FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0238 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 07/24/00

PART DATA

	PART NAME / **VENDOR NAME**	**PART NUMBER** / **VENDOR NUMBER**
LRU	:PNEUMATIC ISOLATION VALVE, HIGH PRESSURE TWO WAY SOLENOID VALVE, NC TYPE 1	MC284-0403-0021
	UNITED SPACE ALLIANCE - NSLD	12199-5

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
VALVE (LV7,8), 2-WAY, PILOTED SOLENOID, PNEUMATIC HELIUM SUPPLY ISOLATION, NORMALLY CLOSED (0.5 INCH DIA).

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY WRIGHT COMPONENTS (NOW PERKIN ELMER) BUT IS NOW MANUFACTURED BY UNITED SPACE ALLIANCE-NSLD AS AN ALTERNATE PRODUCTION AGENCY.

REFERENCE DESIGNATORS: LV7, LV8

QUANTITY OF LIKE ITEMS: 2

FUNCTION:
THE PARALLEL REDUNDANT VALVES ISOLATE THE PNEUMATIC HELIUM SUPPLY FROM THE REMAINDER OF THE SYSTEM AND ASSURE A HELIUM SUPPLY FOR MPS VALVE ACTUATION. THE VALVES ARE OPEN FROM PRELAUNCH THROUGH VACUUM INERTING AND AGAIN FOR ENTRY PURGE.

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NUMBER: 03-1-0238-06

REVISION#: 2 07/24/00

SUBSYSTEM NAME: MAIN PROPULSION
LRU: MPS PNEU GHE SUPPLY ISO SOL VLV (LV7, 8) **CRITICALITY OF THIS**
ITEM NAME: MPS PNEU GHE SUPPLY ISO SOL VLV (LV7, 8) **FAILURE MODE:** 1R3

FAILURE MODE:
EXTERNAL LEAKAGE THROUGH THE PILOT VENT PORT

MISSION PHASE: LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:
102 COLUMBIA
103 DISCOVERY
104 ATLANTIS
105 ENDEAVOUR

CAUSE:
PIECE PART STRUCTURAL FAILURE, BINDING, CONTAMINATION

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN
A) PASS
B) PASS
C) PASS

PASS/FAIL RATIONALE:
A)

B)
PASSES B SCREEN BECAUSE PNEUMATIC HELIUM SUPPLY PRESSURE WILL DECAY.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
PNEUMATIC HELIUM SUPPLY WILL BE LOST (ASSUMES 13 LBS HELIUM IN PNEUMATIC BOTTLE, 0.03 LB/SEC LEAK RATE).

(B) INTERFACING SUBSYSTEM(S):
SAME AS A.

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(C) MISSION:
NO EFFECT.

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

(E) FUNCTIONAL CRITICALITY EFFECTS:
1R/3 3 SUCCESS PATHS. TIME FRAME - MECO.

1) EXTERNAL LEAK THROUGH PILOT VENT PORT.
2) HELIUM LEAK IN THE ACCUMULATOR LEG (ASSUMES LEAK RATE IS NOT SUFFICIENT TO OVERPRESSURIZE THE AFT COMPARTMENT).
3) ENGINE 2/PNEUMATIC CROSSOVER VALVE FAILS TO OPEN WHEN COMMANDED BY CREW. CREW WILL OPEN LV10 AT MECO-30 SECONDS WHEN PNEUMATIC ACCUMULATOR PRESSURE FALLS BELOW 700 PSIA.

