Deep Space Optical Communications

28 July 2015

Tom Glavich

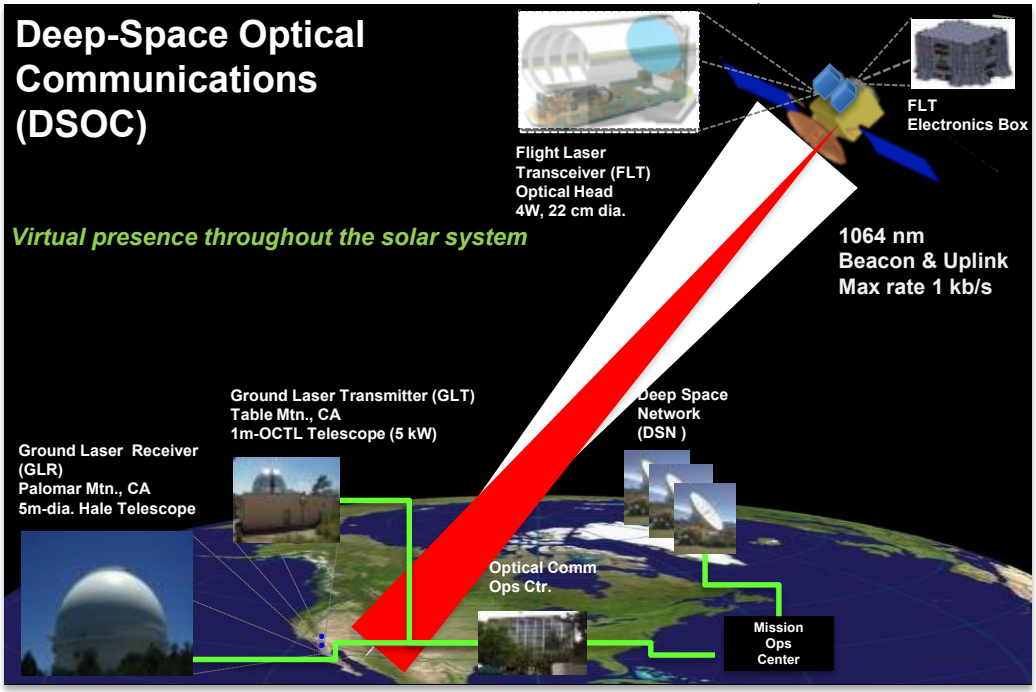
Deep Space Optical Communications (DSOC)

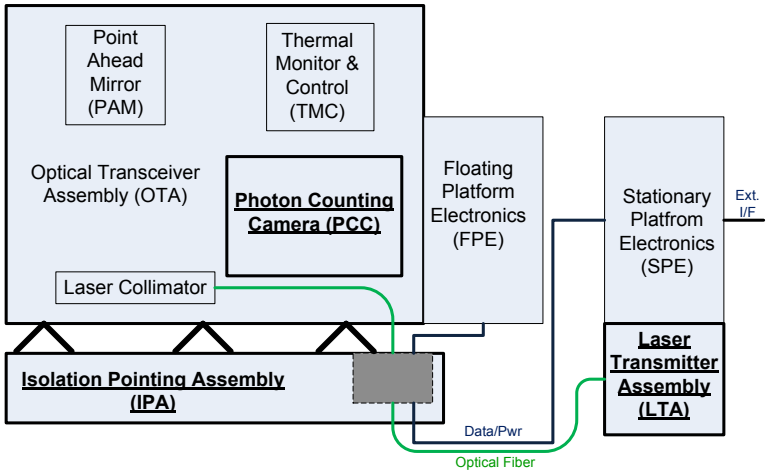
- Deep Space Optical Communication Introduction
- Technology Development Maturation Flow
- Technology Development Progress
  - Flight System
  - Ground System
- Path to Flight Readiness

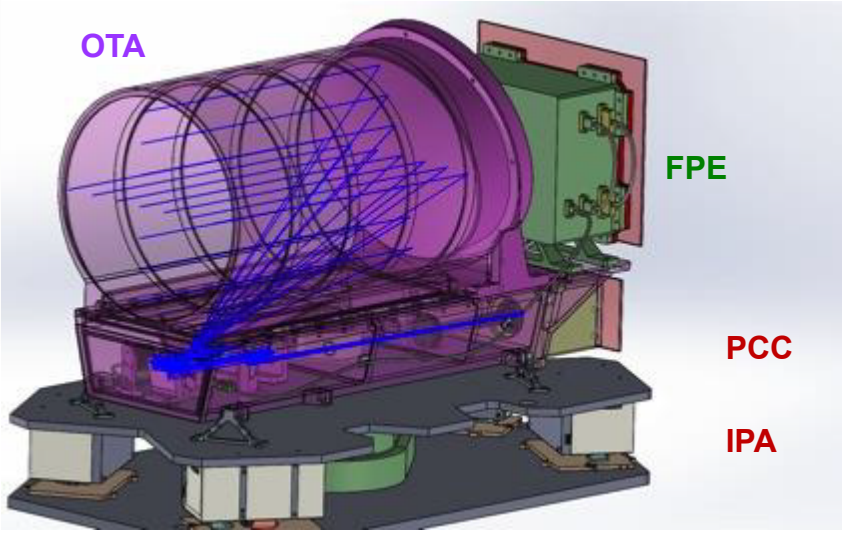
Deep Space Optical Communication Project

