

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0304 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 11/07/00

PART DATA

| | PART NAME | PART NUMBER |
|-----|---|-----------------------------|
| | VENDOR NAME | VENDOR NUMBER |
| LRU | : LH2 TOPPING VALVE, 2.0 INCH, NC, TYPE 1 VACCO INDUSTRIES | MC284-0395-0051 1397-513 |

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

LH2 TOPPING VALVE, 2 INCH, NORMALLY CLOSED, PNEUMATICALLY ACTUATED OPEN.

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY VACCO INDUSTRIES (EATON). THE UNITED SPACE ALLIANCE-NSLD IS A CERTIFIED REPAIR DEPOT BUT HAS NOT YET BEEN CERTIFIED AS AN ALTERNATE PRODUCTION AGENCY.

REFERENCE DESIGNATORS: PV13

QUANTITY OF LIKE ITEMS: 1

FUNCTION:

PROVIDES CONTROL OF REPLENISH/TOPPING OF LH2 DURING COMPLETION OF PROPELLANT LOADING. OPENED AT THE START OF LH2 SLOW FILL. CLOSED FOR LH2 TANK PREPRESSURIZATION AND DRAINBACK OF LH2 FILL LINE. REMAINS CLOSED DURING ENGINE OPERATION. OPENED DURING DUMP/INERTING OPERATIONS.

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LRU: LH2 TOPPING VALVE, PV13

ITEM NAME: LH2 TOPPING VALVE, PV13

CRITICALITY OF THIS

FAILURE MODE: 1R2

FAILURE MODE:

FAILS TO OPEN/REMAIN OPEN FOR DUMP/INERTING

MISSION PHASE:

PL PRE-LAUNCH

LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA

103 DISCOVERY

104 ATLANTIS

105 ENDEAVOUR

CAUSE:

FAILS TO OPEN - PIECE PART STRUCTURAL FAILURE, ACTUATOR LEAKAGE, BINDING, ACTUATOR FILTER CLOGGING.

FAILS TO REMAIN OPEN - PIECE PART STRUCTURAL FAILURE, ACTUATOR LEAKAGE.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN

A) PASS

B) FAIL

C) PASS

PASS/FAIL RATIONALE:

A)

B)

POSITION SWITCH INDICATION CANNOT BE USED TO PASS THE B SCREEN. PIECE PART STRUCTURAL FAILURE MAY BE UNDETECTABLE BECAUSE POSITION SWITCHES ARE LOCATED IN THE ACTUATOR AND NOT AT THE END OF THE VALVE DRIVE MECHANISM.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

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FIRST FAILURE HAS NO EFFECT. FAILURE DURING PRELAUNCH WILL PREVENT TOPPING OF LH2 TANK. LOSS OF BACKUP METHOD TO DETANK (INBOARD FILL AND DRAIN VALVE IS PRIMARY MODE OF DETANKING). FAILURE DURING NOMINAL DUMP HAS NO EFFECT BECAUSE THE INBOARD FILL AND DRAIN VALVE (PV12) IS OPEN FROM DUMP START. LH2 PRESSURE BUILDUP IN RECIRC SYSTEM IS RELIEVED THROUGH RELIEF VALVE (RV7).

RESULTS IN INCREASED LH2 RESIDUALS ON RTLS/TAL BECAUSE DUMP PATH FOR LH2 TRAPPED IN SSMES IS REDUCED TO ONLY THE RTLS DUMP VALVES.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

PRELAUNCH FAILURE WILL RESULT IN LAUNCH SCRUB. RESULTS IN INCREASED LH2 RESIDUALS FOR RTLS AND TAL ABORTS.

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

NO EFFECT.

(E) FUNCTIONAL CRITICALITY EFFECTS:

CASE 1:

1R/2 2 SUCCESS PATHS. TIME FRAME - LH2 DUMP.

- 1) TOPPING VALVE (PV13) FAILS TO OPEN/REMAIN OPEN FOR DUMP.
- 2) LH2 RECIRC MANIFOLD RELIEF VALVE (RV7) FAILS TO RELIEVE.

RESULTS IN LH2 RECIRC MANIFOLD RUPTURE AND LH2 LEAKAGE INTO AFT COMPARTMENT. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

1R/3 4 SUCCESS PATHS. TIME FRAME - LH2 DUMP.

