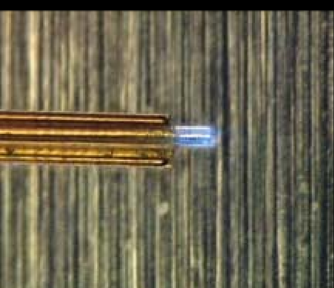
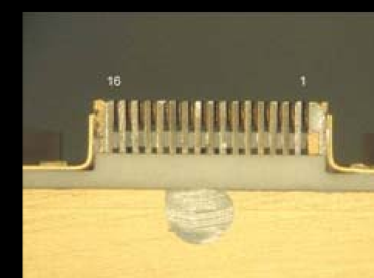


The Fiber Optic Subsystem Components on Express Logistics Carrier for International Space Station

Melanie N. Ott, Rob Switzer, William Joe Thomes,
Richard Chuska, Frank LaRocca, Lance Day

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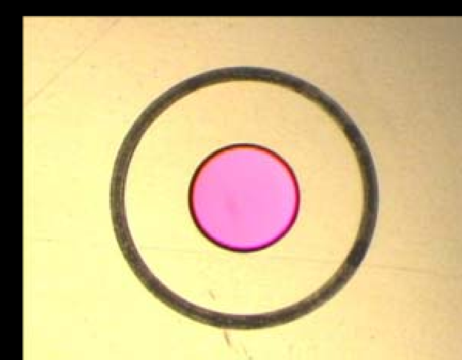


Thirteen Years of Service from the Photonics Group for Photonics & Optical Fiber Components and Assemblies Code 562, Electrical Engineering Division of AETD, NASA GSFC

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 -2008		FLIGHT			Vendor/ Flight
ISS-Express Logistics Career	2006 -2009	X	X	FLIGHT	X	
Air Force Research Lab	2003, 2008		X			
Shuttle Return To Flight	2004 -2005			FLIGHT		
Lunar Orbiter Laser Altimeter	2003 -2008	X	X	FLIGHT	X	Prototype
Mars Science Lab ChemCam	2005 -2008	X	X	FLIGHT	X	Vendor
Laser Ranging, LRO	2005 - 2008	X	X	FLIGHT	X	Prototype
Fiber Laser IIP/IRAD	2003 - 2006	X	X	QUAL		
James Webb Space Telescope OSIM Cryo	2008-2009	X	X	Cryo-Qual	X	
Joint Dark Energy Mission	2009	X		X		
Langley Research Center	2009	X	X	X		

Summary of Specialties

- Space Flight Packaging for Assemblies.
- Manufacturing of Custom Assemblies and Arrays.
- Environmental Screening, Selection and Qualification of Optoelectronic Parts; High Power Laser Diode Arrays, Laser Diodes, Pin Diodes, Transceivers, Modulators
- Optical Fiber Insitu Radiation Testing over Temperature for a Comprehensive Dose Rate/Total Dose/Temperature Model.
- Failure Analysis for Electrical and Optical Components.
- Design, development for risk mitigation of failure modes.
- High Power terminations for space flight instruments and power transfer systems (fiber laser power stage).
- Flight integration.

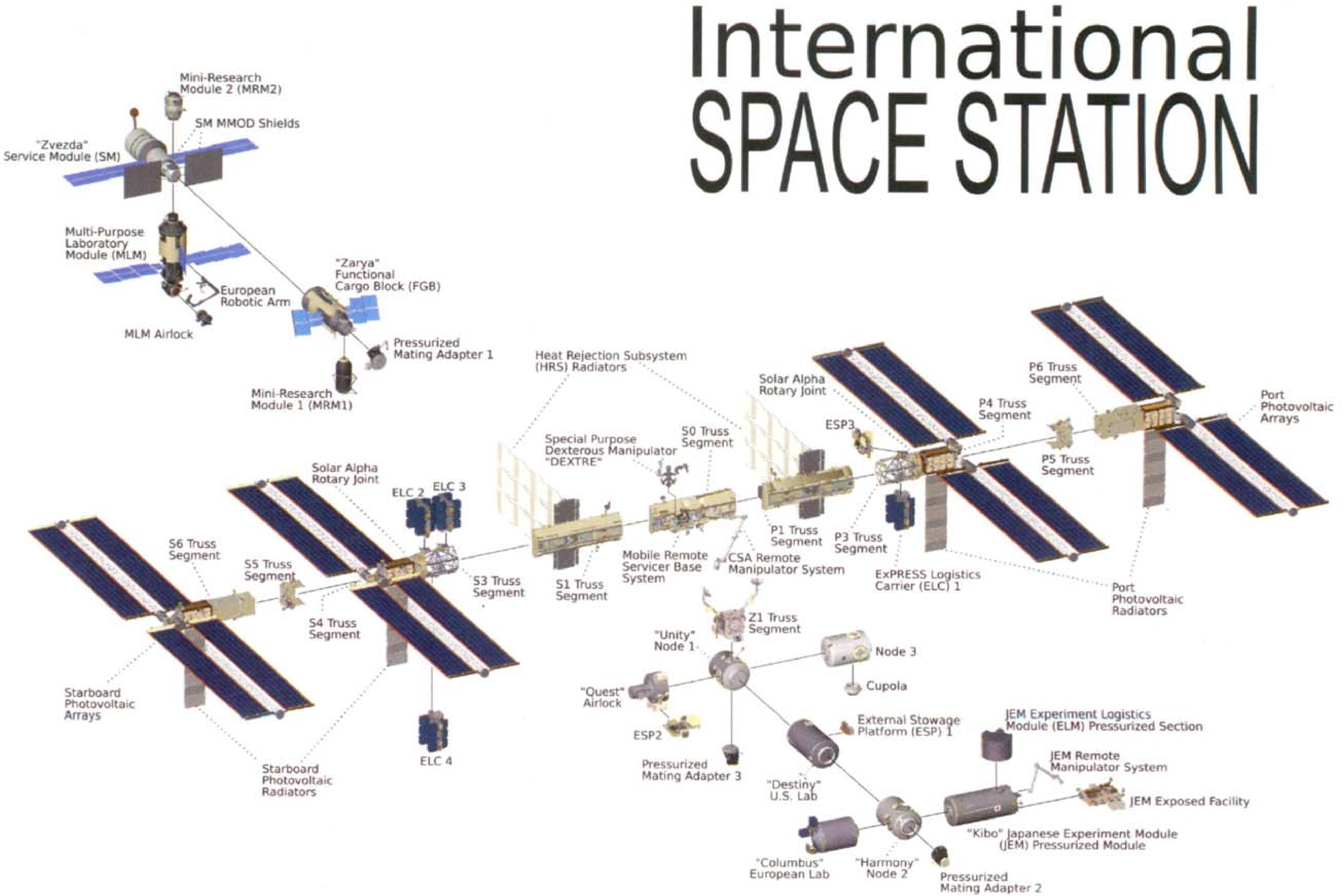
Outline

- International Space Station/ GSFC Transceiver Requirements
- Transceiver Requirement Issues/ Resolution
  - Extinction Ratio, System Requirements
- Harness Diagram
- Integration, Issues and Resolution
- Attenuator Data
- Connector Anomalies
- Other Topics Related

  NEPP Radiation Database Complete

  Small Form Factor Interconnects
- Conclusions

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



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

Extinction Ratio Definitions, For System Level Requirements

P_1 = power high, P_0 = power low

Extinction Ratio (%) ISS Specification, $Re (\%) = (P_0/P_1) * 100\%$;

Extinction Ratio (dB); $Re (dB) = 10*\log(P_1/P_0)$

Extinction Ratio (industry) $Re = P_1/P_0$

Extinction Ratio	%	dB	Ratio
Larger	5 %	13 dB	20
	10 %	10 dB	10
	15 %	8.2 dB	6.7
	25 %	6 dB	4
	40 %	4 dB	2.5
Smaller	60 %	2.2 dB	1.7

Space Station HDRL Requirements

Requirement	Rate	Wavelength	BER	Extinction Ratio
ISS SSP 50184	125 Mbps	1270 – 1380 nm	10^{-9}	5% (13 dB) TX 10% (10 dB) RX
GSFC	125 Mbps	1290 – 1390 nm	10^{-9}	5% (20) 13 dB

Requirement	Optical output TX	Typical TX	Range RX
GSFC	-7 dBm to 0 dBm 200 uW - 1 mW	-4 dBm 400 uW	-36 dBm to 1 dBm 250 nW – 1.25 mW

