National Aeronautics and Space Administration

2022 NASA Optical Communications Update

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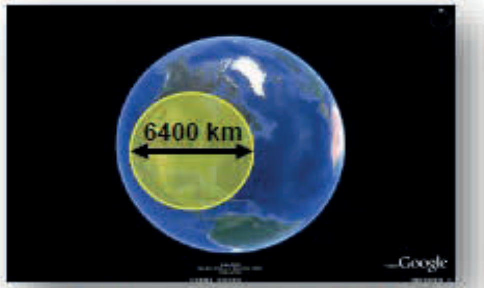
Benefits of Optical Communications

- 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

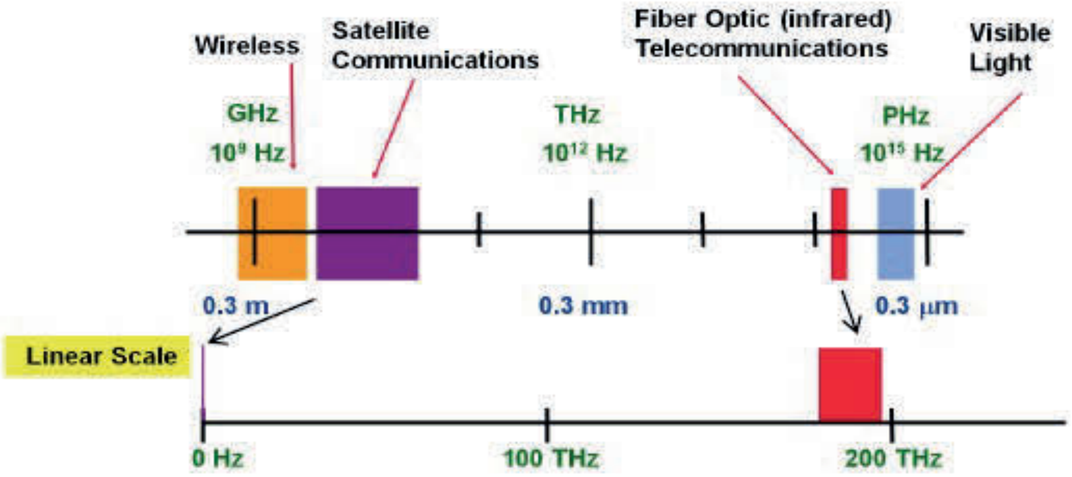
Historic Challenges:
beam pointing, efficient transmitters and receivers, high bandwidth processing, atmospheric effects

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

Lunar Laser Communications Demonstration (LLCD) – Launch Sep 6, 2013

- Flown on Moon on the Lunar Atmosphere and Dust Environment Explorer (LADEE)
  - Goal: demonstrate fundamental concepts of laser communications beyond GEO
- Led by NASA GSFC, space terminal and primary ground terminal (Lunar Laser Communication System) built by MIT/LL
- LLCD resulted in record-breaking achievement using broadband lasers for space communications
- Used pulsed laser beam to exchange data and high-definition video between lunar-orbiting terminal and ground station at White Sands, New Mexico

LLCD system:
- ✓ 50% less mass
- ✓ 25% less power
- ✓ 6x data-rate

than comparable (LRO) RF system

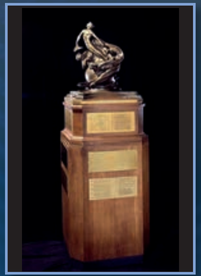
- ***IMMEDIATE LASER CONTACT*** **on October 17, 2013**
- **LLCD returned data by laser to Earth at a record 622 Megabits per second (Mbps)**
- **= Streaming 30+ HDTV Channels Simultaneously**
- **Ended Nov 22, 2013**

Data received via four **40 cm** downlink telescopes ($0.50\ m^2$ surface area)

