

**SSME FMEA/CIL  
REDUNDANCY SCREEN**

Component Group: Electrical Harnesses  
 CIL Item: H116-01, H118-01, H120-01, H122-01  
 Part Number: R0018416, R0018418, R0018420, R0018422  
 Component: Extended Life - Lightning Braided - Main Chamber Pressure 1W16, 1W18, 1W20, 1W22  
 FMEA Item: H116, H118, H120, H122  
 Failure Mode: Open or short circuit in harness. Loss of connector.

Prepared: P. Ho  
 Approved: T. Nguyen  
 Approval Date: 6/3/00  
 Change #: 1  
 Directive #: CCBD ME3-01-5287

Page: 1 of 2

Phase	Failure / Effect Description	Criticality Hazard Reference
P 4.2	<p>Failure of multiple harnesses causing erroneous output signals from both sensor pairs within limits results in loss of engine start inhibit protection. Loss of vehicle during start due to oxidizer duct rupture may result if MCC fails to ignite and failure is not detected.</p> <p>Redundancy Screens: HARNESS SYSTEM - ENGINE SYSTEM: UNLIKE REDUNDANCY</p> <p>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround.            B: Fail - Loss of a redundant hardware items is not detectable during flight.            C: Pass - Loss of redundant hardware items could not result from a single credible event.</p>	1R ME-C3S
S 4.4	<p>Harness failure causing erroneous output signals from both sensor pairs within ignition confirmed limits results in loss of ignition confirm protection. Loss of vehicle due to oxidizer duct rupture may result if MCC fails to ignite and is not detected.</p> <p>Redundancy Screens: HARNESS SYSTEM - ENGINE SYSTEM: UNLIKE REDUNDANCY</p> <p>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround.            B: Fail - Loss of a redundant hardware items is not detectable during flight.            C: Pass - Loss of redundant hardware items could not result from a single credible event.</p>	1R ME-C3S
S 4.6	<p>Failure of one or more harnesses causing erroneous output signals from one or both sensor pairs within redline limits results in loss of redline protection. Loss of vehicle due to HPOTP/OPB failure may result if low main combustion chamber pressure occurs and is not detected.</p> <p>Redundancy Screens: HARNESS SYSTEM - ENGINE SYSTEM: UNLIKE REDUNDANCY</p> <p>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround.            B: Fail - Loss of a redundant hardware items is not detectable during flight.            C: Pass - Loss of redundant hardware items could not result from a single credible event.</p>	1R ME-C1S,M, ME-D1S,M
M 4.2	<p>Multiple harness failure causing both sensor pairs to be outside of qualification limits results in Pc Ref, used in VDT, electrical lockup response. Mission abort may result when electrical lockup occurs during Max Q throttling.</p> <p>Redundancy Screens: HARNESS SYSTEM: LIKE REDUNDANCY</p> <p>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround.            B: Pass - Loss of a redundant hardware items is detectable during flight.            C: Pass - Loss of redundant hardware items could not result from a single credible event.</p>	1R ME-G4M

H - 235

Component Group: Electrical Harnesses  
 CIL Item: H116-01, H118-01, H120-01, H122-01  
 Part Number: R0018418, R0018418, R0018420, R0018422  
 Component: Extended Life - Lightning Braided - Main Chamber Pressure 1W16, 1W18, 1W20, 1W22  
 FMEA Item: H116, H118, H120, H122  
 Failure Mode: Open or short circuit in harness. Loss of connector.

