NASA-STD-8739.11 Tutorial
F1: Fiber Optics, Passive

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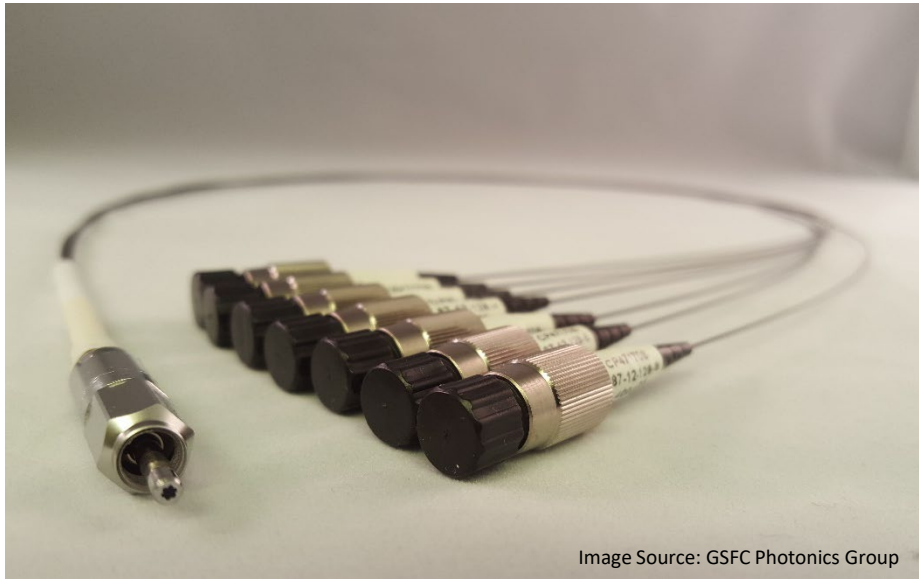
Acronyms

APC	Angled Physical Contact (Polish)
AVIM	Aviation Intermediate Maintenance
COTS	Commercial-Off-The-Shelf
CTE	Coefficient of Thermal Expansion
CVCM	Collected Volatile Condensable Material
EEEE	Electrical, Electronic, Electromechanical, Electro-Optical
ETW	Electronics Technology Workshop
FC	Field Connector
FOTP	Fiber Optic Test Procedure
GSFC	Goddard Space Flight Center.
MIL-SPEC	Military Specification

MM	Multimode (Fiber)
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronic Parts & Packaging (Program)
PC	Physical Contact (Polish)
SCD	Source Control Drawing
SM	Single Mode (Fiber)
SME	Subject Matter Expert
SPC	Statistical Process Control
TIA	Telecommunication Industry Association
TML	Total Mass Loss
UPC	Ultra Physical Contact (Polish)

Covered Part Type Description

- This document covers fiber optic cables assemblies and the elements thereof:
  - Fiber Optic Assemblies: Can be single or multiple bare optical fibers usually encased in a jacketing material and connectorized
  - Bare Optical Fiber: Multimode (Graded and Step Index), Single Mode, Polarization Maintaining, Polarizing
  - Fiber Optic Cable Jacketing
  - Fiber Optic Connectors
- This document does not cover certain types of specialty fiber optics, such as hollow core fiber and photonic bandgap fibers.

