



# LCRD Optical Ground Station 1

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# Laser Communications Relay Demonstration (LCRD)

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California Institute of Technology

- **Optical Ground Station 1 (OGS1) is being developed to support the LCRD project**
- **Capable of sustained bi-directional communications**
  - Up to 1.24 Gbps – DPSK
  - Up to 311 Mbps – PPM
- **LCRD Objectives**
  - Demonstrate bi-directional optical communications
  - Characterize system performance over a variety of conditions
  - Transfer optical communication technology to industry
  - Support, test and demonstrate optical communication standards
  - Demonstrate extensive multi-user networking
  - Demonstrate effectiveness of adaptive optics for communication links

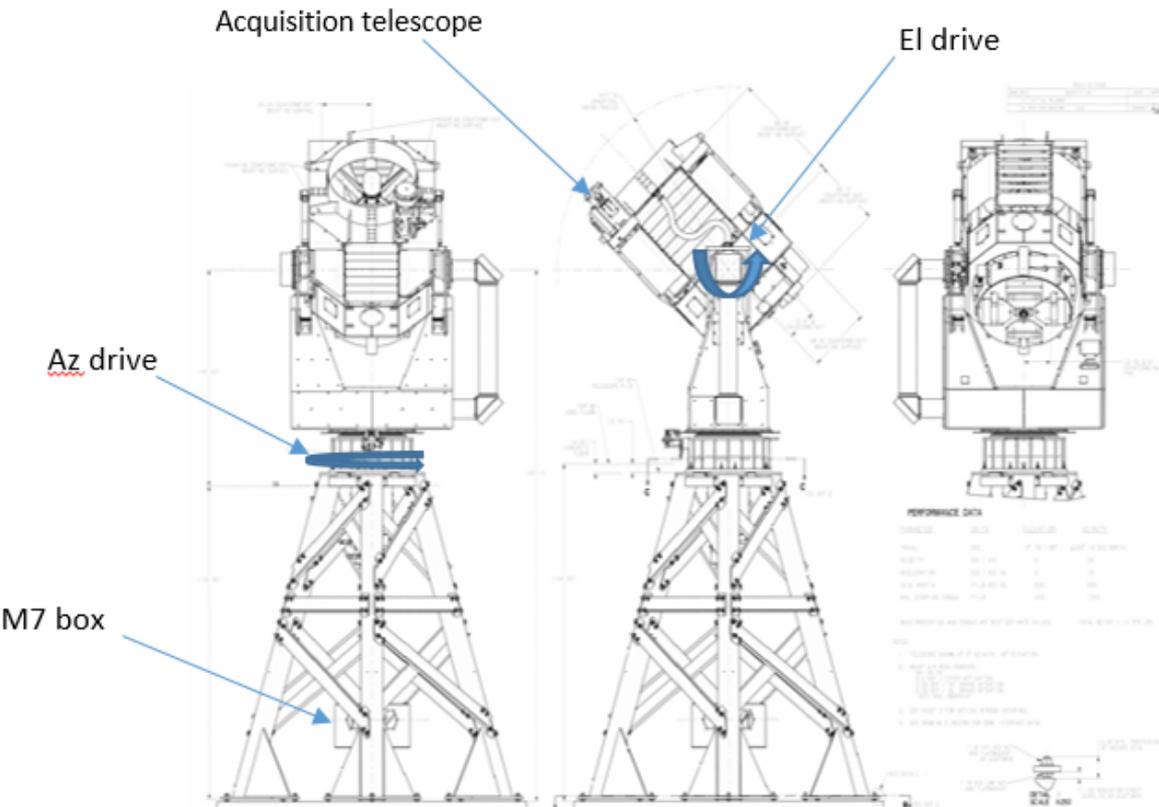




# OCTL Telescope

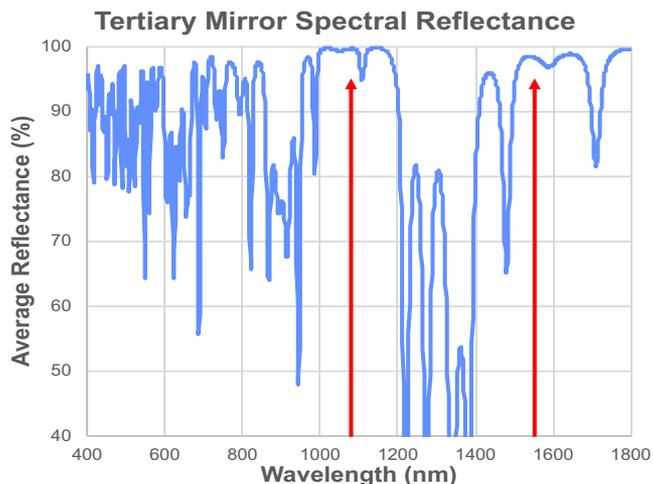
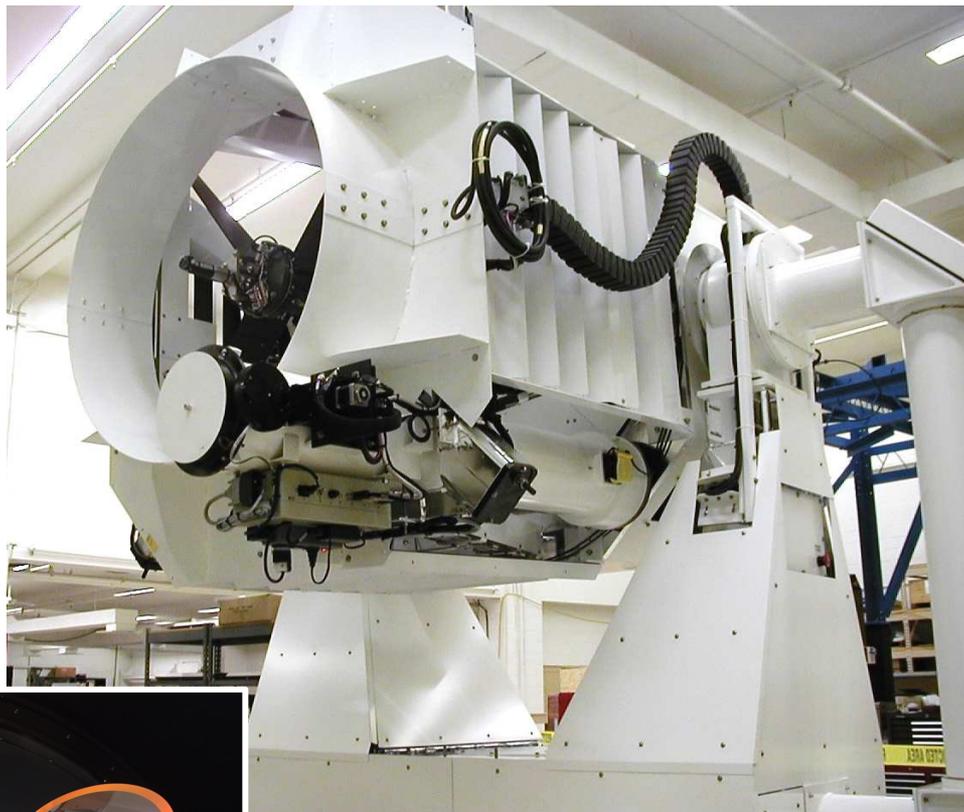
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- 1-meter F/76 telescope in coudé configuration
- Fast-slewing EI over Az mount for satellite tracking
- 4 coudé ports allow concurrent experiments
- Designed for daytime operations





- **Unique Telescope Features**
  - Low-expansion glass mirrors
  - White-painted telescope structures
  - Spider shields
  - Dielectric coude mirrors
    - Excellent transmission at laser wavelengths
    - Robust, cleanable coatings
- **Unique Facility Features**
  - Flat white internal dome paint
  - Coude configuration allows electronic systems to be kept in benign environment

