CODE 562
PHOTONICS
Goddard Space Flight Center

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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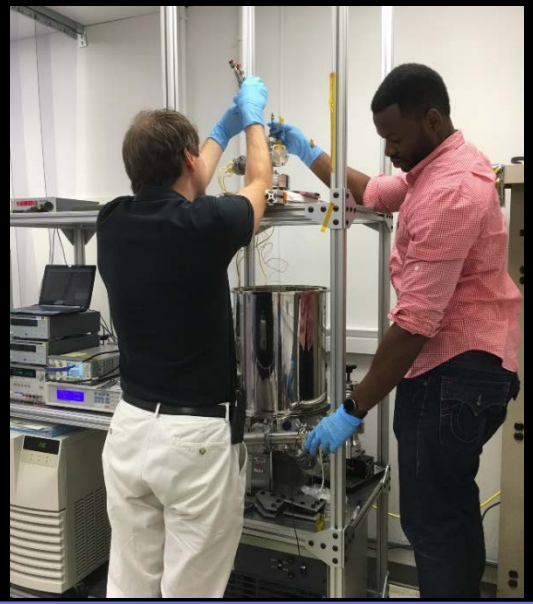
Custom Spaceflight Optical & Optoelectronic Subsystems using Commercial Components

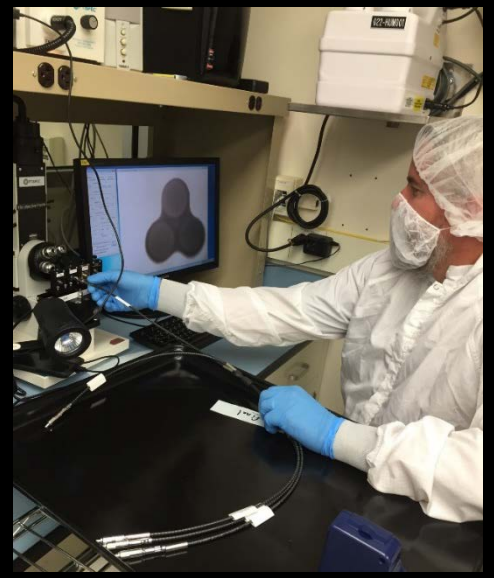
Integration

Materials Selection and Inspections



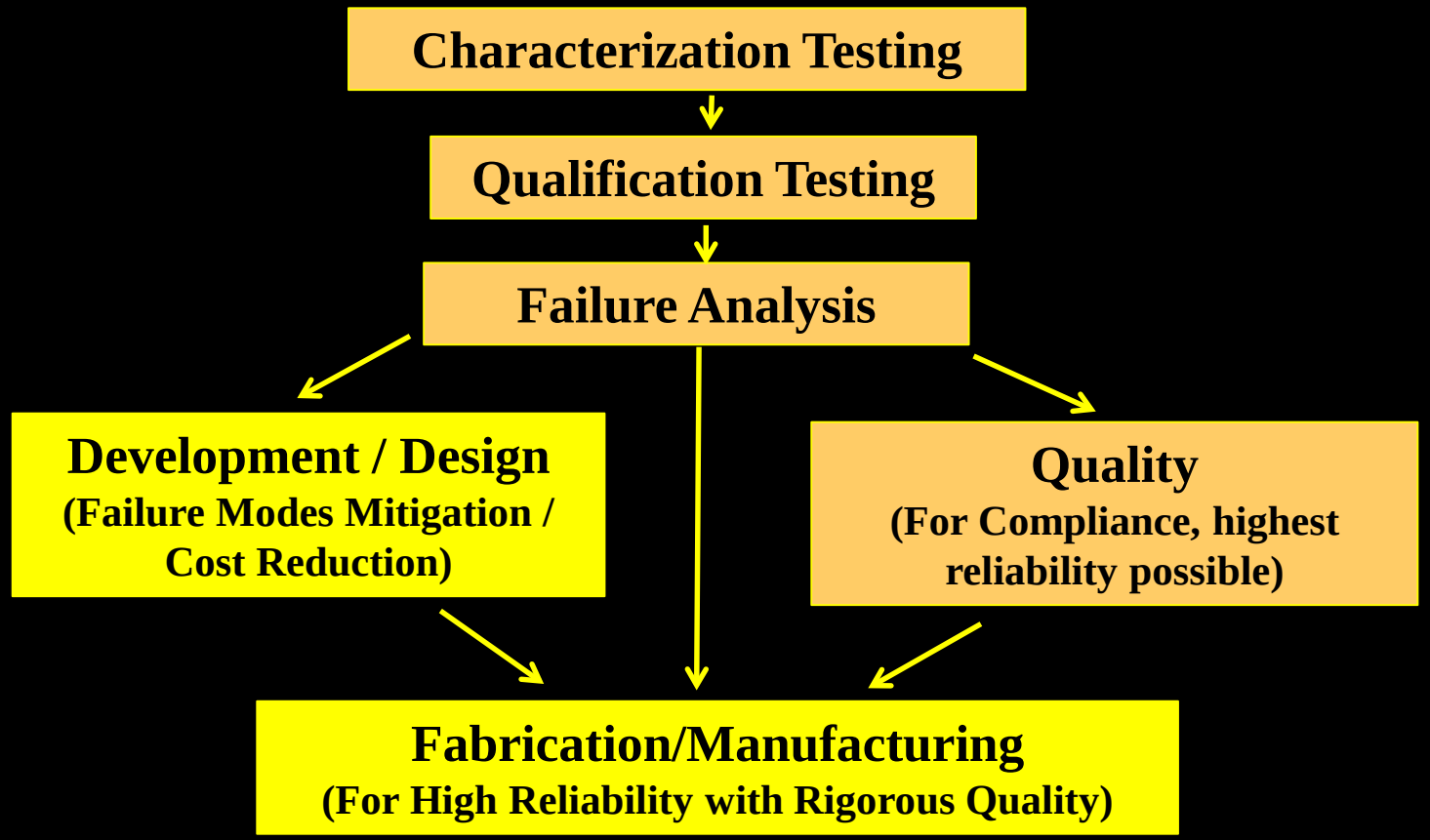
Environmental Testing

Manufacturing



One Stop Shopping for Concept through Delivery

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.

