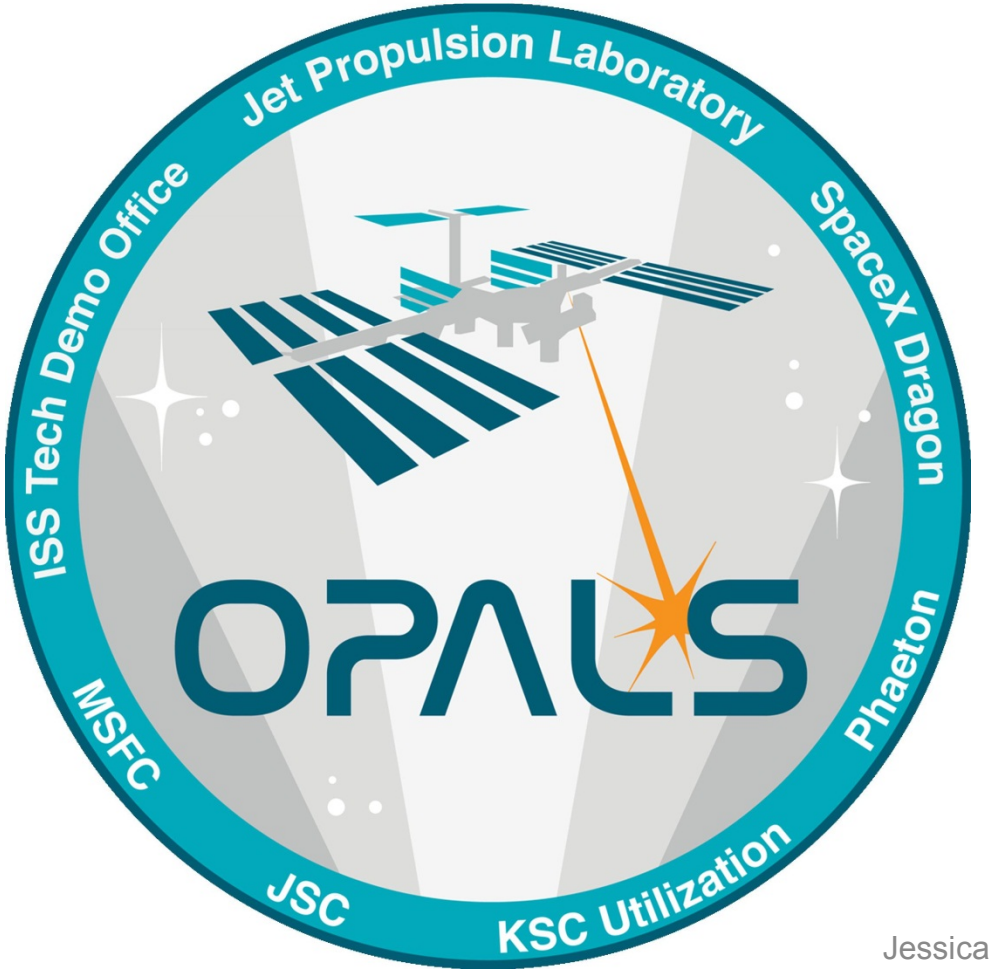
OPALS: Optical PAyload for Lasercomm Science



A COTS-Based Technical Demonstration of Optical Communications

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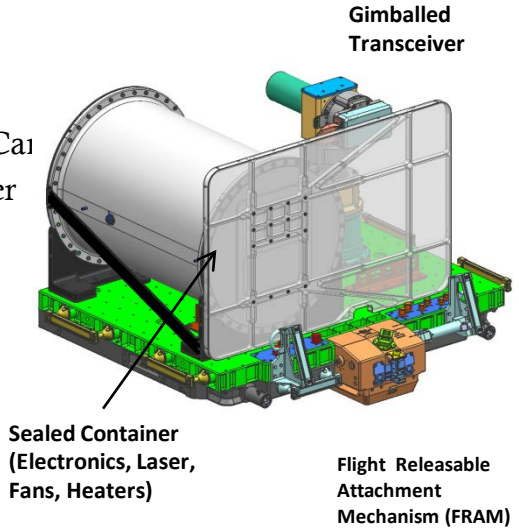
OPALS Summary

Objective: Deliver video from ISS to optical ground terminal via an optical communications link.

- JPL Phaeton/Early Career Hire (ECH) training project
- Implemented as Class-D payload
- Downlink at ~30Mb/s

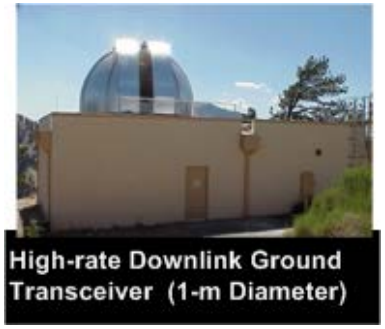
Flight System

- Optical Head
  - Beacon Acquisition Ca
  - Downlink Transmitter
  - 2-axis Gimbal
- Sealed Container
  - Laser
  - Avionics
  - Power distribution
  - Digital I/O board



Implementation

- Ground Station - Optical Communications Telescope Laboratory at Table Mountain Facility
- Flight System mounted to ISS
  - FRAM as standard I/F
  - Attached externally on Express Logistics Carrier



Phaeton budget covers development only. Launch integration and operations costs still being negotiated

Major Milestones:

- ✓ ΔMCR – 10/19/2009
- ✓ SRR – 02/23/2010
- ✓ DR1 – 06/24/2010
- ✓ DR2 – 08/31/2011
- ✓ TRR – 05/15/2012
- PSR – 9/25/2012
- Delivery – 9/28/2012

Launch: July, 2013
Vehicle: SpaceX Dragon CRS3
ISS Increment: 35/36
Operational Lifetime: 90 days

