TECHNICAL REQUIREMENTS FOR CABLE AND WIRING HARNESS

7-31k Wire Harness Design Task Group

Working Draft

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(Design version)

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1. PURPOSE

“Technical Requirements For Cable And Wiring Harnesses” is the design requirements companion to IPC/WHMA-A-620A, “Requirements and Acceptance for Cable and Wire Harness Assemblies”, and IPC/WHMA-A-620AS, “Space Applications Electronic Hardware Addendum to IPC/WHMA-A-620A”. With the present transition from prescriptive “how to” specifications to performance-based standards, much of the design requirements were removed from IPC/WHMA-A-620A and IPC/WHMA-A-620AS. The intent of this document is to set forth the general design requirements for electrical wiring harnesses and cable assemblies.

The target reader of this document is a design or manufacturing engineer, and is responsible for the tailoring of specific requirements of this document to the applicable performance class.

1.1 SCOPE

This document is intended to provide design requirements and technical insight that has been removed from the acceptance standards for cable and wire harness assemblies. Reference materials listed in this text are among those considered as required reading. The design engineer is encouraged to obtain materials referenced in this text, as this text is by no means a comprehensive coverage of design considerations for all possible end item use application.

1.2 CLASSIFICATION

This document recognizes that electrical wiring harnesses and cable assemblies are subject to classifications by intended end-item use. Three general end-product classes have been established to reflect differences in producibility, complexity, functional performance requirements, and verification (inspection/test) frequency. It should be recognized that there may be requirement overlaps between classes.

The USER is responsible for defining the product class. The product class should be stated in the procurement documentation package.

CLASS 1 General Electronic Products
Includes products suitable for applications where the major requirement is function of the completed assembly.

CLASS 2 Dedicated Service Electronic Products
Includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically the end-use environment would not cause failures.

CLASS 3 High Performance Electronic Products
Includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems.

Though not officially recognized as a separate performance classification, a specialized classification for spaceflight is levied by IPC/WHMA-A-620AS, “Space Applications Electronic Hardware Addendum to IPC/WHMA-A-620A”. This classification includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must survive the vibration and thermal cyclic environments getting to and operating in spaceflight.

1.3 DEFINITION OF REQUIREMENTS

The phrase "shall [D1D2D3]" or “shall not [D1D2D3]” is used in the text of this document wherever there is a requirement for materials, preparation, process control or acceptance of a soldered connection.
Where the phrase “shall [D1D2D3DS]” or “shall not [D1D2D3DS]” leads to a hardware defect for at least one class, the requirements for each class are in brackets next to the shall [D1D2D3DS] / shall not [D1D2D3DS] requirement.

- N = No requirement has been established for this Class
- A = Acceptable
- P = Process Indicator
- D = Defect

**Examples:**

- [A1P2D3] is Acceptable Class 1, Process Indicator Class 2, and Defect Class 3
- [N1D2D3] is Requirement Not Establish Class 1, and Defect Classes 2 and 3
- [A1A2D3] is Acceptable Classes 1 and 2, and Defect Class 3
- [D1D2D3] is Defect for all Classes

A defect for a Class 1 product means that the characteristic is also a defect for Class 2 and 3. A defect for a Class 2 product means that the characteristic is also a defect for a Class 3 product, but may not be a defect for a Class 1 product where less demanding criteria may apply.

The word “should” reflects recommendations and is used to reflect general industry practices and procedures for guidance only.

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**1.3.1 HARDWARE DEFECTS AND PROCESS INDICATORS**

When the word “shall” is used it expresses a requirement that is mandatory. Hardware characteristics or conditions that do not conform to the requirements of this specification that are detectable by inspection or analysis shall [D1D2D3] be classified as hardware defects. Hardware defects shall [D1D2D3] be identified, documented and dispositioned, e.g., rework, scrap, use-as-is, or repair.

It is the responsibility of the USER to define additional or unique defect categories applicable to the product. It is the responsibility of the SUPPLIER to identify defects that are unique to the assembly process.

**1.3.2 MATERIAL AND PROCESS NONCONFORMANCE**

Hardware found to be produced using either materials or processes that do not conform to the requirements of this standard shall [D1D2D3] be dispositioned when the condition is a defect. This disposition shall [D1D2D3] address the potential effect of the nonconformance on functional capability of the hardware such as reliability and design life (longevity).

Note: Material and process nonconformance differs from hardware defects or hardware process indicators in that the material/process nonconformance often does not result in an obvious change in the hardware’s appearance but can impact the hardware’s performance; e.g., contaminated solder, incorrect solder alloy (per drawing/procedure).
1.4  MEASUREMENT UNITS AND APPLICATIONS
All dimensions and tolerances, as well as other forms of measurement (temperature, weight, etc.) in this standard are expressed in SI (System International) units (with Imperial English equivalent dimensions provided in brackets). Dimensions and tolerances use millimeters as the main form of dimensional expression; micrometers are used when the precision required makes millimeters too cumbersome. Celsius is used to express temperature. Weight is expressed in grams.

1.4.1  VERIFICATION OF DIMENSIONS
Actual measurement of specific part mounting and solder fillet dimensions and determination of percentages are not required except for referee purposes. For the purposes of determining conformance to this specification, all specified limits in this standard are absolute limits as defined in ASTM E29.

1.5  ENGINEERING DOCUMENTATION
The design engineer is responsible for ensuring that all applicable design details are clearly and completely depicted on the engineering documentation (drawings). The USER (customer) has the responsibility to specify acceptance criteria.

1.6  ORDER OF PRECEDENCE
The contract always takes precedence over this document, referenced standards and drawings.

1.6.1  CONFLICT
a. In the event of conflict between the requirements of this document and the approved assembly drawing(s)/documentation, the USER approved assembly drawing(s) / documentation shall [D1D2D3] govern.

b. In the event of a conflict between the text of this document and the applicable documents cited herein, the text of this document shall [D1D2D3] take precedence.

c. In the event of conflict between the requirements of this document and an assembly drawing(s)/documentation that has not been USER approved, this document shall [D1D2D3] govern.

d. If no criteria is specified, required, or cited, criteria shall [D1D2D3] be established and agreed upon between the Manufacturer and USER.

1.6.2  CLAUSE REFERENCES
When a clause in this document is referenced, its subordinate clauses shall [D1D2D3] also apply.

1.6.3  APPENDICES
Appendices to this document shall [D1D2D3] be binding, unless separately and specifically excluded by the applicable contract, approved drawing(s), or purchase order.

1.7  APPROVAL OF DEPARTURES FROM STANDARDS AND REQUIREMENTS
Special requirements may exist which are not covered by, or do not comply with, the visual examples depicted in this handbook, and which are in conflict with program-specific documents, and/or the program-specified workmanship requirements. Engineering documentation shall [D1D2D3] contain the details for such instances, and shall [D1D2D3] take precedence over appropriate sections of this handbook and the applicable requirements document(s).

1.8  MODIFICATION, REWORK AND REPAIR
The modification, rework, and repair of high reliability electronics demands the highest level of technician skill and attention to detail, and shall [D1D2D3] only be conducted by trained and certified operators. The goal of all rework, repair, or modification activity is to correct, restore, or change functionality in a manner that closely approximates the original "designed" condition.

1.8.1 MODIFICATION
Modification changes the functional capability of the affected hardware. Modifications require written approval from USER and shall [D1D2D3] be fully detailed in the engineering documentation. The modification of a cable or wire harness assembly shall [D1D2D3] be limited to the revision / rerouting of circuit interconnections by the interrupting of conductors, the addition and deletion of conductors, correction of pin-out errors, correction of keying errors, addition of staking, and the addition or deletion of components in the cable or wire harness assembly (i.e.: a connector, addition / removal of contacts, etc.).

The maximum number of modifications shall not [D1D2D3] exceed six (6) per electrical wiring harness or cable assembly.

1.8.2 REWORK
Rework corrects minor assembly and workmanship non-conformances to bring the affected hardware into conformance to the engineering documentation / drawing. Though rework is usually permissible without Material Review Board (MRB) involvement, or notification and approval from the USER, it is recommended that all rework be documented to provide an opportunity for development of corrective action to reduce future rework and production costs.

All rework shall [D1D2D3] meet the workmanship requirements of the applicable design specifications.

1.8.3 REPAIR
Repair restores the functional capability of the affected hardware. However, depending on the severity of the damage, the repair may (or may not) return the affected hardware to full conformance to the engineering documentation / drawing. Repairs are only permitted following review and disposition by a Material Review Board (MRB), and authorization to repair shall [D1D2D3] require approval from the USER prior to the start of actual repair procedures.

Solder Thermal Cycles. The maximum number of solder repairs to any one joint shall not [D1D2D3] exceed three (3) complete cycles (desolder and resolder).

The maximum number of repairs shall not [D1D2D3] exceed three (3) per electrical wiring harness or cable assembly.

2. APPLICABLE DOCUMENTS
The following documents form a part of this standard to the extent specified herein.

2.1 SPECIFICATIONS

Aerospace
- AIR1329B  Compatibility of Electrical Connectors and Wiring
- AIR4487A  Investigation of Silver Plated Conductor Corrosion (Red Plague)
- AIR4789B  Evaluating Corrosion Testing of Electrical Connectors and Accessories for the Purpose of Qualification
- AIR5468B  Ultraviolet (UV) Lasers for Aerospace Wire Marking
- AIR5558  Ultraviolet (UV) Laser Marking Performance of Aerospace Wire Constructions
- AIR5575  Hot Stamp Wire Marking Concerns for Aerospace Vehicle Applications
- AIR5717  Mitigating Wire Insulation Damage During Processing and Handling
- AMS2491D  Surface Treatment of Polytetrafluoroethylene, Preparation for Bonding
- AS4373E  Test Methods for Insulated Electric Wire
- AS5382  Aerospace Cable, Fiber Optic
- AS5649  Wire and Cable Marking Process, UV Laser
- AS7928B  Terminals, Lug: Splices, Conductor: Crimp Style, Copper, General Specification For
- AS22759  Wire, Electric, Fluoropolymer-Insulated Copper or Copper Alloy (111, 89B, 89B, 91B, 92B)
- AS83519B  Shield Termination, Solder Style, Insulated, Heat-Shrinkable, Environment Resistant, General Specification For (1, 2)
- AS9100C  Quality Management Systems - Requirements for Aviation, Space and Defense Organizations

Commercial
- A-A-52083C  Commercial Item Description, Tape, Lacing and Tying, Glass
- A-A-59569B  Commercial Item Description, Braid, Wire (Copper, Tin-Coated, Silver-Coated, or Nickel Coated, Tubular or Flat)
- IPC/WHMA-A-620AS  Space Applications Electronic Hardware Addendum to IPC/WHMA-A-620A
- J-STD-001ES  Space Applications Electronic Hardware Addendum to IPC J-STD-001E Requirements for Soldered Electrical and Electronic Assemblies
- J-STD-004A  Requirements for Soldering Fluxes
- J-STD-006B  Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications
- ANSI/NEMA WC 27500  Standard for Aerospace and Industrial Electrical Cable
- ASTM B-174  Bunch Strand
- ASTM B 8  Concentric Strand
ASTM B 172-01a Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors

ASTM B 173-01a Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors


ASTM B 738-03 Standard Specification for Fine-Wire Bunch-Stranded and Rope-Lay Bunch-Stranded Copper Conductors for Use as Electrical Conductors

Federal

NASA PUBLICATION 1124 Outgassing Data for Selecting Spacecraft Materials (http://outgassing.nasa.gov)


QQ-B-575 Braid, Wire Copper, Tin-Coated Tubular

Military

MIL-A-46146B Adhesives-Sealants, Silicone, RTV, Noncorrosive (For Use With Sensitive Metals and Equipment)

MIL-C-17G Cables, Radio-Frequency, Coaxial, Dual Coaxial, Twin Conductor, and Twin Lead

MIL-C-27500 Cable, Electrical Shielded and Unshielded, Aerospace

MIL-C-39012 Connector, Coaxial, Radio-Frequency, General Specification for


MIL-I-631D Insulation, Electrical, Synthetic-Resin Composition, Non-Rigid

MIL-I-22129 Insulation Tubing, Electrical, Polytetrafluorethylene (PTFE) Resin, Non-Rigid

MIL-I-23053 Insulation sleeving, Electrical, Heat Shrinkable, General Specification for

MIL-STD-202G Test Method Standard, Electronic and Electrical Component Parts (Method 107, Test Condition B)

MIL-T-43435 Tape, Impregnated, Lacing, and Tying

MIL-W-22759 Wire, Electric, Fluoropolymer-Insulated Copper or Copper Alloy
3. DESIGN PHILOSOPHY

Cables and wiring harnesses are equivalent to the human circulatory and nervous system. They deliver energy, transmit command and control instructions, and collect and distribute sensory data describing not only the environment external to the system, but the health and status of the system itself.

Often the most overlooked, ignored, and “taken for granted” component in a design, high quality cables and wiring harnesses are essential to the performance and reliability of any electrical / electronic hardware.

It is the SUPPLIER’s responsibility to ensure that the technical issues associated with the design and manufacture of cable assemblies and wiring harnesses are conveyed to the USER, and that a dialogue is established, so that appropriate and timely decisions are made commensurate with realistic expectations and reality. After all, it doesn’t matter how elegant or innovative the design is if the cable assembly or wiring harness cannot be built, doesn’t fit, or won’t perform as required during use.

3.1 GENERAL DESIGN CONSIDERATIONS

The basic design considerations to assure reliable interconnecting cable and wire assemblies include, but are not limited to:

a. The physical and electrical properties of the wire and cable, including gauge/size; base metal; coatings; strand count and construction; weight; tensile strength; current and voltage derating; etc.

b. The physical and electrical properties of the cable and harness assembly, including active and spare wire count; connectors; EMI / RFI / magnetic shielding; ionizing / non-ionizing radiation; construction (coaxial, discrete wire, hybrid, multi-conductor; optical fiber); redundancy; voltage drop; identification / marking; etc.

c. Material properties, including arc tracking resistance; chemical / material compatibility; flammability; odor, outgassing; low-pressure / vacuum stability; ultra-violet stability; resistance / reactance to corrosives, solvents, oxidizers, chemicals, etc.; resistance to heat / cold; resistance to abrasion damage and cold flow; etc.

d. Application issues, including acoustic, mechanical, thermal shock; acceleration (g-load); environment (condensing / corrosive / explosive atmosphere), electric field density (high voltage / lightning)

e. Non-metallic components - insulation jackets, potting materials, lacing tapes, braid sleeving, plastic straps, wrap sleeving, and plastic tubing

f. Special handling, storage, and processing requirements that may contribute to degradation of performance and/or reliability of hardware in service (i.e.: Red Plague / White Plague control)

g. Foreign Object Debris (FOD)

h. Unique testing requirements
4. GENERAL DESIGN REQUIREMENTS

The design of electrical wiring harnesses and cable assemblies shall be based on the worst-case operational requirements and expected use. These include, but are not limited to: assembly processes; shipping and storage; installation; test; service environment (operational temperature limits, mechanical, thermal, and vibration stress; contamination; corrosives; EMC/EMI/RFI, ionizing / non-ionizing radiation, moisture or other fluid media exposure); post-use test and data recovery; and, life expectancy.

Conditions that contribute to degradation of performance and/or reliability of hardware in service shall require special consideration.

4.1 SELECTION OF PARTS, MATERIALS AND PROCESSES

Parts, materials, and processes covered by documents listed herein are classified as “standard” and shall be used whenever they are suitable for the purpose. Unless otherwise specified in the contract, the parts, materials, and processes:

a. Comply with the approved Materials and Processes Plan / Requirements

b. Be selected based on the worst-case operational requirements and the design engineering properties of the candidate materials. Conditions that contribute to the deterioration of hardware in service shall receive special consideration.

c. Be controlled in accordance with the SUPPLIER’s established and documented procedures

d. Satisfy the specified performance and reliability requirements of the design.

e. Be procured from qualified manufacturers and QPL sources as much as possible. A Certificate of Conformance should be requested for delivery with the order.

The selection and control procedures emphasize quality and reliability to meet the mission requirements and to minimize total life-cycle costs. An additional objective in the selection of parts, materials, and processes shall be to maximize commonality and thereby minimize the variety of parts, related tools, and test equipment required in the fabrication, installation, and maintenance of the hardware.

Whenever a selected specification provides more than one (1) characteristic or tolerance for an item, the SUPPLIER shall use items of broadest characteristics in the equipment and of the greatest allowable tolerances that will fulfill the performance and reliability requirements of the design. When acceptable items of higher than minimum quality are readily available, the utilization of which would not increase the life cycle costs, may be used. When maximum physical dimensions of an item are indicated in the selected specification for the item, all new equipment shall be designed to accommodate the maximum physical size specified, so that all parts having the same type designation will be physically interchangeable in the hardware.

4.1.1 PROCUREMENT - WIRE & CABLE

Wire and cable shall be procured to military specifications from qualified manufacturers and QPL sources as much as possible. A Certificate of Conformance should be requested for delivery with the order. Each cable / wire spool shall be permanently and legibly identified with manufacturer’s cage code or manufacturer’s name, military part number, length, size (AWG) and lot or date code of manufacture that can be used for traceability and age control.
4.1.2 MATERIALS AND PROCESSES

4.1.2.1 FLAMMABILITY
Insulation materials shall be non-combustible or self extinguishing. Selection and use shall be traceable to acceptable flammability test reports. When no test report exists, flammability testing shall be performed using the procedure of NASA-STD-6001, previously NHB 8060.1C (Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion), or as otherwise specified by the USER.

4.1.2.2 OUTGASSING
Nonmetallic materials shall not exceed 1% Total Mass Loss (TLM) or 0.1% Collected Volatile Condensable Material (CVCM), when tested in accordance with ASTM-E595 (Test Method, Outgassing).

4.1.2.3 FOREIGN OBJECT DEBRIS (FOD)
A Foreign Object Debris (FOD) prevention program shall be established for the design, development, manufacturing, assembly, repair, processing, testing, maintenance, operation, and check out to prevent immediate and latent damage and to ensure the highest practical level of cleanliness.

Cleanliness shall be an ongoing effort. Practices shall include assembly in a clean environment and the use of protective plastic sheeting or other coverings over cables and harness assemblies not undergoing active assembly.

Interconnecting cable and harness assemblies shall be clean and free of contamination prior to installation.