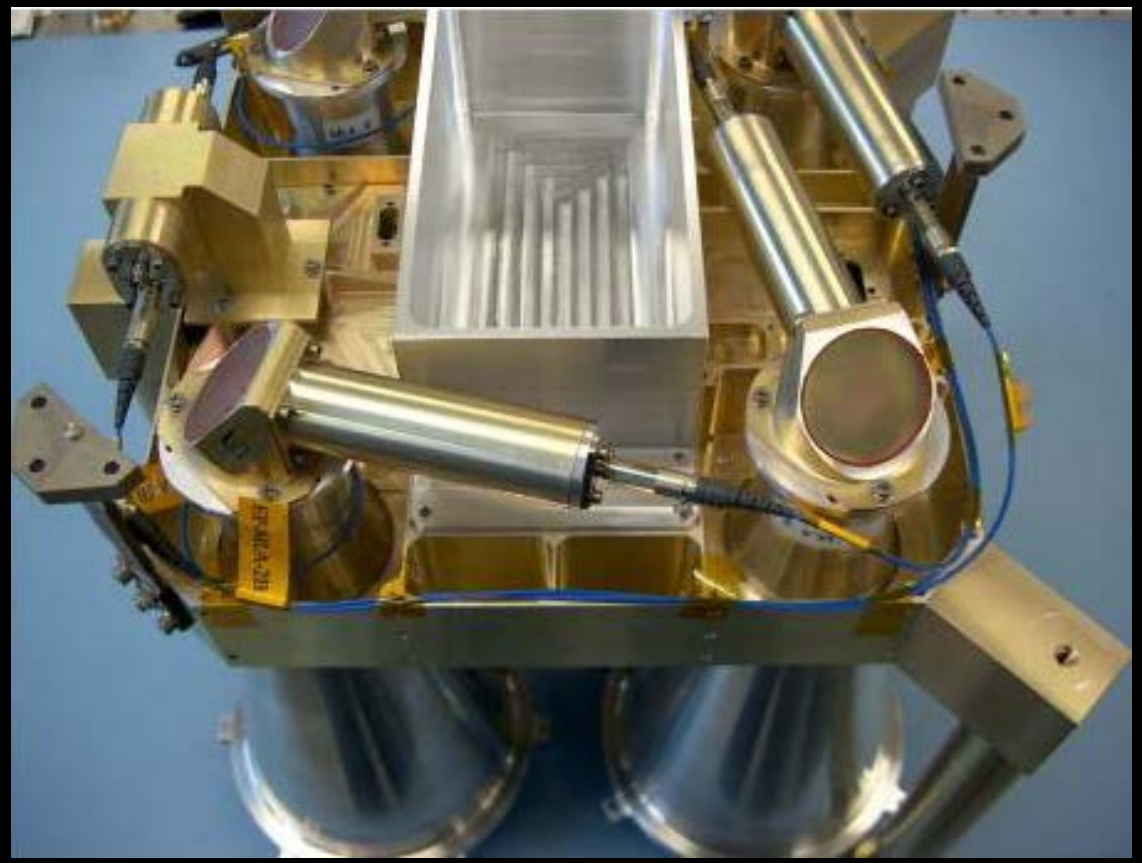
Planetary and Earth Orbiting LIDARS

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)



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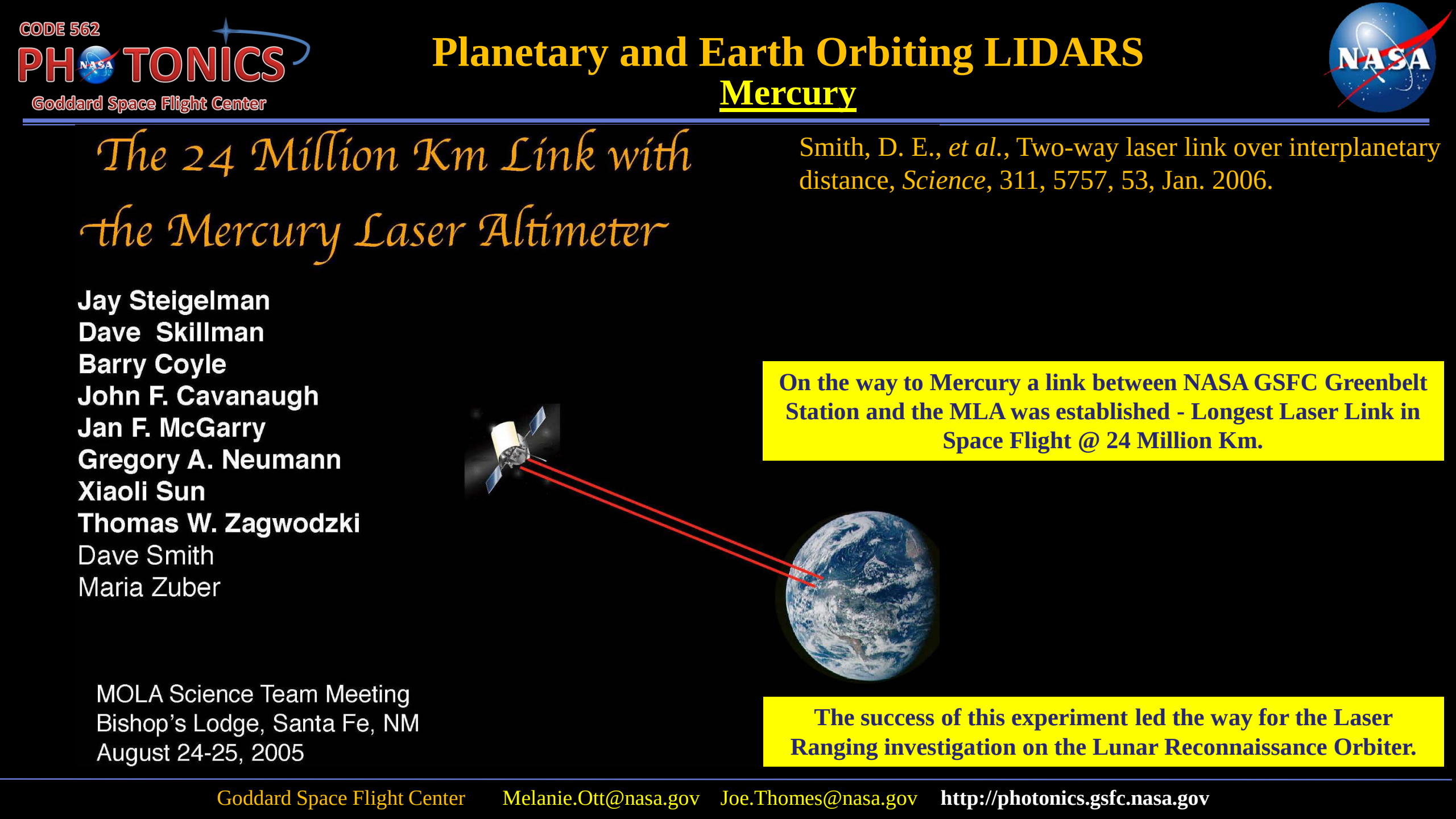
Planetary and Earth Orbiting LIDARS

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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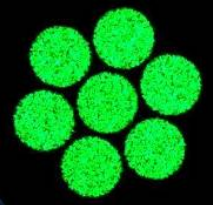
Planetary and Earth Orbiting LIDARS
The Moon

