

InfraRed Imaging Spectrograph (IRIS) for the Thirty Meter Telescope

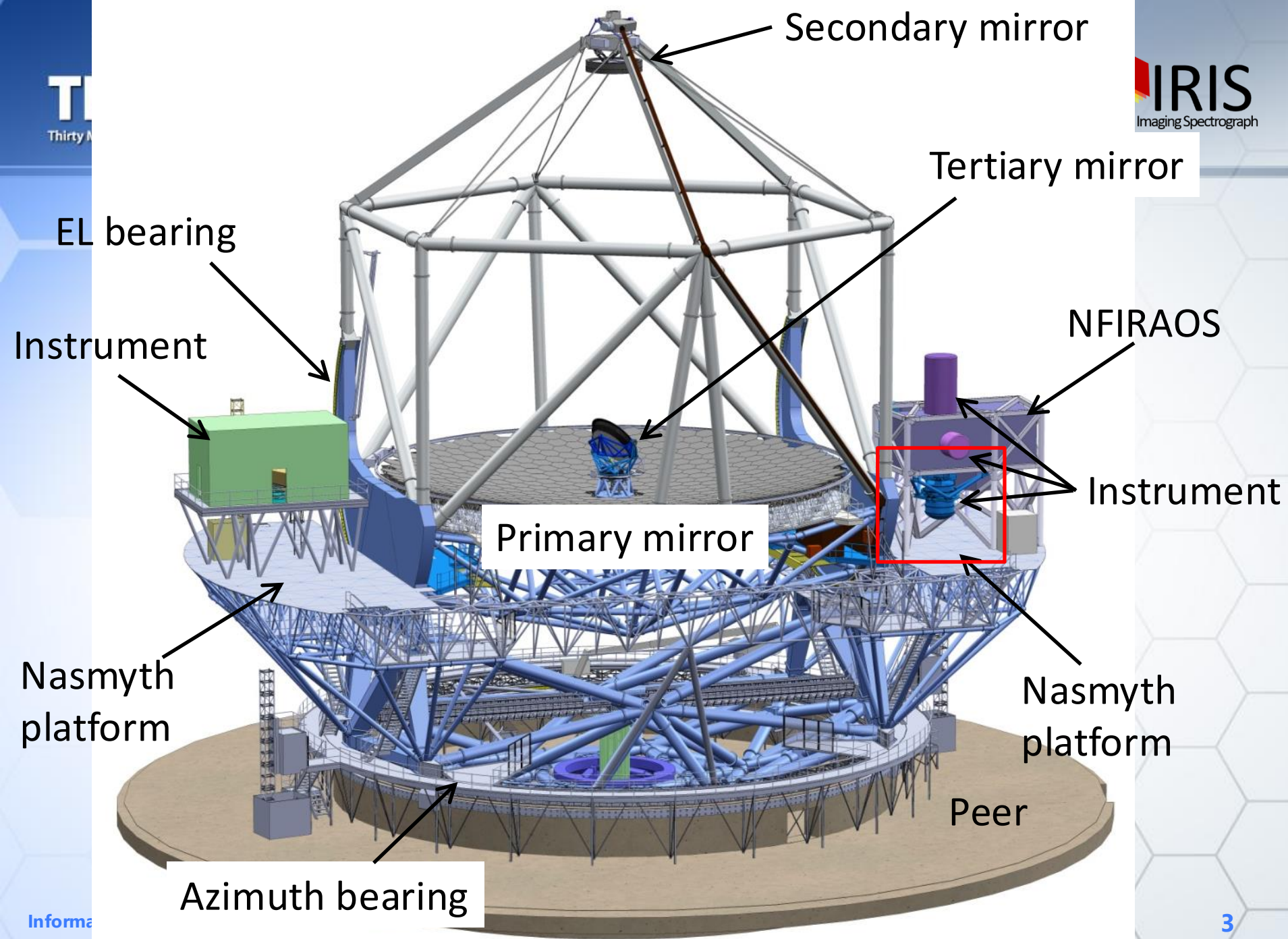
Ryuji Suzuki (TMT project, NAOJ)
2026/8/19

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Agenda

- ◆ IRIS overview
- ◆ Expected performance
- ◆ Technical challenges
- ◆ Development history and current status
- ◆ Design overview
- ◆ Final words



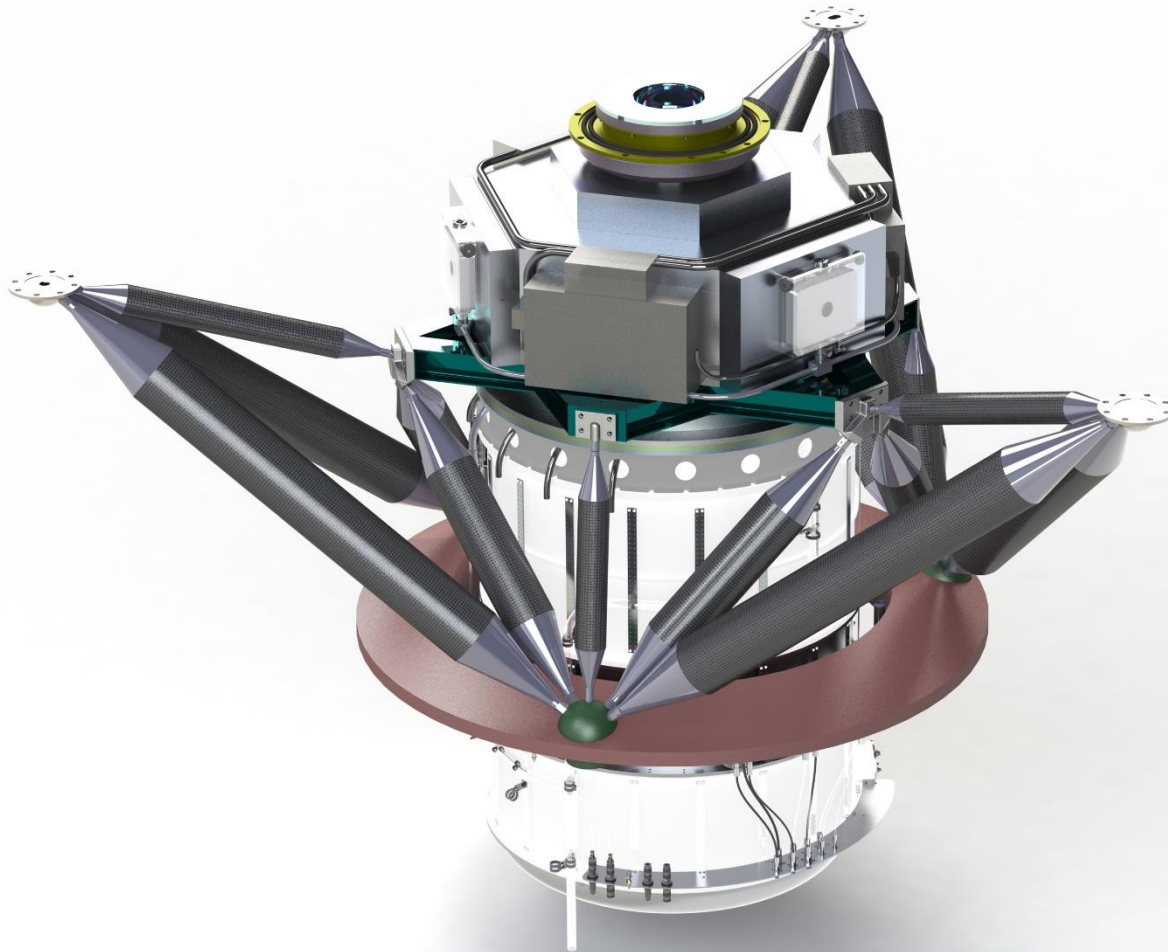
NFIRAOS

IRIS

InfraRed Imaging Spectrograph (IRIS)

- ◆ One of the three first light instruments (IRIS, WFOS, MODHIS)
- ◆ Offers diffraction-limited imaging and IFS obs. in NIR
 - ◇ Work with NFIRAOS
 - ◇ Wavelength : 0.84 – 2.40 microns
 - ◇ Strehl ratio : 0.41(J), 0.60(H), 0.75(K)
- ◆ Imaging mode
 - ◇ Pixel scale : 4 mas/pixel
 - ◇ FoV : 34x34 arcsec² using 2x2 H4RG-15 detectors
- ◆ Integral Field Spectroscopy mode
 - ◇ Spectral resolution : 4,000 / 8,000 / 10,000
 - ◇ Spatial sampling : 4, 9, 25, 50 mas/spaxel

InfraRed Imaging Spectrometer

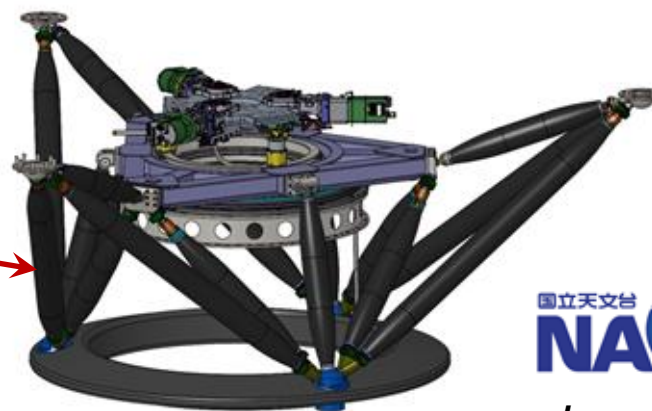


InfraRed Imaging Spectrograph IRIS

Infrared Imaging Spectrograph



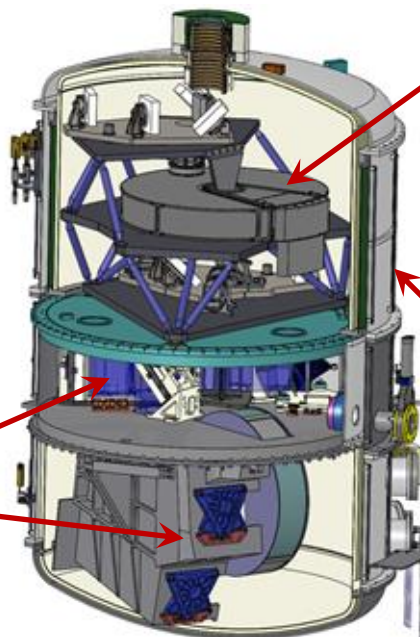
Support structure
Rotator
IR wavefront sensors



Imager



Integral field
spectrograph



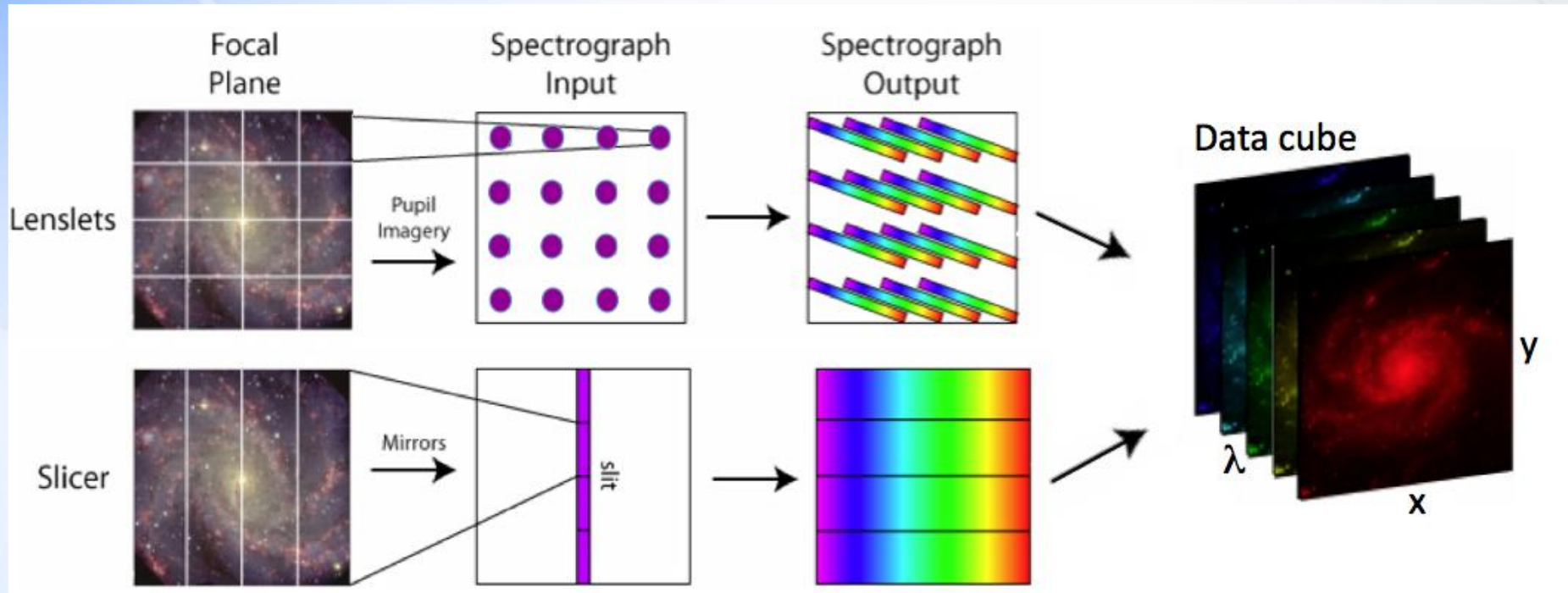
Cryostat

InfraRed Imaging Spectrograph

Unique Performances

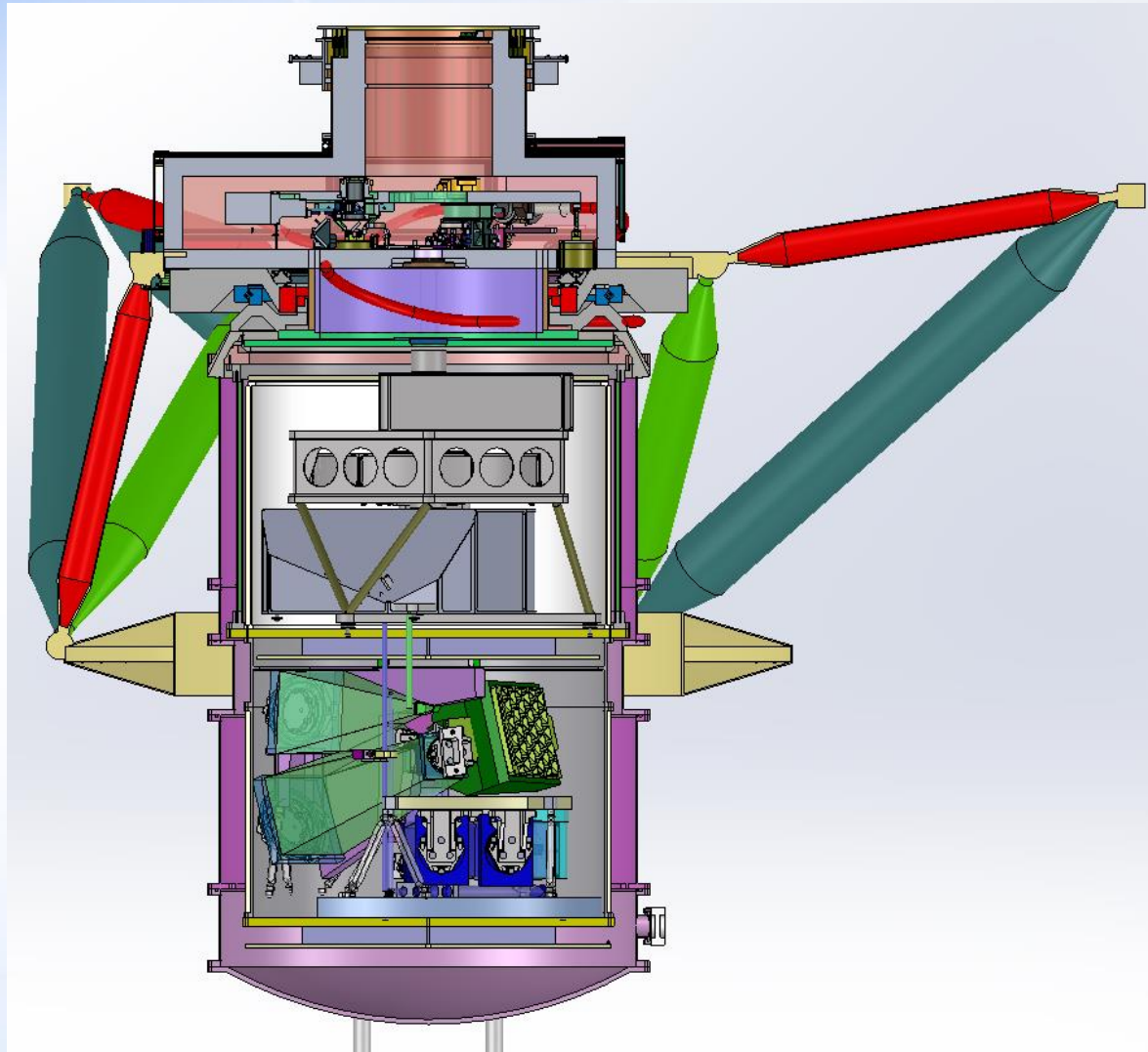
- ◆ Only first light instrument which fully utilizes diffraction-limit performance of TMT
 - ◇ Spatial resolution $\propto D^{-1}$: 10 – 25 mas
 - ◇ Sensitivity to a point source $\propto D^4$: 200 times of Subaru Telescope
- ◆ High precision astrometry
 - ◇ Relative astrometry of 10 micro-arcsec
 - ◇ Most likely only achievable by TMT/NFIRAOS/IRIS
- ◆ Novel Lenslet/Slicer hybrid IFS design
 - ◇ IRIS can cover a wide range of science cases
- ◆ Parallel observation
 - ◇ Imaging and IFS observations can be conducted simultaneously.

Novel Hybrid IFS Design

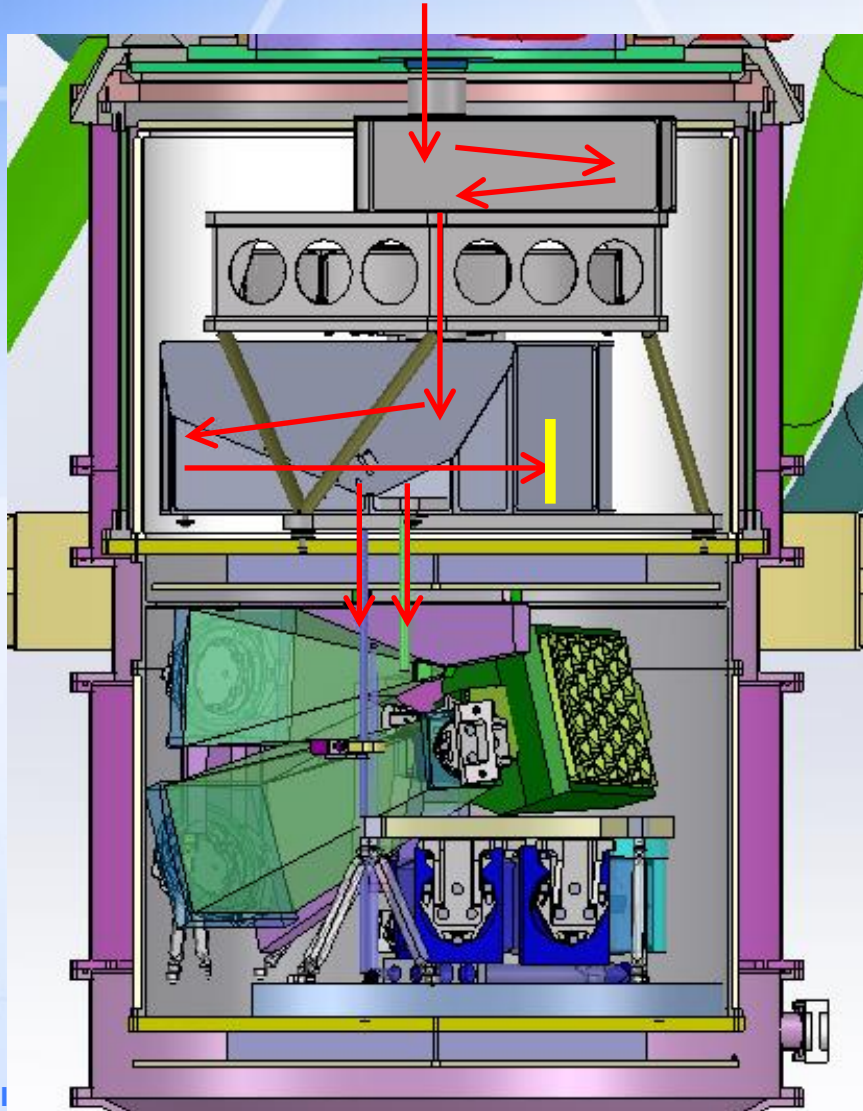


- ◆ Lenslet array for fine spatial scale/point sources
- ◆ Image slicer for wide field coverage/extended objects.