LOSS OF PNEUMATIC ACTUATION HELIUM RESULTS IN LO2 PREVALVE FAILING TO CLOSE AND INABILITY TO MAINTAIN INJECTED HELIUM AND LO2 PRESSURE TO THE HIGH PRESSURE OXYGEN TURBOPUMP TO PREVENT PUMP OVERSPEED AND CAVITATION AT MECO. RESULTS IN UNCONTAINED ENGINE DAMAGE, AFT COMPARTMENT OVERPRESSURIZATION, AND FIRE/EXPLOSION HAZARD. AT MECO, THE ENGINE 2 HELIUM SUPPLY IS SWITCHED IN TO THE PNEUMATIC VALVE SYSTEM (VIA LV10) AS A BACKUP, BY SOFTWARE COMMAND, WHICH MAY ACTUATE THE LO2 PREVALVES CLOSED. POSSIBLE LOSS OF CREW/VEHICLE.

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

(F) RATIONALE FOR CRITICALITY DOWNGRADE:
700 PSIA IS THE LEVEL WHICH SETS OFF THE CAUTION AND WARNING SYSTEM. FLIGHT RULE A5.1.4-1C WILL HAVE THE CREW OPEN THE ENGINE 2/PNEUMATIC CROSSOVER VALVE AT MECO-30 SECONDS TO MAINTAIN SUFFICIENT HELIUM SUPPLY PRESSURE TO CLOSE LO2 PREVALVES AND PROVIDE HELIUM FOR RE-ENTRY PURGE.

-DISPOSITION RATIONALE-

(A) DESIGN:
THE VALVE IS A PILOT OPERATED SOLENOID VALVE CONTROLLING THE APPLICATION OF VALVE INLET PRESSURE TO THE POPPET. THE POPPET IS PART OF A RING ASSEMBLY (PISTON) THAT IS SPRING LOADED TO THE CLOSED POSITION. THE VALVE INLET PRESSURE IS ALWAYS EXERTING AN OPENING FORCE ON THE PISTON. WHEN THE SOLENOID IS DEENERGIZED, THE PILOT VALVE DIRECTS THE INLET PRESSURE TO THE CLOSING SIDE OF THE POPPET, UNBALANCING THE FORCE FROM THE INLET SIDE. THIS ALLOWS THE SPRING

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FORCE PLUS THE PRESSURE- AREA DIFFERENTIAL FORCE TO HOLD THE VALVE CLOSED. WHEN THE SOLENOID IS ENERGIZED, THE PILOT VALVE VENTS THE PRESSURE AT THE CLOSING SIDE OF THE PISTON TO AMBIENT. THIS ALLOWS THE INLET PRESSURE TO OVERCOME THE VALVE SPRING FORCE AND OPEN THE VALVE.

THE PILOT VALVE UTILIZES A 430 CRES BALL AS A CLOSURE DEVICE SEALING AGAINST EITHER OF TWO 17-4PH CRES SEATS. IN THE DEENERGIZED STATE, THE BALL IS HELD AGAINST THE CLOSING SEAT BY A SPRING ACTIVATED PUSHROD.

EXTERNAL LEAKAGE THROUGH THE PILOT VENT WOULD MEAN THE PILOT BALL IS NOT SEALED AGAINST THE CLOSING SEAT DUE TO STRUCTURAL FAILURE OF THE (1) BALL OR (2) PILOT SPRING OR (3) PUSH ROD, OR DUE TO (4) CONTAMINATION BETWEEN THE BALL AND SEAT. LEAKAGE PAST THE (5) INTERNAL SEALS OF THE VALVE COULD ALSO ACCOUNT FOR LEAKAGE OUT THE VENT PORT.

1) THE PILOT BALL IS A STANDARD MS PART MANUFACTURED FROM 430 CRES.

2) THE PILOT SPRING IS MANUFACTURED FROM 0.026 INCH DIAMETER 17-4PH CRES WIRE. THE SPRING HAS A RATE OF 50 POUNDS PER INCH AND, IN THE INSTALLED CONDITION, EXERTS A FORCE OF 6.5 POUNDS. THE SPRING IS HEAT TREATED FOLLOWING FORMING. IF THE SPRING WERE TO FAIL STRUCTURALLY (OTHER THAN DISINTEGRATION) IT WOULD CONTINUE TO EXERT FORCE ON THE BALL BECAUSE IT IS 100% CONTAINED IN THE PILOT SLEEVE (THE SPRING OD IS 0.126 INCH AND THE SLEEVE ID IS 0.128 INCH).