- 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

DSOC System







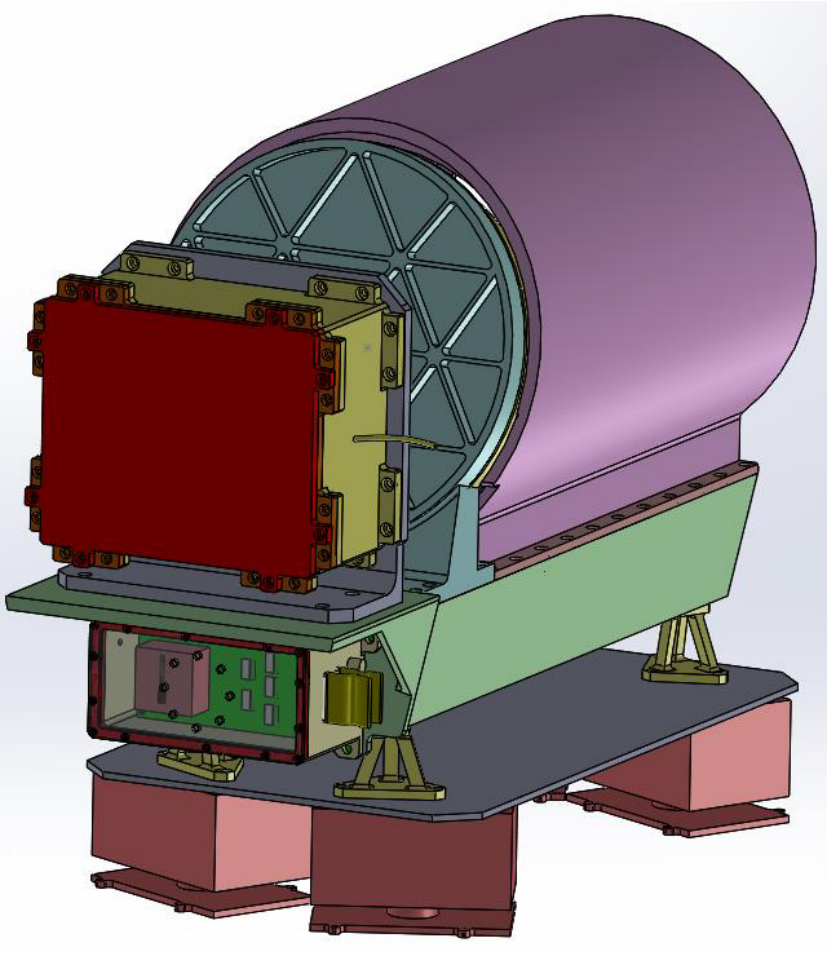
Flight Laser Transceiver

Deep Space Optical Communication Technology Challenges

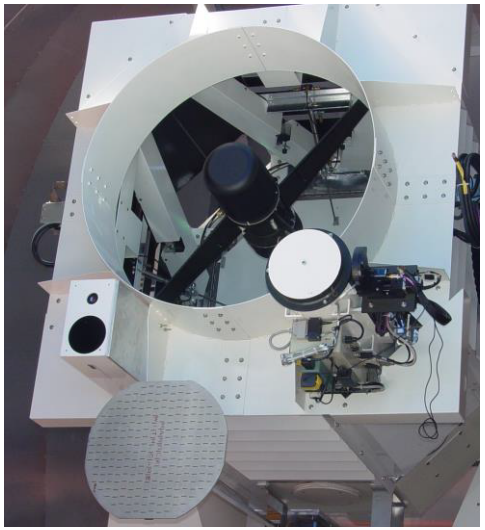
- Deep Space Optical Communications are different from near earth communications
  - One way light times are minutes rather than seconds
  - Distances are large enough that signals are photon limited
- Communication Scenario
  - Uplink signal communicates with DSOC flight terminal by dead reckoning, 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

