OPALS: Optical PAyload for Lasercomm Science

A COTS-Based Technical Demonstration of Optical Communications

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A Different Kind of Opal

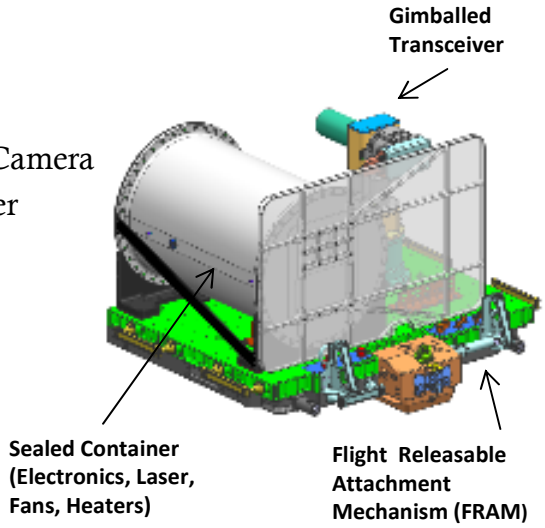
OPALS Summary

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

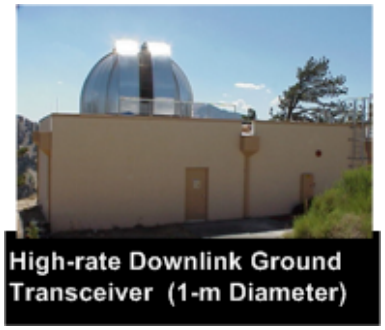
Flight System:

- ❑Optical Head
  - Beacon Acquisition Camera
  - 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


High-rate Downlink Ground Transceiver (1-m Diameter)

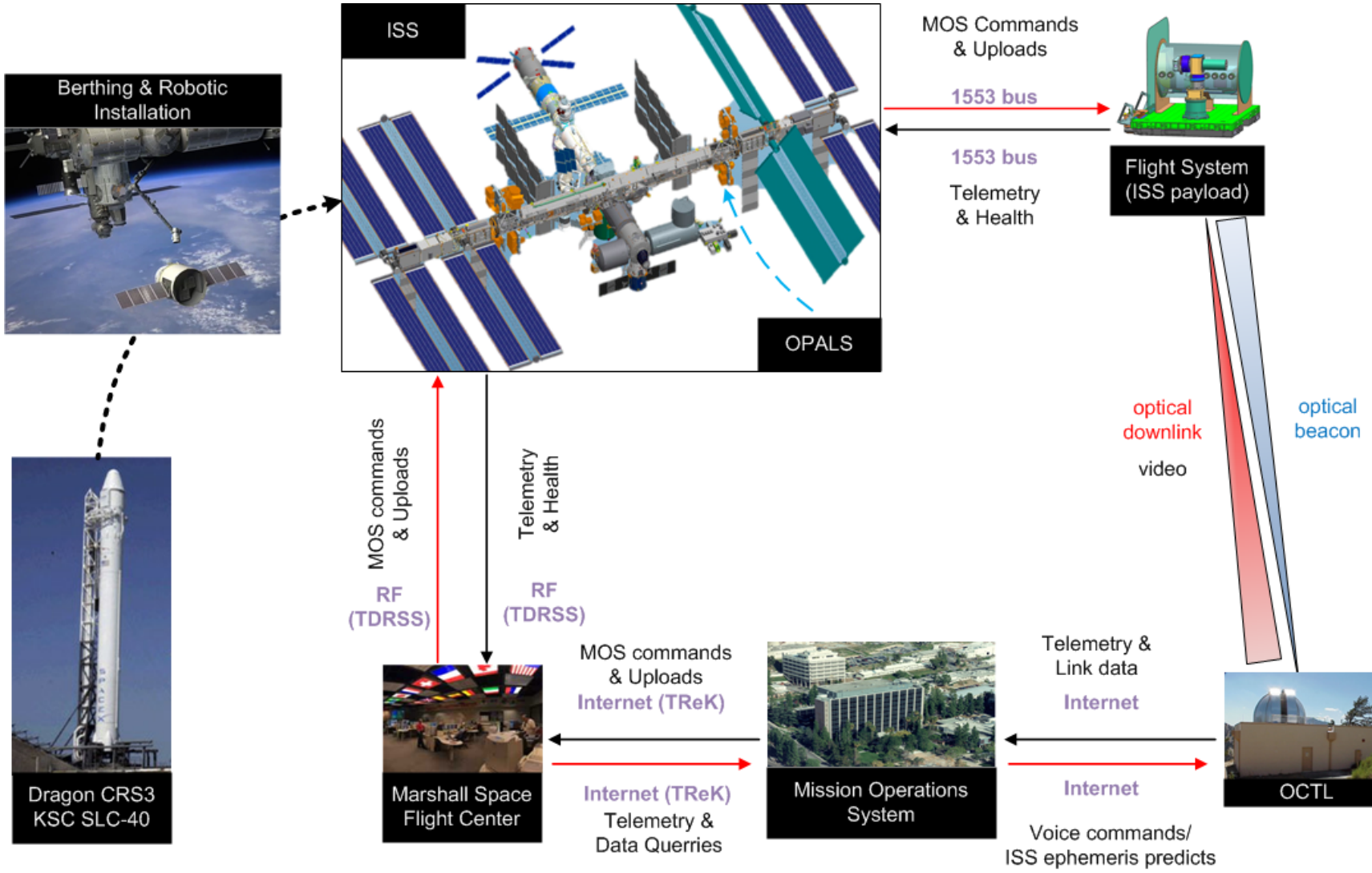
❑ Flight System mounted to ISS
- FRAM as standard I/F
- Attached externally on Express Logistics Carrier

Major Milestones:

- ✓MCR – 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

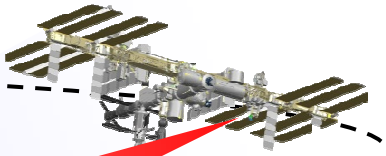
Mission Architecture



Operations Scenario

(5) Active tracking of beacon continues and video data is looped throughout the pass.