3) THE PUSHROD, WHICH CARRIES ONLY AXIAL LOADS, IS MACHINED FROM 17-4PH CRES AND IS HEAT TREATED AND PASSIVATED FOLLOWING MACHINING. IF THE ROD WERE TO FAIL STRUCTURALLY (PARTICULARLY IN THE FULL-DIAMETER PORTION OF THE SHAFT), IT WOULD CONTINUE TO PERFORM ITS FUNCTION BECAUSE IT IS 75% CONTAINED IN THE PILOT SLEEVE (THE ROD OD IS 0.126 INCH AND THE SLEEVE ID IS 0.128 INCH). WITHIN THE REMAINING 25%, THE ROD TAPERS TO A DIAMETER OF 0.030 INCH. THIS PORTION OF THE ROD PASSES THROUGH THE LOWER SEAT (WHICH GUIDES IT) TO MAKE CONTACT WITH THE BALL.

4) CONTAMINATION UNDER THE PILOT BALL IS A DESIGN CONCERN. THEREFORE, ALL HELIUM ENTERING THE PILOT AREA OF THE VALVE MUST FIRST PASS THROUGH A 15 MICRON NOMINAL (25 MICRON ABSOLUTE) RATED FILTER INTERNAL TO THE SOLENOID VALVE.

5) THE HIGH PRESSURE AND VENTED PORTIONS OF THE VALVE ARE SEALED FROM ONE ANOTHER BY USE OF SOFT SILVER PLATED, INCONEL "V" SEALS.

THE VENT PORT CHECK VALVE WAS REDESIGNED TO PREVENT THE POPPET FROM BEING EJECTED DUE TO SHEARING OF THE RETAINING NUT THREAD. A PIN WAS ADDED TO THE CHECK VALVE HOUSING, WHICH RETAINS THE POPPET WITHIN THE CHECK VALVE HOUSING. A NEW ALUMINUM NUT, WHICH PROVIDE A MINIMUM ENGAGEMENT OF THREE THREADS, WAS UTILIZED TO INCREASE RELIABILITY.

(B) TEST:
ATP

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EXAMINATION OF PRODUCT

AMBIENT TEMPERATURE TESTS:

PROOF PRESSURE (9000 PSIG)
EXTERNAL LEAKAGE (4500 PSIG)
INTERNAL LEAKAGE (4500 PSID, ENERGIZED AND DEENERGIZED)
CHECK VALVE LEAKAGE (15 PSID)
ELECTRICAL CHARACTERISTICS
(PULL-IN/DROPOUT VOLTAGE, CURRENT SIGNATURE)
VALVE RESPONSE TIMES (4500 PSIG)

REDUCED TEMPERATURE TESTS (-160 DEG F):

INTERNAL LEAKAGE (4500 PSID, ENERGIZED AND DEENERGIZED)
ELECTRICAL CHARACTERISTICS (PULL-IN/DROPOUT VOLTAGE)
VALVE RESPONSE TIMES (4500 PSIG)

ELECTRICAL TESTS:

ELECTRICAL BONDING
DIELECTRIC WITHSTANDING VOLTAGE
INSULATION RESISTANCE

SOLENOID SUBASSEMBLY TESTS:

ELECTRICAL CHARACTERISTICS
ENCLOSURE LEAKAGE (1 ATMOSPHERE DIFFERENTIAL)

CERTIFICATION

SALT FOG TEST (1 UNIT)

PER MIL-STD-810
AMBIENT PERFORMANCE TEST
ELECTRICAL CHARACTERISTIC
VALVE RESPONSE

SHOCK (1 UNIT)

PER MIL-STD-810
BENCH HANDLING
DESIGN

CONTINUOUS CURRENT TEST (2 UNITS)

