AEROSPACE INFORMATION REPORT

AIR6808™ REV. A

Issued 2020-04
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Superseding AIR6808

Aerospace Vehicle Wiring, Lessons Learned

RATIONALE

The purpose of the update is to synchronize AIR6088 to the latest revision of AS50881, and to provide historical rationale for requirement revisions in the latest revision of AS50881. This update included over 45 paragraphs that changed from the previous revision. Each required a corresponding rationale paragraph to be updated as well. The corresponding rationale paragraph is the purpose of the AIR6088.

INTRODUCTION

AS50881 was developed by the SAE AE-8A System Installation Subcommittee as an industry replacement for MIL-W-5088L. Conformance with the provisions of this document is intended to provide EWIS safety, performance, reliability, maintainability, service life, and lifecycle cost. AS50881 is only applicable to aircraft/air vehicle EWIS. Its scope does not include wiring inside of airborne electronic equipment but does apply to wiring externally attached to such equipment. The information in this document is for air vehicle designers, analysts, quality personnel, and contract officers to better understand AS50881 EWIS requirements. It is written for use by personnel having a basic understanding of EWIS and provides further rationale and explanation of the various EWIS requirements cited in the AS50881 through Revision G. It can also be a useful tool in developing aircraft detailed specification provisions regarding wiring system requirements. SAE AE-8A does not take responsibility or direct the reader to perform any of the cited actions in this document. The contents of this document only provide rationale, historical context, and explanation for AS50881 EWIS requirements.

1. SCOPE

This AIR is limited to the requirements of AS50881 and examines these requirements, providing rationale behind them. AS50881 is only applicable to the aircraft EWIS. Pods and other devices that can be attached to an aircraft are considered as part of the aircraft equipment design. Its scope does not include wiring inside of airborne electronic equipment but does apply to wiring externally attached to such equipment. The AS50881 scope does not include attached devices but does include the interface between the pod/equipment and aircraft wiring. Section 3.3.5 addresses components such as antennas and other similar equipment that were once supplied as Government Furnished Aeronautical/Aerospace Equipment (GFAE).

1.1 Purpose

The purpose of this document is to provide information about how each of the requirements of AS50881 can affect performance, safety, reliability, and maintainability attributes and the potential consequences of their omission.

1.2 Paragraph Organization

The paragraphs listed in Section 3 are the same titles used in AS50881 Revision G Section 3. Section 3 lists the individual EWIS system, process, or performance requirements. Each requirement paragraph from AS50881 is show in green font. Following each AS50881 green requirement paragraph (green font), when applicable, there is a "rationale" paragraph in black font. The rationale following each requirement paragraph in this AIR provides information regarding the EWIS safety, reliability, historical context, and performance implications.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS-STD-595	Colors Used in Government Procurement
AIR65	Thermoelectric Circuits and the Performance of Several Aircraft Engine Thermocouples
AIR1329	Electrical Connectors and Wiring, Compatibility of
AIR4465	Design and Handling Guide Radio Frequency Absorptive Type Wire and Cables (Filter Line, AS85485)
AIR4487	Investigation of Silver-Plated Conductor Corrosion (Red Plague)
AIR5558	Ultraviolet (UV) Laser Marking Performance of Aerospace Wire Constructions
AIR5575	Hot Stamp Wire Marking Concerns for Aerospace Vehicle Applications
AIR5919	Alternatives to Cadmium Plating
AIR6151	Torque, Threaded Application, Electrical Connector, Accessory and Terminal Board Installation
AIR6540	Fundamentals in Wire Selection and Sizing for Aerospace Applications
AIR6820	Electrical Wiring Fuel Compatibility
AIR7506	Impact of High Voltage on Wiring
ARP1308	Electrical Connectors for Aerospace, Shipboard, Ground Vehicles and Associated Equipment
ARP1350	Procedure for Installation and Mounting of Single Hole Mount, Cylindrical, Electrical Connectors (For Pressure Differential Applications)
ARP1870	Aerospace Systems Electrical Bonding and Grounding for Electromagnetic Compatibility and Safety
ARP1897	Clamp Selection and Installation Guide
ARP4404	Aircraft Electrical Installations

ARP5369	Guidelines for Wire Identification Marking Using the Hot Stamp Process
ARP5614	Guidelines for Harness Critical Clamp Locator Marker Installation on Electrical Cable Assemblies
ARP6400	Recommended Practice for Processing and Handling Wire and Cable with Silver Plated Conductors and Shields
ARP6807	Guide for Identification of Terminal Lugs in Electrical Wiring Interconnect Systems (EWIS)
ARP6881	Guidelines for the Use and Installation of Bonded Cable Harness Supports
ARP6903	Guide for Achieving Plating/Finishing Compatibility with Connectors and Accessories used in Electrical Wiring Interconnect Systems (EWIS)
ARP7987	Development, Verification, and Validation of a Thermal Model for Determining Current Derating Design Limits of Aerospace Wires and Wire Bundles
ARP81490	Transmission Lines, Transverse Electromagnetic Mode
AS567	Safety Cable, Safety Wire, Key Washers, and Cotter Pins for Propulsion Systems, General Practices for Use of
AS3509	Cable, Safety, Kit, Nickel Alloy, UNS N0660
AS4372	Performance Requirements for Wire, Electric, Insulated Copper or Copper Alloy
AS4373	Test Methods for Insulated Electric Wire
AS4461	Assembly and Soldering Criteria for High Quality/High Reliability Soldering Wire and Cable Termination in Aerospace Vehicles
AS4536	Safety Cable Kit Procurement Specification and Requirement for Use
AS5117	Clip, Spring Retention - Electrical Cable
AS5419	Cable, Thermocouple Extension, Shielded and Unshielded
AS5768	Tool, Stripper, Electrical Insulation, General Specification For
AS5942	Marking of Electrical Insulating Materials
AS6070	Aerospace Cable, High Speed Data, Copper
AS6136	Conduit, Electrical, Flexible, Shielded, Aluminum Alloy for Aircraft Installations
AS7351	Clamp, Loop Type Bonding
AS7928	Terminals, Lug: Splices, Conductor: Crimp Style, Copper, General Specification For
AS7928/14	Terminal, Electric, Permanent, Crimp Style, Tin-Coated Copper, Insulated, Environment Resistant, Class 1, 150 °C, Heatless Sealing
AS7974	Cable Assemblies and Attachable Plugs, External Electrical Power, Aircraft, General Specification For
AS8700	Installation and Test of Electronic Equipment in Aircraft, General Specification for

AS10380	Coupling Installations, Standard Conduit, Electrical
AS18029	Cover Assembly, Electrical, for MS27212 Terminal Board Assembly
AS21980	Ferrule, Outer, Uninsulated, Shield Terminating, Type I, Two Piece, Class I, for Shielded Cables
AS21981	Ferrule, Inner, Uninsulated, Shield Terminating, Type I, Two Piece, Class I, for Shielded Cables
AS21919	Clamp, Loop Type, Cushioned Support
AS22520	Crimping Tools, Wire Termination, General Specification For
AS22759	Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy
AS22759/14	Wire, Electric, Fluoropolymer-Insulated, FEP-PVF2, Light Weight, Tin-Coated Copper Conductor, 600 Volt, RoHS
AS23053	Insulation Sleeving, Electrical, Heat Shrinkable, General Specification For
AS23053/5	Insulation Sleeving, Electrical, Heat Shrinkable, Polyolefin, Flexible, Crosslinked
AS23053/8	Insulation Sleeving, Electrical, Heat Shrinkable, Polyvinylidene Fluoride, Semi-Rigid, Crosslinked
AS23053/11	Insulation Sleeving, Electrical, Heat-Shrinkable Fluorinated Ethylene Propylene, Non-Crosslinked
AS23053/12	Insulation Sleeving, Electrical, Heat Shrinkable Polytetrafluoroethylene
AS23053/18	Insulation Sleeving, Electrical, Heat Shrinkable, Modified Fluoropolymer, Crosslinked
AS23190	Wiring, Positioning, and Support Accessories
AS25274	Cap, Electrical (Wire End, Crimp Style, Type II, Class 1), for 105 °C Total Conductor Temperature
AS25435	Terminal-Lug, Crimp Style, Straight Type, for Aluminum Aircraft Wire, Class 1
AS25436	Terminal-Lug, Crimp Style, 90° Upright Type, for Aluminum Aircraft Wire, Class 1
AS25438	Terminal-Lug, Crimp Style, Right Angle Type, for Aluminum Aircraft Wire, Class 1
AS25439	Splice-Permanent Crimp Style, 2 Way Type for Aluminum Aircraft Wire, Class 1
AS27212	Terminal Board Assembly, Molded-in-Stud, Electric
AS33481	Contact Bushing, Electric, Wire Barrel
AS33681	Strap, Tiedown, Electrical Components, Identification, Adjustable, Self-Clinching, Plastic, Type II, Class 1
AS33731	Strip, Mounting, Nut Insulating, for AS27212 Terminal Board
AS39029	Contacts, Electrical Connector, General Specification For
AS39029/112	Contact Bushing, Electrical Connector Contact, Wire Barrel
AS50881	Wiring Aerospace Vehicle
AS60491	Sleeve, Protection, for Cable and Harness Protection

AS70991	Terminals: Lug and Splice, Crimp Style, Aluminum, for Aluminum Aircraft Wire
AS81044	Wire, Electrical, Crosslinked Polyalkene, Crosslinked Alkane-Imide Polymer, or Polyarylene Insulated, Copper or Copper Alloy
AS81714	Terminal Junction System (TJS), Environment Resistant, General Specification For
AS81714/11	Terminal Junction System, Terminal Junction Blocks, Sectional, Wire In-Line Junctions, Single, Series I
AS81714/12	Terminal Junction System, Terminal Junction Blocks, Sectional, Wire In-Line Junctions, Double, Series I
AS81714/21	Terminal Junction System, Terminal Junction Blocks, Sectional, Electronic In-Line Junctions, Diode, Series I
AS81714/23	Terminal Junction System, Terminal Junction Blocks, Electronic, In-Line Junctions, Integral Fuse, Series I
AS81714/27	Terminal Junction System, Terminal Junction Blocks, Sectional, Grounding Modules, Stud Type Mounting, Series I
AS81714/28	Terminal Junction System, Terminal Junction Blocks, Sectional, Grounding Modules, Integral, Bracket Mounting, Series I
AS81714/63	Terminal Junction System, Terminal Junction Blocks, Sectional, Grounding Modules, Stud and Flange Type Mounting, Series II
AS81790	Connectors, Receptacle, External Electric Power, Aircraft, General Specification for
AS81824	Splices, Electric, Permanent, Crimp Style, Copper, Insulated, Environment Resistant
AS81824/1	Splice, In-Line, Electric, Crimp, SN/CU, Environmental, Heat-Shrinkable Sleeve (150 °C), 1 x 1 Sealant Opening
AS81824/6	Splice, Electric, Permanent, Crimp, Nickel Plated Insulated Wires, Environmental Class 1, 175 °C
AS81824/12	Splice, Electric, Permanent, Crimp Style, Tin-Coated Copper, Insulated, Environment Resistant, Class 1, 150 °C, Heatless Sealing
AS81824/13	Splice, Stub, Electrical, Permanent, Crimp Style, Nickel/Copper, Insulated, Environment Resistant, 175 °C Max
AS81824/14	Splice, Electric, Permanent, Crimp Style, Nickel-Coated Copper, Insulated, Environment Resistant, Class 1, 175 °C, Heatless Sealing
AS81914	Tubing, Plastic, Flexible, Convoluted, Conduit, General Specification for
AS81969	Installing and Removal Tools, Connector Electrical Contact, General Specification for
AS83519	Shield Termination, Solder Style, Insulated, Heat-Shrinkable, Environment Resistant General Specification for
AS83519/2	Shield Termination, Solder Style, Insulated, Heat-Shrinkable, Environment Resistant With Pre Installed Leads for Cables Having Tin or Silver Plated Shields (Class I)

AS83519/3	Shield Termination, Solder Style, Insulated, Heat-Shrinkable, Environment Resistant With Preinstalled Braid, Class 1, Non-RoHS
AS83519/5	Shield Termination, Solder Style, Insulated, Heat-Shrinkable, Environment Resistant With Preinstalled Braid, Ni Plated, Class 1, RoHS
AS85049	Connector Accessories, Electrical, General Specification For
AS85049/80	Connector Accessories, Electrical, Dummy Contact, Sizes 16, 12, and 8, Category 7 (for MIL-DTL-38999 Connectors)
AS85049/81	Connector Accessories, Electrical, Seal Plug, Size 10, Category 7 (for MIL-DTL-38999 Connectors)
AS85049/82	Connector Accessories, Electrical, Backshell, Straight, Self-Locking, Shield Band Termination (RFI/EMI), Shrink Sleeve Accommodation, Category 3B (for AS50151 Crimp, MIL-DTL-26482 Series 2, AS81703 Series 3 and MIL-DTL-83723 Series III Connectors)
AS85049/83	Connector Accessories, Electrical, Backshell, 45°, Self Locking, Shield, Band Termination, (RFI/EMI), Shrink Sleeve Accommodation, Category 3B (for AS50151 Crimp, AS95234, MIL-DTL-26482 Series 2, AS81703 Series 3 and MIL-DTL-83723 Series III Connectors)
AS85049/84	Connector Accessories, Electrical, Backshell, 90°, Self-Locking, Shield Band Termination (RFI/EMI), Shrink Sleeve Accommodation, Category 3B (for AS50151 Crimp, AS95234, MIL-DTL-26482 Series 2, AS81703 Series 3, and MIL-DTL-83723 Series III Connectors)
AS85049/85	Connector Accessories, Electrical, Backshell, Straight, Self-Locking, Shield Band Termination (RFI/EMI), Shrink Boot Accommodation, Category 3B (for MIL-DTL-38999 Series I and II Connectors)
AS85049/86	Connector Accessories, Electrical, Backshell, 45°, Self-Locking, Shield Band Termination, (RFI/EMI), Shrink Sleeve Accommodation, Category 3B (for MIL-DTL-38999 Series I and II Connectors)
AS85049/87	Connector Accessories, Electrical, Backshell, 90°, Self-Locking, Shield Band Termination (RFI/EMI), Shrink Sleeve Accommodation, Category 3B (for MIL-DTL-38999 Series I and II Connectors)
AS85049/88	Connector Accessories, Electrical, Backshell, Straight, Self-Locking, Shield Band Termination (RFI/EMI), Shrink Boot Accommodation, Category 3B (for MIL-DTL-38999 Series III and IV Connectors)
AS85049/89	Connector Accessories, Electrical, Backshell, 45°, Self-Locking, Shield Band Termination (RFI/EMI), Shrink Sleeve Accommodation, Category 3B (for MIL-DTL-38999 Series III and IV Connectors)
AS85049/90	Connector Accessories, Electrical, Backshell, 90°, Self-Locking, Shield Band Termination, (RFI/EMI), Shrink Sleeve Accommodation, Category 3B (for MIL-DTL-38999 Series III and IV Connectors)
AS85049/91	Connector Accessories, Composite, Electrical, Strain Relief, Straight, Self-Locking, Category 4C (for MIL-DTL-38999 Series III and IV Connectors)
AS85049/92	Connector Accessories, Composite, Electrical, Strain Relief, 90°, Self-Locking, Category 4C (for MIL-DTI-38999 Series III and IV Connectors)
AS85049/93	Connector Accessories, Electrical, Termination, Shield Split Support Ring, Composite, Nonenvironmental, Straight, Category 7
AS85049/103	Connectors, Accessories, Composite, RFI/EMI, Electrical, Strain Relief, Straight, Self-Locking, Category 3C (for MIL-DTL-38999 Series III and IV Connectors)

AS85049/104 Connectors, Accessories, Composite, RFI/EMI, Electrical, Strain Relief, 45°, Self-Locking, Category 3C (for MIL-DTL-38999 Series III and IV Connectors)

AS85049/105 Connectors, Accessories, Composite, RFI/EMI, Electrical, Strain Relief, 90°, Self-Locking, Category 3C (for MIL-DTL-38999 Series III and IV Connectors)

AS85049/128 Shield Band, Connector Accessories, Electrical Backshell, Category 7(for AS85049/82 -/90, /93, /109 - /117 Accessories)

AS85049/138 Connector Accessories, Electrical, Cap, Dust, Plastic, Category 9

AS85848 Sleeving, for Identification Marking, Heat Shrinkable, General Specification for

AS85485 Cable, Electric, Filter Line, Radio Frequency Absorptive

AS85485/8 Cable, Electric, Filter Line, Shielded, Jacketed, Radio Frequency Absorptive, 150 °C, 600-Volt

AS85485/12 Cable, Electric, Filter Line, Small Diameter Wire, Shielded, Jacketed, Radio Frequency Absorptive, 150 °C, 600-Volt

AS90387 Wiring Installation Tools for Plastic and Metal Tiedown Straps

2.2 U.S. Government Publications

Copies of these documents are available online at https://quicksearch.dla.mil.

2.2.1 Specifications, Standards, and Handbooks

Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Acquisition Streaming and Standardization Information System (ASSIST) specified in the solicitation form a part of this specification to the extent specified herein.

2.2.1.1 Specifications

2.2.1.1.1 Military

MIL-A-46146 Adhesives-Sealants, Silicone, RTV, Noncorrosive (for Use with Sensitive Metals and Equipment)

MIL-DTL-17 Cables, Radio Frequency, Flexible and Semirigid, General Specification for

MIL-DTL-3607 Connector, Coaxial, Radio Frequency, Series

MIL-DTL-3650 Connectors, Coaxial, Radio Frequency, Series LC

MIL-DTL-3655 Connector, Plug and Receptacle, Electrical (Coaxial, Series Twin), and Associated Fittings, General Specification for

MIL-DTL-5541 Chemical Conversion Coatings on Aluminum and Aluminum Alloys

MIL-DTL-5846 Chromel and Alumel Thermocouple Electrical Wire

MIL-DTL-24308 Connectors, Electrical, Rectangular, Nonenvironmental, Miniature, Polarized Shell, Rack and Panel, General Specification for

MIL-DTL-25038 Wire, Electrical, High Temperature and Fire Resistant, and Flight Critical, General Specification for

MIL-DTL-25516 Connectors, Electrical, Miniature, Coaxial, Environment-resistant Type, General Specification for

MIL-DTL-32546	Connectors, Electrical, Circular, for High-Speed Data Bus Transmission, Copper Conductor, General Specification for
MIL-DTL-32554	Straps, Tie-Downs, Adjustable, Non-Metallic, Cable Bundling, General Specification for
MIL-DTL-32610	Stripper, Multi-Conductor Electrical Cable, Hand-Operated, General Specification for
MIL-DTL-32633	Connectors, Filter, Electromagnetic Interference (EMI), General Specification for
MIL-DTL-81381	Wire, Electric, Polyimide-Insulated, Copper or Copper Alloy
MIL-DTL-83413/8	Connectors and Assemblies, Electrical, Aircraft Grounding: Type IV Jumper Cable Assembly, Lead, Electrical
MIL-DTL-83517	Connector, Coaxial, Radio Frequency for Coaxial, Strip or Microstrip Transmission Line, General Specification for
MIL-I-631	Insulation, Electrical, Synthetic-Resin Composition, Nonrigid
MIL-I-3190	Insulation Sleeving, Electrical, Flexible, Coated, General Specification for
MIL-M-24041	Molding and Potting Compound, Chemically Cured Polyurethane
MIL-PRF-8516	Sealing Compound, Polysulfide Rubber, Electric Connectors and Electric Systems, Chemically Cured
MIL-PRF-23586	Sealing Compound, Electrical, Silicone Rubber, Accelerator Required
MIL-PRF-29504	Termini, Fiber Optic Connector, Removable, General Specification for
MIL-PRF-39012	Connectors, Coaxial, Radio Frequency, General Specification for
MIL-PRF-46846	Rubber, Synthetic, Heat-Shrinkable
MIL-PRF-49142	Connector, Plug and Receptacle, Electrical, Triaxial, Radio Frequency, General Specification for
MIL-PRF-55339	Adapter, Connector, Coaxial, Radio Frequency, (Between Series and Within Series), General Specification for
MIL-T-81490	Transmission Lines, Transverse Electromagnetic Mode

2.2.1.2 Standards

2.2.1.2.1 Military

MIL-STD-196	Joint Electronics Type Designation System
MIL-STD-464	Department of Defense Interface Standard for Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-681	Identification Coding and Application of Hookup and Lead Wire
MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-889	Dissimilar Metals
MIL-STD-1353	Department of Defense Standard Practice Electrical Connectors, Plug-in Sockets, and Associated Hardware

MIL-STD-1678	Fiber Optics Cabling System Requirements and Measurements
	(Part 1: Design, Installation and Maintenance Requirements)
	(Part 2: Optical Measurements)
	(Part 3: Physical, Mechanical, Environmental and Material Measurements)
	(Part 4: Test Samples Configuration and Fabrication Requirements)
	(Part 5: Design Phase and Legacy Measurement)
MIL-STD-1553	Digital Time Division Command/Response, Multiplex Data Bus
MIL-STD-7080	Electric Equipment, Aircraft, Selection and Installation of
MIL-STD-7179	Finishes, Coatings, and Sealings for the Protection of Aerospace Weapons Systems, General Specification for
MS3471	Connectors, Receptable, Electrical, Series 2, Crimp Type, Cable Connecting, Bayonet Coupling, Classes A, D, L, T, W and K
MS21919	Clamp, Loop Type, Cushioned, Support
MS27488	Plug, End Seal, Electrical Connector
MS90387	Tool, Hand, Adjustable for Plastic and Metal Tiedown Straps (S/S by SAE-AS90387)
NAVMAT P-4855-2	Design Guidelines for Prevention & Control of Avionic Corrosion

2.2.1.3 Handbooks

2.2.1.3.1 Military

MIL-HDBK-502	Product Support Analysis
MIL-HDBK-516	Airworthiness Certification Criteria
MIL-HDBK-522	Guidelines for Inspection of Aircraft Electrical Wiring Interconnect Systems
MIL-HDBK-525	Electrical Wiring Interconnect System (EWIS) Integrity Program
MIL-HDBK-534	Aircraft Fuel System Service Life Extension
MIL-HDBK-863	Wiring Data and System Schematic Diagrams, Preparation of
MIL-HDBK-1646	Selection of Electrical Contacts, Connectors and Associated Servicing Tools

2.2.1.4 Technical Manuals

Documents can be obtained at the NATEC technical data website, https://mynatec.navair.navy.mil/natechome.htm. The link provided is intended for persons with approved access.

NAVAIR 01-1A-505-1, T.O. 1-1A-14, and ARMY TM 1-1500-323-24-1: Installation and Repair Practices Volume I Aircraft Electric and Electronic Wiring

NAVAIR 01-1A-505-2, T.O. 1-1A-14-2, and TM 1-1500-323-24-2: Installation and Repair Practices Volume II Aircraft Circular Electrical Connectors and Accessories

NAVAIR 01-1A-505-3, T.O. 1-1A-14-3, and TM 1-1500-323-24-3: Installation and Repair Practices Volume III Aircraft Rectangular Electrical Connectors and Accessories

NAVAIR 01-1A-505-4, T.O. 1-1A-14-4, and TM 1-1500-323-24-4: Installation and Repair Practices Volume IV Aircraft Fiber Optic Cabling

2.2.1.5 Commercial Item Descriptions (CID)

A-A-52080	Tape, Lacing and Tying, Nylon (Type I), -67 °F (-55 °C) to 250 °F (121 °C)
A-A-52081	Tape, Lacing and Tying, Polyester (Type II), -100 °F (-73 °C) to 280 °F (138 °C)
A-A-52082	Tape, Lacing and Tying, TFE-Fluorocarbon (Type III), -100 °F (-73 °C) to 450 °F (232 °C)
A-A-52083	Tape, Lacing and Tying, Glass (Type IV), -100 °F (-73 °C) to 800 °F (427 °C)
A-A-52084	Tape, Lacing and Tying, Aramid (Nomex), (Type V), -100 °F (-73 °C) to 500 °F (260 °C)
A-A-59163	Insulation Tape, Electrical, Self Adhering Unsupported Silicone Rubber
A-A-59178	Nipple, Electrical Terminal
A-A-59125	Terminal Boards, Molded, Barrier Screw and Stud Types and Associated Accessories
A-A-59474	Insulation Tape, Electrical, High Temperature, Polytetrafluoroethylene, Pressure-sensitive
A-A-59877	Insulating Compound, Electrical, Embedding

2.3 Non-Government Publications

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the ASSIST cited in the solicitation.

Unless otherwise specified, the issues of documents not listed in the ASSIST are the issues of the documents cited in the solicitation.

2.3.1 AIA Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NAS831	Cap-Protective Electrical Connector
NAS837	Plug - Protective Electrical Connector
NASM3036	Grommet, Rubber Hot-oil and Coolant Resistant
NASM20995	Wire, Safety or Lock
NASM21266	Grommet, Plastic, Edging
NASM22529	Grommet, Edging
NASM22529/1	Grommet, Composite, Edging
NASM22529/2	Grommet, Cushion Composite Edging
NASM25440	Washer, for Use with Aircraft Aluminum Terminals

NASM33540 Safety Wiring and Cotter Pinning, General Practice for

2.3.2 ASME Publications

Available from ASME, P.O. Box 2900, 22 Law Drive, Fairfield, NJ 07007-2900, Tel: 800-843-2763 (U.S./Canada), 001-800-843-2763 (Mexico), 973-882-1170 (outside North America), www.asme.org.

