FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-2A-231310 -X

SUBSYSTEM NAME: AFT REACTION CONTROL SYSTEM (RCS)
REVISION: 3 07/15/98

PART DATA

	PART NAME / **VENDOR NAME**	**PART NUMBER** / **VENDOR NUMBER**
SRU	: THRUSTER, VERNIER	MC467-0029

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

REFERENCE DESIGNATORS:

QUANTITY OF LIKE ITEMS: 4
TWO PER POD
(1 DOWN FIRING)
(1 SIDE FIRING)

FUNCTION:
ONE PITCH (Z AXIS-DOWN FIRING) AND ONE YAW (+/- Y AXIS) VERNIER THRUSTER ARE PROVIDED IN EACH ARCS MODULE TO PROVIDE PRECISE LOW LEVEL PULSING AND ATTITUDE HOLD. INCLUDES INLET VALVE, INJECTOR, THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP TRANSDUCER.

FAILURE MODES EFFECTS ANALYSIS FMEA – CIL FAILURE MODE
NUMBER: 03-2A-231310-03

REVISION#: 2 07/15/98

SUBSYSTEM NAME: AFT REACTION CONTROL SYSTEM (RCS)
LRU: **CRITICALITY OF THIS**
ITEM NAME: THRUSTER, VERNIER **FAILURE MODE:** 1R3

FAILURE MODE:
VALVE FAILS OPEN, VALVE FAILS TO CLOSE, VALVE LEAKAGE.

MISSION PHASE: OO ON-ORBIT

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

CAUSE:
CONTAMINATION, PIECE PART STRUCTURAL FAILURE, VIBRATION, MATERIAL DEFECT, ELECTRICAL FAILURE, CORROSION, SEAL WEAR, IMPROPER SOLENOID ACTUATION.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN
A) FAIL
B) PASS
C) PASS

PASS/FAIL RATIONALE:
A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
LOSS OF PROPELLANTS. LOSS OF FUNCTION (VERNIER THRUSTERS) - LOSS OF SINGLE DOWN FIRING VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL.

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(B) INTERFACING SUBSYSTEM(S):
INCREASED GN&C SWITCHING AND USAGE OF ALTERNATE THRUSTERS.

(C) MISSION:
MISSION MODIFICATION MAY BE REQUIRED. LOSS OF VERNIER THRUSTER DURING ISS REBOOST IS A CONCERN AND NEEDS TO BE ADDRESSED.

(D) CREW, VEHICLE, AND ELEMENT(S):
NO EFFECT.

(E) FUNCTIONAL CRITICALITY EFFECTS:
POSSIBLE INABILITY TO PERFORM ENTRY DUE TO INSUFFICIENT PROPELLANT. LOSS OF ALL PROPELLANT MAY RESULT IF ISOLATION CANNOT BE ACCOMPLISHED WITH THE UPSTREAM TANK OR MANIFOLD ISOLATION VALVES. THRUSTERS CANNOT BE FIRED WHILE ON THE VEHICLE DURING GROUND CHECKOUT.

-DISPOSITION RATIONALE-

(A) DESIGN:
25 MICRON FILTRATION & HEATERS PROVIDED TO LIMIT CONTAM & PREVENT FREEZING.

(B) TEST:
THE QUALIFICATION TEST PROGRAM INCLUDED ROUGH HANDLING, BASELINE PERFORMANCE, BASELINE ELECTRICAL AND LEAKAGE, VIBRATION (50 MISSIONS), ABNORMAL OPERATION, SIMULATED REAL TIME DUTY CYCLE, NOZZLE THERMAL TRANSIENT, COLD START VERIFICATION, PROPELLANT COMPATIBILITY, BURST (THRUSTER/INJECTOR 735 PSIG, PROPELLANT VALVE 5000 PSIG, PC TRANSDUCER 10000 PSIG), MISSION SIMULATION THE UNIT ALSO QUALIFIED AS PART OF THE VIBRO-ACOUSTIC TEST AT JSC (131 EQUIVALENT MISSIONS) AND THE HOT FIRE TEST PROGRAM AT WSTF (24 EQUIVALENT MISSION DUTY CYCLES AND APPROX 7 YEARS OF PROPELLANT EXPOSURE).

