The Architecture of the Laser Communications Relay Demonstration (LCRD) Ground Stations, an Overview

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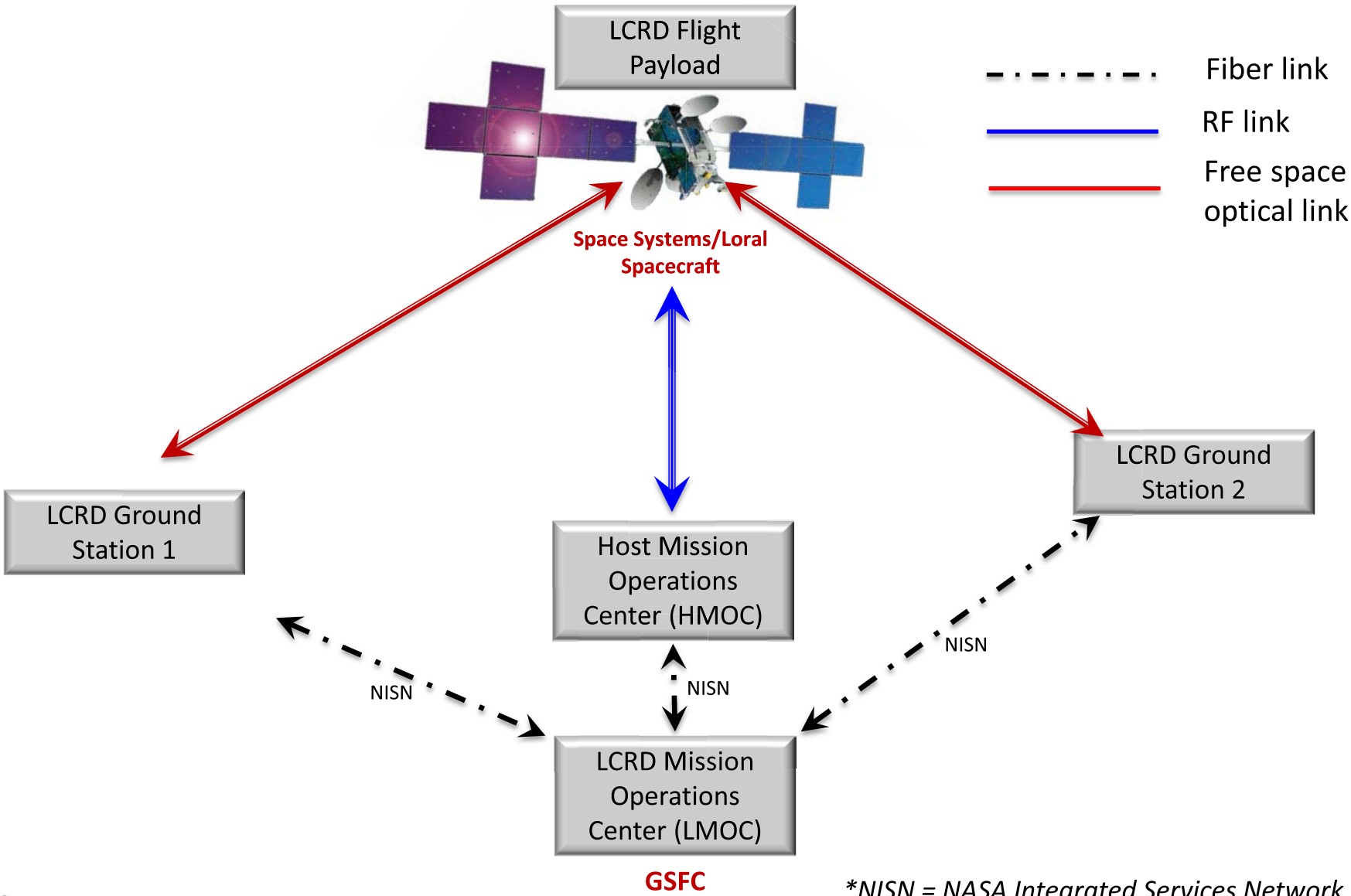
Outline

- LCRD System Architecture Overview
- Goals and Objectives
- Level 1 Requirements
- Design Reference Mission
- LCRD Ground Stations
- Experiment Descriptions
- Summary and Key Milestones

