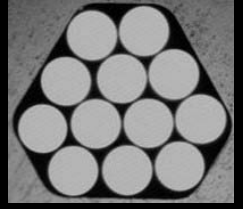
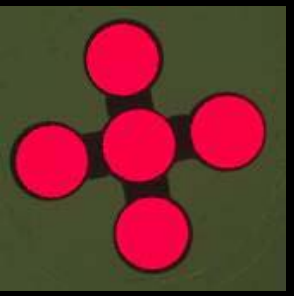
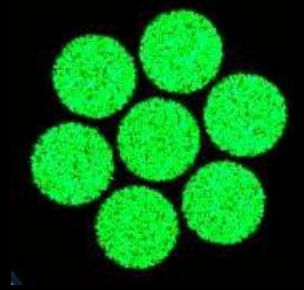
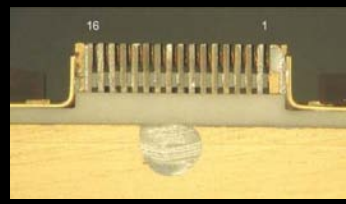
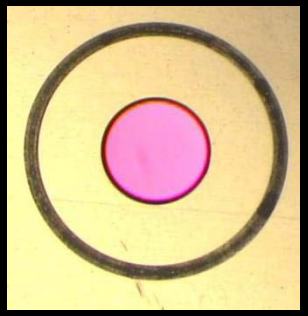
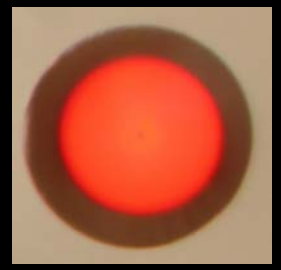




Space Flight Applications of Optical Fiber Components
32 Years of Mission Success
September 21 2010, IEEE AVFOP

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Photonics.gsfc.nasa.gov

Outline

- Introductions - Who
- Successful usage of aerospace optical fiber systems – What, Where, & When.
- Example details
- Conclusion

A Decade of Service from the Photonics Group for Photonics & Optical Fiber Components and Assemblies Code 562, Electrical Engineering Division of AETD, NASA GSFC

Project	Dates	Design	Qualification Performance over Harsh Environment	Manufacturing	Integration	Failure Analysis
ICESAT, GLAS,	1997 - 2005	X	X	GSE		Prototype
ISS	1998 - 2008					Vendor/ Flight
ISS - HDTV	2003	X	X	FLIGHT		
Fiber Optic Data Bus	1997 -2000	X	X			
Messenger – MLA,	2001 - 2004	X	X	FLIGHT	X	
Sandia National Labs (DOE)	1998 -2010		FLIGHT			Vendor/ Flight
ISS-Express Logistics Career	2006 -2010	X	X	FLIGHT	X	
Air Force Research Lab	2003, 2008, 2010		X			
Shuttle Return To Flight	2004 -2005			FLIGHT		
Lunar Orbiter Laser Altimeter	2003 -2008	X	X	FLIGHT	X	Prototype
Hubble Servicing Mission 4	2006			GSE		
Mars Science Lab ChemCam	2005 -2008	X	X	FLIGHT	X	Vendor
Laser Ranging, LRO	2005 - 2008	X	X	FLIGHT	X	Prototype
James Webb Space Telescope	2008 - 2009		X	Cryo GSE		
Fiber Laser & Laser IRADs	2003 - 2010	X	X	QUAL		
Lunar Laser Comm Demo	2009 - 2010	X	X	GSE / Cryo		

What? Where? When?

Historical Overview of Fiber Optics in Space
1978 - 1999

- **1978-1980, Long Duration Exposure Facility (LDEF)**
  - Passive optical fibers and fiber links

- **1989, Cosmic Background Enplorer (COBE) satellite**

  (P.I. Nobel Prize for Physics – GSFC's Dr. John Mather)
  - Used photodiodes and optical fibers in a position and motion sensing of a mirror
  - Several erroneous position determinations observed
  - Little mission impact

- **1993, Photonic Space Experiment (Boeing)**
  - Optical Fiber Radiation Experiment
  - Passive Components Experiment
  - Strained quantum well laser and custom boardband LED experiments
  - Bit Error Rate experiment

IEEE Aerospace Conference, Volume: 4 , 1998, Page(s): 421-434, MSFC 1999 Presentation

Current Fiber Data Links
(based on 1999 survey presentation)

PROJECT	LAUNCH	TECHNOLOGY	SYSTEM WAVE LENGTH
SAMPEX	7/92	MIL-STD-1773 1Mbps	850nm
MPTB	12/97	AS1773 20Mbps	1300nm
MAP	2000	AS1773 20Mbps	1300nm
XTE	12/96	MIL-STD-1773 1Mbps	850nm
HST	02/97	MIL-STD-1773 1Mbps	850nm
PSE	1995	MIL- STD-1773 1Mbps	850nm
TRMM, et al.	11/97	MIL- STD-1773 1Mbps	850nm

IEEE Aerospace Conference, Volume: 4 , 1998, Page(s): 421-434, MSFC 1999 Presentation

Small Explorers (SMEX)

- SAMPEX four instruments, launched 1992 with a 1 Mbps MIL-STD-1773 Optical Fiber Databus.
- Transceivers fabricated by SCI
  - TI photonics parts.
- http://sunland.gsfc.nasa.gov/smex/sampex/
- Still functioning, last reaction wheel lost a few months ago, space craft still functioning.
- Power positive, spinning but functional for science data.
- First solid state recorder flown.

Hubble Space Telescope

- Solid state recorder UTMC protocol chips,
- Boeing transceivers. FO-1773
- Cooprocessor, SM2, 1993
- Servicing, 1995 -1997
- Still functional.

Space Borne Fiber Optic Data Bus

- Parallel Fiber Optic Data Bus, 1393
- ONI (Optivision) later became Space Photonics.
- First flight EO-1, cancelled during integration for funding issues, other instrument over budget.
- MTP Connector – Parallel
- Sandia now using optical fiber assemblies due to qualification of these assemblies during GSFC program.

Instruments & Communications (since 1999)

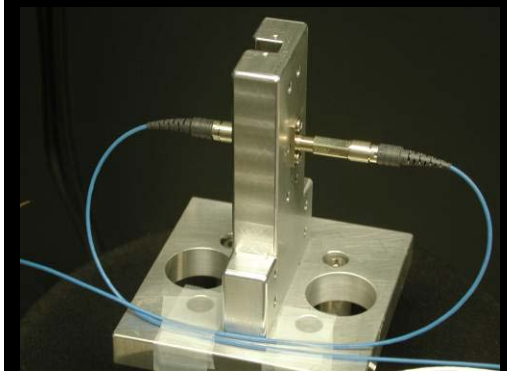
- **International Space Station, US LAB 2001**
  - 125 Mbps, FDDI called High Rate Data Link (HRDL),
  - MIL 38999 Connectors w/ MIL 29504 Termini
  - Sent with cracked fiber, half being used, working NO REPORTED IMPACT.
  - GSFC lead failure analysis found during integration
  - Rocket engine defects are screened for and replaced during integration where possible.
- **Geoscience Laser Altimeter on ICESAT** (2003 launch)
  - Multi and single mode fibers, AVIM,
  - 2 Km of fiber used for delay line.
  - Confirms global warming
- **Mercury Laser Altimeter**, (2004 launch)
  - Receiver optic System(AVIM, Flexlite, Multimode Fiber)
  - Longest laser link established through space 24 MKm
  - Currently sending data from Mercury.

Instruments & Communications (1999 - 2009)

- **Shuttle-Return-to-Flight**
  - NEPTEC high definition laser sensor camera
  - Optical fiber assemblies for laser and receiver optics
  - Terminated @ GSFC,
  - Packaging and failure analysis support for individual vendors.
- **GLAST**, using wavelength shifting fibers (launched 6-11-08)
- **Laser Ranging and Lunar Orbiter Laser Altimeter** (LRO launch 11-08)
  - Array bundles as part of receiver optical systems
  - LR Assemblies 10 m of 7 fiber bundles across 3 subsystems.
- **Express Logistics Carrier interface to ISS (ELC)**
  - (smart warehouse)
  - Space Photonics Transceivers, In house Electronics
  - In house manufacturing of Optical Fiber Harnessing.

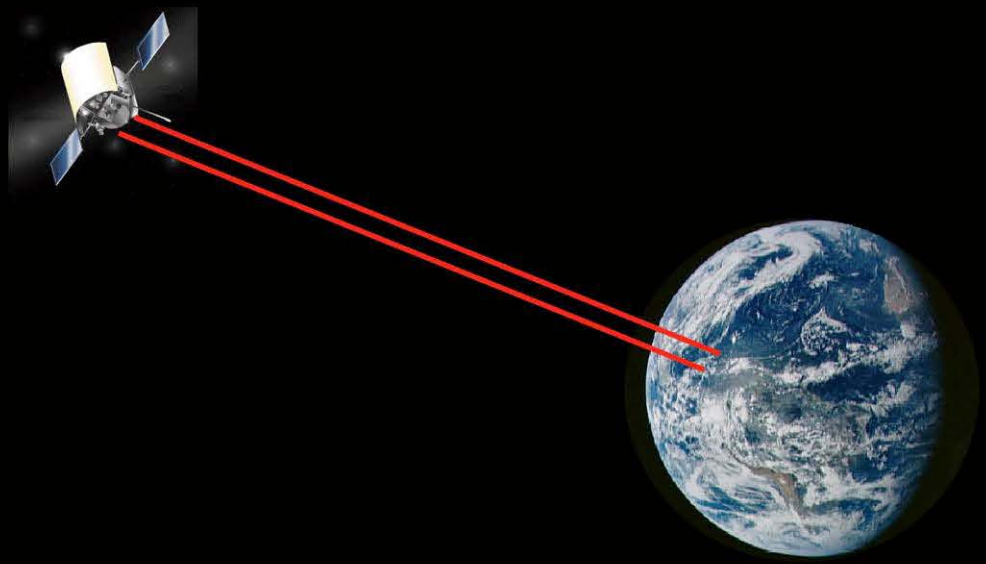
Mercury Laser Altimeter 2001-2003

Receiver telescopes focused into optical fiber assemblies that route to different detectors.
The MLA is aboard MESSENGER on its way to Mercury!



