

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**NUMBER: M0-AD1-M12 -X****SUBSYSTEM NAME:** REMOTELY OPERATED ELECTRICAL UMBILICAL**REVISION:** 2 01/07/02**PART DATA**

PART NAME	PART NUMBER
VENDOR NAME	VENDOR NUMBER
SRU : ARM ACTUATOR	MC287-0057-0002
TELAIR (FORMERLY HOOVER ELECTRIC)	17820-2

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

DUAL MOTOR/BRAKE ASSEMBLY, 3 PHASE AC, 400 HZ.

REFERENCE DESIGNATORS:**QUANTITY OF LIKE ITEMS:** 2

ONE PER ROEU ASSEMBLY

17820-1 (LATCH ACTUATOR) IS A SIMILAR ITEM.

FUNCTION:

THE ARM ACTUATOR USES REDUNDANT MOTORS DRIVING THROUGH A DIFFERENTIAL/GEARBOX TO PROVIDE THE FORCE NECESSARY TO MATE, RELAX AND STOW THE SWING ARM.

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SUBSYSTEM NAME: REMOTELY OPERATED ELECTRICAL UMBILICAL

LRU:

CRITICALITY OF THIS

ITEM NAME: ARM ACTUATOR

FAILURE MODE: 2R3

FAILURE MODE:

BRAKE FAILS TO ENGAGE

MISSION PHASE:

OO ON-ORBIT

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

- 102 COLUMBIA
- 103 DISCOVERY
- 104 ATLANTIS
- 105 ENDEAVOUR

CAUSE:

ADVERSE TOLERANCES/WEAR, CONTAMINATION/FOREIGN OBJECT/DEBRIS, DEFECTIVE PART/MATERIAL OR MANUFACTURING DEFECT, FAILURE/DEFLECTION OF INTERNAL PART OR BROKEN 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 PARTS.

- FAILURE EFFECTS -

(A) SUBSYSTEM:

DEGRADED FUNCTIONAL OPTIONS. LOSS OF ABILITY TO USE THE REDUNDANT DRIVE MOTOR ALONE IF THE MOTOR ALSO FAILS.

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(B) INTERFACING SUBSYSTEM(S):

NO EFFECT. NORMAL MODE OF OPERATION IS WITH BOTH DRIVE MOTORS OPERATING.

(C) MISSION:

FIRST FAILURE - NO EFFECT

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

FIRST FAILURE - 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 ARM MOVEMENT 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 ARM MOVEMENT.
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 ENGAGED POSITION. PARTS CLEANED TO LEVEL 300, ASSEMBLED IN A CLASS OF 100,000 CLEAN ROOM. SHIELDING FROM CONTAMINATION. MOTORS ARE STRESSED FOR OPERATING LOADS WITH MINIMUM S.F. = 1.4 DUAL BEARING SURFACES EMPLOYED. BRAKE SPRING OVERDESIGNED FOR FUNCTION, CENTERED TO PRECLUDE COCKING POSITION SWITCHES ARE HIGH REL 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.

(B) TEST:

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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:

OMRSD - ANY TURNAROUND TEST CHECKOUT TESTING IS ACCOMPLISHED IN ACCORDING WITH OMRSD

(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

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

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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:

CURRENT DATA ON TEST FAILURES, FLIGHT FAILURE, UNEXPLAINED ANOMALIES, AND OTHER FAILURE EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATA BASE.

AD5045 DURING FUNCTIONAL CHECKOUT OF THE ACTUATOR (MC287-0057-002, S/N WX102), THE ELECTRICAL POWER SUPPLY CIRCUIT BREAKER TRIPPED OPEN ON AN OVERLOAD CONDITION. SUBSEQUENTLY, THE ACTUATOR WOULD NOT FUNCTION. PRELIMINARY INVESTIGATION BY THE SUPPLIER (TELAIR) DETERMINED THAT THERE WAS AN OPEN CIRCUIT IN MOTOR B1 OF THIS ASSEMBLY.

THE SUPPLIER (TELAIR) RESPONDED TO THIS MALFUNCTION CONDITION BY SUBMITTING THE MOTOR ASSEMBLY TO AN INDEPENDENT LABORATORY (SCANNING ELECTRON ANALYSIS LABORATORY, INC.) FOR DETAIL FAILURE ANALYSIS. THE LABORATORY CONDUCTED THE INVESTIGATION AND PREPARED REPORT NO. 6227 TO DOCUMENT THEIR FINDINGS. MOTOR ASSEMBLY, P/N 45275-3 WAS FOUND TO HAVE AN OPEN WINDING CAUSED BY DAMAGE AT TELAIR PRIOR TO SHIPMENT. TO ASCERTAIN THE CAUSE OF THE OPEN WINDING, THE LABORATORY DISASSEMBLED THE MOTOR AND INSPECTED THE WINDINGS. A REGION WAS FOUND WHERE APPROXIMATELY THREE WIRES APPEARED TO HAVE BEEN CUT AND ADJACENT INSULATION WAS ABRADED. A CLOSE INSPECTION OF THE MOTOR FRAME REVEALED A SMALL HOLE WHICH ALIGNED PERFECTLY WITH THE CUT WINDINGS AND THE DAMAGED INSULATION. THIS HOLE WAS DRILLED IN THE MOTOR CASE PREPARATORY TO INSTALLATION OF THE RETAINING DRIVE SCREW FASTENER WHICH RETAINED THE NAMEPLATE OF THE MOTOR.

