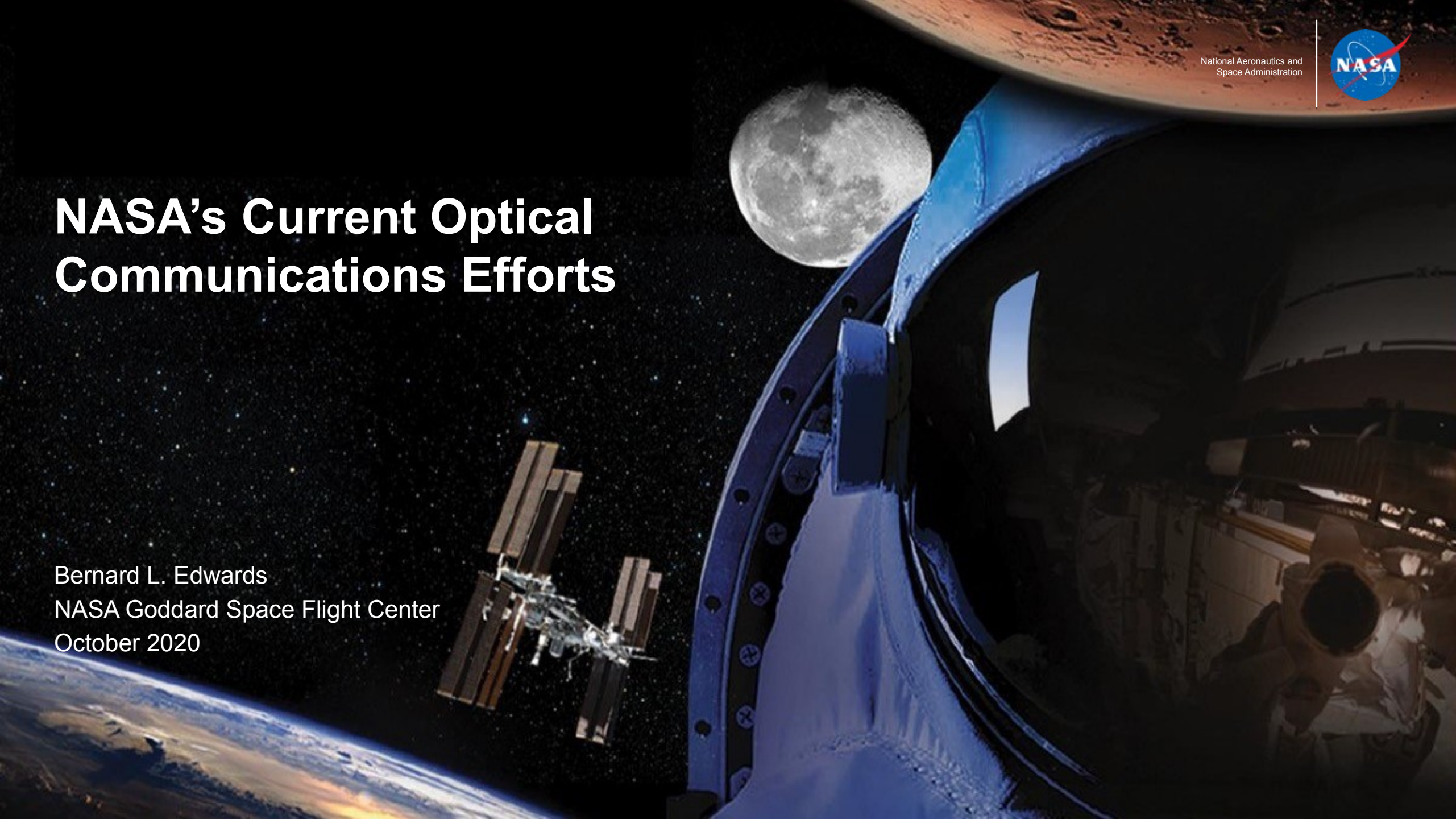


NASA's Current Optical Communications Efforts

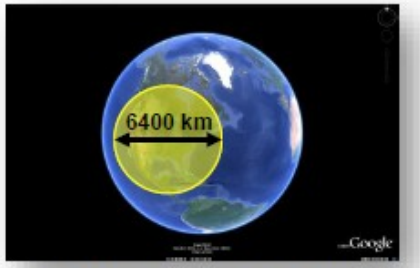
Bernard L. Edwards
NASA Goddard Space Flight Center
October 2020

Benefits of Optical Communications

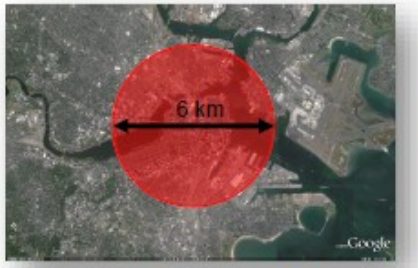
- Extremely narrow beams with small apertures
- Small, low power terminals
- Unlimited, unregulated spectrum
- High data rates
  - Provides high speed real-time data (e.g. for video)
  - Enables shorter contact times
  - Delivers large data volume over the duration of mission

