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.

APPENDIX B ITEM 1 - HYBRID DRIVER CONTROLLER (HDC)
MC477-0261-0002
MC477-0262-0002
MC477-0263-0002
MC477-0264-0002
MC477-0265-0002

DISPOSITION & RATIONALE
(A) DESIGN, (B) TEST, (C) INSPECTION, (D) FAILURE HISTORY:

(A) DESIGN

HERMETICALLY-SEALED, GOLD-PLATED KOVAR CASE, INTEGRATED CIRCUIT DESIGN.

FUNCTIONAL DESCRIPTION

HYBRID DRIVER CONTROLLERS ARE USED TO CONTROL A LARGE NUMBER OF FUNCTIONS IN VARIOUS ORBITER SUBSYSTEMS. HYBRID DRIVERS PROVIDE SOLID-STATE SWITCHING OF 28 Vdc POWER OR GROUND TO VARIOUS LOAD FUNCTIONS AT FIVE DIFFERENT LOAD RATINGS OR CONFIGURATIONS. CONTROL OF THE "ON" OR "OFF" STATE OF THE HYBRID DRIVER IS PROVIDED THROUGH TWO LOGIC INPUTS TO AN "AND" GATE LOGIC WITH A THIRD INPUT AVAILABLE FOR AN "INHIBIT" FUNCTION. THE TYPE I HYBRID DRIVER ALSO PROVIDES FOR ONE INPUT TO THE "AND" GATE TO BE EITHER 5 Vdc OR 28 Vdc AS REQUIRED. UNIQUE CHARACTERISTICS OF EACH OF THE FIVE HYBRID DRIVER TYPES ARE AS FOLLOWS;

MC477-0261-0002	TYPE I	150 mA DC CURRENT RATING. ONE LOGIC INPUT MAY BE EITHER 5 Vdc OR 28 Vdc.
MC477-0262-0002	TYPE II	50 mA DC CURRENT RATING. TIME DELAY BETWEEN LOGIC INPUT AND POWER OUTPUT SELECTABLE TO 0.040, 1 OR 4 SECONDS.
MC477-0263-0002	TYPE III	5 AMPERE DC CURRENT RATING.
MC477-0264-0002	TYPE IV	5 AMPERE DC CURRENT RATING, GROUND SIDE SWITCHING.
MC477-0265-0002	TYPE V	50 mA DC CURRENT RATING. CONTROL VIA LEVEL DETECTION ON INPUT SIGNAL FROM TEMPERATURE SENSOR, BRIDGE OR OTHER SOURCE.

NEXT ASSEMBLY INSTALLATION

THE HYBRID DRIVER CONTROLLER IS MOUNTED TO A PLUG-IN TYPE MODULE WITHIN THE HYBRID LOAD CONTROLLERS.

THE INSTALLATION WITHIN POWER AND MOTOR CONTROL ASSEMBLIES (PCA, MCA) DIFFERS IN THAT EACH DRIVER IS MOUNTED ON A HEAT SINK WITH A PRINTED CIRCUIT BOARD. THE CIRCUIT BOARD PROVIDES AN ELECTRICAL INTERFACE FROM THE MODULE TO THE PRINTED CIRCUIT. THE BOARD PROVIDES A TURRET TERMINAL AS A SOLDERABLE INTERFACE BETWEEN THE NEXT ASSEMBLY INSTALLATION AND THE PRINTED CIRCUIT BOARD. THIS ASSEMBLY IS IDENTIFIED AS A V070-760080-00X OR V070-760085-00X AND IS REFERRED TO AS A HYBRID DRIVER ASSEMBLY. THIS ASSEMBLY IS INSTALLED IN THE CONTROL ASSEMBLIES.

DESIGN EVOLUTION

DURING TESTING OF THE OV-099 NEXT ASSEMBLY BUILD, A BASIC WORKMANSHIP, BOARD MATERIAL, AND PROCESS CONTROL PROBLEM WAS EVIDENCED ON THE V070-760080-00X MOUNTING ASSEMBLY. THESE ARE USED IN CONTROL ASSEMBLIES FABRICATED IN DOWNEY. THIS PROBLEM WAS RESOLVED BY A CONFIGURATION CHANGE TO THE V070-760085-00X MOUNTING ASSEMBLY WHICH WAS USED ON OV-099 AND SUBSEQUENT LRU BUILD (CAR A8745). ALL V070-760080 USAGE WITHIN OV-102 BUILT LRU'S HAVE BEEN APPROVED BY WAIVER. THE FAILURE MECHANISM WAS SCREENABLE BY NEXT ASSEMBLY ACCEPTANCE VIBRATION.