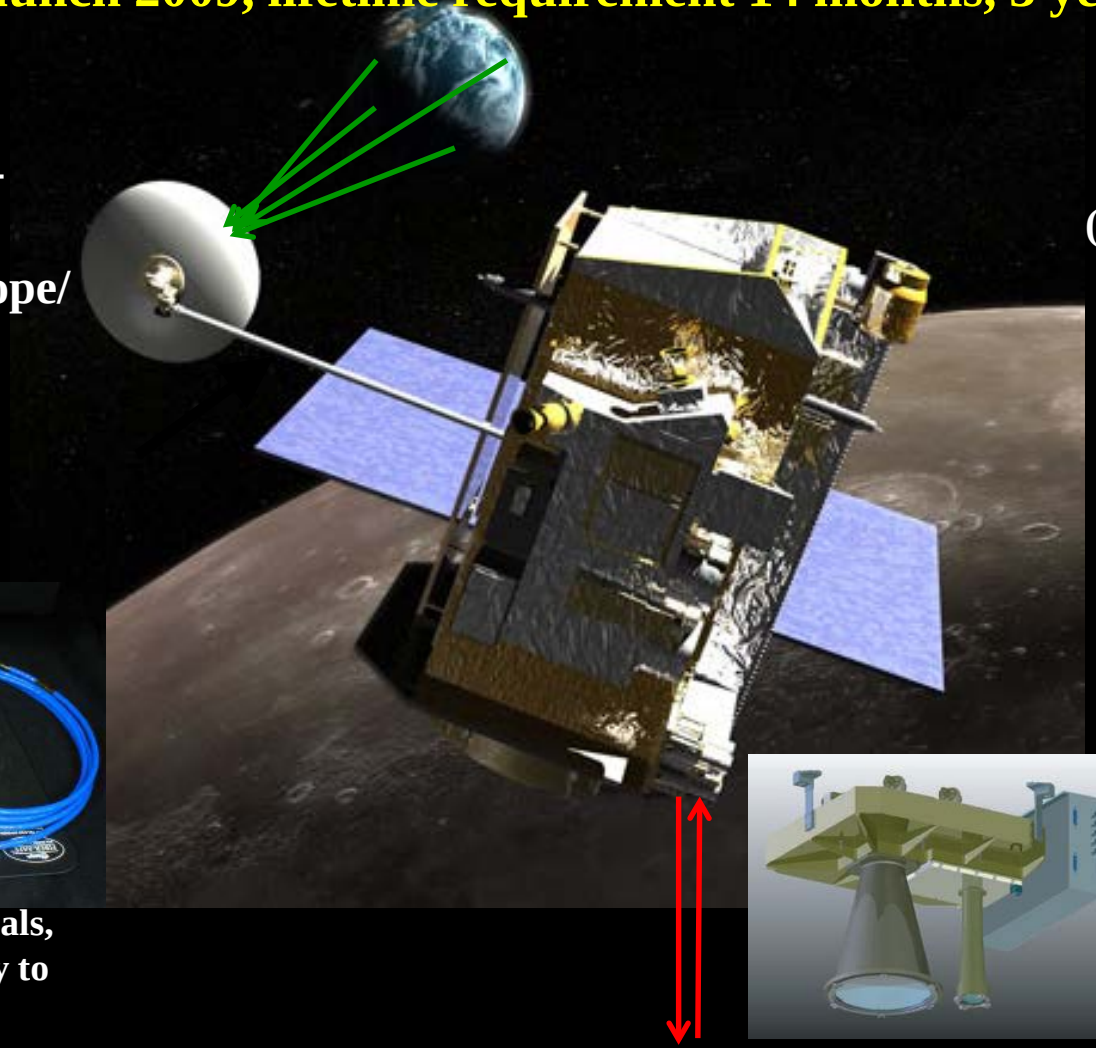
https://lunar.gsfc.nasa.gov

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…..

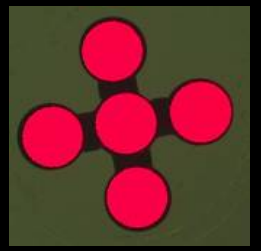
LASER RANGING @ 532 nm - Stations Around the World Transmitting to the receiver telescope/ 7 optical fiber array

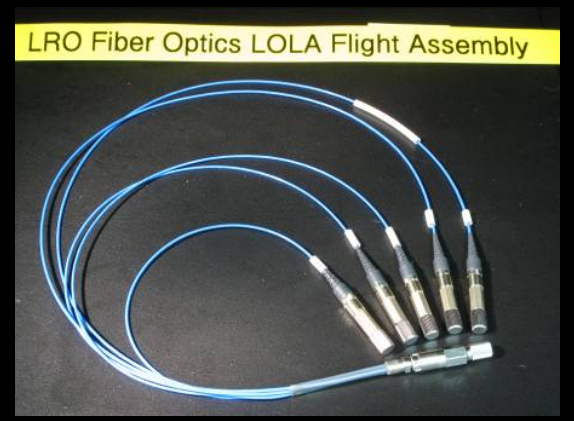


The assemblies traverse two moving gimbals, and a deployable mandrel 10 meters away to LOLA.



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





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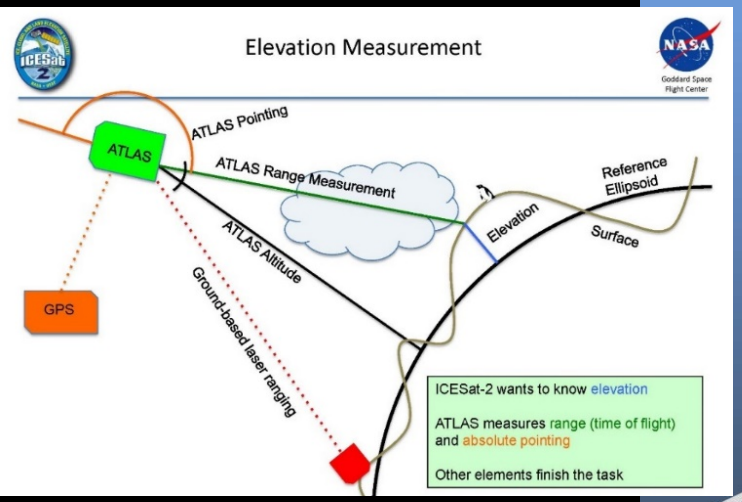
Planetary and Earth Orbiting LIDARS

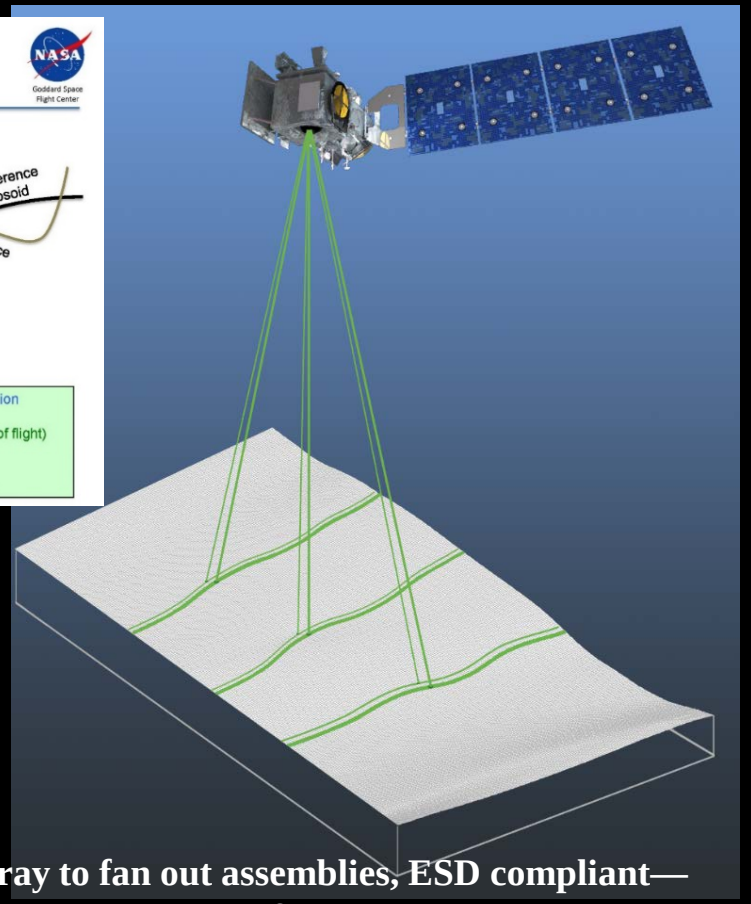
Earth

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.