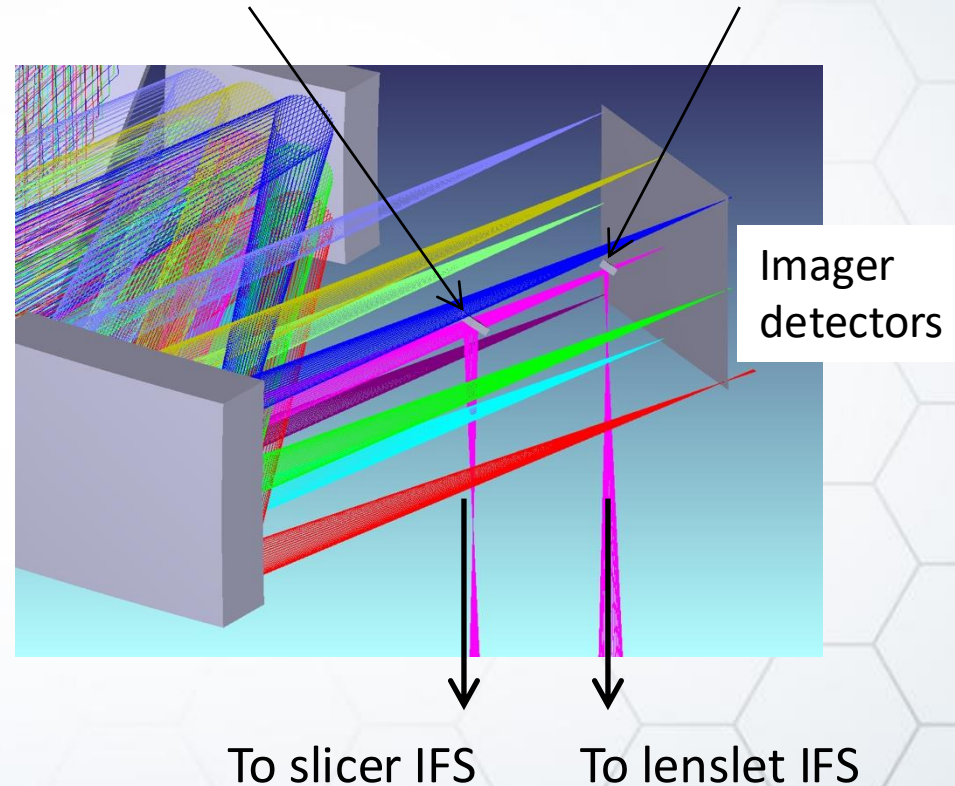
"Sequential Design"

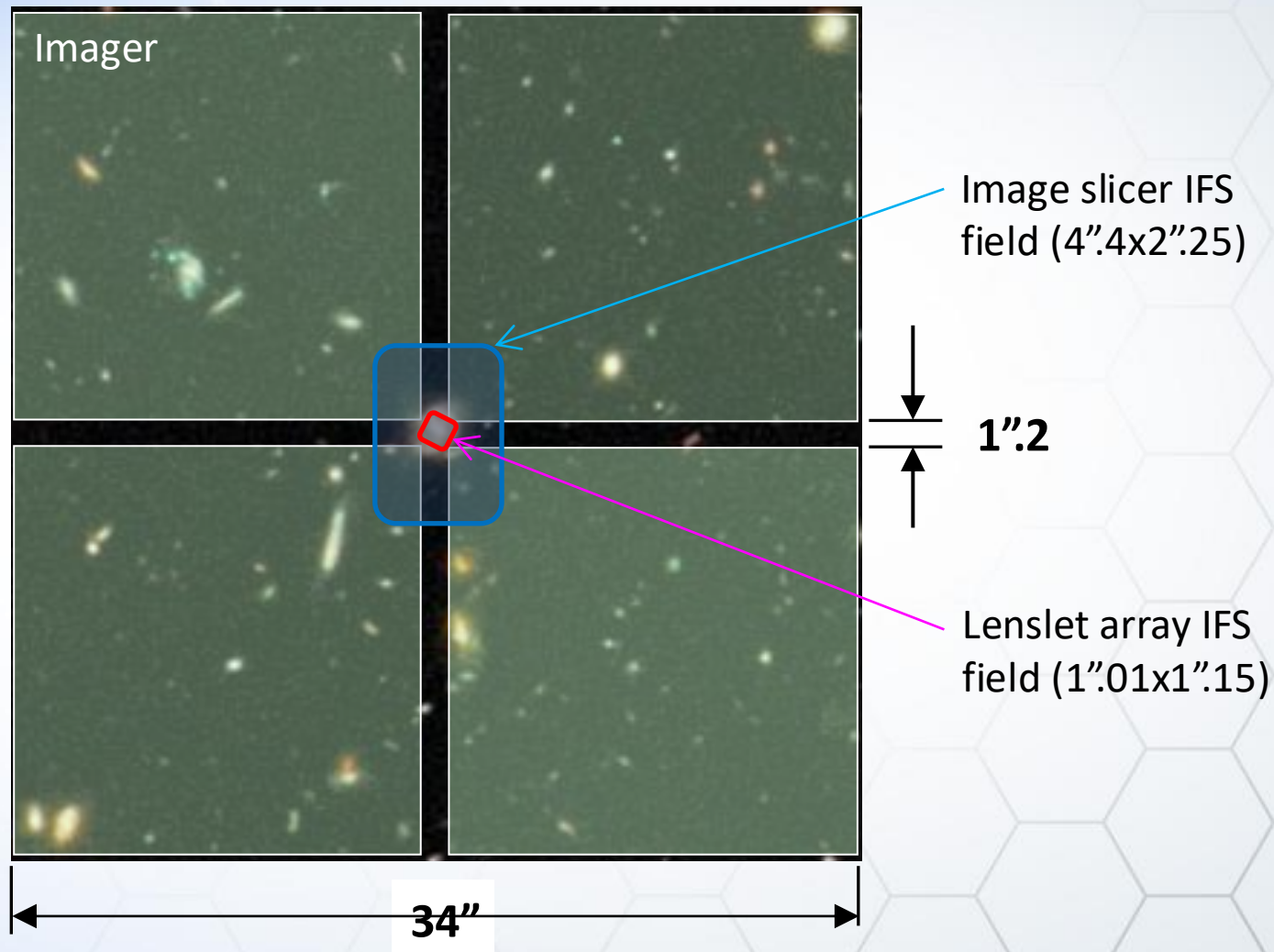


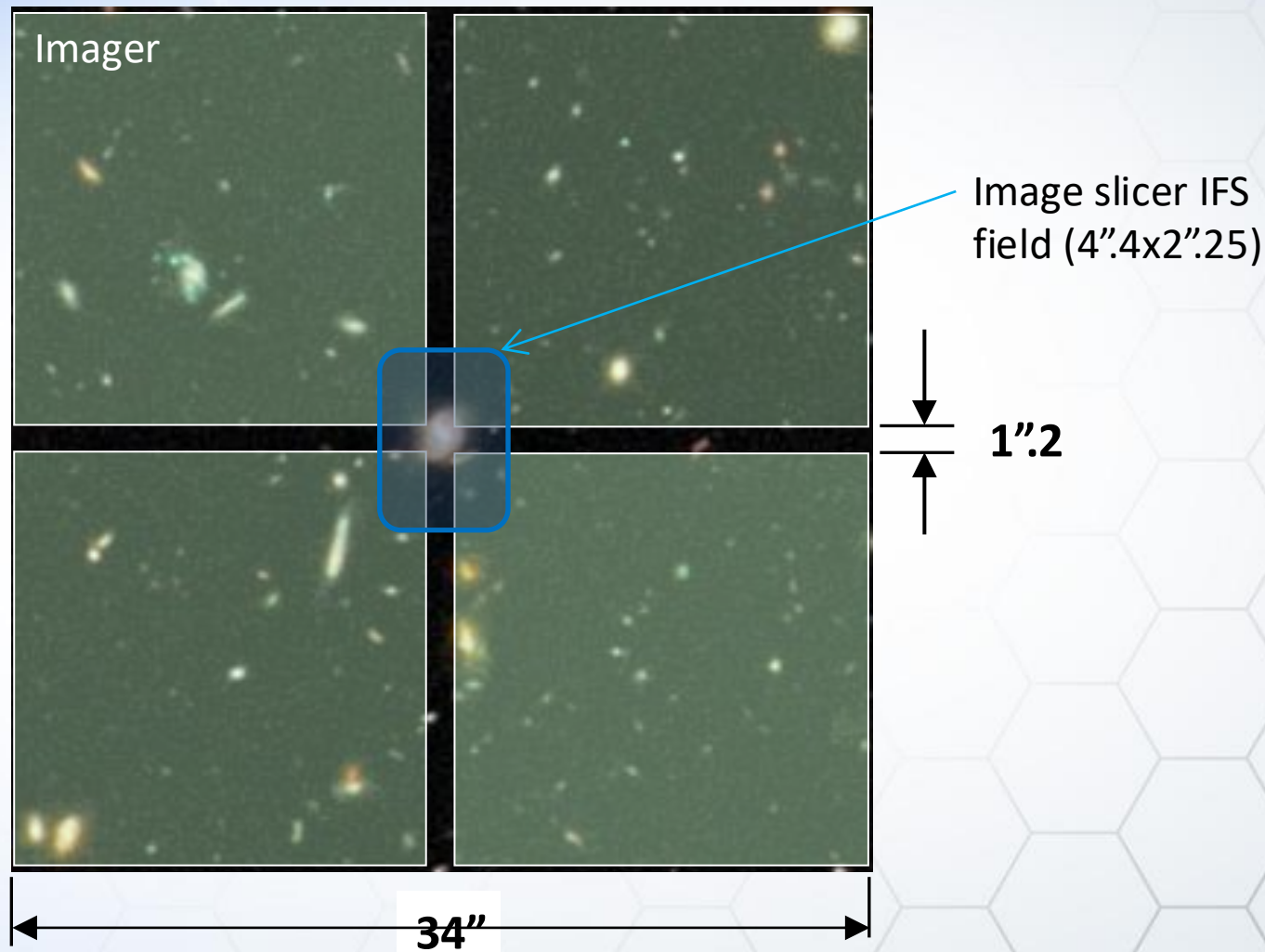
"Sequential Design"

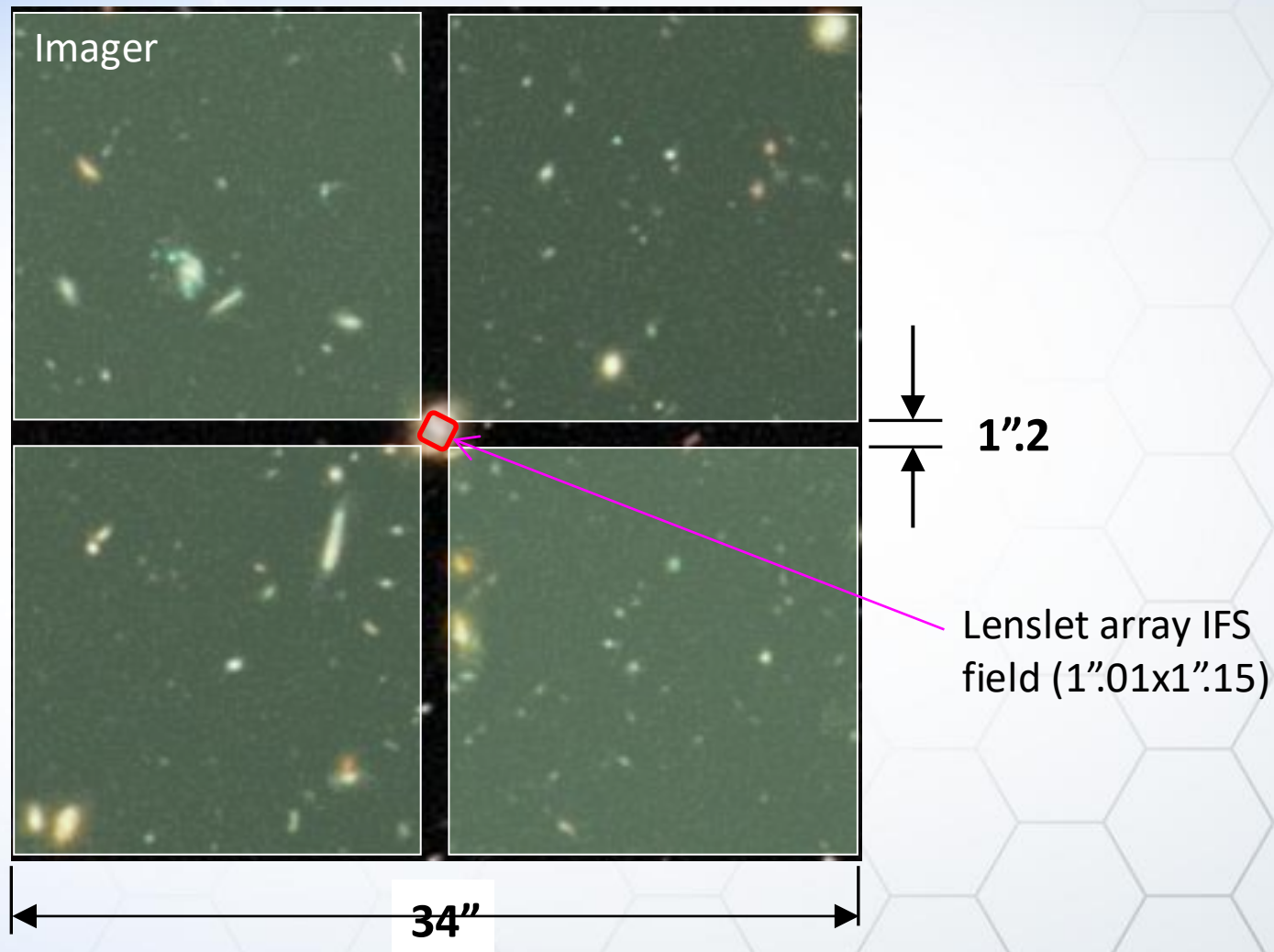


Pick-off for slicer IFS (deployable) Pick-off for lenslet IFS (fixed)

