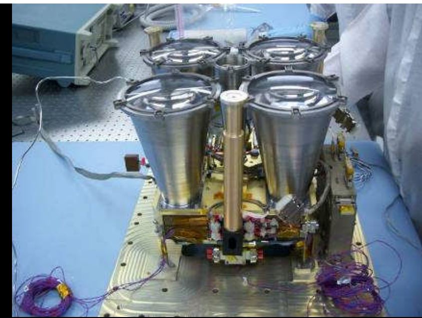
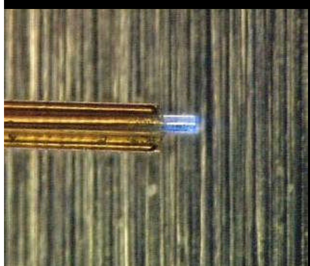
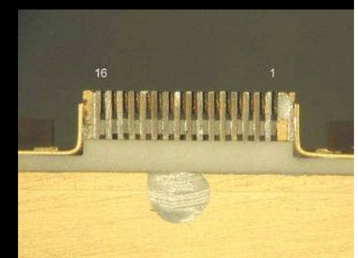


Optical Fiber Assemblies for Space Flight from the NASA Goddard Space Flight Center, Photonics Group

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





Melanie N. Ott
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Applied Engineering & Technology Directorate,
Electrical Engineering Division,
301-286-0127, melanie.n.ott@nasa.gov
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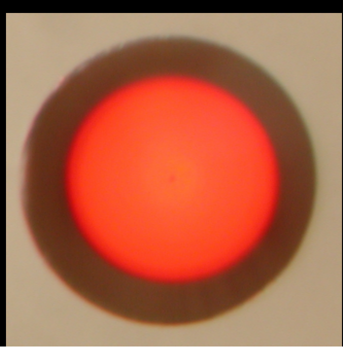
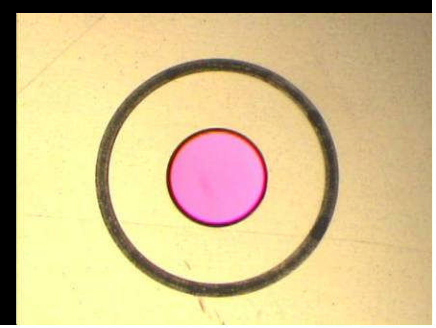




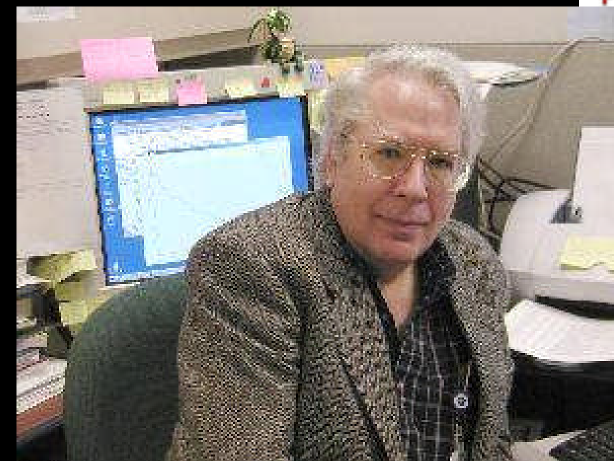
Outline

- Introductions
- Update on the Lunar Reconnaissance Orbiter.
- Mars Science Lab Assemblies.
- Express Logistics Carrier for International Space Station.
- James Webb Space Telescope Cryo Assemblies.
- NEPP Radiation Database 2008.
- NEPP General Studies
  - Diamond small form factor environmental testing results.
- Conclusions.

Mentorship Mapping

Arnold Sommerfeld
Russia, 1868 - 1951
German Physicst
Quantum Theory

Karl F. Herzfeld
Vienna, 1892 – 1978
John's Hopkins University Professor, 1926
Catholic University Professor, 1936



Henning Leidecker, USA,
Catholic University Professor, 1967
NASA Goddard Space Flight Center, 1985
NASA GSFC Chief Parts Engineer, Currently

Students/Nobel Laureates

1)Werner Karl Heisenberg, 1901-1976,
Quantum Mechanics
2) Wolfgang Ernst Pauli, 1900 – 1958,
Theoretical Physics, uncertainty principal
3) Peter Joseph William Debye, 1884 - 1966
Physics, Physical Chemistry
4) Hans Albrecht Bethe 1906 – 2005, Physics
5) Herbert Kroemer, 1928 -
6) Linus Carl Pauling, 1901 - 1994

Melanie N. Ott

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

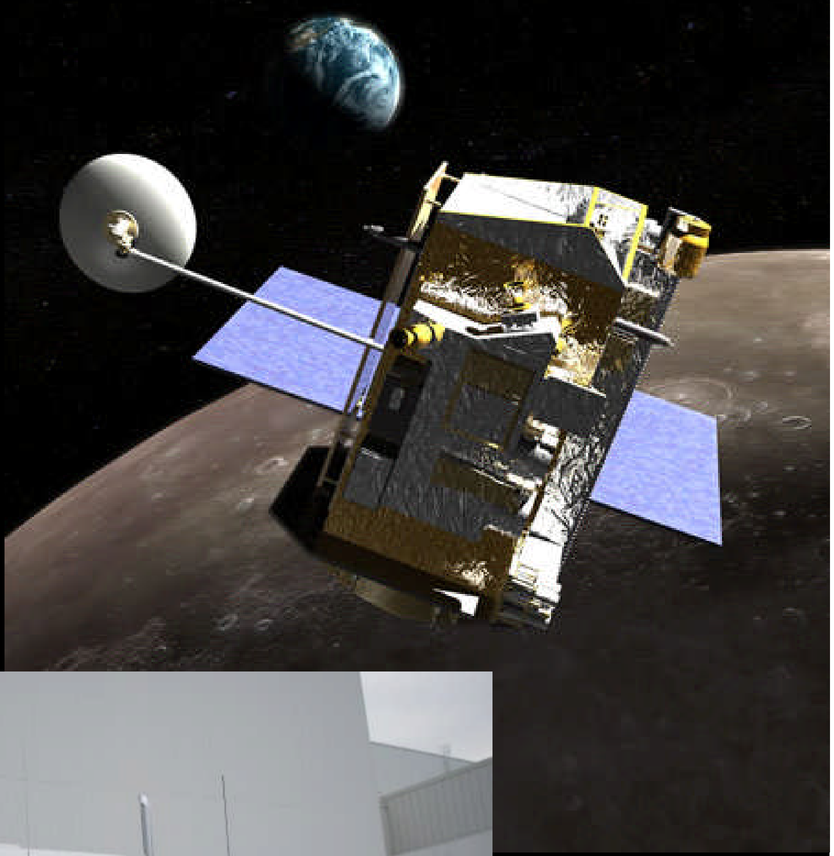
Project	Dates	Design	Qualification Performance over Harsh Environment	Manufacturing	Integration	Failure Analysis
ICESAT, GLAS,	1997 - 2005	X	X	GSE		Prototype
ISS	1998 - 2008					Vendor/ Flight
ISS - HDTV	2003	X	X	FLIGHT		
Fiber Optic Data Bus	1997 -2000	X	X			
Messenger – MLA,	2001 - 2004	X	X	FLIGHT	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	
ESA/NASA SpaceFibre	2008 (TBD)		X	QUAL		

Publications from work noted above can be found @ **photonics.gsfc.nasa.gov**

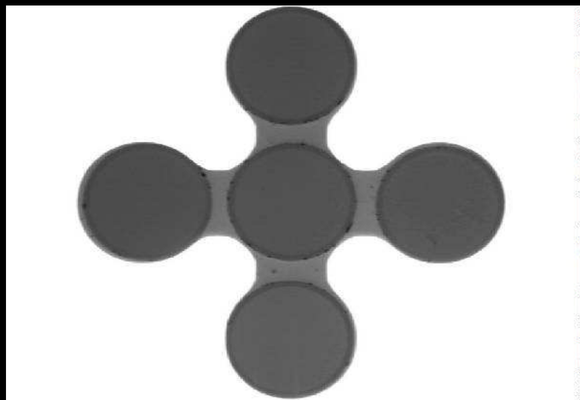
Lunar Reconnaissance Orbiter follow up – post integration

Applications:
1) Lunar Orbiter Laser Altimeter (LOLA) @1064 nm
2) Laser Ranging (from Earth) to LOLA detector for precise distance from earth measurement

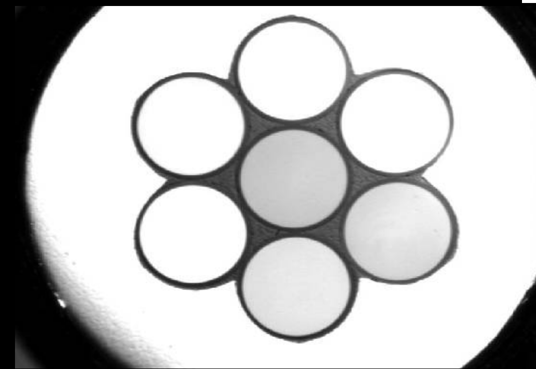
Update on Lunar Reconnaissance Orbiter Laser Ranging Investigation and the Lunar Orbiter Laser Altimeter (LOLA)



The Solution; NASA GSFC Fiber Optic Array Assemblies for the Lunar Reconnaissance Orbiter



Array Side End Face Picture at
200X magnification

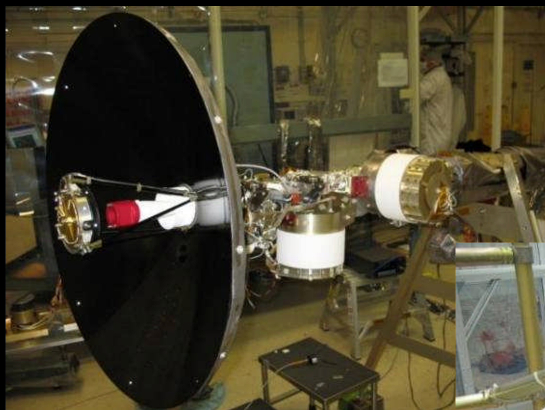


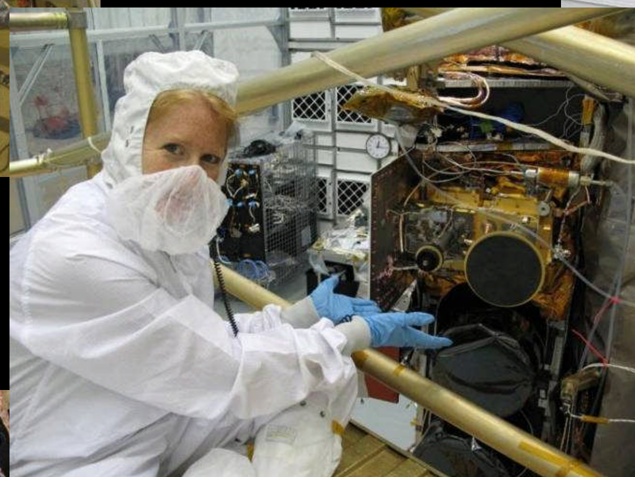
End Face Picture of both assembly ends at
200X magnification

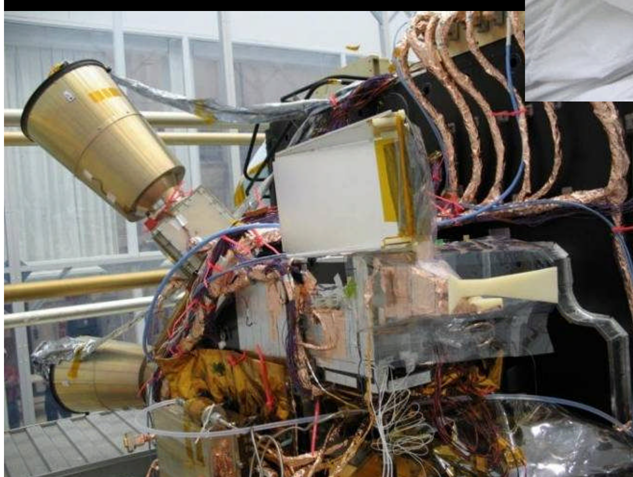
Lunar Orbiter Laser Altimeter (LOLA) Assemblies
Description: 5 Fiber Array in AVIM PM on Side A,
Fan out to 5 individual AVIM connectors Side B
Wavelength: 1064 nm Polymicro FIA200220
1 Assembly for Receiver Telescope ~ 0.5 m long

