Overview

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Mission Statement

LCRD

- The Laser Communications Relay Demonstration (LCRD) will demonstrate optical communications relay services between GEO and Earth over an extended period, and thereby gain the knowledge and experience base that will enable NASA to design, procure, and operate cost-effective future optical communications systems and relay networks.

- LCRD is the next step in NASA eventually providing an optical communications service on the Next Generation Tracking and Data Relay Satellites

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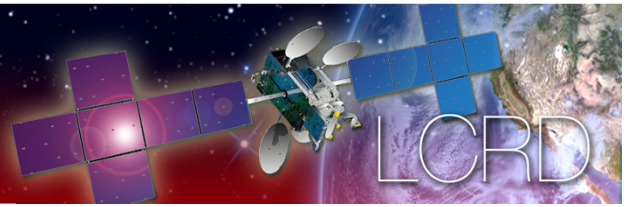
Mission Architecture



LCRD Payload and Host Spacecraft

LCRD Flight Payload
2 Optical Relay Terminals
- **10.8 cm aperture**
- **0.5 W transmitter**

Space Switching Unit

1244 Mbps DPSK
311 Mbps 16-PPM

1244 Mbps DPSK
311 Mbps 16-PPM

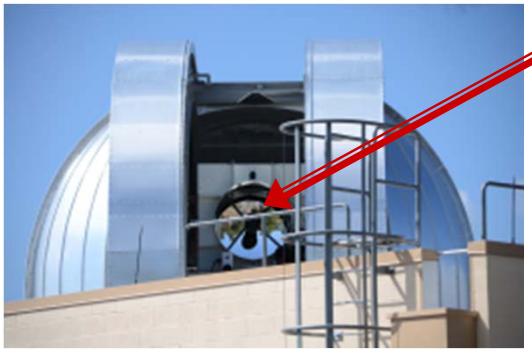
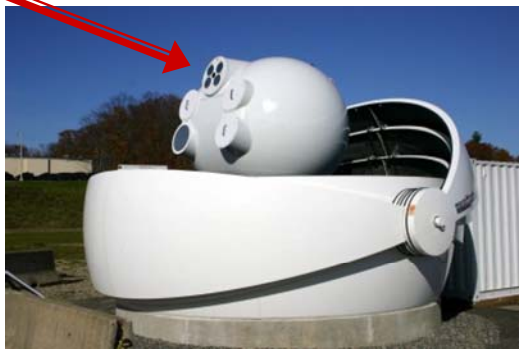


Table Mountain, CA

LCRD Ground Station 1
1 m transmit and receive aperture
- **20 W transmitter**

Mission Concept

- Orbit: Geosynchronous
  - Longitude TBD between 162ºW to 63ºW
- 2 years mission operations
- 2 operational GEO Optical Relay Terminals
- 2 operational Optical Earth Terminals
- Optical relay services provided
  - Ability to support a LEO User
- Hosted Payload
- Launch Date: Dec 2017



White Sands, NM

LCRD Ground Station 2
15 cm transmit aperture
- **20 W transmitter**

40 cm receive aperture

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The Lunar Laser Communications Demonstration (LLCD)

LCRD

- NASA's first high rate space laser communications demonstration
- Space terminal currently flying on Lunar Atmosphere and Dust Environment Explorer (LADEE)
- Launched September 6, 2013 from Wallops Island on Minotaur V
  - Completed 1 month transfer
    - Performed successful lasercom ops up to 311 Mbps downlink
  - Currently in 1 month lasercom demo @ 400,000 km
    - 250 km lunar orbit
    - 622 Mbps downlink; 20 Mbps uplink
  - 3 months science mission to follow

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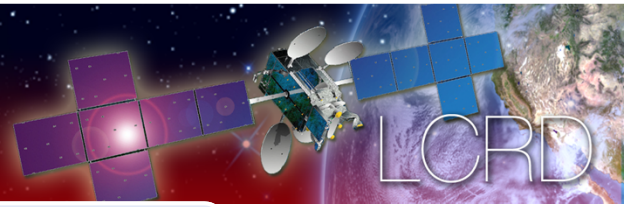
Leveraging LLCD