Historic Challenges:
beam pointing, efficient transmitters and receivers, high bandwidth processing, atmospheric effects

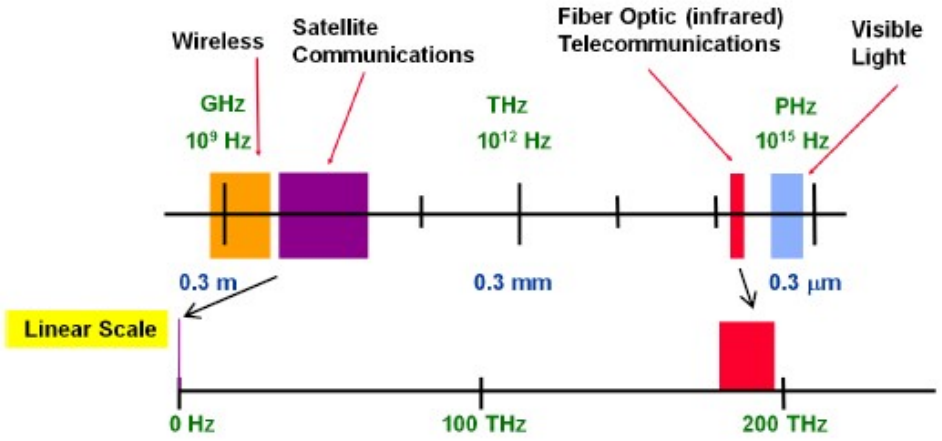
Beam Size From Moon



RF Ka Band (26 GHz)
75-cm Antenna → 6400 km Spot



Optical C-Band (1550 nm)
10-cm Antenna →6 km Spot



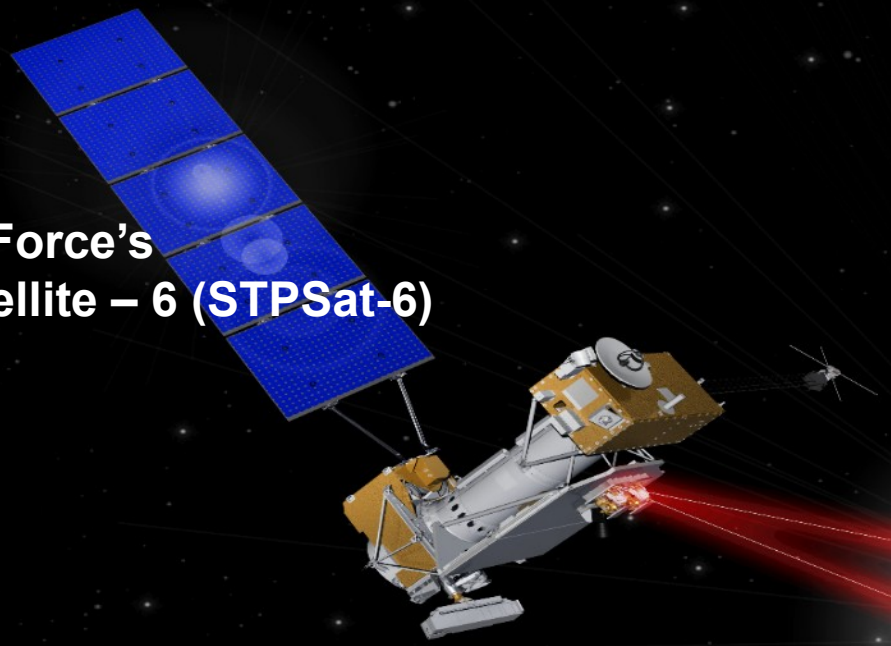
NASA wants to build upon the success of the 2013 Lunar Laser Communications Demonstration (LLCD) and previous efforts

2021 Laser Communications Relay Demonstration (LCRD)

Scheduled launch: February 2021

Mission duration:
Two year ops demo
Six years ops

Hosted payload: US Air Force's Space Test Program Satellite – 6 (STPSat-6)



Ground stations:
- California
- Hawaii

Partnership:
- NASA Goddard Space Flight Center
- NASA Jet Propulsion Laboratory
- MIT Lincoln Laboratory
- STMD/Technology Demonstration Missions
- Space Communications and Navigation

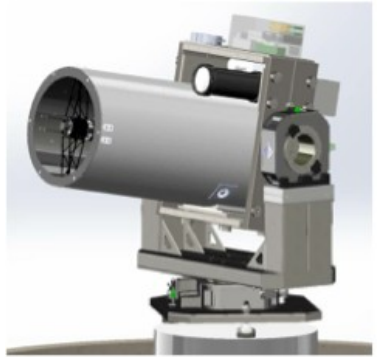
Flight payload:

- Two 10.8 cm Optical Modules and Controller Electronics Modules
- Two software-defined DPSK Modems with 2.88 Gbps data rate (1.244 Gbps coded user rate) that can also support PPM
- 622 Mbps Ka-band RF downlink
- New High Speed Switching Unit to interconnect the three terminals

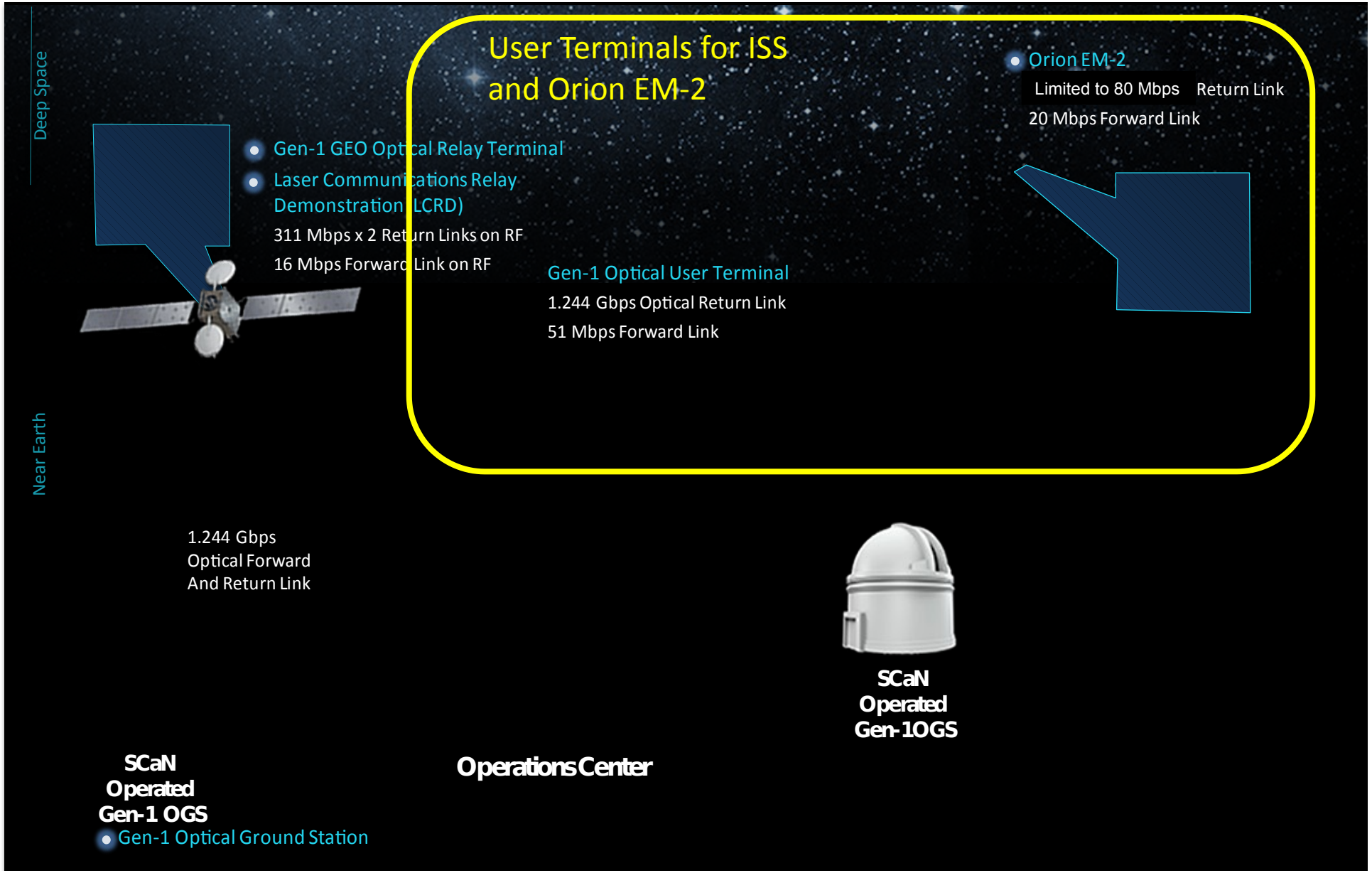
Guest investigators welcome!