4.1.2.4 TIME-CRITICAL OR LIMITED-LIFE
Cables, harness assemblies, and hardware which are time-critical and/or cycle-critical or which have limited storage life shall be subject to the following controls:

a. Each time-critical or limited-life assembly, subassembly, component, and spare shall be clearly and indelibly marked with a serial number.

b. Appropriate documentation shall accompany all time-critical and limited-life items and shall include the date of manufacture of the item and of its most time-critical component. Realistic life limits shall be assigned and documented for each item and shall be suitably altered as new data and new evidence are obtained.

c. Status records shall be maintained on all such items after installation.

d. Operating-time logs shall be maintained for all items having limited operating lives.

e. Components shall have sufficient life remaining to adequately support mission requirements.

f. Special storage requirements shall be carefully defined and strictly observed.

g. A time-age-life cycle database shall be maintained for verification (and notification) of time-age-life component status.

4.1.2.5 RESTRICTED MATERIALS / PROCESSES
All materials used in electrical connectors, cables, and wiring harness assemblies shall be compatible with each other and have acceptable life. For a list of prohibited materials, see Appendix B.
4.1.2.5.1 FLUORINE ATTACK (WHITE PLAGUE)
To reduce the risk of fluorine attack (White Plague), when fluoropolymer-insulated silver-coated copper wiring is either stored in sealed packaging (e.g.: vapor-proof bagging, MBB) or used in enclosed environments / compartments, the fluorine evolution rate shall not exceed 20 PPM when tested in accordance with SAE AS4373E Method 608, Fluoride Offgassing. Bulk wiring and harness assemblies exhibiting fluorine attack shall be rejected.

4.1.2.5.2 CRIMPING OF SOLDER-TINNED AND SOLID CONDUCTORS
Stranded wire shall be used for crimping. Crimping of solid wire, or solder-tinned stranded wire, is prohibited.

4.1.2.5.3 PYROTECHNIC CIRCUITS - WIRE SPLICING
Splicing of wiring in pyrotechnic circuits is prohibited on both hardware firing circuits and ground test firing circuits.
5. ELECTRICAL CHARACTERISTICS

5.1 CIRCUIT CATEGORIES

The electrical characteristics required for interconnecting wiring are the first considerations to be established in designing electrical wiring harness for space vehicles. In particular, the cable / wire type required depends upon the voltage, current capacity, and frequency of the circuits. The five major categories and the various subcategories of circuits are defined in the following subparagraphs and summarized in Table 5.1. Each circuit in each wiring harness or cable assembly shall be categorized in accordance with these definitions.

<table>
<thead>
<tr>
<th>Table 5.1</th>
<th>Summary of Circuit Categories and Shielding Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Circuit Character</strong></td>
<td><strong>Signal Level Volts (V) or Amperes (A)</strong></td>
</tr>
<tr>
<td>Direct Current (DC)</td>
<td>&lt; 10 V and &lt; 5 A</td>
</tr>
<tr>
<td></td>
<td>&lt; 10 V and &gt; 5A</td>
</tr>
<tr>
<td></td>
<td>≥ 10 V</td>
</tr>
<tr>
<td>Alternating Current (AC) &lt; 0.1 MHz</td>
<td>&lt; 5V RMS</td>
</tr>
<tr>
<td></td>
<td>5V to 25 V RMS</td>
</tr>
<tr>
<td></td>
<td>&gt; 25 V RMS</td>
</tr>
<tr>
<td>Alternating Current (AC) 0.1 MHz to 1 MHz</td>
<td>&lt; 1 V RMS</td>
</tr>
<tr>
<td></td>
<td>1 V to 10 V RMS</td>
</tr>
<tr>
<td></td>
<td>&gt; 10 V RMS</td>
</tr>
<tr>
<td>Alternating Current (AC) &gt; 1 MHz</td>
<td>All</td>
</tr>
<tr>
<td>Pulse with rise or fall time &gt; 1 microsecond</td>
<td>&lt; 5 V peak</td>
</tr>
<tr>
<td></td>
<td>5V to 25V peak</td>
</tr>
<tr>
<td></td>
<td>&gt; 25V peak</td>
</tr>
<tr>
<td>Pulse with rise or fall time &lt; 1 microsecond</td>
<td>&lt; 1 V peak</td>
</tr>
<tr>
<td></td>
<td>1 V to 10 V peak</td>
</tr>
<tr>
<td></td>
<td>&gt; 10 V peak</td>
</tr>
<tr>
<td>Electro-explosive (EED)</td>
<td>All</td>
</tr>
<tr>
<td>Bridge Wire Activated Device (BWAD)</td>
<td></td>
</tr>
</tbody>
</table>
5.1.1 CATEGORY I (POWER AND CONTROL)
Includes (a) DC circuits over 10V; (b) DC circuits below 10V and over 5 A; (c) AC circuits below 0.1 MHz with voltages above 25 Vrms; and, (d) pulse circuits with maximum voltages above 25V with rise and fall times greater than 1 microsecond.

5.1.2 CATEGORY II (HIGH LEVEL SIGNALS)
Includes (a) digital circuits with voltage levels from 5 to 25V maximum and rise and fall times greater than 1 microsecond; (b) digital circuits with maximum voltage levels from 1V to 10V and rise and fall times less than 1 microsecond; (c) AC circuits below 0.1 MHz with voltages between 5V and 25V, and (d) AC circuits between 0.1 MHz and 1.0 MHz with voltage levels between 1V to 10V and rise or fall times less than 1 microsecond; (c) AC circuits below 0.1 MHz with voltages between 5V and 25V; and, (d) AC circuits between 0.1 MHz and 1.0 MHz with voltage levels between 1V and 10V.

5.1.3 CATEGORY III (LOW-LEVEL SIGNALS)
Includes (a) DC circuits below 10V and less than 5A; (b) AC circuits between 0.1 MHz and 1.0 MHz with voltage levels less than 1V; (c) AC circuits below 0.1 MHz with voltages less than 5V; (d) digital circuits with maximum voltages less than 1V with rise times less than 1 microsecond; and, (e) digital circuits with maximum voltages less than 5V and rise and fall times greater than 1 microsecond.

5.1.4 CATEGORY IV (ELECTRO EXPLOSIVE DEVICE CIRCUITS)
Includes all electro explosive device (EED) circuits.

5.1.5 CATEGORY V (HIGH-FREQUENCY SIGNALS)
Includes (a) all AC circuits above 1 MHz; (b) high level digital circuits with maximum voltages above 10V and with rise or fall times less than 1 microsecond; and, (c) AC circuits between 0.1 MHz and 1.0 MHz with voltages levels above 10 V.

5.2 SHIELDING REQUIREMENTS
Shielding shall [D1D2D3] be provided as indicated in the following sub-paragraphs. All shielding shall [D1D2D3] be insulated to prevent uncontrolled grounding / ground loops.

5.2.1 CATEGORY I CIRCUITS
Wiring for category I circuits shall [D1D2D3] have the power or signal wire(s) twisted with the return wire. The wiring may be unshielded.

5.2.2 CATEGORY II CIRCUITS
Wiring for category II circuits shall [D1D2D3] have twisted signal and return wires with each pair, or circuit, shielded.

5.2.3 CATEGORY III CIRCUITS
a. Wiring for category IIIa shall [D1D2D3] have twisted signal and return wires. Category IIIa wiring shall [D1D2D3] be shielded as a group from category IIIb and other categories.
b. Wiring for category IIIb shall [D1D2D3] have twisted signal and return wires with each pair, or circuit, shielded.
c. Wiring for category IIIc shall [D1D2D3] have twisted signal and return wires. Category IIIc wiring shall [D1D2D3] be shielded as a group from category IIIa, IIIb, and other categories.
d. Wiring for category IIId and category IIIe shall [D1D2D3] have twisted signal and return wires with each pair, or circuit, shielded.

5.2.4 CATEGORY IV CIRCUITS
Wiring shall [D1D2D3] be twisted pairs, each pair shielded. with multipoint grounding of shields at source and load. The method of shield termination shall [D1D2D3] be via full-peripheral (360 degree) termination at all connector backshells. Wiring for Electro-Explosive (EED) / Bridge Wire Activated Device (BWAD) circuits shall [D1D2D3] be double-shielded.

5.2.5 CATEGORY V CIRCUITS
Wiring interconnections, other than waveguide, shall [D1D2D3] be shielded coaxial cable, balanced shielded cable, or balanced cabled with a characteristic impedance of 100 ohms or less.

5.2.6 BOND CLASSIFICATION
Bond design shall [D1D2D3] prevent intentional electrical current from flowing in ground references except under fault conditions. Cable and harness assemblies (which include the electrical wiring and connectors, tie and protective materials and installation hardware) shall [D1D2D3] be designed and routed such that adequate protection is afforded per applicable shielding and EMI/RFI/EMC criteria. See Table 5.2.6.

a. Electrical bonds, particularly those intended to be semi-permanent or permanent, shall [D1D2D3] be sealed to mitigate the intrusion of electrolyte or FOD into the interstitial space between the two materials. Bonds which are intended to be opened and re-connected during planned or contingency maintenance shall [D1D2D3] be designed to accommodate re-establishing an acceptable bond using techniques and materials that are suitable for the application and the environment.

b. Harness shields external to the equipment, requiring grounding at the equipment, shall [D1D2D3] have provisions for grounding the shields to the equipment chassis through the harness connector backshell. Equipment or element internal secondary power supplies and signal and shield networks may utilize those grounding techniques most appropriate for the application as long as the isolation specified above is maintained.

c. Class L bonds shall not [D1D2D3] be terminated by solder process.

Notes:
1. Grounding is designed to ensure USER safety, proper operation of electrical fault avoidance / detection systems, and electromagnetic interference reduction by establishing a minimum series impedance path between the electrical equipment and the ground plane.

2. A ground is used to establish a zero signal reference for any equipment or other item required to be grounded.

5.2.7 ADDITIONAL SHIELDING
Shielding can be added over that specified for the category of each circuit to prevent excessive radiation from, or excessive pickup on, the circuit. Coax or balanced shielded cable may be used instead of twisted shielded pairs, particularly in applications where the capacitance per meter is critical.

Shielding shall [D1D2D3] be added over that specified for the category of each to the extent required when an electromagnetic pulse (EMP) environment is specified. Shielded circuits may be routed together in a bundle with a common secondary (overbraid) shield.
<table>
<thead>
<tr>
<th>CLASS</th>
<th>FUNCTION</th>
<th>TYPICAL RESISTANCE (ohms)</th>
</tr>
</thead>
</table>
| A     | ≤ 2.5 milliohm* (2.5mΩ) at the frequencies of interest, Z=R+i\omega L  
      • May be any low impedance value deemed appropriate by engineering design for the particular application.  |
|       | ≤ 2.5 milliohm* (2.5mΩ) at the frequencies of interest, Z=R+i\omega L  
      • May be any low impedance value deemed appropriate by engineering design for the particular application.  |
| C     | Max. Resistance = Max Voltage Drop / Max Current  
      • Max. Voltage Drop: <3.5% (28V system, ≤ 1V; 120V system, ≤ 4V)  
      • Not allowed in most NASA programs to prevent structural damage / galvanic corrosion to vehicle structure, unintentional heating, electrical interference, potential shock hazards to crew.  
      • Cable / harness shield shall not be used as the intentional power return path.  |
|       | Max. Resistance = Max Voltage Drop / Max Current  
      • Max. Voltage Drop: <3.5% (28V system, ≤ 1V; 120V system, ≤ 4V)  
      • Not allowed in most NASA programs to prevent structural damage / galvanic corrosion to vehicle structure, unintentional heating, electrical interference, potential shock hazards to crew.  
      • Cable / harness shield shall not be used as the intentional power return path.  |
| H     | 0.1 ohm max from exposed equipment chassis or cable tray to structure  
      • The fault current return path through structure: 500% overload current, 0.5s  
      • Cable / harness shield  |
|       | 0.1 ohm max from exposed equipment chassis or cable tray to structure  
      • The fault current return path through structure: 500% overload current, 0.5s  
      • Cable / harness shields  |
| L     | ≤ 2.5 milliohm (≤2.5mΩ) at 200,000 Amperes  
      • Design to route lightning across outer surface – not penetrate.  
      • Bond strap / conductor terminations shall not be soldered  
      • Bond straps will withstand the magnetic forces from the current they conduct.  |
|       | ≤ 2.5 milliohm (≤2.5mΩ) at 200,000 Amperes  
      • Design to route lightning across outer surface – not penetrate.  
      • Bond strap / conductor terminations shall not be soldered  
      • Bond straps will withstand the magnetic forces from the current they conduct.  |
| R     | ≤ 2.5 milliohm (2.5mΩ) at the frequencies of interest, Z=R+i\omega L  
      • Bond straps should be flat with length to width ratio less than 5:1  
      • Covers wide frequency ranges.  |
|       | ≤ 2.5 milliohm (2.5mΩ) at the frequencies of interest, Z=R+i\omega L  
      • Bond straps should be flat with length to width ratio less than 5:1  
      • Covers wide frequency ranges.  |
| S     | < 1 Ohm: Conducting Structural Items (>100cm²)  
      • < 1000 Ohm: Conductive Mechanical Subassemblies / Parts (>100cm²)  
      • < 1000 Ohm: Non-metallic / Composite Structural Items  |
|       | < 1 Ohm: Conducting Structural Items (>100cm²)  
      • < 1000 Ohm: Conductive Mechanical Subassemblies / Parts (>100cm²)  
      • < 1000 Ohm: Non-metallic / Composite Structural Items  |

5.3 SHIELD TERMINATION AND SHIELD GROUNDING
Shielding shall provide maximum EMI/RFI coverage in the intended application and environment, with a minimum cover limit of 85 percent, or as specified by USER.
a. Multiple point shield grounding shall [D1D2D3] be used on high-frequency circuits (above 0.1 MHz), on digital circuits with rise or fall times less than 1 microseconds, and on all EED firing circuits (category IV).

b. Single and shield grounding shall [D1D2D3] be maintained on all other circuits, expect that when multiple shields are used to prevent induced interference, the outer shield shall [D1D2D3] be multipoint grounded.

c. When single and shield grounding is used to protect a circuit against induced radiation, the ground shall [D1D2D3] be at the receiver or high impedance end.

d. When single and shield grounding is used to minimize radiation from a circuit, the ground shall [D1D2D3] be at the signal source end.

e. Magnetic shielding shall [D1D2D3] be terminated to ground at the signal source end.

f. Shields for Class L bonds shall not [D1D2D3] be terminated by solder process.

5.3.1 METALLIC BRAID SHIELDING

Metal braid shielding shall [D1D2D3] either be woven directly over a core or obtained in prebraided form and installed by sliding it over the wire bundle. Copper braid is the most effective RF shielding. Copper-clad steel-core wire, woven into a flat braid, is also an effective shielding material. Nickel and nickel coated copper should be considered for wiring subjected to high heat environments. A magnetic survey shall [D1D2D3] be conducted if project requirements indicate a sensitivity to magnetic interference.

a. Prewoven metallic braid shall [D1D2D3] be cleaned in a suitable solvent to remove contamination, and dried to ensure all solvent residue is removed, prior to installation over the harness. Aqueous (water-based) solvents shall not [D1D2D3] be used, as this may promote Red Plague if the braid is silver-coated copper.

b. Prewoven metallic braid tubing shall [D1D2D3] be tightened down to contact the wire bundle to present a smooth continuous finish (i.e.: without lumps, puffed areas, kinks, etc.)

c. To prevent mechanical abrasion during installation and mitigate potential long-term damage (cold flow) of the underlying wire insulation jackets, a separator layer (e.g., a tape wrap) shall [D1D2D3] be applied over the wire bundle to give the wire continuous protection.

d. Metal braid shielding shall [D1D2D3] be mechanically and electrically terminated as specified by the engineering documentation. All harness assembly external braid shields shall [D1D2D3] be covered with an insulating cover (i.e.: fabric braid sleeving, shrink tubing, etc.). Exception: Harness assemblies to be installed in high heat environments shall not [D1D2D3] be covered with an insulation sleeving unless specified by drawing.

5.3.2 ELECTROMAGNETIC PULSE (EMP)

Wire shields in all categories shall [D1D2D3] be bonded around the circumference (360 degrees), and preferably within the backshell of the connectors. Inner shields that are designed to be ungrounded at one end shall [D1D2D3] be terminated within the connector shell and the ends secured against fraying. Ungrounded inner shield terminations (floating shields) shall [D1D2D3] be insulated from the connector pins, the backshell of the connector, and from adjacent shields.

5.3.3 CATEGORY IV CIRCUITS

Wire shields in category IV circuits (EEDS) shall [D1D2D3] be bonded around the circumference, and preferably within the backshell of the connectors. Circuits such as pyrotechnic event instrumentation circuits that make a direct connection to the electro explosive device circuit shall [D1D2D3] employ shields which are bonded around the circumference (360 degrees), and preferably with the backshell at the pyro junction or relay box connector. If an EMP environment is not specified, the shield ground at the other instrumentation circuit connector may be grounded through a pigtail to a pin in the connector or directly to the structure.
5.3.4 CATEGORY I, II, III, AND V CIRCUITS (NO EMP)
Wire shields in these categories of circuits that require grounding and are not subjected to an EMP environment, shall [D1D2D3] be grounded to the vehicle structure by the shortest feasible route. The length of the pigtail or connection wire between the shield and the ground shall [D1D2D3] exceed 100 millimeters (mm) for harnesses containing less than 20 shielded wires. The length of unshielded, insulated wire that may show in back to the connector shell shall [D1D2D3] exceed 20 mm. For these circuits, the following methods of grounding the shields are acceptable, in order of preference:

a. On, and preferably within, the electrical connector to provide a low impedance path to structure when joined to the mating connector.

b. By a pigtail to a pin in the electrical connector.

c. By a pigtail directly to structure.

5.3.5 UNGROUNDED / FLOATING SHIELD TERMINATIONS (NO EMP)
Wire shield terminations that are to be ungrounded, and are not subjected to an EMP environment, shall [D1D2D3] be secured against fraying and insulated from the back shell of the connector and from adjacent shields. Where practicable, the ungrounded end of the shield should be terminated by a pigtail to a connector pin to facilitate making shield continuity and resistance measurements. The length of unshielded, insulated wire that may show in back of the connector shell shall [D1D2D3] exceed 20 mm (in.).

