EXPLORATION AND SPACE COMMUNICATIONS PROJECTS DIVISION

National Aeronautics and Space Administration

NASA

A Day in the Life of the Laser Communications Relay Demonstration (LCRD) Project. SpaceOps 2016

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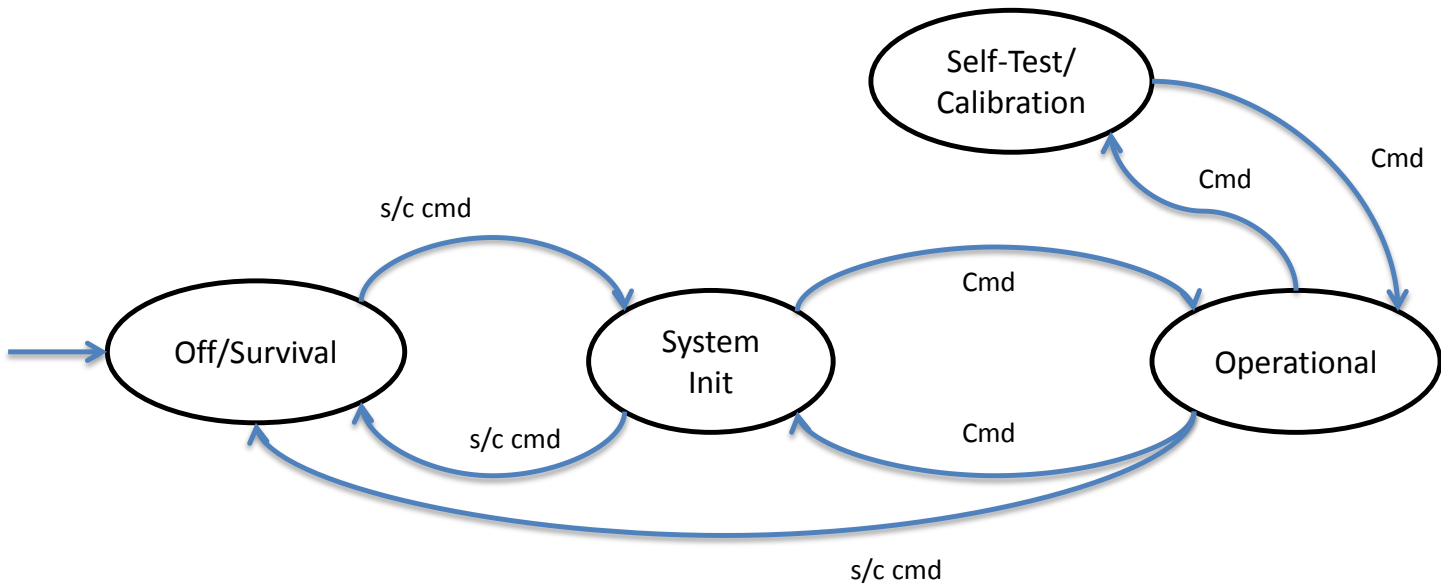Jet Propulsion Laboratory, California Institute of Technology
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NASA GODDARD SPACE FLIGHT CENTER

Mission Statement

- 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 providing optical relay services

Laser Communications Relay Demonstration Mission Architecture

LCRD Flight Payload
2 Optical Relay Terminals
- **10.8 cm aperture**
- **0.5 W transmitter**
- **DPSK and PPM**
Space Switching Unit

Relay Link Features:
- Coding/Interleaving at the link edges
  - Rate ½ DVB-S2 codec (LDPC)
  - 1 second of interleaving for atmospheric fading mitigation

Optical

Optical

2880 Mbps Uncoded DPSK
1244 Mbps Coded DPSK
311 Mbps 16-PPM

RF

Table Mountain, CA

Hawaii (TBR)

Host Mission Ops Center (HMOC)

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**

Remote LCRD Mission Ops Center (R-LMOC)

LCRD Mission Ops Center (LMOC)

