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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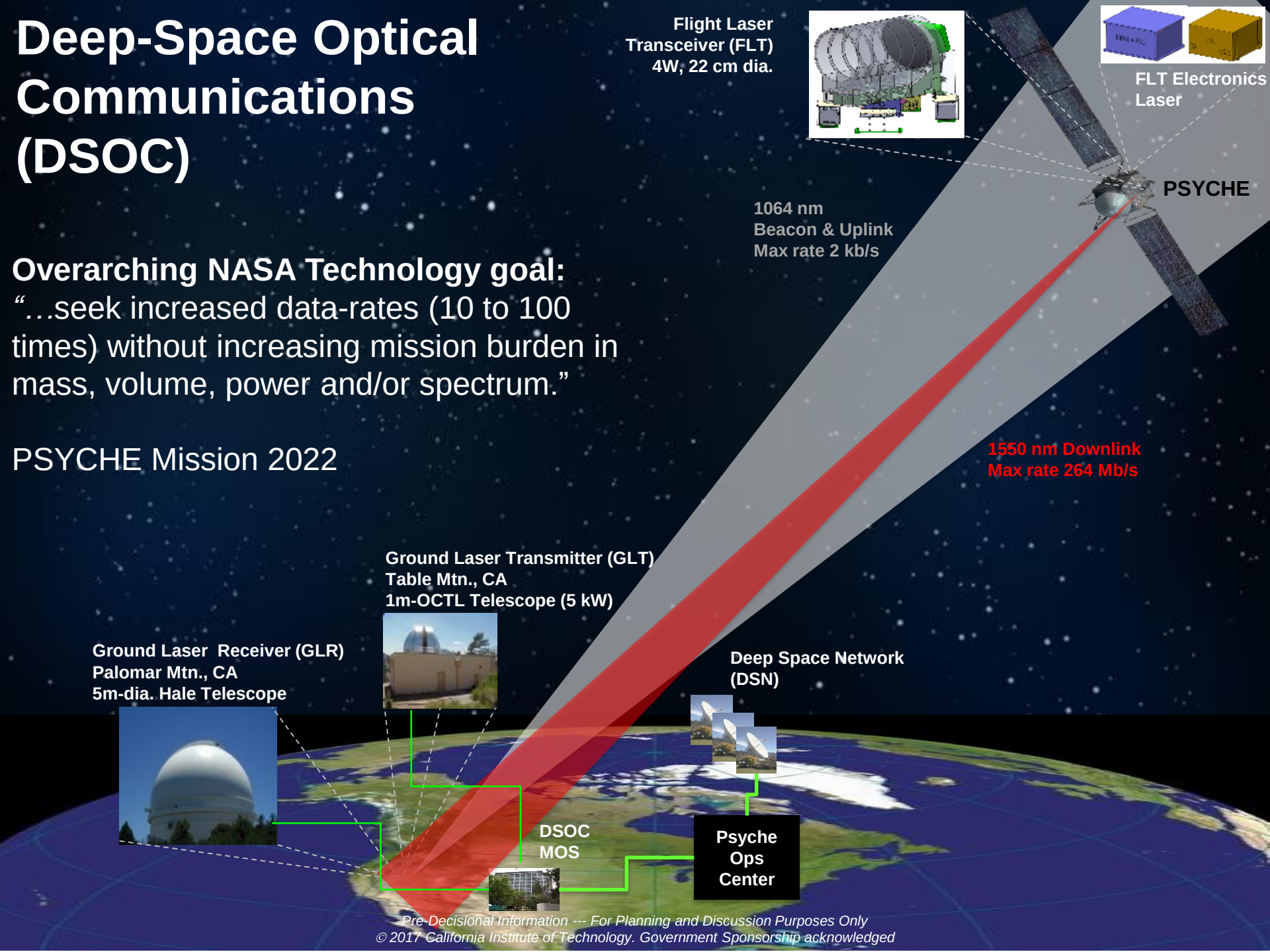
Deep-Space Optical Communications (DSOC)