LCRD Optical Ground Stations

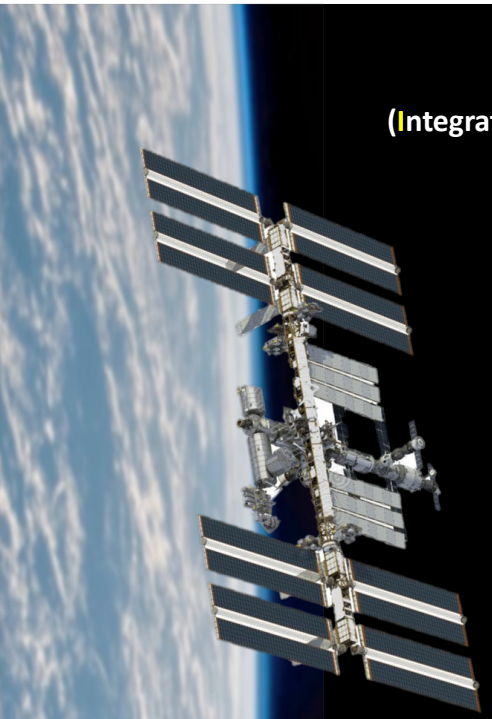
- **The LCRD baseline includes two Optical Ground Stations (OGS)**
  - Supports optical comm relay demonstrations before user terminals are available
  - Allows for future handover demonstrations
- **OGS-1 is the Optical Communications Telescope Laboratory (OCTL) on Table Mountain, California**
  - 1 Meter Receive Aperture
  - This was used in the Lunar Laser Communication Demonstration (LLCD)
- **OGS-2 is at the Maui Space Surveillance Complex on Haleakala, Maui**
  - Single 5.5 m Diameter Dome on the roof contains:
    - 60 cm Receive Aperture
    - 15 cm Transmit Aperture
    - 5.4 W of Transmit Optical Power (outside the dome)



NASA's Optical Plan Forward: User Terminals for LEO and the Moon



Laser Communications for Human Space Exploration



ILLUMA-T
(Integrated LCRD LEO User Modem and Amplifier Terminal)

1.2 Gbps return
51 Mbps forward
To ground via LCRD relay

Feb 2021 delivery to GSFC

Nov 2021 Launch on SpaceX Dragon

~6 Month Mission

O2O
(Orion AM-2 Optical Comm)

80 Mbps return
20 Mbps forward
Direct to ground (WSC, TMF)

8-21 day mission on first crewed Artemis Mission (AM-2)

November 2020 delivery to KSC

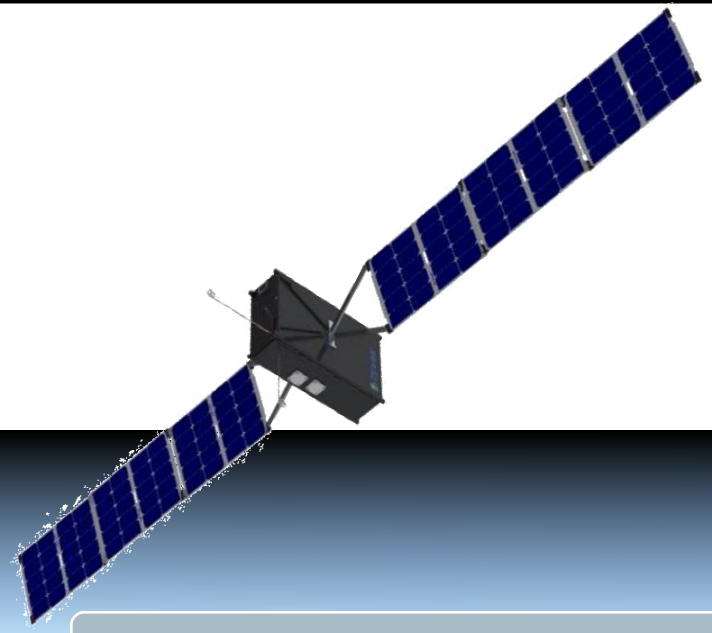
2022 Launch on Orion/SLS

8 – 21 Day Mission

MIT Lincoln Laboratory · NASA Goddard · NASA Johnson Space Center · JAXA

MIT Lincoln Laboratory · NASA Goddard · Lockheed Martin · NASA Johnson Space Center · NASA Marshall Space Flight Center · JPL

NASA's Optical Plan Forward:
LEO Direct to Earth: TeraByte InfraRed Delivery (TBIRD) in 2021



200 Gbps optical link enables delivery of many TeraBytes/day from low-Earth orbit

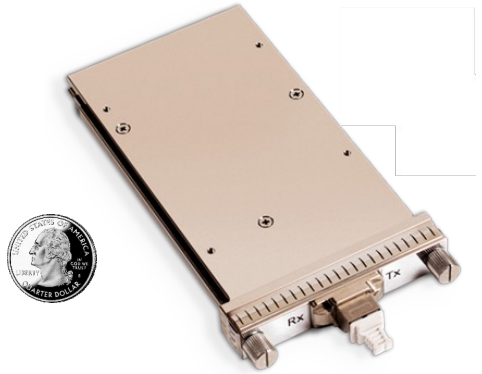
Space terminal based on telecom optical components, small enough for CubeSat