LCRD System Architecture Overview



*NISN = NASA Integrated Services Network

LCRD Goals and Objectives

Goals

- LCRD will demonstrate optical communications relay services between geosynchronous orbit (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

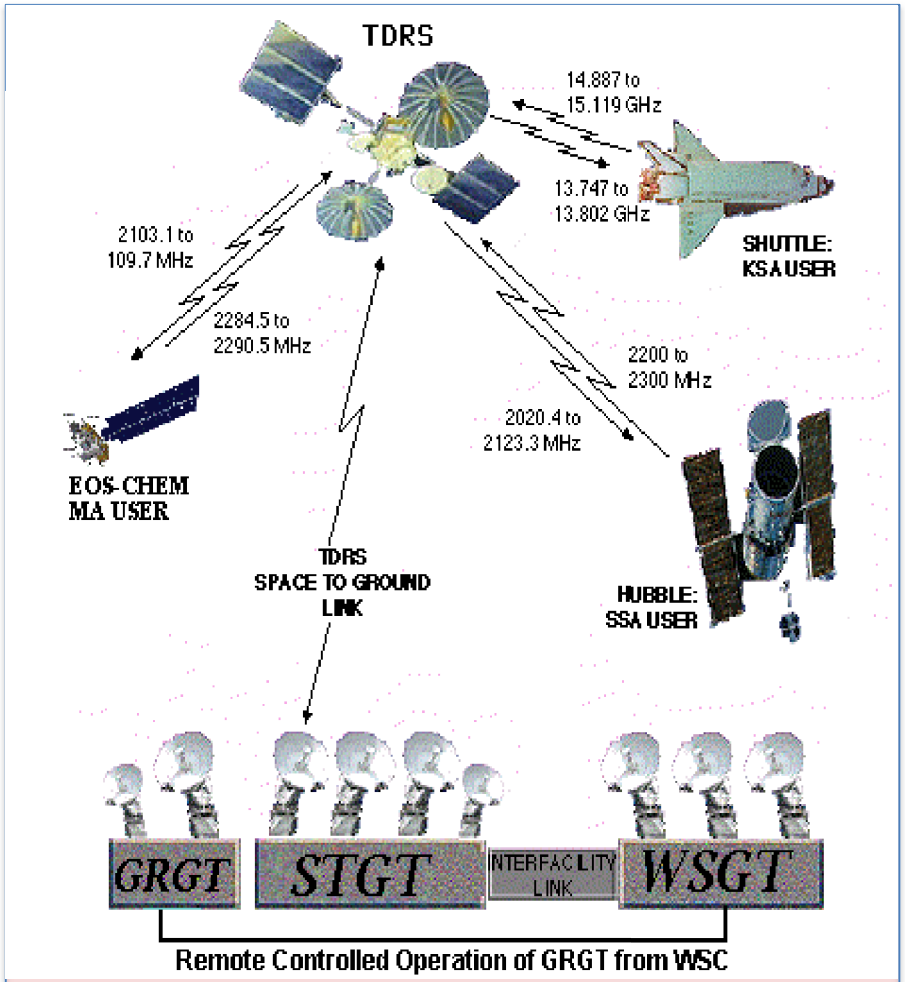
Objectives

- Demonstrate optical communications relay services between GEO and Earth to enable future optical communication systems and relay networks
- Provide the necessary operational experience to guide NASA in developing an architecture and concept of operations for a future optical based network