(B) TEST

CERTIFICATION/QUALIFICATION

HYBRID DRIVER IS QUALIFIED PER MIL-STD-883 AND MEETS THE REQUIREMENTS OF THE ORBITER PROJECT PARTS LIST (OPPL). CERTIFICATION TESTS INCLUDE:

TEST	CAUSE CONTROL					
	a	b	c	d	e	f
ACCEPTANCE	X	X	X		X	X
MOISTURE RESISTANCE		X				
HERMETICITY (GROSS AND FINE TO $5X10^{-7}$ SCC/SEC)		X			X	
CIRCUIT FUNCTIONAL (PARAMETER CHARACTERISTICS)	X	X			X	
MECHANICAL SHOCK (1500G)				X		
VIBRATION (48 MINS PER AXIS, PEAK ACCELERATION OF 20G'S)	X		X		X	
OPERATIONAL LIFE (ON/OFF CYCLING, 1000 HOURS)	X				X	

APPENDIX B ITEM 1 CONT'D

CERTIFICATION AT THE NEXT ASSEMBLY:

CERTIFICATION AT NEXT ASSEMBLY LEVEL WITHIN THE HYBRID LOAD CONTROLLER, POWER CONTROL AND MOTOR CONTROL ASSEMBLIES TEST INCLUDE:

TEST	CAUSE CONTROL					
	-a	b	c	d	e	f
QUALIFICATION ACCEPTANCE VIBRATION (QAVT 0.067 g^2/HZ, 5 MIN/AXIS)	X		X		X	
FLIGHT VIBRATION (0.1 g^2/HZ, 48 MIN / AXIS)	X		X		X	
DESIGN SHOCK (20G, 18 DROPS)	X			X		
OPERATIONAL PERFORMANCE	X	X			X	
SALT FOG		X				
HUMIDITY		X				
THERMAL VACUUM CYCLING (20 TO 120 °F, 120 HRS)						X

ACCEPTANCE AND SCREENING

ALL UNITS ARE SUBJECTED TO PRECAP VISUAL, TESTING AND SCREENING REQUIREMENTS WHICH INCLUDE:

TEST	CAUSE CONTROL					
	a	b	c	d	e	f
PRECAP VISUAL	X	X			X	
INSULATION RESISTANCE		X			X	
STABILIZATION BAKE (125 °C)	X	X			X	X
THERMAL CYCLE (10 CYCLES, -55 TO 125 °C)	X					X
ACCELERATION (5000G)	X				X	
HERMETICITY (GROSS AND FINE TO 5X10^{-7} SCC/SEC)		X				
PIND		X				
BURN IN (168 HOURS AT 125 °C)	X				X	X
FUNCTIONAL (PARAMETER CHARACTERISTICS)	X				X	

APPENDIX B ITEM 1 CONT'D

ACCEPTANCE TEST AT THE NEXT ASSEMBLY:

WHEN INSTALLED AT THE NEXT ASSEMBLY LEVEL, EACH UNIT IS SUBJECTED TO ACCEPTANCE TEST WHICH INCLUDE:

TEST	CAUSE CONTROL					
	a	b	c	d	e	f
VIBRATION (0.04 g^2/HZ)	X		X		X	
OPERATIONAL PERFORMANCE AS A MINIMUM	X					

(C) INSPECTION

RECEIVING INSPECTION (FAILURE CAUSE a,b,e)

VERIFIES ALL INCOMING PARTS AND MATERIALS, INCLUDING PERFORMANCE OF VISUAL AND DIMENSIONAL EXAMINATIONS, IN ACCORDANCE WITH REQUIREMENTS. CERTIFICATION RECORDS/TEST REPORTS ARE MAINTAINED CERTIFYING MATERIALS AND PHYSICAL PROPERTIES.

