DEVELOPMENT AND QUALIFICATION OF A FIBER OPTIC CABLE FOR MARTIAN ENVIRONMENTS

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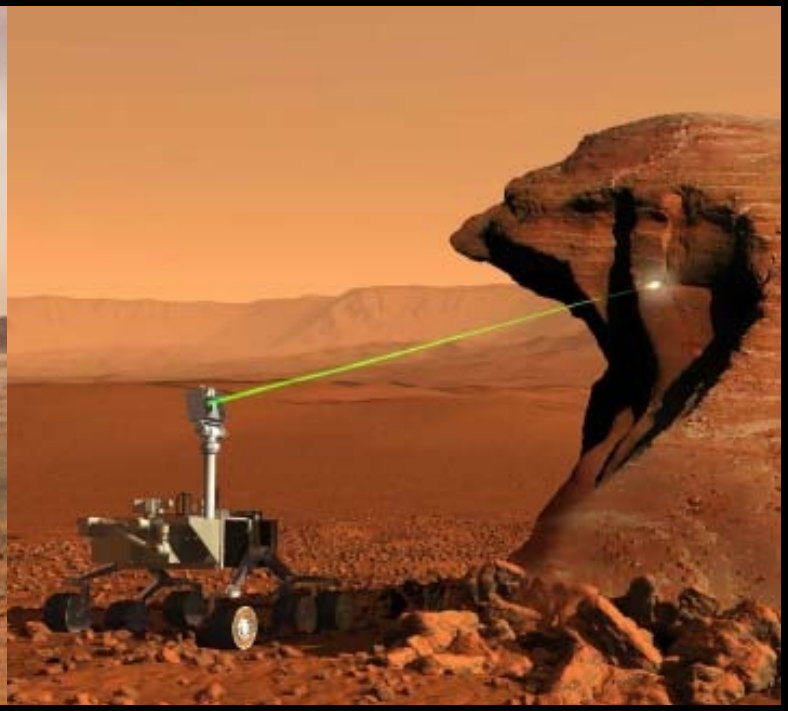


