INTRODUCTION TO APPENDIX B

ITEM 1 - HYBRID DRIVER CONTROLLER MC477-026X-0002
ITEM 2 - REMOTE POWER CONTROLLER MC450-0017-1XXX
MC450-0017-2XXX
MC450-0017-3XXX
MC450-0017-4XXX

FAILURE MODES AND CAUSES

THE FOLLOWING TABLE LISTS FAILURE MODES AND CAUSES WHICH WERE CONSIDERED IN DERIVING THE FAILURE MODES AND EFFECTS ANALYSIS (FMEA'S) FOR THE ABOVE ITEMS.

FAILURE MODE	FAILURE CAUSE	TOGGLE SWITCH	LIMIT SWITCH
LOSS OF OUTPUT, FAILS TO CONDUCT, FAILS TO TURN "ON"	(a) Piece Part Structural Failure	X	X
	(b) Contamination	X	X
	(c) Vibration	X	X
	(d) Mechanical Shock	X	X
	(e) Processing Anomaly	X	X
	(f) Thermal Stress	X	X
INADVERTENT OUTPUT, FAILS "ON" FAILS TO TURN "OFF"	(a) Piece Part Structural Failure	X	X
	(b) Contamination	X	X
	(c) Vibration	X	X
	(d) Mechanical Shock	X	X
	(e) Processing Anomaly	X	X
	(f) Thermal Stress	X	X
FAILURE TO TRIP ON OVERLOAD *	(a) Piece Part Structural Failure	X	
	(b) Contamination	X	
	(f) Thermal Stress	X	

* FAILURE TO TRIP ON OVERLOAD IS A SPECIAL CASE OF FAILED "ON" AND WAS NOT COVERED AS A SEPARATE FAILURE MODE IN THE FMEA'S. RATIONALE FOR ACCEPTANCE OF THIS FAILURE MODE IS AS FOLLOWS: EACH POWER OUTPUT TRANSISTOR IN AN RPC IS INHERENTLY FUSED THROUGH ITS BOND WIRES. TESTING HAS DETERMINED THAT THIS BOND WIRE WILL FUSE OPEN AT APPROXIMATELY 200% OF THE RPC CURRENT RATING IN 2 TO 10 SECONDS IF THE RPC FAILS TO TRIP UNDER OVERLOAD CONDITIONS. THIS FUSE CHARACTERISTIC IS CONSIDERED TO BE ADEQUATE TO PREVENT WIRE HARNESS OVERHEATING FROM OCCURRING UNDER THESE CONDITIONS.

FAILURE MODES EFFECTS ANALYSIS FMEA – FAILURE MODE NUMBER: APPENDIX B-ITEM 2

REVISION#: 0 11/03/87

SUBSYSTEM NAME:
LRU:
ITEM NAME: REMOTE POWER CONTROLLER (RPC)

CRITICALITY OF THIS FAILURE MODE:

FAILURE MODE:
GENERIC DISPOSITION & RATIONALE FOR REMOTE POWER CONTROLLER:
MC450-0017-1XXX, 2XXX, 3XXX, 4XXX

-DISPOSITION RATIONALE-

(A) DESIGN:
THE RPC FUNCTIONS AS A REMOTE POWER SWITCHING DEVICE IN THE DIRECT CURRENT (DC) ELECTRICAL POWER SYSTEM. ACTUATION, OR TURN-ON, IS ACCOMPLISHED BY APPLYING A VOLTAGE GREATER THAN 12 V AT 10 MA TO THE CONTROL TERMINAL ON THE DEVICE. INCLUDED IN THE RPC DESIGN IS A PROVISION TO SENSE AND CURRENT LIMIT AND SUBSEQUENTLY TURN-OFF IF A CURRENT OVERLOAD IS DETECTED THUS PREVENTING DAMAGE TO THE CONTROLLED ELECTRICAL CIRCUIT.

THE RPC IS AN ALL SOLID STATE HYBRID DESIGN THAT MINIMIZES SIZE AND INTERNAL POWER CONSUMPTION. ALL INTERNAL COMPONENTS ARE CONFORMALLY COATED WITH PARYLENE TO ELIMINATE THE POSSIBILITY OF INTERNAL SHORTING BY LOOSE CONTAMINANTS. ADDITIONALLY THE RPC IS HERMETICALLY SEALED IN AN INERT GAS BACKFILLED METAL ENCLOSURE THUS PREVENTING CONTAMINATION OF THE ELECTRONICS FROM MOISTURE OR OTHER CONTAMINANTS THAT MAY BE PRESENT IN THE EXTERNAL ENVIRONMENT.