Lunar Lasercom Space Terminal

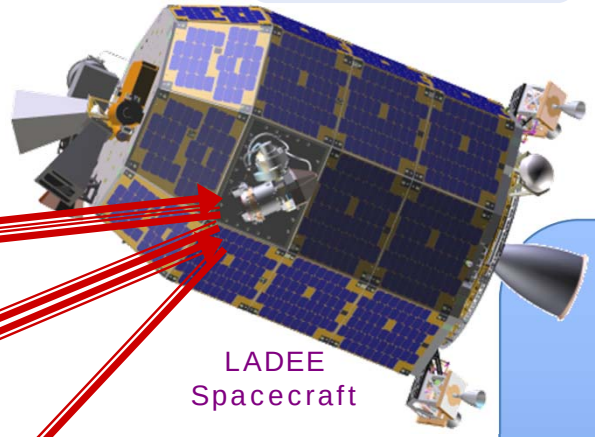
Modem Module

Lunar Lasercom Ground Terminal

White Sands, NM

DL 622 Mbps
UL 20 Mbps

1.55 um band

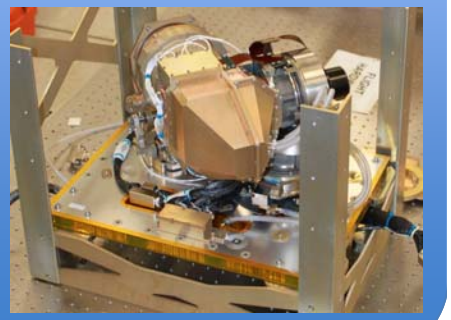


LADEE Spacecraft

Controller Electronics

DL > 38 Mbps

Optical Module



Tenerife

DL > 38 Mbps
UL > 10 Mbps

Table Mtn, CA

Lunar Lasercom Optical Ground System (ESA)

Lunar Lasercom OCTL Terminal (JPL)

LCRD will leverage designs and hardware from LLCD, with modifications to satisfy mission requirements.

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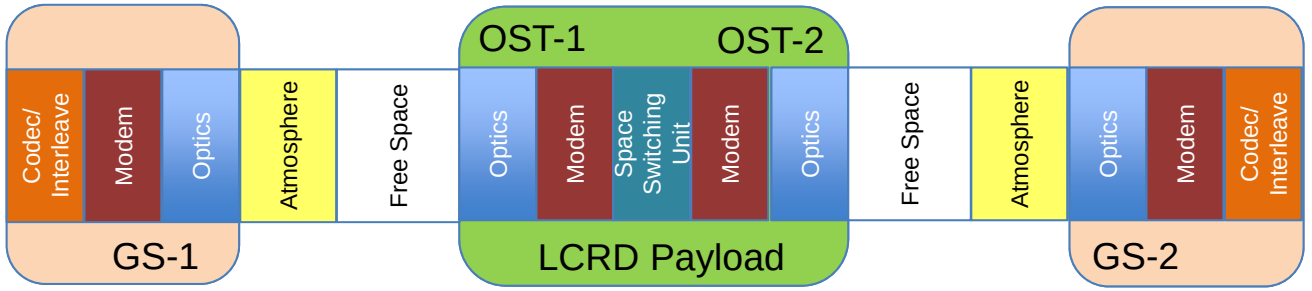
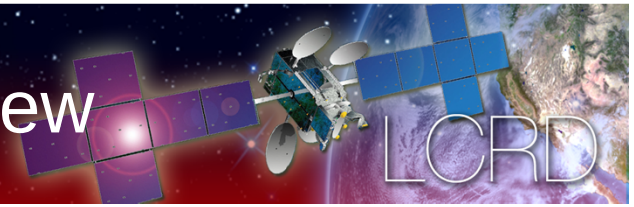
Relay Optical Link

Relay Link Features:

- Coding/Interleaving at the link edges
  - Rate ½ DVB-S2 codec (LDPC)
  - 1 second of interleaving for atmospheric fading mitigation
- Data can be relayed or looped back
- PPM or DPSK can be chosen independently on each leg

