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FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL HARDWARE
NUMBER: MO-AD1-M06-X

SUBSYSTEM NAME: REMOTELY OPERATED ELECTRICAL UMBILICAL
REVISION : 1 02/11/91

	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
■ SRU :	LATCH ACTUATOR	MC287-0057-0001
■	HOOVER ELECTRIC	17820-1

PART DATA

■ EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:
DUAL MOTOR/BRAKE ASSEMBLY, 3 PHASE AC, 400 HZ

■ QUANTITY OF LIKE ITEMS: 2
ONE PER ROEU ASSEMBLY
17820-2 (ARM ACTUATOR) IS SIMILAR ITEM.

■ FUNCTION:
THE LATCH ACTUATOR USES REDUNDANT MOTORS DRIVING THROUGH A DIFFERENTIAL/GEARBOX TO PROVIDE THE FORCE NECESSARY TO LATCH/UNLATCH THE ORBITER-TO-PAYLOAD ELECTRICAL CONNECTOR HALVES.

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SUBSYSTEM: REMOTELY OPERATED ELECTRICAL UMBILICAL

ITEM NAME: LATCH ACTUATOR

CRITICALITY OF THIS FAILURE MODE:2R3

■ FAILURE MODE:
BRAKE FAILS TO ENGAGE

MISSION PHASE:
00 ON-ORBIT

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

■ CAUSE:
ADVERSE TOLERANCES/WEAR, CONTAMINATION/FOREIGN OBJECT/DIRT, DEFECTIVE PART/MATERIAL OR MANUFACTURING DEFECT, FAILURE/DEFLECTION OF INTERNAL PART

■ CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

■ REDUNDANCY SCREEN A) PASS
■ B) FAIL
■ C) PASS

PASS/FAIL RATIONALE:
■ A)
PRELAUNCH INSTALLATION AND CHECKOUT.

■ B)
THERE IS NO SPECIFIC IN-FLIGHT INSTRUMENTATION TO SIGNAL BRAKE OPERATION OR CONDITION.

■ C)
PHYSICAL SEPARATION OF REDUNDANT COMPONENTS.

- FAILURE EFFECTS -

■ (A) SUBSYSTEM:
DEGRADED FUNCTIONAL OPTIONS. LOSS OF ABILITY TO USE THE REDUNDANT

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DRIVE MOTOR ALONE IF MOTOR ALSO FAILS. (SEE (E))

- (B) INTERFACING SUBSYSTEM(S):
NO EFFECT. NORMAL MODE OF OPERATION IS WITH BOTH DRIVE MOTORS OPERATING.

- (C) MISSION:
NO EFFECT.

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

- (E) FUNCTIONAL CRITICALITY EFFECTS:
1. WITH ONE MOTOR BRAKE INOPERATIVE AND WITH AC POWER APPLIED TO BOTH MOTORS THE SYSTEM WILL PERFORM ITS LATCH OR UNLATCH FUNCTION.
2. WITH ONE MOTOR BRAKE INOPERATIVE AND WITH AC POWER APPLIED TO ONE MOTOR BUT NOT TO THE MOTOR WITH THE FAILED BRAKE (SECOND FAILURE) THE ACTIVE MOTOR WILL BACK DRIVE THE INACTIVE MOTOR THROUGH THE GEAR TRAIN DIFFERENTIAL AND THERE WOULD BE NO ACTUATOR OUTPUT. AN EVA WORKAROUND WOULD BE NECESSARY TO ACCOMPLISH A LATCH FUNCTION.
3. IN THE ABSENCE OF ANY APPLIED AC POWER BUT WITH A PHYSICAL FORCE APPLIED ON THE OUTPUT SIDE OF THE ACTUATOR, THAT FORCE WOULD CAUSE THE SYSTEM TO MOVE BY BACKDRIVING THROUGH THE GEAR TRAIN DIFFERENTIAL. BOTH MOTOR BRAKES ARE REQUIRED TO MAINTAIN THE GEAR TRAIN IN AN IMMOBILE STATE.