ASME Y14.100 Engineering Drawing Practices

ASME Y14.24 Types and Applications of Engineering Drawings

ASME Y14.34M Associated Lists

2.3.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D3032 Standard Test Methods for Hookup Wire Insulation

2.3.4 ECIA Publications

Available from Electronic Components Industry Association, 2214 Rock Hill Road, Suite 265, Herndon, VA 20170, Tel: 571-323-0294, www.ecianow.org.

EIA/ECA-364-26 Salt Spray Test Procedure for Electrical Connectors, Contacts and Sockets

2.3.5 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

AC 25.1701-1 Certification of Electrical Wiring Interconnection Systems on Transport Category Airplanes

AC 25.981-1D Fuel Tank Ignition Source Prevention Guidelines

AC 43.13-1B Acceptable Methods, Techniques, and Practices - Aircraft Inspection and Repair

2.3.6 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE Std. 315-1975 Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Letters)

2.3.7 RTCA Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA DO-160 Environmental Conditions and Test Procedures for Airborne Equipment

3. REQUIREMENTS

3.1 Terminology Interpretation

The term “wiring” wherever used throughout this specification shall be interpreted in accordance with 2.3.26.

Rationale: The term “wiring” is interpreted per the callout from the green text font from AS50881 (H) in 2.3.26 which states: “Wires, electrical/optical cables, groups, harnesses and bundles, and their terminations, associated hardware, and support, installed in the vehicle. When used as a verb it is the act of fabricating and installing these items in the vehicle.”

3.1.1 Deviations

Deviations from this specification desired by the contractor (substitution of equipment, material, or installation) shall be specifically brought to the attention of the procuring activity by letter concurrent with or prior to forwarding the design data for approval. All requests for deviations shall include sufficient engineering information to substantiate the deviations.

3.2 Conflicting Requirements

In case of discrepancies between this specification and the type or detail specification for a particular vehicle part, the type or detail specification shall prevail.

Rationale: The intent is for AS50881 to be tailored for specific applications since every original equipment manufacturer (OEM) has unique design and manufacturing practices. This requirement allows exceptions from AS50881 as defined in the air vehicle type or detail specification for particular reasons such as improved materials and components or vehicle-unique configurations. Any exceptions or deviations should be documented and rationale provided to the procurement and/or airworthiness certification authority.

3.3 Selection of Parts and Materials

Parts and materials covered by documents listed herein are standard and shall be used whenever they are suitable for the purpose. Standard parts and materials shall have qualification inspection and be procured from qualified products list (QPL) that has been issued by the qualifying activity as required by the applicable specification. Nonstandard parts and materials must be equivalent to or better than similar standard parts and materials. When this specification fails to provide an applicable specification or standard, the contractor shall use other established specifications or standards. Parts and materials selected from other than this specification are not standard, and approval must be obtained prior to their use in aerospace vehicles. Each vendor source for a nonstandard part or material requires approval. When a nonstandard part is used where a suitable standard part exists, the contractor shall reference the standard part on the drawing, parts lists, or data package, and the installation shall provide for replacement with the standard part.

Rationale: To provide qualification requirement application and to ensure standard and qualified terms align with SD-6 qualification standard. To clearly define the requirement for use of standard/qualified parts and to outline the contactor role and responsibilities in part selection. Note that MIL-DTL-32610 provides a good part selection process; however, for EWIS components, performance verification testing is required.

3.3.1 Requests for Approval of Nonstandard Parts

The data to be submitted with the request for approval of nonstandard parts shall be in accordance with the terms of the contract. For wire and cable applications, use AS4372 data configuration.

3.3.2 Commercial Utility Parts

Commercial utility parts, such as screws, bolts, nuts, cotter pins, etc., may be used, provided they have suitable properties and are replaceable by standard parts without alteration.

3.3.3 Contractor's Specifications

Wiring and wiring devices conforming to contractor's specifications may be used, provided each contractor's specification is approved by the procuring activity and provided no military specification exists. The contractor shall provide substantiating test data and, when required by the procuring activity, shall provide samples for test. The use of contractor's specifications shall not constitute waiver of procuring activity inspections. Contractor's specifications shall follow the format for military specifications. When a detail or general military specification exists for the class of material required, the contractor's specification shall reference the existing military specification and set forth only the needed new requirements and deviations.

Rationale: To provide qualification requirement application and outline the contactor role and responsibilities in part selection. If a nonstandard or commercial part is to be employed, the contractor's role is defined. The goal is to provide the procuring activity with the requisite components and/or information to make a prudent engineering decision based on data, tests, and/or contractor's specifications.

3.3.4 Commonality

An objective in the selection of parts shall be to maximize commonality and minimize the variety of wiring components and related servicing tools required in the construction, installation, and maintenance of the electrical wiring system.

3.3.5 Government-Furnished Aircraft Equipment (GFAE)

Wiring and wiring devices furnished by the government shall be installed without modification unless otherwise authorized or directed by the procuring activity.

3.3.6 Modification

The contractor shall not alter, rework, or modify wiring or wiring devices built to and meeting government specifications, unless authorized or directed by the procuring activity, and such modification shall be subject to government inspection.

Modified parts shall have the government identifying part number removed and shall be identified by contractor part number.

Rationale: Part selection can be critical for survival of aircraft and occupants for the expected aircraft service life. Aircraft operations in severe environment and field level maintenance affect component life. Using standardized aircraft-qualified parts enhances logistic support, safety, and reliability and supports improved mission availability. Modification of a part makes it nonstandard and should be approved by the procurement authority. As an example, some equipment boxes have had connection pigtails that were modified by the OEM without the design authority to make such changes.

3.4 Service Life

Wiring and associated components used for the wiring installation shall be selected and installed to promote ease of maintenance and high reliability over the entire expected service life of the vehicle. The reliability and maintainability goals for the wiring system shall be determined in the acquisition logistics as delineated in MIL-HDBK-502, as will the expected service life. These goals shall be subject to procuring activity approval.

Rationale: An aircraft's wiring system incorporates many thousands of components and material types, all of which need to function as intended for an extended period in a variety of operational and maintenance environments. Aircraft wiring may be installed in areas not readily accessible for maintenance inspection or replacement. The burden of diagnosing and implementing corrective repairs for an excessive number of failures can be overwhelming to maintenance personnel. Premature or undiagnosed failure modes can risk the safety of occupants and performance of assigned missions. If it is not possible for components to meet the designated service life of the aircraft, a list of life-limited parts should be created and maintained as part of the instructions for continued airworthiness (ICAs). For a more detailed discussion on service life, consult MIL-HDBK-525.

3.5 Smoke and Fire Hazard

The wiring and wiring devices shall be selected and installed in such a manner as to minimize the danger of smoke and fire hazards. Adequate protective means, both physical and electrical, shall be employed to provide reliability and safety commensurate with this requirement. Unless otherwise specified, all wire and cable shall meet the flammability requirements of AS4372.

Rationale: Aircraft electrical systems can experience overload, short circuit failures, or combat damage leading to smoke or fire which can cause injury to crew members or loss of pilot vision. For critical circuits that can directly affect safety of flight, consideration should be given to wire types specified in AS50881 Appendix A as being suitable for use in circuits where electrical integrity is required for a limited time in fire conditions. Physical protective means, such as secondary harness protection and/or physical separation, are potential solutions to meet this requirement. A safety and probability analysis should be developed to fully assess the impact of a failure and the mitigation strategy. Thermal or solid-state circuit breakers are potential devices that could minimize the possibility of smoke/fire.

3.6 Materials

Materials used in the installation of wiring and equipment shall be suitable for the purpose and conform to such government specifications as are specifically applicable under the contract.

Rationale: Aircraft must be able to operate in extreme environments for extended periods. Use of nonstandard materials can lead to premature system failures and issues with traceability and/or maintainability. If contractor-specified materials were freely allowed, the overall safety and reliability of a new aircraft model might not be able to be assessed until the program had progressed beyond the point where corrections could be made within the time and cost constraints allowed for the program.

3.6.1 Metals

Metals used in the installation of wiring shall be corrosion resistant or shall be suitably protected to resist corrosion and electrolytic action during normal service life. Finish and coating shall be in accordance with MIL-STD-7179.

Rationale: Corrosion of wiring system components can interrupt circuit continuity or cause components to be unserviceable for disconnection or functional testing. Such deterioration may not be detectable during inspection or until a system failure has occurred. There is a basic incompatibility between maintaining conductive surfaces and corrosion resistance since protection from corrosion is typically accomplished by passivating surfaces and interrupting electron transport between two galvanically coupled materials. Metals selected for the designed application should be inherently resistant to corrosion or made corrosion resistant by coating and/or plating.

3.6.1.1 Dissimilar Metals

Dissimilar metals used shall conform to the requirements of MIL-STD-889. This standard establishes requirements for the selection and protection of dissimilar metal combinations and other significant corrosion behavior factors.

Rationale: Increased circuit resistance can result from corrosion of conductive materials. Dissimilar metals protection avoids system failures, lightning protection loss, and corrosion damage. Application of protective sealants after final assembly may extend corrosion protection but will typically make unit maintenance more time consuming. Dissimilar metals need to be suitably protected against the various forms of corrosion, which include galvanic, surface oxidation, hydrogen embrittlement, intergranular and stress corrosion, and crevice corrosion. For more detail, consult NAVMAT P 4855-2.

3.6.2 Nonmetals

Nonmetals used, including plastics, fabrics, and protective finishes, shall be moisture and flame resistant, shall not support fungus growth, shall not support combustion, and shall not be adversely affected by weathering, applicable fluids, and propellants, temperature, and ambient conditions encountered during operation of the vehicle. Materials that give off a minimum amount of noxious gases shall be selected. Nonmetals may be treated to conform to this requirement. PVC Insulating materials shall not be used unless no other materials suitable for the application are available.

3.6.2.1 Insulating Materials

Insulating materials shall have an arc resistance capability which will meet the circuit requirements.

3.6.2.1.1 PVC Usage

PVC material shall not be used in U.S. Department of Defense contracts for aerospace applications.

3.6.2.1.2 MIL-DTL-81381 Usage

MIL-DTL-81381 shall not be used in U.S. Department of Defense contracts for aerospace applications.

Rationale: Failure or degradation of nonmetallic materials can lead to loss of insulation properties or fractures resulting in short circuits or extensive corrosion. Deterioration of nonmetals can also result in unanticipated movement of live circuit components causing electrical short circuits. Past experience has shown that test equipment and temporary modifications or repairs can contain materials not designed for aerospace applications (such as PVC) which can outgas toxic or corrosive materials or not meet flammability requirements. There have also been instances where an OEM or maintenance group has used a commercial off-the-shelf (COTS) item without verifying its suitability for aerospace use. It is the responsibility of the EWIS designer and/or certification authority to ensure only aerospace-grade materials are used; when not the case, the materials are evaluated for potential issues and a risk and mitigation strategy is in place. The MIL-DTL-81381 restriction was implemented to prevent employment of wire using polyimide in that configuration. Current wire constructions require arc track testing and passing of all wire constructions containing polyimide insulation. AS4373 cites the dry and wet arc test method 508 and 509. The arc track testing is extended to all materials which may exhibit the characteristic.

3.6.3 Sealing Materials

Only materials that are elastomeric and reversion resistant shall be used. Sealing materials required to seal wire junctions and terminations shall be selected from MIL-PRF-8516, MIL-PRF-23586, MIL-A-46146, or other material specifically approved by the procuring activity. MIL-PRF-8516 is the preferred material. The following temperature limits apply (the upper limit includes ambient plus temperature rise):

MIL-PRF-8516 -51 to 93 °C (-60 to 200 °F)

MIL-PRF-23586 -65 to 232 °C (-85 to 450 °F)

MIL-A-46146 -62 to 200 °C (-80 to 392 °F)

Rationale: Elastic materials can provide the necessary sealing against entry of accumulated condensation and other fluids. Many commercial non-aerospace-grade sealants can outgas acidic acid and revert in hot and humid environments. Reversion causes chemical changes to sealants degrading properties and, in the worst case, liquefy.

3.6.3.1 Process

Sealing materials shall be applied in strict conformance with the manufacturer’s instructions. Over-aged material shall not be used. The sealing material shall be held in place by suitable forms during the curing process.

Rationale: All sealants are application-process sensitive and might not perform as intended if not properly applied. Use of materials that have exceeded their storage life, have been improperly stored, or not applied per manufacturer instructions may not seal properly. Unconstrained movement of components prior to complete curing of sealing materials is also likely to compromise environmental protection.

3.6.4 Epoxy Adhesives

Only epoxy adhesives that can withstand sustained use without degradation of mechanical and adhesive properties at the maximum ambient temperatures shall be used for the bonding of fiber optic cables to termini. The time and temperature used for curing of epoxy adhesive used in fiber optic terminations shall be controlled so that a consistent bond is provided under all service conditions. Only epoxies which have inherent resistance to aircraft fluids including, but not limited to, fuel, lubricating oils, and cleaners shall be used. For wiring system applications requiring resistance to petroleum-based fluids, see 3.14.9.

Rationale: Epoxy adhesives have shown superior qualities for performance and longevity in aircraft service conditions. Some epoxies, when subjected to extreme heat, exceed their glass transition temperature (temperature at which the material softens and properties are changed), resulting in loss of adhesion. Curing at stepped temperature levels for specific periods may be required to elevate the glass transition temperature to the necessary level. Verification of cured epoxy properties may not be possible without destructive testing.

Proper surface preparation, such as cleaning, is critical for good epoxy adhesion. Without proper surface preparation, good epoxy adhesion will not be possible and adhesion failure is possible.

3.7 Component Selection and Installation

Components and wiring devices shall be selected for their application and installed in accordance with the requirements of this specification; in addition, selection and installation consideration shall be made relative to vehicle operation and servicing environments to ensure that they are not subjected to conditions exceeding the limits in the applicable wiring component specification.

Rationale: The procuring activity must specify the condition limits the vehicle will experience. The conditions should specify the operational conditions and whether the vehicle will be subjected to field maintenance under less-than-ideal conditions. The maintenance conditions should be specified in order for the contractor’s component selection and installation design to meet requirements.

3.7.1 Maintenance Considerations

The maintainability of the wiring system shall be a prime consideration in the design and selection of harnesses, electrical/optical cable assemblies, and wiring system components. All wiring shall be accessible, repairable, and replaceable at the maintenance level specified by the procuring activity. Other specific requirements concerning maintenance are specified in the appropriate paragraph on the subject.

Rationale: The procuring activity needs to specify the limits of conditions that the vehicle will be maintained in and whether it shall be subjected to field maintenance under primitive conditions in order for the contractor’s installation design to meet requirements. Unit maintenance under primitive conditions, poor lighting, or by inadequately trained personnel can seriously compromise air vehicle safety and reliability unless allowed for during initial design. Access to wiring without structural disassembly is mandatory at any maintenance level in order to facilitate operations.

3.8 Wiring Selection

Wiring shall be of a type suitable for the application. Wire 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. Typical factors to be considered in the selection are voltage, arcing, arc propagation, current, ambient temperature, mechanical strength, abrasion, flexure and pressure altitude requirements, and extreme environments such as Severe Wind and Moisture Problems (SWAMP) areas or locations susceptible to significant fluid concentrations. The wire shall be selected in accordance with Appendix A of this specification. Table A1 lists approved wire types for open wiring applications, which have normal, or medium weight insulation. Table A2 lists approved wire types for protected wiring applications, which have thin wall or lightweight insulation. The wire selection shall take into account all requirements of this specification and the following design considerations. For additional information concerning wire selection and sizing, refer to AIR6540.

Rationale: Wiring types specified in AS50881 Appendix A are qualified to provide lower failure rates on wiring system materials and components and support environmental sealing at connectors. These wiring types avoid conductor and insulation failures on critical flight control, armament, systems, etc., and facilitate service in more extreme operational and maintenance environments. Critical systems should be analyzed and designed so that long-term wire material failure modes, of a type that may be undetectable during initial qualification tests, cannot endanger aircraft crew members or maintenance personnel.

3.8.1 Conductor Degradation

Degradation of tin-, nickel-, and silver-plated copper conductors will occur when exposed to continuous operation at temperatures beyond their continuous rating. These effects shall be taken into account in the selection and application of wiring.

Rationale: Degradation in the form of inter-strand bonding, silver and tin migration, and oxidation of the copper strands can occur with continuous operation near, or exceeding rated temperature, resulting in loss of flexibility, increased electrical resistance, and loss of solderability.

3.8.1.1 Tin Plated Conductors

Wire using tin-plated conductors can be rated to 150 °C, dependent upon the insulation. Tin-copper inter-metallic will form in time resulting in an increase in conductor resistance and embrittlement. This increase in resistance is inverse to size, being up to 4% for the smallest gage. Also, the surface of the tin plating becomes oxidized with time, which inhibits solderability (see 3.8.1.3). These potential problems should be considered in the application of tin-plated copper wire.

Rationale: The 150 °C continuous rating of tin-plated conductor wire is based upon insulation heat resistance, as well as conductor rating. Conservative rating procedures can avoid problems with conductor plating. Selection of solder sleeves (e.g., AS83519/2 rated to150 °C) and other heat processed components must take into consideration the lower temperature rating of the devices to avoid insulation damage when exposed to temperature above the component's rating but below the 150 °C continuous rating of tin-plated conductor wire. As an example, the AS22759/14 wire insulation has a continuous rating of 135 °C.

3.8.1.2 Silver Plated Conductors

Wire using silver-plated conductors can be rated to 200 °C, dependent upon the insulation degradation. Degradation in the form of inter-strand bonding, silver migration, and oxidation of the copper strands can occur with operation near rated temperature, resulting in loss of flexibility. Due to fire hazard, silver-plated conductors shall not be used in areas where they are subject to contamination by ethylene glycol solution. These potential problems should be considered in application of silver-plated copper wire.

Rationale: The 200 °C continuous rating of silver-plated conductor wire is based upon insulation heat resistance, as well as conductor rating. Conservative rating procedures can avoid problems with conductor plating.

Red plague (cupric oxide corrosion of silver-plated copper conductors), another degradation mechanism for silver-plated wires, has also caused millions of dollars in damage to aircraft, particularly during assembly operations. AIR4487 provides additional information on this degradation mechanism.

The 200 °C continuous rating of silver-plated conductor wire is based upon insulation heat resistance, as well as conductor rating. Conservative wire rating procedures can avoid problems with conductor plating. Selection of solder sleeves (e.g., AS83519/2 rated to150 °C) and other heat-processed components must take into consideration the lower temperature rating of the devices to avoid damage when exposed to temperature above the component's rating but below the 200 °C continuous rating of silver-plated conductor wire.

3.8.1.3 Nickel Plated Conductors

Wire using nickel-plated conductors can be rated up to 260 °C, dependent upon the insulation. Not recommended for soldering applications.

Rationale: The 260 °C continuous rating of nickel-plated conductor wire is based upon insulation heat resistance, as well as conductor rating. Nickel-plated conductor wire is the more commonly used wire in aerospace vehicles because of its lower cost and temperature rating.

3.8.1.4 Conductor Solderability

Solderability of tin-plated copper wire degrades significantly within 6 months to a year after production. When significant oxidation occurs, mildly active rosin (RMA) flux is required for proper soldering and depending upon temperature exposure, as well as storage time, an activate rosin (RA) flux may be required. Soldering of tin-plated copper conductors should be avoided, but when required, compensating steps such as re-tinning shall be included in maintenance procedures for re-termination (refer to AS4461).

Rationale: The soldering of nickel-plated wire also presents problems that are not described in this specification. Solder sleeves and other devices intended for silver- or tin-plated wires are not suitable for nickel-plated wire. Generally, most interconnections in the wiring system involve crimped contacts. Soldering issues are more pronounced with relays and other devices that use solder hooks.

3.8.2 Aluminum Wire

The use of aluminum wire requires procuring activity approval. Aluminum wire shall be restricted to size 8 and larger. Aluminum wire shall neither be directly attached to engine mounted accessories nor installed in other areas of severe vibration. It shall not be installed where frequent connections and disconnections are required. All installations of aluminum wire shall be relatively permanent. Aluminum wire shall not be used where the length of run is less than 3 feet, nor in areas where corrosive fumes exist. Aluminum wire shall be terminated only by terminations specifically approved for this application (see 3.20.2 and 6.12).

Rationale: Aluminum wire is used to save weight, but such savings are not justified unless significant weight is saved and all environmental restrictions are observed. Material creepage of aluminum from vibration and stress can result in loosening and high resistance at connections. Fatigue caused by frequent flexure during maintenance can lead to material failure. Restrictions, such as sealed terminations, can prevent potential loss of “gas tight” connection (does not allow potentially corrosive vapor between strands and crimp barrel). Aluminum wire is limited to 150C, whereas copper wire can go to 260C. The higher temperature rating will often provide a better solution with a copper wire.

3.8.3 Fiber Optic Cable Selection

The type, size, construction, and distinct identification for fiber optic cable shall be suitable for the application and shall be approved for use by the procuring activity. Cable shall be of a construction which provides the required optical performance under all service conditions when the overall characteristics of end face polish, cable length, number of connections, installation bend radii, and environmental degradation are taken into account. Cable shall be resistant to environmental degradation and handling damage and shall be of a continuous temperature rating that is compatible with assembly process and installation environment. The fiber optic cable shall be distinguishable from aircraft wire harness assemblies as defined and approved by the procuring activity (refer to MIL-STD-1678).

Rationale: The use of fiber optic cabling provides a number of advantages over its electrical counterpart, including higher data rate transmission, immunity to external interference, e.g., electromagnetic vulnerability (EMV), non-emitting, lighter weight, the ability to support multiple wavelengths along a single fiber, small bend radius when using bend insensitive fiber. A reduction of data strength (light transmission) caused by poor installation (tight bend radius) or terminus end face contamination can lead to increased bit error rate that can affect system operation. MIL-STD-1678 has criteria concerning the selection, usage, and testing of fiber optic cable.

Tested and approved fiber optic cables shall be used. When employing fiber optics into system designs, it is important to remember that assembly, installation, and field servicing require specialized training, tools, and diagnostics.

3.8.3.1 Strength Member

Fiber optic cable shall include a layer of suitable, approved strength member material (e.g., fiberglass, Aramid yarn, or other non-metallic material) that can be mechanically attached to termini assemblies for the purpose of resisting tensile loads (refer to MIL-STD-1678).

Rationale: Attachment of the optical fiber in fiber optic cable terminations and the fiber itself have very limited ability to withstand the tensile loads that can occur on cables during installation and poor installation. Reacting these loads through a properly attached strength member preserves the cable integrity and its optical interface with the termini. MIL-STD-1678 has criteria concerning the usage of a strength member in a fiber optic cable.

3.8.3.2 Jacket

External jacket of fiber optic cable shall be resistant to moisture, mechanical damage, and temperature degradation (refer to MIL-STD-1678).

Rationale: The jacket protects the inner members of such cables against most of the elements, which might otherwise damage or degrade them. MIL-STD-1678 has criteria concerning the selection of an external jacket on a fiber optic cable.

3.8.4 Coaxial Cables

Coaxial cables shall be suitable for the application and shall be selected in accordance with A.3.1.5 of Appendix A.

Rationale: Potential cable degradation can cause communication loss and result in flight hazards. One method of communication degradation can be caused by damage to dielectric layer or termination aging; degradation of either can be difficult to diagnose. The selection guide of approved constructions included in AS50881 Appendix A facilitates predictable system range, operation characteristics, and signal clarity.

For applications above 400 MHz and in critical RF circuits, critical electrical characteristics such as attenuation, capacitance, structural return loss, environmental requirements, short leads, and grounding shall be considered in design. Coaxial cable operating in the transverse electromagnetic mode (TEM) and coaxial cable with tubular metal outer surfaces shall be identified by a violet-colored marker (1-inch nominal width) at intervals not greater than 24 inches of length and within 6 inches of termination. Transmission lines in accordance with MIL-T-81490 need not be identified by colored markers if the color requirements of MIL-T-81490 have been met. For applications above 400 MHz and in critical RF circuits, critical electrical characteristics such as attenuation, capacitance, structural return loss, environmental requirements, short leads, and grounding shall be considered in design. Coaxial cable operating in the transverse electromagnetic mode (TEM) and coaxial cable with tubular metal outer surfaces shall be identified by a violet-colored marker (1-inch nominal width) at intervals not greater than 24 inches of length and within 6 inches of termination. Transmission lines in accordance with ARP81490 need not be identified by colored markers if the color requirements of MIL-T-81490 have been met. ARP81490 is not for U.S. Navy applications.

Rationale: Damage-related degradation of signal carrying properties of coaxial cables may not be apparent by physical inspection nor readily measurable on fielded aircraft without specialized equipment such as a time domain reflectometer (TDR). A very important characteristic of each cable is making such measurements of the cable’s known properties.