CONTAMINATION CONTROL (FAILURE CAUSE b)

QUALITY CONTROL (QC) VERIFIES PROPER MAINTENANCE AND PROCEDURES USED FOR CLASS 100,000 CLEAN ROOM OPERATION (CLEAN ROOM CERTIFICATION BEGAN IN FEBRUARY 1987. PRIOR TO THAT DATE A CONTROLLED WORK AREA WAS MAINTAINED).

ASSEMBLY/INSTALLATION (FAILURE CAUSE a,b,e)

INSPECTION POINTS ARE DETERMINED BY QUALITY ENGINEERING IN ACCORDANCE WITH APPLICABLE REQUIREMENTS AND ARE DOCUMENTED ON INSPECTION PLANNING. WORK STATION DISCIPLINES ADHERED TO AND OBSERVED MORE THAN FIVE TIMES PER WEEK BY QC. PRECAP AND EXTERNAL VISUAL INSPECTIONS OF MICROCIRCUITS PERFORMED UNDER 7X TO 10X MAGNIFICATION. CAPABILITY EXISTS FOR MAGNIFICATION UP TO 350X FOR INVESTIGATION OF ANOMALIES.

NONDESTRUCTIVE EVALUATION (NDE) (FAILURE CAUSE b,e)

RADIOGRAPHIC INSPECTION OF DRIVERS FOR EVIDENCE OF ASSEMBLY ANOMALIES IS VERIFIED. THIS BEGAN WITH LOT DATE CODE 8309.

APPENDIX B ITEM 1 CONT'D

CRITICAL PROCESSES (FAILURE CAUSE a,e)

ALL CRITICAL PROCESSES INCLUDING COMPONENT ATTACHMENT, WIRE BONDING, WELDING, AND SOLDERING, ARE MONITORED AND VERIFIED BY QC AS PROCESS CONTROL SURVEILLANCE ACTIVITY (OPERATIONS AUDIT).

TESTING (FAILURE CAUSE a,b,e,f)

ALL STEPS OF ACCEPTANCE TESTS ARE OBSERVED AND VERIFIED BY QC.

HANDLING/PACKAGING (FAILURE CAUSE c,d)

HANDLING OF CMOS/MOS DEVICES DURING FABRICATION TO PRECLUDE ELECTROSTATIC DISCHARGE (ESD) DAMAGE VERIFIED BY QC. PARTS ARE PACKAGED, PROTECTED, AND VERIFIED BY INSPECTION TO APPLICABLE REQUIREMENTS AT THE SUPPLIER.

(D) FAILURE HISTORY

V070-760080 HYBRID DRIVER ASSEMBLY FAILURES

FAILURE MODE: OPEN/NO OUTPUT, FAILED TO TURN "OFF" WITH INHIBIT SIGNAL

CAR'S A4375, AB1579, AB3118, AB3252, AB3432 AND AB3474
SIX FAILURES WERE EXPERIENCED DURING VARIOUS TEST AT THE NEXT ASSEMBLY LEVEL. THESE TESTS INCLUDED FUNCTIONAL, ACCEPTANCE VIBRATION AND QUALIFICATION VIBRATION AND THERMAL. THESE FAILURES WERE OBSERVED AS INTERMITTENT CONDITIONS AND WERE ISOLATED TO LOOSE TURRETS ON THE PRINTED CIRCUIT BOARD OF THE HYBRID DRIVER ASSEMBLY. THESE CONDITIONS WERE ATTRIBUTED TO INADEQUATE TURRET CRIMPING AND INSUFFICIENT SOLDER CONNECTION BETWEEN THE TURRET AND THE TERMINAL BOARD.

AS A RESULT OF THESE FAILURES THE TERMINAL BOARD WAS DESIGNED TO ELIMINATE THESE DEFICIENCIES AND ASSURE GOOD ELECTRICAL CONNECTIONS. THE REDESIGN RESULTED IN CREATING A NEW PART NUMBER FOR THE HYBRID DRIVER ASSEMBLY, V070-760085.