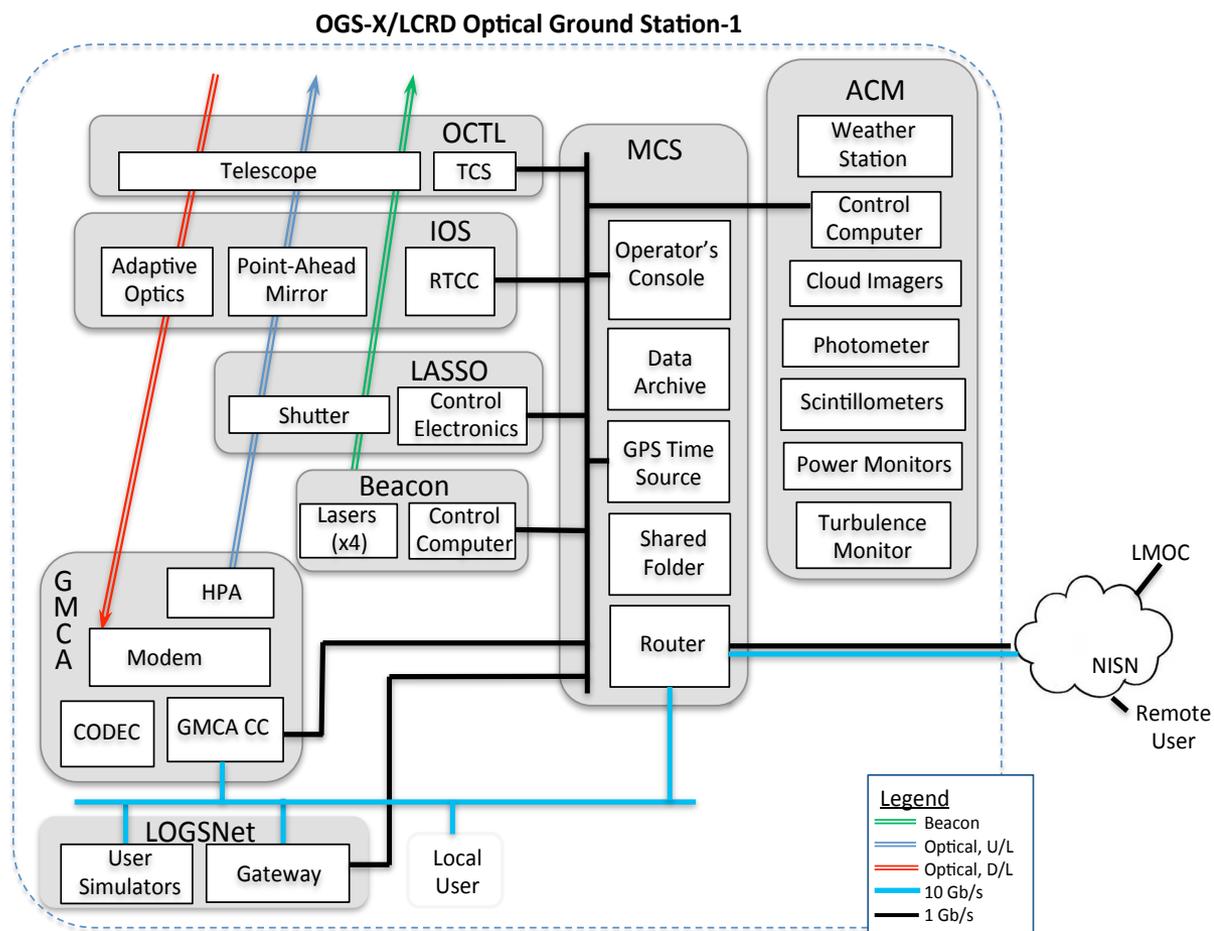




# OGS-1 System

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- Telescope for signal collection and transmission
- Adaptive Optics for efficient signal collection
- Laser safety system
- Multiple beacons for acquisition by spacecraft
- Ground modem for signal retrieval and signal encoding
- Networking gateway for controlling services
- User simulators for evaluating system performance
- Atmospheric monitoring system to understand the Optical Channel
- Monitor and control system for control and coordination