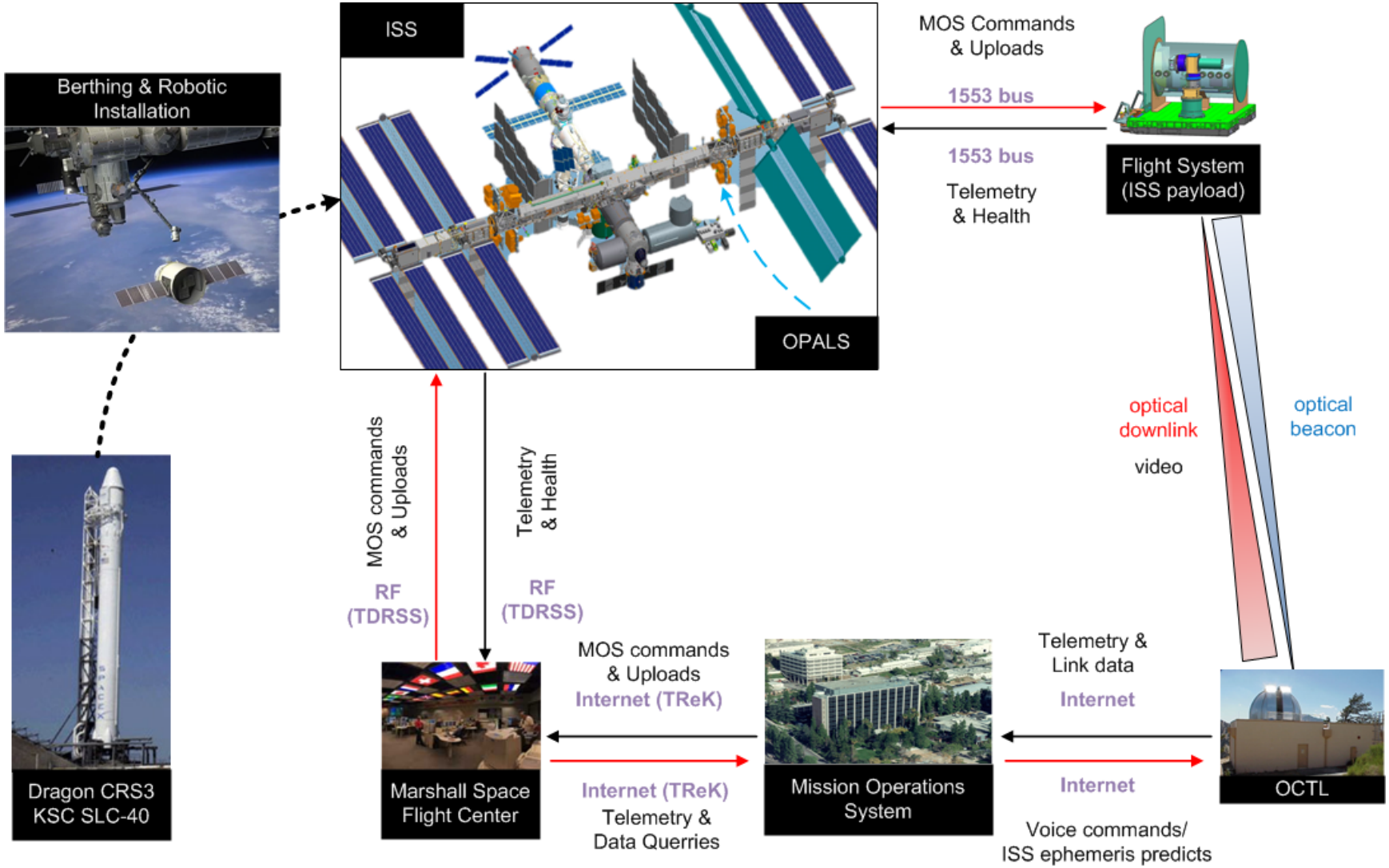
Optical Communications Facet of OPALS

- Optical link performance characterization & validation
- Atmospheric turbulence characterization
  - Obtain downlink aperture-averaged fading statistics by recording received power
  - Obtain uplink scintillation statistics by recording beacon power on flight system
- Link availability studies
  - Geometry, atmospheric & environmental, day vs. night
- Pointing performance
  - OCTL Open loop tracking
  - Flight System acquisition, tracking, stability

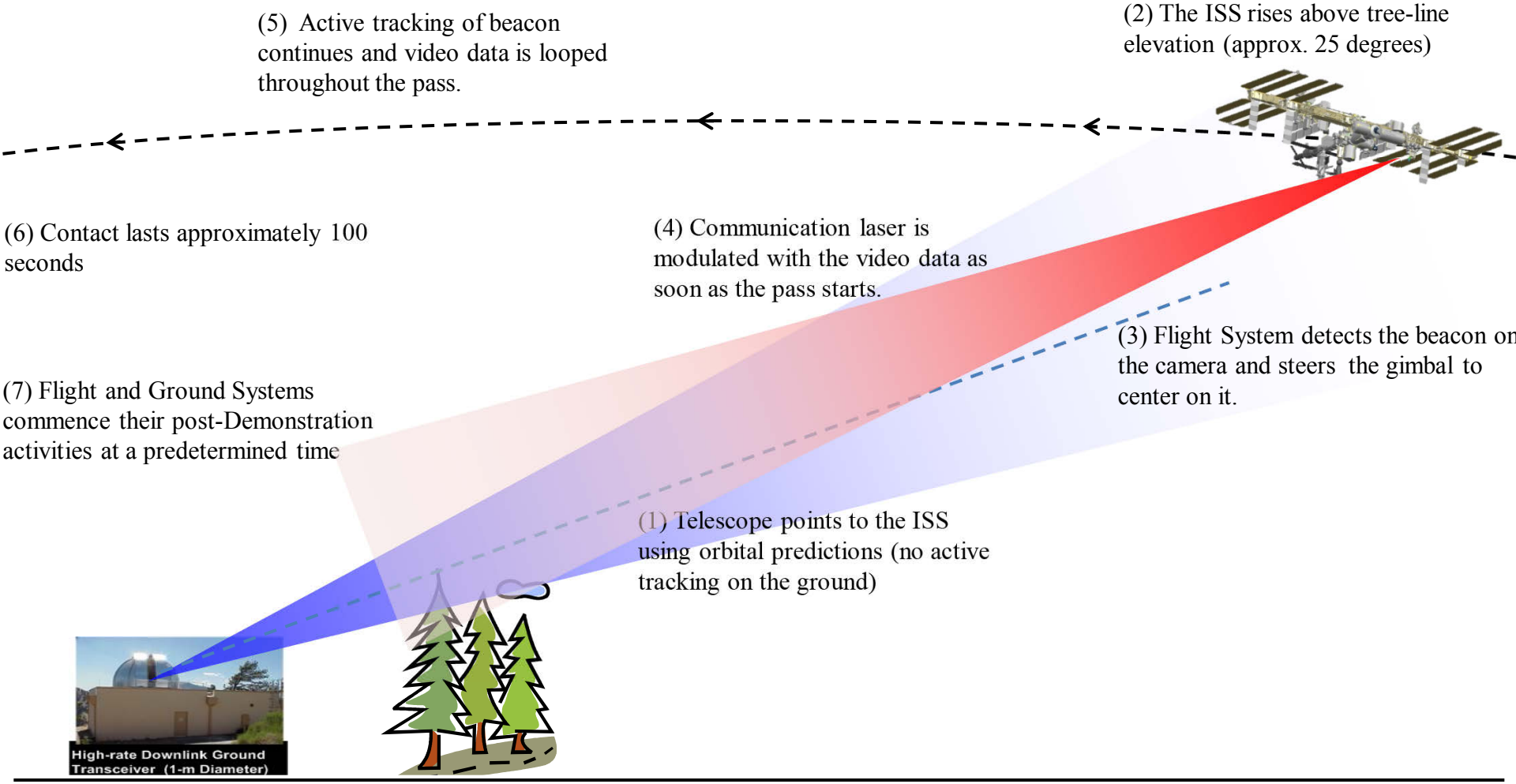
DOWNLINK CHARACTERISTICS		
SIGNALING		
Modulation	OOK	-
Uncoded BER	1.00E-04	-
ECC	Reed-Solomon	-
Modulation Rate	30-50	Mb/s
TRANSMITTER		
Downlink wavelength	1550	nm
Beam Divergence (1/e^2)	1.65	mrad
Average laser power	2.5	W
Power transmitted from FS	>0.833	W
POINTING		
Pointing Bias	150.0	µrad
Pointing Jitter (RMS)	125.0	µrad
LINK GEOMETRY		
Max Zenith Angle	65	deg
Max Range	700	km

BEACON CHARACTERISTICS		
Uplink wavelength	976	nm
Average Laser power	5	W
Beam divergence	1.7	mrad
Power transmitted from OCTL	1.26	W