THESE HYBRID DRIVER ASSEMBLIES INSTALLED AND DELIVERED PRIOR TO THIS CHANGE WERE CONSIDERED SATISFACTORY FOR THEIR INTENDED USAGE. THIS WAS BASED UPON THE FACT THAT THE NEXT ASSEMBLY ACCEPTANCE VIBRATION SERVES AS A SCREEN.

APPENDIX B ITEM 1 CONT'D

NEXT ASSEMBLY LEVEL FAILURES

FAILURE MODE: LOSS OF OUTPUT

CAR AC7609 (PRIME), AC7549, AC7745 AND AC8176
DURING ACCEPTANCE FUNCTIONAL AND VIBRATION TEST AT THE NEXT ASSEMBLY LEVEL, INTERMITTENT OR LOSS OF OUTPUT FAILURES WERE EXPERIENCED. THESE WERE ISOLATED TO HYBRID DRIVERS WITH DEPRESSED BOND WIRES CAUSED BY WORKMANSHIP ERROR WHERE REVERSE CENTRIFUGING WAS LIMITED TO THE NEW OPERATORS AND SPECIFIC LOT DATE CODES. ALL SUSPECT DATE CODES HAVE BEEN REVERIFIED BY X-RAY. ALL NEXT ASSEMBLIES HAVE BEEN RECYCLED, DRIVERS X-RAYED AND REPLACED AS NECESSARY (REF MCR 8168). RADIOGRAPHIC INSPECTION WAS ADDED FOR ALL NEWLY BUILT HYBRID DRIVERS.

CARS'S AC3113 AND AD0776
DURING NEXT ASSEMBLY ENVIRONMENTAL ACCEPTANCE TEST, TWO LOSS OF OUTPUT FAILURES WERE EXPERIENCED. THESE WERE ISOLATED TO LOOSE BOND WIRES WITHIN HYBRID DRIVER MODULES. BOTH CONDITIONS WERE ATTRIBUTED TO HANDLING, ONE DURING THE CLEANING AND LIDDING PHASE, THE OTHER ONE DURING A REWORK PHASE OF THE HYBRID. THESE FAILURES WERE CONSIDERED ISOLATED ESCAPES THAT ARE SCREENABLE AT THE ACCEPTANCE TEST LEVEL.

HYBRID DRIVER FAILURES

FAILURE MODE: LOSS OF OUTPUT

A TOTAL OF TWENTY SEVEN FAILURES HAVE BEEN EXPERIENCED WHERE THE HYBRID DRIVER NO LONGER PROVIDED AN OUTPUT. THESE WERE ISOLATED TO ELECTRICAL OVERSTRESS CREATED BY TEST SET-UP CONDITIONS, IMPROPER TEST EQUIPMENT OR DOWN STREAM SHORTS. TEN OF THESE WERE EXPERIENCED AT THE NEXT ASSEMBLY LEVEL TEST, NINE WERE EXPERIENCED AT THE ORBITER LEVEL, FIVE WERE EXPERIENCED IN SAIL AND THREE AT WHITE SANDS TEST FACILITY.

THESE INDUCED FAILURES HAVE BEEN BROUGHT TO THE ATTENTION OF PERSONNEL INVOLVED. THEY ARE ALSO DETECTED AT THE TIME OF OCCURRENCE OR DURING NEXT FUNCTIONAL TEST.

CAR AC9648 AND AD1737
TWO LOSS OF OUTPUT FAILURES WERE EXPERIENCED WHICH WERE ISOLATED TO MARGINAL OR INADEQUATE WIRE BONDING THAT DEGRADED WITH TIME. ONE WAS EXPERIENCED ON OV-099 AND THE SECOND DURING FUNCTIONAL TEST OF THE NEXT ASSEMBLY AFTER HAVING BEEN IN THE FIELD. THESE WERE CONSIDERED TO BE ISOLATED INSTANCES. ALL HYBRID DRIVER BOND WIRES RECEIVE A 100% PULL TEST.

APPENDIX B ITEM 1 CONT'D

CAR 01F044
DURING THE POST FLIGHT CHECKOUT TEST SEQUENCE, A LOSS OF OUTPUT FAILURE WAS ISOLATED TO A HYBRID DRIVER. THIS CONDITION WAS ATTRIBUTED TO A CRACK IN THE SUBSTRATE CREATED BY OVERBONDING OF AN EMITTER LEAD. THIS FAILURE WAS CONSIDERED AN ISOLATED ESCAPE.