Revolutionary capability for space users

2014 Popular Mechanics Breakthrough Award for Leadership and Innovation for LADEE

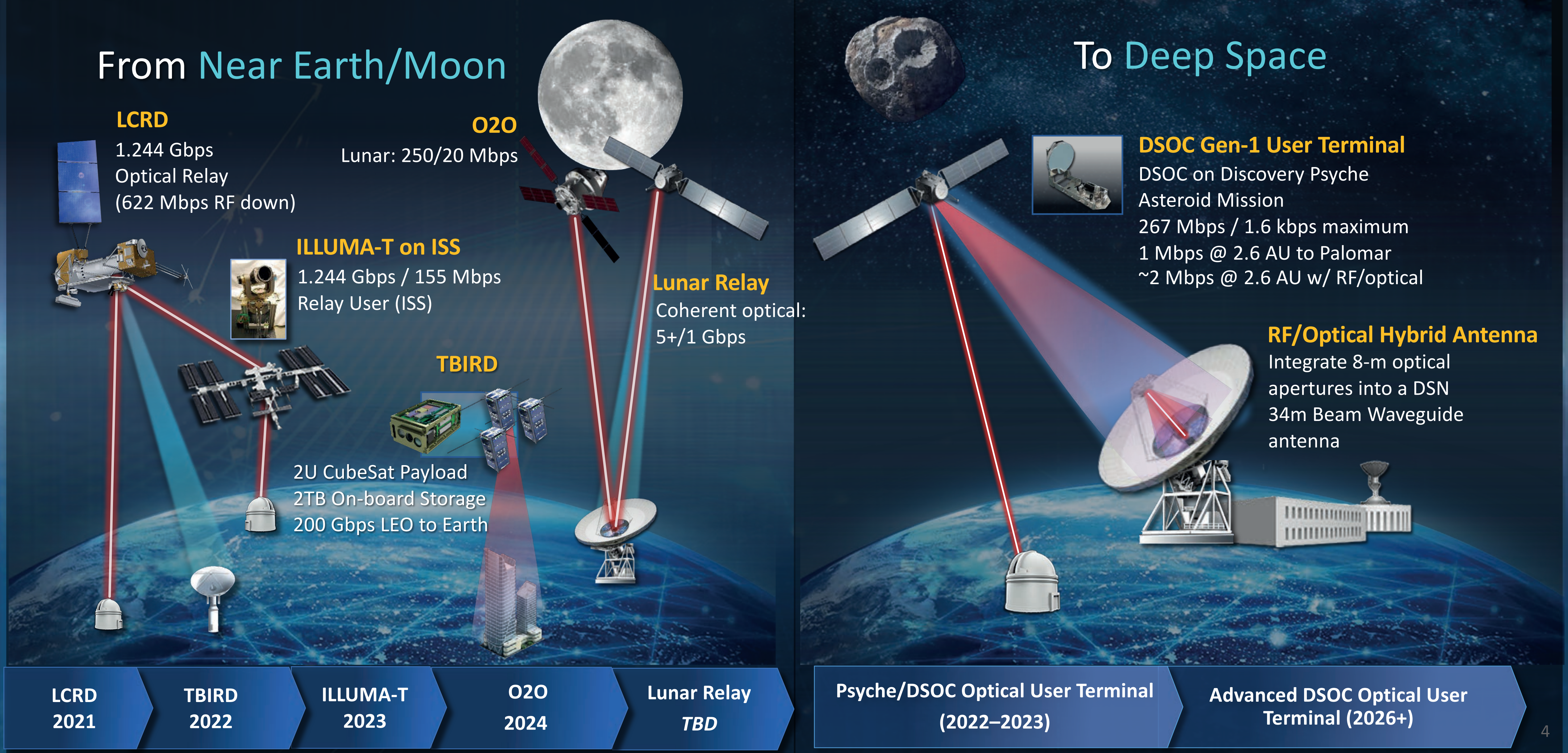
2014 R&D 100 Winning Technology in Communications category



Nominated for the National Aeronautic Association's Robert J. Collier Trophy

Winner of the National Space Club's Nelson P. Jackson Award for 2015

Optical Communications Technology Demonstrations



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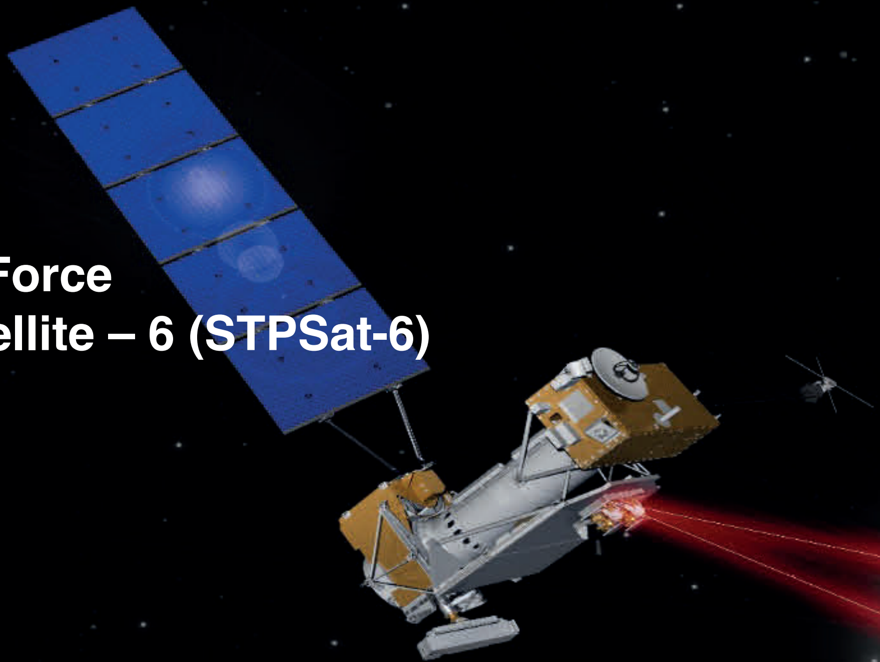
2021 Laser Communications Relay Demonstration (LCRD)