THE MC287-0057-0002 ACTUATOR EMPLOYS TWO DRIVE MOTORS, B1 AND B2, IN ITS PERFORMANCE. CAR AD5046-010 DESCRIBES A FAILURE IN THE B2 MOTOR AND AD5045-010 DESCRIBES THE FAILURE NOTED HERE. 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 AT FULL TORQUE AND HALF SPEED. 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.

TWO ACTIONS HAVE BEEN TAKEN TO PRECLUDE RECURRENCE OF THIS SITUATION:

1. TELAIR HAS CHANGED CONSTRUCTION OF THE ACTUATOR TO ELIMINATE THE DRIVE SCREW FASTENERS THAT WERE USED TO RETAIN THE SHEET ALUMINUM NAMEPLATE. AN ADHESIVE BACKED ALUMINUM FOIL NAMEPLATE IS NOW SPECIFIED AND IS LOCATED ON THE MOTOR AT A POINT READILY VISIBLE WHEN THE MOTOR IS INSTALLED ON THE ACTUATOR. THIS CHANGE IS REFLECTED ON TELAIR CO. DRAWING 17820, REVISION D.

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2. TELAIR HAS RELEASED REVISION "C" OF ACCEPTANCE TEST PROCEDURES HE-2-309-1 FOR ACTUATORS P/N 17820-1 (MC287-0057-0001) AND HE -2-309-2 FOR ACTUATORS P/N 17820-2 (MC287-0057-0002). THESE SIMILAR ACTUATORS BOTH USE DRIVE MOTOR ASSEMBLY, P/N 45275. TO ASSURE THE ACCEPTANCE OF ONLY THOSE MOTORS THAT CONCUR WITH DESIGN REQUIREMENTS, THE REVISED PROCEDURES REQUIRE FINAL TEST INSPECTION AND SIGNOFF FOR:
 - A. PHASE CIRCUIT CONTINUITY,
 - B. PHASE RESISTANCE (LINE TO WYE), AND
 - C. NO-LOAD BENCH OPERATION OF THE ACTUATOR ON BOTH DRIVE MOTORS.

AD5046 DURING FUNCTIONAL CHECKOUT OF THE ACTUATOR (MC287-0057-002, S/N WX102), THE ELECTRICAL POWER SUPPLY CIRCUIT BREAKER TRIPPED OPEN ON AN OVERLOAD CONDITION. SUBSEQUENTLY, THE ACTUATOR WOULD NOT FUNCTION. PRELIMINARY INVESTIGATION BY THE SUPPLIER (TELAIR) DETERMINED WHAT APPEARED TO BE A SHORTED STATOR TURN IN MOTOR B2. FURTHER ANALYSIS AT THE SUPPLIER'S FACILITY DISCLOSED A SHORTED DIODE.

THE SUPPLIER (TELAIR) RESPONDED TO THIS MALFUNCTION CONDITION BY SUBMITTING THE MOTOR ASSEMBLY TO AN INDEPENDENT LABORATORY (SCANNING ELECTRON ANALYSIS LABORATORY, INC.) FOR DETAIL FAILURE ANALYSIS. THE LABORATORY CONDUCTED THE INVESTIGATION AND PREPARED REPORT NO. 6227 TO DOCUMENT THEIR FINDINGS. MOTOR ASSEMBLY, P/N 45275-4 WAS FOUND TO HAVE ONE OF THREE DIODES FAILED. THE INVESTIGATION DETERMINED THAT THE DIODE SHORTED AS A RESULT OF AN ELECTRICAL OVERSTRESS CONDITION WHICH MELTED AS A SECTION OF THE SILICON DIE. THE AMOUNT OF 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 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. THIS FAILURE IS BELIEVED TO BE AN ISOLATED CASE AND NOT A GENERIC CONDITION INHERENT TO THE DIODE COMPONENT.

THE MC287-0057-0002 ACTUATOR EMPLOYS TWO DRIVE MOTORS, B1 AND B2, IN ITS PERFORMANCE. CAR AD5046-010 DESCRIBES A FAILURE IN THE B2 MOTOR AND AD5045-010 DESCRIBES THE FAILURE NOTED HERE. 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.

TWO ACTIONS HAVE BEEN TAKEN IN REGARD TO THIS SITUATION:

1. THE FAILED DIODE HAS BEEN REPLACED AND THE MOTOR SUCCESSFULLY TESTED FOR DESIGN CONCURRENCE.
2. TELAIR HAS RELEASED REVISION "C" OF ACCEPTANCE TEST

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- B. PHASE RESISTANCE (LINE TO WYE), AND
- C. NO-LOAD BENCH OPERATION OF THE ACTUATOR ON BOTH DRIVE MOTORS.

(E) OPERATIONAL USE:

EVA WORK AROUND CAN BE USED TO ACCOMPLISH SWING ARM MOTION.

- APPROVALS -

S&R ENGINEER.	:A. NGUYEN	:/s/A. Nguyen_____
CARGO/INTEG ITM.	:J. CAPALENI	:/s/J. Capaleni_____
DESIGN ENGINEERING	:D. HAEHLKE	:/s/D. Haehlke_____
SSM	:P. REESE	:/s/P. Reese_____
MOD	:K. SMITH	:/s/K. Smith_____
USA/SAM	:R. SMITH	:/s/S.R. Smith_____
USA CARGO/INTG ELEMENT	:H. MALTBY	:/s/H. Maltby_____
USA ORBITER ELEMENT	:S. LITTLE	:/s/S. Little_____