

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0602 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 07/26/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	: REGULATOR, PURGE, 20 PSI VACCO INDUSTRIES	MC284-0399-0004 76500-0004

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

REGULATOR, HELIUM, LO2 MANIFOLD REPRESSURIZATION 20 PSIG (0.5 INCH DIA INLET, 0.75 INCH DIA OUTLET, 0.25 INCH DIA SENSE PORT).

REFERENCE DESIGNATORS: PR5

QUANTITY OF LIKE ITEMS: 1

FUNCTION:

REGULATES THE HELIUM SUPPLY PRESSURE FROM 750 PSI DOWN TO A LOWER PRESSURE TO PURGE THE MPS LO2 FEED AND PRESSURIZATION SYSTEMS FOLLOWING ENGINE SHUTDOWN AND TO PROVIDE FOR SYSTEM REPRESSURIZATION DURING ENTRY. SENSES LO2 MANIFOLD PRESSURE TO CONTROL PURGE FLOW. REGULATOR OPENS AT MANIFOLD PRESSURES BELOW 17 PSI AND CLOSSES AT PRESSURES ABOVE 30 PSI.

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REVISION#: 2 02/08/02

SUBSYSTEM NAME: MAIN PROPULSION

LRU: REGULATOR, PURGE, 20 PSI

CRITICALITY OF THIS

ITEM NAME: LO2 MANIFOLD 20 PSIG REPRESS REG (PR5)

FAILURE MODE: 1R2

FAILURE MODE:

FAILS OPEN/HIGH OUTLET PRESSURE

MISSION PHASE:

PL PRE-LAUNCH
LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA
103 DISCOVERY
104 ATLANTIS
105 ENDEAVOUR

CAUSE:

BINDING, PIECE PART STRUCTURAL FAILURE, CONTAMINATION

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN

A) PASS
B) FAIL
C) PASS

PASS/FAIL RATIONALE:

A)

B)

FAILS B SCREEN DUE TO LACK OF APPROPRIATE INSTRUMENTATION.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

NO EFFECT. THE SERIES REDUNDANT VALVES (LV40, LV41) WILL PREVENT LEAKAGE OF GHE INTO THE MANIFOLD.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

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NO EFFECT.

(D) CREW, VEHICLE, AND ELEMENT(S):
SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

CASE 1:

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

- 1) LO2 REPRESS TOGGLE SWITCH (PANEL R4, S1) FAILS OPEN, RESULTING IN OPENING OF REPRESS ISOLATION VALVES, LV40 AND LV41.
- 2) LO2 REPRESS REGULATOR (PR5) FAILS WIDE OPEN (MAXIMUM FLOW).

RESULTS IN HELIUM ENTERING THE FEEDLINE MANIFOLD. THIS MAY CAUSE MULTIPLE UNCONTAINED ENGINE FAILURES DUE TO HELIUM BUBBLE INGESTION AND TURBOPUMP CAVITATION. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

1R2 2 SUCCESS PATHS. TIME FRAME - MANIF REPRESS DURING ENTRY.

- 1) REGULATOR FAILS OPEN.
- 2) MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

POSSIBLE OVERPRESSURIZATION AND RUPTURE OF THE LO2 FEED MANIFOLD. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

THE 20 PSI HELIUM REGULATOR IS A PILOT OPERATED PRESSURE CONTROL VALVE THAT REGULATES 750 PSI HELIUM TO 17-30 PSIG IN THE O2 AND H2 PROPELLANT FEED MANIFOLDS.

WHEN THE MANIFOLD PRESSURE FALLS BELOW 17 PSIG THE SENSOR DIAPHRAGM COLLAPSES, PUSHING THE PILOT VALVE OPEN. THIS ACTION RELIEVES PRESSURE ON THE CLOSING SIDE OF THE MAIN POPPET AND ALLOWS INLET PRESSURE TO OPEN THE MAIN POPPET. WHEN THE SENSE PRESSURE REACHES 17- 30 PSIG, THE DIAPHRAGM EXPANDS CLOSING THE PILOT POPPET. THIS ALLOWS INLET PRESSURE TO THE CLOSING SIDE OF THE POPPET CLOSING THE MAIN POPPET. THE REGULATOR ALSO CONTAINS AN INTERNAL RELIEF VALVE THAT RELIEVES THE OUTLET PRESSURE THROUGH THE SENSE PORT AT PRESSURES BETWEEN 160 AND 200 PSID.