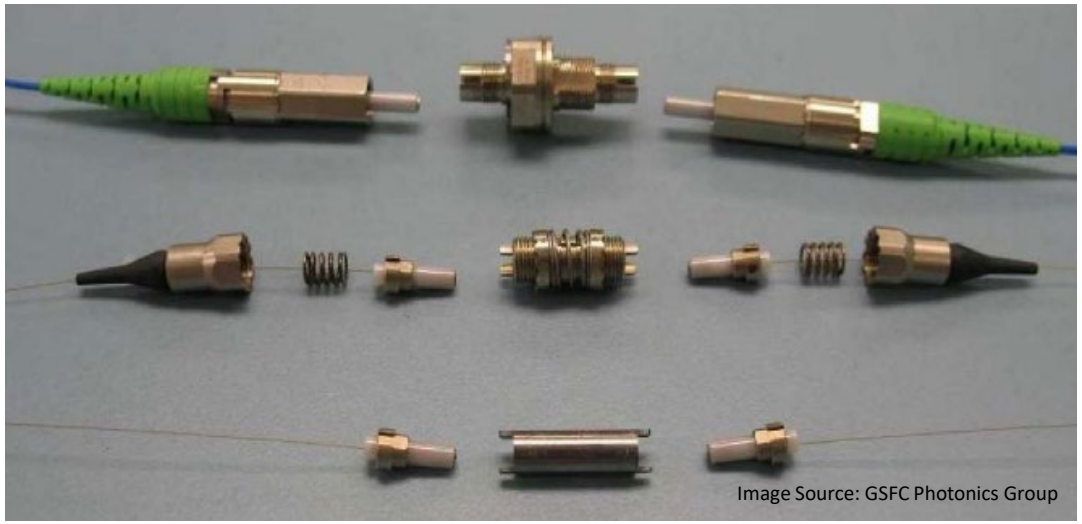


Example of a Fiber Assembly for Critical Applications

Key Considerations: Terminations

1. Fiber termination and handling have a significant impact on the reliability of an optic cable assembly.
   - Lack of proper process control in this area can lead to surface crack growth in the fiber.
   - Crack growth can lead to latent failure mechanisms that are difficult to model or simulate in the laboratory.
2. There are different end polishes depending on the application.
   - Flat Polish: Very little or no dome shape, often used for large core multimode (MM) fiber.
   - Physical Contact (PC) Polish: Slightly curved connector surface, mating connector pairs in physical contact. Back reflections -30 to -40dB.
   - Ultra PC (UPC) Polish: Extended curved connector surface. Back reflections -40 to -55dB.
   - Angled PC (APC) Polish: Adds an 8 degree angle to connector end face. Back reflections <-60dB.
3. Custom terminations shall be rigorously tested and/or analyzed for suitability and reliability in the space environment.
4. Fiber optic connectors for spaceflight require some form of secondary locking mechanism.

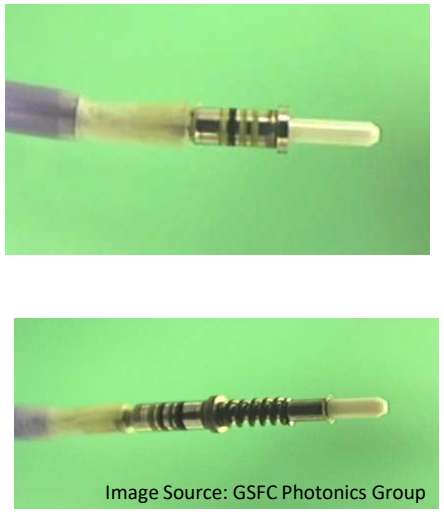
Common Flight and Critical Ground Support Connectors



(Top to Bottom) AVIM, Mini AVIM and Micro AVIM Connectors and adapters



FC Wide Key Connector





MIL-T-29504 Pin Socket Termini For 38999 Connectors

AVIM Family and 38999 connectors feature a secondary locking mechanism. FC connectors require additional staking.

Key Considerations: Materials

1. Acrylates and polyamides are used for flight grade optical fiber coatings.
2. The materials currently in use for loose tube jackets are TeflonTM (PTFE), TefzelTM (ETFE) , KynarTM (polyvinylidene fluoride, or PVDF), HytrelTM (TPE), and KevlarTM (Aramid). All are referenced in F1, Table 5.
3. Ensure that any epoxies being used for flight grade cable assembly terminations are acceptable for space application.
4. The jacket of a fiber optic cable must be thermally pre-conditioned prior to termination.
   - Flight fiber jackets can require on average 60 cycles to achieve required minimum change in length over thermal.
     - New materials should be thermal cycles and measured until the shrinkage is less than 0.1% the length of the jacket over mission survival temperature.
   - Pre-conditioned at lengths as close as possible to the flight configuration lengths.
5. Ensure that the fiber optic cable assembly jacket material, connector and boots meets NASA outgassing requirements. Vacuum baking can help with outgassing.
   - Non-metallic materials in cables shall be traceable to test reports with acceptable levels of TML and CVCM.
6. Custom cable materials and their usage shall be rigorously tested and/or analyzed for compatibility, suitability, and reliability in the space environment, including the effects of CTE mismatch.

Key Considerations: Cleaning & Handling

1. Ensure that there are clear procedures for inspecting, cleaning and handling fiber optic cable assemblies.
2. The number of mates and de-mates of fiber connectors must be controlled, logged, and minimized (especially important for UPC end polished type).
3. Before mating of two fiber connectors, whether for testing or final integration, the end faces must be cleaned and visually inspected based on a clear written process.
4. A 2x margin on the optical fiber manufacturer-recommended minimum bend radius must always be adhered to during transport, handling, testing, and installation to avoid inducing latent defects.