50 HOURS WITH SOLENOID ENERGIZED
TEMPERATURE: +130 DEG F SURROUNDING ENVIRONMENT
INSULATION RESISTANCE TEST (+130 DEG F MAINTAINED)
INSULATION RESISTANCE TEST (AMBIENT TEMPERATURE)

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VIBRATION (2 UNITS)

TRANSIENT: 5 TO 35 HZ

RANDOM (AMBIENT HELIUM):
INLET PRESSURE: 4500 PSIG
108 MINUTES FOR EACH OF 2 AXES
15 MINUTES ENERGIZED
15 MINUTES VALVE CYCLE (1 CYCLE/MINUTE)
78 MINUTES DEENERGIZED

ELECTRICAL CHARACTERISTICS, VALVE RESPONSE, AND INTERNAL LEAKAGE TESTS AFTER EACH AXIS

THERMAL VACUUM AND ENDURANCE TEST (2 UNITS)

9000 CYCLES: 4500 PSIG, AMBIENT HELIUM
500 CYCLES: 4500 PSIG, +130 DEG F HELIUM
500 CYCLES: 4500 PSIG, -160 DEG F HELIUM

OPERATIONAL CYCLE TEST
3 CYCLES PERFORMED DURING EXPOSURE TO FOLLOWING CONDITIONS:
VALVE ENERGIZED/DEENERGIZED
INLET PRESSURE: 4000 TO 200 PSIG
TEMPERATURE: +130 TO +250 DEG F HELIUM
SURROUNDING TEMPERATURE: AMBIENT TO +275 DEG F
SURROUNDING ENVIRONMENT: AMBIENT TO VACUUM

ELECTRICAL CHARACTERISTICS AND INTERNAL LEAKAGE AFTER EACH SET OF CYCLES AT APPROPRIATE TEMPERATURE CONDITIONS

FLOW TEST (1 UNIT)

DIFFERENTIAL PRESSURE TEST
INLET PRESSURE: 950 PSIG
FLOW RATES: 0.06 TO 0.10 LBS/SEC
PRESSURE DROP NOT TO EXCEED 50 PSID

HIGH FLOW CLOSURE TEST
3 CYCLES:
INLET PRESSURE: 4500 PSIG
FLOW RATE: 1 LBS/SEC
CYCLE VALVE CLOSED AND VERIFY CLOSURE BY LEAKAGE TEST

BURST TEST (1 UNITS)
18,000 PSIG

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

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(C) INSPECTION:
RECEIVING INSPECTION
RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESSES CERTIFICATION. BODY HOUSING BAR STOCK IS ULTRASONICALLY INSPECTED.

CONTAMINATION CONTROL
CLEANLINESS LEVEL IS VERIFIED TO 100A. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
ALL DETAIL PARTS AND ASSEMBLIES ARE EXAMINED FOR BURRS, DAMAGE AND CORROSION (AT 10X MAGNIFICATION) AND INSPECTED FOR CORRECT DIMENSIONS PRIOR TO ASSEMBLY. CRITICAL SURFACE FINISHES ARE INSPECTED USING A COMPARATOR AT 10X MAGNIFICATION. OTHER SURFACE FINISHES ARE INSPECTED AND VERIFIED WITH A PROFILOMETER. TORQUES ARE VERIFIED TO BE IN ACCORDANCE WITH DRAWING REQUIREMENTS. BELLOWS ASSEMBLY IS PROOF PRESSURE TESTED AND LEAK CHECKED. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESS
THE FOLLOWING ARE VERIFIED BY INSPECTION:

WELDING
HEAT TREATMENT
PARTS PASSIVATION
POTTING OF SOLDER CUPS
ELECTRICAL WIRE STRIPPING
DRY FILM LUBRICATION
CHROME PLATING

