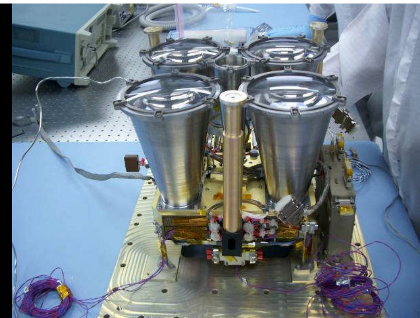
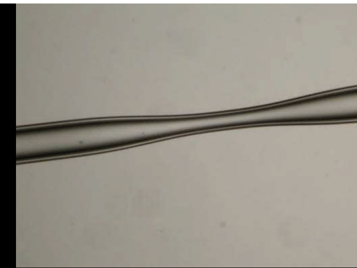
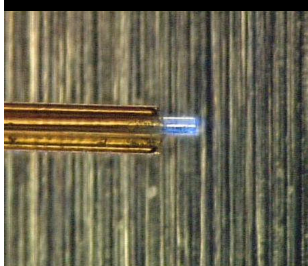
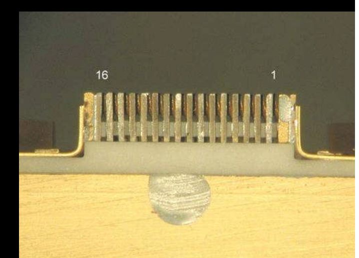




Space Flight Environmental Requirements of Optoelectronic Technologies for NASA Missions & NASA Technology Needs





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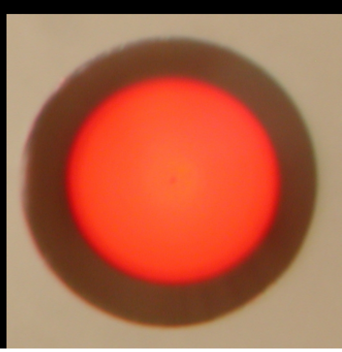
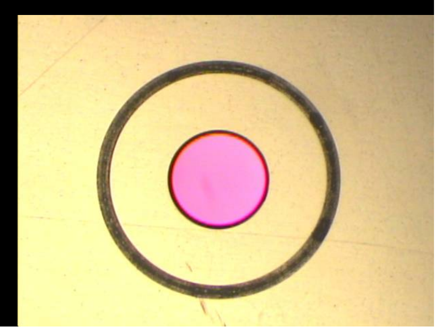




Outline

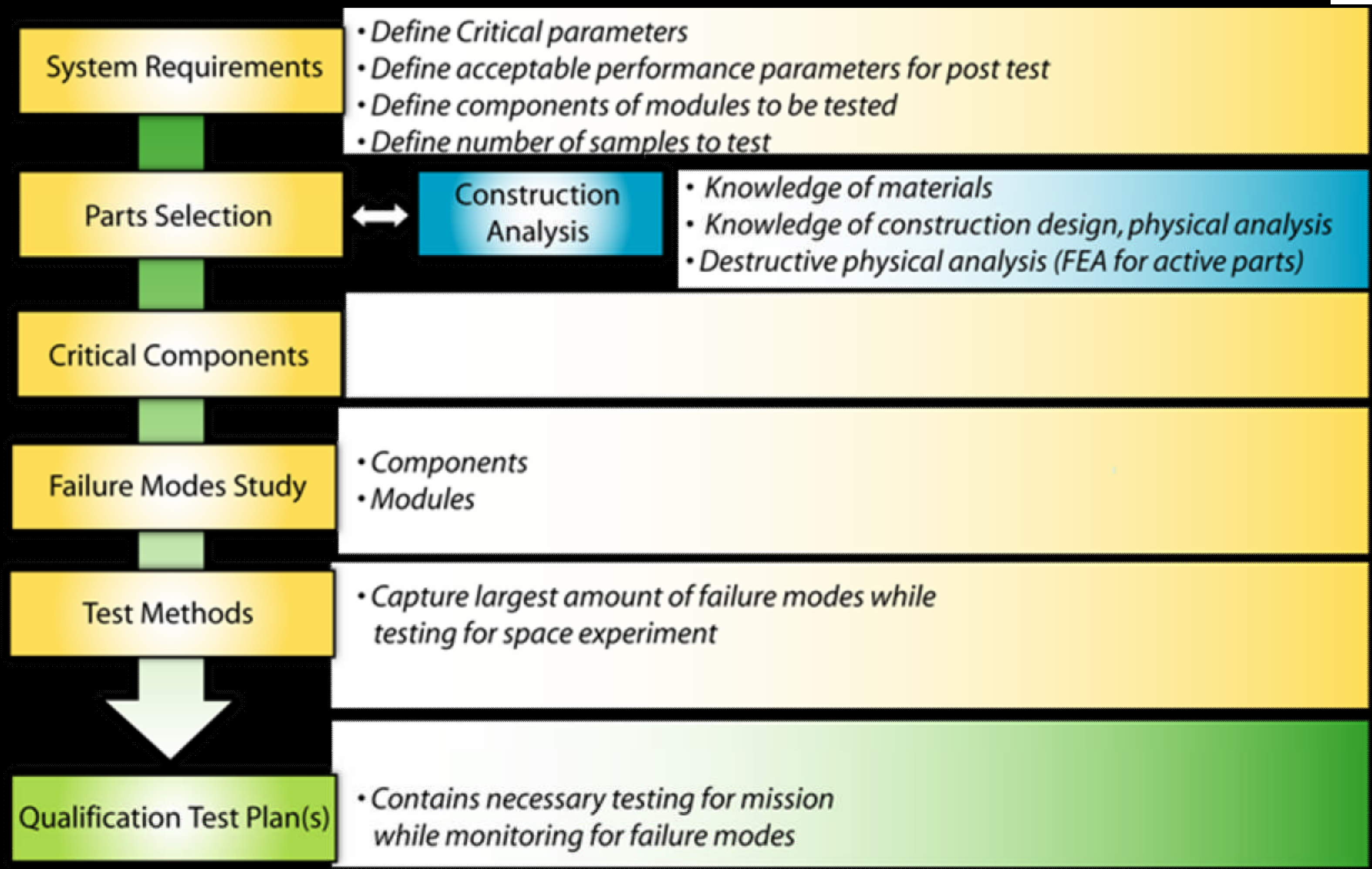
- Introductions
- Commercial Approach for Flight
- Vacuum Requirements
- Vibration Requirements
- Thermal Requirements
- Radiation Requirements
- Technologies for Future Missions
- Conclusion