VARIOUS CURRENT RATINGS ARE AVAILABLE IN ORDER TO PROVIDE THE NECESSARY CURRENT OVERLOAD PROTECTION FOR THE DC SYSTEM AND ARE AS FOLLOWS: 3, 5, 7.5, 10, 15 AND 20 AMPERES.

DESIGN EVOLUTION

THE -1XXX CONFIGURATION USED DURING THE INITIAL OV-102 BUILD CYCLE, SUBSEQUENTLY EXHIBITED SEVERAL PROBLEMS. LEADLESS INVERTED DEVICES (LID'S) BOND WIRES EXPERIENCED FRACTURING DURING EXTREME TEMPERATURE CYCLING AS DESCRIBED AND EXPLAINED IN CAR A7307. EXCESSIVE CURRENT LEAKAGE WAS ALSO ENCOUNTERED, WHICH WAS CAUSED BY FAULTY OUTPUT TRANSISTORS AND FURTHER AGGRAVATED BY RPC CASE AIR LEAKAGE, SEE CAR AB3968. THIS LEAKAGE PROBLEM WAS RESOLVED BY IMPOSING A SCREEN ON ALL INSTALLED CRITICAL RPC'S AND THE CREATION OF A -2XXX RPC TO ELIMINATE ALL OF THE ABOVE PROBLEMS.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- FAILURE MODE NUMBER: APPENDIX B-ITEM 2

THE -2XXX CONFIGURATION WAS USED IN THE INITIAL BUILD OF OV-099 POWER CONTROL ASSEMBLIES. A PROBLEM WAS SUBSEQUENTLY DISCOVERED IN -2XXX PARTS MANUFACTURED AFTER 1981, WHERE THE SUPPLIER DELETED HIS IN-PROCESS SCREEN, ALLOWING SOME RPC'S TO HAVE A HIGHER THAN NORMAL OUTPUT VOLTAGE DROP. THIS CONDITION WAS CHECKED FOR IN UNITS IN THE FIELD BY CONDUCTING A VOLTAGE DROP SCREENING TESTS WITHIN NEXT ASSEMBLIES ALONG WITH ALL LOOSE RPC'S IN STOCK, SEE CAR AC5582. UNINSTALLED -2XXX RPC'S THAT PASSED THE SCREEN TEST WERE RE-IDENTIFIED WITH A V070-760200 P/N.

THE -3XXX SERIES RPC CORRECTED THE VOLTAGE DROP PROBLEM. THESE RPC'S WERE UTILIZED IN THE INITIAL BUILD OF OV-104 POWER CONTROL ASSEMBLIES. IT SHOULD BE NOTED THAT DUE TO VEHICLE/ASSEMBLY INTERCHANGEABILITY, ANY VEHICLES MAY HAVE -1XXX, -2XXX, OR -3XXX RPC CONFIGURATIONS AS THE RESULT OF CONTROL ASSEMBLIES BEING RECYCLED FOR MODIFICATIONS, ETC.

DUE TO PARTS OBSOLESCENCE, REDESIGN TO THE -4XXX CONFIGURATION WAS REQUIRED. PREVIOUS GENERATION RPC'S USED LEADLESS INVERTED DEVICES (LID'S) IN CONTROL CIRCUITRY FOR CMOS PARTS AND OP-AMPS. LID'S ARE NO LONGER AVAILABLE. THE -4XXX DESIGN UTILIZES AN APPLICATION SPECIFIC INTEGRATED CIRCUIT (ASIC) WHICH IS CONSISTENT FOR ALL RATINGS (3, 5, 7.5, 10, 15, AND 20 AMPS). ORIGINAL PART USED BERYLLIUM OXIDE (BEO) AS THE HEAT SINK FOR POWER TRANSISTORS. TO AVOID FUTURE PART OBSOLESCENCE AND BECAUSE OF ENVIRONMENTAL RESTRICTIONS, -4XXX DESIGN USES ALUMINUM NITRIDE (ALN) AS HEAT SINK. IT SHOULD BE NOTED THAT DUE TO VEHICLE/ASSEMBLY INTERCHANGEABILITY, ANY VEHICLES MAY HAVE -1XXX, -2XXX, -3XXX, OR -4XXX RPC CONFIGURATIONS AS THE RESULT OF CONTROL ASSEMBLIES BEING RECYCLED FOR MODIFICATIONS, ETC.