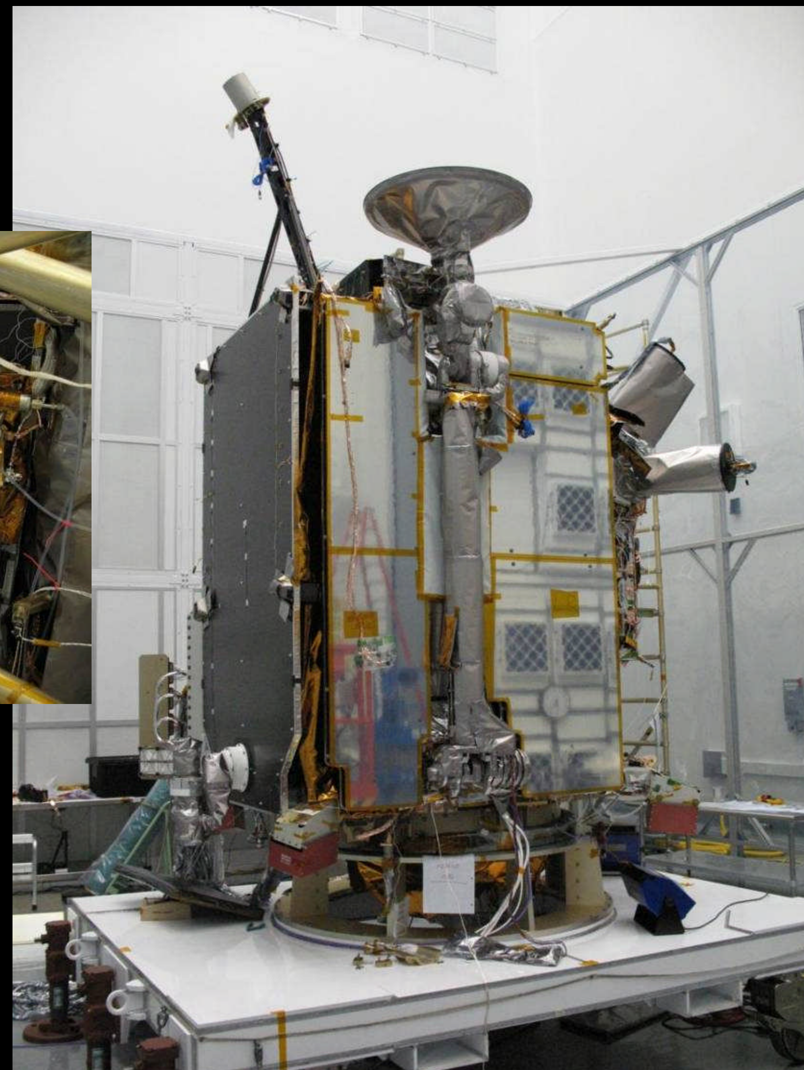
Laser Ranging (LR) for LRO Assemblies
Description: 7 Fiber Array on both Sides in AVIM PM Connector
Wavelength: 532 nm, Polymicro FIA400440
3 Assemblies for Receiver Telescope ~ 10 meters long

Additional Pictures of LRO, June 2008
Integration Complete



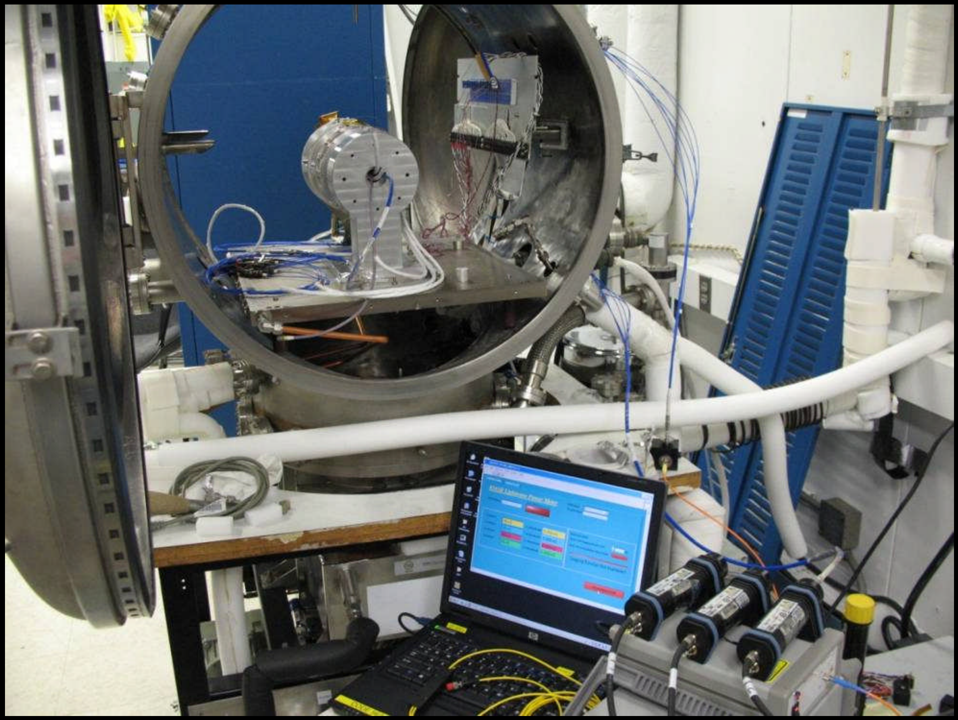


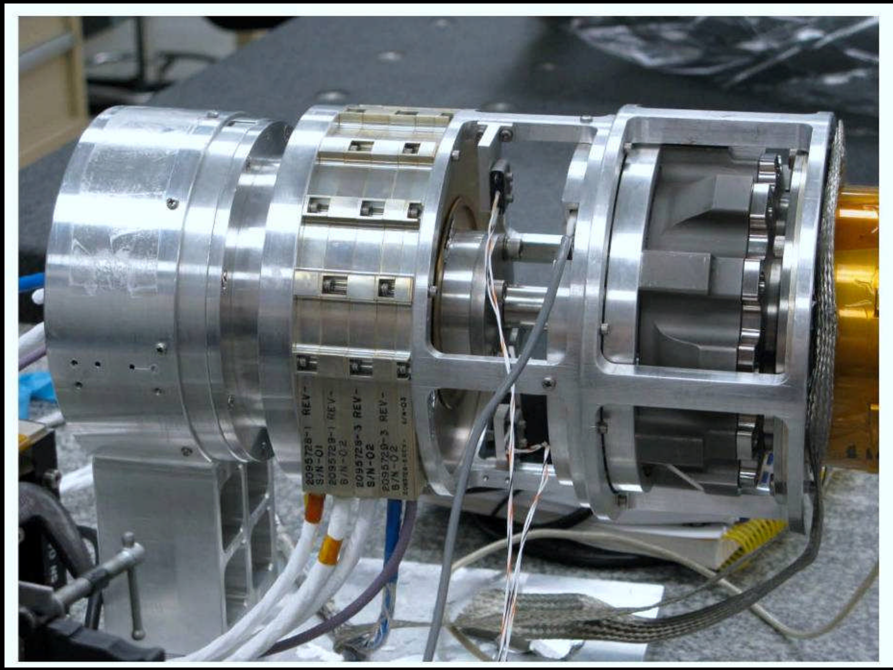




For more information SPIE Vol. 7095 or the website http://photonics.gsfc.nasa.gov

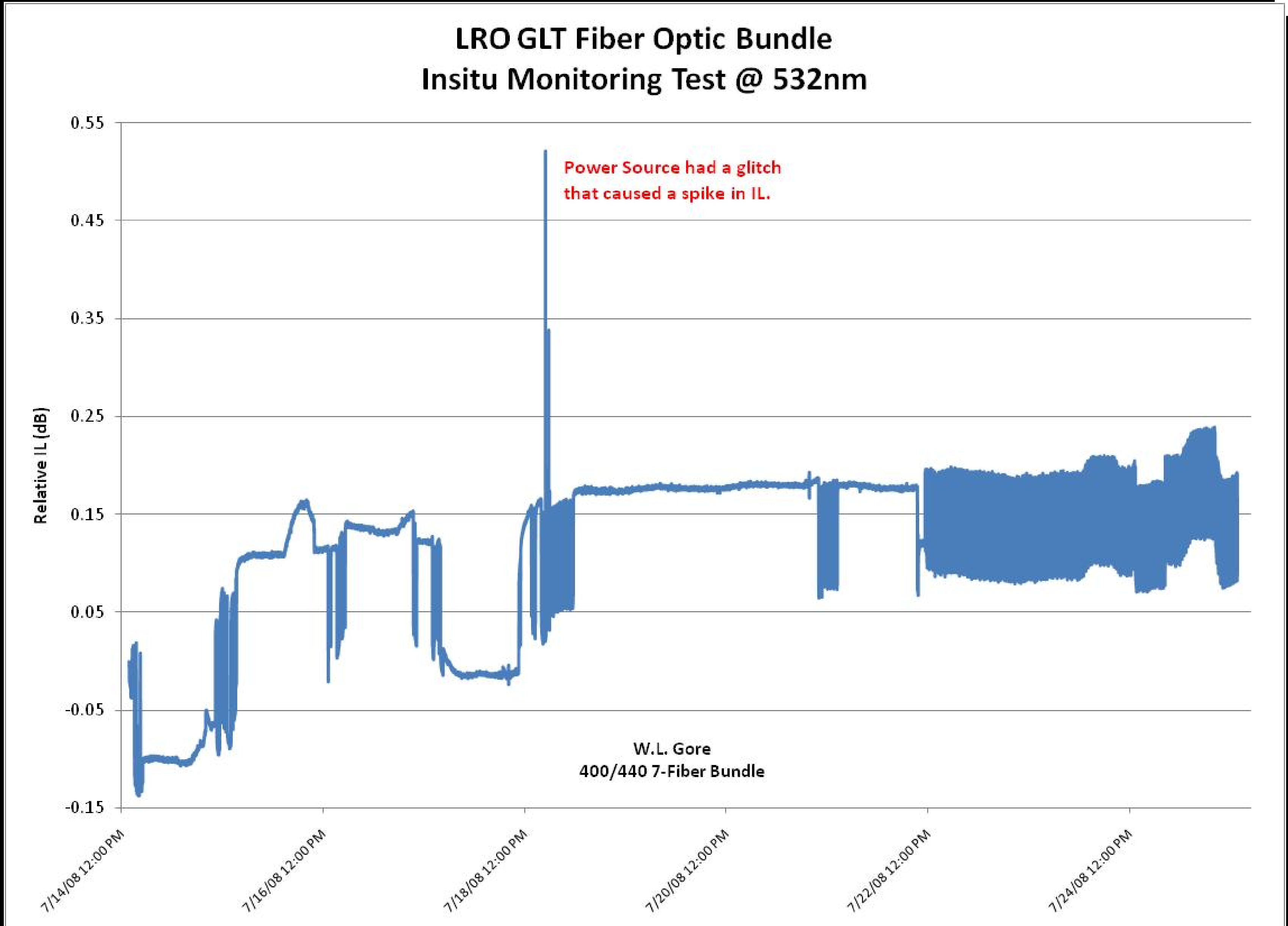
Follow up Testing for Laser Ranging on LRO: Gimbal Life Test with 7 Fiber Optical Cable