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		
NASA Electronic Parts & Pack	1994 - 2009		Evaluations			Evaluations
James Webb Space Telescope OSIM Cryo	2008-2009	X	X	Cryo-Qual	X	

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

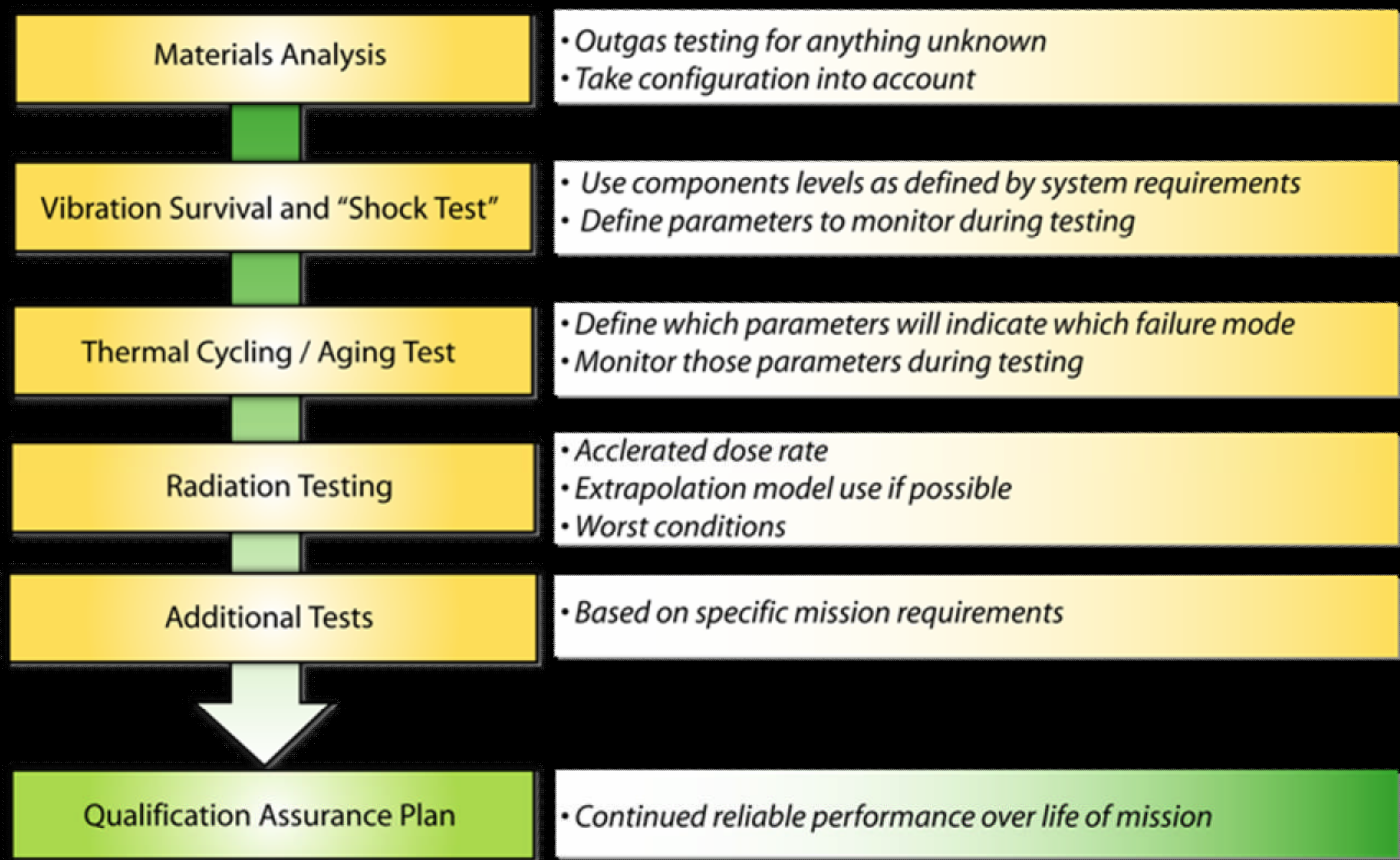
COTS Technology Assurance Approach



Flow chart courtesy of Suzzanne Falvey, Northrup Grumman, based on M Ott reference:

* *Photonic Components for Space Systems*, M. Ott, Presentation for Advanced Microelectronics and Photonics for Satellites Conference, 23 June 2004.

COTS Space Flight "Qualification"



Flow chart courtesy of Suzzanne Falvey, Northrup Grumman, based on M. Ott reference:

* *Photonic Components for Space Systems*, M. Ott, Presentation for Advanced Microelectronics and Photonics for Satellites Conference, 23 June 2004.

Environmental Parameters: Vacuum

Vacuum outgassing requirements:

- ASTM-E595,
  - 100 to 300 milligrams of material
  - 125°C at 10^{-6} Torr for 24 hours
  - Criteria: 1) Total Mass Loss < 1%
    - 2) Collected Volatile Condensable Materials < 0.1%