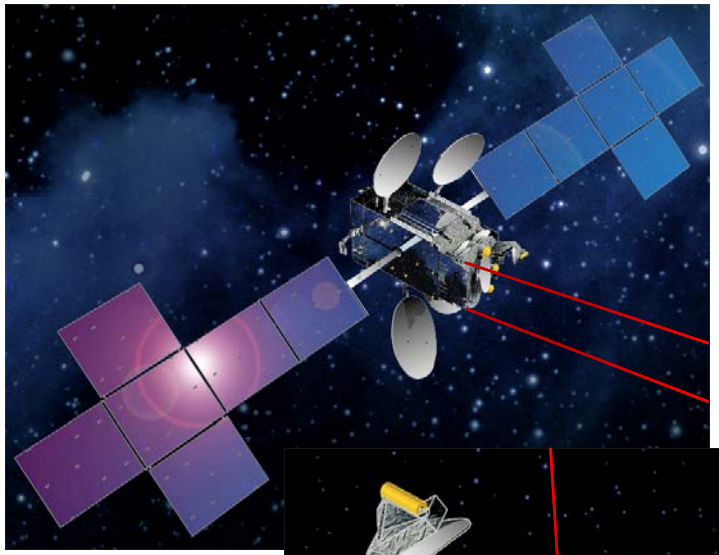


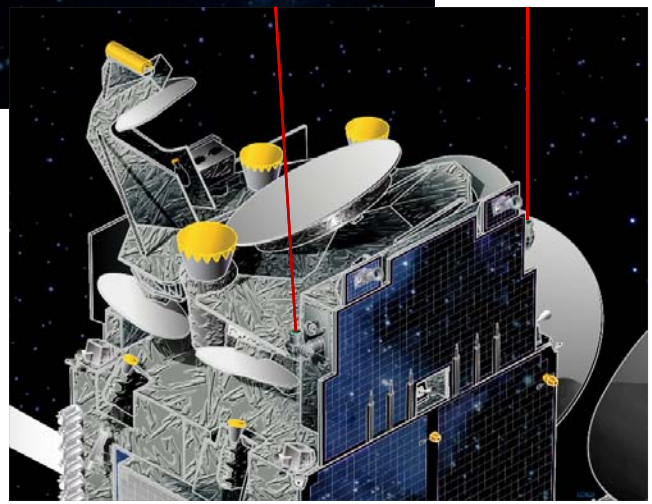
Bus and Payload Overview



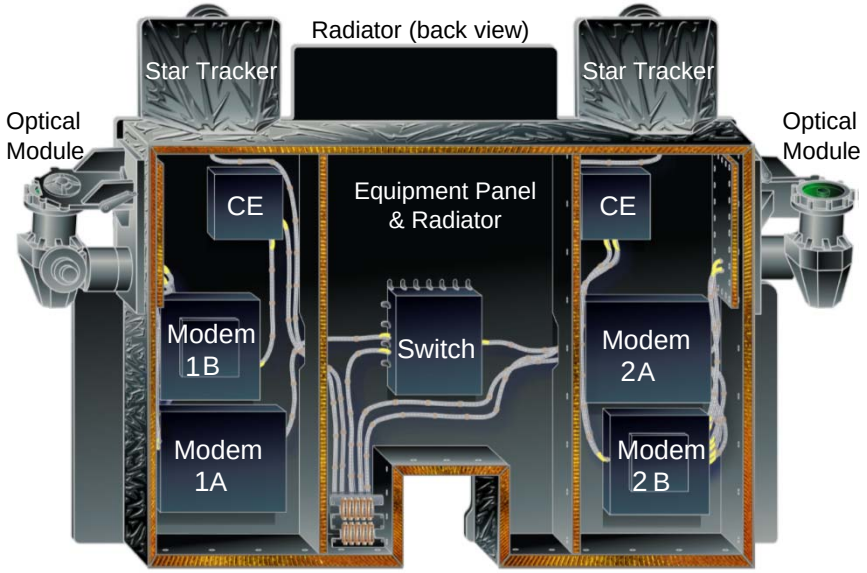
Bus Overview

- Existing SSL commercial satellite bus





- LCRD package is located on the S/C Earth deck, similar to a typical North panel extension
- The enclosure North-facing surface is the main radiator with Optical Solar Reflectors
- Secondary LCRD radiator panel is on the South side
- Star trackers located on the top of the enclosure for optimal registration with OMs