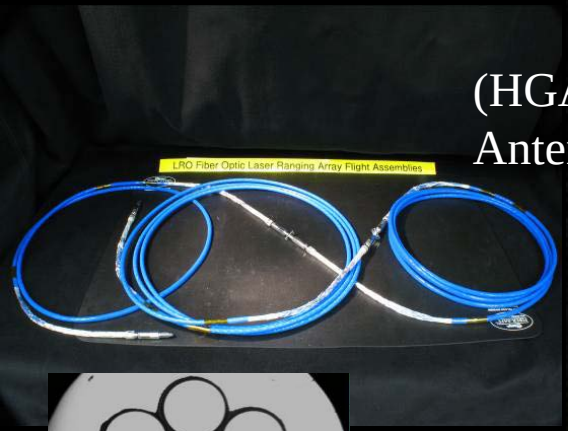
The 24 Million Km Link with the Mercury Laser Altimeter

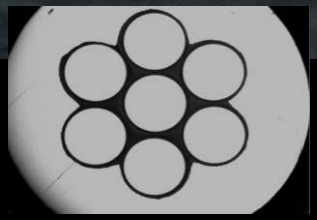
Jay Steigelman
Dave Skillman
Barry Coyle
John F. Cavanaugh
Jan F. McGarry
Gregory A. Neumann
Xiaoli Sun
Thomas W. Zagwodzki
Dave Smith
Maria Zuber



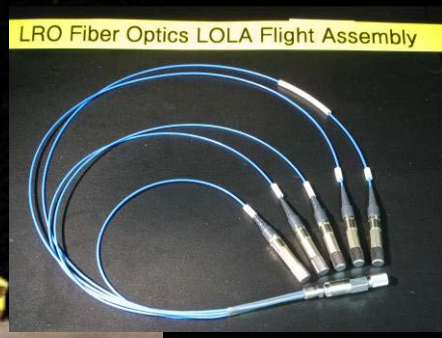
MOLA Science Team Meeting
Bishop's Lodge, Santa Fe, NM
August 24-25, 2005

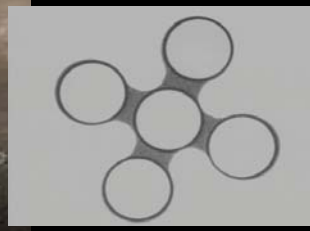
The Lunar Reconnaissance Orbiter; The Laser Ranging Mission and the Lunar Orbiter Laser Altimeter





(HGAS) High Gain Antenna System

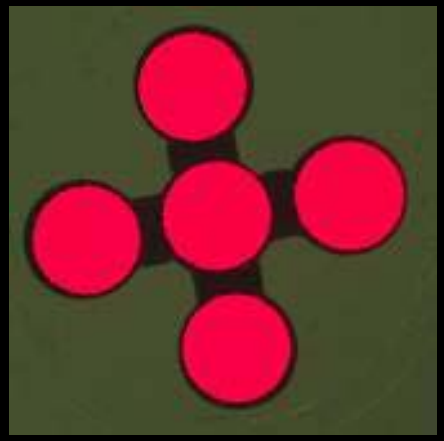




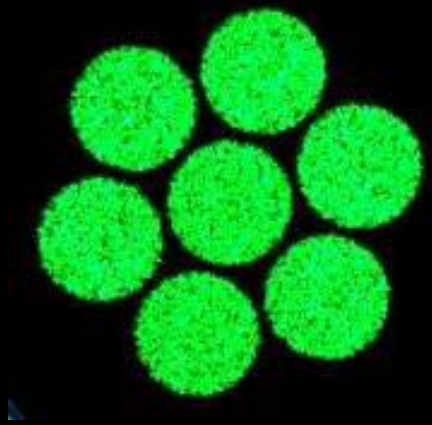
Receiver Telescope mounted on antenna and a fiber array to route signal from HGAS to LOLA

Lunar Orbiter Laser Altimeter (LOLA)

NASA GSFC Fiber Optic Array Assemblies for the Lunar Reconnaissance Orbiter



Array Side End Face Picture at
200X magnification

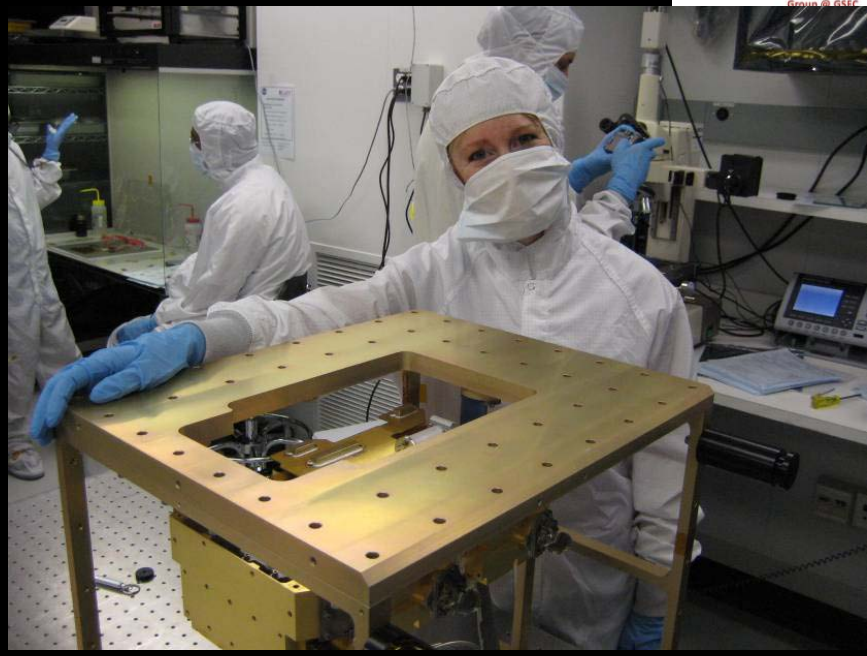


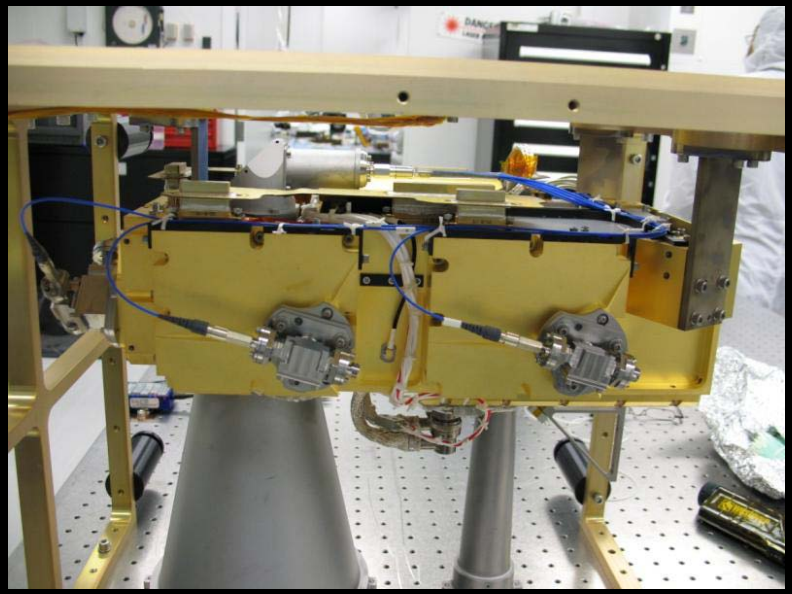
End Face Picture of both assembly ends at
200X magnification

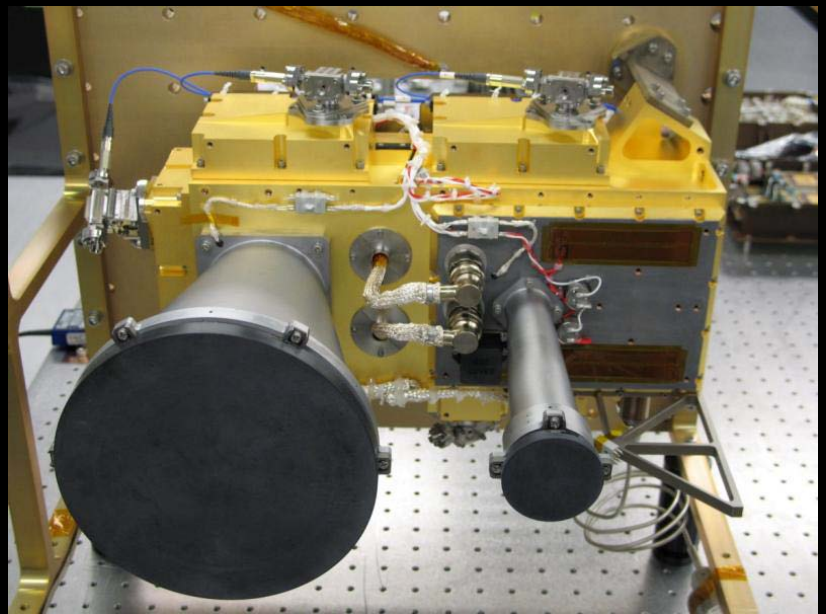
Lunar Orbiter Laser Altimeter (LOLA) Assemblies
Description: 5 Fiber Array in AVIM PM on Side A,
Fan out to 5 individual AVIM connectors Side B
Wavelength: 1064 nm
Quantity ~ 3 Assemblies Max ~ 0.5 m long

Laser Ranging (LR) for LRO Assemblies
Description: 7 Fiber Array on both Sides in AVIM
PM Connector
Wavelength: 532 nm
Quantity ~ 9 Assemblies ~ 1 to 4 m long each

LOLA Integration, October 2007

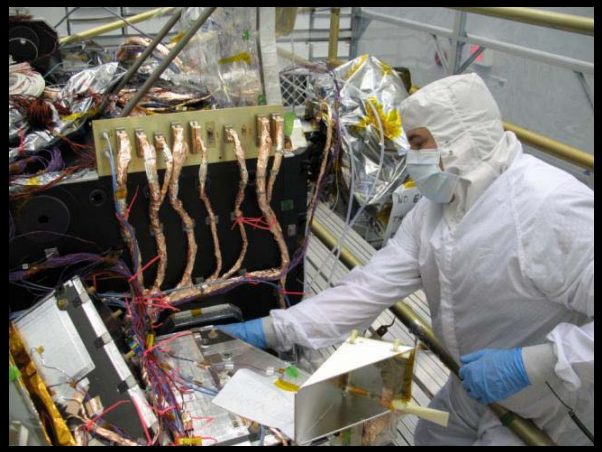


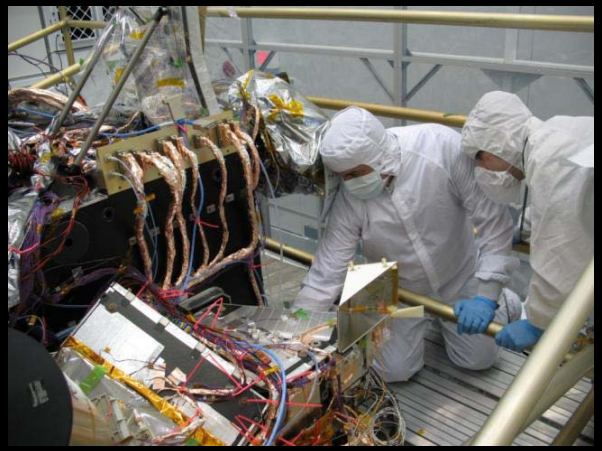




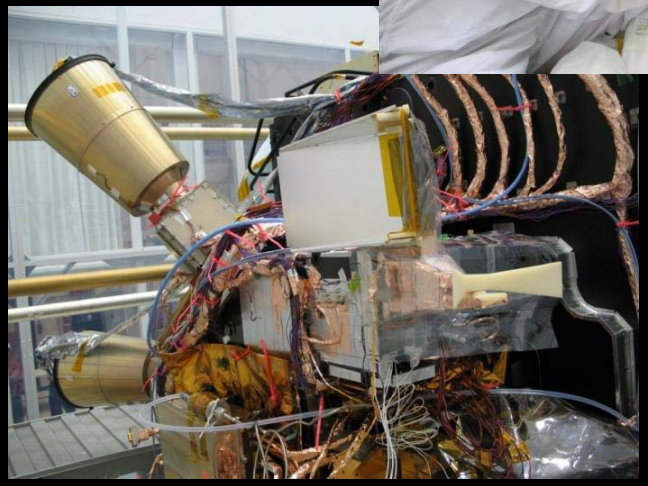
Lunar Recon. Orbiter - LRT & HGAS, 02-2008