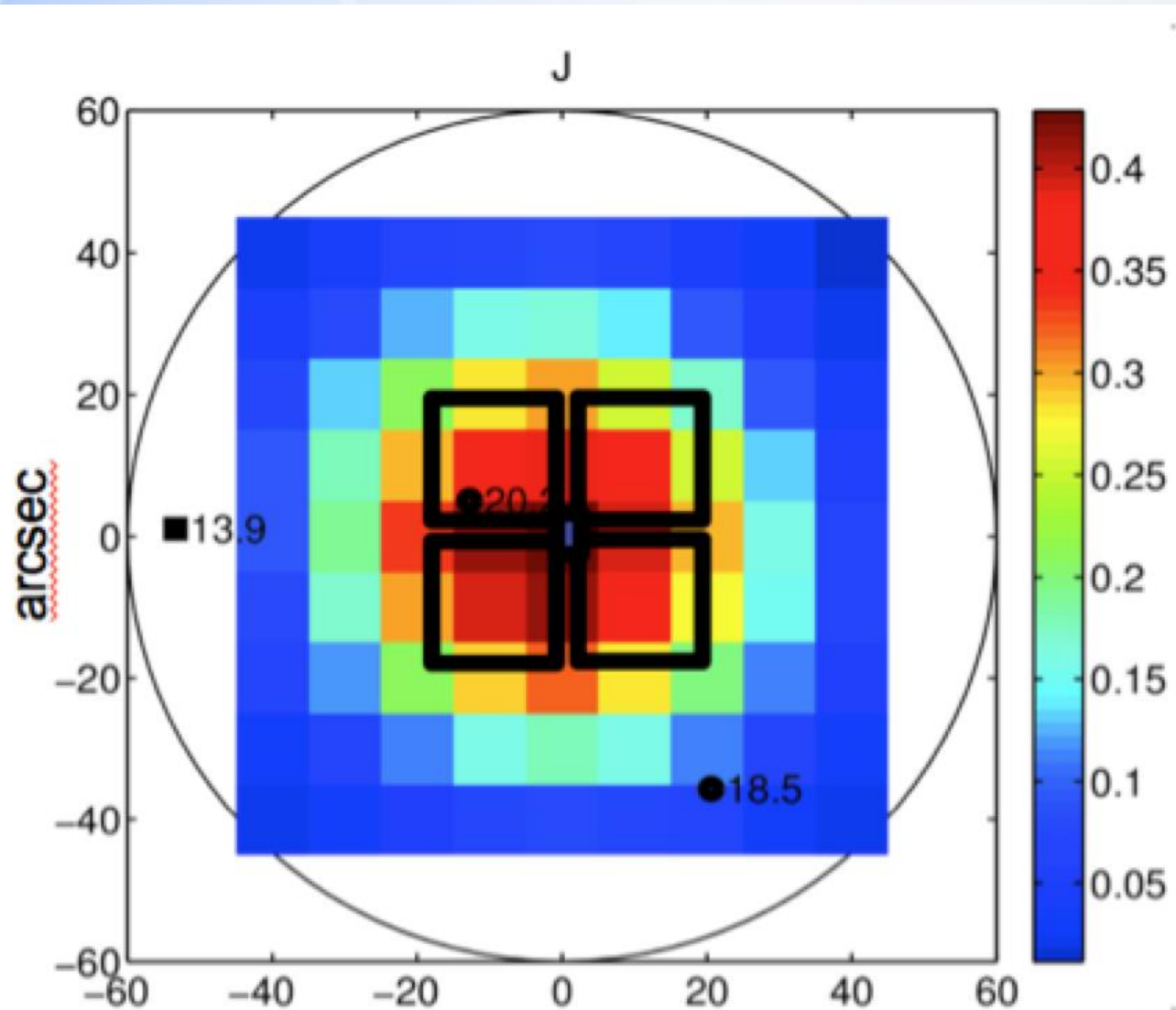




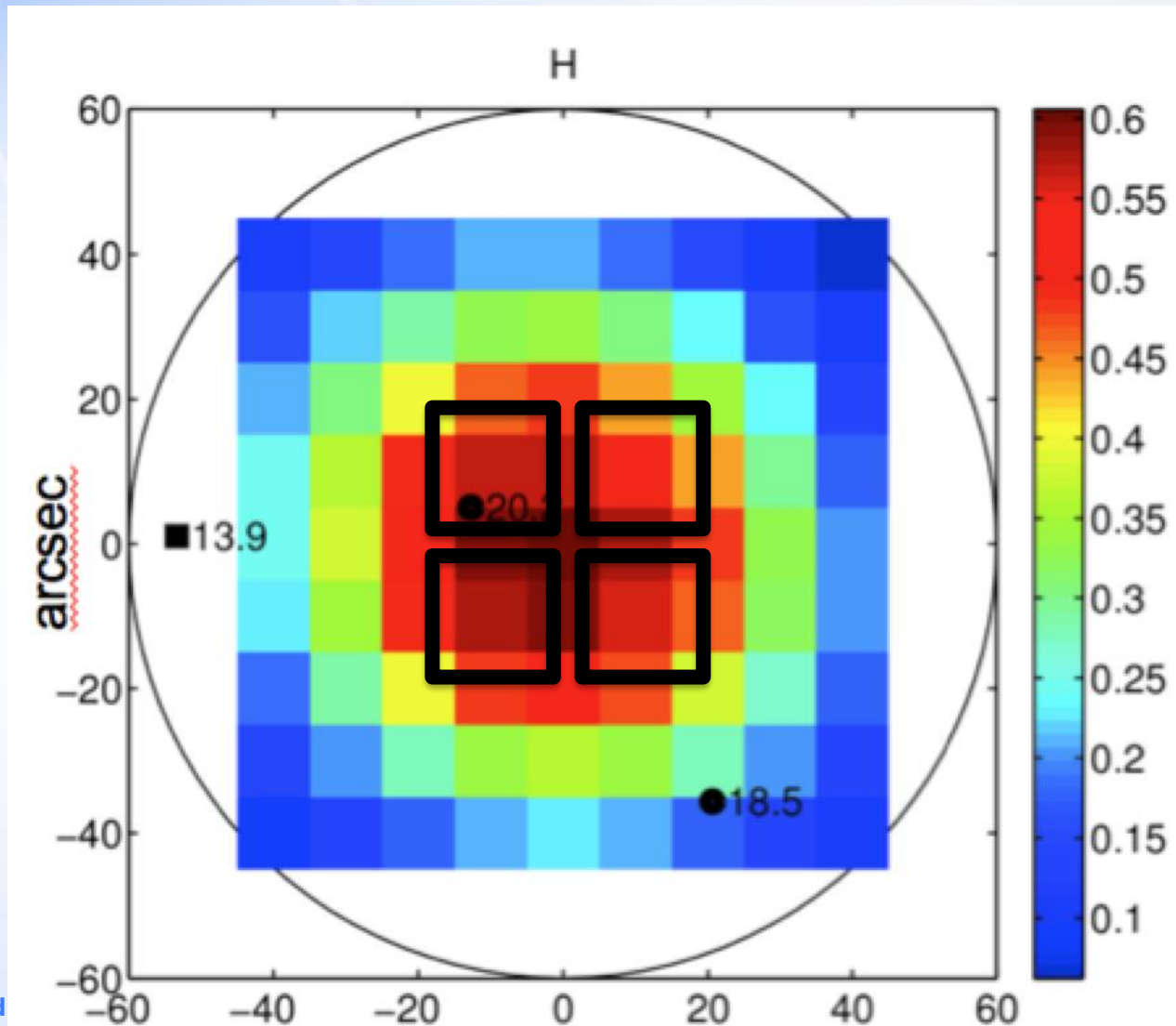




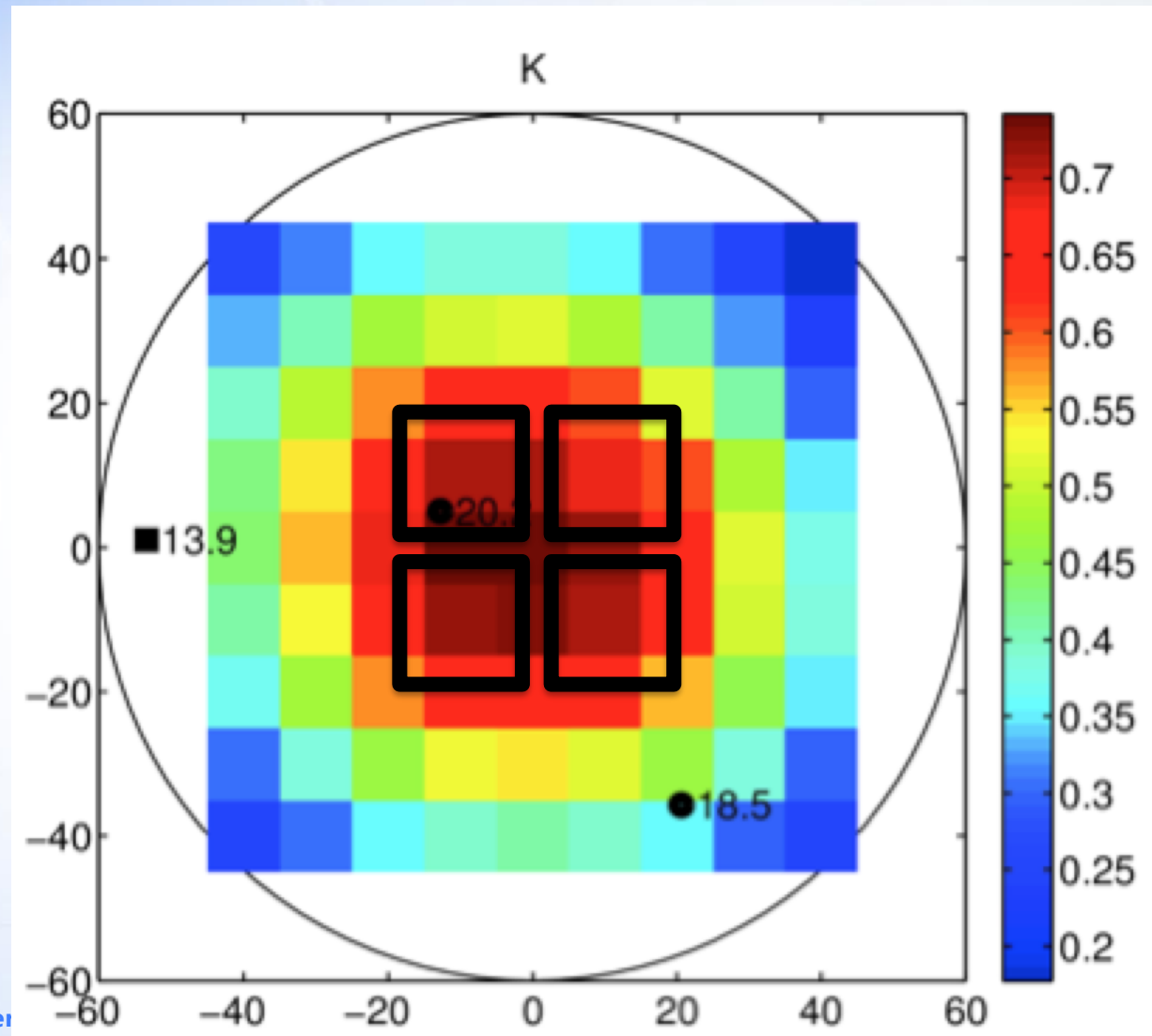
NFIRAOS Strehl performance across 2' wavefront sensors FoV



NFIRAOS Strehl performance across 2' wavefront sensors FoV

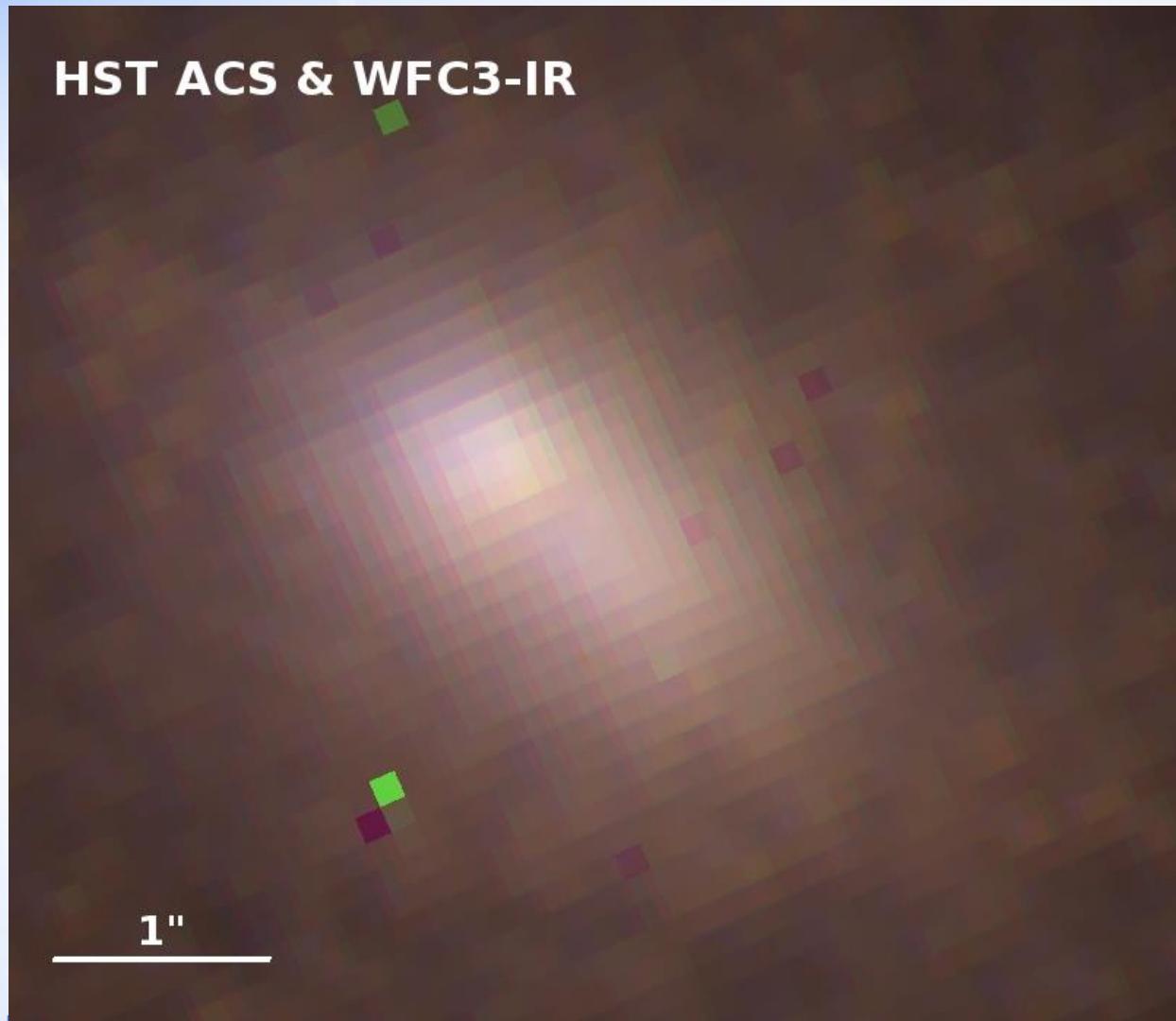


NFIRAOS Strehl performance across 2' wavefront sensors FoV

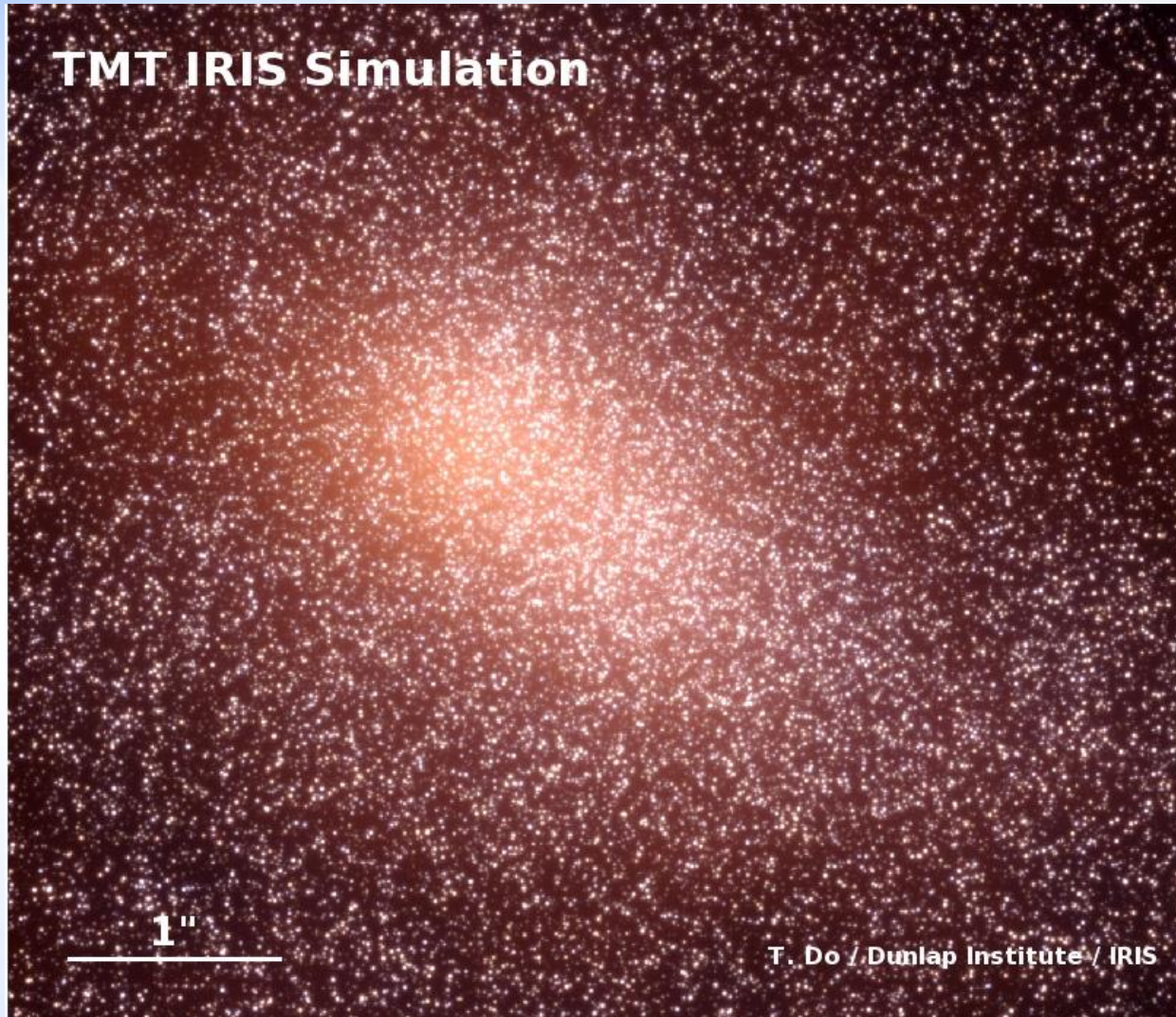


Expected Performance

IRIS Simulator (M31)



IRIS Simulator (M31)



IRIS Simulator (Io)

Keck AO H-band

Io Simulation

IRIS Simulator (Io)

TMT IRIS H-band

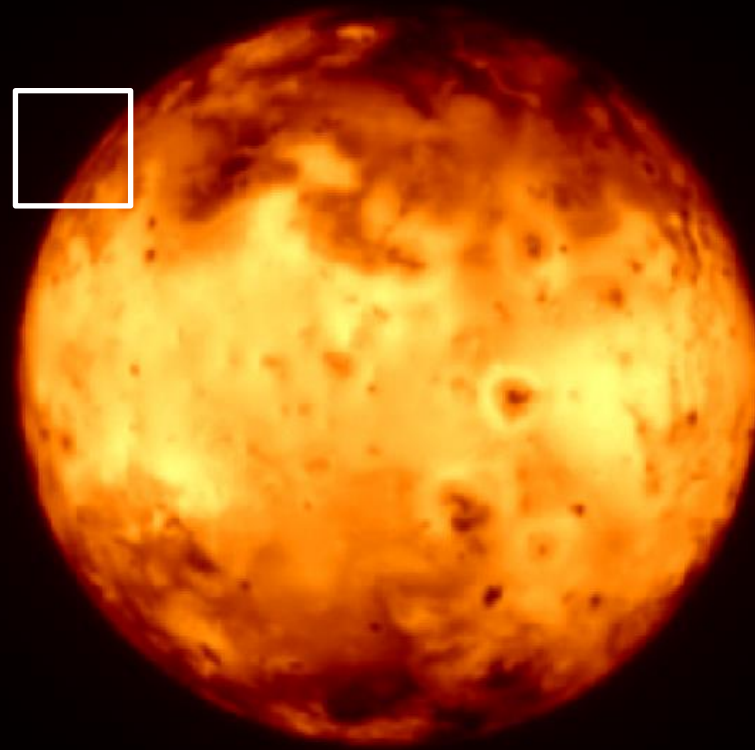


Io Simulation

T. Do/UCLA/IRIS/TMT

IRIS Simulator (Io)