STRUCTURAL FAILURE OF THE MAIN SPRING, THE PILOT SPRING, THE SENSOR DIAPHRAGM, OR THE ISOLATION BELLOWS COULD CAUSE THIS FAILURE MODE. IT IS UNLIKELY FOR THE CRES 302 SPRINGS TO FAIL DUE TO THEIR LOW DESIGN LOADS. THE MOST LIKELY FAILURE OF THE THIN SENSOR DIAPHRAGM OR BELLOWS WOULD BE DUE TO CYCLIC FATIGUE. TO PREVENT THIS, THE DIAPHRAGM IS MADE FROM 347 CRES AND THE BELLOWS FROM 304 CRES. BOTH MATERIALS ARE KNOWN FOR THEIR HIGH CYCLIC FATIGUE LIMIT CAPABILITIES.

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FOR THE REGULATOR TO FAIL OPEN DUE TO BINDING, THE MAIN POPPET RINGS OR BEARINGS WOULD HAVE TO BE GALLED OR DAMAGED. THIS WOULD CAUSE EXCESSIVE FRICTION AND RESTRICT THE POPPET MOVEMENT. THE PILOT SECTION IS PROTECTED FROM BINDING BY THE USE OF FLEXURES IN THE BELLOWS AND PILOT POPPET AREAS TO ALLOW FOR FREE MOVEMENT. IT IS UNLIKELY FOR BINDING OF THE RINGS OR BEARINGS TO OCCUR BECAUSE OF THE LARGE 27 LBS FORCE DIFFERENTIAL ON THE POPPET. HOWEVER, TO PROTECT AGAINST THIS TYPE OF FAILURE, THE RINGS ARE MADE FROM TFE TEFLON, AND THE BEARINGS ARE MADE FROM VESPEL. THE RINGS AND BEARINGS SLIDE AGAINST 6061 ALUMINUM.

FOR THE REGULATOR TO FAIL OPEN DUE TO CONTAMINATION, THE MOST OBVIOUS AREA IS A CONTAMINATED MAIN POPPET SEAT. CONTAMINATION OF THIS TYPE IS PROTECTED AGAINST BY MULTI-FILTRATION OF THE SYSTEM HELIUM. THE HELIUM USED TO CHARGE THE PNEUMATICS SUPPLY IS FILTERED BY THE GROUND SYSTEM. THE HELIUM FROM THE PNEUMATICS SUPPLY IS FILTERED TO 25 MICRONS ABSOLUTE UPSTREAM OF THE 750 PSI REGULATOR. ANOTHER AREA OF CONCERN IS THE PILOT SEAT. A LEAKY PILOT WOULD ALLOW THE MAIN POPPET BACK PRESSURE TO BUILD UP, PREVENTING THE MAIN POPPET FROM CLOSING. THIS SEATING AREA IS PROTECTED FROM CONTAMINATION BY A REGULATOR INTERNAL FILTER ASSEMBLY.

THE REGULATOR SENSE PORT AND THE CONNECTING SENSE LINE IS A VIRTUAL NO-FLOW SYSTEM. ITS PURPOSE IS TO SENSE AND TRANSMIT PRESSURE CHANGES. IT IS POSSIBLE THAT CONTAMINATION MAY ENTER THE SENSE LINE AND/OR THE REGULATOR, BUT IT IS NOT PROBABLE THAT THE CONTAMINATION WOULD BE OF SUFFICIENT QUANTITY OR DENSITY TO PREVENT THE TRANSMISSION OF PRESSURE CHANGES. THE INTERNAL PASSAGES WITHIN THE REGULATOR FROM THE SENSE PORT ARE 0.093 INCH DIAMETER AND APPROXIMATELY 2.5 INCHES IN LENGTH. THE LINE FROM THE SENSE PORT TO ITS SENSING LOCATION IS 0.25 INCH DIAMETER AND APPROXIMATELY THREE FEET IN LENGTH.