LR Segment 3 Flight Routing, April 2008

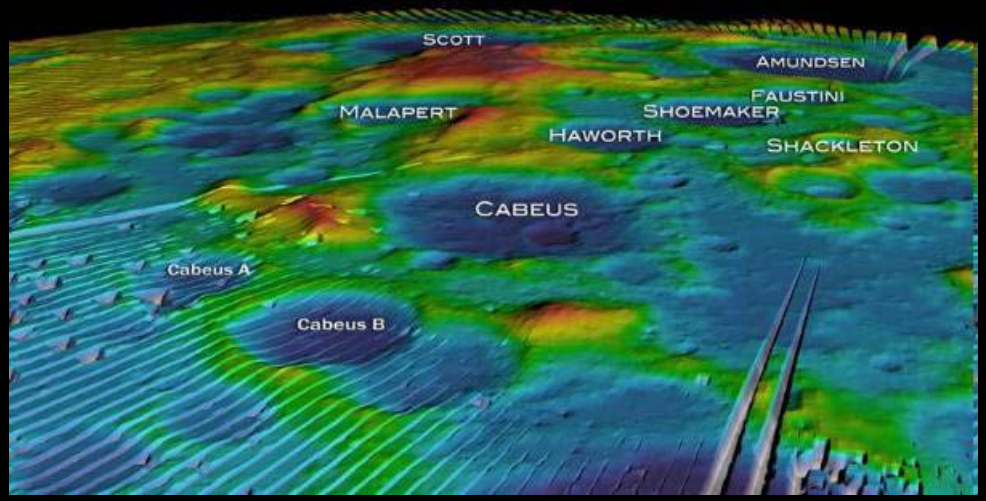




Additional Pictures of LRO, June 2008
Integration Complete



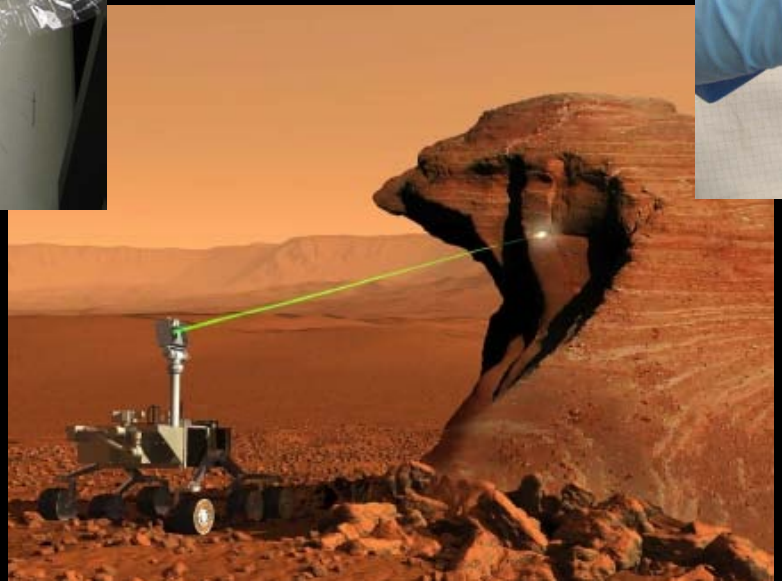
LOLA Progress



Altitude measurements of the south pole from the Lunar Orbiter Laser Altimeter (LOLA) instrument aboard the Lunar Reconnaissance Orbiter. Permanently shadowed areas are coldest, and confirmed to hold ice; permanently illuminated areas may be good spots for solar power stations.

http://www.foxnews.com/slideshow/scitech/2009/09/23/water-moon?slide=9

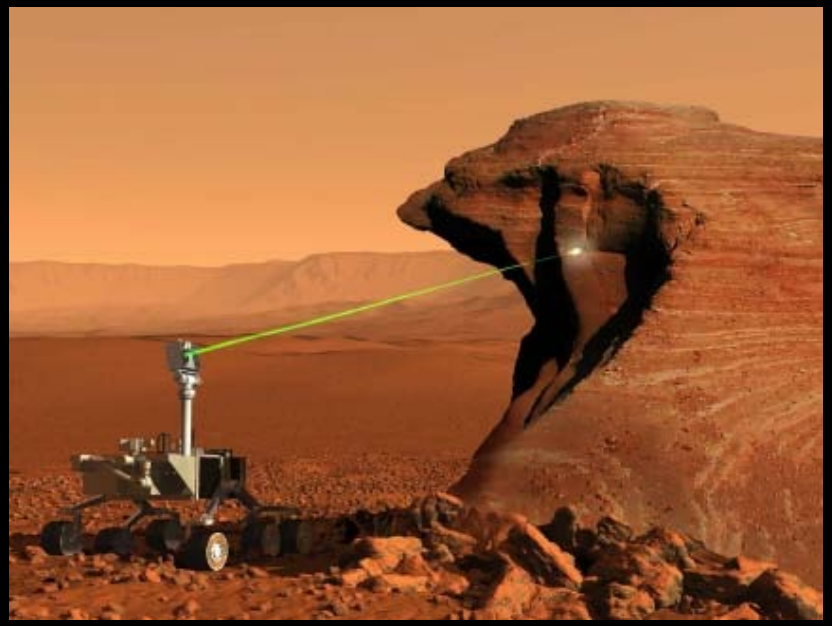
Mars Science Lab, Chem Cam
AVIM connectors – Flexlite Cable

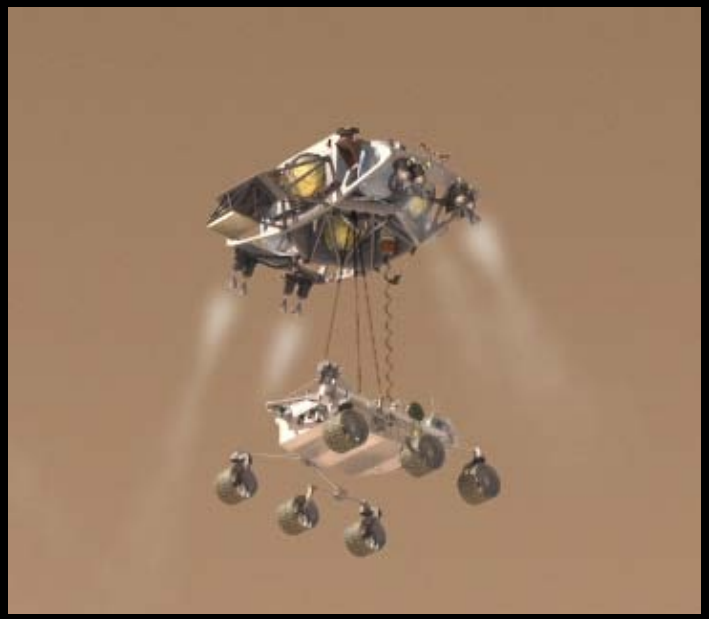


Mars Science Lab – ChemCam Optical Assemblies, Launch delayed.

Similar application as LRO

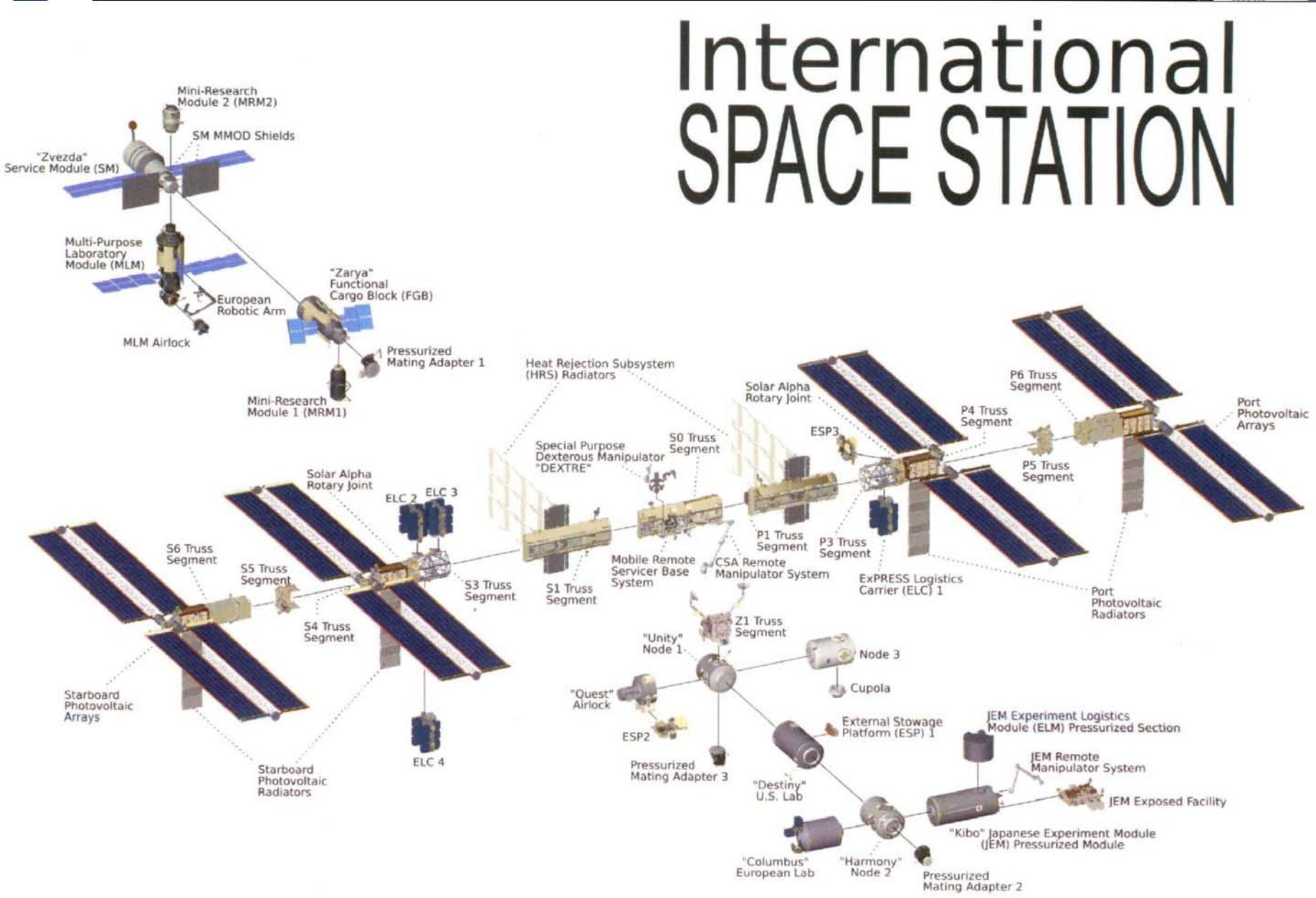
- **Simplex Assemblies for receiver optics to spectrometer.**
- **Tried large core, 300/330 micron acrylate fiber from Nufern for flat broad spectrum with small NA=.13, unstable to bending, evaluated for radiation, W.L. Gore FON 1442, PEEK outer diameter 2.8 mm.**
- **Changed W.L. Gore Flexlite simplex FON1482 with FVA300330500 Polymicro, NA=.22.**
- **Diamond AVIM connector, custom drilling.**
- **Across gimbal system for -135°C to +70°C survival, -80°C to +50°C operational, +110 C high temp bakeout due to decontamination process.**
- **Manufacturing, Environmental Testing including; thermal, vibration, radiation**
  - **Thermal -50°C to +80°C, for 30 cycles as a validation of the termination process.**
  - **Vibration, JPL custom profile ~ 7.9 grms, and 14.1 grms GSFC typical.**
  - **Radiation comparison analysis performed, based on data from previous missions.**