(2) The ISS rises above tree-line elevation (approx. 25 degrees)



(6) Contact lasts approximately 100 seconds

(4) Communication laser is modulated with the video data as soon as the pass starts.

(3) Flight System detects the beacon on the camera and steers the gimbal to center on it.

(7) Flight and Ground Systems commence their post-Demonstration activities at a predetermined ti

) Telescope points to the ISS using orbital predictions (no active tracking on the ground)

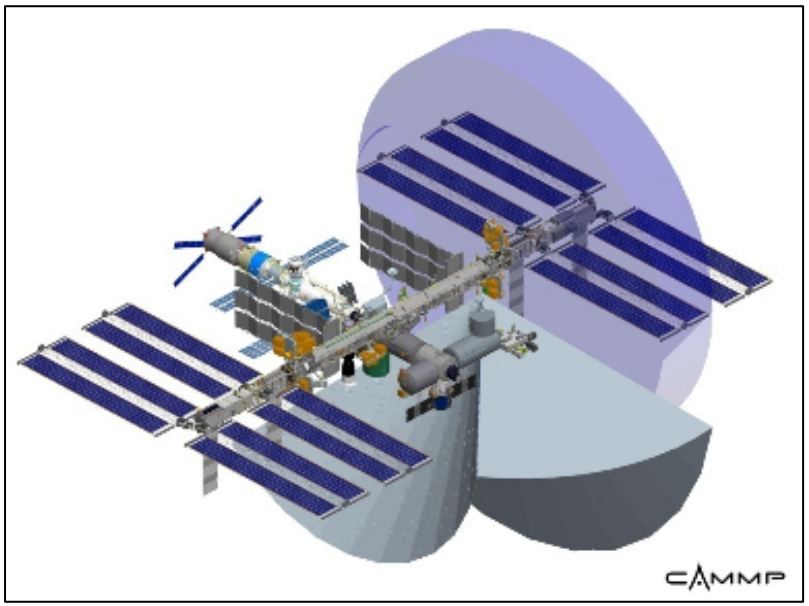
Optical Communications Facet of OPALS

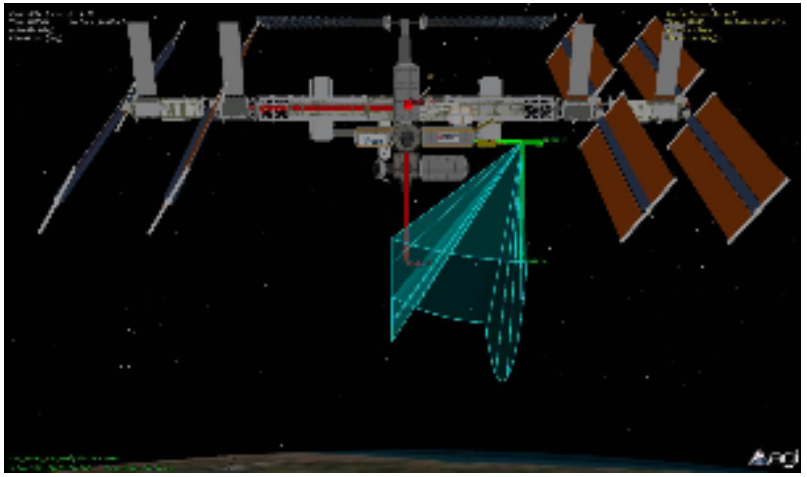
- Optical link performance characterization & validation
- Atmospheric turbulence characterization
  - Obtain downlink aperture-averaged fading statistics by recording received power
  - Obtain uplink scintillation statistics by recording beacon power on flight system
- Link availability studies
  - 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

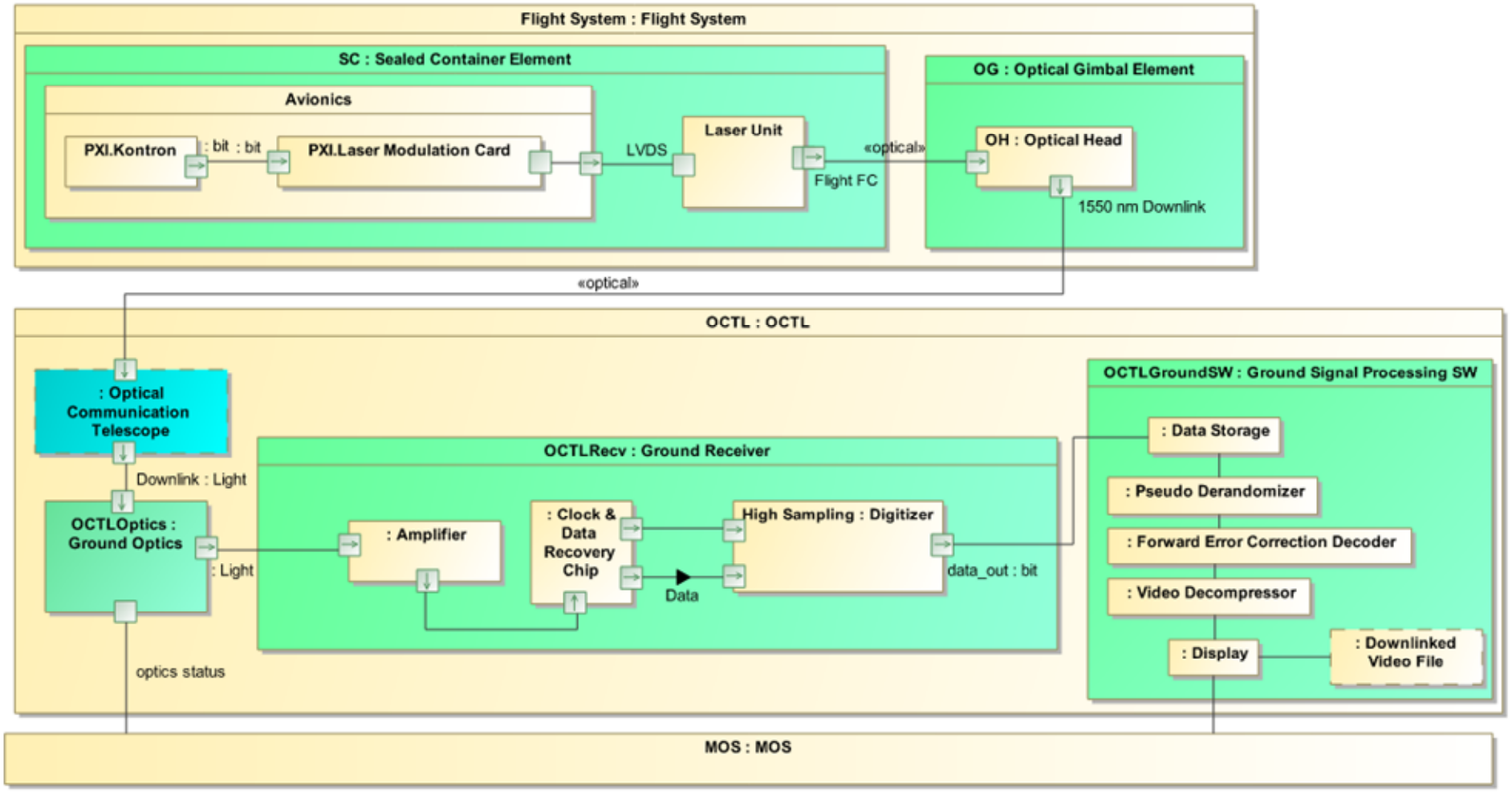
Laser Safety Limitations On Pass Geometry



