Jet Propulsion Laboratory
California Institute of Technology

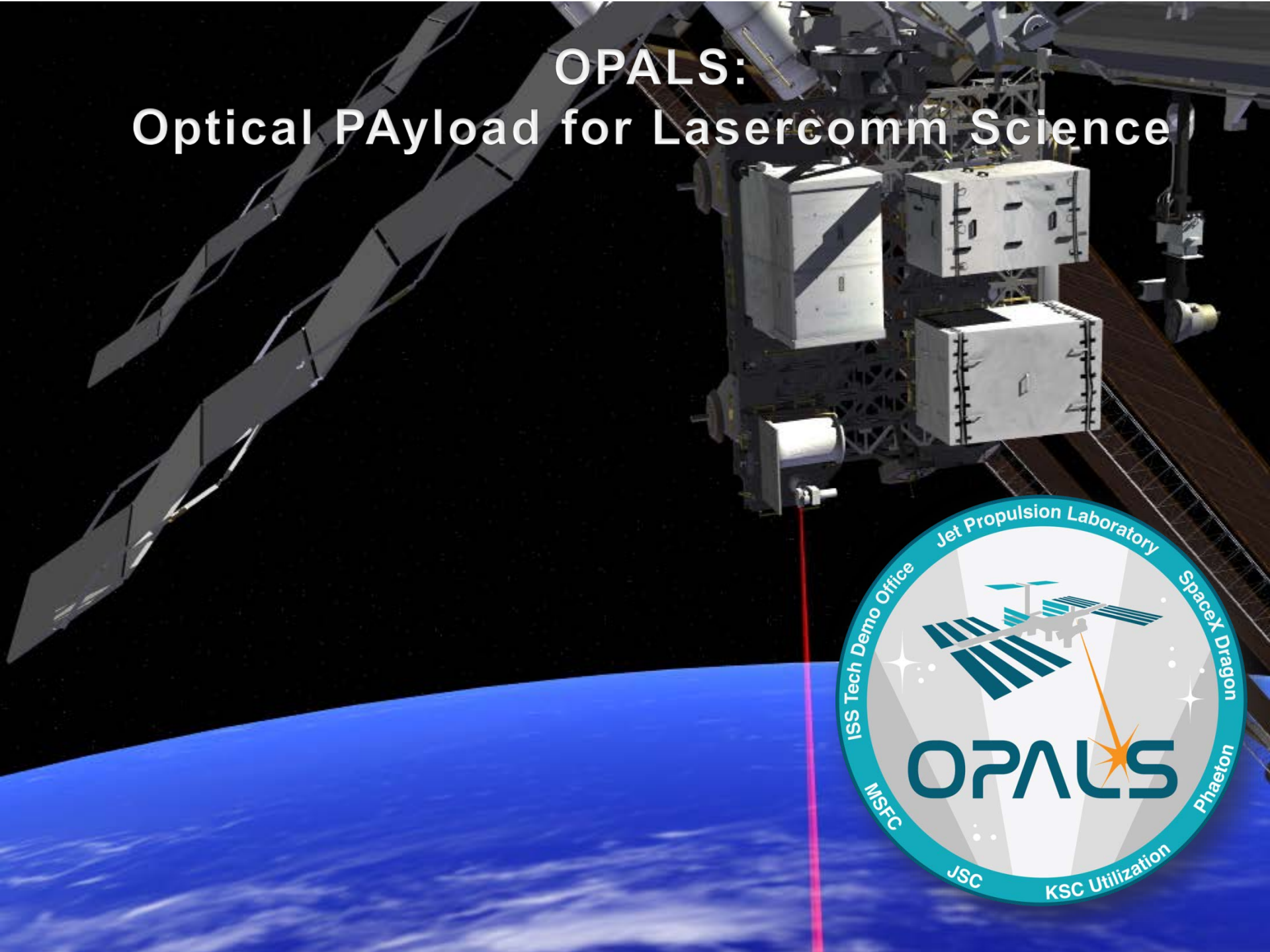
Status of OPALS and DSOC

Presented to the Optical Communications Working Group – CCSDS Fall Meeting 2016