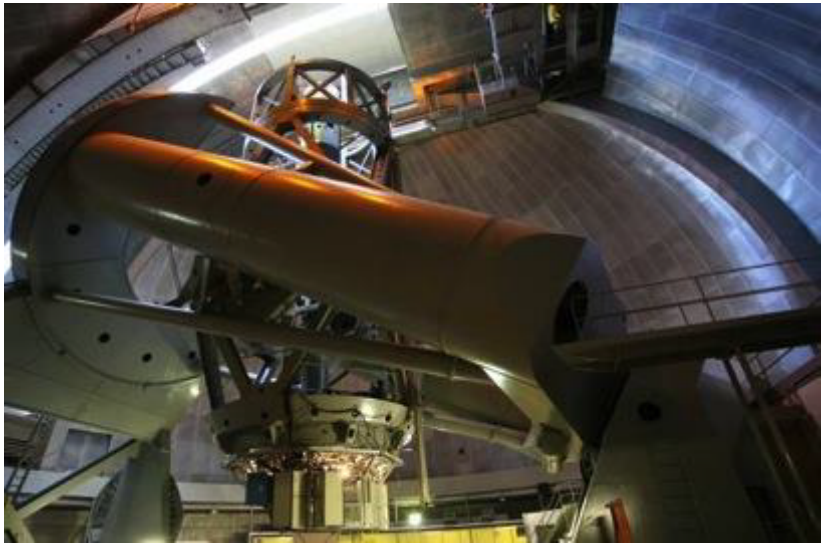
Flight Terminal



OCTL Uplink



Palomar 5 meter Telescope



DSOC Flight System Specification

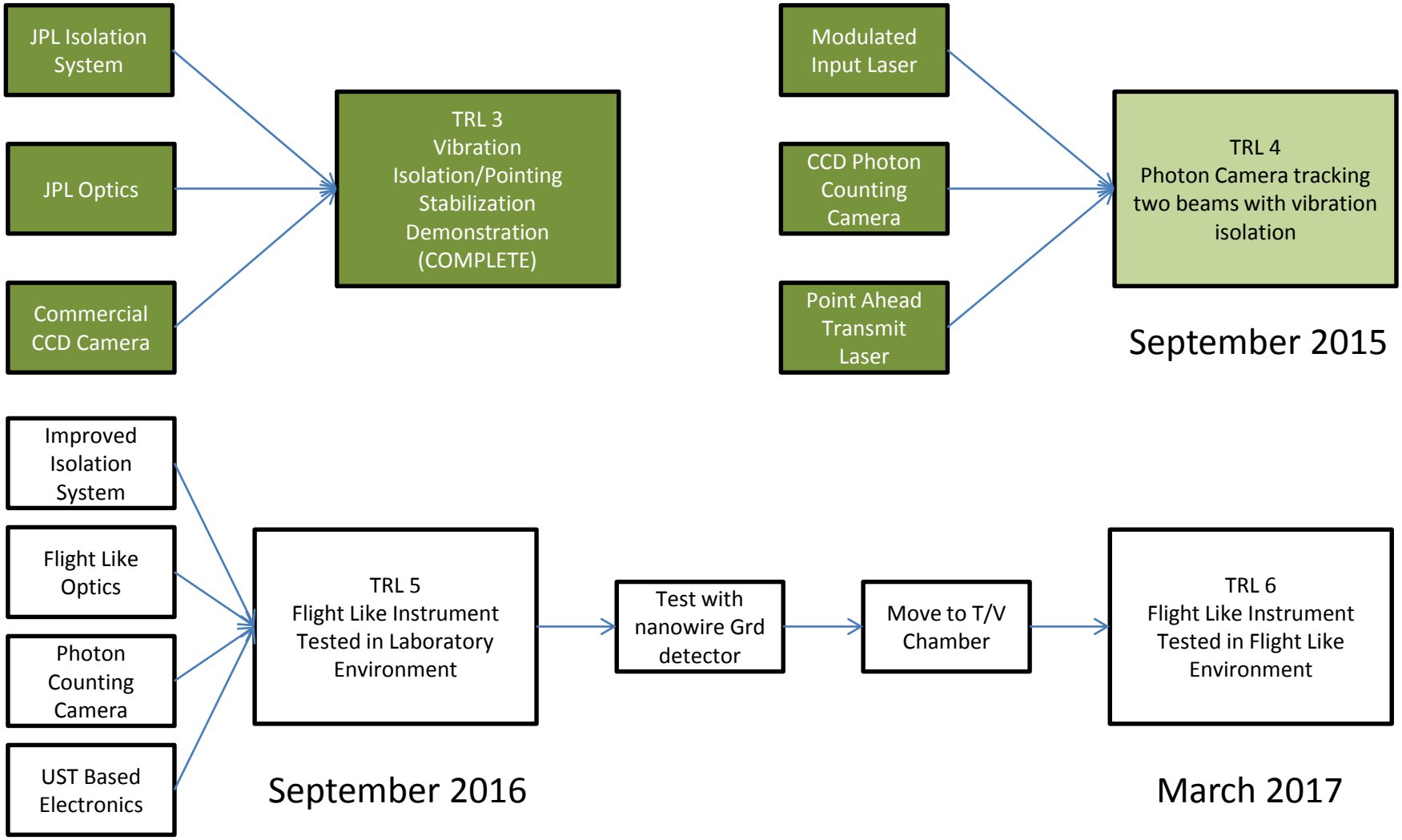
Flight Laser Transmitter

- 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

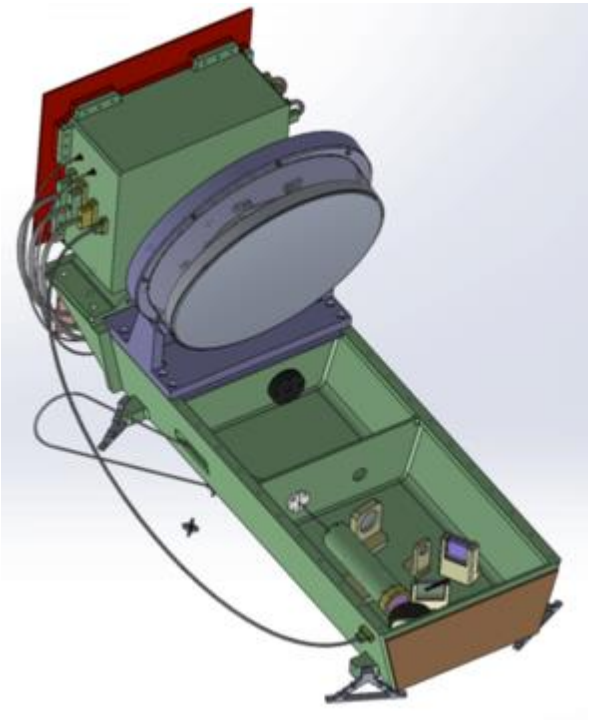
- Uplink
  - OCTL Telescope (1 meter)
  - 5 KW average power
  - Wavelength 1.064 microns
- Downlink
  - Palomar 5 meter telescope
  - Operates day or night
  - Can point within 12 degrees of sun
  - JPL developed superconducting nanowire photon counting detector