CAR 11F011
DURING ORBITER OV-099 STS-11 MISSION, A LOSS OF OUTPUT FAILURE WAS EXPERIENCED WHICH WAS ISOLATED TO A HYBRID DRIVER WHERE AN INTEGRATED CIRCUIT CHIP WAS FOUND SHORTED TO THE GROUND PLANE PIN NUMBER 1. NO SPECIFIC CAUSE WAS DETERMINED.

HARDWARE DELIVERED IS CONSIDERED SATISFACTORY FOR ITS INTENDED USAGE. THIS IS BASED UPON THE FACT THAT THERE HAVE BEEN NO SIMILAR FAILURES OF THIS NATURE.

FAILURE MODE: DELAYED OUTPUT

CAR'S AD0150 AND AD0582
TWO FAILURES HAVE BEEN EXPERIENCED. A HYBRID DRIVER EXHIBITED A DELAY IN PROVIDING AN OUTPUT AFTER THE COMMAND WAS GIVEN. ONE WAS EXPERIENCED DURING ORBITER OV-103 CHECKOUT TEST AND THE OTHER WAS EXPERIENCED DURING A THERMAL TEST AT THE NEXT ASSEMBLY LEVEL. IN BOTH CASES, THE FAILURE WAS ISOLATED TO A QUAD COMPARATOR CHIP AND ATTRIBUTED TO SURFACE CONTAMINATION. THE CONTAMINATION WAS NEVER IDENTIFIED. THE ANALYSIS OF THE FIRST OCCURRENCE FAILURE FOUND THE FAILURE MODE DISAPPEARING WHEN THE HYBRID WAS WASHED WITH DE-IONIZED WATER. DURING THE ANALYSIS ACTIVITY OF THE SECOND UNIT THE FAILURE ALSO DISAPPEARED.

A REVIEW OF THE FABRICATION REQUIREMENTS AND PROCESSES INDICATES THAT FAILURES OF THIS NATURE SHOULD NOT OCCUR AS THE DEVICES ARE FABRICATED IN A CONTROLLED ENVIRONMENTAL AREA.

SUPPLIER'S FABRICATION AREA HAS RECENTLY BEEN CERTIFIED TO A CLASS 100,000 CLEAN ROOM OPERATION.

FAILURE MODE: CONTINUOUS OUTPUT

CAR AB8154
DURING SAIL SYSTEMS TEST A CONTINUOUS OUTPUT VOLTAGE WAS OBSERVED. THE FAILURE WAS ISOLATED TO A TYPE III HYBRID DRIVER WHICH WAS CAUSED BY EXCESSIVE CONDUCTIVE EPOXY THAT ALLOWED CURRENT LEAKAGE AT A TRANSISTOR CHIP. THIS FAILURE WAS CONSIDERED TO BE A WORKMANSHIP ESCAPE THAT SHOULD HAVE BEEN DETECTED DURING PRE-CAP VISUAL. THIS FAILURE IS CONSIDERED TO BE AN ISOLATED ESCAPE.

11/03/87

APPENDIX B ITEM 1-- CONT'D

CAR AC2653
DURING ORBITER OV-103 CHECKOUT TEST A LOW LEVEL VOLTAGE (0.2 VDC) WAS OBSERVED WHEN THERE SHOULD HAVE BEEN NONE. THE FAILURE WAS ISOLATED TO A HAIR LINE CRACK IN A DARLINGTON TRANSISTOR CHIP WITH A HYBRID DRIVER. AVAILABLE FABRICATION HISTORY REFLECTS THAT THIS TRANSISTOR HAD BEEN REPLACED WHICH MAY HAVE CONTRIBUTED TO THIS SPECIFIC FAILURE. THIS FAILURE IS CONSIDERED TO BE AN ISOLATED ESCAPE.

PREPARED BY:		APPROVED BY:		APPROVED BY (NASA):	
DESIGN	R. HERTENSTEIN	DES	11/3/87	SSM	11/3/87
RELIABILITY	M. HOVE	REL	11-3-87	REL	11/3
QUALITY	J. COURSEN	QE		QE	11/3