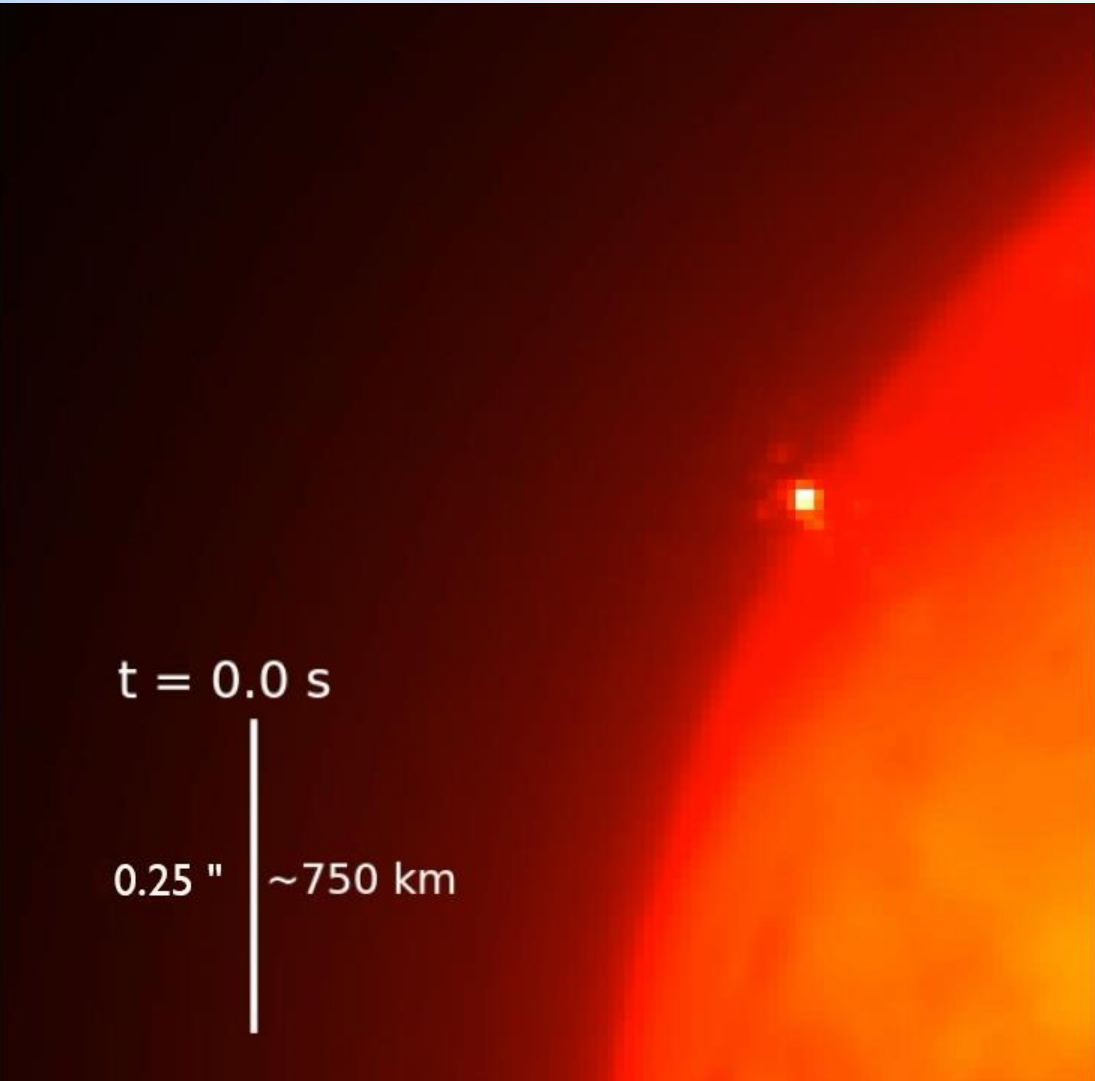
TMT IRIS H-band



Io Simulation

T. Do/UCLA/IRIS/TMT

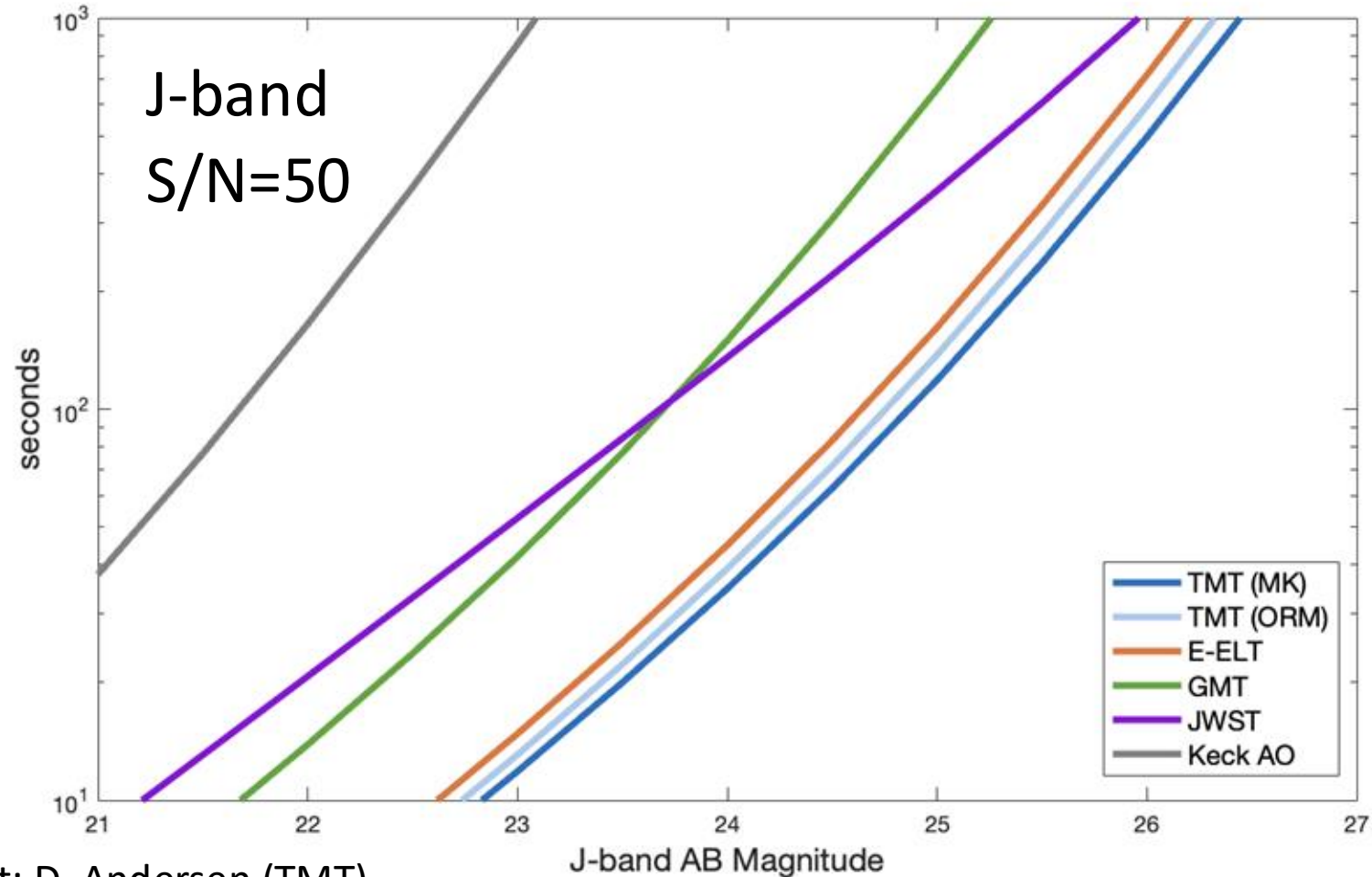
IRIS Simulator (Io)



$t = 0.0 \text{ s}$

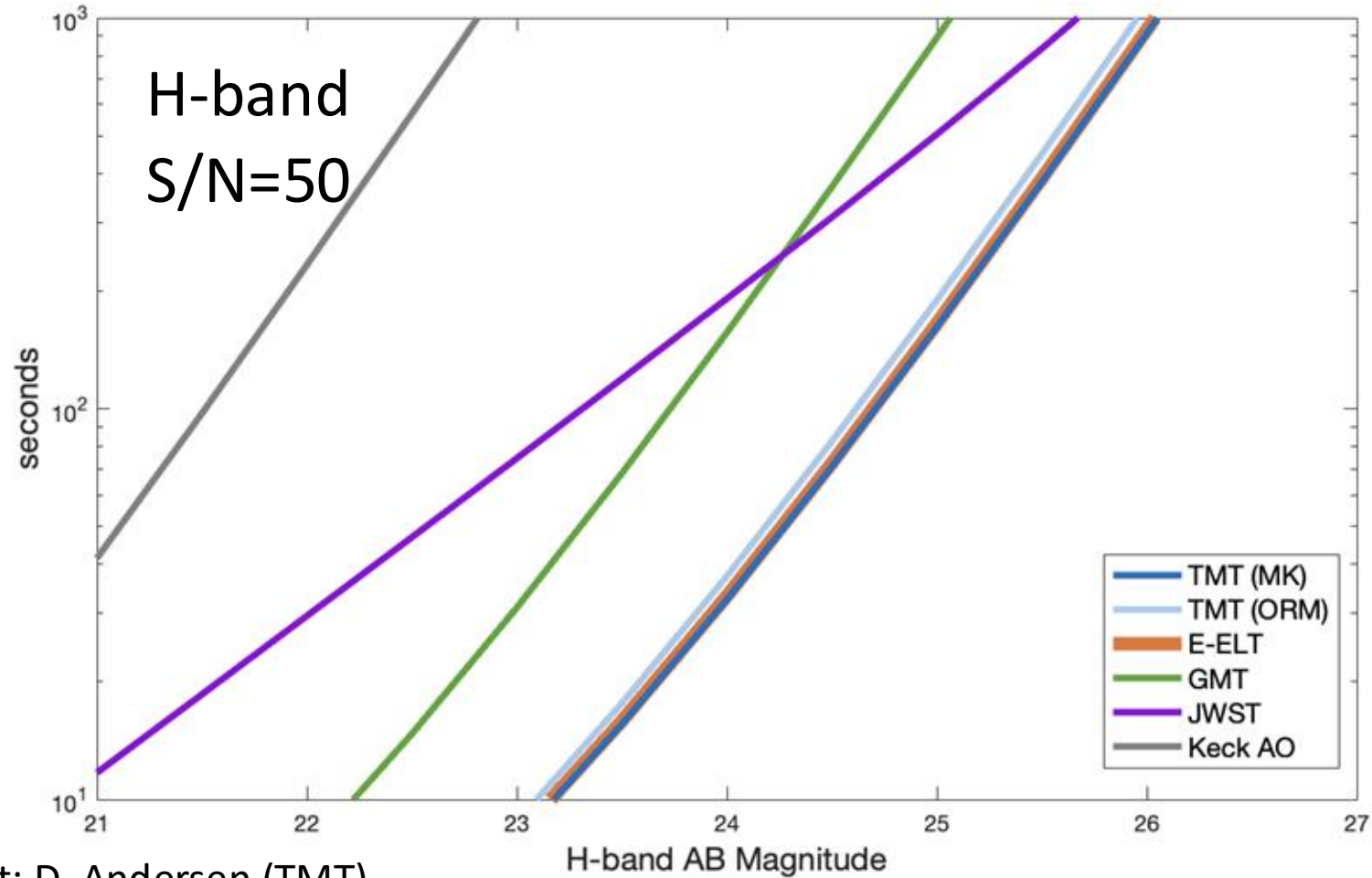
0.25 " ~750 km

Limiting Magnitude (Point source, imaging)



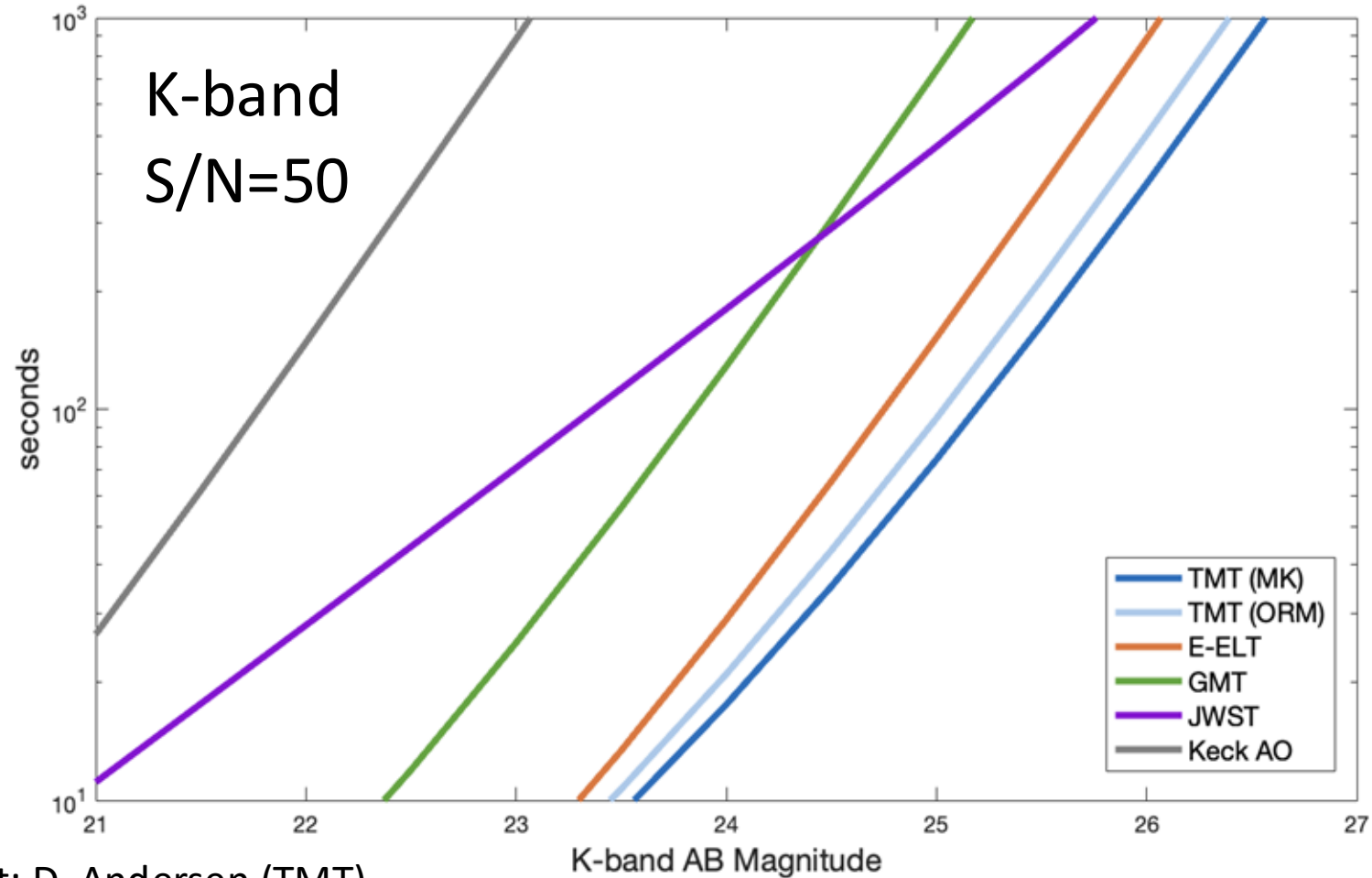
Credit: D. Andersen (TMT)

Limiting Magnitude (Point source, imaging)



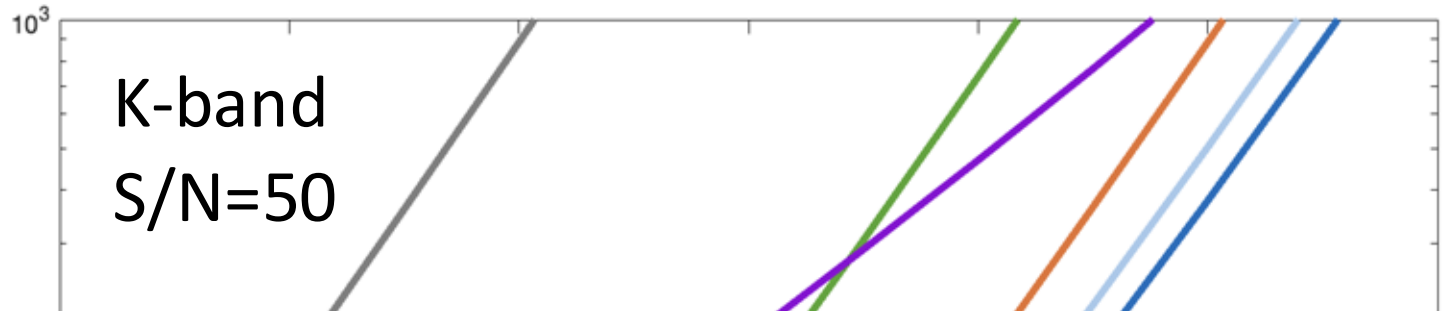
Credit: D. Andersen (TMT)

Limiting Magnitude (Point source, imaging)

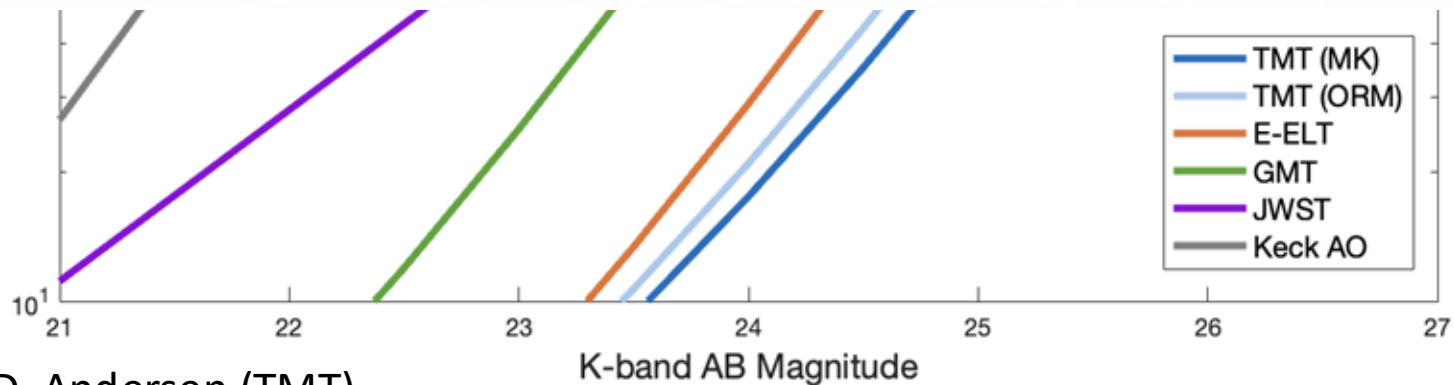


Credit: D. Andersen (TMT)

Limiting Magnitude (Point source, imaging)



TMT IRIS ETC



Credit: D. Andersen (TMT)

Technical Challenges

Development history and current status

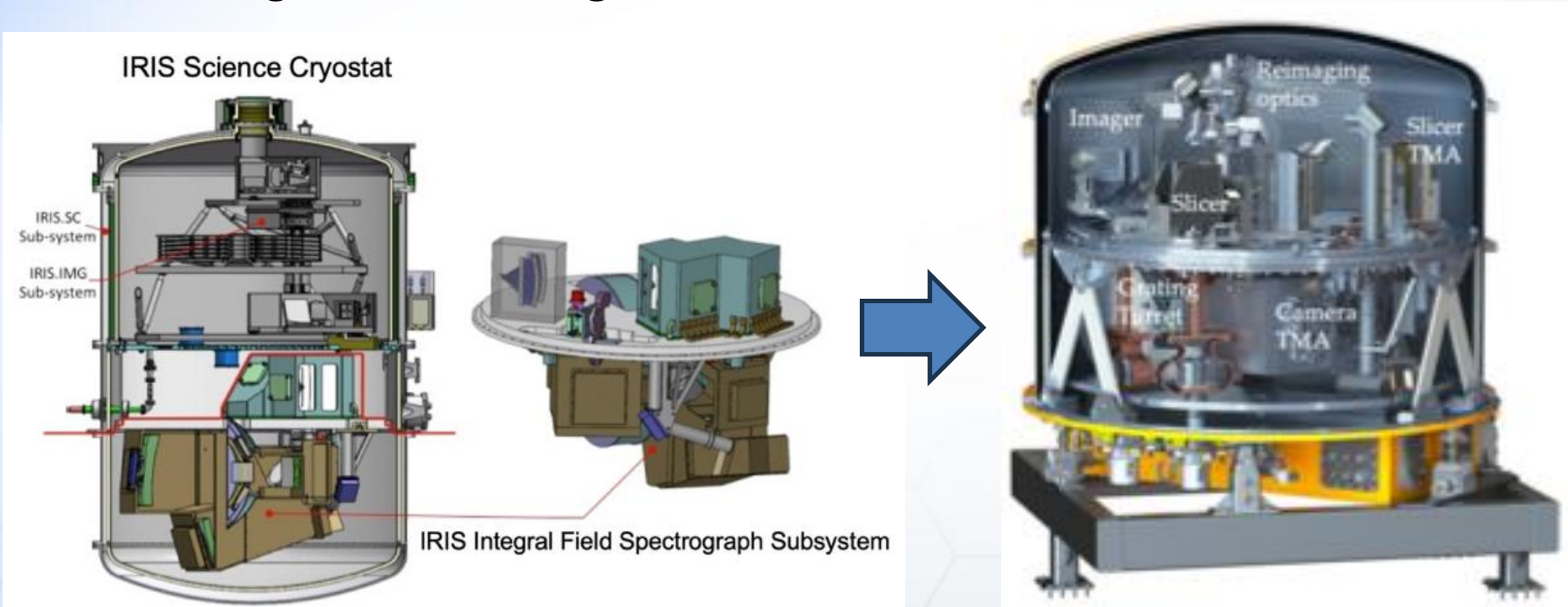
- ◆ Achieving 40 nm rms wavefront error
 - ◇ c.f. $\lambda/20$ p-v ~ 12 nm rms per mirror
 - ◇ Optical design, fabrication
 - ◇ Alignment under cryogenic temperature
 - ◇ Methodology to measure 40 nm rms
- ◆ Achieving relative astrometry of 10 micro-arcsec
 - ◇ Unprecedented accuracy
 - ◇ Calibration is the key
 - ◇ Impose stringent requirements to the design.
- ◆ Achieving maintenance-free operation for 13 years
 - ◇ The cryostat will not be opened for 13 years to keep configuration stable
 - ◇ High standard for the mechanical reliability is required

IRIS Development History

- ◆ 2007 – 2011 : Conceptual design phase
- ◆ 2011 – 2018 : Preliminary design phase
- ◆ 2018 – 2025 : Final design phase
 - ◇ 2021 : Final design review at subsystem-level
 - ◇ 2025 : Final design review-1 at system-level
 - ◆ Systems engineering
 - ◆ Opto-mechanical design update
 - ◇ TBD : Final design review-2 (and -C) at system-level
 - ◆ Software
 - ◆ Management
 - ◆ Canada's contributions

Keck/Liger Development

- ◆ Liger is the exact clone of the IRIS IFS subsystem with some design deviations to adapt to the Keck telescope.
- ◆ The Liger project entered the fabrication phase in 2023, aiming for the first light in 2028.