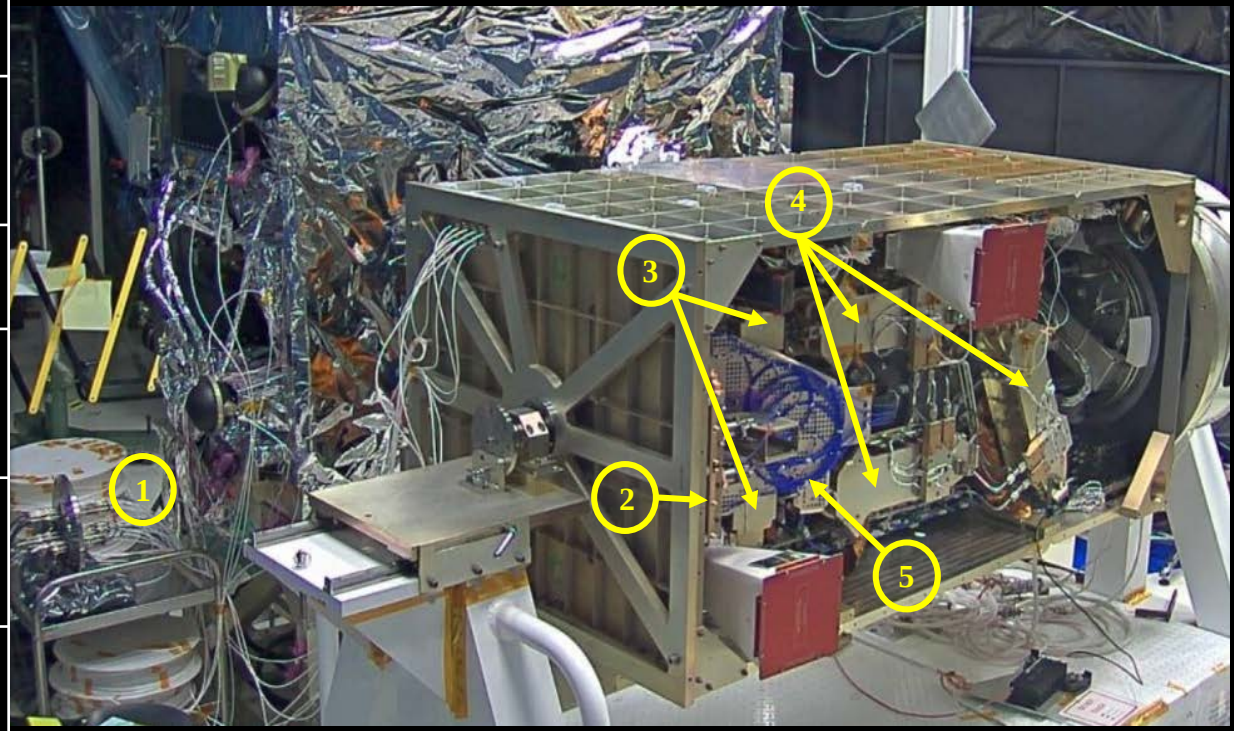
Reference: http://icesat.gsfc.nasa.gov

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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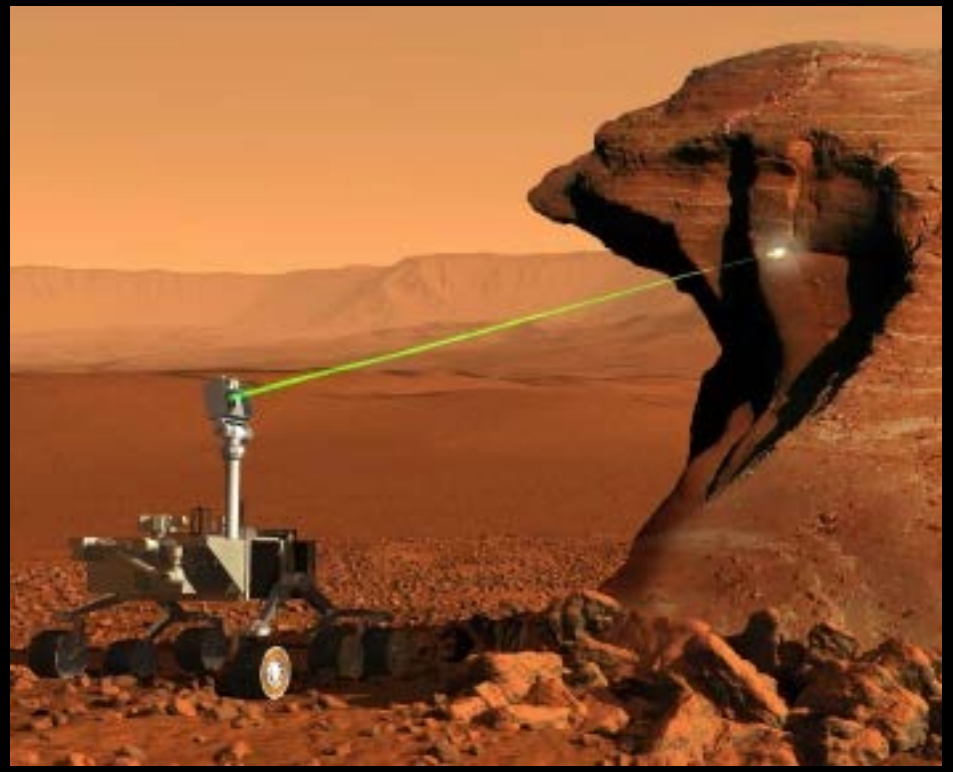
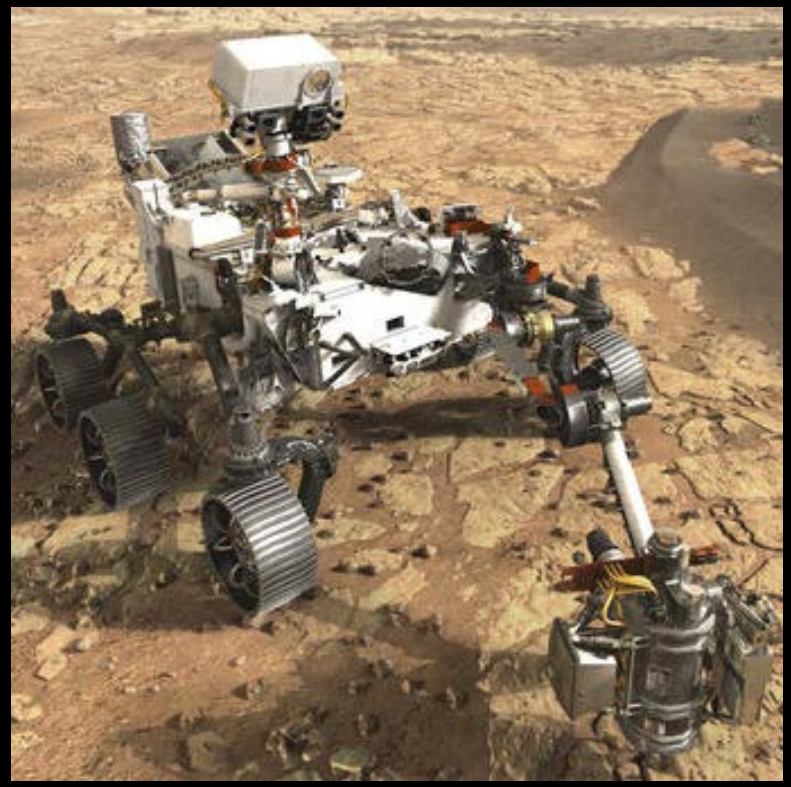
Science, Rovers and Communications
Mars

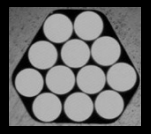


Mars Curiosity Rover; ChemCam Instrument
Launch Nov. 2011,
currently in operation.