~Foot-class ground terminal aperture is low cost and widely deployable

MIT
Lincoln Laboratory

TBIRD: Highly Integrated COTS Components Enable Small, Low-Power Space Terminal Designs

High-Rate Optical Modem



100 Gbps Fiber Telecom Transceiver
Compact Form Pluggable (CFP)

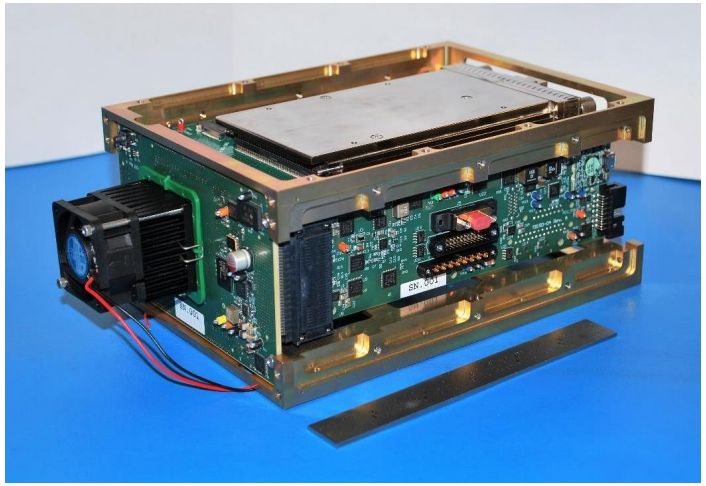
Large, High-Speed Storage

>500 GB, >25 Gbps Readout
Solid-State Drive (SSD)

Optical Amplifier

~1W Erbium Doped Fiber Amplifier
Optical C-Band (~1550nm)

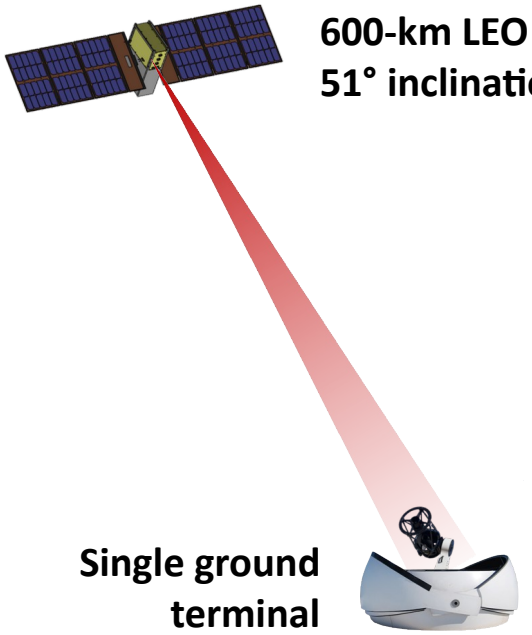
TBIRD Proto-Flight HW
Mass: 2.24 kg
Power: 120W
(5 minute ops)
Volume: 1.8 U