FAILURE MODES EFFECTS ANALYSIS (FMEA) – FAILURE MODE NUMBER: APPENDIX B-ITEM 2

(B) TEST:
QUALIFICATION/CERTIFICATION

QUALIFICATION TESTING AND ANALYSIS ARE COMPLETED AND APPROVED. TESTS INCLUDED:

TEST	CAUSE CONTROL					
	A	B	C	D	E	F
FUNCTIONAL	X				X	
PERFORMANCE (OUTPUT CURRENT, QUALITY, TURN "ON"/"OFF" CHARACTERISTICS, TRIP CHARACTERISTICS, AND VOLTAGE DROP)	X				X	
OVERLOAD RUN-IN (250 CYCLES WITH 400% OVERLOAD APPLIED FOR 2 SECONDS THEN REDUCED TO RATED CURRENT, THEN 250 CYCLES WITH 400% OVERLOAD APPLIED UNTIL TRIP FOLLOWED BY 500 TRIP CYCLES WITH A 175% OVERLOAD)	X				X	
VIBRATION (0.15 G^2/HZ, 48 MINUTES IN ALL THREE AXES)	X		X		X	
THERMAL VACUUM (20 TO 130° F AT 1 X 10^{-6} TORR)						X
SHOCK (20 G IN EACH OF THREE AXES)				X		
ENDURANCE (100,000 CYCLES)	X				X	
ELECTROMAGNETIC INTERFERENCE (MF0004-002 CLASS I, D)	X					
TERMINAL STRENGTH (25 LBS PULL, 5 FT-LBS TORQUE)	X					
LIGHTNING (+/-50 VDC PEAK VOLTAGE APPLY 10 TRANSIENTS (5 POSITIVE, 5 NEGATIVE) THEN APPLY 23 RANDOMLY SPACED TRANSIENTS ALL WITHIN A 2SECOND PERIOD)	X					X
SEAL (1 X 10^{-6} CC/SEC)		X			X	
DIELECTRIC STRENGTH (1000 VRMS)		X			X	
INSULATION RESISTANCE (IR AT 500 VDC, 100 MEGOHMS MINIMUM)		X			X	

ACCEPTANCE AND SCREENING

ALL RPC'S ARE SUBJECT TO 100% ACCEPTANCE TESTING WHICH INCLUDES:

TEST	CAUSE CONTROL					
	A	B	C	D	E	F
VISUAL EXAMINATION	X	X				
FUNCTIONAL	X				X	
PERFORMANCE (OUTPUT CURRENT QUALITY, TURN "ON"/"OFF" CHARACTERISTICS, TRIP CHARACTERISTICS AND VOLTAGE DROP)	X				X	
VIBRATION (0.04 G^2/HZ)	X		X		X	
THERMAL (-45 TO 130° F)						X
SEAL (1 X 10^{-6} SCC/SEC)		X			X	
DIELECTRIC STRENGTH (750 VRMS)		X			X	
INSULATION RESISTANCE (500 VDC, 100 MEGOHMS MINIMUM)		X			X	

(C) INSPECTION:

RECEIVING INSPECTION (FAILURE CAUSE A, B, E)

PIECE PARTS INSPECTED AND TESTED DURING RECEIVING PER SUNDSTRAND QCI AND SAMPLED PER QUALITY CONTROL (QC) MANUAL.

CONTAMINATION CONTROL (FAILURE CAUSE B)

FORMAL PLAN IMPLEMENTED AND VERIFIED BY QC. CLASS 100K CLEAN ROOM WITH PROPER MAINTENANCE AND PROCEDURES VERIFIED BY QC. HERMETIC SEALING/BACKFILLING VERIFIED BY INSPECTION. PARYLENE COATING PROCESS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION (FAILURE CAUSE A, B, E)

DETAILED INSPECTION PERFORMED ON ALL PARTS PRIOR TO NEXT ASSEMBLY. SOLDERING AND ELECTRICAL TERMINATIONS VERIFIED BY INSPECTION. CORROSION PROTECTION PROVISIONS VERIFIED BY INSPECTION.