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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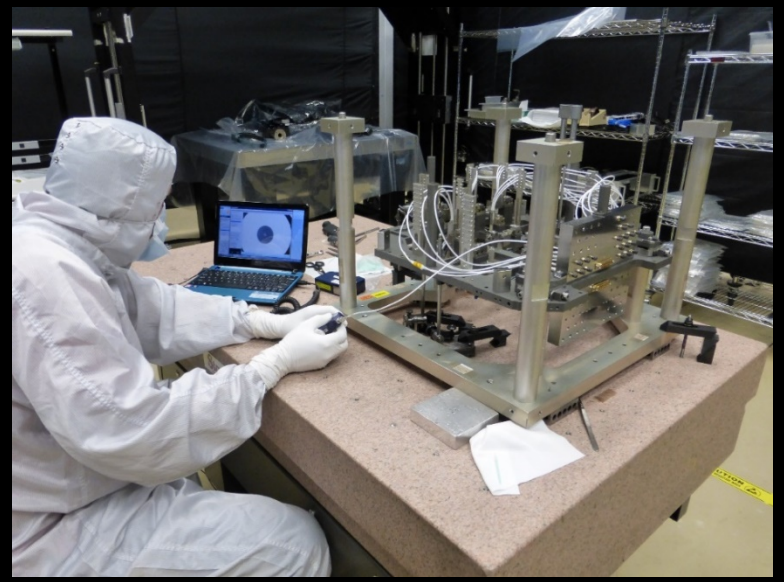
Science, Rovers and Communications

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)



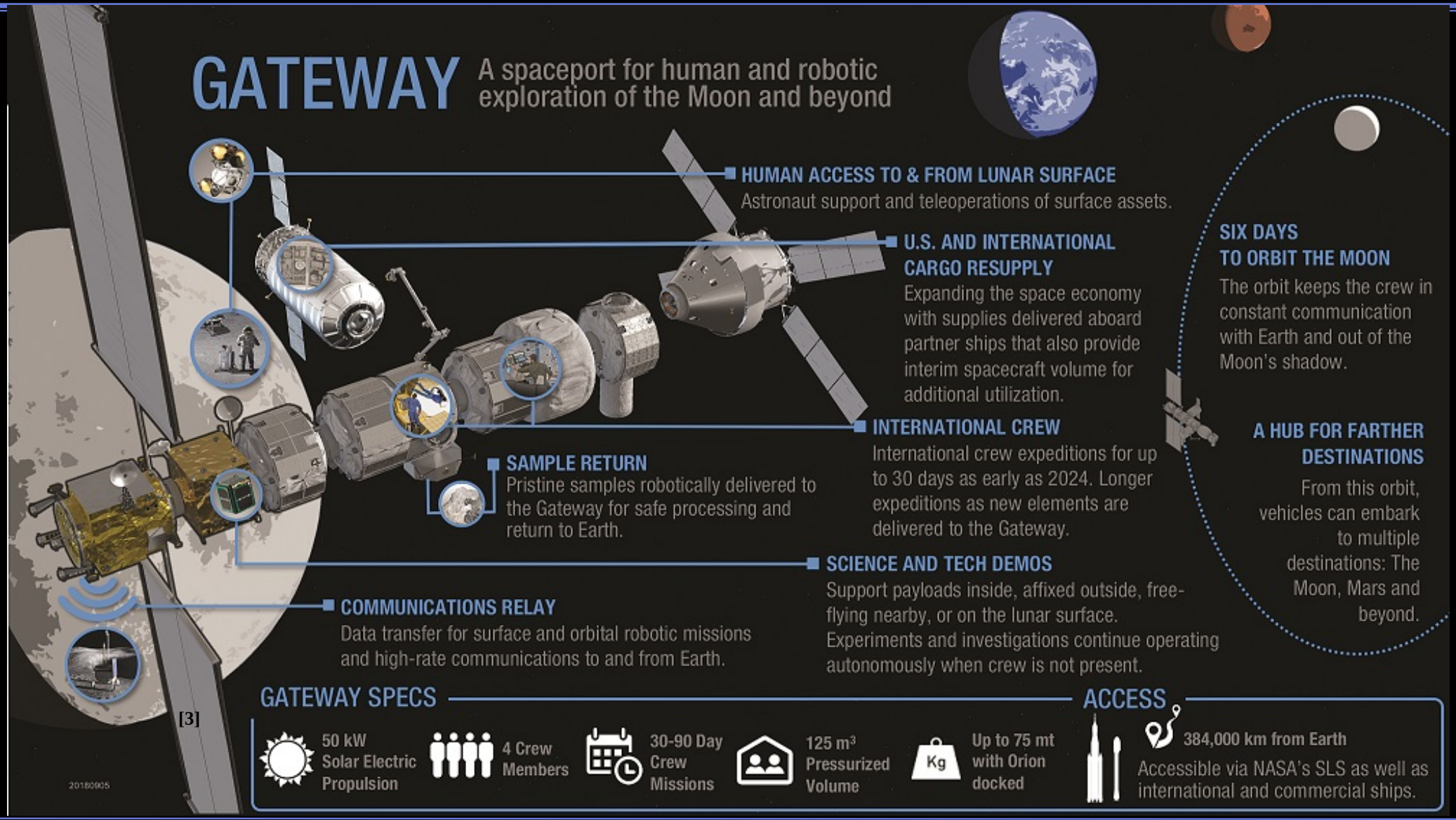
Rob S. @ Ball installs cryo assemblies

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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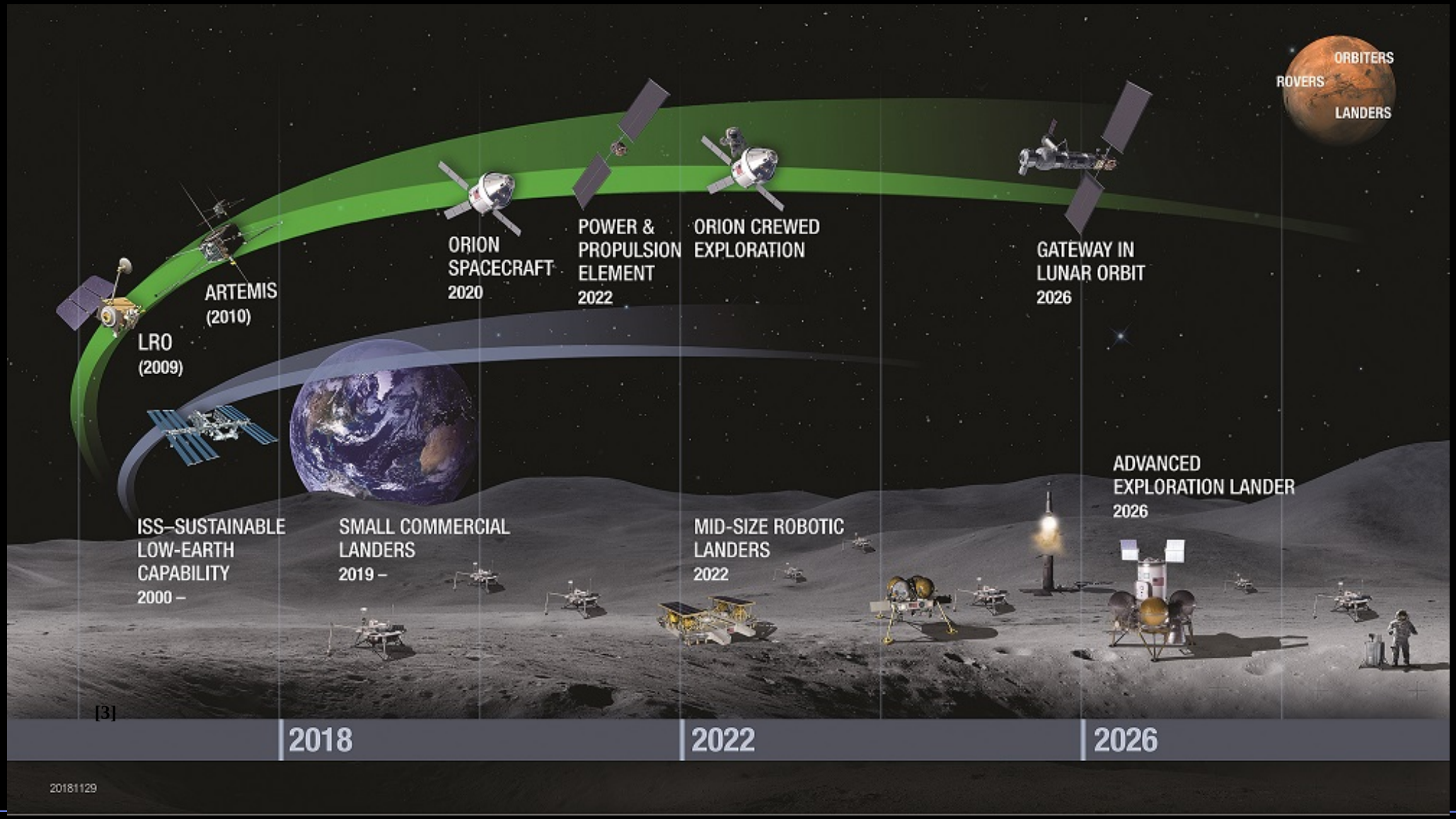
Gateway Roadmap

