

**CRITICAL ITEMS LIST**

PROJECT: SRMS

SYSTEM: MECHANICAL ARM SUBSYSTEM

ASS'Y NOMENCLATURE: END EFFECTOR

ASS'Y P/N: 51140E1470-1E-3

SHEET: 1

FMEA REF.	FMEA REV.	NAME, QTY, & DRAWING REF. DESIGNATION	FAILURE MODE AND CAUSE	FAILURE EFFECT OR END ITEM	HDWR / FUNC. 2/1R CRITICALITY RATIONALE FOR ACCEPTANCE SCREENS: A-PASS, B-PASS, C-PASS
3650	3	MOTOR MODULE ASSEMBLY QTY-1 P/N 51140E1473 OR 51140E2203	<p>MODE: LOW TORQUE OUTPUT FROM MOTOR DRIVE.</p> <p>CAUSE(S): (1) HIGH FRICTION IN MOTOR MODULE BEARINGS, GEAR TRAIN. (2) CLUTCH SLIPPAGE. (3) BRAKE LINING DRAG.</p>	<p>DEGRADED PERFORMANCE OF END EFFECTOR. ALL END EFFECTOR OPERATIONS SLOWED DOWN. MAY NOT FULLY RIGIDIZE. ARM WILL STAY LIMP IF NO RIGID FLAG.</p> <p>WORST CASE ----- UNEXPECTED PAYLOAD MOTION. INCOMPLETE RIGIDIZATION. CREW ACTION REQUIRED.</p> <p>REDUNDANT PATHS REMAINING ----- 1) MANUAL EE MODE RELEASE. 2) BACKUP EE RELEASE.</p>	<p>DESIGN FEATURES -----</p> <p>THE BEARINGS ARE PROCURED BY SPAR AND MEET, OR EXCEED THE REQUIREMENTS OF SPECIFICATION SPAR-SG.393.</p> <p>THE BEARING ANALYSIS USES ULTIMATE LOADS TO DETERMINE THE MARGINS OF SAFETY OF THE LUBRICANT. THE FACTOR BETWEEN WORKING LOADS AND ULTIMATE IS 1.4. THE LUBRICANT FAILURE STRESSES ARE LOWER THAN THE BRINELLING STRESS. LIFE FOR ALL BEARINGS IS GREATER THAN 400 MISSIONS BASED UPON THE ABOVE CRITERIA.</p> <p>THE ALLOWABLE CONTACT STRESS FOR THE LUBRICANT IS ABOUT 1/5TH THE ALLOWABLE CONTACT STRESS FOR THE BEARING, THEREFORE THE LUBRICANT PROPERTIES DICTATE THE DESIGN, THE BEARINGS AS A RESULT ARE LIGHTLY LOADED AND SURFACE FATIGUE IN THE BEARING MATERIAL IS NOT A VIABLE FAILURE MODE.</p> <p>BEARINGS ARE LOCATED IN NON-DEBRIS PRODUCING AREA OF ASSEMBLY.</p> <p>RIGIDIZE DRIVE SHAFT IS SUPPORTED ON TWO DRY-LUBE BEARINGS WHICH ARE VULNERABLE TO DEBRIS:</p> <p>PRODUCED IN THE EE BACK PLATE VOLUME FOR THE 511410C989-1 BEARING.</p> <p>OR</p> <p>ENTERING THE E/E FOR THE 51140C611-3 BEARING.</p> <p>SNARE IDLER GEAR (51140D1645) INCORPORATES A DRY-LUBE BEARING WHICH IS VULNERABLE TO DEBRIS ENTERING THE E/E.</p> <p>THE END EFFECTOR BRAKE DESIGN USES TWO IDENTICAL BEARINGS. THE BEARINGS ARE PERMANENTLY LUBRICATED WITH WET LUBRICANT. THEY ARE SEALED ON BOTH SIDES WITH TEFLON SEALS TO PREVENT THE INGRESS OF DEBRIS.</p> <p>THE END EFFECTOR PRIME AND BACK-UP RELEASE CLUTCH DESIGNS UTILIZE THREE BEARINGS, TWO OF WHICH ARE IDENTICAL. THE BEARINGS ARE PERMANENTLY LUBRICATED WITH WET LUBRICANT. THE TWO IDENTICAL BEARINGS ARE SEALED WITH TEFLON SEALS AND THE OTHER IS SEALED WITH TEFLON COATED FIBREGLASS SEALS, BOTH SIDES, TO PREVENT THE INGRESS OF DEBRIS.</p> <p>ALL SRMS GEARS ARE DESIGNATED IN ACCORDANCE WITH AGMA STANDARDS TO GIVE A MINIMUM OF INFINITE LIFE. THE DEFINITION OF INFINITE LIFE IS THE CONDITION WHERE 10**7 MESH CYCLES OR MORE AT THE APPLIED LOAD WILL NOT RESULT IN TOOTH FAILURE.</p> <p>FOR THIS (THESE) GEAR (S) THE CALCULATED LIFE WAS NOT BASED OR CONTROLLED BY CONSIDERATIONS OF STRESS, BUT INSTEAD WERE SIZED TO SATISFY SPECIAL CONSTRAINTS. CONSEQUENTLY, THE MESH IS WELL WITHIN THE DEFINITION OF INFINITE LIFE AND THE FAILURE MODE STATED IN THE FMEA IS REMOTE.</p> <p>THE SOLID FILM LUBRICANT SYSTEM USED IS LUBECO 905. THIS COMPRISES A SPRAY AND CURE (400 DEGREES F)</p>

PREPARED BY:

MFWG

SUPERCEDING DATE: 12 OCT 89

APPROVED BY:

DATE: 24 JUL 91

CIL REV: 3



**CRITICAL ITEMS LIST**

PROJECT: SRMS  
ASS'Y NOMENCLATURE: END EFFECTOR

SYSTEM: MECHANICAL ARM SUBSYSTEM  
ASS'Y P/N: 51140E1470-1E-3

SHEET: 2

FMEA REF.	FMEA REV.	NAME, QTY, & DRAWING REF. DESIGNATION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	HOWR / FUNC. 2/1R CRITICALITY	RATIONALE FOR ACCEPTANCE SCREENS: A-PASS, B-PASS, C-PASS
3650	3	MOTOR MODULE ASSEMBLY QTY-1 P/N 51140E1473 OR 51140E2203	<p>MODE: LOW TORQUE OUTPUT FROM MOTOR DRIVE.</p> <p>CAUSE(S): (1) HIGH FRICTION IN MOTOR MODULE BEARINGS, GEAR TRAIN. (2) CLUTCH SLIPPAGE. (3) BRAKE LINING DRAG.</p>	<p>DEGRADED PERFORMANCE OF END EFFECTOR. ALL END EFFECTOR OPERATIONS SLOWED DOWN. MAY NOT FULLY RIGIDIZE. ARM WILL STAY LIMP IF NO RIGID FLAG.</p> <p>WORST CASE ----- UNEXPECTED PAYLOAD MOTION. INCOMPLETE RIGIDIZATION. CREW ACTION REQUIRED.</p> <p>REDUNDANT PATHS REMAINING ----- 1) MANUAL EE MODE RELEASE. 2) BACKUP EE RELEASE.</p>		<p>APPLICATION OF MOLYBDENUM DISULPHIDE, IN AN ORGANIC BINDER APPLIED PER PPS:28:11 AND 28:13. BURNISHING AND RUN IN PER SPAR PPS 28:14. THE LUBRICATED BEARING IS TORQUE TRACED TO ENSURE ACCEPTABILITY PER SPAR PPS.28:14.</p> <p>THE GREASE LUBRICANT USED IS BRAYCOTE 601 (FORMERLY 3L-38RP) WHICH HAS A PERFLUORINATED POLYETHER OIL BASE WHICH IS VERY STABLE UNDER VACUUM ENVIRONMENT.</p> <p>THE GREASE IS APPLIED IN PRECISE QUANTITY TO EACH BEARING.</p> <p>THE LIFE OF THE BEARING LUBRICATION HAS BEEN ANALYZED USING ULTIMATE LOADS TO EVALUATE HERTZIAN STRESSES. ULTIMATE LOAD = 1.4 X WORKING LOAD. THE LUBRICANT ON ALL BEARINGS IS GOOD FOR OVER 400 MISSIONS USING THE ULTIMATE LOADS.</p> <p>THE END EFFECTOR CLUTCH IS A MAJOR BOUGHT-OUT-PART WHICH IS SUPPLIED BY HONEYWELL SPERRY CORPORATION AND MEETS OR EXCEEDS THE REQUIREMENTS OF SPECIFICATION SPAR-SG.450 FOR P/N 51140D575-1 AND SPAR-SG.1092 FOR P/N51140D575-3.</p> <p>THE CLUTCH SHAFT AND ARMATURE ARE CONNECTED BY A SPLINE WHICH PROVIDES ROTATION TO THE ARMATURE AND ALLOWS AXIAL SLIDING FOR ENGAGEMENT AND DISENGAGEMENT. THE FOLLOWING IS A LIST OF CHARACTERISTICS TO LIMIT THE POSSIBILITY OF THE CLUTCH HANGING-UP DUE TO MECHANICAL BINDING OF THE SPLINE:</p> <p>THE SPLINES ARE MATCH-MACHINED FOR A PRECISE AND SMOOTH FIT.</p> <p>SERIALIZATION OF THE MATCHED PARTS ASSURES PROPER ASSEMBLY.</p> <p>THE MATCHED SHAFT AND ARMATURE ASSEMBLY IS INSPECTED FOR PROPER CLEARANCE AND SMOOTHNESS OF OPERATION.</p> <p>THE UNIT IS TESTED A MINIMUM OF SEVEN TIMES DURING ACCEPTANCE TESTING FOR POTENTIAL BINDING. THE TEST CONSISTS OF APPLYING FULL RATED LOAD TORQUE WITH THE UNIT ENGAGED. A VOLTAGE IS THEN APPLIED TO DISENGAGE THE UNIT. THE TIME FROM APPLICATION OF VOLTAGE UNTIL FULL DISENGAGEMENT IS MEASURED. ANY BINDING OF THE ARMATURE WOULD EITHER PREVENT DISENGAGEMENT OR CAUSE AN EXCESSIVE TIME DELAY.</p> <p>THE SPLINES ARE LUBRICATED WITH MOLYBDENUM DISULFIDE.</p> <p>THE UNIT LOAD LEVELS ON THE SPLINE ARE LOW.</p> <p>IT SHOULD BE NOTED THAT THESE UNITS DO NOT UTILIZE REDUNDANT SPLINES.</p> <p>THE BEARINGS ARE WET LUBRICATED WITH BRAYCOTE 3L-38RP</p> <p>THE HEAVIEST AMOUNT OF FRICTION MATERIAL DEBRIS IS GENERATED DURING THE CALIBRATION RUN-IN OF THE UNIT. THE RUN-IN CONSISTS OF ROTATING THE UNIT IN ONE DIRECTION AT 50 RPM FOR A TOTAL OF 16 HOURS MINIMUM USING A DUTY CYCLE OF 10 SECONDS ENGAGED AND THEN 10 SECONDS DISENGAGED. THE UNITS RECEIVE A VERY LIMITED AMOUNT OF SLIPPING DURING ON MISSION USAGE. DEBRIS IS PREVENTED FROM ESCAPING FROM THE -3 CLUTCH USED IN THE 51140E1470-3 END EFFECTOR WITH A LABYRINTH NETWORK.</p>