(B) TEST:

ATP

AMBIENT TEMPERATURE TESTS

PROOF PRESSURE (1700 PSIG INLET, 580 PSIG OUTLET AND SENSE)

INTERNAL LEAKAGE

INLET TO OUTLET (850 AND 500 PSIG INLET, 30 PSIG SENSE)

INLET TO SENSE (850 AND 500 PSIG INLET)

SENSE TO INLET (180 PSIG SENSE)

EXTERNAL LEAKAGE (850 PSIG INLET, 285 PSIG OUTLET AND SENSE)

FUNCTIONAL

REGULATION (500 TO 850 PSIG INLET PRESSURE AND 17 TO 30 PSIG SENSE PRESSURE)

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TRANSIENT RESPONSE (SLAM START WITH 500 AND 850 PSIG INLET AND 17 TO 30 PSIG SENSE)

ELECTRICAL BONDING

LOW TEMPERATURE TESTS (-140 DEG F MAX FLUID TEMPERATURE AND BODY TEMPERATURE -100 DEG F MAX)

INTERNAL LEAKAGE

INLET TO OUTLET (850 AND 500 PSIG INLET, 30 PSIG SENSE)
INLET TO SENSE (850 AND 500 PSIG INLET)
SENSE TO INLET (180 PSIG SENSE)

FUNCTIONAL TEST

REGULATION (500 TO 850 PSIG INLET PRESSURE AND 17 TO 30 PSIG SENSE PRESSURE)

TRANSIENT RESPONSE (SLAM START WITH 500 AND 850 PSIG INLET AND 17 TO 30 PSIG SENSE)

CERTIFICATION

TWO UNITS CERTIFIED

VIBRATION AND SHOCK TESTING

RANDOM VIBRATION - 13.3 HOURS IN EACH OF TWO AXES (REGULATOR CENTERLINE AXIS AND MOUNTING HOLE CENTERLINE) [TWO UNITS]
ONE UNIT PRESSURIZED TO 190 PSIG (ALL PORTS)
ONE UNIT PRESSURIZED TO 34 PSIG (ALL PORTS)

TRANSIENT VIBRATION - 5 TO 35 HZ AT + 0.25 G IN EACH OF TWO AXES WITH THE INLET AND OUTLET PORTS PLUGGED. [TWO UNITS]
ONE UNIT WITH SENSE PORT PRESSURIZED TO 190 PSIG
ONE UNIT WITH SENSE PORT PRESSURIZED TO 34 PSIG

DESIGN SHOCK - PER MIL-STD-810 IN EACH OF 2 AXES. [TWO UNITS]

PERFORM AMBIENT INTERNAL AND EXTERNAL LEAKAGE AND FUNCTIONAL TESTS (SEE ATP ABOVE) AFTER VIBRATION AND SHOCK TESTING IN EACH AXIS.

THERMAL CYCLE TEST - WITH INLET AT 750 PSIG AND THE REGULATOR FLOWING, CYCLE +70 F TO -140 F TO +250 F TO -140 F TO +250 F TO -140 F TO +250 F TO -140 F TO 70 F. UPON COMPLETION, PERFORM AMBIENT INTERNAL AND EXTERNAL LEAKAGE AND FUNCTIONAL TESTS (SEE ATP ABOVE). [ONE UNIT]

LIFE CYCLE TESTS

1500 TRANSIENT CYCLES
INCREASE INLET PRESSURE FROM 0 TO 850 PSIG IN 8 MS MAXIMUM

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PERFORM AMBIENT INTERNAL AND EXTERNAL LEAKAGE TESTS AFTER EACH 500 CYCLES.

50 CYCLES

DECAY THE INLET PRESSURE FROM 850 PSIG TO 30 PSIG WITH THE OUTLET PLUGGED.

MAX FLOW TEST

700 PSIG INLET PRESSURE, MAX FLOW RATE OF 0.32 LB/SEC GHE, MEDIA TEMPERATURE 80 DEG F

UPON COMPLETION OF ALL CYCLING, PERFORM AMBIENT AND LOW TEMPERATURE INTERNAL AND EXTERNAL LEAKAGE, AND LOW TEMPERATURE FUNCTIONAL TESTS.

BURST TEST - 3400 PSIG (INLET), 1140 PSIG (OUTLET AND SENSE) ONE UNIT

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:

RECEIVING INSPECTION

INCOMING MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION.

CONTAMINATION CONTROL

ALL PARTS ARE CLEANED PRIOR TO ASSEMBLY AND ARE MAINTAINED TO CLEANLINESS LEVEL 100A.

ASSEMBLY/INSTALLATION

ALL PARTS AND ASSEMBLIES ARE VISUALLY INSPECTED AND CRITICAL DIMENSIONS ARE CHECKED BY 40X MICROSCOPE. PRIOR TO ASSEMBLY, TESTS ARE PERFORMED TO PRECLUDE FAILURES OF THE MAIN POPPET STATIC SEAL, BELLOWS ASSEMBLY AND BELLEVILLE SPRINGS. TORQUING AND LOCKWIRING ARE VERIFIED PER APPLICABLE REQUIREMENTS. ALL MANDATORY INSPECTION POINTS ARE INCLUDED TO ENSURE THAT CORRECT MANUFACTURING PROCEDURES ARE FOLLOWED.