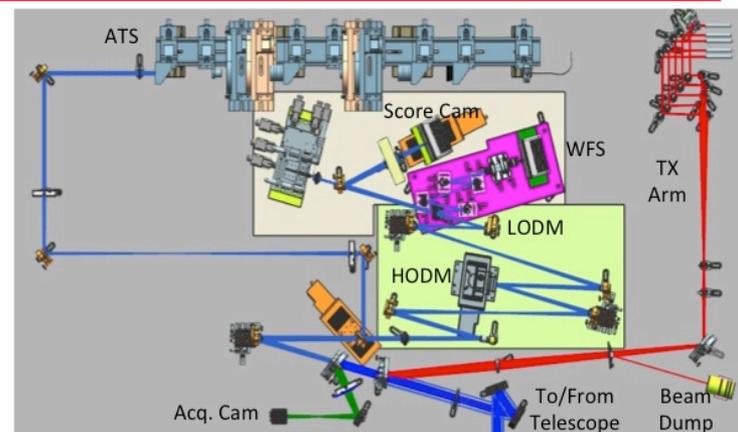


# Unique Features of OGS-1

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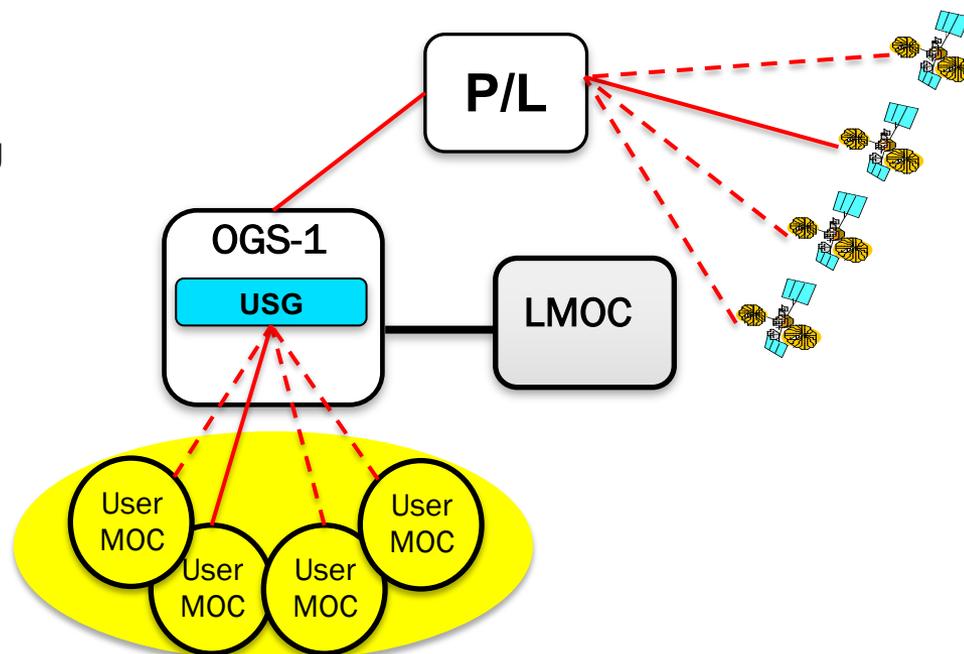
- **Fast Adaptive Optics system**

- Two deformable mirrors to compensate for large stroke and high spatial frequency
- 10 kHz wavefront sensor
- Scoring camera for evaluation of corrected Strehl ratio
- Atmospheric Turbulence Simulator for testing and performance verification