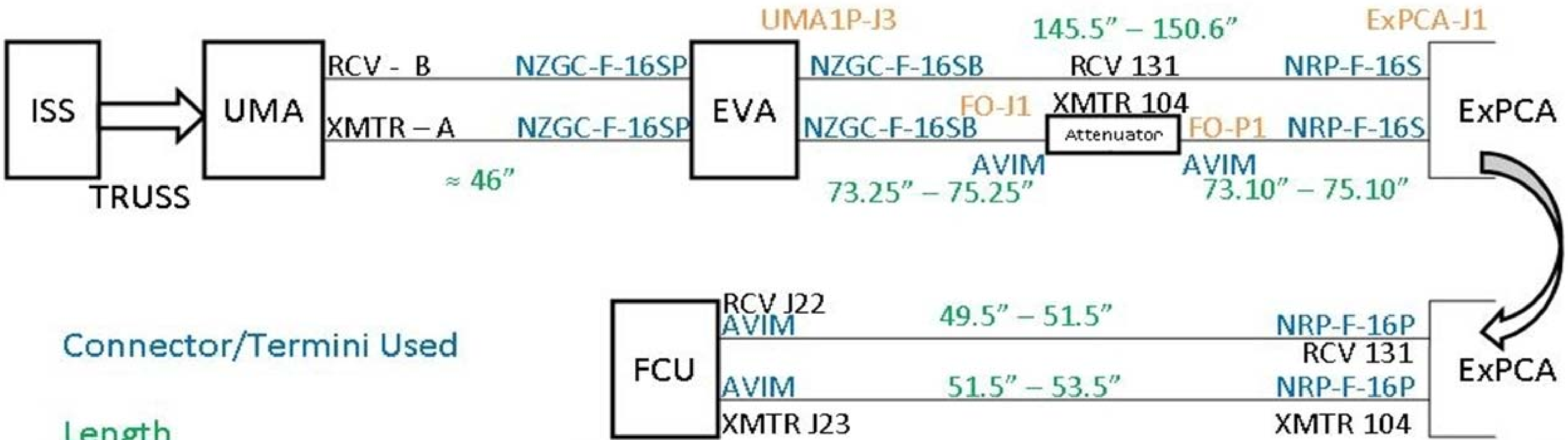
Space Photonics Transceivers

GSFC Thermal Requirement -20°C to +60°C

Specification	Optical Output, TX	Range, RX	Re
SPI			
FCU @28°C	3.0 dBm (2 mW)		
FCU @66°C	-1.5 dBm (700 uW)		
FCU @-18°C	5 dBm (~3.2 mW)		
GSFC	-7 dBm to 0 dBm 200 uW to 1 mW (-4 dBm typical)	-36 dBm to 1 dBm 250 nW to 1.25 mW	Was 13 dB Now 8.2 dB

ISS simulator testing proved GSFC could use 15 % (8.2 dB) for Extinction Ratio
SPI TX/RX worked in simulator to higher than 40% Re or less than 4 dB Re.

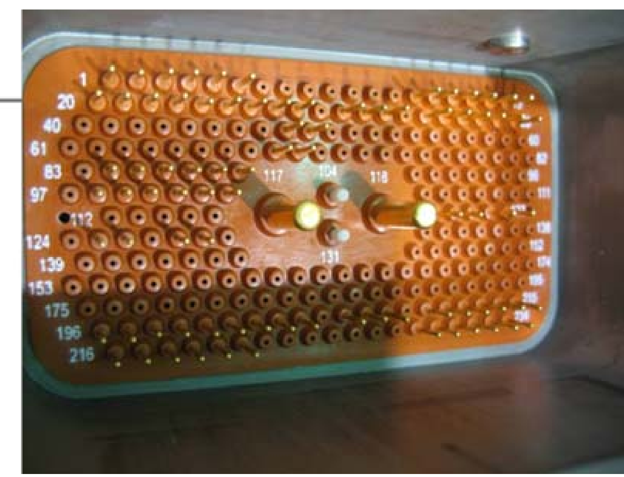
Harnessing Diagram for Express Logistics Carrier on ISS