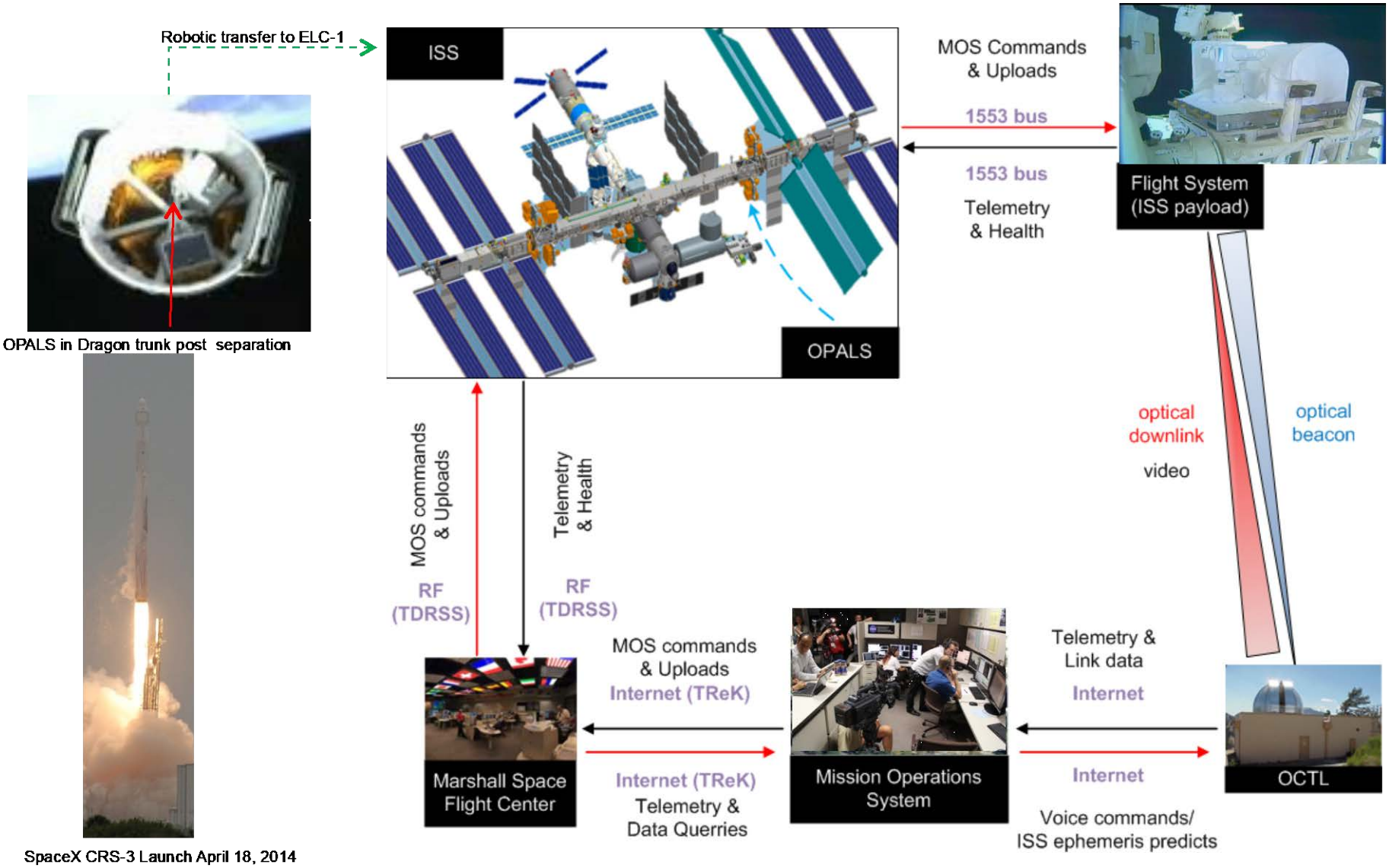
Stephen A. Townes
Chief Technologist
Interplanetary Network Directorate
NASA/JPL
California Institute of Technology

Copyright 2016 California Institute of Technology. Government sponsorship acknowledged.