Chem Cam Application – Optical Fiber Assemblies

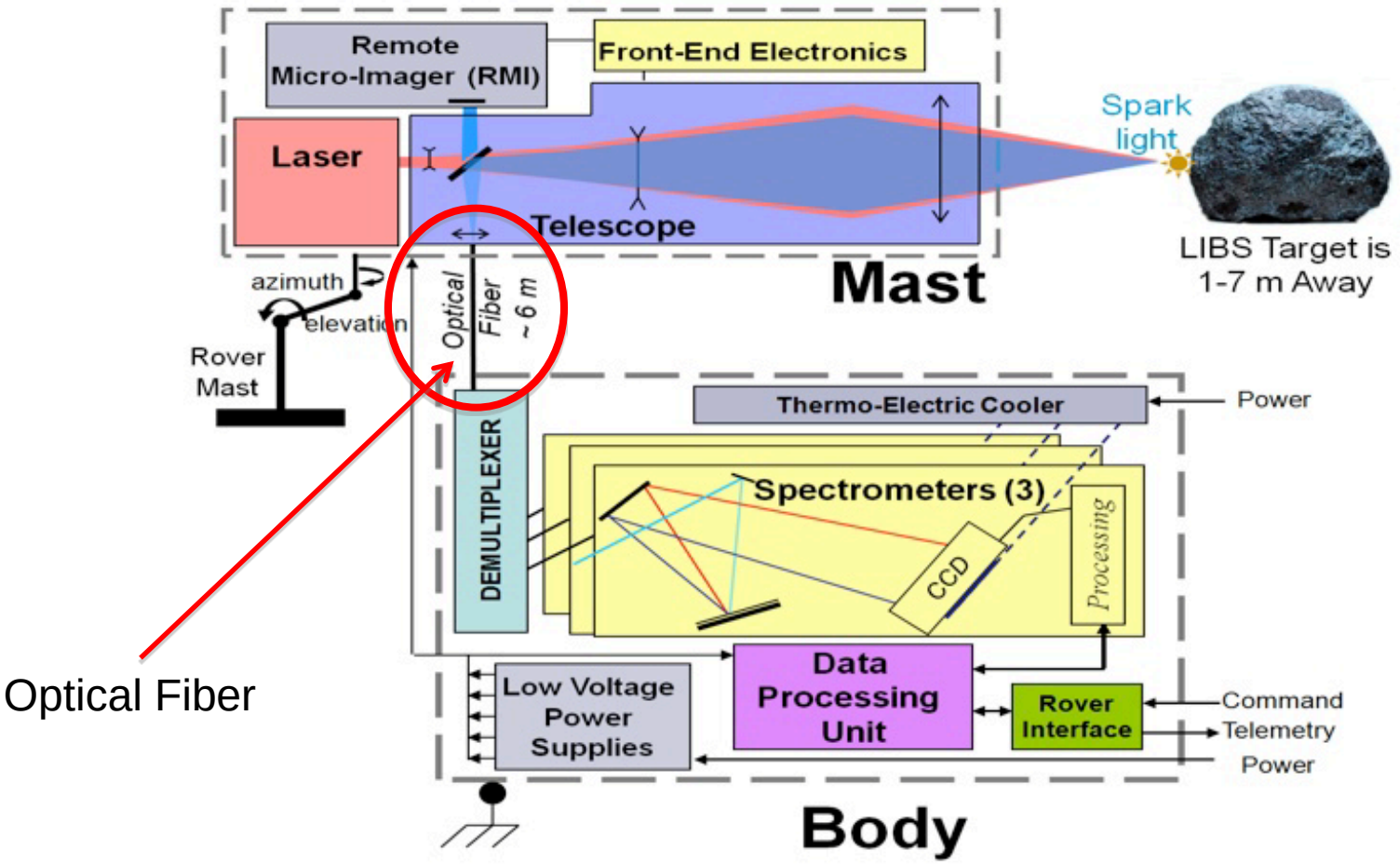
Outline

- ChemCam Description
- Fiber Optic Cable Requirements
- Environmental Requirements and Testing
  - Motion Life
  - Attenuation vs. Motion and Temperature
  - Radiation
  - Planetary Protection
  - Thermal Cycling
  - Cable Vibration
  - Connector Vibration
  - Packaging Qualification and Verification
- Summary

ChemCam and Fiber Description

- ChemCam is a Laser Induced Breakdown Spectroscopy (LIBS) Instrument
  - A pulsed laser creates a plasma at the surface of a target
  - A telescope co-aligned with the laser observes the emissions from the plasma and focuses the light onto a fiber optic
  - The fiber optic carries the signal from the mast unit to the demultiplexer and spectrometers in the rover body.
- Will go to Mars on the Mars Science Laboratory rover
- Laser and Telescope of the LIBS system are about 5.7 m from the spectrometer inputs
  - Fiber is routed from inside of Mast Unit to outside, through twist capsules, down mast, across the rover deck, and into the rover body
  - Fiber is exposed to full martian environment in some places
  - Fiber is subjected to large temperature gradients from inside the rover to outside the rover
- The selected fiber is a combination of commercially available parts and processes:
  - Polymicro FVA300330500 acrylate coated optical fiber
  - Gore Simplex Jacket
  - Diamond AVIM connectors