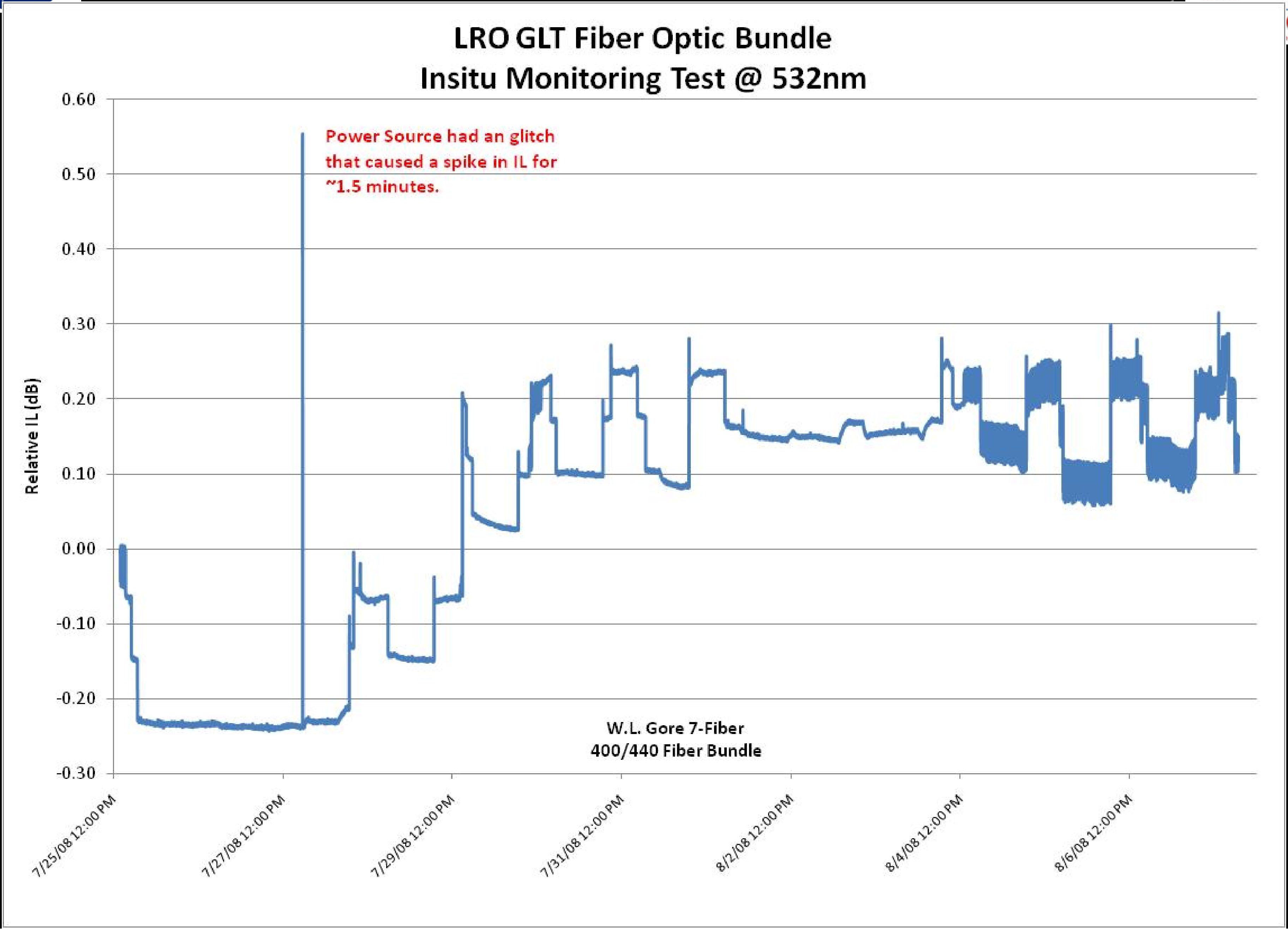


- 532 nm LED source, insitu monitoring w/ source power decoupled, for entire.
- Custom feedthrough and clocking reference assemblies to deliver and receive optical signals.
- 7 optical fiber bundle wrapped on single gimbal slice.
- Fiber bundle was staked with arathane at the entrance and exit of the gimbal slice.
- Total mechanical cycles was 14,000.
- Thermal range was 7°C to +37°C, with 2 hr transitions between temps; long soak times, for 2333 mechanical cycles.
- 78 hour dwell @ extremes in the order, ambient, hot, cold, hot, cold, hot using 2333 mechanical cycles each.
- 1 mechanical cycle = 2 min, total cycles 14000.
- Post testing the IL changed by 0.14 dB (3%).

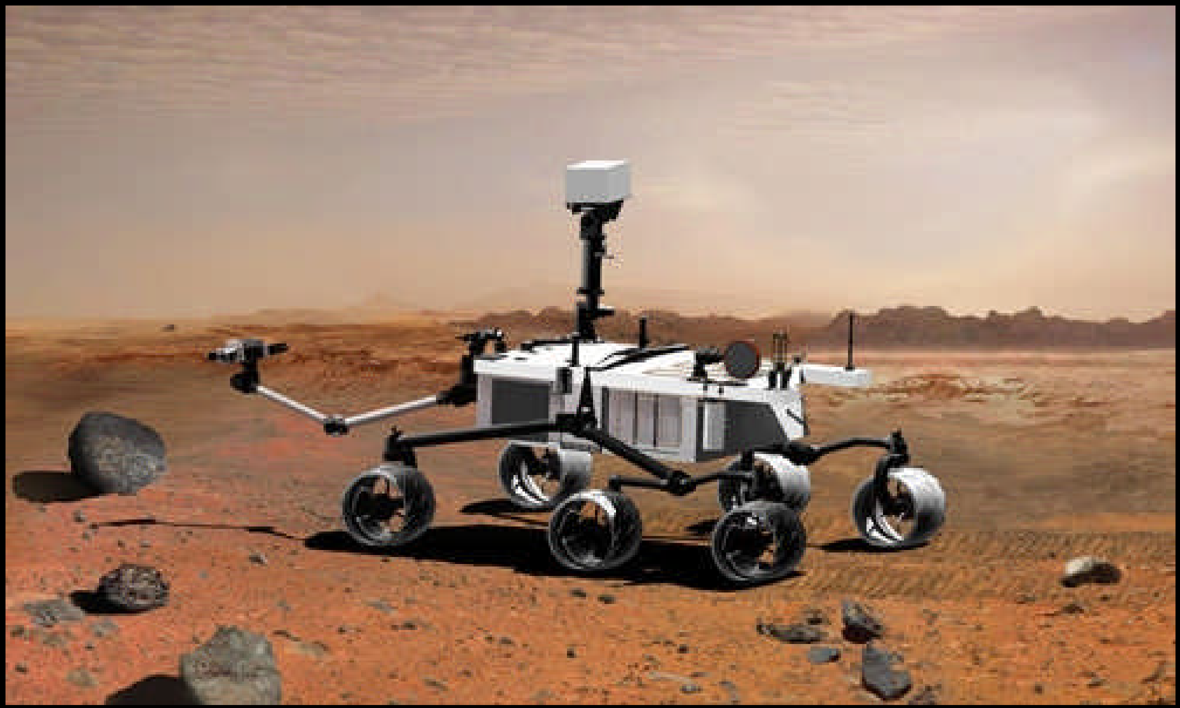
Final Results of Gimbal Life Test for Laser Ranging Application on LRO



Final Results of Gimbal Life Test for Laser Ranging Application on LRO Cont.



Mars Science Laboratory

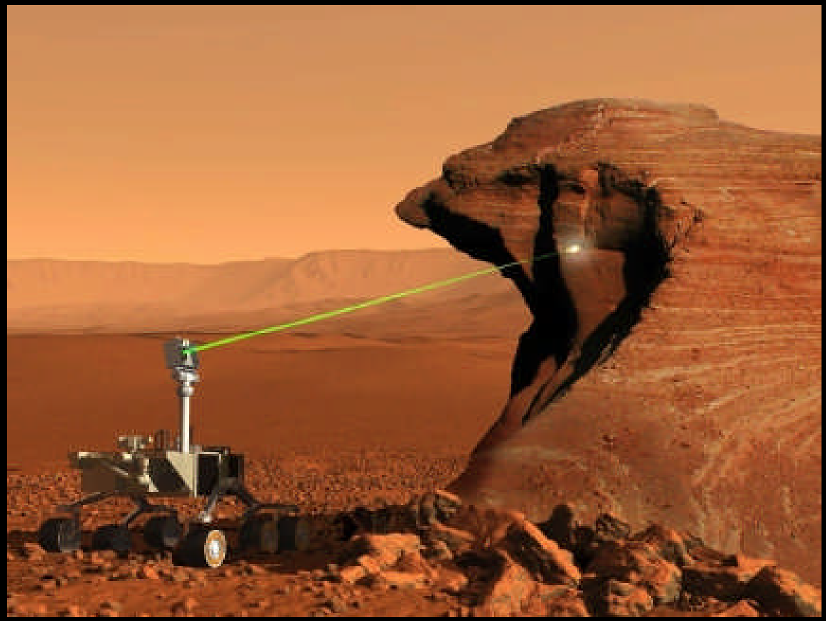


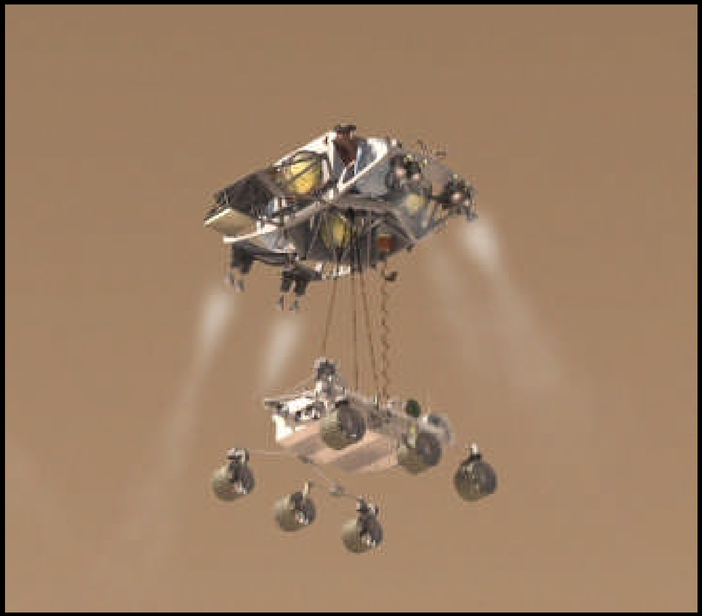
Chem Cam Application – Optical Fiber Assemblies

Mars Science Lab – ChemCam Optical Assemblies, Launch delayed.

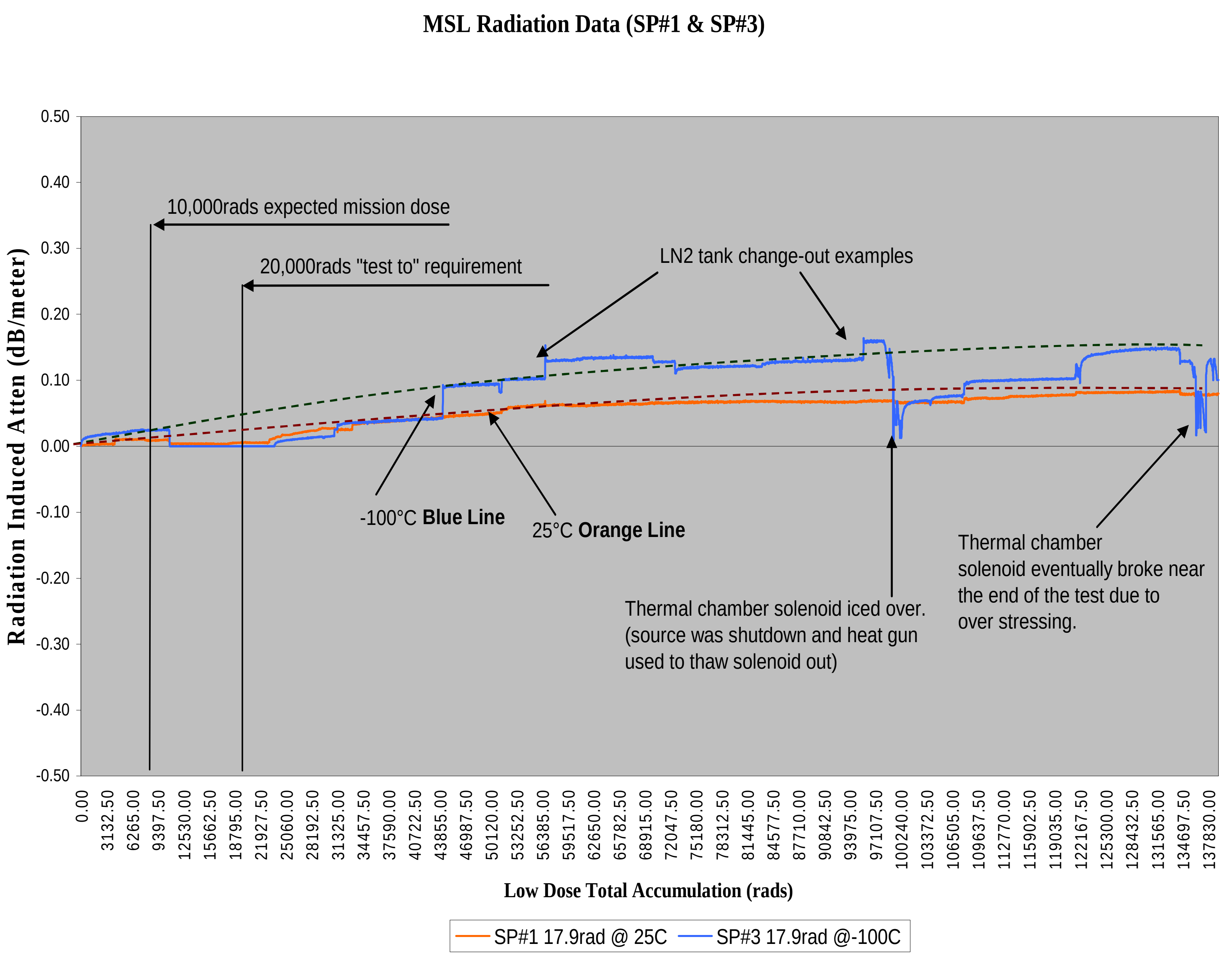
Similar application as LRO

- **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, high temp 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.**





