SUBSYSTEM: RANGE SAFETY COMMAND DESTRUCT

ITEM NAME: Range Safety Distributor

PART NO.: 10406-0147 FM CODE: A02

ITEM CODE: 70-09 REVISION: Basic

CRITICALITY CATEGORY: 1R REACTION TIME: Seconds

NO. REQUIRED: 1 DATE: March 31, 2000 CN 038

CRITICAL PHASES: Boost SUPERCEDES: March 31, 1997 CN 038

FMEA PAGE NO.: F-17 ANALYST: S. Parvathaneni CN 038

SHEET 1 OF 11 APPROVED: S. Parvathaneni CN 038

FAILURE MODE AND CAUSES: Loss of destruct command output to NSDs A and B caused by one of the following failures in RSD system A and one in RSD system B (two failures Required):.

- o PIC A or PIC B Failure.
- o Fire Switch in RS Controller Module fails short(internally)
- o Arm or Fire Switch in RS Controller Module fails open or shorts to ground
- o Open resistor in series with PIC output.
- o Open junction block connection.
- o Open or short in wiring harness.

Note: See 70-09 FM Code A30 for Loss of Power

FAILURE EFFECT SUMMARY: Loss of destruct capability of one SRB, leading to loss of life or injury to the public. One success path remains after the first failure. Operation is not affected until two paths are lost.

REDUNDANCY SCREENS AND MEASUREMENTS:

1. Pass - Checked in bench test, ACO and SIT with the last check being made at ordnance installation. No test can be made after live ordnance is connected.

2. Fail- Unable to detect failure without issuing destruct command.

3. Pass - No known credible cause.

RATIONALE FOR RETENTION:

A. DESIGN

O The Range Safety Distributor (RSD) is totally redundant with regard to the failed functions. The design provides one common housing with a cast aluminum wall separating the two redundant systems (System A and System B) so that no electrical failure in one system can propagate to the other. Redundant arm and fire signals are supplied to systems A and B by IRDs A and B (respectively) via separate cables and connectors. These signals are routed to the arm and fire latch circuits on the range safety controller board by the wiring harness and junction blocks in each unit. The output of the arm latch circuit activates the fire latch circuit and the capacitor firing circuitry on the PIC printed wiring board. The subsequent (greater than 1.1 second after the arm signal) fire signal activates the fire circuit, which then supplies power to the PIC to discharge the stored capacitor energy into the associated NSD through the redundant output connector and cables. The power sources, operational commands, and measurement indicators for Systems A and B are also redundant.

O Two RSD functions are to execute the Arm and Fire commands that are issued by the IRDs. These commands are implemented functionally by setting the arm latch switch to supply power to the fire latch switch and the PIC capacitor charging circuitry and then setting the fire latch switch to trigger to the PIC capacitor discharge circuitry. The PIC discharges the stored capacitor energy into an associated NSD device via output connectors and cables. The design of the RSD implements these functions in hardware by providing connectors, wiring harness, junction blocks, controller boards, PIC boards, and associated power sources and command functions. The specific RSD design feature that was implemented to mitigate all of the listed failure causes is true parallel redundancy.

O There is a single vendor source for the Range Safety Distributor (RSD), Bendix, Guidance Systems Division. The RSD (containing a new design) has completed delta qualification to the twenty mission level. (Ref. Qual Test Report EE-QTR-91-001). The mission qualification is documented in COQ A-RSS-3113-4 and COQ A-RSS-3113-5.

O All electrical and electromechanical component parts used in the RSD have traceability requirements per SE-019-033-2H. In addition, a log book is generated for each RSD assembly at the start of acceptance testing, and a complete historical record is maintained for the life of the RSD.

O The design features noted and the use of high reliability parts selected from or screened to 10REQ-0036 mitigate the probability of the failure causes referenced in the failure mode.

O The design of the RSD implements these functions in hardware by providing connectors, wiring harnesses, controller boards, and associated power sources and command functions. The specific RSD design feature that was implemented to mitigate all of the listed failure causes is true parallel redundancy.

O PIC A or PIC B Failure

- The Pyrotechnic Initiator Controller (PIC) is a Shuttle System Commonality 1 component (the design and qualification is controlled by JSC). The PIC is a two sided PWB that was developed by Martin Marietta for NASA. The PIC is procured by MSFC and provided as GFE to Bendix.