THE VERNIER THRUSTER INTERNATIONAL SPACE STATION (ISS) REBOOST TESTING WAS COMPLETED SUCCESSFULLY WITHOUT ANY DAMAGE TO THE THRUSTER. A TOTAL OF SEVEN REBOOST PROFILES WERE PERFORMED SUCCESSFULLY WITHOUT ANY SUBSTANTIAL CHAMBER DEGRADATION OR STANDOFF EROSION. THE THRUSTER DID NOT EXHIBIT ANY SIGNIFICANT PERFORMANCE CHANGES RESULTING FROM THE REBOOST TESTING. SHORT ON TIMES COUPLED WITH SHORT OFF TIMES RESULTED IN THE HIGHEST HEATING TO THE THRUSTER COMPONENTS. THE REBOOST TESTING

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DEMONSTRATED THE CAPABILITY OF THE VERNIER THRUSTER TO SUCCESSFULLY PERFORM A ONE HOUR REBOOST FIRING PROFILE WITHOUT ANY COMPROMISE TO THE HARDWARE UNDER WORSE CASE CONDITIONS.

ACCEPTANCE TESTING INCLUDES PROOF PRESSURE (PROPELLANT VALVES 1500 PSIG, THRUST CHAMBER/NOZZLE 525 PSIG, PC TRANSDUCER 3000 PSIG, THRUSTER ASSY 525 PSIG), THRUSTER PERFORMANCE, ACCEPTANCE THERMAL AND VIBRATION, EXTERNAL LEAKAGE, RESPONSE OF THE PROPELLANT VALVES, INTERNAL LEAKAGE OF THE VALVES, FLOW CALIBRATION AND CLEANLINESS.

ANY TURNAROUND CHECKOUT TESTING IS ACCOMPLISHED IN ACCORDANCE WITH THE OMRSD. THE OMRSD DATA PROVIDED BELOW IS NO LONGER BEING KEPT UP-TO-DATE. IF THERE IS ANY DISCREPANCY BETWEEN THE GROUND TESTING DATA PROVIDED BELOW AND THE OMRSD, THE OMRSD IS THE MORE ACCURATE SOURCE OF THE DATA.

OMRSD PERFORMS THE FOLLOWING: A THRUSTER VISUAL AND BOROSCOPE INSPECTION EACH FLIGHT BEGINNING WITH THE 2ND FLIGHT. THRUSTER CHAMBER LEAKAGE TEST THE 5TH AND EVERY 5TH FLIGHT THEREAFTER. THRUSTER INSPECTION AFTER USING PRESSURE PLUGS ON A CONTINGENCY BASIS. COATING SURFACE PROTECTION.

(C) INSPECTION:
RECEIVING INSPECTION
INSPECTION VERIFIES RAW MATERIAL AND PHYSICAL PROPERTIES.

CONTAMINATION CONTROL
CLEANLINESS TO LEVEL 200 FOR MMH AND 200A FOR NTO IS VERIFIED BY INSPECTION. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION
FINAL INSPECTION OF ALL DIMENSIONS IS VERIFIED. INJECTOR COOLANT HOLES ARE OPEN AFTER EXCESS WELD BEAD REMOVAL IS VERIFIED BY INSPECTION. SURFACE FINISH IS VERIFIED BY INSPECTION. THRUSTER VALVES ARE VISUALLY AND DIMENSIONALLY INSPECTED DURING FABRICATION. MANUFACTURING, ASSEMBLY, AND INSTALLATION PROCEDURES ARE VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION
FUSED DISILICIDE COATING THICKNESS IS VERIFIED BY EDDY CURRENT. INLET VALVE CLOSURE WELDS ARE ULTRASONIC INSPECTED. OTHER STRUCTURAL WELDS, UNLESS OTHERWISE CALLED OUT, ARE RADIOGRAPHIC INSPECTED AND ARE EITHER PENETRANT OR MAGNETIC PARTICLE INSPECTED.