MSL Nufern Radiation Test Results



Mars Science Lab Chem Cam Radiation Comparison
Nufern Optical Fiber 300/330 micron
Summary @ 330 – 450 nm

Total Dose	Dose Rate	Temp	Attenuation
10 Krad	17.9 rads/min	25°C	< 0.05dB/m
20 Krads	17.9 rads/min	25°C	< 0.05dB/m
10 Krad	17.9 rads/min	-100°C	< 0.05dB/m
20 Krads	17.9 rads/min	-100°C	~0.05dB/m

In general decreasing the dose rate 3 orders of magnitude decreases the attenuation by 1 order of magnitude.

Comparing Polymicro Technologies FV series to the Nufern 300/330 MSL
Nufern 300/330 ~ 0.005 dB/m for 20 Krads, -100°C, 300 – 450 nm
PolyMicro FVA300/330 ~ 0.003 dB/m at 20 Krads, -80°C, 532 nm

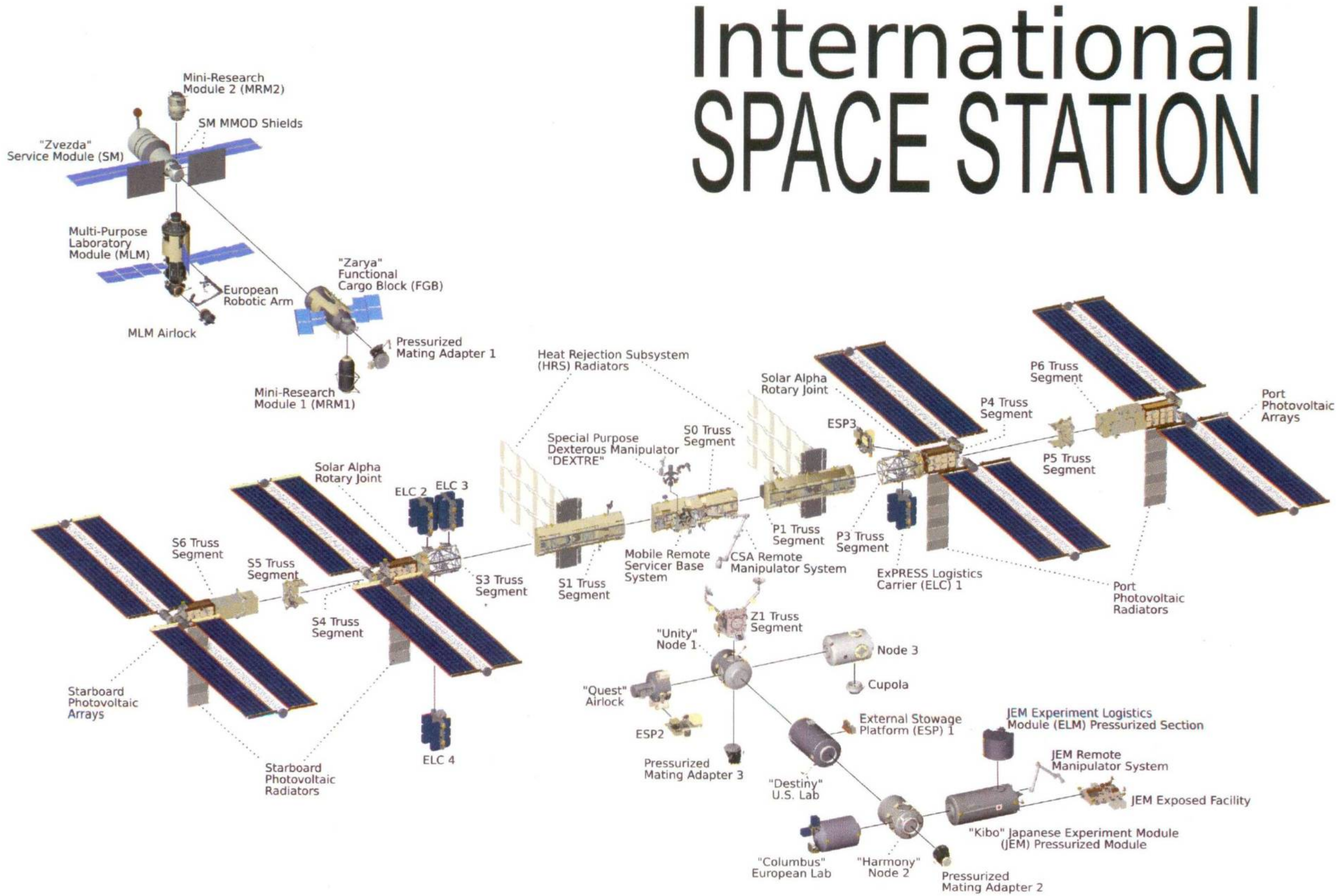
Performance of .12 Nufern Fiber approx. equal to .22 Polymicro Technologies Fiber under similar conditions

Mars Science Lab Delivery December 2008

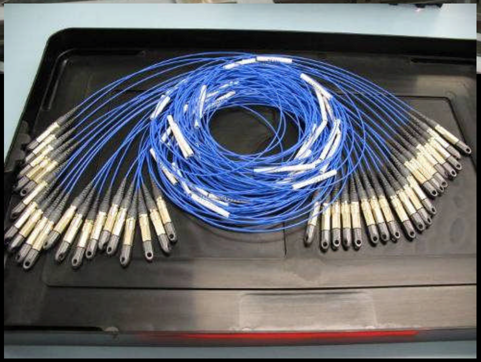
Assemblies were integrated into the flight subsystems at Jet Propulsion Laboratory during early 2009.

Decontamination bake out for all MSL hardware ~110°C

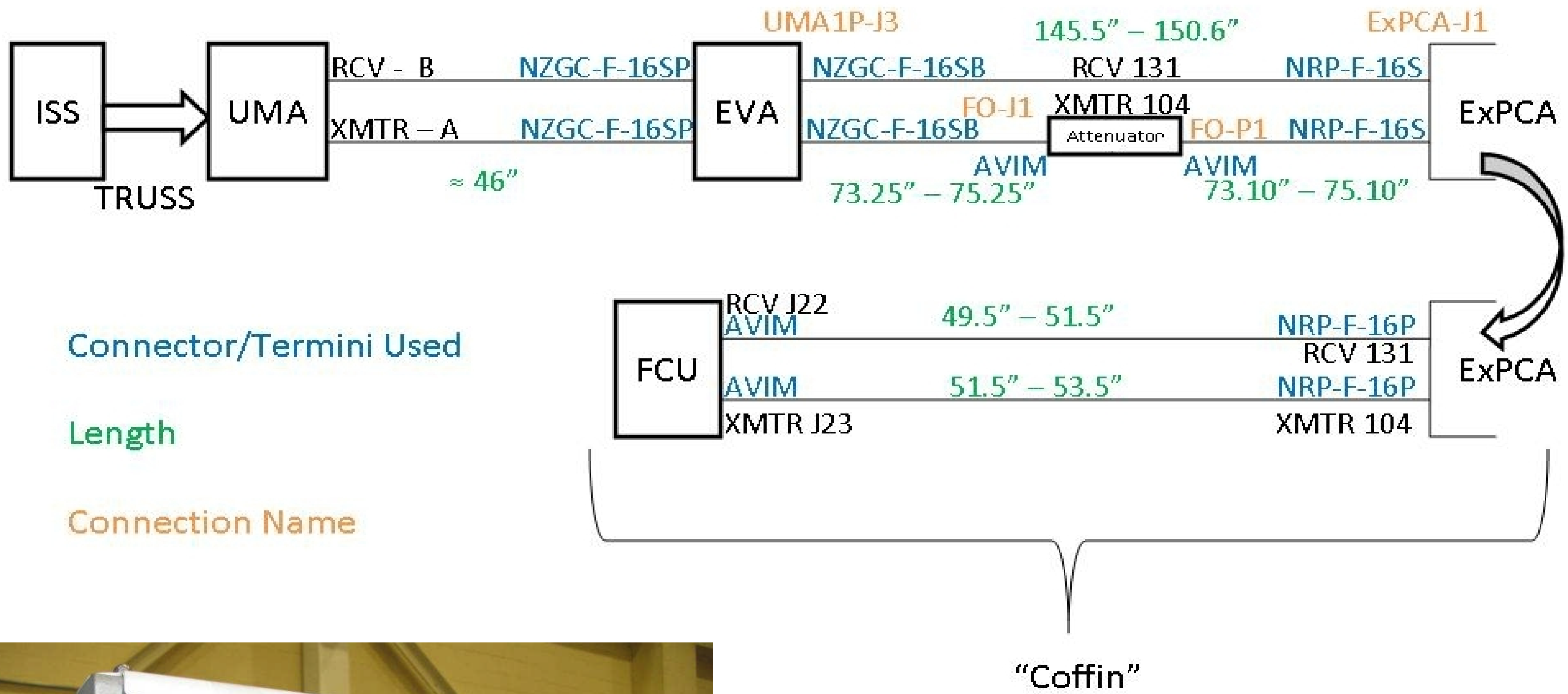
Express Logistics Carrier (ELC modules) "Smart Warehouse for Station"