Launched December 2021

Mission duration:
Two-year ops demo
Six years ops

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



Ground stations:
- California
- Hawaii

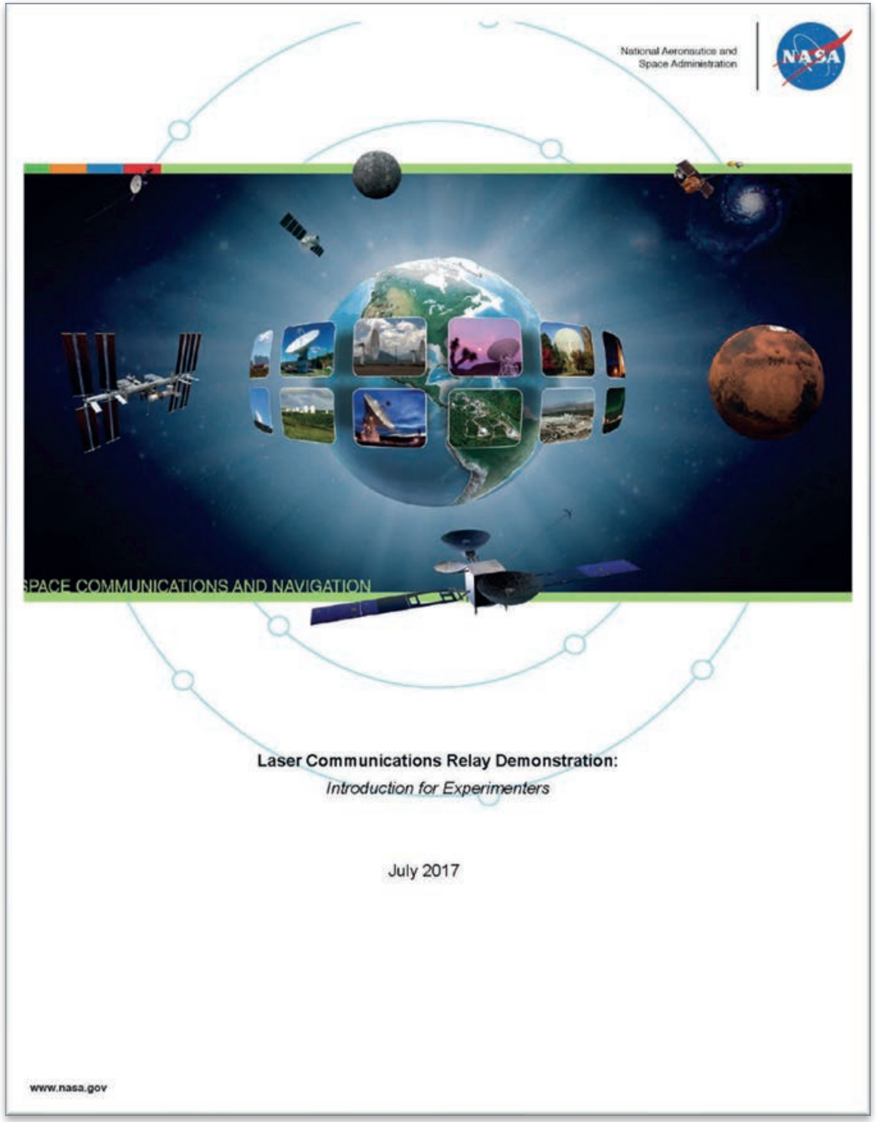
Partnership:
- NASA Goddard Space Flight Center
- NASA Jet Propulsion Laboratory
- MIT Lincoln Laboratory
- STMD/Technology Demonstration Missions
- Space Communications and Navigation

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!
URL: https://esc.gsfc.nasa.gov/projects/LCRD
Email: lcrd-experiments@nasa.onmicrosoft.com

LCRD Experiments Overview



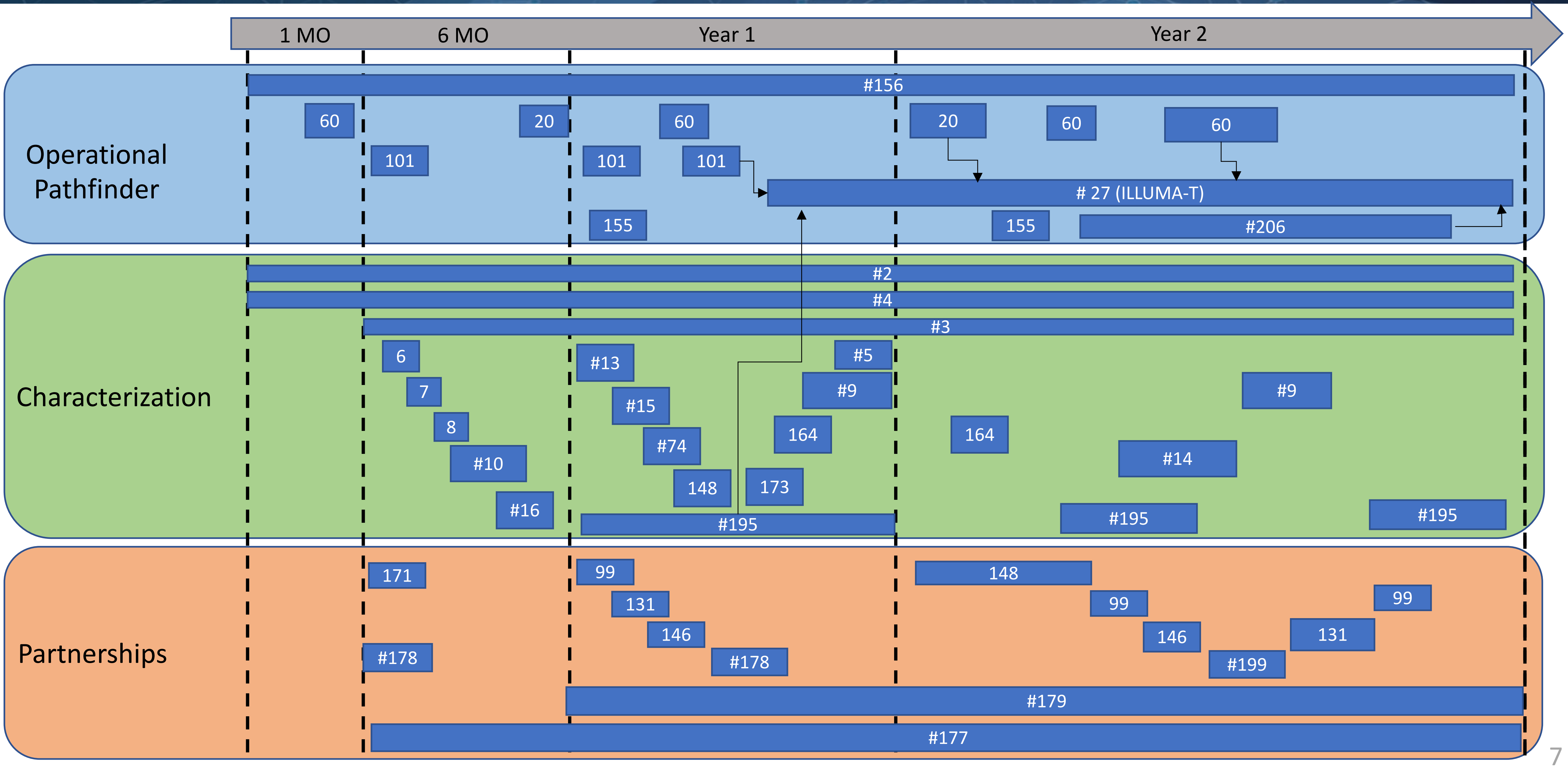
The LCRD Experiment Program began on June 10, 2022