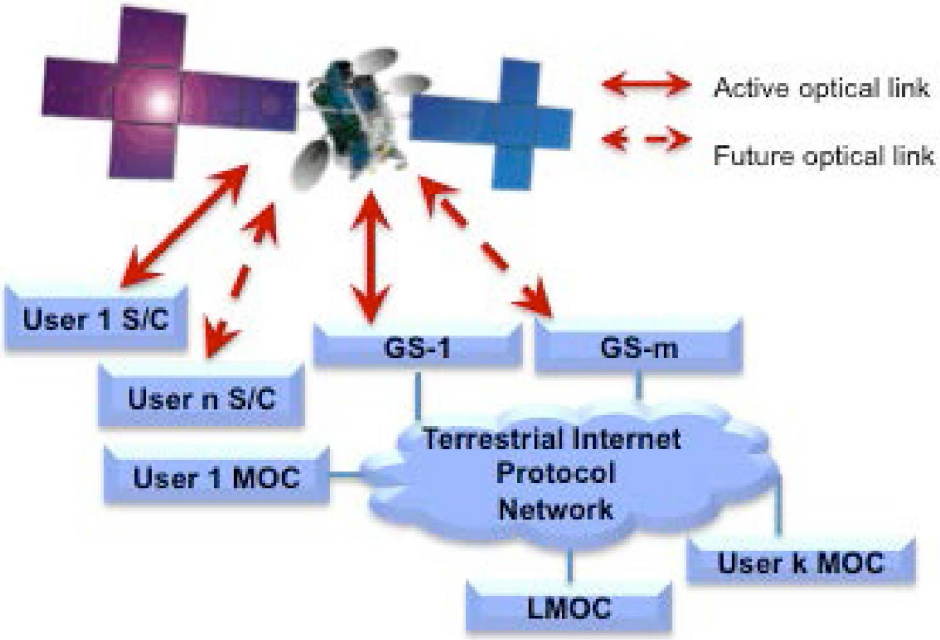
LCRD Level 1 Requirements

	Requirement
1	The LCRD shall enable demonstrations of operational optical relay communications architectures
2	The LCRD shall provide bi-directional direct optical communications services between Earth and GEO
3	The LCRD shall enable bi-directional direct optical communications services between LEO and GEO
4	The LCRD shall provide relay services
5	The LCRD shall provide two simultaneous bi-directional optical relay services from GEO
6	The LCRD shall provide services using PPM modulation
7	The LCRD shall provide services using DPSK modulation
8	The LCRD shall measure and characterize system performance for the life of the mission
9	The LCRD shall be a NASA Class D mission
10	The LCRD shall be designed for a minimum 2-year mission life

LCRD Design Reference Mission



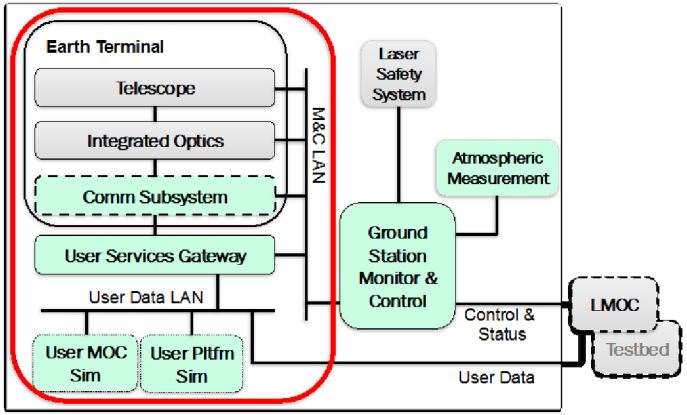
GRGT=> Guam Remote Ground Terminal
STGT=> Second TDRS Ground Terminal
WSGT=> White Sands Ground Terminal



- Future Hybrid Optical/RF Space Network will:
  - Provide simultaneous multiple real-time user support and multiple store & forward user support multiplexed on single trunkline
  - Provide multiple user services: frame, DTN, …
  - Support scheduled and unscheduled Ground Station handovers
  - Support a variety of Users, Mission Operations Centers (MOCs)
- LCRD mission will emulate different relay and user location and orbits by the insertion of delays and disconnections in the data paths

Ground Stations Configuration

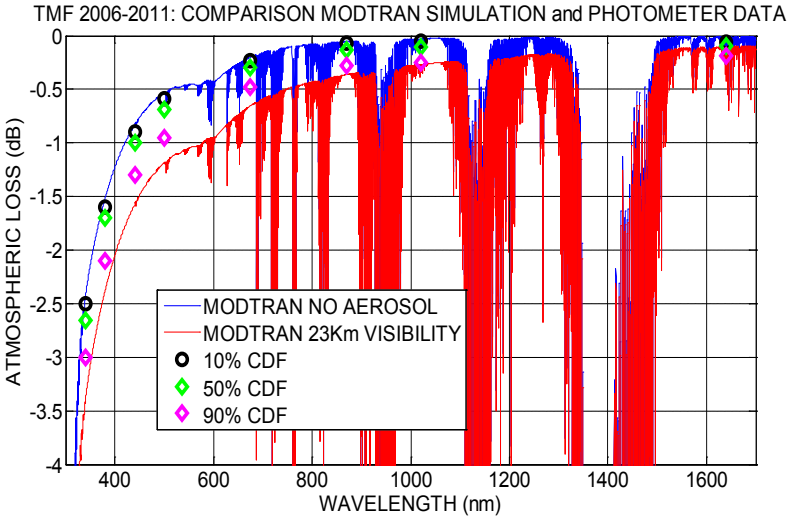
- Telescope Assembly
  - Point to the LCRD Payload in GEO
  - Uplink beacon and comm signals to LCRD Payload
  - Receive downlink from Payload
- Integrated Optics System
  - Couples communications system and beacon to telescope
    - GS1 and GS2 back end telescope optics with AO to measure and correct wave front distortion in received signal
    - One GS 2 telescope coupled to photon counters via multimode fiber