Express Logistics Carrier (ELC modules) "Smart Warehouse for Station

GSFC
CODE 562

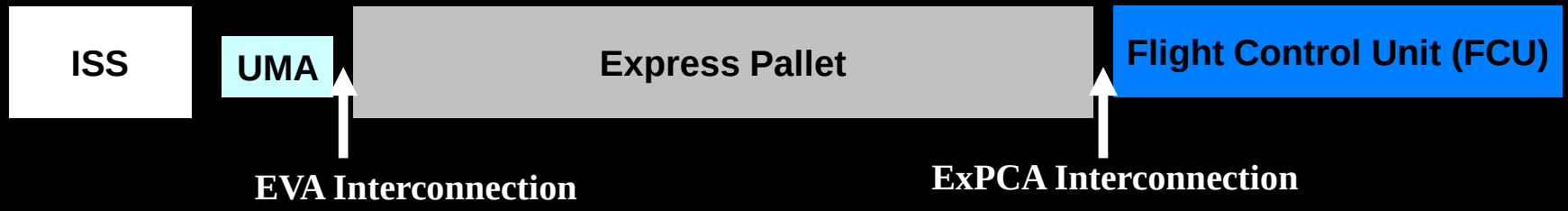


Express Logistics Carrier for ISS; Communications System Assemblies

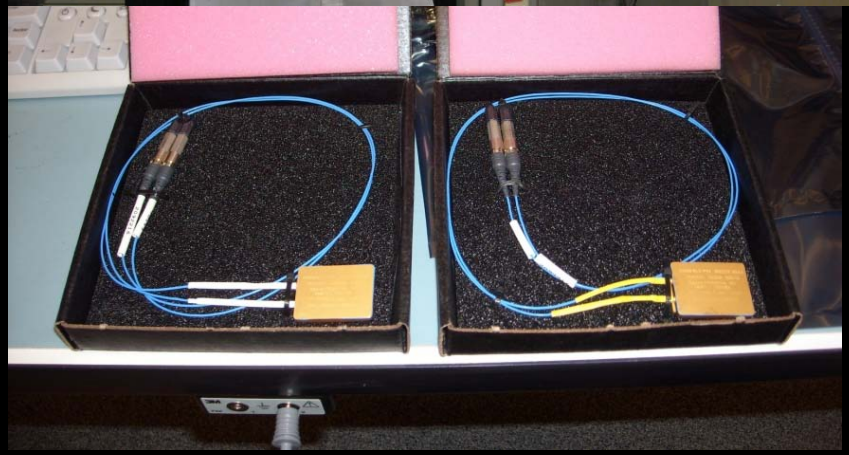
GSFC Photonics Group –
Flight Control Unit Transceiver Assemblies
(Space Photonics) SPI- FCU Transceivers
GSFC Photonics Group - Harnessing

Subsystem Components

Component	Manufacturer	Part Number/ Identifer
Transceivers for FCU	Space Photonics	HMP1-TRX
Transceiver Interconnection	Diamond	AVIM
Transceiver Optical Fiber	Nufern	FUD-2940
Transceiver Cable	W.L Gore	Flexlite, simplex FON1435
ExPCA Interconnection	Sabritec	SSQ22680
ExPCA Termini	ITT Canon	SSQ21636-NRP-F-16 (S,P)
Harness Optical Cable	BICC	SSQ21654-NFOC-2FFF-1GRP-1 (Obsolete)
Attenuator	GSFC/Diamond	Cleanable AVIM Adapter
Attenuator Interconnection	Diamond	AVIM
EVA Connector Circular	Amphenol	SSQ21635
EVA Termini	ITT Canon	SSQ21635-NZGC-F-16 (SB,PB)
ISS-UMA Connector	ISS Supplied	ISS Supplied

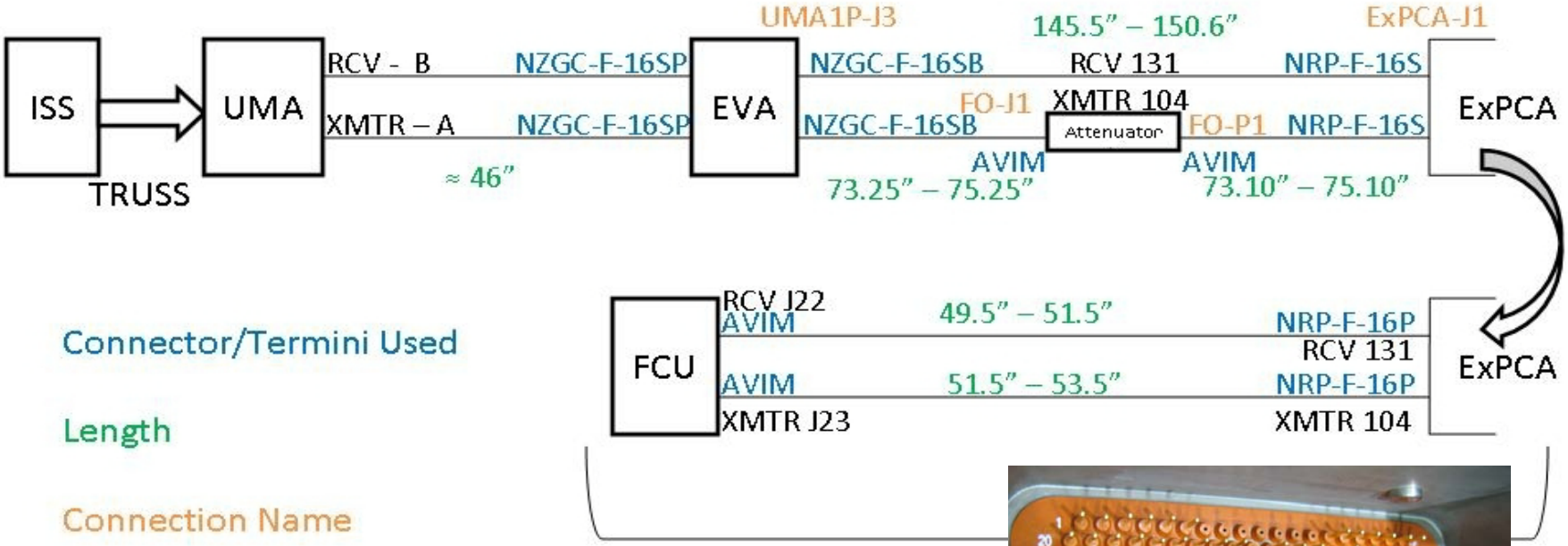


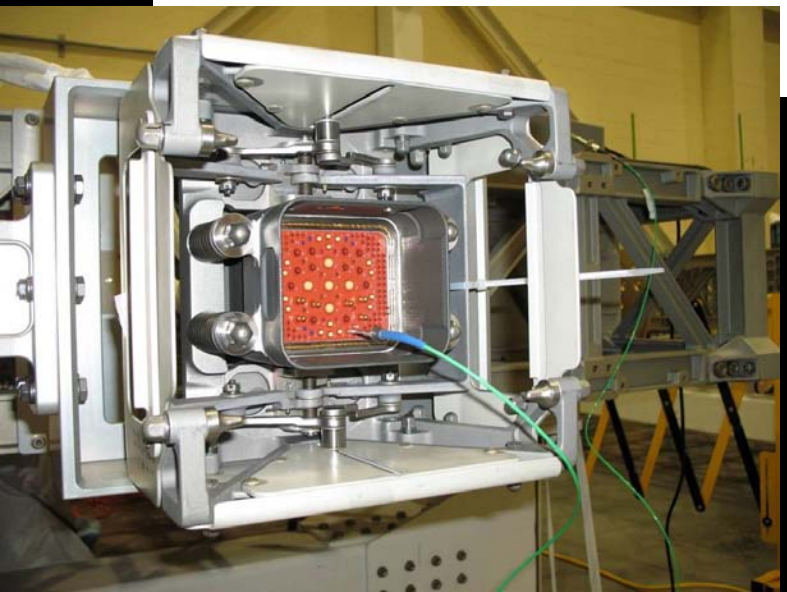
Express Logistics Carrier, Connection to ISS AVIM connectors – Flexlite Cable