5.3.6 MAGNETIC SHIELDS
Magnetic shields (i.e.: mu-metal) shall [D1D2D3] be electrically isolated from the EMI/RFI and over-braid shields (if specified) by protective insulation overwrap / separator over the length of the cable / harness assembly and mechanically and electrically connected to the chassis / structure, either (a) by pig-tail / ground-lead to a chassis-mounted bonding post or (b) through the connector backshell at the source end of the cable / harness assembly.

5.3.7 CIRCUIT ISOLATION
Interconnect wiring in each of the five categories shall [D1D2D3] be isolated from wiring in other categories by maintaining, to the extent practicable, a minimum separation of 30 mm between wires and wire bundles of the different categories. When wires from circuits in different categories use the same connector, the pin assignments and layout shall [D1D2D3] stress isolation between different categories, and grounded spare pins shall [D1D2D3] be fully utilized to provide such isolation.

a. Category IV circuits (electro-explosive devices) shall [D1D2D3] maintain a minimum distance of 30 mm from other category circuits and shall not [D1D2D3] share the same connector with other category circuits.

b. High impedance circuits above 1000 ohms, or sensitive circuits, below 5 V, shall [D1D2D3] be isolated by routing or shielding or both from other circuits even in the same category.

c. Antenna cables shall [D1D2D3] be separated from each other and from other wiring.

d. Where practicable, wiring to redundant subsystems or equipment shall [D1D2D3] be run in separate harnesses or cable assemblies to prevent damage to one subsystem affecting the other.

e. Safety ground wire (if specified) shall [D1D2D3] be routed through the connector to the chassis / structure.

f. EMI/RFI and over-braid shields (if specified) shall [D1D2D3] be mechanically and electrically connected to the chassis / structure, either by pig-tail / ground-lead to chassis-mounted bonding post or through the connector backshell(s).
g. EMI/RFI and over-braid shield circuits shall not be routed through connector contacts, unless specifically specified by drawing.

h. Current shall not intentionally flow through the shield(s) or chassis / structure.

5.3.8 GROUP-GROUNDING OF INDIVIDUAL SHIELD TERMINATIONS

When grounding wires of individual cable shields are grounded to one point, they shall be spliced to a common bond grounding wire.

a. No more than four (4) shield conductors plus one (1) common bond wire shall be terminated in one splice.

b. The common bond wire shall be derated for the combined maximum short circuit / fault current of the shielded circuits.

c. For ordinary RFI/EMI protection, the shield shall be terminated within 100mm (4 inches) of the center conductor termination for the x-distance, and the combined length of shield grounding wires shall not exceed 190mm (7.5 inches).

d. For interference sensitive circuits, the shield shall be terminated within 20 mm (0.75 in.) of the center conductor termination, and the combined length of shield grounding wires shall not exceed 115mm (4.5 in.). When this does not provide adequate isolation, RFI/EMI connector backshells may be necessary.
6. **DESIGN REQUIREMENTS**

The design of electrical wiring harnesses and cable assemblies **shall** [D1D2D3] be based on the worst-case operational requirements and expected use. These include, but are not limited to: assembly processes; shipping and storage; installation; test; service environment (operational temperature limits, mechanical, thermal, and vibration stress; contamination; corrosives; EMC/EMI/RFI, ionizing / non-ionizing radiation, moisture or other fluid media exposure); post-use test and data recovery; and, life expectancy.

Conditions that contribute to degradation of performance and/or reliability of hardware in service **shall** [D1D2D3] require special consideration.

6.1 **RELIABILITY**

The reliability design requirements **shall** [D1D2D3] assure that the overall reliability requirements are met under the most severe extremes of acceptance testing, storage, transportation, testing, and operational environments.

6.2 **INTERCHANGEABILITY**

Any two (2) or more wiring harnesses or cable assemblies bearing the same part number **shall** [D1D2D3] possess such functional and physical characteristics as to be equivalent in performance, durability, and connectivity; and, **shall** [D1D2D3] be capable of being changed, one for another, without alteration of the items themselves or of adjoining items.

6.3 **SERVICE LIFE**

Unless specified by USER, the service life of the wiring harnesses **shall** [D1D2D3] be specified as one year in addition to the service life of the hardware / system for which it has been designed.

6.4 **ERGONOMIC DESIGN**

Hardware designed for use or deployment by humans **shall** [D1D2D3] be designed to work with the human body in the intended environment and application.

6.5 **CABLE / HARNESS LENGTH**

Harness length **shall** [D1D2D3] provide enough additional wire length for reworking the entire connection at least one (1) time. Conductors connecting contacts within the same connector **shall** [D1D2D3] extend 25-50 mm [1-2 in.] from the rear of the connector.

6.5.1 **DATUM**

Wire harness length and/or breakout length, **shall** [D1D2D3] be measured from the connector face at one end of the wire harness (datum) to its final termination and/or breakout point. (i.e. connector face, terminals, splice, etc.).

6.5.2 **BREAKOUTS**

Dimensions for breakouts **shall** [D1D2D3] be referenced from the approximate center-line of the harness / breakout.

6.5.3 **TOLERANCE**

Cable length measurement tolerance shall be as specified in IPC/WHMA-A-620A, Table 11-1 “Cable Length Measurement Tolerance”, unless otherwise on the drawing / documentation. If the engineering
drawing has multiple dimensions called out between a connector and termination, breakout, or overall length, the tolerances shall [D1D2D3] be considered noncumulative and will be applied to the sum of the dimensions (entire length to the termination point), not each individual dimension.

For the purposes of form layout board layout only, the recommended acute angle of the breakouts from the main body of the harness is 45 +/-15 degrees, unless shown otherwise on the drawing. For the purposes of form board layout, breakouts that branch away from the main body of the harness do not have to be routed straight but may be curved, provided the curves do not exceed the minimum bend radius requirements.

### 6.6 ACCESSIBILITY FOR MAINTENANCE

Cable and wiring harness assemblies shall [D1D2D3] be designed with features that contribute to the ease and rapidity of maintenance without removal of other equipment, interconnections, wire bundles, and / or fluid lines. All wiring shall [D1D2D3] be accessible, repairable, and replaceable at the maintenance level specified by the USER.

a. Access - Cable and wiring harness assemblies shall [D1D2D3] be designed with sufficient flexibility, length, and protection to permit disconnection and reconnection without damage to wiring or connectors.

b. Ease of Connect / Disconnect - Electrical connections and cable installations shall [D1D2D3] require no more than one (1) turn to disconnect and reconnect without damage to wiring or connectors.

c. Hand Access - Electrical connections and cable installations shall [D1D2D3] be designed with sufficient clearance so that they can be grasped firmly by hand (bare or gloved) for connecting and disconnecting.

d. Adjacent Connectors or Obstructions - Space between a connector and any adjacent obstruction shall [D1D2D3] be compatible with the size and shape of the plugs.

e. Single Rows - Connectors in a single row which require removal and replacement shall [D1D2D3] be spaced a minimum of 25 mm (1 in.) apart (edge-to-edge) for bare hand access during alignment and mating. A separation of 41 mm (1.6 in.) shall [D1D2D3] be required for gloved hand access and is preferred for bare hand access.

f. Staggered Rows - Staggered rows of connectors shall [D1D2D3] be a minimum of 64 mm (2.5 in.) apart (edge-to-edge) for bare-hand / gloved-hand access.

g. Test Points. Electrical systems and subsystems shall [D1D2D3] be designed to permit checkout tests and shall [D1D2D3] include provisions (e.g., test points) that permit these checkout tests to be conducted without disconnecting mated connectors. Test points shall [D1D2D3] allow checkout of the system without loss of integrity (e.g., loss of signal, loss of continuity, etc.).

h. Tools - If a tool is to be used for mate / demate, the edge-to-edge clearance shall [D1D2D3] facilitate initial access and alignment by hand (bare or gloved).

### 6.7 CABLE / HARNESS MANAGEMENT (ROUTING)

System reliability shall [D1D2D3] be a primary consideration in selecting the routing for wiring harnesses or cable assemblies. Cables and harnesses should be routed along flat surfaces (either vertical or horizontal) whenever possible, shall [D1D2D3] be properly supported and secured by cable clamps, and shall not [D1D2D3] be routed near high electrical noise, heat, or vibration sources.

a. Where practicable, routing shall [D1D2D3] provide accessibility for easy removal and replacement of attached equipment as well as the wire harness.

b. Routing through small structural openings shall [D1D2D3] be avoided where practicable to minimize flexing and handling of the harness during installation.
c. Flat and ribbon cables shall not [D1D2D3] be routed so as to interfere with air ventilation flow patterns.

d. To prevent possible damage from fumes and fluids, a 50 mm [1.97 in.] minimum clearance shall [D1D2D3] be maintained, where practicable, between the harnesses and lines or equipment containing oxygen, flammable liquids or gases, corrosive liquids or gases, or cryogenic liquids or gases. The clearance between wires or cables and heat generating devices shall [D1D2D3] be such as to avoid deterioration of wires or cable from the heat dissipated by the devices.

e. Cable and harness assemblies shall [N1D2D3] have slack lengths or maintenance loops sufficient for the removal of the connectors after the component / hardware has been extracted from its installed location / position, unless adequate internal access (physical and visual) is provided. Additional slack shall [D1D2D3] be provided in the area of terminations to allow the replacement of terminations three (3) times; however, excessive slack shall not [D1D2D3] be provided.

f. Wiring installations where relative movement occurs (such as at hinges, rotating pieces, vibration-isolated hardware, etc.) shall [D1D2D3] be installed or protected in such manner as to prevent deterioration of the wiring by the relative movement of the assembly parts. This deterioration includes abrasion of one wire or cable upon another, cold flow, and excess twisting, bending, and pinching. Cables and harnesses should be installed to twist instead of bend across hinges. Cables and harness assemblies in the vicinity of equipment expected to be routinely serviced or replaced shall [D1D2D3] be protected against damage caused by flexing, pulling, abrasion and other handling stress.

g. Cables or wire harnesses crossing a moving or rotating interface shall not [D1D2D3] contain strain-energy elements to assist deployment. Where cables or wire harnesses must cross a moving or rotating interface, the installation drawings shall [D1D2D3] define dimensions including loop sizes and distances to attachments. Attachment clamps shall [D1D2D3] be provided sufficiently close to any loops so that movement into the path of motion of the moving mechanical assembly cannot occur under any conditions.

h. Connectors shall [D1D2D3] be provided at each end of the loop where practicable to permit assembly and disassembly without disturbing the harness configuration in the area of the interface.

i. Cable and harness assemblies shall [D1D2D3] be routed so that they:

   (1) Cannot be pinched by doors, lids, or slides.
   (2) Will not be used as a translation device (i.e.: a hand hold, step, anchor point, etc.).
   (3) Will not be bent sharply when connected or disconnected.
   (4) Are readily accessible for inspection and repair.
   (5) Do not infringe into the operational envelope nor constitute a safety hazard (i.e.:, sagging, hooking, etc.).
   (6) Are not external to the face of the equipment rack.

6.8 BEND RADIUS

The bend radius for cables and harness assemblies shall not [D1D2D3] be less than ten times (10X) the outside diameter of the largest included wire or cable. At the point where wiring breaks out from a group, harness or bundle, the minimum bend radius shall [D1D2D3] be ten times the diameter of the largest included wire or cable. If wires used as shield terminators or jumpers are required to reverse direction in a harness, the minimum bend radius of the wire shall [D1D2D3] be three times (3X) the diameter at the point of reversal providing the wire is adequately protected.

6.8.1 MINIMUM BEND RADIUS

a. Coaxial cable. The minimum bend radius for coaxial radio frequency cable or harness assemblies containing such cable shall not be less than six times the OD of the cable or harness.
b. Wire size larger than 10. The minimum bend radius for harness assemblies containing wire larger than size 10 shall not be less than six times the OD of the harness.

c. Wire size 10 or smaller. The minimum bend radius for harness assemblies containing only wire size 10 or smaller shall not be less than 3 times the OD of the harness.

<table>
<thead>
<tr>
<th>TABLE 6.8.1</th>
<th>Minimum Bend Radius Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable Type</td>
<td></td>
</tr>
<tr>
<td>Coaxial Fixed Cable, Note 2</td>
<td>6X OD</td>
</tr>
<tr>
<td>Coaxial Flexible Cable, Note 3</td>
<td>10X OD</td>
</tr>
<tr>
<td>Shielded and Unshielded Wires and Cables</td>
<td>≤10 AWG: 3X OD</td>
</tr>
<tr>
<td>Polymide Insulated Wire</td>
<td>10X OD</td>
</tr>
<tr>
<td>Composite, (AS 2759/80/-92)</td>
<td>6X OD</td>
</tr>
<tr>
<td>Semi-rigid Coax</td>
<td>Not less than Manufacturer’s stated minimum bend radius</td>
</tr>
<tr>
<td>Harness assembly</td>
<td>Minimum bend radius of largest gauge individual wire/cable within the harness.</td>
</tr>
<tr>
<td>Breakouts</td>
<td>Minimum bend radius of largest gauge individual wire/cable within the harness.</td>
</tr>
</tbody>
</table>

**Note 1:** OD is the outer diameter of the wire or cable, including insulation.

**Note 2:** Coaxial Fixed Cable: Coaxial cable that is secured to prevent movement; not expected to have the cable repeatedly flexed during operation of the equipment.

**Note 3:** Coaxial Flexible Cable: Coaxial cable that is or may be flexed during operation of the equipment.

### 6.9 BREAKOUTS

The location of breakouts shall [D1D2D3] be specified on the design documentation.

a. Bend radius at breakout. Breakouts shall [D1D2D3] meet the bend radius requirements as specified in Table 6.8.1.

b. Forming and Support. Breakouts shall [D1D2D3] be formed into a twisted or parallel lay bundle, and secured with spot tie, plastic strap, or stitch lacing within two harness diameters (2d) immediately following their emergence from the main bundle. and within 2 breakout harness diameters (2d) after emergence from the trunk bundle.

### 6.10 PROTECTION AND SUPPORT

Installed wiring harnesses and cable assemblies shall [D1D2D3] be protected and supported in accordance with SAE AS50881 paragraph 3.11, and the following:

a. Support devices specified by the engineering drawing (i.e.: cable clamps, etc.) shall [D1D2D3] hold the wiring harnesses and cable assemblies in place without deforming or damaging the wire or cable insulation, or without causing undue mechanical strain on the connections.

b. Main Bundle Support. The main bundle shall [D1D2D3] be secured within two harness diameters (2d) of the emergence of the breakout from the main bundle, within two harness diameters (2d) following the emergence of the breakout, and at intervals not to exceed 24 inches.
c. Breakout Support. Breakouts shall [D1D2D3] be long enough to provide proper support at installation. Breakouts shall [D1D2D3] be secured by connector backshells or clamps as close to the connector as practical but shall not [D1D2D3] violate stress relief.

6.11 FORMING WIRES INTO CABLES AND HARNESSES

Wiring shall [D1D2D3] be assembled into interconnecting cables or harnesses using fabrication methods and assembly techniques that assure the production of high quality interconnecting cables and harnesses. Wiring terminated in connectors shall [D1D2D3] have the first tie located such that the wires are not stressed and do not distort the resilient wire sealing grommet of the connector (if installed).

Spacing dimensions for spot tie, plastic strap, and stitch lacing for trunk, branches, and breakouts shall [D1D2D3] comply with Table 6.11, and the following:

a. Ties shall [D1D2D3] be spaced at intervals required to maintain bundle configuration.

b. Spot ties shall [D1D2D3] consist of a clove hitch followed by a surgeon’s square knot or other non-slip knot.

c. Spot tie ends shall [D1D2D3] be trimmed.

d. When knots are staked, the necessary compounds, as well as any special design requirements, shall [D1D2D3] be specified on the engineering documentation.

<table>
<thead>
<tr>
<th>TABLE 6.11</th>
<th>Minimum bend radius of any individual wire/cable within the harness. Spacing Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harness Diameter mm (inches)</td>
<td>Distance From Back Edge of Connector or Connector Accessory to Start of First Tie mm (inches)</td>
</tr>
<tr>
<td>6.4 (0.25) or less</td>
<td>25.4 - 50.8 (1 - 2)</td>
</tr>
<tr>
<td>6.4 (0.25) - 12.7 (.5)</td>
<td>38.1 (1.50)</td>
</tr>
<tr>
<td>12.7 - 25.4 (.5 to 1)</td>
<td>50.8 - 76.2 (2 - 3)</td>
</tr>
<tr>
<td>25.4 (1) or larger</td>
<td>76.2 - 101.6 (3 - 4)</td>
</tr>
</tbody>
</table>

6.12 SEPARATION OF REDUNDANT SYSTEMS

In cases where wiring redundancy is a requirement, separate cable bundles shall [D1D2D3] be formed.

Exclusion: This requirement is not applicable to cable and wiring harness assemblies mounted in common housings within a redundant system, sub-system, or sub-system element.

a. Cable and wiring harness assemblies of redundant systems, redundant sub-systems, or redundant major elements of sub-systems, having different circuit classifications or redundancy codes and routed in the same area, shall not [D1D2D3] be commonly bundled or routed in the same wire bundle, but may be routed through a common connector if a 20 dB coupling margin is maintained.

b. Verification. Cable and wiring harness assemblies shall [D1D2D3] be designed to permit verification of redundant functions or operational modes any time the system, subsystem, or equipment requires testing prior to use.
c. Coding. Each bundle shall [D1D2D3] be coded with a bundle code which is the same as the circuit classification of the circuits which it contains.

d. Classification. Each bundle classification shall [D1D2D3] be designated on drawings in which the bundle appears. Such bundles shall [D1D2D3] be coded with the circuit classification code, plus a numeric designator code to identify the redundancy classification.

6.13 CORONA SUPPRESSION

Installed cable and wiring harness assemblies susceptible to corona as dictated by the Paschen Curve shall [D1D2D3] be designed such that detrimental corona discharge will not occur under any operating conditions. Test(s) or analysis shall [D1D2D3] be performed to demonstrate that the cable and wiring harness assemblies will remain protected for the intended length of the mission.