Connector/Termini Used

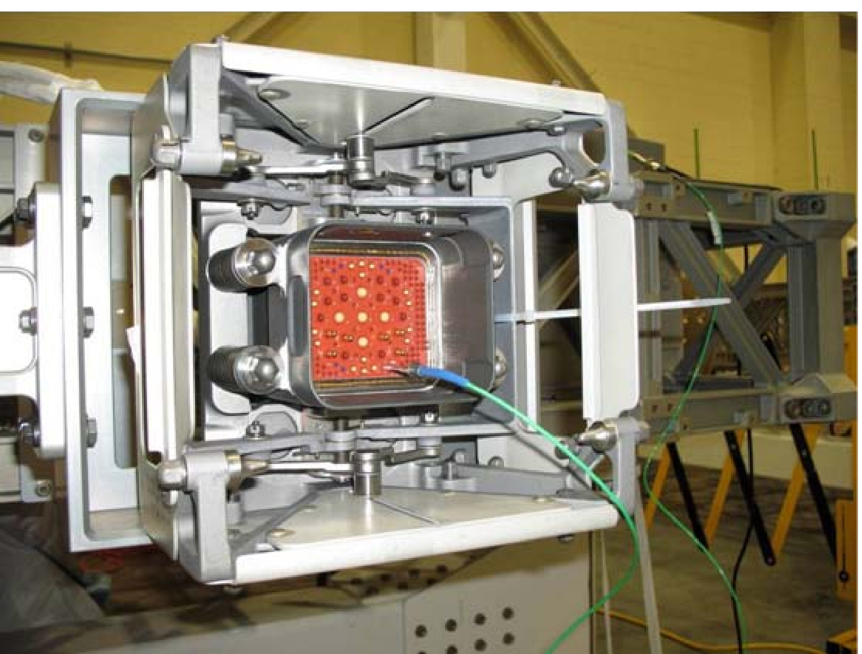
Length

Connection Name



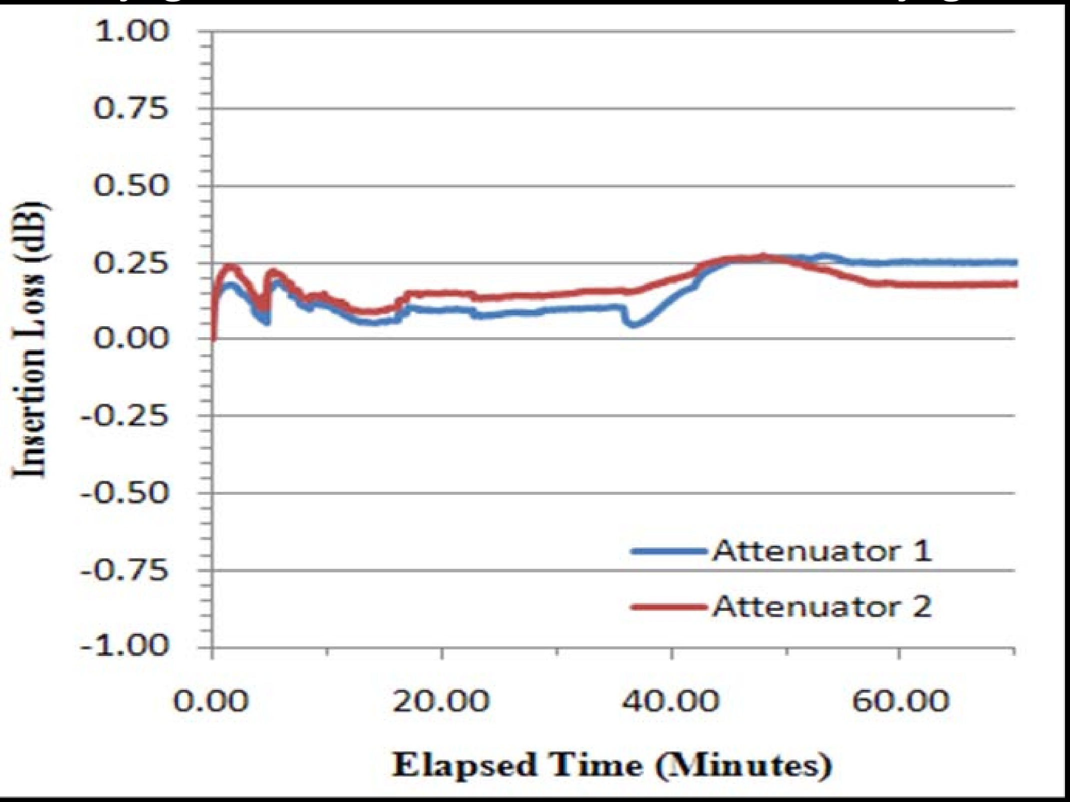
ExPCA Connector

UMA Connector

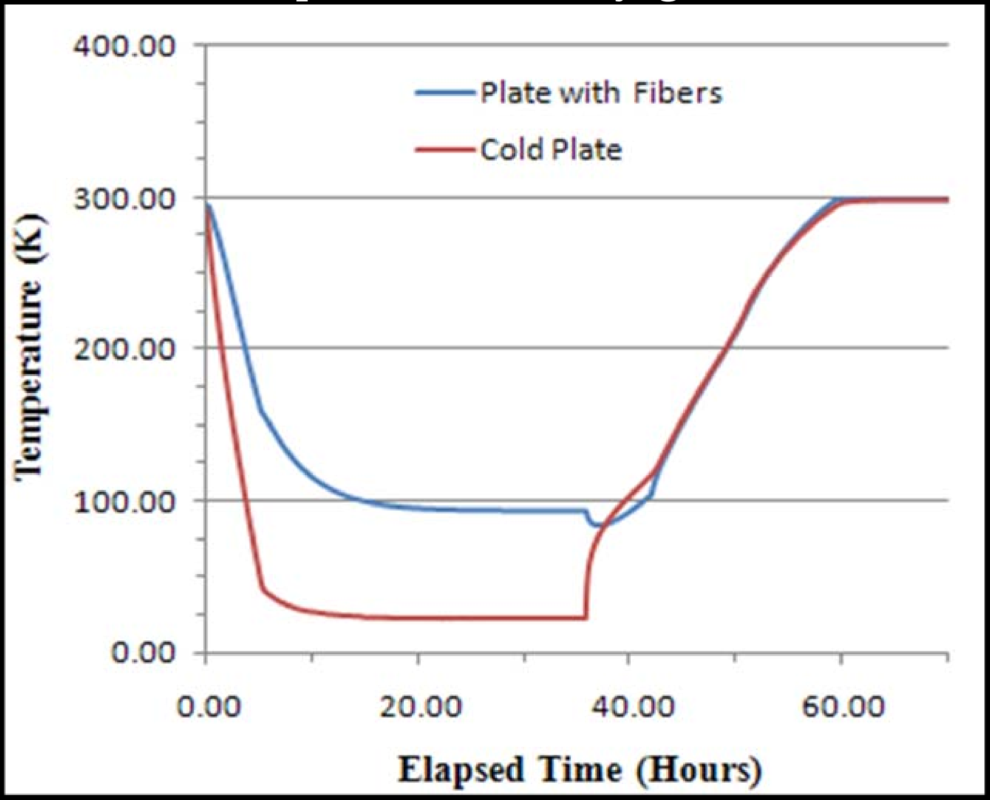


Attenuator Cryogenic Validation Test

Cryogenic Insertion Loss Data vs Time at Cryogenic



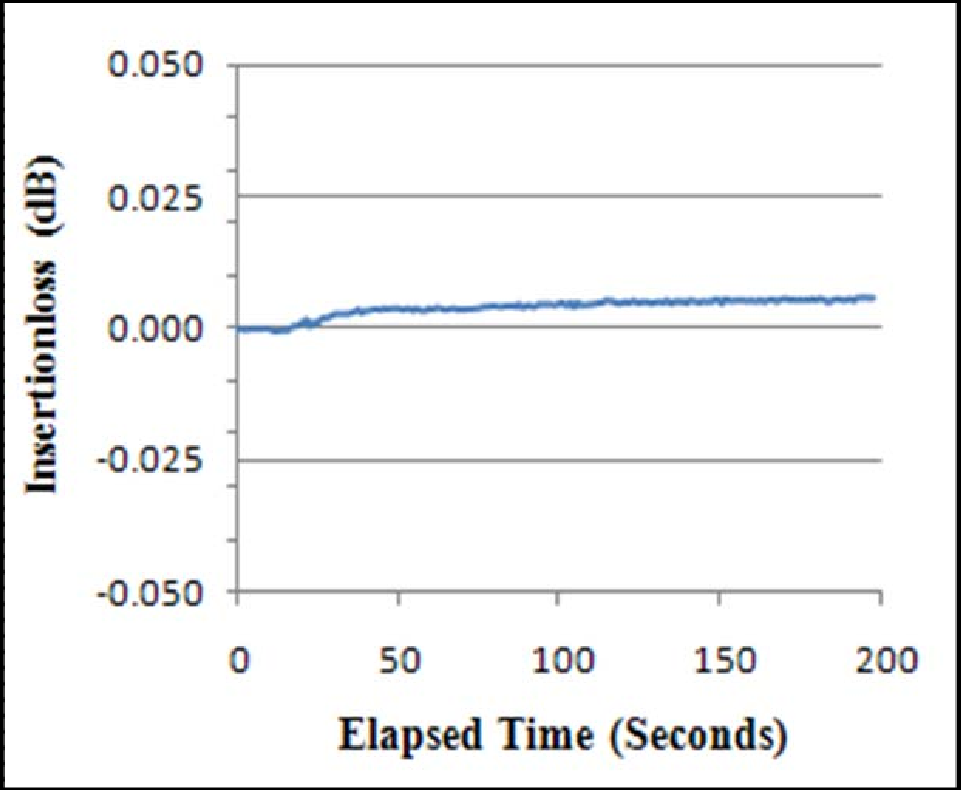
Thermal Couple Data from Cryogenic Test.

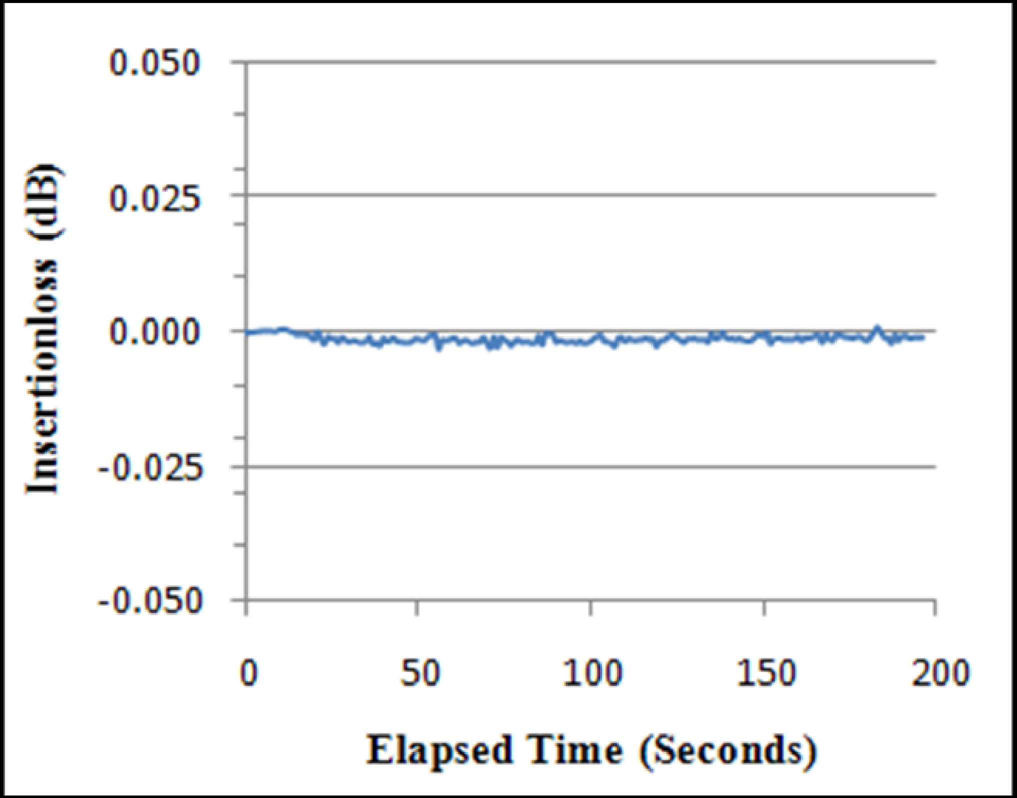


24 hour cryogenic test @ 93K (-180°C) for validation of attenuator Macor components inside of a Diamond AVIM "Cleanable" Adapter

Attenuator Random Vibration Test

Insertion Loss Monitoring during random vibration testing of Attenuator 1 @ 20Grms