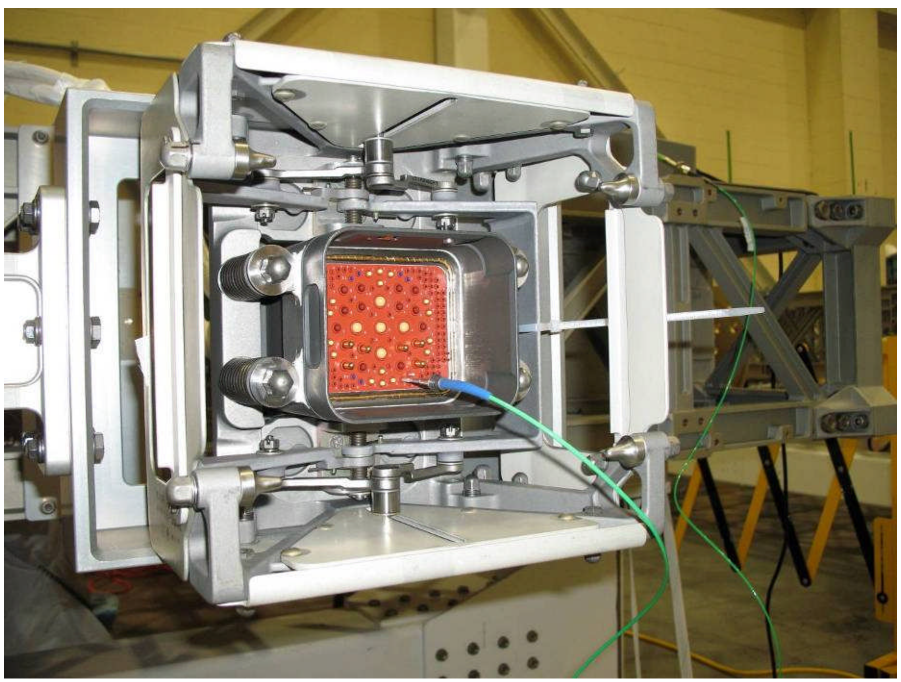


Express Logistics Carrier for ISS; Communications System Assemblies



Control Unit Transceiver Assemblies



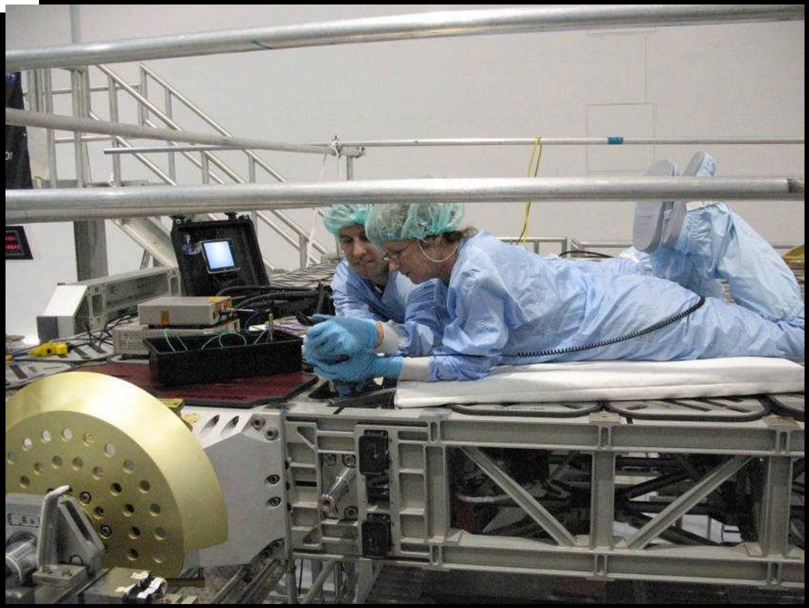


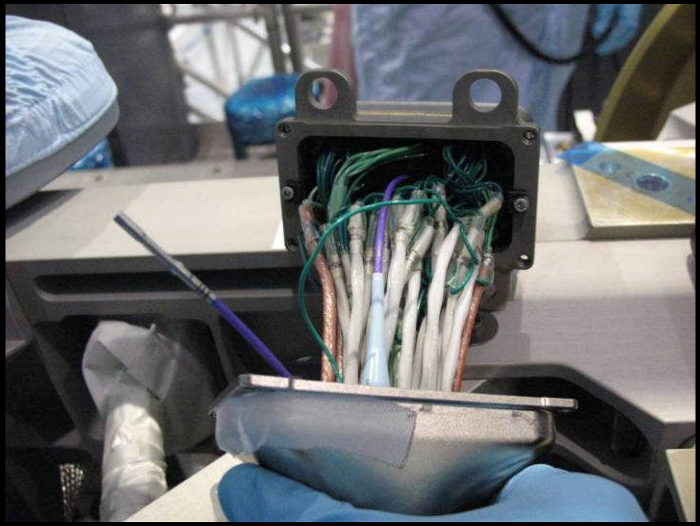
Harnessing Diagram for Express Logistics Carrier on ISS

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.

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

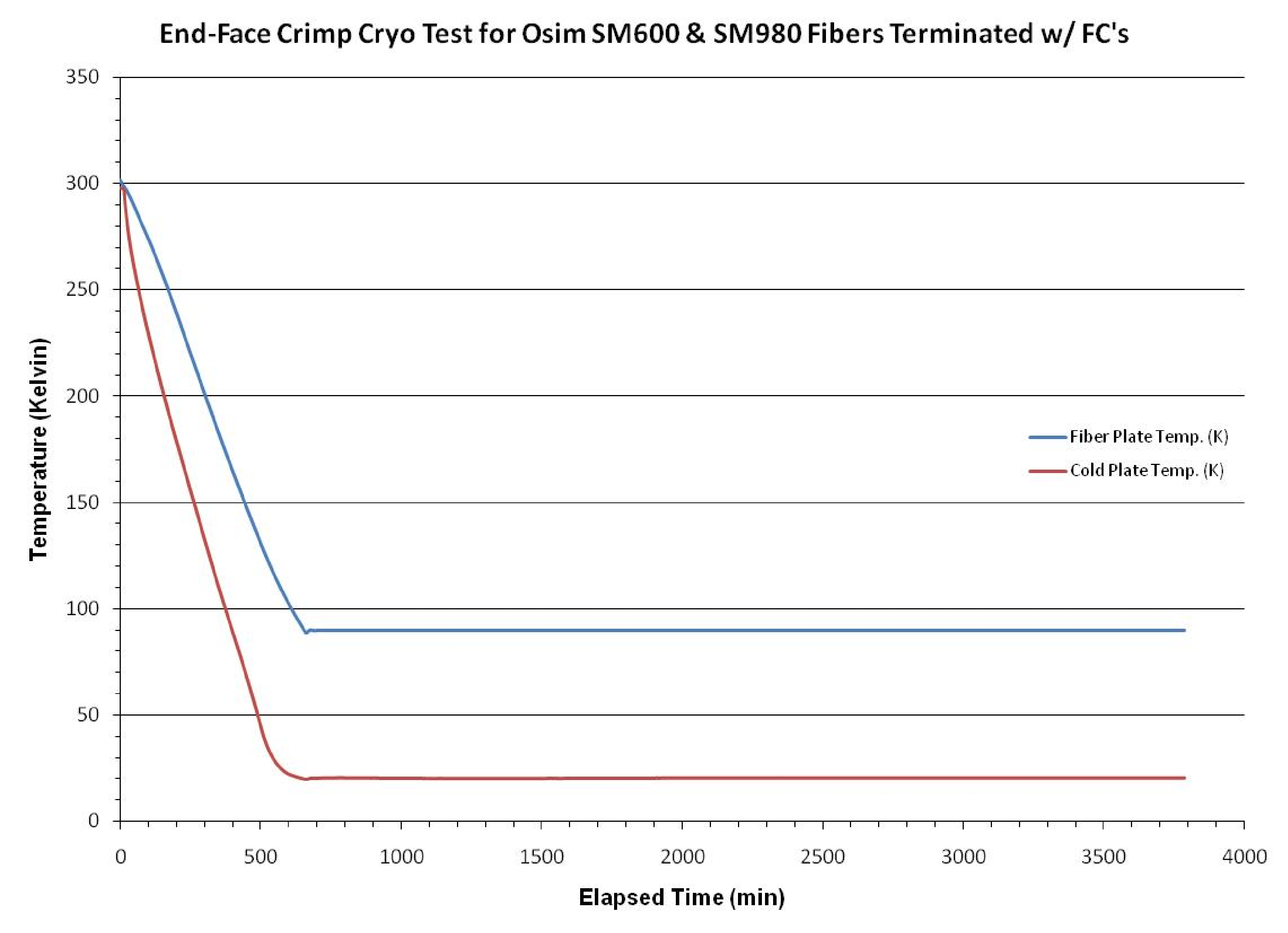
Cryogenic Validation Testing:
To less than 100 Kelvin
For OSIM integration the required Cryo assembies are:
Side A: Ceramic/Titanium ferrules, Side B: Diamond FC

Fiber Optic Terminations

Temperature Controlled Heat Plate

Chamber Cold Plate

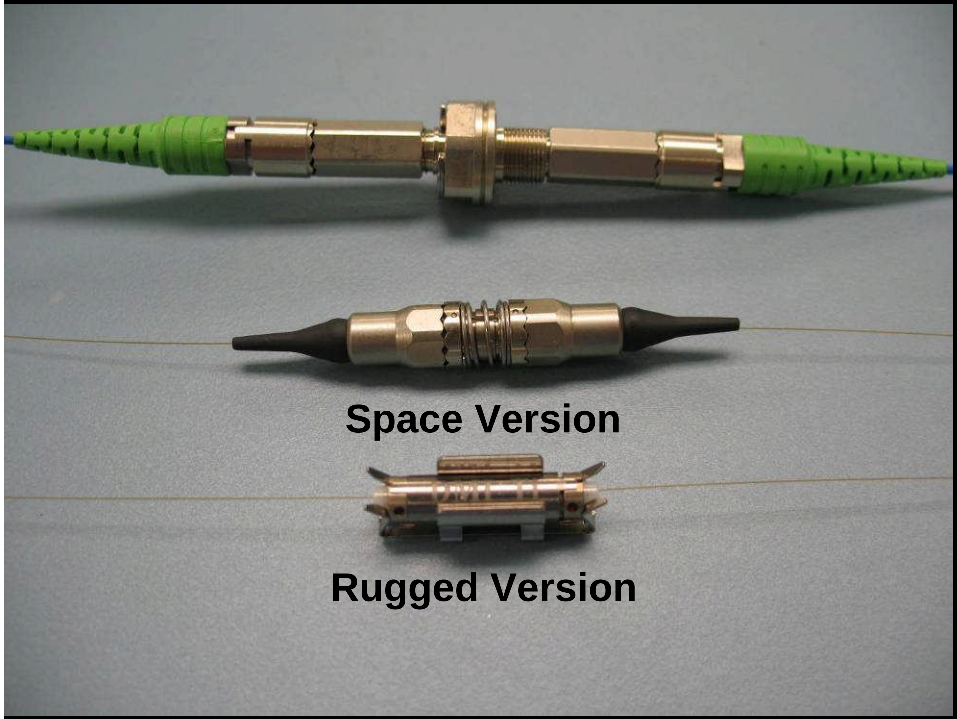
First Cryo Testing with Diamond FC's

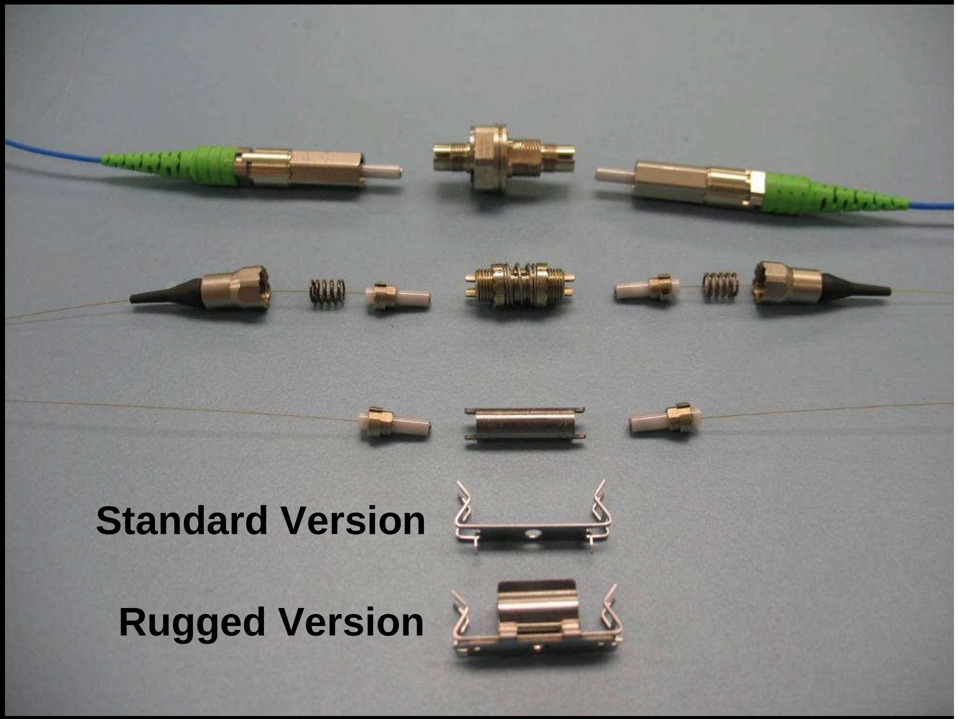


NASA Electronic Parts and Packaging Program
Component Evaluations for Small Form Factor Applications