- DISPOSITION RATIONALE -

- (A) DESIGN:
BRAKE DESIGNED TO FAIL IN THE ENGAGED POSITION. PARTS CLEANED TO LEVEL 300, ASSEMBLED IN A CLASS OF 100,000 CLEAN ROOM SHIELDED FROM CONTAMINATION. MOTORS ARE STRESSED FOR OPERATING LOADS WITH MININUM FACTOR OF SAFETY = 1.4 DUAL BEARING SURFACES EMPLOYED. BRAKE SPRING OVERDESIGNED FOR FUNCTION, CENTERED TO PRECLUDE COCKING, POSITION SWITCHES ARE HIGH RELIABILITY PARTS.

ALL THE MECHANISM MATERIALS HAVE BEEN CHOSEN FOR HIGH STRENGTH/LOW WEAR CHARACTERISTICS. MECHANISM DESIGNED WITH POSITIVE MARGINS OF SAFETY FOR WORSE CASE THERMAL CONDITIONS. ALIGNMENT MECHANISM DESIGNED TO ENSURE PROPER CAPTURE ENVELOPE FOR WORSE CASE THERMAL CONDITIONS. DESIGN OF THE ACTUATION SYSTEM PERMITS PARTIAL WORKAROUND BY CREW EVA ACTIONS.

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(B) TEST:
QUALIFICATION:
THE ROEU MECHANISM IS CERTIFIED PER CR 60-544100-001-C. SYSTEM QUALIFICATION TESTS INCLUDED:

* VISUAL EXAMINATION TO VERIFY CONFORMANCE TO DRAWINGS, IDENTIFICATION MARKINGS, AND CLEANLINESS.
* ENVIRONMENTAL TESTS - VIBRATION (BOOST) FOR 60 SEC/AXIS. FLIGHT VIBRATION FOR 140 SEC/AXIS. FIVE THERMAL/VACUUM CYCLES WITH SIMULATED ROEU/PAYLOAD DISPLACEMENTS.
* OPERATIONAL LIFE TESTS - 84 CYCLES ON ARM AND LATCH MECHANISM.
* QUALIFICATION ACCEPTANCE TESTS TO CERTIFY MECHANISM FOR FIVE ACCEPTANCE THERMAL AND FIVE ACCEPTANCE VIBRATION TESTS.
* MAXIMUM DISPLACEMENT TESTS TO VERIFY OPERATIONAL ENVELOPE.
* LIMIT, LIMIT PLUS LOADS TESTS TO VERIFY STATIC LOADING.
* ARM AND LATCH STALL LOAD TESTS.

ACCEPTANCE:
THE ARM AND LATCH MECHANISMS WERE RIGGED PER CONTROLLED SPECIFICATION ML0308-0185, PLUS:

* ACCEPTANCE VIBRATION RANDOM SPECTRUM 3 MIN/AXIS.
* ACCEPTANCE THERMAL ONE AND ONE-HALF THERMAL CYCLES.

CERTIFICATION BY ANALYSIS/SIMILARITY:
FACTORS INCLUDE: HUMIDITY, FUNGUS, OZONE, SALTSPRAY, SAND/DUST, ACCELERATION, FACTORS OF SAFETY, HAIL, LIGHTNING, RAIN, SOLAR RADIATION (THERMAL AND NUCLEAR), STORAGE/OPERATING LIFE, METEOROIDS, ACOUSTICS, AND EXPLOSIVE ATMOSPHERE.

GROUND TURNAROUND:
THE ROEU IS USED AS PAYLOAD INTEGRATION HARDWARE FOR DESIGNATED PAYLOADS ONLY. THE ROEU IS CANDIDATE EQUIPMENT FOR ALL VEHICLES AND FOR ALL FLIGHTS AND AS SUCH IS EVALUATED DURING GROUND TURNAROUND WHEN REQUIRED. THIS EVALUATION INCLUDES VISUAL INSPECTION FOR EVIDENCE OF UNUSUAL OPERATION AND A COMPLETE FUNCTIONAL CHECK.