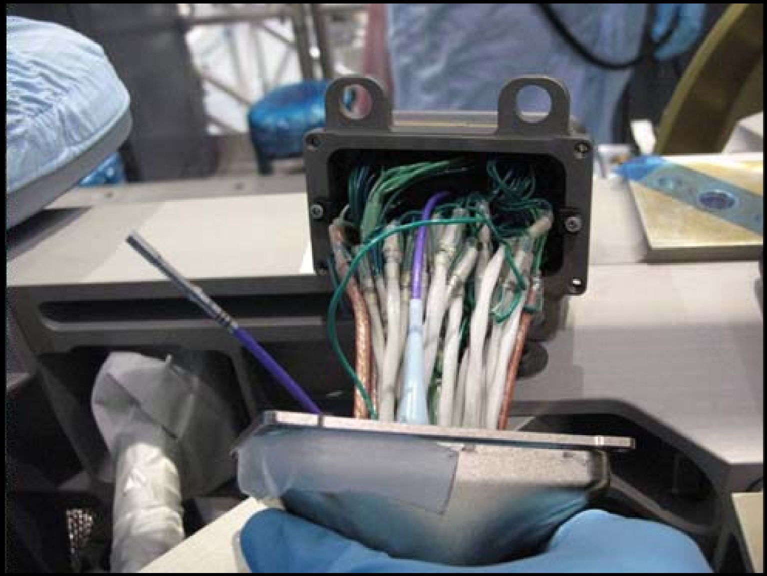
Horizontal Axis,

Vertical Axis

Integration of the ELC assemblies at KSC International Space Station Facility

GSFC

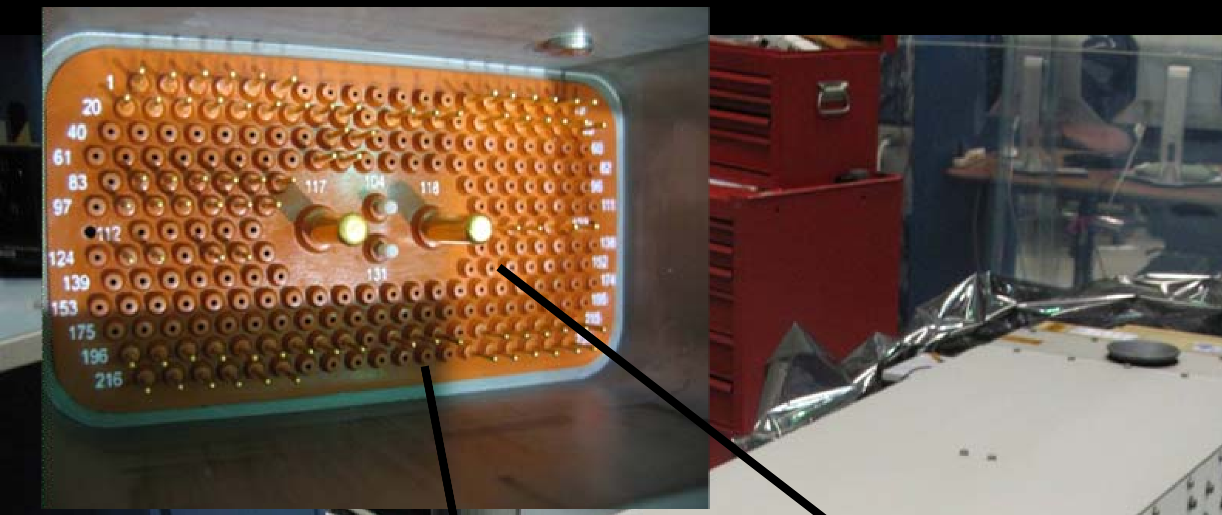
CODE 562 PHOTONICS Group @ GSFC

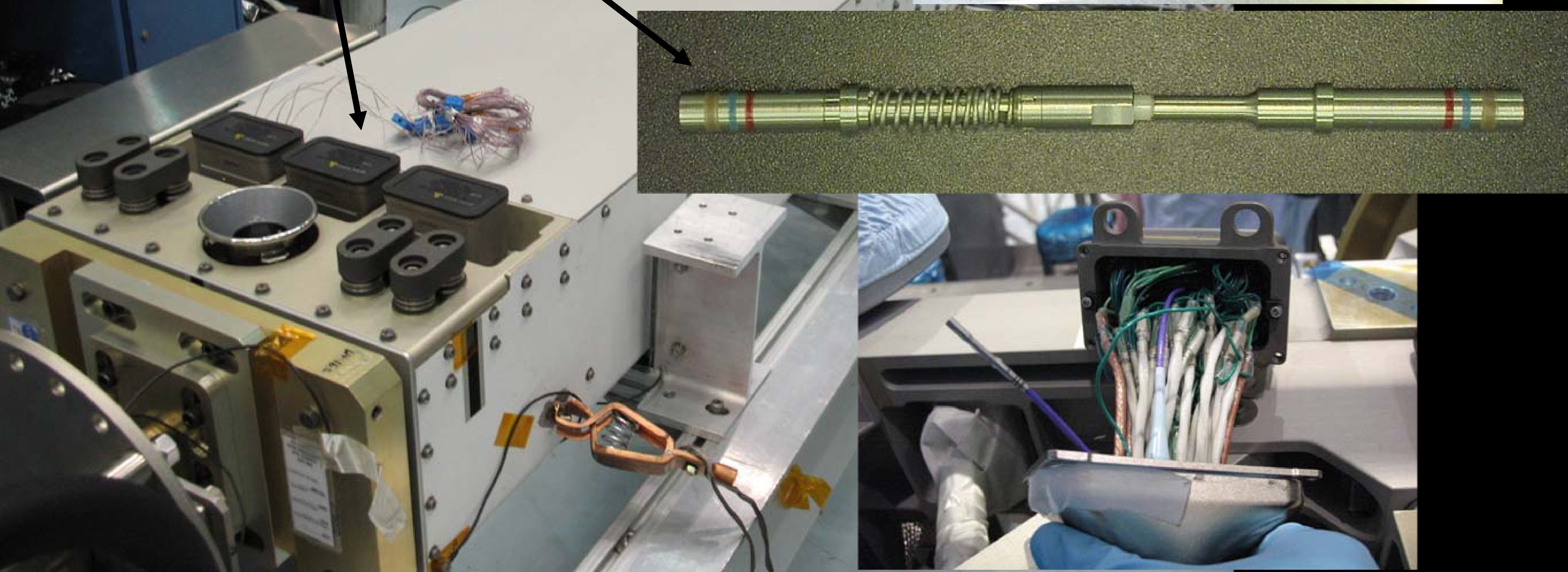


**Last assemblies to integrate into the harnessing were the optical fiber assemblies, reason = risk mitigation.
Schedule constraints led to integration at the
International Space Station Processing Facility at Kennedy Space Center.
Lesson Learned= Integrate sooner.**

ISS Connector/Pin Anomaly

ExPCA Location





ExPCA Connector Anomaly Investigation

Why did the pins break off?