Prepared: P. Ho  
 Approved: T. Nguyen  
 Approval Date: 8/3/00  
 Change #: 1  
 Directive #: CCBD ME3-01-5287

Page: 2 of 2

Phase	Failure / Effect Description	Criticality Hazard Reference
M 4.3	<p>Failure of one or more harnesses causing erroneous signal(s) from one or both sensor pairs within qualification limits will result in off-nominal thrust and mixture ratio operation. Mission abort may result if off-nominal propellant consumption leads to a SLE engine shutdown or premature propellant depletion.</p> <p>Redundancy Screens: HARNESS SYSTEM - ENGINE SYSTEM: UNLIKE REDUNDANCY</p> <p>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround.            B: Fail - Loss of a redundant hardware items is not detectable during flight.            C: Pass - Loss of redundant hardware items could not result from a single credible event.</p>	1R ME-G4M
M 4.4	<p>Multiple harness failures causing both sensor pairs to be outside of qualification limits will disqualify both sensor pairs deleting redline monitoring of this parameter. Loss of vehicle due to HPOTP/OPB failure may result if low main combustion chamber pressure occurs and is not detected.</p> <p>Redundancy Screens: HARNESS SYSTEM - ENGINE SYSTEM: UNLIKE REDUNDANCY</p> <p>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround.            B: Pass - Loss of a redundant hardware items is detectable during flight.            C: Pass - Loss of redundant hardware items could not result from a single credible event.</p>	1R ME-C1S,M, ME-D1S,M
M 4.5	<p>Harness failures causing both sensor channel pairs or remaining qualified sensor pair below the redline limit will result in an erroneous engine shutdown. Mission abort.</p> <p>Redundancy Screens: HARNESS SYSTEM: LIKE REDUNDANCY</p> <p>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround.            B: Pass - Loss of a redundant hardware items is detectable during flight.            C: Pass - Loss of redundant hardware items could not result from a single credible event.</p>	1R ME-G4M
M 4.6	<p>Failure of one or more harnesses causing erroneous signal(s) from one or both sensor pairs within redline limits results in loss of redline protection. Loss of vehicle due to HPOTP/OPB failure may result if low main combustion chamber pressure occurs and is not detected.</p> <p>Redundancy Screens: HARNESS SYSTEM - ENGINE SYSTEM: UNLIKE REDUNDANCY</p> <p>A: Pass - Redundant hardware items are capable of checkout during normal ground turnaround.            B: Fail - Loss of a redundant hardware items is not detectable during flight.            C: Pass - Loss of redundant hardware items could not result from a single credible event.</p>	1R ME-C1S,M, ME-D1S,M

**SSME FMEA/CIL  
DESIGN**

Component Group: **Electrical Harnesses**  
CIL Item: **H116-01, H118-01, H120-01, H122-01**  
Part Number: **R0018416, R0018418, R0018420, R0018422**  
Component: **Extended Life - Lightning Braided - Main Chamber Pressure 1W16, 1W18, 1W20, 1W22**  
FMEA Item: **H118, H118, H120, H122**  
Failure Mode: **Open or short circuit in harness. Loss of connector.**

Prepared: **P. Ho**  
Approved: **T. Nguyen**  
Approval Date: **5/3/00**  
Change #: **1**  
Directive #: **CCBD ME3-01-5287**