(C) INSPECTION:
RECEIVING INSPECTION
MATERIAL AND PROCESS CERTIFICATIONS ARE VERIFIED BY INSPECTION. ALL PURCHASED PART DATA PAKS ARE VERIFIED BY INSPECTION.

CONTAMINATION CONTROL
INSPECTION VERIFIES CLEANLINESS IS MAINTAINED. INSPECTION VERIFIES CORROSION PROTECTION PER MA0608-301.

ASSEMBLY/INSTALLATION

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DIMENSIONS OF DETAIL PARTS VERIFIED BY INSPECTION. FASTENER INSTALLATION IS VERIFIED BY INSPECTION. ASSEMBLY AND RIGGING OF THE ACTUATOR IS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION
N/A FOR BRAKE COMPONENTS.

CRITICAL PROCESSES
APPLICATION OF LB0140-005 DRY FILM LUBRICANT PER MA0112-302 IS VERIFIED BY INSPECTION. HEAT TREATING IS VERIFIED BY INSPECTION.

TESTING
ACCEPTANCE TESTING OF THE ACTUATOR ASSEMBLY PRIOR TO DELIVERY IS VERIFIED BY INSPECTION PER APPLICABLE PROCEDURE.

HANDLING/PACKAGING
HANDLING AND PACKAGING REQUIREMENTS ARE VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:
AD6286:
DURING ACCEPTANCE TESTING OF THE ACTUATOR (MC287-0057-001, S/N WV-101) THE ELECTRICAL POWER SUPPLY CIRCUIT BREAKER TRIPPED OPEN ON AN OVERLOAD CONDITION. SUBSEQUENTLY, THE ACTUATOR WOULD NOT FUNCTION. INVESTIGATION BY THE SUPPLIER (HOOVER ELECTRIC) DISCLOSED A SHORTED DIODE.

NOTE: THE ELECTRICAL POWER SUPPLY ARRANGEMENT IS DIFFERENT BETWEEN THE TEST SET-UP AND THE ORBITER. THE TEST CONSOLE MAKES USE OF A SINGLE POWER SUPPLY WHICH DISCONNECTED BOTH MOTORS WHEN THE CIRCUIT BREAKER TRIPPED. THE ORBITER, ON THE OTHER HAND, UTILIZES A REDUNDANT POWER SUPPLY IN THIS APPLICATION. ACCORDINGLY, THERE WOULD NOT HAVE BEEN A LOSS OF ACTUATOR OPERATION ON THE ORBITER IN THE EVENT OF THIS FAILURE MODE.

THE SUPPLIER (HOOVER ELECTRIC) WAS DIRECTED BY SUBCAR AD6286-011 TO SUBMIT THE UNIT TO AN INDEPENDENT TEST LABORATORY FOR FAILURE ANALYSIS. THE SUPPLIER SUBMITTED THE UNIT TO SCANNING ELECTRON LABORATORIES, INC. (SEAL), WHO CONDUCTED THE INVESTIGATION IN THE PRESENCE OF ROCKWELL INTERNATIONAL STSO QUALITY ENGINEERING PERSONNEL. SEAL CONDUCTED THEIR DETAILED FAILURE ANALYSIS AND PREPARED SEAL REPORT NO. 6318 TO DOCUMENT THEIR FINDINGS. THE MOTOR ASSEMBLY IN THE ACTUATOR WAS FOUND TO HAVE ONE OF THREE 1N5551 DIODES FAILED. THE ANALYSIS REVEALED THAT THE DIODE SHORTED AS THE RESULT OF AN ELECTRICAL OVERSTRESS CONDITION WHICH MELTED A SECTION OF THE SILICON DIE. THE DAMAGE TO THE DIE WAS SO SEVERE THAT ANY DETAILS WHICH MIGHT HAVE INDICATED THE NATURE OF THE OVERSTRESS WERE OBSCURED. CONSEQUENTLY, IT WAS NOT POSSIBLE TO CONCLUSIVELY DETERMINE IF THE DIODE INITIALLY FAILED BECAUSE OF AN

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OVERVOLTAGE OR AN OVERCURRENT CONDITION. AFTER THE SHORT-CIRCUIT OCCURRED IN THE DIODE, THE SUBSEQUENT EXCESSIVE CURRENT FLOW THROUGH THE DEVICE CAUSED THE SILICON DIE TO MELT.