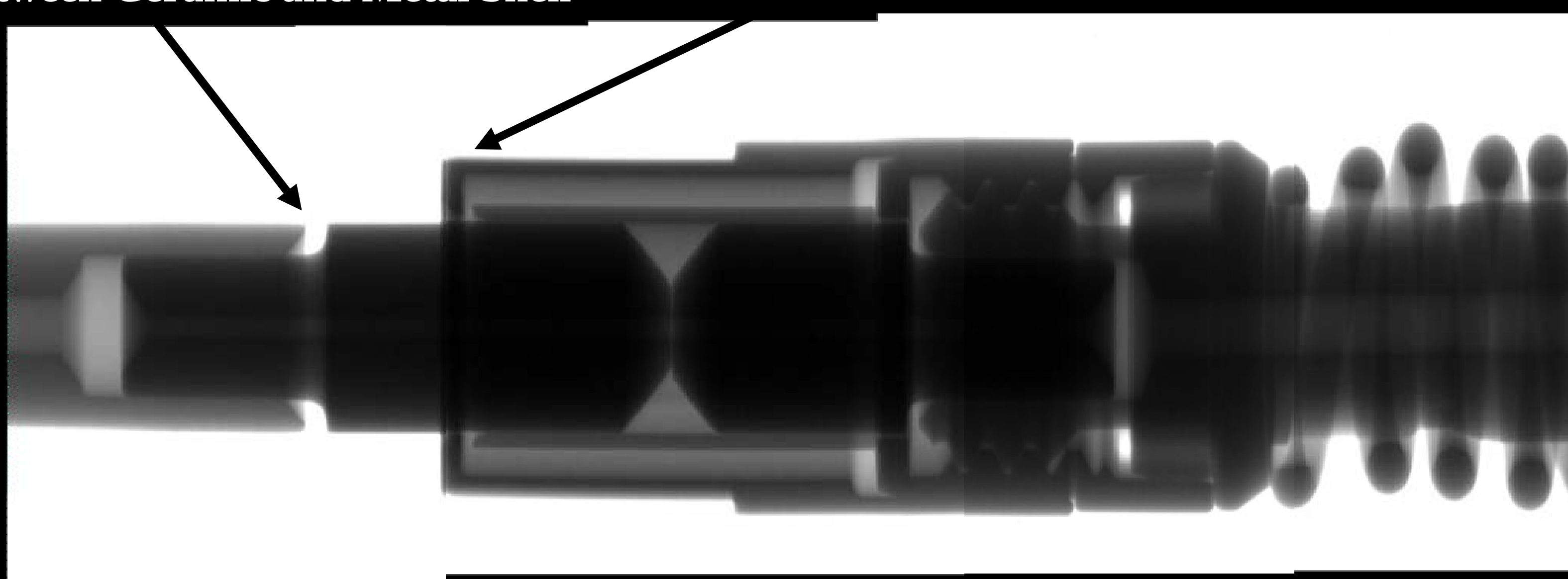
SSQ21636-NRP-F-16 Mated Pair

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

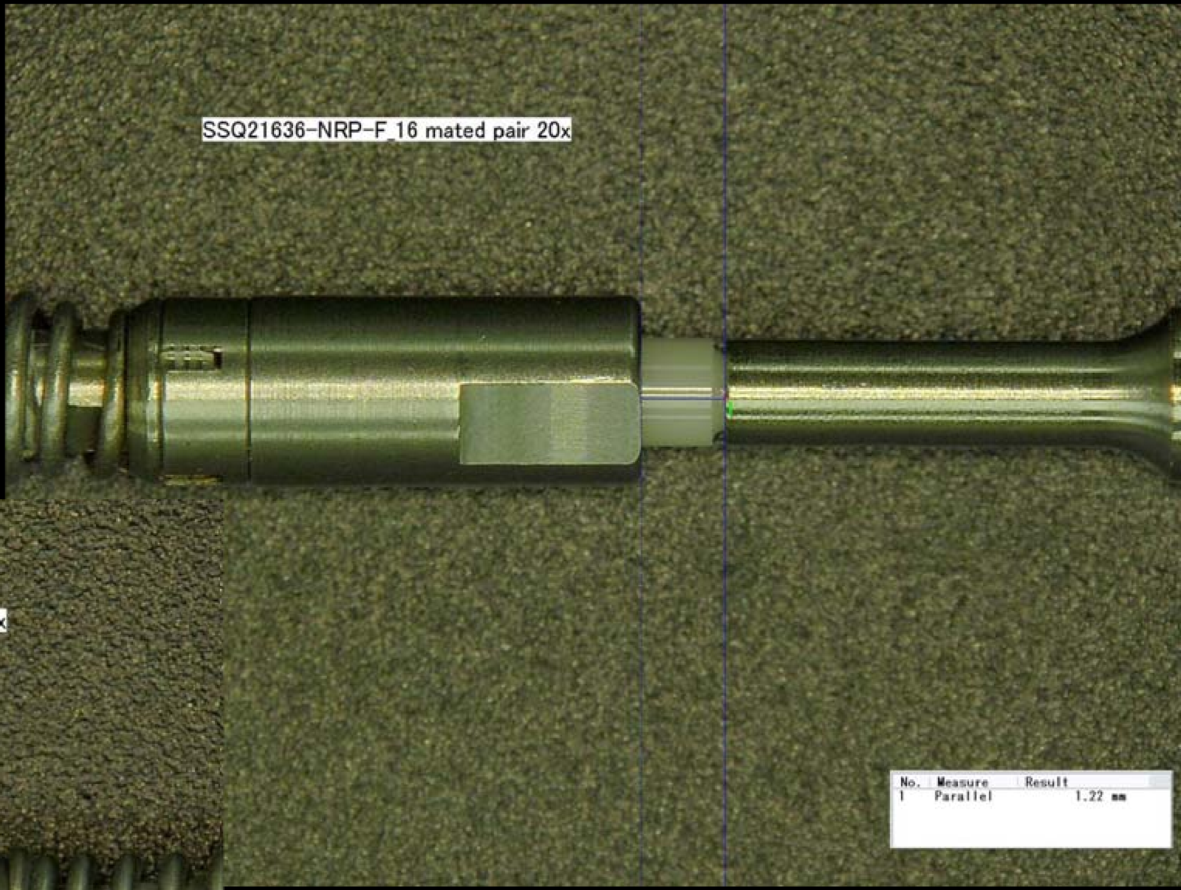


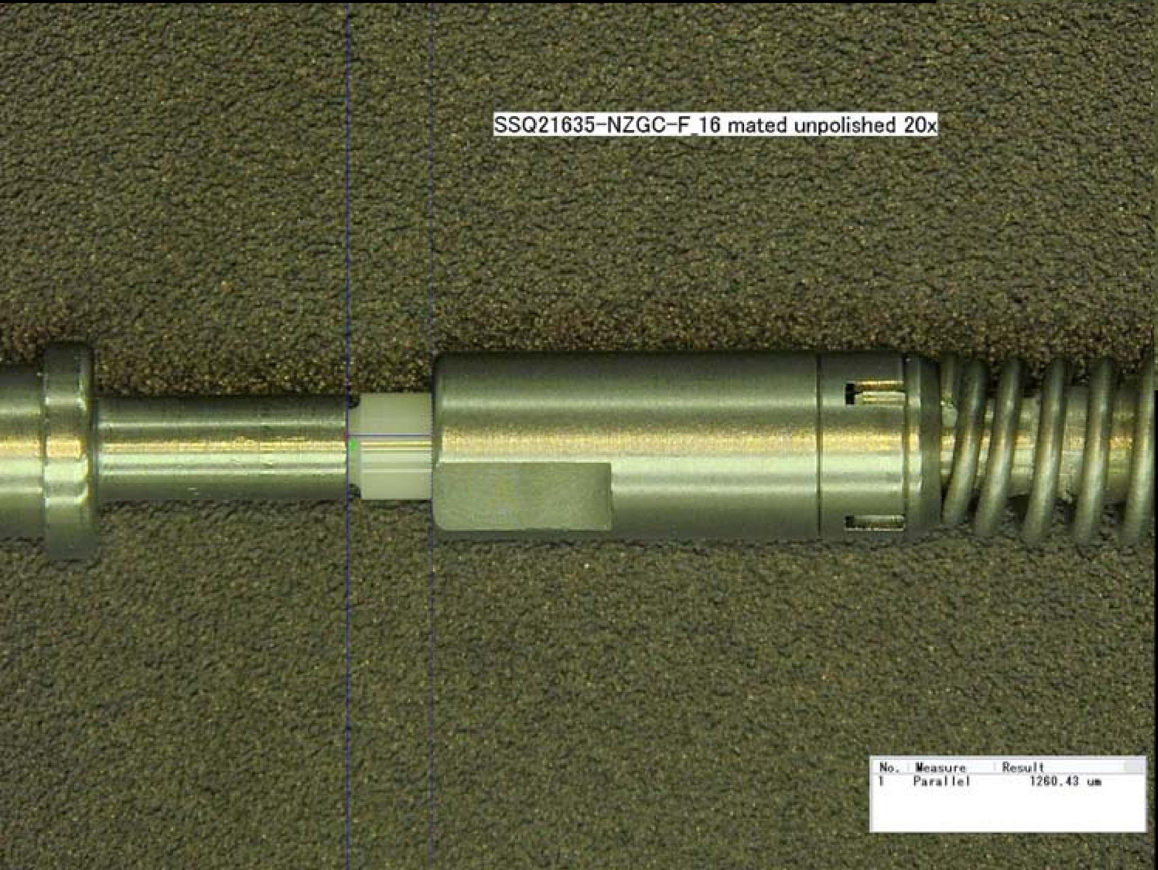
X-Ray Image

SSQ21635 & SSQ21636 Termini

Designed to make breakage more likely at ceramic/metal shell interface

Longer Version NRP-F-16P (S)



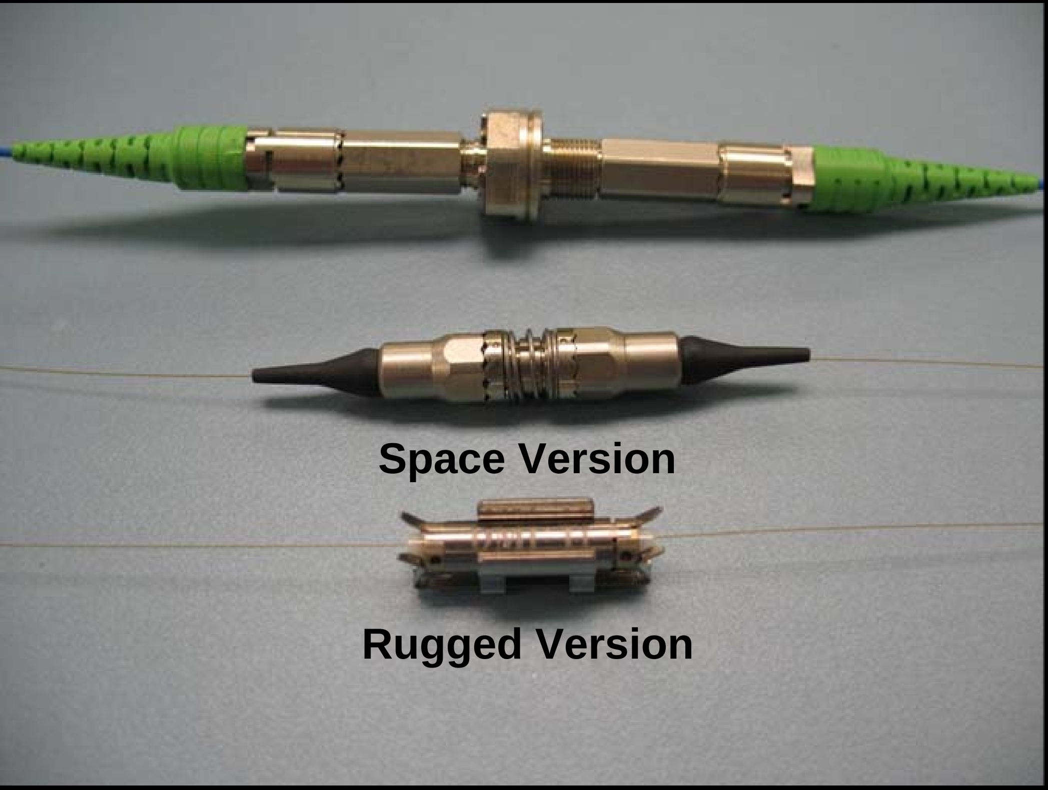


Shorter Version NZGC-F-16-PB (SB)