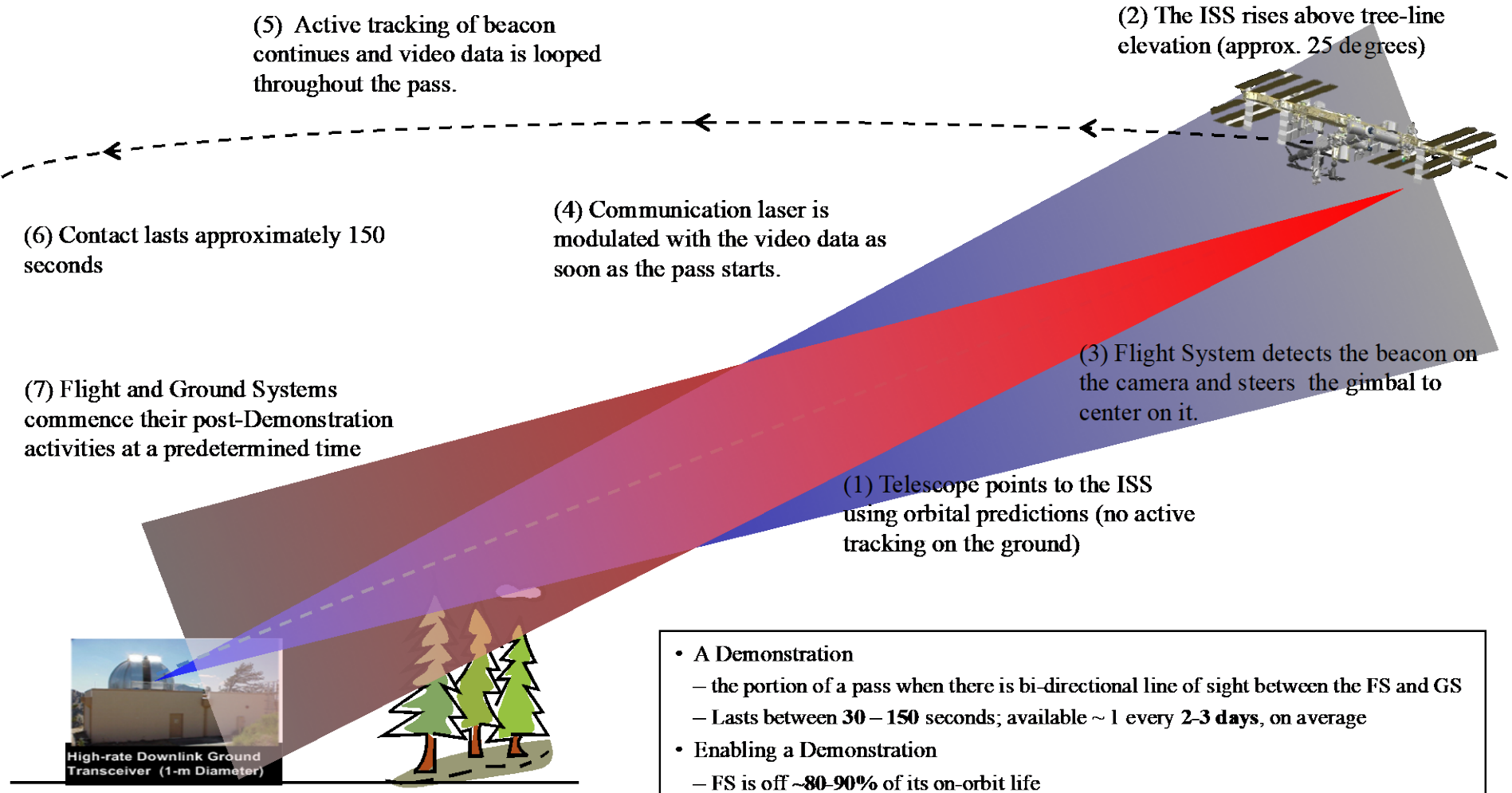
OPALS:
Optical PAyload for Lasercomm Science