- 1) INBOARD FILL AND DRAIN (PV12) FAILS TO REMAIN OPEN.
- 2) TOPPING VALVE (PV13) FAILS TO OPEN.
- 3) EITHER RTLS DUMP VALVE (PV17, 18) FAILS TO OPEN. RTLS DUMP VALVES ARE OPENED FOLLOWING MECO FOR 110 SECONDS, BUT CAN BE OPENED BY THE CREW IF MANIFOLD PRESSURE APPROACHES RELIEF PRESSURE. EFFECTIVE FOR OI-29 AND SUBS THE RTLS DUMP VALVES WILL BE USED FOR VACUUM INERTING.
- 4) MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

LH2 REMAINING IN MANIFOLD CANNOT BE RELIEVED. RESULTS IN OVERPRESSURIZATION AND RUPTURE OF THE FEEDLINE MANIFOLD. RTLS DUMP VALVES ARE OPENED FOLLOWING MECO, BUT NOT LONG ENOUGH TO DUMP SUFFICIENT LH2 TO ALLEVIATE SYSTEM OVERPRESSURIZATION CONCERN. AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

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CASE 3:

1R/3 4 SUCCESS PATHS. TIME FRAME - DETANK.

- 1) INBOARD FILL & DRAIN VALVE (PV12) FAILS TO REMAIN OPEN.
- 2) TOPPING VALVE (PV13) FAILS TO OPEN/REMAIN OPEN.
- 3) HIGH POINT BLEED (PV22) FAILS TO OPEN/REMAIN OPEN.
- 4) ET LH2 RELIEF VALVE FAILS TO RELIEVE.

LH2 REMAINING IN MANIFOLD CANNOT BE OFFLOADED OR RELIEVED. RESULTS IN POSSIBLE OVERPRESSURIZATION AND RUPTURE OF THE FEEDLINE MANIFOLD. AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. RTLS DUMP VALVES (PV17,18) AND LH2 MANIFOLD RELIEF ISOLATION VALVE (PV8) CAN BE OPENED BY GROUND ACTION, BUT THIS WOULD DUMP LH2 ONTO THE PAD SURFACE. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

THE VALVE ACTUATOR IS SPRING LOADED TO THE CLOSED POSITION AND IS DESIGNED TO OPEN WITH THE APPLICATION OF 500 TO 800 PSIG OF HELIUM PRESSURE TO THE VALVE ACTUATOR. THE ACTUATOR PISTON DRIVES A SPRING LOADED RACK WHICH, IN TURN, DRIVES A PINION GEAR SHAFT WHICH ROTATES THE BALL CLOSURE DEVICE. THE PISTON IS OF 304 CRES AND THE RACK AND PINION ARE OF INCONEL 718. THE PINION GEAR/SHAFT IS MACHINED FROM A SINGLE PIECE OF STOCK. STRUCTURAL ANALYSIS INDICATES POSITIVE MARGINS OF SAFETY FOR ALL CONDITIONS OF VALVE OPERATIONS. THE VALVE WAS CYCLED 2000 TIMES (1500 CYCLES AT AMBIENT TEMPERATURE AND 500 AT CRYOGENIC TEMPERATURE) DURING CERTIFICATION TESTING WITHOUT EVER FAILING TO OPEN.

FACTORS OF SAFETY: PROOF - 1.5 BODY, 2.0 ACTUATOR; BURST - 2.0 BODY, 4.0 ACTUATOR. STRUCTURAL ANALYSIS INDICATES POSITIVE MARGINS OF SAFETY FOR ALL CONDITIONS OF VALVE OPERATIONS; FRACTURE/FATIGUE ANALYSES SHOW THAT ALL CRITICAL PARTS ARE SATISFACTORY FOR FOUR TIMES EXPECTED LIFE.

TO PREVENT BINDING, THE ACTUATOR RACK IS GUIDED ON EACH END BY A FLUOROGOLD GUIDE RING. THE CHROME PLATED PISTON SLIDES THROUGH FLUOROGOLD RINGS. THE ACTUATOR AND VALVE BEARINGS ARE OF VESPEL AND FLUOROGOLD AND ARE DESIGNED SO THAT THEY WILL TURN WITHIN THEIR HOUSING IN THE EVENT OF SHAFT/BEARING SEIZURE/BINDING.