- The PIC meets all of the requirements of the RSD specification for the SRB (10SPC-0148), has flown on all Shuttle missions to date and is qualified for twenty-missions.

O Fire Switch in RS Controller Module fails short. (Internally) (Duds PIC)

O Arm or Fire Switch in RS Controller Module fails open or shorts to ground.

The controller card meets all of the requirements of the range safety distributor specification P/N 10SPC-0148 and has the following design features that were incorporated to mitigate the listed failure causes.

- The multi-layered PWB is designed and inspected to the requirements of 56M60420. Electrical connection between layers is completed by plated through holes. The board is conformal coated after the electrical piece parts have been mounted and the board has been tested and inspected.

- Verification of the electrical design included "worst case" electrical stress and thermal analyses, which consider component tolerances and stability through end of life and predicts component temperatures. The mechanical packaging design is also conservative, employing component mounting for stress-free solder connections, high temperature printed wiring boards and conformal coating. (BI-1730)

- The electrical design of the control card is conservative. The electrical component parts are either selected from "EEE Parts Selection and Guidelines" (10REQ-0036) or are screened to the requirements of 10REQ-0036. This parts selection and screening assure the use of only high reliability parts.

- Arm switches are designed to provide a six hundred percent margin on current and one hundred percent on voltage at output. Fire switches are designed to provide a three hundred percent margin on output current and fifty percent on voltage.

- The PWB assembly is designed to operate within spec at 185^{o}F, which allows for a 30^{o}F gradient from the assembly to the 155^{o}F temperature requirement for the RSD case.

- Optical Coupling (isolation on)the cross-strapped command inputs eliminates ground loop problems.

- The use of latching concepts improves the probability to respond to commands for these functions. The On/Off command signals reduce the complexity of the circuits (improved reliability) as compared to sensitive analog linear circuitry.

- Adequate heat sinks are provided for all power transistors.

- The circuits have been designed to be tolerant to wide variations in power levels and voltages.

O Open Resistor in Series with PIC Output

- o The resistors are located on the bottom side of the RSD near the output connectors. The resistor meets all of the requirements of the RSD assembly spec for the SRB (10SPC-0148) has been flown on all Shuttle missions to date and is qualified to the twenty-mission level. This resistor mounted on the terminal board has the following design features that were incorporated to mitigate this cause of failure:
- o The resistor is as selected from "EEE Parts Selection and Application Guidelines," QPL (10REQ-0036) to assure high reliability of the resistor.
- o The resistor is a type RWR89SR300FP (MIL-R-39007/11) and is rated at 3 watts. The nominal in circuit power dissipation is 60 milliwatts. The part is heavily derated.
- o The lead bend radius and bend location provides adequate stress relief to preclude lead or resistor body cracking.
- o The resistor is restrained to withstand shock and vibration by tack bonding and then is conformal coated to mitigate shorts caused by debris.

O Open Junction Block Connection

- o The junction blocks are judiciously located within the RSD case. The junction blocks meet all of the requirements of the RSD assembly spec 10SPC-0148, have been flown on all Shuttle missions to date and are qualified to the twenty-mission level. These junction blocks have the following design features that were incorporated to mitigate this cause of failure:
- o The junction blocks are per MSFC 16A10103. This spec governs the contact arrangement, size, materials, blocking system, mounting points and source.
- o The design of the junction block provides protection from contamination by use of an insulator material around the entry wire. There are no exposed electrical surfaces or points.
- o The tooling and manufacturing processes that govern the assembly of the wiring harness to the junction blocks are all controlled by MSFC specs and procedures.

O Open or Short in Wiring Harness

- o The wiring harness interconnects the connectors, junction blocks, card connectors and terminal boards. The wire and connector pins meet all of the requirements of the RSD assembly spec 10SPC-0148, have been flown on all Shuttle missions to date, and are qualified to the twenty-mission level. The harness has the following design features that were incorporated to mitigate this cause of failure:
- o The circuit board connectors were selected from MSFC 16A10455 and 16A10448 and are torqued to MSFC 16A10310.
- o Wires are terminated per NHB 5300.4 (3A-1) and JD-001, which assure reliable connections.
- o The harnesses are laced per MIL-E-45782 to prevent vibration or shock damage.