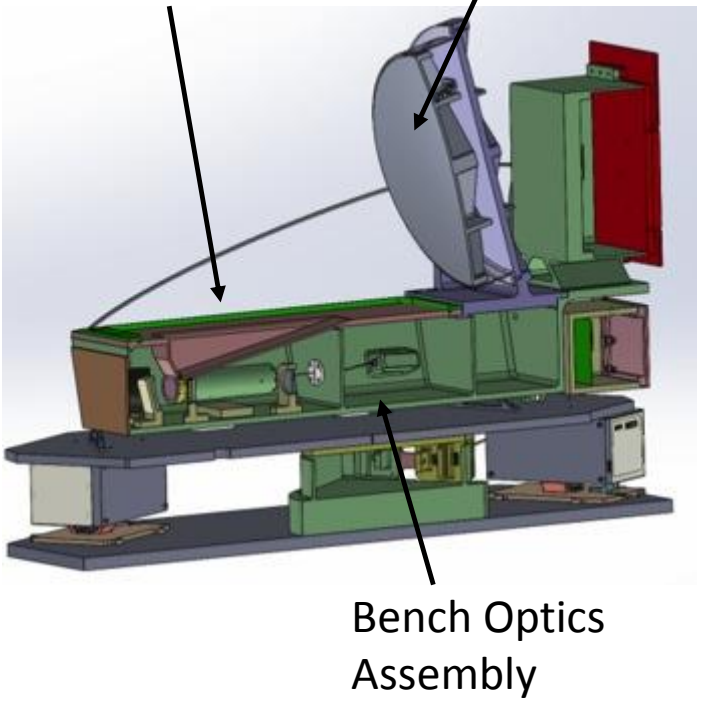
DSOC Technology Maturation

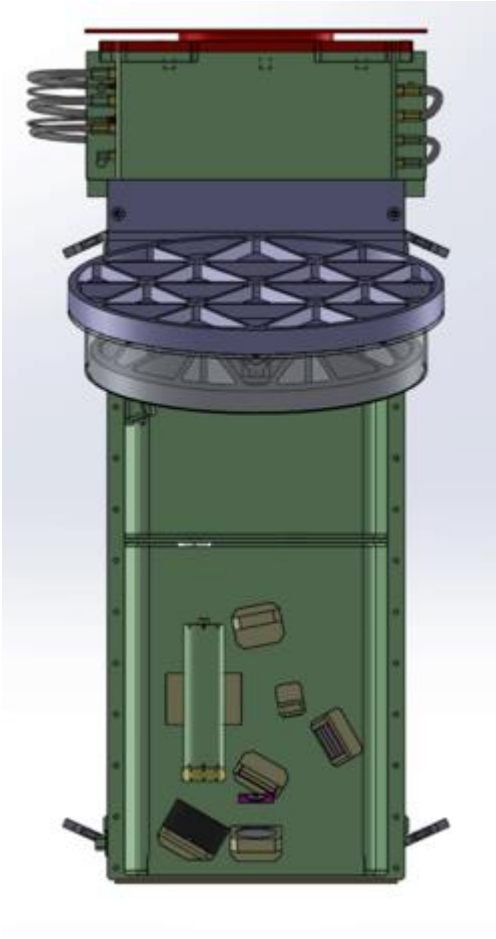


Optical Telescope Assembly (OTA)

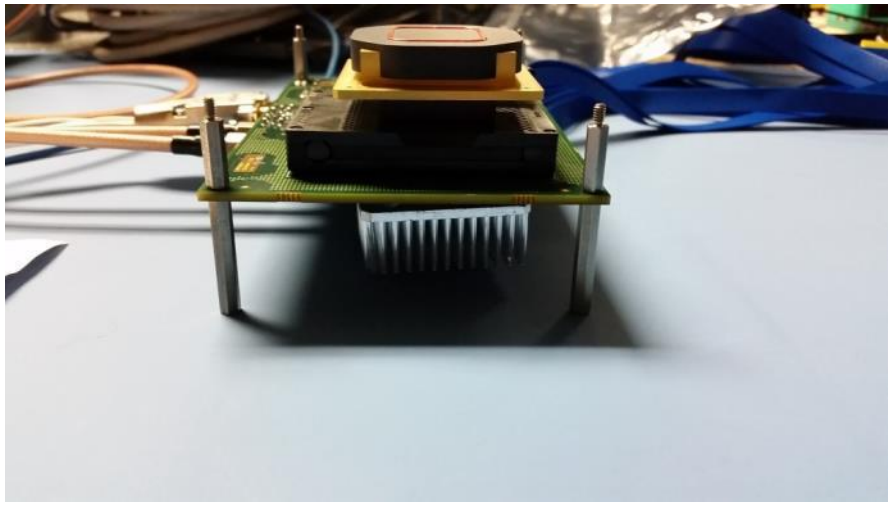
- OTA includes the optical bench, primary mirror mounting assembly, bench optics assembly, and closeout plate
- OTA serves as an integrating structure for the Photon Counting Camera, Floating Platform Electronics, and Isolation and Pointing Assembly