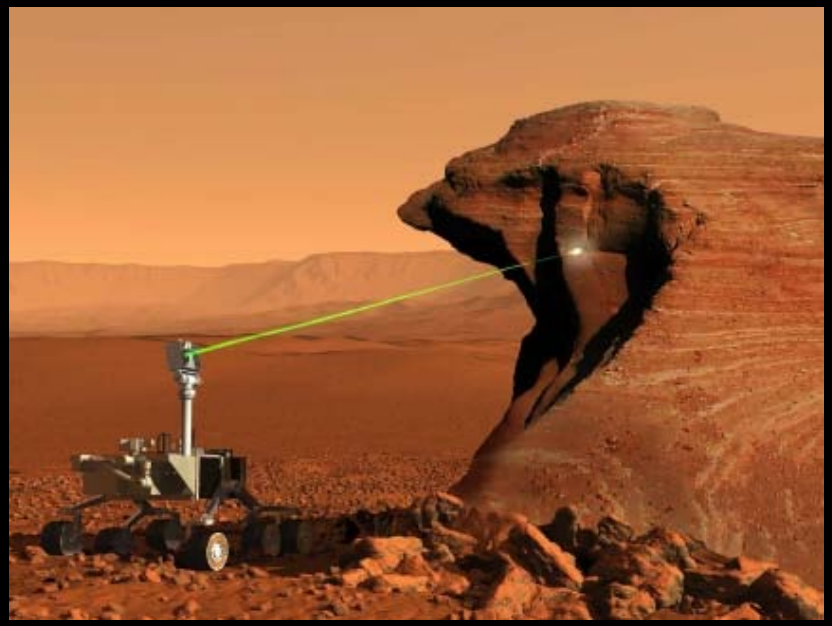
ChemCam Instrument Schematic

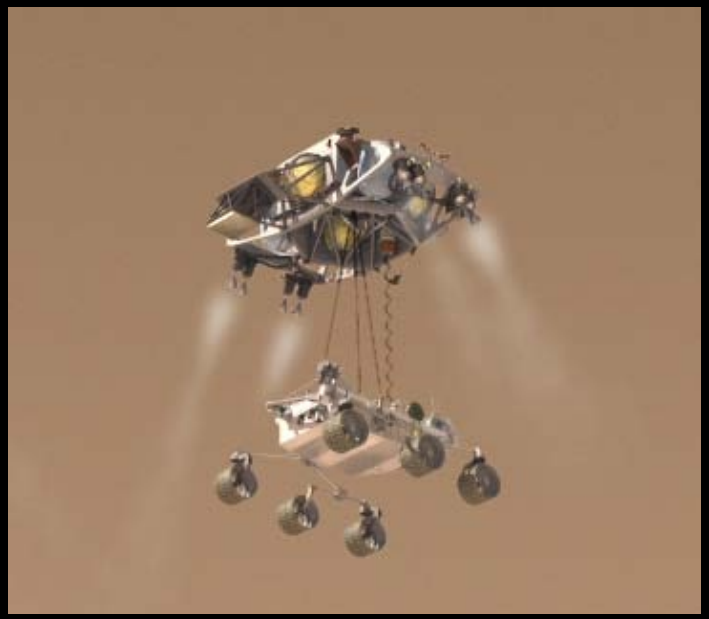


Mars Science Lab – ChemCam Optical Assemblies, Launch delayed.

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.**





ChemCam Spectral Range

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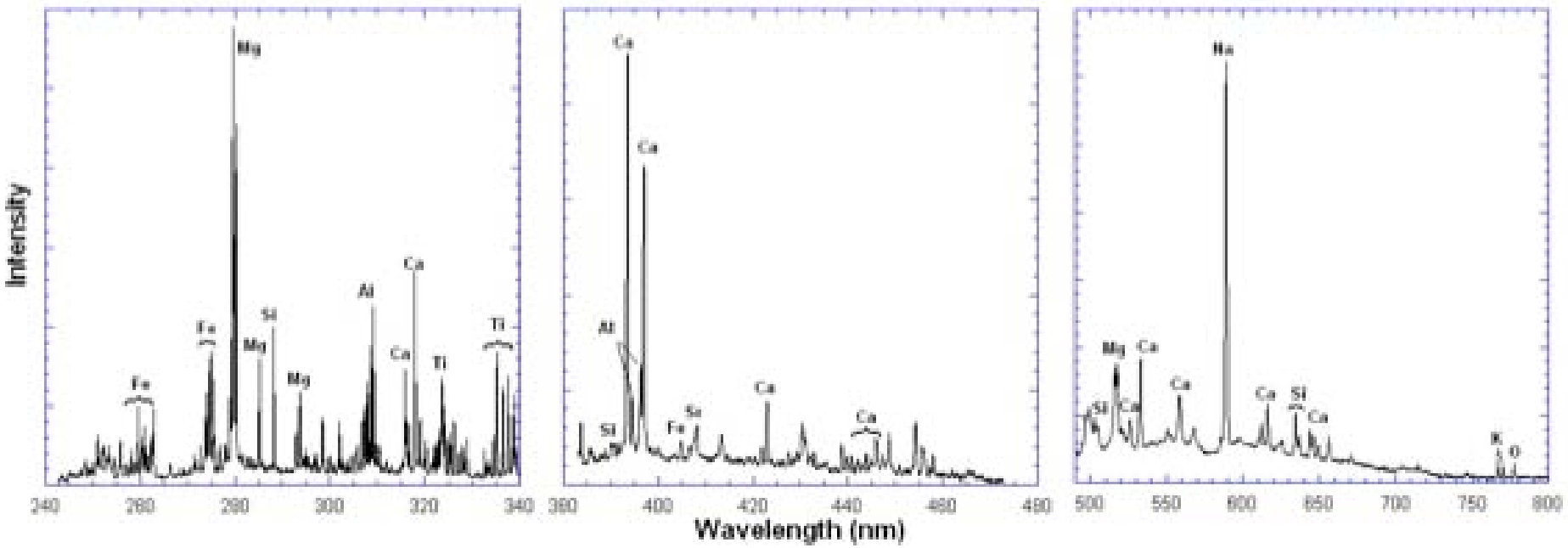
The ChemCam FOC must meet the transmission requirements at the right until end-of-mission

The spectra below indicate many of the spectral lines of interest in each range.