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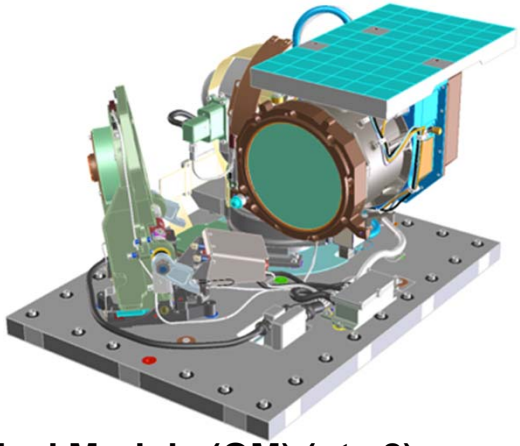
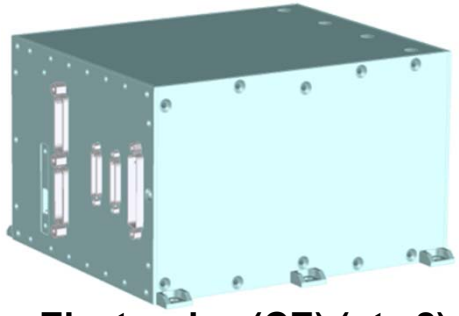
Payload Hardware Overview



Optical Module (OM) (qty 2)

- Gimbaled telescope (elevation over azimuth)
  - 12° half-angle Field of Regard
- 10.8 cm aperture, 14 kg
- Local inertial sensor stabilization

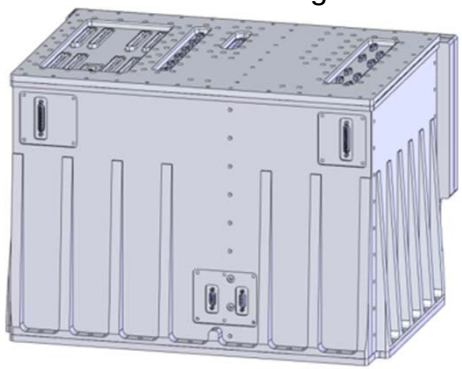


Controller Electronics (CE) (qty 2)

- OM control/monitoring
- Interface to Host Spacecraft
- 7 kg, 151 W

Integrated Modem (qty 2)

- 0.5 W transmitter; optically pre-amplified receiver
- DPSK and PPM modulation
- 27 kg, 130 W
- Supports Tx and Rx frame processing
  - No on-board coding and interleaving



Switch (qty 1)

- Flexible interconnect between modems to support independent communication links
  - High speed frame switching/routing
- Command and telemetry processor