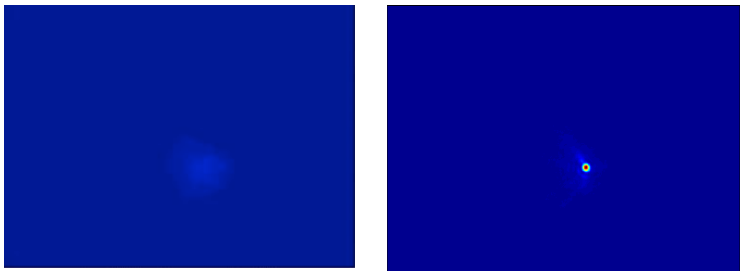
- Communication modem
  - Converts digitally modulated electrical signal to intensity/phase modulated optical signal
  - Encodes and interleaves the packetized data to reduce effects of scintillation-induced fades on optical carrier. Improves reliability and robustness to atmospheric turbulence effects
  - Reverses the process on received downlink signal
- User Services Gateway
  - Provides network-level protocols
  - Enables both real-time and store and forward modes for pass-through or processed data
- User Simulation
  - User MOC Sim: virtual ground operations center(s)
  - User Platform Sim: simulates LEO S/C link

Atmospheric Monitoring at Ground Stations

Atmospheric attenuation

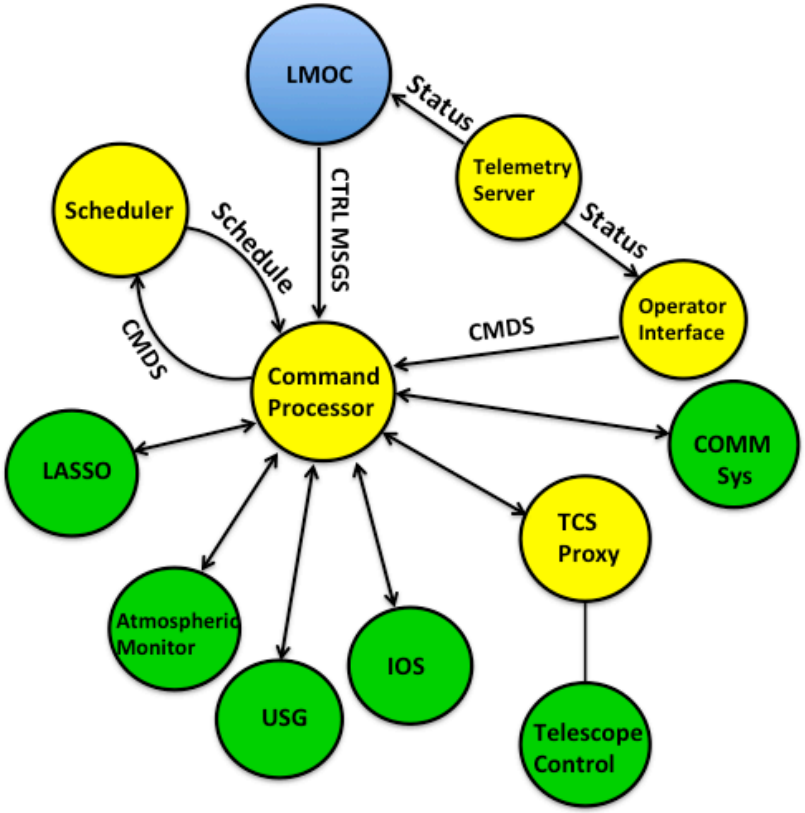


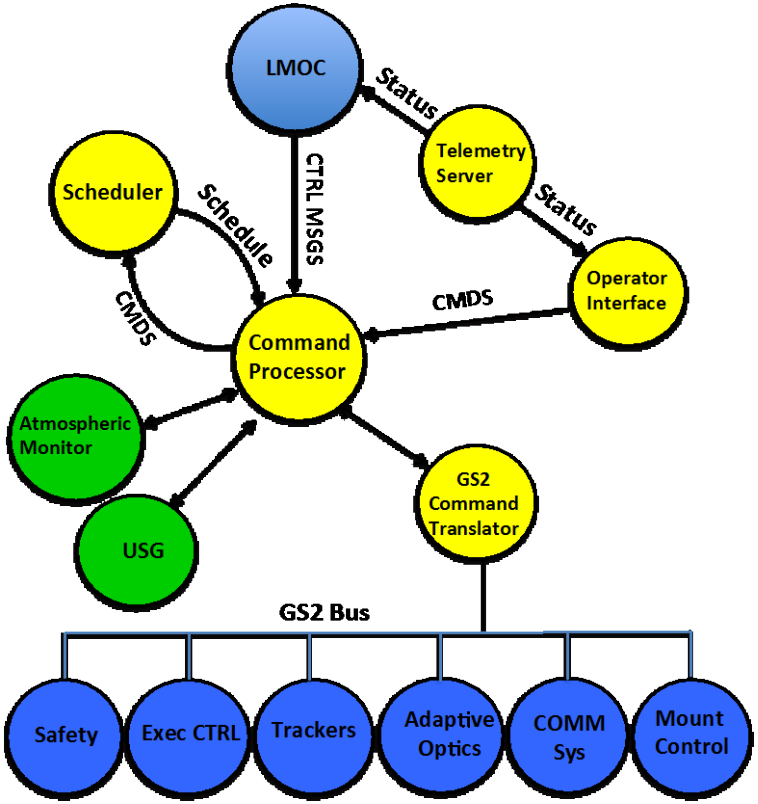
Adaptive Optics
Downlink measurement of r_0



Ground Stations Monitor and Control Software Architecture

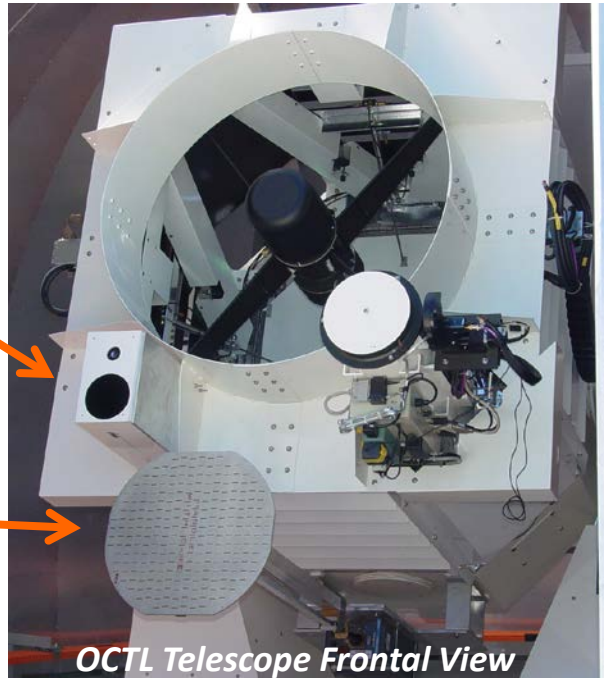
- Monitor and Control System Architecture is common to both GS1 and GS2 and enables implementation of LMOC control of ground stations through Command Processor





- GS1 /GS2 sub-systems:
  - LCRD Mission Operations Center (LMOC), LAser Safety System at OCTL (LASSO) Integrated Optics System (IOS), User Services Gateway (USG), Communications Subsystem (COMM Sys) Telescope Control System (TCS) , Commands (CCMDS), Control Messages (CTRL MSGS)