Component Evaluations for Small Form Factor Applications
results available http://photonics.gsfc.nasa.gov

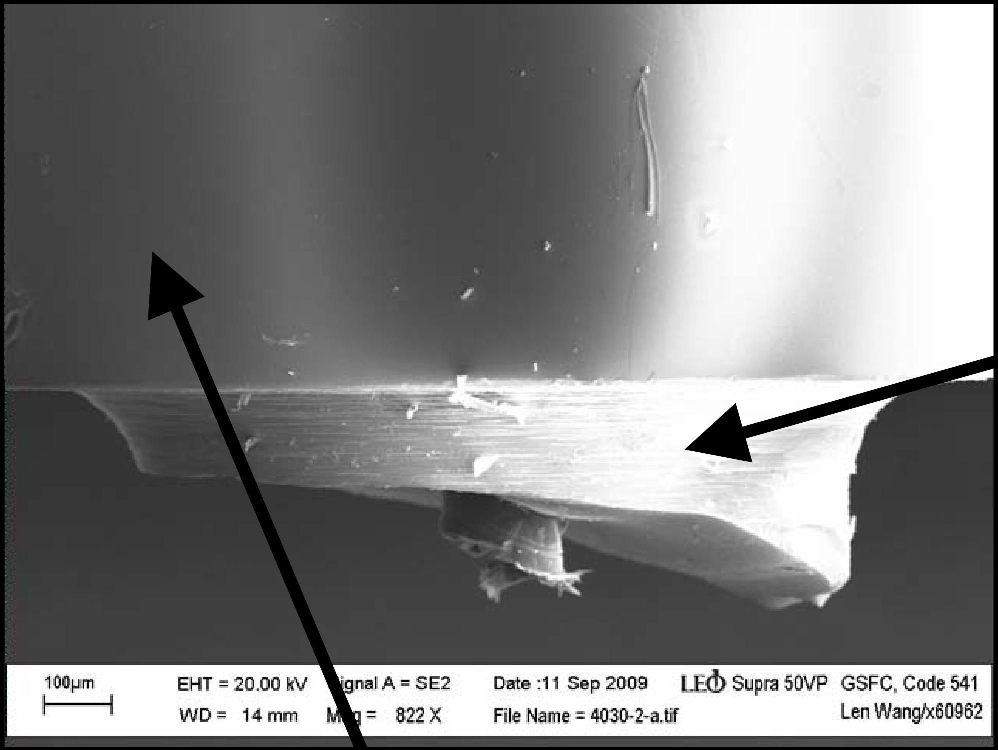
For future transceiver applications, a preliminary technology validation of the Diamond DMI (Mini AVIM)the following tests were conducted:
Pull Force Data, Thermal Testing, Vibration Testing