Wavelength Range (nm)	Transmission %	Insertion Loss (dB)
240-300	54	2.68
300-335	74	1.31
380-470	80	0.97
500-800	85	0.70



Mars Science Lab Delivery December 2008

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

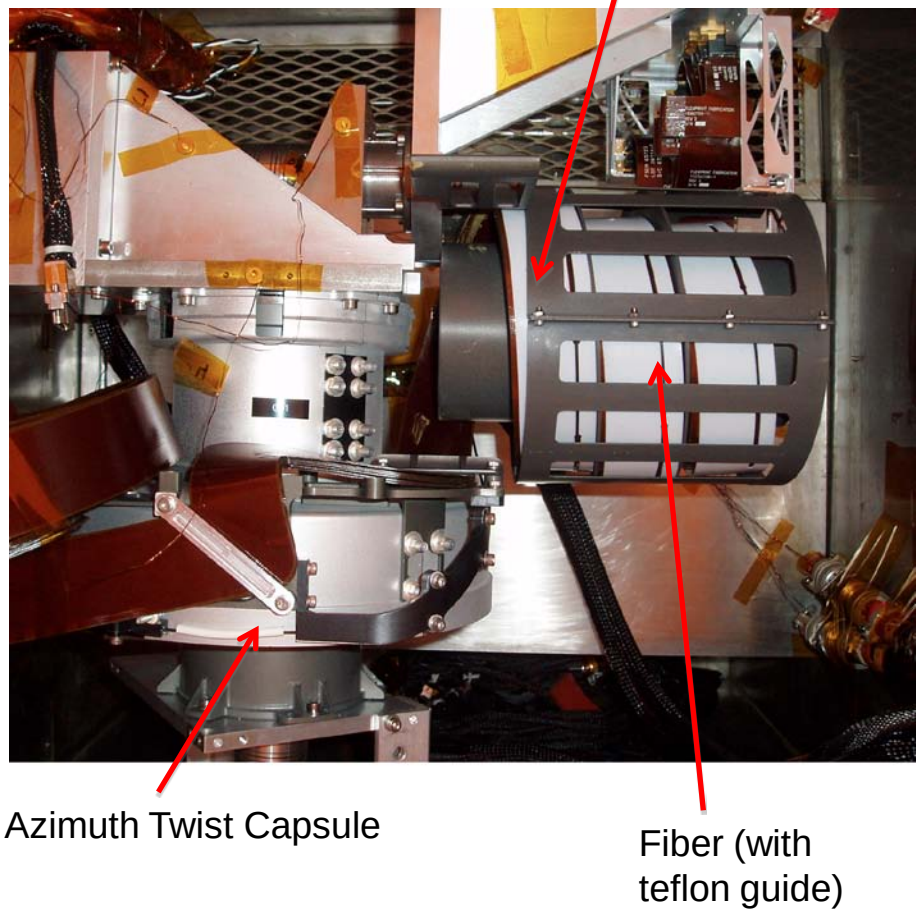
Decontamination bake out for all MSL hardware ~110°C

Environmental Test Requirements

Test	Description	Measurements
Motion life	Motion of the fiber in the azimuth and elevation twist capsules for 3x the number of start/stop cycles and degrees of rotation that the cable would see in a 1 year mission, with temperature varying from -90 C to +70 C	Attenuation vs. wavelength before and after test, as well as at intermediate points during test.
Attenuation vs. motion and temp	Measurement of transmission vs. wavelength at discrete rotations over 180 degrees of elevation (every 30 degrees), 360 degrees of azimution (every 30 degrees), and -90 C to +70 C in temperature (20 degree increments)	Attenuation vs wavelength (240 to 800 nm, 10 nm steps) at each Temperature, Elevation, Azimuth point.
Radiation	Expected change in transmission due to full mission radiation exposure	Done by analysis based on tests of related fiber designs.
Planetary protection	Thermal soak at 109+- 3 C for 50 hours	Attenuation vs. Wavelength before and after test
Thermal Cycling	50 cycles -135 C to +70 C mounted on thermal/mechanical static model of the RSM	Attenuation vs. Wavelength before and after test
Cable Vibration	7.9 grms, 3 axes, 2 minutes/axis	Attenuation vs. Wavelength before and after test
Connector Vibration	8.3 grms 14.4 grms, 3 axes, 2 minutes/axis	Attenuation during test
Packaging Qualificaton and Verification (PQV)	3 Martian years of temperature cycling over the seasonal temperature ranges	Attenuation vs. wavelength before and after test, as well as at intermediate points during test.