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



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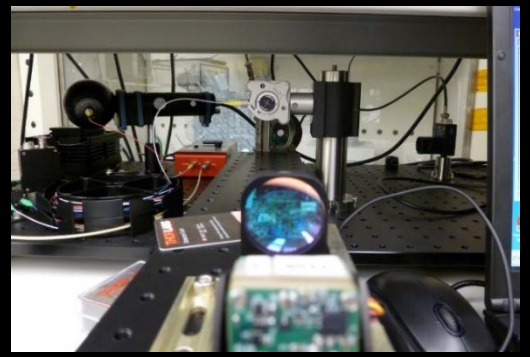
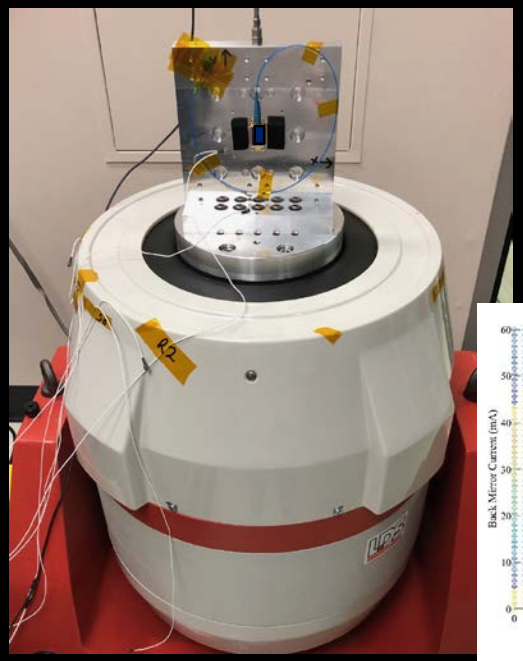


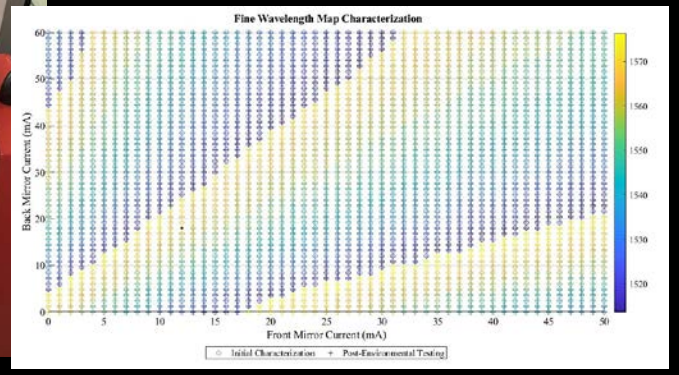
COTS LiDARs for Lander Autonomy

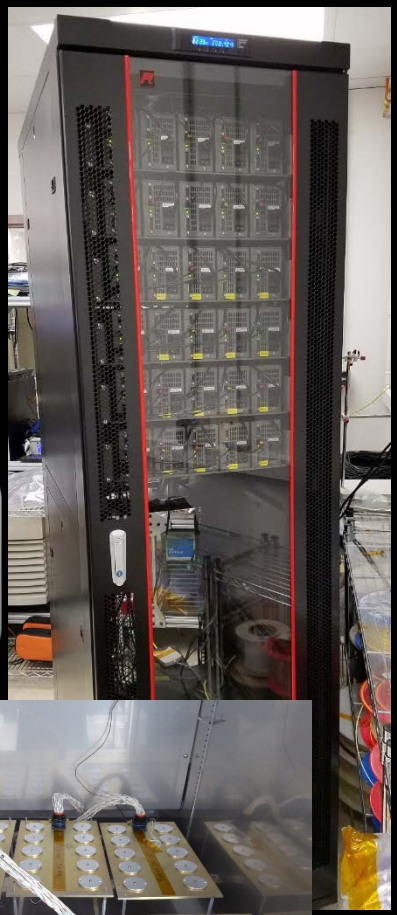
Qualifying Optoelectronics & Photonics for Space

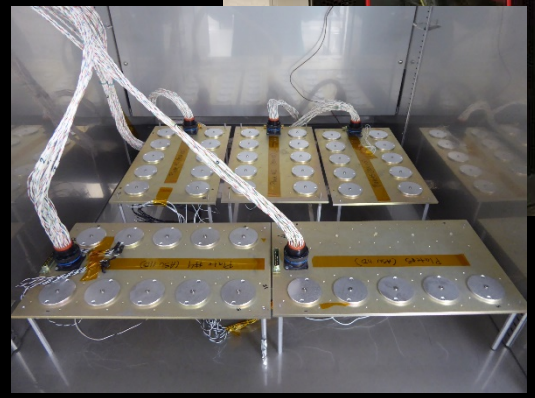
Tunable Lasers for Orbiter Communications