  - Configuration test
  - Optics or laser nearby, is ASTM-E595 enough?
    - -ask your contamination expert

1) Use approved materials, outgassing.nasa.gov
2) Preprocess materials, vacuum, thermal
3) Decontaminate units: simple oven bake out, or vacuum?
4) Vacuum test when materials analysis is not conducted and depending on packaging and device.

Space environment; vacuum is actually 10^{-9} torr, best to test as close as possible for laser systems. Many chambers don't go below 10^{-7} torr.

Vibration Requirements for Typical Launch Vehicles

GSFC

CODE 562 PHOTONICS Group @ GSFC

Typical 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

Environmental Parameters: Vibration

Launch vehicle vibration levels for small subsystem (established for EO-1)

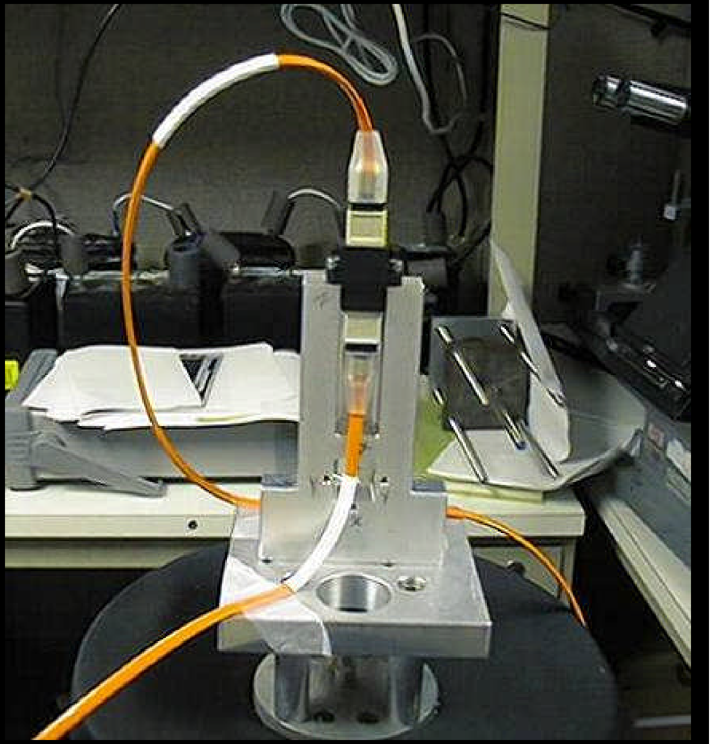
Frequency (Hz)	Protoflight Level
20	0.026 g^2/Hz
20-50	+6 dB/octave
50-800	0.16 g^2/Hz
800-2000	-6 dB/octave
2000	0.026 g^2/Hz
Overall	14.1 grms

However, this is at the box level, twice the protoflight vibration values establish the correct testing conditions for the small component.