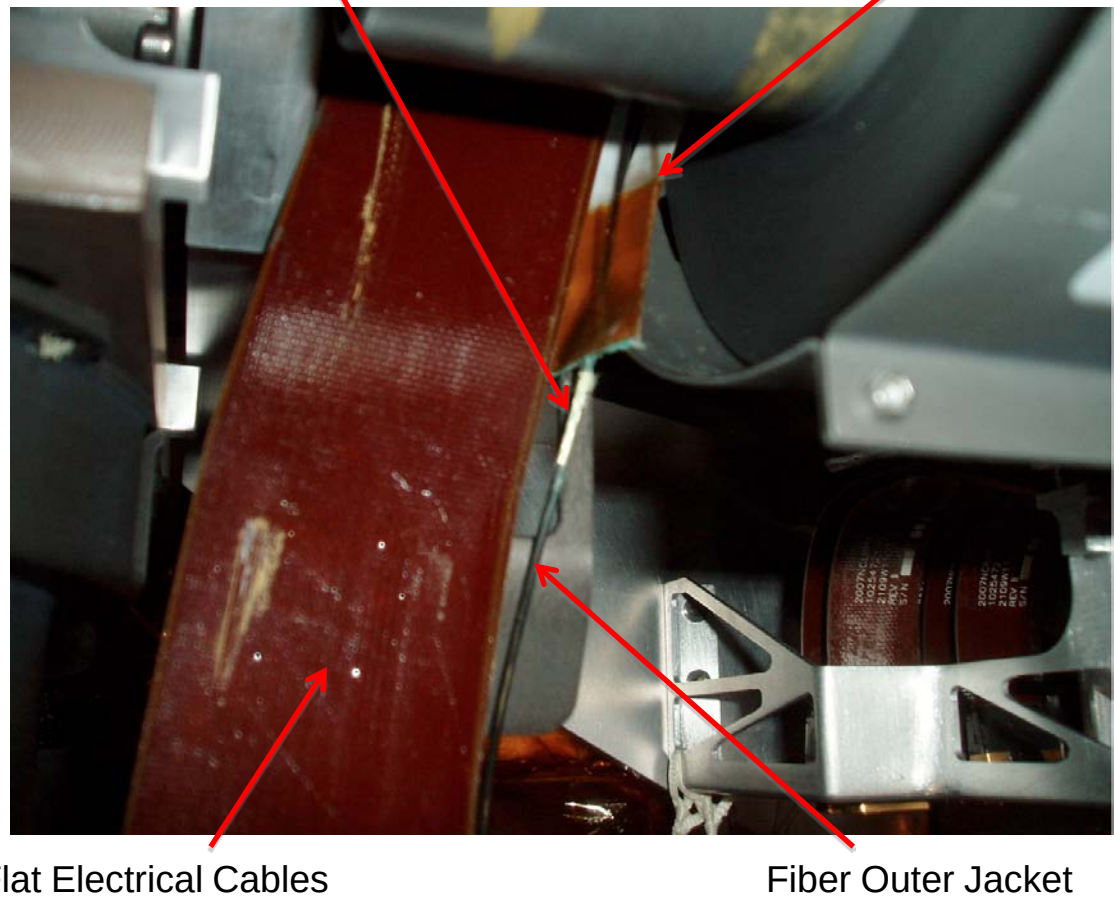
Testing – Motion Life

- The mechanism at the right is a copy of the azimuth and elevation twist capsules.
- They are mounted in an environmental chamber capable of control from -140 C to more than +120 C
- The motors are located outside the chamber but all interfaces to the fiber are identical to the flight system
- This setup was used for motion-life testing and attenuation vs. motion and temperature



Jacket Damage During Motion Life Test

- During the motion-life test, the outer jacket split at the end of the teflon guide after approximately 1 mission lifetime
- The Kevlar strength member in the jacket was undamaged, and the fiber showed no change in transmission.
- The test was completed with no further damage and no effect on transmission.
- The cable routing was revised so that the flat guide remains stacked flat with the electrical cables and the full test was re-run with no damage to the outer jacket.