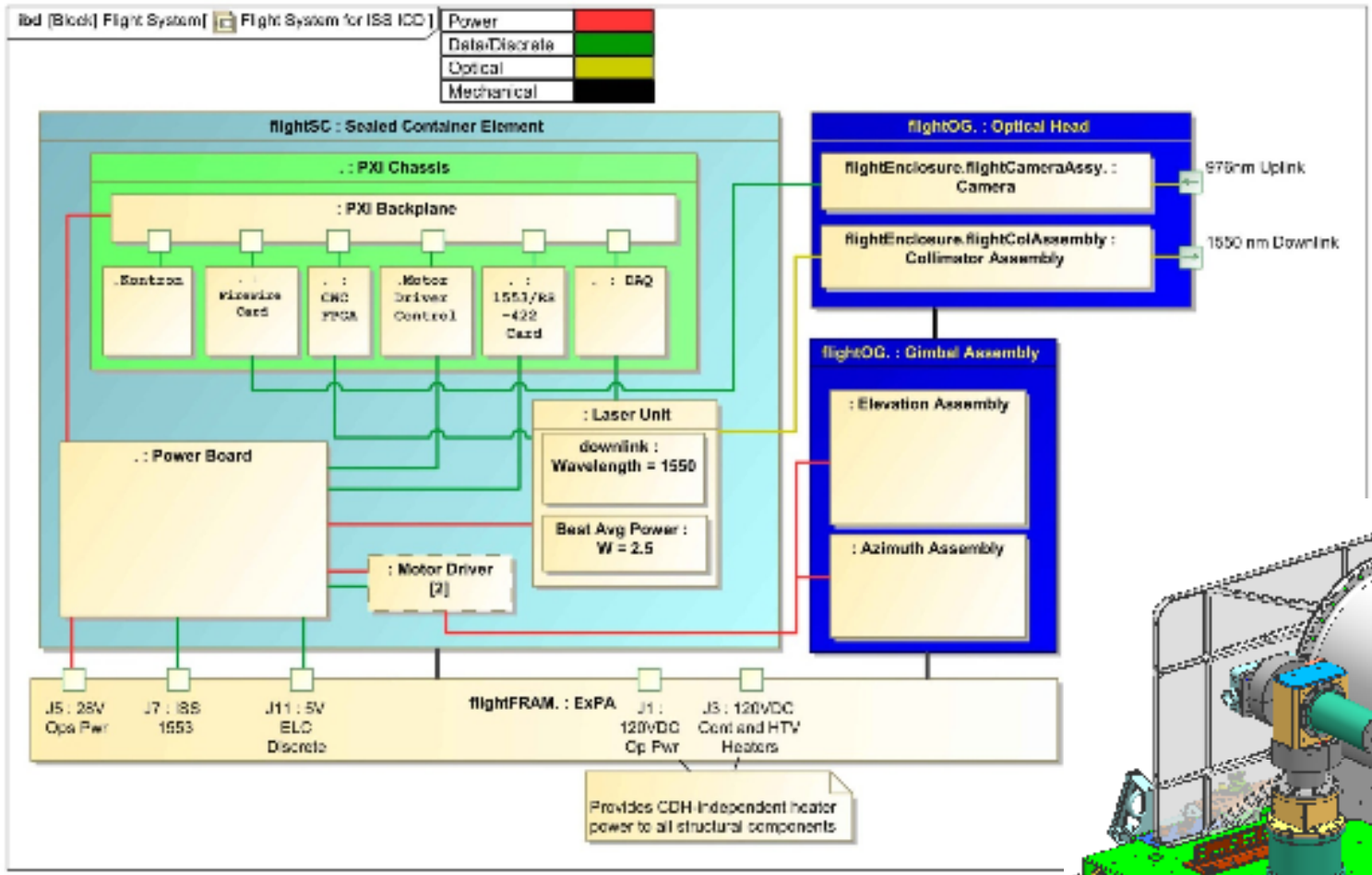


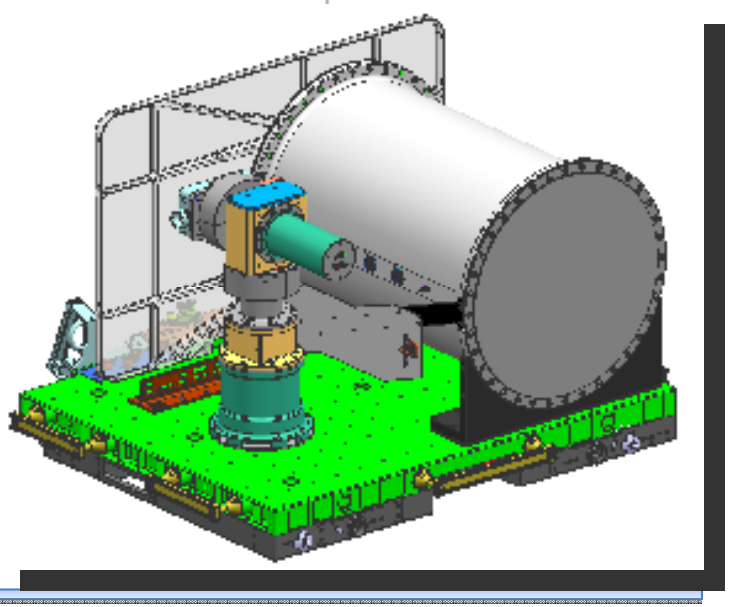
- Range of Motion (wrt to nadir) limited to :
  - 75˚ to -35˚ in AZ (~ along track)
  - 40˚ to -1˚ in EL (~ cross track)
- Favorable Passes ~ 1 every 2-3 days

