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# Development and Qualification of Space Flight Hardware for Optical Systems

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https://photonics.gsfc.nasa.gov

March 4, 2019
Optical Fiber Communications Conference
Session on Space Photonics; Disruptive Satellite Laser Communications and Astrophotonics

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# Meet the Photonics Group of NASA Goddard
## Over 20 years of space flight hardware development, testing, & integration

Back row L-R: Erich Frese, Joe Thomes, Marc Matyseck
Middle row L-R: Rick Chuska, Eleanya Onuma, Cameron Parvini, Rob Switzer
Front row L-R: Hali Jakeman, Melanie Ott, Diana Blair,

Trevon Parker

Alexandros Bontzos

Clairy Reiher

Alejandro Rodriguez

*All great things require a great team!*

***https://photonics.gsfc.nasa.gov***

# Introduction: How to Get to Space

- History of some of our successful remote and earth missions.
- Here is how we accomplished TRL 9 mission success with commercial off the shelf components (COTS).

Incoming Inspection

Integration & Test

**Working with our industry partners to provide full service**

**From incoming inspection of materials all the way to integration of hardware.**

**Our missions require rigor in our work and documentation.**

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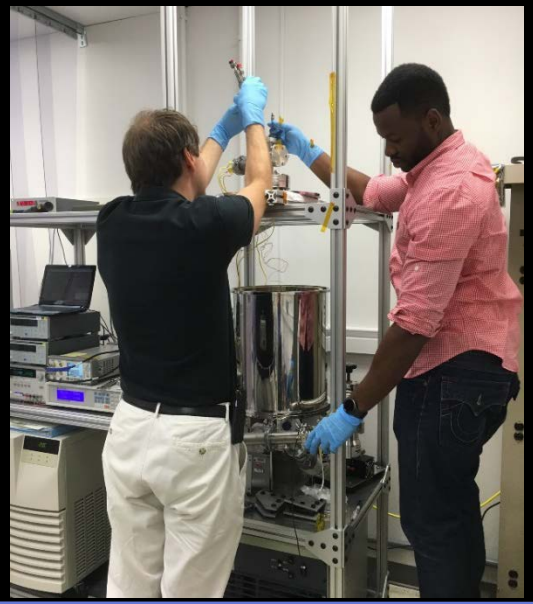
# Custom Spaceflight Optical & Optoelectronic Subsystems using Commercial Components

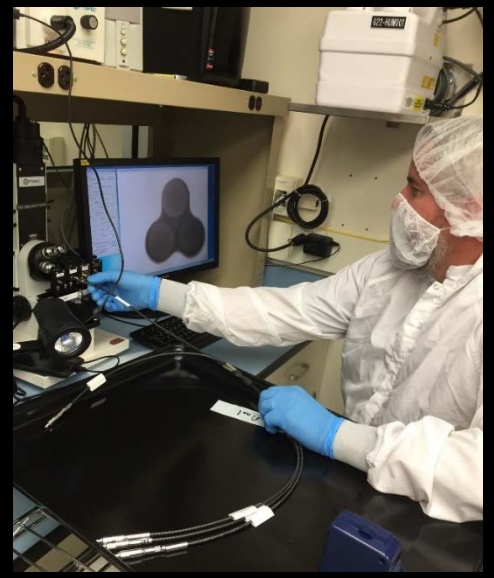
Integration

Materials Selection and Inspections



Environmental Testing

Manufacturing



One Stop Shopping for Concept through Delivery

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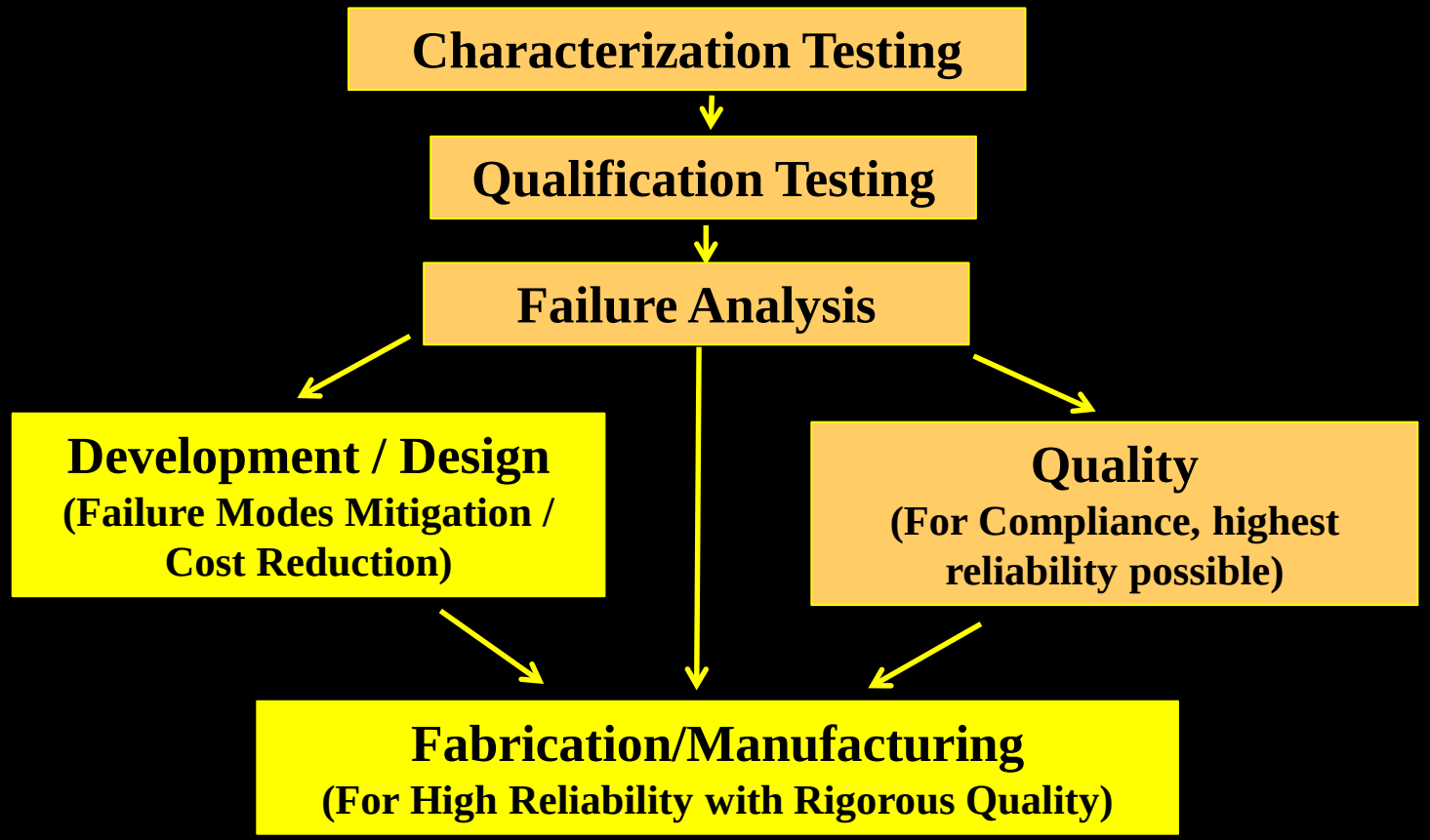
# How Do You Develop and Fabricate Hardware?