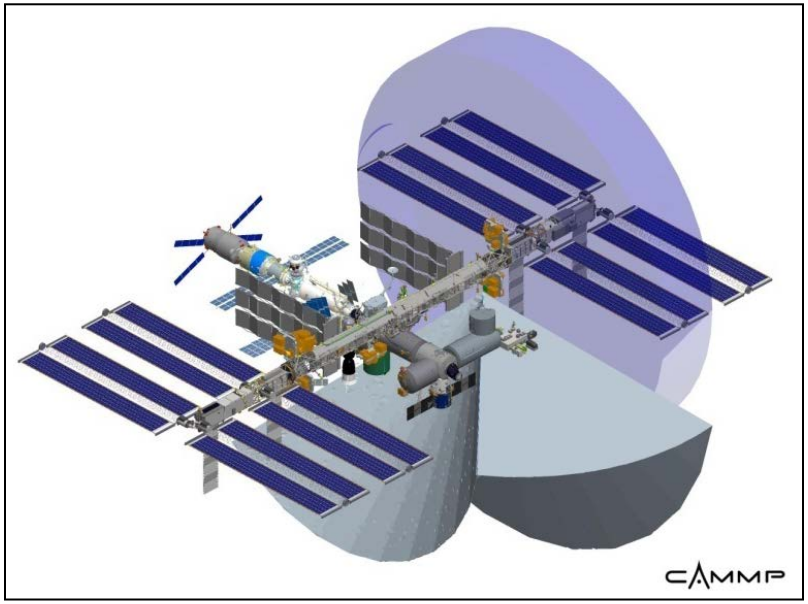
Mission Architecture

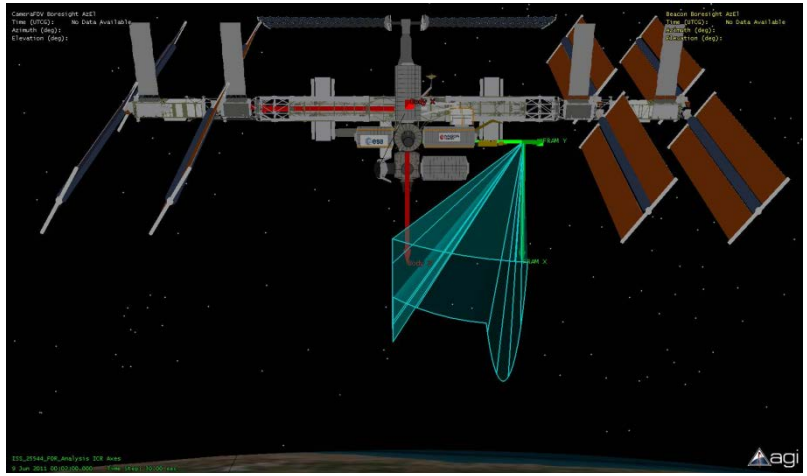


Operations Scenario

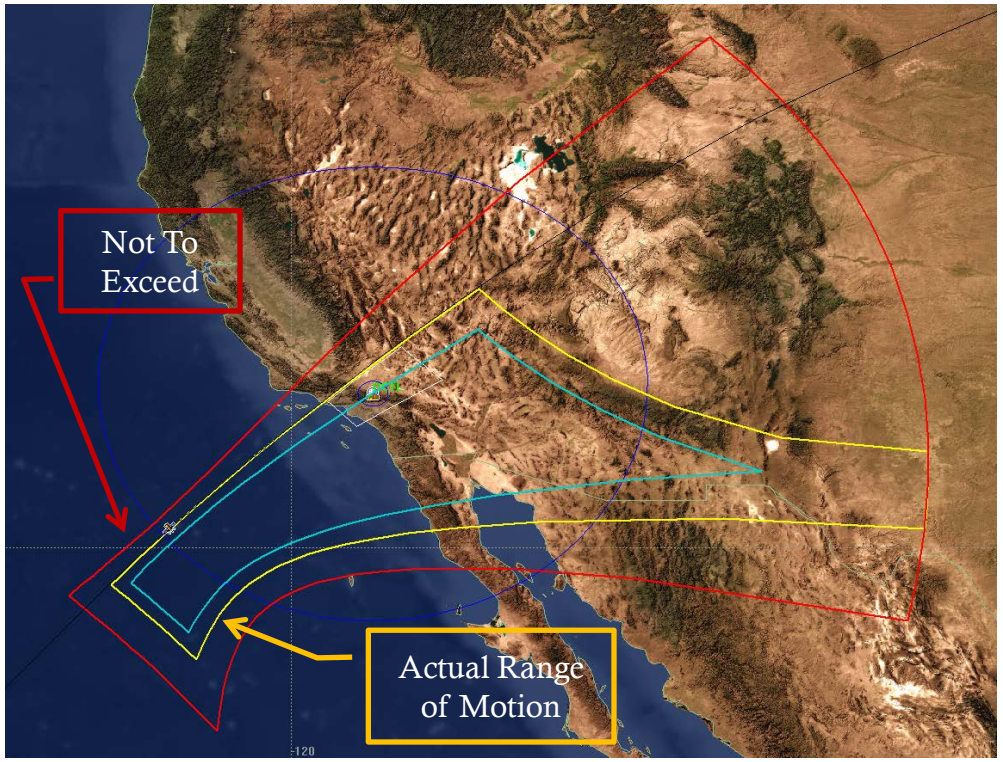


Laser Safety Limitations On Pass Geometry