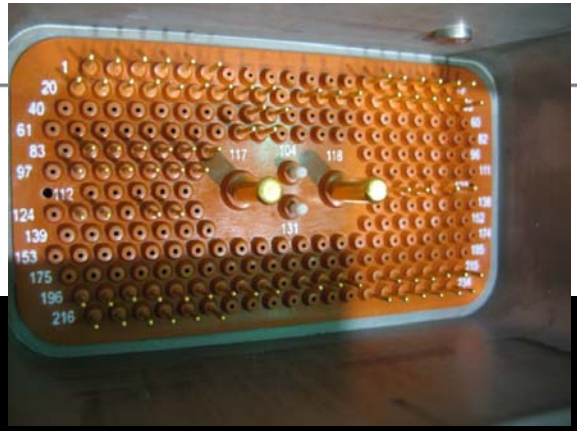


Fiber Optic Flight Assemblies for Space Photonics Transceivers

Harnessing Diagram for Express Logistics Carrier on ISS

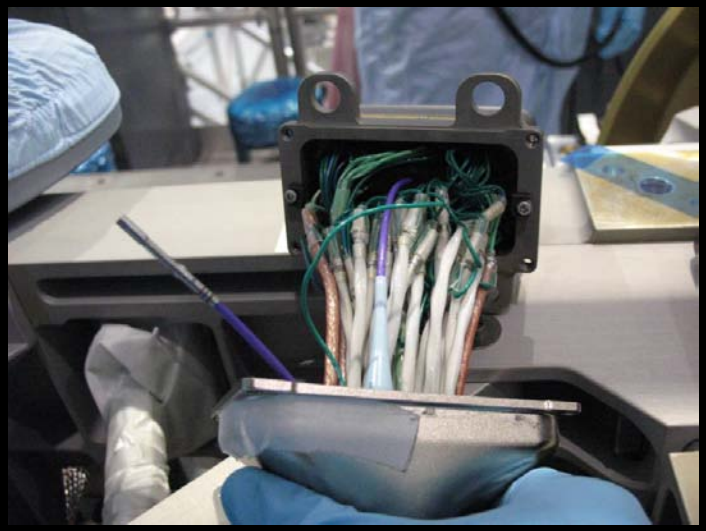






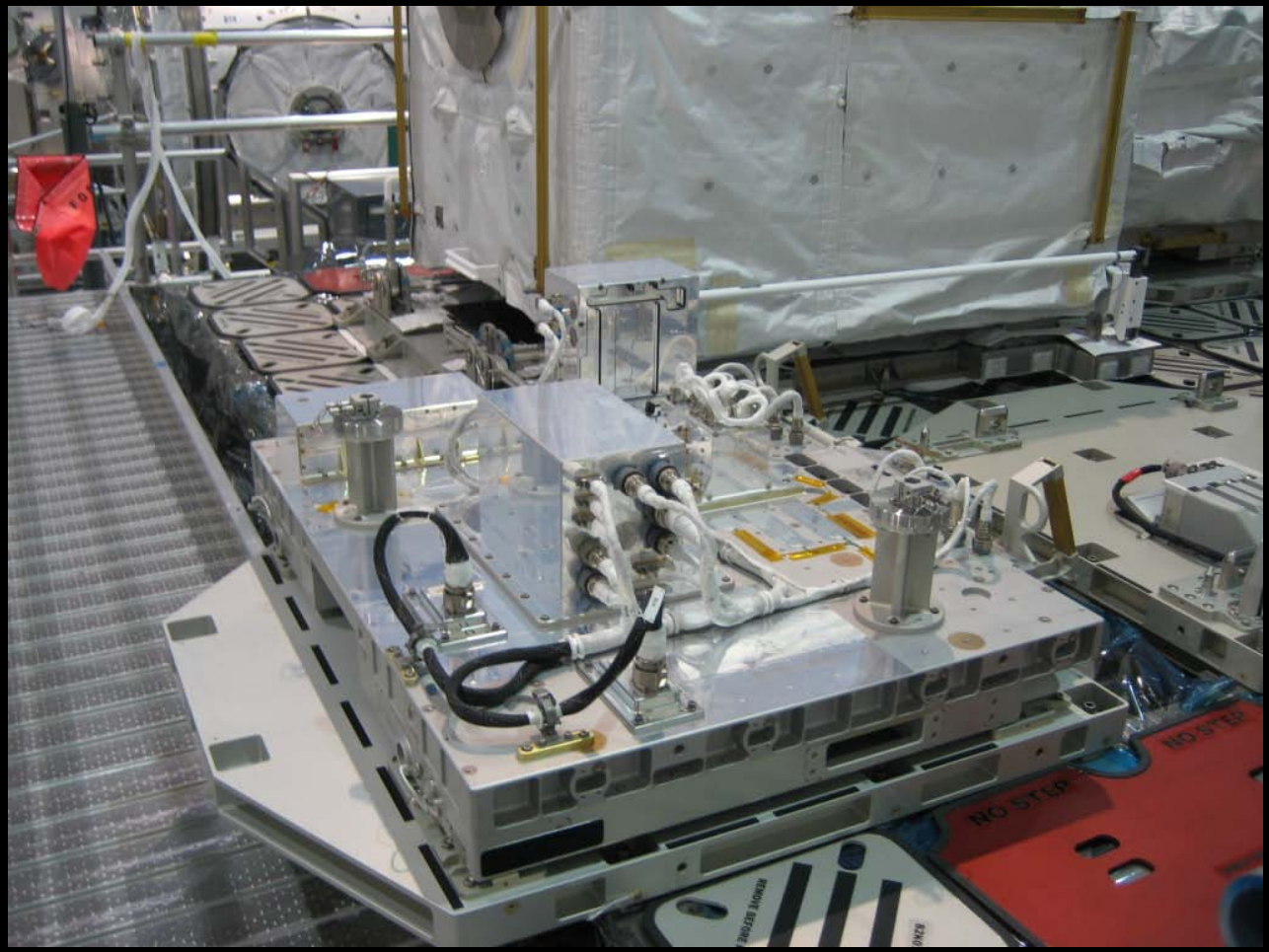
ExPCA Connector

Integration of the ELC assemblies at KSC International Space Station Facility



Last assemblies to integrate into the harnessing were the optical fiber assemblies, reason = risk mitigation.
Schedule constraints led to integration at the
International Space Station Processing Facility at Kennedy Space Center.
Lesson Learned= Integrate sooner.

ELC Cargo on ISS



MISSE-7 the 7th Materials International Space Station Experiment Installed.
High Pressure Gas Tank were installed by the STS-129 Crew on November 23rd 2009 on From ELC-2 to Quest Airlock for entering space walkers.

ELC Launches to ISS on STS-129

Engineers inspect one of the ExPRESS Logistics Carriers in the small clean room at NASA's Goddard Space Flight Center

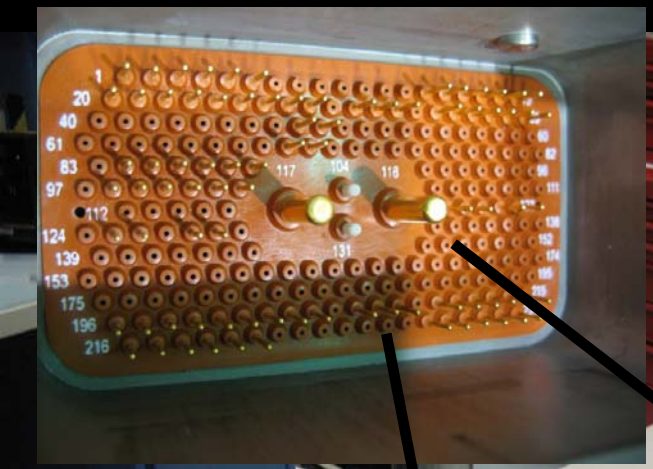
On November 18 2009 Space Shuttle Atlantis and the International Space Station (ISS) astronauts attached the ExPRESS Logistics Carrier-1 (ELC) to the Earth-facing side of the station's left truss, or backbone. This is the first of two ELCs that will be installed on the station's exterior during STS-129, providing easily-accessible spares to increase the longevity of the station. Designed and built at Goddard, this newly formed project designed, built, and tested five unpressurized aluminum carriers and six avionics packages for bringing spare hardware and science to the ISS.

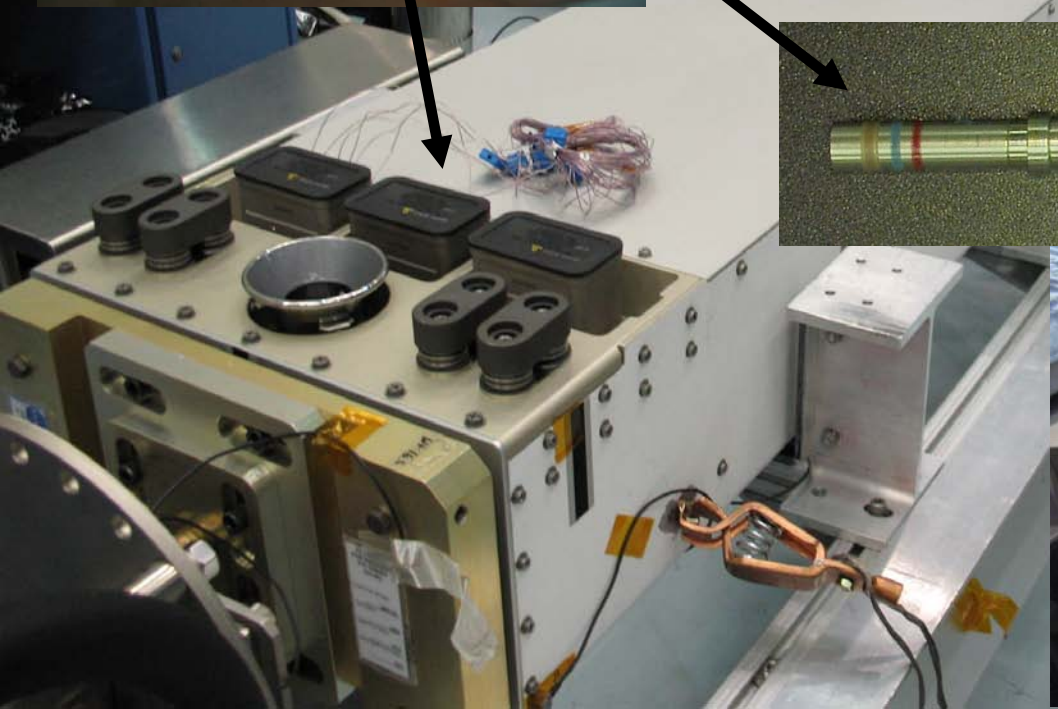
GSFC *Dateline* November 19 2009

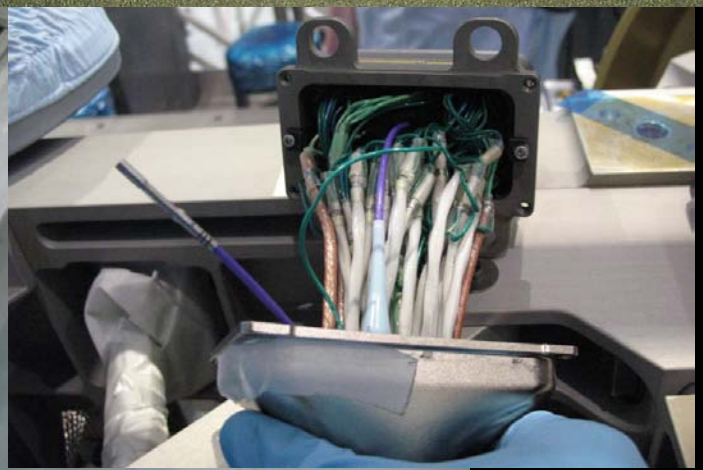
ISS Connector/Pin Anomaly

When we use older technologies we continue to complain about optical fiber being "complicated"