NONDESTRUCTIVE EVALUATION
ALL WELDS ARE VISUALLY EXAMINED AND VERIFIED BY X-RAY OR DYE PENETRANT INSPECTIONS. THE SOLENOID ASSEMBLY IS SUBJECTED TO LEAKAGE VERIFICATION USING RADIOACTIVE TRACER TECHNIQUES. SOME VALVE BODIES WERE SUBJECTED TO 10X MAGNIFICATION INSPECTION ONLY. OTHER VALVE BODIES WERE SUBJECTED TO EDDY CURRENT INSPECTION, IN ADDITION TO 10X MAGNIFICATION. REFURBISHED VALVE BODIES ARE SUBJECTED TO 40X MAGNIFICATION INSPECTION.

TESTING
ATP VERIFIED BY INSPECTION.

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

(D) FAILURE HISTORY:
DURING ENGINEERING EVALUATION TEST (DELAY TEST), THE VALVE EXHIBITED EXTERNAL LEAKAGE THROUGH THE VENT PORT WHILE INSTALLED ON THE MPTA PNEUMATIC PANEL (REFERENCE CAR A9867). THE FAILURE WAS CAUSED BY CONTAMINATION ON THE PILOT BALL/SEAT. THE ORIGINAL PNEUMATIC PANEL WAS SUBJECTED TO SEVERAL REWORKS

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WHICH INCREASED THE POSSIBILITY OF CONTAMINATION. THE PNEUMATIC PANEL WAS REPLACED WITH THE CURRENT FLIGHT CONFIGURATION AND NO REPETITION OF FAILURE OCCURRED AFTER FOUR STATIC FIRINGS.

DURING QUALIFICATION (THERMAL VACUUM TEST), LEAKAGE THROUGH THE VENT PORT OCCURRED AT THE SUPPLIER DUE TO DESIGN ISSUES (REFERENCE CAR AB0231). THE MAIN POPPET WAS REDESIGNED TO LENGTHEN THE DEPTH OF THE MAIN POPPET STROKE. THE CHANGE WAS EFFECTIVE ON THE NEW -0007 CONFIGURATION.

DURING QUALIFICATION (THERMAL VACUUM TEST), LEAKAGE THROUGH THE VENT PORT OCCURRED DURING THE FIFTEENTH CYCLE (REFERENCE CAR AB0614). UPON DISASSEMBLY, THE SLEEVE TYPE SEAL WHICH FITS AROUND THE MAIN POPPET WAS FOUND TO BE CRACKED. A SMALL DAMAGED AREA WAS FOUND ON THE SEAL WHICH BECAME A STRESS RISER AND INITIATED THE CRACK DURING THE EXTENSIVE VIBRATION AND CYCLIC TESTING. THE SUPPLIER REVISED THE INSPECTION PROCEDURE REQUIRING A 10X MAGNIFICATION EXAMINATION FOR CRACKS OR FLAWS ON THE ASSEMBLED VESPEL SEAL.

DURING LAUNCH PREPARATIONS AT KSC, LEAKAGE THROUGH THE VENT PORT WAS DISCOVERED (REFERENCE CAR'S AC6852, AD0976). AFTER CYCLING OF THE VALVE, THE LEAKAGE RATE WAS IN THE SPECIFICATION RANGE AND NO CAUSE OF THE FAILURE WAS DETECTED. THE ANOMALY WAS ACCEPTED FOR STS-9 BY WAIVER NO. M0078-102-322. THE UNIT WAS UPDATED TO A -0011 CONFIGURATION.

TWO CASES DURING QUALIFICATION (VIBRATION TESTING AND HIGH TEMPERATURE TESTING) WHERE EXCESSIVE AND ERRATIC LEAKAGE WAS NOTED AT THE VENT PORT (REFERENCE CAR AB3272). THE CAUSE WAS ATTRIBUTED TO SCRATCHES ON THE PILOT BALL DUE TO HANDLING AND ASSEMBLY. THE SUPPLIER CHANGED THE ASSEMBLY PROCEDURE TO INCLUDE A 30X MAGNIFICATION INSPECTION OF THE BALL PRIOR TO ASSEMBLY.