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PROJECT: SRMS  
ASS'Y NOMENCLATURE: END EFFECTOR

SYSTEM: MECHANICAL ARM SUBSYSTEM  
ASS'Y P/N: 51140E1470-1B-3 SHEET: 3

FMEA REF.	FMEA REV.	NAME, QTY, & DRAWING REF. DESIGNATION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	HDWR / FUNC. 2/1R CRITICALITY RATIONALE FOR ACCEPTANCE SCREENS: A-PASS, B-PASS, C-PASS
3650	3	MOTOR MODULE ASSEMBLY QTY-1 P/N 51140E1473 OR 51140E2203	<p>MODE: LOW TORQUE OUTPUT FROM MOTOR DRIVE.</p> <p>CAUSE(S): (1) HIGH FRICTION IN MOTOR MODULE BEARINGS GEAR TRAIN. (2) CLUTCH SLIPPAGE. (3) BRAKE LINING DRAG.</p>	<p>DEGRADED PERFORMANCE OF END EFFECTOR. ALL END EFFECTOR OPERATIONS SLOWED DOWN. MAY NOT FULLY RIGIDIZE. ARM WILL STAY LIMP IF NO RIGID FLAG.</p> <p>WORST CASE ----- UNEXPECTED PAYLOAD MOTION. INCOMPLETE RIGIDIZATION. CREW ACTION REQUIRED.</p> <p>REDUNDANT PATHS REMAINING ----- 1) MANUAL EE MODE RELEASE. 2) BACKUP EE RELEASE.</p>	<p>THE AIR GAP OF THE UNIT IS VERIFIED TO MEET A MINIMUM VALUE BY THE END PLAY TEST (LARGEST APPLIED LOAD) DURING ACCEPTANCE TESTING.</p> <p>THE STRIPDOWN AND INSPECTION OF FLIGHT HARDWARE RETURNED FOR REFURBISHMENT HAS REVEALED THAT A SIGNIFICANT AMOUNT OF FRICTION MATERIAL DEBRIS MAY HAVE ACCUMULATED AT THE UNIT END-OF-LIFE. IT IS VERY UNLIKELY, HOWEVER, THAT SUFFICIENT FRICTION DEBRIS COULD ACCUMULATE BEHIND THE ARMATURE OR BETWEEN THE FRICTION SURFACES, SO AS TO AFFECT THE UNITS PERFORMANCE</p> <p>THE CLUTCH DESIGN USES ONE COMPRESSION SPRING, PILOTTED ON THE ARMATURE SPLINE TUBE, TO PROVIDE THE FORCE OF ENGAGING THE FRICTION SURFACES. THE TOTAL LOSS OF STIFFNESS OR FRACTURE OF THE SPRING WOULD RESULT IN NO TORQUE TRANSMISSION ACROSS THE CLUTCH. THE SPRING IS NOT SUBJECTED TO FATIGUE FAILURE BECAUSE DURING OPERATION IT IS ESSENTIALLY UNDER CONSTANT STRESS, I.E. CLUTCH ACTUATION INVOLVES SPRING DEFLECTIONS OF 0.003 TO 0.004 INCHES. THE SPRING UNDER OPERATING CONDITIONS HAS A MARGIN OF SAFETY FOR ULTIMATE TENSILE STRENGTH (MUTS) OF POSITIVE 0.04 FOR FRACTURE IN SHEAR.</p> <p>IN THE IMPROBABLE EVENT OF SPRING FRACTURE, THE SPRING HOUSING WILL RETAIN ANY DEBRIS.</p> <p>THE SPRING IS STAINLESS STEEL, FS302 OR FS304, MANUFACTURED TO MATERIAL SPECIFICATION QQ-W-423. DURING THE MANUFACTURING OF A BATCH OF SPRINGS, A LOT IS REMOVED AND INSPECTED BY QC FOR DIMENSIONAL AND MATERIAL COMPLIANCE, AND LOAD VERSUS DEFLECTION.</p> <p>THE END EFFECTOR BRAKE IS A MAJOR BOUGHT-OUT-PART WHICH IS SUPPLIED BY HONEYWELL SPERRY CORPORATION AND MEETS OR EXCEEDS THE REQUIREMENTS OF SPECIFICATION SPAR-SG.451 FOR P/N 51140D574-1B-3 AND SPAR-SG.1093 FOR P/N 51140D2219-1.</p> <p>THE BRAKE DESIGN FEATURES THAT LIMIT THE POSSIBILITY OF AN OPEN OR SHORT CIRCUIT IN THE WINDINGS ARE THE SAME AS THE FEATURES FOR THE CLUTCH DISCUSSED PREVIOUSLY IN THIS CIL ITEM.</p> <p>THE CALIPER BRAKE INCORPORATES MANY DESIGN FEATURES TO IMPROVE THE BRAKES CAPABILITY AND GIVE HIGHER RELIABILITY AS FOLLOWS:</p> <ul style="list-style-type: none"> <li>- SLIP TORQUE CAPABILITY UP TO 85 OZ-IN.</li> <li>- TOTAL INTERNAL CONTAINMENT OF FRICTION DEBRIS WITH THE USE OF LABYRINTH PATHS AND THE PLACEMENT OF THE FRICTION DISKS ON THE OPPOSITE END OF THE BRAKE SHAFT FROM THE PINION GEAR.</li> <li>- MECHANICALLY REDUNDANT SLIDING SPLINES FOR THE CALIPER DISK.</li> <li>- MECHANICALLY REDUNDANT LOCATING PINS WITH VESPEL SLEEVES FOR DISK LOCATION.</li> <li>- BEARING LOADS ARE REDUCED BY A 5 TO 1 FACTOR OVER THE ORIGINAL E/E SNARE BRAKE P/N 51140D574-3.</li> <li>- SLIDING SURFACES ARE LUBRICATED WITH MOLYBDENUM DISULFIDE.</li> <li>- BEARINGS ARE WET LUBRICATED WITH BRAYCOTE 3L-38RP.</li> <li>- AIR GAP CAN BE ADJUSTED WITHOUT BRAKE DISASSEMBLY.</li> </ul> <p>THE BRAKE USES FOUR PINS PRESS FITTED INTO THE CORE TO HOLD</p>