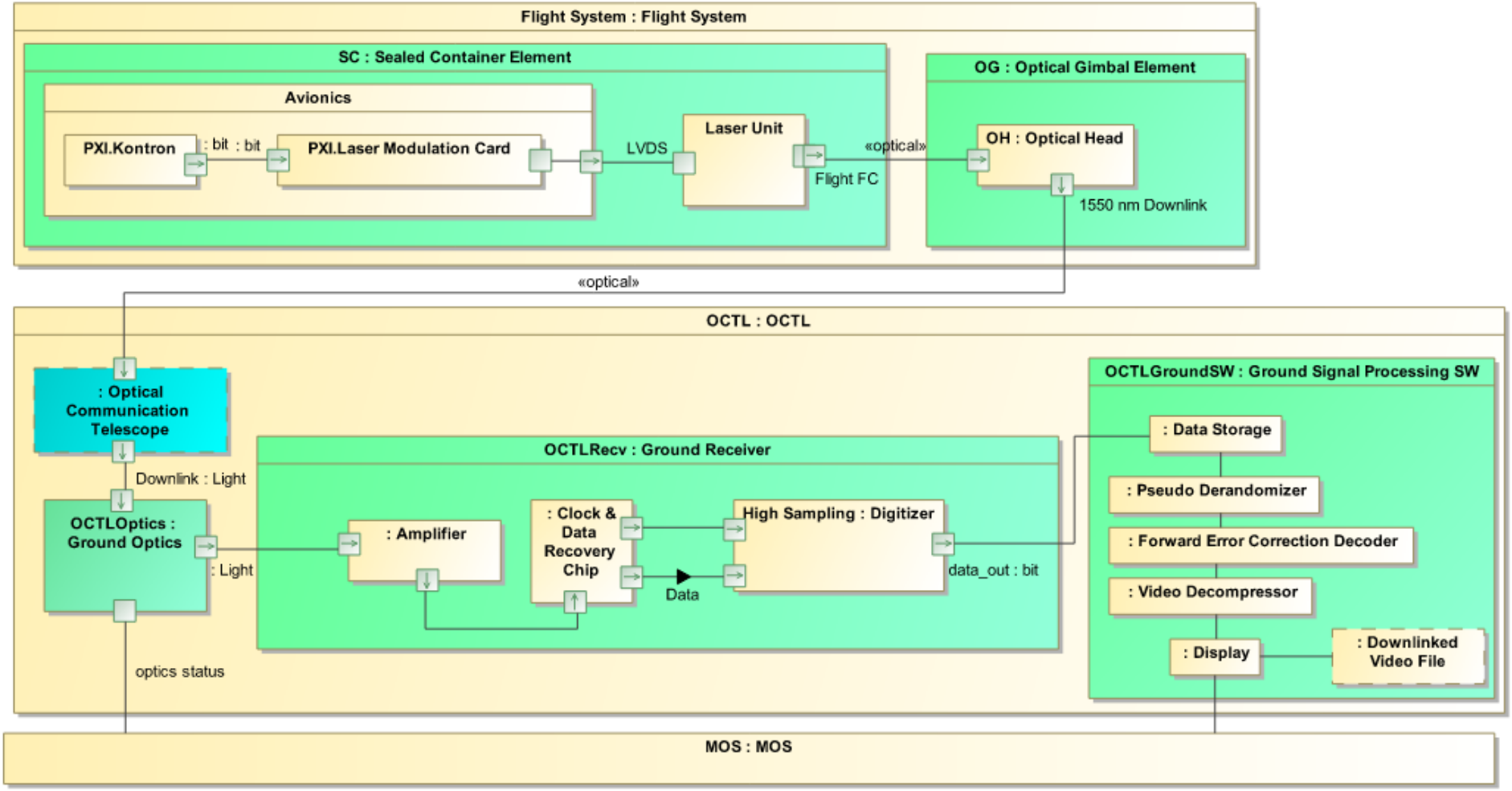




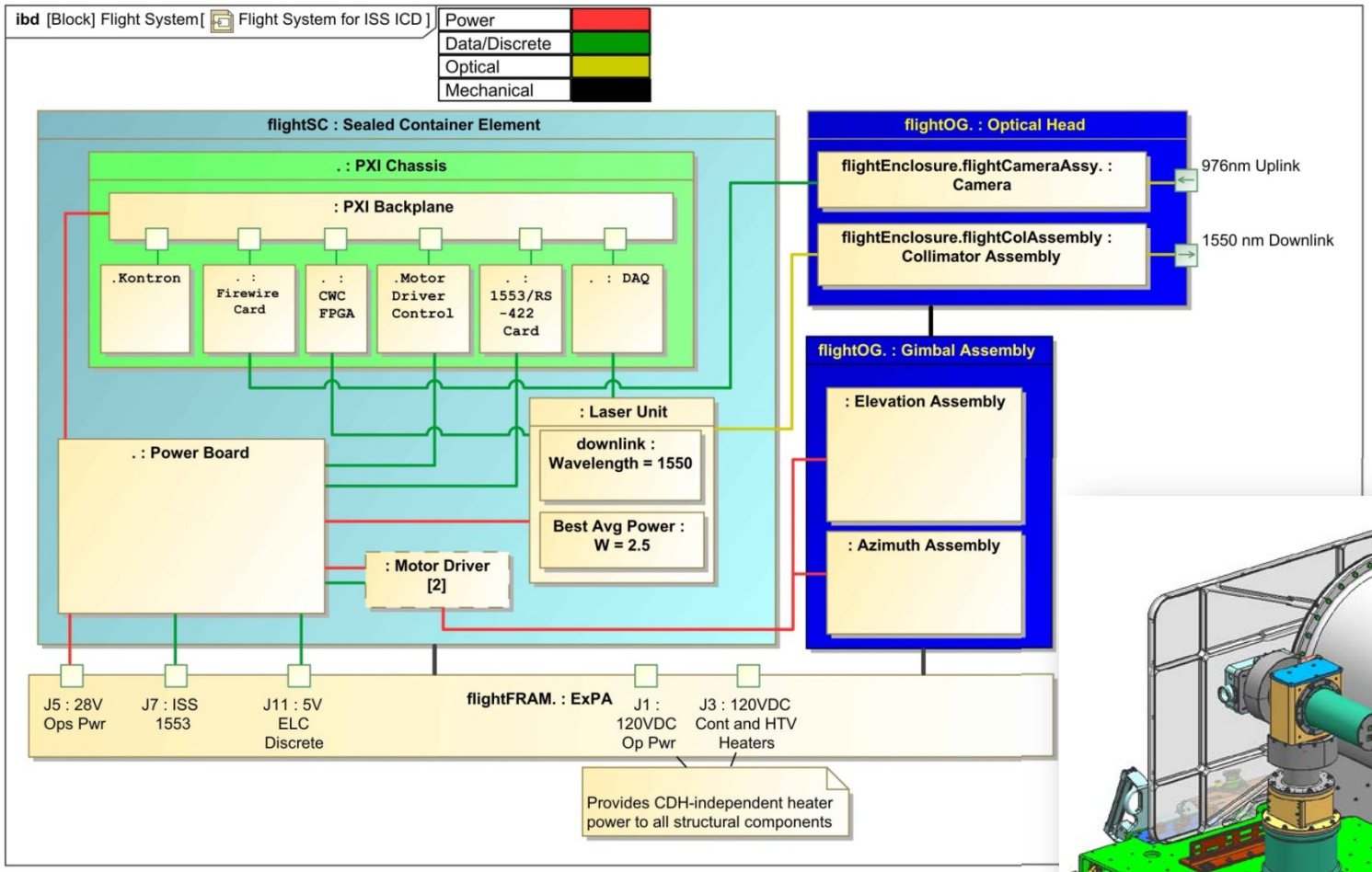
- RoM (wrt to nadir) limited to :
  - 75˚ to -35˚ in AZ (~ along track)
  - 40˚ to -1˚ in EL (~ cross track)
- Favorable Passes ~ 1 every 2-3 days