- **The high priority experiments will demonstrate technology readiness for operational optical communications systems**
  - > Laser Communications Link and Atmospheric Characterization
  - > Relay operations
  - > Optical-based Networking Services
- **Other Experiment Include**
  - > Development of operations efficiency (handover strategies, more autonomous ops, etc)
  - > Planetary/Near-Earth Relay scenarios (additional delays, reduced data rates, non-continuous trunkline visibility
  - > Low Earth Orbit (LEO) - real or simulated
  - > User-to-User Relay
  - > Direct Uplink/Downlink
  - > Commercial applications

LCRD Introduction for Experimenters document describes experiment types as an introduction for the Guest Experimenter Program

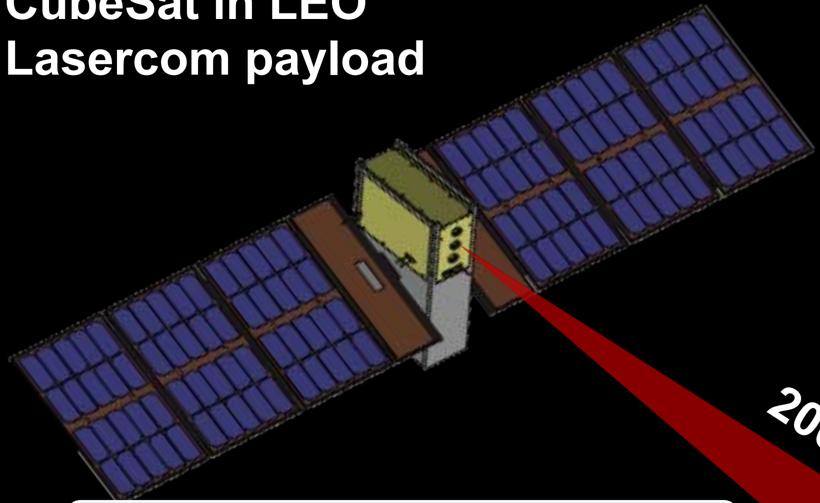
Total of 47 experiments have been proposed and 34 are under consideration and development so far.

Current LCRD Experiment Timeline (subject to change)



LEO Direct to Earth: TeraByte InfraRed Delivery (TBIRD)

6U CubeSat in LEO
3U Lasercom payload



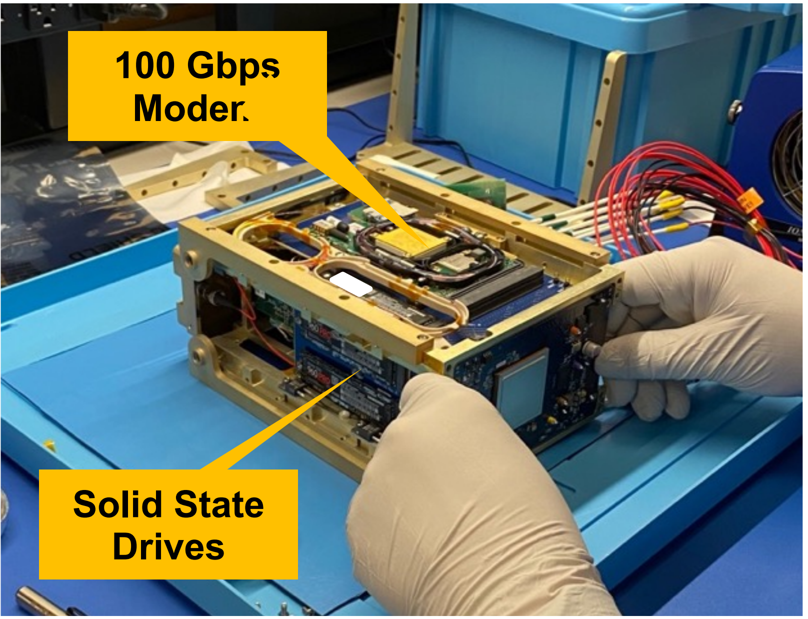
200 Gbps downlink

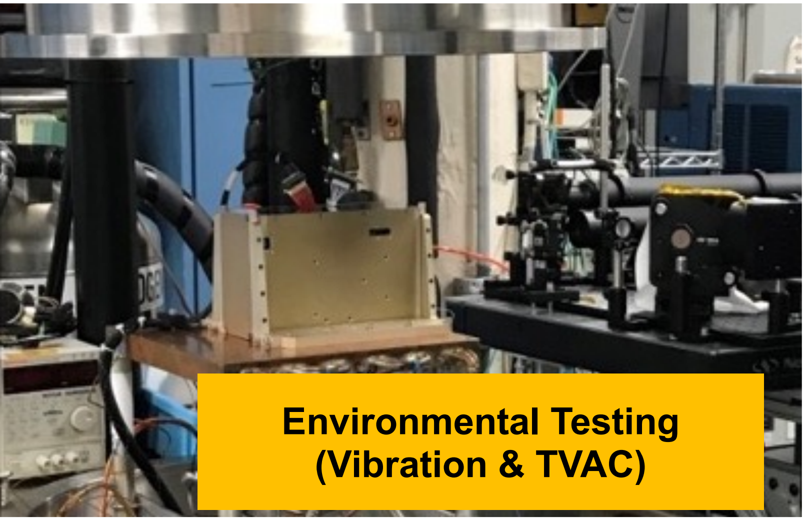
Space terminal based on telecom optical components, small enough for CubeSat