ExPCA Location







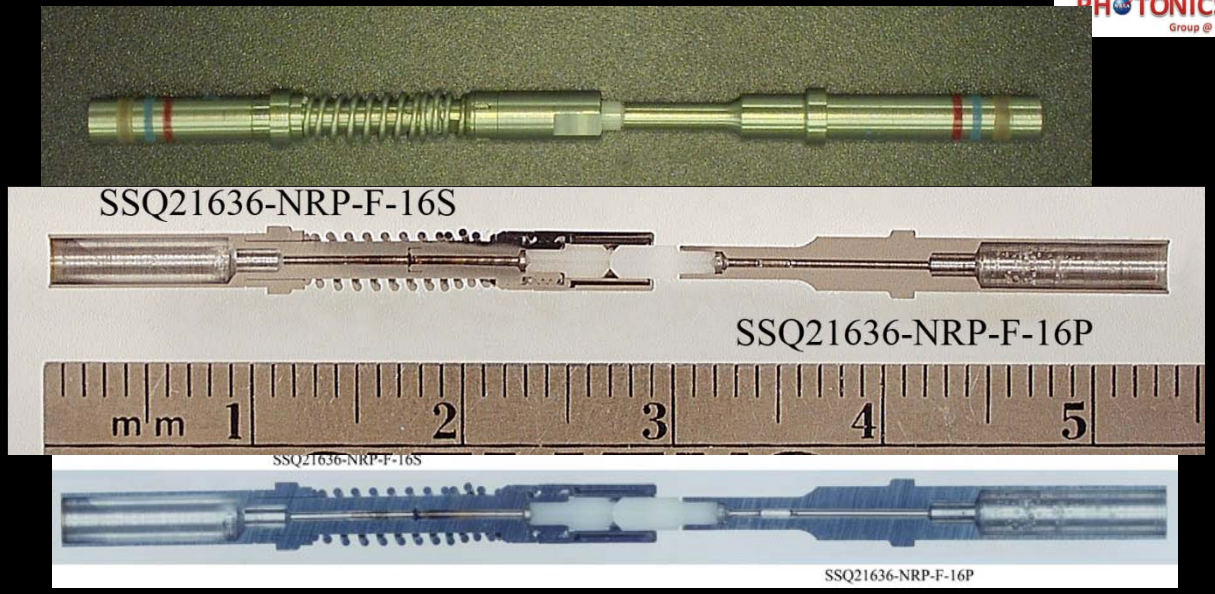
ExPCA Connector Anomaly Investigation

Why did the pins break off?

SSQ21636-NRP-F-16 Mated Pair

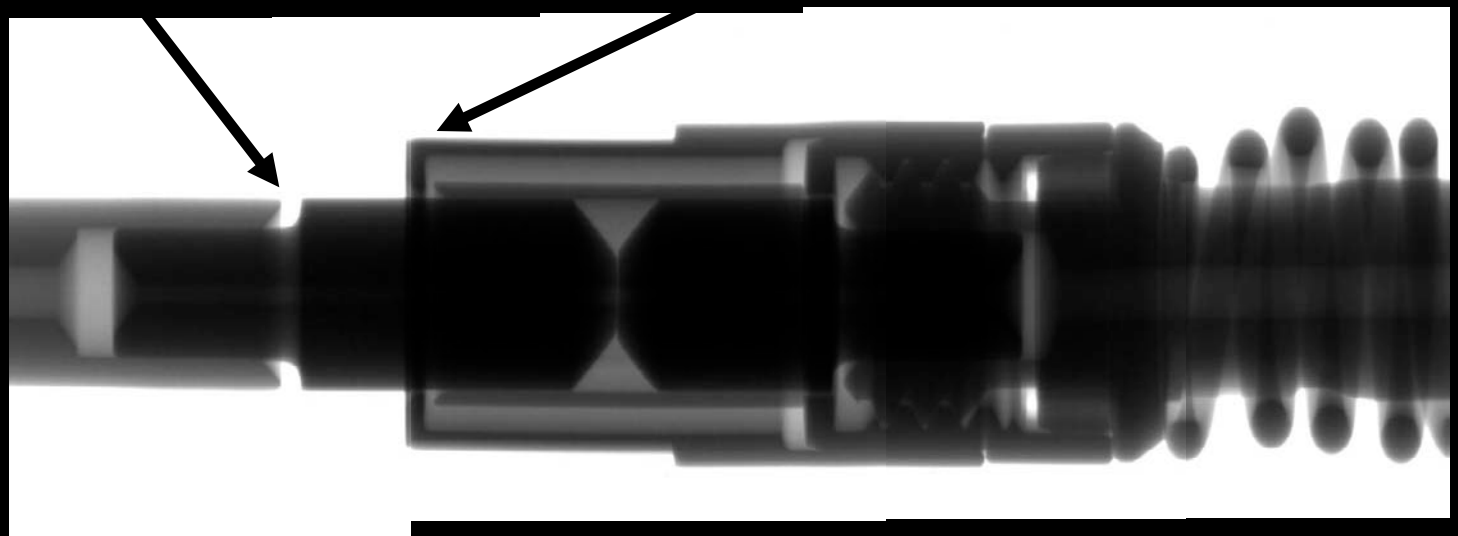
Pin: SSQ21636-NRP-F-16P

Socket: SSQ21636-NRP-F-16S



Gap between Ceramic and Metal Shell

Socket does not engage the entire pin, leaving joint vulnerable

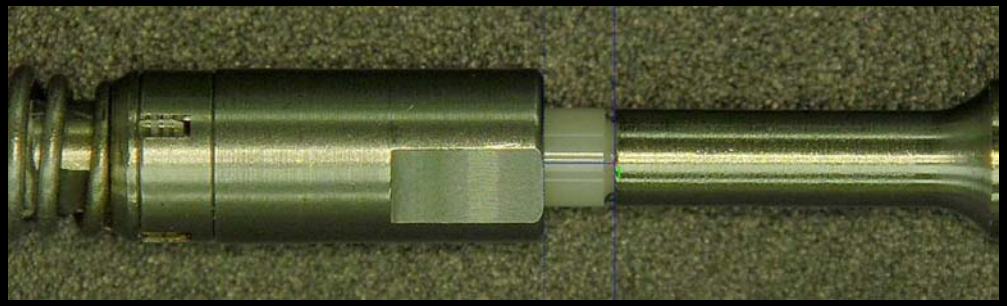


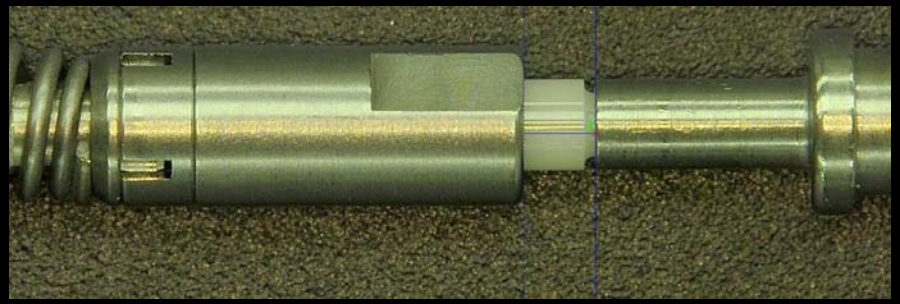
X-Ray Image

SSQ21635 & SSQ21636 Termini

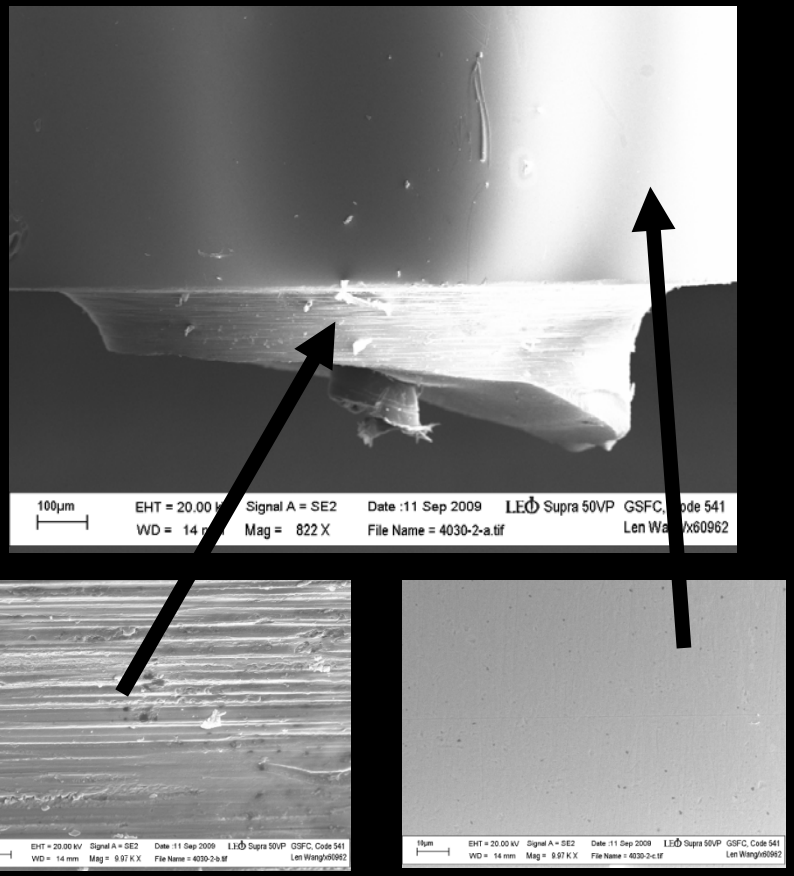
Designed to make breakage more likely at ceramic/metal shell interface
Military 29504 Specification no longer supports this slash sheet (drawing)

Longer Version NRP-F-16P (S)





Shorter Version NZGC-F-16-PB (SB)



<u>Lesson Learned : Support the Development of Current Standards:</u>
<u>JEDEC & SAE</u>