PREPARED BY:

HWG

SUPERCEDING DATE: 12 OCT 89

APPROVED BY:

DATE: 26 JUL 91

CIL REV: 3

**CRITICAL ITEMS LIST**

PROJECT: SRMS  
 ASS'Y NOMENCLATURE: END EFFECTOR

SYSTEM: MECHANICAL ARM SUBSYSTEM  
 ASS'Y P/N: 51140E1470-14-3

SHEET: 4

FMEA REF.	FMEA REV.	NAME, QTY, & DRAWING REF. DESIGNATION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	HDWR / FUNC. 2/1R CRITICALITY RATIONALE FOR ACCEPTANCE SCREENS: A-PASS, B-PASS, C-PASS
3650	3	MOTOR MODULE ASSEMBLY QTY-1 P/N 51140E1473 OR 51140E2203	MODE: LOW TORQUE OUTPUT FROM MOTOR DRIVE.  CAUSE(S): (1) HIGH FRICTION IN MOTOR MODULE BEARINGS, GEAR TRAIN. (2) CLUTCH SLIPPAGE. (3) BRAKE LINING DRAG.	DEGRADED PERFORMANCE OF END EFFECTOR. ALL END EFFECTOR OPERATIONS SLOWED DOWN. MAY NOT FULLY RIGIDIZE. ARM WILL STAY LIMP IF NO RIGID FLAG.  WORST CASE ----- UNEXPECTED PAYLOAD MOTION. INCOMPLETE RIGIDIZATION. CREW ACTION REQUIRED.  REDUNDANT PATHS REMAINING ----- 1) MANUAL EE MODE RELEASE. 2) BACKUP EE RELEASE.	THE ARMATURE FROM ROTATING AND TO ALLOW AXIAL SLIDING FOR ENGAGEMENT AND DISENGAGEMENT. THE FOLLOWING IS A LIST OF CHARACTERISTICS TO LIMIT THE POSSIBILITY OF THE BRAKE HANGING-UP DUE TO MECHANICAL BINDING BETWEEN THE PINS AND THE HOLES.  THE HOLES IN THE ARMATURE AND BRAKE CORE ARE MATCH-BORED (JIG BORED) TO ASSURE GOOD ALIGNMENT.  THE ARMATURE HOLES ARE 0.004 TO 0.005 INCH LARGER THAN THE CORE PINS TO ASSURE ADEQUATE CLEARANCE.  MEASUREMENTS ARE PERFORMED TO CONFIRM A MINIMUM OF 0.002 INCH RADIAL PLAY BETWEEN THE TWO ASSEMBLED PARTS.  THE UNIT IS TESTED A MINIMUM OF SEVEN TIMES DURING ACCEPTANCE TESTING FOR POTENTIAL BINDING. THE TEST CONSISTS OF APPLYING FULL RATED LOAD TORQUE WITH THE UNIT ENGAGED. A VOLTAGE IS THEN APPLIED TO DISENGAGE THE UNIT. THE TIME FROM APPLICATION OF VOLTAGE UNTIL FULL DISENGAGEMENT IS MEASURED. ANY BINDING OF THE ARMATURE WOULD EITHER PREVENT DISENGAGEMENT OR CAUSE AN EXCESSIVE TIME DELAY.  THE PINS ARE LUBRICATED WITH MOLYBDENUM DISULFIDE.  THE PRELOAD SPRINGS SUPPLY THE SPECIFIED LOADING FOR THE BRAKE ANGULAR CONTACT BEARING AND LOCATE THE BEARINGS AND SHAFT ASSEMBLY WITHIN THE BRAKE HOUSING. THE BRAKE DESIGN UTILIZES A MULTIPLE ARRANGEMENT OF WAVE WASHERS TO GENERATE THE REQUIRED PRELOAD. THE UNIT PRELOAD IS VERIFIED BY THE END PLAY TEST (SMALLEST APPLIED LOAD) DURING ACCEPTANCE TESTING.