Design Overview (Final design)

InfraRed Imaging Spectrograph



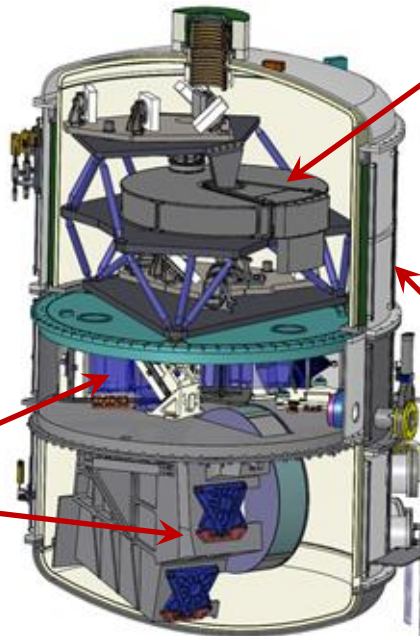
Support structure
Rotator
IR wavefront sensors



Imager



Integral field
spectrograph

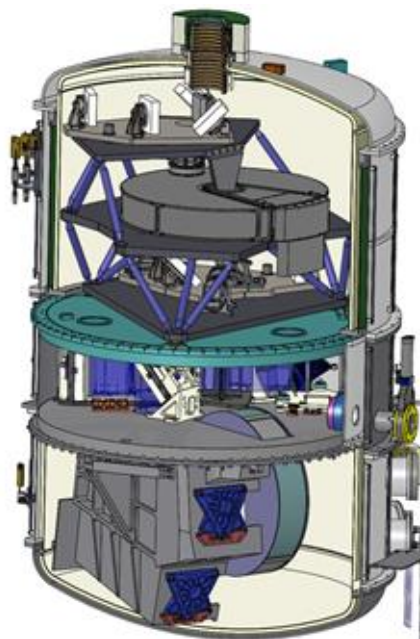
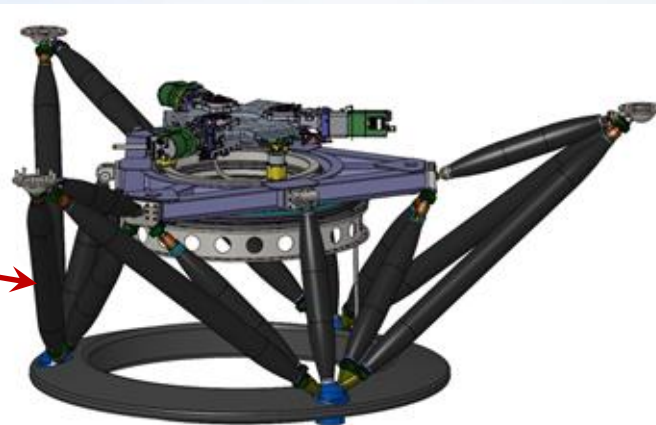


Cryostat

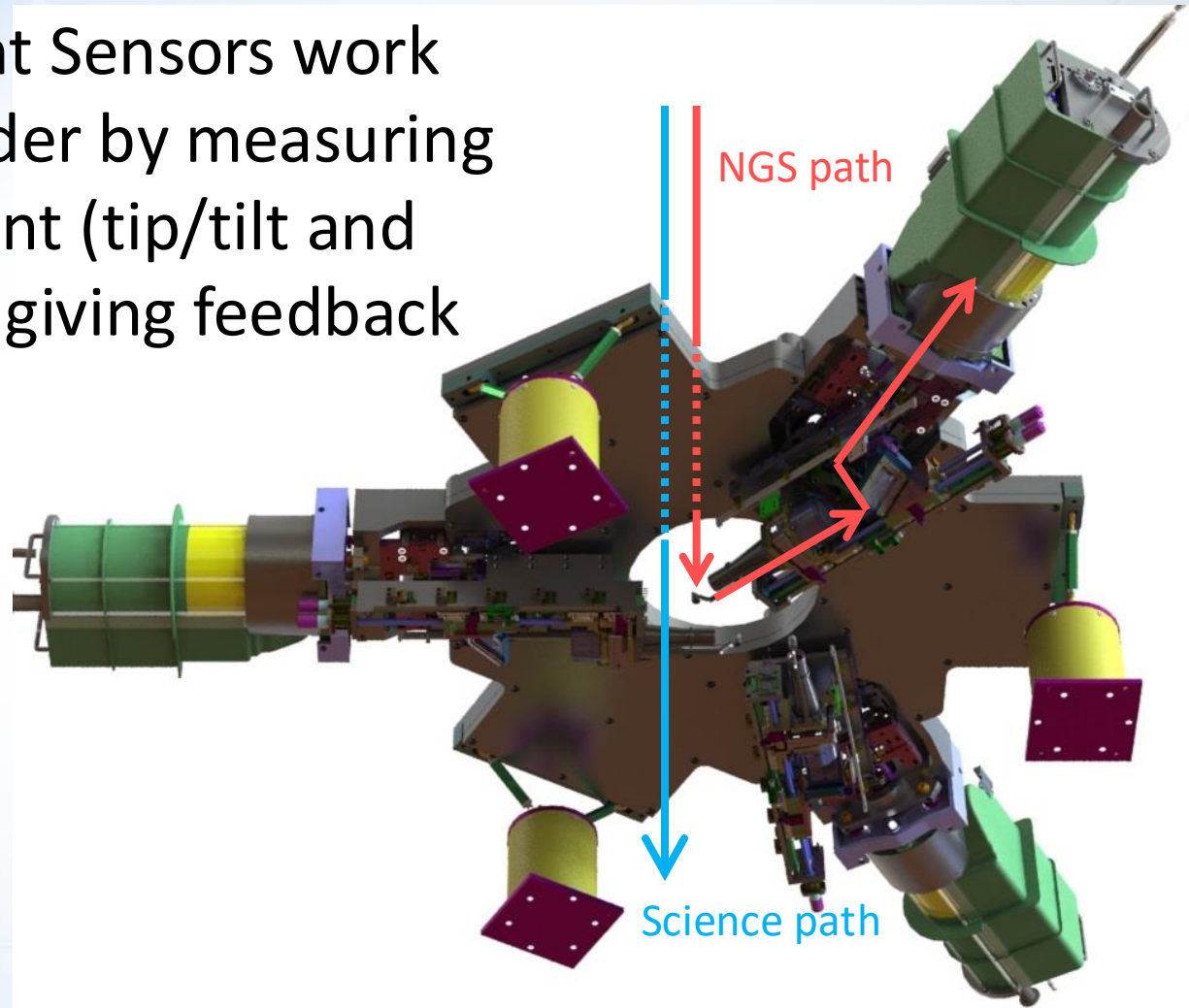
InfraRed Imaging Spectrograph



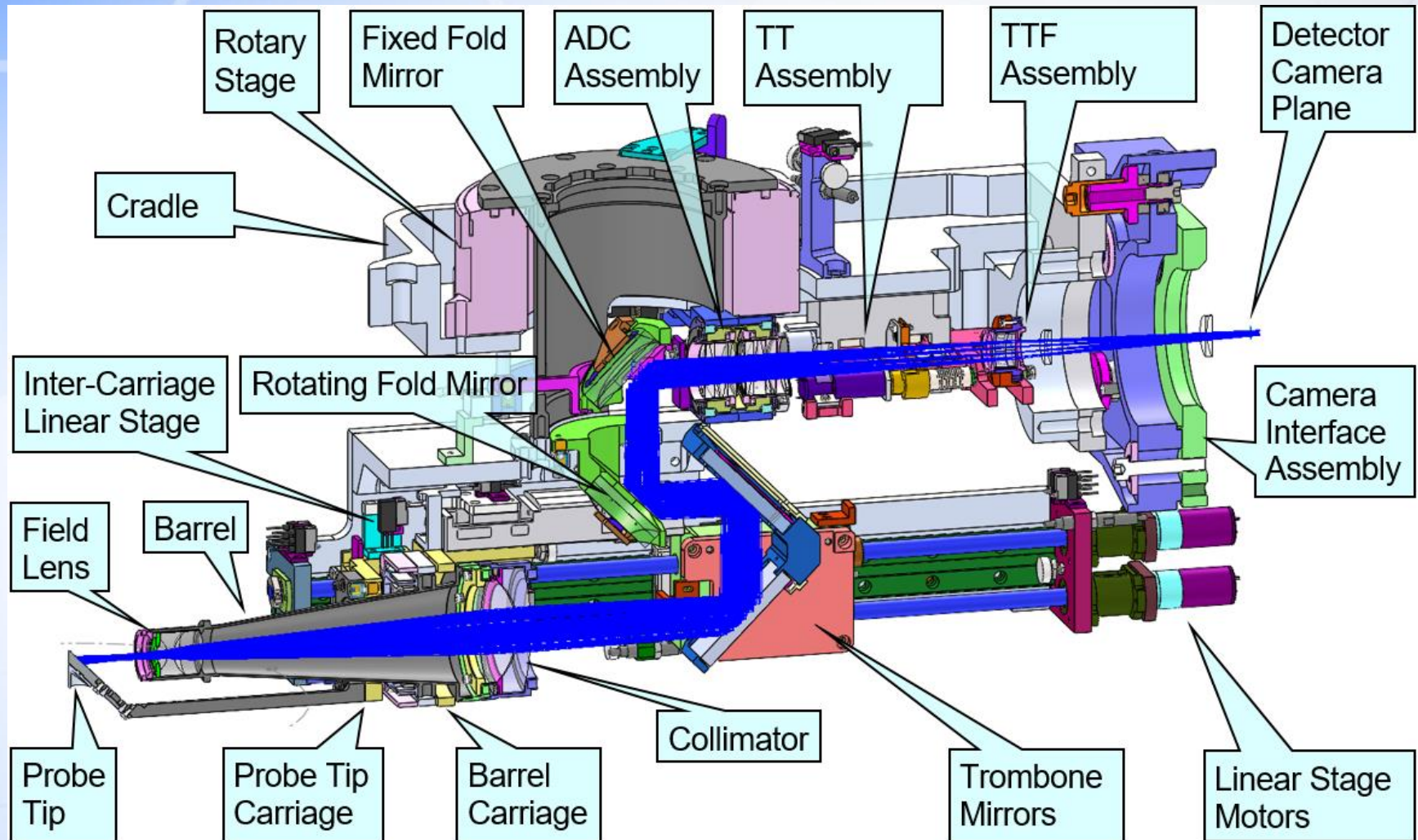
Support structure
Rotator
IR wavefront sensors



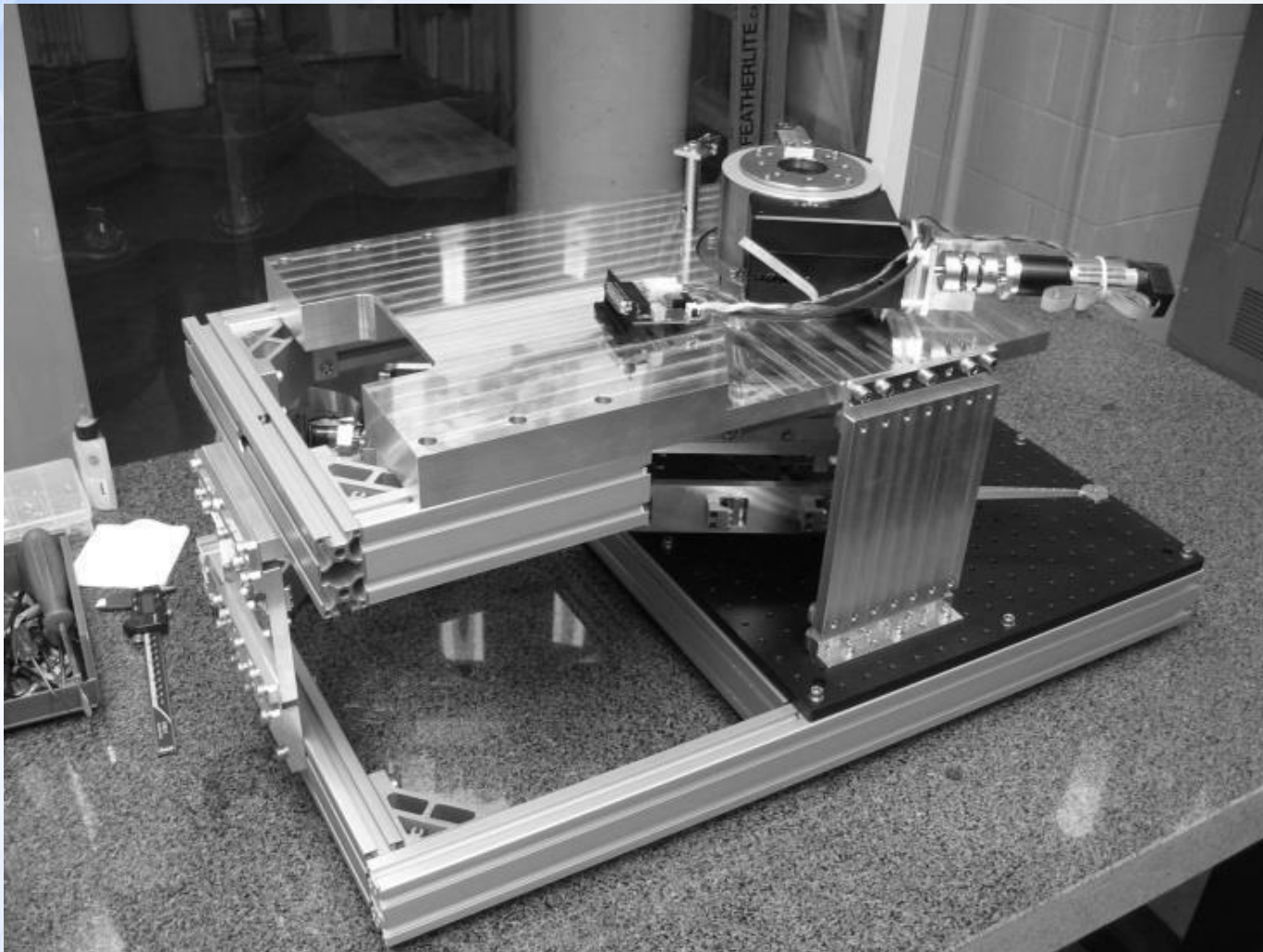
- Three IR Wavefront Sensors work as a telescope guider by measuring low order wavefront (tip/tilt and focus) of NGS and giving feedback to NFIRAOS.