James Webb Space Telescope (JWST) Optical Telescope Element Simulator

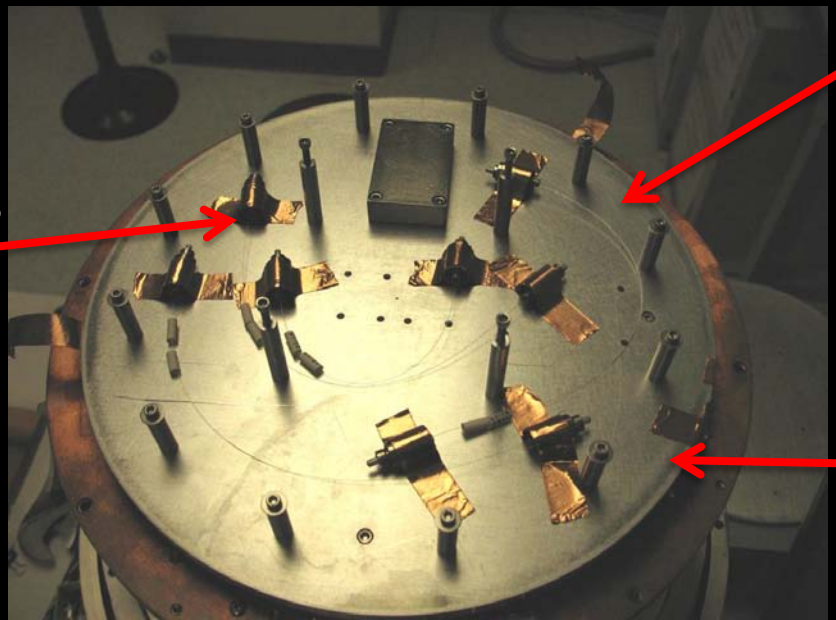
Cryogenic Optical Assemblies for GSFC “Super Ferrule” Connector Design
For simulation of 600 nm to 5600 nm for JWST.

James Web Space Telescope Optical Simulator (OSIM)

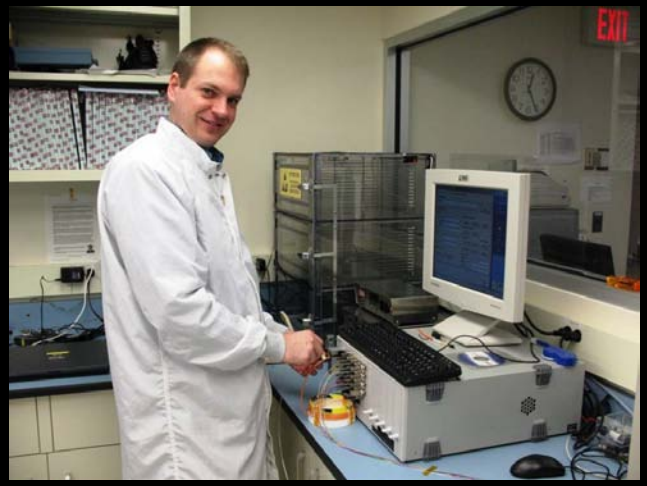
Types of Optical Fiber Tested in Diamond ceramic shell titanium ferrules and FC connectors with and without crimp:

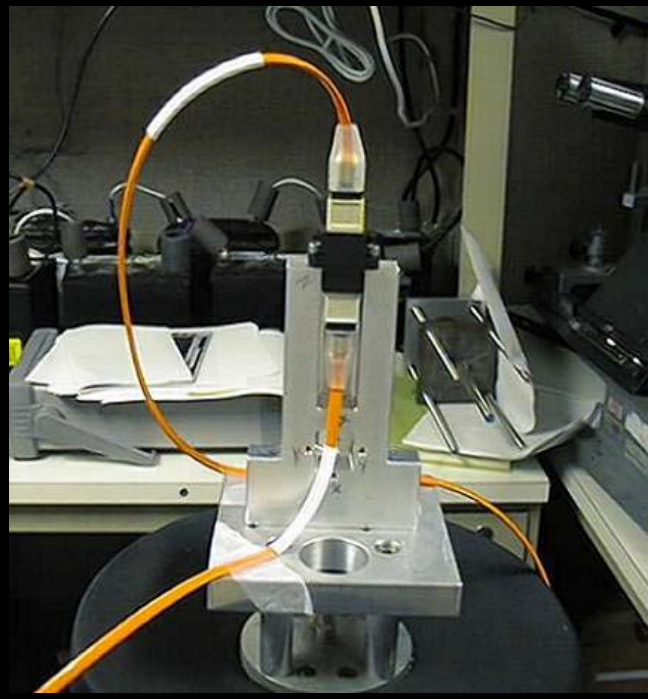
1) Fibercore, Single mode types, SM600 & SM900.
2) Infrared Fiber Systems, ZBLAN doped, 200 micron
3) CorActive AsSe 30 micron

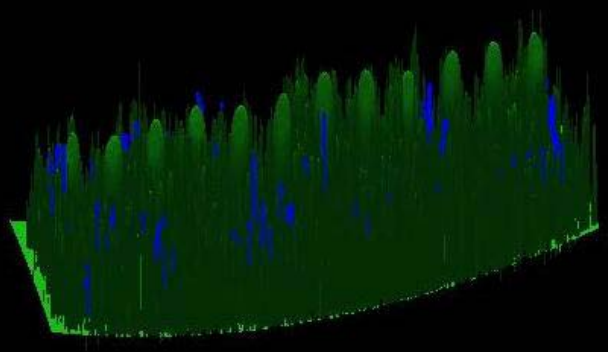
Cryogenic Validation Testing:
To less than 100 Kelvin
For OSIM integration the required Cryo assembies are:
Side A: Ceramic/Titanium ferrules, Side B: Diamond FC

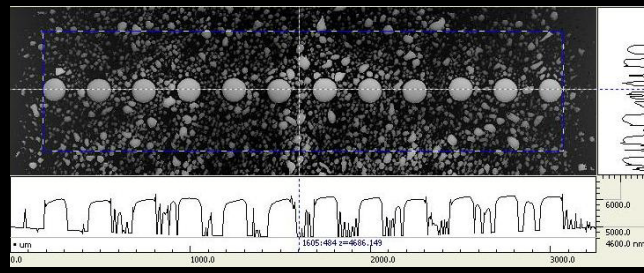


The MTP Connector for Communications Support to NASA & DOE, Sandia Qualification Testing of the MTP, 1998 - 2009









NASA Electronic Parts & Packaging Program (NEPP) Radiation Database 2008

http://nepp.nasa.gov

NEPP Optical Fiber Radiation Database
Commercial Optical Fiber Descriptions
Multimode Optical Fiber Candidates

MULTIMODE FIBER DESCRIPTIONS SUMMARY TABLE

Fiber ID	Manufacturer	Part Number	Fiber Description	Ref#
MM-021002	Heraeus	SSU 1.2 107/00	Step Index; 104/125/250; 0.22na; High OH Low Cl; CCDR 1.2; 40m & 70m	[1]
MM-021003	Heraeus	STU 1.2 237/2000	Step Index; 104/125/250; 0.22na; High OH Low Cl; CCDR 1.2; 40m & 70m	[1]
MM-021004	Mitsubishi Rayon	STR100C-SY	Step Index; 100/150/300; Low OH; 40m & 70m	[1]
MM-021005	FORC	KS-4V	Step Index; 110/125/280; 0.6^2 OH	[1]
MM-022204	Fujikura Ltd.	G-series MM Fiber	F-doped OH free; 200/250; 20m Length	[2]
MM-022205	Mitsubishi	MF Fiber	F-doped OH free; 200/250; 20m Length	[2]
MM-031101	Polymicro	FVP300330370	300/330/370; 0.7m - 1.68m Length	[3]
MM-031102	Polymicro	FIP300330370	300/330/370; 1.68m - 2.06m Length	[3]
MM-031401	Polymicro	FIA200220500	200/220/500; Acrylate; W.L. Gore FON1173; 10m Length	[4]
MM-031402	Polymicro	FIA300330500	300/330/500; Acrylate; W.L.Gore FON1174; 10m Length	[4]
MM-051201	OFS	F14369	Graded Index; Polyimide; Hermetic; 0.20na; 20m Length	[5]
MM-051202	Corning	InfniCol Fiber 50/125	0.20na; Graded-Index; Acrylate; 20m Length	[5]
MM-060204	Nufern	GR50/125-23-HTA	50/125; Graded-Index; <10m Length; Rad-Hard	[6]
MM-060205	Nufern	GR62.5/125-27-HTA	62.5/125; Graded-Index; <10m Length; Rad-Hard	[6]
MM-060206	Nufern	GR100/140-24-HTA	100/140; Graded-Index; <10m Length; Rad-Hard	[6]
MM-060207	OFS	BF04431	62.5/125; Graded-Index; <10m Length; Rad-Hard	[6]
MM-060208	OFS	BF05444	100/140; Graded-Index; <10m Length; Rad-Hard	[6]
MM-061701	Nufern	GR 100/140-24-HTA	12-Fiber 100/140 Graded-Index; 6.35m; Rad-Hard; W.L.Gore FOA 8100/12/1	[7]
MM-071101	ThorLabs	BFL37-200	200/230; Low OH; 50m Length	[8]
MM-071102	ThorLabs	BFH37-200	200/230; High OH; 50m Length	[8]
MM-072101	Polymicro	FIA200220500	200/220/500; Acrylate; 0.22NA; W.L. Gore FON1173 10m Length	[9]
MM-072201	Polymicro	FIA400440580	400/440/500; Acrylate; 0.22NA; W.L. Gore FON1416; 9.5m Length	[10]
MM-090103	Draka	RadHard SMF	DRAKA Elite 50/125/242; 1km length	[11]
MM-090104	Draka	Super RadHard SMF	DRAKA Elite 50/125/242; 1km length	[11]
MM-090201	Nufern	FUD3731	300/330; 0.12NA; W.L. Gore FON1442 PEEK Jacket; 10m Length	[12]

NEPP Optical Fiber Radiation Database
Radiation Effects Summary Multimode Candidates