Testing – Attenuation vs. Motion and Temperature

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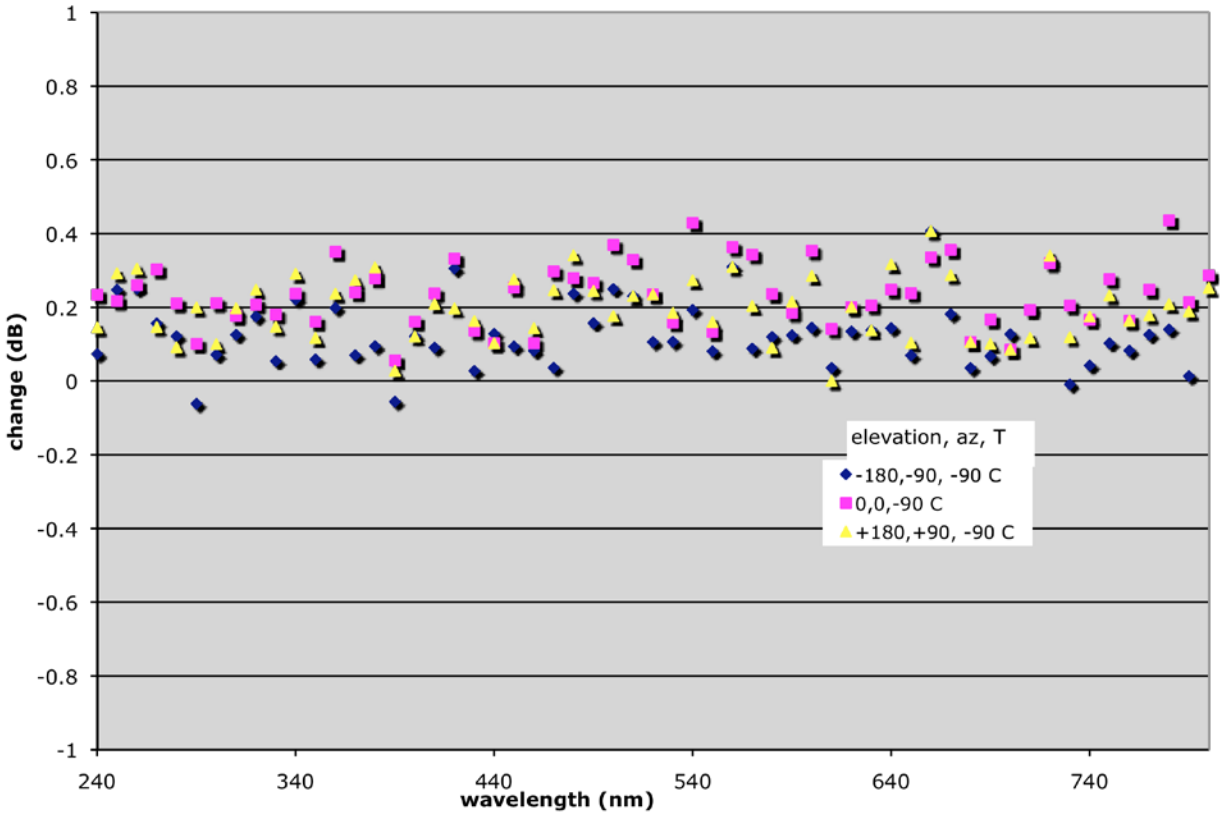
- Attenuation vs Position of the twist capsules and temperature was measured over the full range of motion and temperature.
- The data at the right show the effects at the opposite extrems of motion at -90 C.
- Effects were in the noise over the full range of motion and temperature.



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**

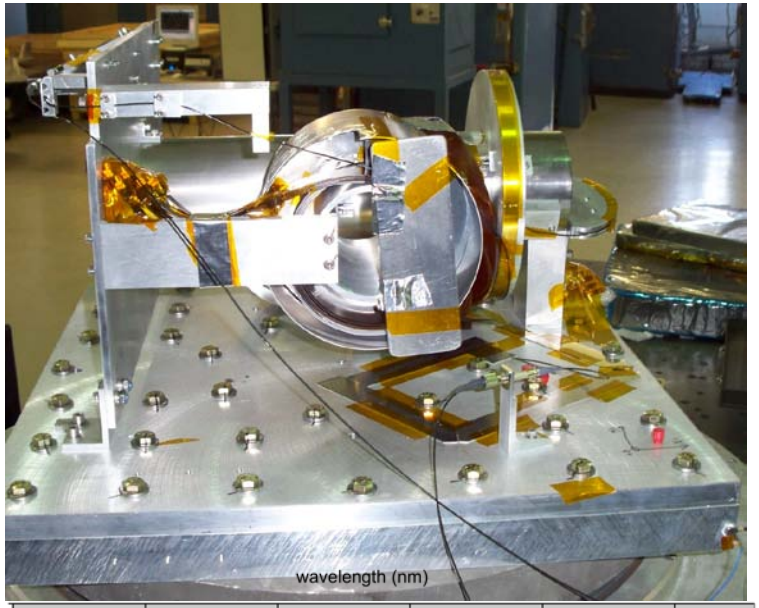
In general decreasing the dose rate 3 orders of magnitude decreases the attenuation by 1 order of magnitude.