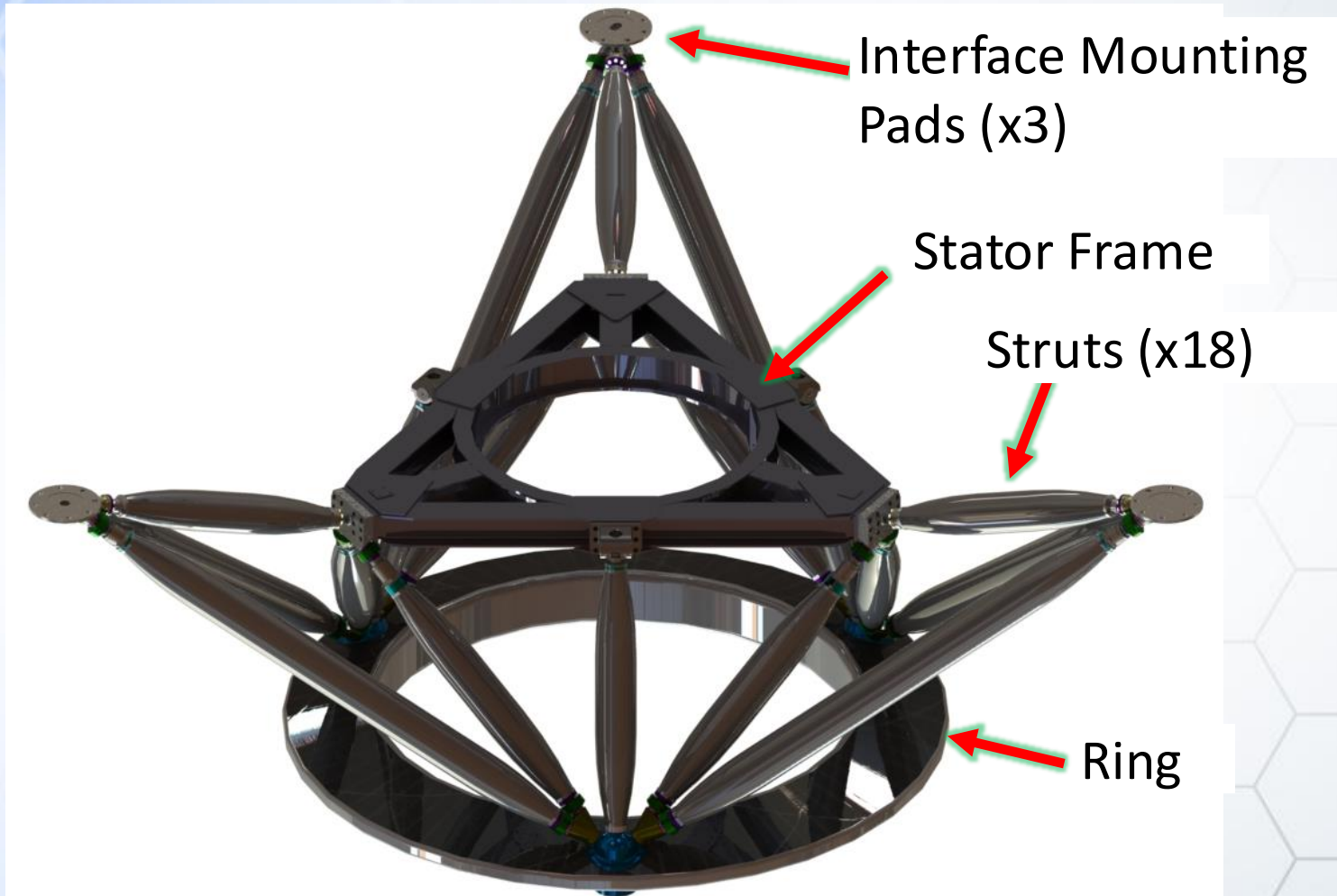
IR WFS Probe



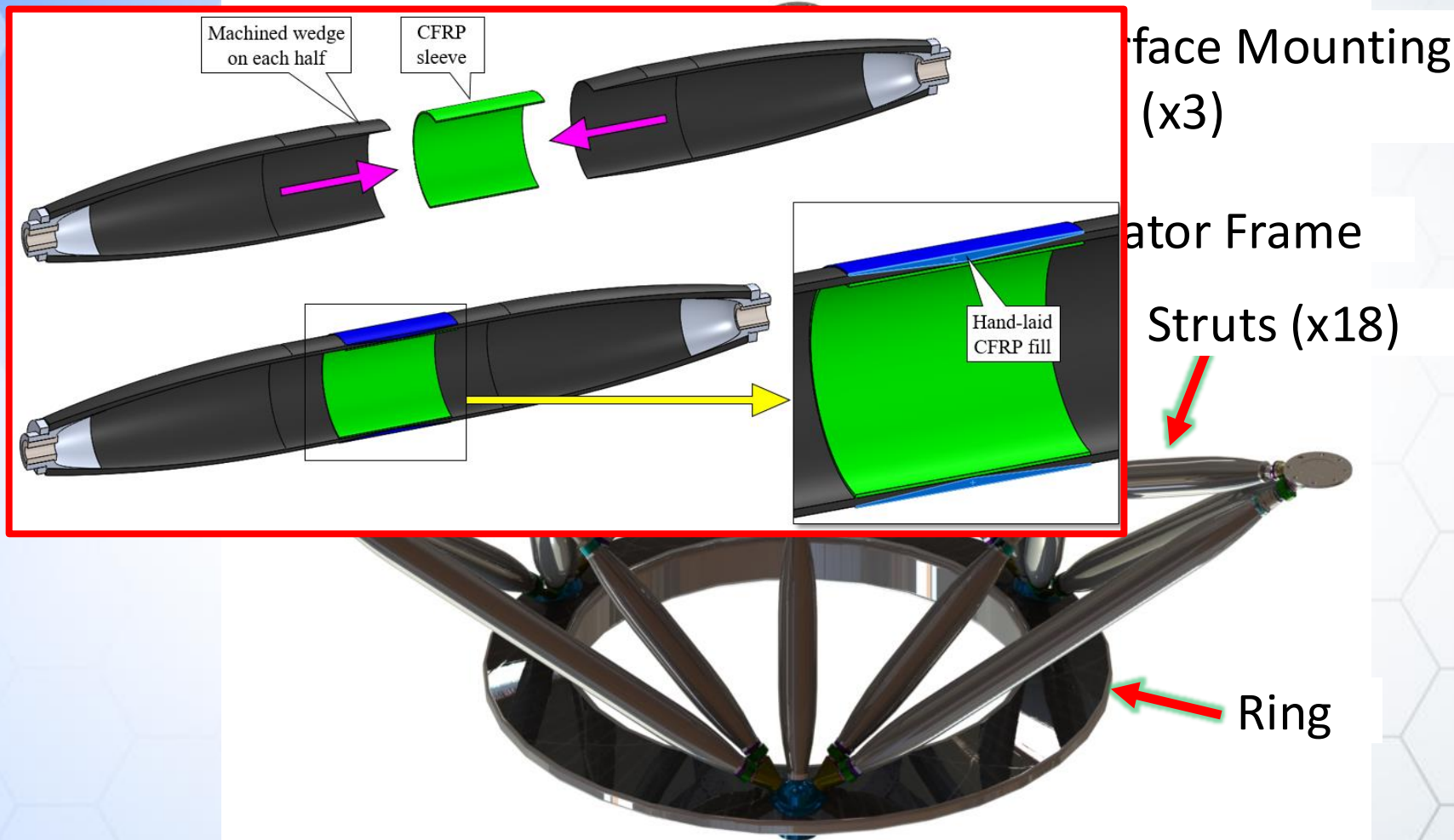
OIWFS Probe Assembly

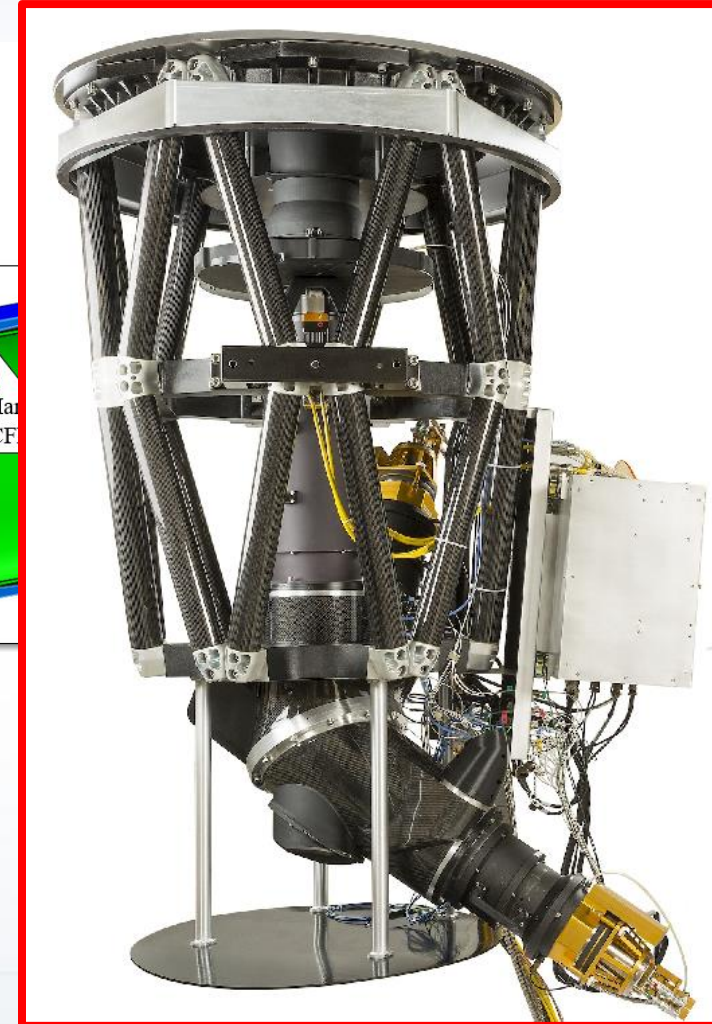
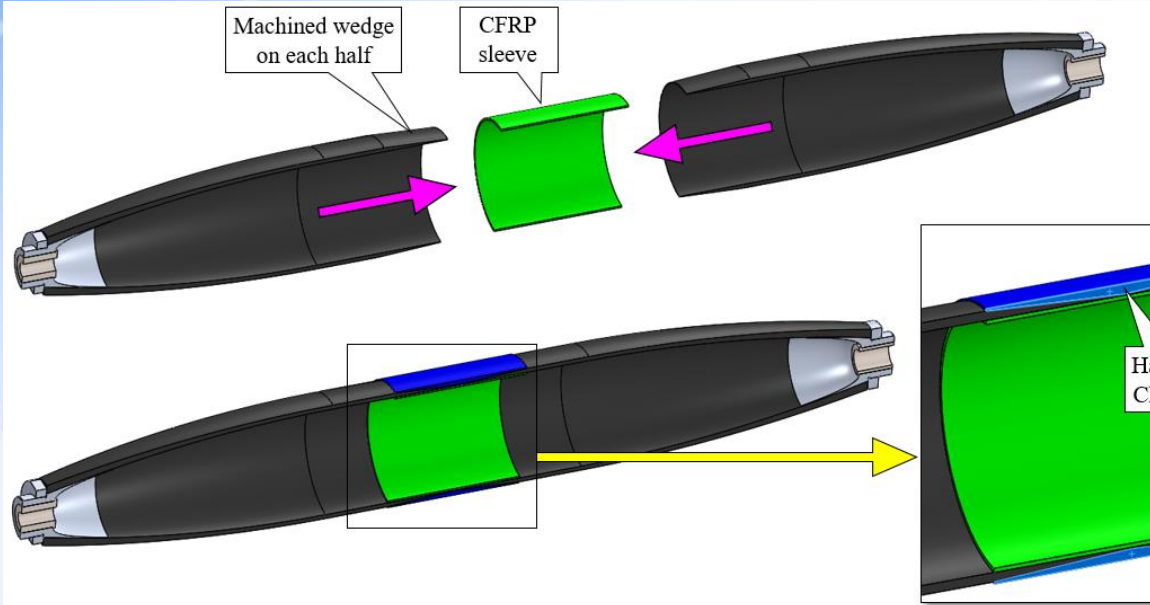


Support Structure Subsystem



Support Structure Subsystem





Sitelle Instrument on CFH Telescope
Courtesy of new.abb.com

InfraRed Imaging Spectrograph IRIS

Infrared Imaging Spectrograph

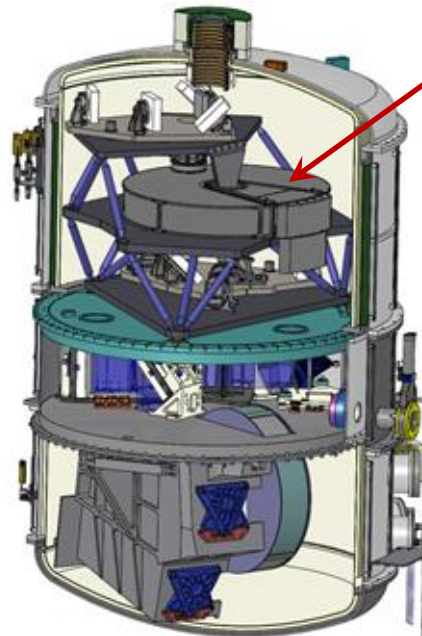


国立天文台
NAOJ

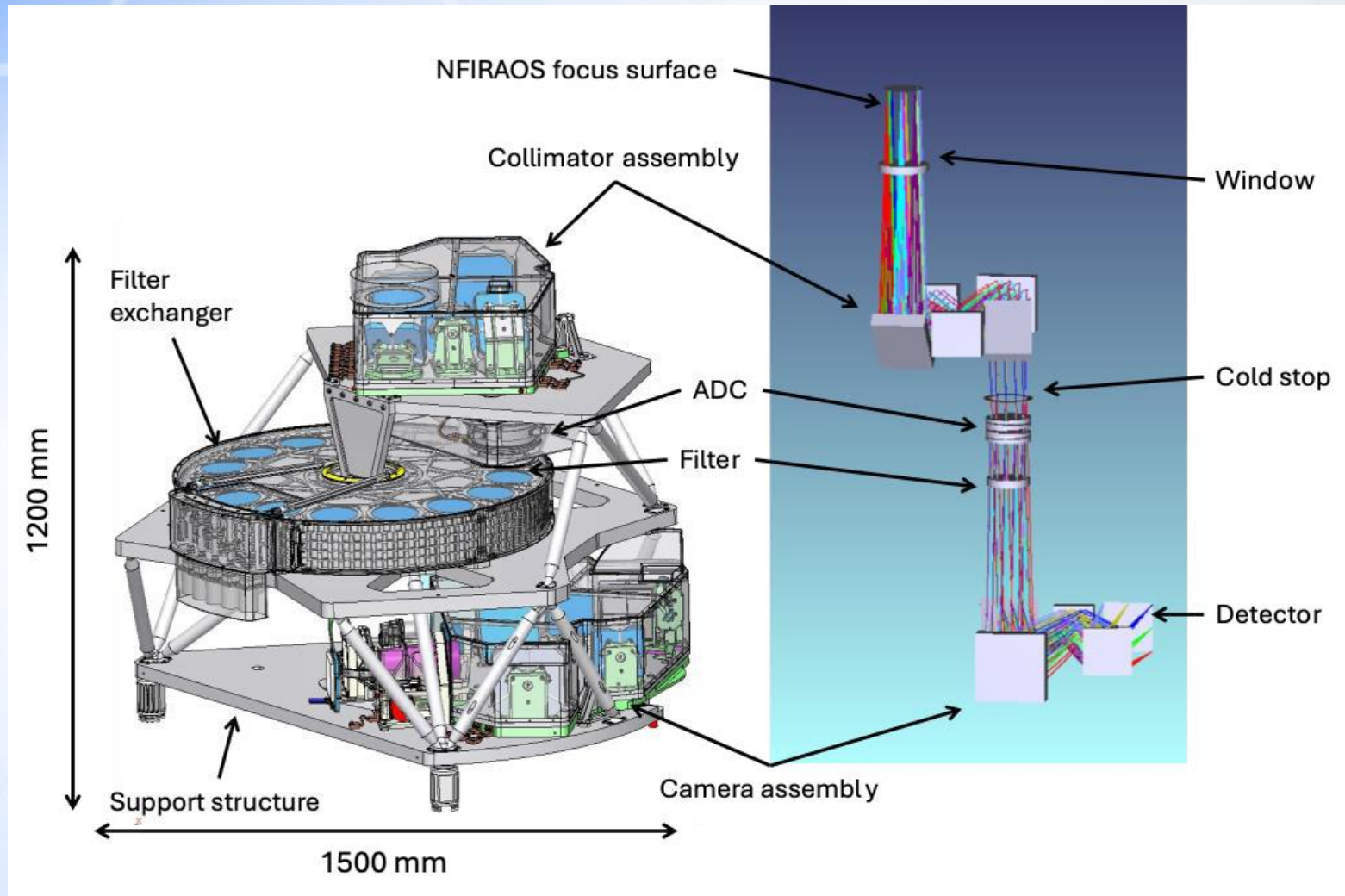


Imager

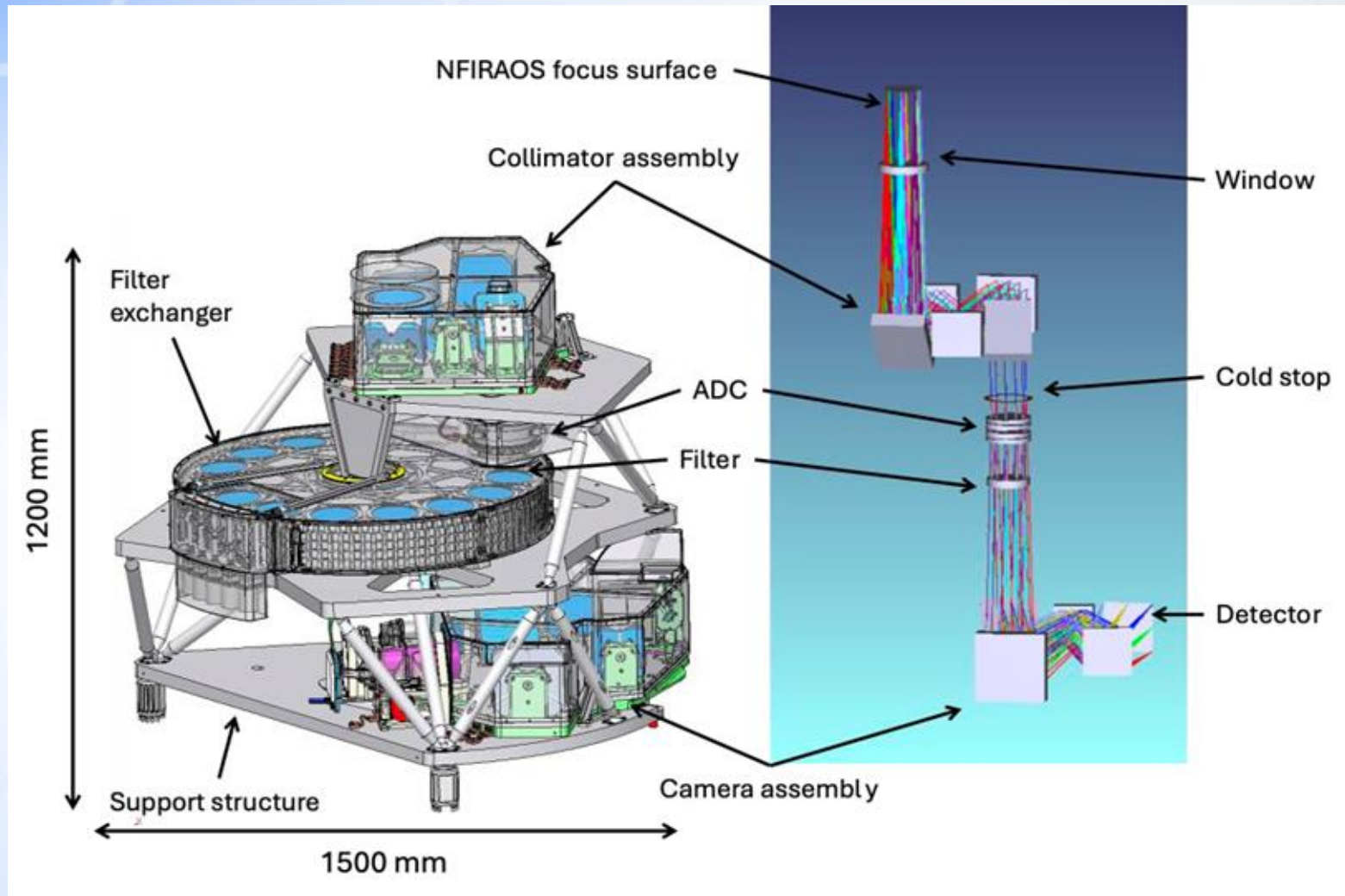
Suzuki et al. (2026)