Detectors for Rover Spectroscopy

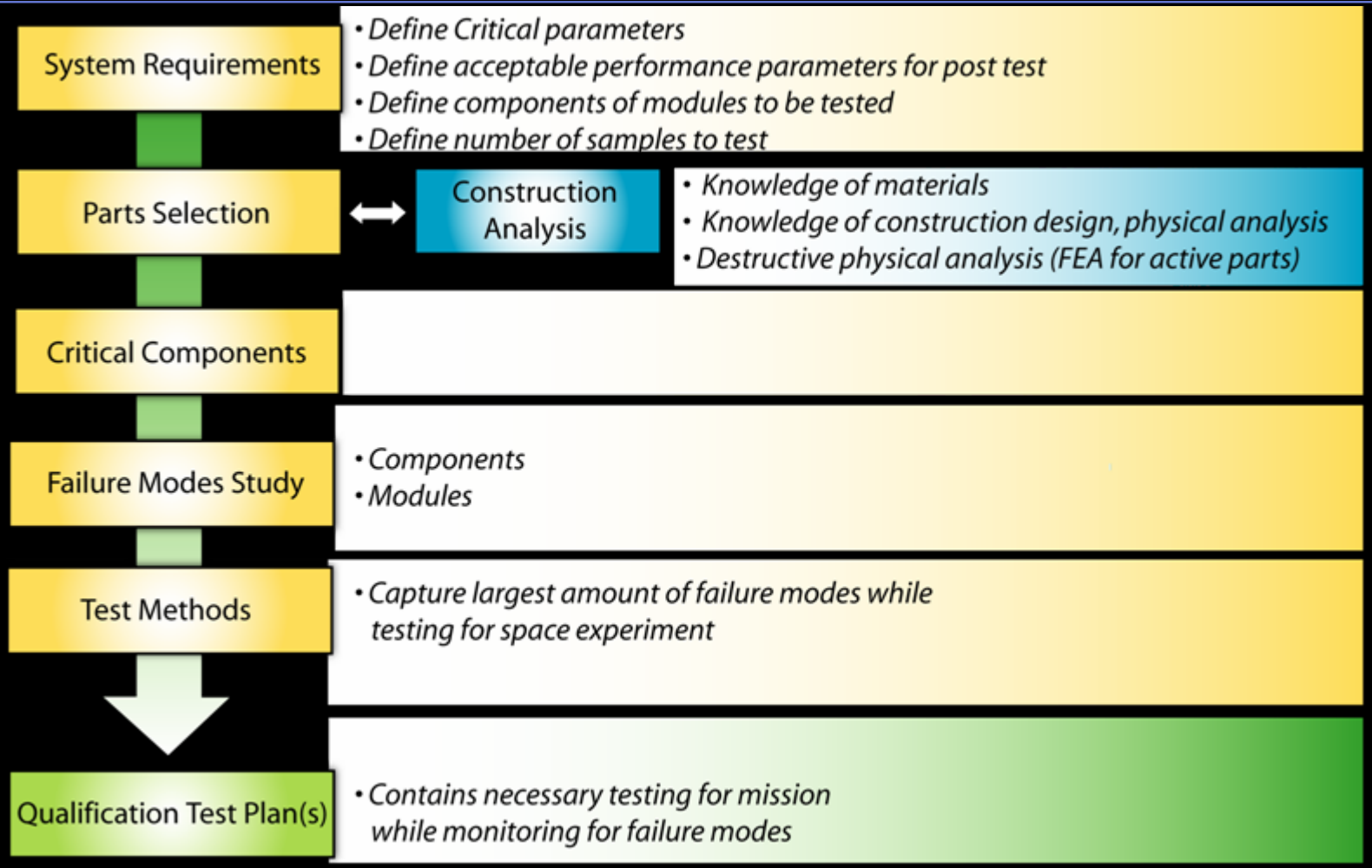






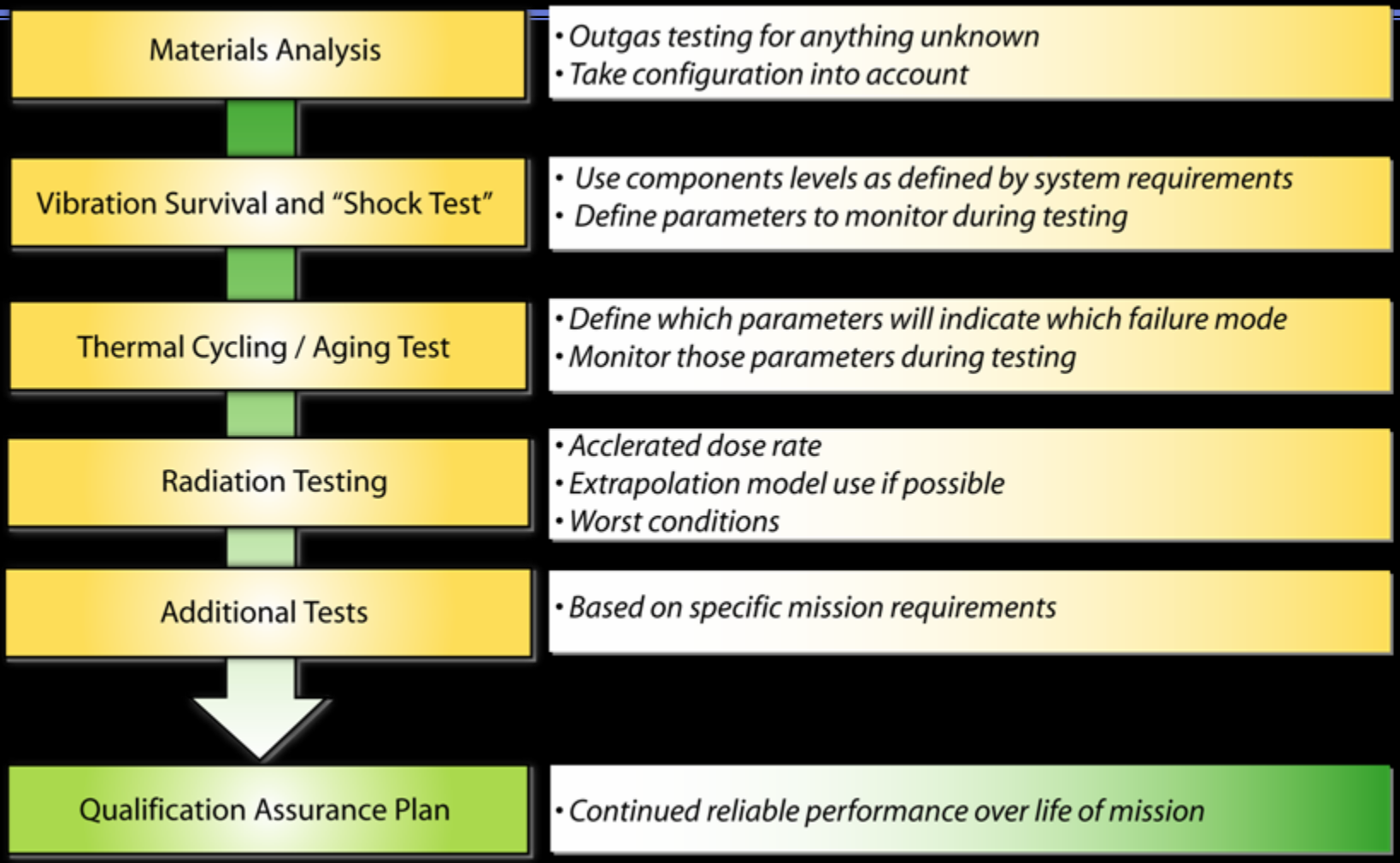


COTS Technology Assurance Approach



* *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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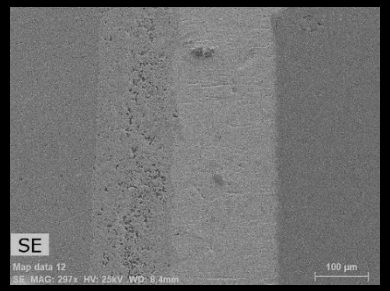
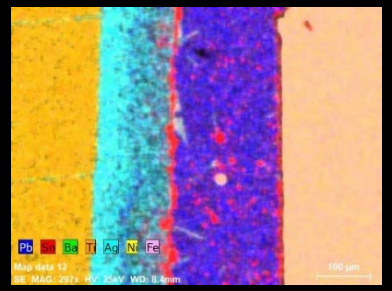
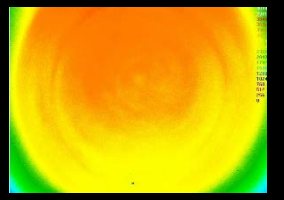
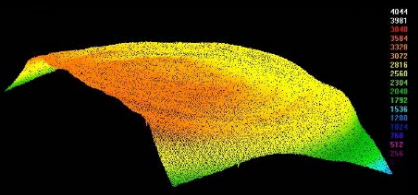


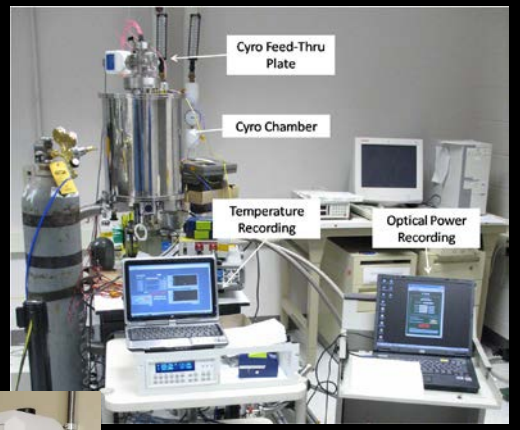


10 k X Mag SEM & Material Identification





LED Beam Profile



Cryogenic Test Facility

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

Materials Screening / Construction Analysis

Optical Inspection & Screening

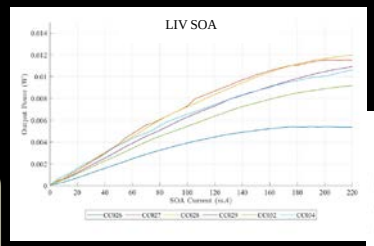
Performance Characterization

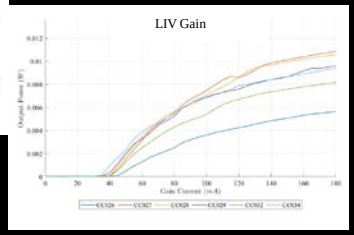
Vibration / "Shock" Testing

Thermal Cycling / Vacuum

Radiation Testing

Additional Testing?