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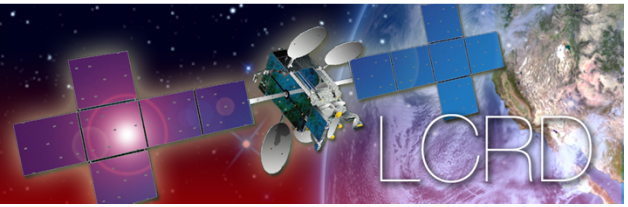
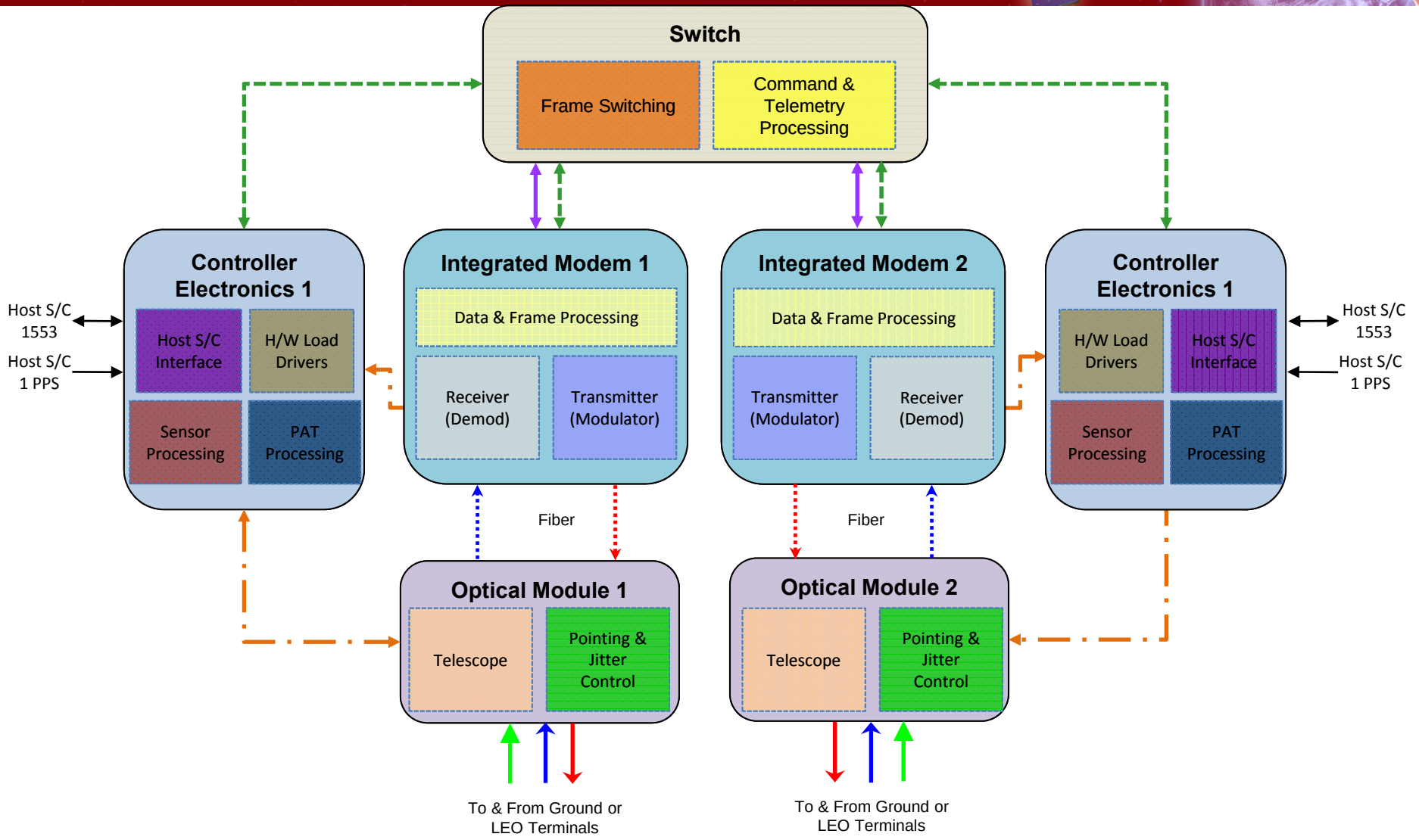
LCRD Payload Functional Diagram





Two Ground Stations

- JPL will upgrade the JPL Optical Communications Telescope Laboratory (OCTL) to form the LCRD Optical Ground Station (LOGS)
  - This is a single large telescope design
  - Adaptive Optics and support for DPSK will be added

- LCRD will upgrade the Lunar Laser Communications Demonstration (LLCD) Ground Terminal (LLGT) developed by MIT Lincoln Laboratory
  - This is an array of small telescopes with a photon counter for PPM
  - Adaptive Optics and support for DPSK will be added

- Both stations will have atmospheric monitoring capability to validate optical link performance models over a variety of atmospheric and background conditions