*Note: For purposes of this standard, the term "corona" is defined as an electrical discharge caused by ionization of gas in the vicinity of an energized conductor. Ionization can occur on the surface of an insulated or uninsulated conductor, as well as in voids and cracks within the insulation jacket.*

6.14 ELECTRICAL DESIGN

The electrical design shall [D1D2D3] provide a two-wire power distribution system in which one wire serves as a return path for load currents.

a. Safety ground wire (if specified) shall [D1D2D3] be routed through the connector to the chassis / structure.

b. EMI/RFI and over-braid shields (if specified) shall [D1D2D3] be mechanically and electrically connected to the chassis / structure, either by pig-tail / ground-lead to chassis-mounted bonding post or through the connector backshell(s).

c. EMI/RFI and over-braid shield circuits shall not [D1D2D3] be routed through connector contacts, unless specifically specified by drawing.

d. Magnetic shields (i.e.: mu-metal) shall [D1D2D3] be electrically isolated from the EMI/RFI and over-braid shields (if specified) by protective insulation overwrap / separator over the length of the cable / harness assembly and mechanically and electrically connected to the chassis / structure, either (a) by pig-tail / ground-lead to a chassis-mounted bonding post or (b) through the connector backshell at the source end of the cable / harness assembly ONLY.

e. Current shall not [D1D2D3] intentionally flow through the shield(s) or chassis / structure.

6.15 WIRE AND CABLE

Interconnecting wire, cable conductors, and shield braid shall [D1D2D3] be high conductive, stranded copper, copper alloy, silver-coated copper, or silver-coated copper alloy. The size of individual wires shall [D1D2D3] be a minimum of 22 AWG. Exceptions include power harnesses where the size of individual wires shall [D1D2D3] be a minimum of 18 AWG, and thermistor wiring where wire sizes smaller that 24 AWG may be considered for use. Wire size 24 AWG and smaller shall [D1D2D3] be high strength copper alloy (HSC), for adequate termination strength and flex life. HSC wire should be checked for magnetic cleanliness. A magnetic survey shall [D1D2D3] be conducted if project requirements indicate a design or system sensitivity to magnetic interference.

a. Silver-Coated Copper. Silver-coated copper, or silver-coated copper alloy should be considered for wiring carrying higher frequency circuits, and may be terminated by solder or crimp processes. Due to potential fire hazard, silver-coated conductors shall not [D1D2D3] be used in areas where they are subject to contamination by ethylene glycol solutions. Use of silver-coated copper or silver-coated copper alloy shall [D1D2D3] require use of a Red Plague Control Plan (RPCP). See Appendix A.
b. Aluminum. The use of aluminum wire (including copper-clad variants) shall require prior USER approval. Aluminum wire shall be terminated only by terminations specifically approved for this application.

c. Nickel / Nickel-Coated Copper. Nickel and nickel-coated copper should be considered for use in low frequency circuits (i.e.: dc and ac power circuits), corrosive, and high heat applications, and should be terminated by crimp processes.

d. Solid conductors. The use of solid conductor in wiring harness design shall require prior USER approval.

e. Selection of wire and cable shall take into account all requirements of this specification and the following design considerations:
   - conductor material and coating
   - strand count and construction
   - circuit characteristics (nominal and maximum voltage, allowable voltage drop, steady-state and intermittent current load, derating, frequency)
   - temperature (operational and storage)
   - mechanical (tensile strength, vibration, flexure, etc.)
   - insulation (dielectric rating, abrasion / cold-flow / cut-through resistance, arc-tracking resistance, flammability / smoke rating, outgassing, ionizing / non-ionizing radiation resistance, etc.)
   - shielding (EMI / RFI, EMP, magnetic)
   - pressure / partial-pressure / vacuum requirements
   - aging effects
   - extreme environments (corrosive, Severe Wind and Moisture Problem - SWAMP areas, fluid / moisture contact / submersion, etc.)

Exceptions:
1. Power harnesses where the size of individual wires shall be a minimum of 18 AWG.
2. Thermistor wiring where wire sizes smaller that 24 AWG may be considered for use.

6.15.1 DERATING
Wire and cable shall be of a type suitable for the intended application, and shall be selected so that the rated maximum conductor temperature is not exceeded for any combination of electrical loading, ambient temperature, and heating effects of bundles, conduit and other enclosures.

Degradation of conductors when exposed to environmental conditions and/or continuous operation at temperatures beyond their upper continuous rating shall be taken into account in the selection and application of wiring and cable.

a. The selection of wire size shall be based upon circuit current and cable size in accordance with the derating requirements of SAE AS50881 paragraph 3.8.8.1, thermal math model, or USER specification.

b. Electrical Wire Current Carrying Capacity. Wires shall be of such cross section as to provide ample and safe current carrying capacity. The maximum design current in any wire shall be limited so that "wire total temperature" will never exceed the rated wire temperature. "Wire Total Temperature" is defined as maximum ambient temperature plus temperature rise.

c. Voltage Drop. The total impedance of wires and ground return paths shall be such that the maximum voltage drop between the power supply bus and the load does not exceed the limits under maximum continuous load conditions.
Note: Published wire temperature ratings are short term ratings. Operating wire in excess of 50 percent of rated temperature requires engineering evaluation.

6.15.2 PROCUREMENT AND ACCEPTANCE TEST

Electrical wire and cable, including wiring used within electrical / electronic assemblies ("black boxes") shall (N1D2D3) be procured and acceptance tested to the appropriate cable specifications listed below:

a. Cable specification: ANSI/NEMA WC27500-2012, "Standard for Aerospace and Industrial Electrical Cable"

b. Cable specification: MIL-DTL-17H, "Cables, Radio Frequency, Flexible And Semi-rigid, General Specification For"

c. Wire specification: AS22759B, "Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy"

d. Thermocouple applications: MIL-DTL-5846D, "Detail Specification Chromel and Alumel Thermocouple Electric Wire"

e. Other wire procurement specifications authorized by the USER.

f. Wire and cable shall (N1D2D3) also comply with applicable Materials and Process (M&P) requirements.

If the wiring used in any application is unknown, as it may be in the case of off-the-shelf equipment, pig-tailed components, heater strips, etc. and if the application is non-critical, the assembly is required only to meet applicable program materials and process requirements.

Two methods for certifying wire are:

a. As required by the procurement specification, Government Source Inspection (GSI) shall certify that the tests specified in Appendix xxx been performed by the wire manufacturer on the length of wire procured. In addition to meeting the requirements of the appropriate procurement specification, each shipment shall be accompanied by the manufacturer’s test report.

b. Wire certification can also be performed by a USER-approved test facility.

6.16 CONNECTORS

Connectors used in the fabrication of wire harnesses and cable assemblies shall (D1D2D3) be suitable for the application. Connectors shall (D1D2D3) be specifically designed and approved for mating and demating in the existing environment under the loads being carried, or connectors must not be mated or demated until voltages have been removed (dead-faced) from the powered side(s) of the connectors.

a. Wire harness connectors shall (D1D2D3) be of the rear insertable / removable crimp contact and quick disconnect type, where feasible.

b. Connector Pins/Sockets. The powered side of a connector pair shall (D1D2D3) be terminated in sockets rather than pins and shall (D1D2D3) have a grounded backshell.

c. When mating/demating recessed / blind connectors (e.g., connectors that will be hidden from sight during mate/demate), the connector design shall (D1D2D3) be scoop-proof and maintain grounding during mating/demating.

d. Designs that are reconfigured such that their fault bond circuit is disturbed during mate/demate operations, shall (D1D2D3) require either redundant fault bonds to grounded structure or a post-installation test to verify a good fault bond has been established prior to power activation.

e. Connectors to be used in an EMP or high-level RF environment shall (D1D2D3) be capable of incorporating RF finger stock at the connector-receptacle interface to provide for shield continuity and shall (D1D2D3) be mechanically capable of being subjected to the coupling nut torque.

f. Connectors that are not self-locking shall (D1D2D3) be safety wired.
g. High Voltage. Circuits carrying potentials in excess of 200VAC rms, or 300VDC through critical pressure environments shall [D1D2D3] be terminated in single-contact, high voltage connectors. If the design requires that high voltage circuits be terminated in multi-contact connectors, contacts shall [D1D2D3] be selected which are the most distant from ground potentials. Shielded wire should not be used in high voltage circuits unless required by special designs. High voltage connectors must be kept free of any contamination which would decrease the voltage flashover characteristics.

h. High Power. Connector interfaces categorized as high-power shall [D1D2D3] have one verifiable upstream inhibit which removes voltage from the connector prior to mate/demate. The design shall [D1D2D3] provide for verification of the inhibit status at the time the inhibit is initiated.

Note: High-power connector interfaces are those that do not limit the short circuit outputs to 16 W or less, or have an open-circuit output voltage of greater than 32 V.

6.16.1 MATING PROVISIONS
Electrical connectors, plugs, and receptacles shall [D1D2D3] be designed to prevent incorrect connection with other accessible connectors, plugs, or receptacles; pin damage; and/or, inadvertent pin connections due to misalignment.

a. Electrical systems shall [D1D2D3] be designed so that all necessary mating and demating of connectors can be accomplished without producing electrical arcs that will damage connector pins or ignite surrounding materials or vapors. Unless connectors are specifically designed and approved for mating or demating in the existing environment under the loads being carried, they shall not [D1D2D3] be mated or demated until voltages have been removed from the powered side(s) of the connector.

b. Equipment, wire harnesses, and connectors shall [D1D2D3] be designed such that blind connections or disconnections are not required to be made during installation, operation, removal, or maintenance unless the design includes scoop-proof or other protective features.

c. Connectors used for acceptance test shall [D1D2D3] comply with this requirement when mated with product connectors.

d. The selection of the technique used shall [D1D2D3] be at the highest level of precedence in the following order:

(1) Use of physical constraints (i.e.: bends, differing branch lengths, etc.) built into a cable or harness that locate similar connectors so they cannot be interchanged.

(2) Selection of different sizes or types of connectors to be located adjacent to each other.

(3) Selection of alternative polarization, keying, and/or clocking of adjacent, similar connectors only if this requirement cannot be met with either method (1) or (2) above.

(4) Permanent identification of mating connectors provided on each side of each connector pair.

(5) Unique labels on each end of the cable / harness assembly identifying the connector name / number and mating connections.

(6) A label located approximately in the center of the cable / harness assembly length identifying cable / harness assembly name / number and purpose.

Note: Although identification markings, labels, or color coding are required, the use of these identification methods alone have been shown to not be insufficient to preclude mismating.

6.16.2 MOISTURE PROTECTION
Electrical connectors and wiring junctions to connectors shall [D1D2D3] be protected from moisture by methods which are demonstrated by test or analysis to provide adequate protection to prevent open and short circuits or a harmful unintended conductive current path. This requirement shall [D1D2D3] include test conditions (except for environmental qualification test articles) and all operating conditions, including
flight, wherein condensation of moisture can occur either during equipment operation before equipment is brought up to operating temperature or after equipment is shut down.

Shrink boots are not acceptable as moisture barriers.

Electrical connectors and wiring junctions to connectors which are not hermetically sealed or otherwise positively protected against moisture shall not be cooled below the dew point of the surrounding atmosphere.

6.16.3 PIN ASSIGNMENT

Electrical circuits shall not be routed through adjacent pins of an electrical connector if a short circuit between them would constitute a single failure that would cause injury to the USER; cause emission of arcs, sparks, molten metal; cause ignition of surrounding materials or vapors; or cause loss or degradation of a critical system.

Note: For purposes of this standard, the term "adjacent" includes pins within reach of a bent pin.

6.16.4 PROTECTIVE COVERS OR CAPS

Electrical plugs and receptacles shall be protected at all times to prevent contamination and/or damage. Protective covers or caps shall be placed over electrical plugs and receptacles whenever they are not connected to the mating part.

The protective covers or caps shall have the following characteristics:

a. Provide protection from moisture for the plugs and receptacles
b. Provide protection against damage to sealing surfaces, threads, and pins
c. Be made of conductive or dissipative materials that provide electrostatic discharge (ESD) protection of components.
d. Be resistant to abrasion, chipping, or flaking.

e. Be positively marked by bright colors or streamers if they are to be removed prior to flight / launch.
f. Be maintained at a level of cleanliness equivalent to the plugs or receptacles on which they are used.
g. Be made of material that is compatible with the connector material.
h. Be made of a material that does not contaminate the connector (i.e.: outgassing / offgassing, etc.).
i. Be provided with restraining devices or suitable storage areas if required for on-orbit activities. Pressure-sensitive tape shall not be used to satisfy this requirement.

6.17 PROTECTION OF SEVERED ELECTRICAL CIRCUITS

Cables and harness assemblies which are to be severed in the normal course of operation (e.g., vehicle separation) shall be protected against short circuiting or compromising other circuits during the remaining phases of the mission by dead-facing to remove all voltages.

Note: For purposes of this standard, the term “severed” is defined as permanently separated by cutting conductors using guillotine devices.

6.18 WIRE TERMINATIONS

Wire terminations to connectors or terminal shall be made with a crimp device where practicable. Not more than one wire (conductor) shall be terminated to any contact of environmentally sealed connectors. Not more than one wire (conductor) shall be terminated in an individual terminal lug. For screw type terminal boards, the harness design shall be such
that the maximum number of lugs to be connected to any one terminal on a terminal board shall [D1D2D3] be four (4) for ring type lugs, or two (2) for spade type lugs.

6.18.1 SPLICES
The use of splices shall [D1D2D3] be minimized as much as possible, and should only be considered where the use of a connector is not practicable or would reduce reliability; and/or, where the use of a splice can optimize complicated wiring when the harness must support branch circuits or parallel-connected devices, or where use of a splice facilities installation (i.e.: joining harness sections / branches).

a. The splice termination shall not [D1D2D3] be located in a flexure zone and shall [D1D2D3] be provided acceptable stress relief. Splices shall not [D1D2D3] be located in breakout / branch areas.

b. Extra care should be exercised with harnesses and cables that have splices so that they are protected from abrasion, cold flow, cut through, vibration, chafing, flexing, sharp edges and excessive handling.

c. For applications involving the mass splicing of conductors in a harness, the splices shall [D1D2D3] be staggered along the length of the harness to minimize the final cross-sectional profile.

d. Splices shall [D1D2D3] be completed with conductors that are properly sized to safely accommodate the power load expected, at the recommended derating.

e. The completed splice termination and any exposed metallization shall [D1D2D3] be over-sleeved with transparent / translucent heat shrink tubing extending a minimum of 5.1mm (0.2 inch) beyond any exposed metal. For mission critical harnesses incorporating splices, two layers of shrink sleeving shall [D1D2D3] be used over the splice area. Splices shall [D1D2D3] be wrapped with protective tape to prevent cold flow of adjacent wiring and possible abrasion of shrink sleeving over the splice area.

Examples of splices demonstrated to be acceptable for high-reliability and space flight applications designs are listed in Table xxxx. It is the engineer’s responsibility to choose the splice most suitable to a specific application.

<table>
<thead>
<tr>
<th>Splice Description</th>
<th>Classification</th>
<th>Assembly Difficulty Level</th>
<th>Termination Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Crimp</td>
<td>Discrete Solder</td>
</tr>
<tr>
<td>Butt</td>
<td>Mechanical</td>
<td>Easy</td>
<td>X</td>
</tr>
<tr>
<td>End</td>
<td>Mechanical</td>
<td>Easy</td>
<td>X</td>
</tr>
<tr>
<td>Lap</td>
<td>Non-Mechanical</td>
<td>Easy</td>
<td>X X</td>
</tr>
<tr>
<td>Lash</td>
<td>Mechanical</td>
<td>Moderate</td>
<td>X</td>
</tr>
<tr>
<td>Modified Pin Terminal (MTP)</td>
<td>Mechanical</td>
<td>Moderate</td>
<td>X</td>
</tr>
<tr>
<td>Parallel</td>
<td>Mechanical</td>
<td>Moderate</td>
<td>X</td>
</tr>
<tr>
<td>Jiffy Junction</td>
<td>Mechanical</td>
<td>Easy</td>
<td>X</td>
</tr>
<tr>
<td>Western Union / Lineman</td>
<td>Mechanical</td>
<td>Difficult</td>
<td>X</td>
</tr>
</tbody>
</table>

6.18.2 DEAD-ENDING
Undesignated wires shall [D1D2D3] be dead-ended with AS25274 caps or with insulation sleeving in compliance with IPC/WHAM-A-620, and in a manner acceptable to the USER. Dead-ending shall [D1D2D3] be located within 101-152 mm [4-6 in.] of connectors, breakouts, or bulkhead feed-through bushings. Dead-ending shall not [D1D2D3] be located under mounting clamps.

6.19 INSULATION COMPATIBILITY WITH SEALING AND SERVICING

Wiring terminations in devices where the wiring must be sealed to provide an environment resistant joint, shall [D1D2D3] have insulation compatible with the sealing feature of the device.

a. When the diameter of the wire is smaller than the minimum allowable diameter, a length of shrink AMS-DTL-23053/5 Class 1 & 3, /8, /11, /12 Class 3, 4, & 5, or /18 Class 2 & 3 sleeving shall [D1D2D3] be installed in back of the contact and shall [D1D2D3] protrude through the environmental seal a minimum of two (2) insulated wire diameters.

b. Elastomer grommets are generally qualified to seal on wires and electrical/optical cables having smooth extruded insulations. Only one wire/optical cable per grommet hole is permitted.

c. Sealing on tape wrapped, braided, striped, or other than smooth circular insulations shall [D1D2D3] be specifically tested for compatibility and shall [D1D2D3] be subject to USER approval, unless compatibility has been demonstrated in the qualification of the terminating device.

d. Post Installation. After installation into the hardware, the integrity of the sealing features of all such devices shall [D1D2D3] be intact, and able to perform their function. A device shall [D1D2D3] be considered as sealed if the outermost sealing feature (web) is in full contact with the device when visually inspected.

e. Wiring shall [D1D2D3] be installed and mechanically secured to prevent transverse (angular) loading that will degrade or compromise the integrity of the sealing feature.

Note: For technical guidance on wire to connector sealing grommet compatibility see SAE AIR1329B, “Compatibility of Electrical Connectors and Wiring”.

6.20 IDENTIFICATION AND MARKING

To facilitate the rapid identification, isolation, and repair of circuits, each wire, cable, and connector in interconnecting cables and wiring harnesses should be permanently marked with a unique identification code.

6.20.1 WIRING DATA

The preparation of wiring data shall [D1D2D3] be in accordance with MIL-HDBK-863, or an equivalent format agreed upon by the SUPPLIER and USER.

6.20.2 IDENTIFICATION OF INDIVIDUAL CONDUCTORS

When specified, interconnecting harnesses shall [D1D2D3] have each wire and electrical / optical cable permanently marked with a unique identification code, throughout its length, at intervals not longer than 7.62 cm [3 in.], as measured from the centerline of a mark to the centerline of the next mark.