The requirement of distinctive color markings is to provide an alert that for maintainers that special handling and termination techniques are required.

ARP81490 is not for U.S. Navy applications because MIL-T-81490 contains strict performance requirements which can be employed in contractual requirement documents, unlike ARP81490, which is for guidance only.

3.8.5 Harnesses

Harnesses shall be of either open or protected design. Open harnesses are preferred for maintenance considerations.

Harnesses may be designed to meet mechanical or shielding requirements. The use of protected harnesses shall be avoided unless wiring design considerations dictate their use and is subject to the approval of the procuring activity. The design details of protected harnesses are also subject to the approval of the procuring activity.

Rationale: The benefit of open harness design is that the wiring is easily accessible for maintenance actions, modifications, and replacement. A potential drawback to open harness design is that the wiring can be easily damaged during normal maintenance activities.

Protected harnesses, those with secondary harness protection, provide for limited maintenance actions and normally require replacement if any problems are identified with the harness. When approved for use, protected harnesses allow application of thin-walled wire insulation; the thin-walled wire insulation provide a weight and volume advantage, but this needs to be considered against the additional weight and volume added by the secondary harness protection.

Secondary harness protection can provide the additional benefits of shielding and jacketing and can employ molded terminations to avoid wire/termination breakage and improve environmental/electromagnetic shielding.

Protected and unprotected wire harnesses may be routed together in the same harness. In these instances, special barrier material may be used where protected and unprotected wire bundles are joined together.

UAV Consideration: Closed harness design is not typically used for UAV design. For UAVs, serviceability and risk are lower considerations than space and weight reduction.

3.8.6 Insulation Compatibility with Sealing and Servicing

Wiring terminations in devices where the wiring must be sealed to provide an environment resistant joint shall have insulation compatible with the sealing feature of the device. For wire to connector sealing grommet compatibility, refer to AIR1329. When the diameter of the wire is smaller than the minimum allowable diameter, a length of shrink AS23053/5 Class 1 or 3, AS23053/8, AS23053/11, AS23053/12 Class 3, 4, or 5, or AS23053/18 Class 2 or 3 sleeving shall be installed behind the contact and shall protrude through the environmental seal. 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. Sealing on tape wrapped, braided, striped, or other than smooth circular insulations shall be specifically tested for compatibility and shall be subject to procuring activity approval, unless compatibility has been demonstrated in the qualification of the terminating device. After installation in the vehicle, the integrity of the sealing features of all such devices shall be intact, and able to perform their function. A device shall be considered as sealed if the outermost sealing feature (web) is in full contact with the device when visually inspected. The wiring shall be installed so that transverse loads will not destroy the integrity of the sealing feature of the wire.

Rationale: Moisture ingress at connector wire entry can cause short circuits and resultant system malfunction or failure. Sealing at the connector avoids pin-to-pin shorts and potential corrosion of wires and contacts. Using the correct size contacts, wire gauge, and wire insulation construction can help to reduce wire breakage, pullout, and ingress of contaminants.

Wire harness routing has an impact on the connector sealing. It is recommended to avoid side loading and sharp bends at the wire exit from the connector as this preserves the sealing capability of the connector's rear grommet.

3.8.6.1 Wire Diameter

The finished wire outside diameter or finished wire diameter plus sleeving (see 3.8.6) shall be within the limits specified for the grommet specified in the appropriate component specification and shall not exceed the capability of contact servicing tools to insert and release contacts.

Rationale: The limits for each connector type and contact size must be observed to allow the successful use of standard contact insertion/extraction tools. Oversized wires (or wires plus sleeving) can become lodged in connectors, and it can be difficult to remove the contact without causing damage to connector contact retention locks.

3.8.6.2 Potting Seal on Wire or Cable

The potting shall be bonded to the outer-most surface of the wire or electrical/optical cable in such a way to ensure an environmental resistant seal.

Rationale: Adherence of potting to the wire surface is dependent upon both the potting material and the wire surface characteristics. It is necessary to follow the manufacturer's recommended preparation and application process to ensure a quality seal and avoid air entrapment during the potting application. Some wire insulation types require surface etching to ensure potting adherence potting to outer wire surface.

3.8.6.3 Insulation Degradation

Wiring shall be handled, stripped, and installed so as not to distort, roughen, or damage the insulation on which sealing is to be affected. Methods of marking and identification shall be applied so as not to provide a track for moisture entry. The impression left on the insulation of shielded and twisted electrical cables can also cause unacceptable degradation of the insulation in relation to the elastomeric seal. Caution shall be used to avoid this condition.

Rationale: Moisture ingress at connectors can cause short circuit system failures or induce interconnection with unrelated systems. When descending from higher altitudes, condensation typically forms on wire bundles in unpressurized zones. This moisture can readily flow along wire surfaces into any available cavity, potentially causing corrosion of conductors or terminations. The absence of a smooth surface at the connector wire grommet entry can affect its ability to provide an environmental seal.

3.8.7 Corona Prevention

In the selection of electrical wiring, considerations shall be given to the prevention of corona discharge. Useful information relating to corona prevention is contained in 6.6 and should be reviewed prior to the selection of all wiring.

Rationale: At very high altitudes and AC voltages exceeding 240 Vrms, electrical discharges can occur on or around thin-walled wire insulation and the surface of any adjacent grounded material. If such conditions are to be encountered, heavier walled wire shall be selected as defined in AS50881 6.6. See 3.19.

This is applicable to any voltage difference, including phase-to-phase wiring or interconnections. The "corona-start voltage" from AS50881 Figure 1 is only applicable to AC-waveforms since it is predicated on relative permittivity. To apply Figures 1 and 2 to a given design, the following steps are recommended:

- Determine the phase-to-phase or phase-to-ground RMS voltage.
- Identify the correct altitude and temperature curve.
- Determine the insulation permittivity, taking into consideration the permittivity over the normal and abnormal temperature and frequency ranges.
- Use the provided formula to determine the equivalent thickness of the wire coating/plating, taking into account the insulation thickness of both wires.
- Find the intersection of the altitude curve and the equivalent thickness to find the corona start/inception voltage.
- Use the equivalent thickness to calculate the required thickness for the insulation used.

It is important to consider the largest voltage transient that may be encountered in the system and a safety factor.

3.8.8 Minimum Wire Size

This specification permits the general use of size 22 wire as the minimum wire size for airplanes, helicopters, and lighter-than-air vehicles. Use of size 24 and smaller gage wires in harnesses shall be limited to wires which have break strength of 20 pounds minimum. Size 24 and smaller gage wires shall not be installed as a single wire. Use of size 26 and smaller requires procurement activity approval. This restriction in aerospace vehicle applications is due to maintenance difficulties.

Rationale: Improperly calibrated crimp tools, vibration, flexure, tensile loading, and thermal cycling can all contribute to conductor strand breakage or erratic system operation (caused by the conductor making intermittent contact). Wiring that requires frequent disconnection and utilizes undersized wires are more susceptible to conductor breakage. Most common wire constructions include high-strength copper alloy variations for smaller wire gauges; these may be used to achieve the break strength minimum specified in this requirement. This requirement precludes the use of smaller wire gauges included in cables.

3.8.8.1 Current Carrying Capacity

Wire shall be sized so that all wires distributing current from a circuit protective device have a capacity which is equal to or greater than the rating of the device under all operating conditions. Circuits shall be individually powered with a single operating current interrupt system. Independently operated circuit protection devices shall not be paralleled or ganged together to achieve a required current rating. Power source feeder wires shall be sized for the rated capacity of the power source. A guideline for the continuous current in each wire is shown in Table 1. Table 1 assumes an ambient temperature of 70 °C, a harness or harness branch of 33 or more electrical wires for sizes 26 through 10, and nine electrical wires for size 8 and larger, carrying 20% or less of rated harness or harness branch current and operating at an altitude of 60000 feet. The use of this tabulation shall not eliminate other requirements for wire selection. Data from Figures 3, 4, and 5 may be used for determining wire size for conditions other than those contained in Table 1. The use of Table 1 and Figures 3, 4, and 5 shall not eliminate other requirements for wire selection. Current carrying capacity listed in Table 1 or calculated using Figures 3, 4, and 5 are capable of handling frequencies up to 800 Hz; above 800 Hz, the AC resistance must be corrected for skin and proximity effects. When reducing wire size, unprotected wires connecting power buses or feeders to any circuit protective devices shall be maintained within the same power panel and kept to a minimum length.

Rationale: Wiring must be protected from excess electrical current by circuit protection devices capable of disconnecting the power after a short overload period. Table 1 can simplify some size calculations. The parameters included in AS50881 Table 1 exceed the altitude and ambient conditions encountered during most aircraft operations, but the table does not cover separately routed power feeders, higher altitudes, or high temperature compartments. The tables do not consider cable jackets or overbraiding, which can significantly increase wiring temperatures or wiring near enclosures or structures.

Power source wires connecting bussing within insulated panels are less susceptible to ground faults if the wire length is minimized. Unless protected, current rise-related heating of wire caused by excess loading will break down, insulating materials over time, and can cause wire-to-wire or wire-to-ground shorts.

Most circuit protective devices operate through sensing of heat buildup which is proportional to load current. Their response time is rapid with the highest current overloads but may be protracted when overloads are only slightly greater than current rating. (For example, MS3320 thermal circuit breakers may indefinitely run at 115% current rating without tripping.) Power feeders should be able to carry the maximum power source current. Undersized wires may fail at random intervals due to insulation breakdown, especially in high temperature areas.

Refer to MIL-STD-7080 4.9.1 and 4.9.2. In order to avoid current-related thermal overload damage to wiring and surrounding materials, wires must be protected through coordination of their capacity with that of the associated circuit protective device. Without this rule in AS50881, wires could be sized to suit the running load (typically well below the circuit protector rating) and not be protected by the circuit protection.

Power feeder wiring needs to be sized to the power source capacity to ensure that the current protective features of the power source system can effectively avoid damage to wiring and surrounding materials in the event of overload. It is impossible, during initial design, to anticipate the extent of additional loads that will be applied to a power source during the lifetime of an air vehicle.

The use of paralleling, jumpering multiple circuit protection devices to achieve a higher rated current (e.g., using two 50 A breakers to achieve 100 A protection), does not guarantee uniform current distribution through each device and can allow one device to be overloaded even if total capacity is adequate. Although not specifically prohibited, paralleling circuit breakers is not a recommended practice.

3.8.8.1.1 Wiring in Harnesses

Table 1 current ratings for electrical wires in harnesses are based upon 33 or more electrical wires for sizes 26 through 10 and nine electrical wires for size 8 and larger operating at 60000 feet altitude, and an ambient temperature of 70 °C. The total current carried by the harness shall not be more than 20% of the numerical total obtained by adding the carrying capacities taken from Table 1 (or calculated from Figures 3, 4, and 5 for ambient, altitudes, or harness loading factors differing from those assumed in Table 1), for the appropriate wire construction temperature rating for all the electrical wires in the harness. For example, if a wire harness contains 33 size 20 electrical wires rated at 200 °C, the numerical total is 297 A, 20% of which is 59.4 A and the maximum allowable total current in the harness is 59.4 A and the maximum allowable current for any size 20 wire in the harness is 9 A. An electrical cable in a harness shall be treated as a number of individual electrical wires equal to the number of conductors in the electrical cable, excluding shields.

In smaller harnesses, the allowable percentage of total current may be increased as the harness approaches the single wire configuration. The harness ratings contained in Table 1 were derived from Figures 3, 4, and 5. Single electrical wire in free air ratings for copper wire were determined at T (200 to 70 °C) (for aluminum wire de-rate the free air rating of copper wire by 20%) and de-rated for (a) operation at 60000 feet altitude, (b) harnesses of 33 electrical wires or more, and (c) carrying 20% or less of rated harness current. For conditions other than (a) through (c), see 6.7.

Rationale: Bundle construction and bundle current loading are primary factors affecting the heat rise within a wire harness. The wire bundle heat rise must be accounted for along with the individual current loading of a wire in determining the required wire size. The conventions required for calculation of loading capacity of individual wires and wires in various wire harness sizes have been verified by individual testing and through extensive application in large aircraft fleets that have encountered diverse, and sometimes extreme, operating conditions. Wires carrying current that are not protected by circuit protector may experience insulation failure or fire damage. Protective layers over the wire or bundle, such as overbraid shield or mechanical chafe protection, have been shown to adversely affect the wire insulation of the wires, as the wire/bundle's ability to reject or transfer the heat during high current loading is reduced.

3.8.8.1.2 Wire Terminations

The continuous current ratings of Table 1 were derived only for wire application and cannot be applied directly to associated wire termination devices (e.g., connector contacts, relays, circuit breakers, switches). The current ratings are limited by the design characteristics of the device. Care shall be taken to ensure that the continuous current value chosen for a particular system circuit shall not create hot spots within any circuit element which could lead to premature failure. Acceptable temperature levels of circuit components shall be those defined by the particular circuit component specification.

Rationale: Devices used in wiring systems have various temperature ratings and are dependent upon the conductor material, plating, and insulation materials used. Wire terminations do not normally match that of the associated wire. Conductive sections or insulating material of termination may fail if the current carrying rating or temperature rating limits of specific devices are exceeded. Loss of power source may be at risk. Insulation breakdown of terminating device plating, degradation, or excess voltage drop may occur. This is likely a greater issue when using fully loaded high temperature rated wire (e.g., 260 °C).

3.8.8.2 Ambient Temperature

The contractor shall ensure that the maximum ambient temperature that the wire bundles will be subjected to, plus the temperature rise due to the wire current loads, does not exceed the maximum conductor temperature rating found in Appendix A in Tables A1 and A2. Figures 3, 4, and 5 may be used to determine the appropriate current loads when the following conditions are known: maximum ambient temperature, maximum conductor temperature, maximum altitude, and the number of electrical wires in a bundle. See example in 6.7 for method of calculation.

Rationale: Heat-related insulation breakdowns over extended periods could result in fires caused by short circuits between wires or to adjacent structure, particularly on heavy current power feeders. Wire bundle heat rise calculation must be based on current in all wires, wire resistance ratings, and number of wires carrying current during full loading at maximum ambient temperatures. Temperature surveys of all aircraft sections, including accounting for protective jacketing or insulated enclosures, should be addressed when wire size and insulation construction are selected.

3.8.8.3 Deleted

3.8.8.4 Voltage Drop

For power distribution circuits, the total impedance of supply and return paths shall be such that the voltage at the load equipment terminals is within the limits of MIL-STD-704.

Rationale: Critical equipment may not function properly if the voltage limits are outside of its specified revision of MIL-STD-704. Typical equipment specifications include identification of the applicable MIL-STD-704 revision that specifies voltage levels at which the equipment will function properly. Also note that different revisions of MIL-STD-704 may apply. The voltage drop calculation must include circuit protective devices, wiring, and all terminations to ensure that the voltage drop is within the specified limits.

Under-voltage protection of power sources may cause shutdowns if voltage limits are exceeded. Power generation equipment is also applicable.

Most electrical system components specifications include requirements on voltage drop. Depending on the component type, the voltage drop is specified at ambient and/or at elevated temperatures. This information can be a used as a starting point for voltage drop calculations.

3.8.9 Maintainability

Wire selection shall be affected by considerations of the types and frequency of maintenance action.

Rationale: Maintenance induced damage is frequently among the leading causes for wiring failure. The wire selection and secondary harness protection should consider the potential impact of normal maintenance activities.

For harnesses routed subject to repeat flexure or attached to equipment requiring frequent removal, wires with a greater number of conductor strands should be considered as they tend to have better flex life endurance and extend service life. Harnesses routed in areas subject to frequent maintenance action should consider abrasion resistant secondary harness protection or wires/cable with greater abrasion resistance properties.

The difficulty of wiring component repair should be considered prior to design implementation. The cost-benefit of using EWIS components requiring specialized tool and/or training should also be a selection factor. Components that require specialized tooling and/or have not been approved by the procuring activity have caused significant issues on several platforms.

3.8.10 Wiring Selection for Special Applications

The general-purpose electrical wires listed in Appendix A do not perform equally in all applications. The detail characteristics of the specific wire types shall be considered for the following special applications.

Rationale: Wire failure in areas of severe environment can cause safety issues with engine operation, wing folding, and landing gear folding. Critical armament and fly-by-wire circuits should receive special attention. Some insulation types do not provide reliable service under severe high temperature, high vibration, flexure, and fluid exposure. Severe heat, wind, and moisture areas need certain environment-resistance properties. Engine compartments, landing gear, wing fold areas, and high wattage lighting, etc., may need special wire types. Fire detection and extinguishing systems require fire zone wire (wires selected from AS50881 Appendix A that retain integrity for a limited period during a fire) so as to be able to continue functioning during a fire.

The use of fire zone wire in a combat aircraft for flight critical wires should be considered. Many combat aircraft (and some civil aircraft) have experienced fires or arcing damage that could cause short circuits. The fire zone wire in Table A1 in AS50881, MIL-DTL-25038 has been used traditionally in applications where fire detection, fire suppression, or fuel shutoff devices are located within engine fire zones. This type of wire can be considered for the most safety-critical circuits, particularly in congested areas where channel separation is minimal. In some helicopters, the multiple channels are each above the other around the main gear box, connecting to the flight control actuators. The combination of ballistic damage and/or ignited fuel or oil could easily expose all channels to fire.

3.8.10.1 Severe Wind and Moisture Problems (SWAMP)

Suitable wire types in accordance with AS22759, listed in Appendix A, are preferred for SWAMP areas or both. Applications include wheel wells, near wing flaps, wing folds, and pylons.

Rationale: Wires having a fluoropolymer insulating jacket, when properly rated, have demonstrated excellent ability to withstand SWAMP area conditions. Other wire types have occasionally succumbed to extended wind and moisture exposure by delaminating or experiencing other forms of degradation.

Long-term humidity exposure and/or force hydrolysis testing should be considered for components located in SWAMP areas. The suitable wire types identified in AS50881 Appendix A should be considered for use in SWAMP zones.

3.8.10.2 Frequency Flexure

Wire types in accordance with AS22759, listed in Appendix A, shall be used for areas that require repeated bending and flexing of the wiring.

Rationale: Wires having a fluoropolymer insulating jacket have demonstrated excellent ability to withstand repeated flexure conditions even when subjected to moisture, other fluids, and handling conditions. Specialized wire types which achieve the correct cross-sectional area by having smaller diameter strands in greater numbers have displayed excellent flexure characteristics in specialized applications.

The frequency of flex and the bend severity (tightness of bend) should be considered when selecting wires for these applications. A smaller harness bend radius will result in a shorter fault-free service life. Tests methods such as AS4373 Method 704 (flex life) can be considered for determining comparative flex life performance. The test is a performance comparison versus a long-term reliability test.

3.8.10.3 Electromagnetic Interference (EMI) and Electromagnetic Vulnerability (EMV) Sensitive Areas

AS85485 cable is preferred for use in EMI and EMV sensitive areas. For complete installation guidance, refer to AIR4465. The following precautions must be taken when routing and installing AS85485/8 or /12 shielded and jacketed filter line wire. The black jacket is conductive and should be routed and clamped or protected to ensure clearance to all exposed (uninsulated) power distribution points. The use of discrete filters or other suitable means should also be considered in instances where more effective attenuation of interference can be provided at specific frequency ranges or where replacement of existing wiring is impracticable. Qualified examples of such devices include active components integrated in terminal junctions (refer to AS81714).

Rationale: The reliable performance of EMI/EMV sensitive wiring can only be assured when adequate shield construction and proper shield grounding are employed. Available means to reduce the impact of EMI/EMV include:

- Filter line cable has excellent attenuation characteristics for high frequency interference but does not attenuate as well at lower frequencies.

- Additional separation and/or ferrous metal shielding are more effective at lower frequencies.

- Discrete filters within sensitive equipment units may be required.

Regardless of the EMI/EMV protection employed, tests should be conducted to verify performance. Performance of shields is very dependent on adequate connection to aircraft ground plane. Such connections must be protected from corrosion. Sealed terminations are advisable. Flight control systems, armament systems, and other critical circuits can malfunction if exposed to high intensity radiated fields or interference from on board electrical or electronic systems.

The new systems are likely to use very high frequencies (>100 MHz) and are very sensitive (millivolts/microvolts) and are more susceptible to interference. The shielding practices that have been used in the past are no longer effective for these new systems. Many shielding techniques were only to reduce coupling between cables and were not intended or required for outside interference. The systems that they were protecting were low frequency systems which were only affected by low frequency switching and analog noise. Many new systems are affected by much lower level interference and higher frequency interference which couples more efficiently to the normal length cables connected to the component and pigtails.

The cables are excellent antennas at higher frequencies but were poor antennas at the lower frequencies. For the new systems, cable/harness shield terminations should employ 360-degree shield connection to the backshells at both ends of the harness (potential terminations for this include: AS85049/103, /104, and/105 type terminations). Pigtails do not offer a low enough impedance to route the signal to the ground/reference.

Because of the complexity of EMI/EMV, it is recommended that determinations on protection should be reviewed by an experienced EMC/EMI engineer and performance be validated through testing.

Shields may not be terminated to saddle bars on backshells. Examples include AS83519/2 solder sleeves with a 22-gauge bleed wire. This termination process has been shown to operate as an antenna and induce unwanted EMI/EMV in harness wiring and adversely affect system operation. Shield terminations using 360-degree shielding are recommended. For individual shielded cable (e.g., WC27500), the AS83519/3 or /5 using braid cable for the bleed wire are recommended. That termination is done at the shield splice or at the banding platform of the EMI/RFI backshell (e.g., AS85049/80 through /92).

The AS81714 terminal junctions such as /21 and /23 have the ability to integrate electronic components (e.g., diodes, capacitors, resistors) which may be integrated in the affected wire as an in-line splice. Thus, tailored devices can be added to provide system-specific EMI/EMV vulnerabilities. For in-line connector-saver type of tailored protection, filter connectors (refer to MIL-DTL-32633) may be developed.

Additional considerations for shielding an EMI/EMV is included in 3.11.1.

3.8.10.4 Thermocouple Wiring

The following is required when using thermocouple wires (see 6.8):

a. Thermocouple contacts shall not be used except to meet system requirements (see 3.8.10.4[b]) such as thermal gradient conditions. Thermocouple crimp contacts in accordance with AS39029 shall be used to meet system requirements such as thermal gradient conditions.

b. Transition from thermocouple wires to copper wires are permitted with the environmental sealed connectors specified in 3.14.1 or AS81714/12, type 2 in-line junction. When gold-plated crimping pairs are used, precautions should be taken to ensure that the connector external temperature ambient and internal hotspot temperature is such that both the wire to contact junctions for the thermocouple wires within the connector are at the same temperature.

   Rationale: Thermocouple material in wire or terminations adds substantially to cost and should only be used to avoid dissimilar metals voltage coupling inaccuracies. The dissimilar metals coupling that exists between thermocouple wire and attached non-thermocouple contacts generates a voltage. When no temperature difference is present on both sides of a mated pair of such contacts, dissimilar metals coupling voltages generated on both sides of the connection offset each other.

   When gold-plated crimped contact pairs are used, precautions should be taken to ensure that the connector external temperature ambient and internal hotspot temperature is such that both of the wires to contact junctions for the thermocouple wires within the connector are at the same temperature.

   Additional design and typical system configurations which employ thermocouples are described in AIR65.

c. Splicing of thermocouple wire shall be avoided. If splicing is necessary (see 3.19) an AS81714/12, type 2 dual in-line junction (splice) or AS81714/11 single in-line junction (splice) or AS81824/1 splice shall be used.

d. The connector, in-line junction, or splice shall provide an environmental seal on the thermocouple wire. The tensile characteristics of the contact/thermocouple combination shall be equal to or greater than the tensile characteristics of the thermocouple wire.

e. AS5419 thermocouple extensions or MIL-DTL-5846 thermocouple wires shall be used to meet system requirements, such as thermal gradient (see 3.8.10.4 [b] for exception).

f. For aircraft engine application and configuration, refer to AIR65.

Rationale: AS81714 splices provide environmental sealing at splicing junctions to preclude the presence of moisture. Moisture can support an electrolytic cell at dissimilar metal junctions and generate false voltages. When such precautions are taken and no thermal gradient across the connection is present, dissimilar metals coupling voltages generated on both sides of the connection offset each other.

3.9 Wire and Electrical/Optical Cable Identification

Each wire and cable shall be marked with an identification code on its jacket or sleeving of the electrical/optical cable. Hot stamp marking shall not be used. Identification marking (wire, cable, sleeves, labels, tags, etc.) shall be in accordance with AS5942 or AIR5558 when laser marking is used.

Rationale: Identification code marking is used to avoid interconnection error-related failures. Hot stamp marking can cause failures by introducing breaks in wiring insulation that result in short circuits failures and arcing (refer to AIR5575). Experience has shown that inadequate operator training with hot stamp equipment, increased temperature, and pressure used to overcome worn dies has initiated cracks that allow wire-to-wire and wire-to-ground shorts. It can also create cracks in fiber optic cable glass strands, resulting in degraded signal transmission due to refractory losses in the resultant air gaps.