LCRD Developed

OGS-X Developed

Joint LCRD/OGS-X Developed

Host Developed

White Sands, NM

LCRD Payload Operational States

- **Off/Survival Mode:** In this mode the LCRD Payload power is removed and only the survival heaters are powered from the Host Spacecraft. The Payload will launch in this mode and remain there until the first power-on event.
- **Payload System Initialization Mode:** In this mode, the Payload is powered on, but not yet ready to support normal operations. The Payload will enter this mode in one of two cases: Payload initial power up after launch or Payload return to power after Off/Survival mode.
- **Payload Self-Test/Calibration Mode:** In this mode, the Payload will have at least the SSU and one OST powered on. The second OST may be either powered off or powered on. This mode is used to execute pre-defined self-test functions within the Payload.
- **Payload Operational Mode:** In this mode, the Payload has been powered up and initial configuration established such that the Payload can communicate with the LMOC via the Host interface, can attempt to acquire an optical communication links with OGSs and/or User platforms, and once a link is established provide forward and return service relays and Direct Uplinks/Downlinks.

# LCRD Mission Operations Center (LMOC) Operations

- Monitor payload and ground system telemetry
- Monitor the atmospheric conditions at each ground station
- Monitor link status for each optical link and the host spacecraft RF link
- Monitor quality of service for each user service
- Respond to user service requests and support requests from the ExpO team and external users
- Perform planned and unplanned ground station handover and ground system reconfiguration operations when required
- Execute performance data monitoring functions and data storage in support of ExpO team analysis
- Implement scheduling change requests from the ExpO team and external users
- Perform routine housekeeping functions including data store back up, periodic payload and ground calibration functions, clock management, data correlation, preventive system maintenance and other planned maintenance and repair activities.
- Contact engineering, ground system, or supervisory personnel in the event of a significant anomaly

LCRD Optical Ground Station Operations

- Provide laser safety functions
- Monitor and control ground station local equipment
- Monitor the atmospheric conditions at the ground station
- Monitor link status for the ground station optical link
- Monitor quality of service for each User service provided at the ground station
- Support diagnostic procedures when degraded performance is detected
- Perform routine housekeeping functions including data store back up, ground station optical calibration functions, clock management, preventive system maintenance and other planned maintenance activities
- Contact engineering, ground system, or supervisory personnel in the event of a significant anomaly