Downlink Interfaces

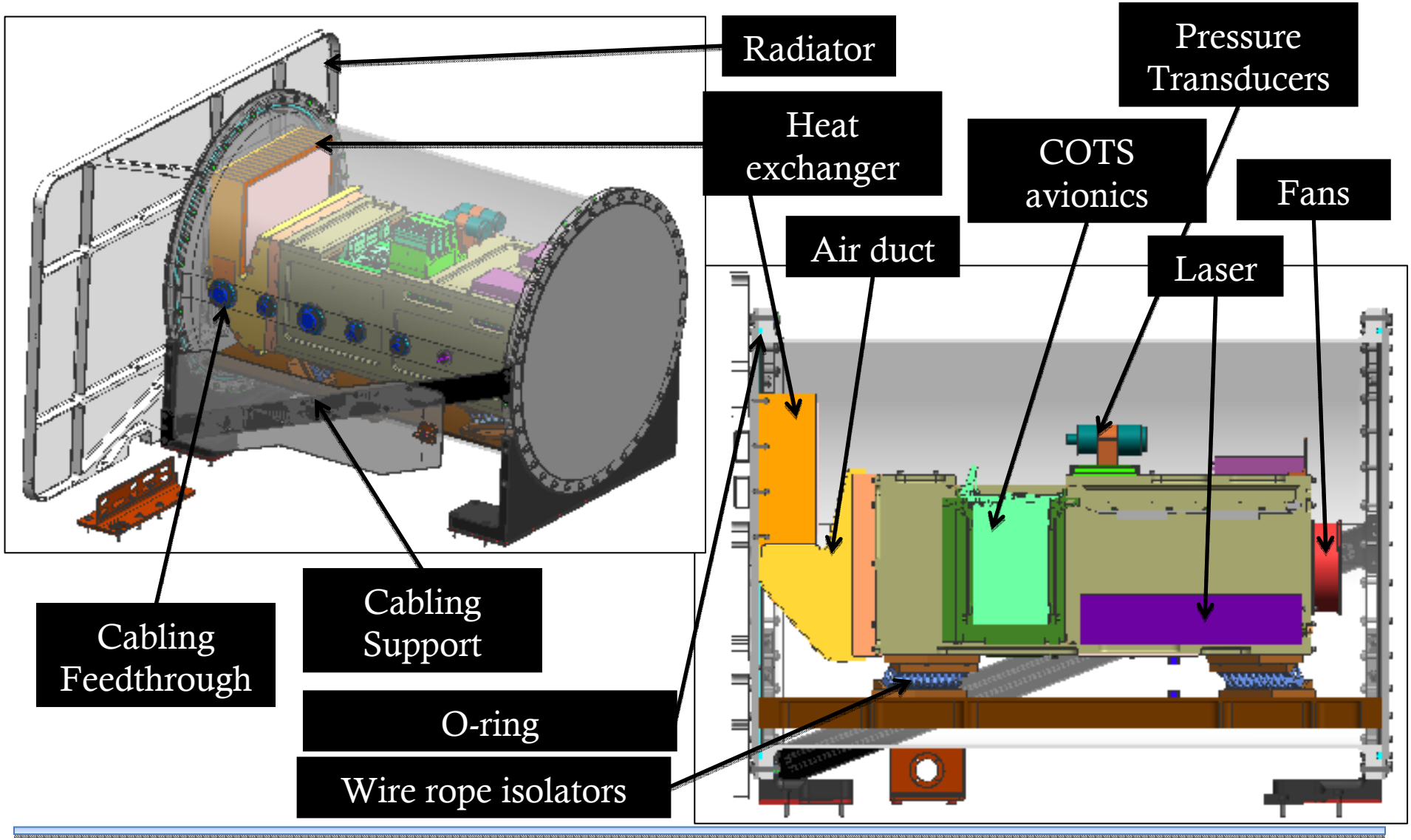


Flight System Interface Diagram

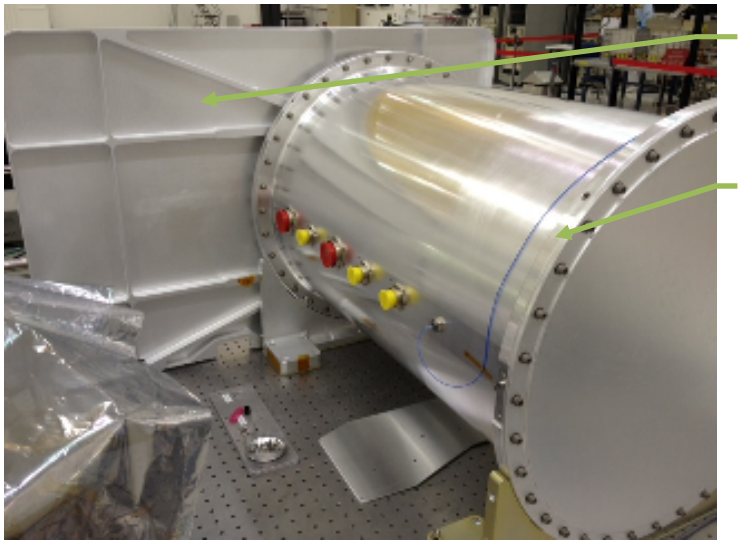


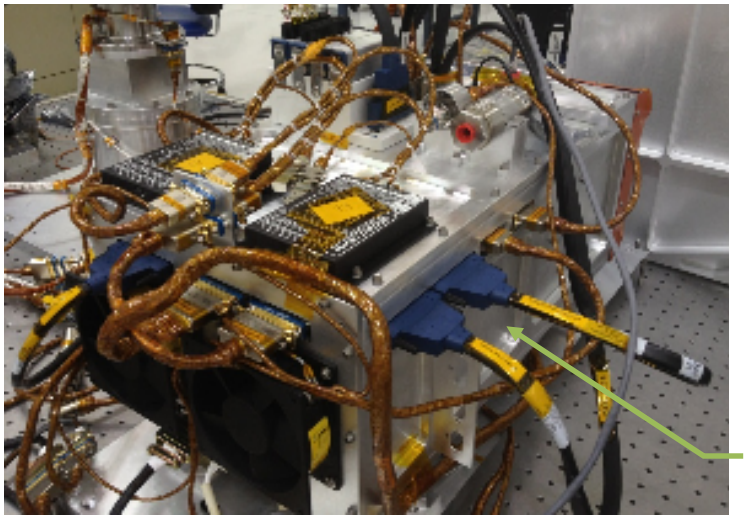


Sealed Container Design



From Paper to Metal