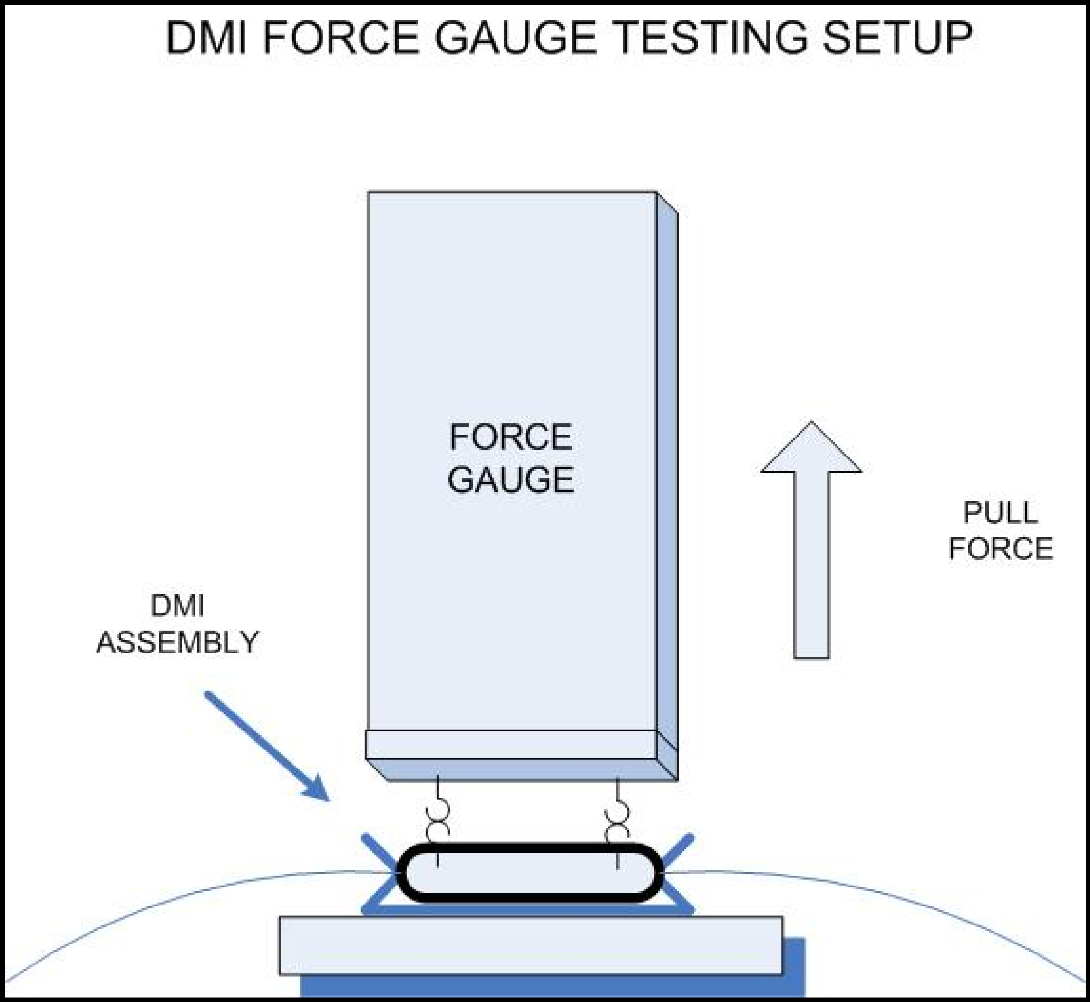
As a technology validation of the Diamond DMI (Mini AVIM) for space form factor applications the following tests were conducted:

Pull Force Data
Thermal Testing
Vibration Testing





Pull Test Data

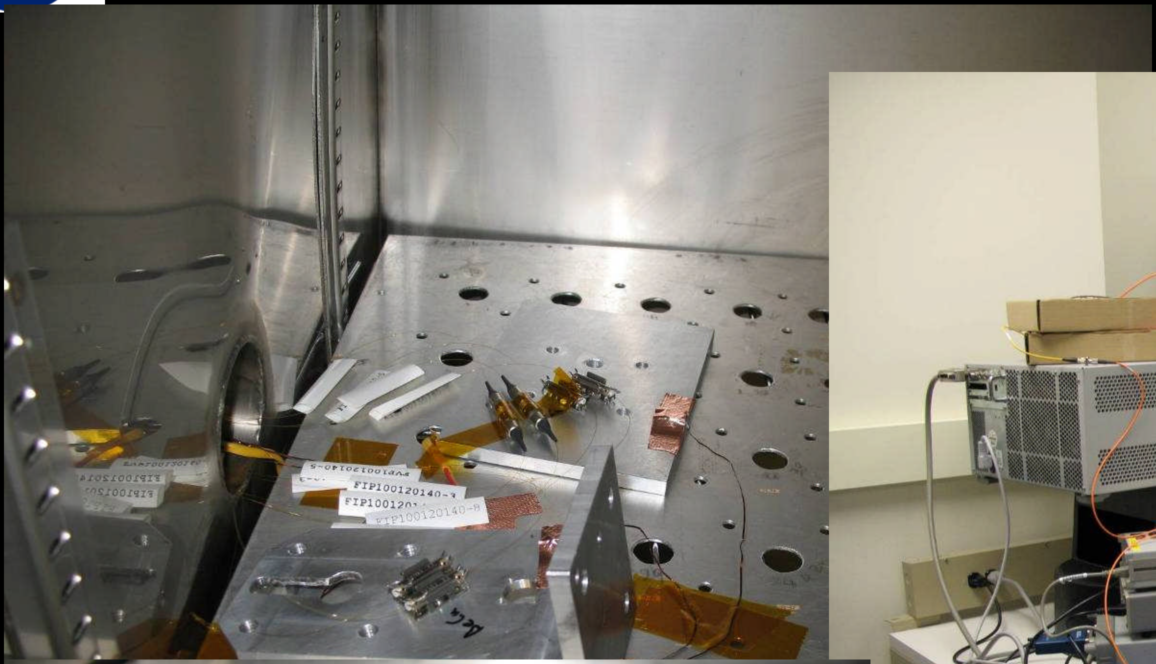


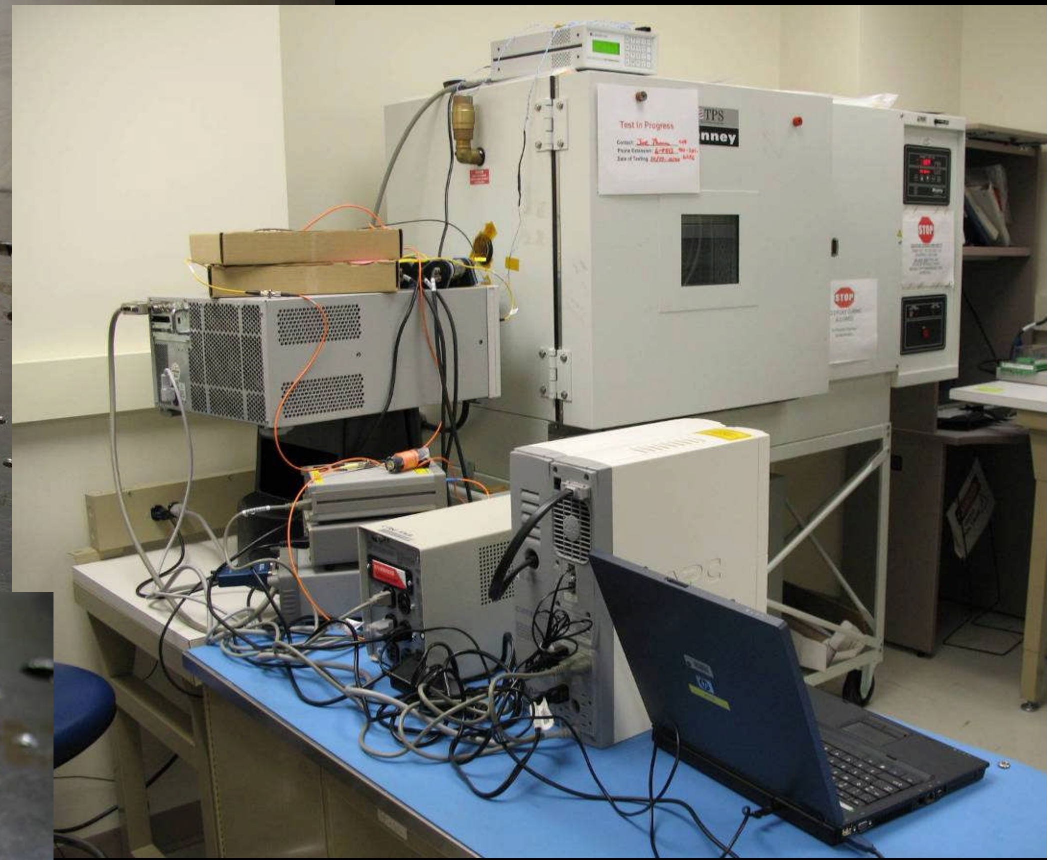
20 trials conducted on each type of spring clip for retention.
Monitored for when connector released from retention spring clip.

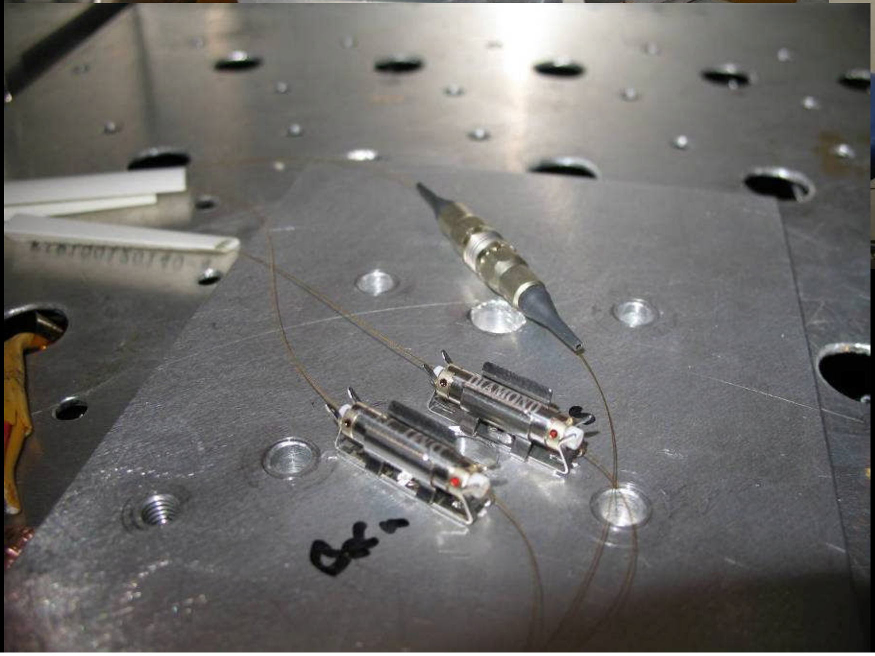
Average Stainless Steel Non Rugged= 6.6 N
Average BeCu Non Rugged = 16.6 N

Average Stainless Steel Rugged= 30.9 N
Average BeCu Rugged = 44.4 N

Thermal Validation Testing DMI (Mini AVIM)