OPALS Architecture



Demonstration Concept



- A Demonstration
  - the portion of a pass when there is bi-directional line of sight between the FS and GS
  - Lasts between **30 – 150** seconds; available ~ 1 every **2-3 days**, on average
- Enabling a Demonstration
  - FS is off **~80-90%** of its on-orbit life
  - On-time negotiated with ISS months in advance; refined weeks-days before
  - ~ 7 **hours** of on-time to prepare for, execute, and wrap-up a demonstration

OPALS Mission Overview

OPALS in Dragon trunk, as seen from Falcon 9 Second Stage

OPALS Installed on ELC-1

OPALS During A Downlink

OPALS Mission:

Demonstrate the feasibility of space-to-ground laser communications transmissions from ISS

Prime Mission Milestones:

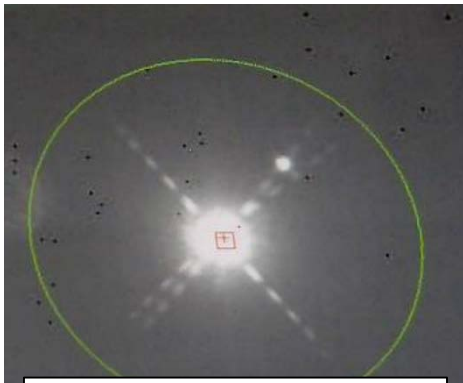
(Funded by ISS Program Office)

- ✓ **Commissioning Phase (May '14)**
- ✓ **First Official Video Downlink (6/5/14)**
- ✓ **First Daytime Video Downlink (6/12/14)**
- ✓ **Low Elevation Transmissions (June '14)**
- ✓ **Geometry/Pointing Sensitivity Tests (Jul-Aug'14)**
- ✓ **PN8 and Engineering Data Downlinks (Sep '14)**
- ✓ **External Ground Station Collaborations (Oct '14)**

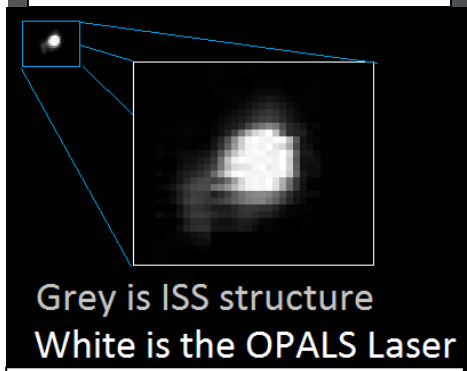
Extended Mission Milestones:

(Funded by ISS Program / SCaN Program)

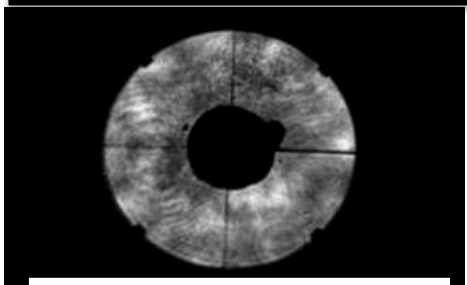
- ✓ **Adaptive Optics Tests with Boeing (Jan-May '15)**
- ✓ **ISS Platform Vibration Experiment (Jul-Sep '15)**
- ✓ **Transmissions to DLR (Oct-Dec '15)**
- • **Transmissions to CNES (May '16-?)**
- ✓ **Transmissions to ESA (Jun-Jul '16)**
- • **Decommissioning (~~Feb '16~~ Dec '16?)**



First Optical Downlink (OCTL)