Page: **1 of 2**

Design / Document Reference

**FAILURE CAUSE: A: Conductor or insulation damage caused by vibration, flexure, routing, or clamping.**

MATERIAL SELECTION OF THE WIRES, INSULATORS, CONNECTORS, AND ASSEMBLY TECHNIQUES ARE CONTROLLED BY SPECIFICATION (1) TO GUARD AGAINST THE FAILURE OF THE HARNESS IN THE ENVIRONMENTS IT IS EXPOSED TO. THESE CONTROLS ARE ESTABLISHED BY GOVERNMENT SPECIFICATIONS FOR CONNECTORS (2) AND WIRE SELECTION (3), AND ARE KEYED TO THE FUNCTION AND USAGE OF THE HARDWARE. TO PRECLUDE SINGLE POINT ELECTRICAL FAILURES, REDUNDANT FUNCTIONS ARE IMPLEMENTED IN SEPARATE HARNESSES, ROUTED THROUGH DIFFERENT PATHWAYS. TO PREVENT DETEIORATION OF THE CONDUCTOR OR INSULATOR, WIRES ARE OF SUCH CROSS SECTION AS TO PROVIDE AMPLE AND SAFE CURRENT CARRYING CAPACITY. THE MAXIMUM DESIGN CURRENT IN ANY WIRE IS LIMITED SO THAT "WIRE TOTAL TEMPERATURE" WILL NEVER EXCEED THE RATED WIRE TEMPERATURE (1). HARNESS ASSEMBLIES INCORPORATE A FLEXIBLE GLASS FILLER CORD TO ENHANCE CABLE ROUNDING (1). THE CORD HELPS IN ELIMINATING EXCESSIVE BEND RADIUS THAT MAY CAUSE WIRE DAMAGE. TEFLON FILM WRAP AND TEFLON TAPE COVER THE WIRE BUNDLES TO PROTECT THE INSULATION FROM ABRASIVE DAMAGE. A WIRE MESH SHEATH PROTECTS THE ENTIRE WRAP FROM SHARP IMPACTS, HANDLING DAMAGE, AND PROVIDES EMI PROTECTION (4). A HEAT SHRINKABLE POLYOLEFIN SEMI-RIGID OVERMOLD IS USED TO PROVIDE HARNESS SUPPORT (4). BRAID WIRE TYPE, SIZE, AND COVERAGE ARE CONTROLLED BY SPECIFICATION (5). CABLE ROUTING IS CONTROLLED BY THE ASSEMBLY DRAWINGS (6) THAT ESTABLISH THE RETAINING CLAMPS AND RESTRAINING TIES. THE SECURING CLAMPS (7) INCORPORATE RUBBER GROMMETS THAT PREVENT PINCHING OR CUTTING OF THE INSTALLED HARNESS.

(1) RL10014; (2) 40M38294, 40M39569; (3) 40M50577; (4) RL00995; (5) RA1613-004; (6) RS007007; (7) RE127-2018

**FAILURE CAUSE: B: Loose, worn, or damaged pin or pins.**

**C: Damaged contact or crimp.**

**E: Connector shell failure.**

**G: Locking feature failure (extended life only).**

CONNECTOR SELECTION OF THE ASSEMBLIES IS CONTROLLED BY SPECIFICATION REQUIREMENTS (1). THE REQUIREMENTS INCORPORATE CONTROLS (2) THAT ARE KEYED TO GUARD AGAINST THE ENVIRONMENTS THEY ARE EXPOSED TO. THE CONNECTORS MEET CEI REQUIREMENTS FOR HIGH CYCLE FATIGUE, LOW CYCLE FATIGUE, AND MINIMUM FACTORS OF SAFETY (3). THE CONNECTORS ARE SELECTED IN ACCORDANCE WITH MSFC STANDARDS FOR USE ON ROCKET PROPELLED VEHICLES (4). BENT OR WORN PINS ARE REMOVABLE AND REPLACEABLE. BAYONET LOCKING RINGS ARE PROVIDED TO PREVENT PRIMARY CONNECTORS FROM DEMATING. EXTENDED LIFE HARNESS SECONDARY CONNECTORS (5) ARE A THREADED COUPLING WITH A RACHET TYPE LOCKING FEATURE. THE SELF-LOCKING FEATURE IS A MULTIPLE BALL RACHET DESIGN. THIS RACHET CONFIGURATION PROVIDES A GREATER COUNTER-CLOCKWISE RACHETING FORCE CREATING A SELF-LOCKING DESIGN. THIS DESIGN ELIMINATES THE NEED FOR CONNECTOR TORQUE LOCK (6). THE SELF-LOCKING CONNECTORS ARE MANUFACTURED FROM STAINLESS STEEL (5). STAINLESS STEEL PROVIDES AMPLE STRENGTH AND CORROSION RESISTANCE.