Photon Counting Flight Camera



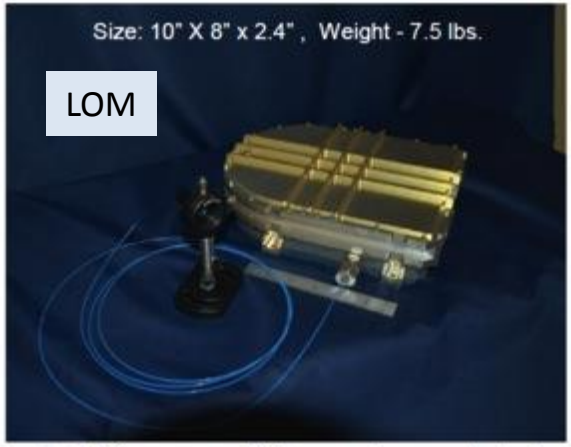
Avalanche photodiode and ROIC

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

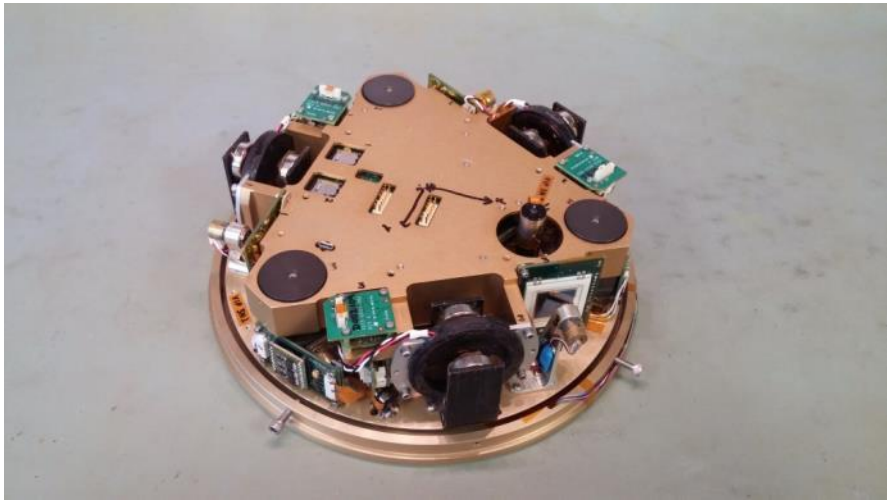


▪ **>15% power efficiency demonstrated**
(electrical in → LOM optical output)