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Ground Station Components

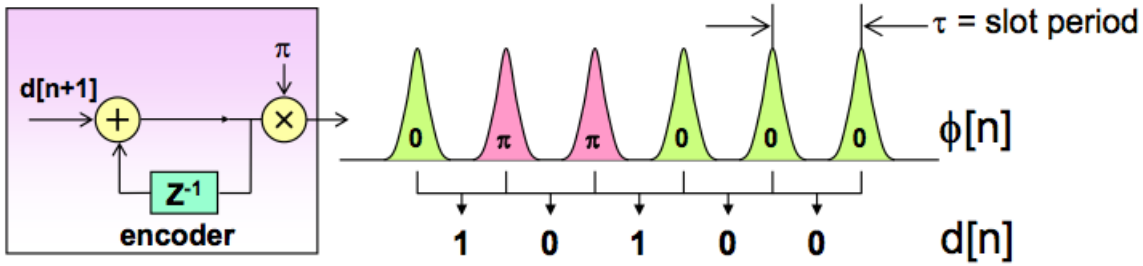
LCRD

Ground Station 1	Ground Station 2
Upgrade of JPL's OCTL	Upgrade of LLGT
20 W transmit power	20 W transmit power
1 meter transmit/receive aperture	40 cm receive aperture; 15 cm transmit aperture
Identical equipment for atmospheric monitoring	
Receive adaptive optics	Receive adaptive optics and uplink tip/tilt correction
Identical Ground Modem, Codec, and Amplifier systems for DPSK and PPM	
Wide angle beacon for initial acquisition	Scanning beacon for initial acquisition
Laser safety system for aircraft avoidance	Operation in restricted flight airspace
	Legacy array of superconducting nanowire single photon detectors

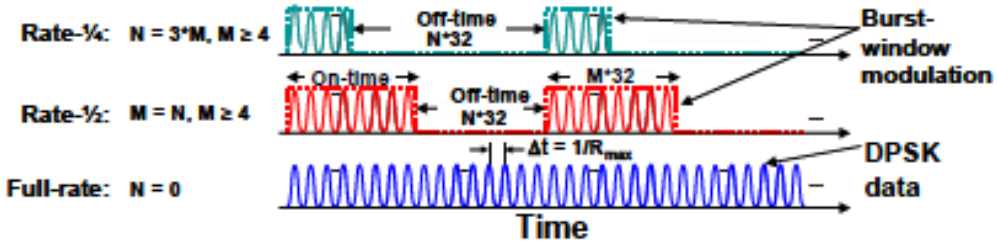
DPSK Modulation/Demodulation

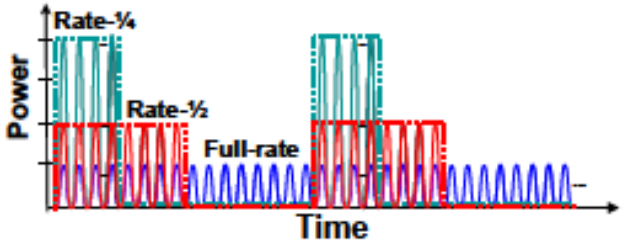
In the DPSK system, each slot contains an optical pulse with phase = 0 or π. Data carried as a relative phase difference between adjacent pulses.

DPSK Transmitter



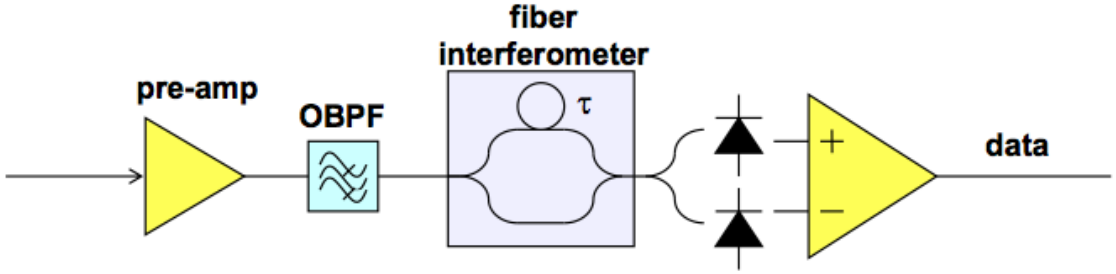
The average power-limited transmitter allows peak power gain for rate fall-back via "burst mode" operation.





At the DPSK receiver, the original sequence is demodulated using a fiber delay-line interferometer to compare the phase of adjacent pulses.