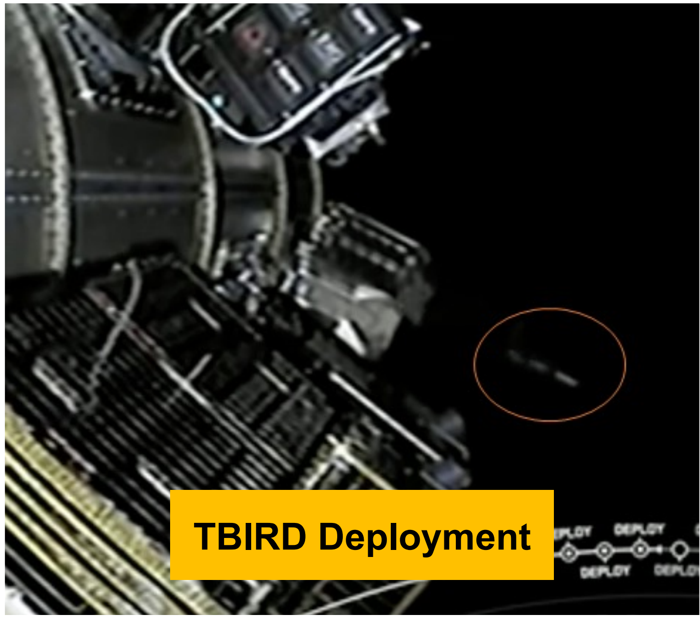
- Leverage fiber telecom equipment for 200 Gbps burst delivery (TBs per pass)
- Demonstrate robust data transfer through atmospheric channel
- 3U lasercom terminal payload hosted on 6U CubeSat
  - MIT/LL and JPL mission partnering
  - NASA Small Sat Pathfinder Tech Demo with Space Technology Mission Directorate

JPL/OCTL 1 m aperture
Multi-Mission Ground Terminal

TBIRD Demonstration







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

April 2022 delivery to GSFC

Early 2023 Launch on SpaceX-27

~6 Month Mission

NASA Goddard · NASA Johnson Space Center · JAXA

O2O

(Orion AM-2 Optical Comm)

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

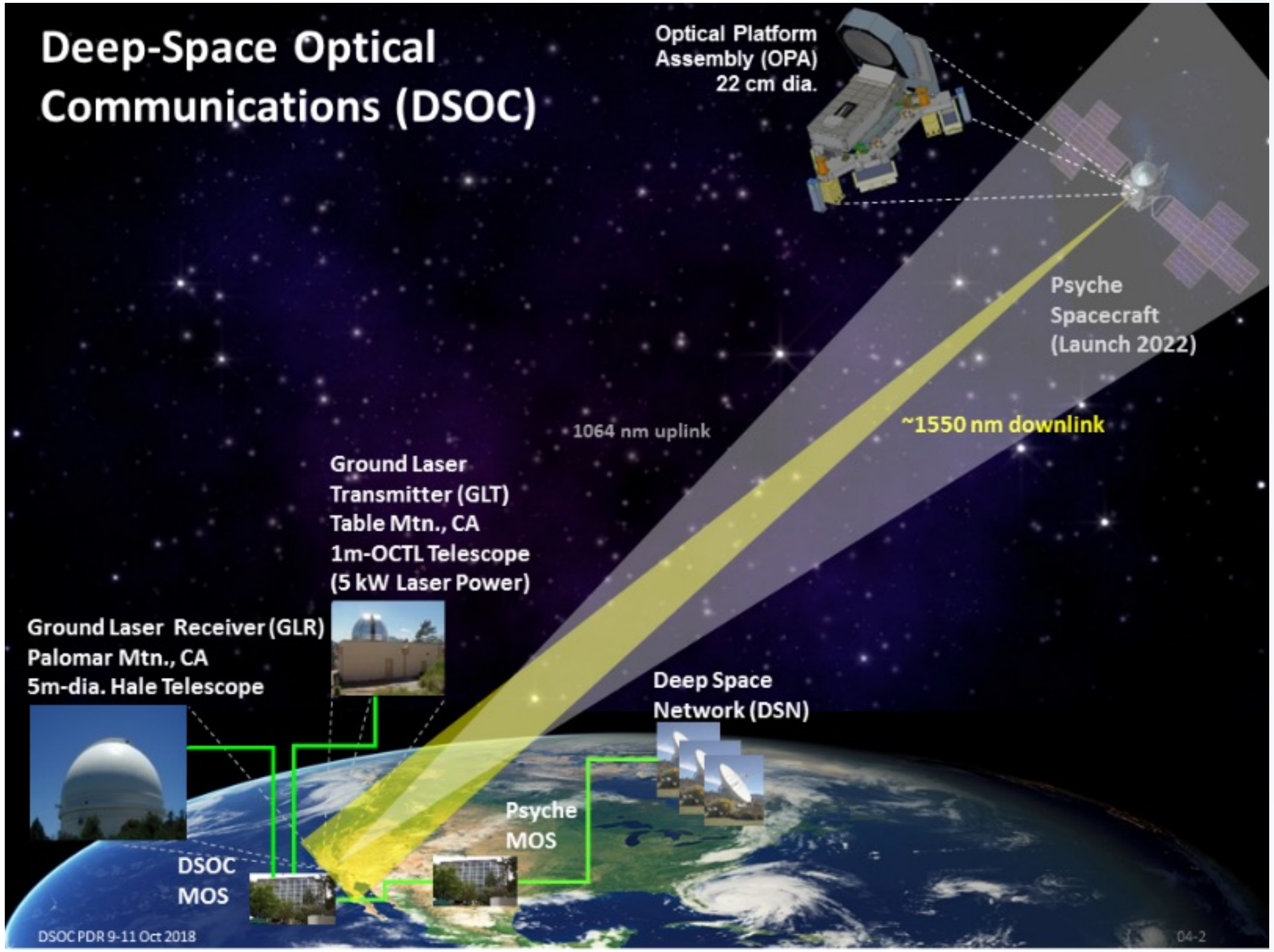
8-21 day mission on first crewed Artemis Mission (AM-2)

