

Status of Free Space Optical Communications Technology at the Jet Propulsion Laboratory

National Aeronautics and
Space Administration



Jet Propulsion Laboratory
California Institute of Technology

Deep Space Optical Communications (DSOC) Laser Communication Relay Demonstration (LCRD)

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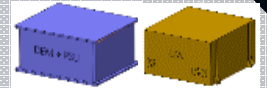
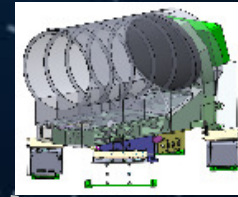
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Deep-Space Optical Communications (DSOC)

Discovery Psyche Mission will carry an optical comm terminal in 2022

NASA Technology goal:
“...seek increased data-rates (10 to 100 times) without increasing mission burden in mass, volume, power and/or spectrum.”

Flight Laser Transceiver (FLT)
4W, 22 cm dia.



FLT Electronics Laser

PSYCHE

1064 nm
Beacon & Uplink
Max rate 2 kb/s

1550 nm Downlink
Max rate 264 Mb/s

Ground Laser Transmitter (GLT)
Table Mtn., CA
1m-OCTL Telescope (5 kW)



Ground Laser Receiver (GLR)
Palomar Mtn., CA
5m-dia. Hale Telescope



Deep Space Network (DSN)

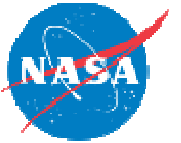


DSOC
MOS



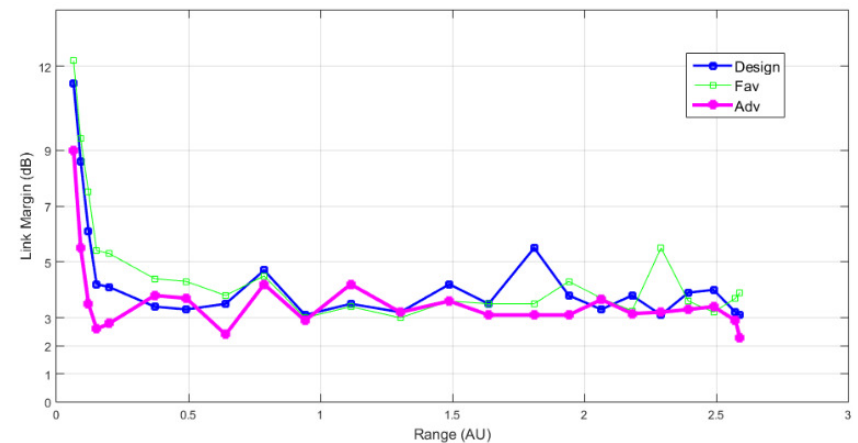
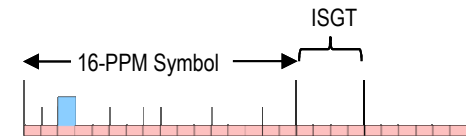
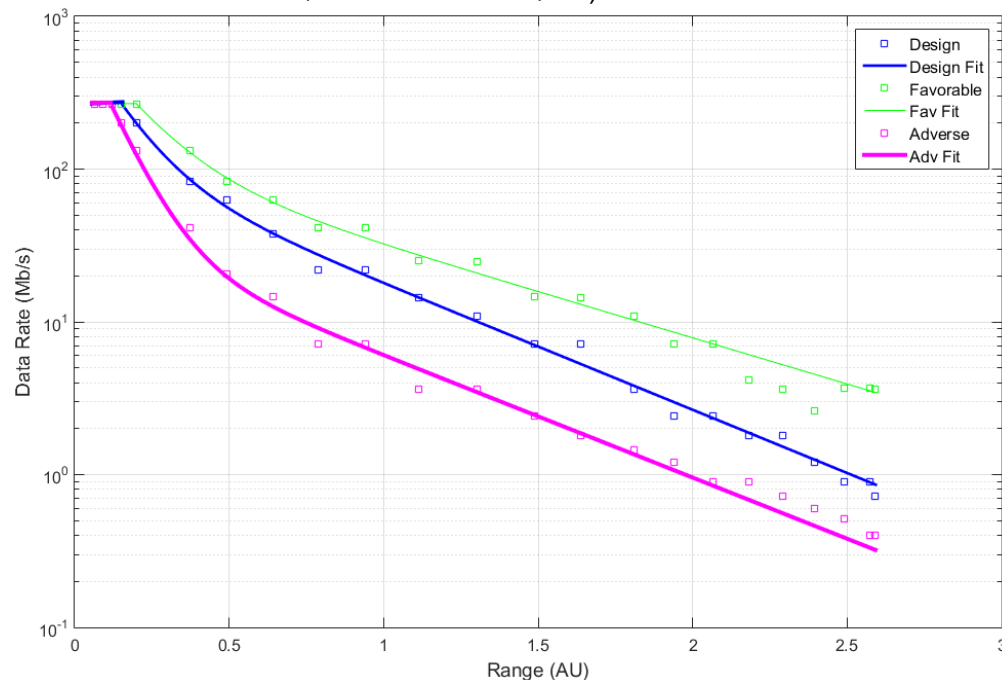
Psyche
Ops
Center