FOR LEAKAGE CONTROL, THE ACTUATOR PISTON SEAL DESIGN USES A KEL-F STATIC LIP SEAL AGAINST THE MOVING, CHROME-PLATED PISTON. THE SEAL IS LOADED WITH A COPPER-BERYLLIUM SPRING AND THE ACTUATOR PRESSURE FURTHER ASSISTS IN MINIMIZING LEAKAGE. EXTERNAL LEAKAGE FROM THE ACTUATOR IS PREVENTED BY THE USE OF A CREEVEY-TYPE SEAL (TEFLON COVER OVER A STAINLESS STEEL SPRING) AND A MYLAR GASKET.

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(B) TEST:

ATP

EXAMINATION OF PRODUCT

AMBIENT PROOF:

VALVE BODY - 195 PSIG, VALVE OPEN AND CLOSED
ACTUATOR - 1700 PSIG

VALVE RESPONSE TIMES - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):

VALVE: 55 PSIG
ACTUATOR: 500 AND 740 PSIG

EXTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):

VALVE BODY: 130 PSIG
ACTUATOR: 740 PSIG

INTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):

INLET-TO-OUTLET @ 55 PSIG
OUTLET-TO-INLET @ 40 PSIG
ACTUATOR: 740 PSIG

POSITION INDICATION: VERIFICATION OF OPERATION

ELECTRICAL CHARACTERISTICS - CONTACT RESISTANCE; INSULATION RESISTANCE; AND DIELECTRIC STRENGTH.

CERTIFICATION

LIFE -

CRYO - 500 CYCLES AT -400 DEG F
AMBIENT - 1500 CYCLES

RANDOM VIBRATION TESTS - IN ALL THREE AXES

13.3 HOURS IN EACH AXIS WHILE PRESSURIZED TO 35 PSIG AND AT -300 DEG F.

DESIGN SHOCK (ALL THREE AXES) - 18 SHOCKS OF 15G EACH, THREE IN EACH DIRECTION.

THERMAL CYCLE TESTS - PERFORMED THREE TIMES

70 DEG F TO -400 DEG F TO 70 DEG F TO 275 DEG F TO 150 DEG F

VALVE RESPONSE TIMES - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):

VALVE: 55 PSIG
ACTUATOR: 500 AND 740 PSIG

EXTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):

VALVE BODY: 130 PSIG
ACTUATOR: 740 PSIG

INTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):

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INLET-TO-OUTLET @ 55 PSIG
OUTLET-TO-INLET @ 40 PSIG
ACTUATOR: 740 PSIG

ELECTRICAL CHARACTERISTICS - CONTACT RESISTANCE; INSULATION RESISTANCE; AND DIELECTRIC STRENGTH.

ELECTRICAL BONDING - LESS THAN 100 MILLIOHMS

BURST - 260 PSIG VALVE BODY, 3400 PSIG ACTUATOR

GROUND TURNAROUND TEST
ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:

RECEIVING INSPECTION
RAW MATERIAL VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION. TEST REPORTS REQUIRED ON CAST MATERIAL. COMPLETION OF HOT ISOSTATIC PRESSING (HIP) PROCESS IS VERIFIED. CAST HOUSING (ROUGH MACHINED) IS INSPECTED FOR POROSITY.

CONTAMINATION CONTROL
CONTAMINATION CONTROL PROCESS AND CORROSION PROTECTION PROVISIONS ARE VERIFIED. THE INTERNAL WETTED SURFACES ARE CLEANED TO LEVEL 400A AND VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
ALL DETAIL PARTS ARE INSPECTED FOR CRITICAL DIMENSIONS, SURFACE FINISH, BURRS, DAMAGE, AND CORROSION. CRITICAL POPPET AND SLEEVE SURFACES ARE LAPPED AND INSPECTED WITH 40X MAGNIFICATION. TORQUES ARE VERIFIED TO BE IN ACCORDANCE WITH DRAWING REQUIREMENTS. PRIOR TO INSTALLATION, SEALS ARE VISUALLY EXAMINED WITH 10X MAGNIFICATION FOR DAMAGE AND CLEANLINESS. ALL SPRINGS ARE LOT TRACEABLE AND LOAD TESTED AT THE PIECE PART LEVEL. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESSES
HEAT TREATMENT OF THE VALVE BALL AFTER MACHINING IS VERIFIED. PART PASSIVATION AND HARD ANODIZING ARE VERIFIED. CERTIFICATION OF WELDING, POTTING, AND SOLDERING IS VERIFIED. PAINTING (ON BODY), ELECTRICAL BONDING, AND DRY FILM LUBRICANT ARE VERIFIED BY INSPECTION. ALL CASTINGS ARE SUBJECTED TO A HIP PROCESS.