Because this specification applies to wiring and not equipment, the hot stamping restriction does not apply to electrical components with lead wires. ARP5369 provides recommended practices to ensure hot stamping is correctly performed.

Inkjet marking can provide adequate mark durability on some insulation materials if properly heat treated. Excimer laser marking provides excellent clarity and durable marking, even on very small wires and on Teflon-insulated wires. The use of sleeve marking provides a convenient and safe method for coaxial and fiber optic cables.

3.9.1 Assignment of Identification Code

The identification code for wiring shall be significant or non-significant in accordance with Appendices B or C, as specified by the procuring activity. Unless otherwise specified, the identification code for all U.S. Military applications, shall be significant in accordance with Appendix B (see 6.2).

Rationale: The accurate reading of wire code numbers is the basis for assisting the operator in routing and connecting wires, connecting the correct terminations, troubleshooting, and repair of any system's wiring.

Wire/cable identification codes that include the wire gauge help prevent using incorrectly sized conductors which could become overheated or fail to provide a durable connection. Wiring termination errors or incorrect sizing could cause system malfunctions which could lead to a mishap.

Reliable electrical and avionics systems require careful routing and termination. The effects of induced EMI from other on-board systems can be avoided by careful organization of wire routing and effective shielding. The required isolation depends heavily on the understanding of the signal characteristics and sensitivity of each wire segment. The use of circuit identification code numbering is an essential tool in avoiding electromagnetic vulnerability.

Non-significant wire numbering is particularly helpful in systems that employ protected harnesses in which wire numbers can be flexibly used for various functions. The identification codes also help when providing provisional wiring for future systems. Significant numbering systems are better suited to open wiring harnesses in which troubleshooting depends heavily on associating specific wires with their function as identified by the wire code.

3.9.2 High Voltage (600 VAC/600 VDC or Greater)

For U.S. Military applications, wire used in high voltage applications (600 VAC/600 VDC or greater) shall be distinguished from other wire/cables by using an orange (preferred International Orange 12197) color as the preferred primary insulation/jacket color. The wire shall be identified with a mark or marker sleeve with HIGH VOLTAGE preceding the existing wire ID marking, at intervals of 6 to 60 inches.

Rationale: Immediate recognition of high voltage cable routing is the desired impact. The color orange is used due to the automotive standard for high voltage cables presently in place internationally.

3.9.3 Marking

Rationale: Reliable aircraft systems depend heavily on correct connections which are facilitated by readable wire identification codes.

3.9.3.1

The wire identification code shall be printed to read horizontally from left to right or vertically from top to bottom. See Figures B1 and B2.

Rationale: Without a consistent, permanent, and non-degrading marking method, numerous connection related mishaps could occur. A well-defined convention and a very detailed set of requirements is necessary to ensure such consistency.

3.9.3.2

The characters shall be legible and permanent, and the method of identification shall not impact the characteristics of the wiring.

Rationale: Reliable marking is a workmanship-sensitive process having numerous opportunities to provide less legible and durable marks. Process control, quality equipment, and well-defined conventions are essential. Marking-induced wire damage could also result in short circuits, arcing, or signal loss.

3.9.3.3

Wiring shall be identified throughout its length at intervals not longer than 3 inches, as measured from the end of a mark to the beginning of the next mark.

Rationale: Wiring IDs greatly aid in troubleshooting and locating specific wires in a large wire bundle. Modern insulation constructions may be a single color making it critical to have reoccurring wiring IDs. Closely spacing wire code markings assures that they will be visible at termination points and when repairing damaged wire segments. Automated equipment controlled by comprehensive computer systems can provide high quality marking that is considerably less labor intensive and error prone than older manual systems. Harness assembly interconnections can be readily accomplished when operators have easily understood code numbers.

3.9.3.3.1

When it is not possible to print directly on a wire or electrical/optical cable, an identification marker shall be used. The marker shall be an AS85848 or AS23053 heat-shrinkable sleeve, an AS23190 (AS33681) identification strap (see 3.11.3.8), or a MIL-I-3190 glass braid. The marker shall not be used as an electrical insulating device. For repairable, protected harnesses, the marker shall be visible during maintenance within the accessible areas at the rear of the connector. The markers shall be used as follows:

NOTE 1: AS23190 (AS33681) identification strap shall not be used within electrical/optical cables, groups, harnesses, or bundles.

NOTE 2: AS23190 (AS33681) identification strap is not authorized for U.S. military aircraft.

a. Electrical/optical cables upon which identification cannot be printed shall be identified by printing the identification code (and individual wire color, when applicable) on a marker placed external to the outer surface. The marker shall be placed at each end within 12 inches or before the first clamp (whichever is less) and at intervals not greater than 3 feet.

b. Wires on which identification codes cannot be marked shall be identified by printed markers at each end within 12 inches or before the first clamp (whichever is less) and at intervals not greater than 3 feet.

c. Wires for which the identifications are reassigned after installation in the aircraft may be re-identified by markers at the termination of each wire segment. It is not necessary to re-identify such wires throughout their lengths.

Rationale: Maintainers that are required to modify or repair wiring must identify each affected wire segment near the termination or damage point. They are required to associate wire identification codes with the contacts on any device removed or replaced or otherwise affected by aircraft modifications. The visibility of these identifiers in areas normally exposed during such activities allows re-termination to be conducted without excessive disassembly of the harness. Marking that is obscured by other wiring requires removal of secondary support ties or harness jacketing to access wire code numbers. The excessive removal of these ties could risk possible insulation damage.

Application of sleeve markers, strap markers, or other means not requiring the use of complex marking equipment enables field operations to incorporate modifications or replacement using wire and cable bulk materials. It also facilitates re-identification of existing wires or cables during modifications without the need for replacement.

3.9.3.3.2

Short electrical wires and electrical/optical cables less than 6 inches long need not be identified on the aircraft but shall be completely identified on the drawing.

Rationale: The termination point at each end of short wires is normally visible during maintenance or modification.

3.9.3.3.3

For developmental model aircraft, wiring identification may be provided at junction and termination points only.

Rationale: Servicing of such aircraft is usually accomplished by skilled technicians. The need for maintenance repairs is slight.

3.9.3.3.4

For protected harnesses and shielded, jacketed multi-conductor electrical cables and when using non-significant wire identification, color coding or its alphanumeric equivalent may be interchanged within the same harness. The alphanumeric equivalent of the color code shall be in accordance with MIL-STD-681. (See C.3.2.3.2 in Appendix C for an example of the alphanumeric equivalent of color coding.)

Rationale: A well-defined convention and a very detailed set of requirements is necessary to ensure the understanding of color code equivalent numbers. Both installers and maintainers benefit from the use of a consistent color code scheme. Maintainers required to modify or repair wiring must first identify each affected wire segment near the termination or damage point. During the repairs/modifications, the maintainers are required to associate wire identification codes with the contacts on any device removed, replaced, or affected.

3.9.3.3.5 Harness Identification

All harnesses shall be identified to facilitate maintenance (see Appendix B). Identification shall be done on nonmetallic bands affixed to the harness and shall be located within 3 inches of the connector identification band and in each bay through which the harness is routed. All markers shall be visible during maintenance within the accessible area.

Rationale: Harness identification is an essential part of performing wiring maintenance on any aircraft. Finding a specific termination or wire would otherwise be impossible, given the possibility of hundreds of separately identified harness assemblies routed within the air vehicle. The application of harness identification markers and ensuring that the markers represent the current harness configuration is essential to correctly interpreting maintenance manuals, verifying modifications, and supporting system/zonal inspections. Nonmetallic identification bands are unable to create short circuit paths between conductors and are unlikely to chafe wire insulation. Unless such bands are located at regular short intervals, they may not be visible without disassembly.

As a means of assigning wire harness identifiers, the use of drawing numbers can be an effective means of assigning harness identifiers. The benefit of this is that the use of a part number in the wiring data base provides a significant means of identifying the configuration when delivered.

UAV Consideration: For those areas that are not accessible regularly, the harnesses may not be labeled. When accessing these areas, additional care should be taken to identify the correct markings.

3.9.3.3.6

Harness critical clamp locator markers are used when there is a design requirement to control harness movement or slack in critical locations and maintain specified adequate clearance and separation from equipment and structure. Clamp locator markers may be up to 2 inches wide. Color and location shall be specified by the design organization and approved by the procuring activity (refer to ARP5614).

Rationale: Since some wire harnesses perform critical functions, flex, or are very long, their installation is pivotal. For example, if a landing gear harness which flexes every time the gear cycles up and down doesn't have the correct amount of slack in the right places, it can be damaged (stretched or pinched). The same goes with very long airframe harnesses which can span the length of an entire airframe. If the right section is not secured at the correct airframe station, there may be excessive/not enough slack at the other end of the harness. Thus, 2-inch-wide critical markers are typically painted on the harness at those clamp locations. Thus, when the clamp secures the harness at that or those locations, the finished installation is per drawing. Note that the OEM drawing identifies where the critical clamp markers are to be located. When the clamp is installed correctly, some of the painted marker needs to be visible on both sides of the clamp. Heat shrink labels should not be used, as they may shift or slide down the harness length, altering the intended location on the harness. Note that ARP5614 provides recommended marking methods and additional guidance on the topic.

3.9.3.3.6.1 For U.S. Department of Defense Contracts for Air Force and Navy

Markers shall be located under the harness clamp, such that the colored marker is exposed on both sides of the clamp. When required, clamp locator markers, as a minimum, shall be placed at each harness endpoint (i.e., last clamp prior to termination) and at the mid-point harness clamp locations. Additional clamp locator markers should be added as necessary, for areas in close proximity to fluid carrying lines, tubes, hoses, moving parts, and components.

a. For harnesses that connect with moving components or surfaces that flex or move, clamp locator markers shall be located at the last clamp point prior to area of harness movement.

b. When required at harness breakouts, clamp locator markers shall be located at the clamp position closest to breakout point except for breakouts that occur within 18 inches of a previously established clamp locator mark location.

3.9.3.4 Identification Requirement for TEMPEST Wire and Cable

For wiring system installation requiring TEMPEST certification, wiring shall be clearly marked independent of their EMI category. Circuits which process classified information shall be identified with a marker label sleeve of the appropriate classification color, with "TEMPEST" printed on the sleeve, followed by the category, or system identification as determined by the procuring activity. These identification sleeves shall be installed every 3 feet as per 3.9.3.3.1 (a) and (b), along the length of the wire or cable. Special routing, shielding, and separation requirements shall meet procuring activity requirements.

3.9.4 Connector Identification

Connectors shall be identified to facilitate mating. All plugs shall have a nonmetallic band affixed to the wire group or harness within 6 inches of the plug and shall be visible in the immediate area of the connector and shall not affect the maintainability of the harness. The band shall bear the P and J number identification and optical identification (if applicable) of both plug and mating receptacle and equipment nomenclature. All receptacles shall be identified with a “J” number on both sides of the aircraft structure in a convenient area adjacent to the receptacle. Receptacle identification may be excluded where available locations cause it to be not readily associated with the subject connector, or where it would not be visible (blind area) during installation or mating. In no case shall the absence of identification result in the possibility of connector mismatching. Receptacles, such as test and power, to which a mating plug is not attached, shall have, in addition, the function of the receptacle identified on the plug side of the structure.

Rationale: Aircraft maintenance or modification often requires disconnection of wiring. The mismatching of connectors with devices (e.g., identical connectors used on adjacent common components) can cause equipment malfunction. The initial buildup and subsequent modifications are more readily accomplished if unambiguous connector mating is provided. Connectors are typically unmated when equipment items are replaced or troubleshooting tests are conducted. Reconnecting is facilitated and made less error prone when “P” and “J” reference designators are clearly identified.

Lack of identification marking could lead to errant attempts at mating and “scooping” damage to connector contacts. See 3.8.1.4.5 for additional discussion.

3.9.5 Wire Size Color Code System

When approved by the procuring activity, a wire size color code system may be used to facilitate the control of wire size. When a wire size color code is used, the wire insulation shall be identified with the appropriate color by one of the following methods. Only one method may be used for each vehicle.

a. Solid colored.

b. Distinctively color banded.

c. Distinctively striped.

The wire size color code is as follows:

Size	Color	Size	Color
26	Black (see 3.8.8)	10	Brown
24	Blue (see 3.8.8)	8	Red
22	Green	6	Blue
20	Red	4	Yellow
18	White	2	Red
16	Blue	1	White
14	Green	0	Blue
12	Yellow		

Rationale: Using color-coding to identify the wire gauge can reduce the probability of using incorrect sized conductors. The using of incorrect wire gauges can affect the current carrying capacity (see 3.8.8.1) and termination integrity.

3.9.6 EWIS Components Identification

EWIS components installed on the aircraft shall be assigned a unique reference designator identification (RDI) number. Components are divided into three major categories: electrical equipment (i.e., WRAs/LRUs, terminal boards, relays, etc.), splice areas, and ground points. Each RDI will have a label or stencil visible on the aircraft structure adjacent to the assigned component. For U.S. Military applications, refer to the RDI format in MIL-HDBK-863 for guidance in identification of EWIS components.

Rationale: Multiple military and industry standards exist for the assignment of reference designators including many unique company variations. This paragraph establishes the baseline standard AS50881.

3.10 Wiring Installation

Wiring installation-design of the wiring installation shall conform to the following precedence:

First: Safety of flight.

Second: The ease of maintenance, removal, and replacement of wiring.

Third: Cost effective aircraft production.

Wiring shall be fabricated and installed so as to achieve the following:

a. Maximum reliability.

b. Minimum interference and coupling between systems.

c. Accessibility for inspection and maintenance.

d. Prevention of damage.

Rationale: Redundant systems wire routing should be separated sufficiently to avoid a single point failure disabling multiple systems. This may be accomplished with a common failure mode analysis examining both the separation at connectors, as well as wire harness routing and harness contents. ARP4404 and MIL-HDBK-525 provide recommended practices for maintaining adequate separation and segregation of critical wiring circuits and functions.

Wiring should not interfere with flight control movements. Routing through severe wind and moisture problem areas should be limited to interconnection to equipment therein. Wire routing should be located where bundles are protected from contact with personnel, equipment, and structure. Where inadvertent contact is not assured under all service conditions, protective grommets and chafe strips should be used. Pre-loading of wiring against these items must be avoided.

For further consideration of wiring system assessment, the FAA Advisory Circular (AC) 25.1701-1 provides a framework for evaluating system separation.

3.10.1 Arrangement of Wiring

Wiring shall be arranged in groups and bundles to facilitate installation and maintenance. Individual groups shall be spot tied; when these groups are bundled, the spot ties shall not be removed (see Figure 6).

Rationale: Individual groups, if part of an associated system, may allow related wiring to be more readily accessed and serviced when spot tied together. Figure 6 has been added to help understand the concept.

3.10.2 Bundle and Group Size

As a design objective, bundles and groups within clamps shall be no more than 2 inches in diameter. Wiring in high density connectors may be run as a single group, provided that all of the wiring in the group is pertinent to a single item, equipment, or system.

Rationale: Individual wires in bundles larger than 2 inches in diameter are more difficult to find and access without excessive disassembly. The potential issue of multiple system damage (in the instance of electrical arcing) and of maintaining the correct bend radius are more difficult to address with larger wiring harnesses.

At the termination of large diameter harnesses, the use of high-density connectors may be necessary. Contact spacing within high-density connectors is very close, and separating wire groups with spot ties can be cumbersome at connector entry areas.

UAV Consideration: The bundling and groupings of wire harnesses is a common design practice and may not be in compliance with this requirement. The limited space in the vehicle makes it difficult to separate harnesses from one another.

3.10.2.1 High Density Harness Size

The number of wires in high density harnesses shall be limited only by efficient and good design. The use of wires larger than size 16 is discouraged unless there are also smaller electrical wires in the same harness.

Rationale: High density harnesses are not typically serviceable in the aircraft and often require removal for servicing. Because of their size and lack of flexibility, the removal of high density harnesses can be a difficult and time-consuming task.

3.10.3 Inspection and Maintenance

In open wiring, groups shall be installed to permit replacement of the group without removal of the bundle. High density harnesses shall be designed so that they are readily replaceable in sections.

Fiber optic cables shall be installed to provide accessibility for inspection and maintenance. Where approved splices are an acceptable method of assembly or repair, space shall be provided for installation, inspection, and testing of individual segments. Fiber optic cables that are not repairable on the aircraft shall be installed in a manner which facilitates testing and replacement of individual segments or entire harness assemblies. Replacement of fiber optic cables or segments shall not require disassembly of any riveted or bonded attachments. Conduits shall be used where necessary to protect fiber optic or to facilitate maintenance in inaccessible areas (refer to MIL-STD-1678).

Rationale: Aircraft availability is improved when changes and repairs can be made on the aircraft without harness removal. Open wire harnesses reduce the complexity of replacement and/or modification (replacement of an individual wire group in an electrical harness may be necessary to accommodate system repairs or updates). The possibility of incidental damage to other wiring in a harness is reduced if the entire bundle need not be removed.

Open wiring groups typically employ connector backshells which can be disassembled for connector access; this access to the connector is a very important asset during wiring maintenance.

High density harnesses are typically replaceable in sections because they use thin-walled wire and are protected with an overall jacket, making repair on the aircraft difficult. Replacement of such harnesses can be paced by the availability of spares.

Fiber optic cables typically require the use of a light source and power meter for testing of individual optical links. Where deeper fault diagnosis is required of an optical link, an optical time domain reflectometer (OTDR) can be used to identify any events within the optical fiber core. When routing fiber optic cables, it is important to ensure that access to the optical links is available to connect any fiber optic test equipment.

Fiber optic cables are typically terminated using a controlled heat source to bond the fiber to the terminus using an approved epoxy adhesive; this may make repairs on the aircraft impractical. The use of easily accessible terminated optical links can facilitate removal of optical cable assemblies or individual segments for repair or replacement. If repairable with approved splices, provide suitable space for the related splicing equipment.

MIL-STD-1678 has significant information concerning the inspection and maintenance of fiber optic cable.

UAV Consideration: Maintenance activities are of less concern with UAV. UAV harnesses are more modular. Field repairs are more limited and more likely to result in the replacement of harness.

3.10.4 Facility for Changes

When required by the procuring activity, the wiring for specified systems shall be installed so as to be readily removed and wiring for new systems readily installed when system changes are undertaken. The installation of such wiring shall be such that only the wiring and equipment related to the system have to be disturbed.

Rationale: Mission related systems (e.g., ferry kits) are sometimes employed briefly to accomplish specialized tasks. The procuring activity can require that no other systems be affected by the installation or removal of such temporary systems. An aircraft may be equipped with fixed provisions to provide electrical power and attachments to accommodate such systems.

When installing new wire (i.e., mod/upgrade), it is recommended that that all existing/installed affected plastic ties (zip ties) be removed and replaced with A-A-52083 or A-A-52084 lacing tape/tie string. Doing so will prevent the practice of adding new wires over existing zip ties which are likely to damage new wire installations.

UAV Consideration: Removable system cables are integrated into the main aircraft bundles due to space limitations and provide for limited change capabilities. The need for system updates often will result in harness replacement.

3.10.5 Dead Ending

Each undesignated wire end shall be dead ended with AS25274 caps or with insulation in a manner acceptable to the procuring activity. Dead ending shall take place within 4 to 6 inches of connectors or feedthrough bushings. All dead ended wires shall be de-energized or disconnected at their power sources so as not to present a hazard to personnel and to prevent accidental shorting of live circuits. Wires to be dead ended shall be due to a repair scenario or temporary stowage and not part of a wiring modification. Wiring no longer required, due to a modification, shall be removed from the aircraft when directed by the procuring activity (see 6.1.1 for additional considerations).

Rationale: Insulating wire ends protects the undesignated wire, avoids the possibility of creating short circuits with installed systems, and provides a consistent location for their eventual connection. The intent is to reduce the risk of electrocution of personnel, improve wiring system safety, and reduce the likelihood of energized wires on inactive circuits.

3.10.6 Routing

Wiring and fiber optic cable shall be routed to ensure reliability and to offer protection from the following hazards:

Rationale: Chafing is among the leading causes for wire harness damage. Chafing can cause short circuit-related system shutdowns, arcing-related fires, and/or other system failures. Equipment and wiring congestion can impede bundle clearance inspection. Vibration-related harness migration can cause slack redistribution related chafing.

The use of secondary harness chafe protection should be considered as a life-limited part and be included as part of maintenance inspections. The duration between each inspection should be based on environmental factors, as well as system criticality and the proximity to critical aircraft components (e.g., fuel tank) (see 3.9.3.3.6, 3.11.12, and 3.11.13).

a. Chafing as defined in 2.3.4.

b. Use as handholds or support for personal equipment.

c. Damage by personnel moving within the vehicle.

d. Damage by stowing or shifting of cargo.

e. Damage by battery or acid fumes or fluids.

f. Abrasion in wheel wells where exposed to rocks, ice, mud, etc.

g. Combat damage (to the maximum extent practicable).

h. Damage to wiring by moving parts.

i. Harsh environments such as SWAMP areas, high temperatures, or areas subject to significant fluid or fume concentration.

j. Crushing, kinking, or stretching fiber optic cable. Precaution should be taken to prevent the cable from being accidentally crushed, kinked, or stretched (refer to MIL-STD-1678).

k. Fiber optic cable should be routed and installed so as to avoid the application of axial, lateral, and torsion loads to the cable and terminations (refer to MIL-STD-1678).

l. When installing fiber optic cables, additional support, routing techniques, and maintenance must be considered. Methods of addressing these requirements shall be approved by the procuring activity (refer to MIL-STD-1678).

m. Wiring shall not be routed through equipment mounting bases.

n. Fiber optic cabling route shall be located so that optical fiber cables will not to be disturbed by disassembly or removal of equipment (refer to MIL-STD-1678).

Rationale: Using bundles as handholds should be avoided as this can easily exceed pull strength of wiring terminations, causing open circuits.

Cargo is likely to be thrown into aircraft during hurried operations. The incidental contact with wiring could exceed pull strength of wiring terminations, cause chafing, or damage impedance-controlled signal cables causing signal attenuation.

When in a vibrating environment, lead-acid batteries, if not properly vented, can outgas damaging vapors to some wire constructions. Battery feeder wires, if short circuited, can discharge continually until battery energy has been depleted, causing fires or structural damage.

External areas of the aircraft, such as the wheel well, are prone to damage from foreign objects. Foreign objects contacting wire bundles at high speed could damage wiring, especially during takeoff and landing. The use of protected harnesses with extra jacketing and molded terminations will perform more reliably under these conditions and is recommended for these areas.

Physical separation of redundant systems can prevent a single event from disabling the aircraft (see 3.10.5). Wiring should be routed well away from fuel lines and tanks, especially where structural deformation could occur causing fluid leaks or damaged wiring during a crash.

Wire harness routing should maintain clearance to moving parts. The potential bundle migration that could occur during operational conditions can be checked by applying slight hand pressure applied to the wire harness and examining the remaining clearance. This clearance should allow for wire harness shifting during extended aircraft operations.

If practicable, wiring should be routed away from SWAMP areas unless connected to components in that area. Flexure, fluid, and heat-resistant wire construction, high tensile strength conductor, and 22-gage minimum wire size should be considered. Protected harnesses with extra jacketing and molded terminations can perform more reliably under extreme environmental conditions.

Damage to glass fiber or terminations could degrade or interrupt signal strength causing system malfunction or shutdown. The routing of such cables should be away from maintenance activity and handling. Extra precautions in the form of support and protective jacketing should be taken during initial installation.

Fiber optic cables should be routed in protected areas with extra primary support or conduits and strain relief type connector backshells. Sharp bends, likely to occur in congested areas or at bundle breakouts, will increase losses and should be avoided. The typically routing must take into consideration that one cable segment will likely be shorter than adjacent ones and carry most of the tensile loads.

Damage and fatigue to glass fiber or termination can increase system dB losses that can eventually prevent conversion to a usable electronic signal. A comprehensive failure modes and effects analysis should be applied to cable routing and construction, taking into account the long-term dB losses that can degrade system performance.

Swaying of shock mounted units could cause chafe damage and wire failure. In these areas, it is possible that wire harnesses may interfere with the sway space clearance and cause premature failure of equipment. Wire harnesses should be routed and supported to avoid such contact.

Equipment maintenance procedures should be taken into account so that units can be dismounted without displacing fiber optic cables. Fiber optic cable routing should be away from maintenance activity and handling to the extent practicable.

3.10.7 Slack in Wiring

In addition to slack provided for drip loops (see 3.11.8) slack shall be provided to meet the requirements of 3.10.7.1 through 3.10.7.5. Slack requirements shall be met on every production vehicle, as well as developmental models. In production wire harness fabrication, provisions shall be incorporated into the harness design and fabrication process to ensure that the installed harness meets these requirements without the need for straining, forcing, or modifying the harness.

Rationale: Insufficient slack can result in tension-related open or intermittent circuits at terminations as the stress on contacts may cause electrical separation (for power circuits, this can lead to series arcing). Inadequate slack can also result in side loading at connector grommets creating gaps for moisture entry, leading to shorting between connector terminations. Disconnecting some equipment requires extra bundle length for dismounting and shifting the item sufficiently to access connections.