**CRITICAL ITEMS LIST**

PROJECT: SRMS  
 ASS'Y NOMENCLATURE: END EFFECTOR

SYSTEM: MECHANICAL ARM SUBSYSTEM  
 ASS'Y P/N: 51140E1470-1B-3

SHEET: 5

FMEA REF.	FMEA REV.	NAME, QTY, & DRAWING REF. DESIGNATION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	HDMR / FUNC. 2/1R CRITICALITY RATIONALE FOR ACCEPTANCE SCREENS: A-PASS, B-PASS, C-PASS
3650	3	MOTOR MODULE ASSEMBLY QTY-1 P/N 51140E1473 OR 51140E2203	MODE: LOW TORQUE OUTPUT FROM MOTOR DRIVE.  CAUSE(S): (1) HIGH FRICTION IN MOTOR MODULE BEARINGS GEAR TRAIN. (2) CLUTCH SLIPPAGE. (3) BRAKE LINING DRAG.	DEGRADED PERFORMANCE OF END EFFECTOR. ALL END EFFECTOR OPERATIONS SLOWED DOWN. MAY NOT FULLY RIGIDIZE. ARM WILL STAY LIMP IF NO RIGID FLAG.  WORST CASE ----- UNEXPECTED PAYLOAD MOTION. INCOMPLETE RIGIDIZATION. CREW ACTION REQUIRED.  REDUNDANT PATHS REMAINING ----- 1) MANUAL EE MODE RELEASE. 2) BACKUP EE RELEASE.	ACCEPTANCE TESTS ----- THE EE ASSEMBLY IS TESTED TO THE FOLLOWING ACCEPTANCE ENVIRONMENTS:  O VIBRATION: LEVEL AND DURATION - REFERENCE TABLE 7  O THERMAL VACUUM: +70 DEGREES C TO -25 DEGREES C (1 1/2 CYCLES) 1 X 10**6 TORR  THE EE ASSEMBLY IS FURTHER TESTED IN THE IN THE RMS SYSTEM TEST (TP518 RMS STRONGBACK AND TP552 FLAT FLOOR TESTS) WHICH VERIFIES THE ABSENCE OF THE FAILURE MODE.  QUALIFICATION TESTS ----- THE EE ASSEMBLY QUALIFICATION TESTING CONSISTED OF THE FOLLOWING ENVIRONMENTS:  O VIBRATION: LEVEL AND DURATION - REFERENCE TABLE 7  O SHOCK: 20G/11 MS - 3 AXES (6 DIRECTIONS)  O THERMAL VACUUM: +81 DEGREES C TO -36 DEGREES C (6 CYCLES) 1 X 10**6 TORR  O HUMIDITY: 95% RH (65 DEGREES C MAINTAINED FOR 6 HRS) (65 DEGREES C TO 30 DEGREES C IN 16 HRS). 10 CYCLES 240 HRS.  O EMC: MIL-STD-461A AS MODIFIED BY SL-E-0002 (TEST CE01, CE03, CS01, CS02, CS06, RE02 (N/B))  O STRUCTURAL STIFFNESS AND LOAD TEST   FLIGHT CHECKOUT ----- PDRS OPS CHECKLIST (ALL VEHICLES) JSC 16987

PREPARED BY:

MEWG

SUPERCEDING DATE: 12 OCT 89

APPROVED BY: \_\_\_\_\_

DATE: 24 JUL 91

CIL REV: 3

**CRITICAL ITEMS LIST**

PROJECT: MECHANICAL ARM SUBSYSTEM SHEET: 6  
 ASS'Y NOMENCLATURE: END EFFECTOR ASS'Y P/N: 51140E1470-18-3

FMEA REF.	FMEA REV.	NAME, QTY, & DRAWING REF. DESIGNATION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	HOWR / FUNC. 2/1R CRITICALITY	RATIONALE FOR ACCEPTANCE SCREENS: A-PASS, B-PASS, C-PASS
3650	3	MOTOR MODULE ASSEMBLY QTY-1 P/N 51140E1473 OR 51140E2203	<p>MODE: LOW TORQUE OUTPUT FROM MOTOR DRIVE.</p> <p>CAUSE(S): (1) HIGH FRICTION IN MOTOR MODULE BEARINGS, GEAR TRAIN. (2) CLUTCH SLIPPAGE. (3) BRAKE LINING DRAG.</p>	<p>DEGRADED PERFORMANCE OF END EFFECTOR. ALL END EFFECTOR OPERATIONS SLOWED DOWN. MAY NOT FULLY RIGIDIZE. ARM WILL STAY LIMP IF NO RIGID FLAG.</p> <p>WORST CASE ----- UNEXPECTED PAYLOAD MOTION. INCOMPLETE RIGIDIZATION. CREW ACTION REQUIRED.</p> <p>REDUNDANT PATHS REMAINING ----- 1) MANUAL EE MODE RELEASE. 2) BACKUP EE RELEASE.</p>	<p>QA/INSPECTIONS -----</p> <p>UNITS ARE MANUFACTURED UNDER DOCUMENTED QUALITY CONTROLS. THESE CONTROLS ARE EXERCISED THROUGHOUT DESIGN PROCUREMENT, PLANNING, RECEIVING, PROCESSING, FABRICATION, ASSEMBLY, TESTING AND SHIPPING OF THE UNITS. MANDATORY INSPECTION POINTS ARE EMPLOYED AT VARIOUS STAGES OF FABRICATION ASSEMBLY AND TEST. GOVERNMENT SOURCE INSPECTION IS INVOKED AT VARIOUS CONTROL LEVELS.</p> <p>WIRE IS PROCURED TO SPECIFICATION MIL-W-22759 OR MIL-W-81381 AND INSPECTED AND TESTED TO NASA JSC08080 STANDARD NUMBER 95A.</p> <p>RECEIVING INSPECTION VERIFIES THAT THE HARDWARE RECEIVED IS AS IDENTIFIED IN THE PROCUREMENT DOCUMENTS, THAT NO DAMAGE HAS OCCURRED DURING SHIPMENT AND THAT APPROPRIATE DATA HAS BEEN RECEIVED WHICH PROVIDES ADEQUATE TRACEABILITY INFORMATION AND IDENTIFIES ACCEPTABLE PARTS.</p> <p>PARTS ARE INSPECTED THROUGHOUT MANUFACTURE AND ASSEMBLY AS APPROPRIATE TO THE MANUFACTURING STAGE COMPLETED. THESE INSPECTIONS INCLUDE,</p> <p>MAGNET WIRE IS PROCURED TO MIL-W-583 AND CHECKED AT INCOMING INSPECTION PER FEDERAL STANDARD J-W-1177 WHICH INCLUDES DIELECTIC, PIN HOLES, BUBBLES, BLISTERS, AND CRACKS IN THE INSULATION.</p> <p>ALL SOLDERING IS ACCOMPLISHED BY OPERATORS, WHO ARE TRAINED AND CERTIFIED TO NASA NH85300.4(3A) STANDARD, AS MODIFIED BY JSC 08800A.</p> <p>BEARINGS RECEIVE DIMENSIONAL INSPECTION AT THE SUPPLIER AND VERIFICATION BY SPAR RECEIVING INSPECTION. PRE-ASSEMBLY INSPECTION VERIFIES CIRCULARITY OF BALL TRACKS AND INNER/OUTER RACE DIAMETERS. AFTER ASSEMBLY PRIOR TO LUBRICATION, RADIAL CLEARANCE MEASUREMENTS ARE TAKEN. FOLLOWING LUBRICATION, RUN-IN/BURNISHING AND CLEANING OF DRY LUBE BEARINGS, SPECIALIZED BEARING INSPECTION EQUIPMENT AT SPAR IS USED TO VERIFY QUALITY AND STICTION LEVELS THROUGH STRIP CHART RECORDING OF TORQUE TRACES. BEARINGS ARE THEN RETURNED TO THE SUPPLIER FOR FINAL RADIAL CLEARANCE MEASUREMENTS. GOVERNMENT SOURCE INSPECTION IS ENVOKED ON ALL BEARING PROCUREMENTS.</p> <p>GEAR INSPECTION, BEFORE GEAR LUBRICATION AND RUN-IN A COMPOSITE ERROR GEAR CHECKER IS USED TO VERIFY THAT INVOLUTE FORM, PITCH CIRCLE CONCENTRICITY AND PITCH DIAMETER ARE TO DRAWING REQUIREMENTS. THIS INSPECTION ALSO INCLUDES TEXTURE EVALUATION. AFTER LUBRICATION, GEARS ARE VISUALLY INSPECTED TO CONFIRM APPROPRIATE LUBRICANT APPLICATION AND GEARS ARE THEN RUN-IN, CLEANED AND VISUALLY INSPECTED.</p> <p>CARPENTER 455 STEEL USED FOR THE MANUFACTURE OF (E.G. GEARS) RECEIVES ADDITIONAL LABORATORY INSPECTIONS WHICH INCLUDE CHEMICAL ANALYSIS, INCLUSION RATING, HARDNESS AND TENSILE TESTING TO VERIFY THE PROPERTIES OF THE MATERIAL SUPPLIED.</p>	