Point Ahead Mirror

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

Vibration Isolation Technology

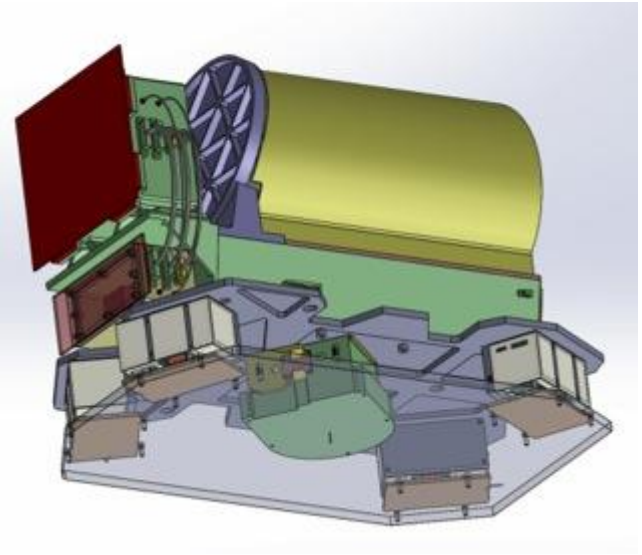


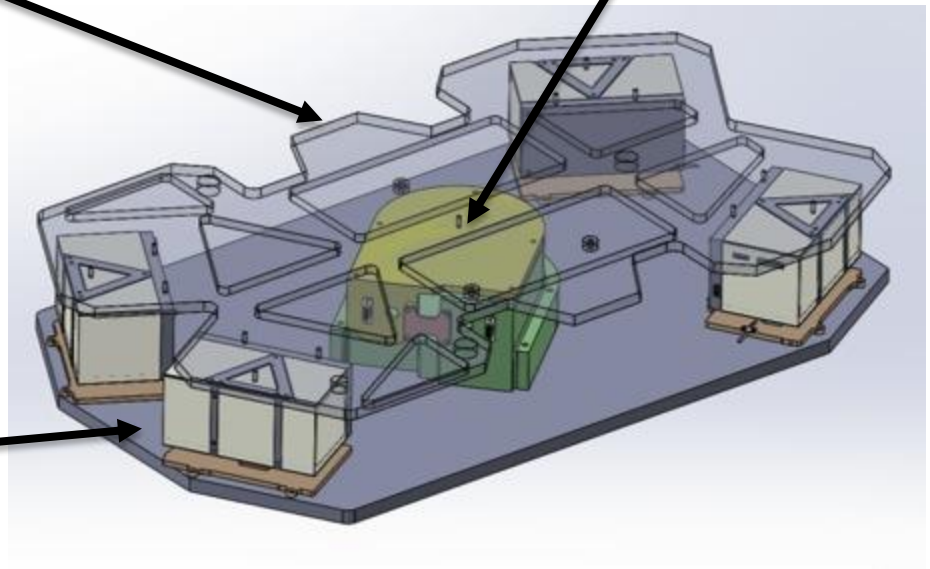
CDI Vibration Isolated Platform

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

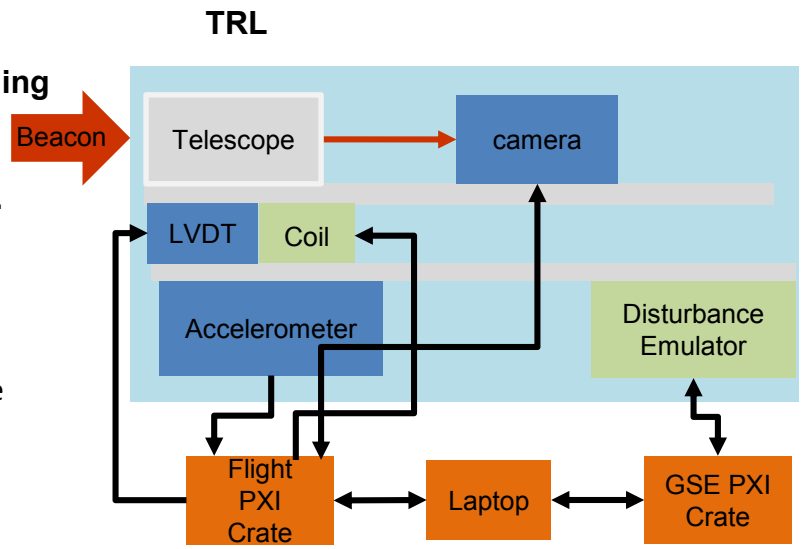


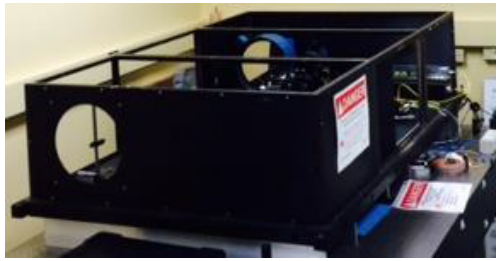


TRL-3 Demonstration

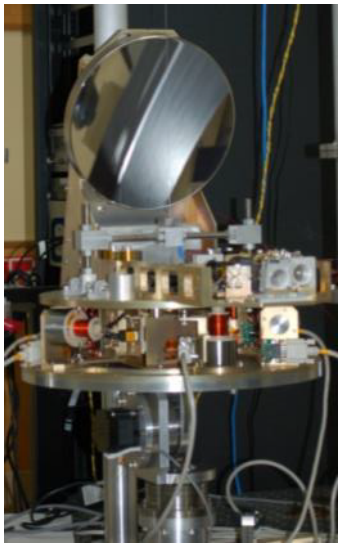
Demonstrate closed loop tracking in a using laboratory development electronics and optics, developmental vibration isolation hardware and a commercial CCD camera.

- 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)

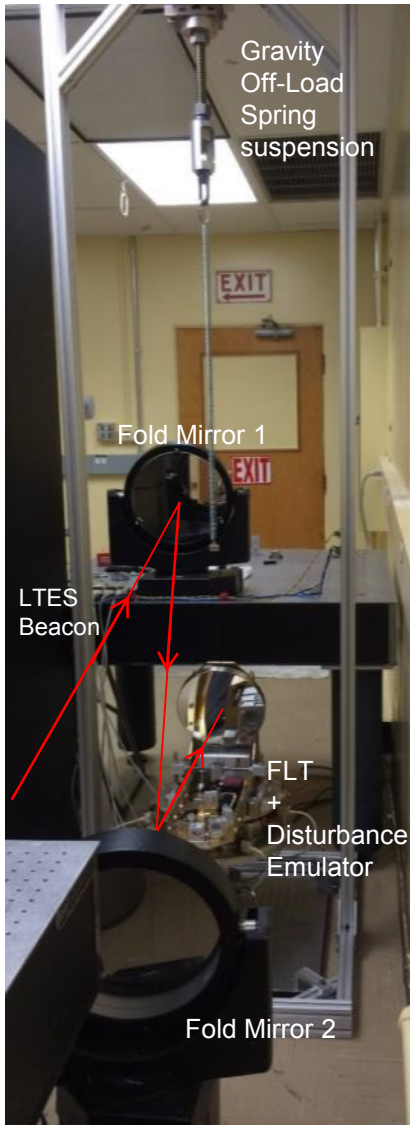




LTES used for generating 20 cm diameter collimated beacon



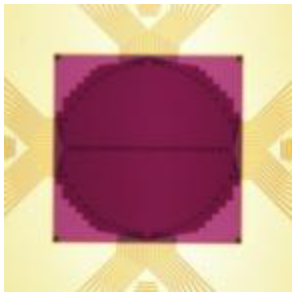
FLT integrated to 2-axis disturbance emulator



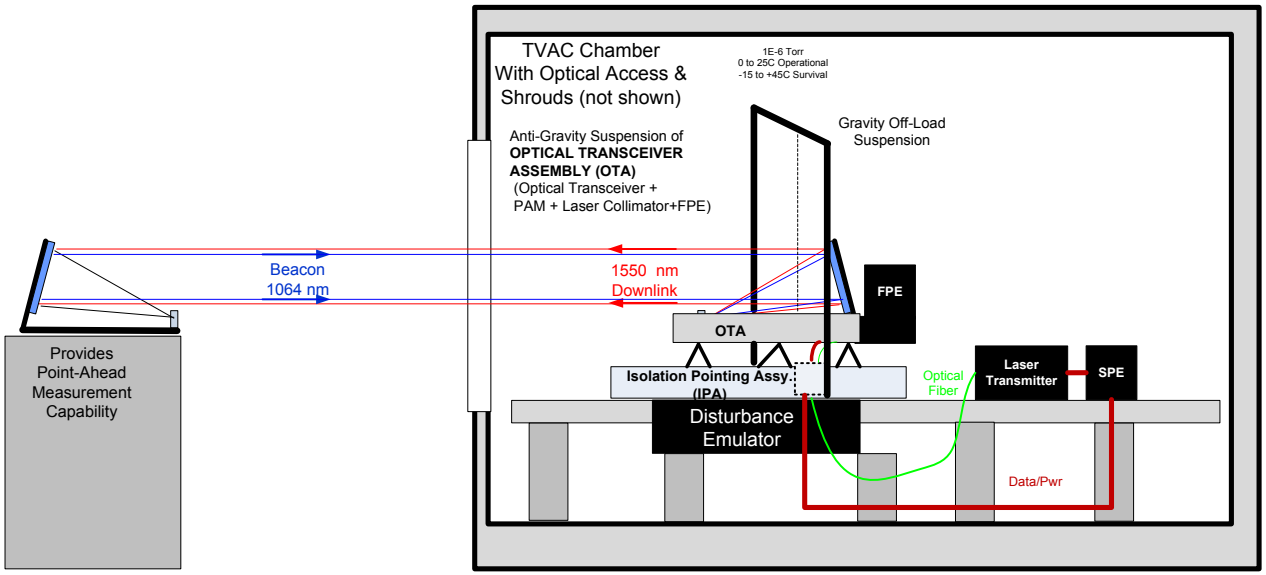
Gravity off-load using spring suspension (beacon path is shown in red)