Exception: Individual wires or electrical / optical cables in a jacketed / shielded-jacketed cable.

a. The identification code should be printed to read horizontally from left to right or vertically from top to bottom. The characters shall [D1D2D3] be legible and permanent and the method of identification shall [D1D2D3] not impair the electrical or mechanical characteristics of the wiring.

b. When it is not possible to print directly upon a wire or electrical / optical cable, an identification marker (i.e.: heat shrinkable sleeving, tape, etc.) shall be placed on the external surface, at each end within 12 inches or before the first clamp (whichever is less), and at intervals not greater than 3 feet. The marker shall [D1D2D3] not be used as an electrical insulating device.
c. Short electrical wires and electrical / optical cables less than 6 inches in length need not be identified, but shall [D1D2D3] be completely identified on the drawing.

d. Wire(s) for which the identifications are reassigned after installation may be re-identified by markers at each termination, but do not need to be re-identified throughout its length.

e. Optical Cable. Optical cable shall [D1D2D3] be uniquely color coded to facilitate identification.

6.20.3 IDENTIFICATION OF HARNESSES
Each cable and harness assembly shall [D1D2D3] be permanently marked with a unique identification code identifying the cable / harness assembly, the function, and the mating equipment nomenclature, per the detailed wire and cable specification.

a. The identification code should be printed to read horizontally from left to right or vertically from top to bottom. The characters shall [D1D2D3] be legible and permanent and the method of identification shall [D1D2D3] not impair the electrical or mechanical characteristics of the wiring.

b. When it is not possible to print directly upon a cable / harness assembly, an identification marker (i.e.: heat shrinkable sleeving, tape, etc.) should be used. The marker shall not [D1D2D3] be used as an electrical insulating device or clamp locator mark.

c. For repairable, protected harnesses, the marker shall [D1D2D3] be visible during maintenance within the accessible area at the rear of the connector.

d. Hot stamp marking shall not [D1D2D3] not be used for wire used in aerospace applications.

6.20.4 IDENTIFICATION OF CONNECTORS
Each connector shall [D1D2D3] be identified by a permanent label / marking device affixed directly to the connector body or to the cable adjacent to the connector, identifying both the connector and mating receptacle, the function, and the equipment nomenclature.

The identification device / marker may be placed directly on the connector or on the cable / harness assembly within 15 cm [6 in.] of the connector. In all cases, the identification device shall [D1D2D3] be of a material, either as applied or with the aid of a protective overcoat (i.e.: tape, clear shrink tubing, etc.), that will resist damage or degradation that would obscure or make the identification information illegible.

a. The identification code should be printed to read horizontally from left to right or vertically from top to bottom. The characters shall [D1D2D3] be legible and permanent and the method of identification shall [D1D2D3] not impair the electrical or mechanical characteristics of the wiring.

b. All plugs shall [D1D2D3] be identified with a “P” designation.

c. Mating connectors / receptacles shall [D1D2D3] be identified with a “J” designation.

d. All bulkhead / structure mounted receptacles shall [D1D2D3] be identified with a “J” number on both sides of the structure, adjacent to the receptacle.

e. Receptacles, such as test and power, to which a mating plug is not normally attached, shall [D1D2D3] have, in addition, the function of the receptacle identified on the plug side of the structure.

6.20.5 TEMPORARY IDENTIFICATION
Temporary identification markers may be used for in-process identification requirements.

a. All temporary markers shall [D1D2D3] be removed from the completed cable / harness assembly.

b. The markers shall not [D1D2D3] leave a contaminating residue and shall not [D1D2D3] damage or degrade the insulation jacket(s).

c. All temporary identification shall [D1D2D3] be removed from each completed harness by the end of the fabrication process.
6.20.6 CLAMP LOCATING MARKS
Marking tape used to position and locate harnesses and cables may be either permanent or temporary in nature. Permanent type marking tapes shall [D1D2D3] meet M&P and environmental requirements.
7. ASSEMBLY AND FABRICATION REQUIREMENTS

7.1 MOCKUP / FORM LAYOUT BOARD
A full-sized, three-dimensional (3-D) mockup (i.e.: wiring boards, mockups, fixturing, etc.) shall [D1D2D3] be provided for all complex interconnecting cables and harnesses to ensure proper routing, wire lengths, connector configurations, support requirements, and access requirements of the wiring harnesses. The mockup may be limited to partial installations which contain the more complex wiring harnesses.

a. The mockup shall [D1D2D3]:
   (1) Incorporate all electrical terminations, with position, tilt, and index identical to the final installation.
   (2) Incorporate all permanent bends, offsets, and physical restraints the interconnecting cable or harness assembly will encounter upon final installation.
   (3) Be designed to limit the amount of bending, pulling, and other handling a harness will receive during installation.
   (4) Be capable of supporting design reviews, electrical acceptance test, and implementing design changes.

b. Connector shells with inserts shall [D1D2D3] be used to reproduce the mating interface and facilitate testing.

c. The default acute angle of breakouts from the main body (trunk) of the harness shall [D1D2D3] be 45 +/-15 degrees, unless specified otherwise on the drawing. Breakouts that branch away from the main body (trunk) of the harness do not have to be routed straight, but may be curved. Curves shall not [D1D2D3] violate minimum bend radius requirements.

d. When approved by the USER, development test, qualification test, or actual hardware may be used for harness mockups instead of creating a separate mockup, provided adequate time is scheduled to support the wiring harness mockup activities.

7.2 WIRE LAY
Harness assemblies consisting of more than four (4) discrete wires or cables that are expected to be flexed during use or connector mating / demating operations shall [D1D2D3] be fabricated with a unidirectional or helical wire twist (lay), with the direction of twist (lay) either right or left to produce an essentially circular cross section for that portion of the wire harness or cable assembly that is subject to movement. Contra-helical or unidirectional twisting of successive layers is optional. Winding should prevent the introduction of residual twist from individual conductors. The length of lay for each layer shall [D1D2D3] be between 8 and 16 times (8X-16X) the outer diameter of the harness cross-section. A twist is defined as one complete 360 degree rotation of a conductor around the cable bundle.

When unidirectional or helical wire twist (lay) is not required, discrete wires or cables may be laid parallel to each other with minimal cross-over before tying into bundles. Harness assemblies requiring preformed bends using this assembly technique shall [D1D2D3] be constructed on a 3-D form board. Minimum bend radius requirements shall [D1D2D3] be observed when constructing preformed bends.

a. Constructing Twisted Pair. When constructing twisted pairs by the twisting of single conductors is specified by engineering drawings, the twist operation should produce a uniform twist pattern. The single conductors defined for twisting by the engineering drawing shall [D1D2D3] be twisted in pairs only and the twist shall [D1D2D3] run throughout the length of the harness or the length of the signal run in the harness (i.e., from connector to connector, to splice, etc....).

b. Twisted Pair. Wires that are twisted by design, such as twisted wire pairs or triplets, shall [D1D2D3] be treated as a single cable (do not untwist). Run all wires and cable in parallel when routing under a backshell clamp.
c. Parallel or Straight Wire Lay. A wiring harness or cable assembly may be fabricated with a parallel or straight wire lay for that portion of the wiring harness or cable assembly which is permanently installed, and which is not subject to movement after installation.

7.3 ETCHING FLUOROCARBON-INSULATED ELECTRICAL WIRE
Electrical wire or cable insulated or coated with polytetrafluoroethylene (TFE) or fluorinated-ethylene-propylene (FEP) shall [D1D2D3] be etched per SAE AMS2491D, “Surface Treatment of Polytetrafluoroethylene, Preparation for Bonding”, prior to potting to ensure mechanical bond strength and environmental seal.

a. Etched surfaces shall [D1D2D3] be processed within 24 hours, or packaged per SAE AMS2491.

b. Etched surfaces packaged per AMS 2491 shall [D1D2D3] be processed within one (1) year.

c. Potting shall [D1D2D3] be accomplished within 1 year of etching, provided the etched wires have been protected from ultraviolet light and contamination.

d. When etching of wire insulation is required to provide satisfactory bonding to potting materials, the end of the wire to be stripped and terminated shall not [D1D2D3] be exposed to the etchant. The preferred process is to form the wire into a U-shape, immersing only the bent portion in the etchant with the open end of the wire above the etchant level. The un-etched end of the wire shall not [D1D2D3] be cut off prior to neutralization of the etchant.

7.4 INTERIM STORAGE AND PROTECTION
The Supplier shall [D1D2D3] establish and implement procedures to protect interconnecting cables and harnesses from damage, Foreign Object Debris (FOD) contamination, and degradation during assembly and test.

a. Connectors not being actively assembled shall [D1D2D3] be individually protected by wrapping them in clean bubble wrap, water-vapor-proof packaging, or covered by a clean ESD-rated dust cap.

b. At the end of the work shift, protective covering shall [D1D2D3] be spread over the harnesses in fabrication.

c. Wiring, cable, and harness assemblies that are not being actively worked on shall [D1D2D3] be stored in water-vapor-proof packaging, or in an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH.

d. Protective coverings and packaging shall [D1D2D3] be compliant with ANSI/ESD S20.20 if Electrostatic Discharge Sensitive (ESDS) parts are utilized.

7.5 STORAGE AND TRANSPORTABILITY
Completed cable and wire harnesses assembled on three-dimensional forming boards should not be removed until all quality assurance (QA) requirements have been verified. Clean, ESD-rated dust caps shall [D1D2D3] be installed on all connectors.

a. Installation. The completed cable and wire harnesses assembly shall [N1D2D3] be moved from the fabrication forming board directly to installation, without intermediate storage to avoid unnecessary handling.

b. Storage. Whenever production schedules, alternate practices, or other considerations, require harness storage, the wire harness shall [N1D2D3] be packaged, handled, and transported in a manner that minimizes possible damage or environmental degradation. When a wiring harness is removed from the fabrication forming board for storage, clean ESD-rated dust caps shall [D1D2D3] be installed on all connector and the entire harness placed in a sealed, vapor-proof, protective bag, with desiccant and a humidity indicator card (HIC).

c. Handling. Unsupported handling should be avoided. Minimum bend radii requirements shall [D1D2D3] be observed.
d. Re-verification. When a harness has been in storage for longer than 6 months, the quality assurance requirements shall [D1D2D3] be re-verified by test or retest immediately prior to installation.
8. **WORKMANSHIP**
All details of workmanship concerned with the fabrication and installation of wiring harnesses shall be controlled such that the finished item is of sufficient quality to ensure proper operation, safety, reliability, and service life.

8.1 **ELECTRICAL ACCEPTANCE TESTING**
As a minimum, testing shall be performed on cables and wire harnesses as defined in IPC-WHMA-A-620AS, Paragraph 19.4.1:

a. Following fabrication and prior to installation
b. Post installation, but prior to connection or reconnection to components, devices, or systems
c. Prior to each use for non-permanently installed cables.
d. Prior to performing dielectric withstanding testing, the dielectric strength of all connectors, wire, components, or devices attached to the harness shall be verified to be greater than the applied test voltage. The test voltage level shall be adjusted to prevent damage to the lowest rated item in the cable.
e. The individual leakage current readings shall be read and recorded for each test performed. Measurement shall have resolution to the nano (10^-9) range. The data shall be maintained and available for comparison as long as the subject cable is in service.
f. Initial and periodic testing for shorting and dielectric failures shall be performed on support and test cables that interface with production hardware, using the test criteria described above.
g. Any trend in dielectric strength degradation / fluctuation greater than one order of magnitude shall be evaluated to determine the cause and worst case effect.
h. Electrical test potentials shall not exceed the dielectric and/or current rating of the most sensitive component in the cable / harness assembly.

8.2 **ELECTRICAL TEST (POST INSTALLATION)**
Post installation testing shall be performed to assure that individual wire conditions have not been degraded by installation operations. The post installation test requirements shall be those identified in this clause. The tests shall be performed after installing the cables or wire harnesses in place, but before mating connectors.

The required tests shall be conducted in this order:

a. Continuity
b. Shorts
c. Dielectric Withstand Voltage (DWV)
d. Insulation Resistance (IR)
9. DEFINITIONS AND ACRONYMS
For purposes of this document, the following additional acronyms, abbreviations, and terms are listed in addition to those listed in IPC-T-50H, “Terms and Definitions for Interconnecting and Packaging Electronic Circuits”. Specialized definitions and acronyms related to “Red Plague” are listed in Appendix A.