(1) RL10014; (2) RES1235, RE1731, RE1761; (3) RL00532, RSS-8516, CP320R0003B; (4) 40M38294, 40M39569; (5) RE1731, RE1761; (6) ECP 797

**FAILURE CAUSE: D: Corrosion or moisture.**

THE ELECTRICAL COMPONENTS OF THE WIRE HARNESS ARE PROTECTED FROM CORROSION BY INHERENT MATERIAL DESIGN AND PROTECTIVE EXTERNAL COVERING OF THE CABLE. THE WIRE INSULATION IS COMPOSED OF TEFLON (1). TEFLON HAS RESISTANCE TO FLUIDS AND ATMOSPHERIC VAPORS. THE CONNECTOR CONTACTS ARE PLATED WITH GOLD OVER NICKEL UNDERPLATE (2). GOLD IS RESISTANT TO WATER CORROSION AND HUMIDITY. EXCEPT FOR POTTED CONNECTORS, THE CONNECTOR BACKSHELL IS PROTECTED BY SILICON RUBBER (3) TO PROTECT THE CONNECTOR FROM THE MAXIMUM SPECIFIED OPERATIONAL ENVIRONMENTS. PIN INSERT INTERFACIAL SEALS (4) ARE PROVIDED TO REDUCE CORROSION. CONNECTORS ARE MAINTAINED IN THEIR SEALED BAGS UNTIL READY FOR ASSEMBLY. CONNECTORS ARE PROTECTED TO PREVENT DAMAGE OR CONTAMINATION RESULTING FROM CONTACT WITH EACH OTHER OR ADJACENT OBJECTS (5).

(1) 40M50577; (2) MSFC-SPEC-250; (3) RL10014; (4) RC1235, RC1731, RC1761; (5) RL00995

Component: Electrical Harnesses  
CIL Item: H116-01, H118-01, H120-01, H122-01  
Part Number: R0018416, R0018418, R0018420, R0018422  
Component: Extended Life - Lightning Braided - Main Chamber Pressure 1W16, 1W18, 1W20, 1W22  
FMEA Item: H116, H118, H120, H122  
Failure Mode: Open or short circuit in harness. Loss of connector.

Prepared: P. Ho  
Approved: T. Nguyen  
Approval Date: 5/3/00  
Change #: 1  
Directive #: CCBD ME3-01-6287

Page: 2 of 2

Design / Document Reference

FAILURE CAUSE: ALL CAUSES

THE CONTROLLER SOFTWARE IS CONFIGURED TO DETECT AND RESPOND PROPERLY TO THE FAILURES IDENTIFIED, IMPLEMENT THE NECESSARY REDUNDANT CONTROLLER CHANNEL SWITCHING AND COMMAND A SAFE ENGINE STATE WHEN REDUNDANCY IS LOST (1). FUNCTIONS ARE CONTROLLED ON REDUNDANT HARNESSSES. THE HARNESS BASIC DESIGN IS TESTED PER HARNESS DESIGN VERIFICATION TESTING (2), INCLUDING VIBRATION TESTING (3), SAFETY FACTOR CRITERIA TESTING (4), DURING SENSOR VIBRATION TESTING (5) WHERE THE FLIGHT DESIGNED HARNESS IS CONNECTED TO THE SENSOR UNDER TEST, AND DURING ENGINE DVS TESTING (6). EXTENDED LIFE HARNESS DESIGN FIRE CERTIFICATION TESTING (8).

(1) CP40GR0008; (2) DVS-SSME-202; (3) RSS-202-6; (4) RSS-202-20; (5) DVS-SSME-203; (6) DVS-SSME-101; (7) VRS344; (8) VRS514

## SSME FMEA/CIL INSPECTION AND TEST

Component Group: **Electrical Harnesses**  
 CIL Item: **H116-01, H118-01, H120-01, H122-01**  
 Part Number: **R0018416, R0018418, R0018420, R0018422**  
 Component: **Extended Life - Lightning Braided - Main Chamber Pressure 1W18, 1W18, 1W20, 1W22**  
 FMEA Item: **H116, H118, H120, H122**  
 Failure Mode: **Open or short circuit in harness. Loss of connector.**

Prepared: **P. Ho**  
 Approved: **T. Nguyen**  
 Approval Date: **5/3/00**  
 Change #: **1**  
 Directive #: **CCBD ME3-01-5287**