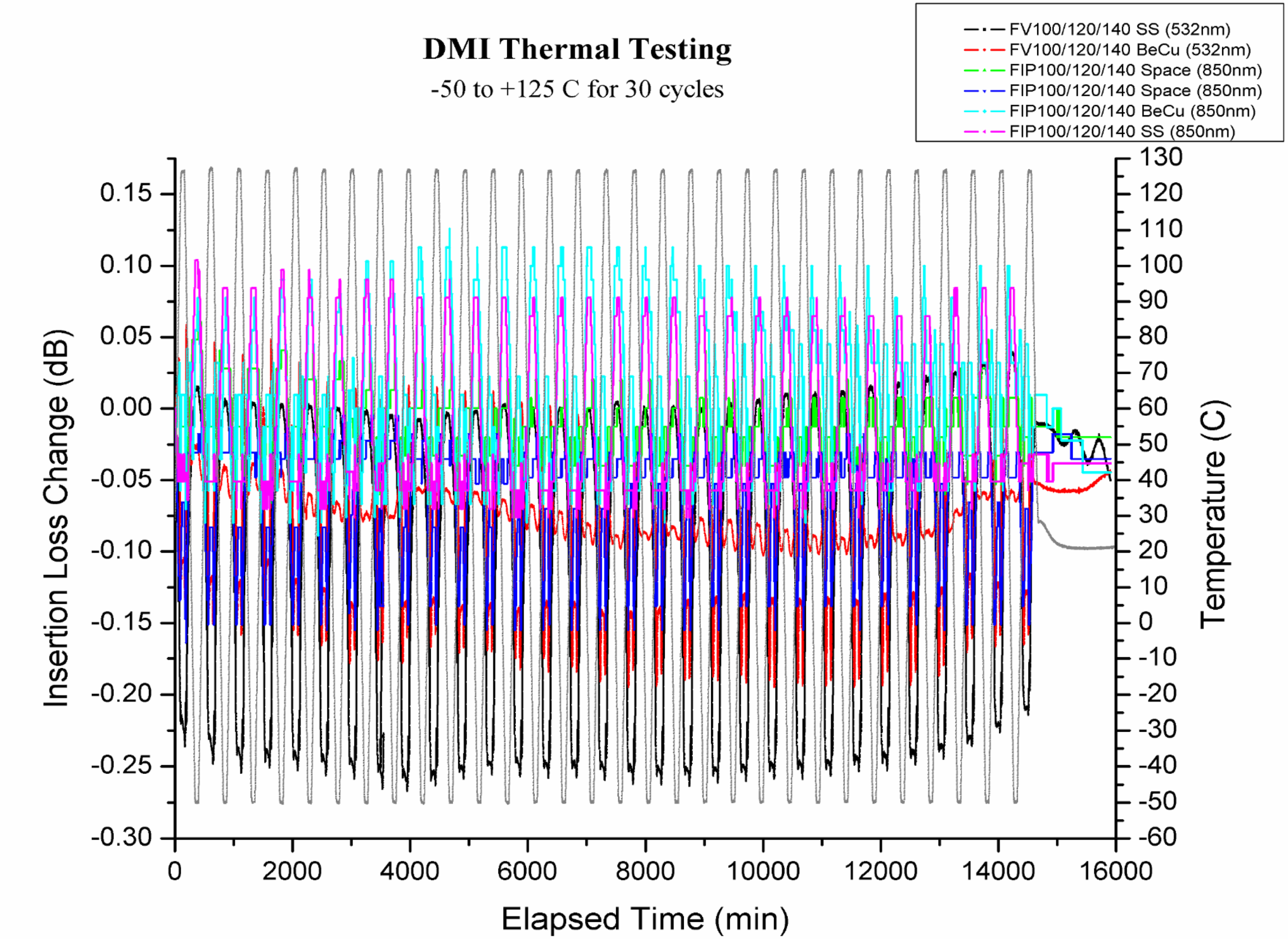






-50°C to +125°C Cycling with In-situ Monitoring for Insertion Loss Changes based on Termination/Connector. Total 30 Cycles

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

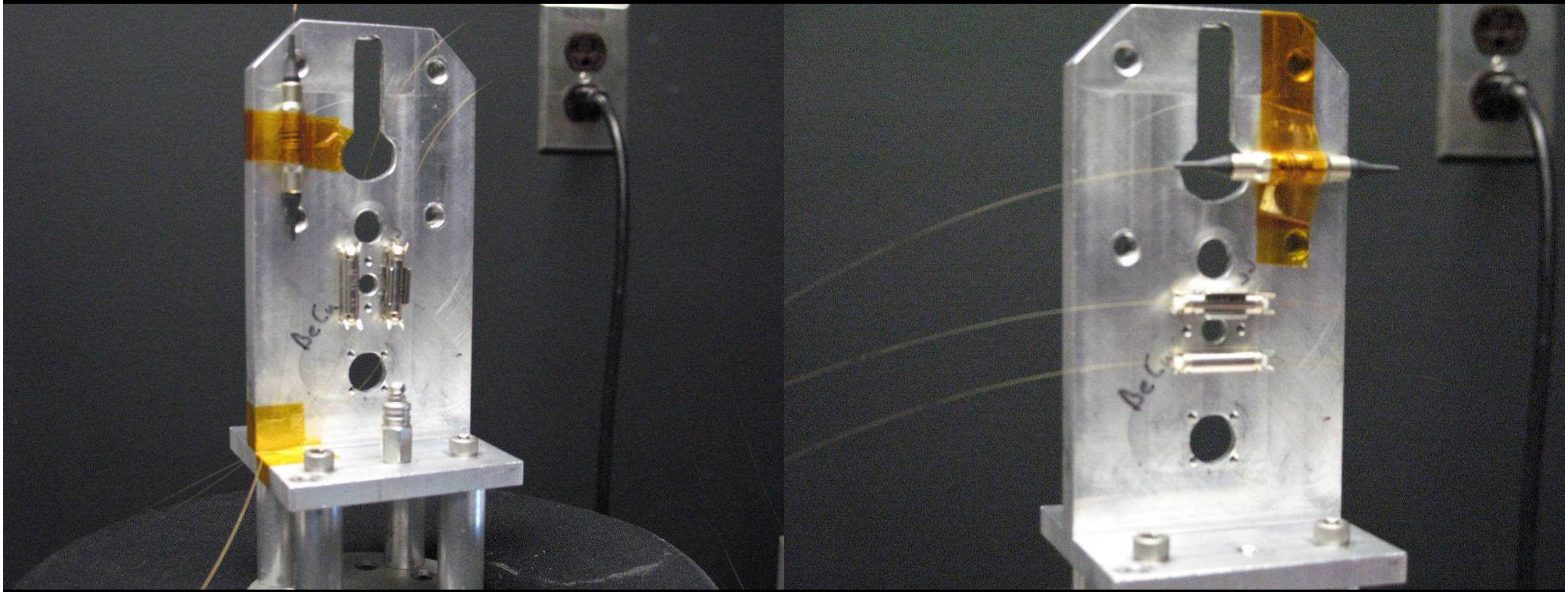
Frequency (Hz)	Level
20	0.013 g^2/Hz
20-50	+6 dB/octave
50-800	0.08 g^2/Hz
800-2000	-6 dB/octave
2000	0.013 g^2/Hz
Overall	9.8 grms

Frequency (Hz)	Level
20	0.052 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	0.026 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	0.156 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

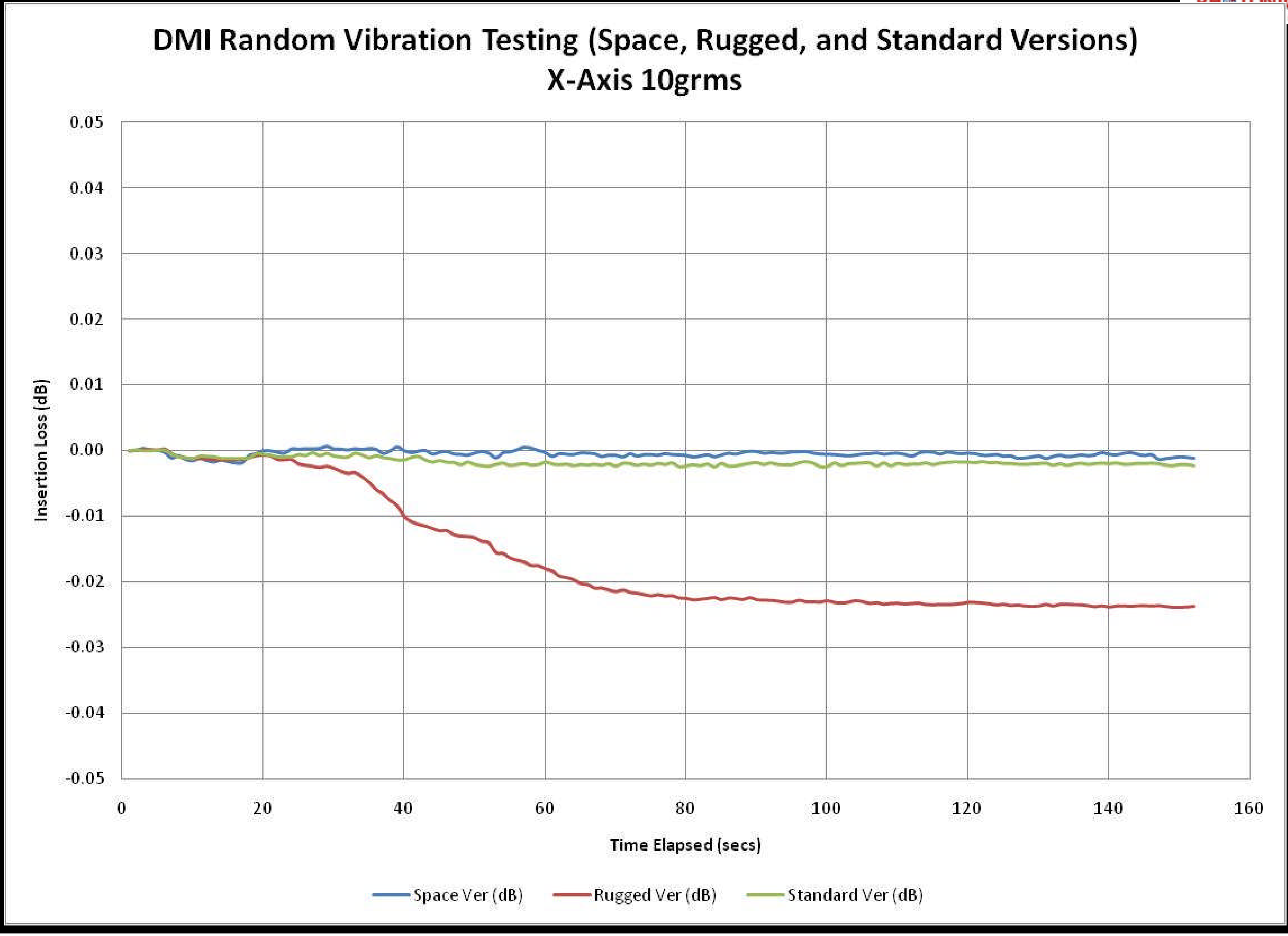
Vibration Validation Testing



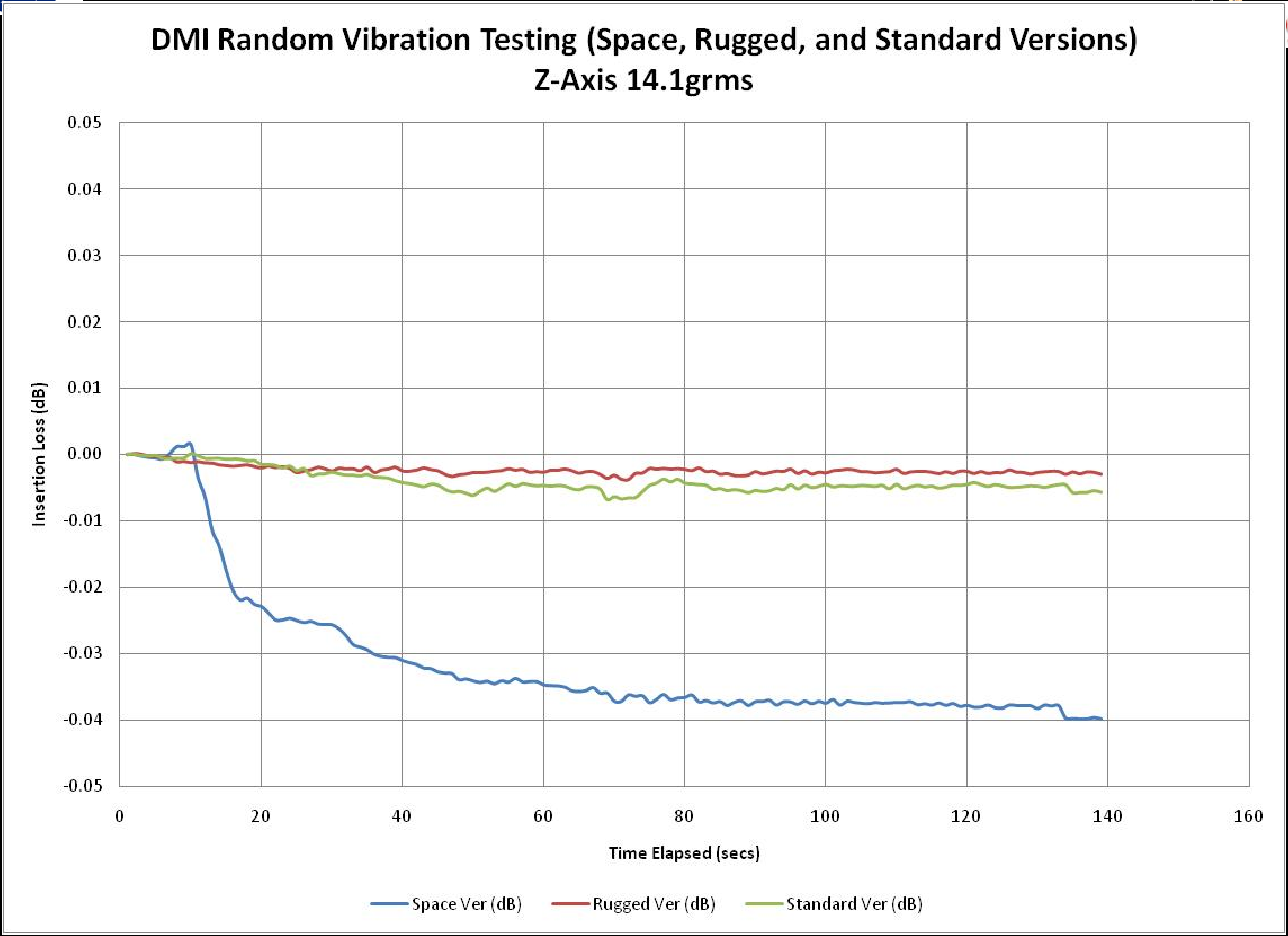
X & Y configurations for the DMI connectors during Random vibration