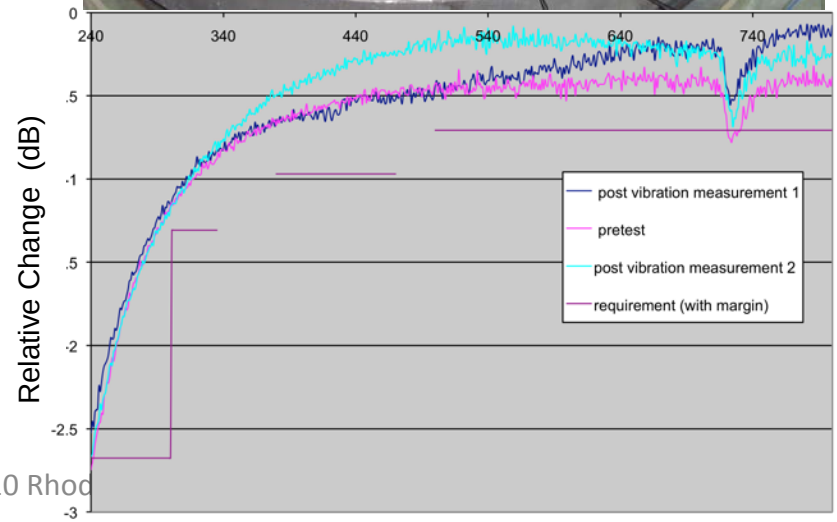
Comparing Polymicro Technologies FV series to the Nufern 300/330 MSL
Nufern 300/330 ~ 0.005 dB/m for 20 Krads, -100° C, 300 – 450 nm
PolyMicro FVA300/330 ~ 0.003 dB/m at 20 Krads, -80° C, 532 nm

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

Testing – Cable Vibration

- The fixture at the right mimics all the cable interfaces to the rover, including turns and fixed attachment points
- It was used for vibration testing of the full cable to the 7.9 grms random launch vibration requirement
- An apparent improvement in transmission was observed after vibration that was traced to drift in the light source used for measurement.





Testing – Planetary Protection and Thermal Cycling

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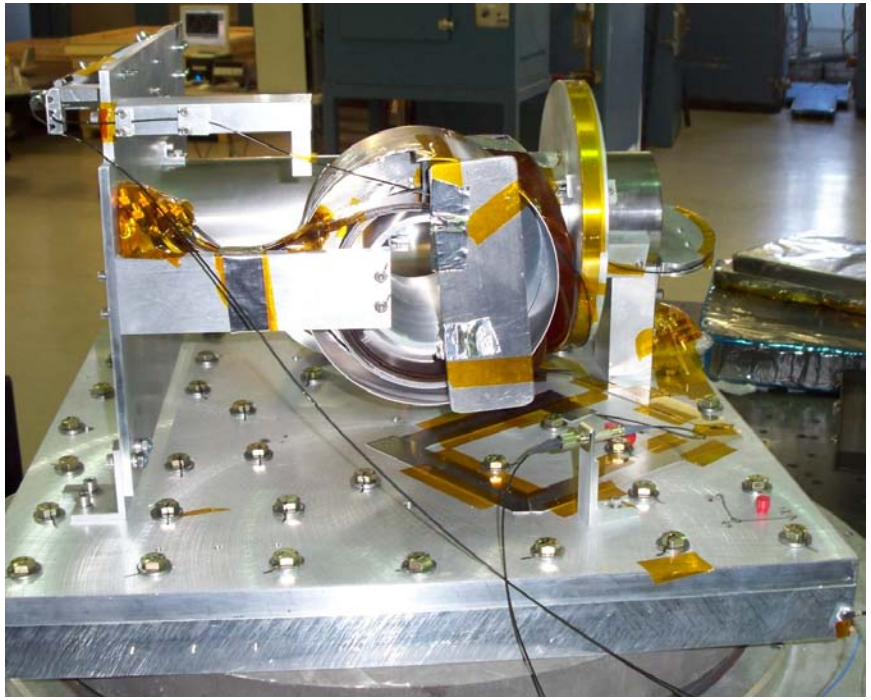
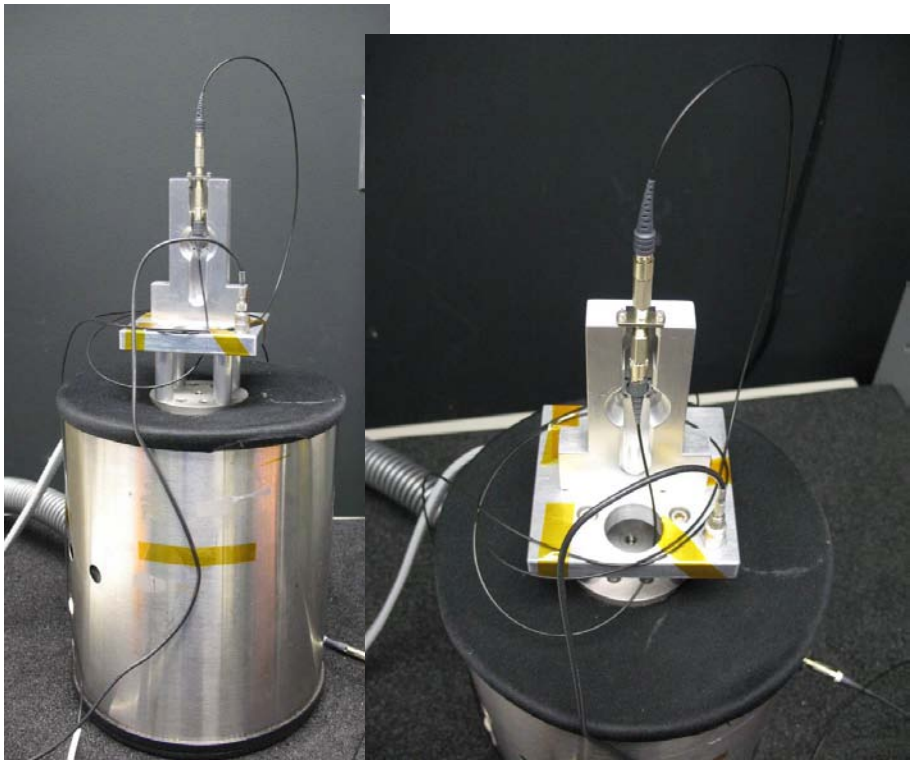
- The same fixture was used for thermal cycling to ensure interactions with the rover as the temperature would have no effect on the cable performance.
- Prior to cycling, a planetary protection bakeout was done at 109+-3 C for 50 hours.
- The fixture is a compacted version of the rover mast (to fit into the test chamber) and copies the relative thermal expansion properties of the mast and deck, while maintaining the relative geometries as well.
- No effects were seen from planetary protection bakeout or thermal cycling the cable 50 times from -135 to +70 C