MULTIMODE FIBER RADIATION EFFECTS SUMMARY TABLE

Fiber ID	λ(nm)	Dose Rate (Gamma)	Total Dose (Gamma)	Temp	Attenuation (dB/m)	Details	[Ref#]
MM-021002	829nm	125 rads/s	1M rads	25°C	0.013	Graph Data	[1]
	829nm	125 rads/s	300 krads	25°C	0.008	Graph Data	[1]
	829nm	125 rads/s	100 krads	25°C	0.0065	Graph Data	[1]
	829nm	125 rads/s	30 krads	25°C	0.005	Graph Data	[1]
MM-021003	829nm	125 rads/s	1M rads	25°C	0.2	Graph Data	[1]
	829nm	125 rads/s	300 krads	25°C	0.25	Graph Data	[1]
	829nm	125 rads/s	100 krads	25°C	0.29	Graph Data	[1]
	829nm	125 rads/s	30 krads	25°C	0.27	Graph Data	[1]
	1310nm	125 rads/s	1M rads	25°C	0.012	Graph Data	[1]
	1310nm	125 rads/s	300 krads	25°C	0.013	Graph Data	[1]
	1310nm	125 rads/s	100 krads	25°C	0.014	Graph Data	[1]
	1310nm	125 rads/s	30 krads	25°C	0.015	Graph Data	[1]
MM-021004	829nm	125 rads/s	1M rads	25°C	0.16	Graph Data	[1]
	829nm	125 rads/s	300 krads	25°C	0.08	Graph Data	[1]
	829nm	125 rads/s	100 krads	25°C	0.045	Graph Data	[1]
	829nm	125 rads/s	30 krads	25°C	0.029	Graph Data	[1]
	1310nm	125 rads/s	1M rads	25°C	0.01	Graph Data	[1]
	1310nm	125 rads/s	300 krads	25°C	0.005	Graph Data	[1]
	1310nm	125 rads/s	100 krads	25°C	0.004	Graph Data	[1]
	1310nm	125 rads/s	30 krads	25°C	0.003	Graph Data	[1]
MM-021005	829nm	125 rads/s	1M rads	25°C	0.65	Graph Data	[1]
	829nm	125 rads/s	300 krads	25°C	0.9	Graph Data	[1]
	829nm	125 rads/s	100 krads	25°C	1.00	Graph Data	[1]
	829nm	125 rads/s	30 krads	25°C	0.96	Graph Data	[1]
	1310nm	125 rads/s	1M rads	25°C	0.027	Graph Data	[1]
	1310nm	125 rads/s	300 krads	25°C	0.028	Graph Data	[1]
	1310nm	125 rads/s	100 krads	25°C	0.026	Graph Data	[1]
	1310nm	125 rads/s	30 krads	25°C	0.025	Graph Data	[1]
MM-022204	600-650nm	333 rads/s	190M rads	25°C	0.9	Reported Data	[2]
MM-022205	600-650nm	333 rads/s	190M rads	25°C	0.25	Reported Data	[2]

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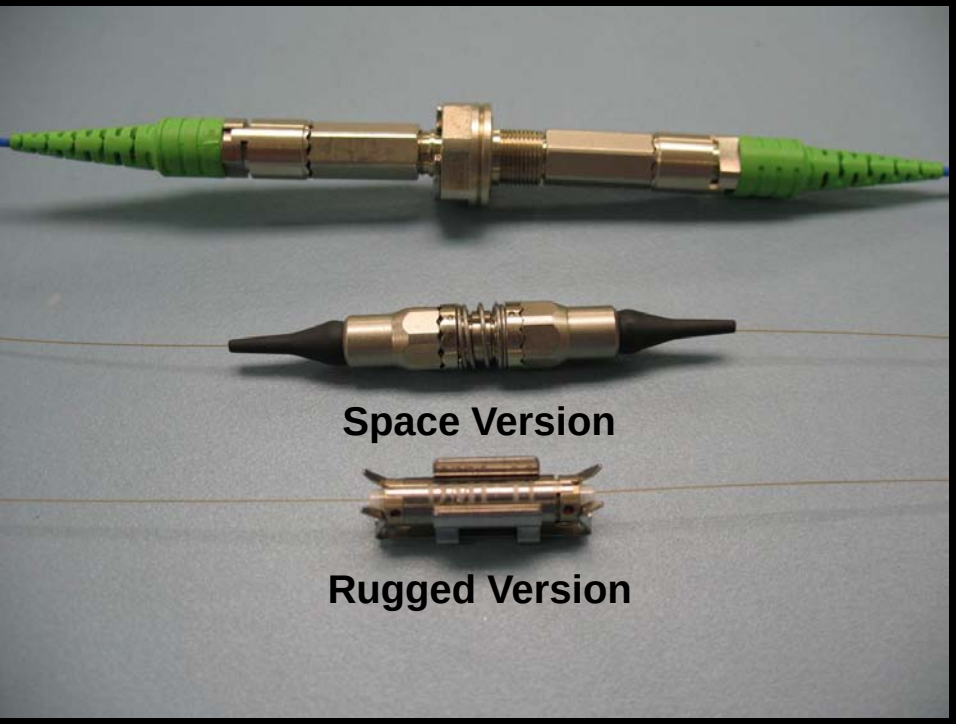
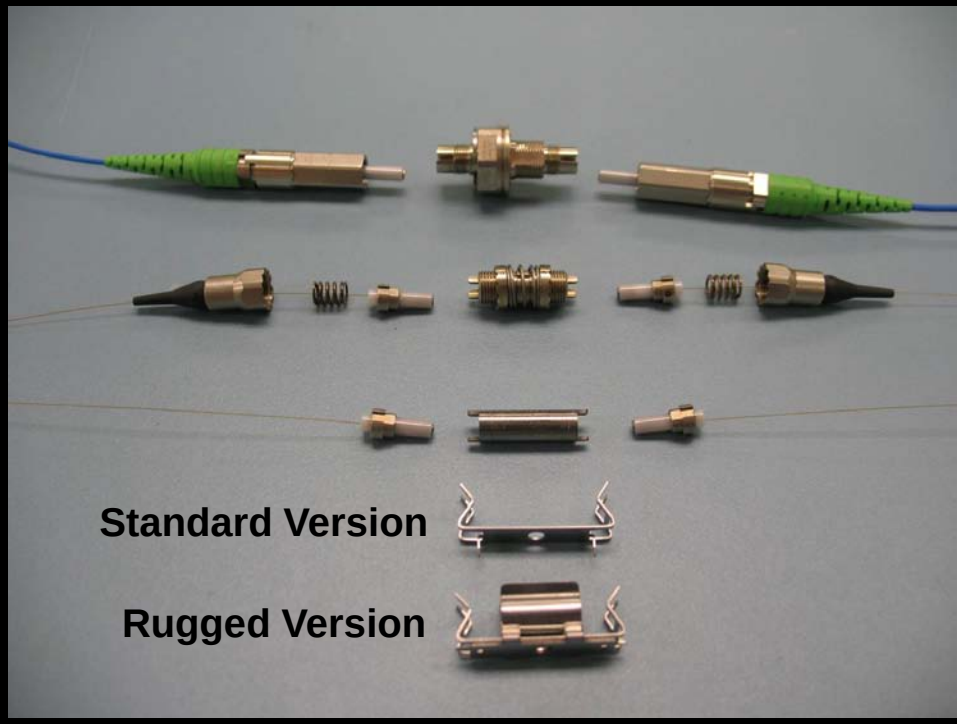
10. M. Ott, X. Jin, F. LaRocca, A. Matuszeski, R. Chuska, S. Macmurphy, "Requirements Validation Testing on the 7 Optical Fiber Array Connector/Cable Assemblies for the Lunar Reconnaissance Orbiter (LRO)", SPIE Optics and Photonics Conference, Photonics Technology for Space Environments II, Vol. 6713, August 2007.

NASA Electronic Parts and Packaging Program
Component Evaluations for Small Form Factor Applications

As a technology validation of the Diamond DMI (Mini AVIM) for space form factor applications the following tests were conducted:

Pull Force Data
Thermal Testing
Vibration Testing





NASA Flight & Test Heritage of the Diamond AVIM

Project	Dev	Launch	Connectors	Description	Details
Geoscience Laser Altimeter System (GLAS) on ICESAT	1998	2001	AVIM Standard Single Mode / Multi Mode / Flat Polish	Gore Flexlite SM & MM 2 Km of SM	Custom drill in ferrule, tungsten carbide shell ferrules
Mercury Laser Altimeter (MLA) MESSENGER	2001	2004	AVIM Standard, Flat Polish	330 um MM Flexlite	Custom drill in ferrule, tungsten carbide shell ferrules
Shuttle Return to Flight NEPTEC Laser Heat Tile Sensor	2003	2005	AVIM standard SM APC & SM	BICC OC1008, one sided terminations.	Standard pilz ferrule, ceramic shell
Lunar Orbiter Laser Altimeter on Lunar Recon Orbiter	2007	2009	AVIM array connector, 303 SS ferrule drill @ GSFC	SS larger PM AVIM for 5 220 um fibers side one, fan out standard side two, Flexlite	Custom drill 220 um on fan out side, with standard AVIM tungsten carbide shell ferrules
Laser Ranging on Lunar Recon Orbiter	2007	2009	AVIM Array connector, 416 SS ferrule flower drill @ Diamond	SS larger PM AVIM for 7 440 um fibers, large custom cable	Both sides array flower pattern. Gimbal, cold, to -55 C.
Mars Science Lab, Chemcam	2008	TBD	AVIM standard custom drill ferrule for 330 um	Flexlite	Gimbal, cold, hot to 110 C
Express Logistics Carrier on ISS	2008	Nov-2009	AVIM standard custom drill for 140 um	Space Station cable & Flexlite	Pilz ceramic shell ferrules
NASA GSFC evaluation of Mini AVIM & DMI	2008	none	Bare fiber for thermal and vibration testing.		
James Webb Space Telescope	2008	GSE	FC & AVIM titanium ferrules.	No cable, cryogenic application.	Multiple sizes, multiple materials

Melanie N. Ott, Photonics Group, NASA Goddard Space Flight Center, October 15, 2009, details and test reports; http://photonics.gsfc.nasa.gov

Some Lessons Learned

- **Know your failure modes or hire an expert to do it for you.**
  - ✓ **Materials analysis now or later, you decide.**
  - ✓ **Vendors get information from outgassing database – its not stand alone**

- **Cracked fiber may not mean catastrophic failure unless you are photon counting. Example ISS.**

- **Need experts to review documentation.**

- **Need good quality documentation;**
  - ✓ **Pre-manufacturing preconditioning of materials.**
  - ✓ **Incoming inspection of all vendor supplied items.**
  - ✓ **Manufacturing procedures.**
  - ✓ **Post manufacturing visual inspections for compliance.**
  - ✓ **Post manufacturing workmanship.**

Conclusion

- Redundancy is used to reduce risk in communication systems.
- Optical fiber systems have been used in space flight for thirty years successfully.
- Knowledge of failure modes and materials is crucial to making feasibility decisions as well as design, manufacturing procedures and test plans.

- Technology Needs for Near Term Future
  - ✓ IR Photonics out to 10 um,
  - ✓ Smaller packaging,
  - ✓ Cyrogenic applications
  - ✓ Outsourcing for LIDAR lasers.
  - ✓ Fiber lasers for LIDAR, Science & Comm
  - ✓ High power optical fiber assemblies
  - ✓ General LIDAR & Laser communications components

Thank you!

For more information please visit the website:

http://photonics.gsfc.nasa.gov