Environmental Parameters: Vibration

Launch vehicle vibration levels for small component (based on box level established for EO-1) on the “high” side.

Frequency (Hz)	Protoflight 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



3 minutes per axis, tested in x, y and z

Typical Thermal Requirements

Commercial/Industry Standard	-25 °C to +85°C
Space Flight Benign (inside box) TXRX	0°C to +50 °C
Military/Space Flight Standard	-55°C to +125°C
Earth Orbiting Extra Vehicular (ISS)	-150°C to +200°C

Environmental Parameters: Thermal

There is no standard, typical and benign –25°C to +85°C.
–45°C to +80°C, Telcordia; -55°C to +125°C, Military

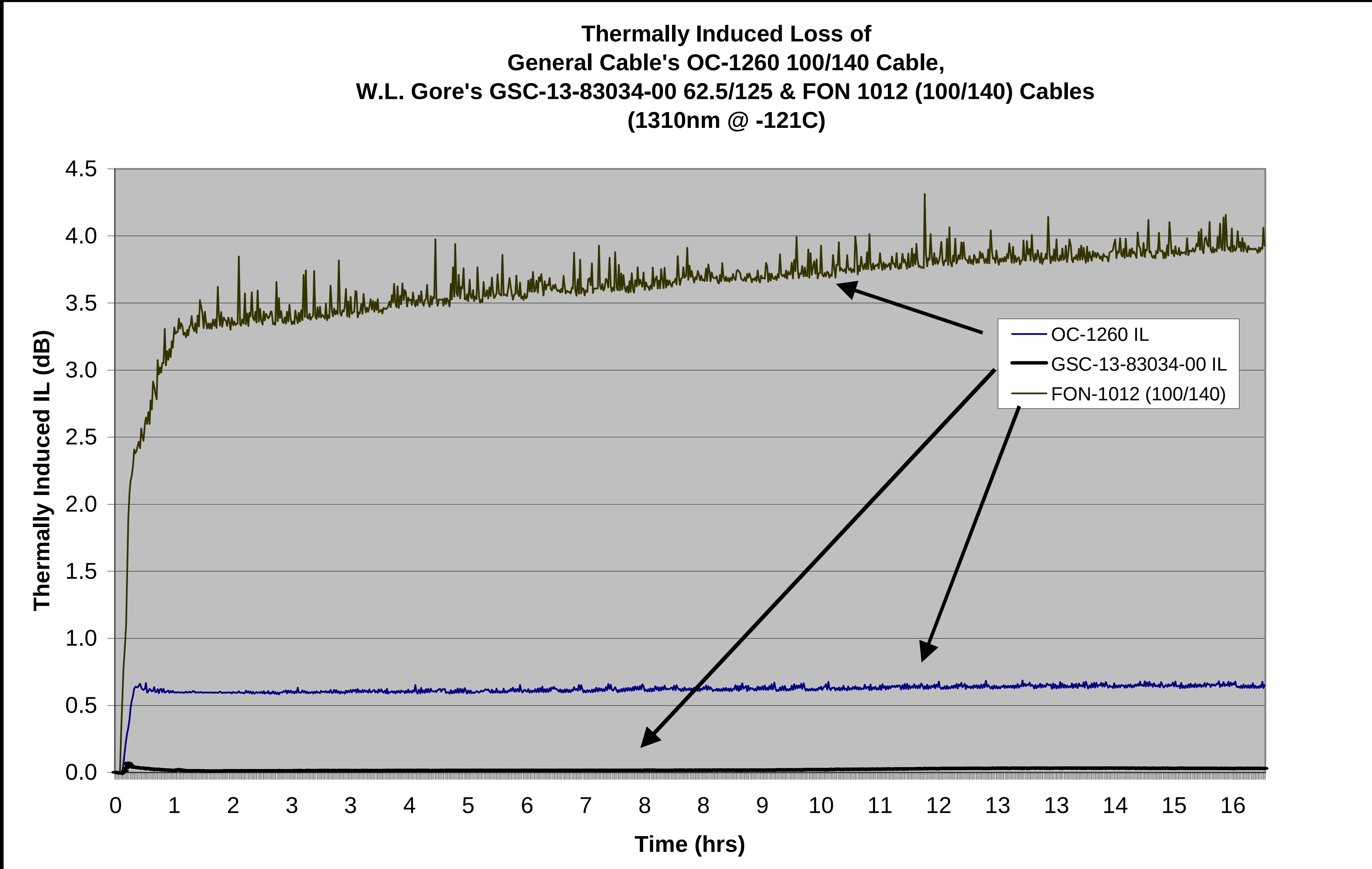
Depending on the part for testing;
Insitu testing is important,
Add 10°C to each extreme for box level survival

Thermal cycles determined by part type, schedule vs. risk
30 cycles minimum for assemblies, high risk
60 cycles for assemblies for higher reliability
100 or more, optoelectronics and longer term missions.