ESA Signal Acquisition at Tenerife



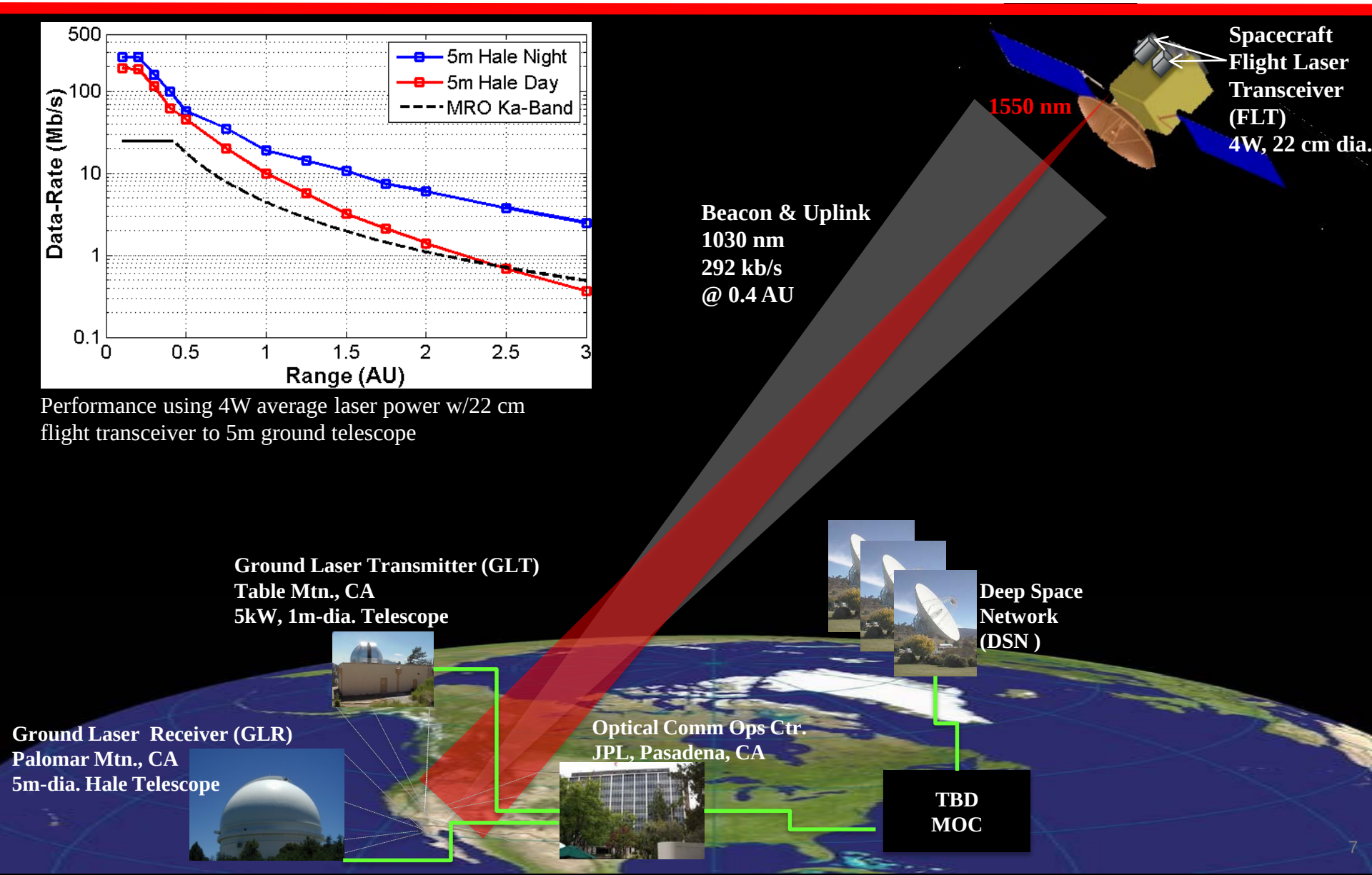
DLR Signal Acquisition at Oberpfaffenhofen

Anomaly Overview & Status

- During GMT_2016_207 (July 25th) operations intended to demonstrate an optical downlink to the CNES ground station in Nice, France, the following was noted:
  - During initial power up and Health & Status checkout, anomalous telemetry values were observed from the VMETRO laser modulation card—indications of “card not found”
  - Investigation confirmed that the VMETRO card was not found on software startup. A power cycle was executed and the same response was observed in telemetry. Due to the unresolved anomaly, the optical downlink experiment was cancelled and OPALS was powered down.
  - A trouble shooting session was performed and the same results were observed
- Explored executing the downlink procedure with laser set to continuous output at a level of 2.5 Watts
  - Laser is capable of emitting 4.2 W (5 W – fiber losses), power is set through software command
  - High enough laser power to provide useful signal to CNES ground station
  - This setting would keep laser at same average power as previous use
  - Procedural changes do not affect hazard controls/inhibits
    - Power level setting is not used as a hazard control, all hazard controls/inhibits still in place
- Two passes were scheduled with CNES for the Week of 26 September 2016
  - The flight systems exhibited anomalous behavior on first pass
  - Second pass cancelled
- Investigating software changes but status TBD