**Risk mitigation to reduce cost - use space flight component failure mode knowledge;**
**Design out what you can –through configuration; packaging, materials, processes, screening.**

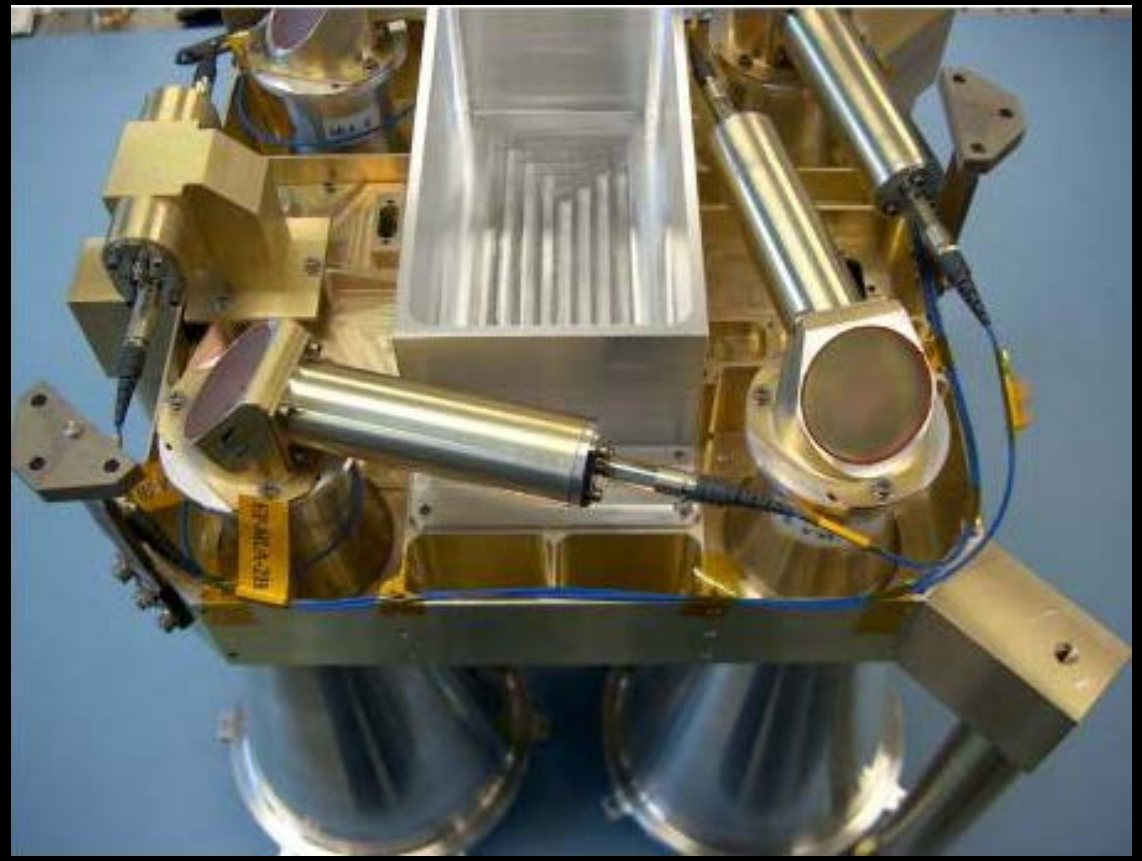
# Planetary and Earth Orbiting LIDARS

## Mercury

### Mercury Laser Altimeter on Mercury Surface, Space Environment, Geochemistry and Ranging

(MESSENGER); development 1999-2003, built by NASA Goddard Space Flight Center

Launch 2004, Operation 2011-2015 (travel time 7 years, 4 years usage, decommissioned in 2015)



**SPIE Vol. 5104**

# Planetary and Earth Orbiting LIDARS

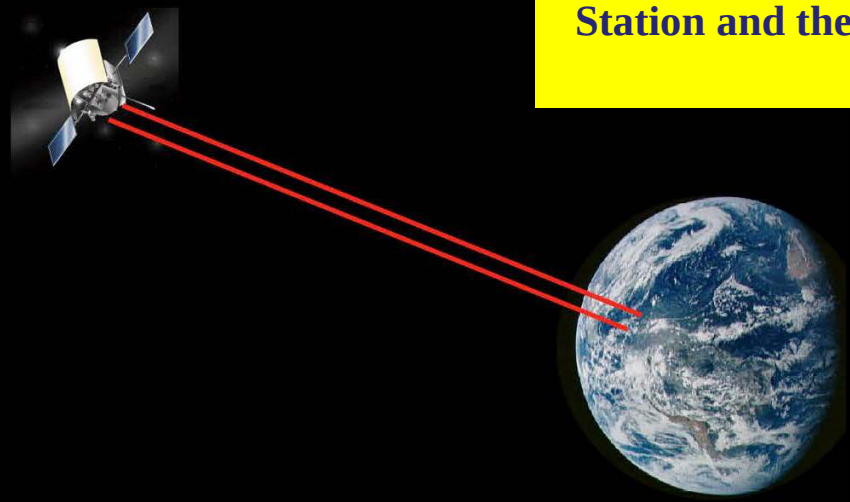
## Mercury

## 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

Smith, D. E., *et al.*, Two-way laser link over interplanetary distance, *Science*, 311, 5757, 53, Jan. 2006.



**On the way to Mercury a link between NASA GSFC Greenbelt Station and the MLA was established - Longest Laser Link in Space Flight @ 24 Million Km.**

**The success of this experiment led the way for the Laser Ranging investigation on the Lunar Reconnaissance Orbiter.**

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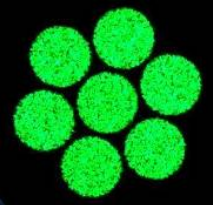
# Planetary and Earth Orbiting LIDARS
## The Moon