Radiator

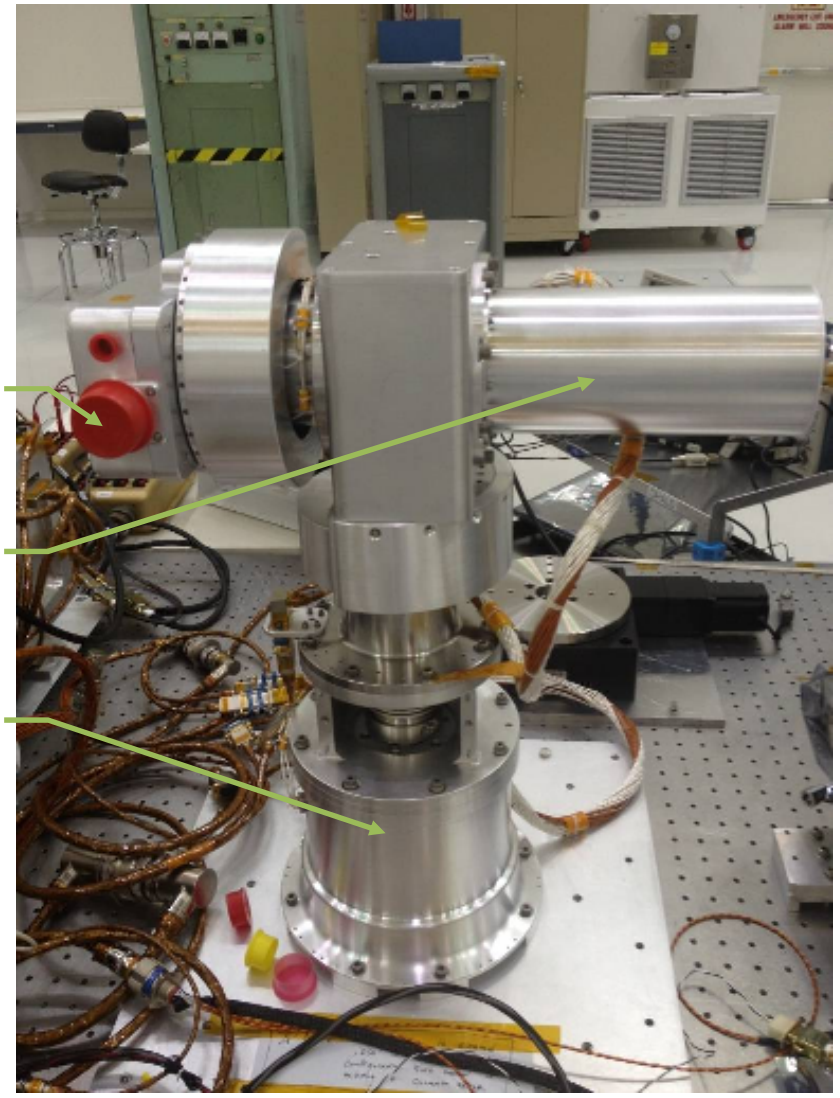
Sealed Container

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
  - GFE & GSE [14 total pieces]
  - Flight ExPA
  - Electrical + C&DH Simulators
  - Mechanical manipulation tools