3.10.7.1 Connector Termination

When wiring is terminated at a connector or terminal junction, a minimum of 0.5 inch of slack for complete connector replacement shall be provided. The slack shall be between the connector and the second wiring support clamp. The 0.5 inch slack requirement shall be interpreted to mean that with the connector unmated and first wire support clamp loosened, the wiring will permit the front end of the connector shell to extend 0.5 inch beyond the point required to normally mate the connector. Slack for replacement of potted connectors shall be, as a minimum, the length of the potting plus 1 inch. Connectors terminating size 8 or larger electrical wires, RF cables, and fiber optics cables shall not be subjected to re-termination slack requirements.

For fiber optic cabling, cable slack at the connector ends of the cabling (i.e., slack from the last primary support at the connector end) shall allow the cabling to extend from 0.5 to a maximum of 1 inch beyond the point required for mating the connector (refer to MIL-STD-1678).

Rationale: Re-termination of a wire normally involves extracting contacts/termini, cutting cable off at crimp barrel or termini bushing, and replacement. If there is insufficient wire slack, this could result in preload on wire or connection after re-termination. Preload on wiring risks tensile load termination failure, resulting in open circuit or shorting to connector backshell. Fiber optic tensile load failure would cause losses in signal strength and optical link loss. MIL-STD-1678 is a resource for the installation of fiber optic cable.

3.10.7.2 Lug Termination

At each end of a wire terminated by a lug, a minimum length of slack equal to twice the barrel length of extra slack shall be provided. For copper wire size 2 and larger and aluminum size 4 and larger, the minimum length of slack shall be equal to one crimp barrel length of the lug. The slacks shall be in the vicinity of the lug and available for replacement of the lug by maintenance personnel.

Rationale: A “gastight” crimp at terminals provides metal to metal contact between wire strands and crimp barrel, preventing oxidation, excess resistance, and resistive heating. Inadequate slack could require replacement of the entire wire or could result in excessive tensile load and potential loosening of the crimped joint.

3.10.7.3 Strain Prevention

The wiring installation shall be designed to prevent strain on wires and electrical/optical cables, junctions, and supports.

Rationale: Strain on wiring and supports can lead to broken terminations, fracturing of support clamps, or abrasion of wire/cable insulation against supports. Stress may also be induced on the “shield ground wires” during the process of recovering the heat shrinkable tubing onto the harness.

3.10.7.4 Free Movement

Wiring shall permit full extension of shock mounts and vibration isolators mounted on equipment.

Rationale: Shock mounts provide sensitive unit protection from damage during aircraft operations. Shock mounted units are qualification tested to verify survival from vibration and specific shock loads. Premature equipment failure from vibration or shock could result if the mount is restricted by wiring.

3.10.7.5 Wire Shifting

The wiring installation shall permit shifting of wiring and equipment necessary to perform maintenance within the vehicle.

Rationale: Insufficient slack could lead to wire strain or abrasion during aircraft maintenance. Maintenance-induced damage could result in premature failure of wiring or equipment. Loosening or removal of primary supports can permit equipment movement. The design of the wire harnesses should not impede such activities.

3.10.7.6 Wiring Pressure Bulkhead

Consideration should be given to wiring and bundle lengths to ensure enough slack or service loops are designed in, so that it allows for flexing, expansion, and relative motion of structure and bulkheads.

Rationale: The introduction of composite airframes brought about flexible bulkheads. Since the wire bundles and bulkhead connectors are attached/terminated at the bulkheads, their flexure needs to be a design criteria. There is a need to account for the motion of the bulkhead as the compartment may expand at altitude or during cabin differential pressures.

3.10.8 Electromagnetic Compatibility

Electrical wiring, including RF and antenna cables, shall be routed so as to minimize electromagnetic interference (EMI) in accordance with MIL-STD-464.

Rationale: EMI sources can induce signals in sensitive wiring causing serious malfunctions such as communication noise, errant control surface movement, or external stores release. Shielding of sensitive wiring can reduce sensitive system vulnerability, but spacing between source and victim is a major factor in preventing unwanted system malfunctions.

Test plans to assess EMI susceptibility should consider environmental impacts such as vibration, temperature cycling, salt spray, CS and RF testing, and lightning-induced effects.

UAV Consideration: RF cables are separated as much as practical. These cables are sometimes bundled with main aircraft bundles due to routing space limitations. When these scenarios occur, it is recommended that the harness is segregated, and RF cables are protected with EMI sleeving.

3.10.9 Ignition

Flexible metallic conduit of a type specifically approved by the procuring activity shall be used for magneto cable circuits. Magneto ground cables (except the induction vibrator output cable) shall not run through conduit or junction boxes containing other electrical cables.

Rationale: Interference carried by magneto cables can disrupt radio, intercom, and other sensitive systems. Substantial shielding of the source is required to ensure attenuation of magneto noise. Coupling of noise sources with sensitive systems is generally proportional to proximity and to the length of parallel run.

3.10.10 Compass Deviation

Electrical wiring and ground return paths shall be installed so as not to cause compass deviation. Each wire carrying direct current in the area of compasses or the sensitive pickup elements of compasses shall have a corresponding ground return wire twisted with it to neutralize the magnetic field.

Rationale: Compass systems are an essential navigation tool and must be accurate to avoid errant flight paths. Twisting the ground return wire neutralizes any errant signal induced in the wiring, but this must extend to the circuit ground point to be effective.

3.10.11 Lug Terminated Wires

Lug terminated wires shall be installed so as to reduce human error in assembly to adjacent terminals. In addition to code identification, wiring shall be so routed and supported so as to reduce human error in assembly to adjacent terminals. Fanning strips are preferred except in junction boxes, fuel tanks, ground studs, and other areas where space is not available.

Rationale: Serious malfunctions or system shutdowns can occur if wire connections are reversed. If the circuits are misconnected, there is a risk of electrical arcing or fire. If identical sized lugs are used, lead lengths may not always assure avoidance of errant connections.

3.10.12 Sensitive Circuits

Sensitive circuits such as low-power level signal circuits shall be kept separate from other circuits at junctions. This shall be accomplished by using separate connectors for the sensitive circuits and by having at least one grounded terminal stud between sensitive circuits and other circuits on a common terminal board.

Rationale: Unwanted coupling or arcing between power and sensitive wiring can occur unless adequate space or a ground plane is interposed between them. Use of separated junctions can ensure that adequate spacing is provided to avoid system interference or unintentional power coupling into a low power circuit.

UAV Consideration: Pilot safety is not a concern with fully unmanned aircraft. Refer to FAA AC 25.981-1D.

3.10.12.1 Electro-Explosive Subsystem Wiring

All circuits associated with electro-explosive subsystems shall be routed in shielded twisted pairs without shield gaps or discontinuities. Wire shields shall be bonded around the circumference of the connectors. All firing and control circuits associated with ordnance and explosive subsystems shall be separated from other circuits at junctions.

Rationale: A small amount of electrical energy is required for actuation of the explosive cartridge that powers the emergency release systems. Shielding of the associated system wiring must ensure isolation from outside sources. Inadvertent actuation of electro-explosive systems can result in jettison of weapons, auxiliary fuel tanks, cargo hook loads, or guillotine operation of rescue hoist cables.

UAV Consideration: Pilot safety is not a concern with fully unmanned aircraft. However, inadvertent actuation of electro-explosive systems, which can result in jettison of weapons, auxiliary fuel tanks, cargo hook loads, or guillotine operation of rescue hoist cables, are a concern.

3.10.12.2 Electro-Explosive Subsystem Wiring (for Air Force Use)

All firing and control circuits system wiring within junction boxes shall be color coded with red stripes in accordance with AMS-STD-595 color 11105.

Rationale: Separation of critical circuitry from other junction box wiring can be difficult in crowded enclosures such as junction boxes. Distinctive color marking can be a significant asset in ensuring isolation of critical systems. Misconnection of circuitry to adjacent wring could result in inadvertent discharge of weapons or separation of external stores.

3.10.12.3 Sensitive Circuits

Fuel probe wiring shall be separated from power wiring throughout its entire length including at connectors, terminations, and junction boxes.

Rationale: Fuel probes (fuel quantity indicator system [FQIS] sensors) measure capacitance between fuel tank probe elements separated by varied fuel and air levels as a dielectric. Terminations to the probe are typically exposed to fuel within the tank. Fuel quantity internal tank circuitry is designed to exclude energy levels greater than 0.02 mJ to prevent inadvertent fuel ignition. (FAA AC 25.981-1D provides thorough guidance on fuel tank ignition protection.) A pin-to-pin short within connectors or wire-to-wire short with other wiring in bundles could result in enough energy transfer to create arcs on probe wiring.

Fuel tank vapor temperature and concentration levels should be considered as the susceptibility to fuel tank ignition may change.

A means of assessing susceptibility is available from the FAA at http://www.fire.tc.faa.gov/systems/fueltank/FTFAM.stm.

See 3.11.12 and 3.11.13 for additional information on fuel tank wiring.

UAV Consideration: Due to space limitations, it is common for the fuel system wiring to be routed with power system wiring. Where possible, a physical barrier should segregate the fuel probe wiring from other circuits if routed in the same harness.

3.10.13 Power Systems

Electrically unprotected wiring of the primary electrical power system shall not be bundled or grouped with distribution circuit wiring. Wiring from two or more sources shall not be in the same bundle or group to prevent a single damage from affecting more than one power source. For secondary distribution circuit wiring from a single source required at multiple component pins, see requirements in 3.19.4 (o) and 3.20. Guidelines for assessing the impact of various voltage and power levels on EWIS can be found in MIL-STD-704 and for commercial applications use RTCA DO-160. Power wires size 10 or larger shall be separated from signal wiring and/or communication cables per MIL-STD-464.

Rationale: Individual distribution system circuit protection devices will de-energize shorted distribution wires but are not able to clear faults from damaged primary source wiring. Primary power sources typically employ under-voltage and feeder-fault protection to shut down electrical power if a ground fault or phase-to-phase fault occurs. Combining primary power wires routing with distribution wiring could risk shutdown of multiple systems. In addition, size 10 and larger wires may have unwanted EMI effects in adjacent signal wiring.

UAV Consideration: Power system wiring is sometimes bundled with distribution wires due to space limitations. The risk of doing this is possible shutdown of multiple systems with the failure of a connector or electrical arcing scenario.

3.10.14 Essential Equipment

Wiring to each system which must operate to maintain flight control of the vehicle under normal or emergency conditions shall be separately routed from other wiring. Essential engine circuits shall have their wiring so routed as to prevent damage to any circuit for one engine from affecting circuits of any other engine. Propeller circuits shall be routed separately from all other circuits.

Rationale: Essential equipment and propeller circuits must operate properly for safe flight. Multiple engine aircraft are designed to tolerate a single engine shutdown or malfunction but may not survive loss of a second engine. Wiring separation is very challenging on aircraft with dense packaging of equipment and wiring. Physical separation of functions must be planned at the earliest stages of design.

UAV Consideration: With the physical space limitations, this may not be possible with UAV applications. Where possible, a physical barrier should segregate the essential equipment wiring from other circuits if routed in the same harness.

3.10.14.1 Full Authority Fly-by-Wire Systems

In addition to the related wire routing/separation and shielding requirements of 3.10.6, 3.10.8, 3.10.13, 3.10.14, 3.10.15, and 3.14.6, the following provisions shall be incorporated:

a. Channel separation: Each channel shall be routed in separate bundles that are distinctively marked throughout their length to associates that bundle with a specific channel. Color coded harness jacketing material, closely spaced color-coded identification sleeves or similar means may be used for this purpose.

   Rationale: Failure of fly-by-wire wiring could cause complete loss of pilot control of the aircraft. The physical and functional separation wire fly-by-wire system wiring can avoid the loss of multiple channels (which are typically redundant), thereby preserving pilot control. The use of distinctive color coding of each channel is intended to ensure critical separation and the handling of such wiring with extra care, during installation and maintenance.

   Wiring for each channel should be routed separately from wiring for other channels and wiring for all other systems. Circumstance precluding separation between channels and other systems wiring must be approved by the procuring activity.

b. Primary flight control wiring: For helicopter wires having functions that can directly affect the flight path of the aircraft or otherwise affect flight safety, those wires shall be size 20 minimum except that size 22 annealed copper wires may be used when routed in twisted triples or with at least three other wires. Wires shall be of a type specified in Appendix A that is suitable for use in circuits where during a fire, maintenance of electrical integrity is required for a limited time. For all other aerospace vehicles, wires shall be per Appendix A.

   Rationale: Helicopters typically operate at higher vibration levels, have harder landings, and are maintained in less controlled environment than fixed wing aircraft. Special precautions to reduce the likelihood of wire breakage are needed. Wires specified in Appendix A for maintaining electrical integrity during a fire can allow time for landing. In some aircraft zones, particularly those near flammable fluid lines, bundle spacing may not be sufficient to avoid fire exposure to multiple channels.

c. Connectors and connector accessories: Connectors and accessories for use in such applications shall be military qualified for aerospace applications. Threaded coupling mated pairs of connectors shall employ self-locking coupling rings. Connector backshells that do not include self-locking coupling mechanisms shall be secured in accordance with 3.14.7 to avoid loosening.

   Rationale: In operation, the loosening of connectors (e.g., through vibration) or unlocked accessories can result in degradation of the performance of the interconnections during the lifecycle by mechanical stress, EMI degradation, and exposure to environmental condition. It can result in the loss of the associated system. Self-locking military aerospace connectors are specifically designed and are often selected for their resistance to moisture ingress-related short circuits, handling damage, loosening in service, and other environment-related failures. These connectors are typically qualified to function in severe environments, are less susceptible to failure than other types, and are more readily maintained. Self-locking coupling rings require substantial torque to un-mate and have the benefit of not requiring a safety wire.

3.10.15 Redundant Circuits

Wiring to equipment performing duplicate functions shall be run in separate bundles with separate connectors to prevent damage to one system from affecting the other. On aircraft that employ dual or multiple, e.g., MIL-STD-1553 multiplex data bus systems, the redundant data bus cables shall be run in separate bundles and routed to prevent damage to one data bus cable from affecting the operation of the other data bus or buses.

Rationale: Redundancy is designed to provide duplicate or backup for essential system functions. Failure of a data bus cable can disable multiple units as a single data bus may support the functionality of multiple components. Such systems are designed to time-share signals between multiple interacting units through separate couplers.

UAV Consideration: With the physical space limitations, this may not be possible with UAV applications. Where possible, a physical barrier should segregate redundant circuit wiring from other circuits if routed in the same harness.

3.10.16 High-Temperature Equipment

Wiring shall be separated from high-temperature equipment, such as resistors, exhaust stacks, heating ducts, and deicers to prevent insulation deterioration.

Rationale: Floodlights, resistors, bleed air lines, heating ducts, etc., create high-temperature zones on and near unit surfaces. Some equipment surfaces that rely on air flow increase in temperature after engine or aircraft shutdown when air flow is discontinued.

3.10.17 Nacelle Wiring

Wiring in an engine nacelle, from the point of disconnection for removal of the engine, shall be interchangeable between all engine installations having identical equipment and for the same series of vehicle. A means for positively ascertaining clamp locations shall be provided for wiring that must be unclamped for engine removal. This shall be accomplished by permanently attaching clamp brackets to supporting parts.

Rationale: Consistency of routing is critical to ensure safe/reliable performance in an engine's severe vibration/temperature environment. Positive clamp locations ensure consistency of routing with original installation and after repairs/modifications. Harnesses routed near the engine are more likely to be subject to removal and replacement than typical harnesses. Mis-wiring of engine accessories could lead to undetected malfunctions and engine shutdown. Clamps such as AS21919 having cushion material that is suitable for the environment are acceptable for nacelle wiring.

3.10.18 Wiring in Bilges

Wiring in bilges shall be installed at least 6 inches from the centerline of the aircraft except when attachment to equipment located in the area is required. Wire types susceptible to moisture degradation shall not be used in bilges.

Rationale: Bilges often contain wiring for safety-related equipment such as anti-collision lights, landing gear, and communication equipment. The moisture gathered in such locations can cause deterioration of some wire constructions and cause wire-to-wire shorts for unprotected wires.

3.10.19 Engine Mounted Accessories

For direct attachment to engine mounted accessories, wire smaller than size 20 shall not be used. When size 20 wires are used, they shall be high-strength alloy conductor and when terminated in connectors, the connector shall provide support and prevent strain on terminations. The wires shall be adequately grouped, spot tied, and supported.

Rationale: Engine environment includes substantial heat, vibration, and fluids, which present a challenge to wiring reliability. Extra wire and termination support is required to avoid failures. Harnesses routed in this area with protective jacketing and molded strain relief at connectors can improve reliability.

3.10.20 Wheel Well Areas

Conduit or other protection shall be provided for all wiring in wheel well areas. Flexible tubing, abrasion resistant tape, or braided outer jackets are acceptable for use where wiring is properly supported. When tubing is used, drainage holes shall be provided at all trap points and at the lowest point between each sup of support clamps. Taping shall be in accordance with 3.11.6. Wire types susceptible to moisture degradation shall not be used in wheel well areas.

Rationale: Wiring in the wheel well is exposed to some of the most severe conditions on the aircraft. Wire harnesses in landing gear areas must be protected from contact with foreign objects that may be thrown into the wheel well during takeoff or landing.

Wheel well wiring is likely to be subjected to and must be protected from high wind loads.

Landing gear design often requires attached harnesses to be flexed repeatedly, which can apply strain at terminations. Landing gear wiring often includes extend and retract actuation, limit switches/proximity sensors, and cockpit indication, all of which are essential to safety.

3.10.21 Slide Mounted Equipment

When connecting wires or electrical/optical cables to slide mounted equipment, sufficient slack shall be provided to permit the slide mounted equipment to slide in and out without damage and permit unmating of the connectors.

Rationale: Wire bundles that have extra slack and are displaced during slide equipment movement need to be protected from potential strain and abrasion. Without the additional slack, it is likely that the wiring will be damaged during routine maintenance activities. The engagement length for mating and unmating of connectors must be considered.

3.10.22 Airborne Equipment Cable Assembly

Wiring and wiring devices utilized to make up airborne equipment cable assemblies are to comply with the requirements herein.

3.11 Protection and Support

Wiring shall be supported to meet the following requirements:

a. Prevent chafing as defined in 2.3.4.

   Rationale: Thousands of opportunities exist for wiring contact with structure and equipment and for other wiring damage on aircraft. Wire harness support prevents abrasion, cut through, and other forms of insulation damage that can lead to short circuit failure of aircraft systems.

b. Secure wiring where routed through bulkheads and structural members.

   Rationale: Abrasion failures can occur over time due to vibration and rubbing contact unless wiring is clamped to maintain positive spacing. Preload on grommets or contact with structure can cause insulation damage which can lead to wire-to-ground or wire-to-wire short circuits.

c. Properly group, support, and route wiring in junction boxes, panels, and bundles.

   Rationale: Contact with components and enclosure surfaces can lead to abrasion or termination damage. In power junction boxes, care must be taken to separate feeders from control wiring.

d. Prevent mechanical strain or work hardening that would tend to break the conductors, optical fibers, and connections.

   Rationale: Lack of wire harness support can lead to wire breakage or termination damage, resulting in short circuit or open circuit failures. Strain on optical cables can result in micro-cracks which cause transmission losses.

e. Prevent arcing or overheated wiring from causing damage to mechanical control cables and associated moving equipment.

   Rationale: Proper wire rating and maintaining positive clearance can avoid arcing failures.

f. Facilitate reassembly to equipment terminal boards.

   Rationale: Crossed connections can cause serious system malfunctions. Lengths should be arranged to avoid errant connections. Careful application of cable ties can help to prevent misconnecting.

g. Prevent interference between wiring and other equipment.

   Rationale: Physical interference with equipment will typically abrades insulation until short circuiting to equipment cases or between adjacent wires occurs.

h. Provide support for wiring to prevent excessive movement in areas of high vibration (see 6.12).

Rationale: Vibration-related shifting of bundles can cause chafing and strain terminations. Errant distribution of slack will occur if the primary support clamps are not properly fitted or secured. Clamp fillers should be used to preclude axial bundle movement.

i. Dress the wiring at connectors and terminating devices in the direction of the run without deformation of grommet seals.

Rationale: Grommet seals can be opened if wiring is routed sharply away from connector centerline axis. Grommet openings can allow moisture ingress, which can lead to corrosion or short circuits. Adapters, wire guides, clamps, potting, or other means are approved means of dressing wires.

3.11.1 Primary Support

Primary support of wiring shall be provided by metal cushion clamps and plastic clamps (see 3.11.1.1) in accordance with AS23190 and AS21919, spaced at intervals not to exceed 24 inches. In addition, where wiring is routed through cutouts in any aircraft structure, clamps shall be installed as necessary to meet the protection and anti-chafing requirements of this specification. Open wiring contained in troughs, ducts, or conduits is exempt from this requirement. Clamps for harnesses other than round shall be shaped to fit the contour of the harness and shall provide a snug fit. Plastic clamps shall not be used to support rigid portions of harnesses. Use of plastic cable straps as primary support is prohibited. The primary support of wiring shall not be attached to adjacent wiring. Only metal clamps with cushions shall be used to support fiber optic cables (refer to MIL-STD-1678). Primary wire support clamps and fasteners used in structural applications shall not be used for bonding and grounding connections. The AS5117 clip shall not be used to support electrical wire harnesses. For additional clamp selection and installation guidance, refer to ARP1897.

Rationale: Lack of wiring support or improper clamp fit can lead to chafing, wire breakage, or termination damage resulting in short circuit or open circuit failures. The primary support clamp snug fit can be ensured by increasing bundle diameter with approved tape material until the wire harness does not slide through the clamp under slight axial pressure. Fiber optic cables could be damaged if supported with distortion by cushioned clamps. Other support devices have not proven reliable under extreme environment conditions. Plastic cable straps, which are prohibited as primary support, have not demonstrated adequate reliability. Currently, 3.11.1 only permits clamps per AS23190 or MS21919. Reference ARP1897 for additional guidance concerning clamp selection and installation.

UAV Consideration: The use of plastic clamps is common to reduce space and weight impact. When doing so, sizing and serviceability should still be considered in selection.

3.11.1.1 Plastic Clamps

Plastic cable clamps in accordance with AS23190 may be used on horizontal wiring runs provided every fourth clamp is a metal cushion type. The first clamp immediately adjacent to wiring terminations for wire bundles greater than 0.125-inch diameter shall be a metal cushion clamp. The use of plastic cable clamps on other than horizontal wiring runs shall be avoided unless the installation is such that slack cannot accumulate between clamping points, and then every fourth clamp shall be a metal cushion type. Any clamp that incorporates a plastic strap is prohibited.

Rationale: Cushioned clamps are more effective in preventing axial bundle displacement. The proper fit of the cushioned clamp prevents possible chafe damage and wire or termination breakage as distributed pressure is placed on the wire harness. Plastic clamps without a cushion can allow vertical bundles to slide out of position under vibration, which can lead to chafe damage or wire breakage.

It is important to note that a wire harness diameter can actually decrease slightly in service, depending on the lay of component wires and cable tie fit.

3.11.1.2 Clamp Size

Primary supporting devices shall be of the size which holds the wiring in place without damaging the wire insulation or degrading the performance of optical or RF cables. If called out clamp size is too large to properly grip the harness and the next size smaller would crush the harness, tape types in accordance with 3.11.2.3 may be used to provide a proper fit in the larger clamp or as fillers under the larger clamp. Build up with tape only to the point that the clamp provides grip.

Rationale: Primary support clamp snug fit shall be ensured by increasing the bundle diameter with approved tape material until the bundle does not slide through clamp under slight axial pressure. The use of non-approved tape or cord is not recommended as it does not provide adequate support.

The clamp sizing is critical for both RF and optical cables. The dielectric layer of RF cables is designed for a particular shape and thickness, and RF signal losses can occur if the clamp fit is too tight. Optical cables in bundles could be distorted by overtightened clamps, causing dB loss increase.

3.11.1.3 Support at Connectors

Wiring terminating at plugs shall be supported to dress the wiring in the direction of the run. This may be accomplished by adapters, clamps, potting, wire guides, or other means acceptable to the procuring activity.

Rationale: If wiring exiting a plug makes an immediate sharp bend, the side loading of wires can create strain on wires and terminations and can cause distortion of the connector rear grommet, allowing moisture ingress. Adapters and other means of securing bundles should be employed to prevent strain on terminations.

3.11.1.4 Metal Cushion Clamps

When metal cushion clamps are used for primary support, their physical properties shall be compatible with the installation environment. Cushion compounds are formulated to meet specific requirements and may not be suitable in other applications.

Rationale: The environmental conditions vary significantly within an aircraft. If not selected with physical properties compatible with their installation environment, clamp metal straps and cushions can be degraded by fluids, heat, UV light, etc. Damage to clamp straps or cushions can cause broken wires or short circuits.

