Deep Space Optical Communications (DSOC)

- Deep Space Optical Communication Introduction
- Technology Development Maturation Flow
- Technology Development Progress
  - Flight System
  - Ground System
- Path to Flight Readiness
Deep Space Optical Communication Project

- The Deep Space Optical Communication Project is in transition from a technology development effort to a flight demonstration.
- DSOC is part of the Discovery 2014 AO
  - Flight Component specifications were part of the Tech Day Presentations
  - We are on a path that will have the DSOC System at TRL 6 in time to support Discovery 14 selected payloads review and delivery cycle
- The DSOC Project includes three segments
  - Ground Uplink Station
  - Flight Laser Transceiver
  - Ground Receiving Station
Deep-Space Optical Communications (DSOC)

Virtual presence throughout the solar system

- **Flight Laser Transceiver (FLT)**
  - Optical Head
  - 4W, 22 cm dia.

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

- **Deep Space Network (DSN)**
  - Mission Ops Center

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

- **Optical Comm Ops Ctr.**

- **1064 nm Beacon & Uplink**
  - Max rate 1 kb/s

- **Laser Collimator**

- **Photon Counting Camera (PCC)**

- **Thermal Monitor & Control (TMC)**

- **Point Ahead Mirror (PAM)**

- **Isolation Pointing Assembly (IPA)**

- **Stationary Platform Electronics (SPE)**

- **Floating Platform Electronics (FPE)**

- **Optical Transceiver Assembly (OTA)**

- **Laser Transmitter Assembly (LTA)**

- **Floating Platform Electronics (FPE)**

- **Stationary Platform Electronics (SPE)**

- **Ext. IF**

- **Optical Fiber**

Flight Laser Transceiver
Deep Space Optical Communication Technology Challenges

• Deep Space Optical Communications are different from near earth communications
  – One way light times are minutes rather than seconds
  – Distances are large enough that signals are photon limited

• Communication Scenario
  – Uplink signal communicates with DSOC flight terminal by dead reckoning, providing a beacon and uplink data
    • Uplink signal at the spacecraft is photon limited
  – The flight system tracks the beacon, and using spacecraft ephemeris and attitude information calculates the point ahead angle required for downlink
  – The downlink beam is directed to where Earth will be
  – The downlink beacon is photon limited on arrival at Earth
  – The sun is often very near the field of regard of the Flight Terminal
DSOC Major Components

Flight Terminal

OCTL Uplink

Palomar 5 meter Telescope
DSOC Flight System Specification

Flight Laser Transmitter

- Laser
  - 4 W average Power
  - Wavelength 1.55 microns
- Telescope
  - 22 cm aperture
  - Capable of pointing up to 3 degrees of sun
- Mass
  - < 38 kg
- Power
  - < 100 W

Ground Systems

- Uplink
  - OCTL Telescope (1 meter)
  - 5 KW average power
  - Wavelength 1.064 microns
- Downlink
  - Palomar 5 meter telescope
  - Operates day or night
  - Can point within 12 degrees of sun
  - JPL developed superconducting nanowire photon counting detector
DSOC Technology Maturation

- JPL Isolation System
- JPL Optics
- Commercial CCD Camera

TRL 3
Vibration Isolation/Pointing Stabilization Demonstration (COMPLETE)

- Modulated Input Laser
- CCD Photon Counting Camera
- Point Ahead Transmit Laser

September 2015

- Improved Isolation System
- Flight Like Optics
- Photon Counting Camera
- UST Based Electronics

TRL 5
Flight Like Instrument Tested in Laboratory Environment

- Test with nanowire Grd detector
- Move to T/V Chamber

September 2016

- Flight Like Instrument
- Tested in Flight Like Environment

March 2017
Optical Telescope Assembly (OTA)

- OTA includes the optical bench, primary mirror mounting assembly, bench optics assembly, and closeout plate
- OTA serves as an integrating structure for the Photon Counting Camera, Floating Platform Electronics, and Isolation and Pointing Assembly
Photon Counting Flight Camera

**TRL 5 Detector**
- Detector developed by Princeton Lightwave (PLI)/Lincoln Labs
  - Detector fabricated by Princeton Lightwave
  - Readout Integrated Circuit (ROIC) by Lincoln Labs
  - Integrated into a camera by Princeton Lightwave
  - First unit (development detector and electronics) delivered and in test at JPL
  - PLI on contract for TRL 5 delivery
Laser Transmitter

- Laser developed through series of Small Business Innovative Research Contracts with Fibertek
- Completed life-test
- Radiation testing of optical amplifier
  - Rad hard fiber
  - Other key components radiated with negligible degradation: pump combiner, WDM and seed laser
- Completed Laser Electrical Module driver update
  - Pre-cursor for space qualified design in process
- Completed a plan for LEM vacuum compatibility
- Defined fiber patch cord and output collimator
  - Identified candidate fibers and connectors
Point Ahead Mirror

- Mounts to fixture on optical bench
- Shim to center pointing down the optical axis
- Delivered by Centrac
Vibration Isolation Technology

Electro-Magnetic Isolation

- Developed by Controlled Dynamics (CDI) under Small Business Innovative Research (SBIR) contracts
  - Integral actuator, sensor and electronics
  - First units to be delivered in early 2016
  - Similar implementations flown on sounding rockets, aircraft and balloons
Vibration Isolation and Pointing

- Moving interface plate
- Umbilical assembly
- Vibration Isolators
TRL-3 Demonstration

Demonstrate closed loop tracking in a using laboratory development electronics and optics, developmental vibration isolation hardware and a commercial CCD camera.

- Mated FLT to disturbance emulator
- Added accelerometers to monitor disturbance
- Implemented gravity off-load using spring suspension
- Aligned FLT to beacon emitted from Laser Test Evaluation Station (LTES)

LTES used for generating 20 cm diameter collimated beacon

Gravity off-load using spring suspension (beacon path is shown in red)

FLT integrated to 2-axis disturbance emulator
TRL 6 Demo

- **GROUND DETECTOR**
  - Tungsten silicide (WSi) SNSPD Detector Array
    - Verified 12-pixel array (Eff. dia. 65 μm) during LLCD
    - In FY14 demonstrated 64-pixel array (Eff. dia. 160 μm)
    - Developing 320 μm, 64-pixel array

- **GROUND SUPPORT EQUIPMENT (GSE)**
  - Simulate
    - Spacecraft disturbance
    - Anti-gravity suspension
    - Ground beacon laser
    - Ground Receiver
Ground Detector Technology

Ground Detector

- Micro devices Laboratory Development
  - 64 nanowire array
  - Functions as photon counting detector
  - Will be located at Coudé focus of 5 meter Hale telescope
  - Operates at 1K
  - Initial devices in test

Photomicrograph of 64 nanowire array
Technology Demonstration Downlink Ground Terminal

- 256 Pixel WSi Superconducting Nanowire Photon-Counting Detector
- TRL 6 FY17
Summary

- DSOC Technology Development Progress is compatible with the Discovery Program Schedule
- Moving to complete TRL 3 – 6 sequence while making hardware and software designs as flight like as possible
- Ensuring that the Flight and Ground Systems remain closely coupled and compatible
- Identified paths for technology development to flight and ground operational readiness