Page: **1 of 2**

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference	
A	1W16 EXTENDED LIFE HARNESS		R0018416	
	1W18 EXTENDED LIFE HARNESS		R0018418	
	1W20 EXTENDED LIFE HARNESS		R0018420	
	1W22 EXTENDED LIFE HARNESS		R0018422	
	ASSEMBLY INTEGRITY	<p>THE FOLLOWING TESTS AND INSPECTIONS ARE PERFORMED DURING MANUFACTURING AND ASSEMBLY ACCEPTANCE:</p> <ul style="list-style-type: none"> <li>- LIGHTNING BRAID IS INSPECTED FOR ACCEPTABILITY.</li> <li>- ALL WIRES ARE SUBJECTED TO SPARK AND DIELECTRIC TESTING.</li> <li>- ALL CONTACTS IN THE CONNECTORS ARE SUBJECTED TO A RETENTION TEST.</li> <li>- A RESISTANCE TEST BETWEEN THE BRAID AND MATING CONNECTOR FLANGE IS PERFORMED ON THE LIGHTNING BRAID/CONNECTOR AND VERIFIED TO BE WITHIN SPECIFICATION.</li> <li>- EACH WIRE RUN IS VERIFIED FOR END-TO-END CONTINUITY.</li> <li>- INSULATION RESISTANCE BETWEEN EACH CONDUCTOR AND EVERY OTHER CONDUCTOR IS VERIFIED TO BE WITHIN SPECIFICATION.</li> <li>- A DIELECTRIC WITHSTANDING VOLTAGE TEST BETWEEN EACH CONDUCTOR AND EVERY OTHER CONDUCTOR, SHELL OR SHIELD VERIFIES THE LEAKAGE CURRENT TO BE WITHIN SPECIFICATION.</li> <li>- ALL SELF-LOCKING CONNECTOR MECHANISM ARE FUNCTIONAL TESTED.</li> </ul>	RL00995 40M50577 RL00995 RL00995 RL00128 RL00128 RL00128 RC1731 RC1761	
	INSTALLATION INTEGRITY	<p>INSTALLATION OF THE HARNESSES IS VERIFIED PER SPECIFICATIONS DEFINING THE:</p> <ul style="list-style-type: none"> <li>- INSPECTION OF HARNESSES PRE- AND POST-INSTALLATION.</li> <li>- ROUTING REQUIREMENTS WHICH INCLUDE:               <ul style="list-style-type: none"> <li>INSTALLATION PATH, CLAMP LOCATIONS, AND SIZES.</li> <li>SEPARATION DISTANCE REQUIREMENTS FROM OBJECTS WHICH COULD CAUSE CABLE OR CONNECTOR DAMAGE.</li> <li>MINIMUM BEND RADII.</li> </ul> </li> <li>- INSPECTION OF CONNECTORS PRIOR TO MATING. THIS INCLUDES BACKSHELL, PINS, CONNECTOR GASKETS AND CONNECTOR PERIPHERIAL O-RING.</li> <li>- TORQUE REQUIREMENTS FOR THREADED CONNECTORS.</li> </ul>	RL00039 RS007007 RS007007 RL00039 RL00039 RL00039	
	B, C, E, G	CONNECTOR		RES1235
		CONNECTOR		RE1731
		CONNECTOR		RE1761
	HARNESS/CONNECTOR ASSEMBLY INTEGRITY	<p>HARNESS/CONNECTOR ASSEMBLY PROCESSES ARE VERIFIED PER SPECIFICATIONS WHICH INCLUDE:</p> <ul style="list-style-type: none"> <li>- CRIMPING OF ELECTRICAL CONNECTOR CONTACTS.</li> <li>- USE OF FLEXIBLE INSULATION SLEEVING.</li> <li>- INSTALLATION OF OVERMOLD AND PROTECTIVE SLEEVE.</li> <li>- SELECTION AND USAGE OF PROTECTIVE CLOSURES</li> </ul> <p>COMPLETED ASSEMBLY IS INSPECTED FOR CONTACT PIN RETENTION AND PROTECTIVE BRAID DAMAGE.</p>	RA1613-005 RB0130-109 RA0805-018 RA0116-054 RL00885	

H - 239

Component: Electrical Harnesses  
 CIL Item: H116-01, H118-01, H120-01, H122-01  
 Part Number: R0018416, R0018418, R0018420, R0018422  
 Component: Extended Life - Lightning Braided - Main Chamber Pressure 1W16, 1W18, 1W20, 1W22  
 FMEA Item: H116, H118, H120, H122  
 Failure Mode: Open or short circuit in harness. Loss of connector.