- o The connectors are located at each end of the RSD housing. The connectors meet all of the requirements of the RSD assembly spec for the SRB 10SPC-0148, have been flown on all Shuttle missions to date and are qualified to the twenty-mission level. The connectors have the following design features that were incorporated to mitigate this cause of failure

- o These exterior flange mount connectors were selected from MSFC 40M39569 and the pin arrangement is in accordance with 16A10300.

- o The selection of the pin arrangement assures that an adjacent pin short will not cause a mission failure.

- o Different keying arrangements on these connectors preclude mismating with the external harness.

- o The connectors are hermetically sealed and therefore prevent airborne contaminants from entering the case.

B. TESTING:

VENDOR RELATED TESTING

O During manufacturing all printed wiring assemblies are tested first at the board level to more stringent requirements and again as part of the completed distributor assembly acceptance testing. Each RSD is acceptance tested. The acceptance test includes a complete functional and environmental test (per Bendix Acceptance Test Procedures 5135181-GTSP and 5135123-GTSP). Acceptance testing establishes the absence of listed failure modes at the time of testing. (All Failure Causes)

O All newly assembled boards are subjected to Fairchild card testing before power is applied. Per Bendix Flow Chart 5116726.

O All printed wire assemblies (PWA) are acceptance tested with the power input and signal inputs at the minimum and maximum voltage. The test temperature is 30^{O}F above the maximum case temperature of the RSD assembly. The elevated temperature and increased input voltage variations are used to mitigate failure of the PWAs when exposed to the RSD level temperature and voltage requirements per Acceptance Test Procedures 5136115-GTS, 5136251-GTSP and 5136994-GTSP. (All Failure Causes)

O A push/pull test is performed on all connectors and junction blocks after the wiring harness is installed in the chassis per Bendix Pull Test Procedure 5136632 GMS.

KSC RELATED TESTING

O Below Referenced OMRSD refurbishment testing is performed every flight.

- RSD Arm and Fire circuits are tested during ACO per 10REQ-0021, para. 1.2.2.13 . Electrostatic Discharge ESD) Protection/Precautions are implemented IAW OMRSD 10REQ-0021 Paragraph 4.11 (All Failure Causes)

- RSD Outputs are verified with a Cross Strapping Test for per OMRSD File II, Vol. 1, requirement numbers S00000.200, S00000.210, S00000.220 and S00000.230 during Systems Integration Test..(All Failure Causes)

- RSD Outputs are verified with a response Test on all five RSS Subsystems per OMRSD File II, Vol. 1, requirement number S00000.380/390 during Final Ordnance Installation on the PAD.(All Failure Causes)

- PIC resistance test is performed at T-24 hours or later. Monitored by measurements B55X1873 and B55X1874 IAW OMRSD File II, requirement S00FAO.015.(PIC Failure, Open Resistor in Series with PIC, Open or Short in Wiring Harness, Open Junction Block)

- RSD outputs receives their final check during Ordnance Installation on the Pad.

REFURBISHMENT/RECERTIFICATION TESTING

- O Previously Flown RSD's are Refurbished and Recertified for flight per 10SPC-0131 and applicable RODs.
- O All USA SRBE/TBE Recertified RSD's are Acceptance Tested per design specification 10SPC-0148. (All Failure Causes)
- O ESD Protection Requirements are imposed per OMRS 10REQ-0021, Para. 4.11