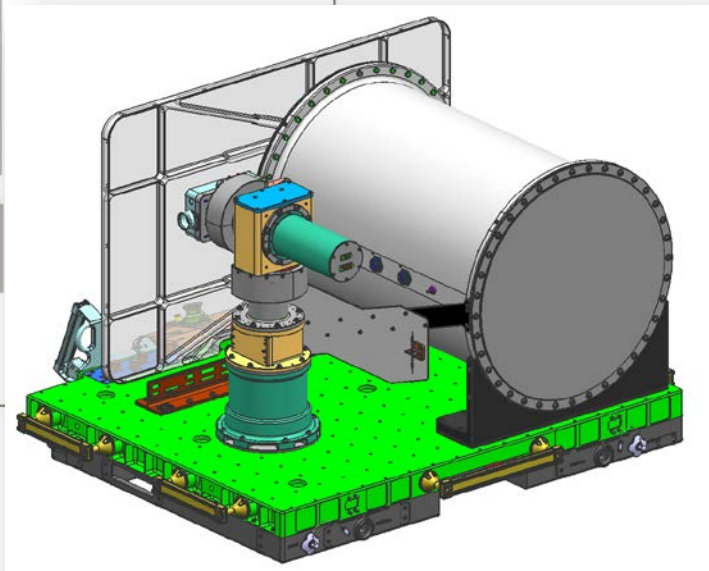


Downlink Interfaces

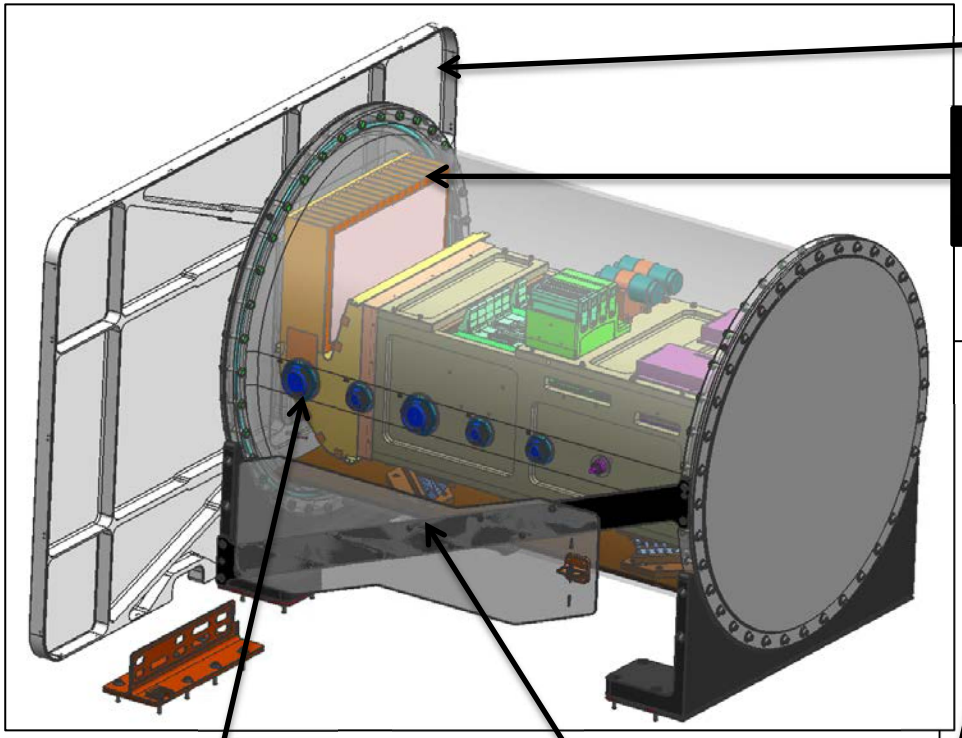


Flight System Interface Diagram





Sealed Container Design



Radiator

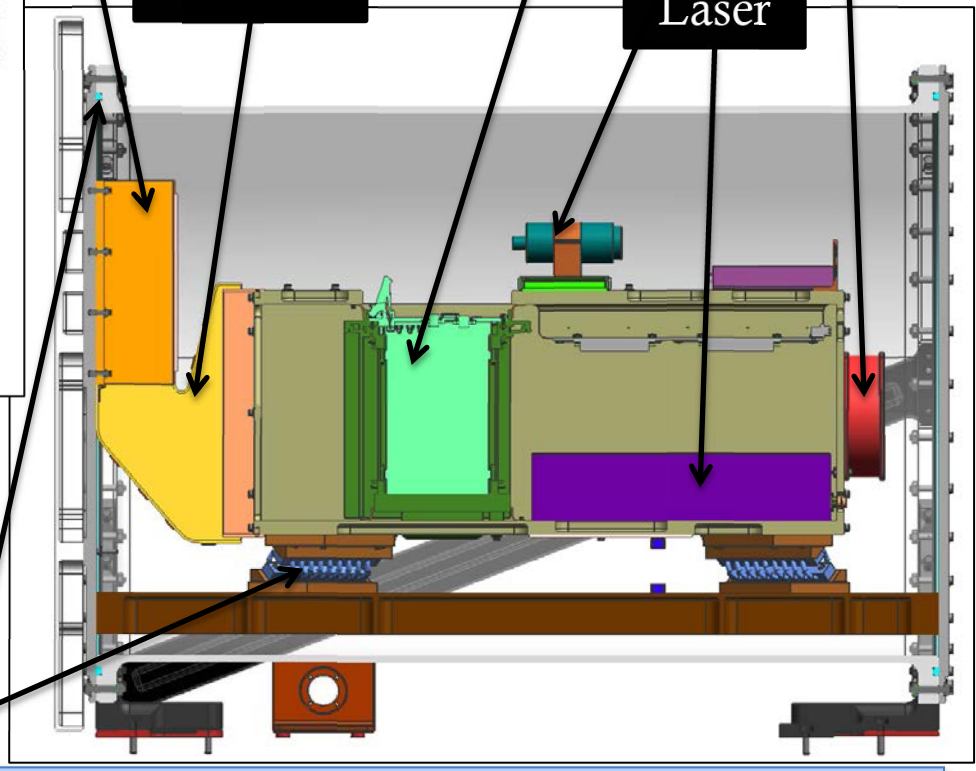
Heat exchanger

Cabling Feedthroughs

Cabling Support Plate

O-ring

Wire rope isolators



Pressure Transducers

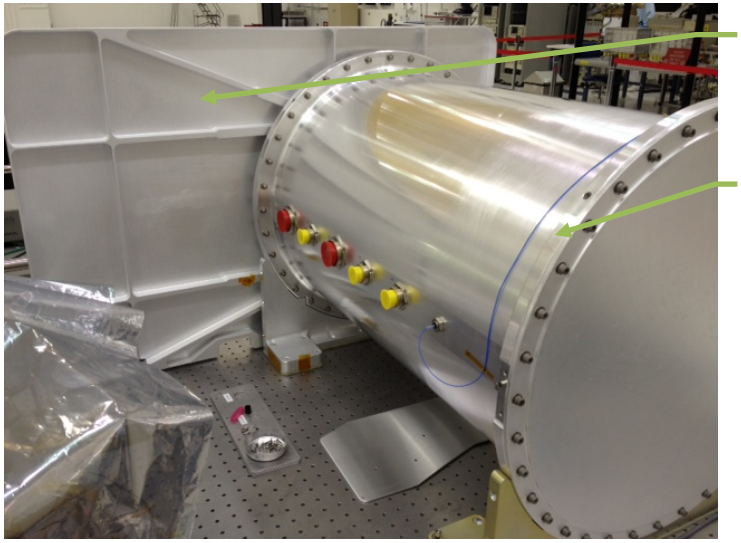
COTS avionics

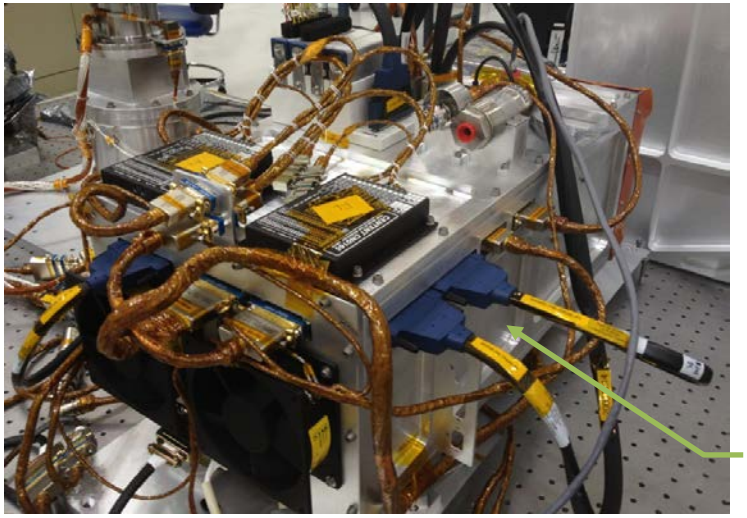
Fans

Air duct

Laser

From Paper to Metal





Radiator

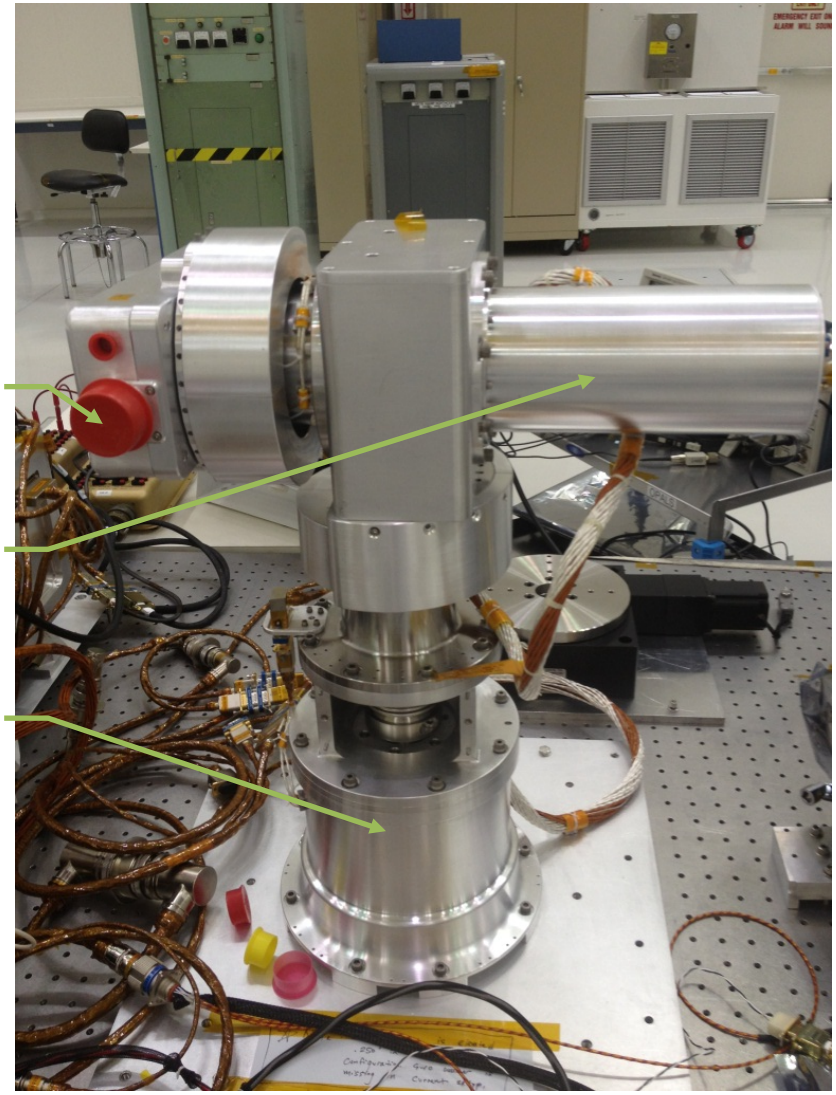
Sealed Container

Optics

Gimbal EL

Gimbal AZ

Avionics & Laser Assy



Quantifying the ISS Interface

Programmatic

- JSC
  - TDO – Tech Demo Office
  - OZ – Payloads
  - ON – Launch
  - OB – ISS
  - PSRP - Safety
- KSC
  - UB – Utilization
- MSFC
  - HOSC – Operations
  - Simulator Support
- SpX
  - Mission Management