- **High bandwidth networking services**

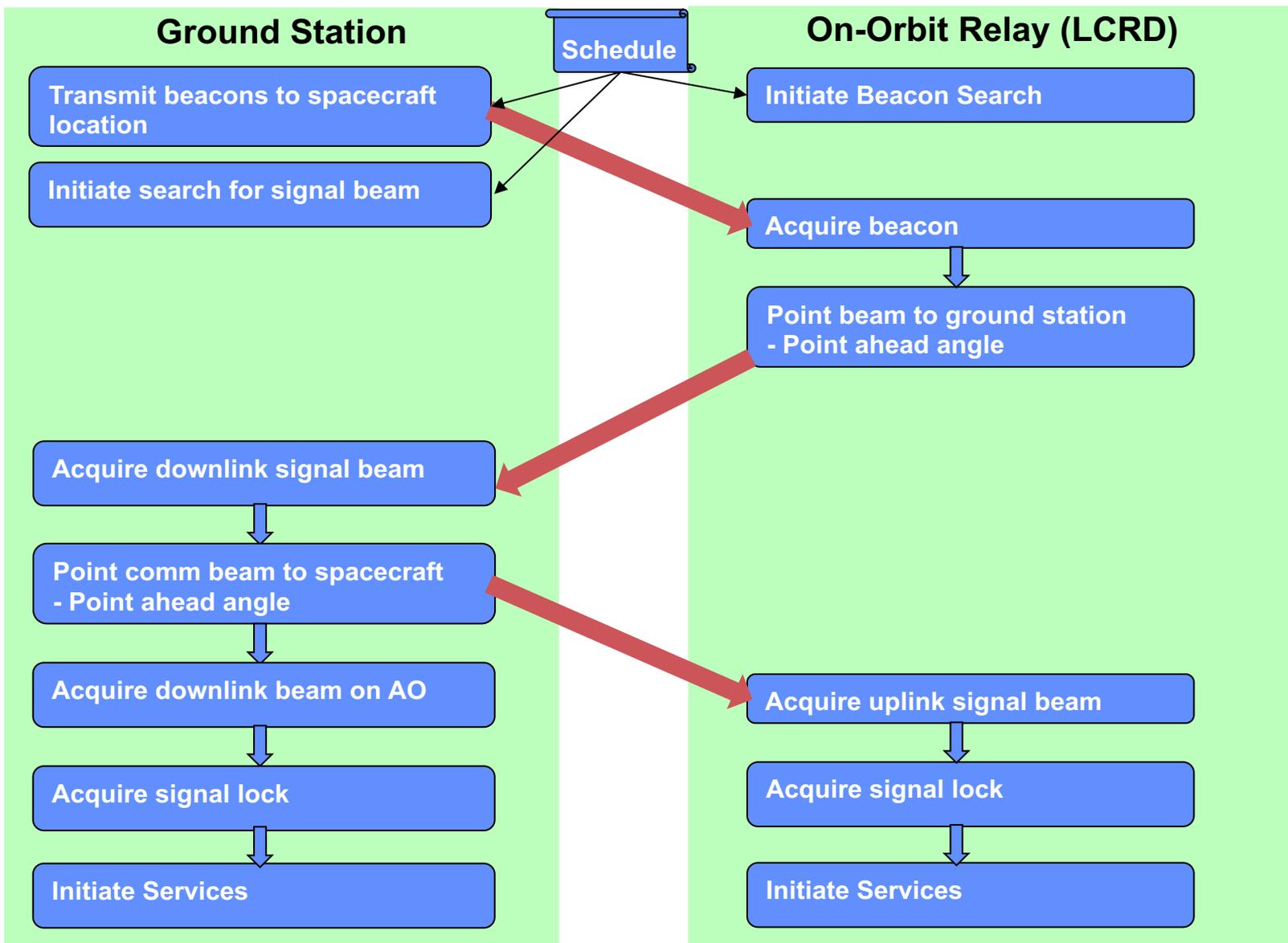
- Up to 12 simultaneous users connecting through User Services Gateway
- Four service types
  - SymbolStream
  - BitStream
  - AOS
  - Tunneled IP
- Supports virtual channels
- Supports simultaneous guest users
- High bandwidth platform and MOC simulators
- Schedule-driven services