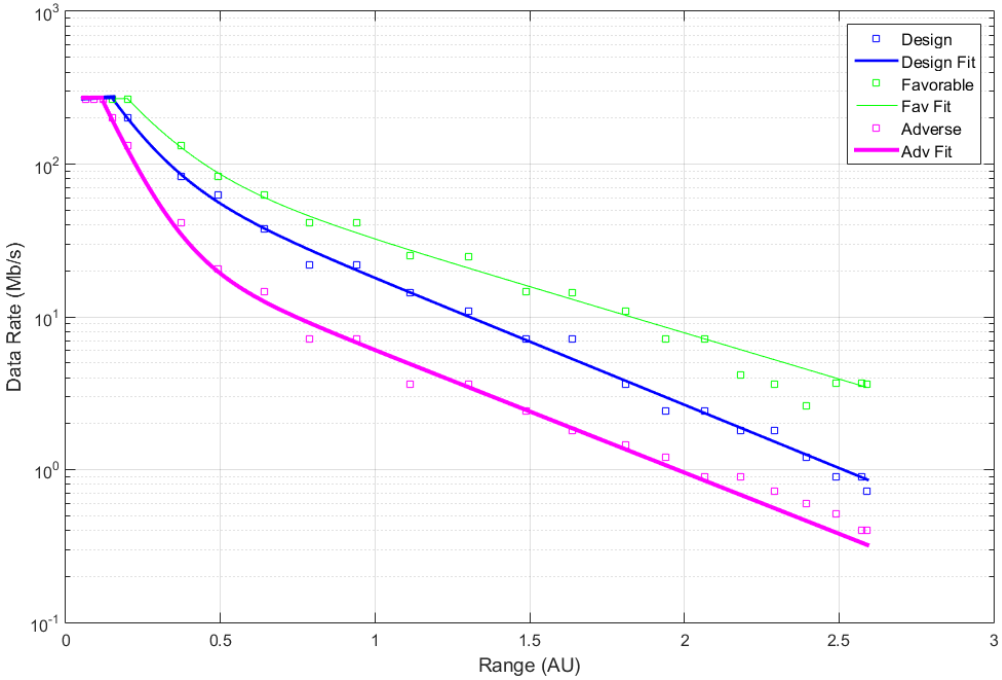
Overarching NASA Technology goal:
"…seek increased data-rates (10 to 100 times) without increasing mission burden in mass, volume, power and/or spectrum."

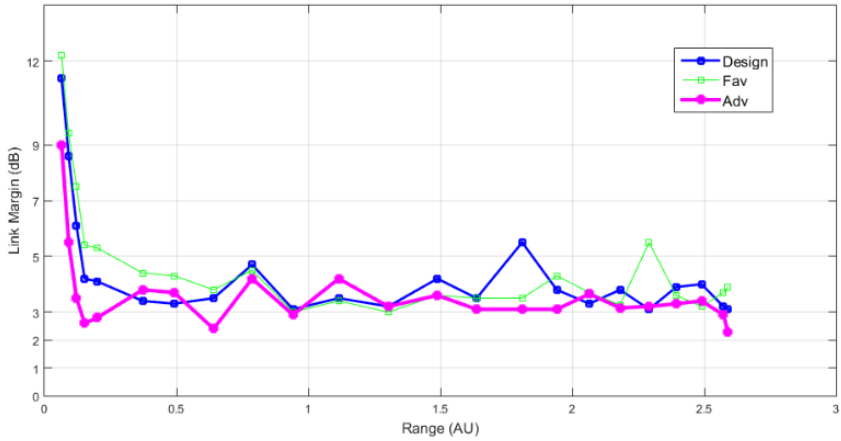
PSYCHE Mission 2022



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*)





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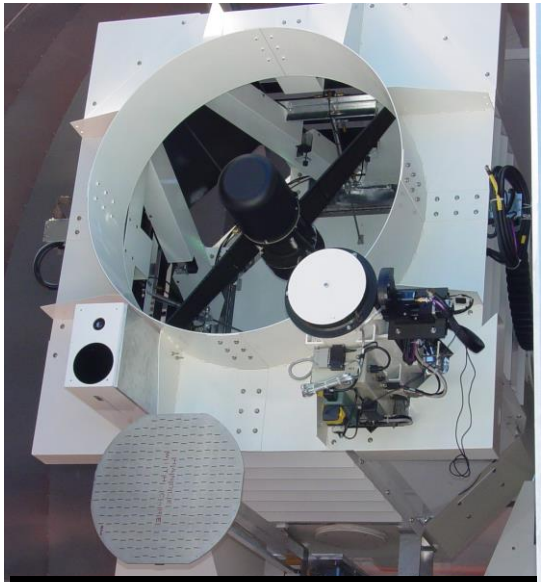
DSOC Ground Subsystem