NONDESTRUCTIVE EVALUATION
PRIOR TO FINAL MACHINING, THE HOUSING IS X-RAYED, ETCH AND DYE PENETRANT INSPECTED, AND LEAK CHECKED AT PROOF PRESSURE. ALL WELDS ON THE ELECTRICAL CONNECTOR ARE DYE PENETRANT INSPECTED AND VERIFIED BY INSPECTION.

TESTING
ATP VERIFIED BY INSPECTION.

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PACKAGING/HANDLING

HANDLING, PACKAGING, STORAGE, AND SHIPPING REQUIREMENTS ARE VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

FAILS TO OPEN

A FAILURE OF THE VALVE TO CLOSE OCCURRED DURING QUALIFICATION TESTING (REFERENCE CAR AC1189). THE CAUSE WAS INTERFERENCE DUE TO THE OVERSIZED DIAMETER OF THE PISTON GUIDE RING GROOVE. THE DESIGN WAS CHANGED (THE GROOVE DIAMETER WAS REDUCED) TO ELIMINATE THE PROBLEM.

A FAILURE AT NSTL OF A VALVE TO ACTUATE WAS CAUSED BY BINDING OF THE ALUMINUM BRONZE BUSHING TO THE SHAFT. AN MCR AUTHORIZED DRAWING CHANGES TO TEFLON COAT AND POLISH THE SHAFT (REFERENCE CAR A7950).

FAILS TO OPEN/REMAIN OPEN (ACTUATOR LEAKAGE)

ATP

DURING ATP PROOF PRESSURE TEST, EXCESSIVE LEAKAGE PAST THE ACTUATOR SEAL WAS NOTED (REF CAR A9705). TEARDOWN REVEALED A SCRATCH ON THE PISTON SEAL. THE SEAL WAS REPLACED AND ACTUATOR MET LEAKAGE REQUIREMENTS. CORRECTIVE ACTION WAS TO INCORPORATE A MANDATORY INSPECTION POINT OF THE SEALS PRIOR TO INSTALLATION.

QUALIFICATION

DURING QUALIFICATION TEST, ACTUATOR LEAKAGE WAS OBSERVED (REF CAR A9894). X-RAY OF THE ACTUATOR REVEALED A BROKEN RACK/PISTON SPRING. UPON TEARDOWN, A BROKEN STATIC SEAL WAS ALSO FOUND. FAILURE ANALYSIS OF THE SPRING DETERMINED THAT THE SPRING FAILED FROM IMPACT EMBRITTLEMENT. THE ACTUATOR SPRING MATERIAL WAS CHANGED FROM TITANIUM TO ELGILOY AND REDUNDANT ACTUATOR STATIC SEALS WERE ADDED. THE QUAL UNIT WAS REWORKED AND SUCCESSFULLY RETESTED.

DURING QUALIFICATION TEST AT CRYO TEMPERATURE, THE ACTUATOR SHAFT SEAL LEAKAGE WAS 400 SCIM, MAX ALLOWABLE IS 100 SCIM (REF CAR AC6963). THE CAUSE ATTRIBUTED TO NORMAL INTERNAL WEAR IN COMBINATION WITH MIGRATING LUBRICANT. THE SPECIFICATION FOR MAXIMUM ACTUATOR SHAFT SEAL LEAKAGE WAS REVISED TO 500 SCIM (TYPE II VALVES ONLY), TO BE MEASURED AFTER EXPOSURE TO QUALIFICATION VIBRATION TEST.