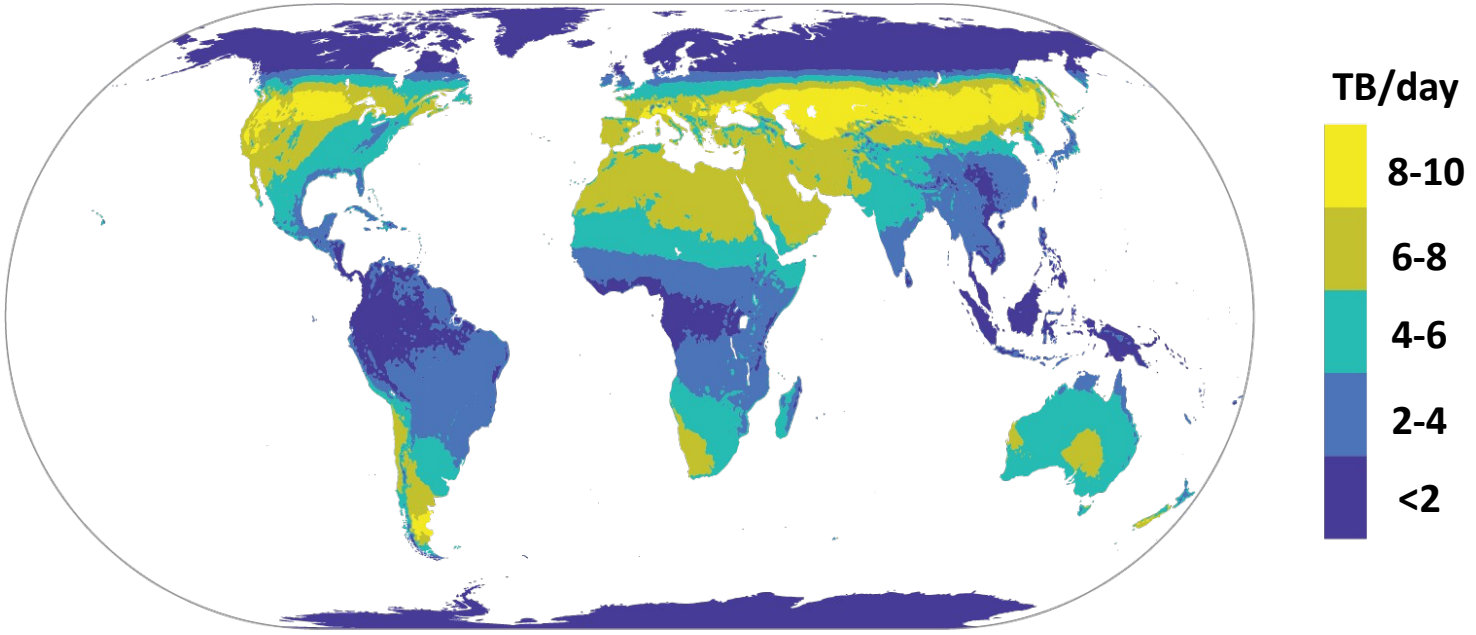
MIT
Lincoln Laboratory

TBIRD Data Volume Performance Example

Example Geometry



Average Terabytes per day from LEO to Earth

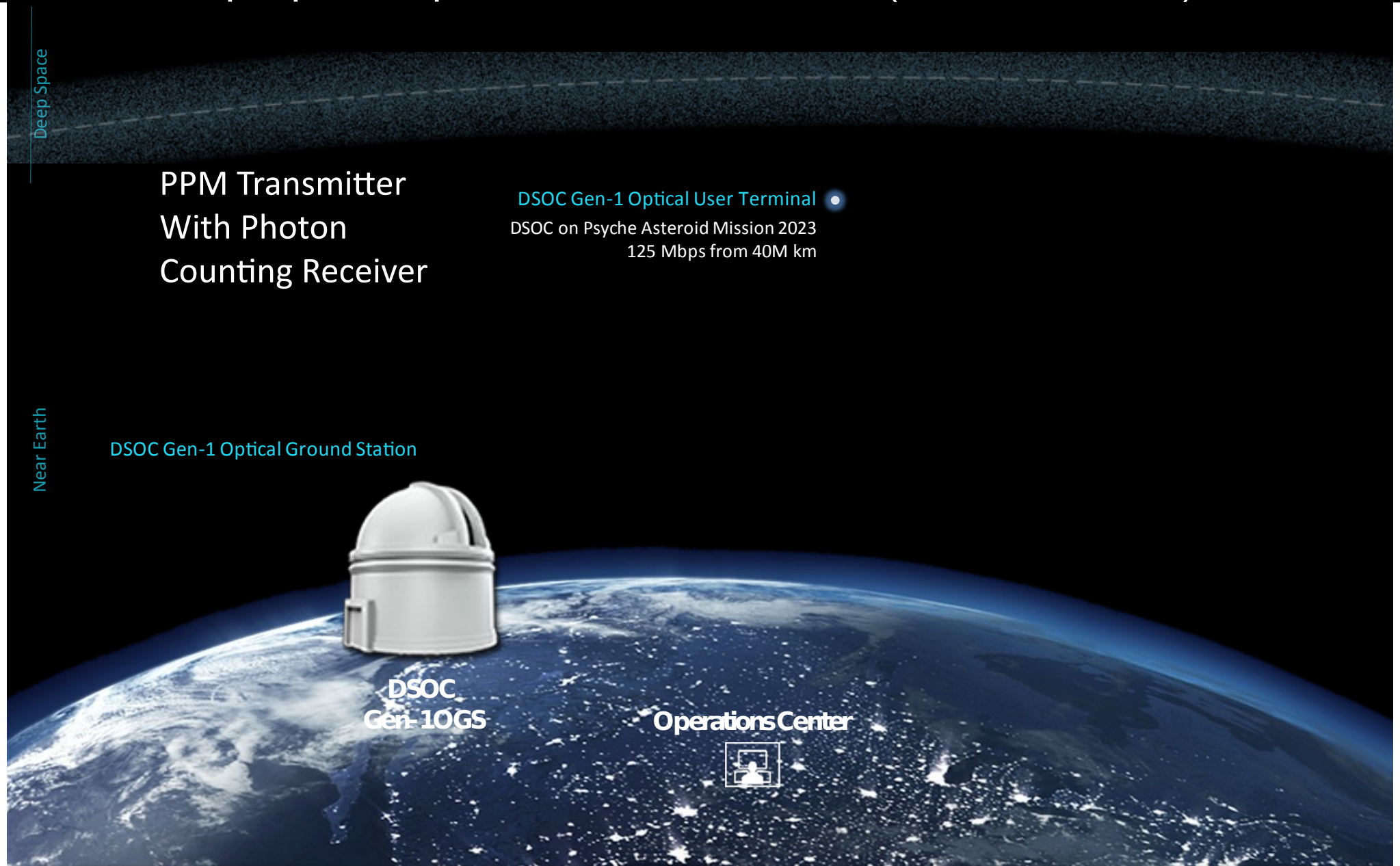


Link analysis accounts for cloud statistics

The TBIRD system is capable of delivering many TBytes per day from LEO to a delay-tolerant ground user

