (FLOW 4000 TO 14800 GPM)

CERTIFICATION TEST RUN AT NOMINAL PRODUCTION SETTING (FLOW RANGE TO 109% POWER LEVEL).

TWO PROOF TESTS - 15650 GPM AND 15850 GPM

LATCH WATER FLOW TESTS: (LO2 CONFIGURATION)

TWENTY-FOUR (24) EXPLORATORY TEST SERIES (FLOW 4000 TO 22100 GPM)

CERTIFICATION TEST RUN AT MINIMUM PRODUCTION SETTING (FLOW RANGE TO 109% POWER LEVEL).

TWO TEST SERIES IN FILL DIRECTION (FLOW 4000 TO 6400 GPM), LATCH PNEUMATIC PRESSURE VENTED (BISTABILITY)

PROOF TEST - 23200 GPM

LATCH CRYO FLOW TESTS: (LH2 VALVE QUALIFIED BY SIMILARITY TO LO2)

SIXTEEN (16) TESTS WITH LN2/LO2 (FLOWS VARY FROM ONE ENGINE AT 65% TO THREE AT 109%).

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DISCONNECT FLAPPER STABILITY/LOADS

CAVITATION

FRICION PRESSURE LOSS

ENGINE CUTOFF SENSOR RESPONSE

STEADY STATE TEST: LN2 (65% AND 109% OF RATED POWER LEVEL),  
LATCH ENGAGED. LO2 (100%, 104% AND 109% OF RATED POWER LEVEL),  
LATCH ENGAGED AND NOT ENGAGED.

TERMINAL DRAIN: (SATURATED LO2) (65% AND 109%) LATCH ENGAGED AND  
NOT ENGAGED.

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

RECEIVING INSPECTION

ALL HARDWARE 100% DIMENSIONALLY INSPECTED.

INSPECTION VERIFIES CERTIFICATIONS OF RAW MATERIAL ARE PART PROTECTION,  
COATING, AND PLATING REQUIREMENTS VERIFIED BY INSPECTION.

CONTAMINATION CONTROL

INSPECTION VERIFIES CLEANLINESS TO LEVEL 400A.

INSPECTION VERIFIES THE CONTAMINATION CONTROL PLAN.

MANUFACTURING PROCESSES, INSTALLATION, AND ASSEMBLY OPERATIONS

ASSEMBLY/INSTALLATION

VERIFIED BY INSPECTION, INCLUDING PARTS PROTECTION.

INSPECTION VERIFIES FASTENERS ARE TORQUED TO REQUIREMENTS.

INSPECTION VERIFIES IMPLEMENTATION OF CORROSION PROTECTION PROVISIONS.

INSPECTION VERIFIES SURFACE FINISHES TO DRAWING REQUIREMENTS.

INSPECTION VERIFIES SEAL INSTALLATION WHICH INCLUDES:

SEAL MATING PART (MATERIAL, SURFACE FINISH, 100% DIMENSIONAL INSPECTION)  
ASSEMBLY (COMPONENT INTEGRITY, SEALS AND SURFACE LUBRICATED,  
ASSEMBLY TECHNIQUE, SEAL INSTALLATION IN CLEANROOM)



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QUALIFIED AND CERTIFIED PERSONNEL AND SPECIAL DESIGNATED TOOLS UTILIZED

SEAL PHOTOS (BLIND INSTALLATION, SINGLE BACKUP RINGS, AND "L" SEALS) AND CORRECT SEAL IDENTIFICATION (PART NO., LOT NO., MATERIAL CONDITION, AGE, CRITICAL CHARACTERISTICS).

CRITICAL PROCESSES

INSPECTION VERIFIES PARTS PASSIVATION AND HEAT TREATMENT

INSPECTION VERIFIES SOLDERING MEETS REQUIREMENTS IMPOSED

NONDESTRUCTIVE EVALUATION

100% DYE PENETRANT AND X-RAY INSPECTION IS PERFORMED ON ANY PARTS DESIGNATED FRACTURE CRITICAL.

TESTING

INSPECTION VERIFIES ATP REQUIREMENTS (NOTE PRIMARY VERIFICATIONS AND WITNESSING).

HANDLING/PACKAGING

INSPECTION VERIFIES IMPLEMENTATION OF HANDLING, PACKAGING, AND STORAGE REQUIREMENTS.

**(D) FAILURE HISTORY:**

CURRENT DATA ON TEST FAILURE, FLIGHT FAILURE, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATABASE.

**(E) OPERATIONAL USE:**

NO CREW ACTION CAN BE TAKEN.

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**- APPROVALS -**

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|                     |                        |                            |
|---------------------|------------------------|----------------------------|
| S&R ENGINEERING     | : W.P. MUSTY           | : /S/ W. P. MUSTY          |
| S&R ENGINEERING ITM | : P. A. STENGER-NGUYEN | : /S/ P. A. STENGER-NGUYEN |
| DESIGN ENGINEERING  | : KOUROSH ANVARI       | : /S/ KOUROSH ANVARI       |
| MPS SUBSYSTEM MGR.  | : TIM REITH            | : /S/ TIM REITH            |
| MOD                 | : BILL LANE            | : /S/ BILL LANE            |
| USA SAM             | : MIKE SNYDER          | : /S/ MIKE SNYDER          |
| USA ORBITER ELEMENT | : SUZANNE LITTLE       | : /S/ SUZANNE LITTLE       |
| NASA SR&QA          | : ERICH BASS           | : /S/ ERICH BASS           |