Layout

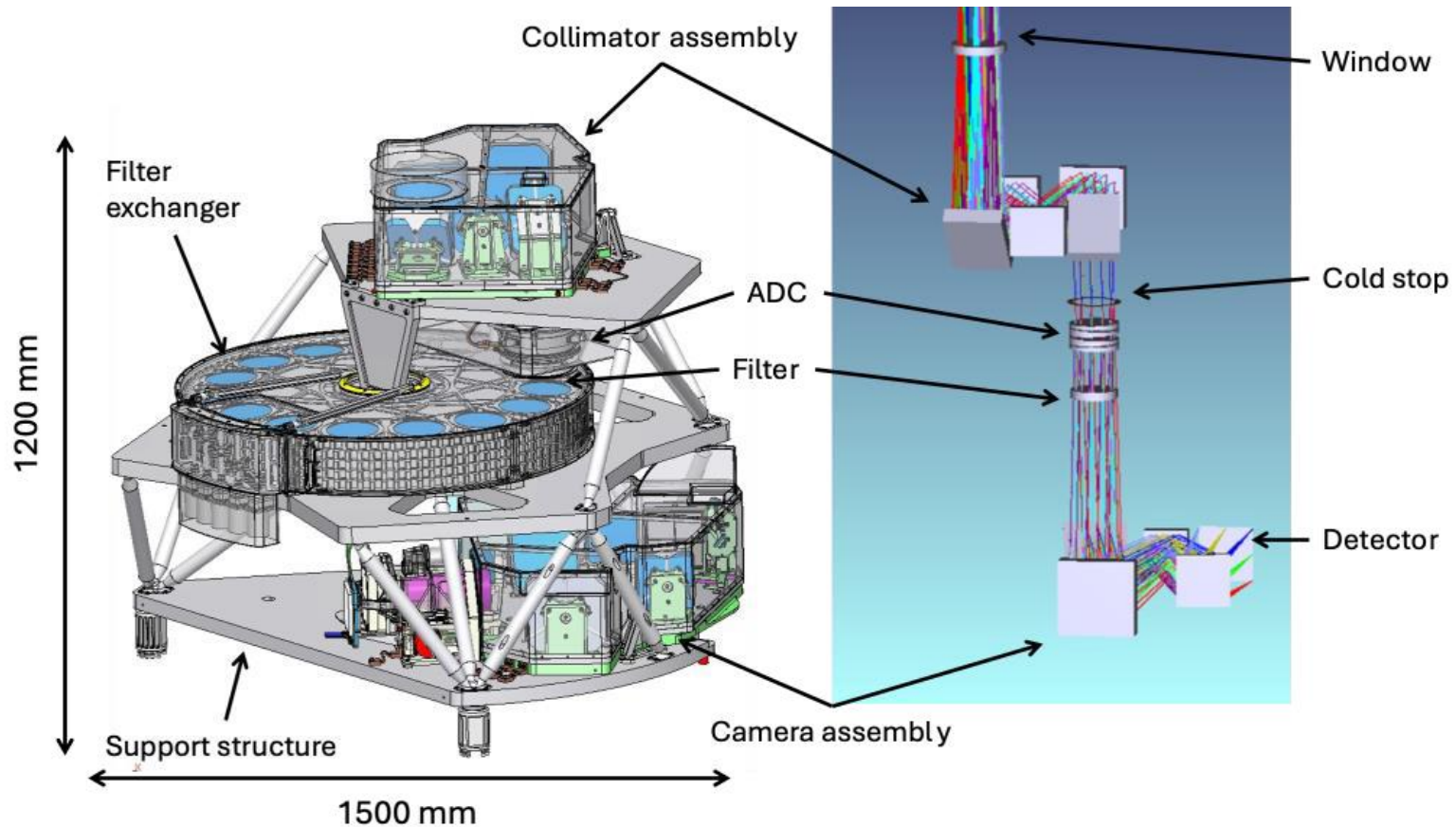


Layout



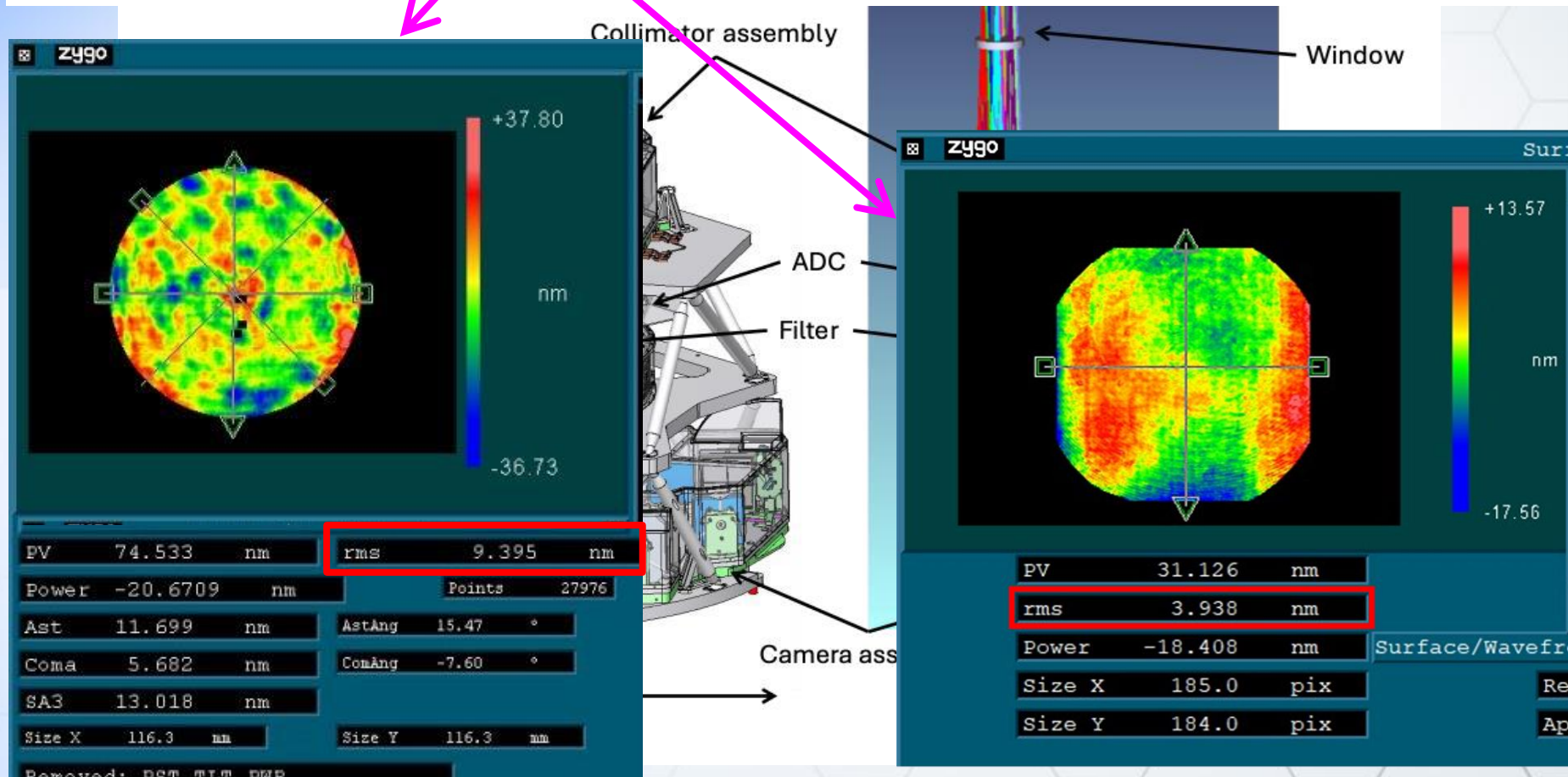
Layout

- 4 aspheric (3 CC, 1 CV), 1 sphere (CV), and 4 flat mirrors.

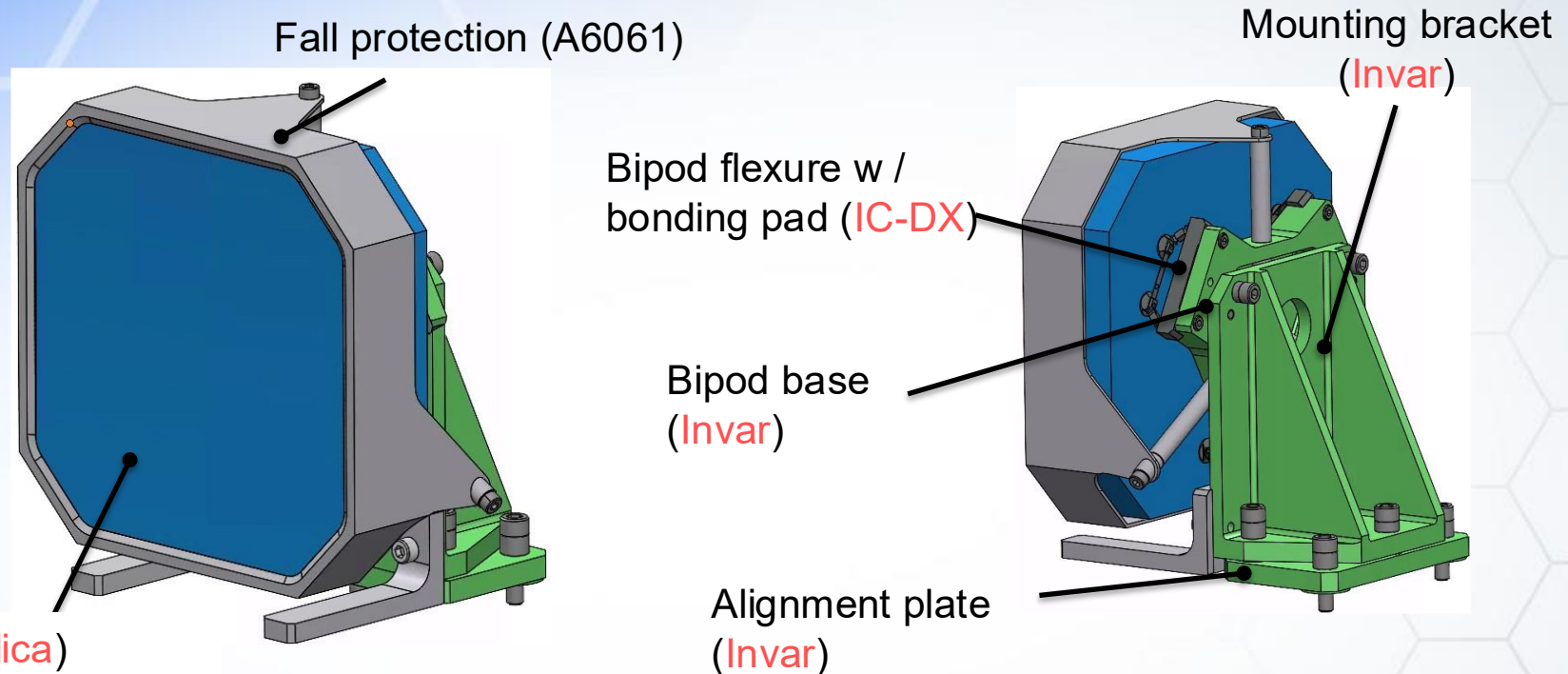


Layout

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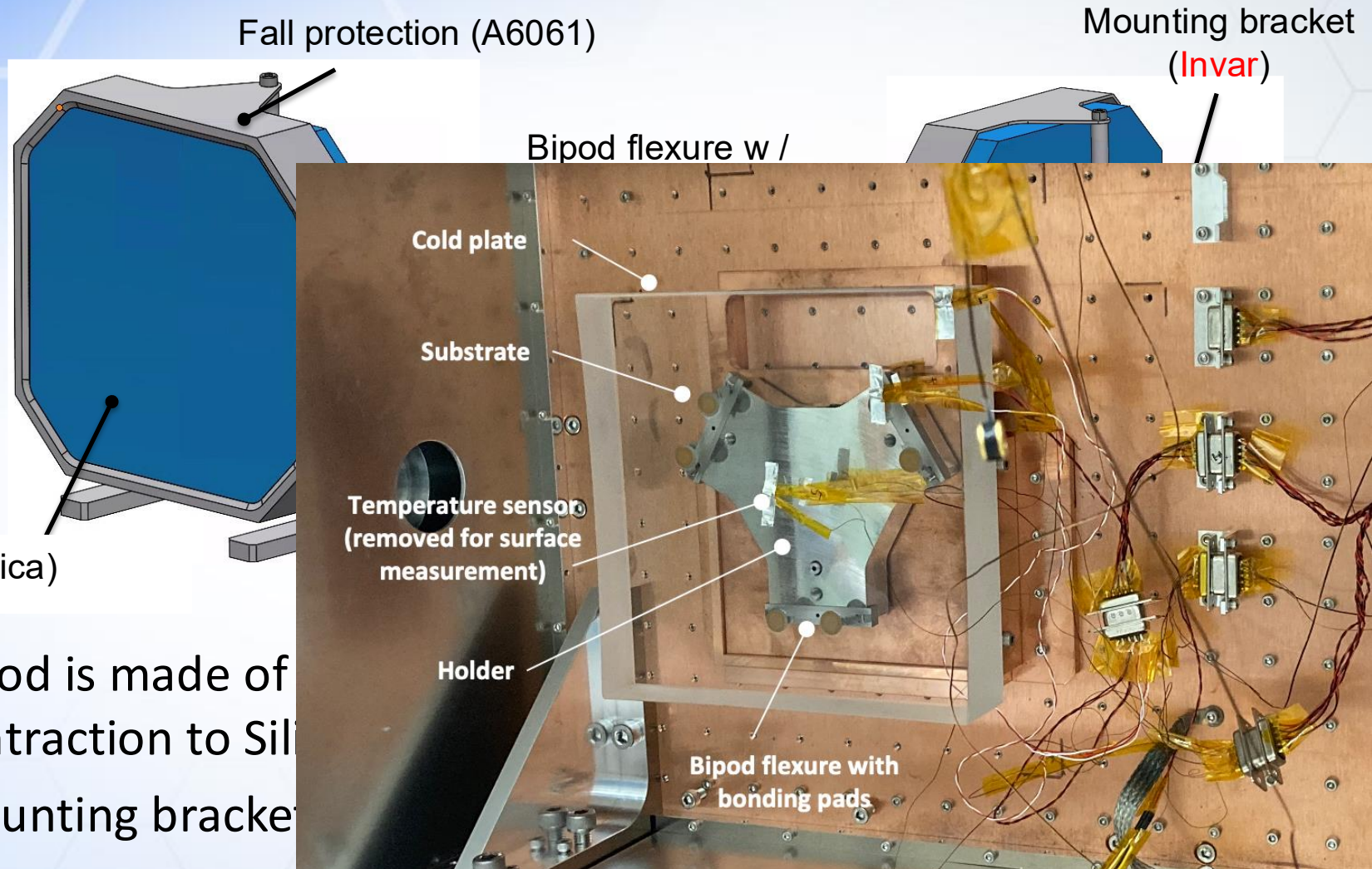


Mirror Mounts



- Bipod is made of special Invar, IC-DX, which has the close thermal contraction to Silica to minimize an impact to the mirror shape.
- Mounting bracket and alignment plate are made of Invar.

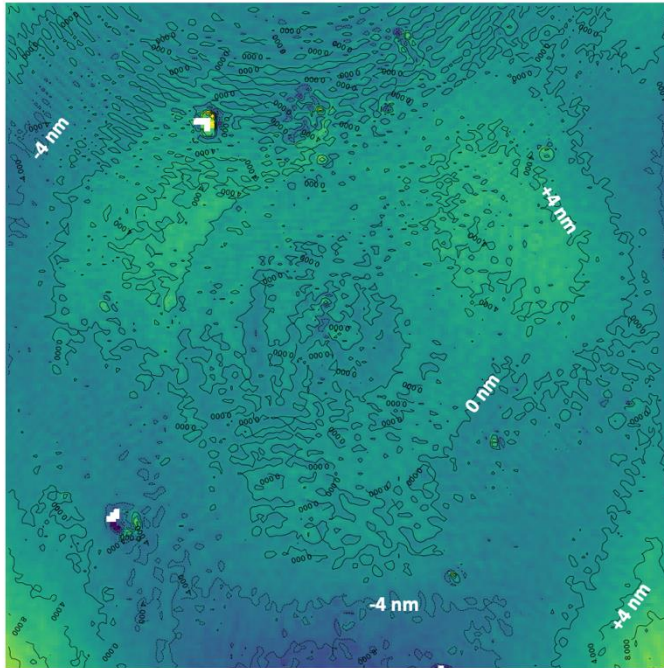
Mirror Mounts



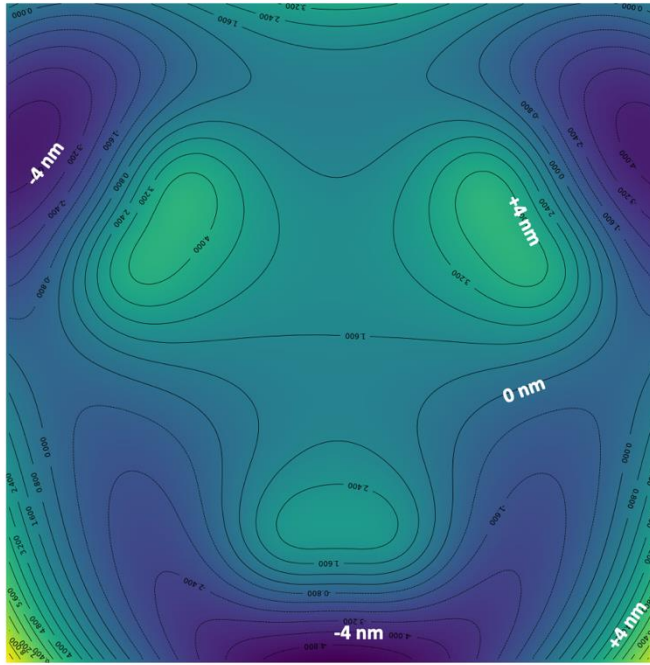
- Bipod is made of contraction to Sil
- Mounting bracke

Mirror Mounts

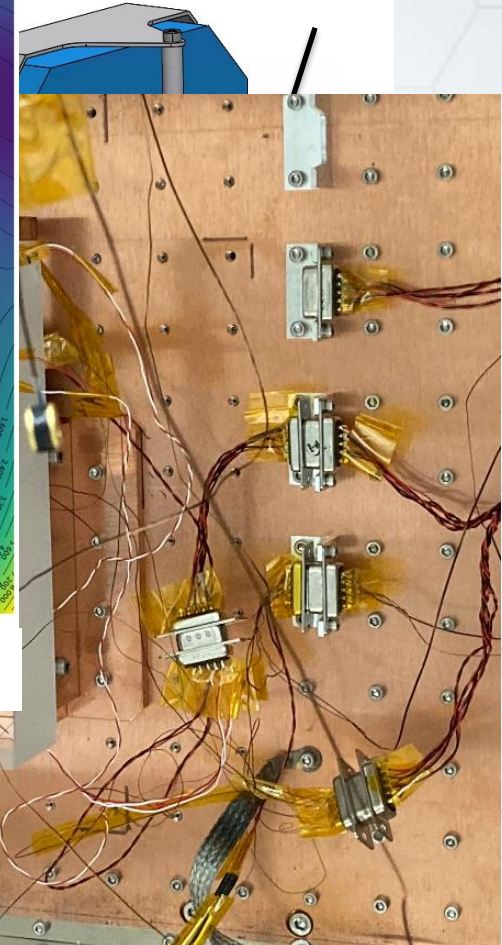
Measured



Predicted

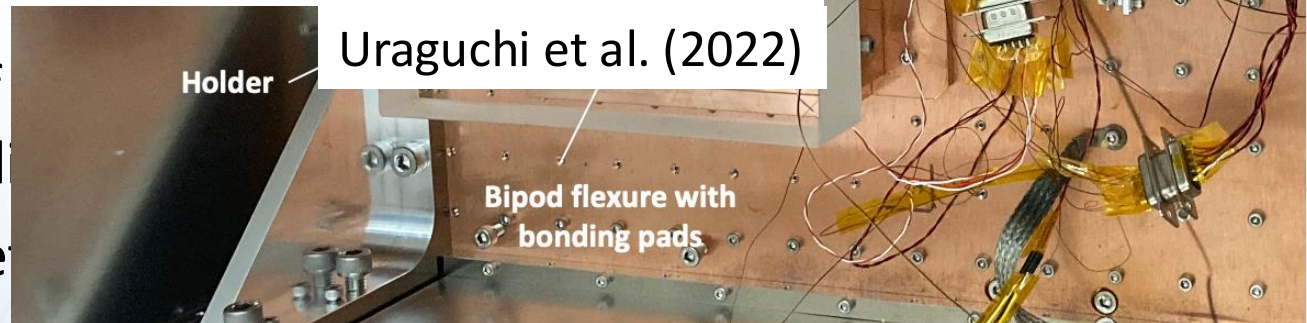


Mounting bracket
(Invar)