CRITICAL PROCESSES (FAILURE CAUSE A, B, E)

ALL CRITICAL PROCESSES INCLUDING SOLDERING, BRAZING, ADHESIVE MOUNTING OF HYBRID ELECTRONIC ELEMENTS, PARYLENE COATING, AND WIRE BONDING, ARE MONITORED AND VERIFIED BY INSPECTION.

TESTING (FAILURE CAUSE A, B, E, F)

A DCAS QC REPRESENTATIVE IS PRESENT DURING THE ATP FINAL PERFORMANCE TESTS. ALL TEST RECORD SHEETS ARE REVIEWED BY WESTINGHOUSE QC PRIOR TO FINAL ACCEPTANCE OF THE UNITS.

HANDLING/PACKAGING (FAILURE CAUSE C, D)

CMOS/MOS DEVICES ARE HANDLED PER QC PROCEDURE TO PRECLUDE ELECTROSTATIC DISCHARGE DAMAGE. PARTS PACKAGED AND PROTECTED ARE VERIFIED BY INSPECTION IN ACCORDANCE WITH APPLICABLE REQUIREMENTS.

(D) FAILURE HISTORY:

MC450-0017-1XXX CONFIGURATION

FAILURE MODE: LOSS OF OUTPUT, INADVERTENT OUTPUT / FAILS TO TURN OFF

CAR A7307 (PRIME)
DURING ACCEPTANCE THERMAL TEST THE RPC'S FAILED TO RESPOND AS REQUIRED: SOME FAILED TO TURN "ON", OTHERS FAILED TO TURN "OFF". A TOTAL OF SEVENTEEN FAILURES WERE EXPERIENCED, THIRTEEN OF THESE WERE EXPERIENCED DURING THE RPC ACCEPTANCE TEST WHILE THE REMAINING FOUR WERE EXPERIENCED AT THE NEXT ASSEMBLY LEVEL DURING THE INITIAL FUNCTIONAL TEST. THESE FAILURES WERE ISOLATED TO OPEN OR HIGH RESISTANCE CONNECTIONS AT THE STITCH WELD WITHIN THE LEADLESS INVERTED DEVICES (LIDS). THESE WERE ATTRIBUTED TO MARGINAL BONDS AGGRAVATED BY THE EXPANSION AND CONTRACTION STRESSES OF THE LID ENCAPSULATING EPOXY CAUSED DURING THERMAL CYCLING.

THIS PROBLEM WAS CORRECTED BY REVISIONS IN THE BONDING AND EPOXY CURING PROCEDURES WHICH WAS EFFECTIVE FOR ALL -2XXX RPC CONFIGURATIONS. RPC'S DELIVERED WERE CONSIDERED SATISFACTORY FOR THEIR INTENDED USAGE AS THE ACCEPTANCE THERMAL TEST ALONG WITH SUBSEQUENT THERMAL EXPOSURE (125° C FOR THIRTY MINUTES) SERVED AS AN EFFECTIVE SCREEN FOR THIS CONDITION. THE REASON THAT FOUR WERE DETECTED FOLLOWING DELIVERY IS THE FACT THAT THE THERMAL EXPOSURE (125° C) WAS CONDUCTED WITH NO SUBSEQUENT FUNCTIONAL TEST UNTIL THEY WERE INSTALLED IN THE NEXT ASSEMBLY.

CAR'S A8592, A9814, AB8405 AND AC1728-110
FOUR OTHER RPC FAILURES (TWO FAILED TO TURN "ON" AND TWO FAILED TO TURN "OFF") WERE ISOLATED TO LID'S. FAILURES WERE CAUSED BY BOND WIRE ROUTING WHICH RESULTED IN ISOLATION BREAKDOWN BETWEEN LEADS (BOND WIRES). THIS PROBLEM WAS ALSO CORRECTED WHEN THE BONDING AND EPOXY CURING PROCEDURES WERE REVISED. AGAIN THE THERMAL CYCLING SERVES AS AN EFFECTIVE SCREEN.

