

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0405 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 08/08/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	:LH2 4" DISCONNECT, RECIRC RTN (ET) VACCO INDUSTRIES	MC284-0390-0014
LRU	:LH2 4" DISCONNECT, RECIRC RTN (ORB) VACCO INDUSTRIES	MC284-0390-0056

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

DISCONNECT, LH2 RECIRCULATION RETURN, 4 INCH DIAMETER, ORBITER & ET HALF

REFERENCE DESIGNATORS: PD3

QUANTITY OF LIKE ITEMS: 1

FUNCTION:

ET/ORBITER RECIRCULATION RETURN DISCONNECT PROVIDES THE PATH FOR LH2 RECIRCULATION. THE DISCONNECT IS A PNEUMATICALLY ACTUATED VALVE THAT IS DESIGNED TO REMAIN IN THE LAST ACTUATED POSITION (BISTABLE). THE DISCONNECT PROVIDES A MEANS FOR TOPPING AND REPLENISHING THE ET TANK, AND RECIRCULATION LH2. THE DISCONNECT VALVE IS CLOSED AFTER MAIN ENGINE CUT-OFF (MECO). THE DISCONNECT VALVE IS CLOSED FOR A PREMATURE ENGINE SHUTDOWN DURING ASCENT OR FOR A PAD ABORT. THE DISCONNECT VALVE IS CLOSED TO PREVENT PROPELLANT LEAKAGE THROUGH THE ENGINE FUEL BLEED VALVE (BLEED VALVE OPENS 16 SECONDS AFTER ENGINE SHUTDOWN). FLUID TRAPPED BETWEEN THE CLOSED ET AND ORBITER HALVES IS RELIEVED THROUGH EITHER THE ET OR ORBITER FLAPPERS. A SEVEN PLY NEGATOR SPRING CONFIGURATION, ATTACHED TO THE MAIN SHAFT, WILL CLOSE THE VALVE MECHANICALLY AT SEPARATION IF THE VALVE WAS NOT CLOSED BY RETRACTION OF THE ACTUATOR ARM.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 03-1-0405-11

REVISION#: 1 08/08/00

SUBSYSTEM NAME: MAIN PROPULSION

LRU: LH2 4" DISCONNECT, RECIRC RTN (PD3)

ITEM NAME: LH2 4" DISCONNECT, RECIRC RTN (PD3)

CRITICALITY OF THIS

FAILURE MODE: 1/1

FAILURE MODE:

RUPTURE/LEAKAGE OF ACTUATOR DURING ASCENT.

MISSION PHASE:

PL PRE-LAUNCH

LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA

103 DISCOVERY

104 ATLANTIS

105 ENDEAVOUR

CAUSE:

FATIGUE, MATERIAL DEFECT, DAMAGED/DEFECTIVE ACTUATOR SEALS

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN

A) N/A

B) N/A

C) N/A

PASS/FAIL RATIONALE:

A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

LOSS OF CONTROL OF THE DISCONNECT VALVE. POSSIBLE DEPLETION OF VALVE ACTUATION PRESSURE DOWNSTREAM OF PNEUMATIC HELIUM ISOLATION CHECK VALVE (CV9) CAUSING FAILURE TO CLOSE LO2 PREVALVES AT MECO. RESULTS IN THE INABILITY TO MAINTAIN INJECTED HELIUM AND LO2 PRESSURE AT THE SSME PUMP, RESULTING IN POSSIBLE PUMP OVERSPEED AND EXPLOSION. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. ENGINE PURGE RESIDUALS ARE

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0405-11**

TRANSFERRED TO VALVE ACTUATION SUPPLY AT MECO BY SOFTWARE COMMAND, WHICH MAY NOT ACTUATE LO2 PREVALVES CLOSED.

LEAKAGE MAY BE DETECTABLE ON GROUND USING HAZARDOUS GAS DETECTION SYSTEM (HGDS). ALSO RESULTS IN LOSS OF GHE SUPPLY DURING PROPELLANT DUMP CAUSING POSSIBLE LOSS OF AFT COMPARTMENT PURGE.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

ON GROUND, POSSIBLE VIOLATION OF HGDS LCC WILL RESULT IN LAUNCH SCRUB.

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

POSSIBLE LOSS OF CREW/VEHICLE.

(E) FUNCTIONAL CRITICALITY EFFECTS:

NONE.

-DISPOSITION RATIONALE-

(A) DESIGN:

DESIGN FACTORS OF SAFETY ARE 2.0 PROOF (1700 PSIG), 4.0 PROOF (3400 PSIG) FOR THE DISCONNECT ACTUATOR. THE ULTIMATE FACTOR OF SAFETY FOR STRUCTURE IS 1.5. THE DISCONNECT ACTUATOR ASSEMBLY IS DESIGNED FOR 1400 CYCLES (OPEN TO CLOSE TO OPEN) AT AMBIENT AND CRYOGENIC TEMPERATURES. THE CAP AND HOUSING ARE MANUFACTURED FROM 304L CRES.

THE ACTUATOR SEALS UTILIZE GOLD PLATED V-SEAL ON THE OPEN PORT; TEFLON FLUORALLOY-S LIP SEALS ON THE SHAFT; KEL-F GASKET ON THE ACTUATOR CAP (PREVENTS LEAKAGE WITH OPEN COMMAND GHE PRESSURE "ON"); AND A GOLD- PLATED V-SEAL (PREVENTS LEAKAGE WITH CLOSE COMMAND GHE PRESSURE "ON") ON THE OPEN PORT OF THE CAP/ACTUATOR INTERFACE.

(B) TEST:

ATP

EXAMINATION OF PRODUCT

PROOF PRESSURE:

ACTUATOR: 1720 PSIG

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0405-11**

ORBITER HOUSING: 156 PSIG, FLAPPERS OPEN AND CLOSED
ET HOUSING: 48 PSIG, FLAPPERS OPEN AND CLOSED

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

ACTUATOR (OPEN AND CLOSED POSITION) - 740 PSIG

BUMPER SEAL LEAKAGE; 740 PSIG

SHAFT SEAL LEAKAGE; 740 PSIG

CAP SEAL LEAKAGE; 740 PSIG (AMBIENT ONLY)

VALVE BODY

SHAFT SEAL LEAKAGE
ORBITER SECTION: 5, 20, 37, AND 120 PSIG
ET SECTION: 5, 20, AND 37 PSIG

CLOSURE SEAL (INTERNAL) LEAKAGE
ORBITER SECTION: 5, 20, 37, AND 120 PSIG
ET SECTION: 5, 20, AND 37 PSIG

MATING SEAL LEAKAGE (47 PSIG)

EXTERNAL LEAKAGE (37 PSIG)

RELIEF FUNCTION:

CRYO (-300 DEG F) CRACK AND RESEAT (.75 TO 10 PSID)

POSITION INDICATOR (AMBIENT):

VERIFICATION OF OPERATION

ELECTRICAL CHARACTERISTICS:

CONTACT RESISTANCE
INSULATION RESISTANCE
DIELECTRIC STRENGTH

RESPONSE TIME:

AMBIENT AND CRYO (-300 DEG F)
400 AND 740 PSIG ACTUATION PRESSURE

CERTIFICATION

COMPONENT QUALIFICATION

INTERFACE CLAMPING FORCE APPLIED DURING ALL AMBIENT AND CRYO TESTING.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0405-11**

OPERATING LIFE:

AMBIENT

800 FLAPPER CLOSURE CYCLES AT 740 PSIG
200 FLAPPER CLOSURE CYCLES AT 400 PSIG

CRYO

300 CLOSURE CYCLES AT 750 PSIG (-400 DEG F)
100 CLOSURE CYCLES AT 400 PSIG (-400 DEG F)

VIBRATION - 3 AXES:

RANDOM VIBRATION (48 MINUTES IN EACH OF THREE AXES WITH CLOSURE IN OPEN POSITION WHILE PRESSURIZED TO 37 PSIG AND AT -300 DEG F (OPEN PRESSURE REMOVED IN LAST 10 MINUTES OF EACH AXIS).

ELECTRICAL CHARACTERISTICS:

CONTACT RESISTANCE
INSULATION RESISTANCE
DIELECTRIC STRENGTH

BONDING:

ELECTRICAL CONDUCTIVITY SHALL NOT EXCEED 100 MILLIOHMS.

CRYOGENIC RELIEF OPERATION:

CRACK AND RESEAT PRESSURE SHALL BE BETWEEN 0.75 AND 10 PSIG

ENGAGE/DISENGAGE CYCLING:

AMBIENT

100 DISENGAGEMENT CYCLES:
15 CYCLES WITH FLAPPERS OPEN USING ACTUATOR PRESSURE
15 CYCLES WITH FLAPPERS MECHANICALLY LATCHED OPEN
70 CYCLES WITH FLAPPERS CLOSED USING ACTUATOR PRESSURE

CRYO

300 DISENGAGEMENT CYCLES, CRYO (-320 DEG F):
12 CYCLES WITH FLAPPERS OPEN USING ACTUATOR PRESSURE
12 CYCLES WITH FLAPPERS MECHANICALLY LATCHED OPEN
276 CYCLES WITH FLAPPERS CLOSED USING ACTUATOR PRESSURE

10 DISENGAGEMENT CYCLES, CRYO (-400 DEG F):
3 CYCLES WITH FLAPPERS OPEN USING ACTUATOR PRESSURE
3 CYCLES WITH FLAPPERS MECHANICALLY LATCHED OPEN
4 CYCLES WITH FLAPPERS CLOSED USING ACTUATOR PRESSURE

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

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0405-11**

ACTUATOR (OPEN AND CLOSED POSITION)

BUMPER SEAL LEAKAGE; 740 PSIG

SHAFT SEAL LEAKAGE; 740 PSIG

VALVE BODY

SHAFT SEAL LEAKAGE

ORBITER SECTION: 5, 20, 37, AND 120 PSIG

ET SECTION: 5, 20, AND 37 PSIG

CLOSURE SEAL (INTERNAL) LEAKAGE

ORBITER SECTION: 5, 20, 37, AND 120 PSIG

ET SECTION: 5, 20, AND 37 PSIG

MATING SEAL LEAKAGE (47 PSIG)

EXTERNAL LEAKAGE (37 PSIG)

VALVE RESPONSE TIMES:

CRYO (-300 DEG F) AND AMBIENT

VALVE PRESSURIZED TO 5 PSIG AND AMBIENT PRESSURE

ACTUATOR PRESSURIZED TO 740 PSIG AND 400 PSIG

BURST TEST:

ORBITER SECTION 180 PSIG; FLAPPER IN CLOSED POSITION

ET SECTION 56 PSIG; FLAPPER IN CLOSED POSITION

ACTUATOR 3400 PSIG; SIMULTANEOUSLY APPLIED TO OPEN AND CLOSED PORTS.

THE CONSOLIDATED CONTROL VALVES WERE QUALIFIED BY SIMILARITY TO THE FOLLOWING TESTS THAT WERE PERFORMED ON AMETEK/CALMEC VALVES:

VIBRATION - 3 AXES:

TRANSIENT VIBRATION (SINUSOIDAL SWEEP): 5 TO 35 HZ AT AMBIENT CONDITIONS

RANDOM VIBRATION (48 MINUTES IN EACH OF THREE AXES WITH CLOSURE IN OPEN POSITION WHILE PRESSURIZED TO 37 PSIG AND AT -300 DEG F (OPEN PRESSURE REMOVED IN LAST 10 MINUTES OF EACH AXIS).

SALT FOG: 48 HOURS, INTERNALLY PRESSURIZED TO 5 PSIG

SHOCK, BENCH HANDLING (DEMATED)

THERMAL CYCLE (3 CYCLES): +70 TO -400 TO -20 TO +70 DEG F

OPERATING LIFE:

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0405-11**

AMBIENT

1500 FLAPPER CLOSURE CYCLES AT 740 PSIG
1000 FLAPPER CLOSURE CYCLES AT 400 PSIG

300 DISENGAGEMENT CYCLES:

50 CYCLES WITH FLAPPERS OPEN USING ACTUATOR PRESSURE
50 CYCLES WITH FLAPPERS MECHANICALLY LATCHED OPEN
150 CYCLES WITH FLAPPERS CLOSED USING ACTUATOR PRESSURE
50 CYCLES WITH ACTUATOR OPENING AND CLOSING PORTS PRESSURIZED
SIMULTANEOUSLY AND CLOSURE DEVICES OPEN

CRYO

700 CLOSURE CYCLES AT 740 PSIG (-400 DEG F)
300 CLOSURE CYCLES AT 400 PSIG (-400 DEG F)

10 DISENGAGEMENT CYCLES (-400 DEG F):

2 CYCLES WITH FLAPPERS OPEN USING ACTUATOR PRESSURE
2 CYCLES WITH FLAPPERS MECHANICALLY LATCHED OPEN
4 CYCLES WITH FLAPPERS CLOSED USING ACTUATOR PRESSURE
2 CYCLES WITH ACTUATOR OPENING AND CLOSING PORTS PRESSURIZED
SIMULTANEOUSLY AND CLOSURE DEVICES OPEN

290 DISENGAGEMENT CYCLES (-300 DEG F):

50 CYCLES WITH FLAPPERS OPEN USING ACTUATOR PRESSURE
50 CYCLES WITH FLAPPERS MECHANICALLY LATCHED OPEN
140 CYCLES WITH FLAPPERS CLOSED USING ACTUATOR PRESSURE
50 CYCLES WITH ACTUATOR OPENING AND CLOSING PORTS PRESSURIZED
SIMULTANEOUSLY AND CLOSURE DEVICES OPEN

ELECTRICAL CHARACTERISTICS:

CONTACT RESISTANCE
INSULATION RESISTANCE
DIELECTRIC STRENGTH

BONDING:

ELECTRICAL CONDUCTIVITY SHALL NOT EXCEED 100 MILLIOHMS.

BURST TEST:

ORBITER SECTION 180 PSIG; FLAPPER IN CLOSED POSITION
ET SECTION 56 PSIG; FLAPPER IN CLOSED POSITION
ACTUATOR 3400 PSIG; SIMULTANEOUSLY APPLIED TO OPEN AND CLOSED PORTS.

UMBILICAL SEPARATION TEST

THE DISCONNECT WAS INSTALLED IN THE UMBILICAL ASSEMBLY DURING THE SEPARATION TEST PROGRAM. THE UMBILICAL ASSEMBLY WAS SUBJECTED TO RANDOM VIBRATION TESTS (4.4 HOURS PER AXIS) WHILE FILLED WITH LH2. THE DISCONNECT WAS ALSO SUBJECTED TO UMBILICAL RETRACT TESTS AT BOTH NOMINAL CONDITIONS AND

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0405-11**

SIMULATED HYDRAULIC RETRACT ACTUATOR FAILURE CONDITIONS. THE DISCONNECT WAS ALSO SUBJECTED TO 5 BACKUP MODE CLOSURE TESTS.

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

(C) INSPECTION:

RECEIVING INSPECTION

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

CONTAMINATION CONTROL

CONTAMINATION CONTROL PROCESSES AND CORROSION PROTECTION PROVISIONS ARE VERIFIED. INTERNAL SURFACES CLEANING TO LEVEL 400 IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

COMPONENT

ALL DETAIL PARTS ARE INSPECTED UNDER 40X MAGNIFICATION FOR BURRS, DAMAGE, AND CONTAMINATION. CRITICAL DIMENSIONS, CLEARANCE, AND SURFACE FINISHES ARE VERIFIED. SEALS ARE VISUALLY EXAMINED PRIOR TO INSTALLATION FOR DAMAGE AND CLEANLINESS. FLAPPER SPRINGS ARE INSTALLED AND VERIFIED BY INSPECTION AFTER LOAD TEST. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

UMBILICAL ASSEMBLY

HEAT TREATED AND DRY FILM LUBE COATED BELLEVILLE SPRINGS ARE VISUALLY INSPECTED AND LOAD TESTED PRIOR TO ASSEMBLY. CORRECT INSTALLATION OF THE BELLEVILLE WASHERS IS A MANDATORY INSPECTION POINT. THE SHIMS, WHICH ARE REQUIRED TO SET THE HEIGHT OF THE 4 INCH DISCONNECT MATING SURFACE ABOVE THE 17 INCH DISCONNECT MATING SURFACE AS EXTERNAL FORCE IS APPLIED TO THE 4 INCH DISCONNECT, ARE DIMENSIONALLY INSPECTED. THE SHIMS, WHICH ARE REQUIRED TO SET THE PRELOAD IN THE UNMATED CONDITION, ARE DIMENSIONALLY INSPECTED.

CRITICAL PROCESS

PARTS PASSIVATION, HEAT TREATMENT, AND ANODIZING ARE VERIFIED. ETCHING OF AL ALLOY, CLEANING AL SAND CASTINGS, BRUSH CLEANING, AND SOLDERING ARE VERIFIED BY INSPECTION. DRY FILM LUBRICANT APPLICATION IS VERIFIED.

NONDESTRUCTIVE EVALUATION

CASTING AND ROUGH MACHINING OF THE BODY ARE INSPECTED BY X-RAY AND DYE PENETRANT.

TESTING

ATP IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING

IN-PROCESS OPERATIONS ARE VERIFIED BY INSPECTION TO PROTECT PARTS AND PRECLUDE MISHANDLING. PARTS PACKAGING IS VERIFIED BY INSPECTION.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0405-11**

(D) FAILURE HISTORY:

DURING INITIAL LEAKAGE TESTS OF THE ACTUATOR AT CYROGENIC TEMPERATURES, EXCESSIVE LEAKAGE WAS MEASURED. THE LEAKAGE WAS ATTRIBUTED TO EXCESSIVE CURLING DUE TO IMPROPER TEMPERATURE STABILIZATION OF THE BUMPER SEALS PRIOR TO ASSEMBLY. THE ASSEMBLY PROCEDURE WAS CHANGED TO INSURE PROPER SEAL TEMPERATURE STABILIZATION PRIOR TO INSTALLATION (REF CAR A4988).

EXCESSIVE ACTUATOR LEAKAGE DURING ATP WAS ATTRIBUTED TO A LARGE METAL CHIP LODGED ACROSS THE BUMPER SEAL AREA. TO PREVENT THE INTRODUCTION OF METAL CHIPS, THE ASSEMBLY PROCEDURE WAS CHANGED TO INCLUDE HAND LAPPING THREADED PORTIONS OF THE ACTUATOR PORTS AND ELIMINATE THE USE OF LOCK WASHERS TO MINIMIZE THE GENERATION OF METAL CHIPS (REF CAR A5161).

DURING SUPPLIER ATP, WITH ACTUATION PRESSURE APPLIED TO THE OPEN PORT, 65 SCIM LEAKAGE WAS MEASURED AT THE CLOSE PORT. MAXIMUM ALLOWED WAS 45 SCIM. THE SPECIFICATION WAS CHANGED TO ALLOW A MAXIMUM OF 125 SCIM (REF CAR AC3342). SIMILAR ATP FAILURES WERE EXPERIENCED AS FOLLOWS: AC3976 (79SCIM), AC291 (98SCIM), AC4389 (96.9 SCIM). ALL THESE FAILURES WERE CLOSED BY INCREASING THE MAXIMUM ALLOWABLE LEAKAGE TO 125 SCIM.

DURING LIFE CYCLES QUALIFICATION TESTING, EXCESSIVE LEAKAGE WAS MEASURED PAST THE PISTON RINGS. FAILURE WAS DUE TO LEAKAGE PAST THE PISTON RINGS CAUSING INSUFFICIENT PRESSURE TO MOVE THE PISTON. THE METHOD OF MACHINING THE PISTON RINGS WAS CHANGED TO INSURE A MATCHED SET WAS USED FOR EACH ASSEMBLY (REF CAR A8636, AB0640)

AFTER 150 CYCLES OF LIFE CYCLE TESTING, THE ACTUATOR LEAKAGE WAS 1600 SCIM. MAXIMUM ALLOWABLE IS 45 SCIM. FAILURE ANALYSIS DISCLOSED A METALLIC PARTICLE IMBEDDED IN THE BUMPER SEAL. THE PARTICLE WAS PROBABLY INTRODUCED INTO THE ACTUATOR WHEN A NEW INLET FILTER WAS INSTALLED IN THE ACTUATOR. PARTICLE WAS REMOVED, AND TECHNICIANS CAUTIONED (REF CAR AB1805).

DURING SUPPLIER QTP, THE ACTUATOR LEAKAGE PAST THE BUMPER SEAL WAS EXCESSIVE. IN ADDITION, SHAFT SEAL LEAKAGE WAS EXCESSIVE. FAILURE ANALYSIS DISCLOSED TINY TEFLON AND METALLIC PARTICLES ON THE ACTUATOR BUMPER SEALS. THE ACTUATOR ASSEMBLY PROCEDURE WAS MODIFIED TO PREVENT INTRUSION OF CONTAMINATION. THE MEASURED SHAFT SEAL LEAKAGE WAS ATTRIBUTED TO CRYO PUMPING AND WAS CORRECTED BY THE ADDITION OF A GHE PURGE (REF CAR AC1523).

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:

HELIUM BOTTLE PRESSURE IS ON DISPLAY IN COCKPIT. CREW ACTION CAN CLOSE ISOLATION VALVES DURING ASCENT. PRIOR TO MECO ISOLATION VALVES (LV7,LV8) CAN BE REOPENED OR THE LEFT ENGINE LOW PRESSURE GHE CROSSOVER VALVE (LV10) CAN BE OPENED.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0405-11**

- 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	: MIKE FISCHER	: /S/ MIKE FISCHER
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