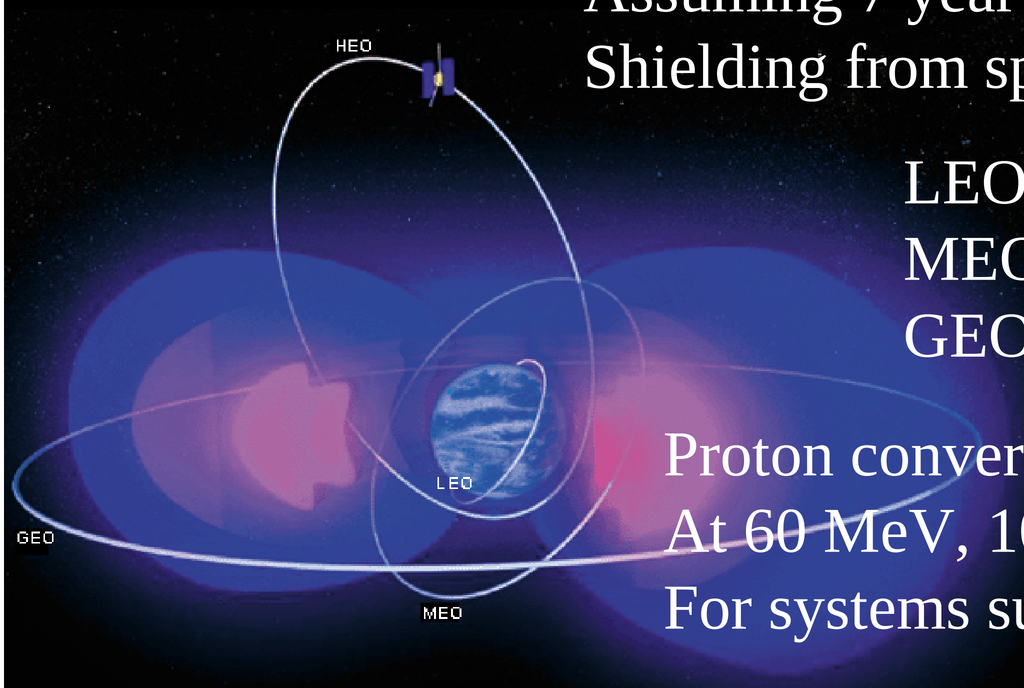
Knowledge of packaging and failure modes really helps with cycles determination.

ISS Cable Candidates; Thermal Pre Qual, -121°C

9 meters



Environmental Parameters: Radiation



Assuming 7 year mission,
Shielding from space craft

LEO, 5 – 10 Krads, SAA
MEO, 10 –100 Krads, Van Allen belts
GEO, 50 Krads, Cosmic Rays

Proton conversion to Total Ionizing Dose (TID)
At 60 MeV, 10^{10} protons/Krad for silicon devices
For systems susceptible to displacement damage

Testing for displacement damage: 3 energies in the range ~ 10 to 200 MeV.
If you have to pick one or two energies stay in the mid range of 65 MeV and lower. Less probability of interaction at high energies.
Ballpark levels: 10^{-12} p/cm^2 LEO, 10^{-13} p/cm^2 GEO, 10^{-14} p/cm^2 for special missions (Jupiter).

Environmental Parameters: Radiation

Typical space flight background radiation total dose
30 Krads – 100 Krads over 5 to 10 year mission.

Dose rates for fiber components:

- GLAS, 100 Krads, 5 yr, .04 rads/min
- MLA, 30 Krads, 8 yr, .011 rads/min (five year ave)
- EO-1, 15Krads, 10 yr, .04 rads/min