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

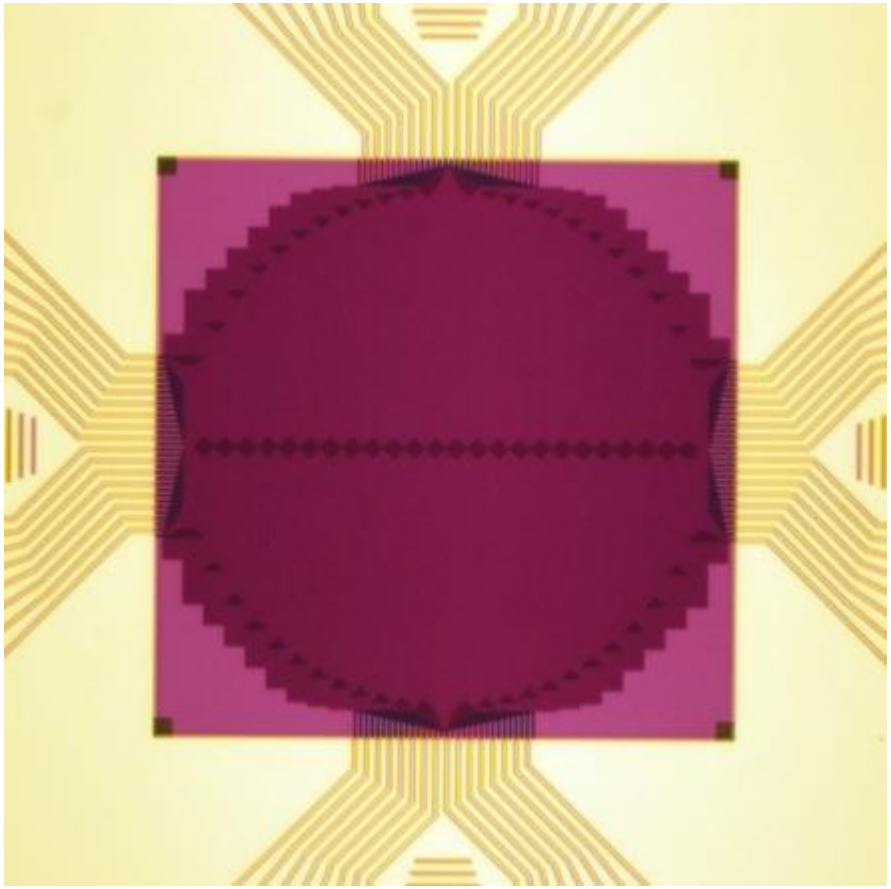


320-μm, 64 pixel WSi SNSPD Array



11-foot Thermal-Vacuum Chamber

Ground Detector Technology



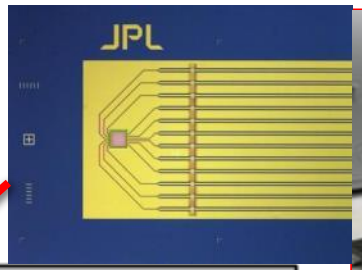
Photomicrograph of 64 nanowire array

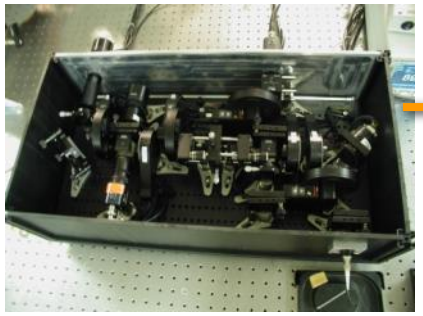
Ground Detector

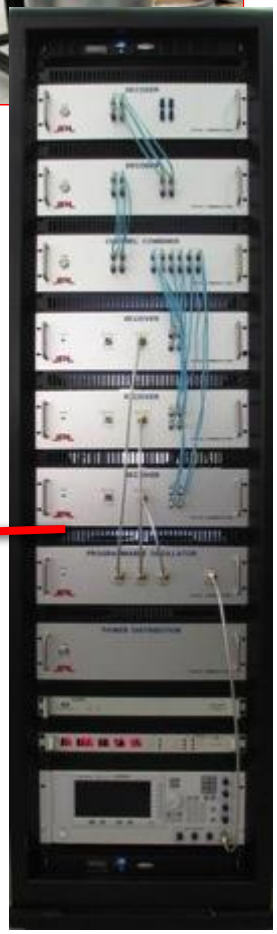
- Micro devices Laboratory Development
  - 64 nanowire array
  - Functions as photon counting detector
  - Will be located at Coudé focus of 5 meter Hale telescope
  - Operates at 1K
  - Initial devices in test