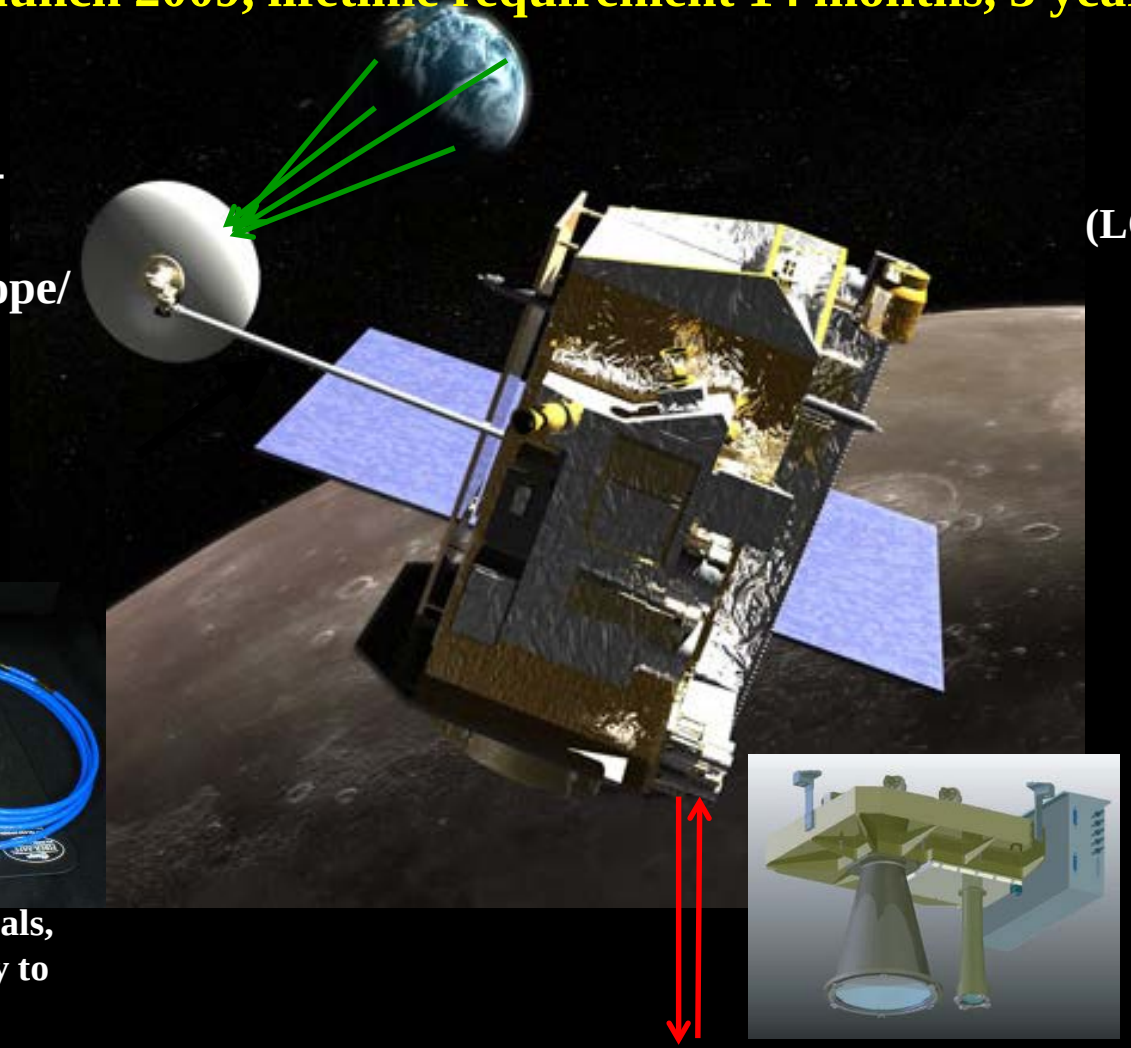
https://lunar.gsfc.nasa.gov

**Laser Ranging Experiment & Lunar Orbiter Laser Altimeter (LOLA) –Lunar Reconnaissance Orbiter (LRO) Developed 2005-2008; Launch 2009, lifetime requirement 14 months, 3 years desired, actual 8 years and counting…..**

**LASER RANGING @ 532 nm - Stations Around the World Transmitting to the receiver telescope/ 7 optical fiber array**

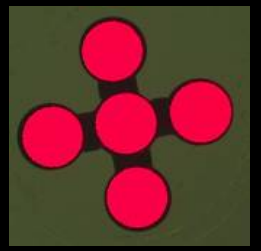


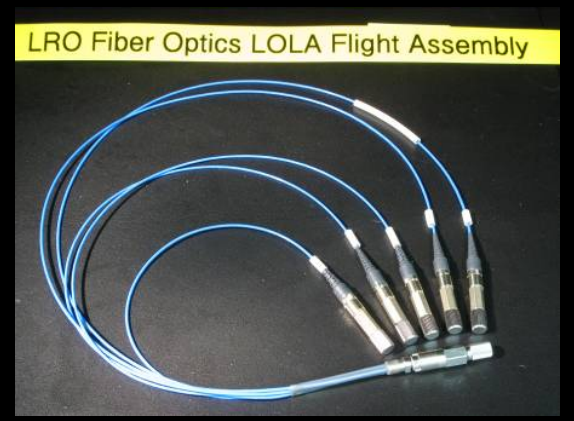

**The assemblies traverse two moving gimbals, and a deployable mandrel 10 meters away to LOLA.**





**Lunar Orbiter Laser Altimeter (LOLA) Measuring moon topography @ 1064 nm with a 5 fiber array**



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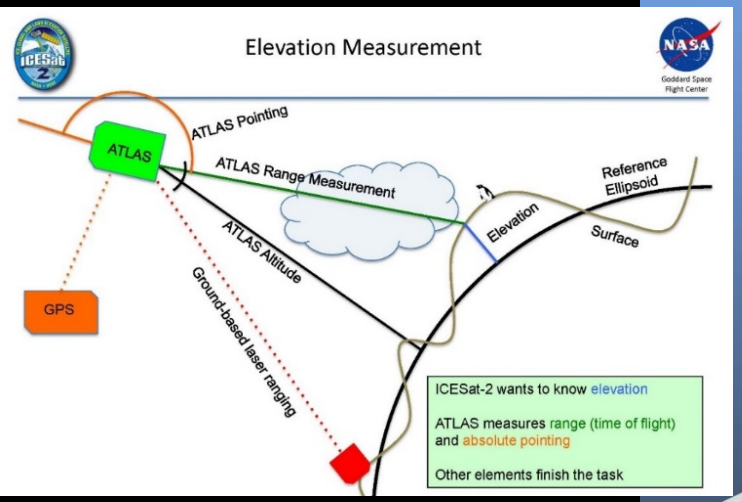
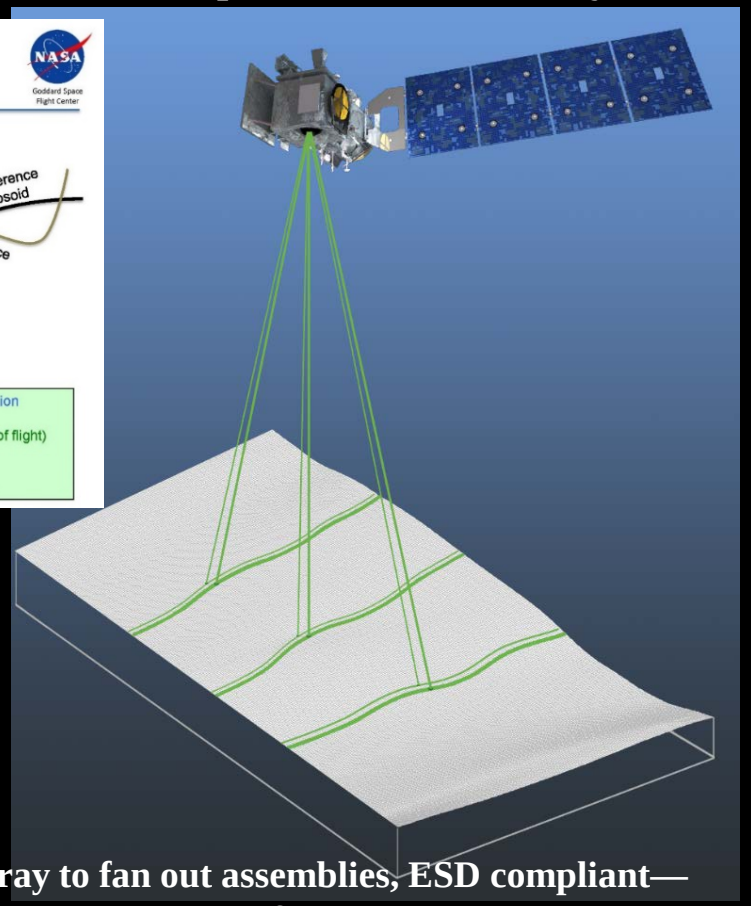
# Planetary and Earth Orbiting LIDARS
## Earth

https://icesat.gsfc.nasa.gov

Ice, Cloud and Land Elevation Satellite **(ICESat-2) – (ATLAS)** Advanced Topographic Laser Altimeter System (2012 – 2018)
Launched 2018, currently in operation. Expected lifetime > 3 years – measuring the height of sea ice to within an inch.




**ATLAS uses ranging measurements with 532 nm and has a sophisticated real time, calibration system.**



**25 simplex, 4 bundle/array to fan out assemblies, ESD compliant—**
**5 different types of fiber; dual and quad fiber arrays; 52 interconnections.**
**Commercial LED - on board calibration system**
**Fibertek lasers**

**Melanie Ott (fiber system lead) inspecting the final flight configuration for fiber optic system. Transmission requirement of >98% for optical fiber receiver system.**