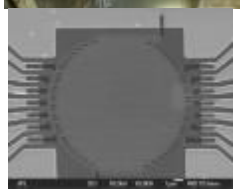
- **DSOC technology demonstration would utilize**
  - Ground Laser Transmitter at OCTL telescope near Wrightwood, CA
    - Retrofit high power (5 kW) laser transmitter
  - Ground Laser Receiver at Hale telescope at Palomar Mountain, CA
    - Retrofit photon-counting detector and signal processing electronics
  - Mission ops center for coordinating ops at JPL (not shown)



Ground Laser Transmitter (GLT)
– 1064 nm Ground Lasers

Optical Communication Telescope Laboratory (OCTL) 1m aperture
Az/El Drive

Hale Telescope
5 m aperture
Palomar Observatory
RA/DEC Drive



Ground Laser Receiver(GLR)
– Photon-counting ground detectors
– 50% Eff. WSi nanowire arrays

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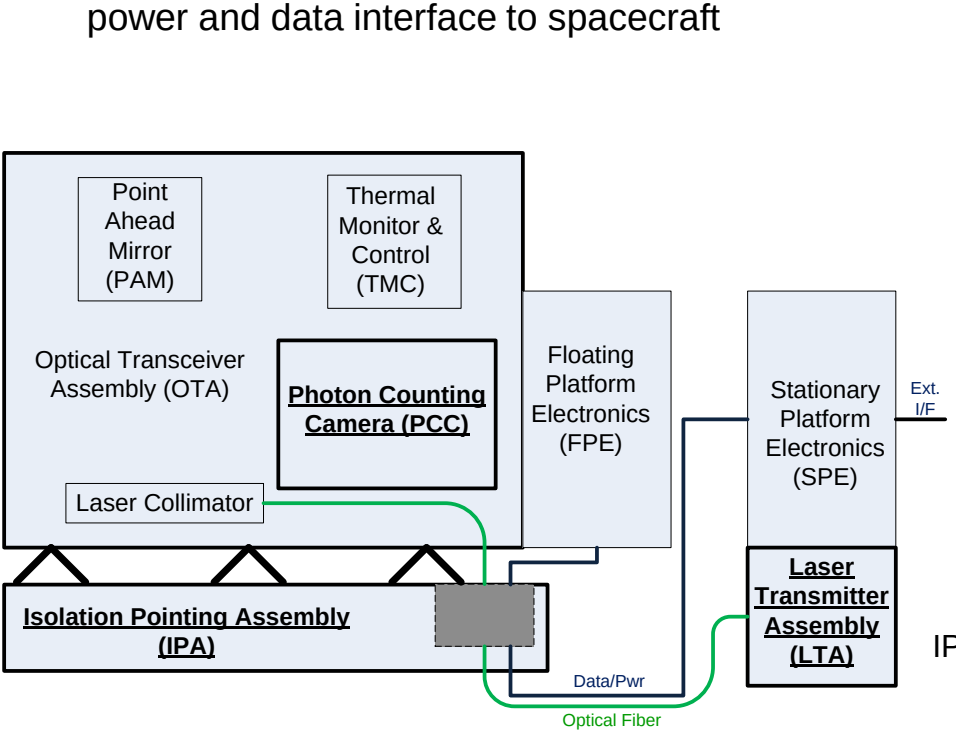
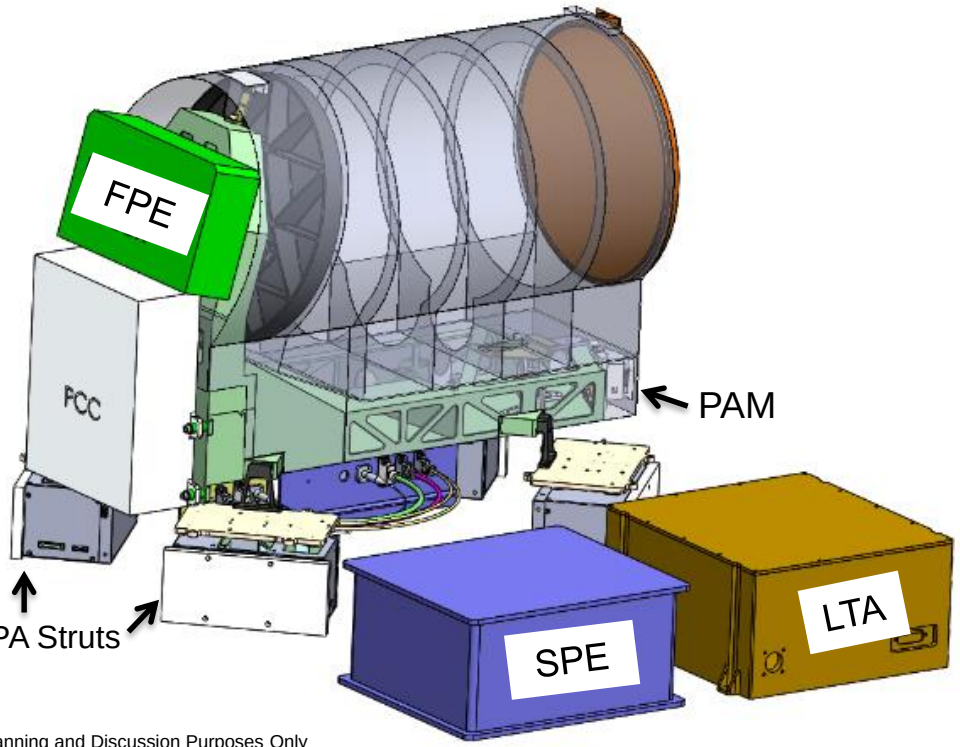
DSOC Flight Laser Transceiver (FLT)