DURING CRYOGENIC QUAL TESTING, ACTUATOR PISTON SEAL LEAKAGE OF 130 SCIM WAS NOTED. MAX ALLOWABLE IS 100 SCIM (REFERENCE CAR AB1806). THE LEAKAGE WAS DUE TO METALLIC PARTICLE GENERATION DURING ASSEMBLY FROM IMPROPERLY CLEANED PARTS CAUSING GALLING DURING ASSEMBLY. SUPPLIER ACTUATOR ASSEMBLY PROCEDURE PS-352M WAS CHANGED TO ADD CAUTION AND INSPECTION NOTE.

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DURING QUALIFICATION TESTING, ACTUATOR PISTON SEAL LEAKAGE OF 200 SCIM WAS DETECTED. MAX ALLOWABLE IS 100 SCIM. LEAKAGE WAS DUE TO METALLIC PARTICLES GENERATED DURING ASSEMBLY WITH AN INADEQUATE ASSEMBLY TOOL. REDESIGNED TOOL ELIMINATED THE PROBLEM (REFERENCE CAR AB0197).

DURING QUALIFICATION TESTING, LEAKAGE AT THE ACTUATOR PISTON SEAL RETAINER INTERFACE WAS 560 SCIM. MAX ALLOWABLE IS 100 SCIM (REFERENCE ARE AB0088). LEAKAGE WAS DUE TO INSUFFICIENT SEAL RETAINER TORQUE OF 70 FT-LBS. ASSEMBLY TORQUE WAS INCREASED TO 95 - 100 FT-LBS WITH REPEAT APPLICATIONS AT 5 MINUTE INTERVALS UNTIL SUB-ASSEMBLY STOPS MOVING. IMPLEMENTED OV-102 AND SUBS.

FIELD

DURING MPTA CHECKOUT, HELIUM WAS LEAKING THROUGH THE VENT PORT OF THE ACTUATOR CAUSING THE VALVE TO FAIL TO REMAIN OPEN (REF CAR A9630). DURING DISASSEMBLY, IT WAS FOUND THAT THE STATIC SEAL WAS PROTRUDING OUTSIDE ITS RETAINER AREA AND THAT THE SEAL RETAINER TORQUE WAS LOW. IT WAS CONCLUDED THAT THE ACTUATOR STATIC SEAL RETAINER TORQUE RELAXES EITHER FROM SEAL MATERIAL COLD FLOW OR RETAINER BACKING OFF. THE VALVE WAS REDESIGNED TO ADD REDUNDANT ACTUATOR SEALS AND LOCKTITE IS APPLIED TO THE RETAINER TO PREVENT TORQUE RELAXATION AND A SERIES OF RETORQUING TO MINIMIZE COLD FLOW. THE VALVE WAS REWORKED AND PASSED SUBSEQUENT LEAKAGE TESTS.

AT PALMDALE ACTUATOR LEAKAGE OCCURRED FROM UNDER THE ENDCAP OF THE ACTUATOR (REFERENCE CAR AD2446). THE ORIGIN OF THE LEAK WAS DUE TO TWO DAMAGED GASKETS P/N 1397-60 AND A SEAL P/N 1397-29-2. THE FAILURE WAS DUE TO A FAILURE TO BACK UP THE END CAP ON THE ACTUATOR WHILE TURNING A LINE FITTING DURING THE INSTALLATION OF THE VALVE. GASKETS AND SEAL REPLACED. NO FURTHER ACTION REQUIRED.

DURING CHECKOUT AT PALMDALE ON OV-099, THE ACTUATOR END CAP LEAKED EXCESSIVELY (REFERENCE CAR AC2152). NEW SEALS AND END CAP WERE INSTALLED ON THE VEHICLE BY THE SUPPLIER AND PASSED SUBSEQUENT LEAK TEST. CAUSE FOR LEAKAGE WAS NOT DETERMINED.

FAILS TO REMAIN OPEN

THERE HAVE BEEN NO ACCEPTANCE TEST, QUALIFICATION TEST, FIELD OR FLIGHT FAILURES ASSOCIATED WITH THE VALVE FAILING TO REMAIN OPEN EXCEPT FOR ACTUATOR LEAKAGE (NOTED ABOVE).

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 -

| | | |
|---------------------|------------------------|---------------------------|
| 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 | : EARL HIRAKAWA | :/S/ EARL HIRAKAWA |
| 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 |