DPSK Receiver

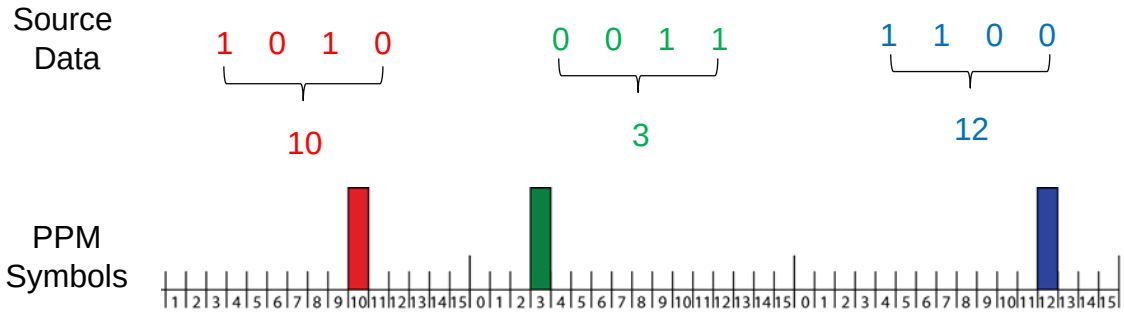


PPM Signaling

For PPM, the binary message is encoded by placing a signal pulse in exactly one of M time slots. (M=16 for LCRD.)

- **Optical modulation accomplished with the same hardware that implements burst-mode DPSK, with the applied phase irrelevant for PPM**

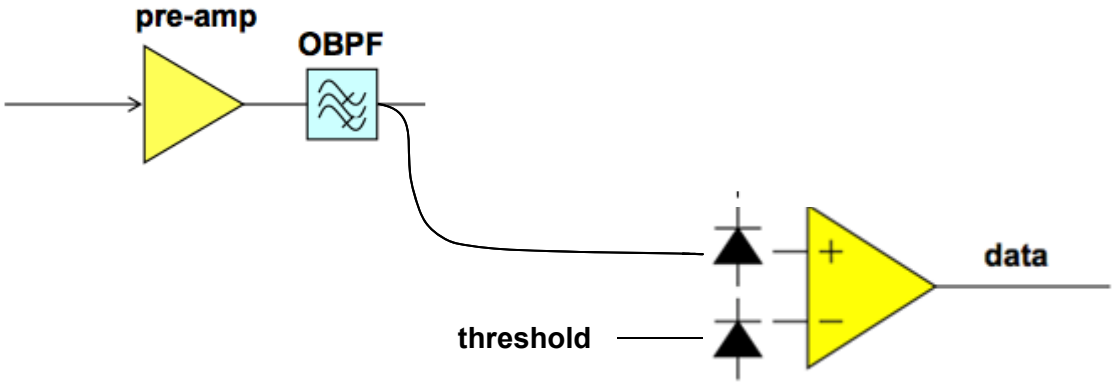
PPM Signaling



PPM demodulation is accomplished by comparing the received power in each slot with a (controllable) threshold value

- **Uses the same pre-amplifier and optical filter as the DPSK receiver, but bypasses the delay-line interferometer**

PPM Receiver



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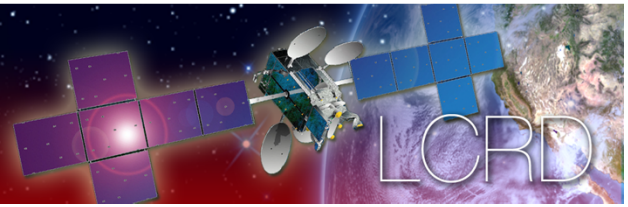
Summary



- The LCRD optical communications terminal leverages previous work done for NASA
- With a demonstration life of at least two years, LCRD will provide the necessary operational experience to guide NASA in developing an architecture and concept of operations for a worldwide network
  - Unlike other architectures, it will demonstrate optical-to-optical data relay
- LCRD will provide an on-orbit platform to test new international standards for future interoperability
  - LCRD includes technology development and demonstrations beyond the optical physical link
- NASA is looking forward to flying the LCRD Flight Payload as a hosted payload on a commercial communications satellite
- NASA can go from this demonstration to providing an operational optical communications service on the Next Generation Tracking and Data Relay Satellites