# Nominal LCRD Acquisition Flow
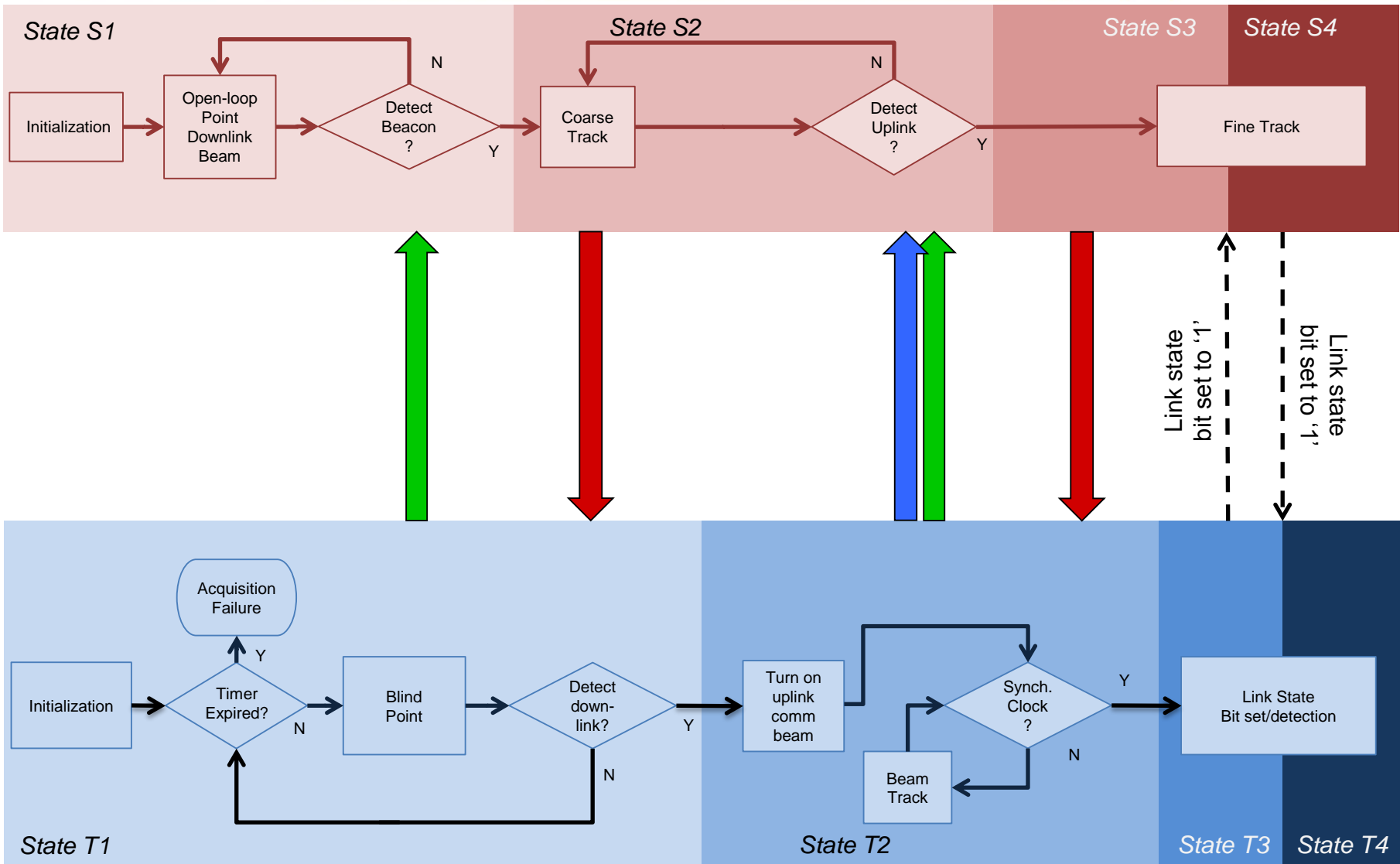
Optical Trunk Line
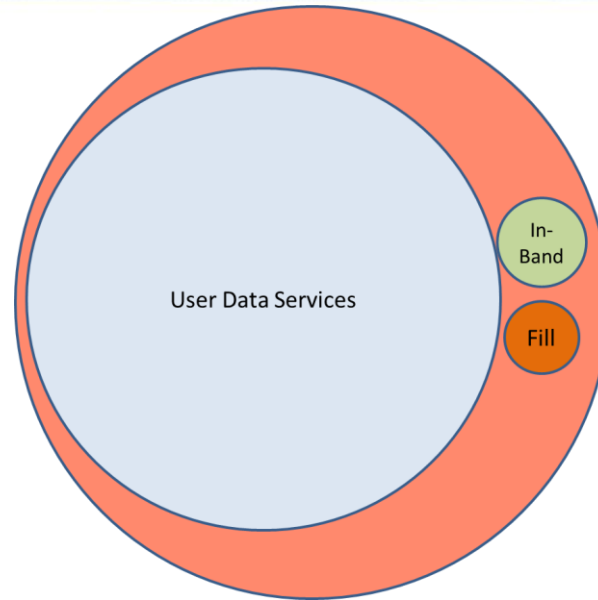
- LCRD provides the capability to multiplex user service data and payload command and telemetry data using the same optical link.

- The optical trunk line can support a slot rate of 2.88 Gbps in each direction for any modulation or data rate.

- LCRD supports multiplexing of multiple data streams over a single optical link in both directions: user service data frames, payload command and telemetry frames, and idle fill frames

Optical Ground Station Handover

1. User(s) and LCRD assets notified of impending ground station handover if possible.

2. OGS-B brought to operational/hot stand by state. This state means being configured to begin the acquisition sequence with the Payload and in the same optical link configuration (data rate an modulation) and ground system configuration as OGS-A for user services and in-band command/telemetry.