DURING CHECKOUT AT DOWNEY, THE VALVE EXHIBITED AN AUDIBLE LEAK OUT THE VENT PORT WHEN THE UNIT WAS ENERGIZED IN THE OPEN POSITION (REFERENCE CAR AB4373). CONTAMINATION LODGED TEMPORARILY ON THE SEATING SURFACE WAS DETERMINED AS THE CAUSE OF THE LEAKAGE. NEW FABRICATION PROCEDURES WERE WRITTEN TO INSURE HELIUM PANEL CLEANLINESS.

DURING HELIUM SYSTEM LEAK TEST OF OV-102, LEAKAGE THROUGH THE PILOT VENT PORT WAS OBSERVED WHEN THE IN INTERCONNECT VALVE LV61, (ENGINE #2B PNEUMATIC PANEL) WAS ENERGIZED AND DE-ENERGIZED (REFERENCE CAR AB5472). INVESTIGATION CONCLUDED THAT THE STATIC SEAL WAS IMPERFECT OR MISHANDLED. THIS IS THE FIRST REPORTED FAILURE OF NATURE AND WAS CONSIDERED TO BE AN ISOLATED CASE. THE REFURBISHED VALVE PASSED ATP.

ON OV-102 AT KSC, THE VALVE LV63 LEAKED THROUGH THE VENT PORT AT HIGH PRESSURE WHEN IN THE ENERGIZED POSITION (REFERENCE CAR AC6889). CONTAMINATION WAS FOUND ON BOTH THE FIRST AND SECOND TEFLON RINGS ON THE MAIN POPPET. PITS AND SCORING WERE FOUND ON THE I.D. OF THE BODY ASSEMBLY SURFACE. THE VALVE PERFORMED AS REQUIRED AFTER CLEANING. SPECIAL PURGE PORTS WERE ADDED TO THE HELIUM PANEL ASSEMBLIES IN ORDER TO REDUCE BRAZING REWORK AND ASSOCIATED CONTAMINANTS.

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TWO CASES ON OV-102 AT KSC, WHERE THE VALVES LV6 AND LV61 LEAKED THROUGH THE VENT PORT IN THE DE-ENERGIZED POSITION (REFERENCE CAR'S AD1386, AD1362). A BURR WAS FOUND IN THE SLEEVE ASSEMBLY AREA. PERSONNEL WERE INSTRUCTED TO ADHERE TO THE PROPER QUALITY ASSURANCE AND CLEANLINESS PROCEDURES.

DURING ATP AT DOWNEY, THE VALVE LEAKED THROUGH THE VENT PORT WHILE ENERGIZED AT LOW INLET PRESSURE (REFERENCE CAR AC4293). A PIECE OF EPOXY WAS FOUND ON THE UPPER END OF THE MAIN POPPET WHERE IT SEATS AGAINST THE VESPEL SEAL. THE EPOXY WAS FROM AN EXCESSIVE AMOUNT OF EPOXY BEING USED AND EXTRUDED OUT OF THE THREADS OF THE MAIN POPPET SEAL RETAINER. SUPPLIER ADDED A CAUTIONARY NOTE TO THEIR ASSEMBLY PROCEDURE, IN ADDITION TO THE NOTE ALREADY ON THE DRAWING, TO INSPECT FOR AND REMOVE EXCESS EPOXY. THE ATP WAS REVISED TO ADD AN ENERGIZED LEAK TEST AT LOW PRESSURE.

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.

- 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	: DAVE NEARY	: /S/ DAVE NEARY
MPS SUBSYSTEM MGR.	: TIM REITH	: /S/ TIM REITH
MOD	: JEFF MUSLER	: /S/ JEFF MUSLER
USA SAM	: MICHAEL SNYDER	: /S/ MICHAEL SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	: /S/ BILL PRINCE