CAR AB3968 (PRIME)
DURING ORBITER SYSTEM CHECKOUT TESTS, VARIOUS STATUS MEASUREMENTS WHERE OBSERVED TO BE "ON" WHILE THE ACTUAL LOAD OR LINE REPLACEABLE UNIT (LRU) WAS NOT POWERED UP. THIS CONDITION WAS OBSERVED SIX TIMES AT THE VEHICLE LEVEL AND THIRTY FIVE TIMES DURING SUBSEQUENT SCREENING TEST.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- FAILURE MODE NUMBER: APPENDIX B-ITEM 2

THESE FAILURES WERE ATTRIBUTED TO A PARTICULAR OUTPUT TRANSISTOR CHIP WHICH WHEN EXPOSED TO MOISTURE EXHIBITED EXCESSIVE I_{CBO} CURRENT LEAKAGE. THE INVESTIGATION DISCLOSED THAT THE FAILED RPC'S ALSO EXHIBITED LOSS OF ITS HERMETIC SEAL. THE SEAL FAILURES WERE INDUCED BY THE MOUNTING TABS STRESSING AND CRACKING THE SOLDER SEAL BETWEEN THE RPC COVER AND BASE.

THESE CONDITIONS WERE CORRECTED BY MORE CLOSELY CONTROLLING THE PROCUREMENT OF THE OUTPUT TRANSISTORS. FURTHER, TO REDUCE THE STRESS ON THE SOLDER SEAL, THE RPC FABRICATION PROCEDURES WERE REVISED; HEADER ON BASE ASSEMBLIES ARE PRE-TINNED, THE HEADER ASSEMBLIES ARE MOUNTED ON A 0.005 INCH PEDESTAL WITH MOUNTING TABS TORQUED DOWN DURING THE COVER-TO-HEADER ASSEMBLY SOLDER SEAL PROCESS. THESE CHANGES WERE INCORPORATED INTO THE -2XXX RPC CONFIGURATION.

A SPECIAL CURRENT LEAKAGE SCREEN TEST WAS ESTABLISHED AND CONDUCTED ON ALL RPC APPLICATIONS.

MC450-0017-2XXX CONFIGURATION

FAILURE MODE: EXCESSIVE VOLTAGE DROP (NOT CONSIDERED FOR FMEA AS THE WORST CASE IS LOSS OF OUTPUT)

CAR AC5582
DURING MANUFACTURING VERIFICATION TEST THE RPC'S WERE OBSERVED TO EXHIBIT EXCESSIVE VOLTAGE DROP; VOLTAGE DROP FROM BUS VOLTAGE INPUT TERMINAL TO THE LOAD OUTPUT TERMINAL WAS APPROXIMATELY 1.4 VOLTS WHEN IT SHOULD BE LESS THAN 0.5 VOLTS. THIS FAILURE WAS ASSOCIATED WITH THE RPC VOLTAGE REGULATOR INTEGRATED CIRCUIT CHIP WHICH IN THE RPC APPLICATION MAY "LOCK-UP" WHEN THE RPC IS TURNED "ON" INTO VERY SMALL OR NO LOAD CONDITIONS. INVESTIGATION REVEALED THAT THE RPC MANUFACTURER HAD DISCONTINUED AN IN-PROCESS SCREENING TEST THAT DETECTED RPC'S WITH THIS TENDENCY.

THE RPC DESIGN WAS MODIFIED TO INCORPORATE A RESISTOR TO ELIMINATE A RACE CONDITION THEREBY PRECLUDING THE POSSIBLE "LOCK-UP" CONDITION. THIS MODIFICATION WAS INCORPORATED IN-LINE INTO THE -3XXX RPC CONFIGURATION.

ROCKWELL ESTABLISHED AND INITIATED A SCREENING TEST FOR THE RPC'S DELIVERED. ONE HUNDRED AND NINETEEN RPC'S WERE FOUND TO EXHIBIT THE EXCESSIVE VOLTAGE DROP CONDITION. THESE WERE RETURNED TO THE SUPPLIER AND UPGRADED TO THE -3XXX CONFIGURATION.

CURRENT DATA ON TEST FAILURES, FLIGHT FAILURES, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATABASE. THERE ARE NO UNRESOLVED GENERIC ISSUES.

(E) OPERATIONAL USE:

FAILURE MODES EFFECTS ANALYSIS (FMEA) – FAILURE MODE NUMBER: APPENDIX B-ITEM 2

- APPROVALS -

PAE MANAGER	: K. L. PRESTON	: 2-12-96
PRODUCT ASSURANCE ENGR	: N. HAFEZIZADEH	: 2-7-96
DESIGN ENGINEERING	: B. KRAHL	: 2-12-96
NASA EPD&C SSMA	:	: for Frank Hughes 3/4/96
NASA EPD&C SSM	:	: 3-19-96