VENDOR RELATED INSPECTION

- O Solder, flux, conformal coating, wire and copper clad board material are sample inspected upon receipt. USA SRBE PQAR verifies material certification and receiving inspection/test records per USA SRBE SIP 1091.
- O Junction blocks, card connectors and environmentally sealed connectors are sample inspected upon receipt (1 percent AQL). USA SRBE PQAR verifies material certification and receiving inspection/test records per USA SRBE SIP 1091.
- O Transistors, optical couplers, and diodes receive one hundred percent functional testing at Bendix. Capacitors and resistors are sampled at Bendix, one percent AQL. Magnetics have 100% visual, dimensional, and functional acceptance by Bendix Quality. USA SRBE PQAR verifies test data on electronic parts and screening test data per USA SRBE SIP 1091.
- O Bendix QA inspects printed wiring boards to the requirements of 50M60420.
- O USA SRBE PQAR verifies traceability records per USA SRBE SIP 1091.
- O USA SRBE PQAR verifies crimping, conformal coating and traceability records per USA SRBE SIP 1091. (Arm or Fire Switch Failed)
- O Bendix QA inspects one hundred percent of the solder and crimp connections that go into the harness per Bendix Flow Chart 5116726. (Open Resistor, Wiring Harness) (BI-1841)
- O The final loading of the modules into the distributor is witnessed by Bendix per Bendix Flow Chart 5116726. USA SRBE PQAR performs visual inspection of the unit after installation of plug-in boards per USA SRBE SIP 1091.
- O Final acceptance is witnessed by Bendix Quality per Bendix Flow Chart 5116726. USA SRBE PQAR witnesses final manual acceptance testing and verifies data for all automated final acceptance testing per USA SRBE SIP 1091. (All Failure Causes)
- O Critical Processes/Inspections/Operations:
    - o Soldering per NHB5300.4(3A-1) (BI-1903R1)
    - o Conformal Coating per MSFC-PROC-508
    - o Staking per MSFC-STD-136
    - o Crimping per Bendix-PROC-5136598

KSC RELATED INSPECTIONS

O USA SRBE Quality monitors and accepts distributor bench testing. (All Failure Causes)

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O USA SRBE Quality witnesses torquing of distributor to equipment panel and electrical bonding resistance between distributor and panel.

O Data from the Following OMRSD Required Test is verified to be Acceptable by a Quality Representative:

- RSD Functional Test per 10REQ-0021, paragraph 1.2.2.13 after installation. (All Failure Causes)

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- RSD Output data on all RSD's during Cross Strap Test per OMRSD File II, Vol. I, Requirements S00000.200, S00000.210, S00000. 220, S00000.230. (All Failure Causes)

- RSD Output data on all five RSS Subsystems during Final Ordnance Installation Test on the Pad Per OMRSD File II, Vol. I, Requirement S00000.380/390. (All Failure Causes)

REFURBISHMENT/RECERTIFICATION INSPECTION

O RSD's are inspected externally after each Flight per 10SPC-0131 for bent or broken connector pins and other visible damage.

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O RSDs are inspected internally after every third flight or five years, which ever come first for bent or broken connector pins, cracked solder joints, loose or broken components, arcing or burning of conformal coating, physical damage, torque or other items as applicable to product quality. The S&A, PIC, and controller modules are not disassembled for inspection. The RSD Assembly is cleaned and cosmetic damages repaired. If anomalies beyond the repairable limits outlined in 10SPC-0131 are noted, the RSD is returned to the vendor for repair and acceptance testing.

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O USB Quality Witness acceptance testing of all USA SRBE/TBE Florida Operations refurbished RSDs per applicable RODS(All Failure Causes)

D. FAILURE HISTORY

Failure Histories may be obtained from the PRACA database.

E. OPERATIONAL USE

O Not applicable to this failure mode.

F. WAIVER/DAR

o BI-1730, 4-26-89, CCBD SB3-01-2322

- SPECIFIED REQUIREMENT:

10CEI-0001 Paragraph 3.3.5.11 states that "Malfunction or inadvertent operation of vehicle electrical or electronic equipment caused by exposure to conducting or non-conducting debris or foreign material shall be prevented by design."

- DEPARTURE:

  RSDs PWAs have an exposed uninsulated air gap between each board and its card edge connector. The contacts and solder joints inside this "gap" are not conformal coated and thus subject to debris related problems.

- JUSTIFICATION:

  PWAs are inspected and cleaned to NHB 5300.4 (1C), (1D-1), (3A-1) and MSFC-STD-136 specifications. PWAs are assembled in a controlled environment and each distributor must pass vibration tests at ATP as well as a thorough electrical and functional checkout.

o BI-1841, 6-21-90, CCBD SB3-01-3470

- SPECIFIED REQUIREMENT:

  Crimping of electrical connections shall be in accordance with JD-001.

- DEPARTURE:

  RSDs do not meet crimping requirements of JD-001 paragraph 3.1.2, 3.4.2 and 3.2.1.4.

- JUSTIFICATION:

  All crimps have undergone 100 percent visual inspection by certified operators and inspectors. No-inflight failures have occurred due to improperly crimped connections.