### 9.1 DEFINITIONS

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessories</td>
<td>Mechanical devices, such as cable clamps or backshells, added to connector bodies.</td>
</tr>
<tr>
<td>Adapter</td>
<td>An intermediate device to provide for attaching special accessories or to provide special mounting means.</td>
</tr>
<tr>
<td>Barrel (Contact Wire Barrel)</td>
<td>The section of contact that accommodates the stripped conductor.</td>
</tr>
<tr>
<td>Bend Radius</td>
<td>The radius of a formed bend, either temporary or permanent, measured in multiples of cross-sectional diameters, to which a component lead, conductor, cable (metallic, fiber, hybrid), harness (metallic, fiber, hybrid), optical fiber, or wire, can be bent without inducing permanent damage or reduction in performance, power, or reliability.</td>
</tr>
<tr>
<td>Bend Radius, Long-term</td>
<td>The radius of a formed bend in a component lead, conductor, cable (metallic, fiber, hybrid), harness (metallic, fiber, hybrid), optical fiber, or wire, in the permanently installed configuration.</td>
</tr>
<tr>
<td>Bend Radius, Short-term</td>
<td>The radius of a formed bend in a component lead, conductor, cable (metallic, fiber, hybrid), harness (metallic, fiber, hybrid), optical fiber, or wire, during assembly, installation, or storage.</td>
</tr>
<tr>
<td>Birdcaging</td>
<td>The radial expansion of individual strands in a stranded conductor (bowing outward) that can occur in the exposed portion of the conductor between the insulation strip and termination point.</td>
</tr>
<tr>
<td>Braid</td>
<td>A fibrous or metallic group of filaments interwoven to form a protective covering over one or more wires.</td>
</tr>
<tr>
<td>Breakout</td>
<td>The designed separation of a conductor or group of conductors from the main body of wires in a harness assembly to form a branch.</td>
</tr>
<tr>
<td>Bubble Pack</td>
<td>A laminated plastic sheet that is formed with patterned air entrapment (&quot;bubbles&quot;). The bubbles provide excellent cushioning for anything enclosed between layers of the material.</td>
</tr>
<tr>
<td>Cable</td>
<td>An engineered wiring product, consisting of a single insulated and shielded wire, or consisting or multiple insulated wires contained within a common insulating jacket. A cable may be shielded or unshielded.</td>
</tr>
<tr>
<td>Cable, Biaxial (twin-lead)</td>
<td>An engineered wiring product, consisting of two individually insulated 50 Ω coaxial cables, bonded together to resemble a lamp or speaker wire.</td>
</tr>
</tbody>
</table>
| Cable, Coaxial                            | An engineered wiring product, typically supplied in the form of a central solid or stranded conductor insulated by a dielectric material, held in
| **Cable, Coaxial, Flexible** | Flexible coaxial cable is constructed of a central solid or stranded conductor surrounded by a flexible low-loss r-f dielectric core material, which holds the inner conductor in concentric orientation to a braided metal outer conductor(s), and covered by a protective outer jacket / covering. |
| **Cable, Coaxial, Formable / Hand-formable** | Formable / hand-formable coaxial cables are constructed of a central solid conductor surrounded by a flexible low-loss r-f dielectric core material, which holds the inner conductor in concentric orientation to a tin-dipped and fused metallic braid as the outer conductor. This offers the advantage of being capable of being bent and formed without the use of tools or bending jigs, while providing the electrical signal performance of semi-rigid coaxial. |
| **Cable, Coaxial, Semi-rigid** | Semi-rigid, coaxial cables are constructed of a central solid conductor surrounded by a flexible low-loss r-f dielectric core material, which holds the inner conductor in concentric orientation to a solid, continuous, metal outer conductor (tube). |
| **Cable, Flat** | An engineered wiring product, consisting of two or more individually insulated, round or flat solid conductors that are mechanically bonded in a parallel alignment, to a flat insulating base material to form a planar composite construction. |
| **Cable, Hybrid** | An engineered wiring product consisting of two or more wiring technologies (i.e.: multi-conductor, coaxial, and / or fiber optic) bound together by an overall insulation jacket (unshielded); or, bound and wrapped with an overall metallic covering (braid or foil), and covered by an overall insulation jacket (shielded). |
| **Cable, Multiconductor** | An engineered wiring product, typically constructed of two (2) or more individually insulated conductors, bound together by an overall insulation jacket (unshielded); or, bound and wrapped with an overall metallic covering (braid or foil), and covered by an overall insulation jacket (shielded). |
| **Cable, Shielded** | An engineered wiring product consisting of one or more insulated conductors, wrapped with an overall metallic covering (braid or foil), and covered by an outer insulation jacket. |
| **Cable, Tri-axial** | An engineered wiring product consisting of three concentrically oriented, electrically isolated conductors (a center conductor, inner conductive shield, and outer conductive shield) covered by an overall insulation jacket. In application, the outer shield is electrically grounded, which protects the inner (floating) shield from electromagnetic interference (EMI). |
| **Cable, Twin-axial** | An engineered wiring product consisting of a balanced, twisted-pair of insulated conductors, bound together by an overall insulation jacket or dielectric core and held in concentric orientation to a overall conductive metallic sheathing (braid or foil) that serves as an EMI/RFI shield, and covered by an overall insulation jacket. Twinaxial cables are used primarily for the transmission of control, data, or high frequency (HF)
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable Clamp</td>
<td>A mechanical clamp attached to the wire entrance of a connector to support the cable or wire bundle, provide stress relief, and absorb vibration and shock.</td>
</tr>
<tr>
<td>Certification</td>
<td>The act of verifying and documenting that personnel have completed required training, have demonstrated specified proficiency, and have met other specified requirements.</td>
</tr>
<tr>
<td>Class 100,000</td>
<td>A clean room in which the particulate count does not exceed a total of 3500 particles per liter (100,000 particles per cubic foot) of a size 0.5 micron and larger, or 25 particles per liter (700 particles per cubic foot) of a size 5.0 microns and larger.</td>
</tr>
<tr>
<td>Clean Area</td>
<td>A general assembly area in which gross airborne particles and the introduction of other contaminants (i.e.: aerosols, dusts, tobacco smoke, food, beverages, cosmetics, etc.) are controlled through exercise of routine “housekeeping” discipline. This area may be open (i.e.: enclosed by visible perimeter markers / tape stripe, islanding by aisle separation), or enclosed by physical barrier (i.e.: partitions, walls); with limited pass-through access, ESD-protected, and environmentally controlled (i.e.: temperature, humidity, and positive-pressure). Most manual electronics assembly and soldering and cable / harness assembly is conducted in areas described as Clean Areas, with entire sections of an assembly facility designated as “Clean Areas”.</td>
</tr>
<tr>
<td>Clean Room</td>
<td>A dedicated, isolated physical structure / room in which the concentration of airborne particles is precisely controlled, and which is designed, constructed and used in a manner to minimize the introduction, generation, and retention of particles inside the room, and in which other relevant parameters (i.e.: temperature, humidity, and pressure) are controlled as necessary.</td>
</tr>
<tr>
<td>Clean Zone</td>
<td>A dedicated space in a Clean Room in which the concentration of airborne particles is precisely controlled, and which is constructed and used in a manner to minimize the introduction, generation, and retention of particles inside the zone, and in which other relevant parameters, e.g. temperature, humidity, and pressure, are controlled as necessary. This zone may be open or enclosed and there may be multiple Clean Zones located within a Clean Room.</td>
</tr>
<tr>
<td>Coldflow / Cold Flow</td>
<td>The permanent, non-recoverable distortion, deformation, or displacement of an insulation jacket resulting from application of intermittent and/or constant mechanical stress below the polymer’s elastic limit at temperatures within the polymer’s working range.</td>
</tr>
<tr>
<td>Conductor</td>
<td>A lead or wire, solid, stranded, or printed wiring path serving as an electrical connection.</td>
</tr>
<tr>
<td>Connector, Backshell</td>
<td>The main portion of a connector to which contacts and other accessories are attached.</td>
</tr>
<tr>
<td>Connector, Body</td>
<td>An elastomeric seal used on the cable side of a connector body to seal the connector against contamination and to provide stress relief.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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</tr>
<tr>
<td>Connector, Insert</td>
<td>The part of a connector that holds the contacts in position and electrically insulates them from each other and the shell.</td>
</tr>
<tr>
<td>Contact</td>
<td>The conductive element in a connector or other terminal device that mates with a corresponding element for the purpose of transferring electrical energy.</td>
</tr>
<tr>
<td>Contact, Crimp</td>
<td>A contact whose crimp barrel is a hollow cylinder that accepts the conductor. After a conductor has been inserted, a tool is used to crimp the contact metal firmly onto the conductor.</td>
</tr>
<tr>
<td>Contact, Insertable/Removable</td>
<td>A contact that can be mechanically joined to or removed from an insert. Usually, special tools are used to insert (lock) the contact into place or to remove it.</td>
</tr>
<tr>
<td>Contact, Pin</td>
<td>Male-type contact designed to slip inside a socket contact.</td>
</tr>
<tr>
<td>Contact Retention</td>
<td>The axial load in either direction that a contact can withstand without being dislodged from its normal position within an insert or body.</td>
</tr>
<tr>
<td>Contact, Socket</td>
<td>A female-type contact designed to slip over a pin contact.</td>
</tr>
<tr>
<td>Contaminant</td>
<td>An impurity or foreign substance present in a material that affects one or more properties of the material. A contaminant may be either ionic or nonionic.</td>
</tr>
<tr>
<td></td>
<td>- An ionic, or polar compound, forms free ions when dissolved in water, making the water a more conductive path.</td>
</tr>
<tr>
<td></td>
<td>- A nonionic substance does not form free ions, nor increase the water’s conductivity. Ionic contaminants are usually processing residue such as flux activators, finger prints, and etching or plating salts.</td>
</tr>
<tr>
<td>Crimp</td>
<td>The physical compression (deformation) of a contact barrel around a conductor to make an electrical and mechanical connection to the conductor.</td>
</tr>
<tr>
<td>Crimping</td>
<td>A method of mechanically compressing or securing a terminal, splice, or contact to a conductor.</td>
</tr>
<tr>
<td>Drain Wire</td>
<td>A wire that runs linearly along a foil shield wire or cable and is used to make contact with the shield. Grounding of foil shields is done with drain wires.</td>
</tr>
<tr>
<td>Electromagnetic Interference (EMI)</td>
<td>The unwanted intrusion of electromagnetic radiation energy whose frequency spectrum extends from subsonic frequency to X-rays.</td>
</tr>
<tr>
<td>Ferrule</td>
<td>A short metal tube used to make crimp connections to shielded or coaxial cables.</td>
</tr>
<tr>
<td>Grommet</td>
<td>An insulator that covers sharp edges of holes through panels and partitions to protect wire insulation from cut-through damage.</td>
</tr>
<tr>
<td>Harness</td>
<td>One or more insulated wires or cables, with or without helical twist; with or without common covering, jacket, or braid; with or without breakouts; assembled with two or more electrical termination devices; and so arranged that as a unit it can be assembled and handled as one assembly.</td>
</tr>
<tr>
<td>Insertion Tool</td>
<td>A device used to install contacts into a contact cavity in a connector.</td>
</tr>
<tr>
<td>Term</td>
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<tr>
<td>Interfacial Seal</td>
<td>A sealing of mated connectors over the whole area of the interface to provide sealing around each contact.</td>
</tr>
<tr>
<td>Jacket</td>
<td>The outermost layer of insulating material of a cable or harness.</td>
</tr>
<tr>
<td>Joint</td>
<td>A termination.</td>
</tr>
<tr>
<td>Key Keying</td>
<td>A mechanical device or feature in addition to, or in lieu of, a polarization feature that ensures the coupling of identical connectors / components can occur in only one orientation and only to similar keyed connectors / components.</td>
</tr>
<tr>
<td>Lay</td>
<td>The twist (helical) pattern of wire stands in a stranded wire, insulated wires in a cable, or insulated wires and cables in a harness assembly.</td>
</tr>
<tr>
<td>Length of lay</td>
<td>The axial length of one complete turn of the wiring helix.</td>
</tr>
<tr>
<td>Mate</td>
<td>The mechanical and electrical joining of two connectors</td>
</tr>
<tr>
<td>Minimum Electrical Spacing</td>
<td>The minimum allowable distance between adjacent non-common conductors or conductive surfaces (i.e.: mounting hardware, brackets, metal-cased components, etc.), at a given voltage and altitude, that is sufficient to prevent dielectric breakdown, corona, or both, from occurring between the conductors.</td>
</tr>
<tr>
<td>Mission Essential Support Equipment</td>
<td>Equipment used in a closed loop within the system, where the failure of this equipment would degrade the mission or imperil personnel. This category includes items of ground support equipment whose functions are necessary to support the pre-countdown and countdown phases, whose failure can create a safety hazard, cause damage to flight hardware, or create an inability to detect a problem in the flight hardware.</td>
</tr>
<tr>
<td>Moisture Barrier Bag (MBB)</td>
<td>A bag used to package moisture-sensitive devices (MSD) that is electrostatic discharge (ESD) safe and is designed to restrict the ingress of water vapor.</td>
</tr>
<tr>
<td>Molding</td>
<td>The process of creating a defined shape or pattern by shaping pliable raw material (i.e.: epoxy, plastic, etc.) using a reusable, rigid frame, pattern, or mold/casting. Molding is typically used to create sealed and environmentally resistant (ER) connector assemblies. The mold / casting is removed, cleaned, and reused once the curing process is complete.</td>
</tr>
<tr>
<td>Offgassing</td>
<td>The release of a volatile part(s) from a substance when placed in a vacuum environment that may affect crew members.</td>
</tr>
<tr>
<td>Orbital Replaceable Unit (ORU)</td>
<td>Hardware assemblies / sub-assemblies designed to allow removal and replacement during microgravity flight.</td>
</tr>
<tr>
<td>Outgassing</td>
<td>The release of a volatile part(s) from a substance when placed in a vacuum environment.</td>
</tr>
<tr>
<td>Potting</td>
<td>The process of filling of a connector backshell, shape/shell with a material that excludes moisture and provides stress relief. The connector backshell or a potting shape/shell typically remains a part of the assembly once the curing process is complete.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>Protoflight</td>
<td>A test program intended to combine the objectives of the qualification and acceptance test programs; i.e. design confidence for use in the service environments and adequate workmanship/quality. All protoflight components, assemblies, and flight elements are intended for subsequent flight use. The protoflight approach uses reduced test levels, cycles, and/or duration from the standard qualification test requirements, to allow the protoflight tested hardware to be used for flight. Protoflight carries a high level of technical risk in comparison to a full qualification test program, due to there being no demonstrated flight duration capability (i.e., number of cycles; or time of operation or exposure to a service environment) and, in some cases, lower demonstrated margins over the service environment extremes.</td>
</tr>
<tr>
<td>Protoflight Hardware</td>
<td>Flight hardware utilized for qualification testing in lieu of a dedicated test article. The approach includes the use of reduced test levels and/or durations and post–test hardware refurbishment, where required, to allow tested hardware to be used subsequently for flight.</td>
</tr>
<tr>
<td>Purple Plague</td>
<td>AuAl$_2$. One of five (5) brittle gold-aluminum intermetallics formed when bonding gold directly to aluminum. Although highly conductive, the appearance of Purple Plague (AuAl$_2$) is coincident with development of Tan Plague (Au$_2$Al), which can cause Kirkendall voiding and failure in interconnection bonds. Typical MTTF: 15 – 25 years</td>
</tr>
<tr>
<td>Qualification</td>
<td>Qualification is the process that proves the design, manufacturing, and assembly of the hardware and software complies with the design requirements when subjected to environmental conditions.</td>
</tr>
<tr>
<td>Qualification Test Article</td>
<td>A qualification test article is a flight article modified to the extent necessary to conduct the qualification test.</td>
</tr>
<tr>
<td>Radiofrequency (RF)</td>
<td>The frequency spectrum from 15 kHz to 100 GHz. Cables are seldom used above 18 GHz.</td>
</tr>
<tr>
<td>Radiofrequency Interference (RFI)</td>
<td>Electromagnetic radiation in the radiofrequency spectrum from 15 kHz to 100 GHz.</td>
</tr>
<tr>
<td>Red Plague (Cu$_2$O)</td>
<td>The sacrificial corrosion of copper in a galvanic interface comprised of silver and copper, resulting in the formation of red cuprous oxide (Cu$_2$O) and black cupric oxide (CuO). Risk of developing Red Plague in silver-plated copper wiring is relatively low, if the wire has a non-porous silver plating with a uniform plating thickness of at least 2 µm (0.078 mil), and is stored in a humidity-controlled environment. Typical MTTF: 15 – 25 years</td>
</tr>
<tr>
<td>Sealing Plug</td>
<td>A plug that is inserted to fill an unoccupied contact aperture in a connector. Its function is to seal an unoccupied aperture in the assembly, especially in environmental connectors.</td>
</tr>
<tr>
<td>Shielding (v)</td>
<td>The metal covering surrounding one or more conductors in a circuit to prevent interference or signal radiation.</td>
</tr>
<tr>
<td>Shielded Cable</td>
<td>Cable surrounded by a metallic covering intended to minimize the effects of electrical crosstalk interference or signal radiation.</td>
</tr>
<tr>
<td>Solder Cup Terminal</td>
<td>A hollow, cylindrical terminal designed to accommodate one or more...</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>Solder Sleeve</td>
<td>A heat-shrinkable solder termination device with meltable sealing preforms at ends.</td>
</tr>
<tr>
<td>Splice</td>
<td>The joining of two or more conductors to each other.</td>
</tr>
<tr>
<td>Spacecraft</td>
<td>Devices, manned or unmanned, which are designed to be placed into a suborbital trajectory, an orbit about the earth, or into a trajectory to another celestial body.</td>
</tr>
<tr>
<td>Strain Relief</td>
<td>A connector device that prevents the disturbance of the contact and cable terminations.</td>
</tr>
<tr>
<td>Stranded Conductor</td>
<td>A conductor composed of a group of smaller wires.</td>
</tr>
<tr>
<td>Stress Relief</td>
<td>The formed portion of a conductor that provides sufficient length to minimize stress between terminations.</td>
</tr>
<tr>
<td>Strip</td>
<td>To remove insulation from a conductor.</td>
</tr>
<tr>
<td>Tab Terminal</td>
<td>A flat-surface terminal that is broad compared to the metal thickness. Wires are often soldered along the flat surface.</td>
</tr>
<tr>
<td>Tang (Connector Backshell)</td>
<td>A backshell tang is a tapering metal projection (straight, 45°, or 90° to the axis of the connector) designed to accommodate cable-tie attachments. The cable-ties grip and hold harness wires exiting from the connector, thus providing stress relief for the wires.</td>
</tr>
<tr>
<td>Tines</td>
<td>Tines are the members of a contact retention system that capture or &quot;lock&quot; removable crimp contacts into the contact cavities.</td>
</tr>
<tr>
<td>Tin Pest (a.k.a.: Tin Disease / Tin Plague)</td>
<td>The progressively destructive and irreversible allotropic transformation of pure tin from an electrically conductive metal (a.k.a.: beta-tin / β-tin), to a crumbly, white, non-metallic, non-conductive powder (a.k.a.: alpha-tin / α-tin / white tin), when exposed to temperatures below +13°C (+56°F) for long periods of time. Allooying pure tin with at least 5% lead (Pb) or at least 0.5% antimony (Sb) or bismuth (Bi) is considered to be effective at preventing tin pest.</td>
</tr>
<tr>
<td>Tinning</td>
<td>The selective coating of a solderable surface with a uniform layer of tin-lead (SnPb) solder.</td>
</tr>
<tr>
<td>Transfer Soldering</td>
<td>A manual soldering process where solder terminations are completed by the transfer of a molten ball of solder on the soldering iron tip to the termination area. The application of a small amount of solder to the soldering iron tip to facilitate thermal transfer during the manual soldering process is not Transfer Soldering. Transfer soldering is prohibited.</td>
</tr>
<tr>
<td>Wicking</td>
<td>A flow of molten solder, flux, or cleaning solution by capillary action.</td>
</tr>
<tr>
<td>Wire</td>
<td>A single metallic conductor of solid, stranded, or tinsel construction, designed to carry currents in an electrical circuit. It may be bare or insulated, but does not have a metallic covering, sheath, or shield.</td>
</tr>
<tr>
<td>Wire Dress</td>
<td>The arrangement of wires and laced harnesses in an orderly manner.</td>
</tr>
</tbody>
</table>
9.2 ACRONYMS AND ABBREVIATIONS

ANSI ............ American National Standards Institute
ASTM ............ American Society for Testing and Materials
ATP ............. Acceptance Test Procedure
ATT .............. Acceptance Thermal Test
AVT ............ Acceptance Vibration Testing
CFR ............. Code of Federal Regulations
cm² .............. Square Centimeters
COTS .......... Commercial Off-The-Shelf
CVCM .......... Collectable Volatile Condensable Material
dB ............. decibels
DOT ............. Department of Transportation
DWV ............. Dielectric Withstanding Voltage
EEE ............. Electrical, Electronic and Electromechanical
EIA ............... Electronic Industries Association
ENIG ............ Electroless Nickel Immersion Gold
EPA ............. Environmental Protection Agency
ESD ............. Electrostatic Discharge
EV ............... Exposure Value
EVA ............ Extravehicular Activity
FMEA ........... Failure Modes and Effects Analysis
FOTP ........... Fiber Optic Test Procedure
Ft ................. Feet
GFE ............. Government Furnished Equipment
Hrs ............... Hours
IEEE ............ Institute of Electrical and Electronics Engineers
IPC .............. Interconnecting and Packaging Electronic Circuits
IVA ............... Intravehicular Activity
lbf ................. Pounds force
LCC ............ Leaded Chip Carrier
LED ............. Light Emitting Diode
lm/m² ............ Lumens per square meter
LO₂ ............ Liquid Oxygen
MIL-STD ....... Military Standard
min ................. Minutes
mm ............ Millimeter
M/M ........ Multi-Mode
STATEMENT OF STANDARD

Red Plague (cuprous / cupric oxide corrosion) can develop in silver-coated copper (SCC), silver-coated copper-alloy (SCA), and silver-coated ultra-high strength copper alloy (SCU) wire and cable when a galvanic cell forms between the copper base metal and the silver coating in the presence of moisture (H₂O) and oxygen (O₂). Once initiated, the sacrificial corrosion of the copper base conductor can continue indefinitely in the presence of oxygen (O₂). The color of the corrosion by-product (cuprous oxide crystals) may vary depending on the amount of oxygen available, but is commonly noted as a red / reddish-brown discoloration on the silver plating surface – hence the term “Red Plague”.

A.1 RED PLAGUE CONTROL PLAN (RPCP)

The use of silver-coated copper (SCC/SCC1), silver-coated copper-alloy (SCA/SCA1), and silver-coated ultra-high-strength copper alloy (SCU) wire and cable shall require the implementation of a Red Plague Control Plan (RPCP) to control exposure to environmental conditions and contamination that may result in immediate or latent damage that may adversely impact performance or reliability.

A.1.1 QUALIFIED / APPROVED SUPPLIERS

Wire and cable shall be procured in accordance with the wire procurement specification, from suppliers listed on the Qualified Manufacturers List (QML) or suppliers approved by the USER.

A.1.2 SILVER COATING REQUIREMENTS

SCC / SCA: Silver-Coated Copper (SCC) and Silver-Coated Copper-Alloy (SCA) primary and shield conductors shall have a coating thickness of not less than 1 micron (~40 micro-inches) average, when measured in accordance with ASTM B 298-07.

SCC1 / SCA1: Silver-Coated Copper (SCC1) and Silver-Coated Copper-Alloy (SCA1) primary and shield conductors shall have a coating thickness of not less than 2 micron (~80 micro-inches) average, after stranding, the coating thickness on each of the individual conductor strands shall not be less than 1 micron (~40 micro-inches) when inspected using micro-section analysis in accordance with ASTM B 961-08. After stranding, the coating thickness on each of the individual conductor strands shall not be less than 1 micron (~40 micro-inches) when inspected using micro-section analysis in accordance with ASTM B 961-08.

SCU: Silver-Coated Ultra-High-Strength Copper-Alloy (SCU) primary and shield conductors shall have a coating thickness of not less than 1 micron (~40 micro-inches) when measured in accordance with ASTM B 298-07.

1. The silver coating exhibit a non-porous, smooth, and continuous finish with no evidence
of lumps, kinks, splits, scrapes, corrosion, contamination, or exposed base material after stranding. The continuity (non-porosity) of the coating shall [D1D2D3] be determined on representative samples by the sodium polysulfide test, in accordance with ASTM B 298–07.