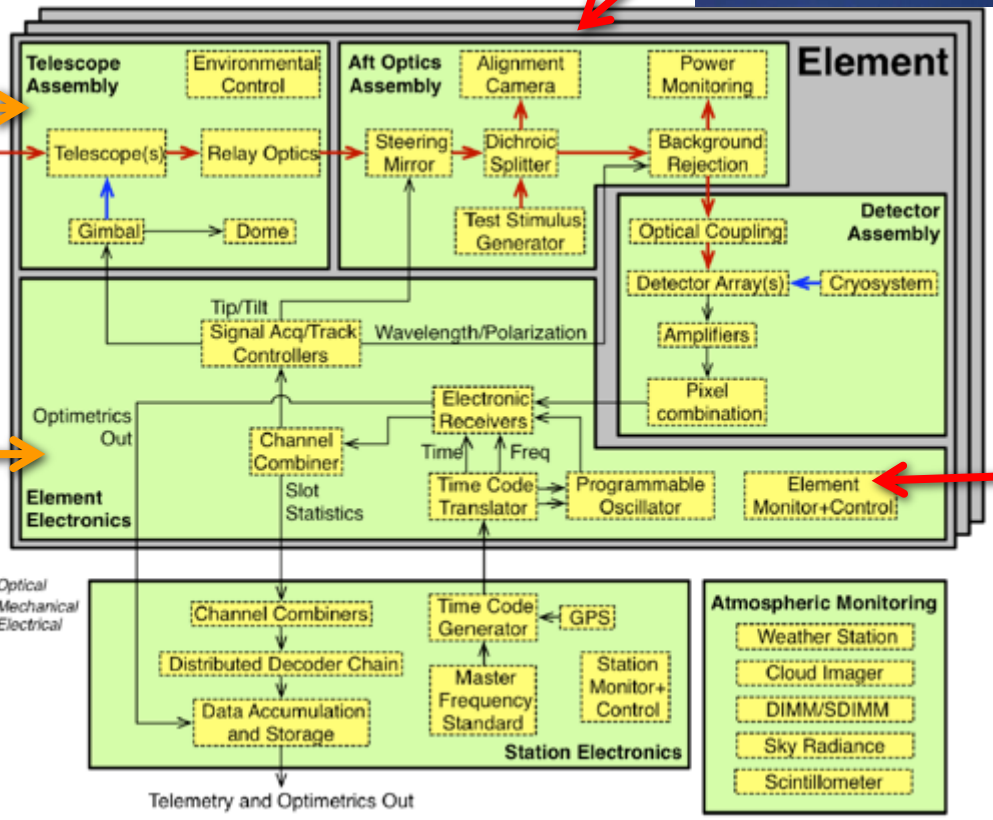
Technology Demonstration Downlink Ground Terminal

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

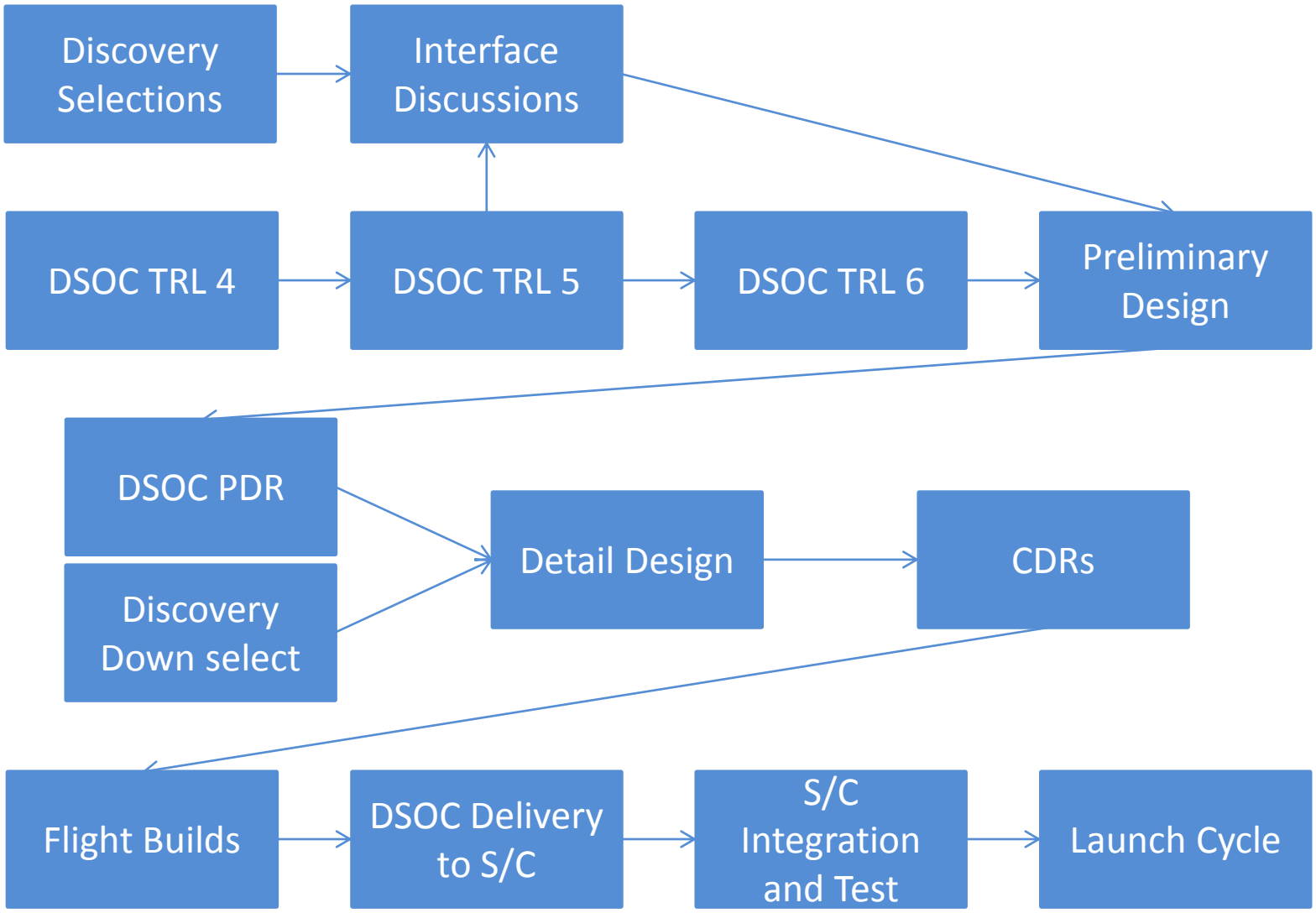








DSOC Technology Readiness to Flight



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