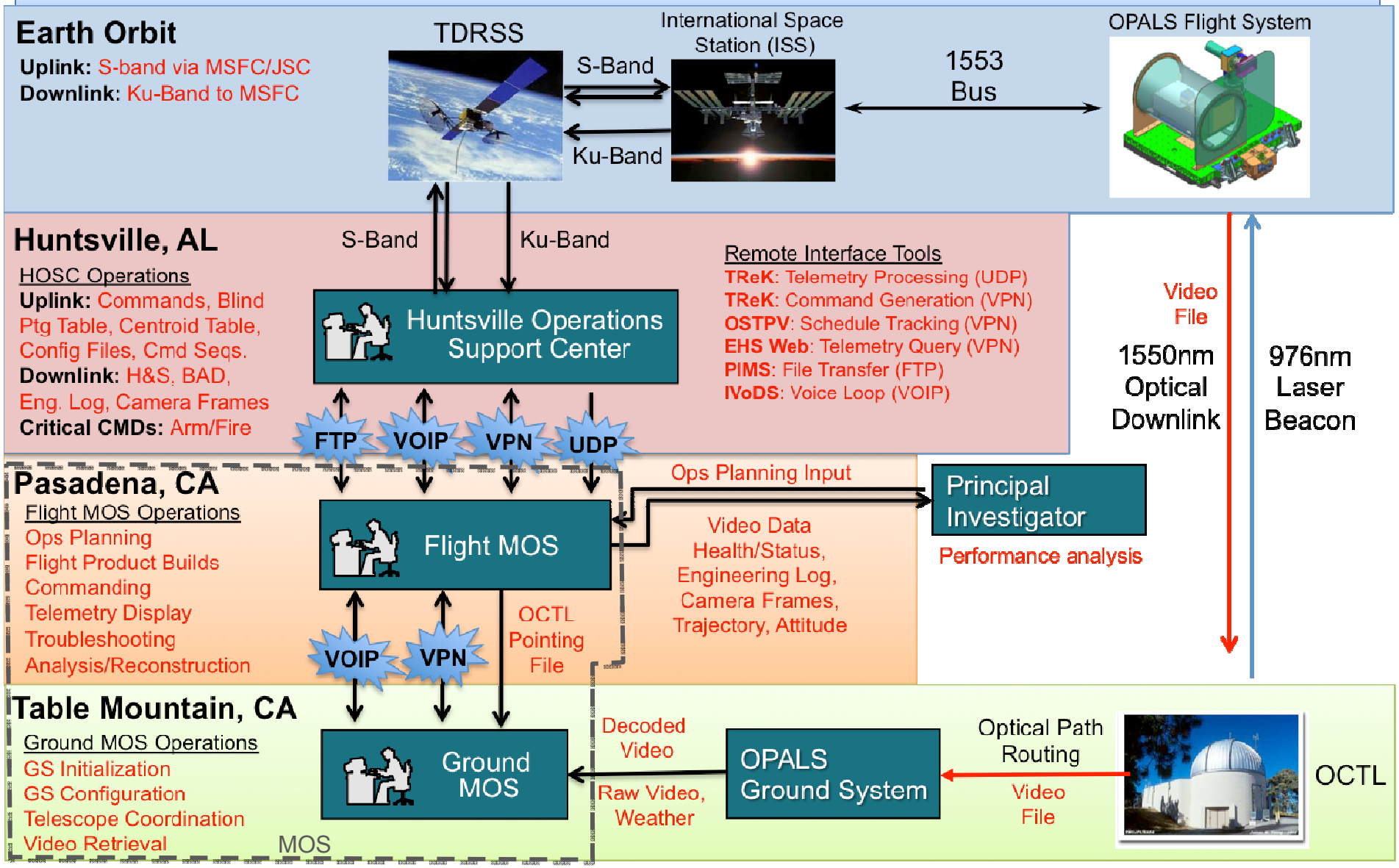
Technical

- Resources
  - Mass: using 340 of the 490 lbs allocated (excludes ExPA)
  - Power: using ~200W (peak) of the 500W allocated
  - Volume: 33.2” x 45.86” x 26.87” allocated
- 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%)
- 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

