NASA’s Optical Communications Missions in 2020-2022

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2013: NASA’s First, Historic Lasercom Mission

The Lunar Laser Communication Demonstration (LLCD)

LLCD returned data by laser to Earth at a record 622 Megabits per second (Mbps)

= streaming 30+ HDTV channels simultaneously!
LLCD’s Multiple Ground Terminals: An International Collaboration

Geographic site diversity is required to reduce the likelihood that clouds will interrupt the link; it also allowed the opportunity to demonstrate international interoperability while sharing the costs of the system of LLCD.
Laser Communications Relay Demonstration (LCRD)

Scheduled launch: August 2020

Mission duration:
Two year ops demo
Six years ops

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

Partnership:
STMD/Technology Demonstration Missions and SCaN

Ground stations: California and Hawaii

Guest investigators welcome!

Flight payload:
- Two LLCD-heritage Optical Modules and Controller Electronics Modules
- Two software-defined DPSK Modems with 2.88 Gbps data rate (1.244 Gbps user rate)
- 622 Mbps Ka-band RF downlink
- New High Speed Switching Unit to interconnect the three terminals
LCRD with Two Optical Ground Stations and LCRD Mission Ops Center (LMOC)

Two Terminals at 1550 nm
1.244 Gbps User Rate
Full Duplex (Bi-Directional)

622 Mbps Ka-band RF Downlink to WSC

LCRD Flight Payload On STPSat-6

CURRENTLY INTEGRATION AND TEST

Table Mountain, CA
Optical Ground Station 1 (OGS-1)

White Sands, NM
STPSat-6 Mission Ops Ops Center

Remote LCRD Mission Ops Center (R-LMOC)

Hawaii
Optical Ground Station 2 (OGS-2)

NASA Goddard Space Flight Center

INSTALLED AND UNDER TEST

LCRD Developed
OGS-X Developed
Joint LCRD/OGS-X Developed
Space Network Developed
Integrated Laser Communication Relay Demonstration Payload at NASA Goddard Space Flight Center
NASA’s Optical Plan Forward: User Terminals for LEO and the Moon

User Terminals for ISS and Orion EM-2
- Gen-1 GEO Optical Relay Terminal
- Laser Communications Relay Demonstration (LCRD)
- 311 Mbps x 2 Return Links on RF
- 16 Mbps Forward Link on RF

Gen-1 Optical User Terminal
- 1.244 Gbps Optical Return Link
- 51 Mbps Forward Link

Orion EM-2
- Up to 531 Mbps PPM Return Link
- 20 Mbps Forward Link

Deep Space
- Gen-1 Optical Relay Terminal

Near Earth
- Gen-1 Optical Ground Station

Operations Center
ILLUMA-T on the ISS (2022)

O2O on Orion EM-2 (2022)

PFU Subassemblies

Optical Module (OM):
- Latch & Gimbal Assembly (LGA)
- Telescope & Relay Assembly (TRA)
- Backend Optical Assembly (BOA)

Control Electronics (CE)

ILLUMA Modem (IM)

Modem Module (MM)

Power Converter Unit (PCU)

High-rate optical communication link
Supporting Orion crew exploration vehicle

ISS (LEO) User Terminal on JEM-EF for Operations with NASA Laser Communication Relay Demonstration (LCRD) in GEO

BOTH PREPARING FOR CDR IN NOVEMBER 2019
ILLUMA-T Location on ISS:
The Japanese Expansion Module

Future home for ILLUMA-T and NSQL JEM-EF #3

ISS RAM Direction

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Integrated LCRD LEO User Modem and Terminal (ILLUMA-T) on the ISS: Space Terminal Elements

- Instrument Sled & ATCS Cold Plates
- 2.88 Gbps DPSK Laser Modem (MM)
- Power Converter Unit (PCU)
- Controller Electronics (CE)
- Fiber Spool Assembly (FSA)
- JEM Enclosure
- OM Isolation
- H-Fixture
- Payload Interface Unit (PIU)
- Grapple
- Sled Sub-Assembly
- Dragon SC Interface
- MAScOT 10 cm (4”) Optical Module (OM)
Now CCSDS Blue Books for Lunar, Deep Space and Disadvantaged Optical Comm – Standard for O2O