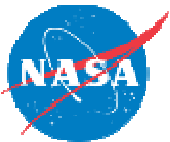
DSOC Predicted Downlink Performance



• Summary of initial downlink analysis

- Assumes 4 W average laser power @ 1550 nm transmitted through 22 cm aperture transceiver
- Received by 5 m diameter ground aperture and detected using photon-counting detector assembly
- Pulse position modulation (M-ary PPM) orders with M=16, 32, 64, 128 with discrete slot-widths of [0.5, 1, 2, 4, 8] ns
- Discrete code rates of 0.33, 0.5 and 0.6667
- Inter-symbol guard times (ISGT) used to assist temporal synchronization
- Results show fits to data obtained after initial analysis
- Atmospheric model derived transmission, sky radiance and “seeing” (*models have been authenticated with site statistics gathered at Table Mtn., CA and Goldstone, CA*)

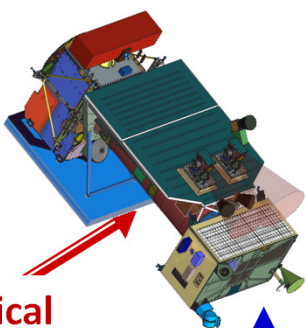




LCRD Mission Architecture

LCRD GEO 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 1/2 DVB-S2 codec (LDPC)
 - 1 second of interleaving for atmospheric fading mitigation

OGS-1 Table Mountain, CA



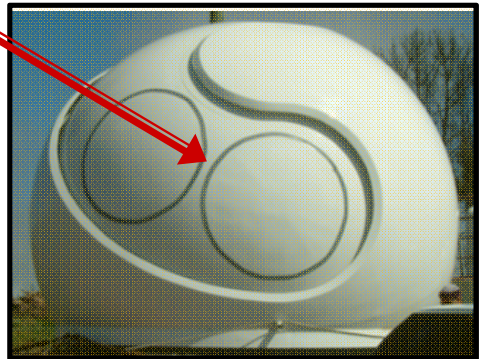
Optical

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

RF

Optical

OGS-2 Hawaii (TBR)



**Host Mission
Ops Center (HMOC)**

Optical Ground Station 1

- 1 m transmit and receive aperture
- 10 W transmitter
- DPSK and PPM

Optical Ground Station 2

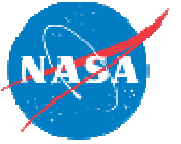
- 60 cm receive aperture
- 15 cm transmit aperture
- 10 W transmitter
- DPSK

