The Laser Communications Relay Demonstration Experiment Program

Dave Israel/NASA GSFC

October 2017
**Demo Description**
A minimum two-year flight demonstration (goal of five years) to advance optical communications technology toward infusion into deep-space and near-Earth operational systems while growing the capabilities of industry sources.

**Objectives**
- Demonstrate bidirectional optical communications between geosynchronous Earth orbit (GEO) and Earth.
- Measure and characterize the system performance over a variety of conditions.
- Develop operational procedures and assess applicability for future missions.
- Provide an on-orbit capability for test and demonstration of standards for optical relay communications.

**Anticipated Benefits**
- A reliable, capable and cost-effective optical communications technology for infusion into future operational systems.
LCRD will engage various pre-determined experiments to test new laser communications technology and techniques for LEO and deep-space applications, and to gather valuable data. The Guest Experimenters Program encourages individuals and groups from international organizations, government, academia and industry to propose diverse experimentation ideas.

- Experiments will begin immediately following launch and payload checkout.
- The highest priority experiments will demonstrate technology readiness for the next-generation relay capability:
  - Laser communications link and atmospheric characterization
  - Relay operations
  - Optical-based networking services
- Other experiments include:
  - Development of operations efficiency
  - Planetary/near-Earth relay scenarios
  - Low Earth Orbit (LEO), real or simulated
  - Direct uplink/downlink
  - Commercial applications

The LCRD Introduction for Experimenters document describes possible experiments and processes for experiment solicitation.

lcrd.gsfc.nasa.gov
LCRD Mission Architecture

LCRD Flight Payload
- 2 optical relay terminals
  - 10.8-cm aperture
  - 0.5-W transmitter
  - DPSK and PPM
- Space Switching Unit
- High data rate RF

Optical Relay Link Features
- 2880 Mbps Uncoded DPSK
- 1244 Mbps Coded DPSK
- 311 Mbps 16-PPM
- Coding/Interleaving at link edges
  - Rate ½ DVB-S2 codec (LDPC)
  - One second of interleaving for atmospheric fading mitigation

Optical Ground Station 1
- 1-m transmit and receive aperture
- 10-W transmitter

Optical Ground Station 2
- 60-cm receive aperture
- 15-cm transmit aperture
- 10-W transmitter

Table Mountain, California

Satellite T&C, Ranging

High Data Rate System (RF)

STPSat-6 Antenna and Ground Equip. (SAGE)

LMOC Extension

STPSat-6 Satellite Ops Center (SSOC)

LCRD Mission Ops Center (LMOC)
LCRD has a flight segment and a ground segment:

Key:
- Optical Link
- High Rate Radio Frequency Link
- Terrestrial Link

STPSat-6 Spacecraft

DGS-1 (California)
DGS-2 (Hawaii)
RF GS (New Mexico)

LMOC Extension (Maryland)
LMOC (New Mexico)
LCRD will fly on the Air Force Research Laboratory’s Space Test Program Satellite (STPSat-6) mission.

STPSat-6 is scheduled to launch in 2019.
LCRD Ground Segment

Optical ground stations subsystems:

- Optical Link to/from LCRD Flight Segment
- Optical Telescope Assembly
- Ground Modem
- CODEC
- User Services Gateway (USG)
- User MOC Simulator
- User Platform Simulator
- User Element Simulators

LCRD Optical Ground Station

- Interface to/from User Facility

RF ground station subsystems:

- RF Link to/from LCRD Flight Segment
- RF Equipment
- CODEC
- User Services Gateway (USG)
- User MOC Simulator
- User Platform Simulator
- User Element Simulators

LCRD RF Ground Station

- Interface to/from User Facility

LCRD Mission Operations Center:

Mission Planning and Scheduling * Payload Telemetry and Command * Data Storage
Data Analysis * Central Operations Monitoring and Control * Service Management
Ground Station Remote Monitoring * Experiment Operations
LCRD Example Experiments

LCRD is capable of simulating numerous optical communication scenarios, and LCRD experiments will involve elements both on the ground and in space.
Example Scenario: User with Relay Provider

User with Relay Provider

Scenario:

LCRD Configuration:

All links are bidirectional, and it is possible to independently control the data rates, coding and modulation on each link; therefore, one could demonstrate a user with asymmetric data rates.
Example Scenario: Direct-to-Earth User

Direct-to-Earth User

Scenario: 

LCRD Configuration:

(Ussr Spacecraft)

(User Spacecraft)

(User Data)

(User MOC)

DTE DGS

DGS-1
(.User Spacecraft)

RF GS

DGS-2
(DTE DGS and User MOC)

Key: Optical Link

Terrestrial Link

When executing the simulated user downlink to the ground, the LCRD flight segment can employ a modulation scheme different than that employed on the uplink to send the simulated user data from the ground to the LCRD flight segment.
Example Scenario: Relay Provider for Multiple Users

Relay Provider for Multiple Users

Scenario:

(User 1 Spacecraft) -> (Relay) -> (User 2 Spacecraft)

Key:
- Optical Link
- Radio Frequency Link
- Terrestrial Link

(Relay)  (Relay)

User 1 MDC  User 1 MDC  DGS-1 (User 1 Spacecraft)

Relay RF GS  User 2 MDC  RF GS (Relay RF GS and User MDCs)

DGS-2 (User 2 Spacecraft)
Example Scenario: Relay Provider with Station Handover

Relay Provider with Station Handover

Scenario:

Key:
- Optical Link
- Radio Frequency Link
- Terrestrial Link

LCRD Configuration:

The relay hands off its trunkline (between its OST and the ground) from one ground station to another.

Related experiments could characterize the process for handing over relay spacecraft communications from one optical ground station to another, observing the time advance necessary to schedule handovers and the effects of weather conditions.
Example Scenario: User with Relay Provider (Dual Trunkline)

The optical and RF trunklines can operate simultaneously, allowing this configuration to support numerous scenarios. For example, it can demonstrate that an optical relay using an optical trunkline could support a user spacecraft with specific characteristics. It could also demonstrate whether LCRD can accommodate specific requirements for real-time data delivery.
Example Scenario: DTE Provider Supporting Multiple Users

Direct-to-Earth Provider Supporting Multiple Users

Scenario:

LCRD Configuration:

This scenario simulates a DTE ground station provider supporting more than one DTE user spacecraft.

The DTE optical ground station would provide services based on a predetermined contact, servicing User 2 spacecraft as User 1 moves out of sight.
Example Scenario: DTE User Supported by Multiple Ground Stations

Direct-to-Earth User Supported by Multiple Ground Stations

Scenario:

LCRD Configuration:

In this scenario, two different optical ground stations are potentially available to support a DTE user spacecraft. Experiment can support scenarios involving limited station availability.
Example Scenario: Relay Provider for Multiple Users

User with Relay Provider (User Modem Test)

Scenario:

LCRD Configuration:

Experimenters can use LCRD to test new hardware and software technologies in various experiment configurations.

For example, to test a user spacecraft modem design, an experimenter could install a candidate modem at an LCRD optical ground station to interface directly with the optical telescope assembly.
Proposing LCRD Experiments

More details about example experiments can be found in the **LCRD Introduction for Experimenters** document at lcrd.gsfc.nasa.gov.

Additional details about proposal requirements and the proposal process can also be found at the LCRD website shown above.
QUESTIONS?

DAVE ISRAEL
NASA/GSFC CODE 450
GREENBELT, MD 20771

DAVE.ISRAEL@NASA.GOV