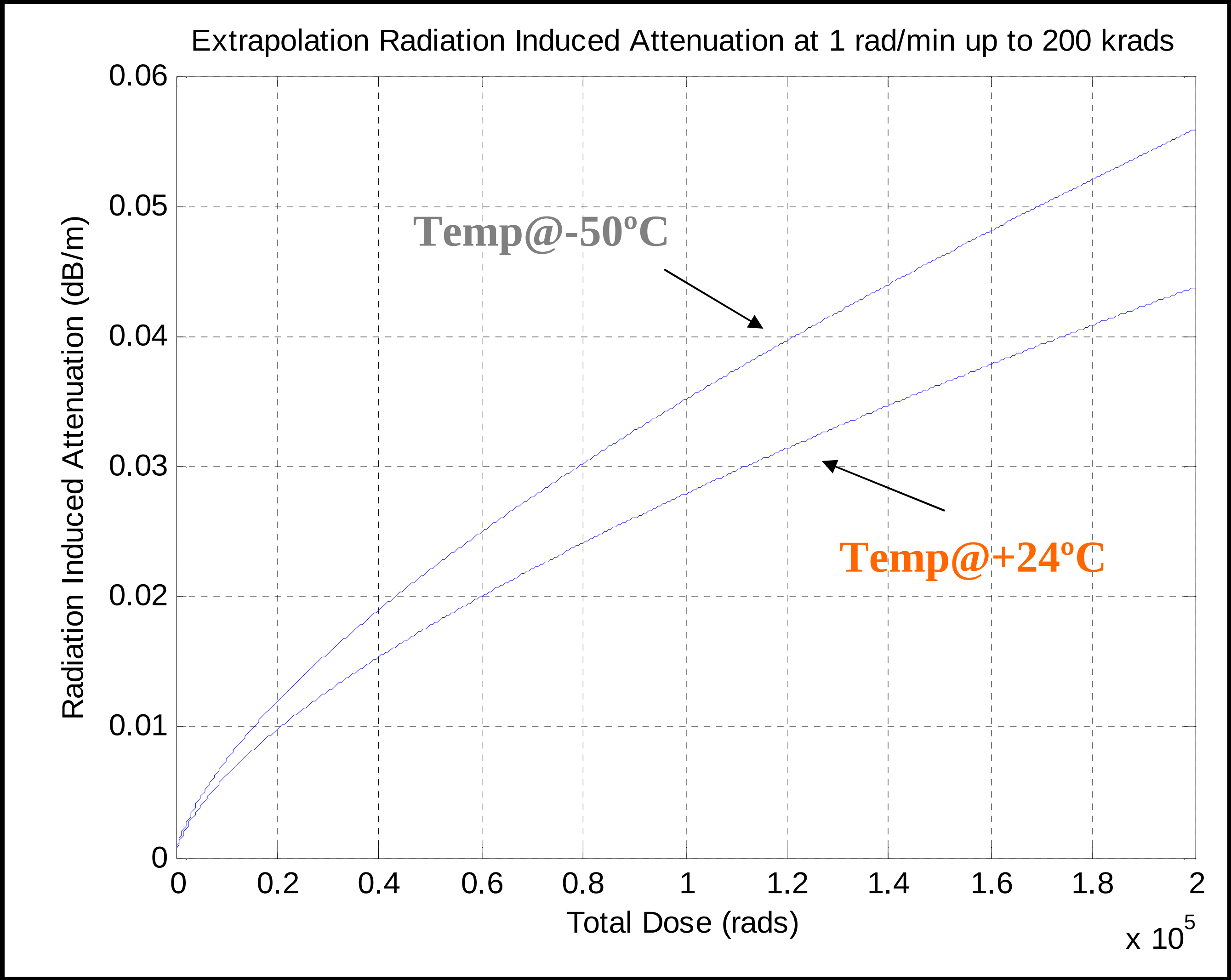
Any other environmental parameters that need to be considered?

For example,

1) radiation exposure at very cold temp, or prolonged extreme temperature exposure based on mission demands.

2) Motion during cold exposure.

Radiation Effects Laser Ranging Array Assemblies



400/440 micron polymicro Technologies flexlite @ 532 nm

For 1 rad/min, -50°C up to 200 Krads, Radiation Induced Atten ~ 0. 56 dB for 10m
For 1 rad/min, 24°C up to 200 Krads, Radiation Induced Atten ~ 0. 44 dB for 10m

Radiation Testing @ 1300 nm, OFS optical fiber

Part	Dose Rate	TID	Temp	Attenuation
BF05444 100/140/500	**0.1 rads/min**	**100 Krad**	**25°C**	**0.0048 dB/m**
BF05202 100/140/172 RH	**14.2 rads/min**	**5.1 Krad**	**-125°C**	**0.14 dB/m**
BF05202 100/140/172 RH	**42 rads/min**	**100 Krad**	**-125°C**	**1.5 dB/m**
CF04530 100/140/172 S	**14.2 rads/min**	**5.1 Krad**	**-125°C**	**0.053 dB/m**
CF04530 100/140/172 S	**42 rads/min**	**100 Krad**	**-125°C**	**0.064 dB/m**
BF04431 62.5/125/250	**0.1 rads/min**	**100 Krad**	**-25°C**	**0.91 dB/m**
BF04431 62.5/125/250	**0.1 rads/min**	**100 Krad**	**25°C**	**0.59 dB/m**

“Radiation Effects Data on Commercially Available Optical Fiber,” M. Ott, IEEE NSREC 2002

NASA Required Technologies Based on Small Business Innovation Research Grants

Emphasis Categories
General Application Areas
General Application Technologies
Specific Examples

SBIR Program Topic List Categories

Aeronautics Research
- A1 Aviation Safety
- A2 Fundamental Aeronautics
- A3 Airspace Systems
- A4 Aeronautics Test Technologies