- 200+ individuals from 35 teams

Technical

- Requirements
  - 694 Levied by 57003-ELC
    - 411 Applicable (52% of project requirements)
    - 81 Requirement changes since CDR (12%)
  - 117 Levied by 57012
    - 41 Applicable (5.2% of project requirements)
    - 22 Requirement Changes since CDR (39%)
- GFE & GSE [14 total pieces]
  - Flight ExPA
  - Electrical + C&DH Simulators
  - Mechanical manipulation tools
- Testing
  - Preliminary electrical interface testing required 50+ Support Staff (KSC, JSC, MSFC Travelers)
  - Most power & data verifications must be done on ELC simulator at KSC

BACKUP

JPL
Jet Propulsion Laboratory
California Institute of Technology

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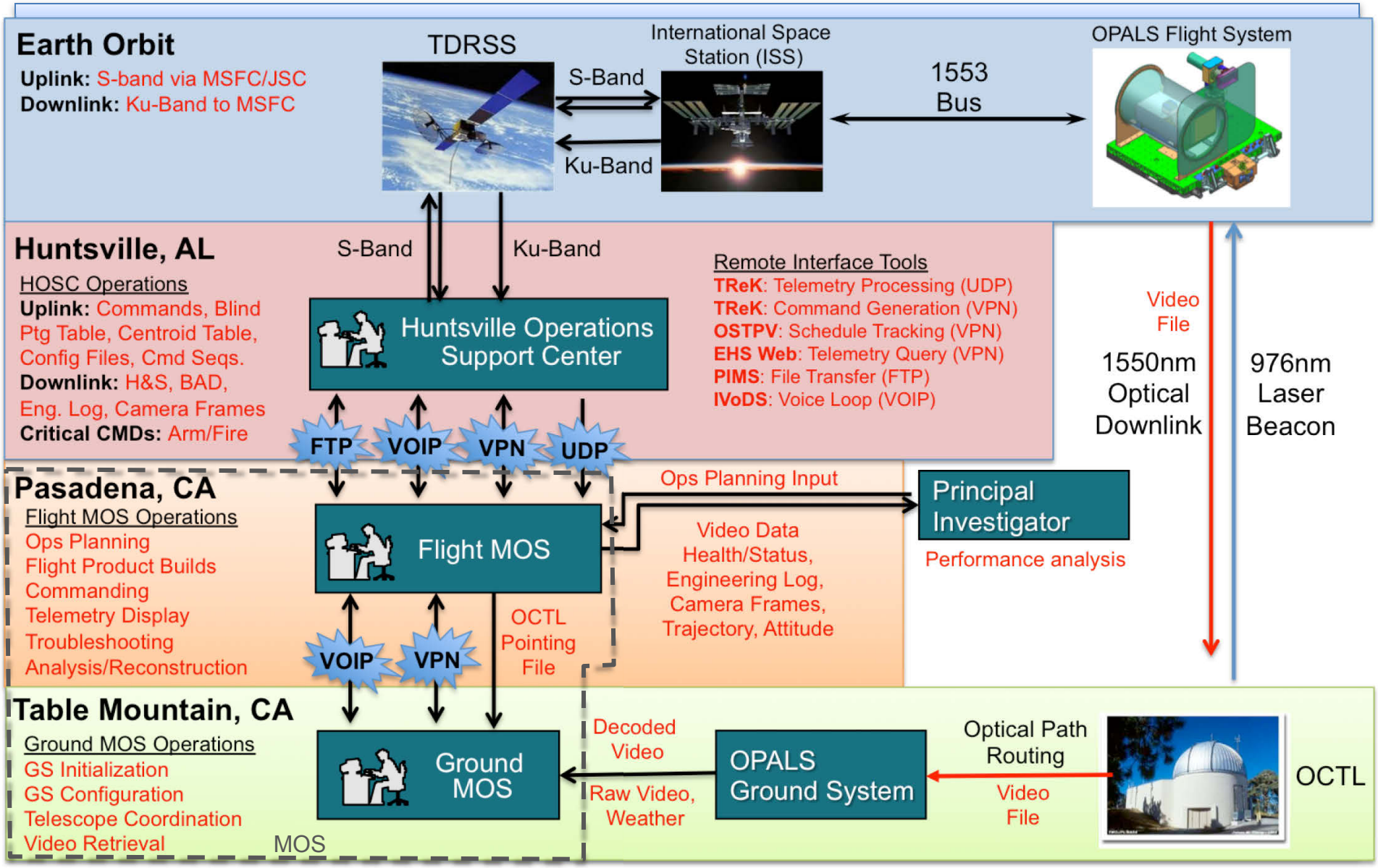
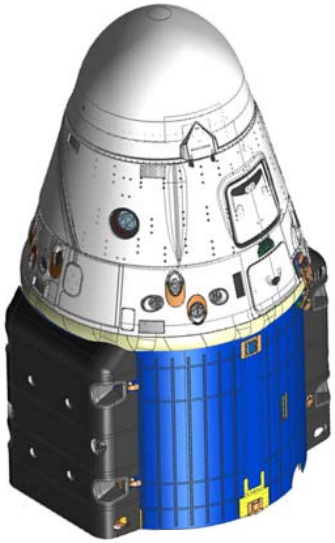
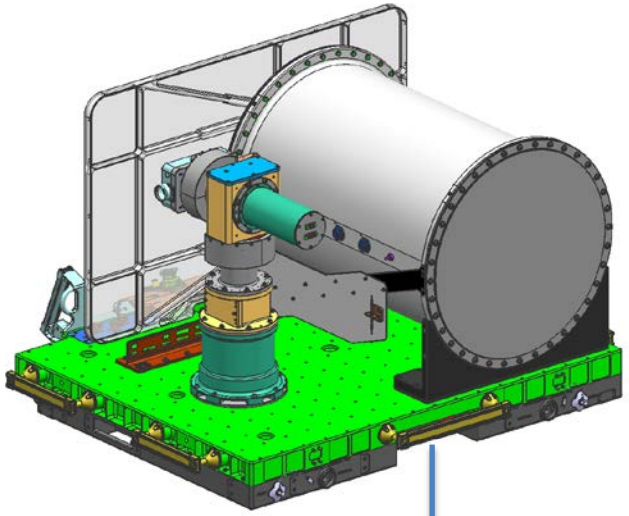
MOS/GDS Interfaces