3.11.1.5 Adhesive Mounted or Bonded Harness Supports/Studs

Mechanically attached supports and studs are the preferred wiring support method. For U.S. military aircraft, the use of adhesive mounted harness support/studs shall be avoided in conjunction with flight critical wiring, power carrying wiring, areas of frequent crew/maintainer access, and areas with high vibration and temperature extremes. Positive separation shall be maintained between supported wiring and fluid carrying lines. Install areas should be in areas that are visually inspectable for periodic inspection and readily accessible for repair. Usage of these devices requires procurement authority approval. It is recommended that every fourth support/stud be mechanically attached to structure. Guidance on use and installation of adhesive mounted supports is given in ARP6881 (see 6.12).

Rationale: Adhesively mounted or bonded harness supports are a necessity in applications with composite structures. The limitation on their employment comes from the risk of one or more becoming dislodged, thus allowing the harness primary support to fail. Critical safety concern is when high energy wiring harness can potentially chafe against a fuel or hydraulic fluid tube. This risk is mitigated by designating a proper amount of metal cushioned clamps in order to provide support for the wire harnesses. ARP6881 provides pivotal installation, tools, and inspection processes for the adhesive types of support mounts.

3.11.2 Secondary Support

Secondary support of wiring harnesses, bundles, or groups (support between primary supports) shall be provided by devices selected from 3.11.2.1 through 3.11.2.5. Lacing shall be placed as secondary support at spacing no greater than 6 inches.

3.11.2.1 Harness Lacing Tape

Tying tapes shall be in accordance with A-A-52080, A-A-52081, A-A-52082, A-A-52083, A-A-52084, or MIL-DTL-32554 (see 3.11.2.5). The physical properties of the tapes must be compatible with the installation environment. Use of tying tapes shall be in accordance with types, finish, and sizes as defined in 3.11.2.1.1 on aircraft intended for military procurement or use.

Rationale: Lacing tapes of these general types fit in the component item descriptions best aligned with aviation and equipment. Note that not all of these types cited conform to the strict EWIS performance requirements (e.g., vibration performance/knot retention and flammability).

3.11.2.1.1 Harness Lacing Tapes for U.S. Military Applications

For U.S. military applications, the A-A-52084 Aramid Finish C (sizes 2 or 3) and A-A-52083 Glass Finish C (size 3) tapes and MIL-DTL-32554 (see 3.11.2.5) shall be used for general applications. The A-A-52083 Glass Finish C (size 3) or Finish D with the additional Finish C (sizes 2 or 3) tape shall be used for high temperature (engine area) applications. For areas requiring low reflectivity compatibility (i.e., flight deck), use A-A52084 Aramid Finish C (sizes 2 or 3) BLACK (example: A-A-52084-C2-BLK).

Rationale: These two types of lacing tapes, with the associated size and finish, were deemed as the ones meeting the strict aerospace requirements. Sizes 2 and 3 are the mid-range width and tensile strength, while finishes C and D are the only ones offering suitable knot retention performance and flame-retardant characteristics. Limiting the scope ensured that the two types required reduce the logistic requirement, allow for inspection, and assure conformance to requirement, as they are visually different than other types. The temperature rating of these two types aligns with the highest wire temperature rating and thus conforms to the most stringent system requirement.

3.11.2.1.2 Lacing tape shall be tied using a clove hitch knot followed by a separate square knot except for harness break-out, and special applications defined on Engineering drawings. Tying tapes shall be placed as secondary support in panels and junction boxes at a spacing no greater than 1-1/2 inches.

Rationale: The reason for higher frequency of ties inside a junction box when compared to the rest of EWIS is due to the high density of wiring and breakouts inside the panels.

3.11.2.1.3 Tying tapes shall not be placed within 1 inch of the back of connector as secondary support in panel and junction boxes. This is to prevent undue stress on the contact crimp terminations.

Rationale: Circuit breaker panels and junction boxes have typically a high density of wires and bundles which require secondary support (spot ties) for suitable routing and security to prevent chafing. Having spot ties installed closer than 1 inch to the connector termination compresses the wires and applies undue stress on the connector or terminal junction sealing grommet. When compressed, the sealing grommet may not fully seal the wire cavity, allowing fluids to enter the connector. Fluids inside the connector may lead to shorting out the circuit and system failure.

3.11.2.2 Plastic cable straps in accordance with AS23190 installed with tools in accordance with MS90387. Use of plastic cable straps as secondary support shall not be permitted on aircraft intended for military procurement or use.

Rationale: The USAF and Navy have had many problems with broken wire harness plastic tie wraps from aging and collateral wiring damage from the plastic edges. NAVAIR gave a detailed presentation on problems with plastic tie wraps, and this issue was discussed and voted upon over several AE-8A committee meetings. Lacing ties would be the expected replacement for the plastic tie wraps. If this is unacceptable, AS50881 can always be tailored with the approval of the procuring activity. SAE continues to allow the use of plastic tie wraps using the same provisions found in Revision C for civilian aircraft. AS50881 Revision C was the last revision to allow the use of plastic tie wraps for secondary securing devices.

The reason for this restriction on plastic cable straps has to do with wire chafing and foreign object damage (FOD) when the straps fail/break.

1. Plastic straps, over time, become brittle and break, allowing harnesses to sag without the intended support and create chafing conditions. In addition to environmental effects and aircraft dynamics, maintainers will often push and pull wiring during repair and maintenance operations of equipment and while gaining access to facilitate other maintenance. A series of additional breakages can easily happen when several straps in a row break.

2. Broken straps become an FOD problem in and around mechanical linkages.

3. Even though previous revisions of MIL-W-5088 and AS50881 have allowed use of plastic straps with restrictions, in reality, there is a widespread abuse of them. They are fast and easy to use. We have found the “if one is good, ten are better anywhere and everywhere” philosophy being applied too many times. All the restrictions were being ignored.

4. To reduce the possibility of an increase in optical link losses or fiber breakage.

Many procurement programs prohibit use of plastic straps in mod and production programs. No plastic straps are allowed for new installations. When wiring maintenance is done, the affected wiring shall be secured with string ties. Upon restoration, lacing tape/tie string (A-A-52084 or A-A-52083) should be installed.

UAV Consideration: The use of plastic cable straps is common to reduce space and weight impact. When doing so, the operational environment should be considered for part selection.

3.11.2.3 Insulation Tape

Insulation Tape shall be in accordance with 3.11.3.9 or 3.11.6.1 and may be used for additional protective covering for a protected harness (see 2.3.20).

Rationale: Standardization of types of tapes is necessary to better align with the application environment and to reduce logistic requirements. Approved tying materials in AS50881 3.11.2.1 through 3.11.2.3 have been tested and do not break down in the military operational and maintenance environment. Environmental degradation can cause unapproved materials to fail, resulting in splaying of individual wires. This splaying can cause chafing or other wire damage and circuit failure. Beeswax cord, plastic cable straps, or other non-approved tying materials do not provide reliable support in the military aircraft environment.

3.11.2.4 Deleted

3.11.2.5 Cable Lacing Fastener (CLF) System Usage

Cable lacing fastener (CLF) shall be in accordance with MIL-DTL-32554. The physical properties of the tapes must be compatible with the installation environment (see 6.13).

3.11.2.5.1 CLF shall be installed with MIL-DTL-32555 tools.

3.11.2.5.2 Use of CLF is for general EWIS applications and same environment as A-A-52084.

3.11.2.5.3 When installed with three wraps, CLF may be used as secondary support in fuel exposure areas.

3.11.2.5.4 CLF shall be placed as secondary support in panels and junction boxes at a spacing no greater than 1-1/2 inches.

3.11.2.5.5 CLF shall not be placed within 1 inch of the back of connector as secondary support in panel and junction boxes. This is to prevent undue stress on the contact crimp terminations.

3.11.2.5.6 When installed with three wraps, CLF may be used for tying bundles containing RF cables with solid dielectric and optical cables (see 3.11.3.10.3), so long as the provision of 3.11.5 are met.

Rationale: The CLF system is a new technology that can supplement lacing tape application. The CLF shall be used according to manufacturer’s instructions and shall comply with the requirements for lacing tape.

3.11.3 Limitations on Support

3.11.3.1 Continuous lacing shall not be used except in panels and junction boxes where this practice is optional.

Rationale: The use continuous lacing is not recommended as it interferes with maintainability an access to the wire harness.

3.11.3.2 Deleted

3.11.3.3 The use of insulating sleeving for the protection of wiring shall be kept to a minimum. Provisions shall be included to eliminate the possibility of entrapment of liquids.

Rationale: Insulating sleeve can trap liquids and their use is not recommended. When insulating sleeves are used, a means to prevent fluid accumulation is required (e.g., drain holes in sleeving).

3.11.3.4 Deleted

3.11.3.5 Wiring shall not be tied or fastened together in conduit or insulation sleeving.

Rationale: The practice of tying wires together in a sleeve or conduit impairs maintenance activities and prevents the removal of individual wires.

3.11.3.6 Electrical/optical cable supports shall not restrict the wiring in such manner as to interfere with operation of shock mounts.

Rationale: Interfering with the free movement of shock-mounted units can cause premature vibration and shock failures.

3.11.3.7 Tape or cord shall not be used for primary support.

Rationale: Tape and cord do not have adequate strength to support wire bundles. The use of clamps is recommended for primary support (see 3.11.1).

3.11.3.8 Plastic Cable Straps Usage Restriction

Plastic cable straps shall not be used in areas when the restrictions of 3.11.3.8.1 through 3.11.3.8.8 apply.

Rationale: The restriction of nylon plastic self-clinching straps (zip ties) stems from numerous filed reports citing the Nylon straps turn brittle and break in service, creating an FOD potential. The strap's locking tab/head is large and square in shape, and it induces a chafe spot on adjacent structure, wire bundles, and fluid carrying tubes. The straps also have the potential of damaging the wires if overtightened (particularly in fiber optic and coaxial cable installations). Furthermore, the straps are about 10X heavier than lacing tape and require a specialized tool to correctly set the correct tension/installation. The straps are only rated to 105 °C and are not flame retardant, and the normal ones are limited to no UV exposure. The numerous colors available from many sources confuse the users and do not conform to the natural/black convention. The UV-black straps are extremely brittle and can induce chafing on wires in the bundle. Some strap designs have the serrated teeth on the inner surface, abrading the wires. Safety, performance, durability, and collateral damage are the key reasons for prohibiting the plastic straps from military designs/applications.

3.11.3.8.1 Where the total temperature (ambient plus rise) exceeds 85 °C (185 °F).

Rationale: Strap materials eventually fail at temperatures above 85 °C.

3.11.3.8.2 Where failure of the strap would permit movement of the wiring against parts which could damage insulation or allow wiring to foul mechanical linkages.

Rationale: Wire harness contact with parts can abrade with wire insulation. Broken straps become an FOD problem in and around mechanical linkages.

3.11.3.8.3 Where failure could permit the strap to fall into moving mechanical parts.

Rationale: Broken strap sections can jam mechanical parts such as flight control pushrods or linkages, affecting flight safety.

3.11.3.8.4 In high vibration areas (see 6.12).

Rationale: Fatigue strength of straps may not be adequate for extended periods. If straps are used in vibration areas, data must be provided to show the long-term part reliability and/or support a planned inspection/replacement program.

UAV Consideration: The use of plastic cable straps is common to reduce space and weight impact. When doing so, the operational environment should be considered for part selection.

3.11.3.8.5 In areas of severe wing and moisture problem areas (SWAMP), such as wheel wells, near wing flaps, wing folds, umbilical or other areas specified in the detail specification or contract.

Rationale: Plastic straps do not have adequate strength or environmental resistance to support the weight of wire bundles when exposed to SWAMP conditions.

3.11.3.8.6 Where exposure to ultra-violet light might exist, unless the straps are resistant to such exposure.

Rationale: Not all straps can withstand UV light without deterioration.

3.11.3.8.7 To tie wires, electrical cables, groups, or harnesses within bundles.

Rationale: If tied into a bundle, their raised sharp surfaces will abrade insulation on adjacent wires. There are currently straps available with smoothed edges to reduce the stress of wires.

3.11.3.8.8 When the bundle contains any fiber optics cable (refer to MIL-STD-1678).

Rationale: Fiber optic cables can be subjected to crushing effects leading to increased optical link losses or fiber breakage.

3.11.3.9 Silicone Adhesive Polytetrafluoroethylene (PTFE) Tape

Silicone adhesive polytetrafluoroethylene (PTFE) Type 1 tape in accordance with A-A-59474 may be used as secondary support to wrap wires in bundles together to provide a proper fit or as additional electrical protection. When additional mechanical protection is needed (see 3.11.6.1). The choice of tape must take into consideration temperature and fluid conditions. Alternate tape types may be considered if the characteristics of the tape specified cannot fulfill the intended application. Plastic tapes that absorb moisture or have volatile plasticizers that produce chemical reactions with other wiring shall not be used.

Rationale: In order to ensure proper clamp fit, the wire bundle can be built up with Type 1 A-A-59474 tape so that it cannot slide through clamps under slight hand pressure. Not all tapes are the same, and the tape selection and application must take into account area environmental conditions. Additional mechanical protection can be provided in severe environmental areas with A-A-59163 self-adhering unsupported silicone tape wraps per AS50881 3.11.6.1. Environment-related delamination or other forms of deterioration can expose wiring to abrasion damage. PTFE tape has excellent insulating properties under limited conditions. Alternate tape types may be used if the characteristics of tapes specified cannot fulfill the intended application.

3.11.3.10 Cable Lacing Fastener (CLF) System Usage Restriction

CLF shall not be used in areas when the restriction of 3.11.3.10.1 through 3.11.3.10.3 apply:

3.11.3.10.1 Where failure would permit the strap to fall into moving mechanical parts.

3.11.3.10.2 To provide secondary support to wire, electrical cables, groups, or harnesses within bundles where CLF fastener may impose damage to adjacent wires or cables where supported would be on top of another fastener.

3.11.3.10.3 Where the bundle contains a fiber optic cable unless approved by the procuring activity and the cable is conducive to its usage.

Rationale: The CLF system is a new technology that can supplement lacing tape application. The CLF shall be used according to manufacturer's instructions. This section is expressing a particular concern with failure of the CLF and resulting FOD that can occur with the strap and buckle.

3.11.4 Anti-Chafing Provision

Chafing shall be prevented by routing and clamping bundles to prevent contact with equipment and structure. Spiral wrap and other chafe guard materials shall not be used in lieu of primary supports for separation from equipment and structure. Wiring inside slip on, loose braid sock, or otherwise metal braided shielded harnesses shall be protected from chafing on the braid sock (EMI backshell) or shield. Protection shall be accomplished by using AS60491, AS23053 material or a 25% overlap of A-A59474 tape. Any protection must extend the full length of slip on or braid sock. Metal braided or shielded harnesses shall have a protective external nonmetallic covering, except for fire zone areas where it is optional.

Rationale: Chafing is the most common failure mode on air vehicle wiring. Chafing from relative motion and rubbing contact abrades insulation, eventually leading to short circuiting of wiring to adjacent structure or wires. The metal braid used to provide shielding or mechanical protection on a protected harness can cause chafing of adjacent wiring and can even damage equipment if there is contact between the two items. Internal chafing of wires in such harnesses is typically prevented by a “barrier layer” between the wire bundle and the outer braid. The barrier layer for machine braid is often the reverse application of mylar or PTFE tape (the adhesive is away from the wire bundle). By reducing tape overlap to 25%, bundle flexibility is improved, and overall weight is reduced, while providing suitable chafing protection to the thin wall/light weight wire construction used inside protected harnesses. Spiral wrap can prevent damage temporarily, but wearing through or shifting of its wraps may result in failures unless primary support maintains clearance to surrounding items.

Wire harnesses should be designed with the goal of preventing maintenance related wiring damage during equipment removal or installation.

UAV Consideration: Where physical separation is possible, cushioned primary support clamps may be used for separation from equipment and structure. It is possible that in some areas, physical separation is not possible due to space limitations. Wire harnesses in areas where physical separation is not possible should be protected with secondary protection material and should be identified for regular inspection.

3.11.4.1 Edge and Ring Grommets (see 3.11.6.4)

Edge and ring grommets are designed for incidental contact only and shall not be used as a primary or secondary means of chafe protection. The wire harness/cable shall be supported with a primary support clamp adjacent to the hole in the structure so that a minimum clearance (grommet to closest wire) is no less than 1/8 inch (0.125 inch). If harness routing requires a change in direction through the hole then primary support is required on both sides, unless 3/8 inch (0.375 inch) minimum wire clearance can be maintained. Grommets shall be used when physical separation between wiring and equipment or structure edges is less than 3/8 inch (0.375 inch) apart. The grommets shall be securely fastened. The choice of grommets shall be determined by the grommet characteristics described in the component specification and the environmental application. When mounted in feed through holes (cutouts), the remaining opening (split or gap between grommet and adjacent clip) in edge grommets shall be no wider than 1/16 inch (0.063 inch). The split shall be a diagonal cut. The split or gap shall be placed in such a manner that, if the wiring comes in contact with the grommet, the split shall be on the opposite side located away from the wire pressure direction. Edge grommets shall be selected to conform with the sheet thickness (structure thickness) ranges and geometric configuration (flat versus flanged or beaded hole) specified in the grommet specification. NASM22529 cushioned metal edge grommets shall not be used on holes smaller than 2 inches in diameter.

Rationale: Grommets play a vital role in preventing chafe damage where wiring passes through holes or is located in close proximity to structure. Positive clearance is preferred to avoid wire damage. Edge grommets shall be selected to conform with the structure thickness and of material suitable for the application and environment. Edge grommets shall be selected to conform to the structure thickness ranges and geometry specified in their specification. Improperly installed grommets can result in direct wire contact with structure or with sharp edges of split section of grommet. Grommets must be securely fastened so that they will not be displaced during bundle installation or aircraft operation. Minimum clearance from wire harness to grommet (1/8 inch) was defined and added minimum limitation to 1/6 inch if the harness is secured with a primary support clamp at the lightning hole in the bulkhead. The rationale is that the harness, once securely fastened to the airframe structure with a cushioned metal clamp, will not move or chafe against the bulkhead. The further clarification, in the event that the harness changes direction on the other side of the bulkhead, the requirement for another clamp was added. Any change in harness direction was left undefined, as with the minimum grommet to harness clearance of 1/16 inch, there is no room for error or chafe potential.

UAV Consideration: Where possible, P-clamps are utilized for separation from equipment and structure. It is possible that in some areas physical separation is not possible due to space limitations. Wire harnesses in areas where physical separation is not possible should be protected with secondary protection material and should be identified for regular inspection.

3.11.4.2 Metallic Shielded/Braided Protected Harnesses

Where a separator/binder layer is used, the tape must be of a fungus-resistant material with a temperature rating equivalent to, or higher than, the cable rating down the entire length of the harness. Non adhesive backed tapes shall be installed using a minimum 50% overlap to increase harness flexibility and reduce weight. A 25% overlap may be employed when using an adhesive backed tape such as A-A-59474.

Rationale: The material used for separation between the wire bundle and metal-overbraid should exhibit similar performance characteristics as the wire bundle.

3.11.5 Special Cable Support

Support of individual optical or RF cables and of bundles containing optical or RF cables shall be subject to the following additional requirements.

a. Both primary and secondary support devices shall be installed so as not to exert greater pressure on the cable than the minimum required to prevent slipping.

b. Pressure shall be evenly distributed around bundles containing cables, or around the cable if individually supported.

c. The support devices shall not deform the cables so that the characteristics of the cables are degraded.

d. Lacing tape as specified in 3.11.2.1 (see 3.11.2.5.6 for CLF usage) shall be used for tying bundles containing RF cables. Selection of the tape and installation shall meet the requirements of 3.11.5 (a), (b) and (c), except that AS23190 plastic straps may be used when approved (see 3.11.2.2) for tying bundles containing RF cables with solid dielectrics. Straps shall be installed with tools in accordance with AS90387. The tension adjustment on the AS90387 tool shall be set so that the requirement of 3.11.5 (a) is met (see 3.11.3.8.8 for optical cables).

Rationale: RF and optical cables are susceptible to damage from routine maintenance actions and, in particular, poor clamping/support practices.

a. Overtightening of either of primary or secondary support is likely to crush RF cable dielectric layer causing RF losses and reflection of the RF signal.

b. Uneven pressure can deform RF cable dielectric layer causing RF losses and reflection of RF signal.

c. Uneven support can deform RF cable dielectric layer causing RF losses and reflection of RF signal.

d. Cable damage may not be apparent during inspection of the cable exterior jacket or with a dielectric withstand test. The location of the damage may only be detectable with use of a TDR and appropriate profile data defining acceptable cable performance limits. Improper clamping of optical cable can likewise cause damage by fracture of the glass fiber or making sharp bends, which can create excessive dB losses. An OTDR is needed to measure such losses and locate the fault or source.

UAV Consideration: With the physical space limitations, the specialized support for optical/RF cables may not be possible with UAV applications, and these cables may be routed with other power and signal cables. Care should be taken to ensure that the installed harness is not placed under stress that may impact optical/RF signal strength.

3.11.6 General Purpose Protection and Support Hardware

The following items may be used for the protection and support of wiring and related equipment.

3.11.6.1 Tape Protection

Self-adhering unsupported silicone tape in accordance with A-A-59163 may be used to wrap around wires or bundles for additional protection, such as in wheel wells. The tapes shall be applied so that overlapping layers shed liquids and shall be provided with drainage holes at all trap points and at each low point between clamps. The tape shall have the ends tied or otherwise suitably secured to prevent unwinding. When alternate tapes are considered (see 3.11.3.9 for guidance).

Rationale: Landing gear wells on some aircraft have wire bundles routed through them that can be subject to high wind loads, flexing, high vibration, and contact with foreign objects. A-A-59163 silicone tape can improve environmental stress resistance. Moisture entrapment can lead to insulation deterioration or wire-to-wire shorting if any adjacent wire insulation discontinuities exist. Although silicon self-adhering tape is intended to remain secured in position, extended exposure to the environment or foreign materials inadvertently deposited on its surfaces can cause unravelling if it is not secured to the wire harness.

3.11.6.2 Insulating Sleeving for Uninsulated Terminal Lugs and Splices

Unless pre-insulated splices and terminal lugs are used, they shall be protected with insulation sleeving. The sleeving shall cover the splices or terminal barrels and at least 0.5 inch of the adjacent wire insulation. Sleeving temperature ratings shall be compatible with the temperature service requirements in the area where they are installed.

Rationale: To establish a requirement to environmentally seal unsealed splices and terminals, as well as to provide a method for estimating conductor temperature in order to determine what temperature rated sleeve to use. Note the highest temperature rated, qualified AS23053 heat shrink is the /12, which is rated to a maximum of 250 °C.

3.11.6.2.1 Insulating Sleeving, Heat Shrinkable

Heat shrinkable insulating sleeving shall conform to AS23053 or MIL-PRF-46846.

Rationale: Both AS23053 and MIL-PRF-46846 offer a wide range of materials, configurations, and sizes of approved heat shrink. Selecting heat shrink from these two specifications assures performance, reliability, and configuration.

3.11.6.2.2 Insulating Sleeving, Non-Heat Shrinkable

Insulation sleeving shall conform to MIL-I-631 or MIL-I-3190. PVC material is not approved. Non-heat shrinkable sleeving shall be tied securely in place.

Rationale: Size selection of heat shrinkable sleeving should allow for a snug fit in the desired location when fully heat-recovered. For non-shrinkable tubing, if tubing is not secured, it can slide along wire exposing the area it is intended to protect and may become FOD. PVC is prohibited because of its low temperature rating (105 °C) and outgassing hydrochloric gas when burning and forming hydrochloric acid, which is hazardous and corrosive.

3.11.6.3 Terminal Nipples

A-A-59178 terminal nipples shall be used to protect overall insulation and for protection on terminal lugs and studs where termination covers or potting is not employed.

Rationale: Stud terminations that do not have a terminal cover are subject to shorting. Nipples can provide shock hazard and shorting protection to both terminal lug and stud. A-A-59178 terminal nipples shall be sized to fit terminal lug and stud extension to avoid sliding off.

3.11.6.4 Grommets

Edge grommets shall be in accordance with NASM21266 or NASM22529/2. The NASM21266 grommet shall be permanently bonded. Ring grommets shall be in accordance with NASM3036.

Rationale: Use of unapproved edge or ring grommets could result in improper fit on material thickness or degradation when exposed to heat or fluids. NASMS21266 "caterpillar" type edge grommets may be subject to aging failure (these may fracture when in use or attempting to fit into hole). NASM22529 edge grommets have spring type tines to facilitate adherence to material edge and do not rely on bonding adhesion. The NASM22529/1 edge grommets do not have a chafe protection cushion; they are painted metal only. The additional limitation of grommet type was added to ensure that only approved grommets are those with a cushion type of material.

3.11.7 Radius of Bend Measured to Inside Surface

a. Wire, electrical cable, and harness. For wiring groups, bundles, or harnesses and single wires and electrical cables individually routed and supported, the minimum bend radius shall be ten times the outside diameter of the largest included wire or electrical cable. At the point where wiring breaks out from a group, harness, or bundle, the minimum bend radius shall be ten times the diameter of the largest included wire or electrical cable, provided the wiring is suitably supported at the breakout point. If wires used as shield terminators or jumpers are required to reverse direction in a harness, the minimum bend radius of the wire shall be three times the diameter at the point of reversal providing the wire is adequately supported.