- Blue Books Published for Physical Layer, and Coding and Synchronization released August 2019
Optical Comm on Orion EM-2 (O2O)
Latest Implementation on Spacecraft (2022 Launch)

Crew Module Adaptor (CMA)

O2O Modem Module (MM)

O2O Power Converter Unit (PCU)

Star Tracker

S-band Phased Array Antenna (PAA)

10 cm Optical Module (OM) (bracket interface TBD)

O2O Controller Electronics Module (CEM)
Deep Space Optical Communications (DSOC) will fly on the Psyche Mission in 2022.
The Key to Reducing SWaP and Cost:
Photonic Integrated Circuits

US Industry has commercialized “Integrated photonics” to allow many electro-optical components, even glass fibers, to be “squeezed down”…..

For NASA, this means that optical systems for communications and sensors can be reduced in size, mass, and cost by >> 100x by leveraging this commercially-available technology (some customization may be required)

...into the optical equivalent of a micro-electronics “integrated circuit”

COTS Laser Comm Modem
..based on Integrated Photonics
TeraByte InfraRed Delivery (TBIRD): 200 Gbps from LEO to Earth with On-board 2.0 TB Storage

- Will demonstrate new approach for large volume data delivery from low-Earth orbit
  - Buffer and burst
  - Use high rate 100G commercial fiber transceivers

- 2020 launch on NASA-provided 6U CubeSat
200 Gbps TBIRD Flight HW at MIT Lincoln Laboratory based on Integrated Photonics and Coherent DSP ASIC

TBIRD
Mass: 2.24 kg
Power: 120W
(5 minute ops)
Volume: 1.8 U
Beyond 2024: Lunar Point-of-Presence (L-PoP) Concept

Networked Optical Data Trunks to/from Earth Orbiting L-PoP (2028)

Orion MPCV 233 Mbps – 2.1 Gbps

LunaNet SmallSat Constellation For Networking and Positioning, Navigation, and Timing

1+ Gbps Forward
10+ Gbps Return

Lunar Surface RF Link

2024 @ South Pole
National Space Quantum Lab Proposal with Ground Stations and SmallSats: An Entangled Source in Space

National Space Quantum Laboratory
On the International Space Station
Quantum-Entangled Modem transported
Over Classical Free-Space Optical Communications Link

Collaborator
Quantum Cubesat Launched from the ISS

Near Earth
OGS with Quantum Networking
Ground Fiber Quantum Networking
OGS with Quantum Rx
Ground Quantum Lab
Quantum Memory

Large OGS with Quantum Rx
Ground Fiber Quantum Networking
Ground Quantum Lab
Ground Quantum Lab
Summary: NASA’s Current Optical Comm and Nav Flight Missions

- **SCaN Operated Gen-1 OGS**: 1.244 Gbps Optical Forward and Return Link
- **Gen-1 GEO Optical Relay Terminal**: 311 Mbps x 2 Return Links on RF, 16 Mbps Forward Link on RF
- **Laser Communications Relay Demonstration (LCRD)**: 311 Mbps x 2 Return Links on RF, 16 Mbps Forward Link
- **Orion EM-2**: Up to 531 Mbps PPM Return Link, 20 Mbps Forward Link
- **Gen-1 Optical User Terminal**: 1.244 Gbps Optical Return Link, 51 Mbps Forward Link
- **Deep Space Near Earth Gen-1 Optical User Terminal**: 1.244 Gbps Optical Return Link
- **DSOC Gen-1 Optical User Terminal**: 200 Gbps DTE Optical User Terminal, Up to 200 Gbps Optical Return Link in 1.9U Volume
- **Mission Operated LC-OGS**: 4 Gen-1 OGSs with PPM Support And A-O or Coherent Combining, 1 DSOC Gen-1 OGS
- **DSOC Gen-1 OGS**: 125 Mbps from 40M km
- **Mission Data Storage**
- **Operations Center**
- **> 97% Availability**
Questions?

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