Early 2023 Delivery to KSC

2024 Launch on Orion/SLS

NASA Goddard · Lockheed Martin · NASA Johnson Space Center · JPL · NASA Marshall Space Flight Center

Deep Space Optical Communications (DSOC)



Level 1 requirements (Phase A Starting FY17)

- **DSOC-PROG-1: DSOC shall demonstrate on the ground a deep-space optical communications link demonstrating the data rates for the simulated distances defined in table 1A:**
- **DSOC-PROG-3: DSOC shall demonstrate a deep-space optical communication downlink from space for data rates and distance as defined in table 1B:**
- **DSOC-PROG-4: DSOC shall demonstrate optical communication uplink data rates to space of 1.6 kbps for multiple ranges between 0.25 and 1 AU**
- **DSOC-PROG-5: The DSOC flight terminal shall operate in space for at least one year**

FY17-FY23 Key Milestones:

FY17 **Complete WSi detector array fabrication**
FY18 **SRR/MDR, End-to-end signaling testbed**
FY19 **System PDR**
FY20 **Ground PDR, System CDR**
FY21 **Integration & Test of GLR and GLT**
FY22 **Operations Readiness Review**
FY22-23 ~~Operations for Technology Demo~~
FY22 *Pause due to Psyche flight software V&V issues*

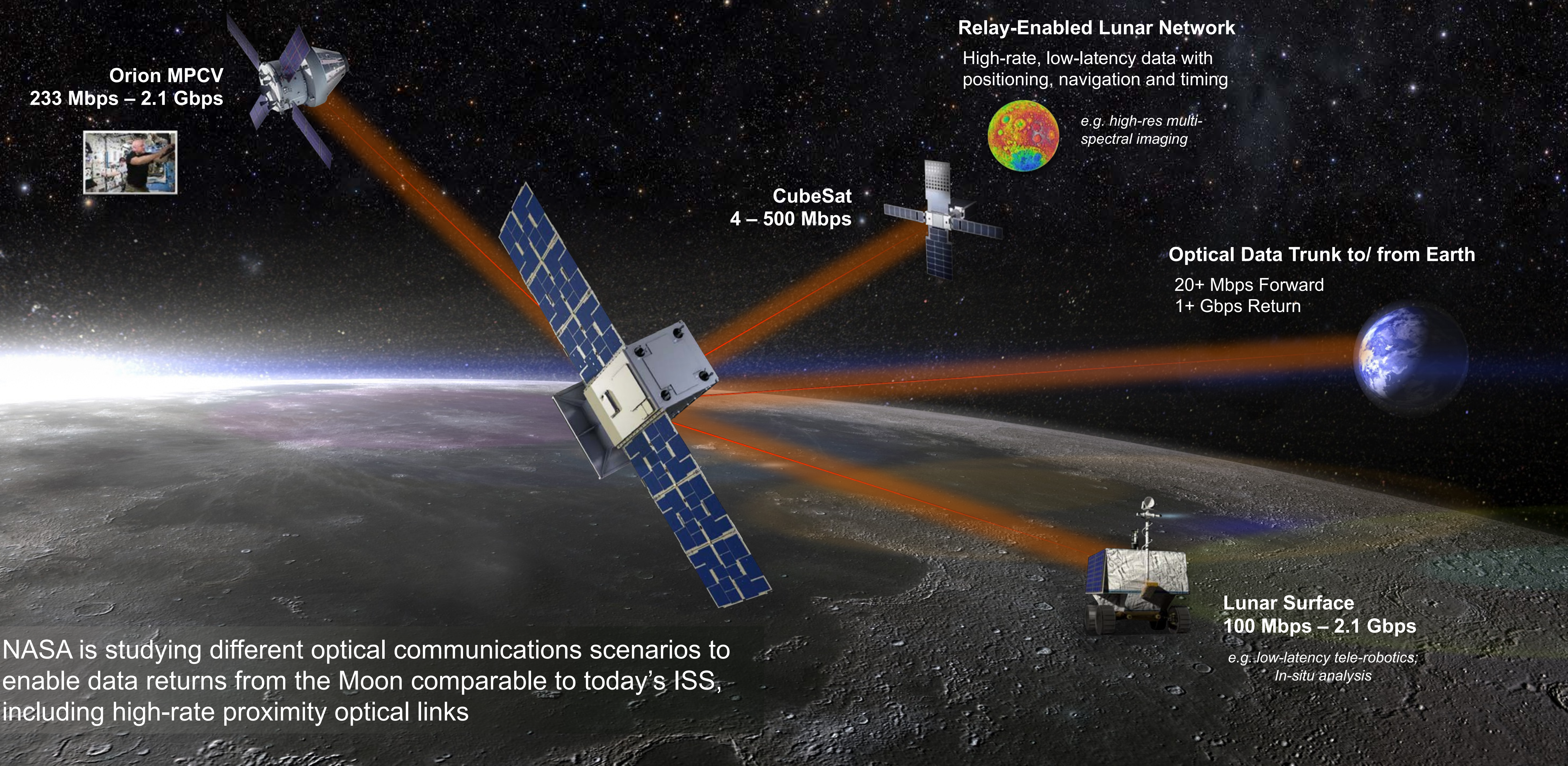
TABLE 1A

Downlink Data Rates	Simulated Distance
132 Mbps	0.25 AU
> 200 kbps	2.8 AU

TABLE 1B

Downlink Data Rates	Simulated Distance
> 132 Mbps	D < 0.25 AU
> 14 Mbps	0.25 < D < 1 AU
> 2 Mbps	1 AU < D < 2 AU
> 200 kbps	2.0 AU < D < 2.7 AU