Deep-Space Optical Communications (DSOC)

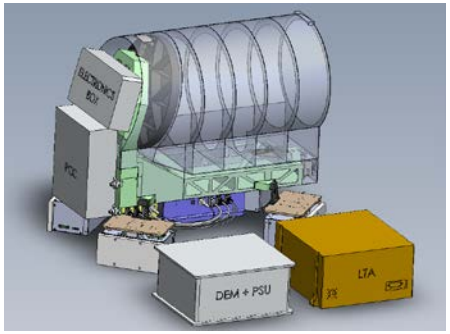
Performance using 4W average laser power w/22 cm flight transceiver to 5m ground telescope



DSOC – Game Changing Development

- **Deep Space Optical Communications (DSOC) Project at JPL was managed by NASA Space Technology Mission Directorate (STMD) Game Changing Development (GCD) Program**
  - Co-funded by Science Mission Directorate (SMD) and the Space Communications and Navigation (SCaN) Office in the Human Exploration and Operations Directorate (HEOMD)
  - Mature key technologies to be ready for mission selected by Discovery 2014 mission
  - Launch no later than Dec. 2021
  - Discovery 2014 incentivized missions to carry DSOC terminal
- **Three of five selected Step 1 proposals included DSOC**
  - Near Earth Object Camera (NEOCAM)
  - Venus Emissivity, Radio Science, InSAR, Topography and Spectroscopy (VERITAS)
  - Psyche—mission to asteroid Psyche

  (We continue to advocate with Mars missions, Asteroid Rendezvous and Retrieval Mission and others)
- **DSOC completing developing components for**
  - Prototype Flight Laser Transceiver (FLT)
  - Ground Detector and Signal Processing
- **DSOC transitioning to STMD/Technology Demonstrations Mission (TDM) in FY17**
  - Continue testbed development with GCD Program developed components
  - Prepare for Preliminary Design Review assuming Step 2 proposal selection in January 2017 includes DSOC terminal

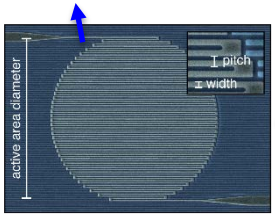


Flight Laser Transceiver
22-cm diameter
4 W average laser power
@ 1550 nm

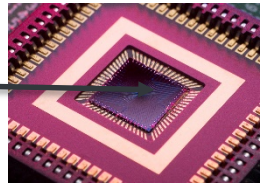
Ground Laser Receiver (SCaN funded)
5-m diameter Hale Telescope, Palomar Mtn.
Retrofitted with Photon-Counting Receiver

Ground Laser Transmitter (SCaN funded)
Uses existing 1-m diameter OCTL.
Retrofitted with 5 kW laser @ 1064 nm

DSOC Key Components and Technologies



Electron microscope detail of 320-µm active area tungsten silicide (Wsi) superconducting nanowire single photon detector (SNSPD) array