   Rationale: Bending wire or cable into a tight radius can cause tensile strain on outer part of conductors and insulation and eventual damage when in service. Bending wire or cable into a tight a radius can cause some insulation constructions to buckle and weaken the insulation properties. Some tape wrapped constructions will delaminate under mechanical stress (particularly at elevated temperatures). These buckled areas will eventually become breaks in insulation and require repair/replacement. Qualification tests of wires in Table A-I, A-II, and their cable constructions has verified ability to withstand bends within the specified limits without degradation.

b. Protected harnesses. The minimum bend radius, as measured on the inside radius of a protected harness, shall be six times its outer diameter. In no case shall the bend radius of a protected harness be less than ten times the diameter of the largest included wire or electrical cable.

   Rationale: Bending of the harness on too tight a radius could damage the harness jacket, allowing moisture ingress and fraying. In some instances, where larger wires are included, the insulation jacket on an individual wire could be damaged if applicable wire bend radius limits are exceeded.

c. Coaxial cables. The minimum radius of bend shall not adversely affect the characteristics of the cable. For flexible type coaxial cables, the radius of bend shall not be less than six times the outside diameter. For semi-rigid types, the radius shall not be less than ten times the outside diameter.

   Rationale: Flexible coaxial cables specified in AS50881 A.3.1.5 have been tested and qualified to withstand bending on the above radii without damage or excessive losses. Semi-rigid types have a tubular metal construction requiring bending on a larger radius to avoid damage.

d. Fiber optics cable. The minimum radius of bend for fiber optics cables shall be in accordance with the cable manufacturer's recommendations and shall be sufficient to avoid excessive losses or damage to the cable.

   Rationale: The transmission characteristics of fiber optics cable are diminished with bends. Tight bends can substantially increase losses and incur damage to strength members, jackets, and glass fiber. Bends at breakouts of multiple fiber optic cable bundles must be carefully controlled to conform to minimum bend radius requirements.

e. These requirements also apply during shipping, handling, and storage.

   Rationale: Prior to installation, violating the bend requirements specified in AS50881 3.11.7 can cause damage to wires, cables, and/or protected harnesses. Hanging wire bundle from supports or penetrations during installation has been shown to be the source of damage. Review of these incidents has found that, during installation, the wire harness weight caused tight bends structure leading to insulation damage.

3.11.8 Drip Loop

Where wiring is dressed downward to a connector, terminal block, panel, or junction box, in addition to the requirement of 3.10.7.1, a trap or drip loop shall be provided in the wiring to prevent fluids or condensate from running into the above devices. Potted connectors and connectors containing only fiber optic termini are exempt from this requirement (refer to MIL-STD-1678).

Rationale: Gravity causes moisture to travels along wire bundles and between individual wires. Bundles should be left long enough to make a drip loop. This allows water to drain from the wire/bundle, keeping the moisture out of connectors and electrical units.

Moisture ingress can cause wire-to-wire shorts and system shutdowns. Moisture is likely to be conductive and can cause an unwanted connection between adjacent termination circuits, causing shutdowns or unplanned actuation.

Potted plugs are one means of reducing the ingress of fluids into connectors. The potted plugs are encapsulated so that moisture running along the wire bundle cannot enter its terminations. The potting and wire type selected must be such that the applied potting material adheres to wiring and connectors. Wire test standard ASTM D3032 provides a means to assess the potting material-wire adhesion. Potting of connectors should be limited, or last resort, since the application of potting compound makes the plug no longer maintainable as typical polysulfide potting compounds cannot removed without damage to wires. Per 3.14.8, "for Air Force and Navy procurement, all potting of connectors is discouraged and requires specific application approval."

3.11.9 Wiring Near Moving Parts

Wiring attached to assemblies where relative movement occurs (such as at hinges and rotating pieces) shall 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 electrical/optical cable upon another and excess twisting and bending. Bundles shall be installed to twist instead of bending across hinges. Electrical/optical cables in the vicinity of line replaceable units (LRUs) and weapon replaceable assemblies (WRAs) shall be protected against damage caused by flexing, pulling, abrasion, and other effects of frequent removal and replacement of equipment.

Rationale: Wires and cables subject to unit movement can fail when they experience excessive tensile loads abrade against each other or are damaged by twisting and bending. Conductor fatigue failure can result in open or intermittent, or circuits causing system malfunctions or shutdown. Some wire constructions have demonstrated better resistance to flexing and bending. Consult wire specification for specific attributes (see 3.7).

3.11.9.1 Wiring Near Flight Controls and Rotating Shafts

Clamping of wires routed near movable flight controls must be attached with steel or titanium hardware and must be spaced so that failure of a single attachment point cannot result in interference with controls or shafts. The minimum positive separation between wiring and all components of movable flight controls and rotating shafts shall be at least 0.5 inch throughout the full range of movement.

Rationale: Aircraft flight control and rotating shaft movements should not be impaired by using fasteners that could be strained or over-torqued and fracture during service. Steel and titanium hardware is capable of withstanding installation torque and bundle weight without fatigue failure during the aircraft's full-service life. Maintaining a minimum positive clearance of 0.5 inch allows for possible bundle shifting and flexing during aircraft flight operations.

Note that this separation distance only considers the mechanical movement of the wire harness and does not consider the potential damage from electrical arcing.

3.11.10 Special Protection

Power feeders, including wires, electrical cables, and buses, shall be given particular mechanical protection such as in the form of extra insulation, standoff mounting, and separation. Bus centers shall be located within insulated enclosures, isolated in order to prevent a fault to ground or phase-to-phase fault that would disrupt the electrical power system. Wiring installed in locations, such as bilges and on decks or floors, shall be so located or protected that they will not be damaged by maintenance personnel during normal maintenance or crew movement. Wiring installed in locations where fluids may be trapped and the wires and cables contaminated, shall be properly routed and protected against fluid damage. See 3.8.10.3 for installation guidelines on filter line cable.

Rationale: Electrical power feeder failure is likely to result in a fire. Loss of a power source through ground fault or phase-to-phase fault will also result in loss of all circuits connected to that power source. Protection of the remaining source of redundant power systems is typically provided by current limiting devices, which will isolate the faulted bus, leaving all of its systems unpowered. Selection of power feeder wiring should include consideration for extra abrasion resistance and cut through strength. The weight of this extra protection is slight versus that of conductors.

3.11.11 Gas and Fluid Carrying Lines and Tubes

Wiring shall be supported independent of and with the maximum practicable separation from all fluid-carrying lines, tubes, and equipment. Separation clamps shall not be used for primary support (see 2.3.19) but are permitted to maintain separation requirements for wiring. Wiring shall be routed above, rather than below liquid carrying lines, tubes, and equipment to prevent contamination or saturation of the wiring in the event of leakage. Where this routing is not practicable, the wiring shall pass below the lines at an angle rather than parallel to the lines, so as to minimize the length of wiring directly beneath the lines and in the path of a potential leak. Terminating devices shall not be placed under any lines. Wiring shall not be attached to fluid-carrying lines, tubes, and equipment unless they require electrical connections, or their separation is less than 2 inches. In areas where separation is less than 2 inches, the wiring shall be installed to maintain positive separation of at least 0.5 inch. Examples: (a) separate the wiring from the line with a suitable separation device; (b) attach the wiring to primary support(s) at the closest proximity of the wiring to the line. Where lines and wiring are installed such that they are separated by rigid nonmetallic conduit, metal conduit, ribs, webs, frames, channels, extrusions, stringers, or other suitable barriers, the above minimum separation requirements do not apply.

Rationale: Gas- and fluid-carrying lines typically carry flammable material and are subject to leakage. Maintaining 2 inches of separation minimizes exposure of flammable material to electrical energy. Routing wires above such items prevents direct leakage on them. Routing wires at an angle rather than parallel to fluid lines minimizes the possibility of leakage falling directly on wiring. Not clamping to them reduces the possibility of wiring causing leaks and avoids paths between fluids and wiring. Careful planning of overall wire routing paths in the early stages of design can eliminate unnecessary routing of wiring in close proximity to fluid- and gas-carrying lines, tubes, and equipment. Grounded shields on wires can eliminate the probability of insulation breaks exposing live conductors to possible fuel leakage. This requirement can be interpreted to mean that wiring can be routed beneath liquid-carrying lines for any distance as long as it is angled downward so that leaked fluids flow away from the point of the leak.

3.11.12 Wiring Through Fuel Tanks

Wiring should not be routed through fuel tanks except where there is no alternative. Wiring that must be routed through fuel tanks, but that is not part of the fuel management or control wiring shall be routed through a dry access channel or passage so as to preclude contact of the wiring insulation and the fuel. The channel or passage shall be of a size to facilitate the removal and repair of the wiring without removal of the fuel tank, and shall have a fluorocarbon liner, which will preclude electrical contact. The routing of fiber optic cables through fuel tanks is not recommended (refer to MIL-STD-1678).

Rationale: Exposure of electrical energy to fuel vapor of significant concentration can cause an explosive reaction. Fuel can be vaporized at some temperatures and must be isolated from wiring. A dry channel with fluorocarbon lining can prevent chafing of and arcing in an inaccessible area. Such arcing can erode a pathway through some materials exposing fuel to wire. Early coordination between wiring and fuel system design activities can minimize the need for routing unrelated wiring through fuel tanks.

3.11.13 Wiring Inside Fuel Tanks

Wiring that is essential to the operation of fuel management or control system, may be routed inside fuel tanks only if there is no alternative and requires the approval of the procuring activity. Wiring that is used in circuits that are capable of generating energy levels greater than 0.02 mJ must be isolated from fuel. Isolation may be achieved by using grounded metal conduit having a fluorocarbon liner, approved components, approved materials for sealing, potting (see 3.14.8); routing through conduit or use a fuel-resistant Fluoropolymer molded harness, etc. (refer to MIL-HDBK-534). Wiring that comes in contact with fuel must have an insulation system which is compatible with the fuel and fuel vapor. Clamps and hardware used to attach wiring inside fuel tanks must also be compatible with the fuel and fuel vapor. Environmentally sealed connectors and terminations used to attach wiring inside fuel tanks must also be compatible with the fuel and fuel vapor. Tie tape, string, mechanical straps, or other items that could become loose and clog fuel filters shall not be used inside fuel tanks. Fiber optic cables and silver-plated conductors (see 6.11) shall not be used inside fuel tanks. Refer to AIR6820 for extended fuel performance characteristics of common wire types and wire selection guidance.

Rationale: Fuel quantity internal tank circuitry is designed to exclude energy levels greater than 0.02 mJ to prevent inadvertent fuel ignition (refer to FAA AC 25.981-1D). Other systems within these tanks must be protected to prevent arc exposure to fuel. The 0.02-mJ energy level limit precludes inadvertent fuel and fuel vapor ignition.

Wire/cable insulation, as well as any primary/secondary harness support, and secondary harness protection exposed to fuel must be of a type that will not cause fuel contamination. Materials not compatible with fuel can break down and contaminate fuel, potentially causing malfunctions or blockage of fuel lines. To prevent inadvertent exposure of higher voltages into the fuel system, circuit for wire which must come in contact with fuel should be isolated from other wiring throughout its routing and at junctions.

The fluorocarbon lining of conduit through which wiring carrying more than 0.02 mJ of energy is carried is intended to prevent wire chafing and arcing in an inaccessible area. Grounding this conduit will cause circuit protection of arcing wiring to isolate the circuit before penetration of conduit occurs.

The use of silver-plated copper conductors is prohibited inside fuel tanks since silver can combine with sulfur or water and form silver-sulfide or oxide deposits between exposed conductors (terminal block connections, etc.). The silver-sulfide deposits reduce the insulation resistance between conductors and can ignite fuel vapor when exposed to very low levels of electrical energy. If use of silver in electrical components and wiring in the tank is determined to be critical, it should be defined as a critical design configuration control limitation. Refer to AS50881 6.11 for additional resources related to fuel tank wiring.

3.11.14 Airborne Equipment External Wiring

GFAE equipment shall be considered the same as airborne equipment.

Equipment furnished with wiring and connectors which are excessive in length shall not have the wiring length reduced. The excess length shall be grouped and supported in a manner which will prevent damage to the wiring and possible fouling of moving parts.

Rationale: Performance of GFAE cannot be ensured if its wiring or connection devices have been damaged. Careful grouping and supporting of the wiring are recommended to avoid wiring damage to GFAE units; preventing this damage can avoid subsequent failures if it is installed in other applications.

Cutting off GFAE wiring is not authorized and would impair interchangeability with identical units on other aircraft. Stowage which avoids contact with moving parts will prevent interference with aircraft operations.

3.12 Ground Return

The electrical power source ground terminals shall be connected to the primary metallic structure of the vehicle. Individual ground wire connections shall be made using terminal lugs secured by threaded fasteners. Assembly procedures in accordance with ARP1870 are recommended for electrical bonding and grounding. For current return leads of size AN-4 (AWG-4) or larger wire, the bonding connection shall not be made directly to primary structure but shall be made by connecting the ground wire's terminal to a tab of sufficient size to conduct ground current, attached to the structure with at least three fasteners not arranged in a straight line pattern. The vehicle structure shall serve as the ground return circuit unless system considerations require separate ground return wiring. Equipment that incorporates a ground terminal shall be grounded by the shortest suitable ground wire. Equipment that is internally grounded and that does not incorporate a ground terminal shall be grounded by the shortest practicable ground wire if suitable grounding is not provided by the equipment mounts, or if corrosion of the mounts is likely to occur. Ground return wiring shall not be connected to magnesium. Electromagnetic environmental effects interface requirements and verification criteria shall be in accordance with MIL-STD-464.

Rationale: The primary aircraft structure typically provides the path for all circuit grounds to return current to the source. AN-4 and larger leads typically carry more current than can be safely conducted by terminals attached directly to structure. These applications require a tab to increase the effective conductive path cross section.

Rivets securing a tab to structure can fatigue and loosen if arranged in a straight line. Such failures can result in extreme heat causing structural failure, series arcing, or fire.

Individual ground wire connections to structure should be as short as practicable and should be made with threaded fasteners. Such attachments can readily be checked to verify tightness and continuity with structure. These connections require cleaning non-conductive materials from structure to ensure direct low resistance connections between terminal and structure. See 3.12.4 and 3.12.5 on bonding.

Aircraft composite structure can present a problem in attachment of ground returns. A specified ground bus metallic strip or extra length wires can be used to connect to grounded structure.

3.12.1 Shielded Wire Grounding

Shielding shall be in accordance with vehicle system requirements. In harness applications, and applications containing multi-conductor, shielded cable, shields shall be terminated within the booted areas of breakout terminations. When pigtails are used in military EMC environments, extra precautions need to be taken to maintain electromagnetic shielding; this is typically achieved by using a 360 degree shield similar to AS85049/103, /104, and /105 type terminations on all harness connectors. Electromagnetic environmental effects interface requirements and verification criteria shall be in accordance with MIL-STD-464.

Rationale: Electromagnetic interference can induce unwanted signals in sensitive aircraft wiring that can cause lost communications, instrumentation anomalies, and unplanned control movements. The distance between shield terminations and connectors creates a window through which EMI can penetrate unless protected by a conductive backshell or overbraid connected to the grounded connector shell. Grounding of connector housings, their backshell accessories, and shield overbraids must provide a low impedance path to the metal airframe structure for cable and harness overbraids and shielding to be effective. Both MIL-STD-464 and ARP1870 offer additional requirements and further define bonding and grounding requirements. Additional considerations for shielded wire ground are included in 3.12.1.

3.12.1.1 Shield Terminators

AS83519 shield terminators shall be used in terminating shields except when the operating temperature they are to be installed in exceeds the maximum rated operating temperature of the device. Control temperature solder devices shall be installed in accordance with AS4461. The unterminated end of a shield shall be covered with an appropriate temperature-rated AS23053 or equivalent shrink sleeving. For elevated temperature shield terminations, employ the uninsulated two-piece AS21980 and AS21981 crimp ferrule combination and cover with an appropriate temperature-rated AS23053 or equivalent shrink sleeving. All shielded cable terminations shall be installed no closer than 1.5 inches from the rear of the connector grommet to allow for contact extraction. All shield terminations shall be staggered to allow for accessory removal and shall not be located under the saddle clamp of the connector accessory or primary support. Shield terminator leads shall not be terminated to saddle clamp hardware. Multiple shield terminator leads shall not be linked in series (daisy chained).

Wire harness flexible metallic shield or EMI accessory shall extend beyond the shield terminations to provide suitable EMI protection to the affected system in accordance with MIL-STD-464.

Rationale: When solder sleeves are used to make shield grounds, AS83519 sleeves with integral ground leads provide excellent performance and are more easily terminated than those without such leads. Guidelines regarding the application of AS83519 solder sleeves reflect color and solder flow indications and must be conformed to for successful soldering and sealing of the connection.

The evolution of AS83519 solder sleeves now includes those for higher temperature solder, those with shield braid drain wire, and those with ability to accommodate multiple wire terminations.

The temperature required to heat shrink and flow solder in AS83519 devices may exceed the 135 °C rating of tin-plated wire causing insulation damage.

Careful configuration selection is required to align the solder sleeve's configuration (solder material) with the compatible cable's plated shield material. Note that nickel-plated cable shields are not compatible with tin-lead solder sleeves, such as that used in the AS83519/2.

3.12.1.2 Shielded Wire Harness

When selecting harness or cable shielding material, ensure careful consideration is given to both the mating accessory (i.e., AS85049) and the shielding material. For metallic, non-metallic, and blended shielding designs, careful attention shall be given to the plating to ensure galvanic compatibility for the anticipated service life of the system. In order to prevent wire chafing against the inside of shielded harnesses, see 3.11.4. For shield splice, employ AS85049/93 split ring secured with AS85049/128 bands.

Rationale: For galvanic compatibility of connector to accessory, additional guidance is available in ARP6903, AIR5919, and MIL-STD-889. These documents provide the basis for compatibility of dissimilar metals. Incorrect/incompatible materials selection directly affects the electrical and mechanical bonding performance of the termination. The lifecycle performance of the EWIS can be adversely impacted along with the applicable aircraft system performance. Note that MIL-STD-464 provides some data on shield termination performance examples and their in-service level of degradation.

3.12.1.3 Shield Terminations for High Speed Data Cable

For high speed cable terminations (i.e., AS6070) with signals faster than 10 kHz, shield terminations shall be per connector manufacturer's requirements.

Rationale: With the advent of various data bus protocols of higher speeds, it became evident that there are various means of achieving suitable data rate performance. AS6070 is the dedicated high-speed data cable parent specification. Though commercial industry technology advances quickly, the AS6070 detail sheets define and standardize mature and legacy data bus protocols. The terminations and connector interfaces are different for most of the protocols, and they are best defined by the connector manufacturers' requirements. One example of a standardized high-speed connector is the MIL-DTL-32546. For verification of optimum performance, the shield finishing performance should comply with the system level requirements.

3.12.2 Multiple Grounds

No more than four ground wires shall be terminated in one lug provided that their total circular mil area is within the range of the crimp barrel. No more than four lugs shall be connected to one common ground stud. Ground modules in accordance with AS81714/27, AS81714/28, AS81714/63 may be used for multiple grounds. No more than 16 ground wires shall be connected in a ground module. Unwired contacts shall not be installed in unused terminal junction module cavities. Sealing plugs in accordance with MS27488 shall be installed in unused module holes. Sealing plugs shall be installed headfirst. The AS81714/27 and AS81714/63, Type S grounding module mounting studs shall have the same bonding surface preparation requirements as per 3.12.4 and shall employ hardware attachment requirements as per 3.12.5. Each ground for electric power sources (primary, secondary, conversion, emergency) shall be connected to separate ground points. Grounds for utilization equipment may be connected to a common ground point only when supplied from the same power source provided this equipment does not perform duplicate or overlapping functions.

Rationale: If not properly secured, the loss of a single ground stud can impact the functionality of multiple systems. Loss of power source grounds risks shutdown of numerous connected systems. The simultaneous loss of numerous or redundant systems can be a traumatic event for crewmen trying to perform a mission and control an aircraft. Assessing the full effect of multiple system failures is unlikely, especially when flying in close proximity to obstacles or during landing and takeoffs.

Exceeding four wires on a common stud avoids distortion and breakage of terminal lugs. More than 16 wires on an AS81714 terminal junction system module risks numerous simultaneous system failures. Grounds for utilization equipment performing duplicate or overlapping functions risks redundant systems failure. Terminal lugs can be performed to nest together without risk of breakage. AS81714 modules bus all connections together in a common ground plane. Combining a number of ground wires in a parallel loop connected at both ends risks undetected loss of redundancy and should be avoided.

Regarding the AS81714 terminal junctions, insertion of unwired contacts in the unused cavities is not recommended. The AS81969 unwired or standard extraction tools will not fit inside the tool to extract the unwired contact. This requires the terminal junction assembly replacement if any of the unwired cavities need to be employed. Instead, it is recommended to insert the applicable sized MS27488 sealing plug, large (head) end first. This has been shown to fit well and not engage the locking mechanism of the terminal junction. Another method is by crimping the contact onto a 6-inch jumper wire and insert in each unused cavity, then install a dead end cap or stub splice (refer to AS81824/13) to terminate the wire end.

This has been a requirement since MIL-W-5088B, dated 18 June 1956. It was considered too large of a risk to have more than four wires to a ground stud. Revision (H) of MIL-W-5088 allowed up to 16 ground wires to one ground stud at the request of the Navy. This lasted a few years, until aircraft got into the field and there were multiple failure/shutdowns. The biggest issue was maintenance; when a ground wire had to be removed and the ground stud was disturbed, all items attached to the stud had to go through a time-consuming functional test.

During this period, the ground module was developed and eliminated many of these issues. For example, when a single contact is removed for maintenance reasons, only one contact is disturbed. By removing only a single contact from the ground module, only the disconnected circuit had to undergo functionally testing.

3.12.3 Insulated Equipment Boxes

Electrical equipment, such as relays mounted on insulated surfaces, shall be individually connected to ground rather than series connected and then grounded by a single wire to a ground stud. For recommended fastening hardware, tightening methods, and torque values, refer to AIR6151.

Rationale: Insulated enclosures are well suited for protection of power source and cross-feed contactors. They avoid dissipating large amounts of power to structure and provide protection of buses from errant contacts.

Single wire failures that occur on series connected grounds may disable multiple functions. Further, redundant functions could be lost if the grounding was interrupted for multiple units in an enclosure. Connecting each device to ground, using a separate wire for each device, will reduce the impact of wire failure. Doing this coupled with the recommendations of 3.11.2 can help to reduce time needed for repair or replacement.

When determining the particular design to implement, internal relay and contactor ground faults should be considered. If shock hazard grounds are used, contactors having an internal ground fault will cause circuit protection to isolate the system.

AIR6151 has been published and designated as the common document which identifies installation torque values for EWIS components.

3.12.4 Bonding Surface Preparation

Surface preparation for an electrical ground shall be accomplished by removing all anodic film, grease, paint, lacquer, or other high-resistance materials from the immediate area to ensure a suitable minimum radio frequency (RF) impedance connection between the terminal and adjacent structure. The means used to remove any protective finish shall produce a smooth surface without removing excessive material under the protective finish. After cleaning, but before grounding hardware installation, cleaned surfaces shall be protected with a corrosion-resistant conductive protective film in accordance with MIL-DTL-5541 Class 3. For military applications, use MIL-DTL-5541 Type II, Class 3. After hardware assembly, the mating surfaces around the ground hardware shall be restored to the original finish, or if subject to fuel exposure, shall be sealed with a compound in accordance with environmental requirements of the area.

Rationale: The corrosion of ground connections is of particular concern for aircraft zones exposed to salt water, fuel, and/or aircraft engine exhaust; both aircraft zones tend to have more corrosive moisture condensation. Bare metal, particularly in the previous mentioned zones, require conductive surface protection to avoid corrosion that may impact the low impedance connection. Areas not in contact with terminal require original finish because exposed MIL-DTL-5541 film does not resist corrosion.

3.12.5 Bonding and Grounding Attachments

Bonding and grounding attachments hardware shall be of conductively plated material and construction that is suitable for the temperature and the other environmental and mechanical requirements of the connection. All threaded hardware connections shall utilize a split lock washer with either plain or self-locking hardware to ensure a tight connection under all conditions. Aluminum hardware and MIL-DTL-83413/8 bonding jumpers shall not be used at temperatures above 300 °F. Cadmium-plated steel hardware shall not be used at temperatures above 450 °F. Cadmium-plated hardware shall not be used in space applications. Self-tapping screws, zinc-plated, unplated, and anodized hardware shall not be used. Internal or external tooth lock washers shall not be used. Bonding jumpers shall be the non-quick disconnect type and shall be in accordance with MIL-DTL-83413/8 or contractor designed equivalent.