MIT
Lincoln Laboratory

NASA's Optical Plan Forward: Deep Space Optical Communications (DSOC in 2022)



Laser Communications from the Moon for Future Artemis and Science Missions

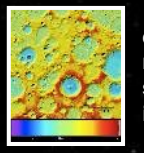
Optical Data Trunk to/from Earth

20+ Mbps Forward
1000+ Mbps Return

Gateway-Enabled Lunar Network

High-rate, low-latency data
Positioning, navigation and timing

CubeSat
4 – 500 Mbps



e.g. high-res multi-spectral imaging

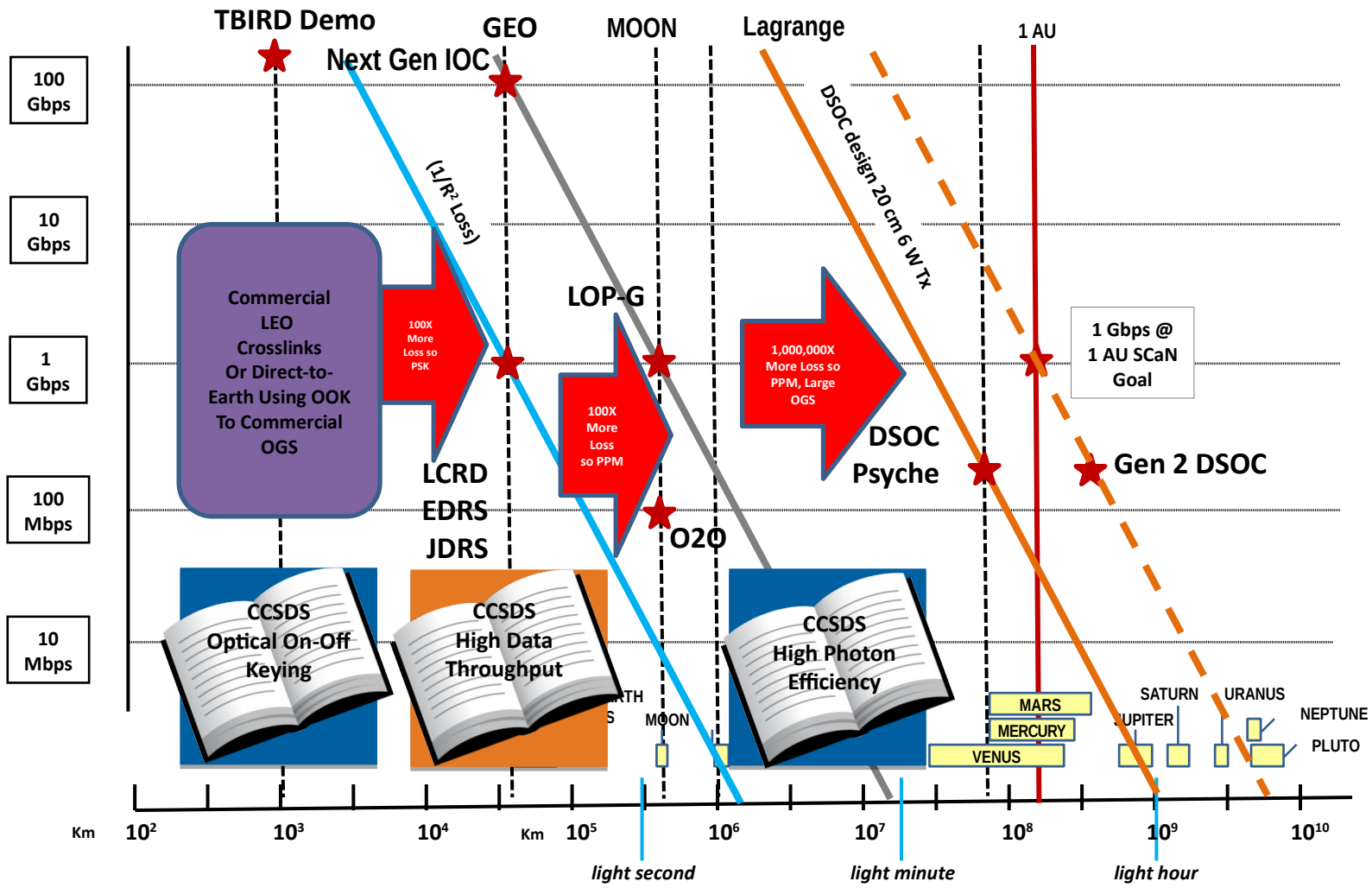
e.g. low-latency tele-robotics; In-situ analysis