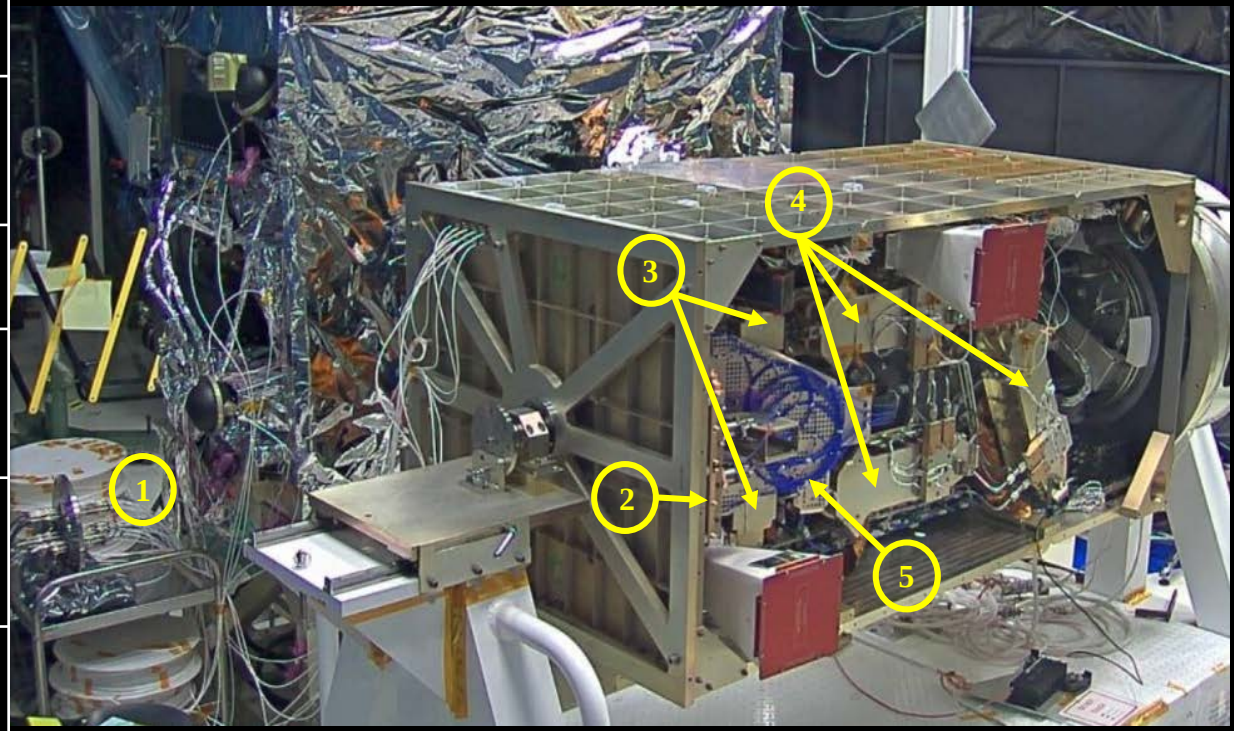
Reference: http://icesat.gsfc.nasa.gov

# Planetary and Earth Orbiting LIDARS
# Earth

## GEDI: Global Ecosystem Dynamics Investigation LIDAR (2016-2018)

Launched Dec 2018, operating currently on International Space Station

| # | GEDI Subsystem | Hardware Deliveries |
|---|---|---|
| 1 | Checkout Equipment | Development, fabrication & integration: laser & detector test rack used for qualification of flight instrument, TVAC fiber assemblies down to -120°C. |
| 2 | Detector Qualification | Qualification of engineering & flight unit detectors |
| 3 | Laser Beam Dithering Unit | Development, fabrication, qualification & integration of engineering and flight units |
| 4 | Optical Laser Components | Development, qualification & fabrication of flight laser fiber optic feedthrough. Incoming inspection of laser components. |
| 5 | Flight Fiber Optic System | Development, qualification & integration of flight 600/600µm fiber optics transmission >97%; 200/220µm triple fiber arrays for start pulse. Adapter inspections and screening. |



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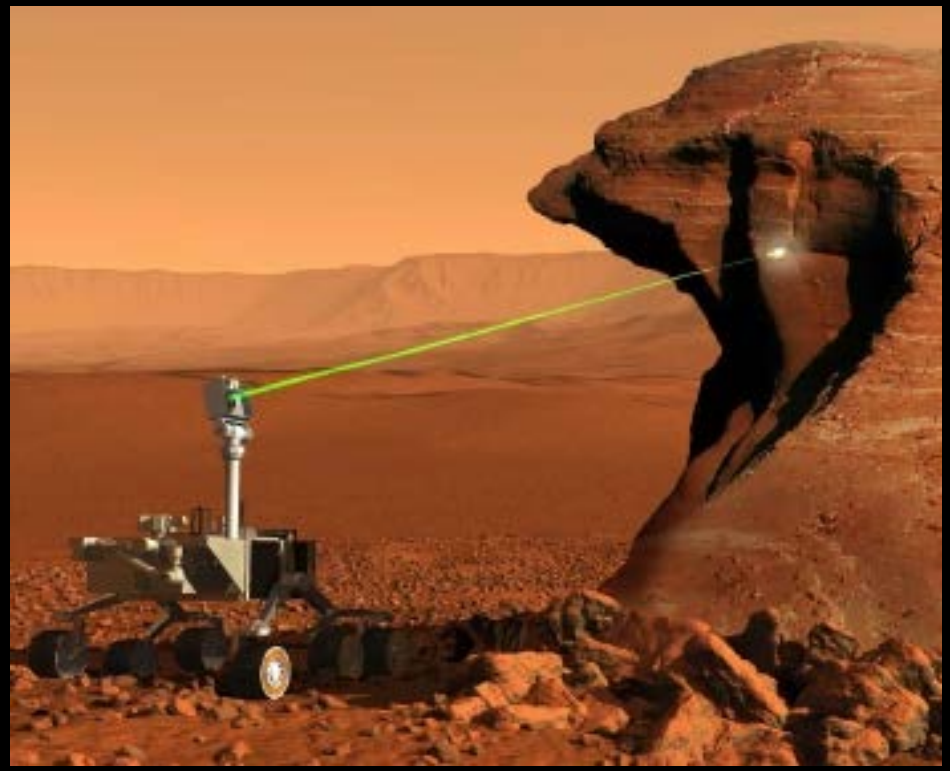
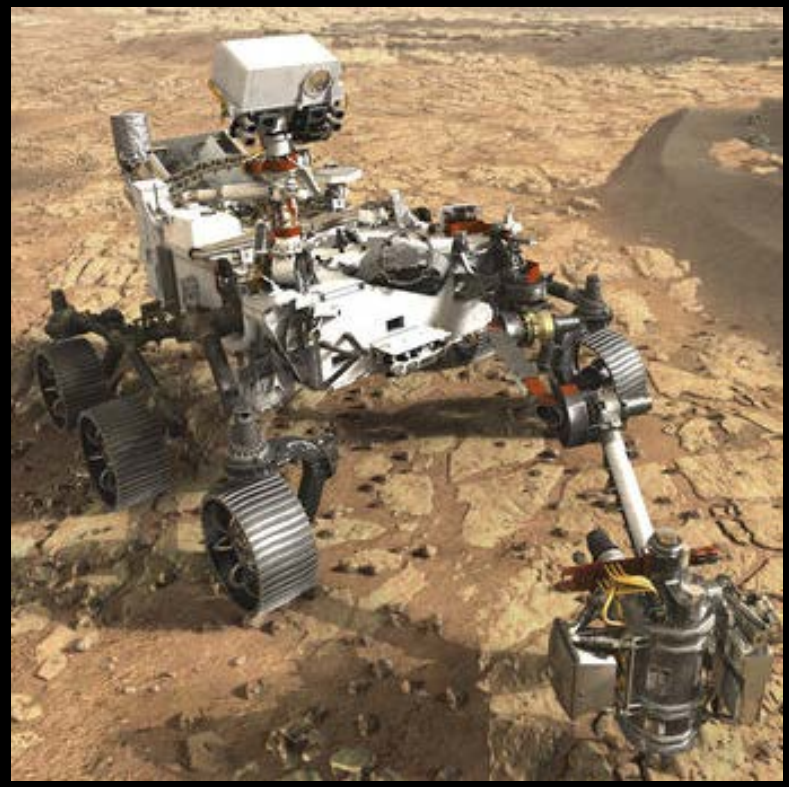
# Science, Rovers and Communications
## Mars

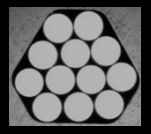


Mars Curiosity Rover; ChemCam Instrument
Launch Nov. 2011,
currently in operation.

Hali Jakeman inspects the flight Mars2020 assemblies



Mars 2020 Rover, SuperCam Instrument
Currently in integration and test.