Key Considerations: Environmental Effects

1. Thermally induced shrinkage of cable jacketing can lead to catastrophic mechanical failure of the cable assembly, so thermal pre-conditioning of the cable jacketing shall be performed prior to termination.
2. A changing thermal environment can cause significant thermally induced variation in the optical performance of a fiber optic cable assembly.
3. For fiber optic assemblies operating at cryogenic temperatures, some additional considerations pertain. Reliability at cryogenic temperatures may not be driven by the same mechanisms as for normal temperature ranges, and radiation darkening of optical fiber is worse at colder temperatures.
4. Vibration testing of an optic cable assembly requires mating pairs of connectors in similar flight configuration and routing. In routing fibers, the following rules should be considered
    1. Fiber optic cable shall not be routed on the same conduit as electrical cable or secured with the electrical harness
    2. All fibers shall have a minimum bend radius twice as recommended by the manufacturer.
    3. Optical fiber cable(s) shall be secured at least every 20 cm (NASA-STD-8739.5).
    4. The ties shall not pinch, deform, kink or otherwise stress the optical fiber assembly. Optical fiber shall be free to move axially.

Key Considerations: Radiation

1. Radiation can cause temporary or permanent damage to the performance of an optic cable assembly. Radiation effects should be assessed via testing and/or analysis.
2. Optical fiber can darken under radiation exposure, causing loss in optical transmittance. Some fiber designs are more susceptible than others. Transmitting light through the optical fiber during exposure can sometimes mitigate radiation effects via photobleaching. Radiation darkening is usually worse at lower temperatures.
3. The mechanical properties of the fiber optic cable jacket can change or degrade with radiation exposure (embrittlement, contamination concerns due to powdering or flaking of the surface).

Major Changes from EEE-INST-002

- 8739.11 includes assurance levels for fiber optic assemblies to guide screening and lot acceptance testing.
  - Testing is further broken down to the bare optical fiber, jacketing, connectors and assemblies.
  - Removed guidelines on testing at manufacturer vs. customer.
- It moves away from the Telecommunication Industry Association (TIA) Fiber Optic Testing Procedures (FOTP), instead specifying Mil standards for fiber optic testing.
  - These standards generally call out TIA test standards, so the test procedures themselves are not altered.
- A section on fiber optic derating requirements was added.
  - There are no known derating factors for optical fiber, but there are operational and environmental limits that must be adhered to preserve the reliability of fiber optic cable assemblies.
  - Examples of operational and environmental limits: operating and storage temperature, optical power density, min bend radius, radiation.

Major Changes from EEE-INST-002

Table 2A. VISUAL & MECHANICAL INSPECTIONS FOR BARE OPTICAL FIBER

Parameters and Inspections		Inspection For		
		Level 1	Level 2	Level 3
Wavelength	As specified in SCD	X	X	X
Proof Strength	MIL-PRF-49291 Paragraph 4.7.2.3	X	X	X
Minimum Bend Radius	As specified in SCD	X	X	X
Operating temperature	As specified in SCD	X	X	X
Numerical Aperture **2/**	MIL-PRF-49291 Paragraph 4.7.3.3	X	X	
Attenuation **4/**	MIL-PRF-49291 Paragraph 4.7.3.2	X	X	
Core diameter (MM fiber)	MIL-PRF-49291 Paragraph 4.7.2.1.1	X	X	X
Mode Field Diameter (SM only)	MIL-PRF-49291 Paragraph 4.7.2.1.2	X	X	
Cladding diameter	MIL-PRF-49291 Paragraph 4.7.2.1.4	X	X	X
End Face Inspection Photos **3/**	As specified in SCD	X	X	
Core-to-cladding offset	MIL-PRF-49291 Paragraph 4.7.2.1.6	X		
Coating diameter	MIL-PRF-49291 Paragraph 4.7.2.1.7	X		
Fiber mass/unit length	MIL-PRF-49291 Paragraph 4.7.2.2	X		

- Removes scintillation and ambient light susceptibility testing.
- Stripability and life aging moved to lot acceptance.

