

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**

NUMBER: 03-1-0405 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 08/08/00

**PART DATA**


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

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**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

DISCONNECT, LH2 RECIRCULATION RETURN, 4 INCH DIAMETER, ORBITER &amp; 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.

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

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

**CRITICALITY OF THIS**

**FAILURE MODE: 1/1**

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**FAILURE MODE:**

RUPTURE/LEAKAGE OF DISCONNECT BODY DURING LOADING, ASCENT, DUMP, OR INERT.

**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 BODY JOINT SEALS

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

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**REDUNDANCY SCREEN**

A) N/A

B) N/A

C) N/A

**PASS/FAIL RATIONALE:**

A)

B)

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

LH2 LEAKAGE INTO THE AFT COMPARTMENT. PRELAUNCH GN2 PURGE OF THE AFT COMPARTMENT MAY LOWER THE GH2 CONCENTRATION BUT FIRE/EXPLOSION HAZARD STILL PRESENT. LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYOGENIC EXPOSURE. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE HAZARD. LEAKAGE IN THE AFT COMPARTMENT IS DETECTABLE DURING LOADING USING THE

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HAZARDOUS GAS DETECTION SYSTEM (HGDS). LEAKAGE OVERBOARD IN THE ET UMBILICAL AREA MAY BE DETECTABLE BY HYDROGEN LEAK DETECTORS (LD54 & LD55).

ALSO, RESULTS IN LOSS OF HELIUM SUPPLY DURING MANIFOLD REPRESSURIZATION CAUSING LOSS OF AFT COMPARTMENT PURGE.

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

**(C) MISSION:**  
ON GROUND, 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.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**  
THE DISCONNECT HOUSING IS MADE FROM A-356 ALUMINUM. DESIGN FACTORS OF SAFETY ARE 1.3 PROOF, 1.5 BURST FOR THE DISCONNECT ASSEMBLY. ULTIMATE FACTOR OF SAFETY FOR STRUCTURE IS 1.5. THE MATED ORBITER AND EXTERNAL TANK DISCONNECTS ARE DESIGNED TO A BURST PRESSURE OF 56 PSIG WITH THE FLAPPERS OPEN. THE ORBITER DISCONNECT ASSEMBLY IS DESIGNED FOR 1400 CYCLES AT AMBIENT AND AT CRYOGENIC TEMPERATURES. THE EXTERNAL TANK DISCONNECT ASSEMBLY IS DESIGNED FOR 150 CYCLES AT AMBIENT/CRYOGENIC TEMPERATURES. STRUCTURAL ANALYSIS INDICATES POSITIVE MARGINS OF SAFETY FOR ALL CONDITIONS OF VALVE OPERATION; FRACTURE/FATIGUE ANALYSIS SHOW THAT ALL CRITICAL PARTS ARE SATISFACTORY FOR FOUR TIMES EXPECTED LIFE (ET - ONE MISSION, ORBITER - 100 MISSIONS).

POTENTIAL DISCONNECT LEAK PATHS ARE:

ORBITER BODY ASSEMBLY/DRIVE SHAFT  
ET BODY ASSEMBLY/DRIVE SHAFT

THE ORBITER AND ET SHAFTS HAVE DUAL TEFLON SEALS WHICH ARE SPRING LOADED USING BERYLLIUM COPPER SPRINGS. LEAKAGE PAST THE SHAFT SEALS (ET AND ORBITER) IS BLED INTO CAVITIES WHICH ARE PRESSURE RELIEVED BY A CHECK VALVE (5 PSI) TO THE EXTERIOR OF THE DISCONNECT.

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**(B) TEST:**

ATP

EXAMINATION OF PRODUCT

PROOF PRESSURE:

ACTUATOR: 1720 PSIG

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:

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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.

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

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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):

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).

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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:

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

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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 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**

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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.

**(D) FAILURE HISTORY:**

A FAILURE INVOLVING EXCESSIVE SHAFT SEAL LEAKAGE WAS REPORTED. THIS WAS ATTRIBUTED TO METAL PARTICLES EMBEDDED IN THE SHAFT SEAL DUE TO IMPROPER CLEANING PROCEDURES PRIOR TO ASSEMBLY. A PRE-ASSEMBLY CLEANING PROCEDURE WAS INSTIGATED FOR THE SHAFT AND SEAL (REF CAR AC7681).

DURING EARLY QUALIFICATION TESTING, THE TANK HALF OF THE DISCONNECT LEAKED THROUGH POROSITY IN THE CASTING. LEAKAGE WAS 12.5 SCIM. THE DISCONNECT WAS CONSIDERED SATISFACTORY FOR USE ON MPTA BECAUSE OF LOWER OPERATING PRESSURES. THE ACCEPTANCE TEST FOR NEW CASTINGS WAS EXPANDED TO INCLUDE TWO THERMAL CYCLES (-300 TO +160 TO -300 DEG F AND REPEAT) AND THEN LEAK TESTED AT 300 PSIG. THE MAXIMUM ALLOWABLE CASTING LEAKAGE IS 0.5 SCIM GHE (REF CAR A6907).

DURING QUALIFICATION TESTING, AFTER 316 OPEN/CLOSE CYCLES, THE ET HALF DRIVE SHAFT BEARING LEAKED EXCESSIVELY. FAILURE ANALYSIS SHOWED THE BEARING HAD TAKEN A PERMANENT CIRCUMFERENTIAL SET. THE BEARING MATERIAL WAS CHANGED FROM 25% FILLED TFE (FLUOROGOLD) TO VESPEL SP-21 AND WAS INCORPORATED INTO ALL PRODUCTION UNITS (EXCEPT MPTA) (REF CAR A6994).

EXCESSIVE LEAKAGE OF THE SHAFT SEAL OCCURRED DURING OPERATIONAL LIFE CYCLING FOR QUALIFICATION. THE CAUSE WAS DUE TO A SHORT SEAL RETAINER (NOT TO DRAWING REQUIREMENTS) RESULTING IN INSUFFICIENT SQUEEZE ON THE SHAFT SEAL BY THE RETAINER, THE RETAINER NUT DRAWING WAS REVISED TO ADD 0.007 INCH MORE SQUEEZE TO THE SHAFT SEAL FLANGE (REF CAR AC1016).

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:**

FLIGHT:  
NO ACTION CAN BE TAKEN.

GROUND:  
GROUND OPERATIONS SAFING PROCEDURES CONTAIN SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE HYDROGEN SYSTEM.

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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	: 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