CRITICAL PROCESSES

ALL SOLDERING IS PERFORMED BY CERTIFIED PERSONNEL AND IS VERIFIED BY INSPECTION. SEALS ARE VISUALLY EXAMINED PRIOR TO INSTALLATION FOR DAMAGE. ALL CRES DETAILS ARE PASSIVATED TO PRECLUDE CORROSION. TIG WELDED PARTS ARE WITNESSED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

HELIUM LEAK DETECTION IS VERIFIED BY INSPECTION. WELDING SAMPLES ARE EXAMINED AND VERIFIED BY INSPECTION. SEALS ARE VISUALLY EXAMINED PRIOR TO INSTALLATION FOR DAMAGE. ALL CRES DETAILS ARE PASSIVATED TO PRECLUDE CORROSION.

TESTING

ATP IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING

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PACKAGING FOR SHIPMENT IS VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

DURING ATP, TWO REGULATORS FAILED INTERNAL LEAKAGE REQUIREMENTS (REFERENCE CAR A5761). THE SUPPLIER CONTRACT WAS CANCELLED AND DELIVERED HARDWARE WAS BOUGHT ON WAIVERS TO BE USED FOR MPTA USE ONLY. FLIGHT HARDWARE OF A COMPLETELY DIFFERENT DESIGN WAS BOUGHT FROM A DIFFERENT SUPPLIER (CONSOLIDATED CONTROLS).

DURING ATP SLAM START TEST ON THE FIRST CONSOLIDATED CONTROLS UNIT, THE OUTLET PRESSURE REGULATED HIGH DUE TO A DAMAGED PISTON RING SEAL (REFERENCE CAR A9929). THE SEAL DAMAGE MAY HAVE OCCURRED DURING A PREVIOUS DISASSEMBLY OF THE REGULATOR. THE SEAL WAS REPLACED AND ATP WAS PASSED.

DURING QUAL TEST A UNIT FAILED TO LOCK UP (DR AB4064). TWO PIECES OF AN O-RING WERE FOUND LODGED IN THE POPPET SEAT. THE SOURCE OF THE O-RING WAS DETERMINED TO BE THE TEST STAND. SUBSEQUENT LEAK CHECKS MET ALL SPECIFICATION REQUIREMENTS. PRECAUTIONARY MEASURES WERE TAKEN TO PREVENT FURTHER CONTAMINATION.

GENERAL SYSTEM CONTAMINATION

THIS FAILURE MODE HAS OCCURRED ON THIS COMPONENT DUE TO CONTAMINATION. ADDITIONALLY, GENERAL MPS SYSTEM CONTAMINATION HAS OCCURRED WHICH MAY LODGE ANYWHERE IN THE SYSTEM CAUSING THIS FAILURE MODE (REFERENCE THE FOLLOWING PARAGRAPHS).

CONTAMINATION FAILURES HAVE OCCURRED AT ALL PHASES OF MANUFACTURING AND PARTS REPLACEMENT. IN ALL CASES, STRICT ADHERENCE TO CLEANLINESS CONTROL PROCEDURES IS THE PRIMARY METHOD OF CONTAMINATION PREVENTION.

NUMEROUS LARGE PARTICLES OF BLACK RUBBER MATERIAL WERE FOUND DURING A POST FLIGHT EXAMINATION OF THE LH2 17 INCH DISCONNECT OF OV099 (FLIGHT 7, REFERENCE CAR AC9800). THE LO2 AND LH2 SYSTEMS OF ALL VEHICLES WERE EXAMINED. NO RUBBER WAS FOUND IN ANY OTHER VEHICLES. AFTER EXTENSIVE INVESTIGATION THE ORIGIN WAS NOT DETERMINED.