Table 2B. INSPECTIONS FOR FIBER JACKETING 1/ 2/

Properties and Inspections	Requirements	Inspection For		
		Level 1	Level 2	Level 3
Tubing Dimensions & Tolerances	As specified in SCD	X	X	X
Tubing and Strength Member Materials	As specified in SCD or per manufacturer specification	X	X	X
Operating Temperature	As specified in SCD (-60 °C to +85 °C typical)	X	X	X
Flexural Modulus	As specified in SCD	X		
Cable Blocking (doesn't stick to itself on the reel)	MIL-PRF-85045, Para 4.7.6.11	X		
Tensile loading and elongation **3/**	MIL-PRF-85045, Para 4.7.5.1	R	R	
Cable shrinkage **4/ 5/**	MIL-PRF-85045, Para 4.7.5.17 Alternatively, preferred method is thermal cycling over survival temperature limits, with measurements of cable shrinkage every 5-10 cycles; repeated until cable shrinkage is <0.1%	X	X	R
Thermal Vacuum Outgassing	MIL-PRF-85045, Para 4.8.5.1	X	X	X

- Focuses on jacketing material without internal fiber.

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Major Changes from EEE-INST-002

Table 2C. PROPERTIES AND MECHANICAL TESTS FOR FIBER OPTIC CABLE CONNECTORS 1/ 3/

Inspections	Requirements	Inspection For		
		Level 1	Level 2	Level 3
Operating Temperature	As specified in SCD	X	X	X
Torque	As specified in SCD	X	X	X
Connector materials	As specified in SCD For MIL-PRF-38999 style connectors, see MIL-PRF-64266, Para 3.3	X	X	
Critical dimensions & tolerances 2/	As specified in SCD For MIL-PRF-38999 style connectors, see MIL-PRF-64266, Appendix A	X	X	

- Removes shock and vibration testing requirements on connectors. Assumes shock and vibration must be completed in similar flight configuration and routing.

Table 2D. FIBER OPTIC CABLE ASSEMBLY SCREENING 1/

Inspection/Test	Test Methods, Conditions, and Requirements	Assurance Level		
		Level 1	Level 2	Level 3
Visual Inspection: Cable Assembly	Per MIL-PRF-85045 Paragraph 4.7.2, (proper dimensions, construction, markings and workmanship) And verification of completion Tables 2A, 2B and 2C prior to manufacturing. 2/	X	X	
Visual Inspection: End Face Geometry Fiber concentricity in ferrule Defects (scratches/pits/chips/cracks) Contamination	Visual inspection of end face at minimum 200X magnification	X	X	
Optical Tests 3/	Insertion Loss per MIL-PRF-64266 Paragraph 4.9.3.1 PER (if applicable) using temperature variation method 4/ Any other optical tests per SCD	X	X	R
Temperature Cycling 5/	MIL-PRF-85045 Paragraph 4.7.6.1	X 20 Cycles	X 10 Cycles	
Post-Cycling Optical Tests 3/	Same as Step 3 herein	X	X	X
Visual Inspection: Cable Assembly & End Face	Same as Step 1 and 2	X	X	X

- Adds temperature cycling at the screening level, with before and after optical testing and visual inspections.

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Major Changes from EEE-INST-002:

Table 3B. FIBER OPTIC CABLE ASSEMBLY LOT ACCEPTANCE TEST

Inspection/Test	Test Methods, Conditions, and Requirements	Quantity (Accept Number)	
		Level 1	Level 2
Subgroup 1		10(0)	6(0)
Optical Tests	Per Table 2D	X	X
Random Vibration	MIL-STD-1678/3 Measurement 3201, Paragraph 5.3, Test Condition C.	X 3(0)	X 3(0)
Post-vibe Optical Tests	Per Table 2D	X	X
Temperature Cycling	See MIL-PRF-64266 Paragraph 4.9.6.3.2 for guidance. Temperature range as specified in engineering documentation or mission requirements.	X	X
Post-Cycling Optical Tests	Per Table 2D	X	X
Visual and mechanical inspection	Per MIL-PRF-85045 Paragraph 4.7.2, (proper dimensions, construction, markings and workmanship)	X	X
Subgroup 2		10(0)	6(0)
Temperature Test (Aging) **2/**	MIL-PRF-64266 Paragraph 4.9.6.2, at 110 °C or fiber maximum operating temperature per the manufacturer rating (whichever is less)	X	X
Optical Tests	Per Table 2D	X	X
Visual and mechanical inspection	Per MIL-PRF-85045 Paragraph 4.7.2, (proper dimensions, construction, markings and workmanship)	X	X

- 8739.11 only specifies lot acceptance testing to level 1 and 2 assurance levels.
- Lot acceptance focus on the environmental stress and aging of the assemblies.

Send email to address below for questions

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