Meeting with Diamond in Mid Oct to discuss next generation enhancements

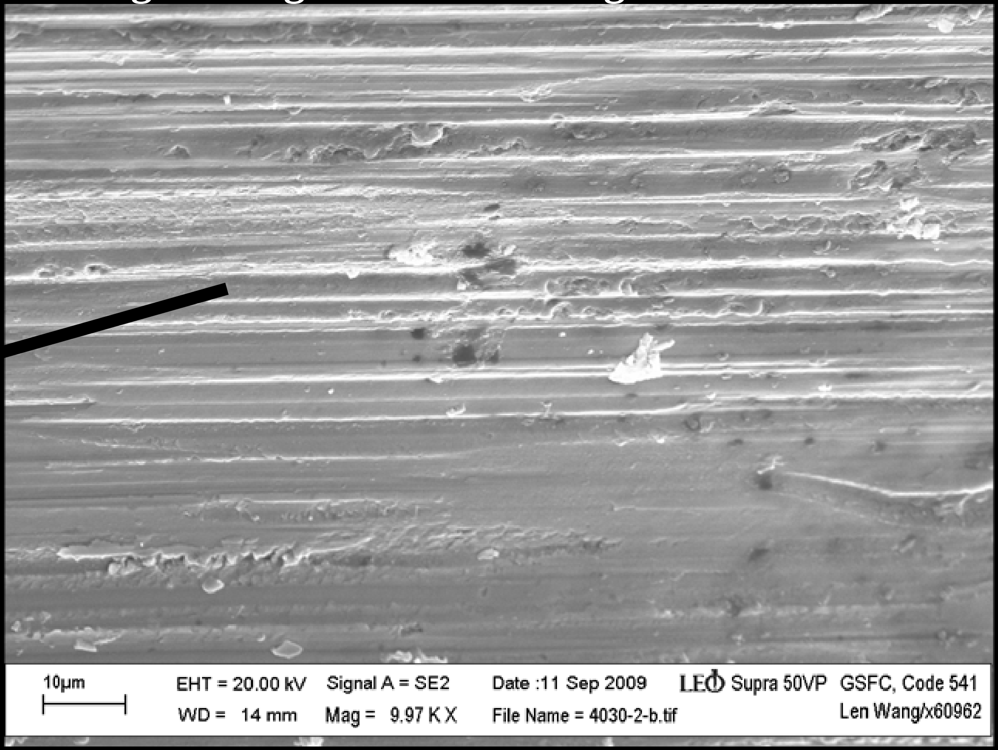


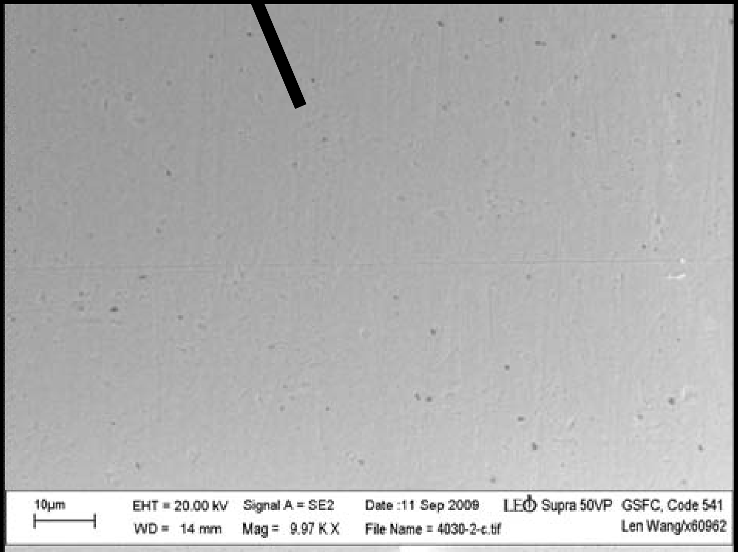
Surface Images of Pin

Side view of ceramic pin near crack region



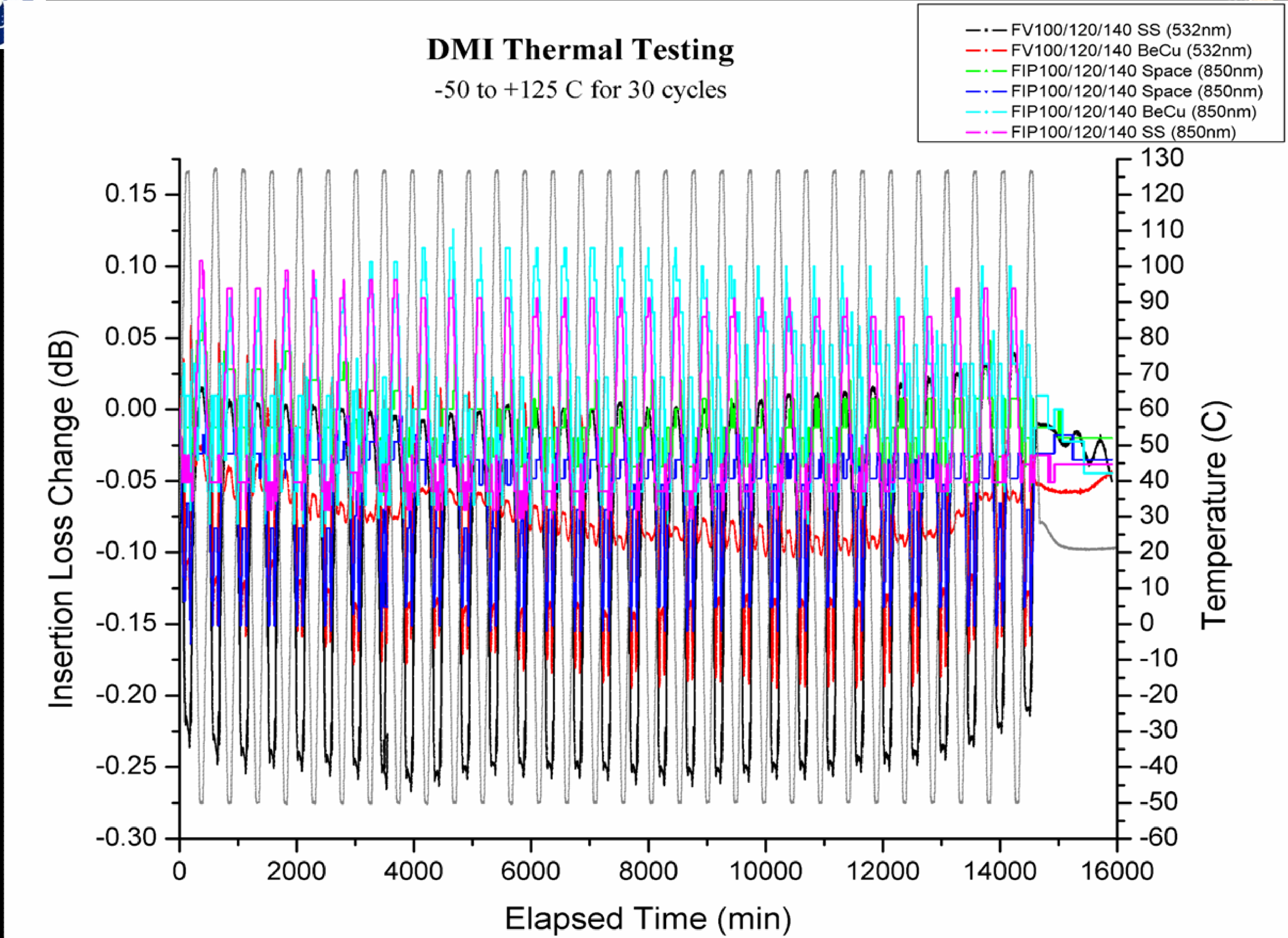
Side view of ceramic pin near crack region
Higher magnification of rough area





Side view of ceramic pin away from tapered region

Thermal Validation Testing of the Diamond DMI Connectors



Ruggedized and Space Version

Vibration Validation Testing

Four Tests Conducted with insitu monitoring: 10 grms, 14 grms, 20 grms, 35 grms
Random Vibration conducted for 3 mins per axis, for each of x, y, z axis configuration

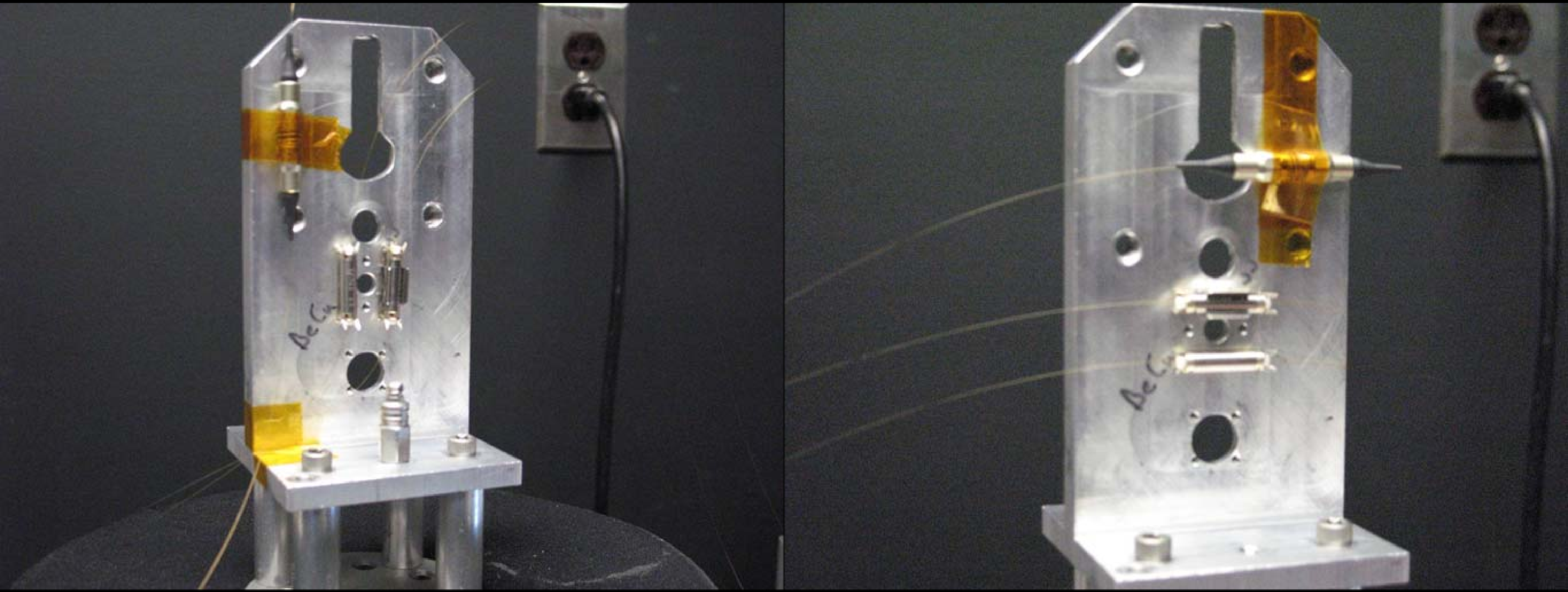
Frequency (Hz)	Level
20	0.013 g^2/Hz
20-50	+6 dB/octave
50-800	0.08 g^2/Hz
800-2000	-6 dB/octave
2000	0.013 g^2/Hz
Overall	9.8 grms

Frequency (Hz)	Level
20	0.026 g^2/Hz
20-50	+6 dB/octave
50-800	0.16 g^2/Hz
800-2000	-6 dB/octave
2000	0.026 g^2/Hz
Overall	14.1 grms

Frequency (Hz)	Level
20	0.052 g^2/Hz
20-50	+6 dB/octave
50-800	0.32 g^2/Hz
800-2000	-6 dB/octave
2000	0.052 g^2/Hz
Overall	20.0 grms

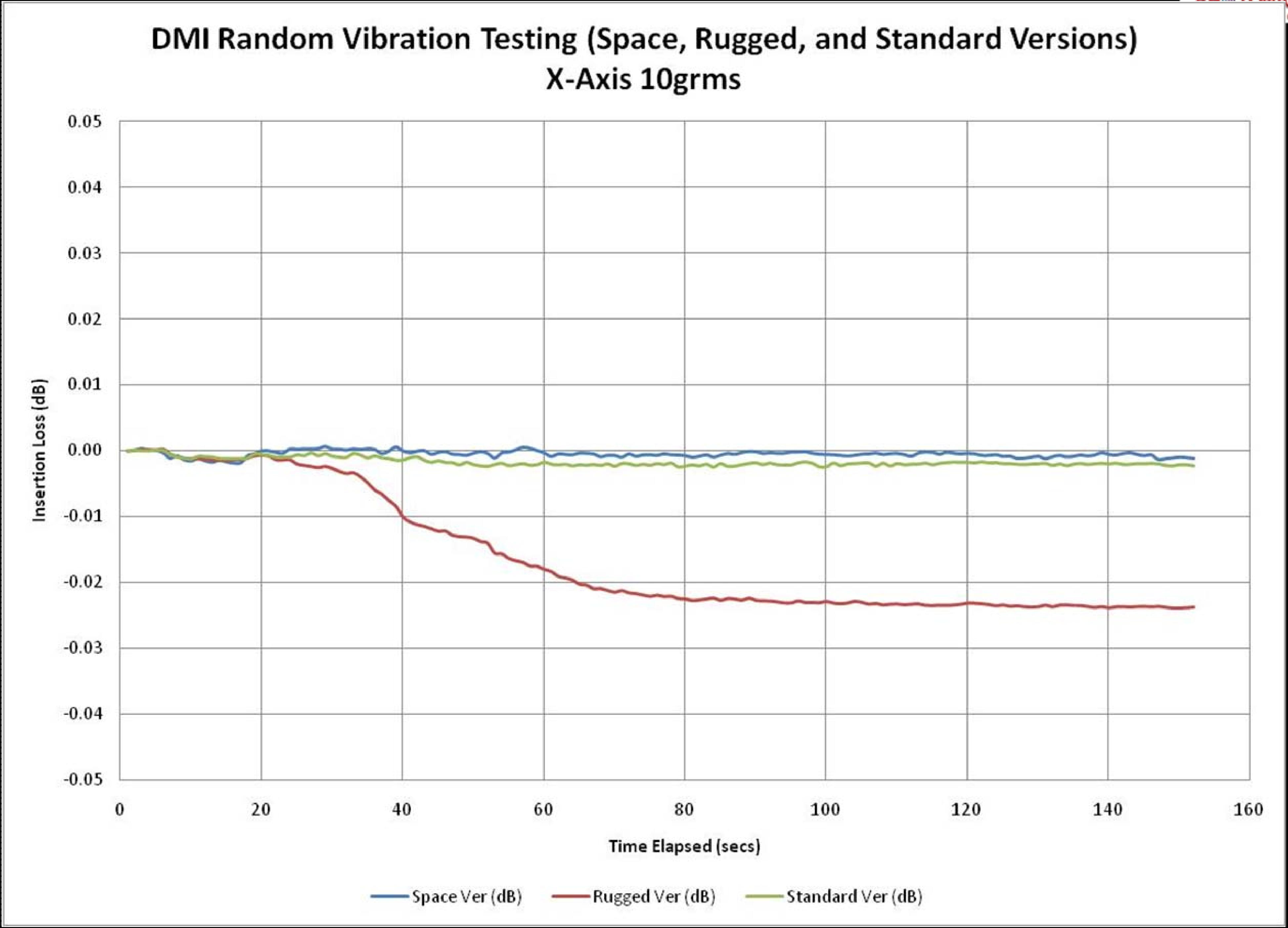
Frequency (Hz)	Level
20	0.156 g^2/Hz
20-50	+6 dB/octave
50-800	0.96 g^2/Hz
800-2000	-6 dB/octave
2000	0.156 g^2/Hz
Overall	34.63 grms