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

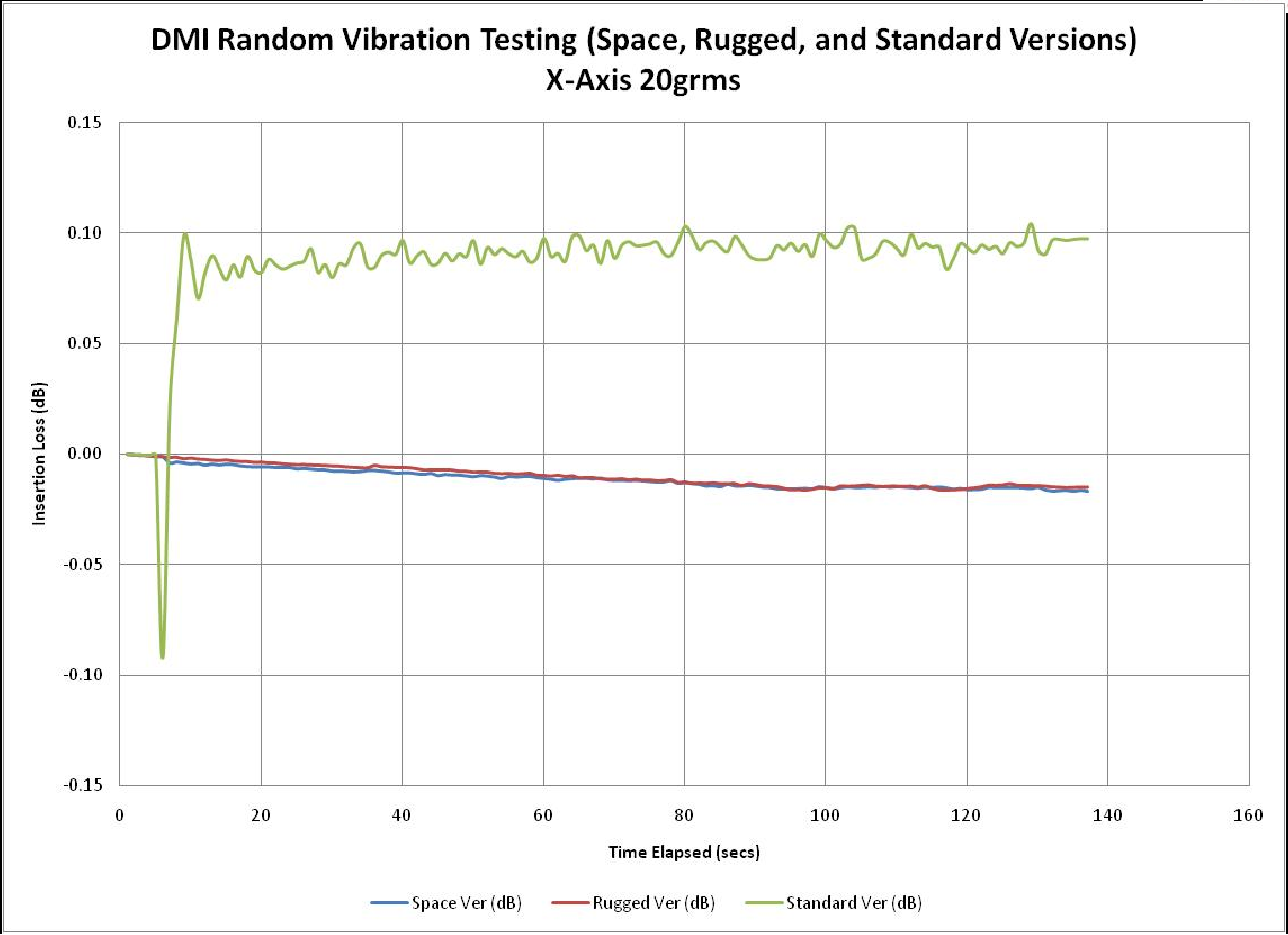
GSFC



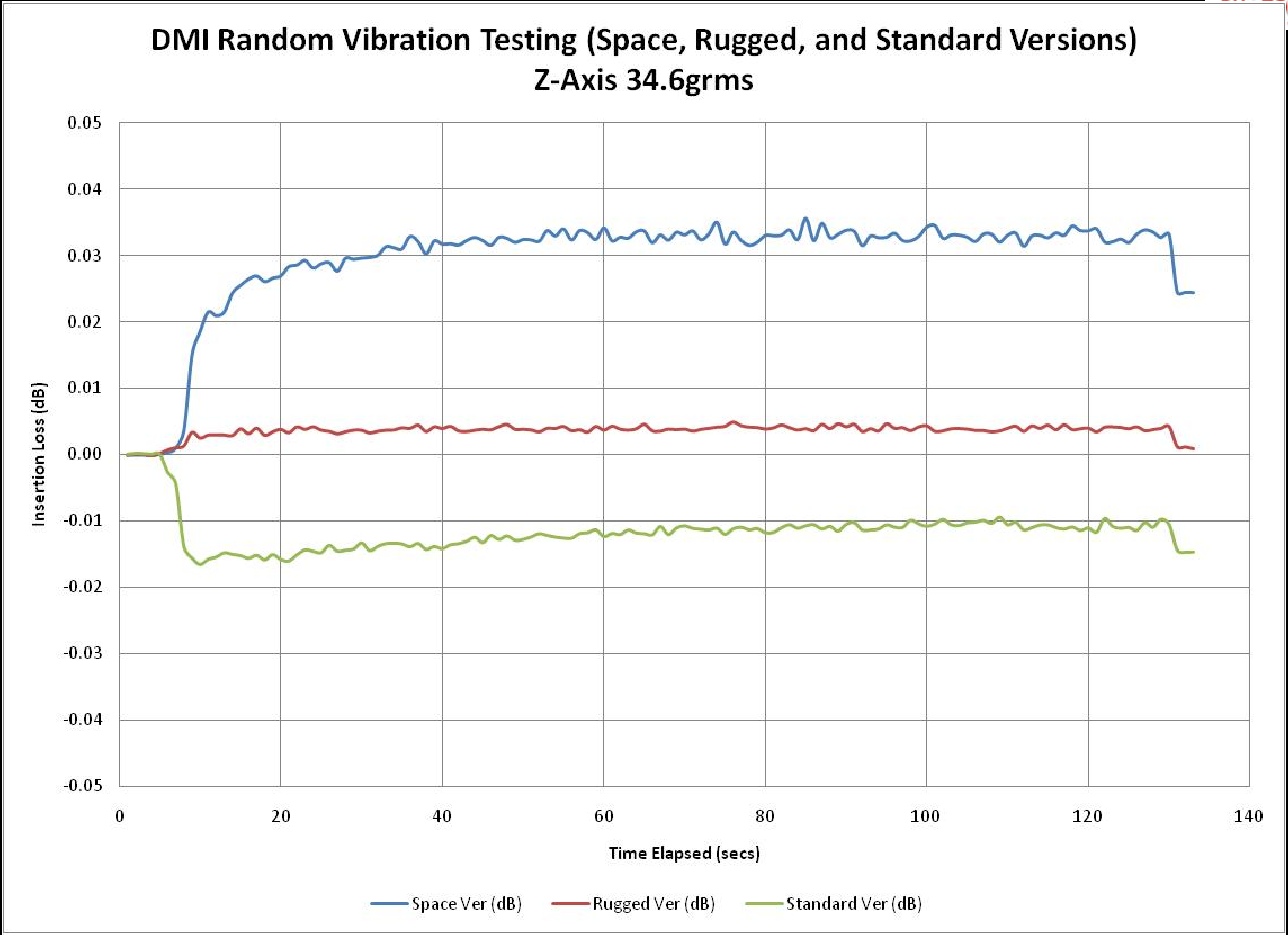
Vibration Validation Testing Results for the DMI (Mini AVIM System) for 14.1 grms



Vibration Validation Testing Results for the DMI (Mini AVIM System) 20 grms (worst performing)



Vibration Validation Testing Results for the DMI (Mini AVIM System) 35 grms (worst performing)



Vibration Testing Summary

DMI SPACE VERSION

Axis	grms Level	Max IL	Avg IL
X	10grms	-4.8E-04	6.6E-04
Y	10grms	-8.3E-05	2.2E-04
Z	10grms	1.2E-03	1.9E-03
X	14.1grms	-1.6E-03	9.4E-05
Y	14.1grms	6.6E-04	1.3E-03
Z	14.1grms	-3.1E-02	1.4E-03
X	20grms	-1.1E-02	0.0E+00
Y	20grms	-1.1E-02	2.1E-03
Z	20grms	-2.0E-02	3.5E-04
X	34.6grms	6.5E-03	1.1E-02
Y	34.6grms	2.4E-03	6.3E-03
Z	34.6grms	3.0E-02	3.6E-02

DMI RUGGED VERSION

Axis	grms Level	Max IL	Avg IL
X	10grms	-1.6E-02	2.9E-04
Y	10grms	4.2E-04	9.8E-04
Z	10grms	1.2E-05	3.4E-04
X	14.1grms	-1.3E-02	1.7E-05
Y	14.1grms	-2.4E-03	0.0E+00
Z	14.1grms	-2.3E-03	1.8E-04
X	20grms	-9.9E-03	0.0E+00
Y	20grms	-5.2E-03	2.3E-04
Z	20grms	1.2E-03	4.7E-03
X	34.6grms	4.1E-03	7.6E-03
Y	34.6grms	6.7E-03	1.0E-02
Z	34.6grms	3.6E-03	4.9E-03

DMI STANDARD VERSION

Axis	grms Level	Max IL	Avg IL
X	10grms	-1.7E-03	7.6E-05
Y	10grms	-3.6E-04	2.5E-04
Z	10grms	1.5E-03	2.4E-03
X	14.1grms	-2.5E-03	1.3E-04
Y	14.1grms	3.7E-04	1.2E-03
Z	14.1grms	-4.1E-03	8.0E-05
X	20grms	8.6E-02	1.0E-01
Y	20grms	-8.5E-03	7.4E-05
Z	20grms	3.2E-03	6.8E-03
X	34.6grms	2.7E-03	6.8E-03
Y	34.6grms	-5.9E-04	6.0E-03
Z	34.6grms	-1.2E-02	1.4E-04

Data shows less than 0.05 dB Insertion Loss change or not above noise floor.

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.

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Thank you very much for the invitation!

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