METAL SHAVINGS HAVE BEEN DISCOVERED IN LINES AND COMPONENTS, WHICH WAS MOST LIKELY GENERATED WHEN THEY WERE CUT OUT AND/OR REPLACED (REFERENCE CARS AC9868, A9654, AC2210, AB1706; DR AD2226). METHODS ARE BEING REVISED TO MINIMIZE PARTICLE GENERATION WHEN INSTALLING/REPLACING COMPONENTS, LINES, AND FITTINGS REQUIRING WELDED OR BRAZED JOINTS (PRODUCT QUALITY IMPROVEMENT COUNCIL). PERSONNEL HAVE BEEN CAUTIONED. ROCKWELL PROBLEM ACTION CENTER WILL CONTINUE TO MONITOR BRAZING/WELDING REWORK CONTAMINATION. PROCEDURES ARE BEING REVISED TO IMPROVE CLEANLINESS MAINTENANCE DURING COMPONENT BUILD UP AND REWORK (REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

A PIECE OF A BRAZING PREFORM LODGED IN A 2-WAY SOLENOID VALVE ON OV- 099 AT PALMDALE CAUSING A LEAKAGE FAILURE (REFERENCE CARS AC2111, AB2538). STEEL AND ALUMINUM PARTICLES CAUSED EXCESSIVE LEAKAGE ON THE 850 PSIG HELIUM RELIEF VALVE

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(REF CAR AC2229). FOR BOTH FAILURES CORRECTIVE ACTION WAS TO ADD SPECIAL PURGE PORTS TO THE MPS HELIUM PANEL ASSEMBLIES TO IMPROVE THE QUALITY OF FINAL CLOSEOUT BRAZES.

SEVERAL FOREIGN MATERIALS WERE INTRODUCED INTO THE MPS SYSTEM DURING MANUFACTURE AND PARTS REPLACEMENT. EXAMPLES ARE: GLASS CLOTH IN LINE TO PREVENT TRAVEL OF CHIPS DOWN LINE; POLYSTYRENE OBJECT TO HOLD VALVE POPPET OPEN WHILE PURGING; COTTON SWAB MATERIAL AND GLASS BEADS FROM CLEANING OPERATION; MISCELLANEOUS PLASTIC; FOAM; AND TAPE (REFERENCE CARS AB4751, AC2217, AC6768, AC9868, MPS3A0005, AC7912, AB0530). MATERIALS WERE REMOVED AND PERSONNEL WERE CAUTIONED. A HIGH FLOW DELTA P TEST AT PALMDALE WAS ADDED TO VERIFY THAT LINES WERE NOT PLUGGED. GRIT BLASTING (GLASS BEADS AND SAND USED TO CLEAN A LINE) IS NO LONGER PERFORMED. PROCEDURES ARE BEING REVISED TO IMPROVE CLEANLINESS MAINTENANCE DURING COMPONENT BUILD UP AND REWORK (REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

ONE PIECE OF WIRE WAS FOUND IN THE INTERNAL RELIEF VALVE OF THE LO2 PREVALVE ON OV103 (REFERENCE CAR AC9101). THE SOURCE OF THE CONTAMINATION WAS NEVER FOUND, BUT IT WAS BELIEVED TO BE FROM THE ET. OTHER CONTAMINATION HAS BEEN FOUND ON THE FEEDLINE SCREENS, SUCH AS AN UNIDENTIFIED ROUND OBJECT AND VARIOUS METALLIC PARTICLES (REFERENCE CARS AB0529 AND AB0530). SOURCE OF CONTAMINATION WAS UNDETERMINED. BORESCOPE EXAMINATIONS ARE CONDUCTED ON ALL FEEDLINE SCREENS EVERY FIFTH FLIGHT TO VERIFY CLEANLINESS. CONTAMINATION WAS REMOVED WHEN POSSIBLE.

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:

PNEUMATIC ACTUATION HELIUM BOTTLE PRESSURE IS ON A DEDICATED DISPLAY IN COCKPIT. CREW ACTION IS TO FOLLOW NORMAL LEAK ISOLATION PROCEDURE. PRIOR TO MECO, ISOLATION VALVES (LV7, LV8) WILL BE REOPENED AND THE LEFT ENGINE HELIUM CROSSOVER VALVE (LV10) WILL BE OPENED.

PNEUMATIC TANK, REGULATOR, AND ACCUMULATOR PRESSURE ARE ON S/M ALERT FDA SYSTEM AND THE BFS SYSTEM SUMMARY DISPLAY. THIS ALLOWS THE FLIGHT CREW TO RESPOND TO A PNEUMATIC HELIUM SYSTEM LEAK INDEPENDENT OF GROUND CONTROL.

- 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	: CHARLES EBERHART	:/S/ CHARLES EBERHART
MPS SUBSYSTEM MGR.	: TIM REITH	:/S/ TIM REITH
MOD	: JEFF MUSLER	:/S/ JEFF MUSLER
USA SAM	: MICHAEL SNYDER	:/S/ MICHAEL SNYDER

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USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	:/S/ BILL PRINCE