2. Micro-section inspections shall [D1D2D3] be in accordance with ASTM-B961 except that the coating thicknesses specified herein shall [D1D2D3] be in effect. When required by the USER, photographs shall [D1D2D3] be captured and saved as proof of inspection. The magnification scale of photographs shall [D1D2D3] be identified.

3. Micro-section analysis shall [D1D2D3] be performed by a lab certified to IPC-QL-653A, or as agreed upon by the USER.

4. All wire and cable shall [D1D2D3] have full lot traceability and manufacturer’s test reports, certified by the Government Source Inspector (GSI). Test reports, and all tested and untested micro-section analysis coupons, shall [D1D2D3] be delivered to the USER as part of the procurement.

A.1.3 FLUORINE ATTACK (WHITE PLAGUE)
To reduce the risk of fluorine attack (White Plague), when fluoropolymer-insulated silver-coated copper wiring is either stored in sealed packaging (e.g.: vapor-proof bagging, MBB) or used in enclosed environments / compartments, the fluorine evolution rate shall not [N1D2D3] exceed 20 PPM when tested in accordance with SAE AS4373E Method 608, Fluoride Offgassing. Bulk wiring and harness assemblies exhibiting fluorine attack shall [N1D2D3] be rejected.

A.1.4 LIMITED LIFE ARTICLE
SCC/SCC1, SCA/SCA1, and SCU wire and cable with a shelf life exceeding 10 years from manufacturing date shall [D1D2D3] be segregated and shall [D1D2D3] not be used in harness assemblies and hardware fabricated to this standard. Completed cable, harness assemblies, and hardware incorporating SCC/SCC1, SCA/SCA1, and SCU wire and cable, with a combined storage and use life exceeding 10 years from date of assembly shall [D1D2D3] be identified, periodically inspected and tested, and tracked as a “Limited-Life Article”.

A.1.5 ENVIRONMENTAL REQUIREMENTS
SCC/SCA, SCC1/SCA1, and SCU wire and cable shall [D1D2D3] be protected to reduce and control exposure to environmental conditions and contamination that promote the development of cuprous / cupric oxide corrosion (Red Plague).

A.1.5.1. SHIPPING AND STORAGE
Wire and cable shall [D1D2D3] be shipped and stored in sealed water-vapor-proof packaging (i.e.: Moisture Barrier Bag, dry pack, etc.), with capped ends, activated desiccant, and an irreversible humidity indicator card (i-HIC).


2. Capping. Wire and cable ends shall [D1D2D3] be capped with heat shrinkable end-caps conforming to SAE-AMS-DTL-23053/4, or dipped in Red “GLPT” Insulating Varnish (10-9002-A / 10-9008 / N.S.N. 5970-00-901-5331) for a length of approximately 2.5 cm (1 in).

3. Desiccant (Activated). The bagged, activated desiccant shall [D1D2D3] conform to MIL-D-3464 Type 2. The minimum quantity of desiccant to be used (unit packs) shall [D1D2D3] be based on the protective package’s interior exposed surface area, in accordance with MIL-STD-2073-1E, Method 50, Formula 1.

5. Wire and cable shall not be stored in paper wrapping materials or cardboard boxes.

Note: Silver is highly susceptible to attack by contaminants present in the atmosphere and common “green” packaging materials. Paper wrapping materials, rubber bands, and cardboard boxes should be avoided because such materials contain and outgas small amounts of sulfur. (ref.: MIL-HDBK-338B [11.4.1])

A.1.5.2. ASSEMBLY
All assembly processes, including Receiving Inspection and Kitting, shall be conducted in an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH.

1. Wire and cable shall not be removed from its protective packaging until it has reached thermal equilibrium with the assembly environment to reduce the risk of condensation formation.
2. Unused Wire. Prior to returning wire back to storage, wire ends shall be capped to prevent diffusion of air and water vapor into the wire through open ends, and stored in water-vapor-proof packaging per 4.4.1, or in an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH.
3. Wiring, cable, and harness assemblies that are not being actively worked on shall be stored in water-vapor-proof packaging per 4.4.1, or in an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH.
4. Completed cable and harness assemblies shall be stored in water-vapor-proof packaging per 4.4.1, or stored in an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH, until ready for installation.
5. Aqueous solvents and cleaning systems shall not be used.

A.1.5.3. 70%RH INDICATION
Wire and cable shall be quarantined and dispositioned by the appropriate Material Review Board when the humidity indicator card (HIC) registers 70%RH exposure.

A.2 RECEIVING INSPECTION
Receiving Inspection shall confirm conformance to the requirements of this RPCP and the wire procurement specification. The following verifications and tests shall be performed on each lot of wire / cable received:

1. Verification of compliance with GSI certification / documentation requirements (4.1).
2. Verification of compliance with minimum silver coating thickness and quality requirements (4.2).
3. Verification of compliance with shelf life requirements (4.3).
4. Verification of compliance with environmental protection requirements (4.4).
5. One (1) test specimen, approximately 30 cm (12 in) in length (including the capped end), to perform the required inspection(s) shall be required:
   a. From each end of each continuous, unspliced length reel or spool.
   b. From each end of reeled or spooled wire sections (non-continuous lengths).
   c. From each end of coiled lengths.

A.2.1 VISUAL INSPECTION
Primary and shield conductors shall be visually inspected for mechanical damage and cuprous / cupric oxide corrosion (Red Plague). The silver coating shall exhibit a non-porous, smooth, and continuous finish with no evidence of lumps, kinks, splits, scrapes, corrosion, contamination, or exposed
base material.

1. Magnification. Magnification power for visual inspection shall be based on the inspection activity or conductor size, per J-STD-001E. For wire and cable with mixed conductor sizes, the greater magnification may be used for the entire inspection. The tolerance for magnification aids is ± 15% of the selected magnification power. Magnification aids should be maintained and calibrated as appropriate (see IPC-OI-645).

2. Illumination. Illumination intensity on the surface being inspected shall be at least 1000 lm/m² (~93 foot-candles). The light source type shall be as specified by engineering documentation.

A.2.2 ACCEPTANCE
Wire and cable that has been accepted shall be stored in water-vapor-proof packaging per 4.4.1, or stored in an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH.

A.3 ASSEMBLY REQUIREMENTS
The following controls shall be imposed during the assembly of hardware incorporating SCC/SCC1, SCA/SCA1, and SCU wire and cable:

A.3.1 PRE-PRODUCTION SAMPLE
Prior to material take off for assembly or kitting, a pre-production sample of the wire / cable shall be visually inspected for mechanical damage and cuprous oxide corrosion. Any evidence of non-conformance shall require quarantine of the entire spool and disposition by the appropriate Material Review Board (MRB).

A.3.2 WIRE STRIPPING
To reduce exposure to moisture and oxygen, wire insulation shall be stripped just prior to termination.

1. Solder terminations. The insulation shall be left on the wire until assembly, at which time the wire shall be stripped and immediately solder tinned to minimize the exposure time of the silver-copper endface to atmospheric moisture and oxygen.

2. Crimped terminations. The crimp termination of silver-coated cooper wire is not recommended, unless additional mitigation (i.e.: heavier plating thickness, environmentally rated connector, conformal coating, shrink sleeving, etc.) is implemented to protect the exposed end of the conductor(s).

A.3.3 BEND RADIUS
Wire and cable shall not be bent less than minimum bend radius requirements to avoid cracking of the insulation and/or silver coating.

A.3.4 CLEANING SOLVENTS
Aqueous solvents and cleaning systems shall not be used for cleaning and flux removal.

A.4 NON-CONFORMANCE
Non-conformance to any of the above requirements shall require:

1. Immediate rejection and segregation of the wire, cable and/or harness assemblies from stock and
2. Relocation to a dry area or otherwise protected (i.e.: placed in a nitrogen-purged dry box, MBB, etc.) to prevent continued environmental damage.

3. Disposition by the appropriate Material Review Board (MRB).

4. Non-conformances dispositioned other than scrap shall [D1D2D3] be approved by the USER.

A.5 CAPPING

Capping provides a simple and effective environmental barrier to oxygen and moisture contamination of the cut / exposed ends of silver-coated copper wire and cable by sealing the cut / exposed ends of the wire / cable with double-wall (melt-liner) heat shrinkable tubing or preformed end cap, or by dip coating with Red “GLPT” Insulating Varnish.

A.5.1 SHRINK TUBING METHOD

This method uses double-wall (melt-liner) shrink tubing conforming to SAE-AMS-DTL-23053/4D to create a crimped-end “cap” to environmentally seal the exposed end of the wire / cable. If a preformed double-wall (melt-liner) heat shrinkable end cap is used, the crimping of the “tail” (step e) is not required.

1. Clean the wire / cable end and approximately 5 cm (2 in) of the insulation jacket with IPA. The wire / cable shall [D1D2D3] be positioned with the cut end pointed downward to minimize wicking of cleaning solvent. Do not use aqueous cleaners.

2. Cut shrink tubing sections approximately 5 - 8 cm (2 to 3 in) in length.

3. Insert approximately 2.5 cm (1 in) of the open-end silver-plated copper wire / cable into one end of the shrink tubing, with the remaining shrink tubing forming an open “tail”.

4. Use a heat gun to shrink the tubing down over the wire / cable and to shrink the “tail”.

5. When the inner wall of the shrink tubing has melted, crimp the “tail” (only) with smooth-jaw pliers to flatten and close the tubing. Hold pressure on the “tail” for 20 to 40 seconds until the inner liner cools and solidifies.

6. Visually inspect to verify that the tubing has been shrink tightly, that the melt liner has adhered to the wire / cable insulation, and that the crimped “tail” is sealed. The sleeving shall [D1D2D3] not exhibit damage (i.e.: blisters, lumps, dents, tears, pinholes, seams, cracks, foreign matter, or other defect) that would compromise the environmental seal.

A.5.2 DIP COATING METHOD

This method creates an environmental seal by coating and saturating the exposed end of the wire / cable with Red “GLPT” Insulating Varnish (or other approved sealant). Though the basic process involves dipping the wire / cable end into the varnish / sealant, the process could be modified to use brush or swab applicators, if approved by the USER.

1. Clean the wire / cable end and approximately 5 cm (2 in.) of the insulation jacket with IPA. The wire / cable shall [D1D2D3] be positioned with the cut end pointed downward to minimize wicking of cleaning solvent. Do not use aqueous cleaners.

2. Allow to dry and visually inspect for cleanliness.

3. Slowly dip the end of the cable / harness into the varnish to a depth of approximately 2.5 cm (1 in). A slow dip speed is recommended to prevent bubbles forming on wire / cable end and to prevent splashing of the varnish.

4. Slowly remove the wire / cable from the varnish and allow to dry. The wire / cable shall [D1D2D3] be positioned with the coated end pointed downward to minimize wicking of varnish and to allow excess material to drip.

5. Visually inspect to verify that the coating is cured (non tacky) and that coverage is continuous and of uniform thickness. The coating shall not [D1D2D3] exhibit defects (i.e.: incomplete coverage, exposed
conductor surfaces, pinholes, cracks, foreign matter, etc.) that would compromise the environmental seal.

A.6 ACRONYMS AND ABBREVIATIONS AND GLOSSARY OF TERMS
For purposes of this document, the following additional acronyms, abbreviations, and terms are listed in addition to those listed in IPC-T-50H, “Terms and Definitions for Interconnecting and Packaging Electronic Circuits”.

ACRONYMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSI</td>
<td>Government Source Inspector</td>
</tr>
<tr>
<td>i-HIC</td>
<td>Irreversible Humidity Indicator Card</td>
</tr>
<tr>
<td>SCA</td>
<td>Silver-Coated Copper-Alloy, 1 micron (~40 micro-inches)</td>
</tr>
<tr>
<td>SCA1</td>
<td>Silver-Coated Copper-Alloy, 2 micron (~80 micro-inches)</td>
</tr>
<tr>
<td>SCC</td>
<td>Silver-Coated Copper, 1 micron (~40 micro-inches)</td>
</tr>
<tr>
<td>SCC1</td>
<td>Silver-Coated Copper, 2 micron (~80 micro-inches)</td>
</tr>
<tr>
<td>SCU</td>
<td>Silver-Coated Ultra-High Strength Copper Alloy</td>
</tr>
</tbody>
</table>

GLOSSARY OF TERMS

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable</td>
<td>An engineered wiring product, typically constructed of one (1) or more individually insulated conductors, bound together by an overall insulation jacket (unshielded); or, bound and wrapped with an overall metallic covering (braid or foil), and covered by an overall insulation jacket (shielded).</td>
</tr>
<tr>
<td>Capping</td>
<td>A process involving the sealing of the cut / exposed ends of the wire / cable with a double-wall (melt-liner) heat shrinkable tubing or preformed end cap, or by dip coating with Red “GLPT” Insulating Varnish, to create an environmental barrier to oxygen and moisture contamination.</td>
</tr>
<tr>
<td>Conductor</td>
<td>A material capable of carrying an electrical current, and formed into a wire exhibiting a flat, round, square, or braided cross-sectional profile.</td>
</tr>
<tr>
<td>Dew Point</td>
<td>The temperature at which a volume of air at a given atmospheric pressure reaches saturation and the entrained water vapor precipitates and condenses.</td>
</tr>
<tr>
<td>Dry Pack</td>
<td>An environmental protection system consisting of activated</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Electrical / Electronic Assembly</td>
<td>Any configuration of discrete and/or integrated electrical, electronic, and/or electro-mechanical components; sub-assemblies; Printed Wiring Assemblies (PWA); discrete wiring, cabling, or harnesses; fiber optic components, or combinations thereof, that are joined together to perform a control or processing function (i.e.: measurement, sensing, or transmission of data or power).</td>
</tr>
<tr>
<td>Red Plague (Cu₂O)</td>
<td>The sacrificial corrosion of copper in a galvanic interface comprised of silver and copper, resulting in the formation of red cuprous oxide (Cu₂O) and black cupric oxide (CuO). Galvanic corrosion is promoted by the presence of moisture (H₂O) and oxygen (O₂) at an exposed copper-silver interface (i.e.: conductor end, pin-hole, scratch, nick, etc.).</td>
</tr>
<tr>
<td>Supplier</td>
<td>Contractors and sub-tier contractors.</td>
</tr>
<tr>
<td>Unit Pack (Desiccant)</td>
<td>The standardized unit of desiccant material, which at thermal equilibrium with air at +77°F (+25°C), will adsorb at least 3 gm (~0.1 oz) of water vapor at 20% relative humidity (RH) and at least 6 gm (~0.2 oz) of water vapor at 40%RH.</td>
</tr>
<tr>
<td>Wire</td>
<td>A single, bare or insulated, conductor of solid, stranded, or tinsel construction, designed to carry current in an electrical circuit.</td>
</tr>
</tbody>
</table>

**REMARKS**
## APPENDIX B - PROHIBITED MATERIALS

<table>
<thead>
<tr>
<th>Material</th>
<th>Prohibition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beryllium (Be)</td>
<td>Beryllium <strong>shall not</strong> [D1D2D3] not be used for primary structural applications or as an alloying constituent exceeding 4% (percent) by weight. Beryllium is allowed as an alloying constituent up to a maximum of 4% (percent) by weight.</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>Cadmium and cadmium plating in electrical connectors, cables, wiring harness assemblies, and mechanical fasteners <strong>shall not</strong> [D1D2D3] be used where exposure to elevated temperatures and reduced atmospheric pressures could cause sublimation (vaporization) and deposition of cadmium on optical or electrically energized surfaces.</td>
</tr>
</tbody>
</table>

### Rationale

There are several reasons for prohibiting the use of Cadmium plating in space flight electronic systems.

1. Cadmium has the ability to sublimate (vaporize), if exposed to temperatures in excess of +75 °C (+167 °F), and reduced atmospheric pressure or vacuum. This temperature is well under the rated temperatures of approved wire insulations thereby reinforcing the need for a cadmium prohibition as today’s wire gauge selections often take advantage of insulation temperature tolerances. The resulting toxic, heavy-metal vapor can be inhaled by crewmembers, or condense onto surfaces as a thin, electrically conductive layer, impacting the performance of electrical circuits and optical systems.

2. Cadmium plating on tool surfaces can be transferred to the surfaces of hardware and fasteners.

3. Cadmium is subject to the spontaneous growth of Cadmium whiskers. The propensity of Cadmium to grow whiskers appears to be lower than that of zinc and especially tin. Cadmium whiskers (like tin whiskers) grow spontaneously and are capable of causing electrical failures ranging from parametric deviations to sustained plasma arcing that can result in catastrophic short circuits.

### Recommendations

Cadmium plating is commonly used on connectors, connector hardware and mechanical hardware such as fasteners. It provides excellent resistance to salt corrosion and is therefore offered in many military specifications predominantly for use in naval applications. However, most applications are not concerned with salt corrosion and the risks associated with use of Cadmium plating noted above outweigh the benefits of its use.

There are several alternatives to Cadmium plating that are suited for spaceflight use:

1. For connectors, electroless nickel plating is preferred. Gold plating is preferred when the application requires additional shielding effectiveness, improved electrical conductivity in RF applications, or where low residual magnetism is desired.

2. Passivated stainless steel is the preferred material for hardware items such as fasteners.

Consult your materials or parts specialists for suggested alternatives to Cadmium plating.
<table>
<thead>
<tr>
<th>Material</th>
<th>Requirement Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>The breakage / shattering of glass presents an acute eye and laceration injury and Foreign Object Debris (FOD) hazard. Glass is prohibited unless it is suitably contained.</td>
</tr>
</tbody>
</table>
| Glycol Ethylene Glycol Propylene Glycol | When solutions containing ethylene glycol and propylene glycol are used in hardware which have electrical or electronic circuits containing silver or silver-coated copper, a silver chelating agent such as benzotriazole (BZT) **shall [D1D2D3]** be added to the solution to prevent spontaneous ignition from the reaction of silver with ethylene glycol and propylene glycol.  

When solutions containing other glycols (aliphatic dihydric alcohols) are used in these conditions, testing **shall [D1D2D3]** be conducted to determine if the same spontaneous ignition reaction can occur as with ethylene glycol and propylene glycol, and a silver chelating agent **shall [D1D2D3]** be added to the solution if ignition can occur. |
| Magnesium (Mg)      | Magnesium alloys **shall [D1D2D3]** not be used except in areas where minimal exposure to corrosive environments can be expected and protection systems can be maintained with ease and high reliability. Magnesium alloys **shall [D1D2D3]** not be used in the primary structure or in other areas subject to wear, abuse, foreign object damage, abrasion, erosion, or at any location where fluid or moisture entrapment is possible. |
| Mercury (Hg)        | Equipment containing mercury **shall not [D1D2D3]** be used where the mercury could come in contact with electrical connectors, cables, and wiring harness assemblies during manufacturing, assembly, test, checkout, and use.  