Simulated by User MOC Simulator



# Acquisition Sequence





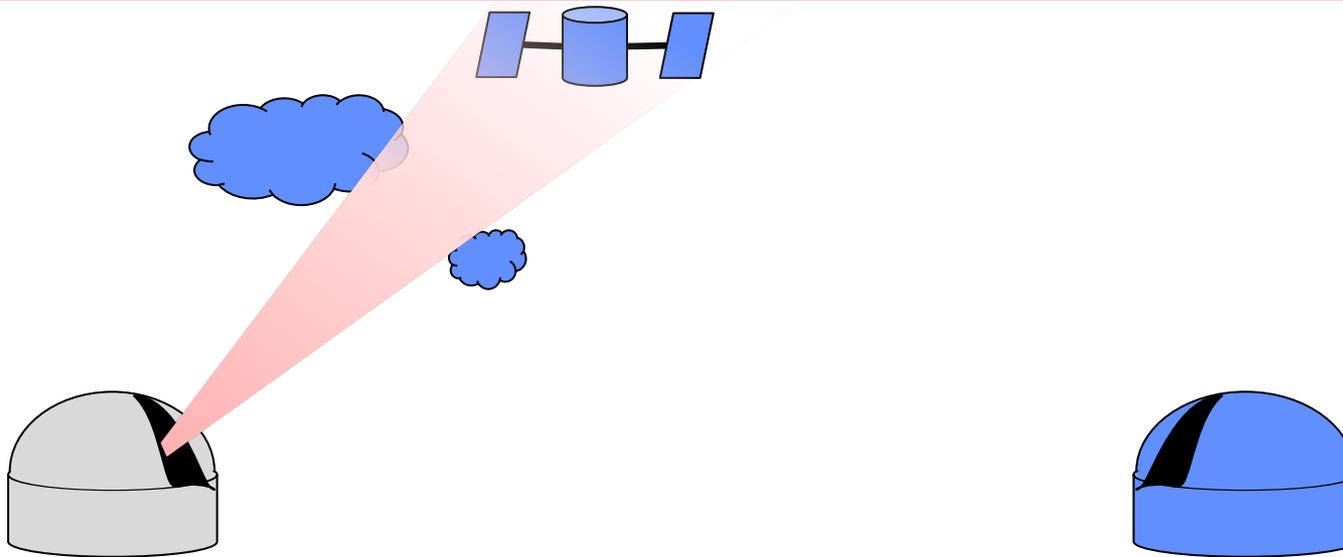
- **Experiment Team evaluates weather predictions for ground stations**
- **LMOC Disseminates Operational Schedule Excerpts (OSE) for:**
  - **Monitor and Control System (MCS)**
  - **User MOC Simulator (UMS) or User MOC**
  - **User Platform Simulator (UPS) or User Platform**
- **LMOC Coordinates laser transmission with USAF Laser Clearinghouse (LCH)**
- **OGS-1 Monitor and Control System (MCS) configures OGS-1 Subsystems**
  - **Load Predictive Avoidance File in Laser Safety Computer**
  - **Load TLE Pointing File in telescope control system**
- **OGS-1 Operations Team Prepares for Operations**
  - **Check Internal Laser Transmission Path**
  - **Start up/warm up beacon/comm laser systems**
  - **Load Software/Confirm preparation of operational systems**
  - **Visually inspect/evaluate telescope mirrors**
  - **Evaluate weather suitability for operation**
  - **Establish LMOC-OGS-1 voice, data communications**
  - **Evaluate/Adjust laser alignment**
  - **Evaluate AO system performance**
  - **Compute MGS adjustment to AO System influence function**
  - **Switch from Atmospheric Turbulence Simulator input to Telescope Input**
  - **Rotate telescope mirror M7 to LCRD table in coude room**
  - **Open telescope dome**



- **Receive execute command directing to appropriate schedule**
- **MCS directs UMS and UPS to retrieve and configure for schedule**
- **MCS Initiates Operations (automatic according to schedule)**
  - **Laser Safety System allows transmission of beacon and comm lasers**
  - **Operator to verify comm laser point-ahead angle on beam monitoring system**
  - **MCS Initiates search for spacecraft downlink beam with acquisition camera**
  - **MCS commands telescope to center downlink spot in acquisition FOV**
  - **Acquire LCRD beam on AO system**
    - **Continuously measure/correct wavefront**
  - **Initiate closed-loop operation of fiber coupling system**
  - **Acquire signal on Ground Modem**
  - **Configure service commands**
  - **Start flowing data according to traffic profile**
- **Periodic evaluation of system performance during operations**
  - **Coupling efficiency of downlink signal to single-mode fiber**
  - **Strehl ratio on AO scoring camera**
  - **Uplink beacon pointing drift, divergence and power**



# Signal Handover



- **Execute link initiation to alternate ground station**
- **Terminate services**
  - **Cancel command**
    - Leaves existing services running
    - Suspends startup of future services
  - **Abort command**
    - Terminates existing services
    - Brings subsystems to pre-ops conditions