- **The Flight Laser Transceiver (FLT) makes up the flight subsystem**
  - **Silicon carbide (SiC)** Optical Telescope Assembly (OTA) receives beacon and transmits downlink
  - **Photon Counting Camera (PCC)** detects "dim" 1064 nm laser beacon transmitted from Earth
  - **Isolation Pointing Assembly (IPA) "**floats" OTA to stabilize and steer OTA line-of-sight
  - **Laser Transmitter Assembly (LTA)** delivers high peak power pulse train modulated by downlink data
  - **Electronics** – firmware/software platforms, power and clock distribution for "floating" and stationary parts, power and data interface to spacecraft





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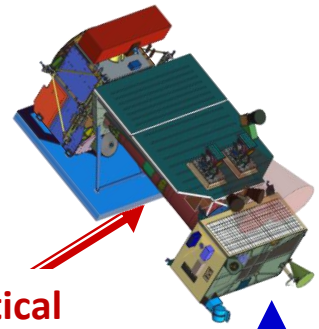
LCRD Mission Architecture

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

Space Switching Unit



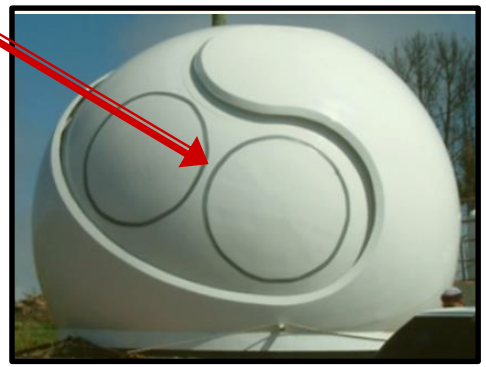
Relay Link Features:
- Coding/Interleaving at the link edges
  - Rate ½ DVB-S2 codec (LDPC)
  - 1 second of interleaving for atmospheric fading mitigation

OGS-1 Table Mountain, CA

Optical

Optical

OGS-2 Hawaii (TBR)



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

RF

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)

White Sands, NM

Remote LCRD Mission Ops Center (R-LMOC)