Rationale: Lock washers ensure intimate surface connection and self-locking hardware avoids loosening of surface connection. Corrosion or other degradation of fastener hardware will lead to a slow, long-term increase in circuit resistance, eventually leading to open circuit connections. Anodized finishes are non-conductive. Zinc-plated and un-plated hardware are not suitable for long-term use.

Cadmium-plated steel hardware retains corrosion resistance and conductivity over extended periods. When attaching to steel or titanium structure, use of dissimilar metals with incompatible finishes requires special attention. The use of cadmium plating is limited to below 450 °F, as the plating breaks down in these conditions. Cadmium platings are not recommended for space applications.

The restriction on self-tapping screws is that these components displace material and any corrosion-resistant surface treatment allowing exposure of unprotected surfaces. These unprotected surfaces are corrosion prone.

Distortion of terminal lugs during tightening can lead to material fractures.

3.12.6 External Ground Terminals

Equipment which includes a ground terminal or pin, which is internally connected to exposed metallic frames or parts shall have a ground wire connection to the terminal or pin.

Rationale: Equipment ground provisions are intended to provide circuit, static, or shock hazard ground and may not function properly if not connected to the airframe. Internal ground faults could result in creation of a shock hazard for crew or maintenance personnel if unit housing is not electrically connected to the airframe. Equipment housings are not always metal-to-metal electrically bonded to airframe structure, particularly if not made of conductive material. In such instances, a specific ground wire connection is typically provided for this purpose.

3.13 Conduit

Conduit may be used where necessary to protect wiring or to facilitate maintenance in inaccessible areas. Use of conduit requires procuring activity approval unless specifically required elsewhere in this specification. Metallic conduit may be used for shielding to meet the requirements of MIL-STD-464, subject to approval of the procuring activity.

Rationale: Wiring paths through areas that cannot readily be accessed can take advantage of conduit for initial installation, maintenance, and modification. Wiring passing through inaccessible areas can be subject to deterioration or chafing without detection unless access means are provided for its removal and inspection. Wiring exposed to environmental or service damage during operations or maintenance activity should be protected to avoid insulation or conductor damage.

If the case of wire failure, it should not be assumed that the conduit will be able to contain the fault without penetration. Incidents have been recorded in which the conduit was breached during a wire failure event.

3.13.1 Rigid Metallic

Rigid metallic conduit shall be aluminum or aluminum alloy tubing.

Rationale: Aluminum is lightweight, conductive, and does not readily corrode. For all metal conduits, electrical bonding to the aircraft ground is required. Approved bonding clamps have aluminum surfaces to provide metal-to-metal contact.

3.13.2 Flexible Metallic

Flexible metallic conduit shall conform to AS6136 and shall be used only when rigid metallic conduit is impractical.

Rationale: Flexible conduit can be installed in congested areas and formed to fit available spaces. The benefit is they can provide harness protection and support where it would be otherwise impractical. The use of flexible metal conduit requires fittings and must have smooth internal surfaces as to reduce potential chafing locations.

Flexible metallic conduits may not be suitable for all applications, particularly those with sharp bends. Bends in flexible conduit can kink if bent too sharply, causing wire chafe or pinch areas within the conduit.

3.13.3 Flexible Nonmetallic

Nonmetallic conduit shall conform to AS81914 and be of a material satisfactory for the installation environment. Polyvinyl chloride shall not be used.

Rationale: Lightweight conduits having smooth internal surfaces can provide access in otherwise inaccessible areas. The severe and varied environment can be a challenge to nonmetallic conduits. Conduit material failure caused by mechanical stress and/or degradation can damage wire.

The use of PVC conduit is not recommended as it can outgas toxic material at elevated temperatures.

AS81914 defines the standard flexible conduit configurations approved for aerospace applications.

3.13.4 Size

In determining the diameter of conduit to be used, the wiring which is to be installed therein shall be bundled together and the maximum diameter measured. The maximum diameter shall not exceed 80% of the internal diameter of the conduit. Maximum diameter wires and electrical/optical cable permitted by applicable specifications shall be used or allowed when taking this measurement.

Rationale: The internal conduit clearance must be sufficient to allow for wire harness installation and wire removal for inspection. The smoothness of internal conduit surfaces limits the possibility of abrasion. In areas not readily inspected, additional sleeving over wires can prevent chafe damage of wires that experience relative motion and eventual damage in conduits.

3.13.5 Fittings

Conduit fittings in accordance with AS10380 or other applicable drawings shall be used in conjunction with metallic conduit. Nonmetallic conduit shall be terminated with an approved AN or MS fitting. Rigid metallic and nonmetallic conduit used for wiring in an accessible area(s) need not be terminated provided the conduit is suitably flared or rounded and sharp edges removed.

Rationale: Approved metal conduit fittings have internal features that avoid damage during installation or removal of wires. Sharp conduit edges or tight bend radii of the wire harness leaving the conduit can cause chafing of wiring. Flaring or rounding the end of metallic conduit allows routing into bends and pulling wires through from an angle without damage to insulation. The conduit should not be designed with tight internal bends as this will create areas more prone to abrasion.

See 3.13.11 for information on harness bend radius.

3.13.6 Conduit Installation

Conduit shall be installed to withstand vibration and normal service handling (see 6.12).

Rationale: Conduits must be secured in place and located to avoid shifting and interference with equipment removal. Installing conduit in some areas may require access before all structure is installed.

Conduits are frequently used as handholds during installation and maintenance activities and should be designed to withstand these stresses. The supporting equipment for conduits should also be able to withstand this stress.

3.13.7 Support

Conduit shall be supported so that strain on the ferrules is relieved.

Rationale: If an installation preload exists, vibration and strain on supports could cause fatigue failure, resulting in wire abrasion or inability to extract wiring for inspection.

3.13.8 Drainage

Where practicable, metallic and nonmetallic conduit shall be installed so that fluids or condensate will not be trapped. Suitable drainage holes shall be provided at the low points, except for magneto ground cable conduit and metallic flexible conduit. Tape (non-adhesive) used as a wraparound on wiring shall also have drainage holes at the low points. Burrs shall be removed from drainage holes in metallic conduit and from the conduit fittings.

Rationale: Moisture accumulation in conduits can result in wire-to-wire shorts, ice damage, and/or deterioration of insulation material. The inclusion of suitably sized drain holes in the conduits allows for moisture drainage. When the drain holes are created, the drain holes edges need to be rounded to avoid chafing to the contained wire harness.

When routing magneto ground cables through conduits, drain holes can provide a means for short wavelength RF fields to exit the conduit and interfere with nearby systems. The impact on nearby systems should be considered possible EMI.

3.13.9 Grounding

Metallic conduit carrying electrical wiring shall have a low-resistance bond of less than 0.10 Ω to structure at each terminating end and break point. The bonding path may be through the equipment at which the conduit terminates. Bonding connections to the conduit shall be made with an AS7351 clamp and a bonding jumper, with one terminal secured to the clamp with threaded fasteners. Surfaces between clamp and conduit and between terminal lug and clamp tab shall be prepared to ensure a suitable low-resistance bond. After cleaning, but before clamp installation, aluminum conduit surfaces shall be conductive conversion coated in accordance with MIL-DTL-5541. After bonding hardware assembly, mating surfaces around the ground hardware shall be restored to the original finish or, if subject to fuel exposure, shall be sealed with a compound in accordance with MIL-PRF-8516.

Rationale: Shielding effectiveness of conduit-enclosed wiring relies on low resistance ground connection to aircraft structure. If all of the metal-to-metal interfaces are not properly prepared and refinished, the resistance to aircraft structure could gradually increase until no conduit shielding is provided. See 3.12.4 and 3.12.5 on bonding requirements.

The 0.10-Ω resistance required of bonding connections and shielding has been found to effectively prevent errant signals from being imposed on sensitive circuits during operation. During their initial acceptance, aircraft systems are typically tested in high intensity electromagnetic fields to determine if all systems can function normally in this environment. If the effectiveness of any of the aircraft's shielding is later diminished, systems may malfunction.

See 3.8.10.3 on EMI requirements.

The MIL-PRF-8516 is well suited for the application as it is tested for electrical insulation characteristics (minimum of 4000 MΩ insulation resistance) and is of polysulfide material family with suitable cure times. It meets the fuel requirements and seven other fluid exposure requirements.

3.13.10 Ignition Conduit

The ignition ground conduit for each engine shall be separately routed to prevent a single damage from affecting more than one engine.

Rationale: The loss of wiring in engine ground conduit can result in a disabled engine. Physical separation of ignition conduit is an important means of protecting redundancy and can be accomplished with careful planning early in the design process.

See 3.11.9 for considerations on system separation.

3.13.11 Radius of Bends

The radius of bend of conduit shall allow the bend radius requirements of 3.11.7 to be met. Conduit and conduit fitting bends shall not cause chafing of the wiring.

Rationale: Conduit material properties can vary considerably and can have an impact on the required minimum bend radius. Some conduit materials kink, cause wire chafing, and eventually fracture if not formed properly. Tight conduit bends can result in internal sharp edges that can damage insulation.

3.13.12 Wire Conduit Support

Wiring entering or exiting metallic conduits shall be supported with a primary support clamp within 10 inches from the end of a conduit to secure the wiring and prevent chafing. See Figure 6.

Rationale: The requirement for the support clamp for the wire bundle is to prevent wire chafe damage/degradation at metallic conduit flared end. In addition, it further aligns with existing requirement in FAA AC 43.13-1B and Military Wiring Maintenance manual NAVAIR 01-1A-505-1.

3.14 Connectors

Except for hermetic connectors with only pin type design, connectors shall be selected so that contacts on the "live" or "hot" side of the connection are socket type rather than pin type to minimize personnel hazard and to prevent accidental shorting of live circuits when the connector is unmated. When using special contacts such as thermocouple or coaxial, circular electrical connectors shall be specified on installation drawings using the A and B suffix when applicable in the connector part number. The "A" designation without pins and the "B" designation without sockets indicate special applications for the connector. The selection and use of connectors for fiber optics cable (refer to MIL-STD-1678) shall be approved by the procuring activity. Only connectors that withstand a minimum of 500 hours salt spray when tested per EIA 364-26 or equivalent shall be used. Rack and panel connectors known as D Sub connectors (such as MIL-DTL-24308) shall not be used except for mating to receptacles on airborne electronic equipment (WRAs/LRUs) and shall be subject to procuring activity approval. Galvanic compatibility of materials and platings used for mating connector plugs, receptacles, and accessories shall be assured (refer to ARP6903). Approved Cadmium alternate finish/plating configurations are identified in AIR5919. For connector selection, refer to MIL-STD-1353 and ARP1308.

Rationale: When unmated with aircraft electrical power on, contact with connector pins can result in shock hazard and unintended shorting of circuits together. This convention can readily apply to equipment disconnects that can be unmated for circuit testing. Certain finishes have substantial differences in material EMF properties from that of shell materials. Use of anodic shell material with cathodic plating (e.g., aluminum shell with nickel plating) can cause rapid migration of shell material due to dissimilar metal corrosion. Refer to MIL-STD-889. Additional, specific guidance on plating compatibility for EWIS connectors and accessories is provided in ARP6903. The ARP provides all common connector configurations and plating and/or finish and their galvanic compatibility by groups.

It is not always possible to match connector shell materials. Scratches and other discontinuities in material finish can cause dissimilar metal corrosion causing connectors to become un-mateable after long-term service in a salt-laden environment. If connector material cannot be changed (e.g., equipment disconnects), application of an approved sealing material to outer connector shell surfaces can prevent this condition.

3.14.1 Environment Resisting Connectors

Circular power and circular signal connectors shall be sealed against the ingress of water and water vapor under all service conditions including changes in altitude, humidity, and temperature. The connectors shall have an interfacial seal, as well as sealing at wire ends. Environment resisting connectors having wire sealing grommets are preferred; however, potting may be used where a grommet seal connector would not be suitable (see 3.14.8). The outside diameter of the wiring terminated at the connector that has a wire sealing grommet shall comply with the wire diameter range specified for that connector (see 3.8.6). No corrosion preventative compound (CPC) shall be applied on any internal surfaces of connectors (i.e., on the exposed pins, sockets, or termini). CPCs are also prohibited externally on connectors containing fiber optic or coaxial connectors (refer to MIL-STD-1678).

Rationale: Moisture ingress can cause pin-to-pin shorts if it collects on connector interface or between contact cavities. It can also cause corrosion between contact and stripped wire ends, which can result in open circuits. Potting must adhere to wire and the connector grommet face or shell to ensure seal integrity. Selection of a wire and connector combination that results in sealing of wire entry grommets in accordance with AIR1329 and avoidance of side loading at wire entry will preclude moisture ingress. Where diameter of intended wire is too small to provide a grommet seal, a larger wire can be used, or a heat shrink sleeve can be applied to grommet area of wire. Overall wire diameter should be checked for compatibility with wire insertion/extraction tool.

3.14.2 Contacts

Connectors using removable crimp type contacts are preferred to solder contact types for general use. For flight control system cables, crimp type contacts are required; solder type contacts are prohibited. Contacts shall be in accordance with AS39029 or the applicable connector specification. Wire size shall be within crimp barrel size range as specified in contact specification. Wire barrel contact bushings, in accordance with AS39029/112, shall be used when crimping some wire sizes in size 0, 4, and 8 contacts. Contractors may use automatic, semi-automatic, or hand crimp tools for production. Contacts crimped with contractor's tooling will provide the same performance as specified by AS39029 or the connector specification. Contractors will only specify AS22520 tools for the tools specified in the component specification or contact replacement.

Improper crimp joint of conductors may deteriorate with temperatures which will cause high voltage drops in low signal applications and hot spots in power applications. The use of the designated and calibrated crimp tools is essential. In crimped applications, tin- and nickel-plated wire have considerable resistance increases when subject to elevated temperature cycle aging tests.

Rationale: Selection and proper application of approved contacts and tools is required in order to ensure intimate low resistance wire/crimp barrel contact that resists corrosion (called a "gas tight" crimp). Calibration (go/no-go test) of crimp tools is an essential part of achieving acceptable crimp joints and should be checked at regular intervals. Incorrect or worn tools can cause high resistance crimp joints or damage to conductor strands. In order to ensure continued proper crimp tool application, a "pull" test is used that measures tensile strength of the crimp joint in order to indicate mechanical performance of the crimp joint. Wires that pull out have improper crimp.

There are also AS39029 contacts that have a unique crimp barrel size on a standard size contact body that will accommodate different size wires. Many contact manufacturers offer special contacts with crimp barrels that accommodate different wire sizes than what is specified in AS39029. There are also available crimp sleeves similar to AS33481 (refer to AS39029/112) for adapting smaller wires that are not within the normal crimp range of the contacts. In such instances, buildup of wire insulation diameter may be required to ensure a proper seal at the connector sealing grommet. Refer to AIR1329 for connector sealing range compatibility details.

The AS39029 contact specification provides suitable performance when contact is crimped on the tin-, silver-, and nickel-plated normal copper alloy conductor. However, there is no performance data for any of the high-strength copper alloy constructions. The last addition to the AS50881 focused on the aspect for crimped applications, identifying that tin- and nickel-plated wire have considerable resistance increases when subject to elevated temperature cycle aging tests. Thus, it is recommended that the design authority needs to test the selected termination if high-strength copper conductor is employed, with particular focus on nickel-plated conductor.

3.14.2.1 Spare Contacts

When crimp contact connectors are used, the unused contacts shall be installed in unused cavities. MS27488 or applicable sealing plugs shall be inserted in unused grommet holes of environment resistant connectors. Sealing plugs shall not be installed where they interfere with the free movement of the spring-loaded socket termini on connectors containing fiber optic termini (refer to MIL-STD-1678). When installing sealing plugs in connectors, components, or terminal junction module grommets, the head of the sealing plug shall be inserted first. For potted connectors, each spare contact shall have a pigtail attached, consisting of a wire of the largest size that can be accommodated by the contact and extends 5 to 7 inches beyond the potting material. The pigtails shall be identified and dead-ended. In firewall applications, there shall be no unwired spare contacts. All unused contact cavities shall be wired. The pigtails shall be identified and dead-ended with M81824/13 end caps (for applications exposed up to 175 °C) or with polytetrafluoroethylene insulated end caps (for applications exposed to temperatures above 175 °C). AS85049/80 shielded, coaxial, and twinax dummy contacts shall be installed in designated unused pin contact cavities in the unpressurized areas (except firewall).

Rationale: Lack of a spare contact in each cavity can allow moisture entry into unmated connectors and inhibit wiring modification. Lack of a sealing plug in each unused wire hole can allow moisture to enter through grommets. Addition of wires to spare contacts of potted plugs must be accomplished by splicing to end capped spare wires. Moisture ingress can cause pin-to-pin shorts if it collects on connector interface if connectors are not fully tightened or between contact cavities.

Moisture can also cause corrosion between contact and stripped wire ends, which can result in open circuits. Connectors designed for shielded, coaxial, or twinax contacts must use corresponding dummy contacts. Special extraction tools are available in connector support kits for removal of spare contacts from connectors. The use of the proper tooling helps to avoid distorting or tearing wire entry grommets. Insertion/extraction tools are designed to fit through connector grommets on most rear-release crimped contact connectors. Older front-release connectors are configured for tool entry through mating end.

Termination in a terminal junction (refer to AS81714) has been updated to eliminate the likelihood of sealing plug engagement in the connector or TJ locking mechanism.

3.14.2.2 Electrical Connectors that Contain Fiber Optic Termini

Electrical connectors that contain fiber optic termini shall have empty cavities filled with either spare electrical contacts or dummy termini unless they interfere with the configuration of the mating connector. Connectors with fiber optic pin termini, whose mating connector have the alignment sleeves built-in, must use special contacts with shorter pins to preclude damage to the mating termini (refer to MIL-STD-1678).

Rationale: Use of fiber optic termini designed to fit into contact cavities of standard electrical connectors has considerable logistic advantage over termini that must use specialized connectors. They allow use of multi-contact terminations where optical data bus systems are used. Such termini require spare cavities to be filled. If spare pins or termini are used and the mating termini have built-in alignment sleeves, they can interfere with mating unless shorter than standard pins are used. Moisture entry openings into the spare contact cavities of electrical connector type bodies that use optical termini can corrode termini or contact lock springs or allow particle entry that can interfere with light transmission.

3.14.2.3 Fiber Optic Termini

Termini shall be in accordance with MIL-PRF-29504 or the applicable connector specification (refer to MIL-STD-1678).

3.14.3 Fireproof and Firewall Connectors

These connectors shall be thread-coupled, self-locking connectors with crimp contacts and corrosion-resistant steel shells. Where it is necessary to maintain electrical continuity for a limited time under continuous flame, both the receptacle and mating plug shall be fireproof. If only flame integrity is necessary without the need for electrical continuity, only the receptacle needs to be fireproof. Fireproof and firewall connectors shall meet the Class K, KT, or KS requirements of the applicable military specification.

Rationale: In order to prevent an engine fire from spreading into other compartments, engine compartments are separated from other areas by stainless steel or titanium firewalls. Electrical connections that penetrate these zones cannot compromise the zone fire integrity. In order to ensure firewall flame integrity, connectors that do not allow burn-through must be selected (MIL-DTL-38999 Class K and S connectors are identified as being rated for firewall use). For systems that must continue to operate during an engine fire (e.g., fire extinguishing), both plug and receptacle firewall connectors must function properly for a specified time duration and need to have fireproof characteristics to ensure continuity. Non-fireproof environmental connector use on one side will allow material failure causing loss of electrical continuity during a fire.

3.14.4 Coaxial and Triaxial Connectors

Coaxial and triaxial connectors shall be suitable for the application and shall be covered by military specification. Series N, C, BNC, TNC, SC, SMA, SMB, and SMC shall be in accordance with MIL-PRF-39012. Category B connectors of this specification shall be used only on original equipment. When using Category B connectors, the contractor shall specify an equivalent field replaceable connector as defined on the latest issue of MIL-PRF-39012 for replacement as a maintenance or repair item. Category B connectors are not recommended for maintenance or repair. Category E and F connectors of this specification shall be used for applications using semi-rigid coaxial cables. Pulse series connectors shall be in accordance with MIL-DTL-3607, LC series with MIL-DTL-3650, twin series with MIL-DTL-3655, environment resisting series with MIL-DTL-25516, strip line with MIL-DTL-83517, adapters with MIL-PRF-55339, and triaxial connectors with MIL-PRF-49142. Where connector parameters beyond the scope of the military specification are required, nonstandard commercial types may be utilized provided that they meet the general requirements of the applicable military specification and are approved by the procuring activity.

Rationale: The range and performance of RF systems is a very critical part of aircraft operations and mission effectiveness. Cable construction, including connector selection, plays a major role. Avionics technicians are typically assigned to service and test these systems. Specialized training and connector support kits are often developed for each aircraft model in order to ensure the availability of tooling and instructions for RF cable assemblies. Highly specialized and correctly applied RF connectors must be used for each cable construction to limit system dB losses. Incorrectly selected or assembled connectors reflect excessive RF energy and may deteriorate in service. Unique military specifications define required characteristics and verification test methods. The range, clarity, and other qualities of RF systems depend on connector/cable performance.

Category B type connectors are installed with specialized tools that are not readily available to field units. Field replaceable equivalent types that can be assembled with standard tools, avoid replacement of entire assemblies. Such replacement would typically involve very substantial time, equipment, and panel removal for access. The availability of replaceable plugs also reduces the need to provision spares for each complete cable assembly type and length.

3.14.4.1 Coaxial Rigid Lines

Coaxial rigid lines that employ air dielectric shall be provided with air passage bulkhead connectors and pressure fitting connectors for purging and pressurization of the lines.

Rationale: The characteristic system impedance is dependent upon the dielectric between inner and outer coaxial conductor. Maintaining dielectric properties between inner and outer conductors of these lines requires continued pressurization of the space between them. Maintaining pressurization between inner and outer conductor as a means of retaining uniform spacing and impedance requires specialized fittings and pressurization equipment.

3.14.5 Connector Installation

Connectors shall be used to join harnesses to equipment or other harnesses when frequent disconnection is required to remove or service equipment, components, or wiring. Connectors shall be located and installed so that they will not provide hand holds or footrests to operating and maintenance personnel or be damaged by cargo and stored material. Receptacles in pressurized structure shall preferably be installed with the flange to the high-pressure side. Fasteners shall be used in all holes of flange mounted connectors. Cadmium-plated connectors or accessories shall not be used inside fuel tanks or anywhere that connectors can come in direct contact with titanium or carbon fiber composite components or structure. For recommended fastening hardware, tightening methods, and torque values, refer to AIR6151 and ARP1350.

Rationale: Location of receptacles, including equipment disconnects, should allow clearance along the connector axis for engagement and disengagement without gouging of shell material or compressing wire bundles against adjacent equipment or structure. Misuse or inadvertent plug contact with a receptacle (scooping) can damage terminations causing open, short, or intermittent circuit malfunctions. Connectors should be located so that viewing of receptacle keyway feature is readily accomplished.

Connector mating and unmating characteristics can be damaged if threaded or bayonet coupling features are distorted by improper handling or inadvertent contact damage. Protective finishes can be scratched, exposing underlying metal to form a dissimilar metals corrosion cell. Utilization of all fastener holes in flange mounted connectors supports proper metal-to-metal shell bonding to structure and avoids leaks in pressure in pressurized aircraft zones.

The reference to AIR6151 provides details on installation torque values for EWIS components, while ARP1350 provides guidance on sealed bulkhead connector installations.

3.14.5.1 Circular Connector Installation

Adequate space shall be provided for mating and unmating circular connectors without the use of tools. At least 1 inch shall be provided around the coupling rings of circular connectors, unless size of the equipment or area available for connector installation, and the number and size of the connectors prohibit this spacing. In such cases, at least 0.75 inch clearance shall be provided around the connector. Where connectors can be sequentially mated and unmated a 1 inch clearance in a swept area of at least 270 degrees around the connector at the start of the removal and replacement sequence shall be provided. Where the 0.75 inch or 1 inch/270 degree swept area requirement cannot be met, demonstration of connector removal and installation shall constitute compliance, when approved by the procurement activity.

Airframe connectors, when installed with the axis in a horizontal direction, shall be positioned so that the master keyway is located to the top. When the connector axis is vertical, the master keyway shall be positioned to the front of the vehicle. Both plug and receptacle shall be visible for engagement and orientation of the polarizing key(s).

Rationale: Finger space around coupling rings is required to apply mating/unmating torque. Sequential disconnection provides more space as each connector is handled. AS50881 does not control the design of most equipment units but does address space around them. The location of airframe mounted disconnects is subject to AS50881 requirements. Lack of adequate space can contribute to pin contact “scooping” bend damage or misuse of tools not suitable for the application. Not only plug connectors but unit receptacles can be damaged during unmating if adequate finger space exists or wiring displacement is not allowed for. Non-self-locking threaded connectors also may require provisions for safety wiring.

Connectors for redundant systems should be spaced apart sufficiently so that a single damage will not affect more than one channel.

On some air vehicles, time for removal and replacement of major assemblies is specified (e.g., helicopter engines and main transmission). Access to connectors must support these time limits.