3. User services and/or in-band command/telemetry over the optical link terminated at OGS-A and the Payload.

4. Users establish forward/return data link with OGS-B and terminate with OGS-A.

5. Payload is configured via the host spacecraft RF link to point an OST at OGS-B and is ready to begin acquisition.

6. OGS-B and the payload complete acquisition sequence and establish optical communications link.

7. User services and/or in-band command/telemetry resume through OGS-B.

Pre-Handover Configuration

Post-Handover Configuration
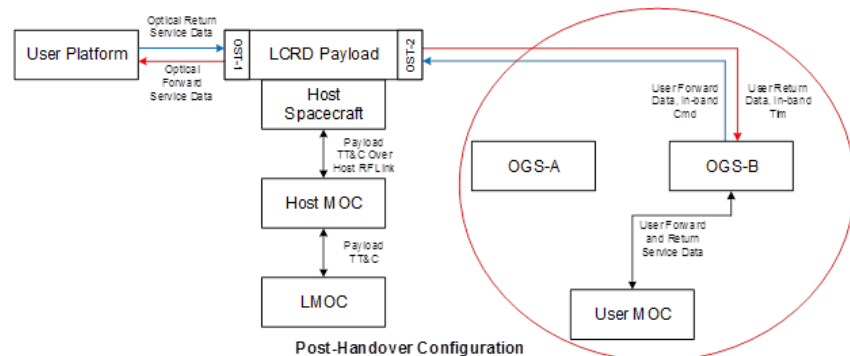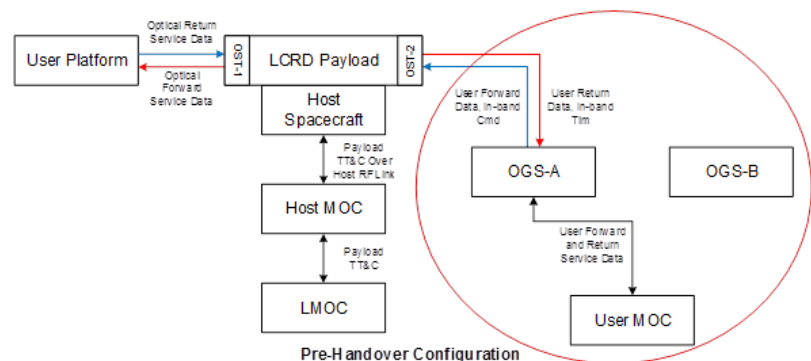
LCRD Experiments

- 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 (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 Experiment Capabilities

- User MOC Simulators (UMSs) and User Platform Simulators (UPSs)
- Data collection and tools for analysis of data and link characteristics
- Simulation of various latencies in data transmission and receipt
- Variations in scheduled service data rates and combinations of service data rates
- Data rate variations in response to deteriorating link conditions
- Variations in user traffic loading relative to allocated service data rates
- Simulation of weather and atmospheric effects
- Simulation of different line-of-site distances
- Variations in relay asset availability

LMOC LCRD Schedule Types

- **Mission Timeline**
  - Human-readable, high-level,
  - Long-term operations schedule incorporating long-range planning inputs.
- **Active Schedule**
  - Medium-term planning product consisting of the conflict-free, constraint checked, and optimized schedule of committed operational services and all LCRD activities necessary to support those services.
  - Configuration of all LCRD assets and support schedules or constraints from external entities
  - Updated a minimum of once per week for LCRD operations covering the next fourteen 24-hour operational days.
  - Used to generate predictive avoidance request messages to LCH and a high-level activity schedule containing times the LCRD payload will operate and any operational events that may impact host spacecraft flight or ground operations.
- **Operational Schedule**
  - Short-term schedule provided to the LMOC subsystems to be executed for asset configuration and control.
  - This schedule is generated once before every "operational day"
  - Coordinates the configuration of all assets to support user services and experiments.
  - May be regenerated at any time during an operational day for unplanned OGS handovers, unplanned maintenance or downtime events for the LMOC, LCRD payload, each OGS, or external support assets, changes to experiment or demonstration support plans, change requests from users, or any other reason.
  - An Operational Schedule Excerpt (OSE) will be generated from the full Operational Schedule and distributed to each required asset

Summary

- 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

- The initial LCRD ground segment systems can evolve into the future operational systems as the experience is gained

- NASA can go from this demonstration to providing operational optical relay services in next generation systems

MISSION

As a national resource, the ESC enables scientific discovery and space exploration by providing innovative and mission-effective space communications and navigation solutions to the largest community of diverse users.

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