**Development, fabrication, qualification of flight hardware delivery for JPL**

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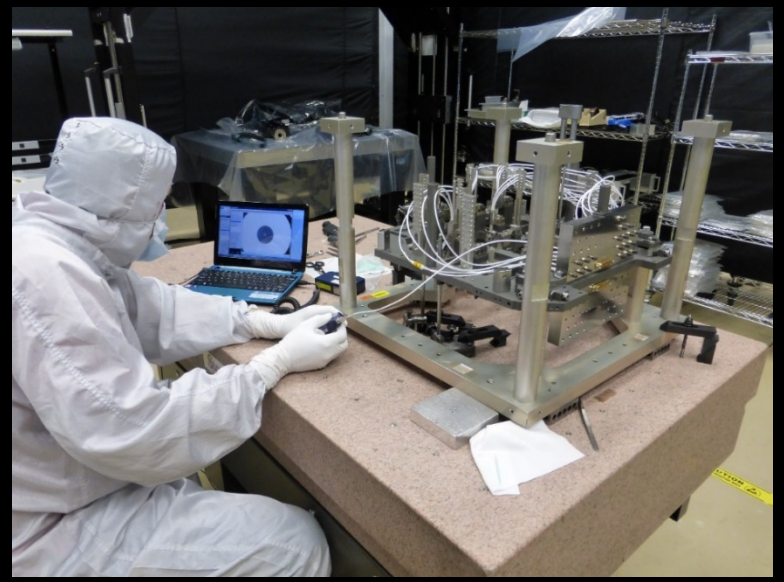
# Science, Rovers and Communications

**Communications: Multimode and Singlemode**;

- Express Logistics Carrier on International Space Station. – Qualification of transceivers, fiber optic assemblies (2006 – 2010)
- Lunar Laser Communications Demonstration for MIT LL (2010)
- Communications for Cloud Aerosol Transport System; cats.gsfc.nasa.gov (2014) w/ FiberTek, Micropac
- Laser Communications Relay Demonstration; Screening and qualification (laser diodes & photonic components) (2014); Gooch & Housego

**Science: Infrared, and/or polarization maintaining, single and multimode, thermal vacuum and cryogenic applications:**

- James Webb Space Telescope; Ball Aerospace, Johnson Space Center & GSFC. (2008-2018)



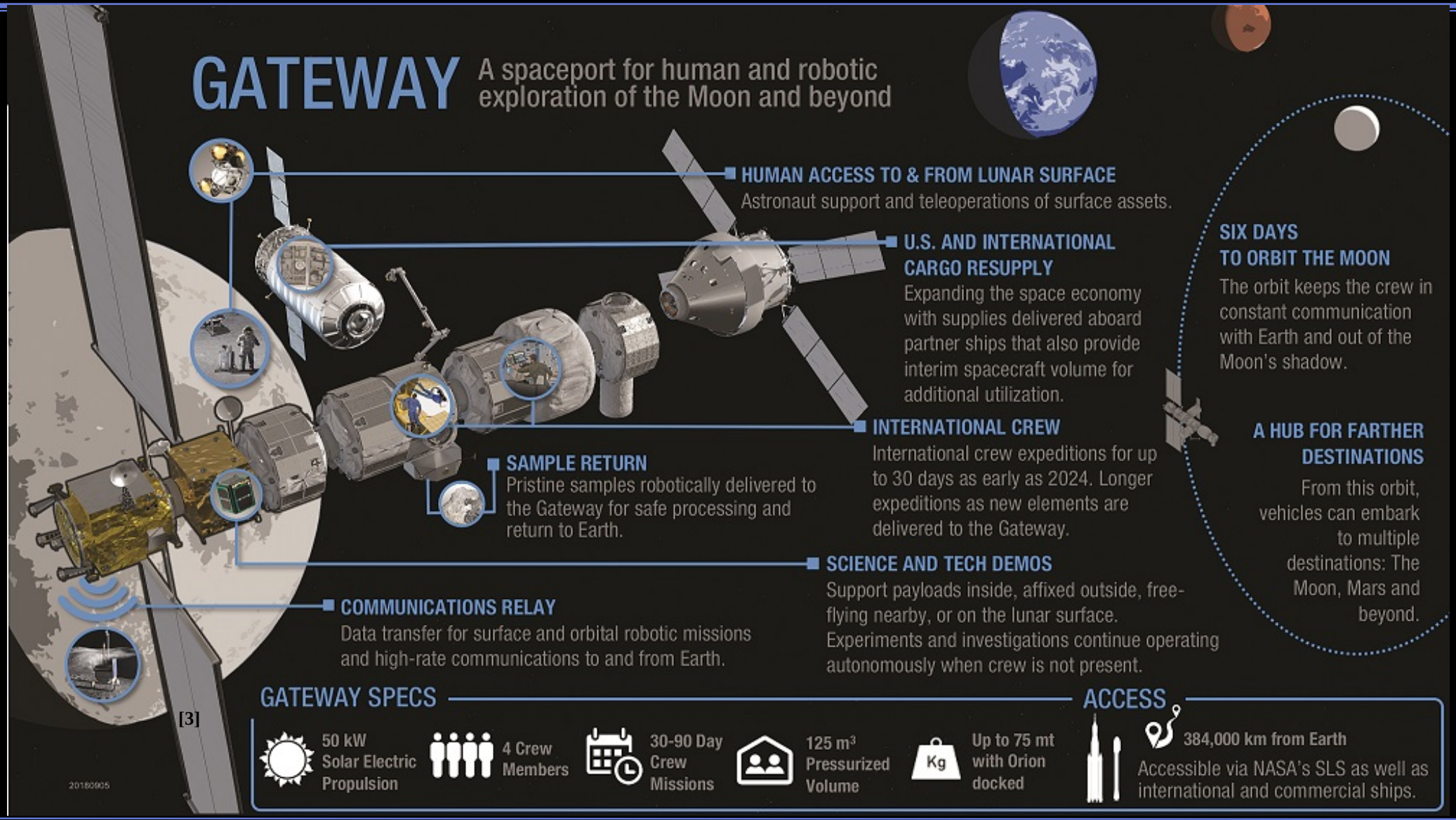
**Rob S. @ Ball installs cryo assemblies**