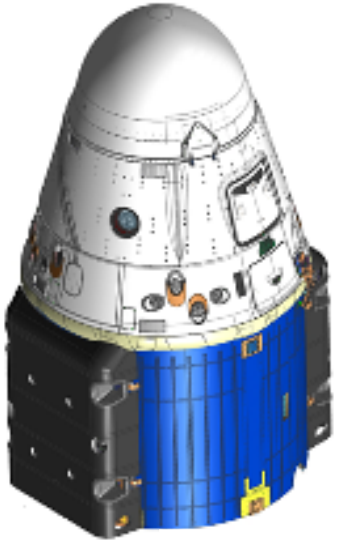



BACKUP

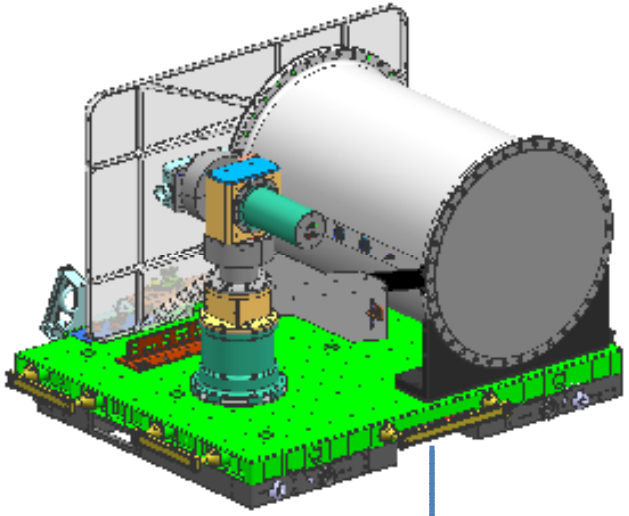
MOS/GDS Interfaces



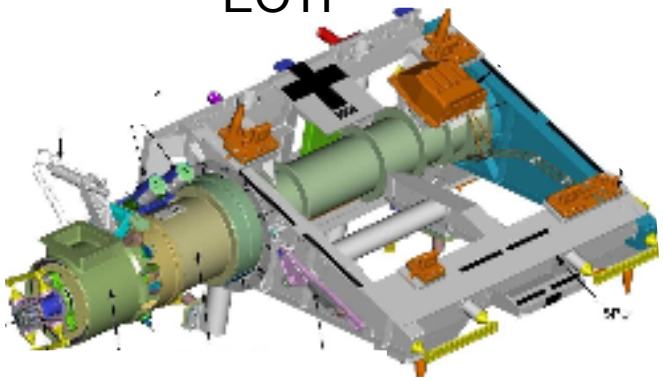
FRAM Interface



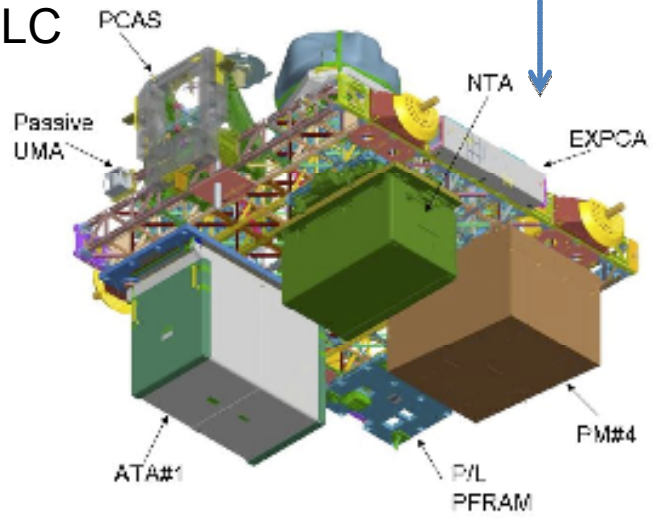
LV
Dragon



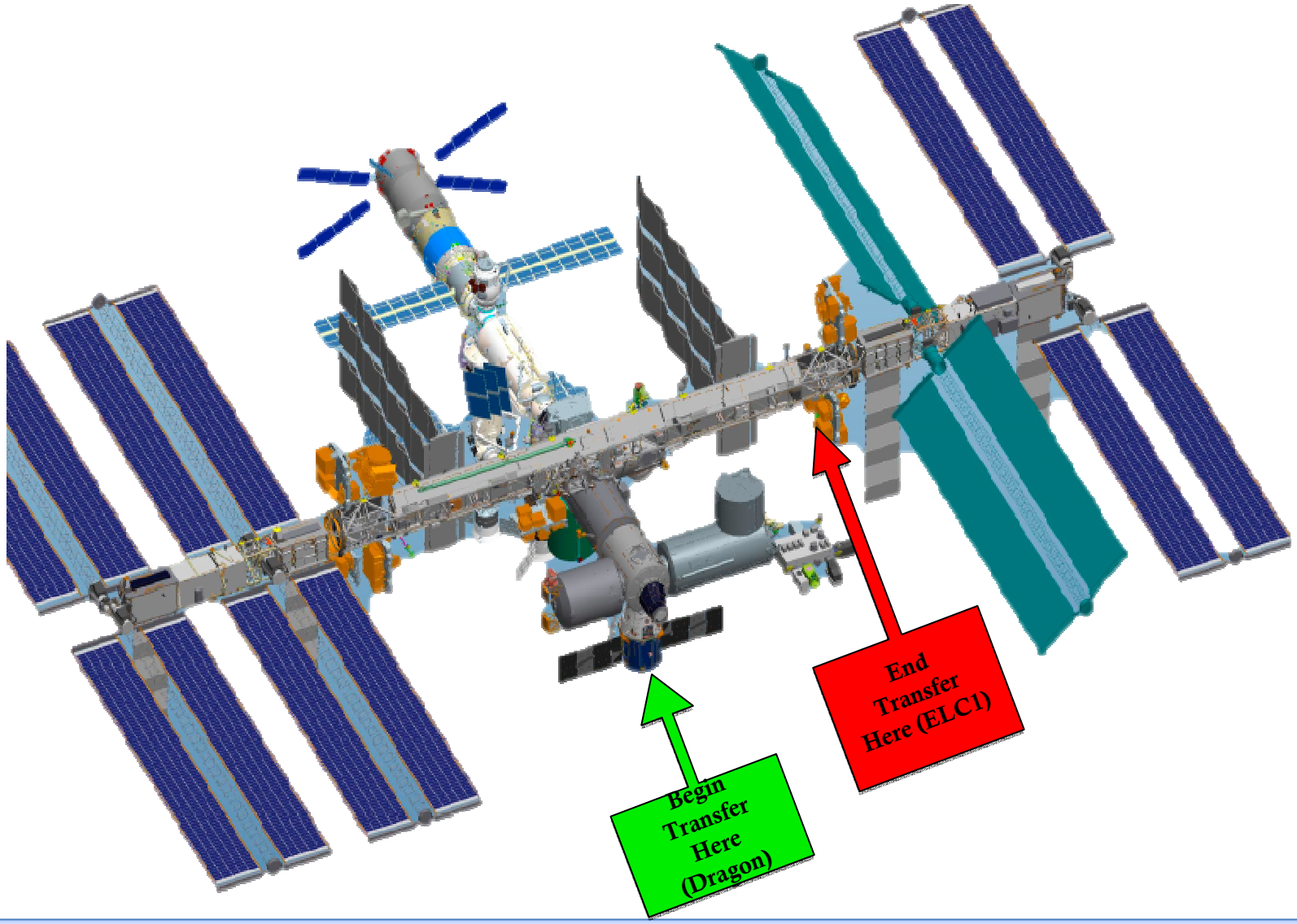
Robotics
EOTP



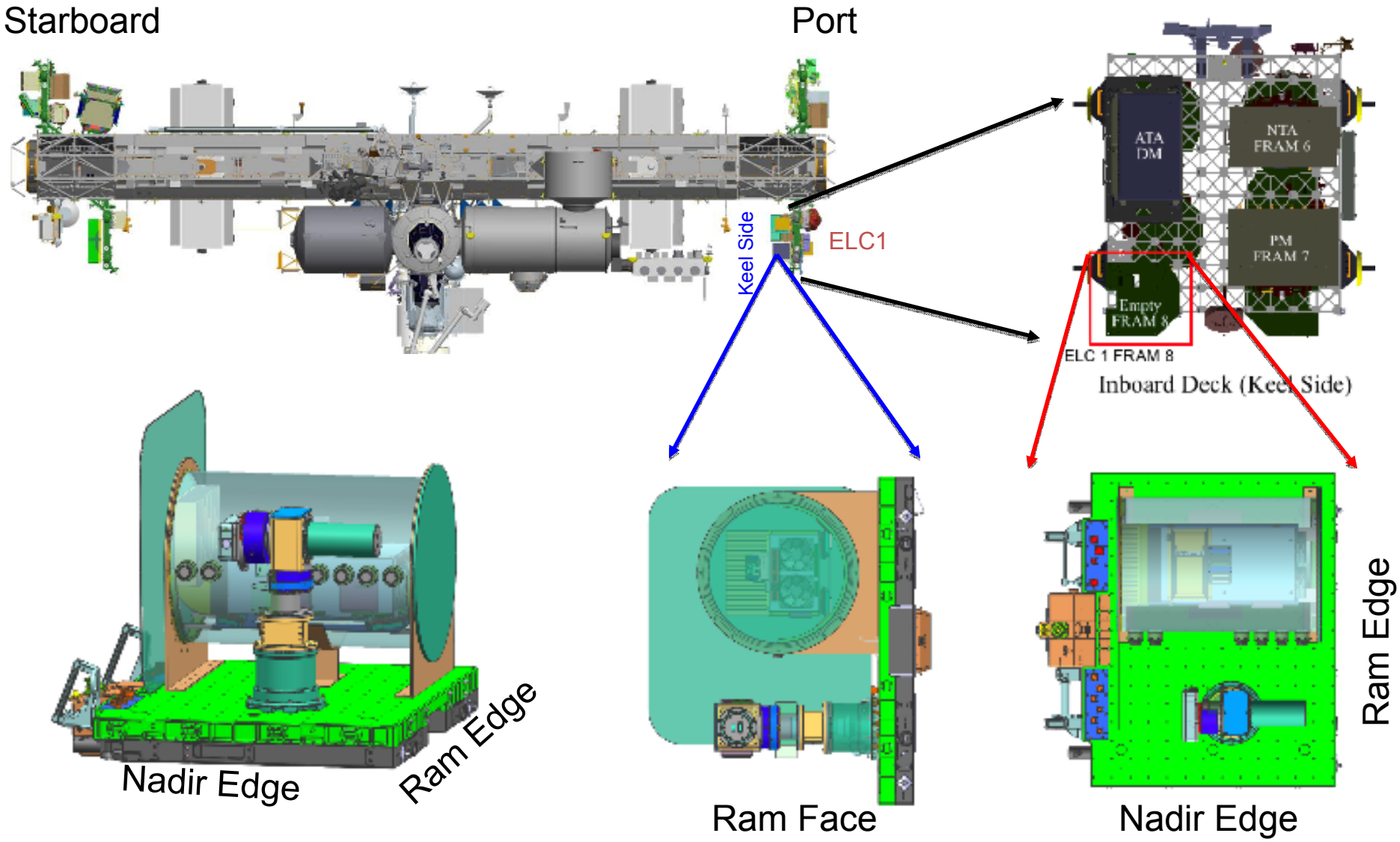
ISS
ELC



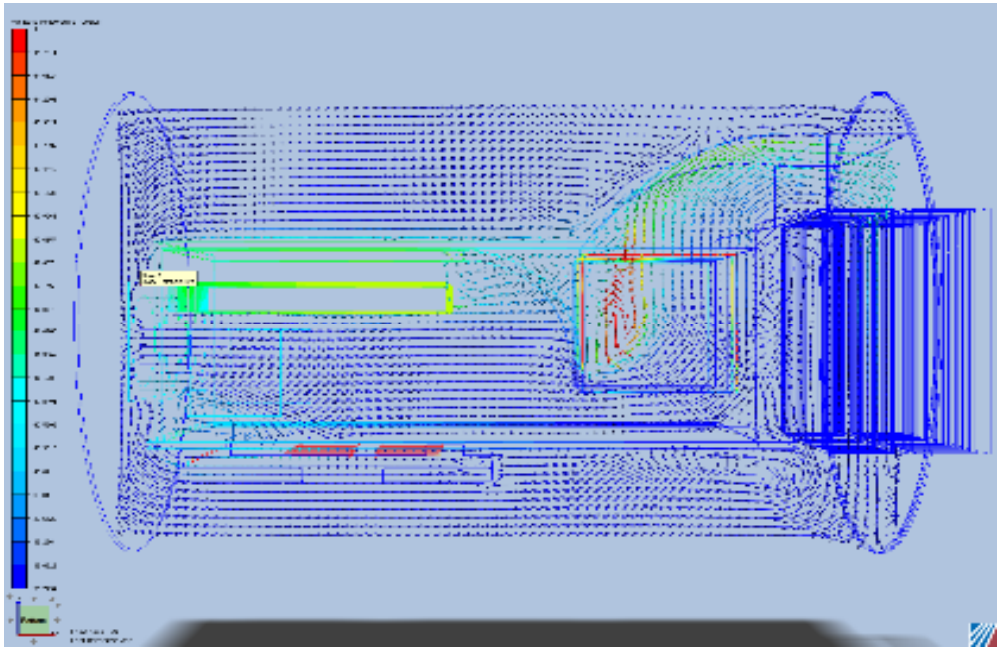
OPALS Transfer Range



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