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PROJECT: SRMS  
ASS'Y NOMENCLATURE: END EFFECTOR

SYSTEM: MECHANICAL ARM SUBSYSTEM  
ASS'Y P/N: 51140E1470-1A-3

SHEET: 7

FMEA REF.	FMEA REV.	NAME, QTY. & DRAWING REF. DESIGNATION	FAILURE MODE AND CAUSE	FAILURE EFFECT OR END ITEM	HOWR / FUNC. 2/1R CRITICALITY RATIONALE FOR ACCEPTANCE SCREENS: A-PASS, B-PASS, C-PASS
3650	3	MOTOR MODULE ASSEMBLY QTY-1 P/N 51140E1473 OR 51140E2203	<p>MODE: LOW TORQUE OUTPUT FROM MOTOR DRIVE.</p> <p>CAUSE(S): (1) HIGH FRICTION IN MOTOR MODULE BEARINGS, GEAR TRAIN. (2) CLUTCH SLIPPAGE. (3) BRAKE LINING DRAG.</p>	<p>DEGRADED PERFORMANCE OF END EFFECTOR. ALL END EFFECTOR OPERATIONS SLOWED DOWN. MAY NOT FULLY RIGIDIZE. ARM WILL STAY LIMP IF NO RIGID FLAG.</p> <p>WORST CASE ----- UNEXPECTED PAYLOAD MOTION. INCOMPLETE RIGIDIZATION. CREW ACTION REQUIRED.</p> <p>REDUNDANT PATHS REMAINING ----- 1) MANUAL EE MODE RELEASE. 2) BACKUP EE RELEASE.</p>	<p>SHAFTS ARE DIMENSIONAL INSPECTED TO DRAWING REQUIREMENTS THROUGHOUT THE MANUFACTURING STAGES. FOLLOWING HEAT TREATMENT THE SHAFTS ARE SUBJECTED TO MAGNETIC PARTICLE INSPECTION FOR CRACKS.</p> <p>INSPECTION VERIFIES THAT KITTED PARTS ARE CORRECT PRIOR TO ASSEMBLY AND TRACEABILITY INFORMATION RECORDED.</p> <p>INSPECTION TO DRAWING IS CONDUCTED THROUGHOUT THE ASSEMBLY PROCESS, INCLUDING INSPECTION OF LOCKING, WITNESSING OF TORQUING AND APPLICATION OF TORQUE STRIPING.</p> <p>MOTOR MODULES ARE TESTED TO THE REQUIREMENTS OF SPAR-TM.1624 WHICH INCLUDES, CONTINUITY AND ISOLATION CHECKS, STICTION, COMMUTATOR TIMING, AMBIENT AND THERMAL TESTING. (SPAR/GOVERNMENT REP. - MANDATORY INSPECTION POINT).</p> <p>INTEGRATION OF MOTOR MODULE TO END EFFECTOR LRU - INSPECTIONS INCLUDE GROUNDING CHECKS, CONNECTORS FOR BENT OR PUSHBACK CONTACTS, INCONNECT WIRING ETC.</p> <p>PRE-ACCEPTANCE TEST INSPECTION, WHICH INCLUDES AN AUDIT OF LOWER TIER INSPECTION COMPLETION, AS BUILT CONFIGURATION VERIFICATION TO AS DESIGN ETC., (MANDATORY INSPECTION POINT).</p> <p>A TEST READINESS REVIEW (TRR) WHICH INCLUDES VERIFICATION OF TEST PERSONNEL, TEST DOCUMENTS, TEST EQUIPMENT CALIBRATION/ VALIDATION STATUS AND HARDWARE CONFIGURATION IS CONVENED BY QUALITY ASSURANCE IN CONJUNCTION WITH ENGINEERING, RELIABILITY, CONFIGURATION CONTROL, SUPPLIER AS APPLICABLE, AND THE GOVERNMENT REPRESENTATIVE, PRIOR TO THE START OF ANY FORMAL TESTING (ACCEPTANCE OR QUALIFICATION).</p> <p>ACCEPTANCE TESTING (ATP) INCLUDES, AMBIENT, VIBRATION AND THERMAL-VAC TESTING, (SPAR/GOVERNMENT REP. - MANDATORY INSPECTION POINT)</p> <p>SRMS SYSTEMS INTEGRATION, THE INTEGRATION OF MECHANICAL ARM SUBASSEMBLIES AND THE FLIGHT CABIN EQUIPMENT TO FORM THE SRMS. INSPECTIONS ARE PERFORMED AT EACH PHASE OF INTEGRATION WHICH INCLUDES GROUNDING CHECKS, THRU WIRING CHECKS, WIRING ROUTING, INTERFACE CONNECTORS FOR BENT OR PUSH BACK CONTACTS ETC.</p> <p>SRMS SYSTEMS TESTING - STRONGBACK AND FLAT FLOOR AMBIENT PERFORMANCE TEST. (SPAR/GOVERNMENT REP. - MANDATORY INSPECTION POINT)</p>