CRITICAL PROCESSES
WELDING, SOLDERING AND APPLICATION OF DISILICIDE COATING IS VERIFIED BY INSPECTION. TEST SPECIMENS OF THE COATING ARE INSPECTED AND TESTED PER MPS-0545 REQUIREMENTS. THE COATED ASSEMBLIES ARE ALSO HEATED TO 2500 DEG F TO VERIFY COATING INTEGRITY. THE SURFACE IS THEN INSPECTED WITH A BORESCOPE AND A VIDEO TAPE RECORD IS MADE OF THE COATING CONDITION. WELDS (INCLUDING RESISTANCE WELDS PER MPS 1600, TACK WELDS AND STRUCTURAL WELDS) ARE VISUALLY INSPECTED TO SPECIFICATION REQUIREMENTS.

TESTING
ATP IS WITNESSED AND VERIFIED BY INSPECTION. WATER FLOW TESTS, PER INTERNAL TEST PROCEDURE, VERIFIES BY INSPECTION NO OCCLUDED PASSAGES. TEST FIRING WITH HEAT SENSORS VERIFY BY INSPECTION THAT THERE ARE NO HOT SPOTS. ELECTRICAL COMPONENTS ARE TESTED FOR INSULATION RESISTANCE AND DIELECTRIC STRENGTH AND VERIFIED BY INSPECTION.

HANDLING/PACKAGING
HANDLING AND STORAGE ENVIRONMENTS ARE VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:
CURRENT DATA ON TEST FAILURES, FLIGHT FAILURES, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATA BASE. THE FAILURE HISTORY DATA PROVIDED BELOW IS NO LONGER BEING KEPT UP-TO-DATE

THERE HAVE BEEN APPROXIMATELY 30 REPORTED VERNIER THRUSTER VALVE LEAKAGE INCIDENTS. OF THE 30, 10 WERE QUAL FAILURES (8 OXIDIZER AND 2 FUEL) AND 20 WERE ATP AND GROUND TURNAROUND FAILURES (13 OXIDIZER AND 7 FUEL). MOST VALVE LEAKAGE FAILURES WERE DUE TO CONTAMINATION. CORRECTIVE ACTION WAS TO CONTINUE IMPROVING CLEANLINESS CONTROLS. NO DESIGN CHANGES WERE REQUIRED.

ONE FAILURE WAS DUE TO CONTAMINATION BUILD-UP AROUND THE SPRING. THE CORRECTIVE ACTION WAS TO CHANGE THE METHOD OF DE-SCALING THE SPRING (CAR AC6975). ONE FAILURE WAS DUE TO METALLIC NITRATE BUILD-UP ON THE ARMATURE TIP (CAR AB6961)

(E) OPERATIONAL USE:
CLOSE UPSTREAM MANIFOLD ISOLATION VALVE. THE TANK ISOLATION VALVE IS A BACKUP TO THE MANIFOLD ISOLATION VALVE. IN THE EVENT OF THE LOSS OF VERNIER THRUSTER CAPABILITY, THE PRIMARY THRUSTERS CAN BE USED FOR THE VERNIER FUNCTION. SOME MISSION OBJECTIVES MAY NOT BE MET DUE TO INCREASED RATE OF PROPELLANT CONSUMPTION ON PRIMARY THRUSTERS.

- APPROVALS -

PAE MANAGER	: D. F. MIKULA
PRODUCT ASSURANCE ENGR	: L. X. DANG
DESIGN ENGINEERING	: L. TOAPANTA
BOEING SUBSYSTEM MANAGER	: D. PERRY
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