GSFC

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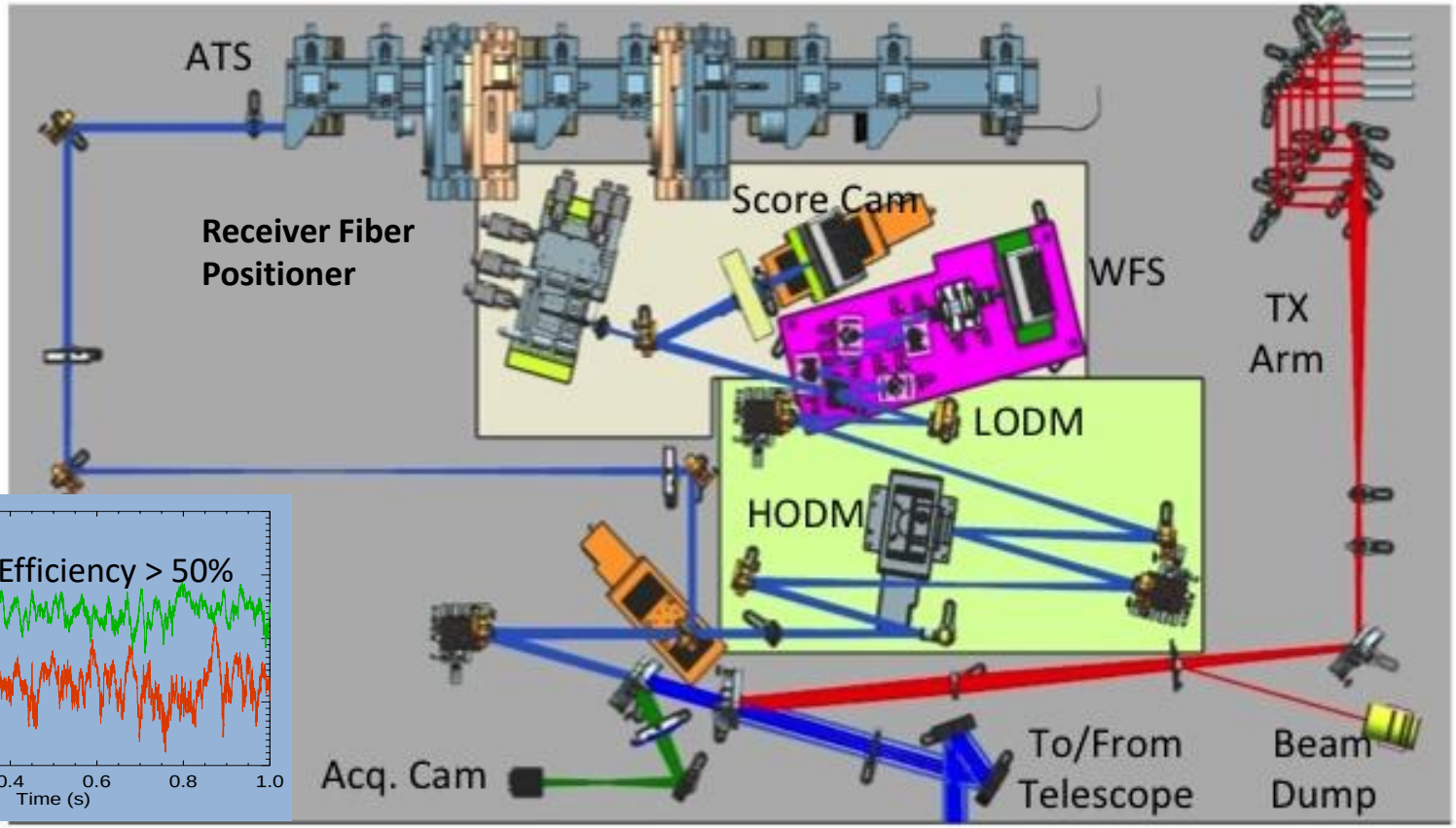
OGS-1 IOS Adaptive Optics System

- Reimages the telescope pupil (where most wavefront aberration occurs) to:
  - Tip-tilt mirror (to correct for image drift and global atmospheric tilt)
  - High Order Deformable Mirror (corrects low amplitude, high spatial frequency aberrations)
  - Low Order Deformable Mirror (corrects high amplitude, low spatial frequency aberrations)
  - Wavefront Sensor (for measuring wavefront distorsion) with Frame Rate up to 10 Khz
- Reimages the far field to:
  - The scoring camera (to independently measure how well the AO system is performing)
  - The single mode optical fiber (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 260 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
  - OGS-1 comprehensive of number subsystems, including monitor & control, atmospheric monitoring, networks
  - Date of Launch 2019

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