Vibration Validation Testing



X & Y configurations for the DMI connectors during Random vibration

Vibration Validation Testing Results for the DMI (Mini AVIM System) for 10 grms

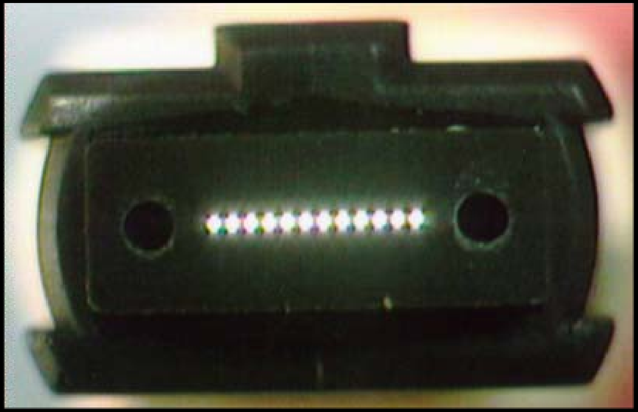


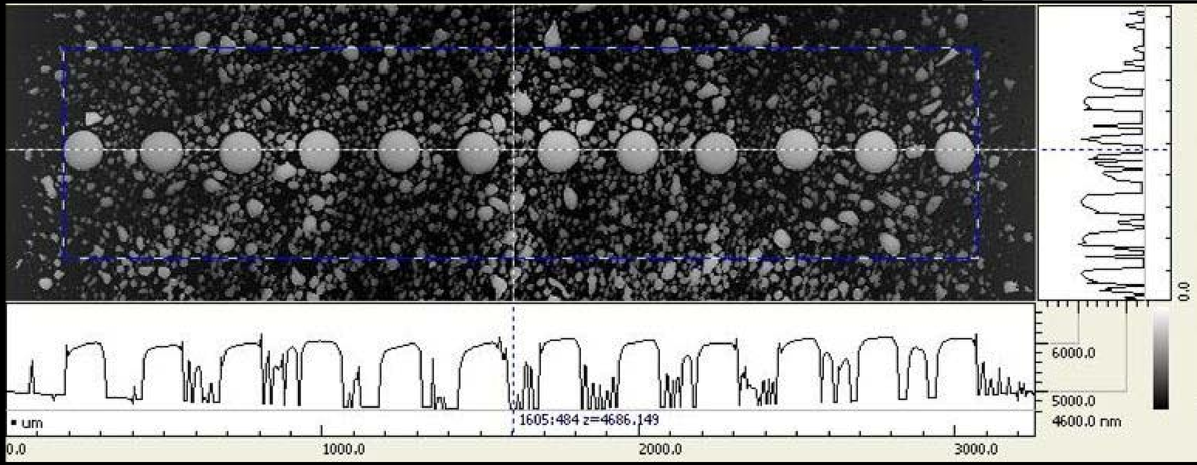
Diamond DMI Small Form Factor Conclusions

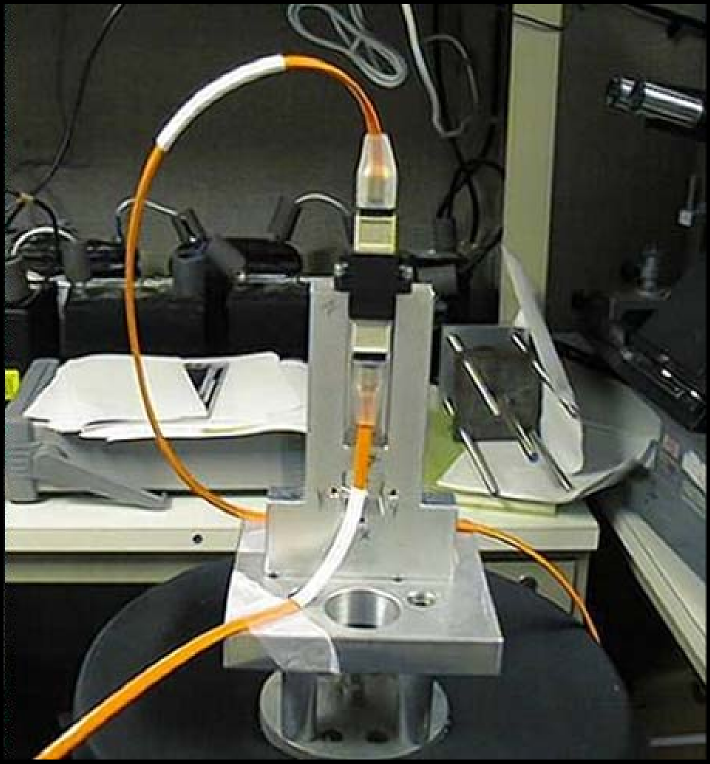
Thermal Cycling resulted in less than 0.25 dB max change in Insertion Loss for all types during cycling – nominal as compared to the AVIM.

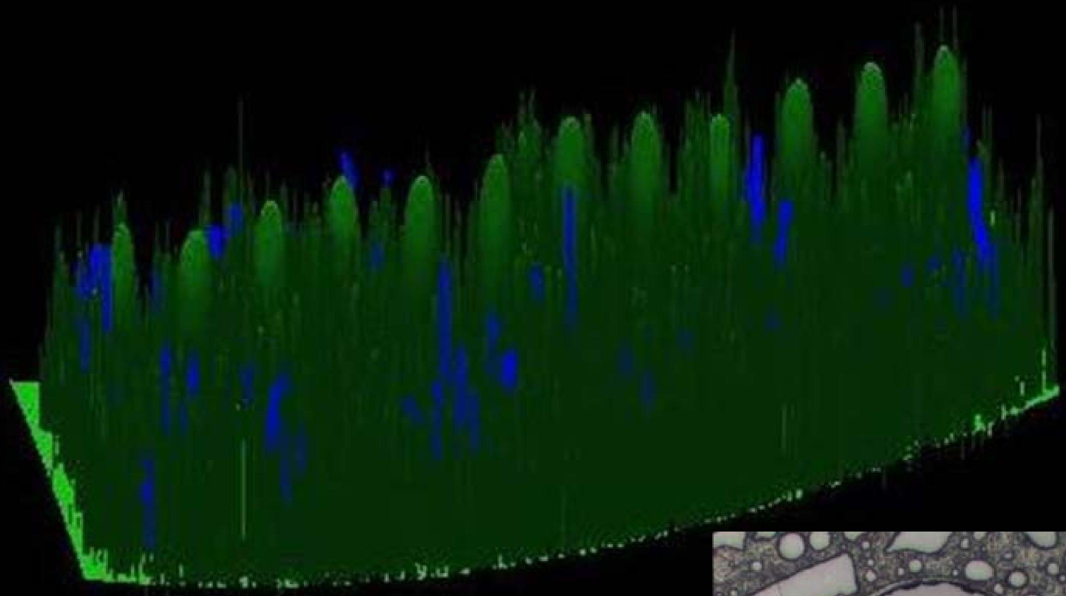
Vibration Testing results conclusion; no significant changes – nominal as compared to AVIM.

MTP Connector Used for Flight Transceivers (Multimode Comm)









Conclusion

ISS SSP 50184 HRDL optical fiber communication subsystem, has system level requirements that were changed to accommodate large loss optical fiber links previously installed.

SSQ22680 design is difficult to implement, no metal shell over socket/pin combination to protect weak part of pin.

Additions to ISS are planned for future.

AVIM still used for interconnection in space flight applications without incident.

Stay tuned for more data available on the small form factor DMI or Mini AVIM.

Thank you very much for the invitation!

For more information please visit the URL

http://photonics.gsfc.nasa.gov

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