Potential Laser Communications from the Moon for Future Artemis and Science Missions



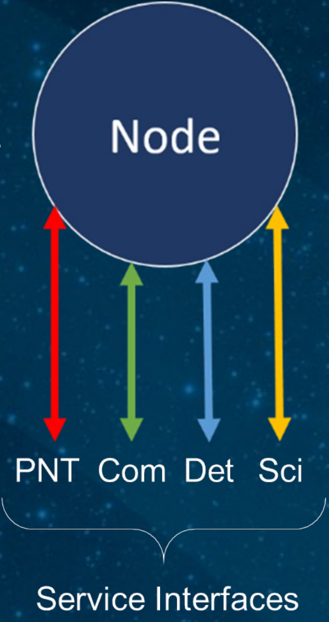
NASA is studying different optical communications scenarios to enable data returns from the Moon comparable to today's ISS, including high-rate proximity optical links

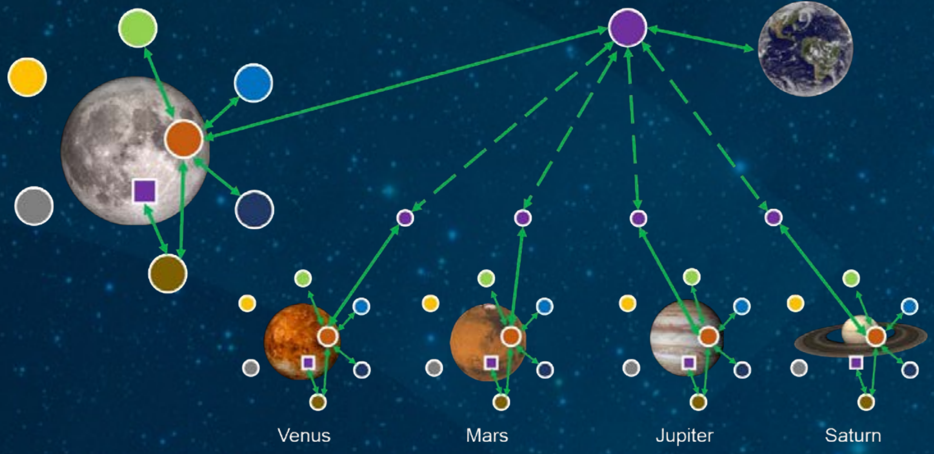
LunaNet

- A flexible scalable architecture for providing communications and navigation services to all lunar missions
- Disaggregated approach allows for phased implementation of infrastructure as driven by user needs and technology developments
- Architecture implementation comprised of NASA, International, and Commercial interoperable lunar surface, lunar orbiting, and earth-based elements
- Incorporates in-situ capabilities to detect events and distribute situational alerts
- Is fully compatible with future deployments at Mars or any other destination

LunaNet Service Types

1. **Communications Services (Com):** Data transfer services capable of moving addressable and routable data units between nodes in a single link or over a multi-node, end-to-end path via communications or networking services.
2. Position, Navigation, and Timing Services (PNT): Services for position and velocity determination, and time synchronization and dissemination. This includes search and rescue location services.
3. Detection and Information Services (Det): Services providing detection of events in order to generate timely alerts for human and asset safety and protection. These services publish other beneficial information to users as well.
4. Science (Sci): Services that use the RF and/or optical capabilities of the node as a science instrument or part of an instrument.

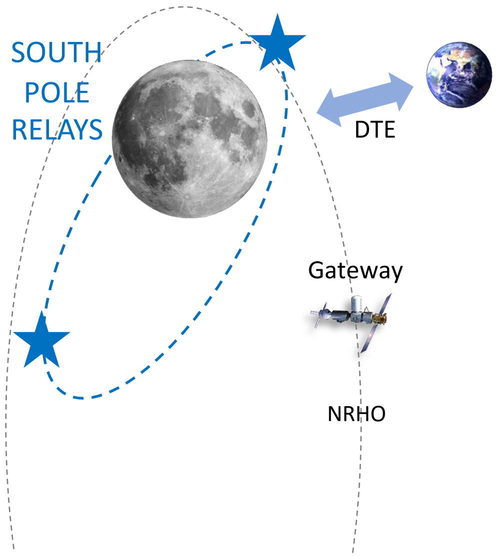




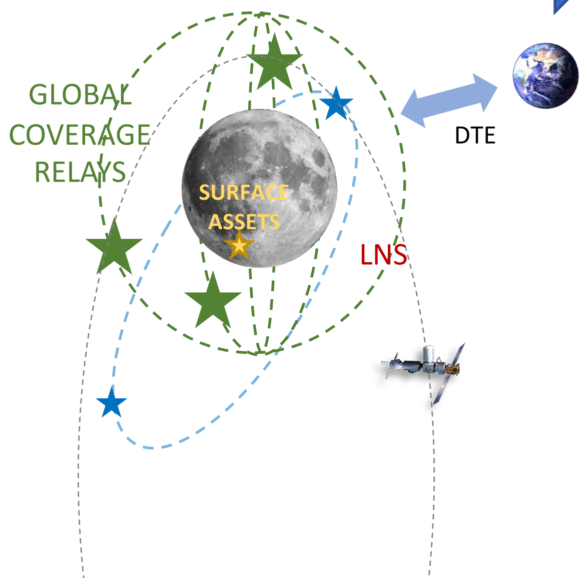
Just as the Internet and GPS have transformed our lives on Earth, LunaNet will transform lunar science and exploration.