Safe Laser Beam Propagation Through Navigable Airspace



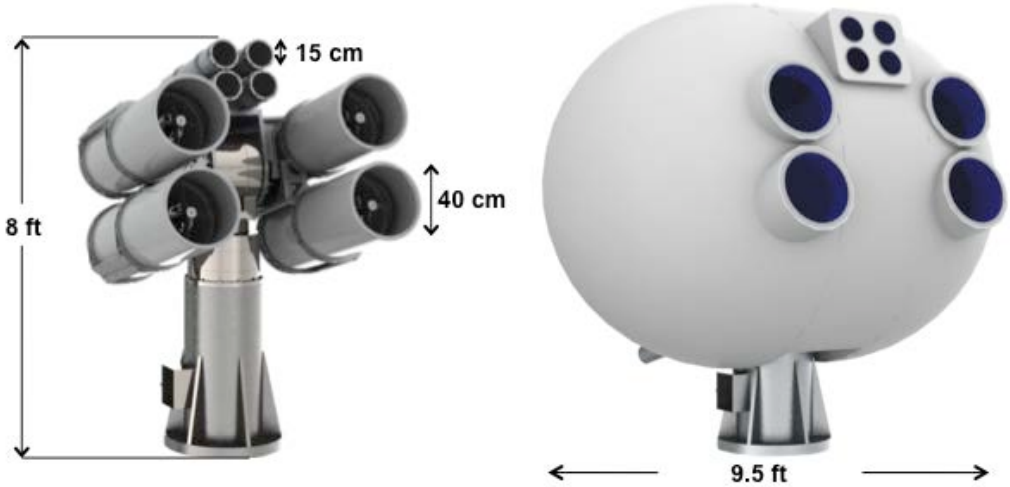
- GS1:LAser Safety System from OCTL (LASSO)
  - Wide field long wave infrared cameras detects aircraft out to 3.4 km
  - Radar system detects aircraft out to 58 km @ 20° elevation
  - Automatically shutters laser when aircraft at risk is detected
- GS2: Located in controlled airspace operations coordination with local White Sands Complex (WSC) air traffic control

Ground Stations Detail

	GS1	GS2
Locale		
Terrain	Mountainous	Desert
Mean sea level (MSL) altitude, km	2.2	~1.22
Longitude	117°40’58.07”W	106°36’31”W
Latitude	34°22’54.31”N	32°30’03”N
Transmitter/receiver		
Configuration	Mono-static	Bi-static
Receiver aperture, m	1	0.4
Uplink full beam divergence 1/e^2, µrad	20	16
Adaptive optics	Shack-Hartmann WFS	Dither AO
Safety System		
	3-Tier Laser Safety System at OCTL	Controlled air space LCH approved

Ground Stations Telescopes

GS1: 1-m multi-function telescope installed at JPL's Table Mountain Facility Wrightwood CA



GS2: Transportable telescope, refurbished from LLCD, 4x40-cm receiver apertures (2 used for LCRD) with 4x15-cm transmitters (1 used for LCRD) installed at White Sands Complex (WSC), NM

Planned Experiments Simulate TDRSS Delivery Service

#	EXPERIMENT	GS1	GS2	SPACE TERMINAL
1	Realtime Relay (DPSK to DPSK)	DPSK User	DPSK GS	GEO Relay
2	Realtime Relay (PPM to PPM)	PPM User	PPM GS	GEO Relay
3	Realtime Relay (DPSK to PPM)	DPSK User	PPM User	GEO Relay
4	Realtime Relay (PPM to DPSK)	PPM User	DPSK GS	GEO Relay
5	Direct Uplink & Downlink (DPSK)	DPSK GS	N/A	User
6	Direct Uplink & Downlink (PPM)	PPM GS	N/A	User
7	Handovers with DPSK/ PPM direct uplink/downlink configurations	User	User	GEO Relay

Summary

- We have presented overview of the LCRD mission, its goals and objectives and described the optical ground stations with LLCD heritage
- The two-year LCRD mission is the path forward to NASA's future hybrid optical/RF TDRSS to provide high bandwidth support for its space network. It will demonstrate a variety of operational scenarios while taking advantage of the site diversity afforded by the California and New Mexico ground stations
- Key LCRD Mission milestones are:
  - Mission Concept Review: September 2012
  - Systems Requirements Review: March 2013
  - Preliminary Design Review: September 2013
  - Critical Design Review: November 2014
  - Ground Stations Operational Readiness Review: August 2017
  - Launch: December 2017