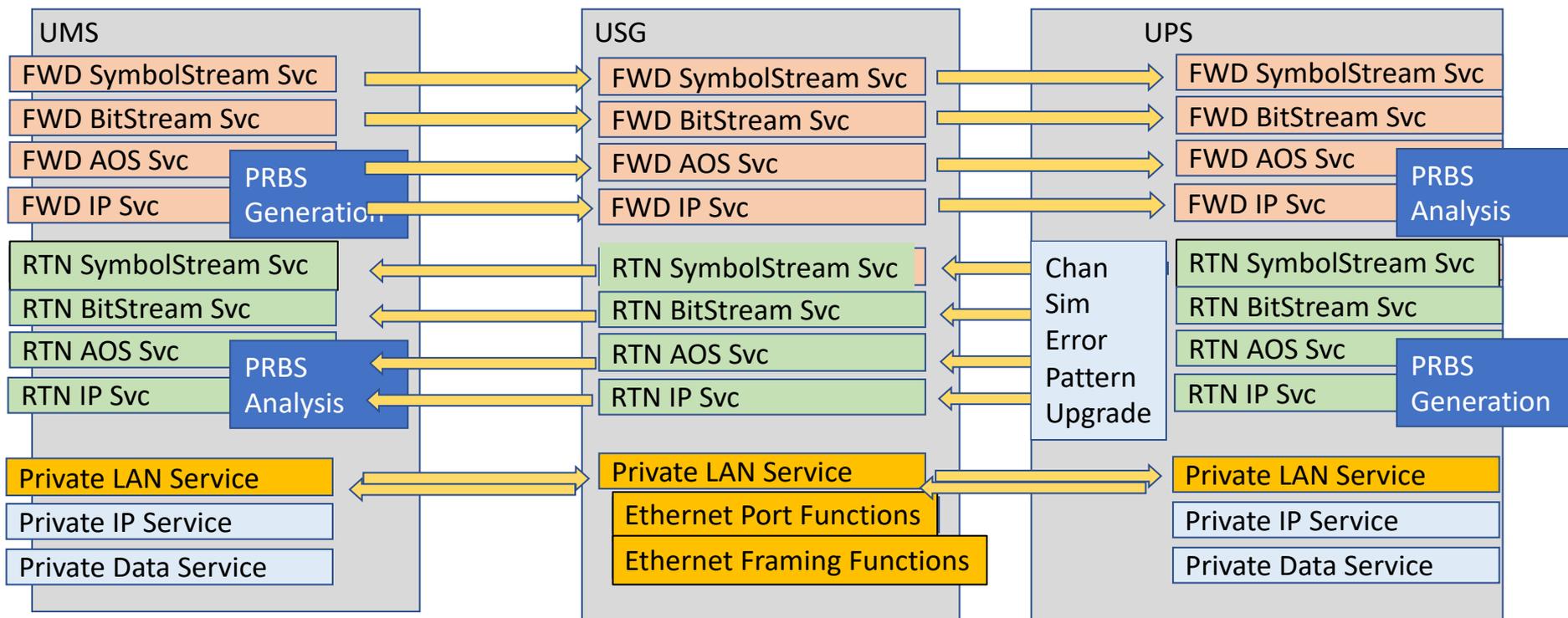
- **Terminate existing services**
- **Shutdown Systems**
  - Ramp down/shut down lasers
  - Close Telescope Dome
  - Shutter and park telescope
  - Data throughput performance summary
  - Weather/channel performance summary
  - Download summaries to ITOS/LMOC
  - Shut down ground modem/codec software
  - Shut down beacon system software
  - Shut down AO system software
  - Shut down laser cooling systems
  - Shut down LOGSNet System software
  - Shut down telescope system software and hardware
- **Secure operation logs**
- **Secure facility**



- **Allows for schedule coordination prior to start**
  - **Tool development to coordinate operations**
- **Allows LMOC to direct operations with short notice**
  - **Multiple schedules may exist for various contingent operations**
  - **Allows LMOC to direct which schedule to execute**
  - **Allows LMOC to terminate one schedule and pick up another**
  - **Allows LMOC to easily suspend and subsequently resume schedules**



- **Simulators available to serve as User MOC and/or User Platform**
- **Networking system supports multiple service types in forward and return**
- **Demonstrated private LAN service and virtual LAN at OGS-1**
- **Developing PRBS generation and analysis tools**





# Summary

- **OGS1 is in development to support LCRD**
  - Characterizes performance over a broad range of atmospheric conditions
  - Supports high-bandwidth networking services
- **Supports different signaling modulations**
  - DPSK to demonstrate high-bandwidth links
  - PPM to demonstrate deep-space networking links
- **Supports multiple concurrent services**
- **Operations concepts and timelines are taking shape**
  - Relies heavily on LMOC-Directed Schedules
  - Supports on-the-fly schedule changes
  - Supports service handover to other ground stations
- **We anticipate excellent performance of OGS-1 for LCRD**



# Acknowledgements

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- **Supporting Development**
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  - **Dr. Lewis C. Roberts – Integrated Optical System Lead**
  - **Mr. Vachik Garkanian – Telescope Lead**
  - **Mr. Thang Trinh – Monitor and Control System Lead**
  - **Dr. Malcolm W. Wright – Beacon Laser System Lead**
  - **Dr. Ryan Rogalin – Ground Modem, Codec, Amplifier Interface**
  - **Ms. Janet P. Wu – Laser Safety System Lead**
  - **Mr. William Walsh – LOGS Networking System Lead**
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