**Rationale**  
Mercury (Hg) is a particularly hazardous material because of its toxicity and tendency to penetrate joints and amalgamate structure materials. Metal contaminated while under high stress will receive greater penetration of mercury and degradation of ability to withstand stress than will metals under relatively low stress. Aluminum contaminated by contact with mercury will rapidly corrode, as the mercury prevents formation of the protective oxide layer on the aluminum’s surface.  

An environment containing mercury vapor in concentrations of 0.005 mg/m³ () or greater is not acceptable for continuous human occupancy.  

Coronal discharge can occur at low voltage potentials in the presence of mercury vapor.  

**Recommendations**  
1. Well-protected lamps containing mercury, including those used in the fluorescent die-penetrant inspection are exempt from this requirement.  
2. Mercury must not be removed from metal surfaces with any abrasive cleaning method. The removal of oxide films on the metal will cause immediate mercury penetration. |
<p>| Polyvinyl Chloride (PVC) | The use of polyvinylchloride (PVC) insulated wire or cable <strong>shall [D1D2D3]</strong> be limited to applications where temperatures do not exceed +49°C (+120°F). Non-lead stabilized PVC (classified as RoHS compatible) <strong>shall not [D1D2D3]</strong> be used without USER approval. Polyvinylchloride (PVC) insulation <strong>shall not [D1D2D3]</strong> be used in vacuum environments. |</p>
<table>
<thead>
<tr>
<th><strong>Rationale</strong></th>
<th><strong>Recommendations</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Silver (Au)</strong></td>
<td>Silver-plated hardware and finishes <strong>shall not</strong> be used in applications where condensing moisture, salt fog, sulfur compounds, or atomic oxygen are present. Use of electroplated silver is prohibited as a plated surface on printed wiring boards, terminal boards and bus bars. Bare or defectively insulated silver or silver-coated copper components such as wire, pins, sockets, or connectors impressed with a direct current potential can spontaneously ignite and burn when exposed to ethylene glycol solutions that do not contain a silver chelating agent. Silver underplate on gold connector contacts (Exception: movable contacts inside hermetically sealed relays). Porosity in the gold plating can cause exposed silver and oxidation, which can cause increased electrical resistance. The exposed silver can also migrate.</td>
</tr>
<tr>
<td><strong>Tin (Sn)</strong></td>
<td>Pure tin plating containing less than 3% lead (Pb) by weight as a finish coat on mechanical, EEE, electromechanical, or electro-optical parts or devices is prohibited. Pure tin finishes are susceptible to the spontaneous growth of electrically conductive single crystal structures known as tin whiskers. Over time these whiskers may grow to be several millimeters (mm) long. Tin whiskers are capable of causing electrical failures ranging from parametric deviations to sustained plasma arcing (in vacuum) that can result in catastrophic short circuits. The problem with tin whiskers has been known since the 1940 – 1950s, and was solved over 30 years ago by prohibiting the use of pure tin plating on component leads, component bodies, connectors, and mechanical components. Tin whisker is considered an electronics reliability concern and whisker FOD in the habitable section of the vehicle may present a possible health risk to the crew. Tin whiskers are electrically conductive, crystalline structures of tin that grow as a result of mechanical stress in the tin crystal lattice, from surfaces where tin (especially bright electroplated tin) is used as a final finish. Whisker growth does not require moisture or ionic contamination as an activator, and growth rates from 0.03 to 0.9 mm/yr have been reported, with lengths of several millimeters (mm) and in rare instances to lengths up to 10 mm. Because they are crystalline structures they are very strong, and capable of conducting significant amounts of power before melting or vaporizing.</td>
</tr>
<tr>
<td><strong>Recommendations</strong></td>
<td>1. Growth of whiskers has been shown to be controllable by tinning with tin-lead (SnPb) solder, and as little as 2 %Pb (lead) in the alloy or tin plating will significantly reduce whisker growth. 2. Conformal coatings will not stop whisker development. Preliminary results</td>
</tr>
</tbody>
</table>
from various NASA and industry-sponsored studies indicate that resilient conformal coatings (i.e.: urethanes (UR), silicones (SR), etc.) appear to only slow whisker growth.

3. Rigid coatings such as acrylics (AR), epoxies (ER), and paraxylene (XY) may offer some whisker protection, but present additional reliability and rework issues that must be taken into consideration by the design engineer.

| Titanium (Ti) | Titanium shall not [D1D2D3] be used with Liquid Oxygen (LOX) or Gaseous Oxygen (GOX) at any pressure or with air at oxygen partial pressures above 34.5 kPa (5 psia).

Rationale
With a few exceptions, common structural metallic materials are flammable in oxygen at modest pressures. However, most metals can be used safely in oxygen, provided that the system is designed to eliminate potential ignition sources.

Recommendation(s):
1. Titanium alloys are extremely flammable and should be used only in exceptional circumstances.
2. In some applications, use of Titanium (Ti) may be acceptable via a Project approved waiver process that includes review and approval by both Materials and Parts Engineering disciplines.
3. Care shall [D1D2D3] be exercised to ensure that cleaning fluids and other chemicals used on titanium are not detrimental to performance or reliability. Surface contaminants which can induce stress corrosion, hydrogen embrittlement, or reduce fracture toughness include the following: hydrochloric acid, cadmium, silver, chlorinated cutting oils and solvents, methyl alcohol, fluorinated hydrocarbons, and components containing mercury.

| Zinc (Zn) | Zinc plating is prohibited on EEE parts and connector hardware.

Rationale:
There are several reasons for prohibiting the use of zinc in space flight electronic systems:

1. Zinc is known to sublimate in a vacuum environment, especially at elevated temperatures. The sublimation products are conductive and can result in short circuits.
2. Electrically-deposited zinc (Zn) coatings have been shown to exhibit spontaneous metallic whisker growth that appears to be more aggressive than that observed with electrically-deposited bright tin (Sn).
3. The propensity for whisker growth and the possibility of microscopic metallic fiber FOD in an IVA environment presents a serious reliability and health concern.
4. Zinc whiskers are capable of causing electrical failures ranging from parametric deviations to sustained plasma arcing that can result in catastrophic short circuits. See prohibition against pure tin plating for additional insight regarding the risks of metal whiskers.
5. The use of zinc chromate coatings in the habitable section of the vehicle is considered a crew health risk.
Recommendation(s):
In some applications use of Zinc plating may be acceptable via a Project approved waiver process that includes review and approval by both Materials and Parts Engineering disciplines.

1. Zinc (galvanized) plating is occasionally used on mechanical hardware such as fasteners for its corrosion resistant properties. By using alternative plating materials most designs can avoid the risks associated with the use of Zinc plating while still achieving suitable corrosion resistance.
2. Consult your materials or parts specialists for suggested alternatives to Zinc plating.

<table>
<thead>
<tr>
<th>Radiation Cross-Linked Tefzel (XL-TEFZEL, XL-ETFE)</th>
<th>Rationale:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recommendation(s):</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lock Washers (Star and Tooth Type)</th>
<th>Rationale:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lock washers with a “star” or “tooth” locking feature have a potential to create foreign object damage (FOD).</td>
<td>Recommendation(s):</td>
</tr>
<tr>
<td></td>
<td>Fasteners requiring a lock washer should use a split washer design.</td>
</tr>
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<thead>
<tr>
<th>Silver-Coated Copper Wire With Less Than 40 Micro-Inches of Silver Coating</th>
<th>Rationale:</th>
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<tbody>
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<td>Recommendation(s):</td>
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<tr>
<th>Use of Silver-Coated Copper Wire Without a Red Plague Control Plan (RPCP).</th>
<th>Rationale:</th>
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<tbody>
<tr>
<td>Inadequate silver plating thickness results in wire corrosion, known as “Red Plague.”</td>
<td>Recommendation(s):</td>
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<tr>
<th>Parylene (Paraxylene) Coatings Containing Chlorine</th>
<th>Rationale:</th>
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<td>Chlorine may corrode metals or form undesirable electrically conductive substances.</td>
<td>Recommendation(s):</td>
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<th>Natural Rubber Materials</th>
<th>Rationale:</th>
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<tr>
<td>Natural rubber materials outgas sulfur when subjected to heat, low pressure, or vacuum conditions; have limited resistance to extreme temperatures, sunlight, or ozone; are fungus nutrients; and, exhibit significant compositional variation from batch to batch.</td>
<td>Recommendation(s):</td>
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<td>Topic</td>
<td>Recommendation(s)</td>
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<tr>
<td>Acetic Acid Cure RTV Silicone Sealants, Adhesives, and Coatings</td>
<td>Rationale: Release of acetic acid during cure of Room Temperature Vulcanizing (RTV) silicones creates potential corrosion and contamination.</td>
</tr>
<tr>
<td>Soldering Of Solid Gold Ribbon Leads and Wires With Tin-Lead Solder</td>
<td>Rationale: Unlike gold-plated leads or wires from which the gold can be stripped prior to soldering, solid gold ribbon leads and wires cannot be stripped, and soldering with tin-lead eutectic solder can result in the failure of the solder joint due to gold embrittlement. Recommendation(s): Use either</td>
</tr>
<tr>
<td>Ultrasonic Cleaning</td>
<td>Ultrasonic cleaning systems shall not [D1D2D3] not be used to clean electronic parts and assemblies. Rationale: The high acoustic energy levels used in ultrasonic cleaning systems can damage sensitive parts inside electronic parts and overstress solder joints. Recommendation(s):</td>
</tr>
<tr>
<td>MIL-DTL-16878 Aromatic Kapton-Insulated Wiring</td>
<td>WIRE - KAPTON INSULATED (ALL SLASH SHEETS) MIL-HDBK-454 states that MIL-DTL-16878 wire shall not [D1D2D3] be used for Air Force or Navy aerospace or NASA applications. In addition, the ordering requirements for these specifications are inadequate to ensure that the wire, plating, and insulation will satisfy flight requirements. Rationale: Recommendation(s):</td>
</tr>
<tr>
<td>Immersion Cleaning of Connectors and Harness Assemblies</td>
<td>Rationale: Recommendation(s):</td>
</tr>
<tr>
<td>Sulfides or Free Sulfur</td>
<td>Materials containing or coated with substances known to be detrimental to metals used in electrical connectors or optics shall not [D1D2D3] be used adjacent to exposed electrical contact or optical surfaces. The use of materials containing or coated with sulfides or free sulfur is prohibited [D1D2D3].</td>
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STATEMENT OF STANDARD

A Foreign Object Debris (FOD) prevention program shall be established for the design, development, manufacturing, assembly, repair, processing, testing, maintenance, operation, and check out of the equipment to prevent immediate and latent damage and to ensure the highest practical level of cleanliness.

a. Cable and wiring harness assemblies shall be designed with debris-proof covers, shrouds, containers, housings, potting, or conformal coatings that protect the entire system prior to use, or that prevent debris from entering into critical areas of the mechanism where the debris could cause arcing, binding, jamming, seizing, or unwanted current paths.

b. Connectors not being actively assembled shall be individually protected by wrapping them in bubble pack or other physical covering (i.e.: clean, ESD-rated dust caps, etc.).

c. Clean, ESD-rated dust caps shall be installed on all unmated connectors.

d. Interim Assembly / Temporary Storage - Wiring, cable, connectors, and harness assemblies that are not being actively worked on shall be stored in water-vapor-proof packaging, or covered by Electrostatic Discharge (ESD) protective covering in accordance with ANSI/ESD S20.20 and stored in an environmentally-controlled and monitored area where dew point is not attained and the relative humidity is less than 70%RH.

If necessary, connectors that were subjected to frequent mating and demating operations during fabrication and test shall receive additional cleaning prior to the final mating. Visual examination of the contact surfaces of connectors shall not reveal the presence of contaminants such as metal flakes or large dust particles. If required, additional cleaning should be performed by vacuum removal methods and solvent-brushing.

e. After harness fabrication is complete and certified, the complete harness shall be cleaned with an approved solvent, inspected with both black and white light and then vacuum baked (bakeout) at a temperature of +20°C above the maximum environmental test temperature. The bakeout will continue until a chamber pressure of 1X10^-6 Torr is reached and the QCM requirements have been fulfilled.

f. Completed Assemblies - Completed cable and harness assemblies shall be placed in a sealed, vapor-proof, protective bag, with desiccant and a humidity indicator card (HIC). Clean, ESD-rated dust caps shall be installed on all unmated connectors.

g. Cleaning The Harness Assembly - Particles and debris shall be cleaned from the
h. Cleaning Harness Connectors - The following cleaning procedures shall [D1D2D3] be used with connectors:

(1) For solder-type connectors, flux rundown into the mating part of socket contacts shall [D1D2D3] be removed (Requirement). Solvent cleaning by brushing may be used. Contact surfaces of pins, sockets, and connector bodies shall [D1D2D3] be free of flux residue (see Figure 15-1), solder splash, metal flakes, moisture, and other contaminants that may jeopardize the integrity of the connector system.

(2) Crimp-type multi-pin and coaxial electrical connectors should be solvent-cleaned by brushing before assembly to the harness or unit cable. Contact surfaces of pins and sockets and the interior surfaces of the connector shall [D1D2D3] be free of contaminants.

i. Cleaning Connector Covers - The internal surfaces of dust covers and connector covers shall [D1D2D3] be cleaned by solvent brushing and allowed to air dry before the covers are fitted onto cleaned connectors.

j. Cleaning Coaxial Connectors (Assembled) - Coaxial connectors shall [D1D2D3] not have accumulated contaminants such as metal flakes, dirt, moisture, and other foreign materials. The connector interface shall [D1D2D3] be cleaned by brushing with solvent, vacuum procedures, or a combination thereof until the contaminants have been removed.

k. Metallic Braid - All tubular metallic braid shall [D1D2D3] be cleaned with an approved solvent before being incorporated into the harness. Aqueous (water-based) solvents shall not [D1D2D3] be used.

l. The FOD prevention program shall [D1D2D3] conform to NAS 412 "Foreign Object Damage/Foreign Object Debris (FOD) Prevention".

**REMARKS**

Overbraid / metallic tubular braid shielding must be cleaned to remove the oils and the tarnish inhibitors used during the weaving process. While use of an ultrasonic cleaning process is recommended, a manual process of three immersion-removal-drain cycles (with a gentle agitation by hand while immersed) with room temperature isopropyl alcohol (IPA) should be sufficient. The third cycle should be clean IPA and used as a final rinse. Once dried, the braid should be visibly inspected at 4X-10X magnification to verify it is clean, particulate free, and should not have a sticky / tacky feel when touched.

Silver-coated copper braid should not exhibit visible indications of Red Plague (a dusty reddish / pink tint at the intersections of braid weave).

Aqueous (water-based) solvents / cleaning processes shall not be used if the braid is silver-coated copper (commonly used for flight hardware), as this may promote Red Plague.
STATEMENT OF STANDARD

Electrical wire and cable, including wiring used within containerized electrical/electronic assemblies ("black boxes") shall [D1D2D3] be procured and acceptance tested to the appropriate cable specifications listed below:

- Cable specification ANSI/NEMA WC27500, Standard for Aerospace and Industrial Electrical Cable.
- Cable specification MIL-C-17, Cables, Radio Frequency, Flexible and Semi-rigid.
- Wire specification AS22759, Wire, Electrical, Fluoropolymer Insulated Copper or Copper Alloy
- Other wire procurement specifications may be authorized by the USER.
- Wire and cable shall [D1D2D3] also comply with applicable Materials and Process (M&P) requirements.

If the wiring used in any application is unknown, as it may be in the case of off-the-shelf equipment, pig-tailed components, heater strips, etc. and if the application is non-critical, the assembly is required only to meet applicable program materials and process requirements.

Two methods for certifying wire are:

a. As required by the procurement specification, Government Source Inspection (GSI) shall [D1D2D3] certify that the test specified below has been performed by the wire manufacturer on the length of wire procured. In addition to meeting the requirements of the appropriate procurement specification, each shipment shall be accompanied by the manufacturer’s test report.

b. Wire certification can also be performed by a USER-approved test facility.

In either case, testing shall [D1D2D3] consist of the tests below. Testing for insulation flaws of cable’s basic wires shall [D1D2D3] be done prior to cable assembly.

100-Percent Testing
a. Insulated single conductor wires and cable basic wires
   (1) Impulse dielectric test (no greater than 80% of military specification)

b. Cable
   (1) Dielectric withstand of component wires
   (2) Jacket flaws for shielded cables

Sample Testing
As a minimum, a sample or samples of each lot of wire/cable shall be subjected to the following applicable quality conformance inspections. (Applicability is determined by the specifications cited above).

1. Insulated single-conductor wires and cable basic wires
   a. Conductor resistance
   b. Wrap test
   c. Shrinkage (heat resistance)
   d. Cold bend followed by wet dielectric
   e. Visual and mechanical examination (finished wire O.D., identification of product, conductor diameter, strand diameter, conductor stranding, wire base metal, and the plating material)
   f. Polyimide cure test (applicable to modified aromatic polyimide coatings only)
   g. Cross-link proof testing for cross-linked insulation materials

2. Cable
   a. Shield coverage
   b. Identification of product
   c. Jacket wall thickness
   d. Cold bend
   e. Thermal shock
   f. Stress-Crack Resistance testing (MIL-C-17 Cable only)

Any failure during sample testing shall be cause for immediate rejection of the entire lot.

Certification Processes
Certification of a USER-approved test facility is done by an audit team with representatives from the USER, or their representatives. The team shall assure the test lab is qualified to perform the test methods referenced in this standard.

At the using installation, before placing wire/cable into bonded storage, representatives from the Engineering team and/or receiving inspection function shall verify that the test report indicating conformance with all applicable procurement specification requirements accompanies each lot shipped.

Storage shelf life: Silver plated wire and cable that has exceeded a shelf life of 10 years from its manufacturing date shall be downgraded to non-flight status and not be used on flight hardware.

**REMARKS**

The primary reason for downgrading silver-coated wire after ten (10) years of age is to control increased solderability problems with silver and the potential for Red Plague for wire stored in a high moisture environment. See Red Plague Control Plan (RPCP), Appendix A.