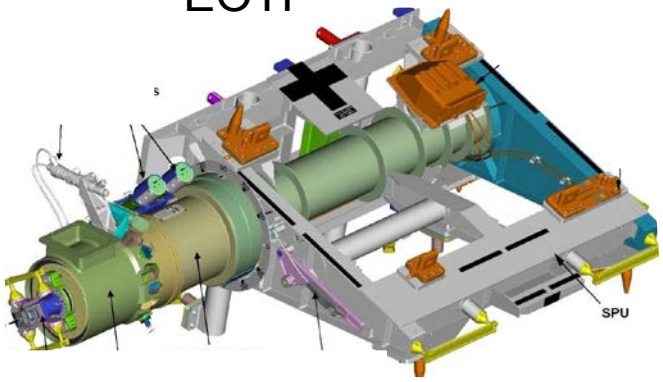
FRAM Interface



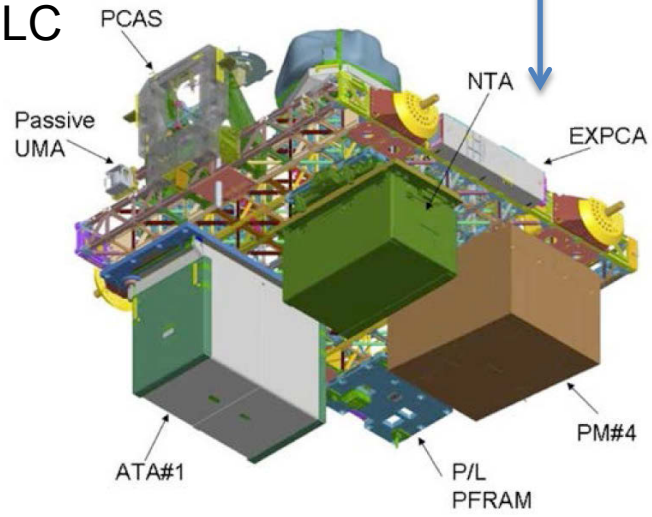
LV
Dragon



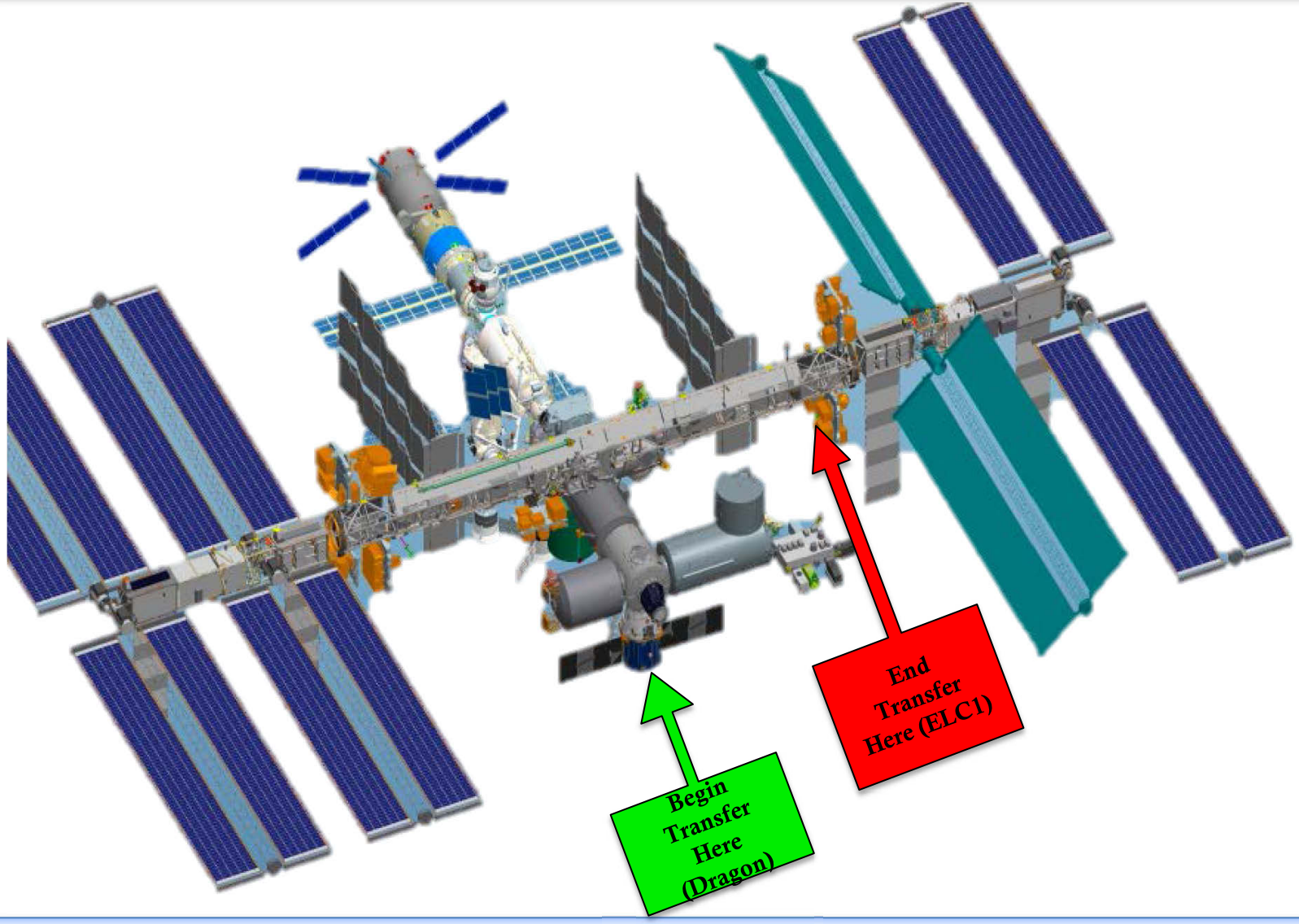
Robotics
EOTP



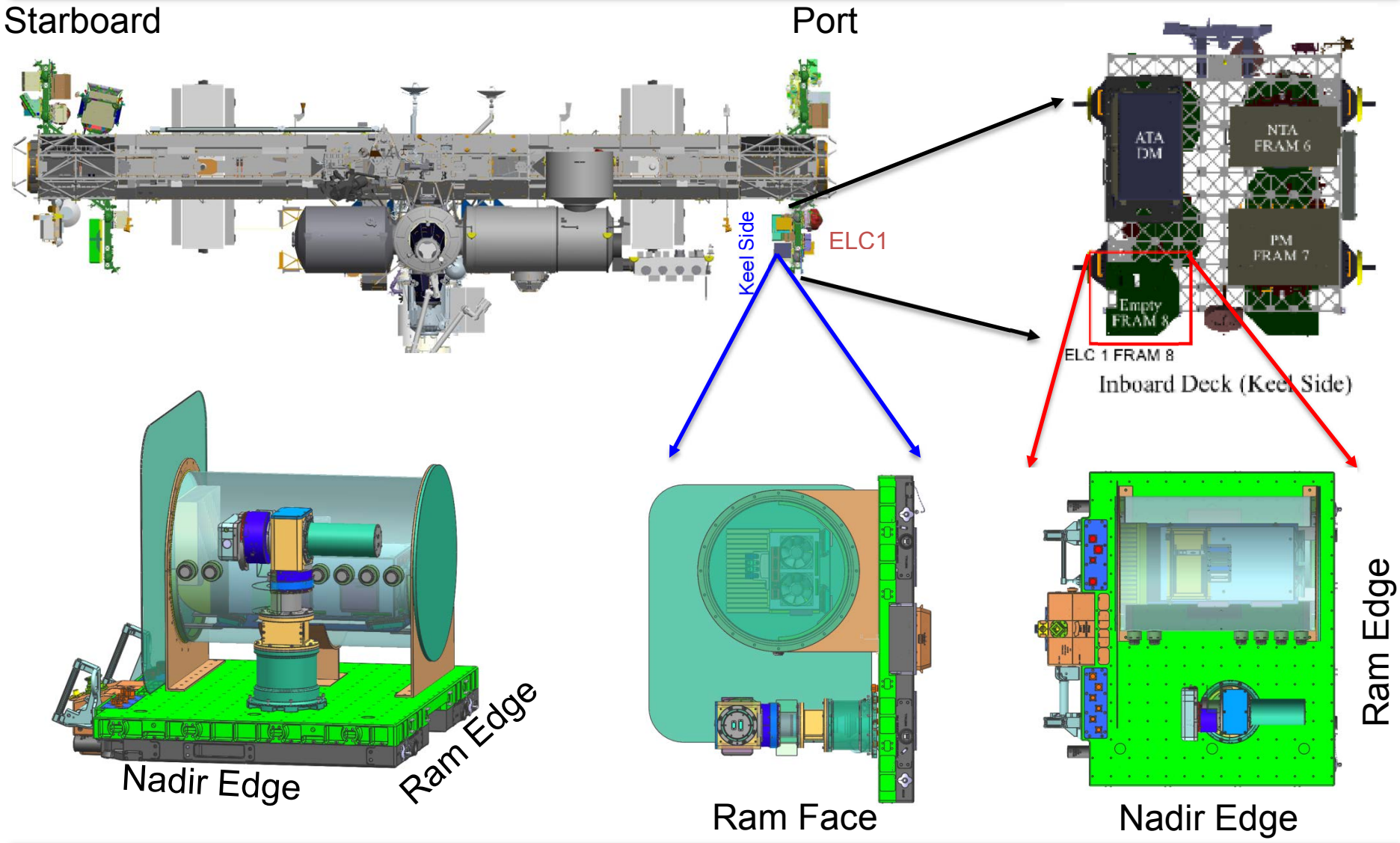
ISS
ELC



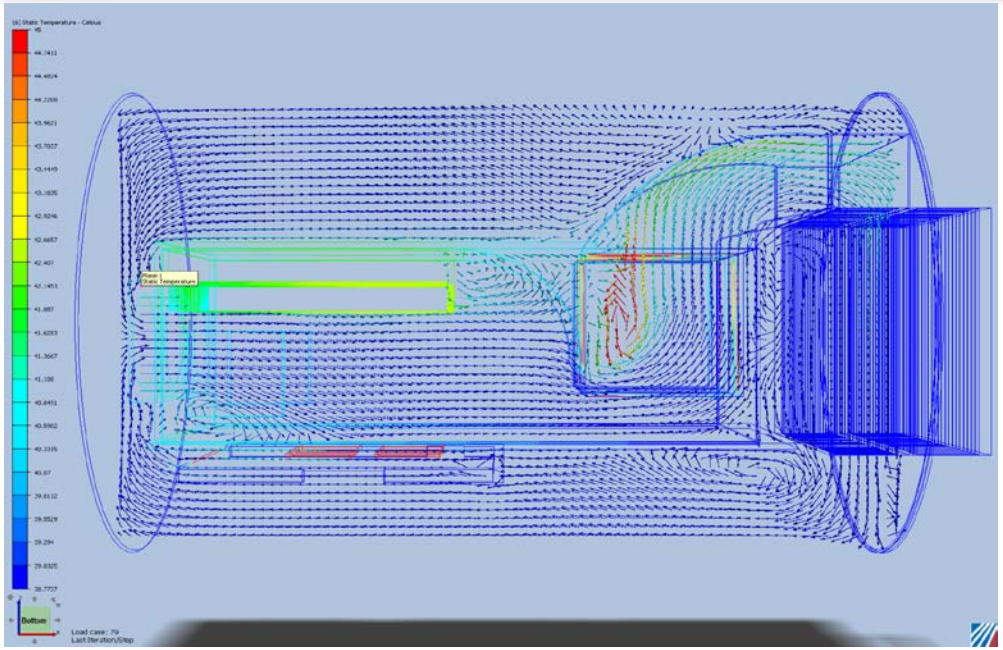
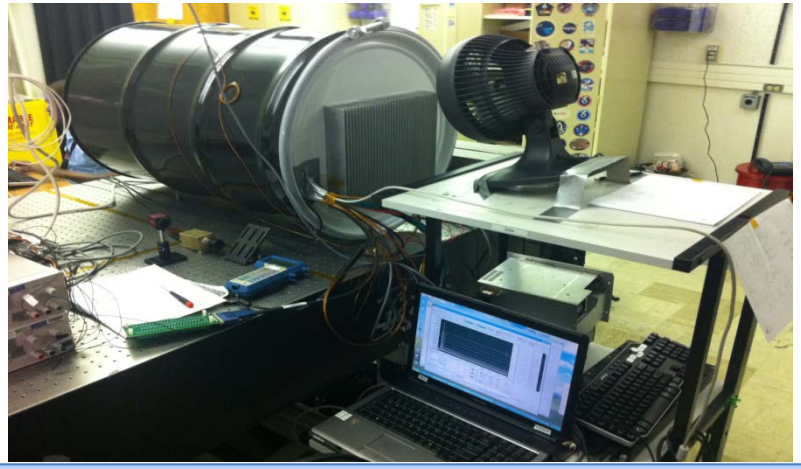
OPALS Transfer Range



OPALS Location on ISS



Design Validation of Force Convection



- Used Computational Fluid Dynamics (CFD) to optimize arrangement of elements within sealed container, size heat exchanger, evaluate flow rates, and trade possible gasses
- Performed flow test in lab to validate CFD values
- Dye pen inspection to ensure ring forging has no cracks after machining