THE TEST EQUIPMENT USED BY ROCKWELL, BOTH LABORATORIES AND TEST AND MANUFACTURING, WAS EXAMINED, IN ACCORDANCE WITH SUBCAR A06286-012, TO PROVIDE ASSURANCE THAT THE TEST EQUIPMENT WAS NOT CONTRIBUTING TO THE FAILURE OF THE ACTUATORS. IT WAS FOUND THAT THE TEST CONSOLE USED BY MANUFACTURING PRODUCED TURN-ON VOLTAGE TRANSIENTS OF AT LEAST 800 VOLTS PEAK, AND THE TEST CONSOLE USED BY LABORATORIES AND TEST PRODUCED TURN-ON VOLTAGE TRANSIENTS OF AT LEAST 600 VOLTS PEAK. THE DIODES USED IN THE ACTUATOR MOTORS ARE RATED AT 400 VOLTS PIV.

THE MC287-0057-0001 ACTUATOR EMPLOYS TWO DRIVE MOTORS IN ITS PERFORMANCE. THE ACTUATOR DESIGN IS SUCH THAT A BEVEL DIFFERENTIAL BALANCES THE MECHANICAL LOAD BETWEEN THESE TWO MOTORS. THIS DESIGN CHARACTERISTIC ALSO PERMITS A SINGLE MOTOR TO MOVE THE GEAR TRAIN THROUGH ITS DESIGNATED CYCLE. ACCORDINGLY, IT IS NOT CONSIDERED LIKELY THAT A MALFUNCTION IN ONE MOTOR WOULD CAUSE AN EXCESSIVE LOAD TO BE EXPERIENCED BY THE REMAINING MOTOR AND INDUCE A FAILURE THERE.

THE CORRECTIVE ACTIONS WHICH HAVE BEEN TAKEN IN REGARD TO THIS FAILURE ARE:

1. ALL UNITRODE DIODES IN BOTH MOTORS OF THE FAILED ACTUATOR HAVE BEEN REPLACED WITH THEIR EQUIVALENT UNITS MANUFACTURED BY SENSITRON, INC., IN ACCORDANCE WITH SUBCAR A06286-011. THE UNITRODE DIODES WERE FROM A LOT WHICH HAD BEEN THE SUBJECT OF AN ALERT.

2. THE REPAIRED ACTUATOR WAS SUBJECTED TO A FULL ACCEPTANCE TEST BY HOOVER ELECTRIC, AS MODIFIED BY SUBCAR A06286-011. AFTER PASSAGE OF THE TEST, THE ACTUATOR WAS RETURNED TO ROCKWELL INTERNATIONAL STSD.

3. VARISTORS HAVE BEEN ADDED TO BOTH TEST CONSOLES, AND TESTS HAVE SHOWN THIS MODIFICATION TO BE EFFECTIVE IN LIMITING THE TURN-ON VOLTAGE TRANSIENTS TO A MAXIMUM OF 340 VOLTS PEAK, WHICH IS WELL BELOW THE PIV RATING OF THE DIODES. THIS TEST CONSOLE MODIFICATION REMOVES ANY POSSIBILITY, HOWEVER REMOTE, THAT THE CONSOLES MAY HAVE CONTRIBUTED TO THE DIODE FAILURES.

■ (E) OPERATIONAL USE:
NONE

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- APPROVALS -

RELIABILITY ENGINEERING	M. P. RAGUSA	
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