**Eleanya Onuma installs vacuum feedthroughs**

**Rob Switzer and Melanie Ott,**
**ELC integration @ Kennedy Space Center**

# The Future Perspective

https://spacenews.com/is-the-gateway-the-right-way-to-the-moon/

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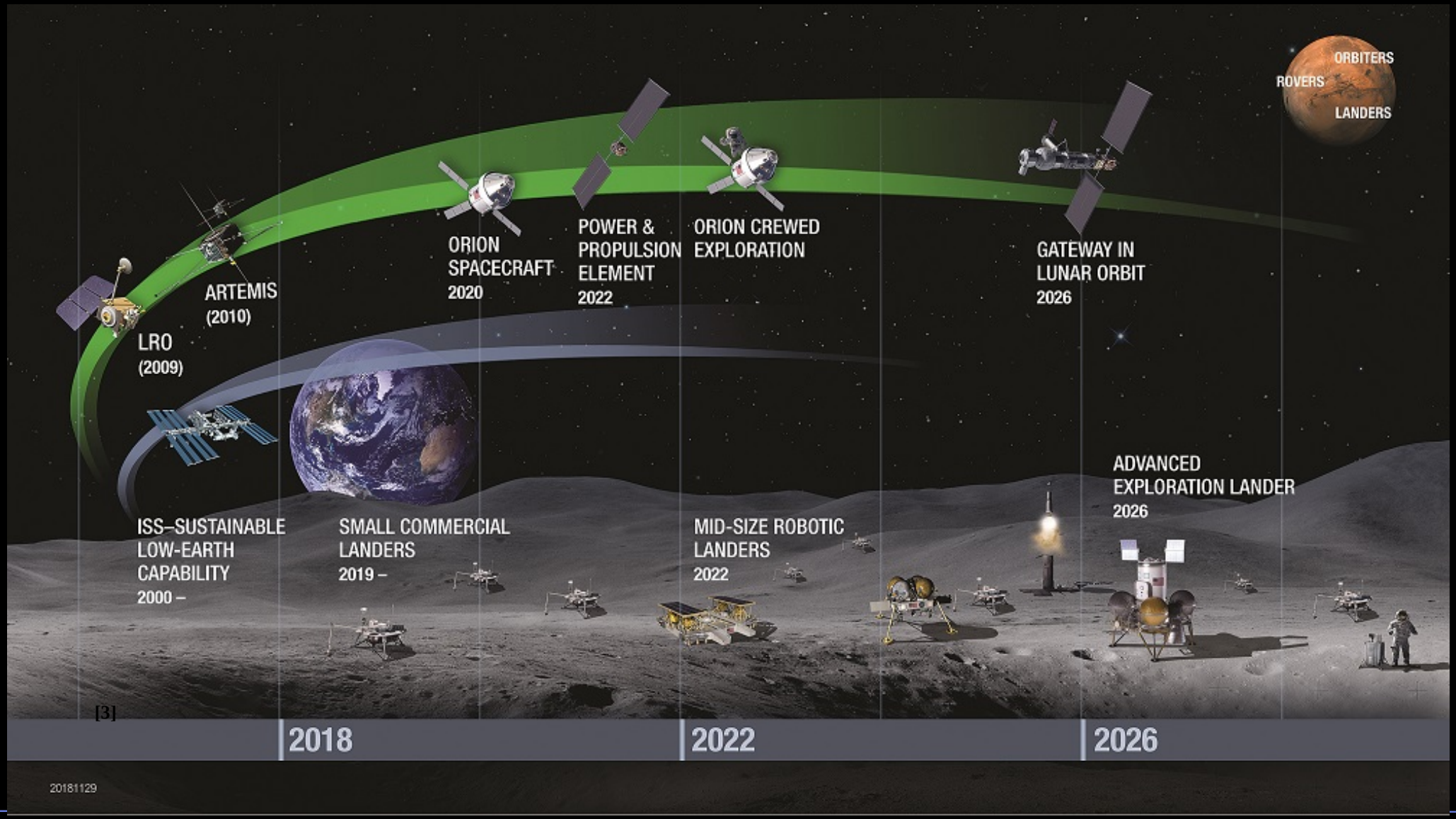
# Gateway Roadmap

https://spacenews.com/is-the-gateway-the-right-way-to-the-moon/

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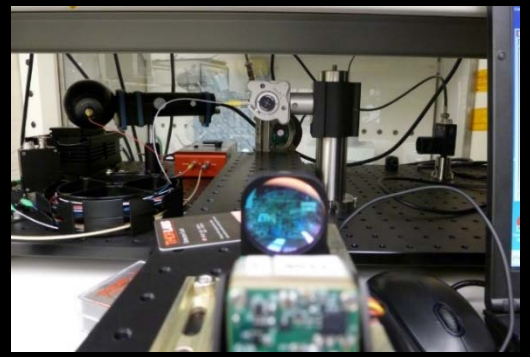
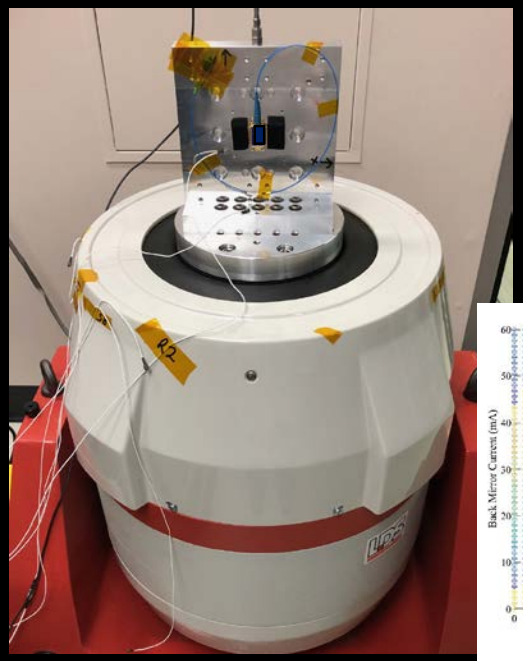


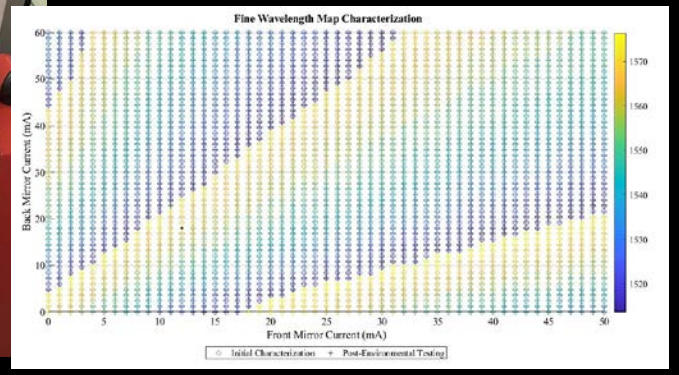

COTS LiDARs for Lander Autonomy

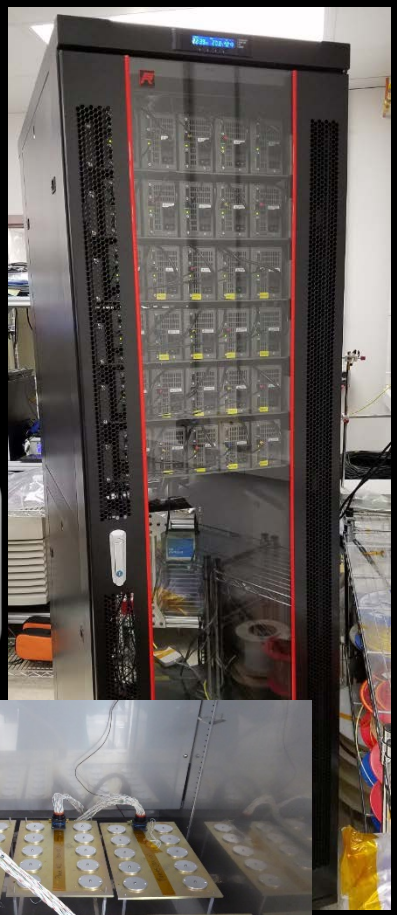
**Qualifying Optoelectronics & Photonics for Space**

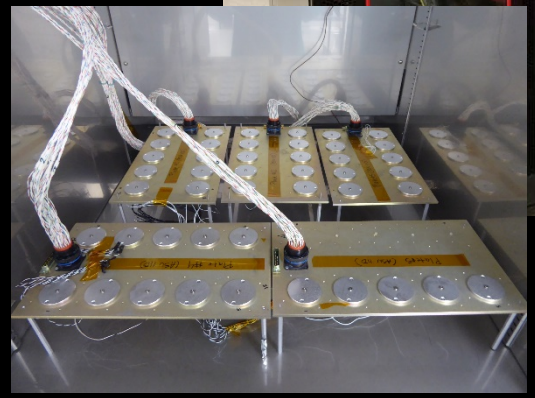
Tunable Lasers for Orbiter Communications