Exploration Systems
- X1 Avionics and Software
- X2 Sensors for Autonomous Systems
- X3 Environmental Control and Life Support (ECLS)
- X4 Extra Vehicular Activity (EVA)
- X5 Lunar In-Situ Resource Utilization (ISRU)
- X6 Structures, Materials and Mechanisms
- X7 Lunar Operations
- X8 Energy Generation and Storage
- X9 Propulsion and Cryogenic Systems
- X11 Thermal Management
- X12 Exploration Crew Health Capabilities
- X13 Space Human Factors and Food Systems
- X14 Space Radiation

Science
- S1 Sensors, Detectors, and Instruments
- S2 Advanced Telescope Systems
- S3 Spacecraft and Platform SubSystems
- S4 Low-Cost Small Spacecraft and Technologies
- S5 Robotic Exploration Technologies
- S6 Information Technologies

Space Operations
- O1 Space Communications and Navigation
- O2 Space Transportation
- O3 Processing and Operations

Application Areas

Constellation

ARES Launch Vehicles
Orion Module
Altair Lunar Lander
Base Stations
Communications

Space Science

Joint Dark Energy Mission

Planetary Science

Earth Science LIDARs
Mars Rovers

Space Station

General Application Technologies

Laser Sources

Pulsed Fiber Lasers/Semiconductor Lasers
100 ns, 8-40 Hz, ujoules/mjoules,
532 nm, 1064 nm, 2 microns,

Sources for Laser Communications and Sensing Systems,
CW modulated external, 1500 nm, 1064 nm – Frequency Stable

Laser Pump/Sources

Pumps for Erbium & Ytterbium Fiber Laser Systems.
Calibration systems.
Communications Systems
Sensing & Inspection Systems
Docking Systems

LEDs

On board calibration systems.
Sensing Systems
Docking Systems

General Application Technologies

Detectors

UV/VIS General Telescopes and Science

UV/VIS/IR Narrow and Broadband Focal Plane Arrays
- Science Spectroscopy
- Imaging Systems & Telescopes
- LIDAR – wind, ranging, etc.
- Docking Systems

Large Area UV, VIS & IR

Photon Counting 1064 nm & 2 um

Avalanch Photodiodes and Arrays

Other Technology Areas

Radiation Hardened Transceivers- Transmitter/Receiver Combination for optical communications systems. 1310 nm, 1550 nm.

Wavelength Converters for LIDAR

Switching Technologies for LIDAR and Communications wavelengths.

High Efficiency Fiber Coupled Packaging Methods

Radiation Hardened Specialty Optical Fiber for High Power

Small Form Factor Reliable Interconnect

Specific Examples, http://sbir.nasa.gov, 2008 Phase 1

YEAR /Center-Cat.	Technology	Vendor
2008-LaRC-A1	Fiber Laser Coherent LIDAR/Wake Vortex Detection	FiberTek, Inc.
2008-LaRC-A1	LIDAR-Wake Vortex	Q-Peak
2008-LaRC-A1	All-Fiber-Optic Ultrasonic Health Management System	Luna Innovations Inc.
2008-ARC-A4	Fiber Optic 6 Component Force Measurement System	Luna Innovations Inc.
2008-JSC-X5	Lunar Surface Solar Electric Power System	Deployable Space Systems
2008-GRC-X7	Fiber Optic Liquid Sensor or Cryo Propellant Gauging	Broadband Photonics
2008-GRC-X7	Multi-Agent Optical Sensor Chip for Cryo Fluids Leak det.	Intelligent Optical Sys.
2008-GSFC-S1	High Reliability Freq. Stablized CW Laser Source	FiberTek, Inc.
2008-LaRC-S1	Tunable Seed Lasers for Laser Remote Sensing of CO2&O2	Vescent Photonics
2008-GSFC-S1	OptoCeramic High Speed Fiber Multiplexer for MM fiber	Boston Applied Tech.
2008-LaRC-S1	1.26 um Single Freq. Fiber Laser	NP Photonics
2008-GSFC-S1	Er/Yb..All Fiber Laser Transmitter	NP Photonics
2008-GSFC-S1	λ Stabilized Seed Source for Multi λ LIDAR Applications	ADVR, Inc.
2008-LaRC-S1	Q-Switched High Power Single Frequency 2 um Fiber Laser	AdValue Photonics, Inc.
2008-LaRC-S1	Efficient and Compact Semiconductor Laser Transmitter Modules	EM4, Inc.
2008-LaRC-S1	Single-Freq. Semiconductor Lasers @ 1.5 & 2 um	nLight Photonics
2008-GSFC-S1	High Reliability Freq. Stable Semiconductor Laser Source	Princeton Optronics, Inc.
2008-ARC-S1	X-Ray Diffraction & Fluorescence Instr. for Lunar	inXitu Inc.
2008-JPL-S1	Hyperspectral Infrared Focal Plane Array and Camera..	QmagiaQ
2008-GSFC-S1	Integrated Spatial Filter Array	Luminit, LLC
2008-GSFC-S1	Polarimetric and Nonpolarimetric Multi λ Focal Plane Arrays	Phoebus Optoelectronics LLC

Specific Examples, http://sbir.nasa.gov, 2008 Phase 1, Cont.