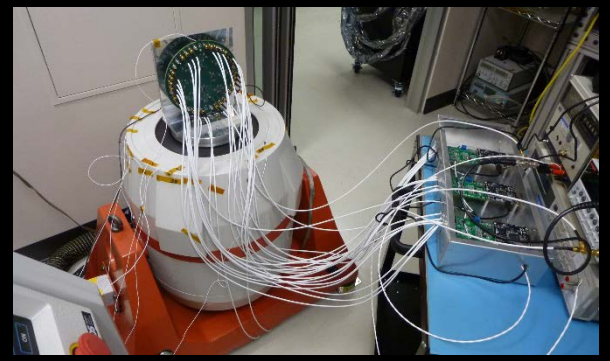




Optical Power, Current, Voltage Characterization

Radiation Test Equipment

White Light LED Testing in Environmental Chamber

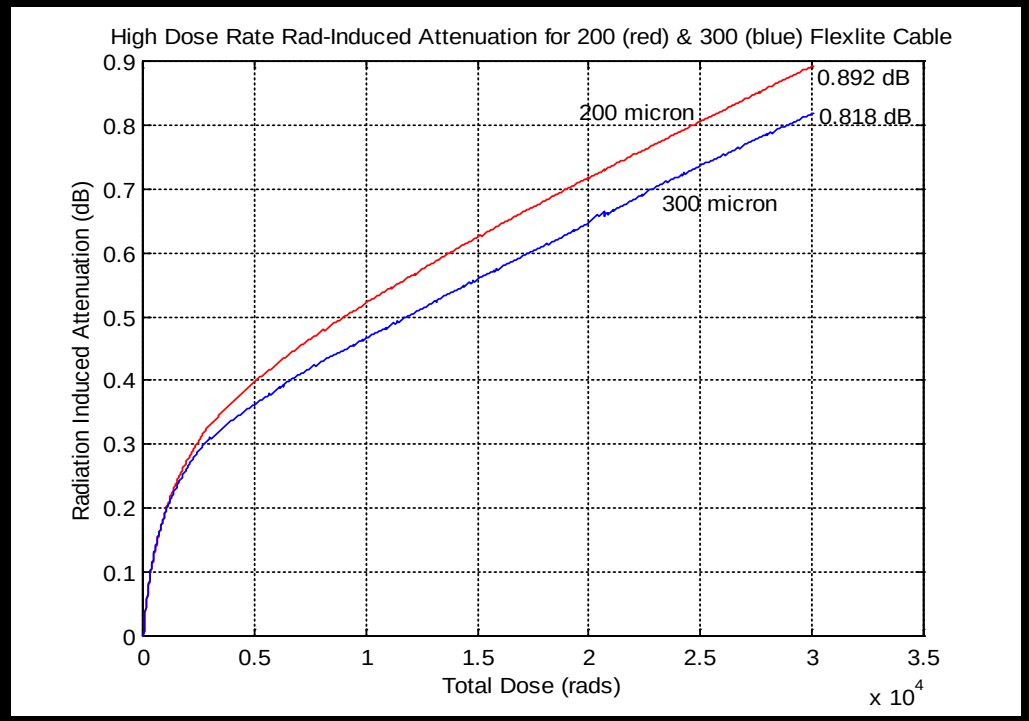


Random Vibration Test & Shock Equipment

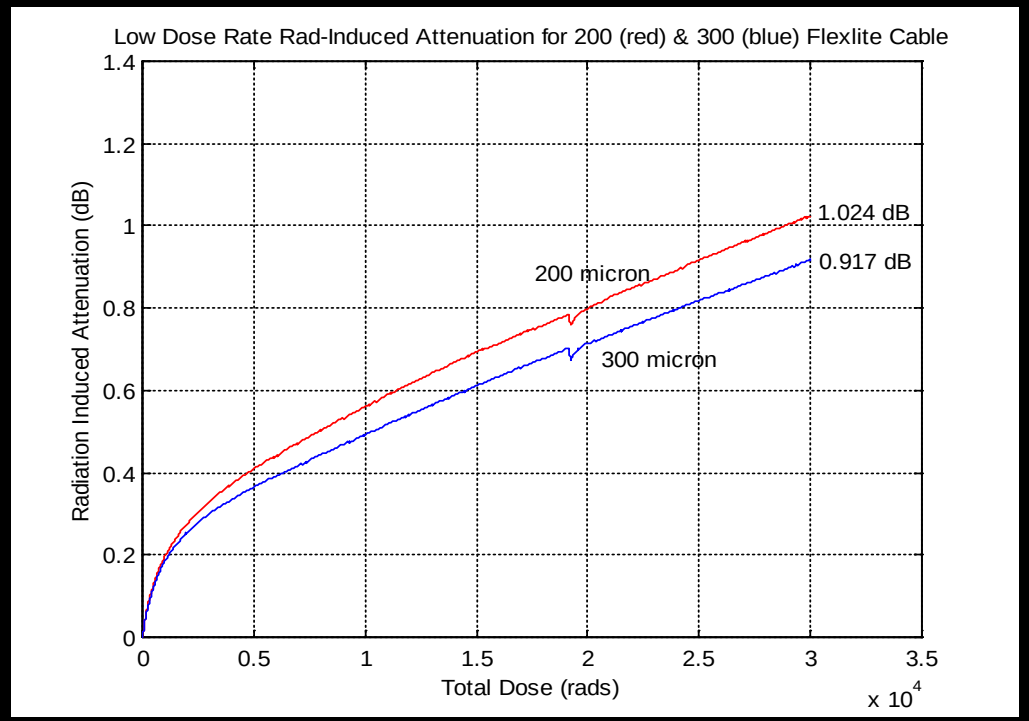
Total Dose Radiation Performance

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

Acronyms

- ATLAS = Advanced Topographic Laser Altimeter System
- COTS = Commercial Off The Shelf
- EEE = Electrical, Electronic, and Electromechanical
- ESD = Electrostatic Discharge
- FEA = Failure Effect Analysis
- GEDI = Global Ecosystem Dynamics Investigation
- ICESat-2 = Ice, Cloud, and land Elevation Satellite-2
- LED = Light Emitting Diode
- LiDAR = Light Detection and Ranging
- LOLA = Lunar Orbiter Laser Altimeter
- LRO = Lunar Reconnaissance Orbiter
- MESSENGER = Mercury Laser Altimeter on Mercury Surface, Space Environment, Geochemistry and Ranging
- MIT LL = Massachusetts Institute of Technology, Lincoln Laboratory
- MLA = Mercury Laser Altimeter
- MOLA = Mars Orbiter Laser Altimeter
- SEM = Scanning Electron Microscope
- TRL 9 = Technical Readiness Level 9
- TVAC = Thermal Vacuum

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

And thank you for your time.