Detectors for Rover Spectroscopy

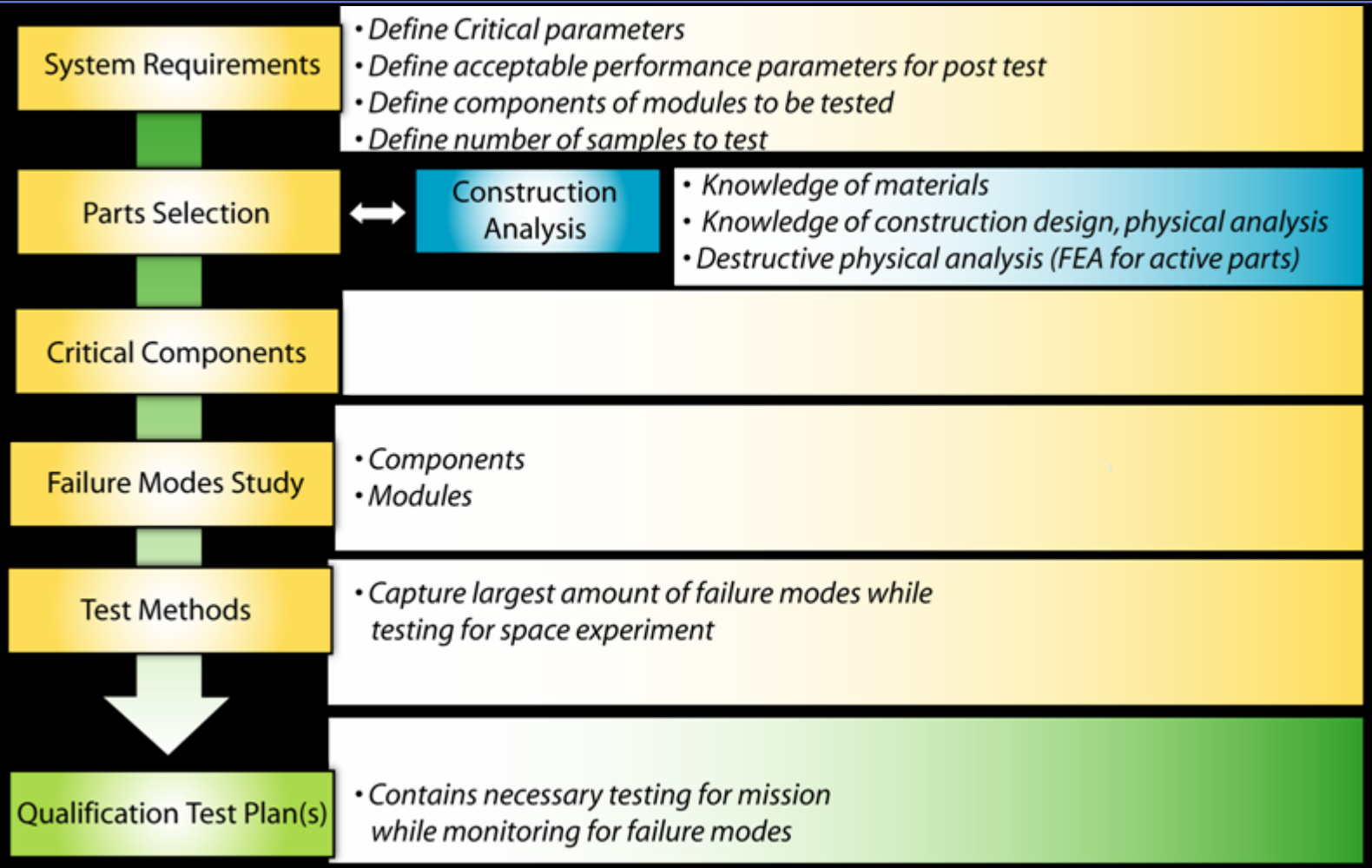




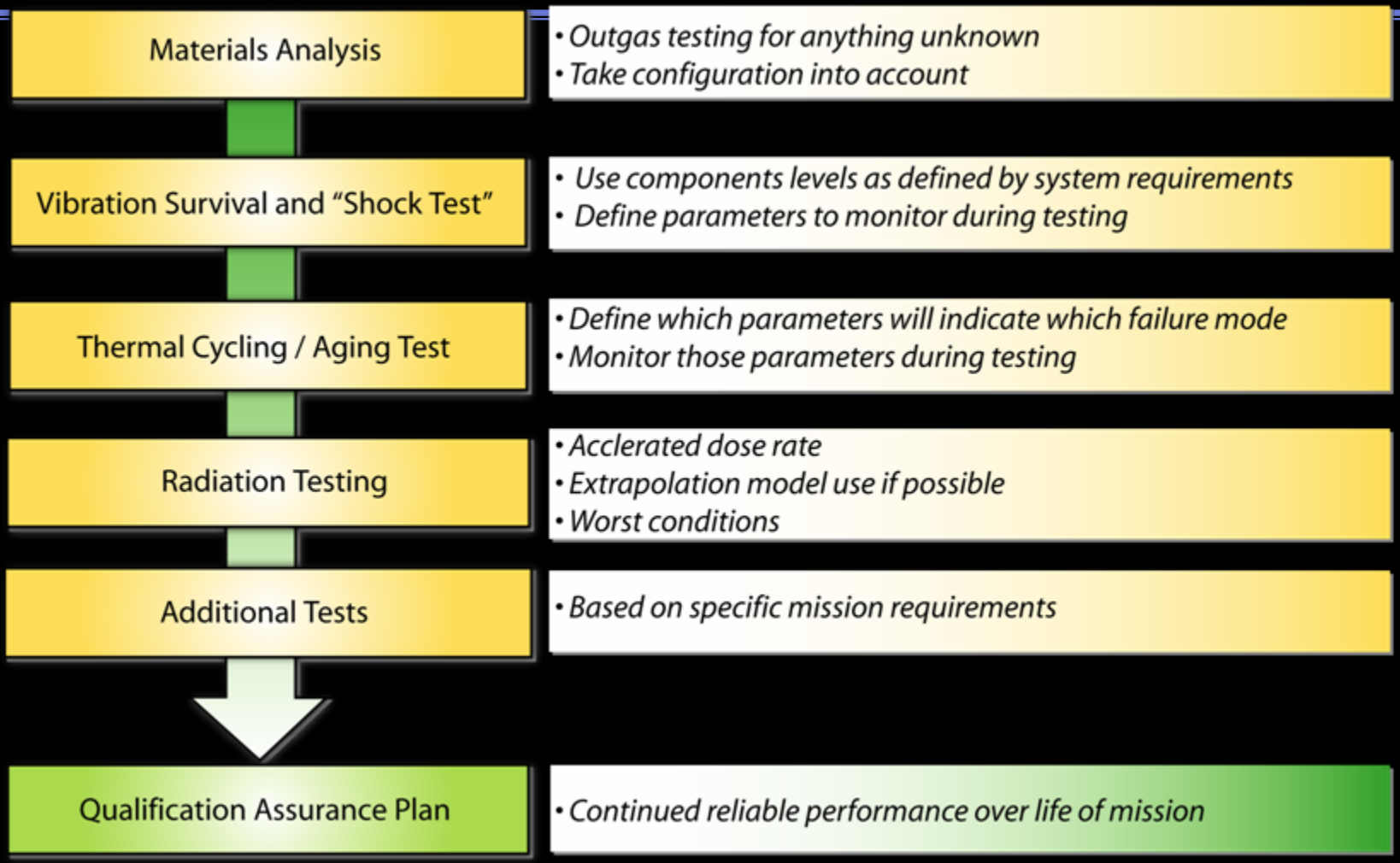


# COTS Technology Assurance Approach




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

# COTS Space Flight "Qualification"




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

**We perform selection, test and qualification of laser components the way the Parts Lab supports EEE parts.**

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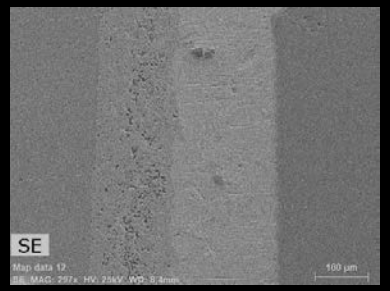
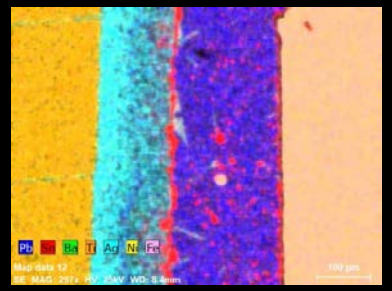
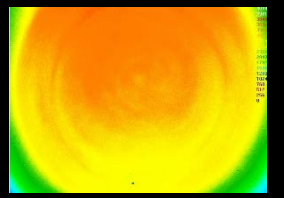
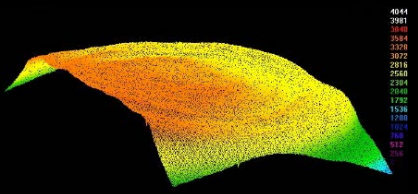