YEAR /Center-Cat.	Technology	Vendor
2008-GSFC-S1	Multi-Layer Far-Infrared Component Technology	Zyberwear, Inc.
2008-GSFC-S1	Single Photon Counting Readout Cir./APD Arrays UV to IR	Epitaxial Techologies, LLC
2008-GSFC-S1	GaN-Based, Low Voltage, APD's for Compact UV Imagers	SVT Associates
2008-GSFC-S1	Longwave Imaging for Astronomical Applications	QmagiQ
2008-GSFC-S1	Quad Photoreceiver for Laser Interferometric Gravity Wave Det.	Discovery Semiconductors, Inc.
2008-GSFC-S1	Highly Efficient FUV Photodetector w/ AlGaN Photocathode	Physical Optics Corporation
2008-ARC-S1	Next Generation, UAV-Class Ozone Photometer	Physical Optics Corporation
2008-MSFC-S1	Compact Ultrasensitive SO2 Monitor	Novawave Technologies
2008-GSFC-S1	In Situ Aerosol Detector	Vista Photonics, Inc.
2008-ARC-S1	Laser Ablation – Optical Cavity Isotopic Spectrometer	Applied Spectra, Inc.
2008-ARC-S1	Lab on a Chip, LCVR Polarimeter for Life Exploration	Intelligent Optical Systems, Inc.
2008-JPL-S1	Deep UV Semiconductor Sources for Planetary Science Instr.	Photon Systems
2008-MSFC-S1	Electro-Optic Tunable Laser Sensor	ADVR, Inc.
2008-ARC-S1	Deep UV Raman/Fluorescence Stand Off Sensor for Lunar Science	Photon Systems
2008-GRC-S3	InGaN High Temp Photovoltaic Cells	Integrated Micro Sensors, Inc.
2008-JPL-S5	Flash3D EDL Sensor Technology Advancement	Advanced Scientific Concepts Inc.
2008-O1-JPL	High-Efficiency & Power Laser Transmitter, for Deep Space Comm.	Vega Wave Systems, Inc.
2008-O3-KSC	Photonic Sensor for Nondestructive Testing of Pressure Valves …	Los Gatos Research

Specific Examples, http://sbir.nasa.gov, 2007 Phase 2, Cont.

YEAR /Center-Cat.	Technology	Vendor
2007-JSC-X2	Flash 3D Rendezvous and Docking Sensor	Advanced Scientific Concepts Inc.
2007-GSFC-X2	Using a Bore sight Camera as an AR&D Sensor	Advanced Optical Systems, Inc.
2007-LaRC-X2	Flash 3D Enhancements for Autonomous Precision Landing, Hazardous Detection & Avoidance	Advanced Scientific Concepts Inc.
2007-LaRC-X2	High Sensitivity Indium Phsophide Based APD Focal Plane Arrays	nLight Photonics
2007-LaRC-X2	Efficient 3-D Ladar Source	Q-Peak, Inc.
2007-GRC-X4	Compact Optical Carbon Dioxide Monitor for EVA	Vista Photonics, Inc.
2007-JSC-X4	Holographic Waveguided See – Through Display	Luminit, LLC.
2007-LaRC-S1	Fabry-Perot Based Ranging Interferometer Receiver for High Spectral Resolution LIDAR	Michigan Aerospace Corp.
2007-LaRC-S1	Single Freq. Lasers for Space Based Wind & Aerosol LIDAR	Fibertek, Inc.
2007-LaRC-S1	Efficient Tm-Fiber Pumped HO:YLF Laser System for Coherent LIDAR	Q-Peak, Inc.
2007-LaRC-S1	High Energy Single Freq. Fiber Laser @ Low Rep. Rate	PolarOnyx, Inc.
2007-GSFC-S1	SiC APD's and Arrays	Aymont Technology, Inc.
2007-GSFC-S1	Silicon Microchannel Plate Lare Area UV Detector	Physical Optics Corp. EP Div.
2007-GRC-S3	Lightweight InP Solar Cells for Space Applications	MicroLink Devices
2007-GRC-S3	Nanostructured InGaP Solar Cells	Kopin Corporations
2007-JPL-S5	Flash 3D Planetary Entry, Descent and Landing Sensor Hardening	Advanced Scientific Concepts Inc.

For more information please visit the URL

http://photonics.gsfc.nasa.gov