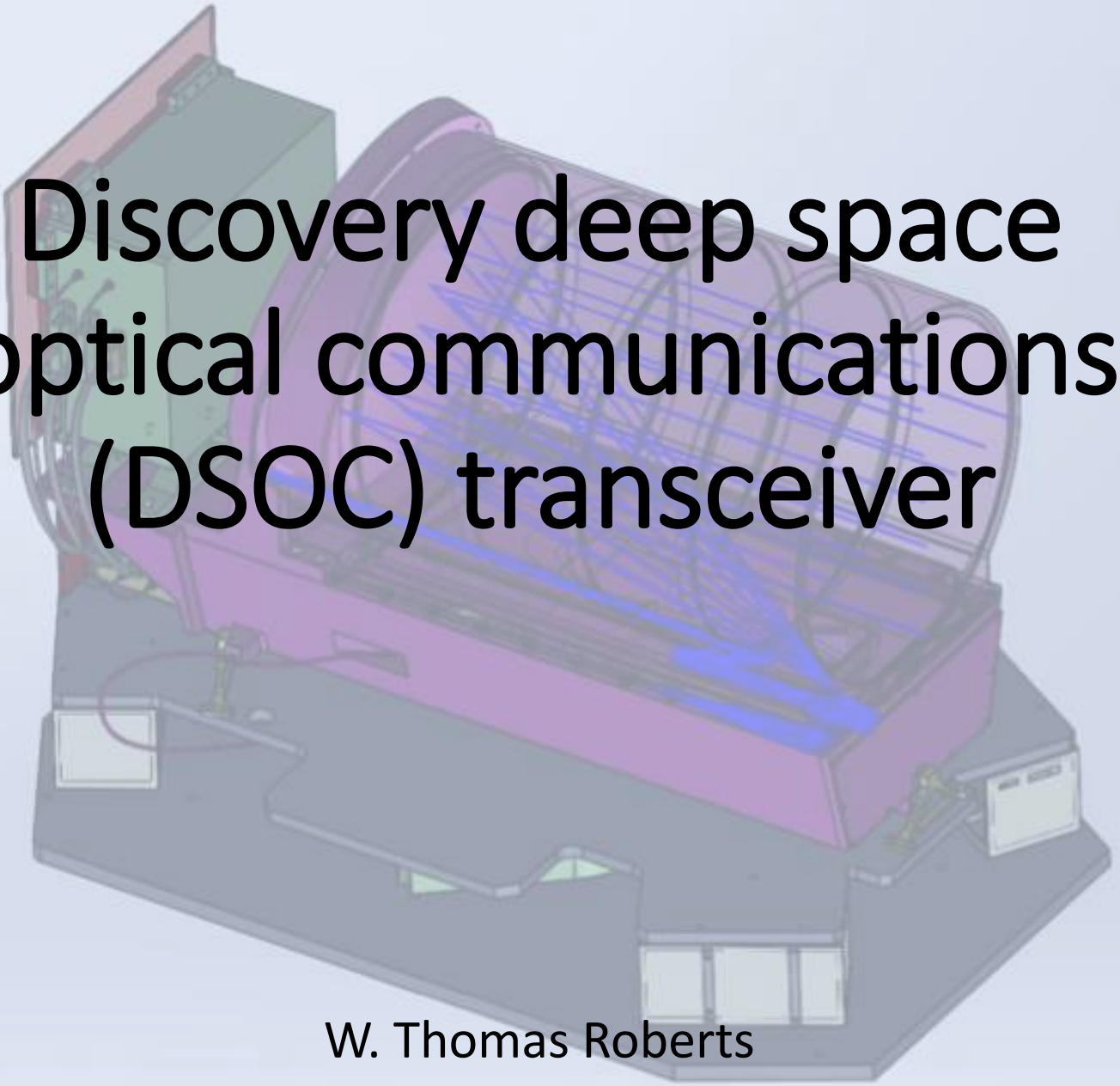
Discovery deep space optical communications (DSOC) transceiver



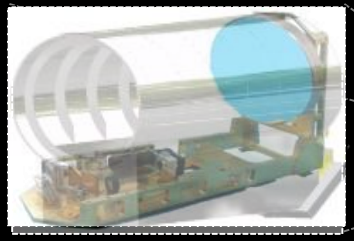
W. Thomas Roberts

Jet Propulsion Laboratory, The California Institute of Technology

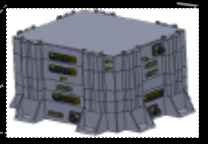
Deep Space Optical Communications (DSOC)

Jet Propulsion Laboratory
California Institute of Technology

Deep-Space Optical Communications
(DSOC)



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



FLT
Electronics Box

1550 nm
Downlink

1064 nm
Beacon & Uplink

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

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

Deep Space
Network
(DSN)

Optical Comm
Ops Ctr.

Mission
Ops
Center

The DSOC Flight Laser Transceiver

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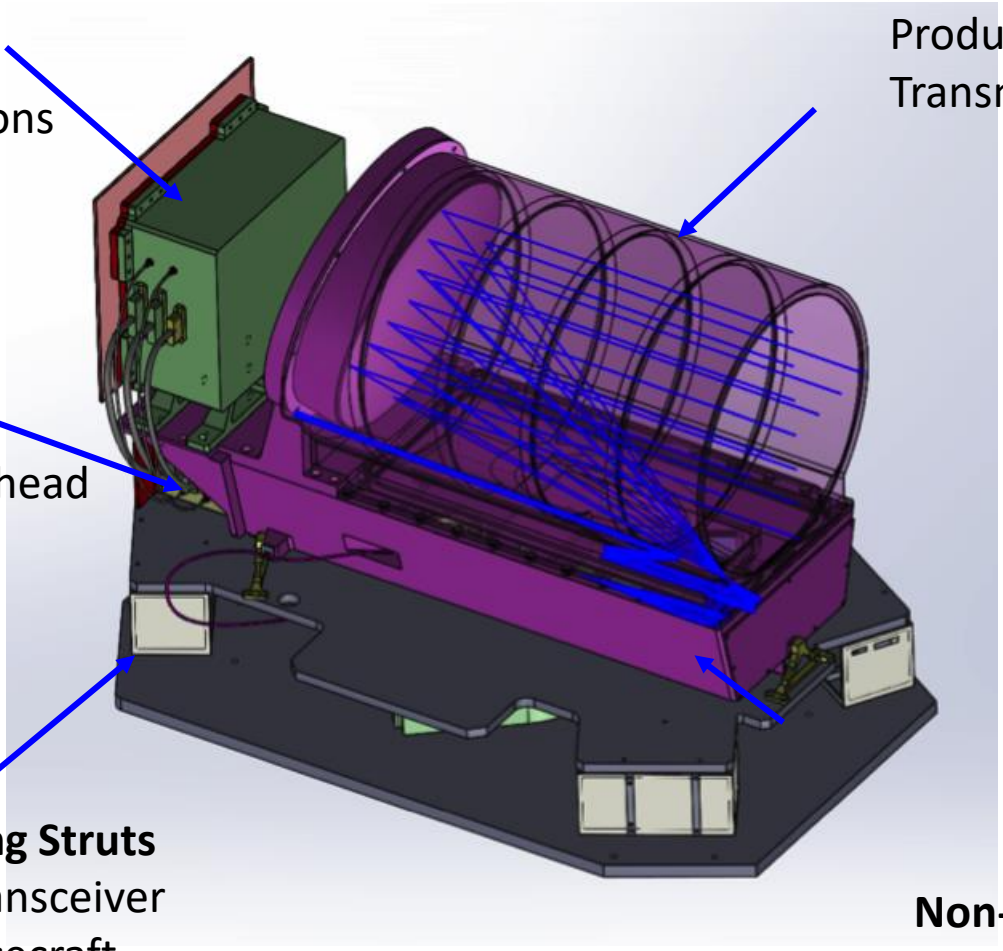
Floating Electronics
- Signal conditioning
- On-board calculations

Optical Transceiver Assembly
- Produces image of beacon
- Transmits downlink beam



Imaging Camera
- Imaging beacon
- Measuring point ahead

Isolation and Pointing Struts
- Fine pointing of transceiver
- Isolation from spacecraft

Non-floating Systems (not shown)
- Laser Transceiver
- Stationary Electronics

Deep Space Optics Concerns

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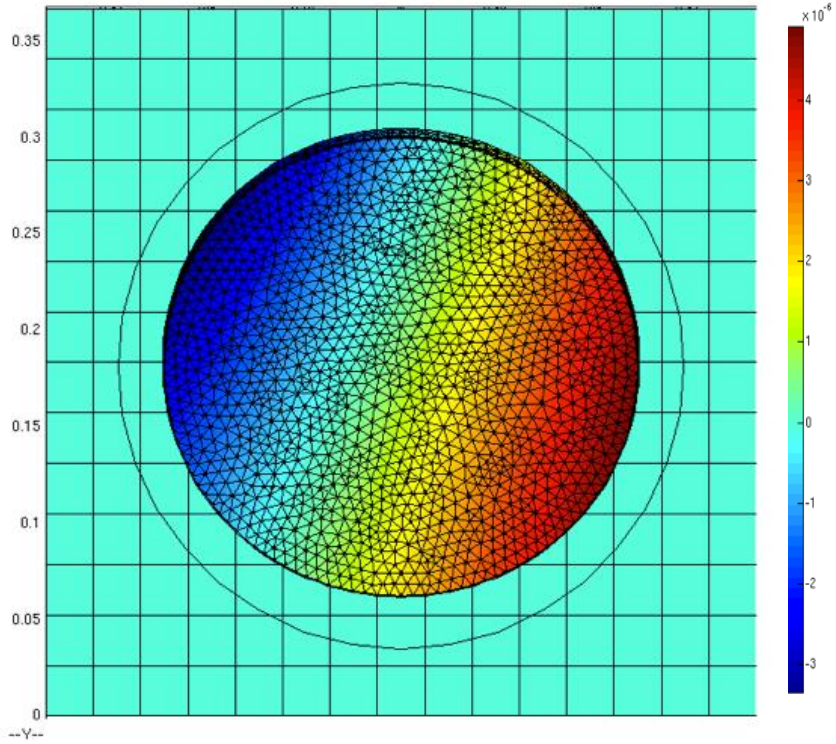
- Differential heating of optics and optical bench
  - Causes warping of mirrors
  - Causes misalignment of optics
- Stray light masking of beacon
  - From deep space, expecting to collect ~10^6 to 10^8 ph/sec from the beacon
  - Need to keep background per pixel well below that
  - Need to maintain track of beac while pointing to about 3 degrees of the Sun



DSOC Transceiver Optical Sub-Systems

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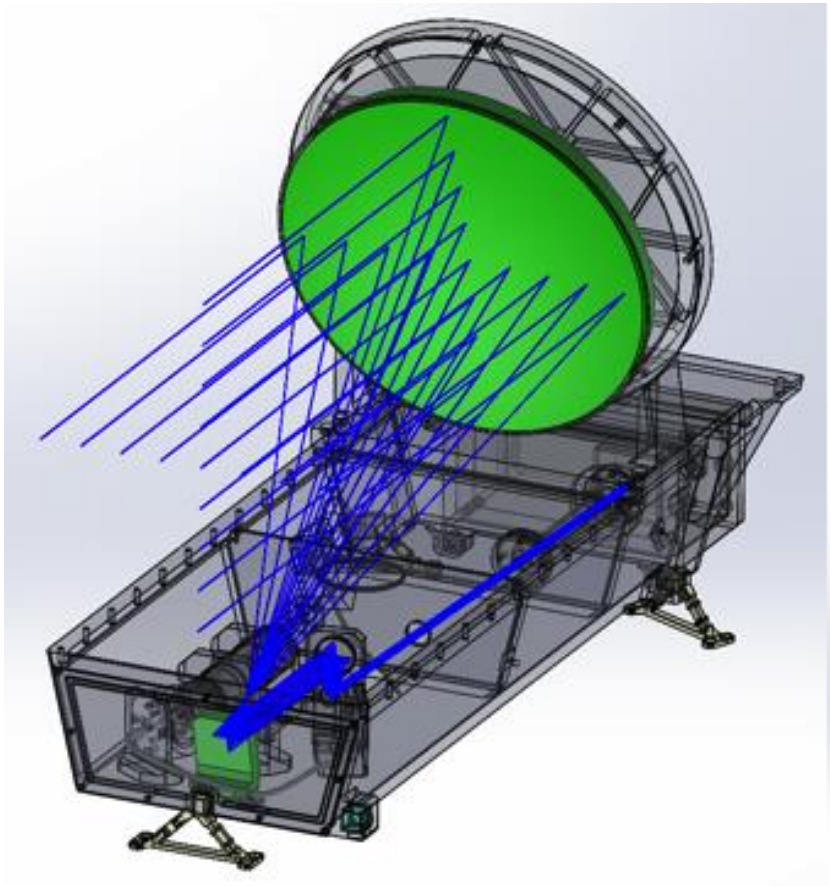
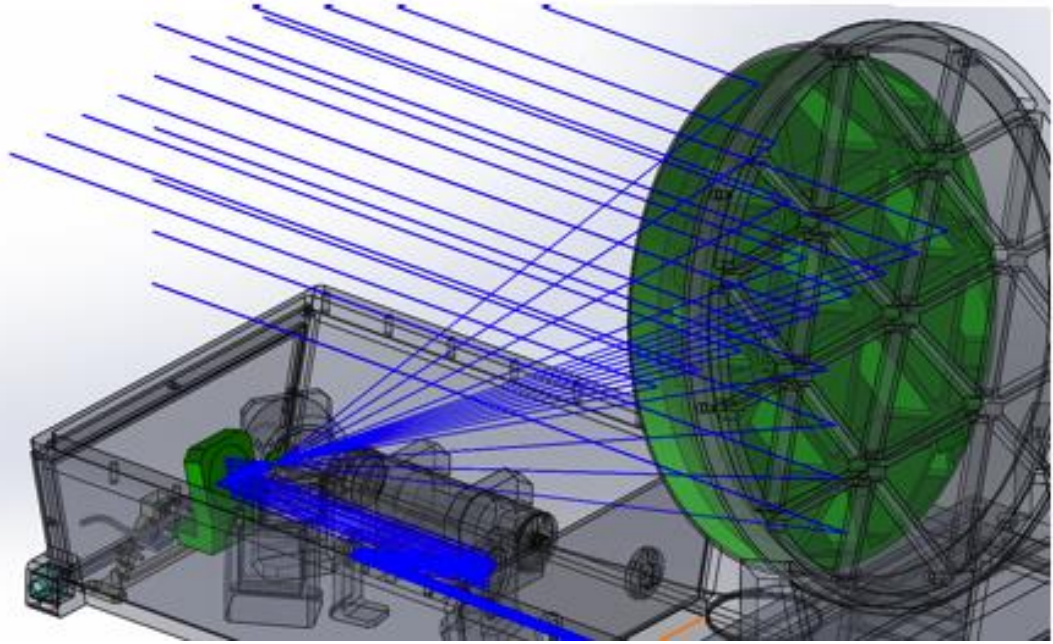
- Off-axis Gregorian Collecting Telescope
  - Collects light from earth beacon
  - Expands beam for narrow-field transmission





DSOC Transceiver Optical Sub-Systems

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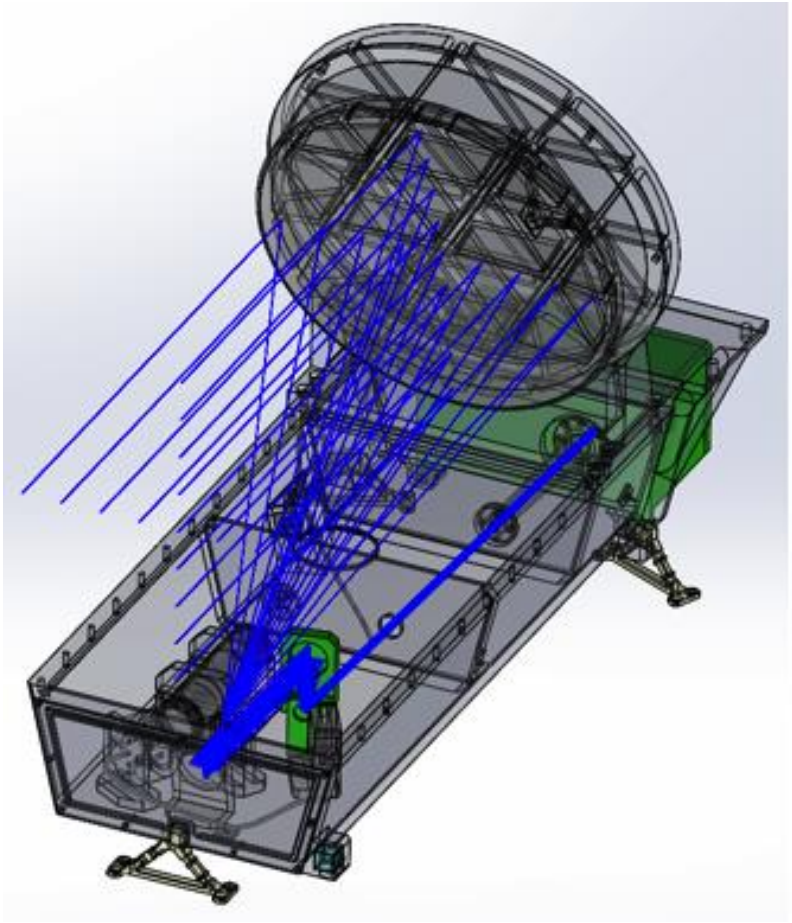
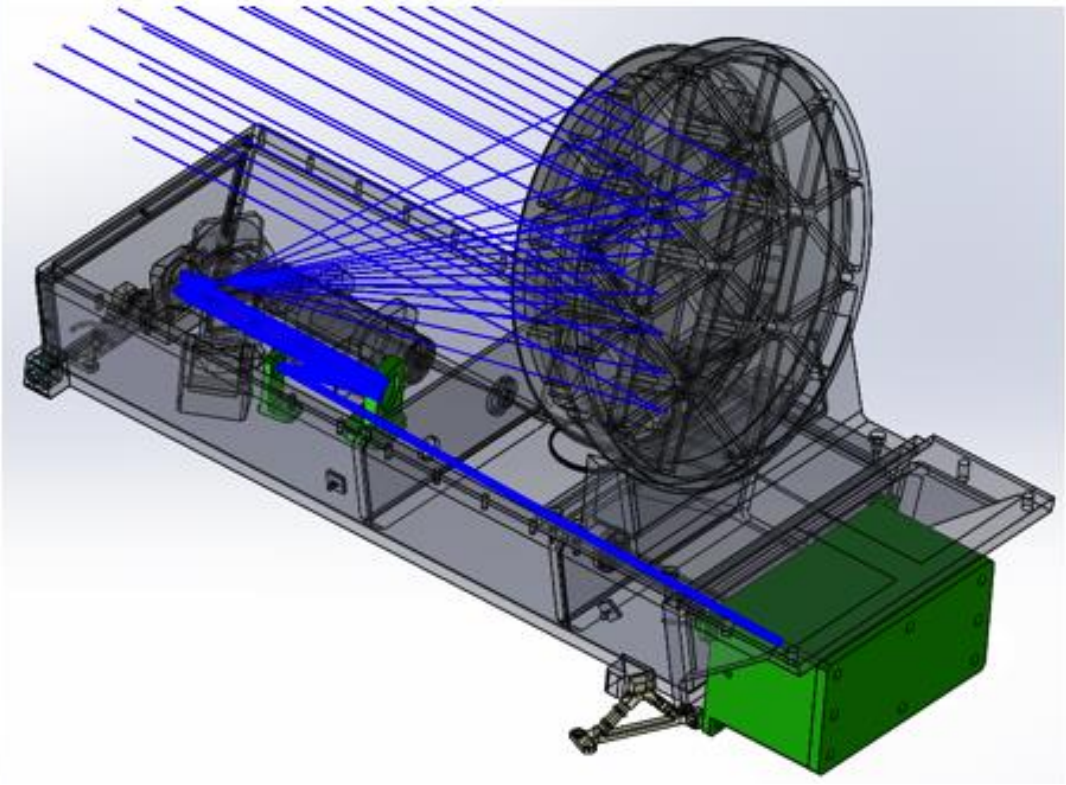
- Off-axis Cassegrain telescope
  - Generating focus of beacon on array





DSOC Transceiver Optical Sub-Systems

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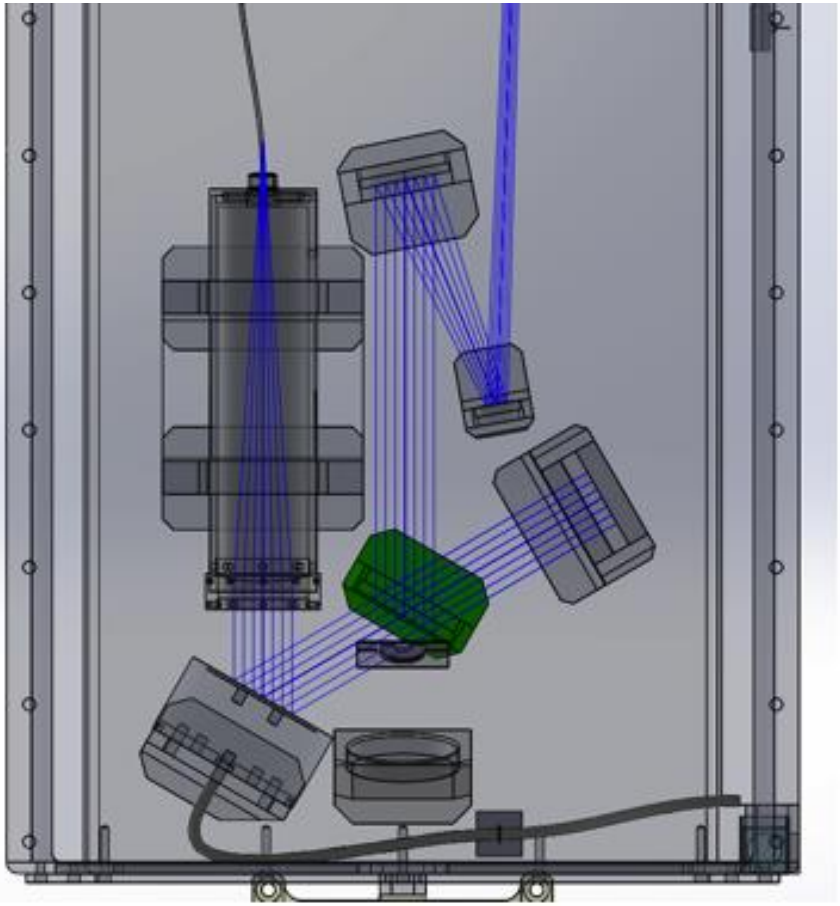
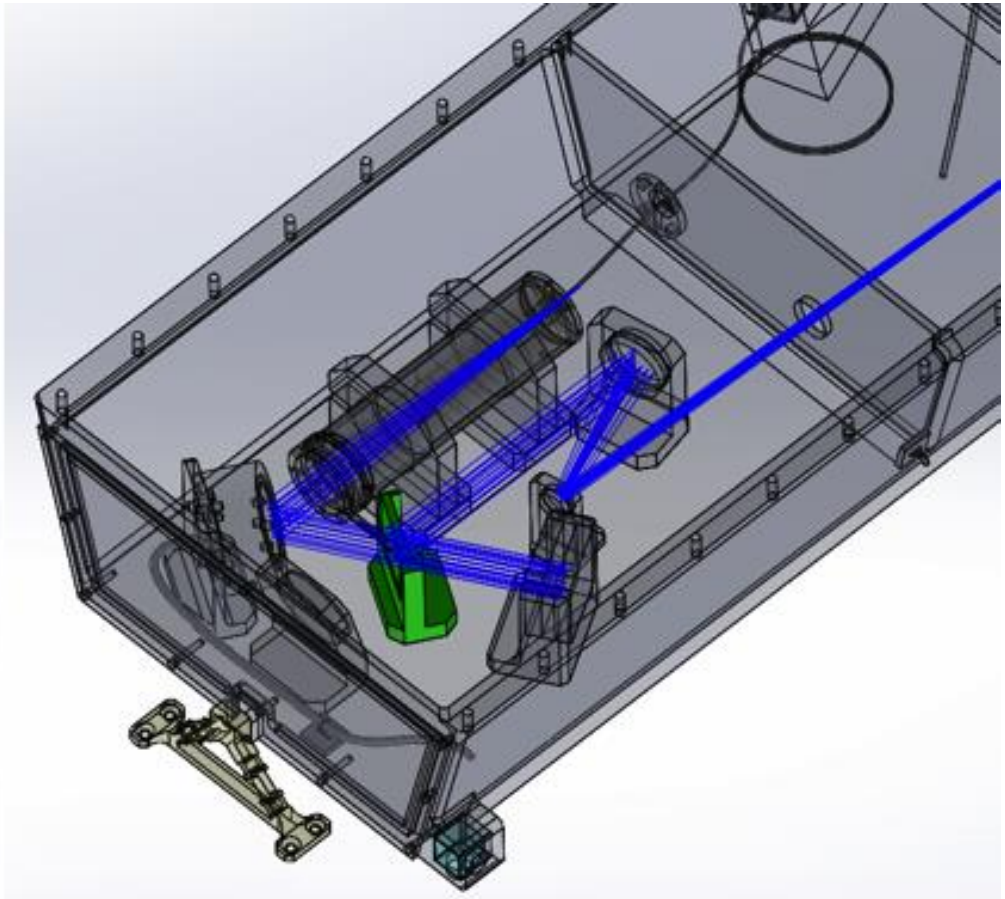
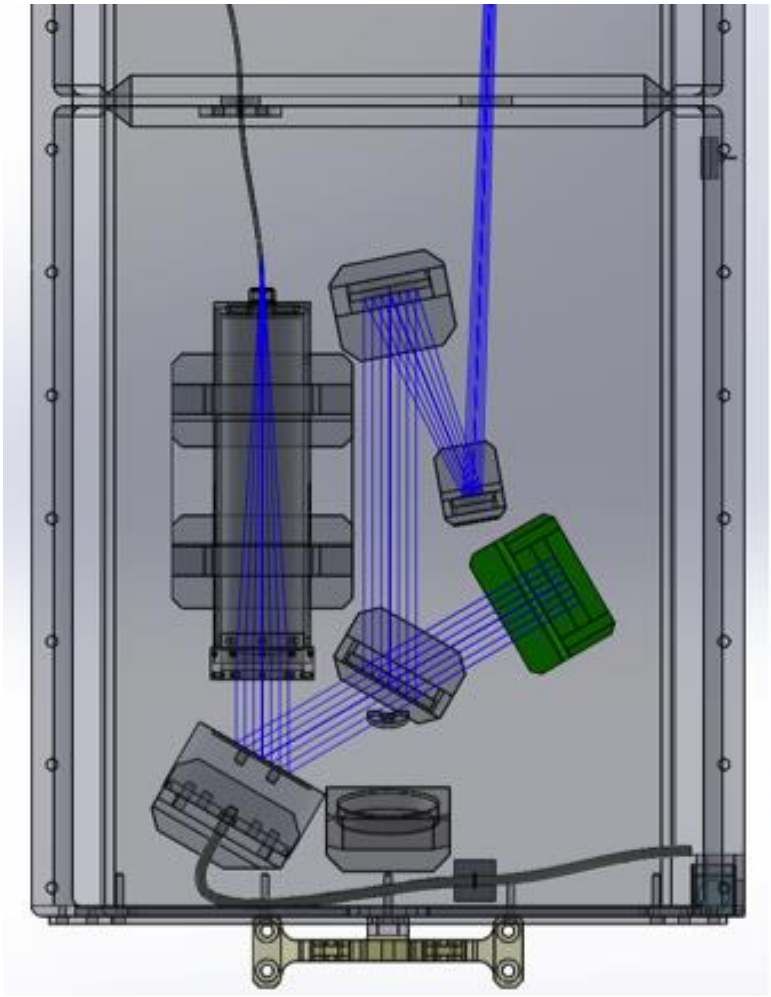
- Dichroic Beam Splitter Assembly
  - Separates/combines different channels

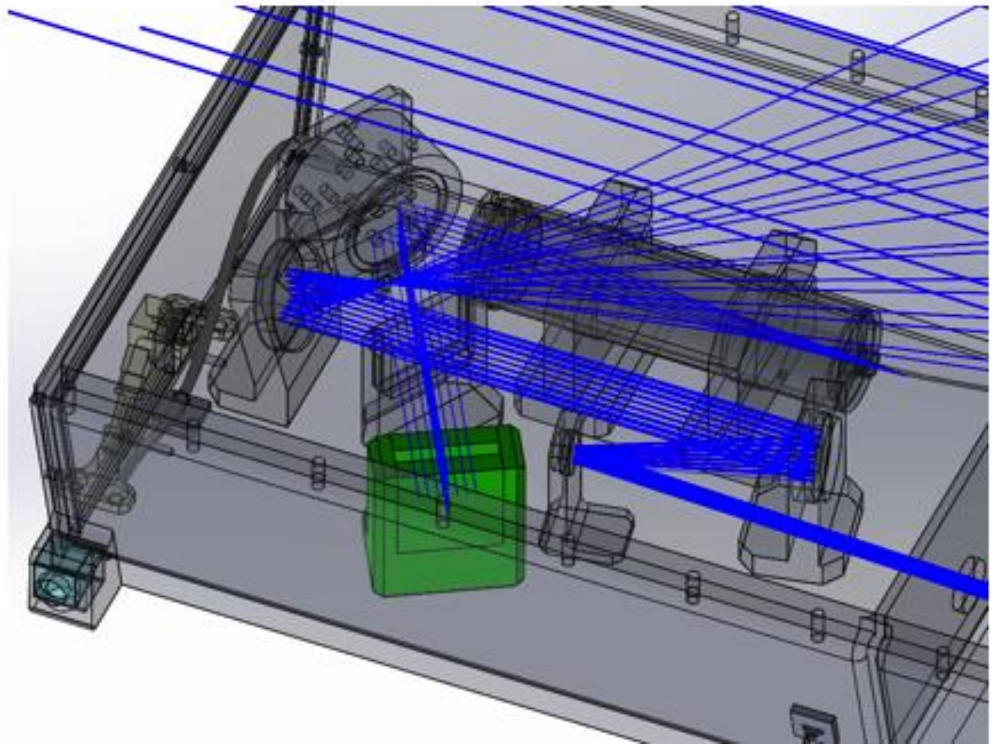




DSOC Transceiver Optical Sub-Systems

- Retro-mirror assembly
  - Reflects residual transmit beam back to detector array
  - Filters for attenuating signal





DSOC Transceiver Optical Sub-Systems

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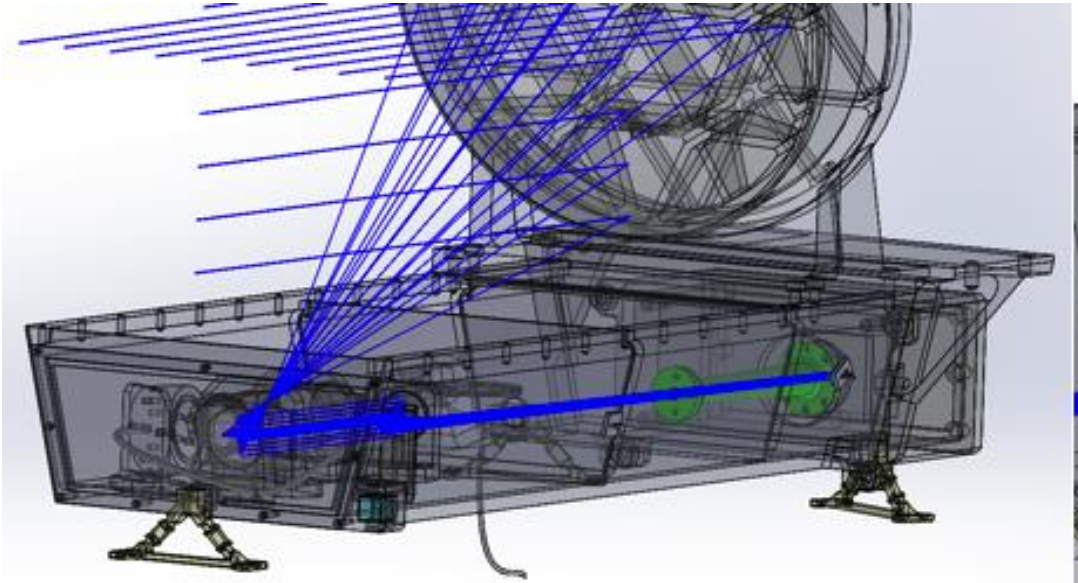
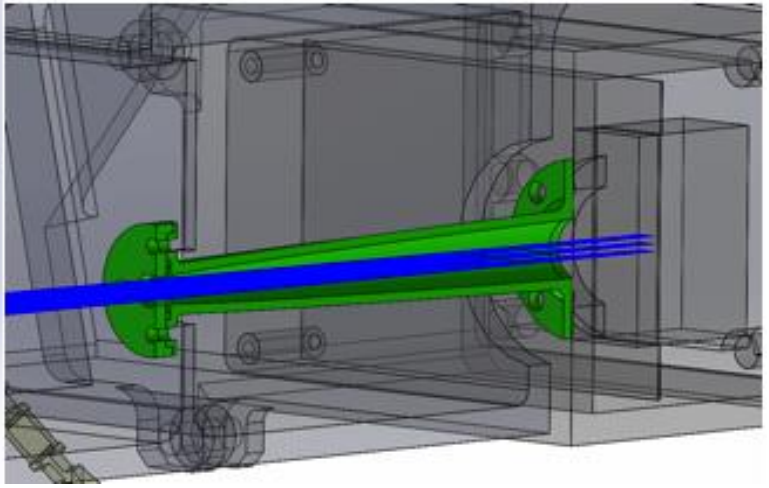
- Camera baffle assembly
  - Reduces residual scattered light
  - Holds narrow-band filter
  - Attaches to camera housing





DSOC Transceiver Optical Sub-Systems

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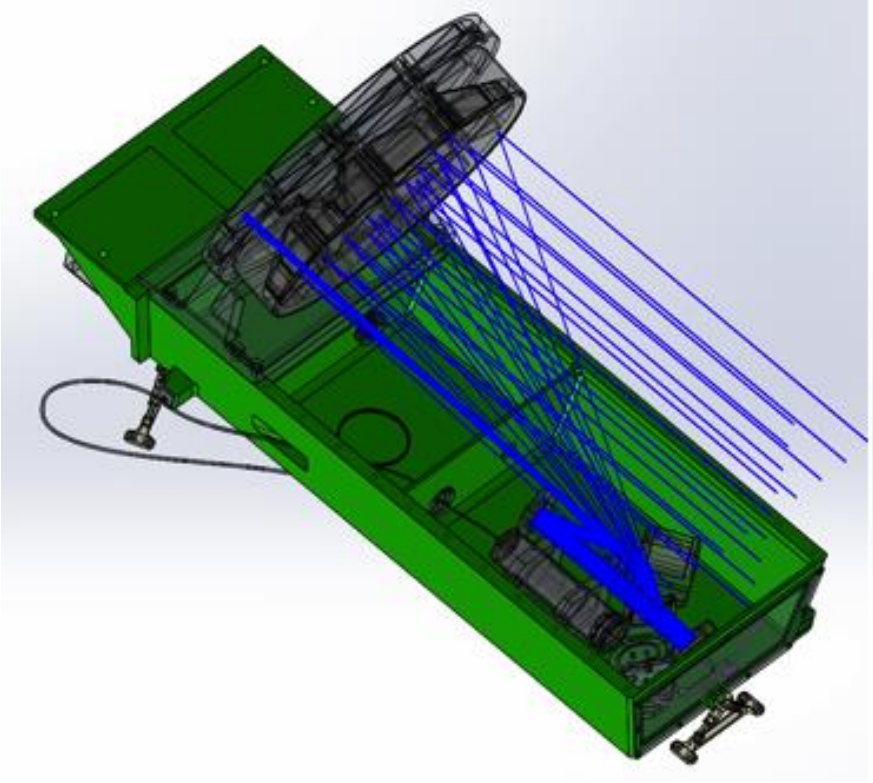
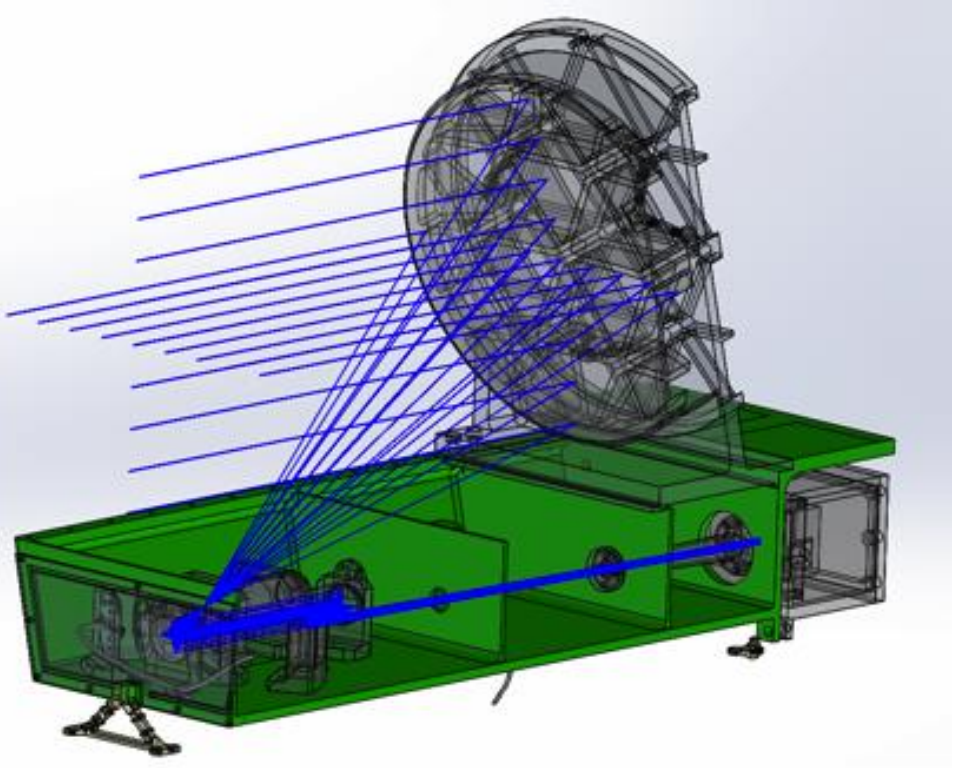
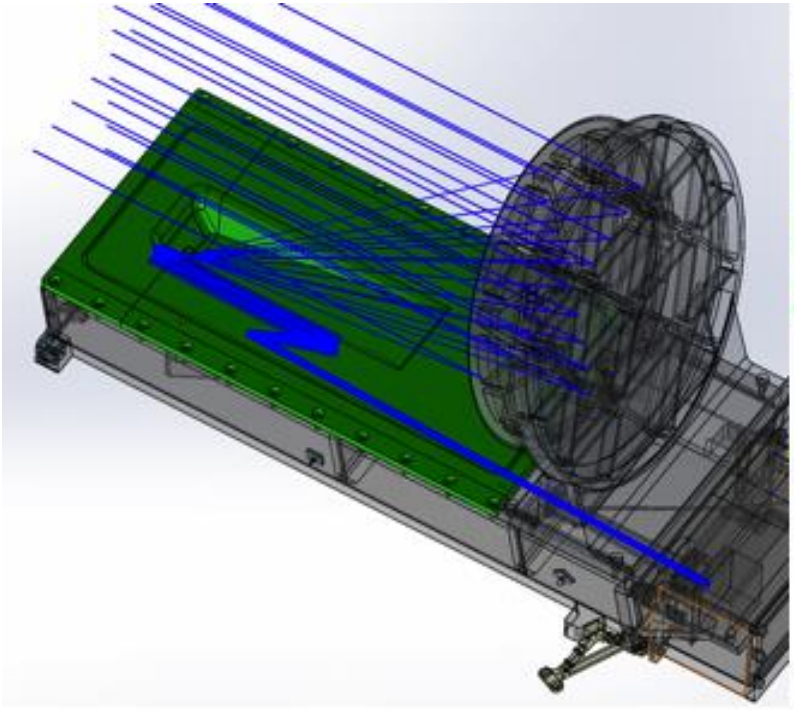
- Optical Bench
  - Maintains elements in alignment
  - Encloses aft optics to reduce stray light
  - Provides attachment points for camera and pointing

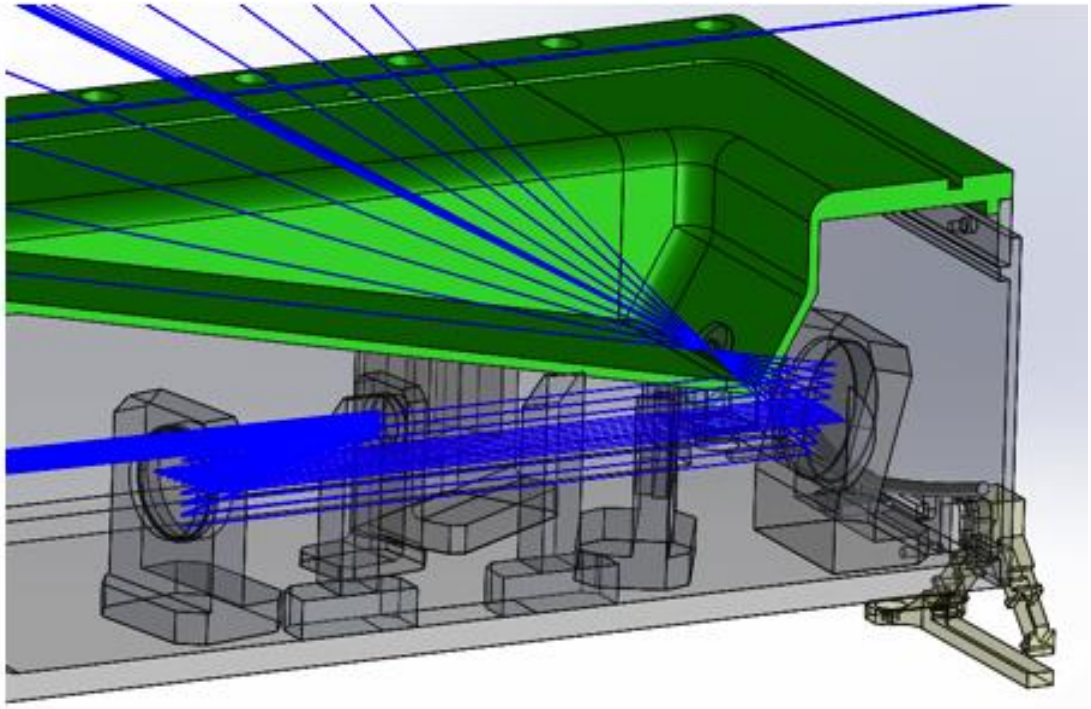




DSOC Transceiver Optical Sub-Systems

- Top cover plate
  - Protects aft optics and reduces stray light
  - Interfaces with Gregorian field stop





DSOC Transceiver Optical Sub-Systems

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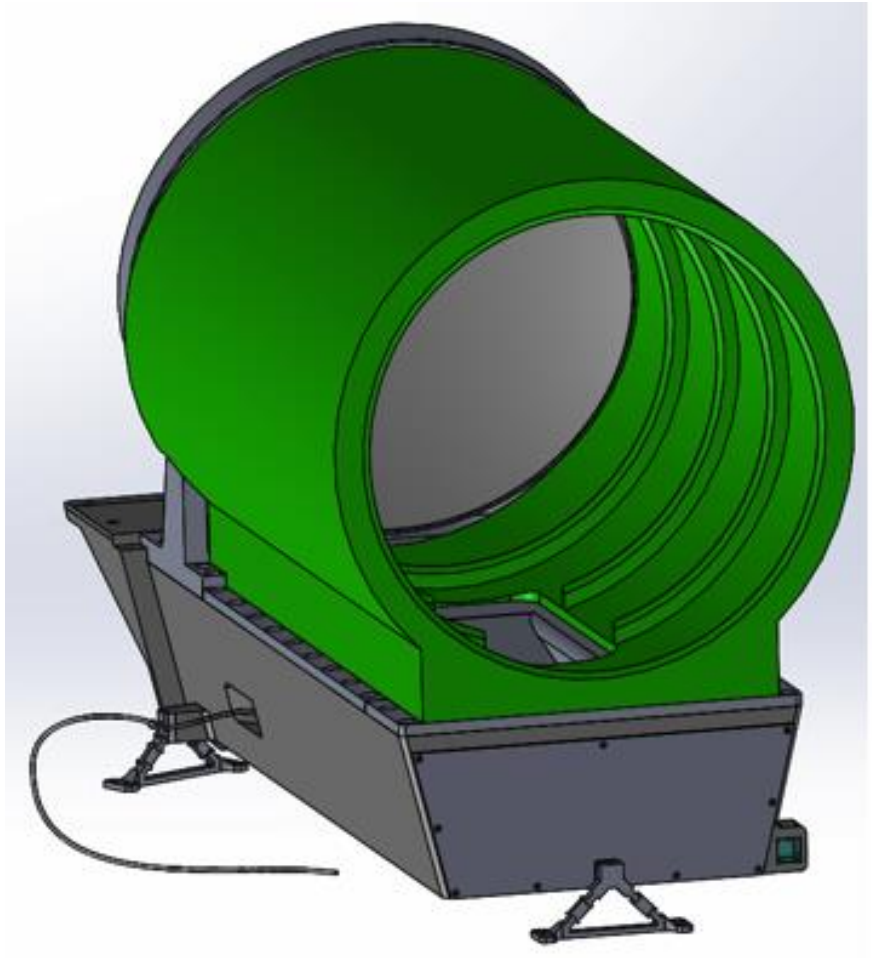
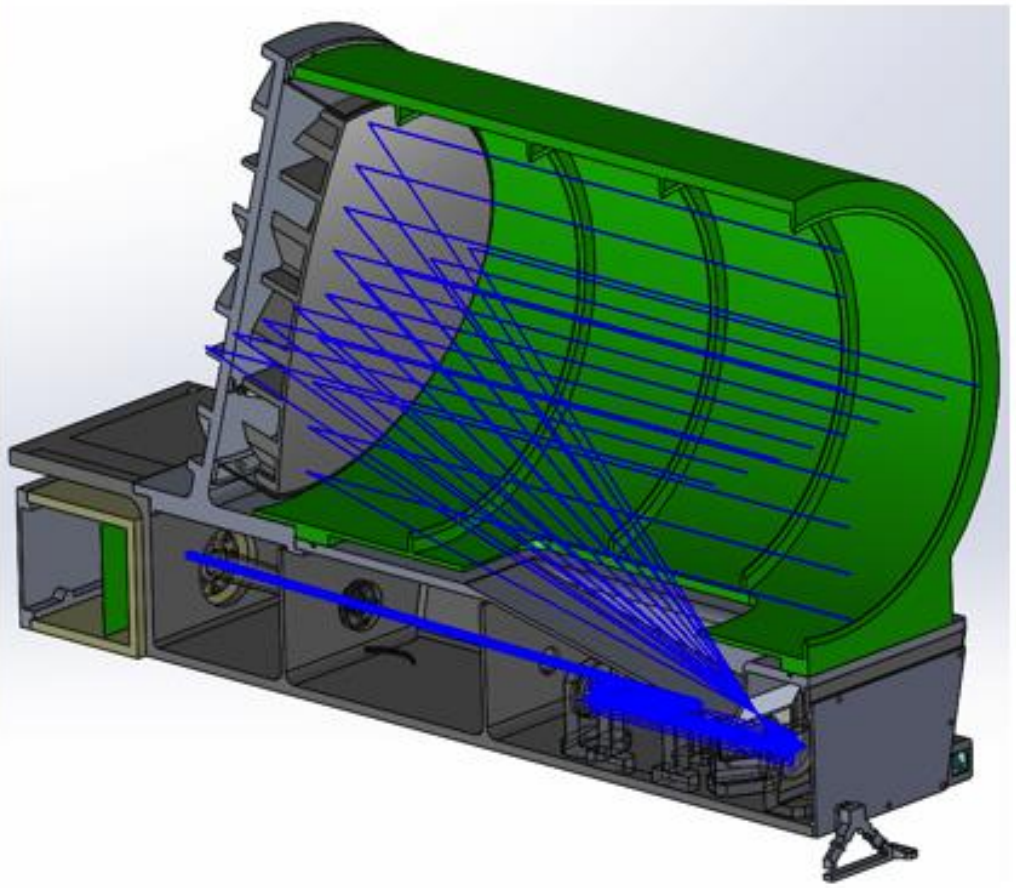
- Stray Light Shield
  - Protects primary mirror
  - Reduces stray light





DSOC Transceiver Optical Channels

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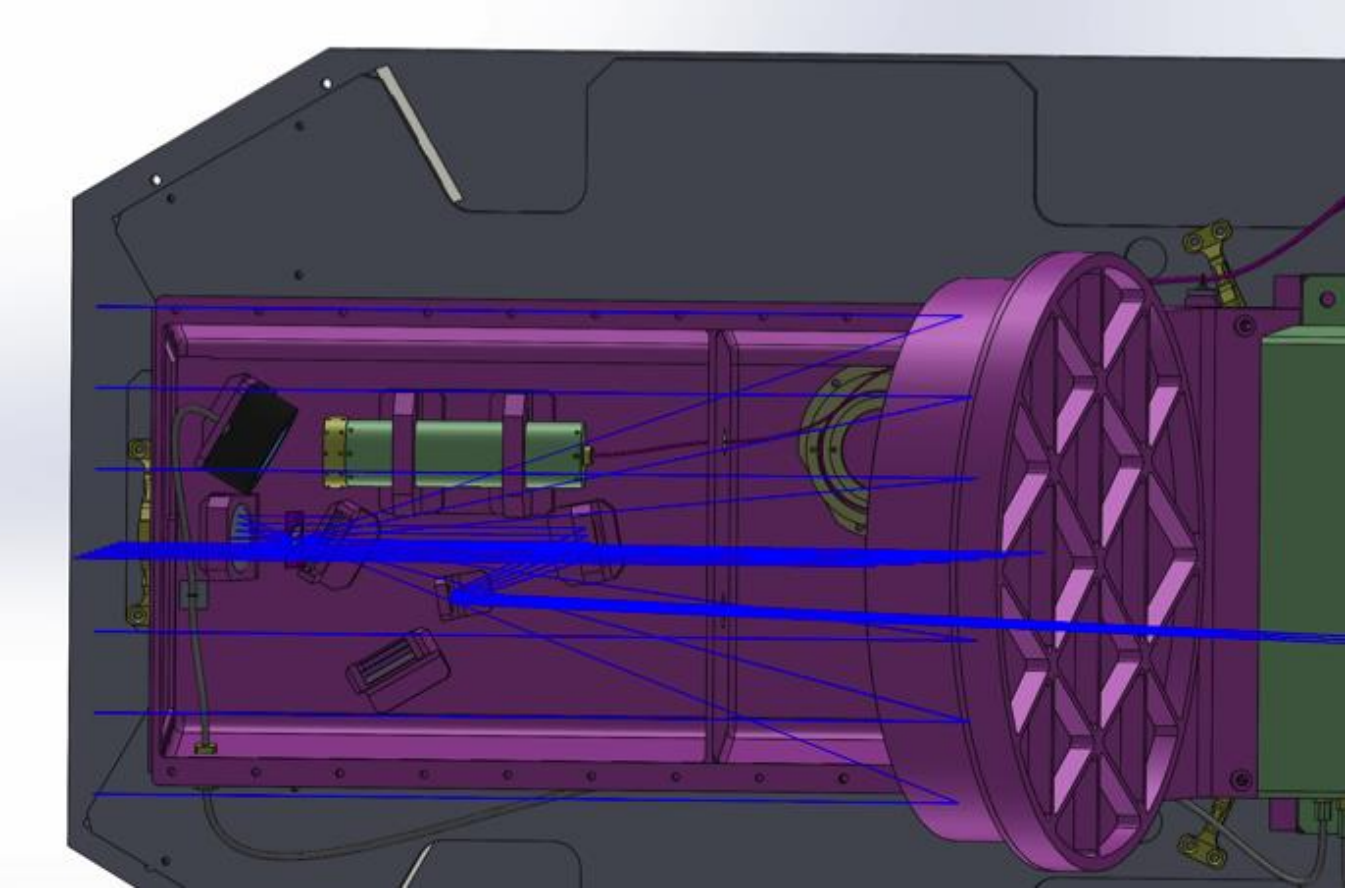
- Receive Channel
  - Receives uplink beacon from Earth
  - Transmits light through DBS
  - Focuses image on camera for centroiding



DSOC Transceiver Optical Channels

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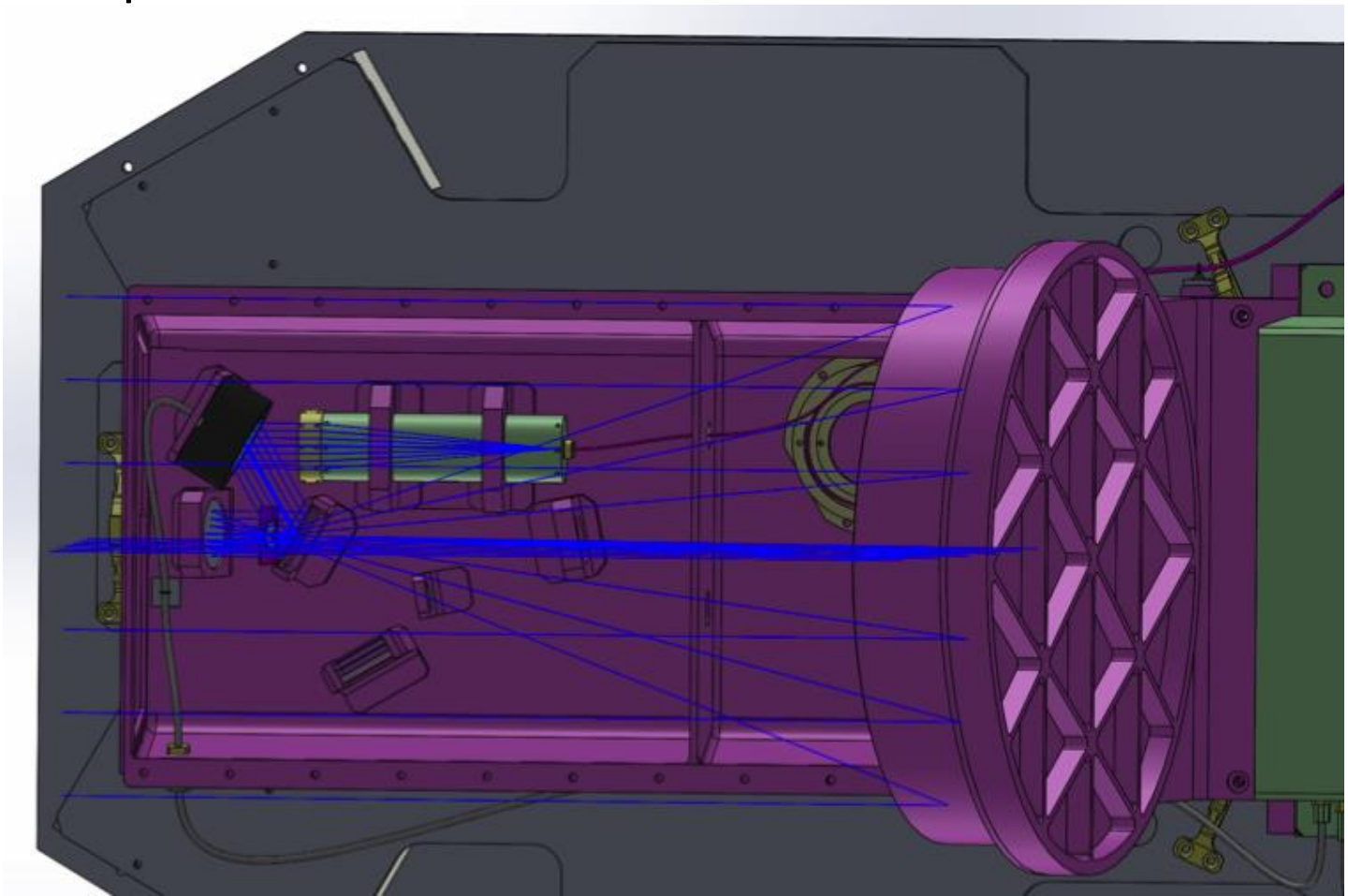
- Transmit Channel
  - Introduces point-ahead angle
  - Reflects beam off DBS
  - Expands beam for efficient transmission



DSOC Transceiver Optical Channels

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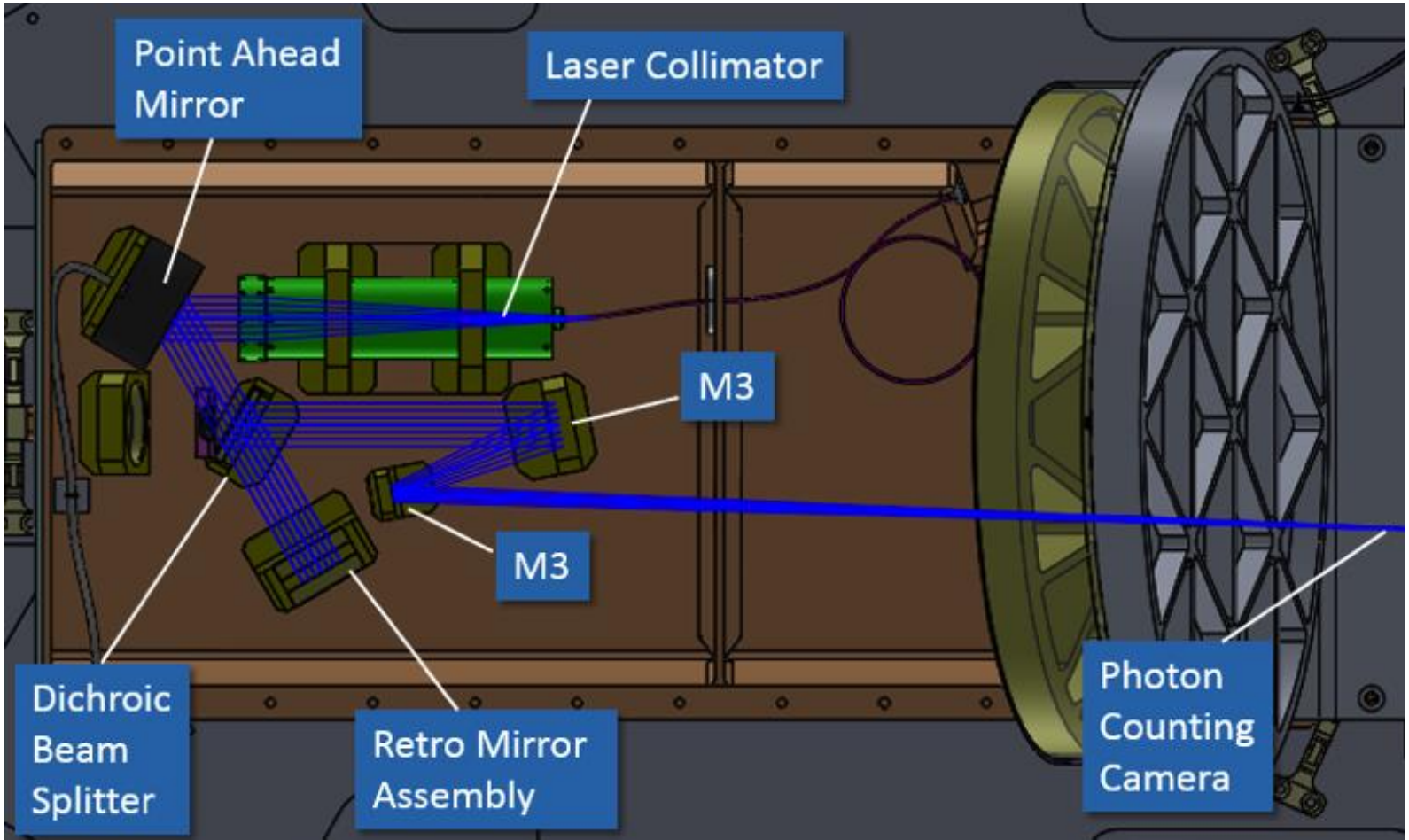
- Retro Channel
  - Residual transmit light leaking through DBS
  - Injects beam into receive channel
  - Produces spot on camera to verify correct point-ahead



Design Features

- Gregorian telescope
  - Limits solar scattering to primary mirror
  - Protects systems from exposure to focused sunlight
- Off-axis design
  - Avoids obscuration loss
  - Allows enclosure of all optics past field stop
- Single-material design
  - Negates telescope misalignment from temperature changes
- Three channel design
  - Makes almost all elements common-path
  - Protects from optical element misalignment

DSOC Scatter Performance Prediction

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California Institute of Technology

- Almost all stray light comes from primary mirror scatter
- Only improvement paths:
  - Lower scatter of primary mirror surface
  - Less contamination of primary mirror surface

#	Path	Percent contribution	Running total
1	S --> Primary --> Det	99.3	99.3
2	S --> Floor --> Field stop edge --> Det	0.4	99.7
3	S --> Primary --> Narrow band filter --> Det	0.1	99.8
4	S --> Floor --> Primary --> Det	0.1	99.9

*Analysis performed by Mr. Gary Peterson of Breault Research Organization

Aluminum Test Model

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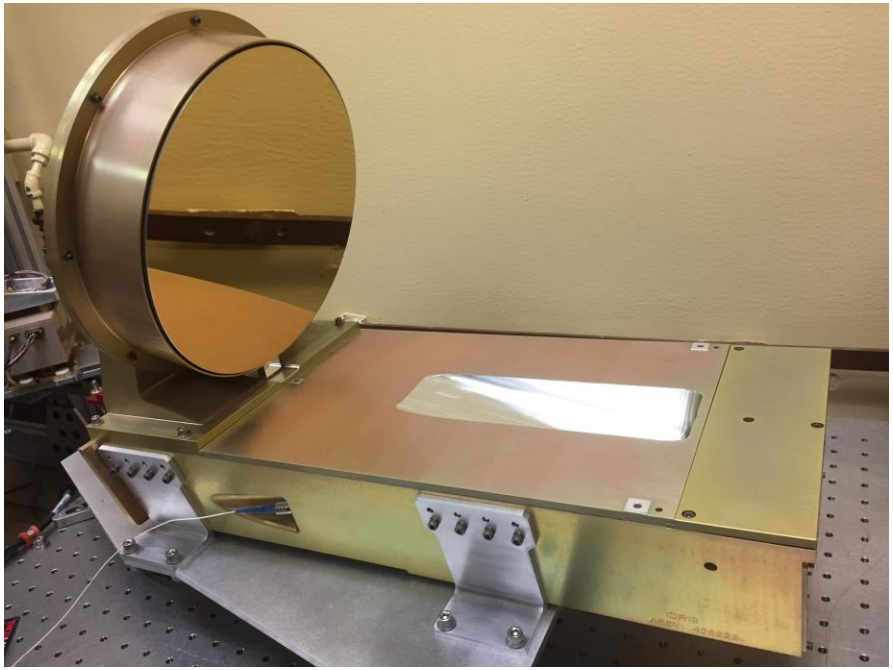
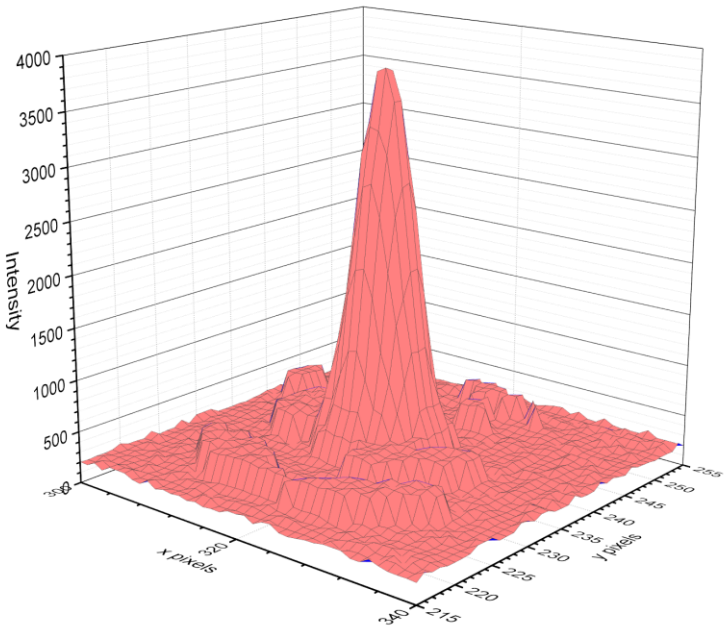
California Institute of Technology

- Developed for laboratory testing and concept verification
  - 20 A rms surface roughness
  - Diffraction-limited receive-channel performance





Summary

- The DSOC Flight Laser Transceiver has been designed to perform under harsh space conditions
  - High temperature changes
  - Differential heating of the unit
  - Extreme stray-light rejection
- Design is expected to meet requirements
  - Diffraction-limited receipt of earth-based beacon
  - Diffraction-limited transmission of downlink beam
  - Support precision pointing of downlink beam
  - Maintain performance when pointing close to Sun
- An Aluminum test model has been developed
  - Confirms diffraction-limited receive channel
  - Performance and validation testing ongoing

Acknowledgements

- Michael Borden for providing CAD figures
- Mike Chainyk for CIELO modeling and figures
- Joseph Kovalik for preliminary test results
- Gary Peterson from Breault Research Organization for stray light analysis

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