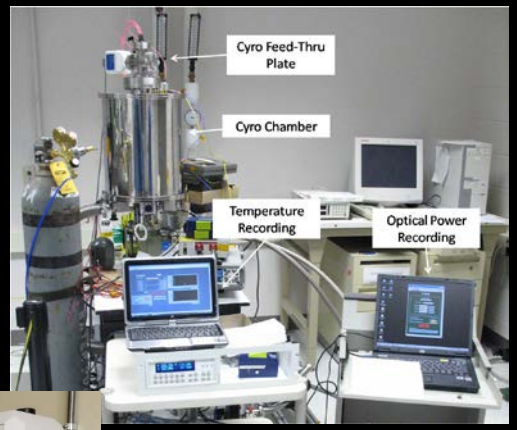



10 k X Mag SEM & Material Identification





LED Beam Profile




Cryogenic Test Facility

**ASTM-E595: 300 mg, 125°C, $10^{-6}$ Torr, 24 Hr**

**Materials Screening / Construction Analysis**

**Optical Inspection & Screening**

**Performance Characterization**

**Vibration / "Shock" Testing**

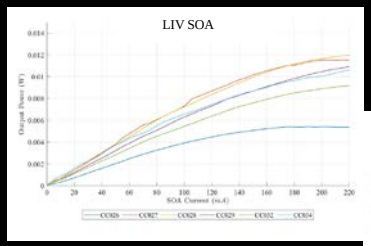
**Thermal Cycling / Vacuum**

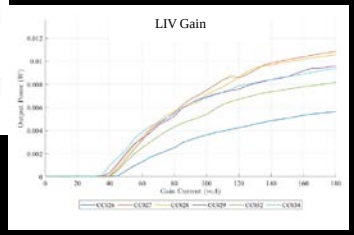
**Radiation Testing**

**Additional Testing?**

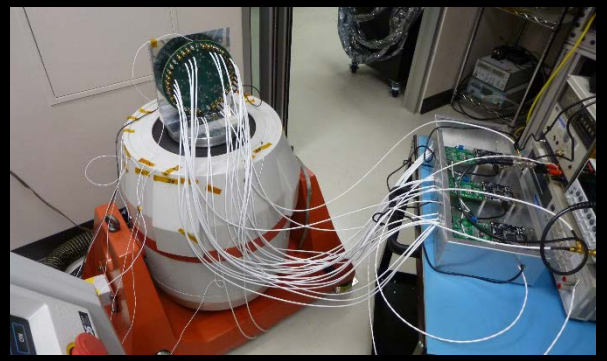
Radiation Test Equipment


White Light LED Testing in Environmental Chamber




Optical Power, Current, Voltage Characterization

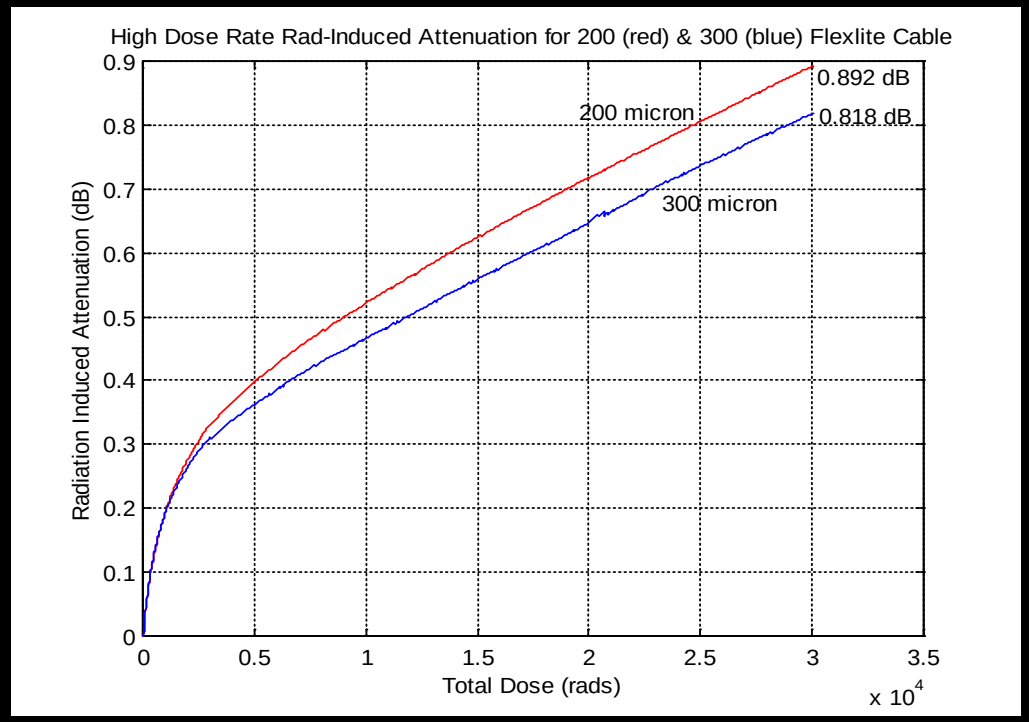


Random Vibration Test & Shock Equipment

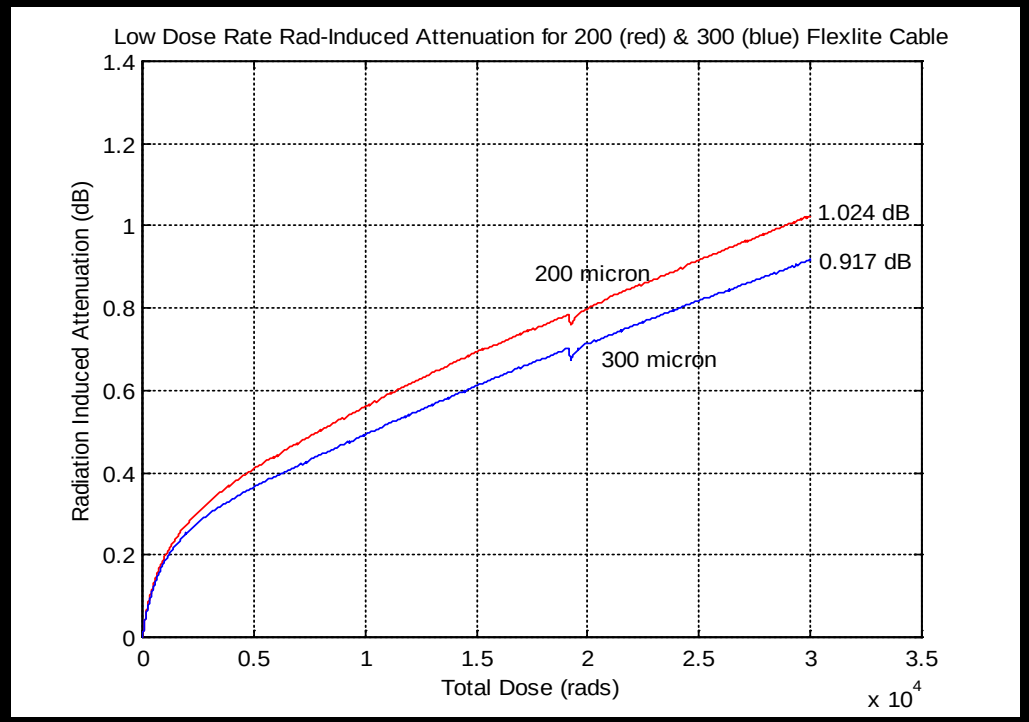
# Total Dose Radiation Performance

## Not usually a detriment but for calibration purposes is always necessary;

## Example Mercury Laser Altimeter Optical Fiber Radiation Data




Flexlite Radiation Test, 22.7 rads/min at –18.3°C




Flexlite Radiation Test, 11.2 rads/min at –24.1°C

**Radiation Conclusion: < .07 dB, using 11.2 rads/min, -24.1°C, 26.1 in, "dark"**
**Results for 10 m, at 30 Krads, -20°C, 850 nm, 23 rads/min ~ 1 dB or 0.10 dB/m**

# Thank You to Our Partners!
## (not all are listed here)


**And thank you for your time.**