Testing – Connector Vibration

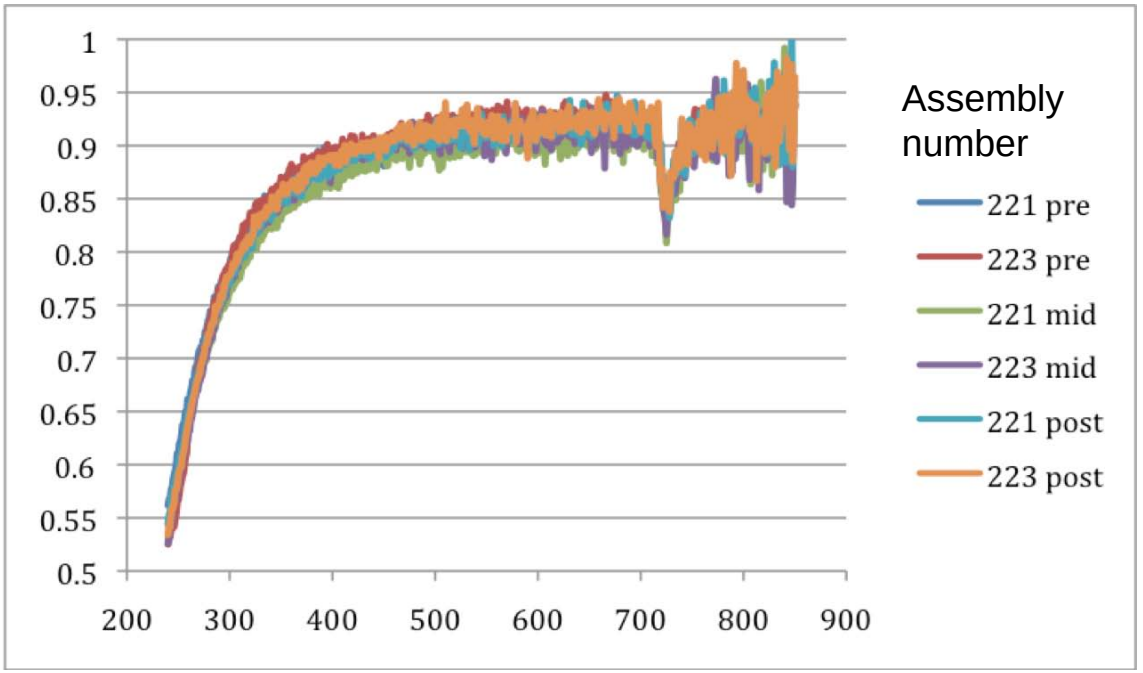
- In addition to cable vibration, connectors were subjected to random vibration testing while measuring transmission.
- During vibration, the changes in transmission were at the millidB level– essentially the noise level of the measurements.



AVIM connector mounted on lab vibration fixture

Testing – Packaging Qualification and Verification

- PQV testing was thermal cycling of two complete cables for 3 full mission lifetimes, including seasonal variations
- Cable transmission was measured periodically.
- No changes in transmission were observed.



Normalized transmission

Summary

- Demonstrated that a fiber optic cable using semi-custom parts can survive the environments of a mars mission with little or no degradation
  - Commercially available fiber
  - Jacket is a standard process fit to our fiber dimensions
  - Commercially available connectors

Acknowledgement

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.