PREPARED BY: MFVG

SUPERCEDING DATE: 12 OCT 89

APPROVED BY: \_\_\_\_\_

DATE: 24 JUL 91

CIL REV: 3



**CRITICAL ITEMS LIST**

PROJECT: SRMS  
 ASS'Y NOMENCLATURE: END EFFECTOR  
 SYSTEM: MECHANICAL ARM SUBSYSTEM  
 ASS'Y P/N: 51140E1470-1E-3 SHEET: 8

FMEA REF.	FMEA REV.	NAME, QTY, & DRAWING REF. DESIGNATION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	HDWR / FUNC. 2/1R CRITICALITY	RATIONALE FOR ACCEPTANCE SCREENS: A-PASS, B-PASS, C-PASS
3450	3	MOTOR MODULE ASSEMBLY QTY-1 P/N 51140E1473 OR 51140E2203	<p>MODE: LOW TORQUE OUTPUT FROM MOTOR DRIVE.</p> <p>CAUSE(S): (1) HIGH FRICTION IN MOTOR MODULE BEARINGS, GEAR TRAIN. (2) CLUTCH SLIPPAGE. (3) BRAKE LINING DRAG.</p>	<p>DEGRADED PERFORMANCE OF END EFFECTOR. ALL END EFFECTOR OPERATIONS SLOWED DOWN. MAY NOT FULLY RIGIDIZE. ARM WILL STAY LIMP IF NO RIGID FLAG.</p> <p>WORST CASE UNEXPECTED PAYLOAD MOTION. INCOMPLETE RIGIDIZATION. CREW ACTION REQUIRED.</p> <p>REDUNDANT PATHS REMAINING 1) MANUAL EE MODE RELEASE. 2) BACKUP EE RELEASE.</p>		<p>FAILURE HISTORY ----- THE FOLLOWING FAILURE ANALYSIS REPORT(S) ARE RELEVANT:</p> <p>FAR 2378: S/N 301 JUN 84</p> <p>DESCRIPTION ----- RIGID, LOAD TOO LOW, CLUTCHES FAILED</p> <p>CORRECTIVE ACTION ----- REPLACED CLUTCHES. REFER TO FAR 2381.</p> <p>FAR 2381: S/N 304 JUL 84</p> <p>DESCRIPTION ----- SLIP TORQUE TOO LOW REFER TO FAR 2378.</p> <p>CORRECTIVE ACTION ----- CLUTCH REDESIGNED TO INCREASE SLIP TORQUE FROM 35-52.5 OZ.IN TO 45-67.5 OZ.IN.</p> <p>FAR2408: S/N 317 OCT.87</p> <p>DESCRIPTION ----- E/E CLUTCH HIGH RUNNING FRICTION AT HOT ATP TEMPERATURES DUE TO POOR WORKMANSHIP IN SETTING THE GAP BETWEEN THE POLE PIECE AND THE ARMATURE.</p> <p>CORRECTIVE ACTION ----- UNIT WAS REASSEMBLED TO DRAWING REQT'S. AN M.I.P. INSPECTION WAS INTRODUCED IN THE BUILD INSTRUCTIONS TO ENSURE CORRECT GAP DISTANCE.</p> <p>FAR 5012: S/N 203 DEC 79</p> <p>DESCRIPTION ----- FAILED TORQUE TEST O.K. AFTER RUN IN</p> <p>CORRECTIVE ACTION ----- INCREASED RUN-IN TIME</p> <p>FAR 5023:</p>