**LCRD Mission
Ops Center (LMOC)**

**Remote LCRD Mission
Ops Center (R-LMOC)**

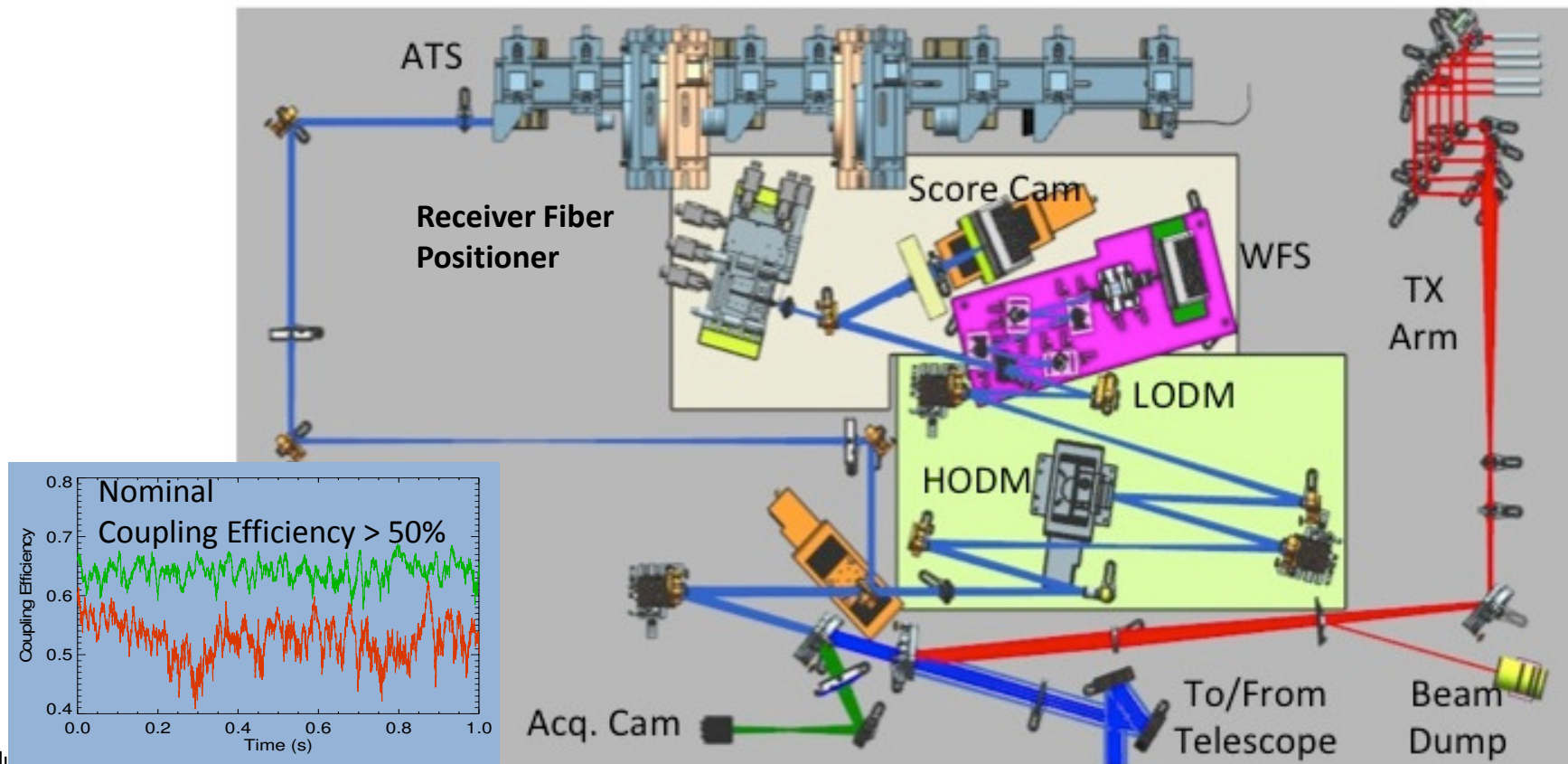
White Sands, NM

GSFC

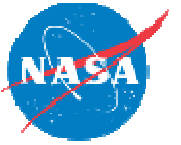


OGS-1 Adaptive Optics System

- Reimages the telescope pupil (where most wavefront aberration occurs) to:
 - Tip-tilt mirror (to correct for image drift and global atmospheric tilt)
 - Wavefront Sensor (for measuring wavefront distortion) with Frame Rate up to 10 KHz
 - High Order Deformable Mirror (corrects low amplitude, high spatial frequency aberrations)
 - Low Order Deformable Mirror (corrects high amplitude, low spatial frequency aberrations)
- Reimages the far field to:
 - The scoring camera (to independently measure how well the AO system is performing)
 - The single mode optical fiber (to inject the downlink signal into the ground receiver)



Summary



- Psyche mission is contemplating an optical Flight Laser Terminal (FLT) for Deep Space Optical Communication
 - Flight Laser Terminal (FLT) 22cm aperture
 - Downlink Data Rate up to 264 Mb/s
 - Ground Laser Receiver (GLR) 5m Hale Telescope (Palomar, CA)
 - Ground Laser Transmitter (GLT) 1m OCTL (Table Mountain, CA).
 - Date of Launch 2022
- The OCTL telescope (Table Mountain, CA) is the host of the optical ground station 1 (OGS-1) of the LCRD experiment.
 - Relay link up to 1.24 Gb/s between ground stations
 - Adaptive Optics allows single mode receiver in fiber
 - Integration and testing of OGS-1 starts October 2017
 - OGS-1 comprehensive of number subsystems, including monitor & control, atmospheric monitoring, uplink beacon, networks
 - Date of Launch 2019