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.

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

FAILURE MODE:
HOT GAS LEAKAGE, BURNTHROUGH

MISSION PHASE: OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102	COLUMBIA
103	DISCOVERY
104	ATLANTIS
105	ENDEAVOUR

CAUSE:
THERMAL CYCLING/STRESS FATIGUE, INJECTOR FRACTURE, VIBRATION, SHOCK, SEAL LEAKAGE, CONTAMINATION, HIGH TEMP/LOCALIZED HOT SPOTS/INADEQUATE COOLING. INLET VALVE LEAK, NOZZLE RESTRICTION. PARTIALLY BLOCKED INJECTOR NOZZLE OR MATERIAL DEFECT.

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 FUNCTION - CURRENTLY LOSS OF SINGLE PITCH VERNIER THRUSTER CAUSES LOSS (SHUTDOWN) OF VERNIER CONTROL. HOWEVER, IF EITHER ONE OF TWO

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PARTICULAR YAW JETS FAILS THE CREW CAN OVERRIDE THE FAILURE AND CONTINUE TO USE VERNIER JETS.

(B) INTERFACING SUBSYSTEM(S):
USE OF ALTERNATE THRUSTERS. POSSIBLE DAMAGE TO TPS. HOT GAS LEAKAGE INTO THE POD.

(C) MISSION:
MISSION MODIFICATION DECISION IF FAILURE SHOULD CAUSE DAMAGE PROPAGATION. LOSS OF VERNIER THRUSTER DURING ISS REBOOST IS A CONCERN AND NEEDS TO BE ADDRESSED.

(D) CREW, VEHICLE, AND ELEMENT(S):
POSSIBLE LOSS OF CREW/VEHICLE. BURNTHROUGH MAY CAUSE HIGH TEMPURATURE DAMAGE TO SURROUNDING AND ADJACENT THRUSTERS RESULTING IN POSSIBLE ENTRY HAZARD IF TPS IS DAMAGED. OVERPRESSURIZATION OF MODULE MAY ALSO OCCUR IF VENT DOORS ARE CLOSED.

(E) FUNCTIONAL CRITICALITY EFFECTS:
NO EFFECT.

-DISPOSITION RATIONALE-

(A) DESIGN:
STRUCTURAL MARGINS (2.0 TO 4.0) MINIMIZE FAILURE EFFECT(S). 25 MICRON FILTRATION & HEATERS PROVIDED TO LIMIT CONTAM & PREVENT PROPELLANT FREEZING. IMPROVED COATING TECHNIQUES IMPROVES LIFE. REDUNDANT SEALS FOR VALVE MOUNTING. CHAMBER MACHINING QUALITY WAS IMPROVED AND THE DISILICIDE COATING THICKNESS INCREASED TO IMPROVE CHAMBER LIFE. THESE IMPROVEMENTS WERE REQUALIFIED TO EXTEND LIMITED LIFE TO: AFT DOWN 10 MISSIONS, AFT YAW 17 MISSIONS AND ALL OTHERS TO 28 MISSIONS.

(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 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 NOZZLES ARE OPEN, 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

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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 IN THE INJECTOR. 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

CAR AC0474: NOZZLE COATING DEFECTS HAVE OCCURRED ON 12 VERNIER THRUSTERS. SOME CHAMBER DEFECTS WERE AS A RESULT OF THROAT PLUG INSTALLATION. CORRECTIVE ACTION WAS TO LIMIT THE USE OF THE THROAT PLUG AND IF USED INSPECT COATING AFTER PLUG REMOVAL. THE THRUSTER CHAMBER AND NOZZLE HAS BEEN REQUALIFIED TO EXTEND THE AVAILABLE LIFE TO AFT DOWN 10 MISSIONS, AFT YAW 17 MISSIONS AND ALL FWD TO 28 MISSIONS. THE CURRENT LIFE LIMIT FOR THRUSTERS IS UNDER THE MISSION LIFE OF THE ORBITER AND IS NOT CONTROLLED BY THE LIMITED LIFE SPECIFICATION BECAUSE VERNIER THUSTERS ARE INSPECTED FOR COATING CONDITION AFTER EACH MISSION PER OMRSD REQUIREMENTS. ANY NOTED DEFECTIVE COATING IS CAUSE FOR REPLACING THRUSTER.

(E) OPERATIONAL USE:
NONE

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- APPROVALS -

PAE MANAGER	: D.F.MIKULA	: D.F. Mikula 22.JUL.98
PRODUCT ASSURANCE ENGR	: L.X.DANG	:
DESIGN ENGINEERING	: L. TOAPANTA	: 7/15/98
BOEING SUBSYSTEM MANAGER	: D. PERRY	: 7/20/98
NASA MOD	:	: 8/18/98