**CRITICAL ITEMS LIST**

PROJECT: SRMS  
ASS'Y NOMENCLATURE: END EFFECTOR

SYSTEM: MECHANICAL ARM SUBSYSTEM  
ASS'Y P/N: 51140E1470-1E-3

SHEET: 9

FMEA REF.	FMEA REV.	NAME, QTY, & DRAWING REF. DESIGNATION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	HDWR / FUNC. 2/1R CRITICALITY	RATIONALE FOR ACCEPTANCE SCREENS: A-PASS, B-PASS, C-PASS
3650	3	MOTOR MODULE ASSEMBLY QTY-1 P/N 51140E1473 OR 51140E2203	<p>MODE: LOW TORQUE OUTPUT FROM MOTOR DRIVE.</p> <p>CAUSE(S): (1) HIGH FRICTION IN MOTOR MODULE BEARINGS, GEAR TRAIN. (2) CLUTCH SLIPPAGE. (3) BRAKE LINING DRAG.</p>	<p>DEGRADED PERFORMANCE OF END EFFECTOR. ALL END EFFECTOR OPERATIONS SLOWED DOWN. MAY NOT FULLY RIGIDIZE. ARM WILL STAY LIMP IF NO RIGID FLAG.</p> <p>WORST CASE UNEXPECTED PAYLOAD MOTION. INCOMPLETE RIGIDIZATION. CREW ACTION REQUIRED.</p> <p>REDUNDANT PATHS REMAINING 1) MANUAL EE MODE RELEASE. 2) BACKUP EE RELEASE.</p>	S/N 202 MAY 80	<p>DESCRIPTION ----- CAPTURE CLUTCH TORQUE SLIP LOW, DUE TO EXTENSIVE TESTING</p> <p>CORRECTIVE ACTION ----- LIFE LIMITED ITEMS CLUTCH BRAKE</p> <p>FAR 5027: S/N 202 AUG 81</p> <p>DESCRIPTION ----- RIGID LOADS TOO HIGH REFER TO FAR 5028</p> <p>CORRECTIVE ACTION ----- REFER TO FAR 5028</p> <p>FAR 5028: S/N 202 AUG 81</p> <p>DESCRIPTION ----- RIGID LOADS TOO LOW, BALL SPLINE FAILED, VIBRATION DAMAGED</p> <p>CORRECTIVE ACTION ----- UNIT REBUILT, BALL SPLINE MODIFIED.</p> <p>FAR 2415: EE S/N 303 APR 88</p> <p>DESCRIPTION ----- RIGIDIZE FLAG FAILED TO ACTUATE DUE TO LOW RIG LOAD. LOW RIG LOADS DUE TO BADLY WORN RIGIDIZE GEAR TRAIN.</p> <p>CORRECTIVE ACTION ----- MOTOR MODULE REDESIGNED TO STRADDLE-MOUNT RIGIDIZE GEAR TRAIN.</p> <p>FAR 2416: EE S/N 303 APR 88</p> <p>DESCRIPTION ----- EE RIGIDIZED TO ONLY 1168 LBS. SPEC IS 1200 LBS. LOW RIG LOADS CAUSED BY BADLY WORN RIGIDIZE GEAR TRAIN. REF FAR-RMS-2415.</p> <p>CORRECTIVE ACTION ----- MOTOR MODULE REDESIGNED TO STRADDLE-MOUNT RIGIDIZE GEAR TRAIN.</p>

PREPARED BY: MFVG

SUPERCEDING DATE: 12 OCT 89

APPROVED BY: \_\_\_\_\_

DATE: 24 JUL 91

CIL REV: 3

**CRITICAL ITEMS LIST**

PROJECT: SRMS  
ASS'Y NOMENCLATURE: END EFFECTOR

SYSTEM: MECHANICAL ARM SUBSYSTEM  
ASS'Y P/N: 51140E1470-1B-3

SHEET: 10

FMEA REF.	FMEA REV.	NAME QTY, & DRAWING REF. DESIGNATION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	HDWR / FUNC. 2/1R CRITICALITY RATIONALE FOR ACCEPTANCE SCREENS: A-PASS, B-PASS, C-PASS
3650	3	MOTOR MODULE ASSEMBLY QTY-1 P/N 51140E1473 OR 51140E2203	<p>MODE: LOW TORQUE OUTPUT FROM MOTOR DRIVE.</p> <p>CAUSE(S): (1) HIGH FRICTION IN MOTOR MODULE BEARINGS, GEAR TRAIN. (2) CLUTCH SLIPPAGE. (3) BRAKE LINING DRAG.</p>	<p>DEGRADED PERFORMANCE OF END EFFECTOR. ALL END EFFECTOR OPERATIONS SLOWED DOWN. MAY NOT FULLY RIGIDIZE. ARM WILL STAY LIMP IF NO RIGID FLAG.</p> <p>WORST CASE ----- UNEXPECTED PAYLOAD MOTION. INCOMPLETE RIGIDIZATION. CREW ACTION REQUIRED.</p> <p>REDUNDANT PATHS REMAINING ----- 1) MANUAL EE MODE RELEASE. 2) BACKUP EE RELEASE.</p>	<p>OPERATIONAL EFFECTS ----- EE DOES NOT OPERATE NOMINALLY WHEN COMMANDED. ARM REMAINS LIMP UNTIL EE MODE SWITCH IS TURNED OFF DURING AN AUTO CAPTURE SEQUENCE.</p> <p>CREW ACTION ----- FOR ANY OFF NOMINAL OPERATION OF THE EE, THE EE MODE SWITCH SHOULD BE TURNED OFF. ATTEMPT TO CAPTURE IN THE ALTERNATE MODE. IF THE SNARES REMAIN OPEN, MANEUVER ARM AWAY FROM PAYLOAD. IF THE SNARES ARE PARTIALLY CLOSED, ATTEMPT RELEASE USING A PRIMARY EE MODE. IF SNARES OPEN, MANEUVER THE ARM AWAY FROM THE PAYLOAD. IF SNARES DON'T OPEN, ATTEMPT TO RELEASE IN BACKUP MODE. IF SNARES OPEN, MANEUVER ARM AWAY FROM THE PAYLOAD. MANEUVER ORBITER AWAY FROM PAYLOAD. IF SNARES CANNOT BE OPENED, IN ANY MODE, EVA CAN BE USED TO RELEASE THE PAYLOAD OR THE ARM/PAYLOAD COMBINATION CAN BE JETTISONED.</p> <p>CREW TRAINING ----- CREW WILL BE TRAINED TO RECOGNIZE OFF NOMINAL EE OPERATIONS AND TO MANEUVER THE ORBITER AWAY FROM A FREE FLYING PAYLOAD AT ANY TIME DURING ARM OPERATIONS.</p> <p>MISSION CONSTRAINT ----- WHEN CAPTURING A FREE FLYING PAYLOAD, THE EE MUST BE FAR ENOUGH AWAY FROM STRUCTURE TO PROHIBIT CONTACT REGARDLESS OF PAYLOAD ROTATIONS. THE EE MODE SWITCH SHOULD BE PLACED BACK IN THE OFF POSITION IMMEDIATELY AFTER THE SPEC DRIVE TIME HAS ELAPSED.</p> <p>OMRSD OFFLINE ----- VERIFY CORRECT TIME TO RIGIDIZE.</p> <p>OMRSD ONLINE INSTALLATION ----- NONE</p> <p>OMRSD ONLINE TURNAROUND ----- VERIFY CORRECT THAT TIME TO RIGIDIZE.</p>