Potential LunaNet Architecture Evolution

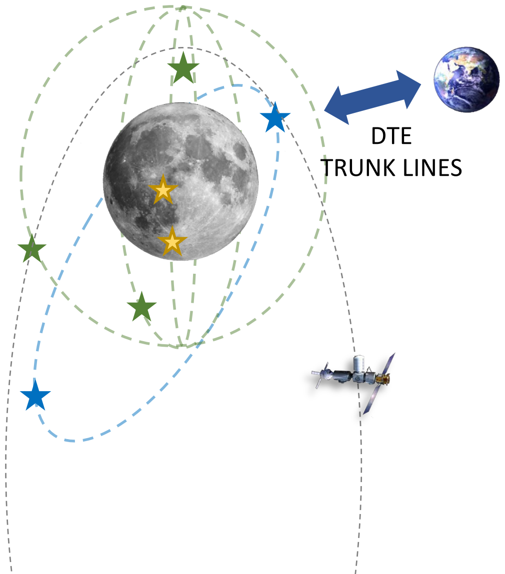
Initial Phase: By 2024-2025 | **Growth Phase: 2026-2030** | **Desired Future State: 2030 + Beyond**



- ***DTE service for Near Side, lunar orbiters and surface missions***
- ***Intensive relay service for South Pole and a selected area of the Far Side***
- ***Initial PNT service and lunar surface networks***
- ***LunaNet interoperability established from the beginning***

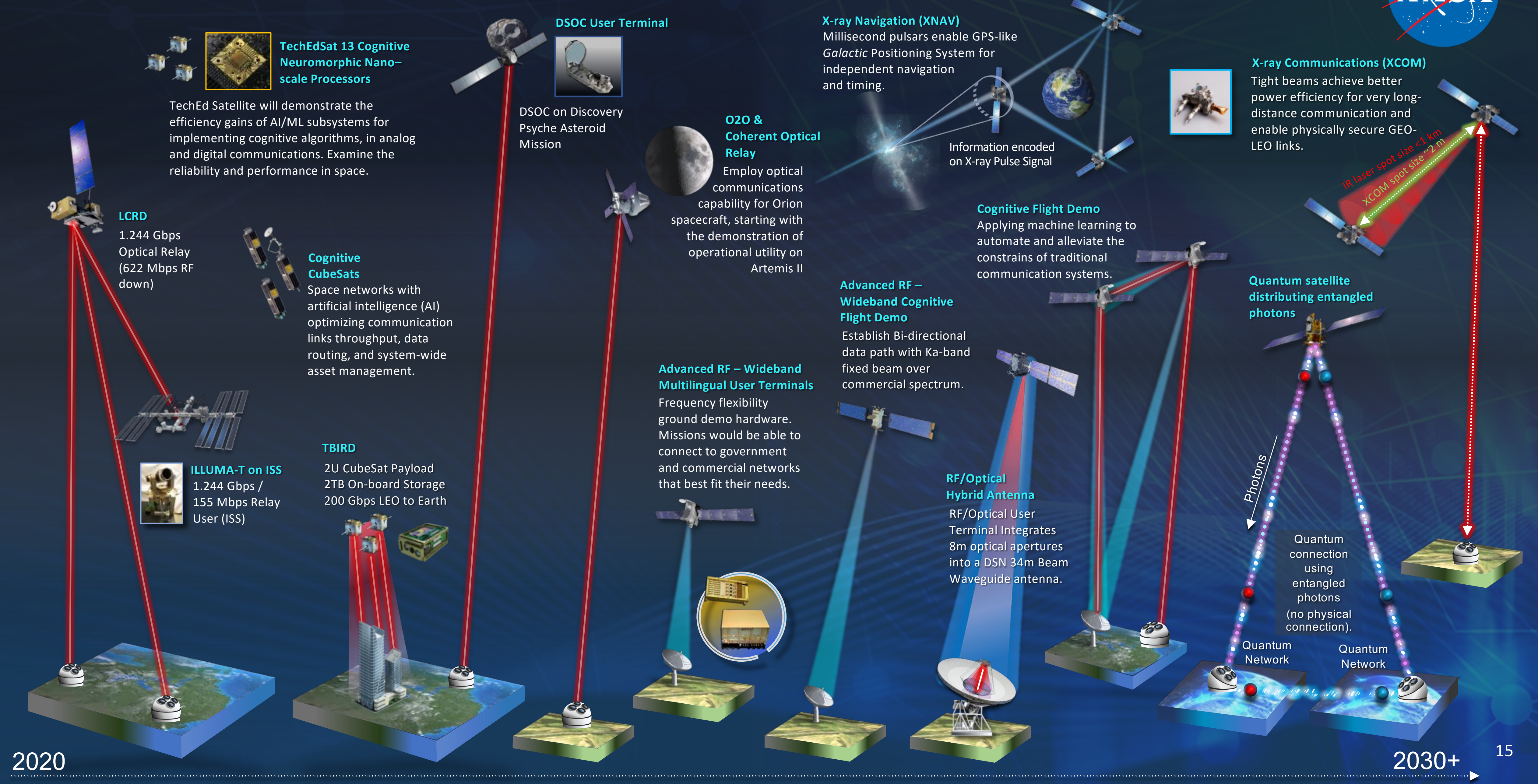


- ***Continued DTE service for Near Side***
- ***Expanded relay service for South Pole and multiple Far Side regions***
- ***Limited relay service for other globally-dispersed locations and orbiters***
- ***Lunar Navigation Service for PNT***
- ***Surface networks***
- ***Introduction of optical links***



- ***Satellite constellations with multiple operators functioning as cooperative set of networks***
- ***Intensive coverage of specific regions and regular coverage of all regions***
- ***Optical trunk line links***
- ***Surface network assets in multiple locations***

SCaN Technology Timeline: From Near Earth/Moon to Deep Space



Thank You for Your Attention

Contact

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