Prepared: P. Ho  
 Approved: T. Nguyen,  
 Approval Date: 5/3/00  
 Change #: 1  
 Directive #: CCBDEME3-01-5287

Page: 2 of 2

Failure Causes	Significant Characteristics	Inspection(s) / Test(s)	Document Reference
D	CONNECTOR CONNECTOR CONNECTOR		RES1235 RE1731 RE1761
	CLEANLINESS OF COMPONENTS	CLEANLINESS REQUIREMENTS ARE VERIFIED PER SPECIFICATION DURING MANUFACTURING OF THE HARNESS ASSEMBLY.  METAL TYPE DUST AND MOISTURE PROOF CAPS ARE VERIFIED INSTALLED ON THE CONNECTOR WHEN NOT IN USE.	RL00995 RL00995
	SURFACE FINISH	THE PLATING ON THE CONNECTOR CONTACTS ARE INSPECTED PER SPECIFICATION REQUIREMENTS.	RC1235 RC1731 RC1761
	ASSEMBLY INTEGRITY	PRIOR TO CONNECTOR MATING, THE CONNECTOR IS INSPECTED FOR ANY CORROSION OR DAMAGE WHICH WOULD ALLOW MOISTURE TO ENTER THE CONNECTOR.	RL00039
ALL CAUSES	1W16 EXTENDED LIFE HARNESS 1W18 EXTENDED LIFE HARNESS 1W20 EXTENDED LIFE HARNESS 1W22 EXTENDED LIFE HARNESS  ASSEMBLY INTEGRITY	      ALL CONTROLLER DATA FROM THE PREVIOUS FLIGHT IS REVIEWED. ANY ANOMALOUS CONDITION NOTED REQUIRES FURTHER TESTING OR HARDWARE REPLACEMENT PRIOR TO THE NEXT FLIGHT.  RE-TEST REQUIREMENTS AFTER HARNESS REPLACEMENT OR CONNECTOR DEMATE VERIFY THAT THE PROPER CONTROLLER ELECTRICAL CHECKOUTS ARE PERFORMED TO RE-VALIDATE THE HARNESS ASSEMBLY.  HARNESSES ARE INSPECTED FOR DAMAGE, PROPER ROUTING, AND PROPER TORQUE LOCK APPLICATION DURING POST FLIGHT EXTERNAL INSPECTION.  HARNESS OPERATION IS VERIFIED EVERY MISSION FLOW AND AFTER ANY REPAIR OR REPLACEMENT BY THE FOLLOWING CONTROLLER ELECTRICAL CHECKOUTS: (LAST TEST)	R0018416 R0018418 R0018420 R0018422  MSFC PLN 122B  OMRSD V41ZA0.010  OMRSD V41BU0.030  OMRSD V41AQ0.010 OMRSD V41AS0.030 OMRSD V41AS0.020

Failure History: Comprehensive failure history data is maintained in the Problem Reporting database (PRAMS/PRACA) Reference: NASA letter SA21/88/308 and Rockwell letter 88RC09761.

Operational Use: FAILURE MODE CAN BE DETECTED IN REALTIME BY THE FLIGHT CONTROL TEAM WHO WILL EVALUATE EFFECTS UPON VEHICLE PERFORMANCE AND ABORT CAPABILITY. BASED ON THIS EVALUATION THE APPROPRIATE ABORT MODE OR SYSTEM CONFIGURATION WILL BE SELECTED. FAILURE DETECTION CUES AND ASSOCIATED SSME PERFORMANCE DATA HAVE BEEN COORDINATED BETWEEN THE ENGINEERING AND FLIGHT OPERATIONS ORGANIZATIONS WITH THE RESPONSES DOCUMENTED IN MISSION FLIGHT RULES.

H - 240