  Although the positioner is part of the crimp tool setup, proper positioner selection is verified by certified operators and inspectors prior to use of a tool in crimping operations.

O BI-1903R1, 2-15-91, CCBD SB3-01-3982A

- SPECIFIED REQUIREMENT:

  Removal of Flux and Residue from each soldered connection shall be in accordance with NHB 5300.4(3A-1), para. 3A802.

- DEPARTURE:

  Inaccessibility of solder joint between Transistor Q2 and the series regulator PWB does not allow for proper cleaning of the solder flux and residue from each soldered connection.

- JUSTIFICATION:

  All solder joints on Q2 RSD series regulators have been inspected by X-ray to verify solder connections. All RSD PWAs were built using SN63 solder with RMA Flux. The area in question is sealed to moisture by conformal coating prior to the series regulator PWB being installed in the SRB RSD. The RSD is a sealed unit with the seal integrity verified prior to each flight. Conformal coating and inert environment reduce the possibility of organic/inorganic growth. Voltage regulation is functionally tested during ATO, ACO, SIT, Ordnance installation and final countdown. Regulated voltage LCC exists to terminate a countdown if violated.

O BI-1981, PN 10406-0147-851, SN 1000120, 01/04/96, CCBD SB3-01-5009 (BI-077 - BI-999)

- SPECIFIED REQUIREMENT:

  10CEI-0001
  Paragraph 3.2.7.2.1 - Ascent Vibration, Acoustic and Shock environments Paragraph 3.2.7.2.2 - ReentryVibration, Acoustic and Shock environments

- DEPARTURE:

  The RSD's have always been Tested with an imposed Acceleration Spectral Density Tolerance of +3/-1.5 DB. The vendor had vibration abort limits set significantly higher during Acceptance Test for repaired RSD's.

- JUSTIFICATION:

  The exceedance was within the Flight/Reentry Qualification Vibration Envelope. The Qualification Unit (IEA) has been through 20 Flight Qualification Missions. The Flight Qualification is to the maximum expected environments over the life of the RSD. This is a High Frequency narrow band spike that is separated by over 1 octave from the broad resonances.

O BI-1984, PN 10406-0147-854, SN 1000133, 1000139, 02/08/96, CCBD SB3-01-5022 (BI-078 - BI-999)

- SPECIFIED REQUIREMENT:

  10CEI-0001
  Paragraph 3.2.7.2.1 - Ascent Vibration, Acoustic and Shock environments Paragraph 3.2.7.2.2 - ReentryVibration, Acoustic and Shock environments

- DEPARTURE:

  The RSD's have always been Tested with an imposed Acceleration Spectral Density Tolerance of +3/-1.5 DB. The vendor had vibration abort limits set significantly higher during Acceptance.

- JUSTIFICATION:

  The exceedance was within the Flight/Reentry Qualification Vibration Envelope. The Qualification Unit (RSD) has been through 20 Flight Qualification Missions. The Flight Qualification is to the maximum expected environments over the life of the RSD.

O BI-1987, PN 10406-0147-851, SN 1000113, 1000139, 03/18/96, CCBD SB3-01-5036

O BI-1987a, PN 10406-0147-851, SN 1000112, 1000115; PN 10406-0147-854, SN1000135, 03/18/96, CCBD SB3-01-5065

O BI-1987b, PN 10406-0147-851, SN 1000108, 1000109, 1000125, 1000126; PN 10406-0147-854, SN1000107, 1000116, 1000123, 1000131, 1000137, 1000138, 07/11/96, CCBD SB3-01-5081

- SPECIFIED REQUIREMENT:

  10CEI-0001
  Paragraph 3.2.7.2.1 - Ascent Vibration, Acoustic and Shock environments Paragraph 3.2.7.2.2 - ReentryVibration, Acoustic and Shock environments

- DEPARTURE:

  The RSD's have always been Tested with an imposed Acceleration Spectral Density Tolerance of +3/-1.5 DB. The vendor had vibration abort limits set significantly higher during Acceptance test for repaired RSD's.

- JUSTIFICATION:

  The exceedance was within the Flight/Reentry Qualification Vibration Envelope. The Qualification Unit (RSD) has been through 20 Flight Qualification Missions. The Flight Qualification is to the maximum expected environments over the life of the RSD. This is a High Frequency narrow band spike that is separated by over 1 octave from the broad resonances.