Lunar Surface
100 Mbps – 2.1 Gbps

Orion MPCV
233 Mbps – 2.1 Gbps

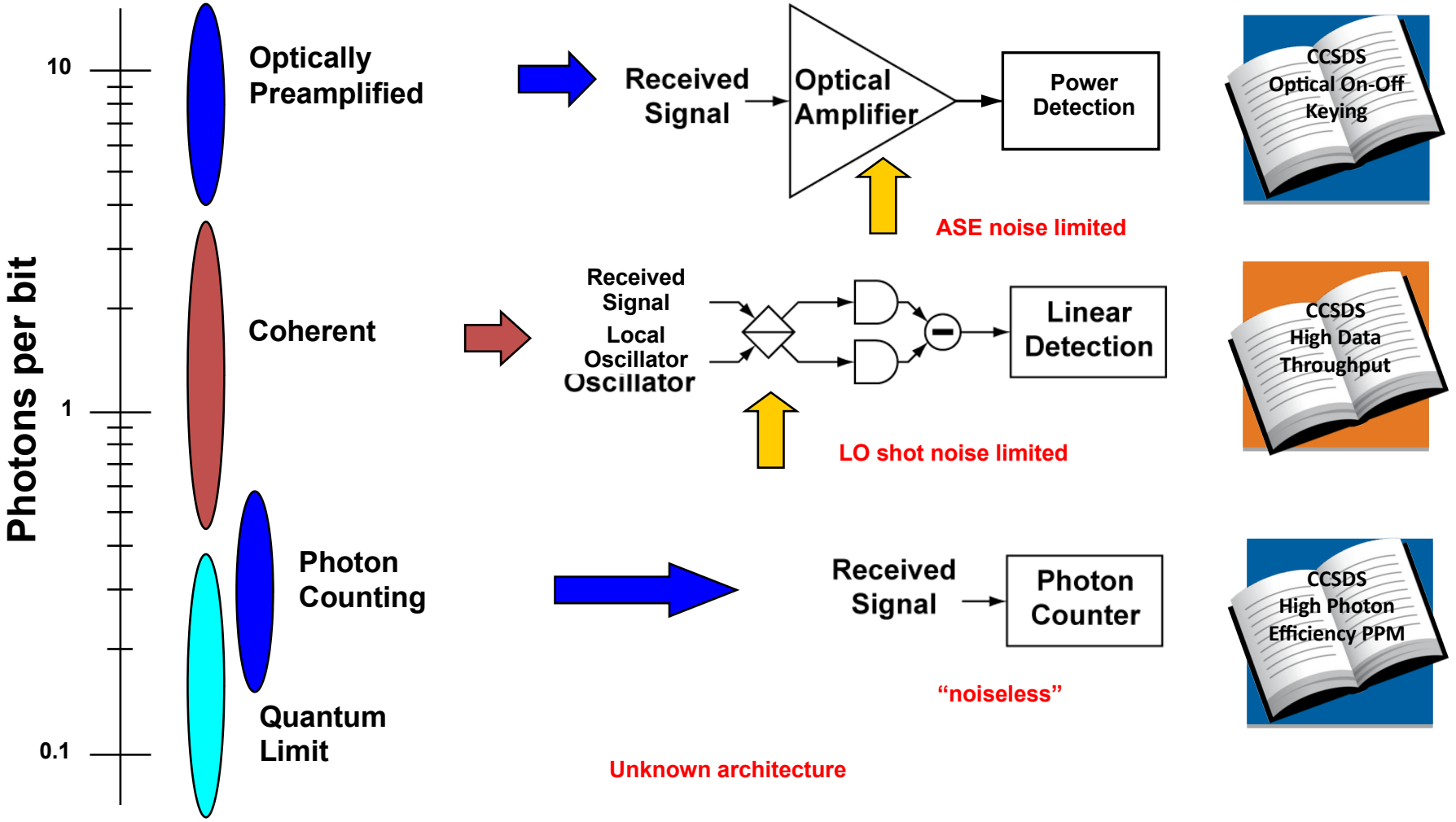
NASA is studying different optical communications scenarios to enable data returns from the Moon comparable to today's ISS, including high-rate proximity optical links

NASA's Optical Plan Forward: Optical Communication Standards in CCSDS



Range of Communication Link (km)

Detection Sensitivity in Optical Communications



Questions?

Please feel free to contact:

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