Packaged Nanowire Array

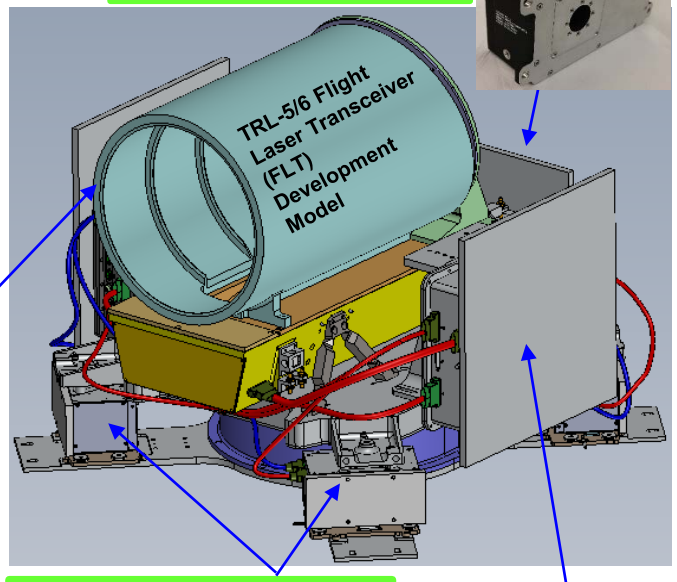
Ground Technology

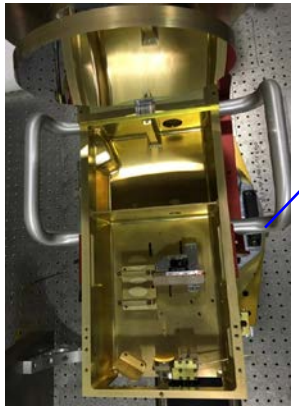
- Key technologies for overcoming link difficulty
- Space:
  - Photon-counting camera (PCC)
    - Allows detection of dim beacon from deep-space ranges
    - Acquisition/tracking/uplink data
  - Isolation and pointing assembly (IPA)
    - Lowers control bandwidth for stabilization and narrow beam pointing
  - High peak to average power laser transmitter assembly (LTA)
    - Photon-efficient signaling (PPM with photon-counting)
- Ground:
  - High efficiency ground photon-counting detector array
    - Superconducting nanowire single photon detector (SNSPD) array
    - Enables detection of faint signals from deep-space
- Technologies integrated to optics and electronics and tested
  - Aluminum optical transceiver assembly (OTA)
  - Point-ahead mirror (PAM)
  - Representative Electronics firmware and software
  - Ground Support Equipment (GSE) for disturbance injection, gravity off-load, ground emulator testing
  - FLT is tested in lab environment and then thermal vac

TRL-5 FLIGHT LASER TRANSCEIVER

Point-Ahead Mirror

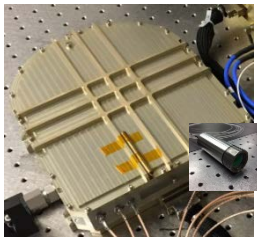
Photon-Counting Space Receiver
– 30% PDE Rad Tolerant



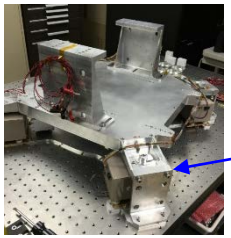


Aluminum Optical Telecsope Assembly

Isolation Pointing Assembly Struts
– 50 dB rejection



Laser Transmitter (Avg. Pwr 4 W, Pk-to-Avg ratio 660)



Single strut photo

Flight like electronics (Based upon Universal Space Transponder components)

DSOC Transition to Tech Demo Mission

- DSOC TDM is new for FY17 (Starting October 2016)
- Considerable recent effort on TRL development under GCD funding.
  - FY15 demonstration of TRL-4 in upgraded testbed
  - Laser Transmitter Assembly ready for delivery to I+T
  - Point-Ahead Mirror tested and delivered to I+T
  - Aluminum Optical Transceiver Assembly delivery to I+T (July)
  - Photon Counting Camera to be delivered to I+T
  - Pointing and Isolation struts due to delivered to I+T
  - Electronics for readout/control delivered to I+T
  - Dramatic capability improvement in single-photon ground detector
- Hardware to be used for system testbed to be maintained through TDM program
- Schedule milestones: (details depend on Discovery mission selection)
  - Start of FY17: TDM start (continues from Technology investments by GCD)
  - PDR: driven by mission selection and funding profile
    - Late 2017 to mid 2018
  - CDR: driven by mission selection and funding profile
    - Late 2018 to late 2019
  - Deliver FLT to ATLO: late 2019 to mid-2020

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov