NGAO TT/TTFA Review

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Outline

- OpticalDesign
  - Object Selection Mechanisms Relay
  - TT and TTFA Optical Relay
  - Photometry
- Mechanical Design

  Cryostat

  Opto/Mech

  Packaging
- Electronics
- Future Work

Overview

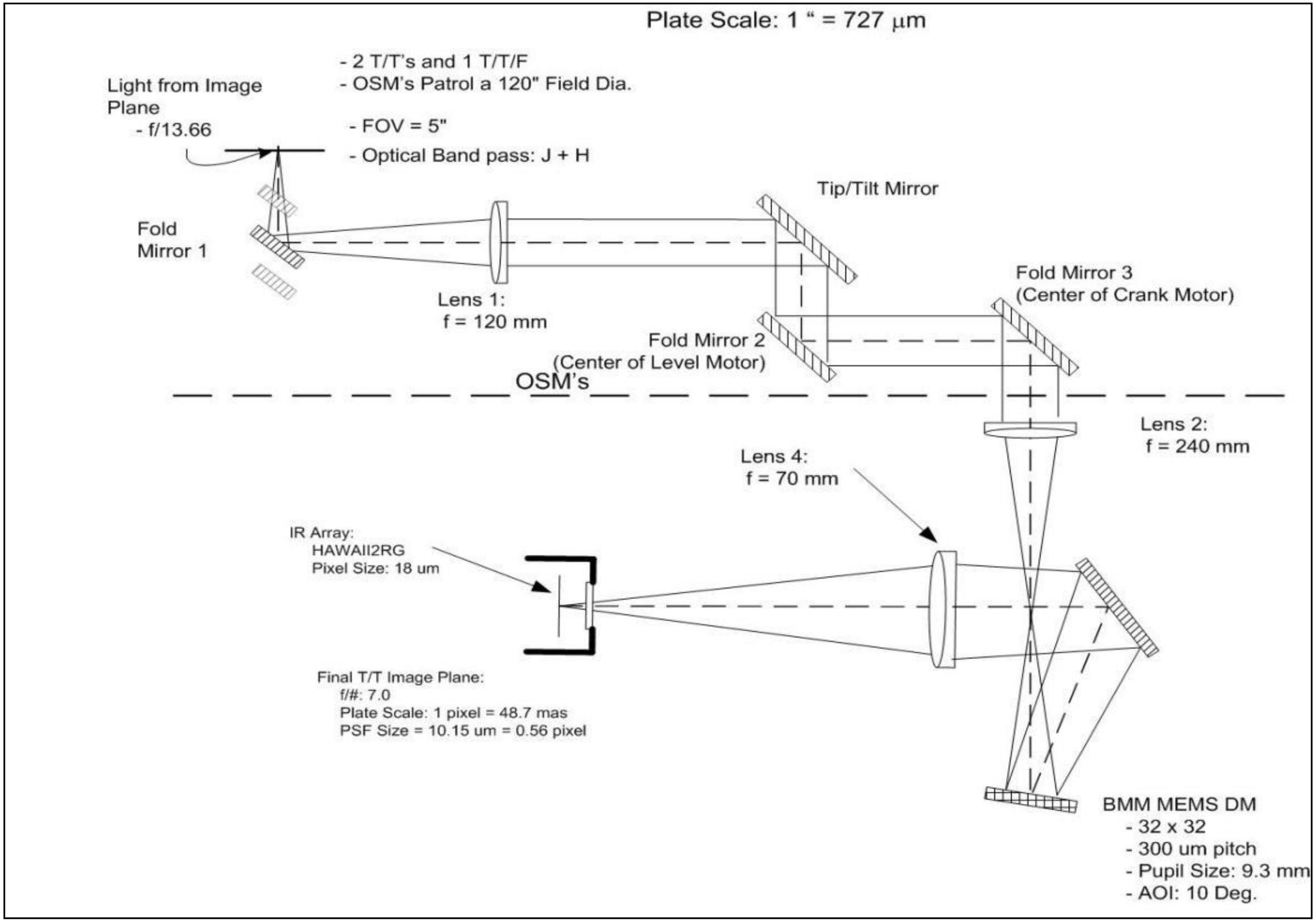
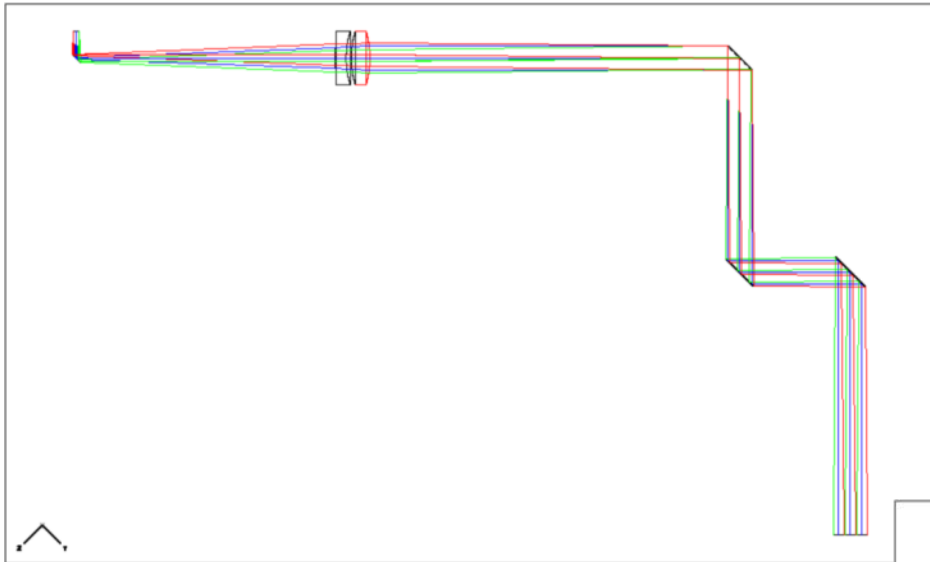
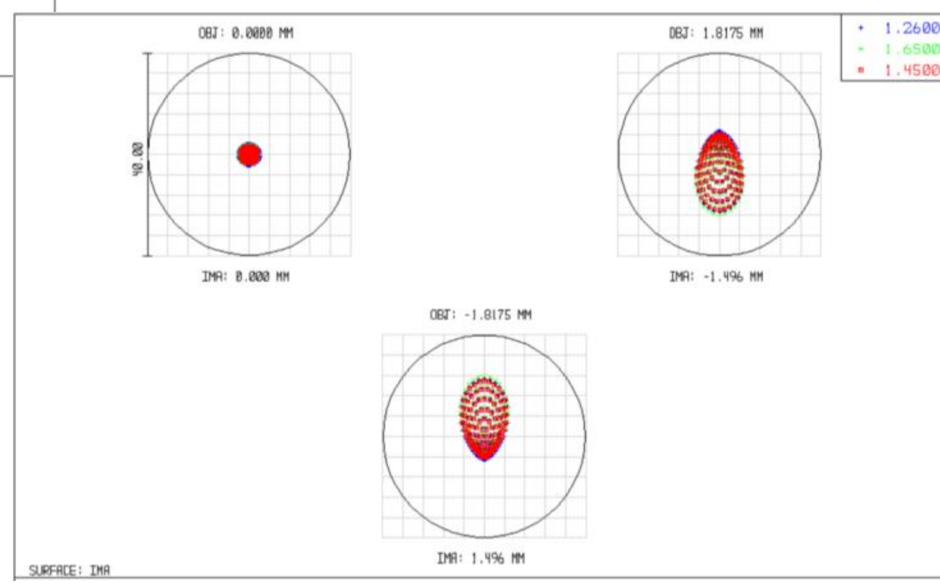


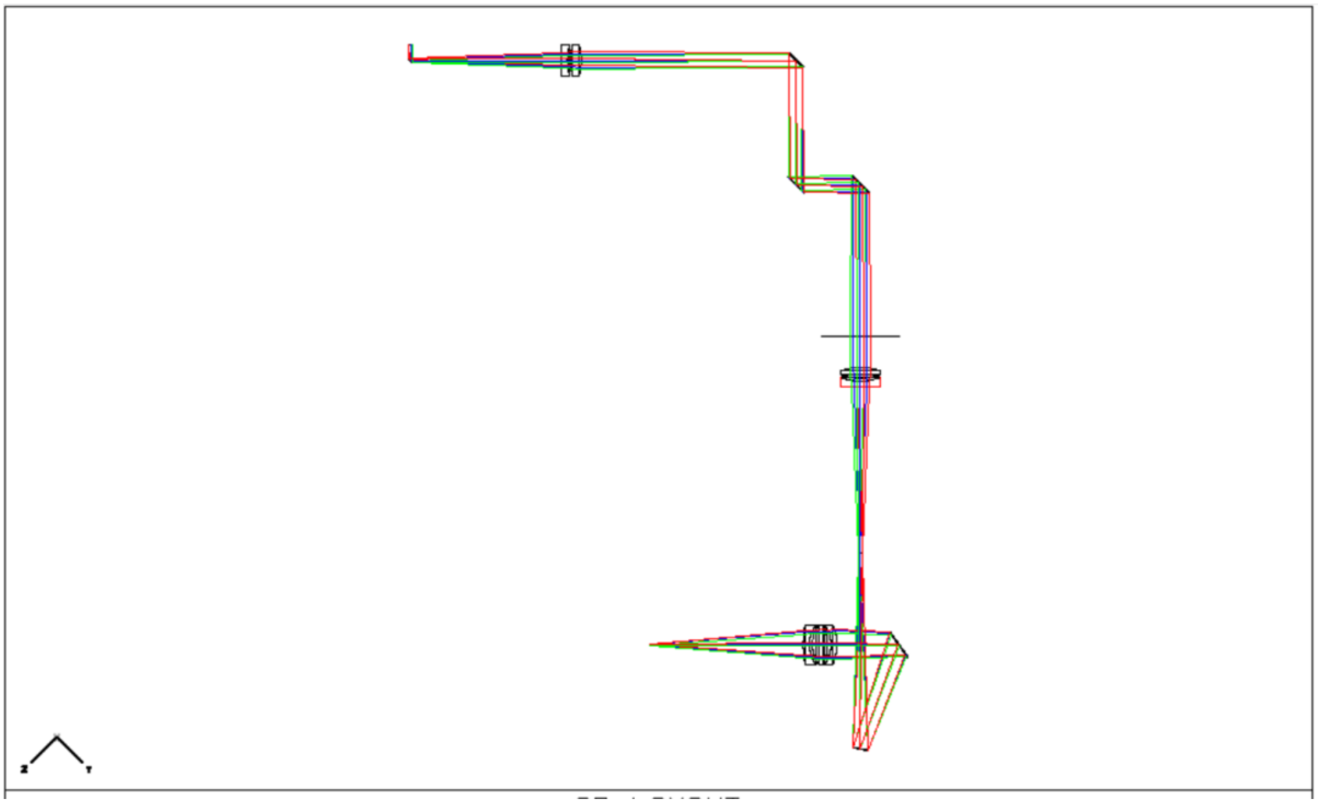
Plate Scale: 1 " = 727 μm
- 2 T/T's and 1 T/T/F
- OSM's Patrol a 120" Field Dia.
Light from Image Plane
- f/13.66
- FOV = 5"
- Optical Band pass: J + H
Tip/Tilt Mirror
Fold Mirror 1
Fold Mirror 3
(Center of Crank Motor)
Lens 1:
f = 120 mm
Fold Mirror 2
(Center of Level Motor)
OSM's
Lens 2:
f = 240 mm
Lens 4:
f = 70 mm
IR Array:
HAWAII2RG
Pixel Size: 18 um
Final T/T Image Plane:
f/#: 7.0
Plate Scale: 1 pixel = 48.7 mas
PSF Size = 10.15 um = 0.56 pixel
BMM MEMS DM
- 32 x 32
- 300 um pitch
- Pupil Size: 9.3 mm
- AOI: 10 Deg.

Optical Design:
Object Selection Mechanism

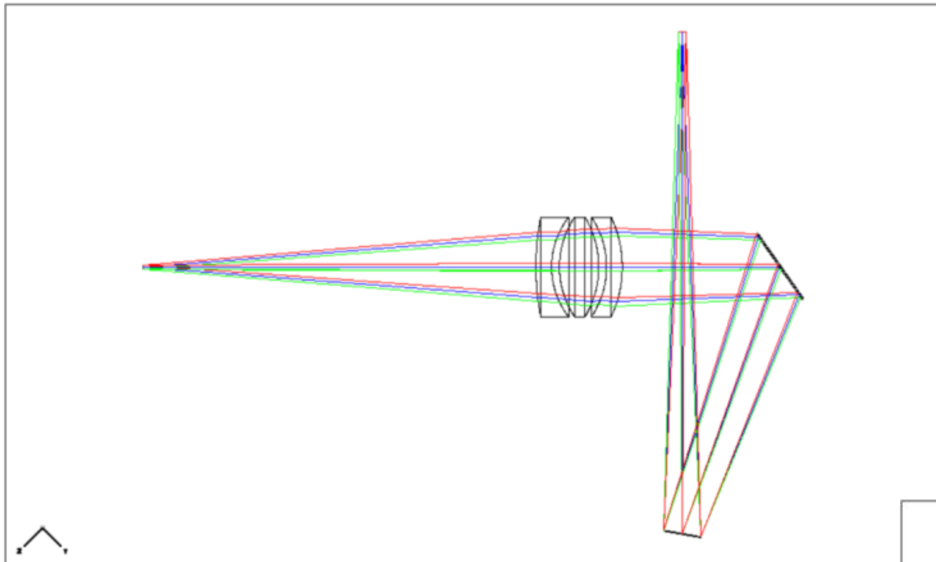


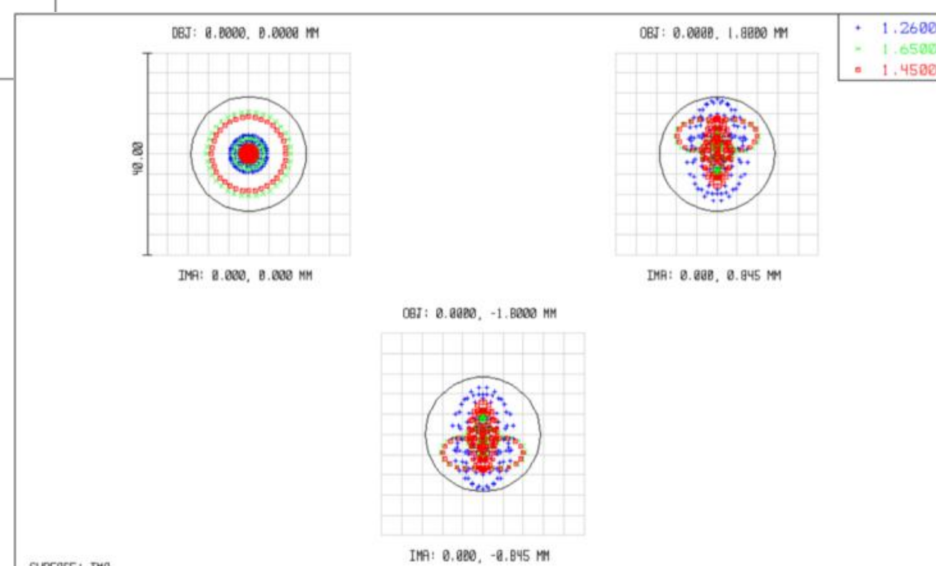


Optical Design: TT Optical Relay

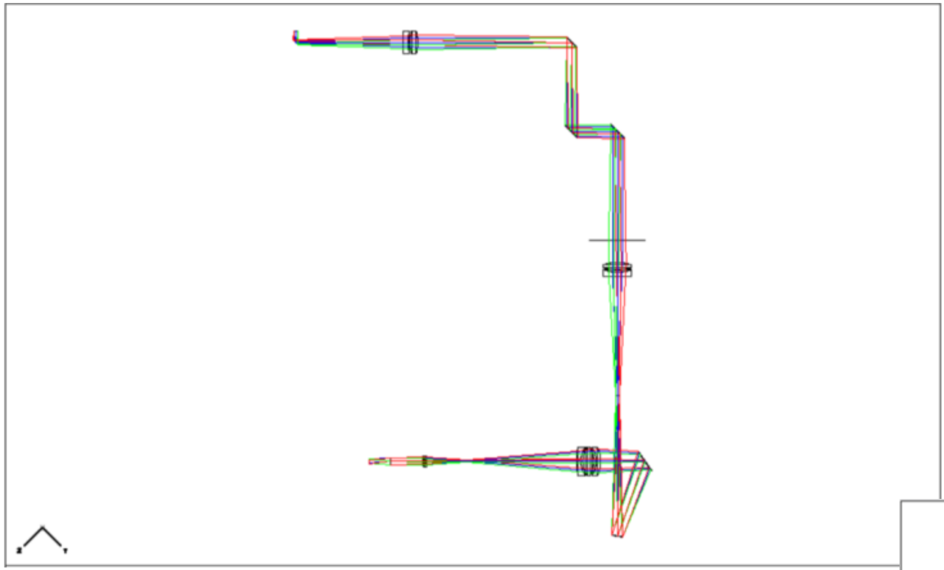


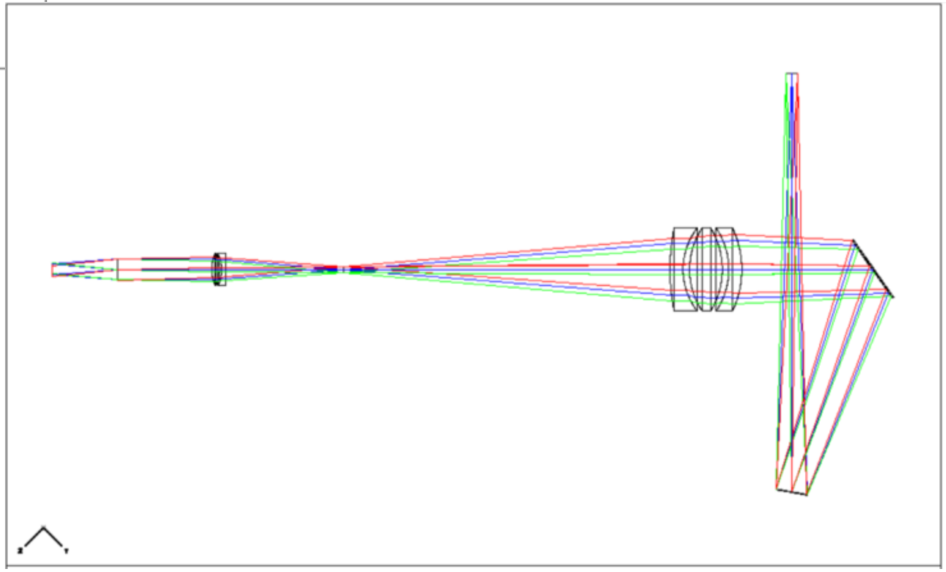
Optical Design:
TT Optical Relay



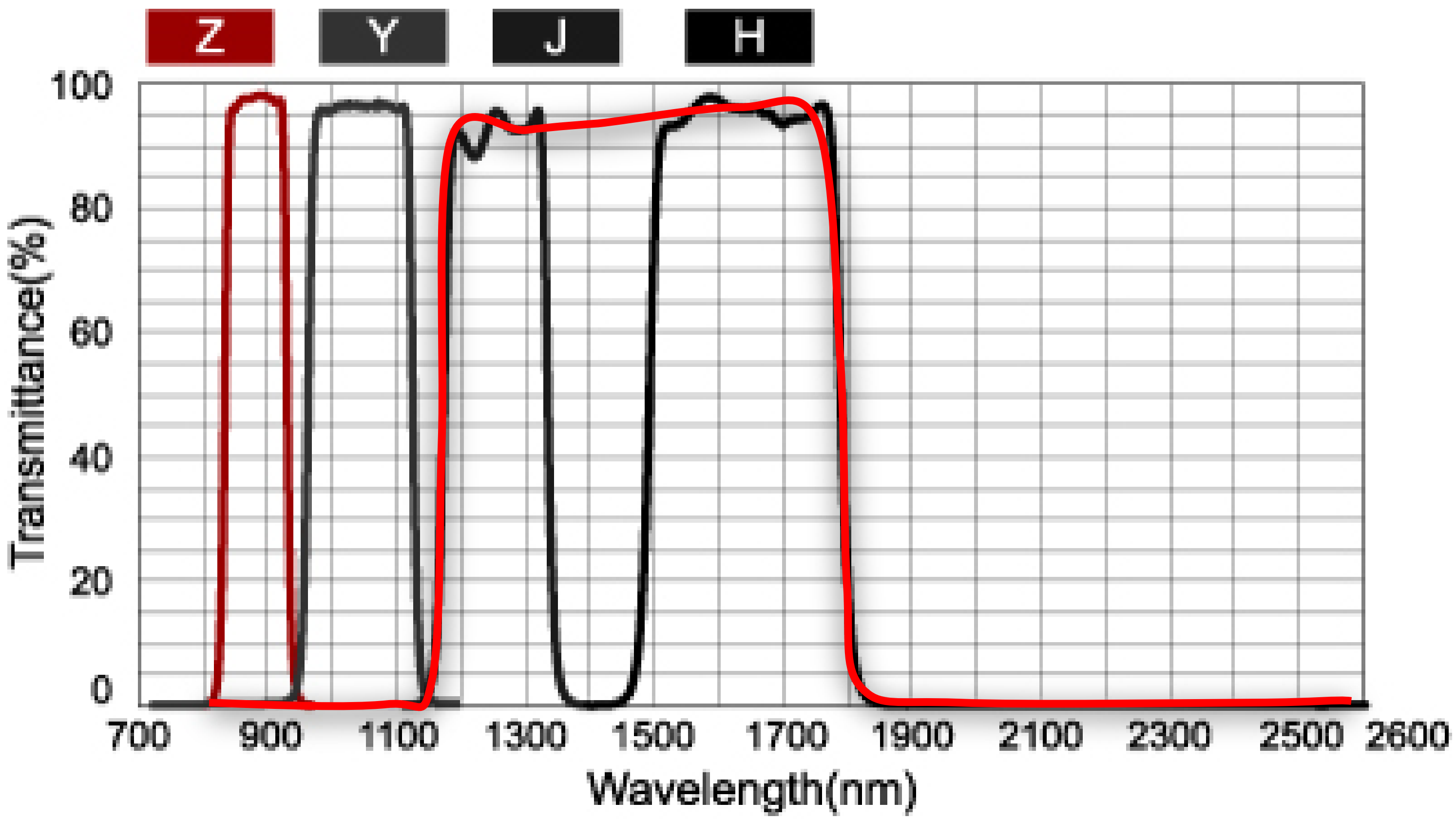


Optical Design: TTF Optical Relay





J + H Filter



Z
Y
J
H
100
80
60
40
20
0
Transmittance(%)
700
900
1100
1300
1500
1700
1900
2100
2300
2500
2600
Wavelength(nm)

Photons from thermal background

Spectral Radiance = $\left(\frac{2c}{\lambda^4}\right)\left(\frac{1}{e^{\frac{hc}{\lambda kT}}-1}\right)$ Photons/sec/steradian/um/m^2

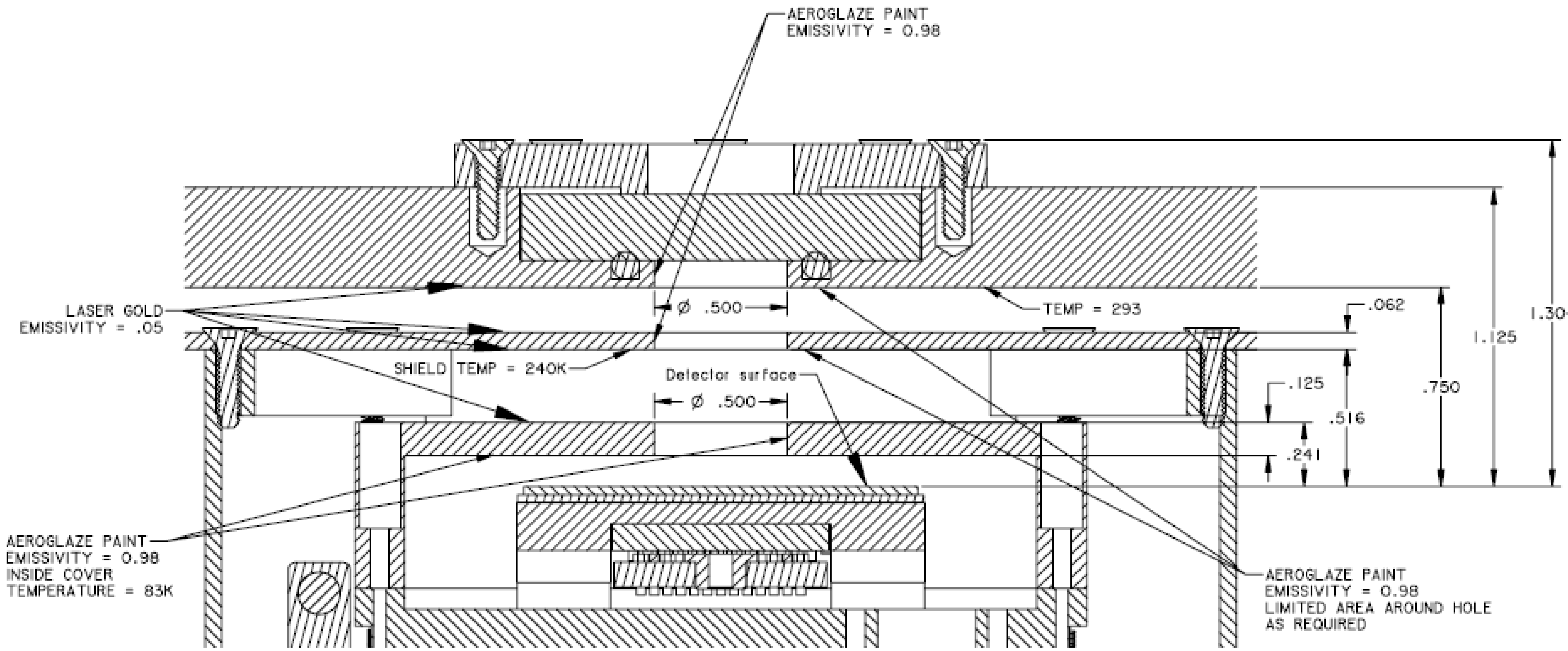
Band Radiance= $\int_{\lambda_1}^{\lambda_2}\left(\frac{2c}{\lambda^4}\right)\left(\frac{1}{e^{\frac{hc}{\lambda kT}}-1}\right)d\lambda$ Photons/sec/steradian/m^2

Photon Flux = Band Radiance * Solid Angle * Detector Area

Temperature	H + J Band Radiance	Solid Angle	Photon Flux
240 K	1.227 E 10	2 π	25 photons/sec
300 K	1.195 E 13	0.1 π (f/1.5)	1248 photons/sec
300 K	1.195 E 13	2 π	24 300 photons/sec

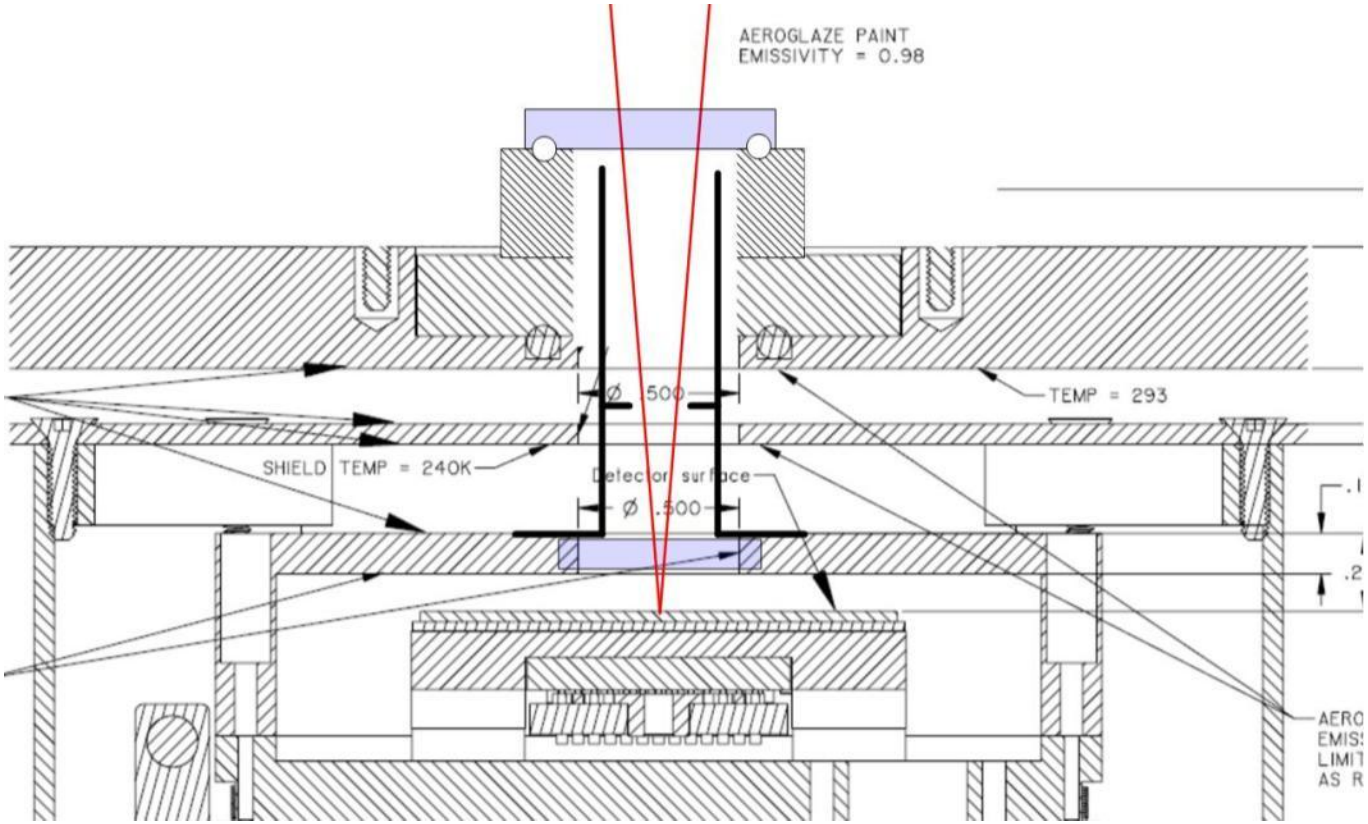
H + J Band: 1.13 um to 1.805 um, inclusive
Detector Area: (18 um)^2

Current Design



J + H Photons = Pixel Area *(BandRadiance@83K*(Ω(f/0)- Ω(f/.5)) +
BandRadiance@240K*(Ω(f/.5)- Ω(f/1.2)) +
BandRadiance@300K*Ω(f/1.2))
= 1992 photons/sec

Revised Design



J + H Photons = Pixel Area *(BandRadiance@83K*(Ω(f/0)- Ω(f/.5)) +
BandRadiance@240K*(Ω(f/.5)- Ω(f/5)) +
BandRadiance@300K*Ω(f/5))
= 128 photons/sec

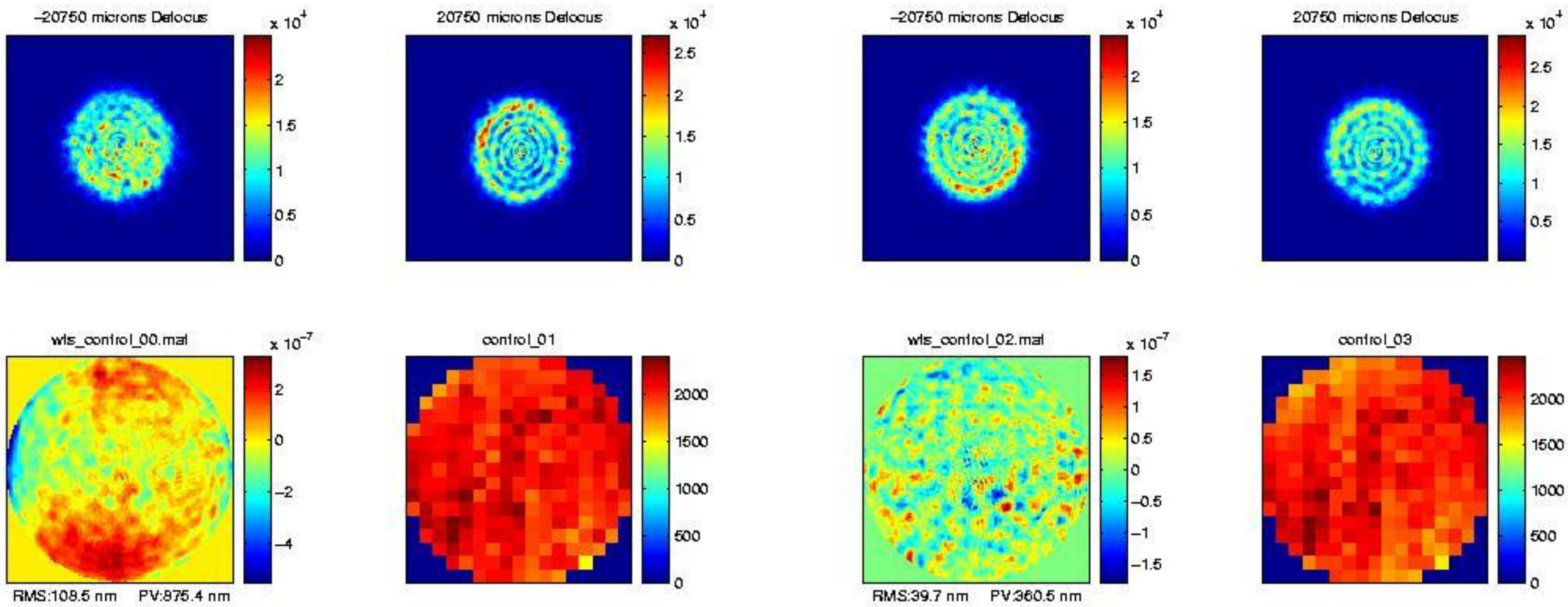
Wavefront Calibration Using MGS

BEFORE

- Starting from best hand tuned image on the PALAO white light source
- Wave front error ~ 110 nm rms

AFTER

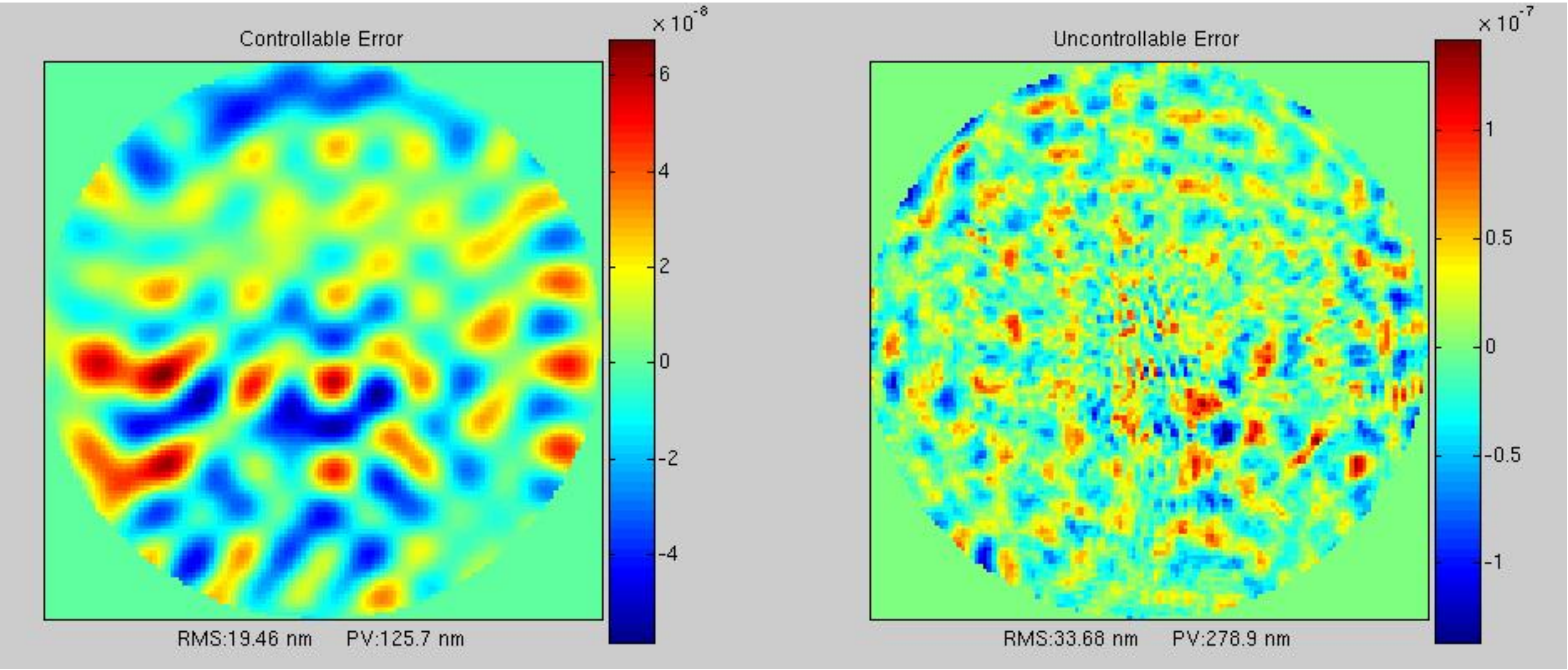
- After 3 MGS iterations (~ 15 minutes)
- Wave front error ~ 39 nm rms



Credit: G. Serabyn, R. Burruss

Wavefront Calibration Using MGS

- Best MGS result through a low pass filter
- 8 cycles / pupil
- 19 nm controllable WFE
- 33 nm uncontrollable high frequency WFE



Credit: G. Serabyn, R. Burruss

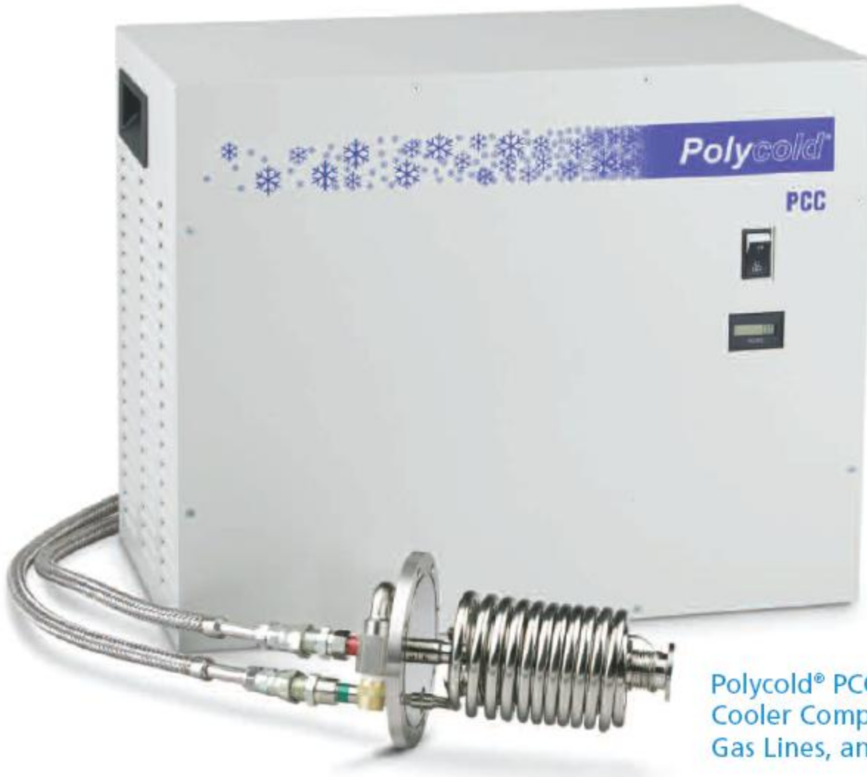
Cryostat Design

- Baseline detector for the LOWFS TT and TTF arms is the Hawaii 2RG.
- HW2RG detector needs to be maintained at a stable temperature below ~93◦K to provide to reasonable dark current and sensitivity
- Temperature requirements:
  - Baseline set temperature: < 93◦K
  - Baseline required temperature stability: ± 0.1◦K ?

Cryostat Design

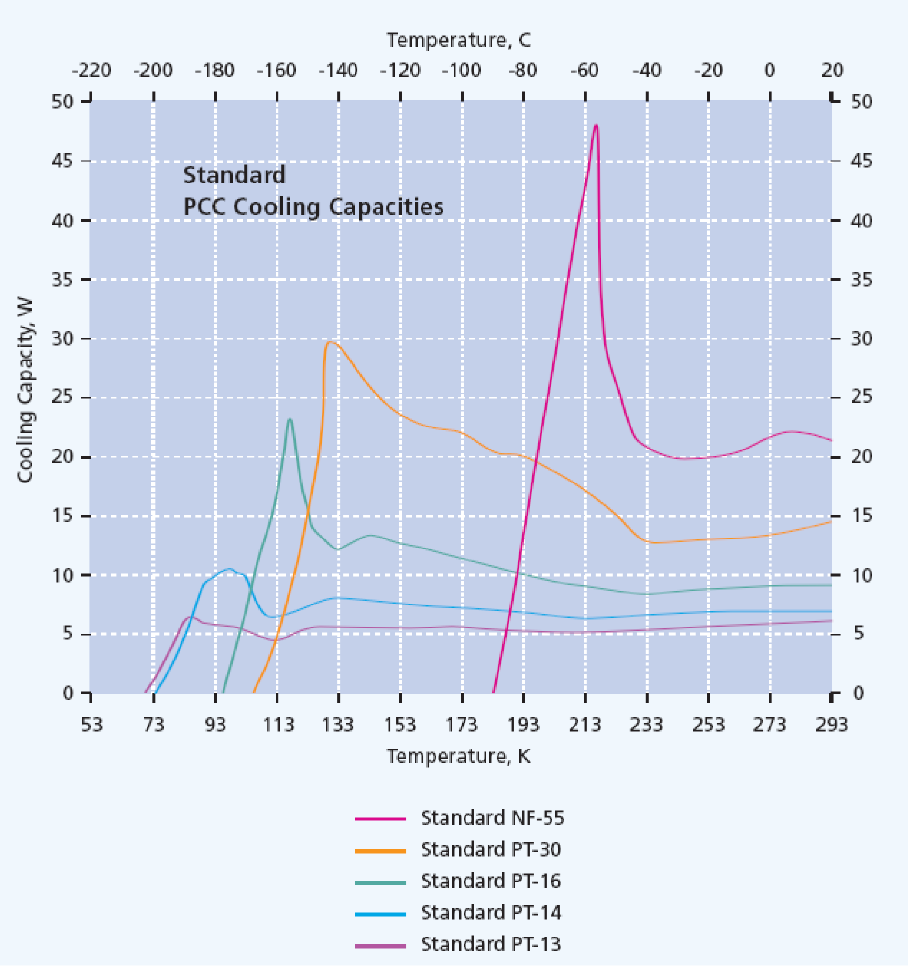
- Purpose of the cryostat is to provide the environment and equipment necessary to meet the temperature requirements of the detector.
- We have selected to use a Polycold PCC compact cryocooler as the means of cooling the detector.
  - The PCC cryocooler can provide the required cooling while minimizing the mechanical vibrations introduced into the system.
  - The PCC cryocooler is easy to implement.
  - The PCC cryocooler system is reliable – no moving parts in the cold head.
  - Cryocooler is inexpensive – On the order of $17K for the system
  - Use PT14 gas mixture – 10 Watt cooling capacity at 93◦K

Cryocooler

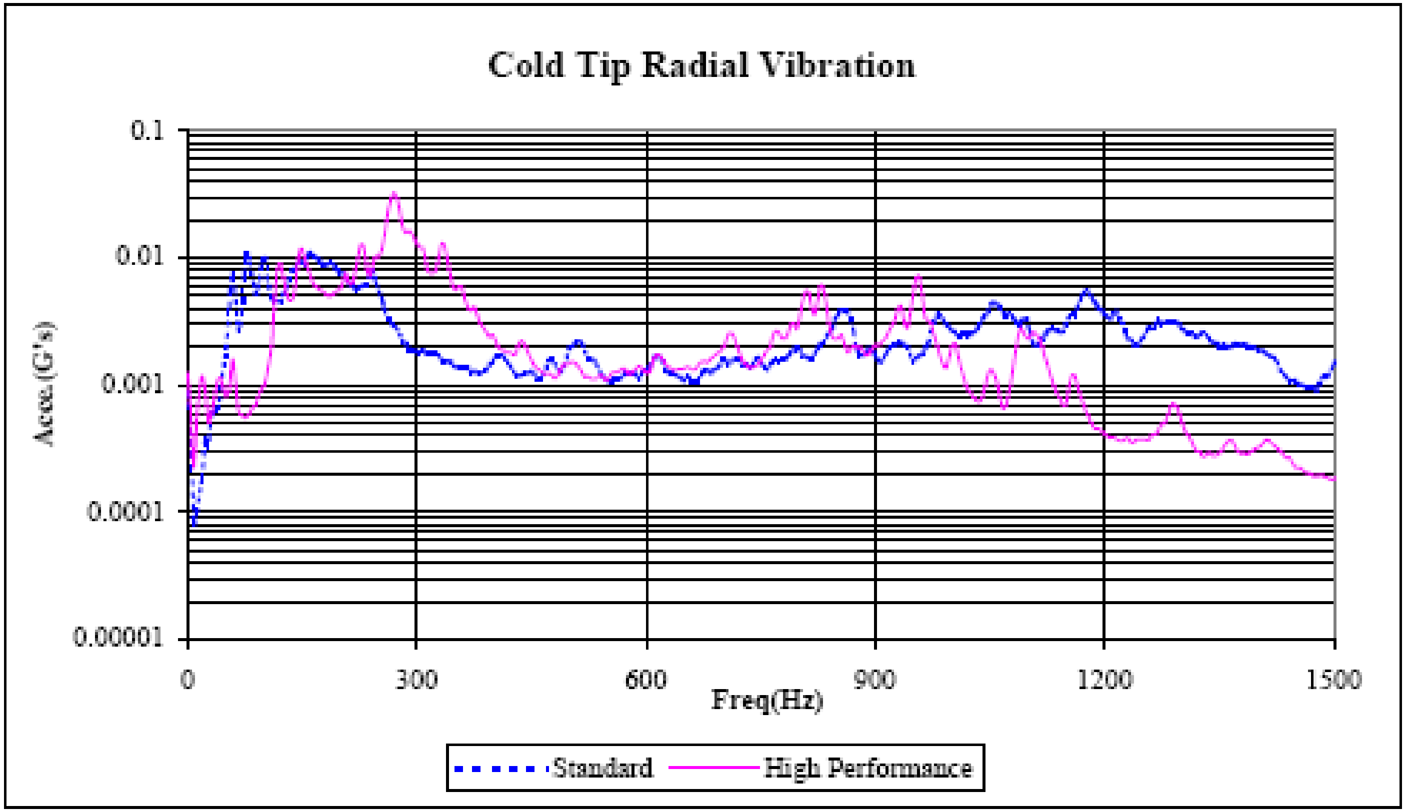


Polycold® PCC Compact
Cooler Compressor,
Gas Lines, and Cold End

Cooling Capacity

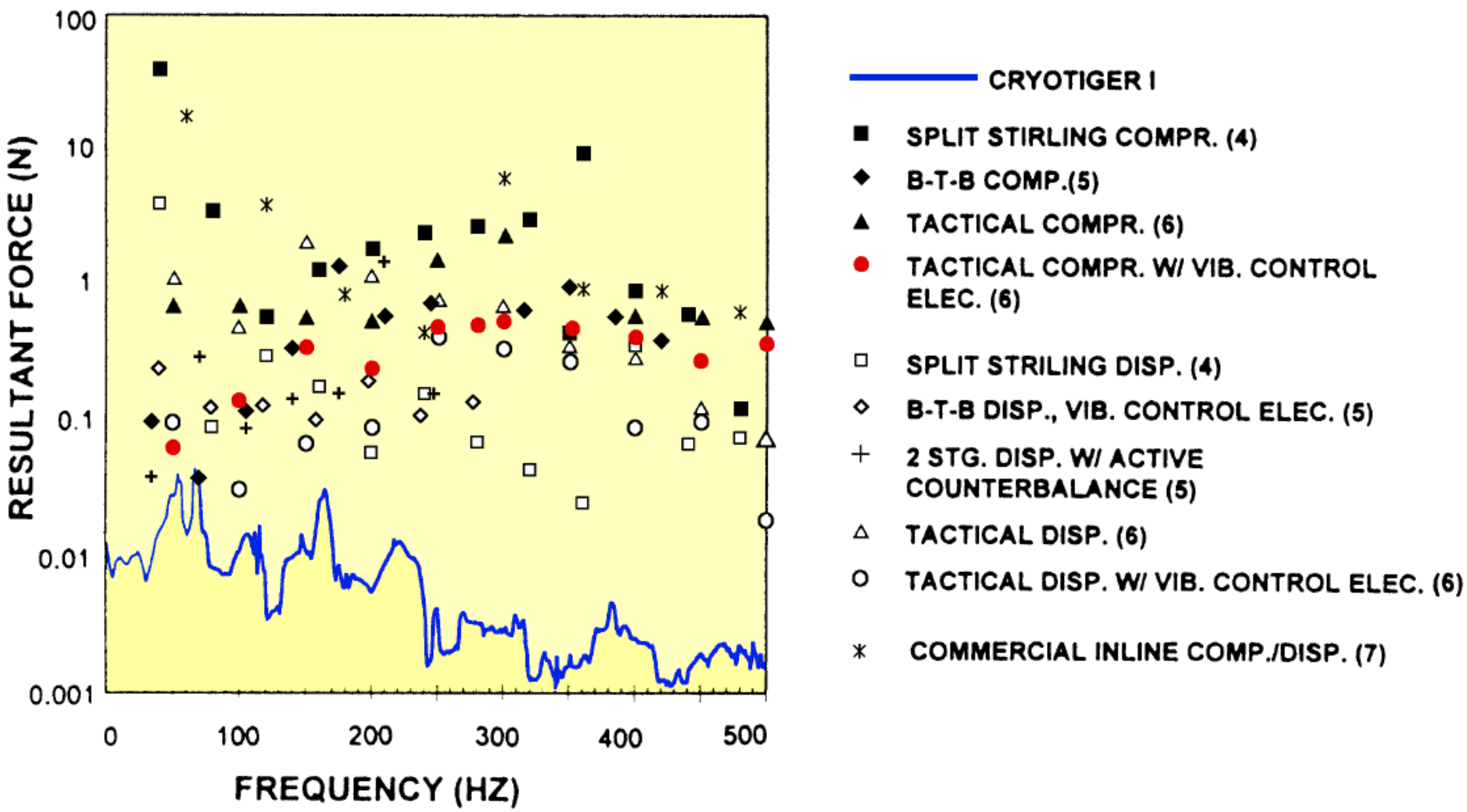


VIBRATION



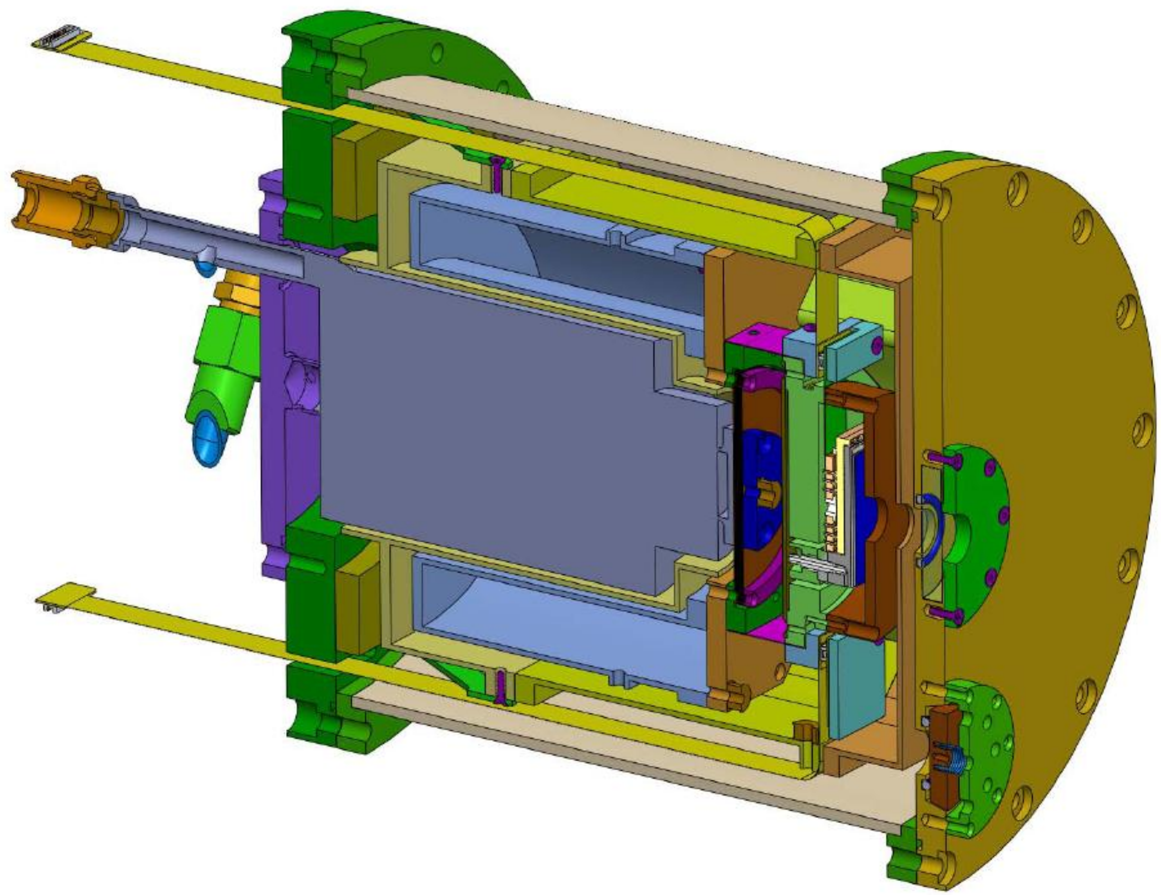
Cold Tip Radial Vibration
0.1
0.01
0.001
0.0001
0.00001
Acce.(G's)
0
300
600
900
1200
1500
Freq(Hz)
Standard
High Performance

VIBRATION



100
10
1
0.1
0.01
0.001
RESULTANT FORCE (N)
0
100
200
300
400
500
FREQUENCY (HZ)
CRYOTIGER I
SPLIT STIRLING COMPR. (4)
B-T-B COMP.(5)
TACTICAL COMPR. (6)
TACTICAL COMPR. W/ VIB. CONTROL ELEC. (6)
SPLIT STRILING DISP. (4)
B-T-B DISP., VIB. CONTROL ELEC. (5)
2 STG. DISP. W/ ACTIVE COUNTERBALANCE (5)
TACTICAL DISP. (6)
TACTICAL DISP. W/ VIB. CONTROL ELEC. (6)
COMMERCIAL INLINE COMP./DISP. (7)

CRYOSTAT DESIGN



Temperature stability

- The cold temperature of the detector achieved by the cryocooler when the heat load and cooling capacity are balanced is expected to be between 73◦K and 90◦K
- Temperature stability requirement will be met by using a heater to raise the detector temperature above equilibrium temperature without the heater. Temperature stability is achieved by controlling the thermal energy added to the system by means of a closed loop temperature controller.

Temperature Controller

- **Maximum flexibility: Two multipurpose input channels support Diode, Platinum RTD and most cryogenic NTC resistive temperature sensors. A Thermocouple input is optional.**
- **Loop #1 Primary control loop: 50 Watt, 50Ω, three-range linear heater output.**
- **Loop #2 Secondary control loop of the Model 32B is a 10 Watt, 50Ω, linear output. The standard Model 32 provides a second loop output of zero to ten volts.**
- **Fail-safe cryostat over-temperature protection features protect user equipment from damage.**
- **Proven, tested autotuning optimized for cryogenic systems.**

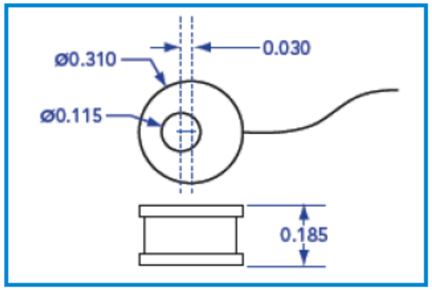
The **Over Temperature Disconnect** feature will disable the heater if an over temperature condition exists on any selected input channel. A fail-safe mechanical relay is used to disconnect the controller's heater thereby ensuring that the user's equipment is always protected.

The **Maximum Setpoint** feature is used to prevent the user from inadvertently entering a higher setpoint than the equipment can tolerate.

Setting the **Maximum Power Limit** will ensure that the controller can never output a heater power above the set limit.

Temperature Sensor

S900-BB



S900 Bobbin Package

Temperature Range: 1.5 to 400K.

Marking: Individual serial number.

Mass: 1.1g excluding leads.

Construction: Bobbin Material is gold plated oxygen free hard copper. Sensor bonding is Stycast® epoxy.

Color Code	
V+	Clear
V–	Green
I+	Black
I–	Red

Leads: 36", 36AWG Phosphor-Bronze. Four-lead color coded cryogenic ribbon cable. Insulation is heavy Formvar® . Strain relief is Teflon®.

Mounting: 4-40 brass machine screw. A thin layer of Apiezon® N grease is recommended.

Specifications

Temperature Range: 1.5K to 400K for the BB and SM packages. 1.5K to 500K for the CP package.

Standard Curve: Cryo-con S900.

Excitation Current: 10µA ±0.1%

Repeatability: 10mK @4.2K, 16mK @77K, 75mK @273K.

Magnetic Field Use: Not recommended for fields above 0.1 Tesla or temperature below 40K.

Use in Radiation: Not recommended for high radiation environments.

Maximum Temperature: Do not store above 500K.

Maximum Reverse Voltage: 60V.

Maximum Excitation Current: 2mA.

Power Dissipation: 16µW at 4.2K.

- Plan on using four (4) temperature sensors.
  - Detector body (sensor for control loop)
  - Cold plate
  - Cold finger tip
  - Radiation shield.
- Reduction in radiation shield temperature indicates cryostat needs to have vacuum service.

HEATER

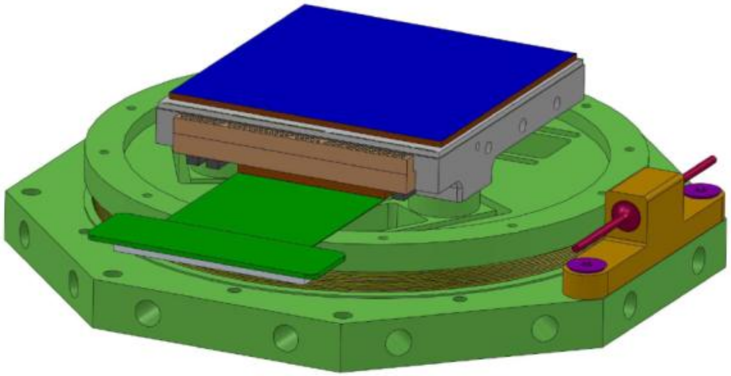
- Use 50W Nichrome wire

Nichrome Heater Wire

Part #: 3039-006

Features

- 100' Reel.
- 80% Nickel, 20% Chromium.
- 32AWG, 0.008" diameter.
- Polyimide film insulation operates to 500K.
- Nominal Resistance: 10Ω per foot.



Temperature Monitor

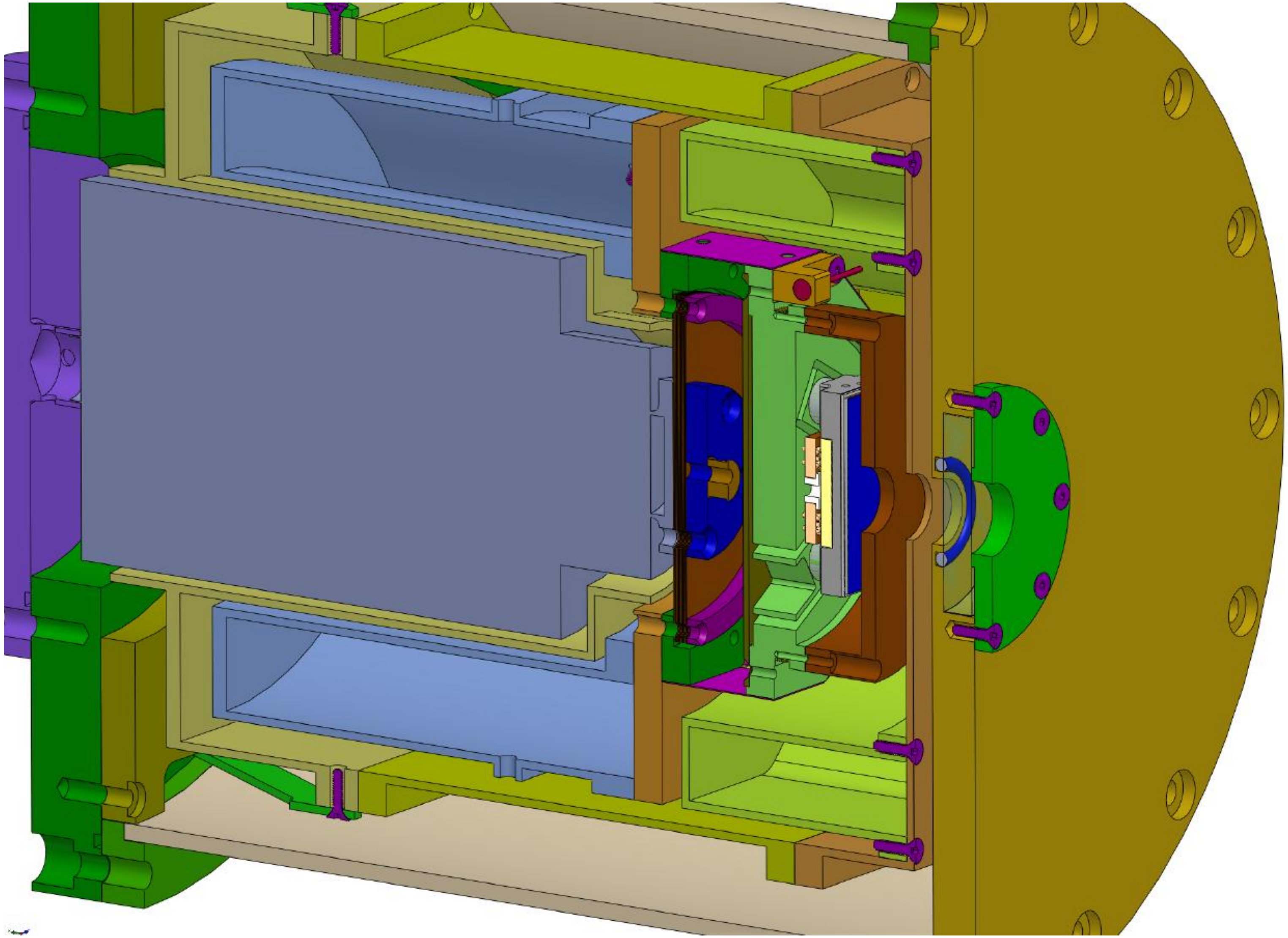
Cryogenic Temperature Monitor
Model 18
Eight input channels with Ethernet connectivity

- Eight input channels that can be independently configured to support Diode, Platinum RTD and many cryogenic NTC temperature sensors.

Getters

- Use both a activated carbon and zeolite getter to minimize the required interval between vacuum pumping.
  - Charcoal getter: Used to capture gas molecules
    - Activated Carbon (Coconut Charcoal)
    - 6 to 12 mesh (1.68 mm to 3.35 mm)
    - Fisher Scientific C270-C
    - 2.1 Kg for $405.00
    - 1.8 to 2.1 Kg/litre
  - Zeolite getter: Used to capture water molecules
    - Molecular Sieve, Type 5A, 1/16” Pellets
    - Silica Gel, Aluminum Oxide, Calcium Oxide , Sodium Oxide
    - Effective pore size: 5Å
    - EMD Chemicals Inc. part # MX1583N
    - 2.85 Kg/litre

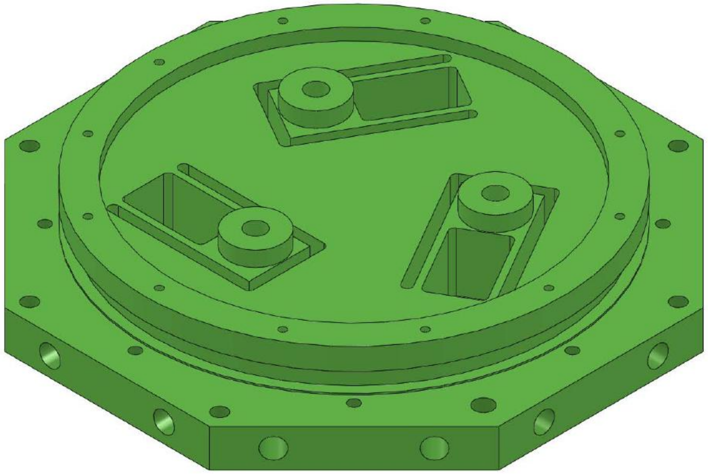
GETTER LOCATIONS

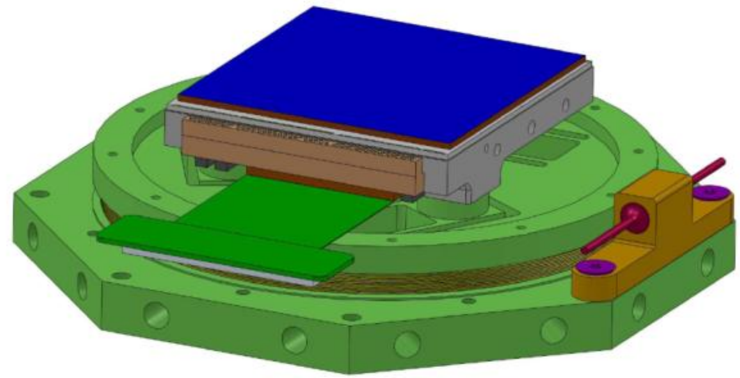


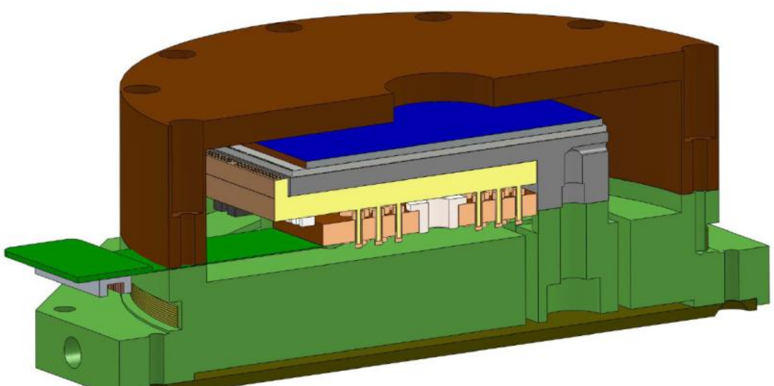
Array Mounting

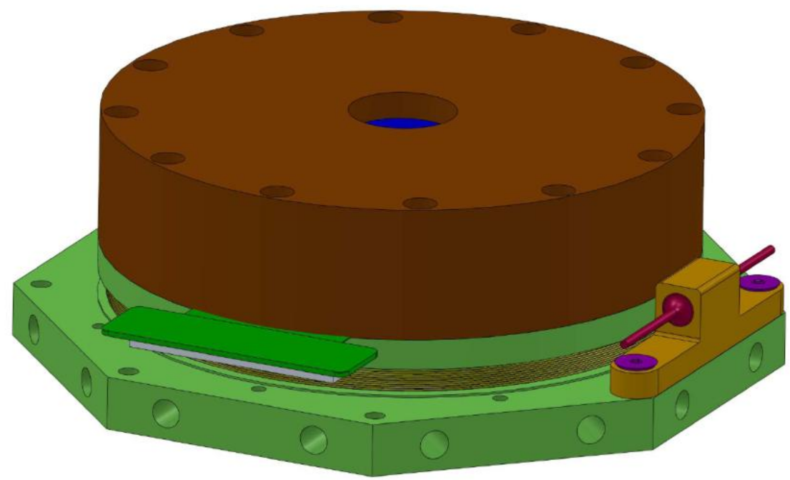
- HW2RG is provided bonded to either an invar or Molybdenum base. Our base line is the invar base.
- To avoid introducing stresses into the invar base the array will be mounted to an aluminum base that has stress reliving flexures cut into it.

Array Mounting





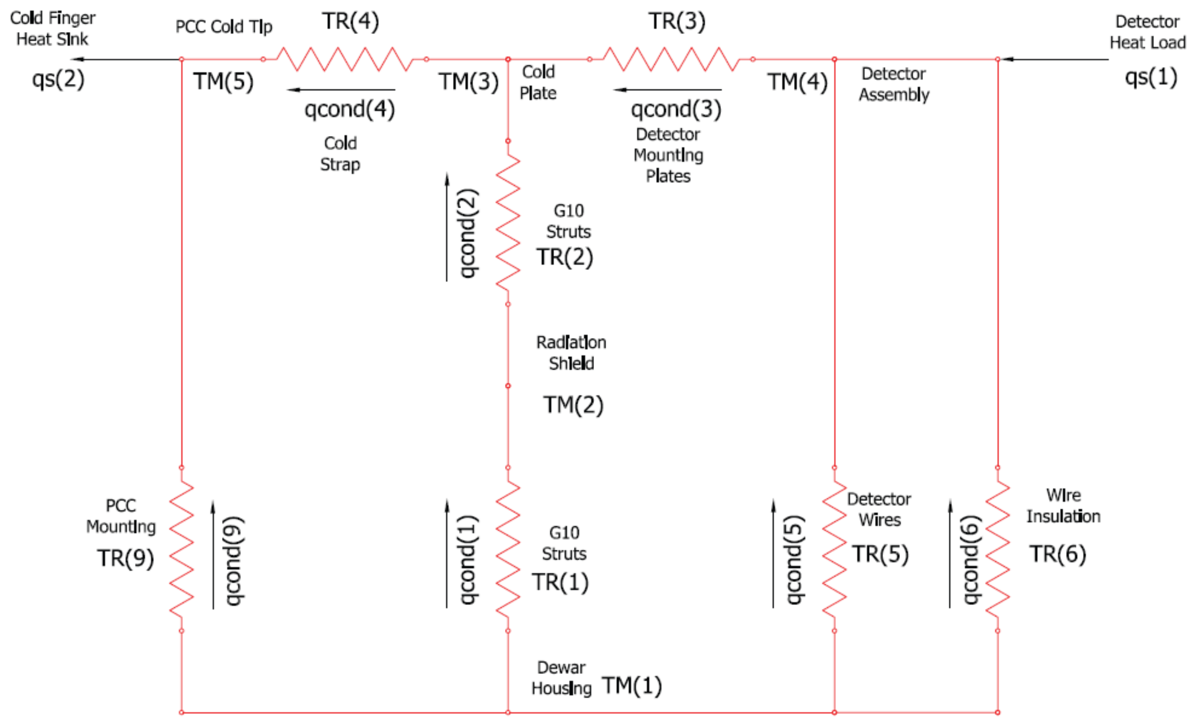




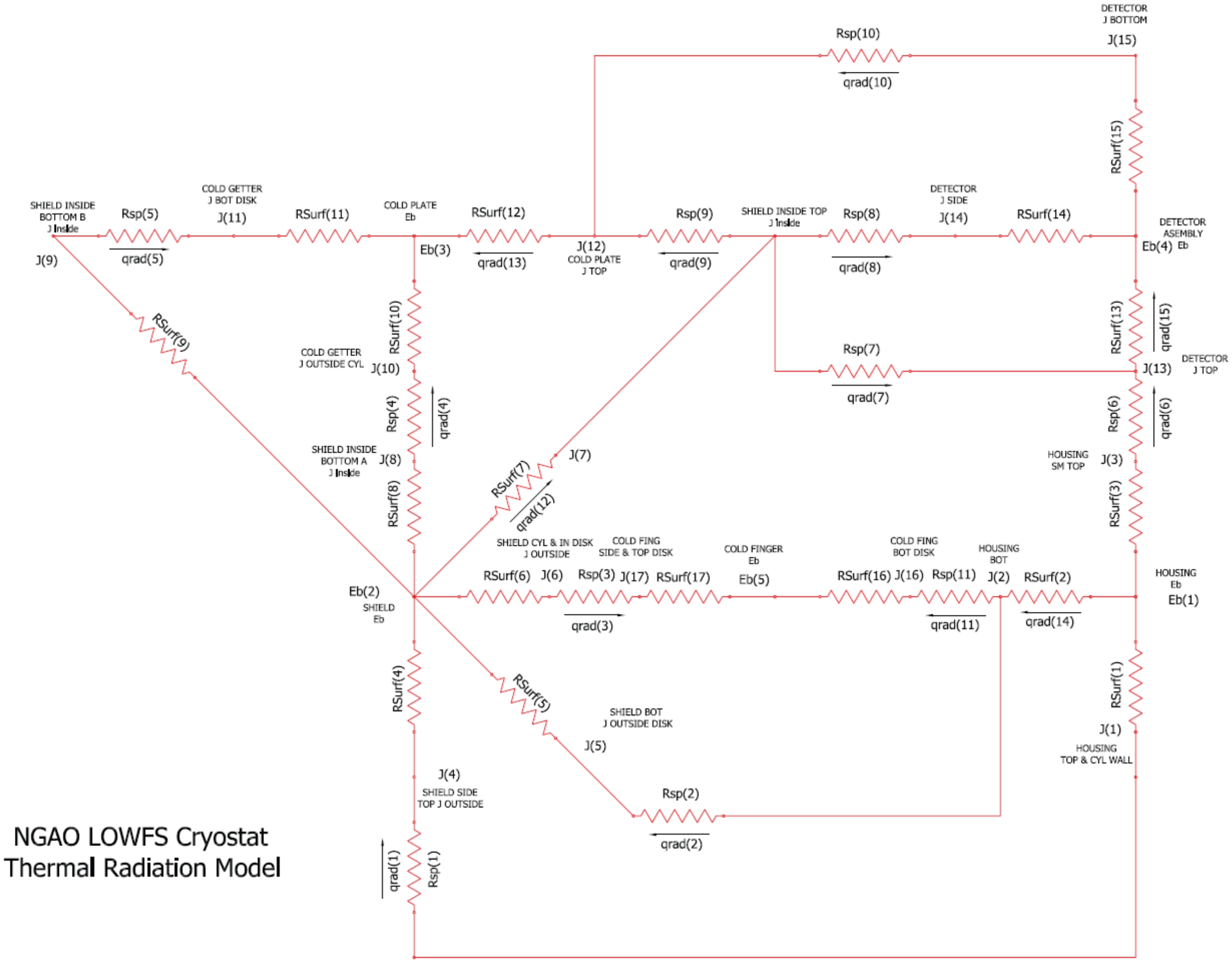
Cryostat Thermal Analysis

- Lumped parameter thermal model was developed to simulate thermal performance of proposed cryostat design.
- Model was implemented using matlab.
- Cool down of cryostat was simulated.
- Model included conduction and radiation heat transfer.
- Detector heat load of 0.25 watts was assumed

CONDUCTION NETWORK MODEL



RADIATION NETWORK MODEL



NGAO LOWFS Cryostat
Thermal Radiation Model

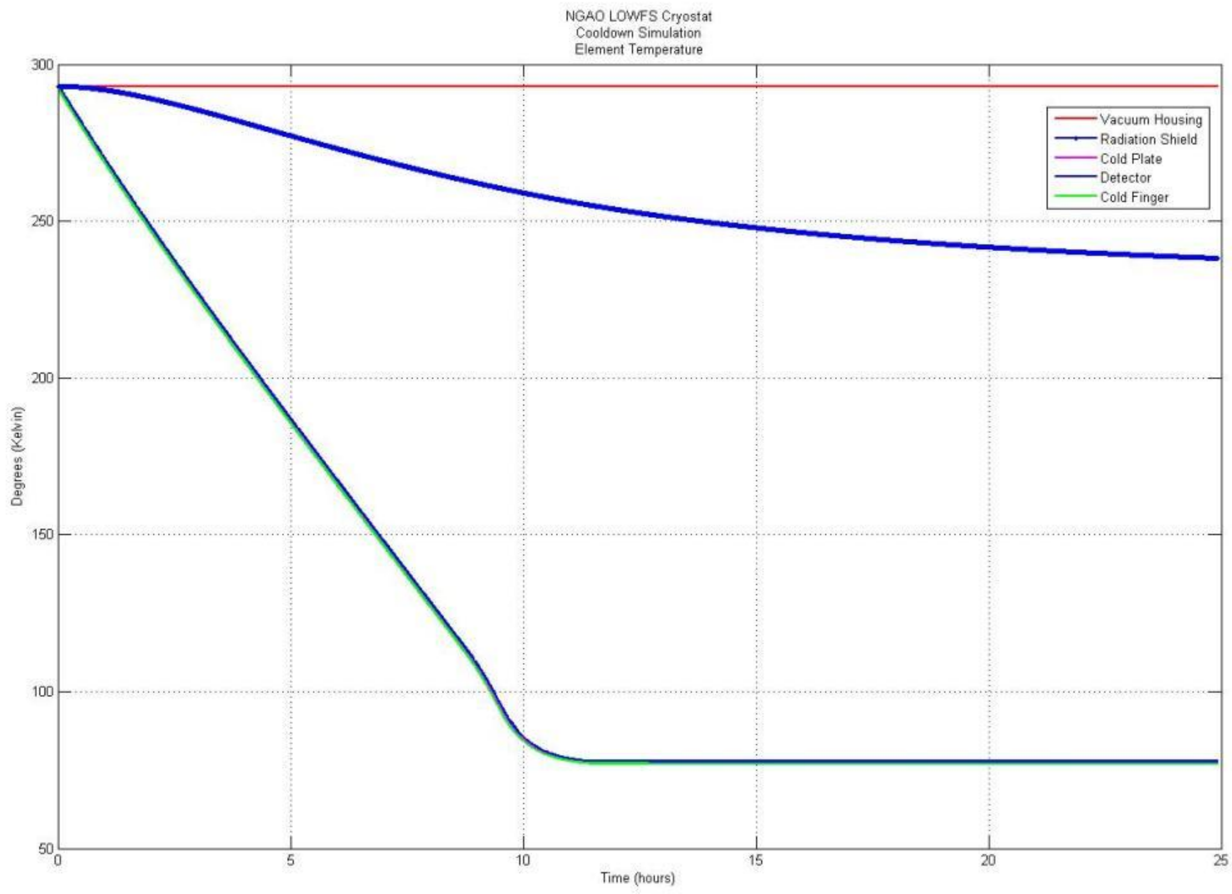
Thermal Analysis Results

- Initially modeled 2 cables to detector as printed copper foil on kapton 0.005 inch thick by 0.800 inch wide by 7 inch long each.
- Conduction heat flow was significant at 2.35 watts.
- With copper
  – Heater controller set temp: 83◦K
  – Total load on cryo-cooler: 4.1 watts
  – Detector heating: 0.25 watts
  – Heater load: 0.35 watt
  – Radiation heat transfer: approximately 1.1 watt
  – Conduction electrical wires: 2.35 watt
  – Conduction other: 0.07 watt

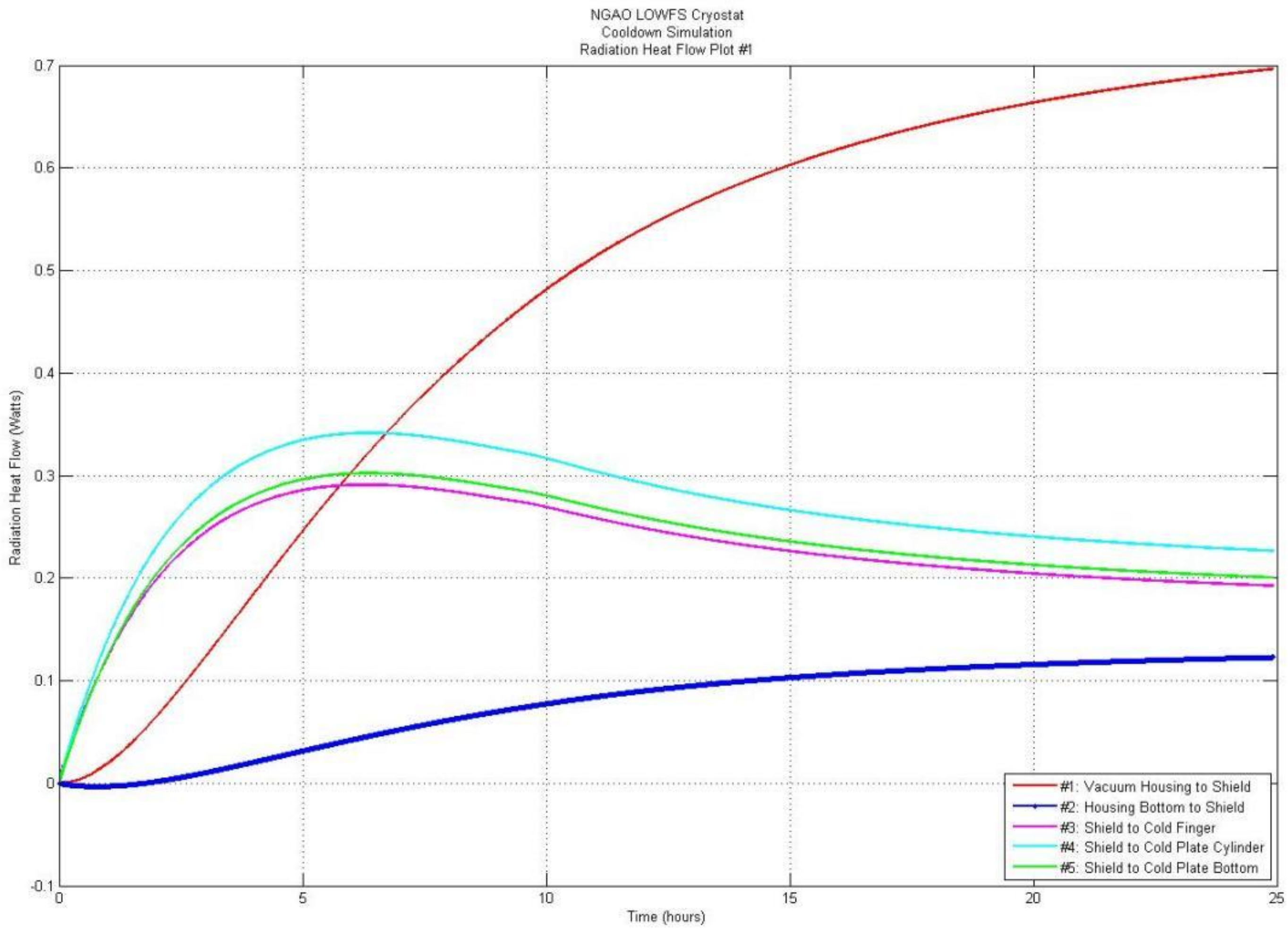
Thermal Analysis Results

- Subsequently modeled 2 cables to detector as printed phosphor-bronze foil on kapton 0.005 inch thick by 0.800 inch wide by 7 inch long each. Need to insulate cables from thermal shield.
- With phosphor-bronze
  - Heater controller set temp: 78°K
  - Total load on cryo-cooler: 2.2 watts
  - Detector heating: 0.25 watts
  - Heater load: 0.54 watt
  - Radiation heat transfer: approximately 1.1 watt
  - Conduction electrical wires: 0.19 watt
  - Conduction other: 0.07 watt
  - Time to cool down: Approximately 12 hours

Thermal Analysis Results



Thermal Analysis Results



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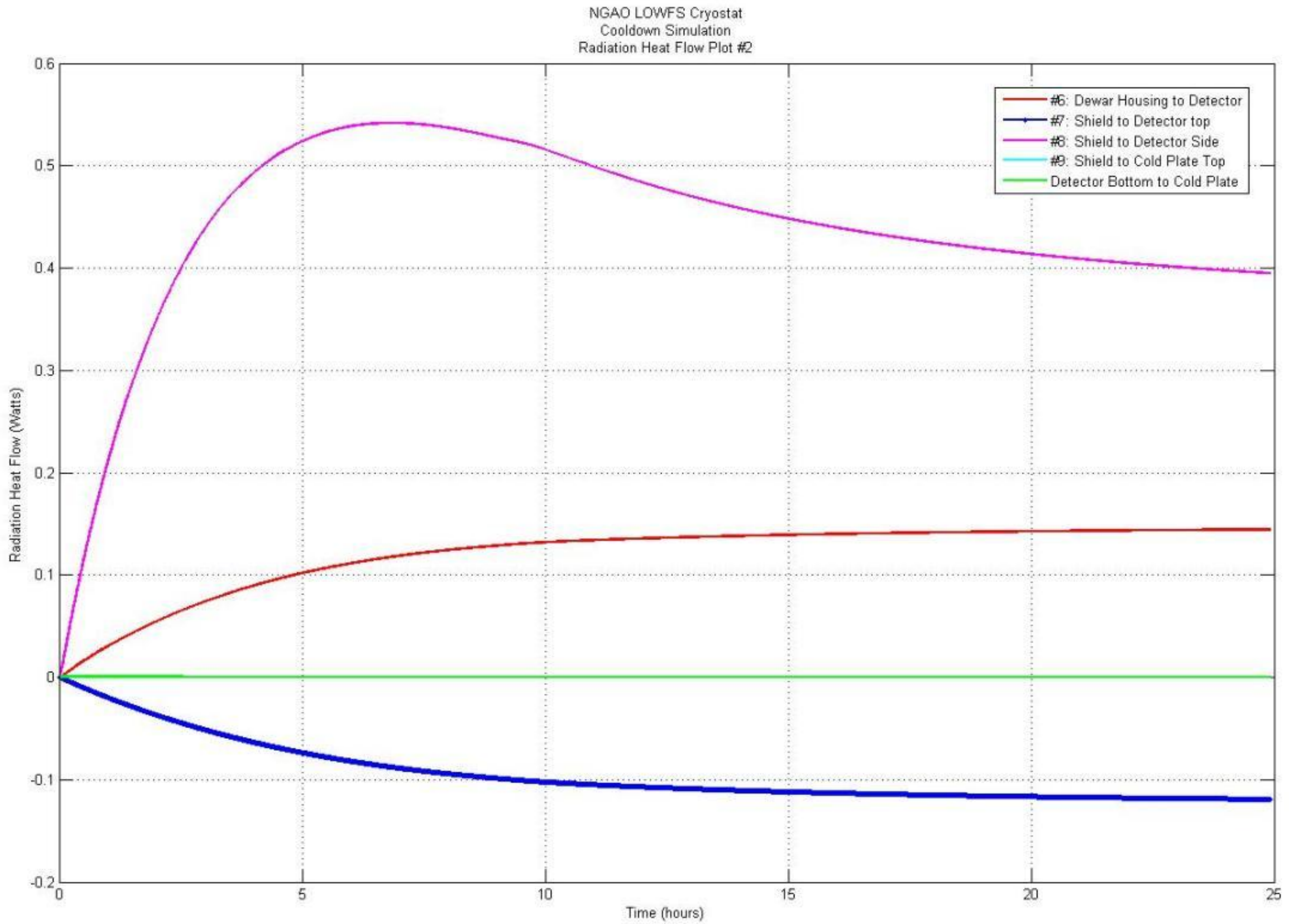

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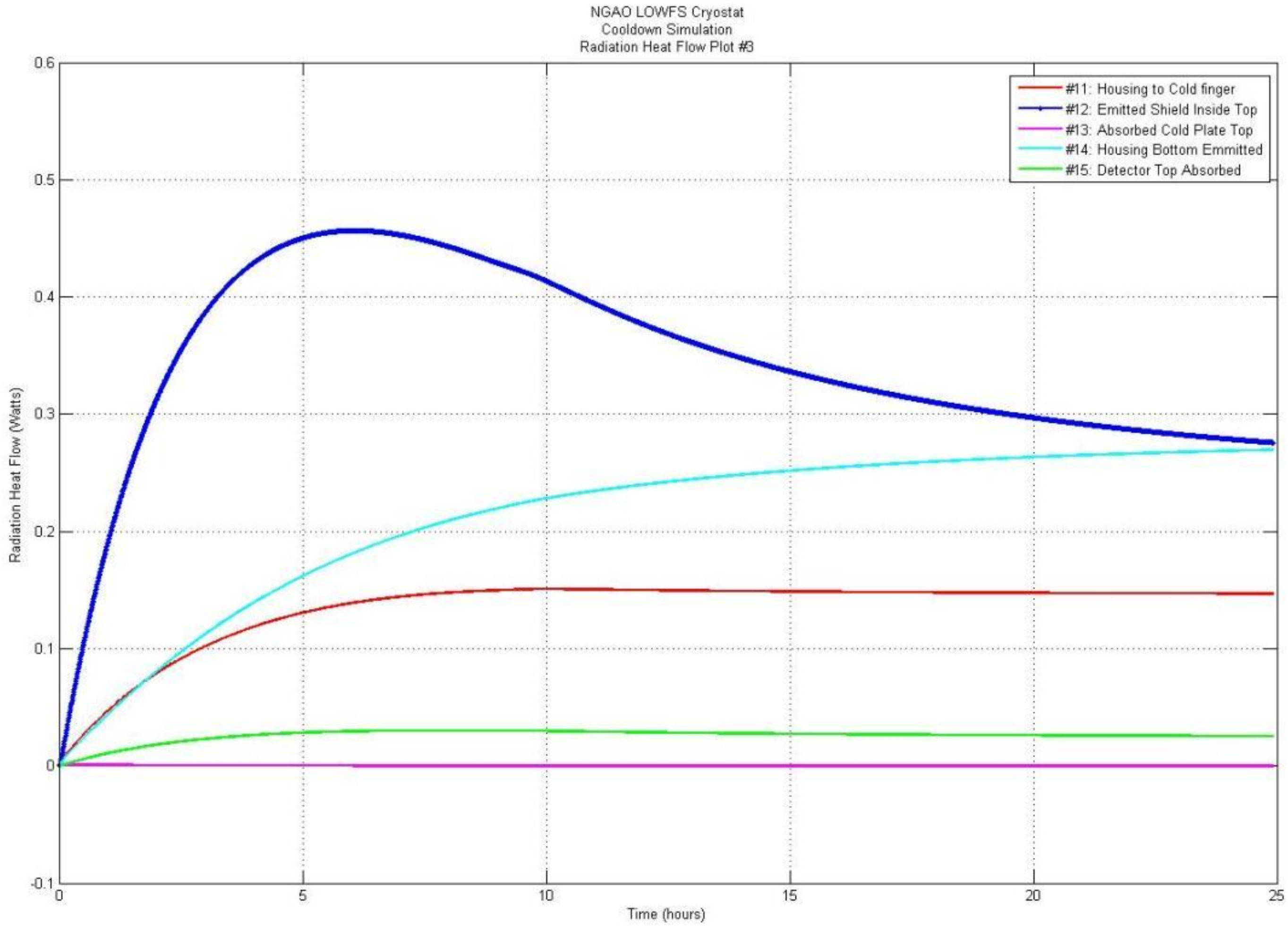
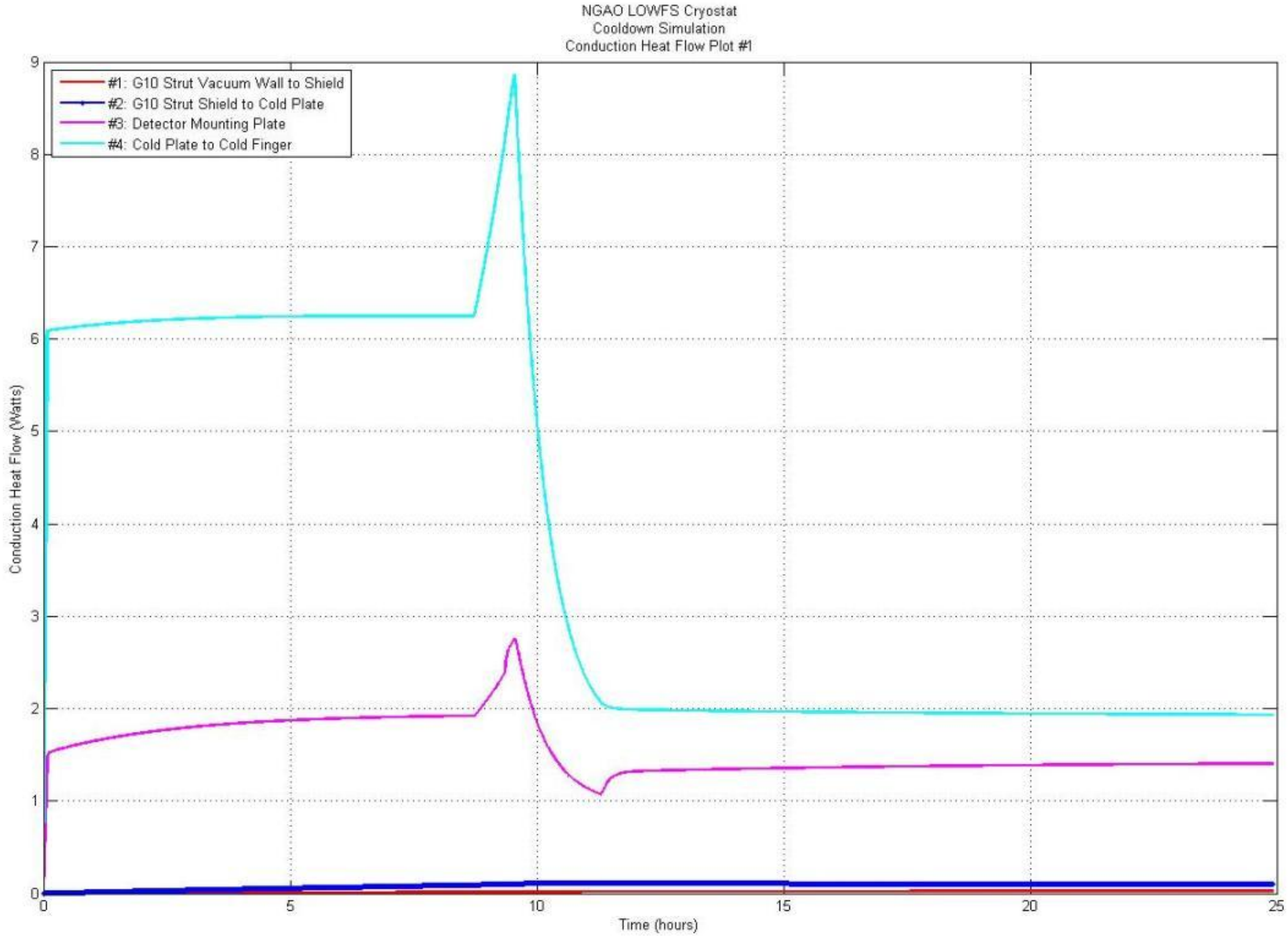
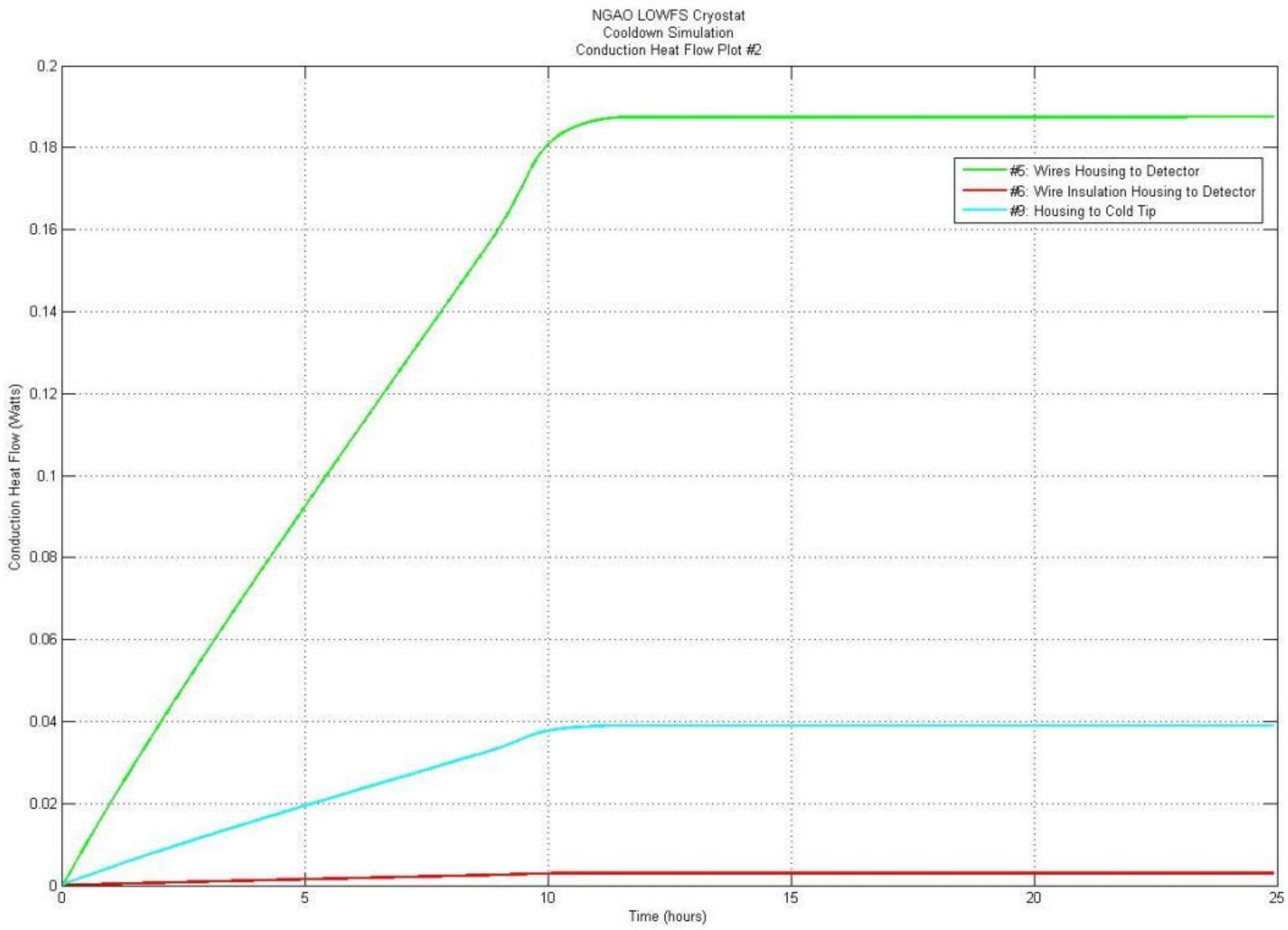


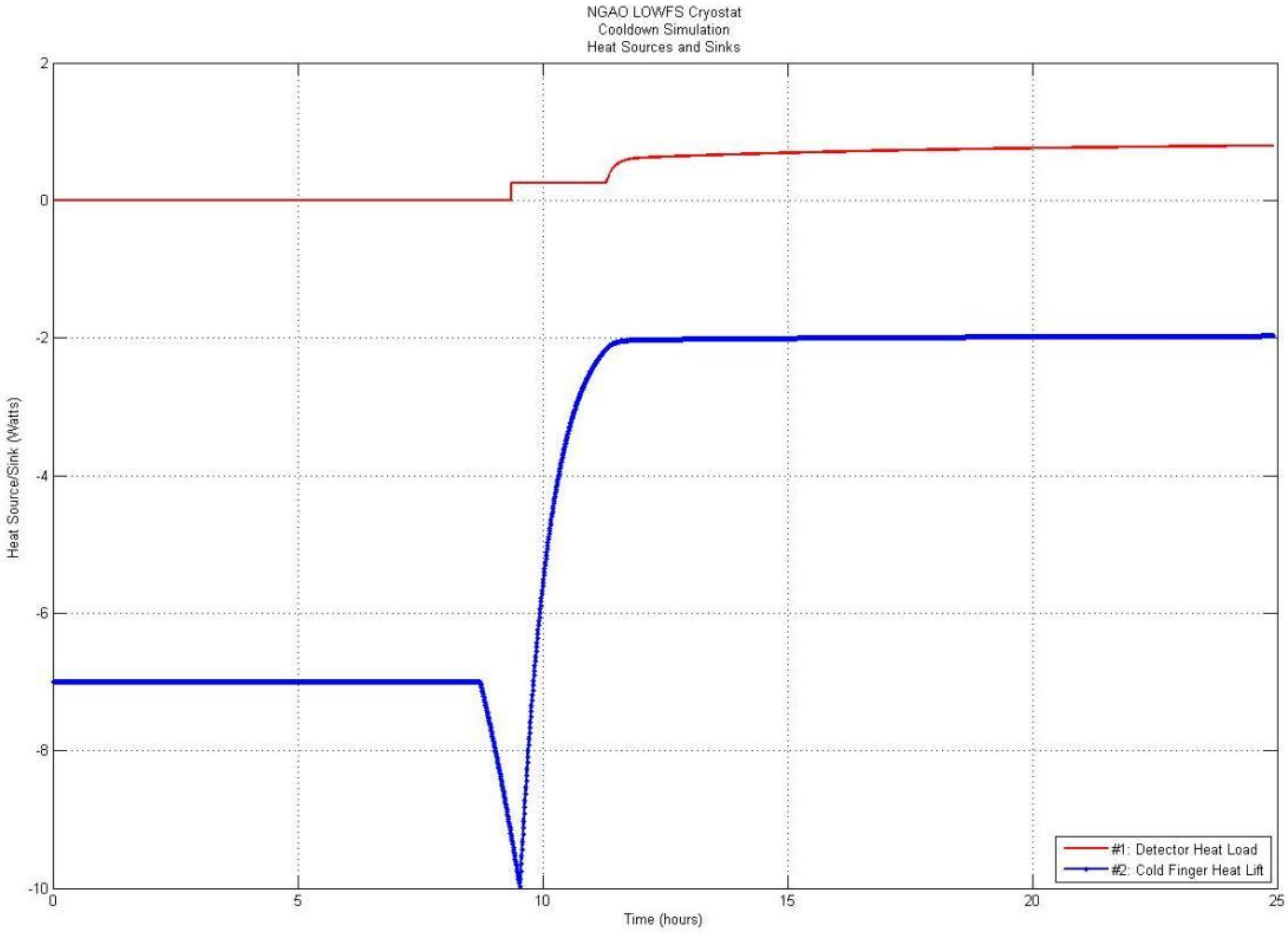
Thermal Analysis Results



Thermal Analysis Results



Thermal Analysis Results

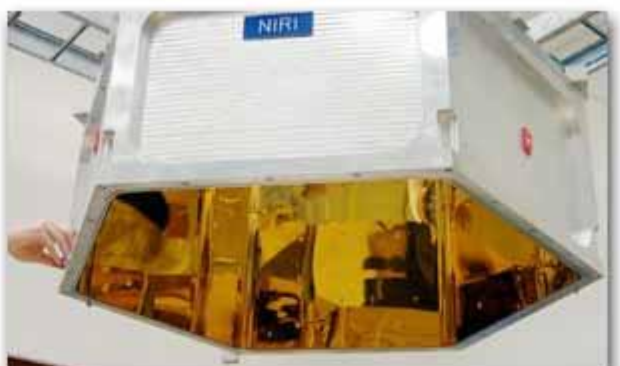


Radiation Shield and Surface Coatings

- Radiation shield was used to reduce radiation heat transfer.
- Internal Cryostat surfaces not directly seen by the detector surface shall be coated with electroless nickel plating and Epner Gold low emissivity coating.
  - Aluminum and Beryllium Substrates:
    Typically, aluminum and beryllium substrates are coated with .004”-.008” optical grade electroless nickel-phosphorus prior to imparting the final optical figure and subsequent Laser Gold plating. Epner Technology is presently researching techniques that will eliminate the heavy nickel, i.e gold direct on the diamond turned or polished surface. Stay Tuned.
  - Simplified Basic Specification:
    “Gold coat per Epner Technology, Brooklyn, New York Laser Gold specification #2011”. With this call out your parts will be plated with a .25 micron of Laser Gold. This assumes the component will be received at Epner ready for Laser Gold plating that is in nickel or copper or stainless steel. No polishing at Epner is anticipated.
  - More Detailed Specification:
    Electrochemically deposited gold. Total reflectivity shall be equal to or greater than 97% at 0.7 microns when measured on a Perkin-Elmer Lambda 750 Spectrophotometer with integrating sphere or equivalent. The spectrophotometer must be calibrated against an NIST infrared standard #2011. A suitably prepared witness sample plated concurrently with the product may substitute for direct measurement when applicable. Hardness shall be minimum 180 Knoop when measured by the diamond indented method of ASTM-B-578-87.

Epner Gold Coating

- Emissivity less than 0.05
- Gemini Near IR Imager:
  Laser Gold helps cryostat keep it's cool. Almost 3.5 sq. Meters of stainless steel heatshield surface was coated with 2.5 microns of Laser Gold, a pure, hard electroplated gold that exhibits the theoretically low emissivity of that precious metal.
  On highly polished panels, Laser Gold produces the low emissivty that minimizes the thermal heat transfer from the vacuum jacket to the cryogenic work surfaces.



Laser Gold: Material Comparison Emissivity Data

Subject: Low Emissivity Gold Plating Vendor Qualification Test Results
Targeting Hemispherical Emissivity of < 0.04

Substrate	Epner Emissivity (Hem)	Company B Emissivity (Hem)	Company C Emissivity (Hem)
1100 Al - Side A	0.023	0.027	0.036
1100 Al - Side B	0.017	0.030	0.036
1100 Al - Side A		0.031	
1100 Al - Side B		0.034	
Average	0.02	0.0305	0.036
6061-T6 AL - Side A	0.021	0.018	0.021
6061-T6 AL - Side B	0.014	0.018	0.021
6061-T6 AL - Side A		0.027	
6061-T6 AL - Side **B**		0.021	

Black Coating

- Surfaces that can be seen directly by the detector surface will be coated with black coating: Aeroglaze Z306 paint .

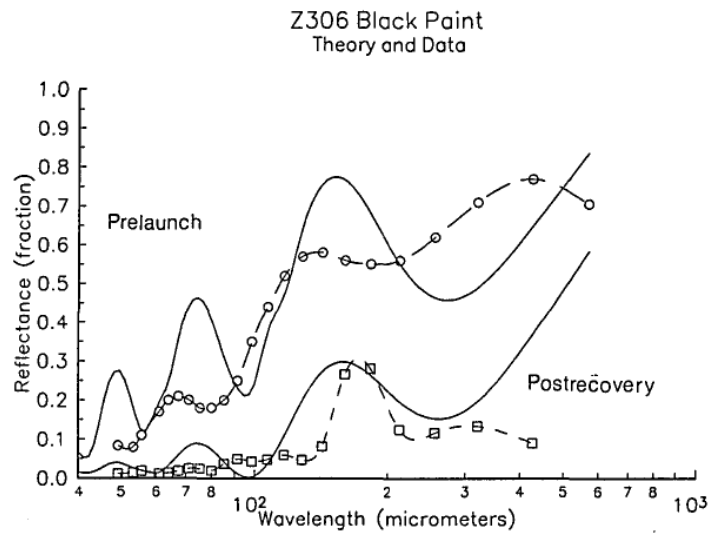
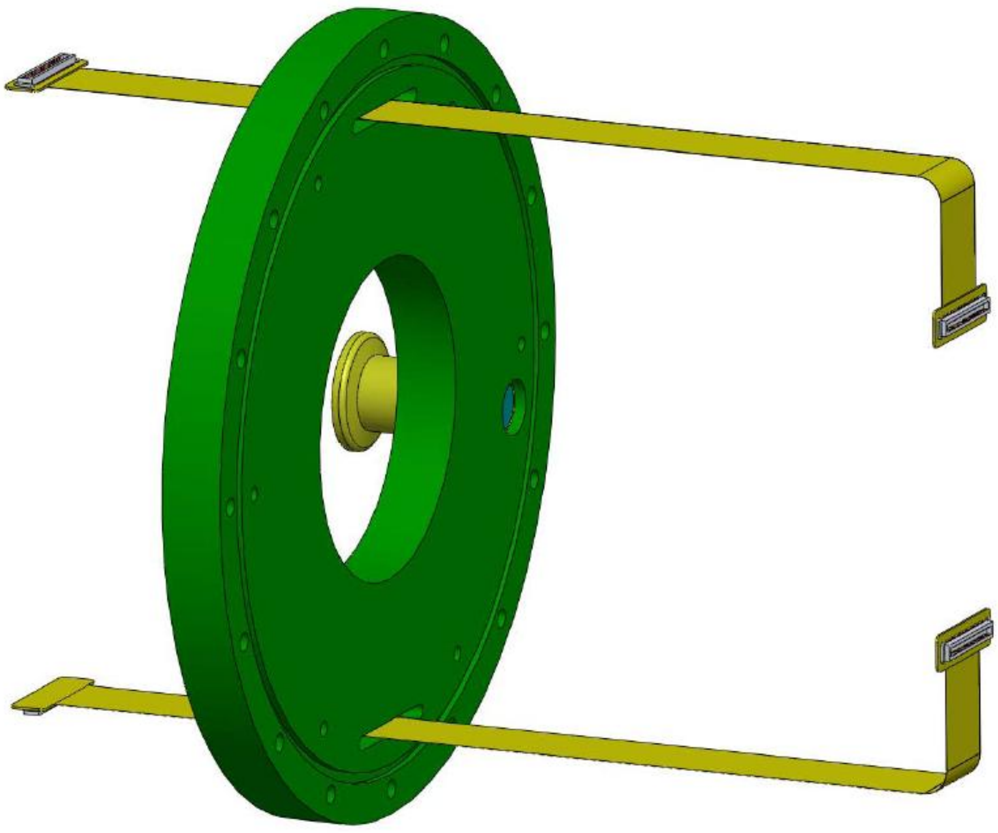


Fig. 11. Comparison between reflectance data (dashed curves) for sample Z-306 and reflectance calculated by using the model of Smith[8] (solid curves). The calculations use increased absorption for postrecovery data. The left-hand side pair of curves represent prelaunch data; the right-hand side pair of curves represent postrecovery data. See text for details.

CRYOSTAT ASSEMBLY SEQUENCE



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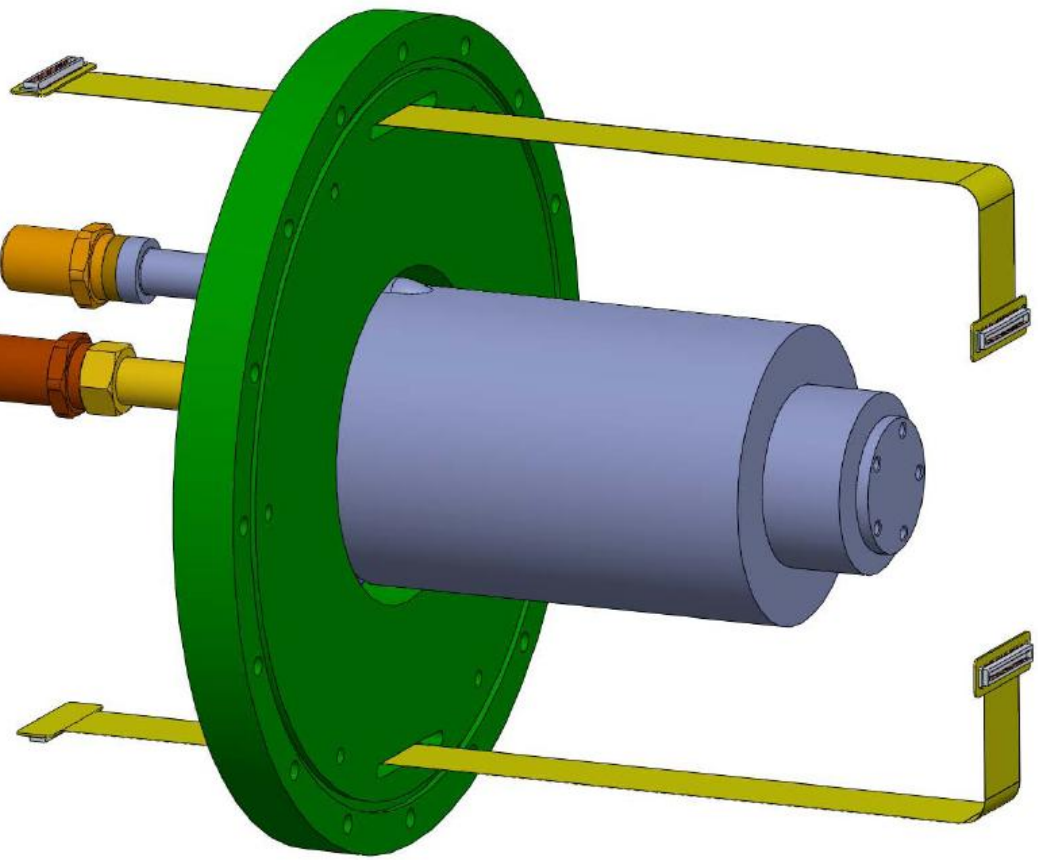
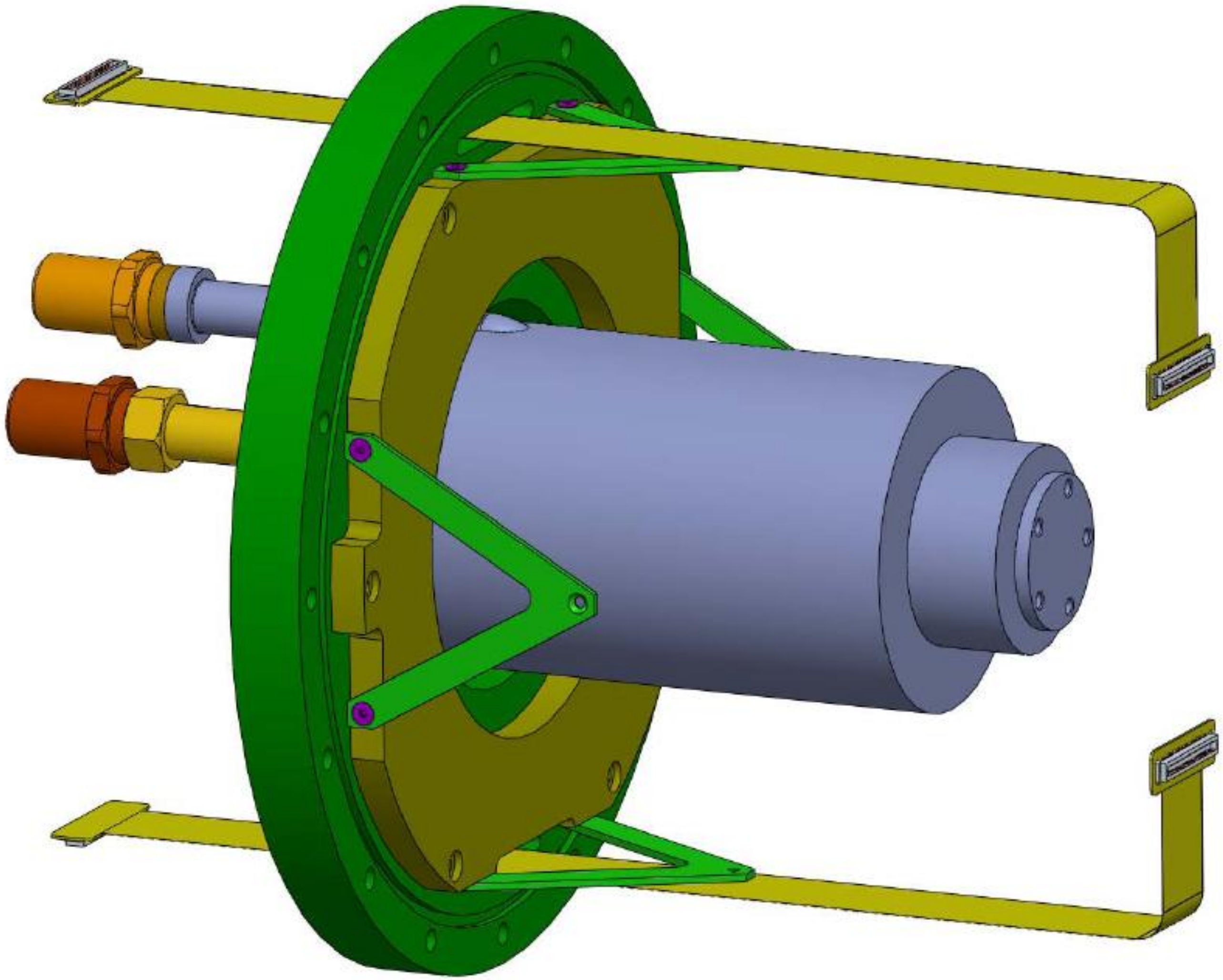


CRYOSTAT ASSEMBLY SEQUENCE



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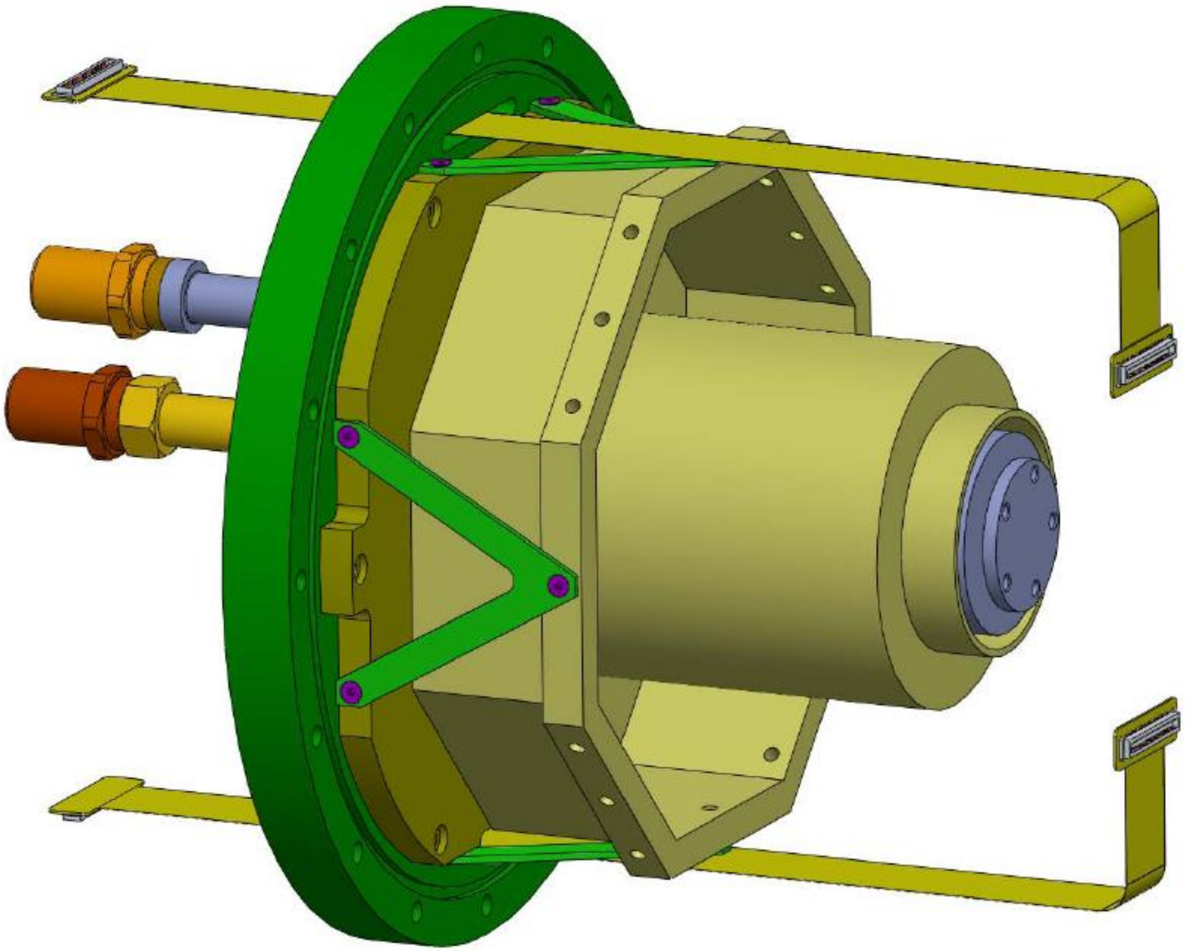

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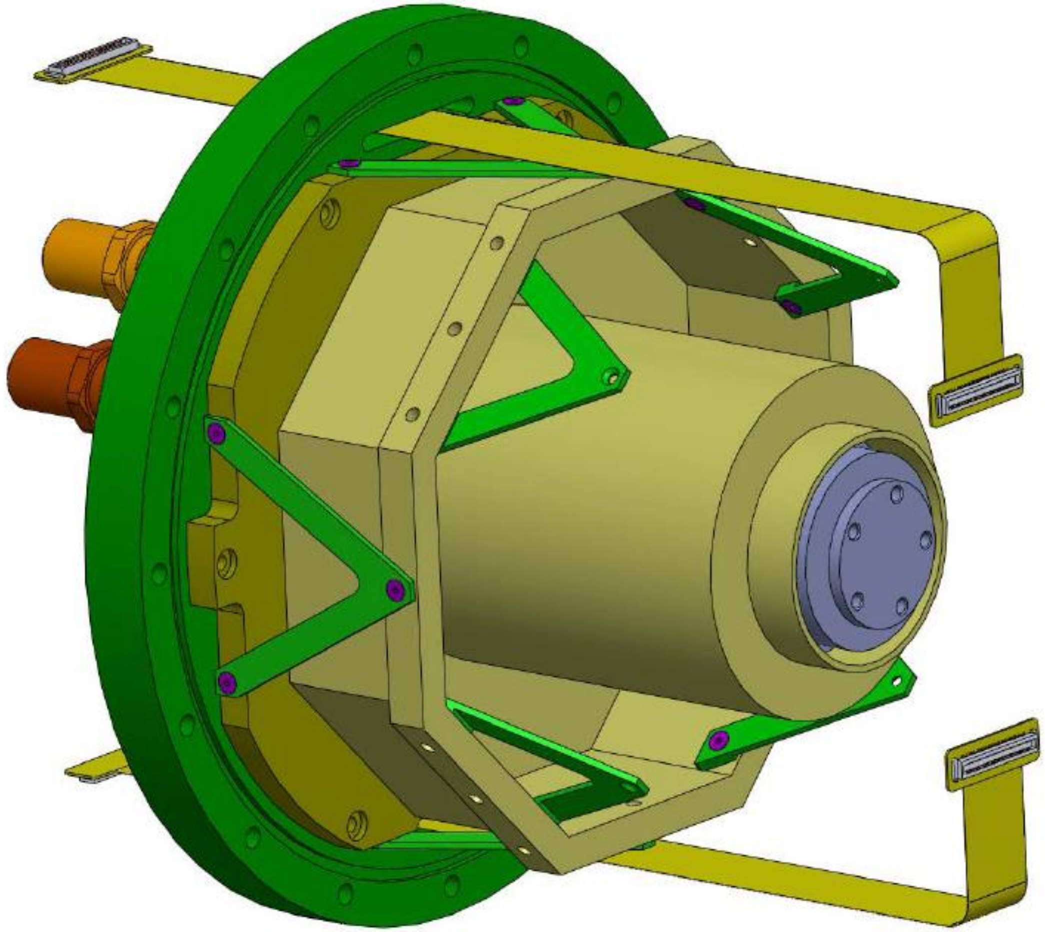

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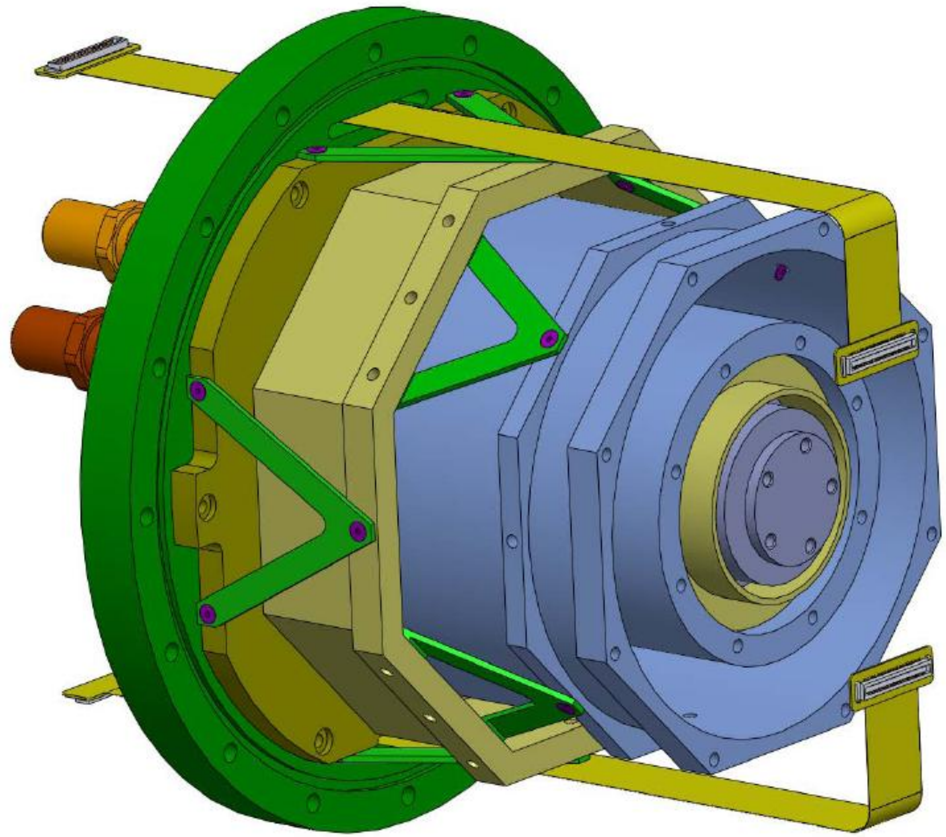

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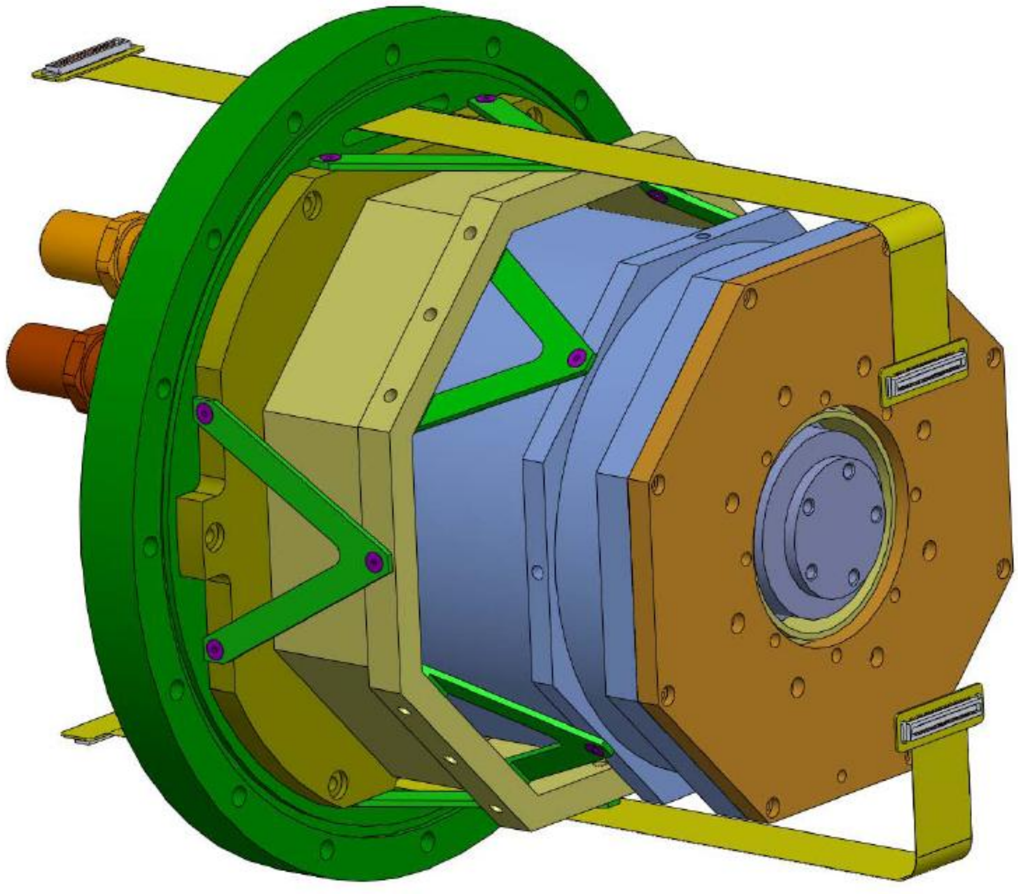

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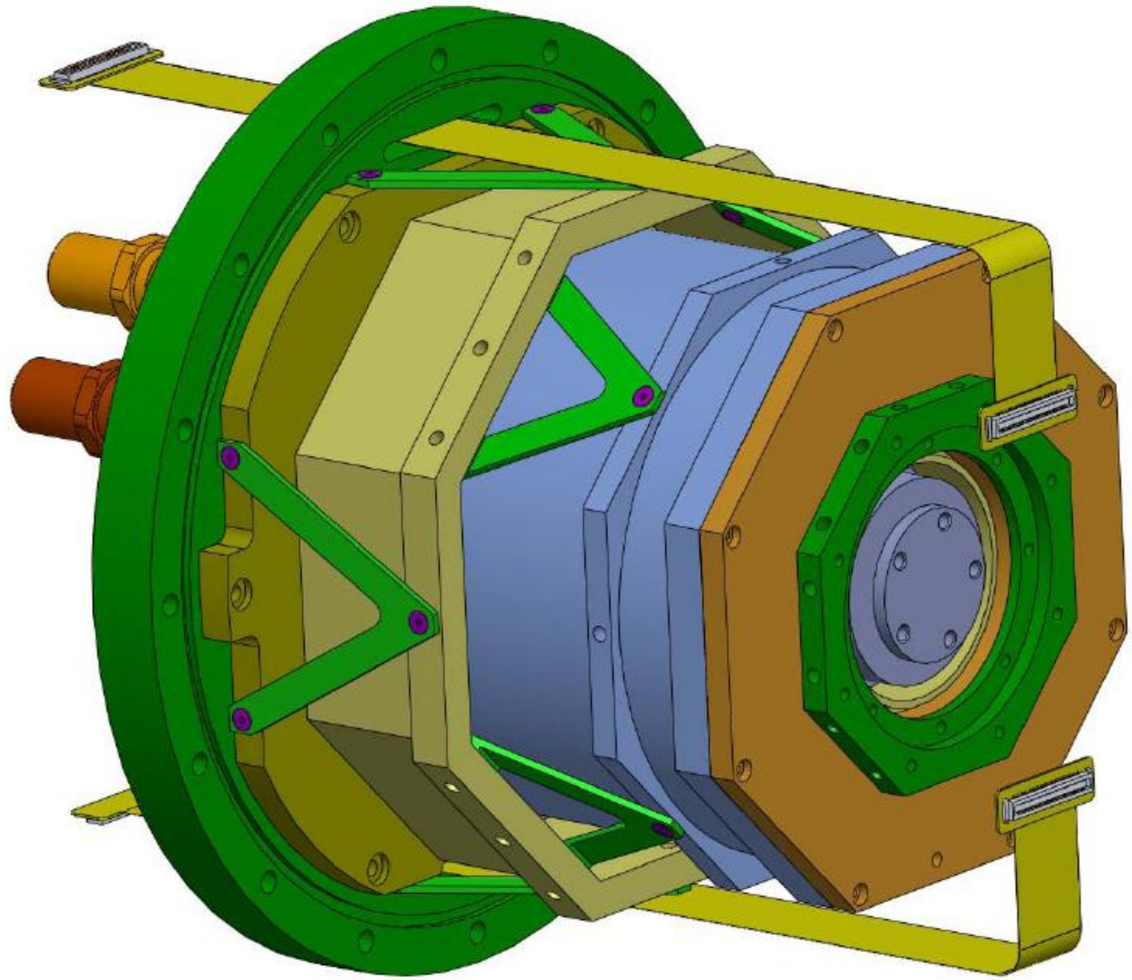

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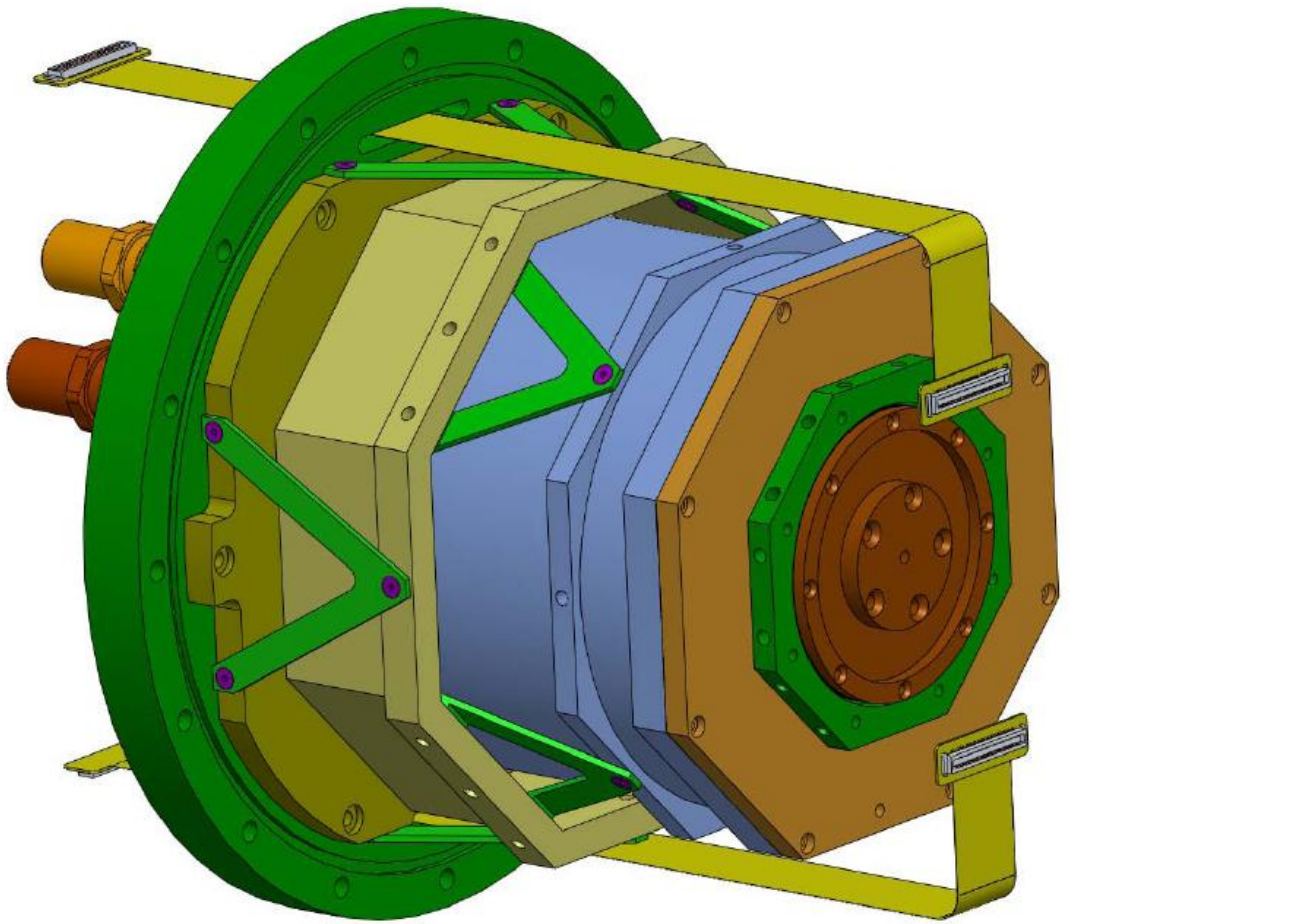

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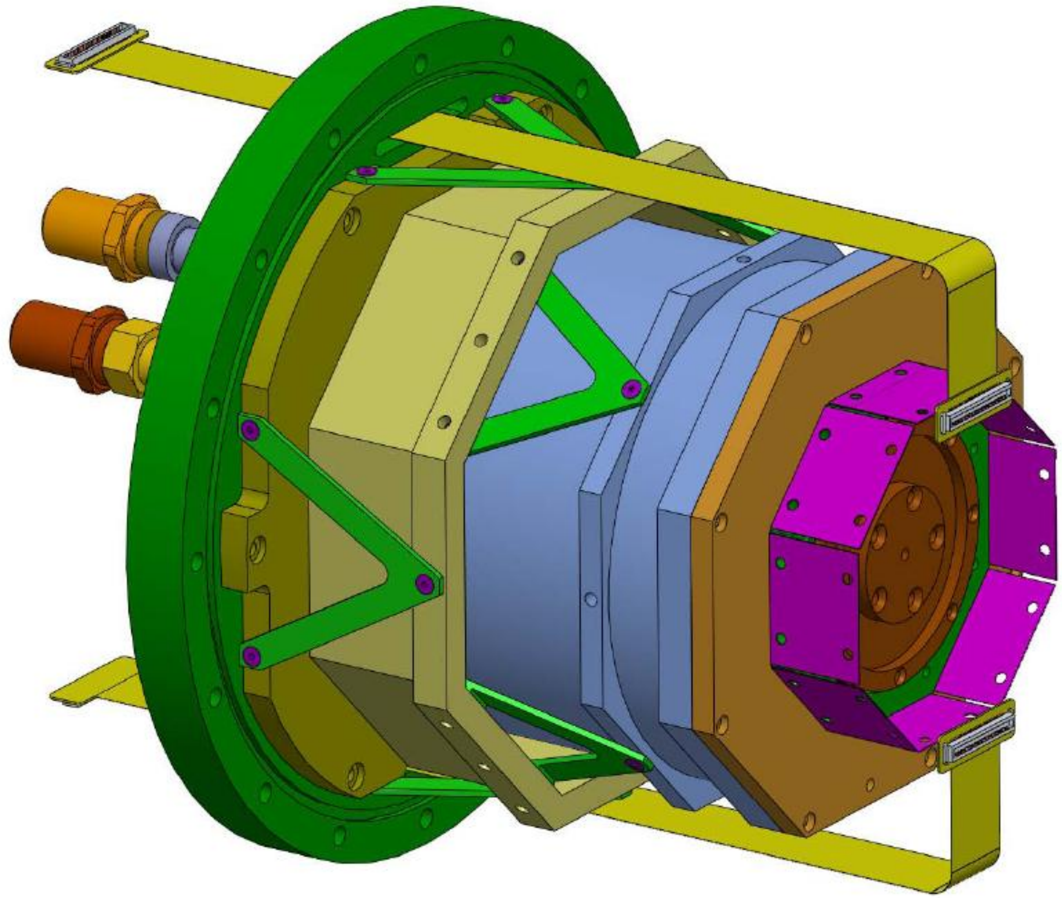

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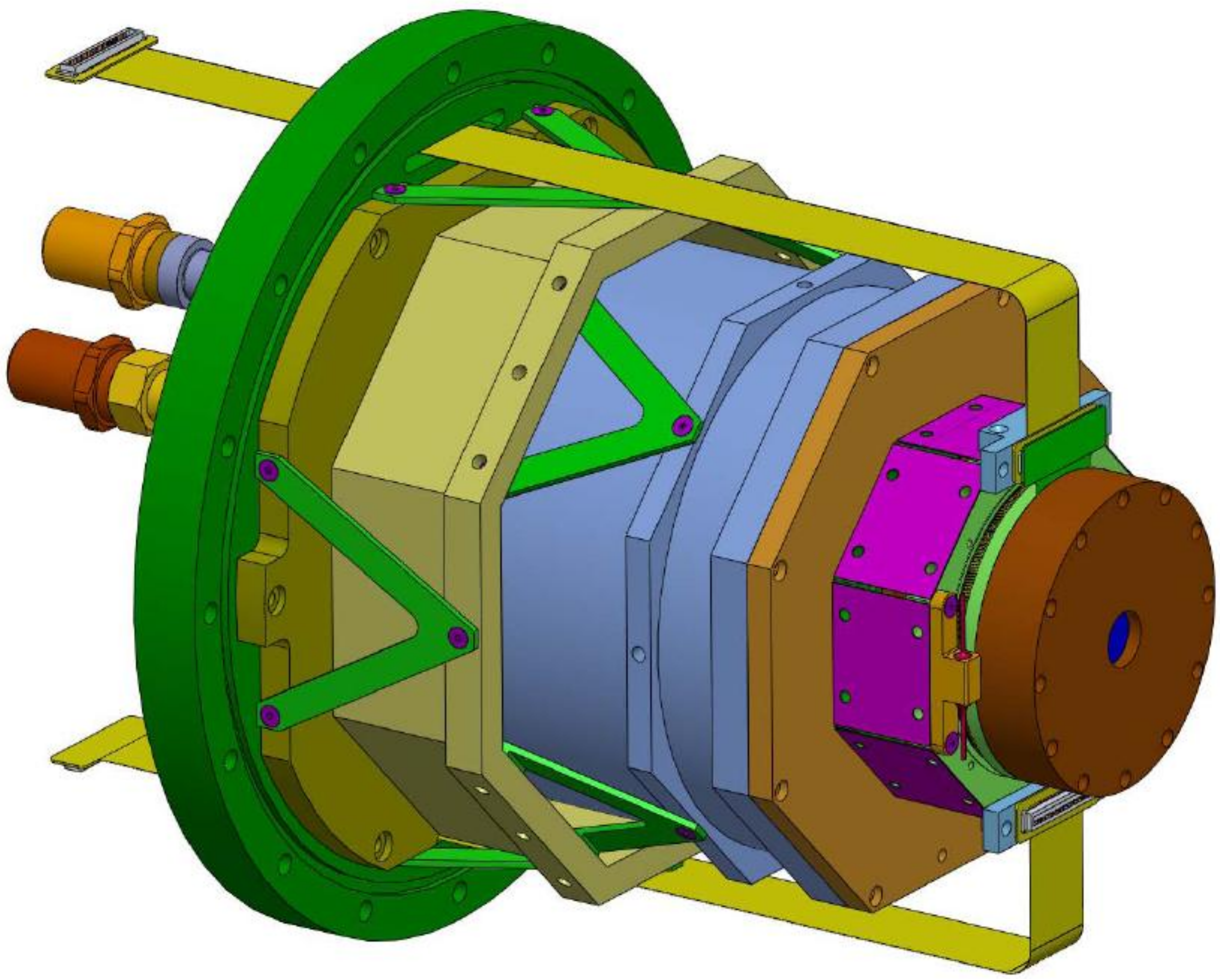

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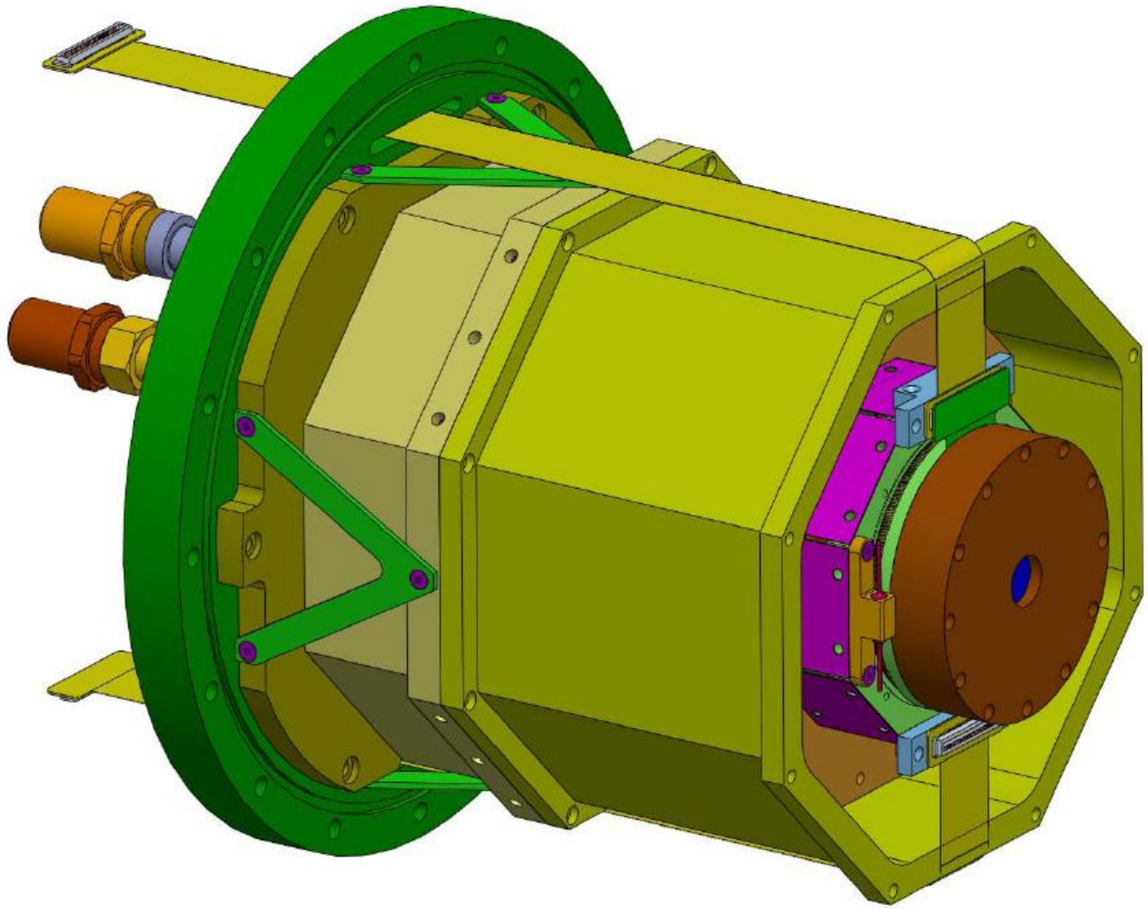

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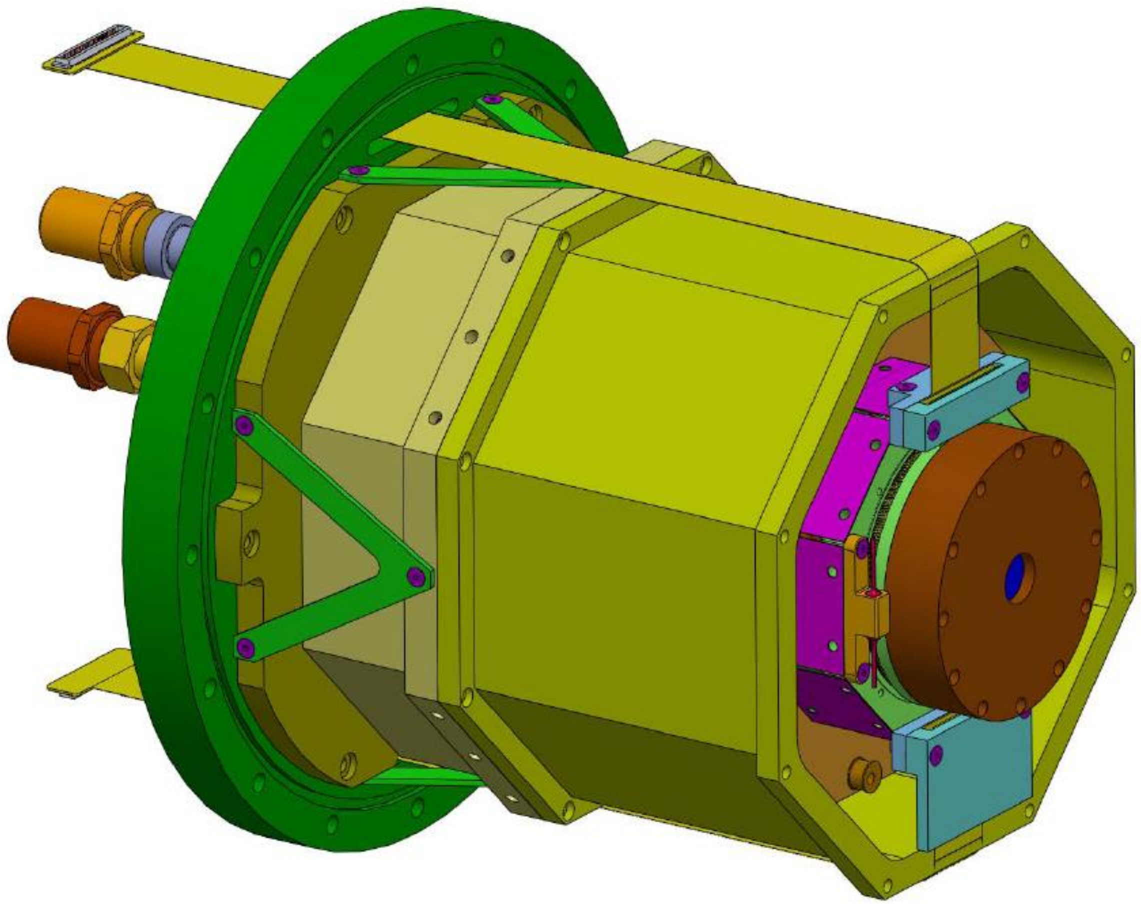

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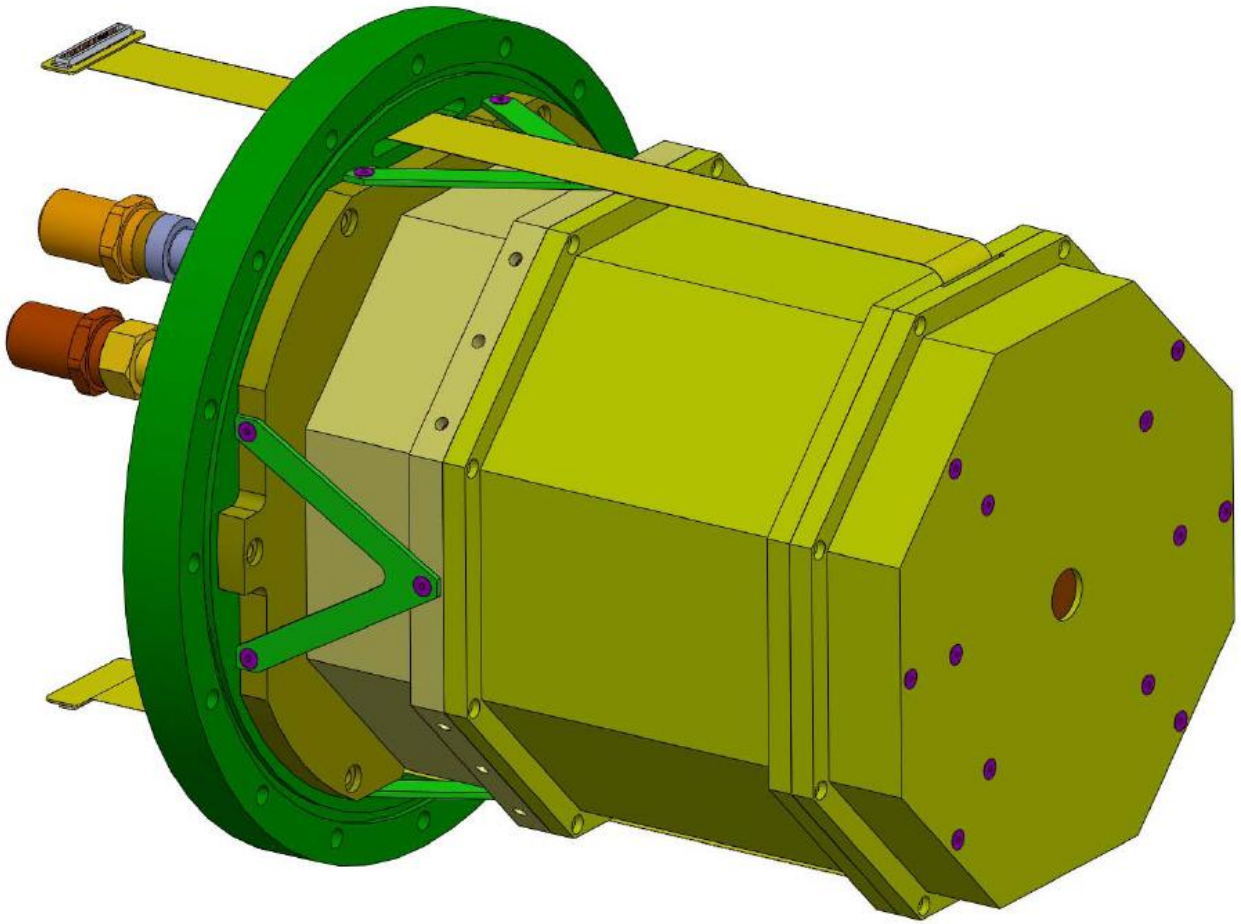

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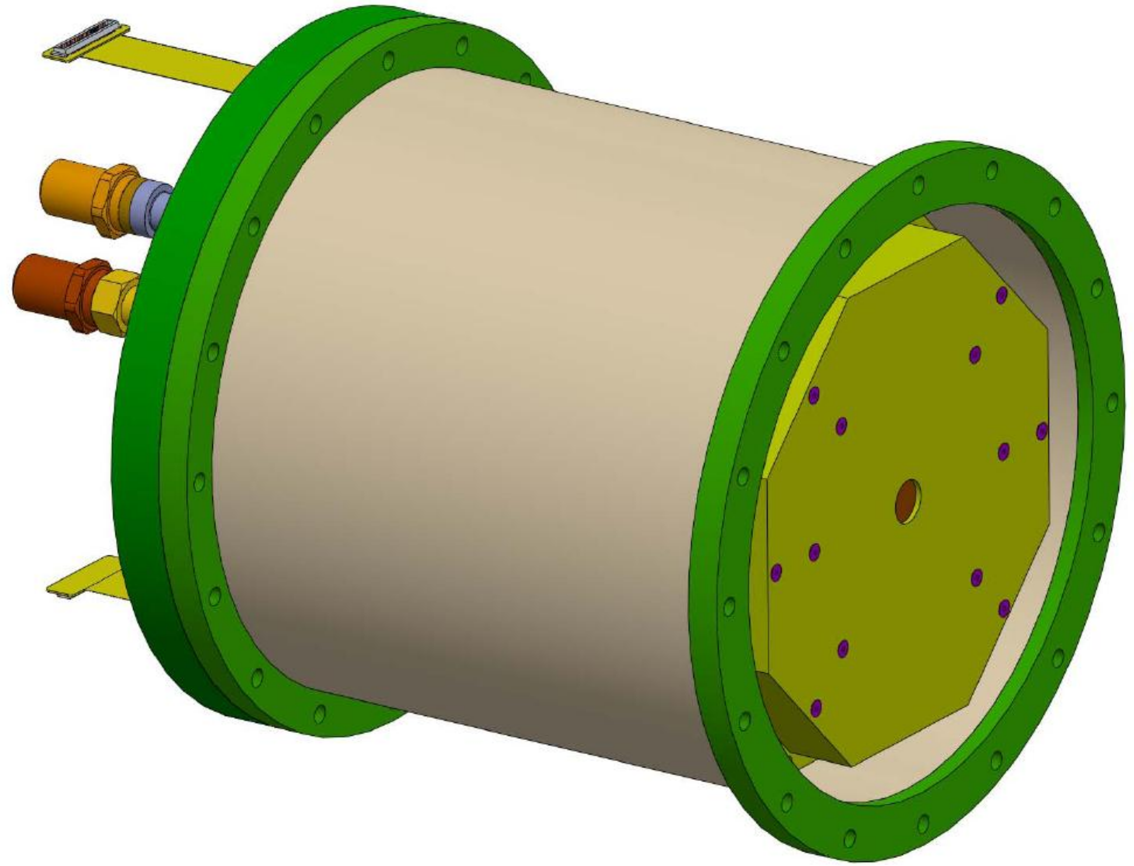

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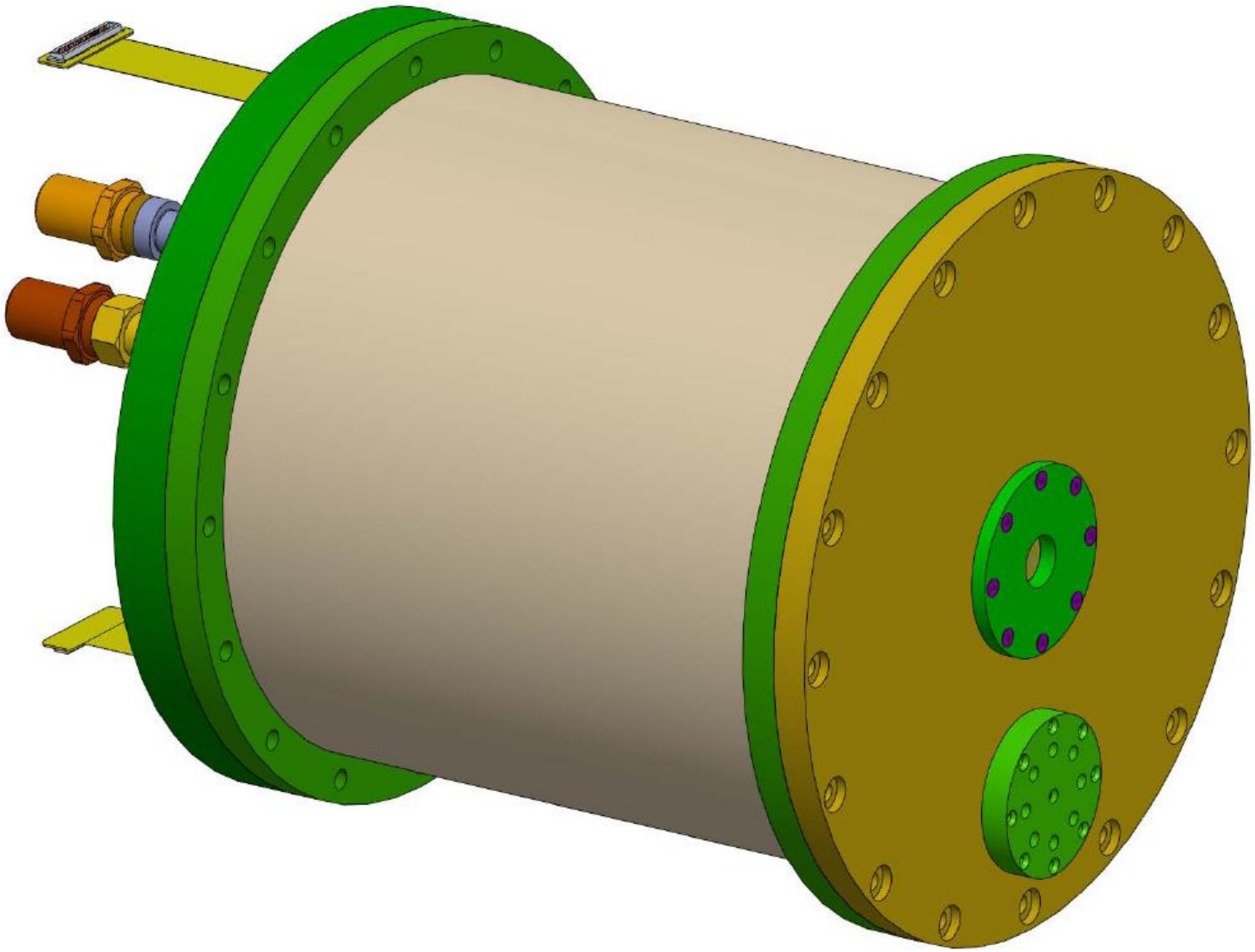
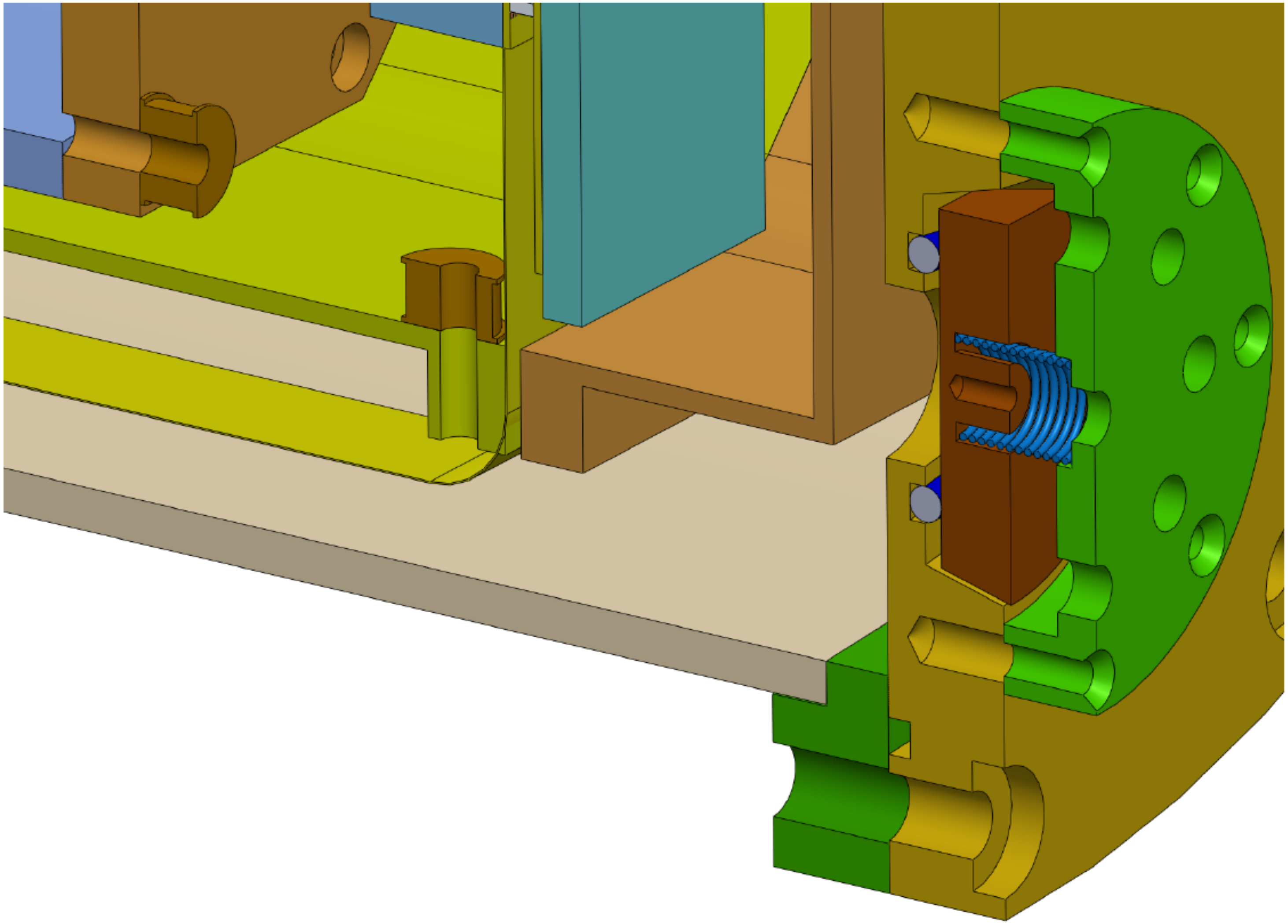
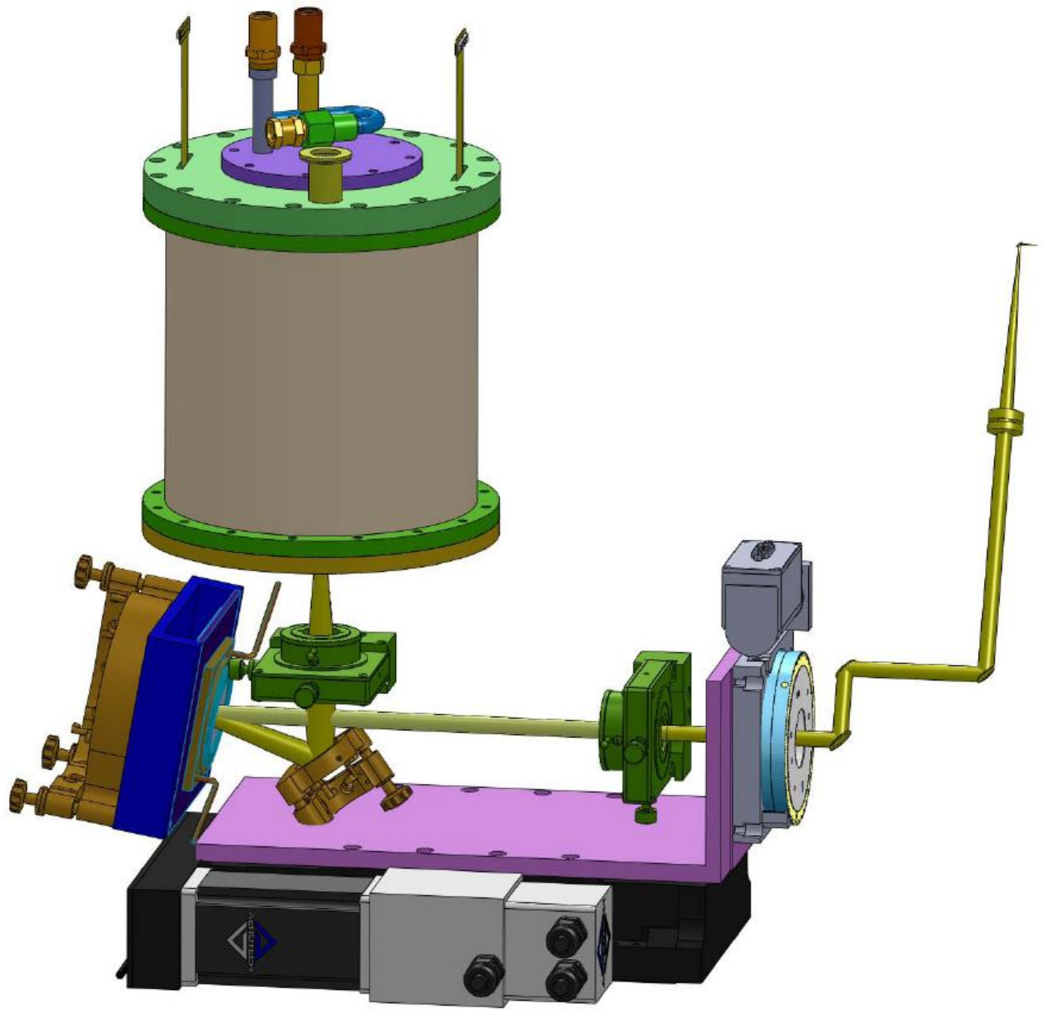


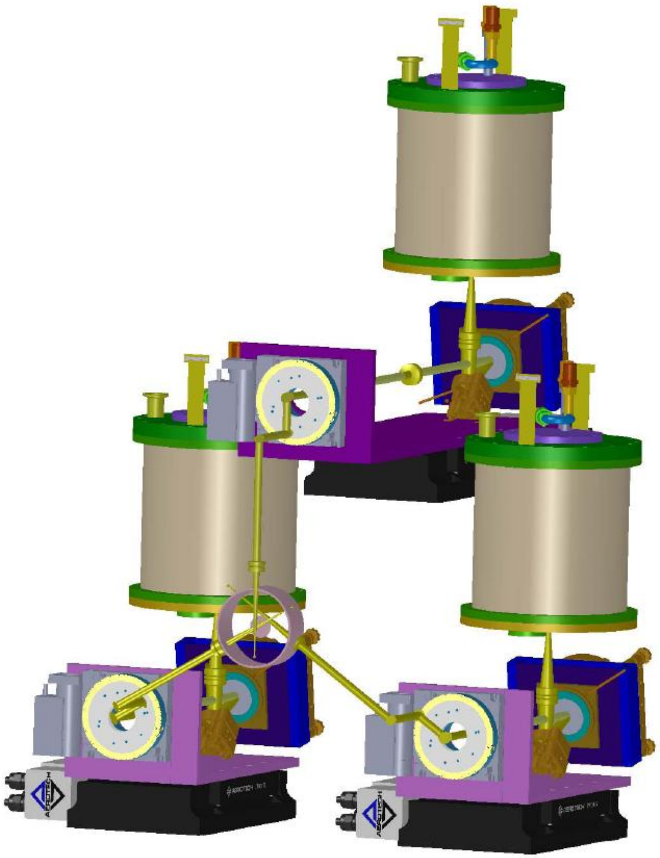
Safety
Pressure Relief Valve

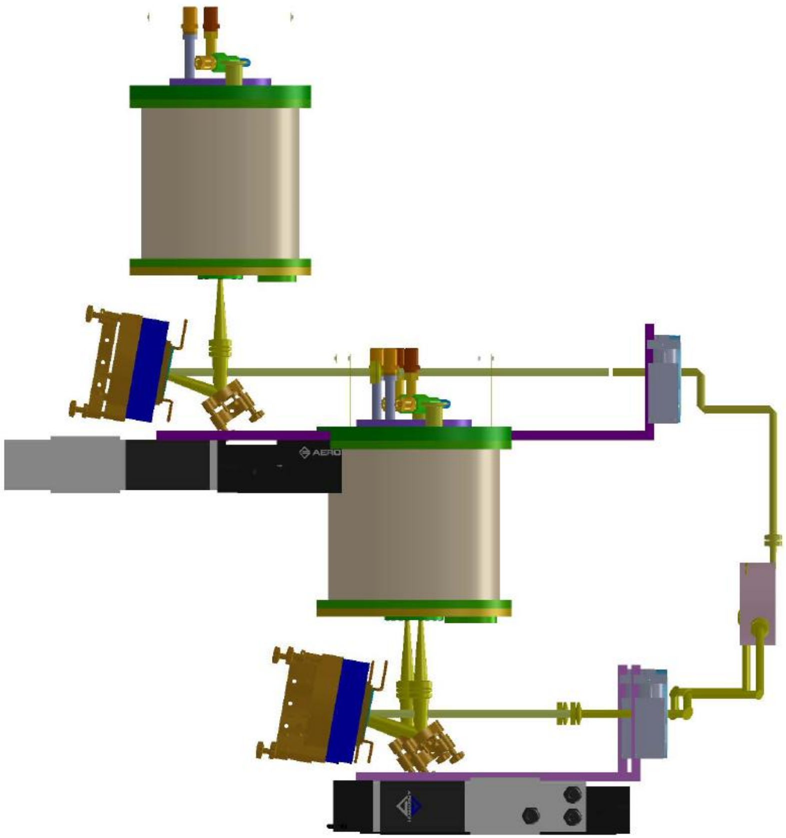


Opto-Mechanical LOWFS Mounting

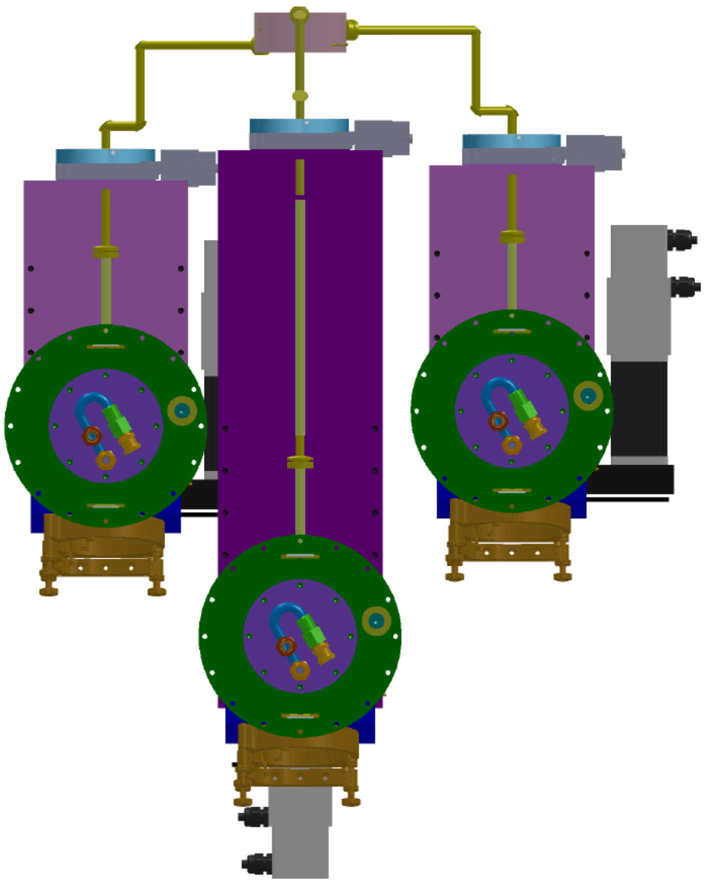


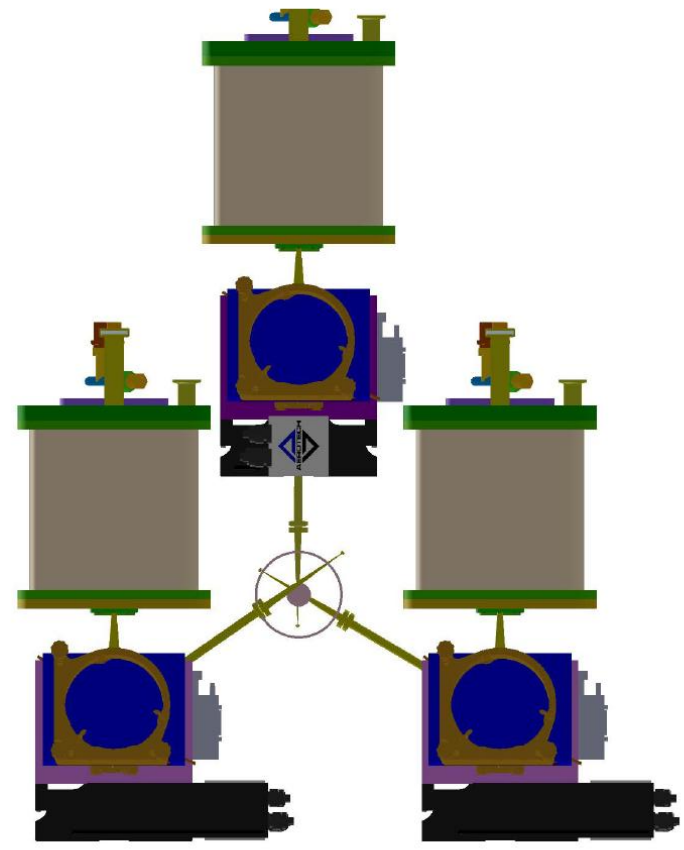
Opto-Mechanical LOWFS Mounting





Opto-Mechanical LOWFS Mounting



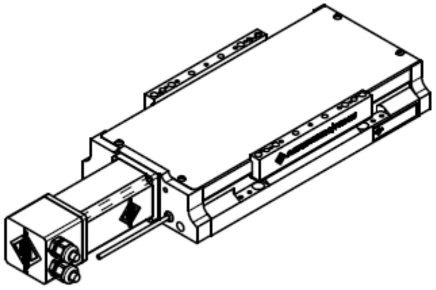


Opto-Mechanical LOWFS Mounting

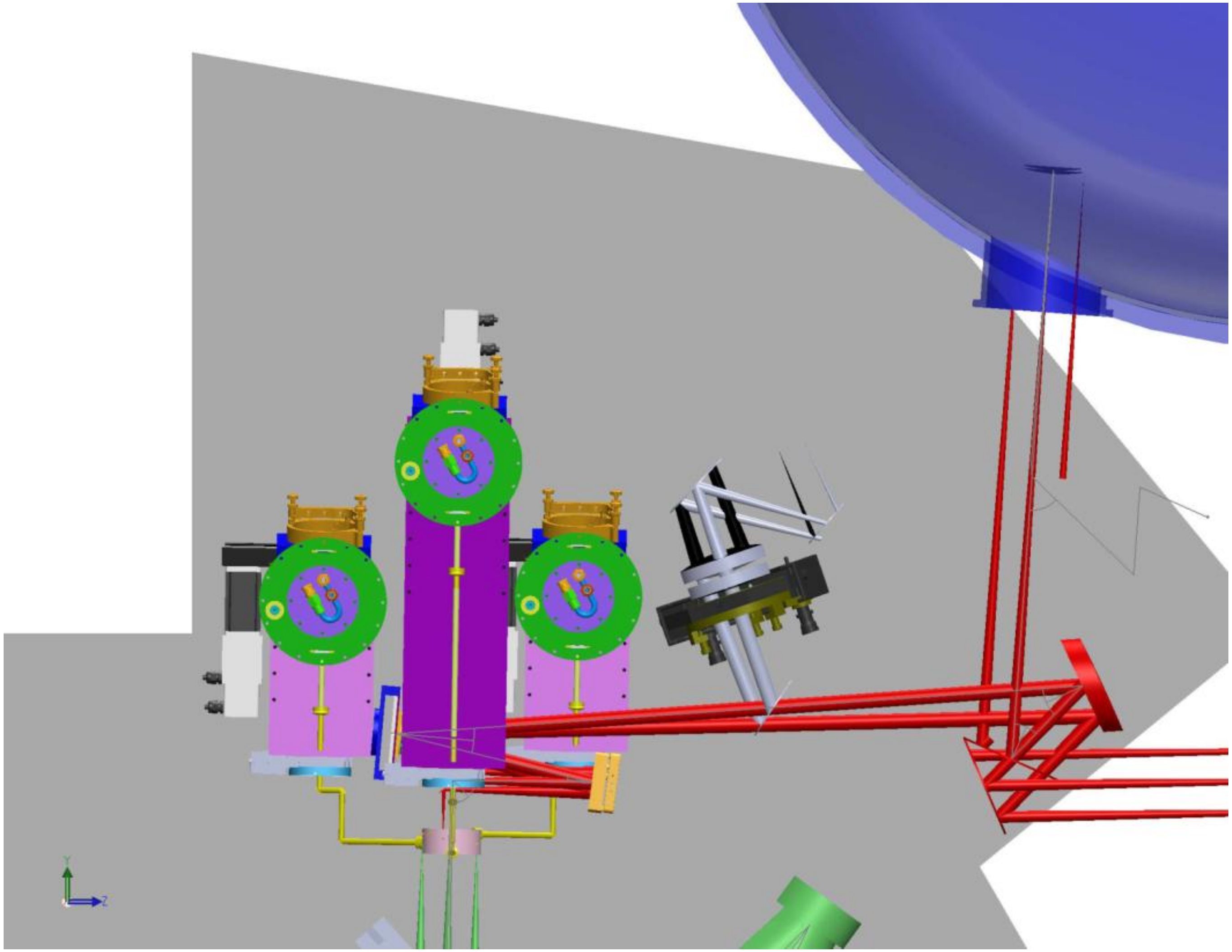
- Would like to use off the shelf stage to position LOWFS components.
- Compact, easy to implement, reduced cost risk (ie cost of stage well defined)
- Aerotech PRO165-50 stage Budgetary cost $6500 each + 2000 for controller & cables each

Basic Model		PRO165-50	PRO165-100	PRO165-150	PRO165-200	PRO165-250
Total Travel		50 mm	100 mm	150 mm	200 mm	250 mm
Drive System		Precision Ball Screw/Brushless Servomotor (BMS100-A-D25-E2500H)				
Bus Voltage		Up to 160 VDC				
Continuous Current	A_{pk}	Up to 2.1 A				
	A_{rms}	Up to 1.5 A				
Feedback		Noncontact Rotary Encoder (2500 line)				
Resolution	5 mm/rev lead	0.5 µm with 2500 line Quadrature Encoder				
Maximum Travel Speed(1)	5 mm/rev lead	300 mm/s (12 in/s)				
Maximum Load(2)	Horizontal	45 kg				
	Vertical	25 kg				
	Side	45 kg				
Accuracy	5 mm/rev lead	±6 µm	±6 µm	±8 µm	±8 µm	±8 µm
Bidirectional Repeatability	5 mm/rev lead	±1 µm				
Straightness and Flatness		3 µm	5 µm	6 µm	10 µm	10 µm
Nominal Stage Weight	With Motor	7.3 kg (16.0 lb)	7.9 kg (17.4 lb)	8.5 kg (18.7 lb)	9.0 kg (19.8 lb)	9.6 kg (21.1 lb)
	Less Motor	5.8 kg (12.8 lb)	6.4 kg (14.1 lb)	7.0 kg (15.4 lb)	7.5 kg (16.5 lb)	8.1 kg (17.8 lb)
Construction		Black Anodized Aluminum Body with Hardcoated Tabletop				

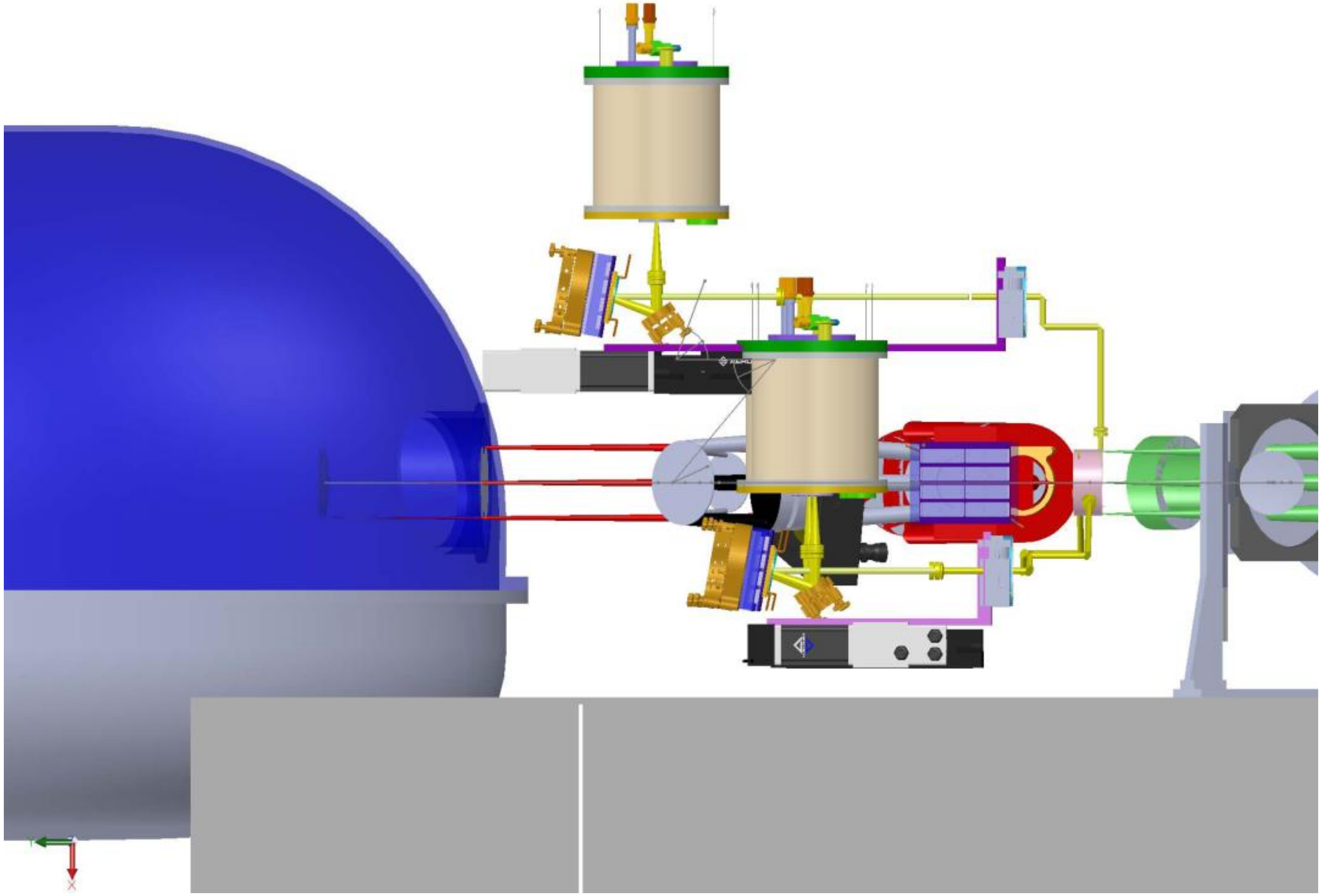
Notes:
1. Excessive duty cycle may impact stage accuracy.
2. Payload specifications are for single-axis system and based on ball screw and bearing life of 2500 km (100 million inches) of travel.
3. Specifications are for single-axis systems, measured 50 mm above the tabletop. Performance of multi-axis systems is payload and workpoint dependent. Consult factory for multi-axis or non-standard applications.



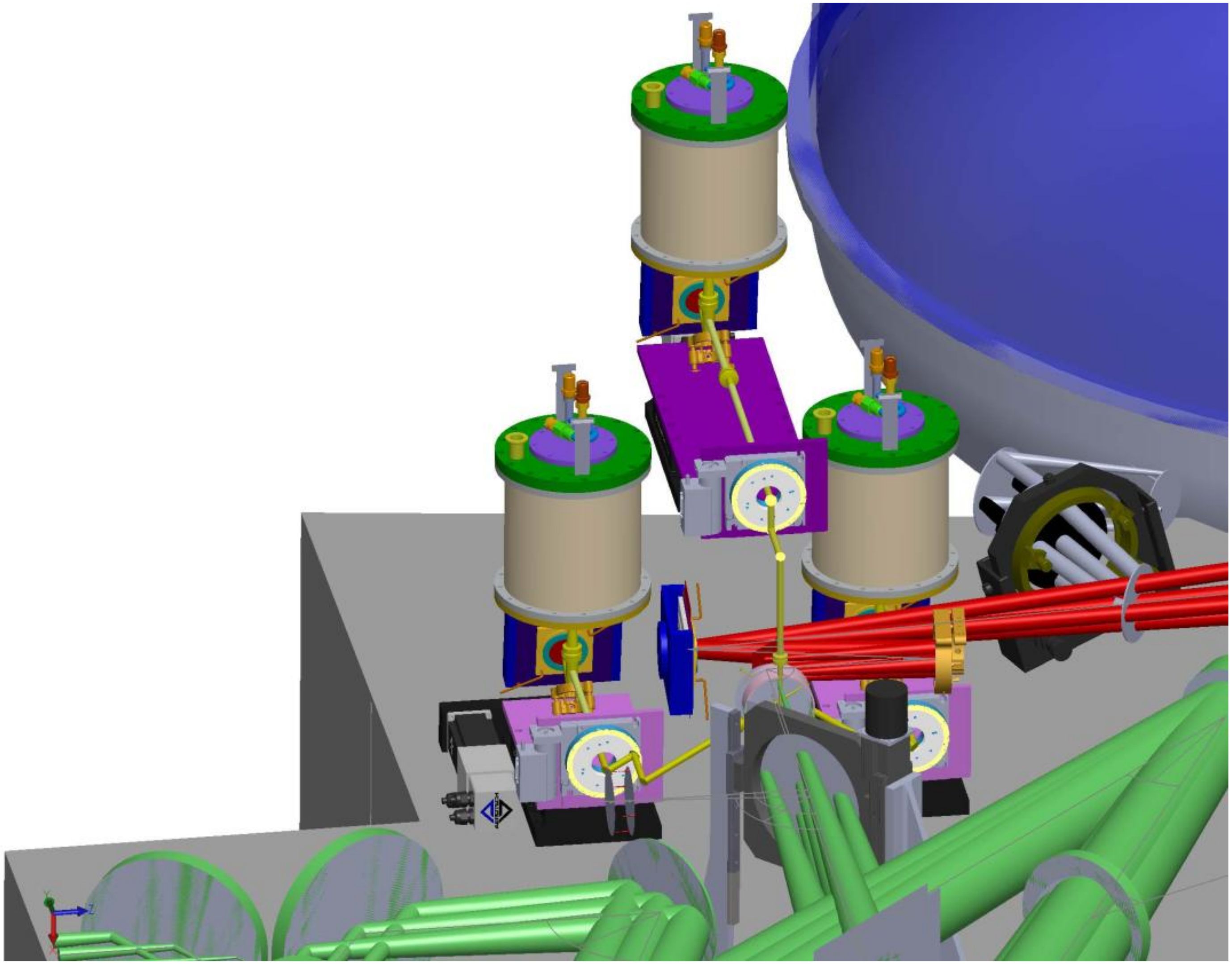
LOWFS Mounting on the Bench



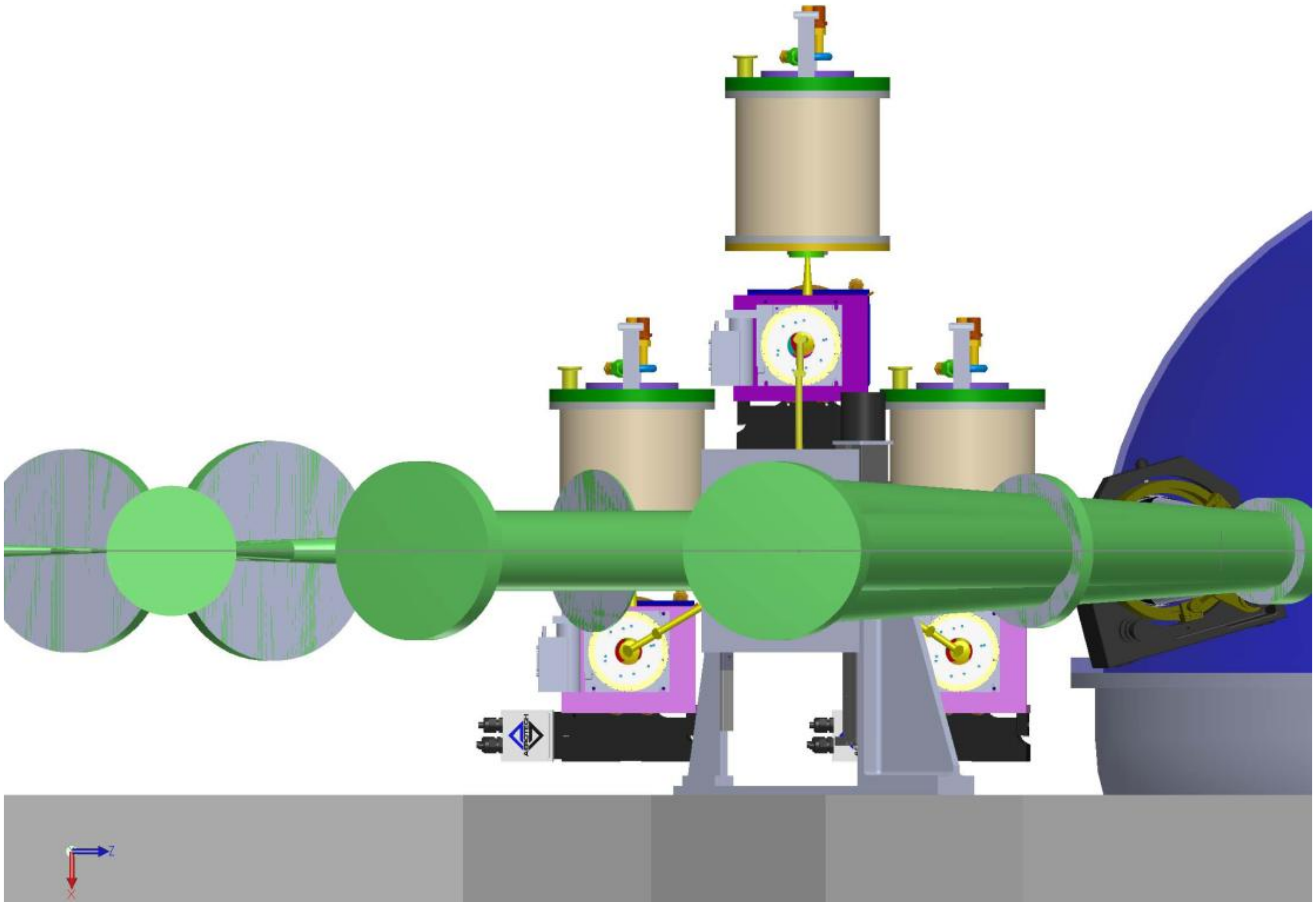
LOWFS Mounting on the Bench



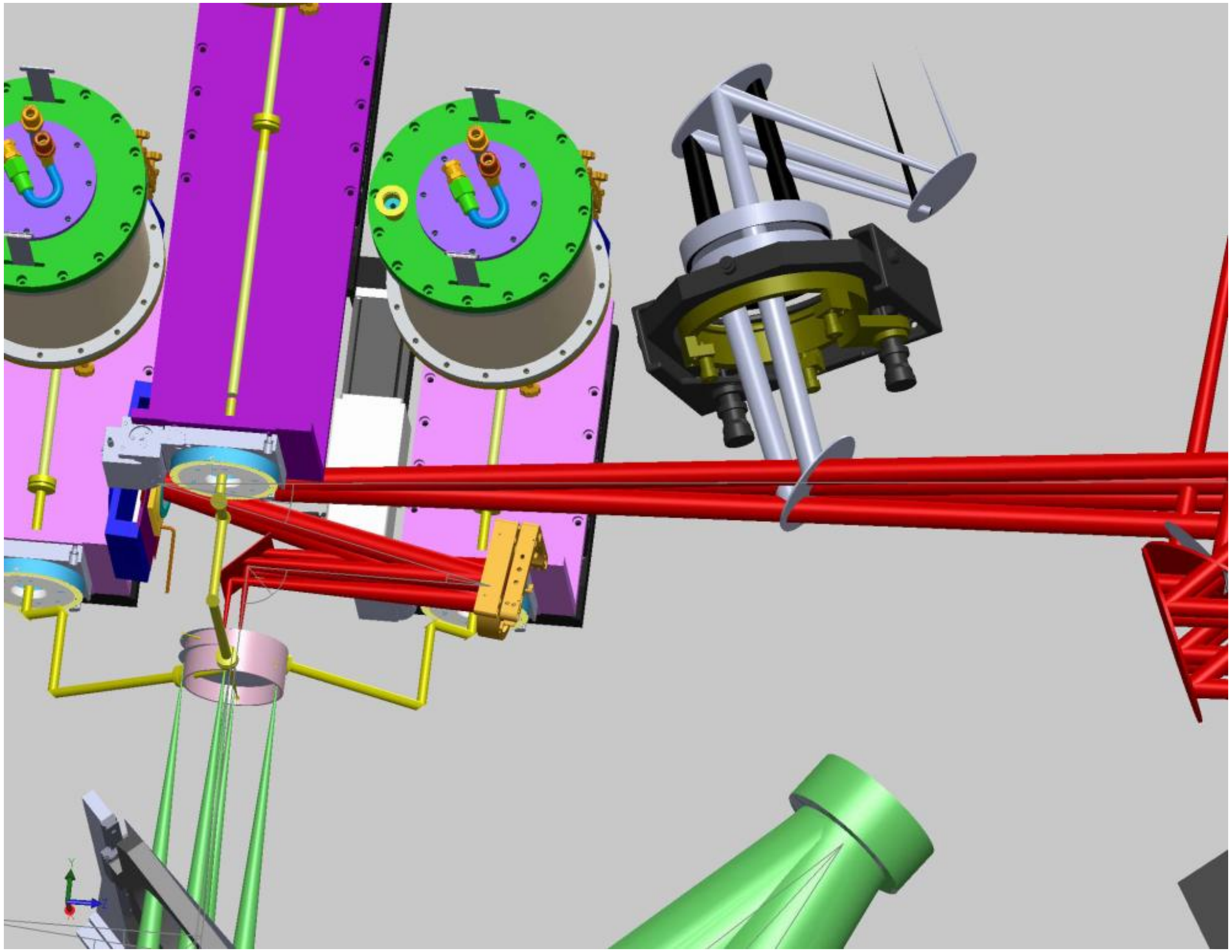
LOWFS Mounting on the Bench



LOWFS Mounting on the Bench



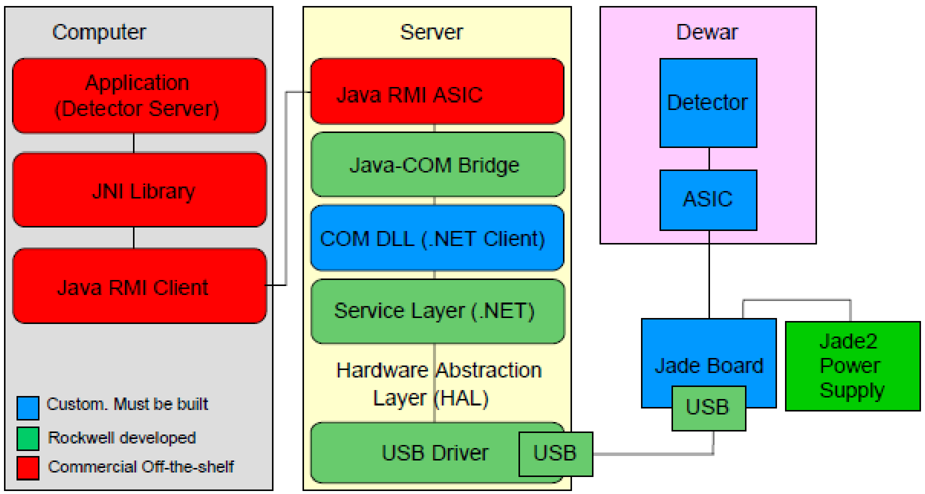
LOWFS Mounting on the Bench



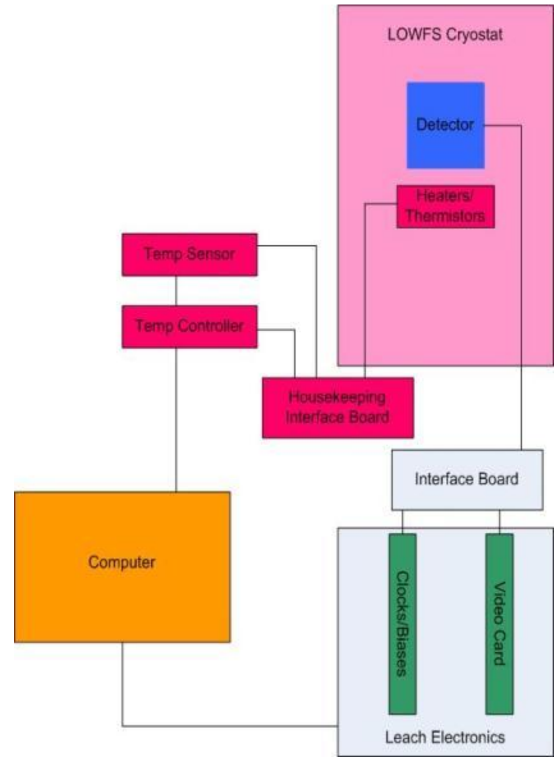
Opto-Mechanical Work

- Fine tune fitting of LOWFS hardware on Bench.
- Need to configure layout to work around hardware in close proximity

Electronics Design



HAWAII with ASIC



HAWAII with Leach

Remaining Work

- Design
  - Truth WFS
  - Cold snout modification to Cryostat
  - Fine Tune Packaging
  - J + H Optical Filter Design
- Management
  - Costing
  - WBS
  - Risks