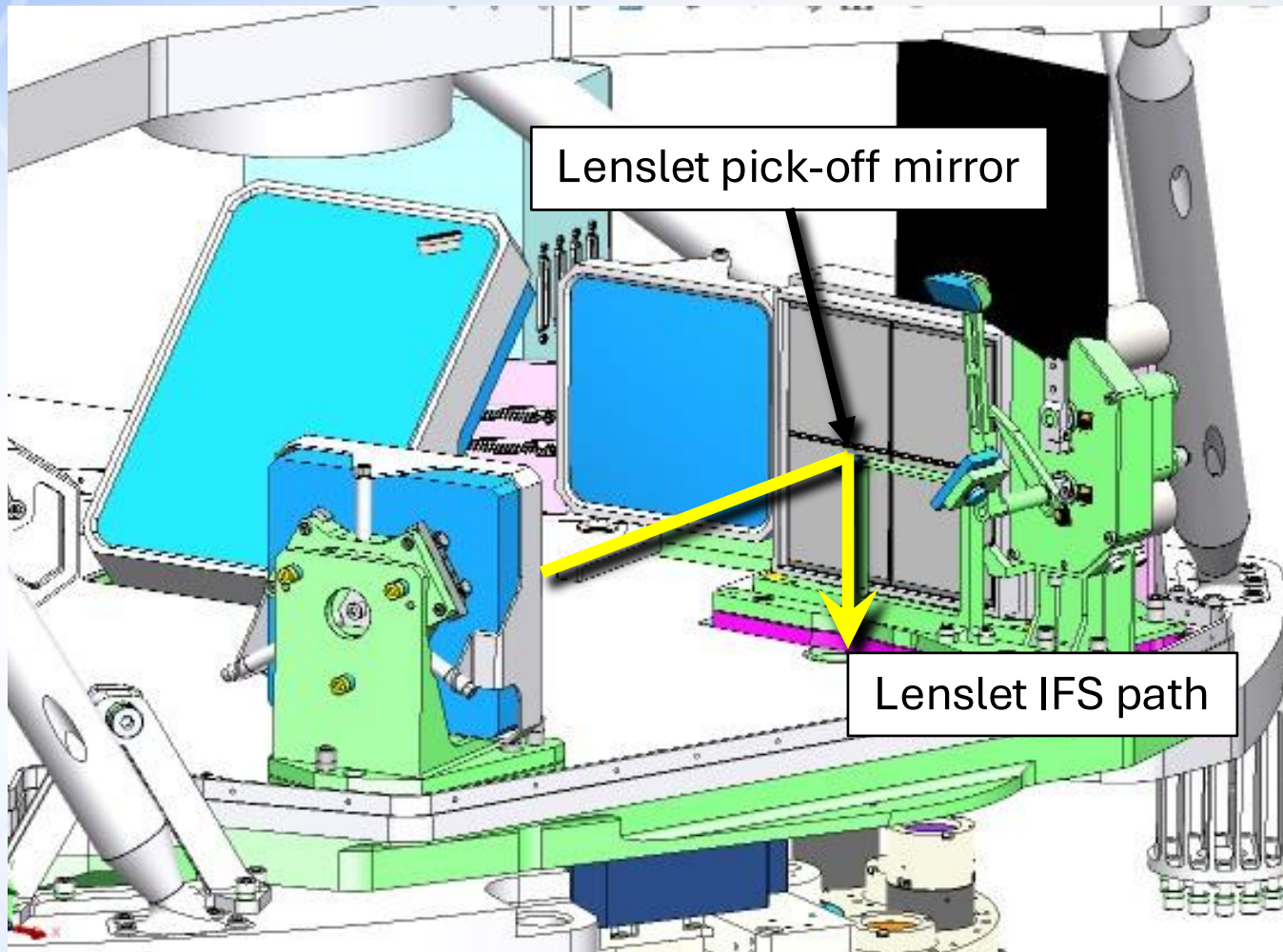


- Bipod is made of contraction to Sil
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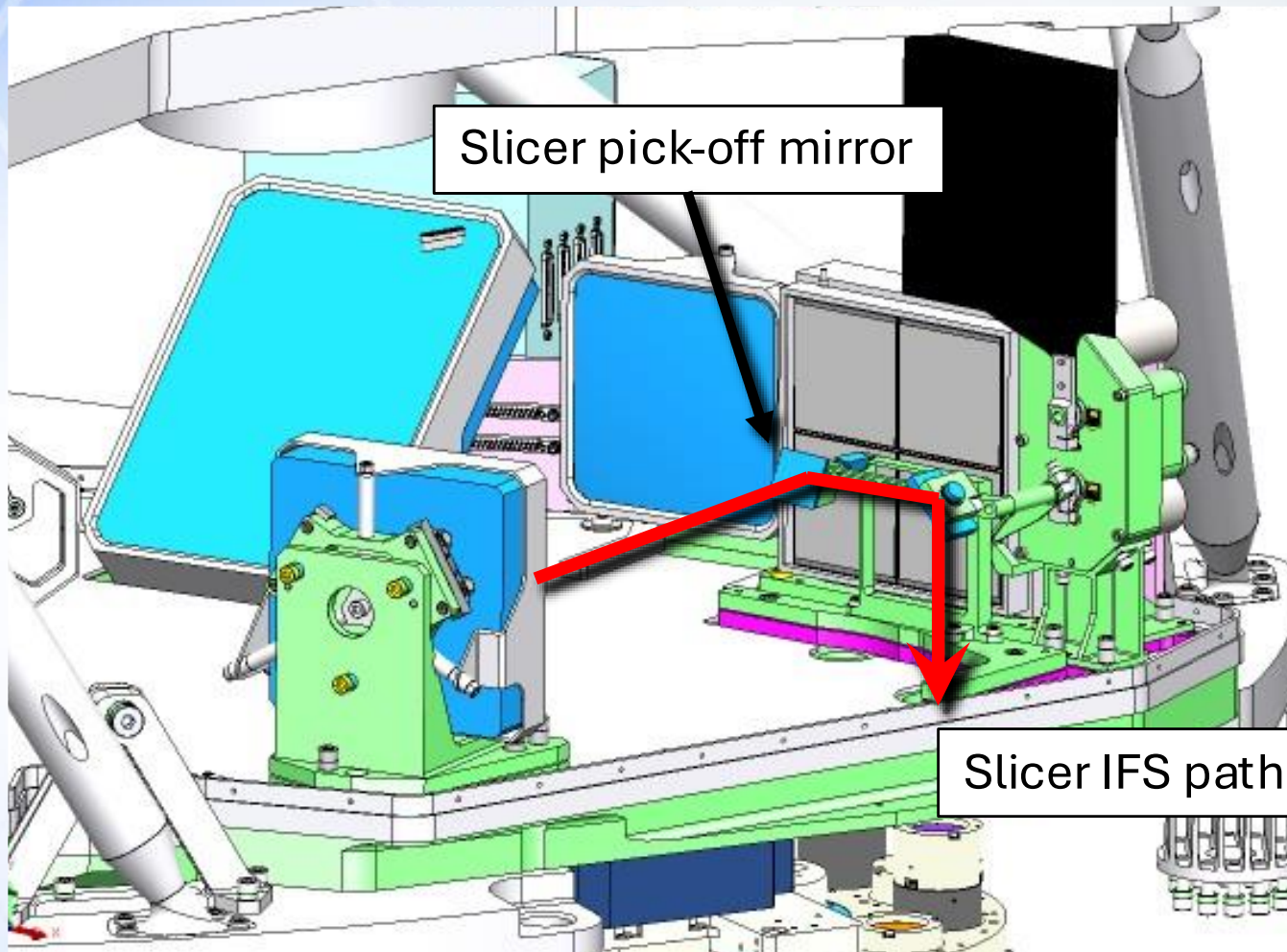
Uraguchi et al. (2022)



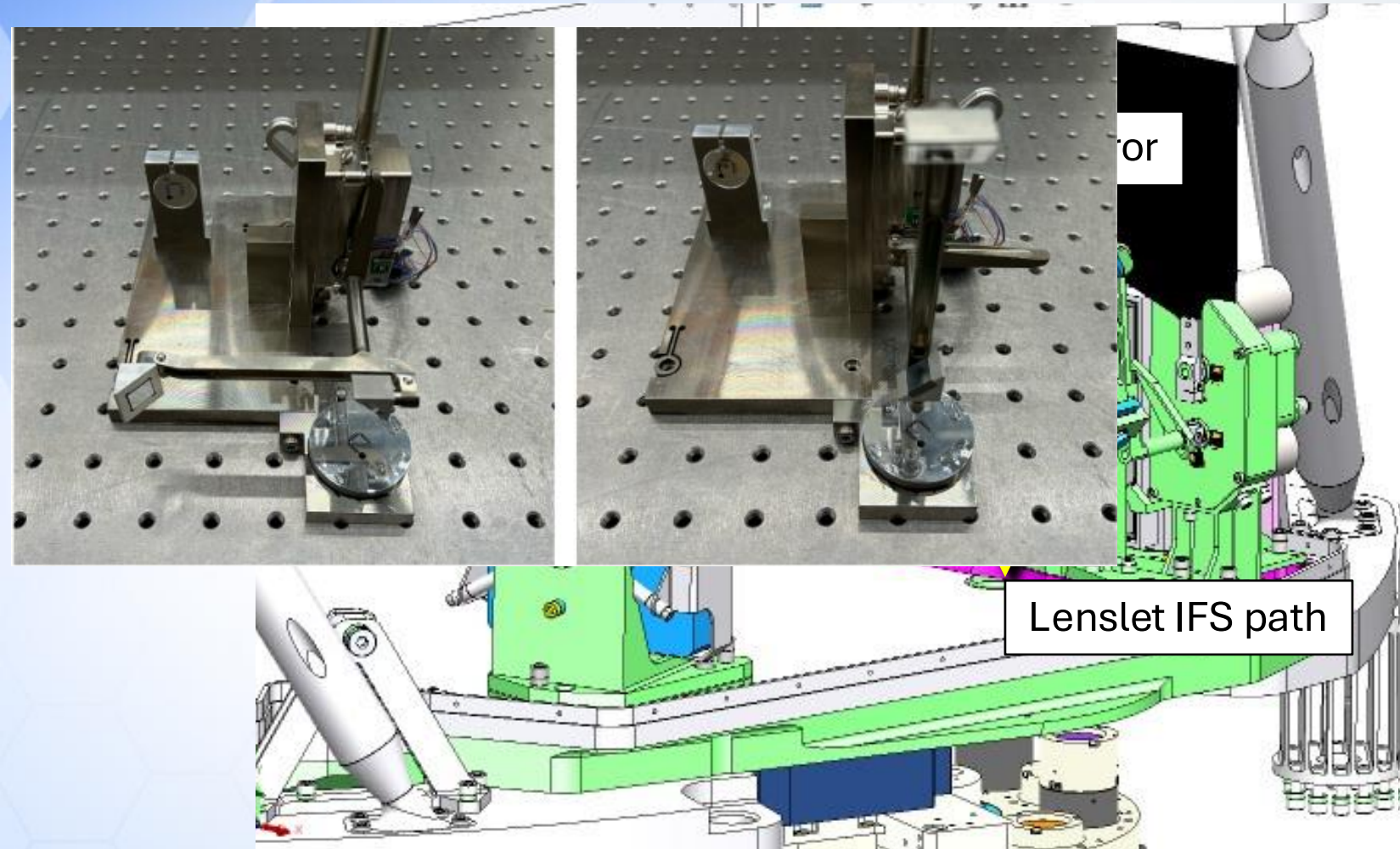
Pickoff Mirror



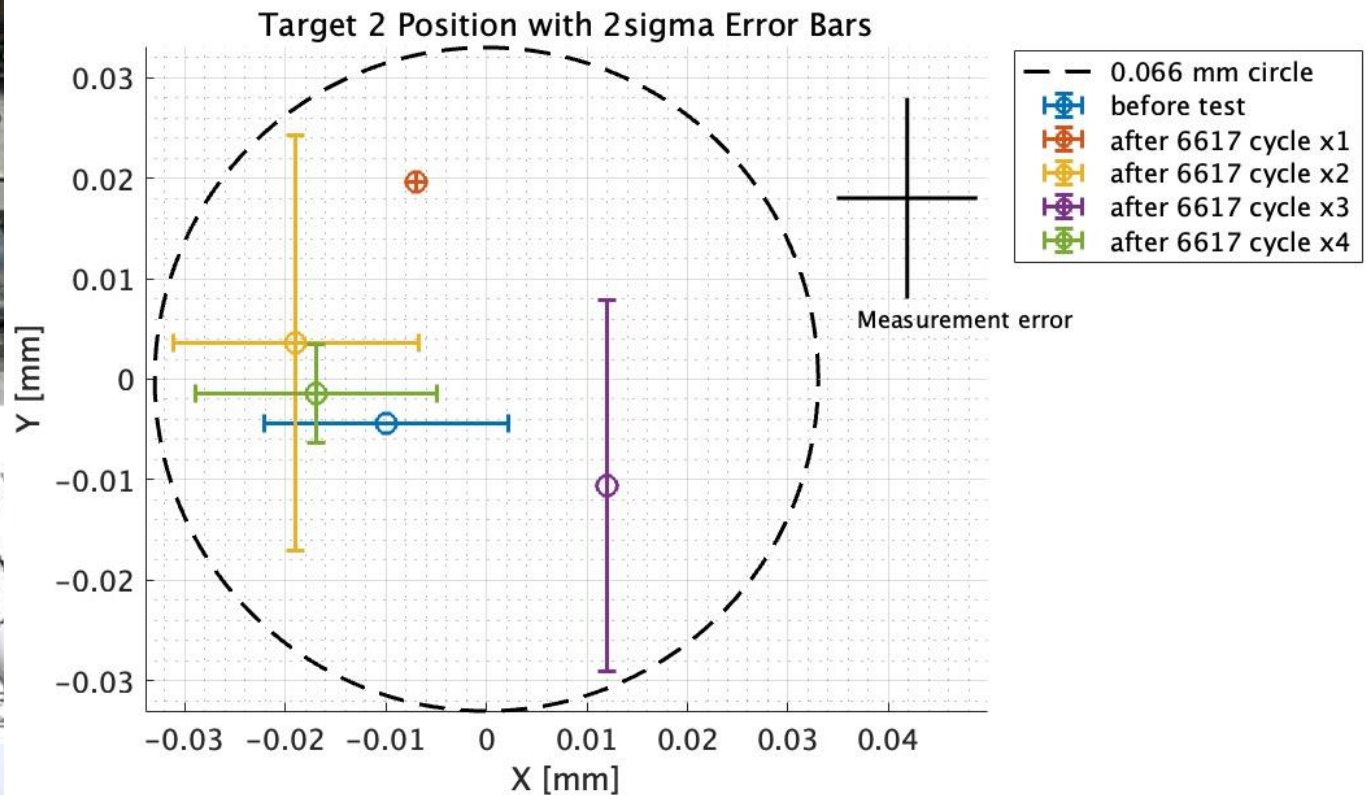
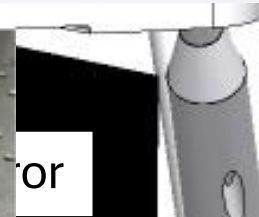
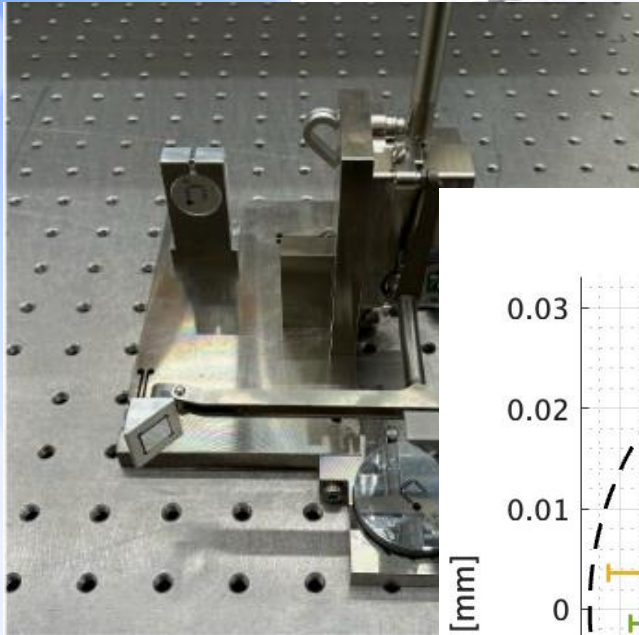
Pickoff Mirror

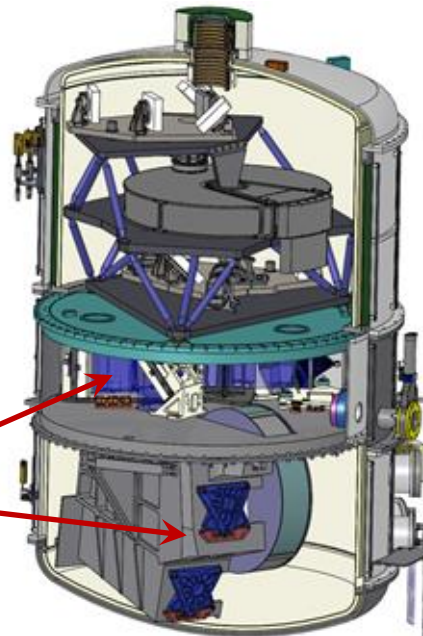


Pickoff Mirror



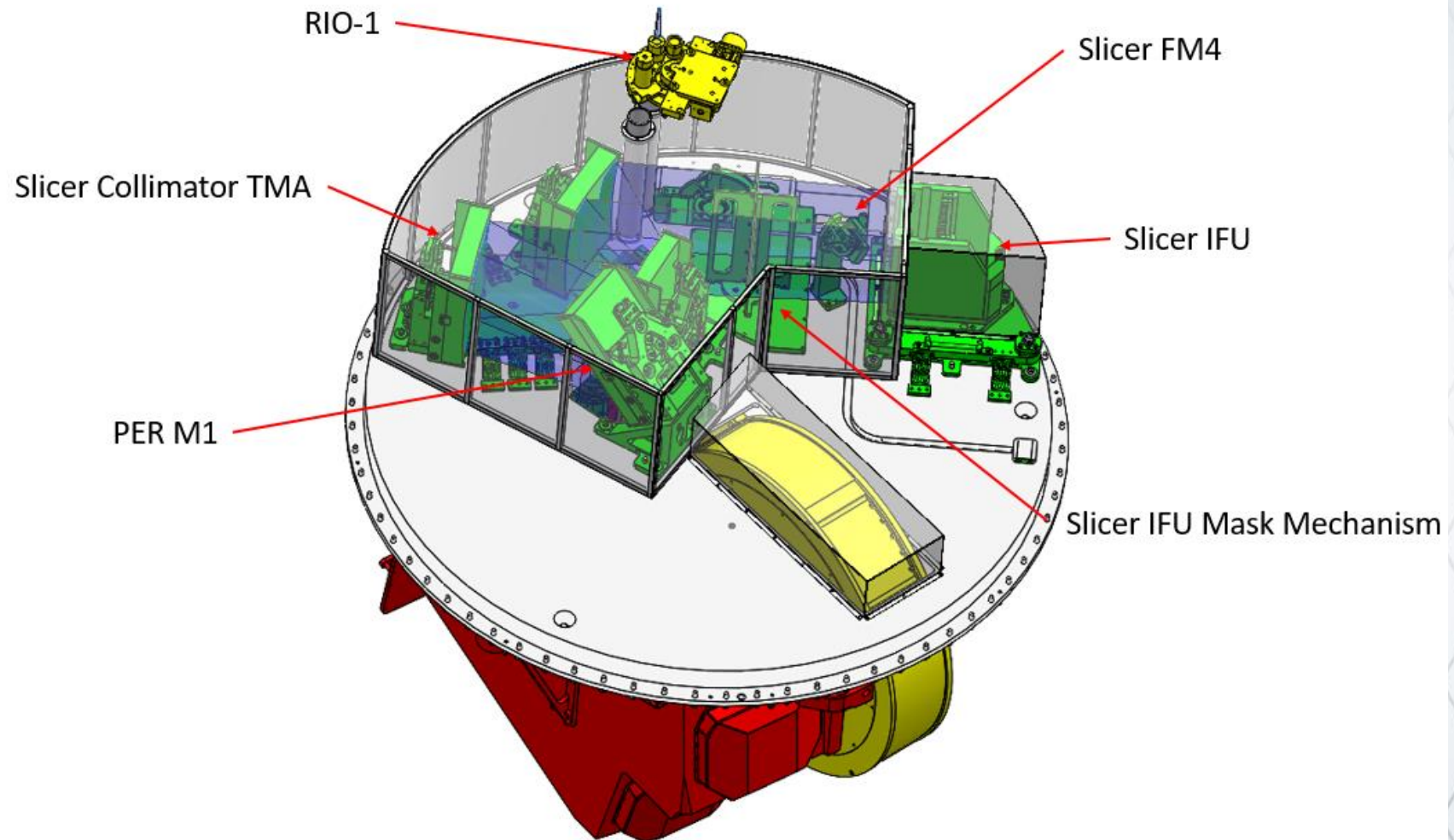
Pickoff Mirror



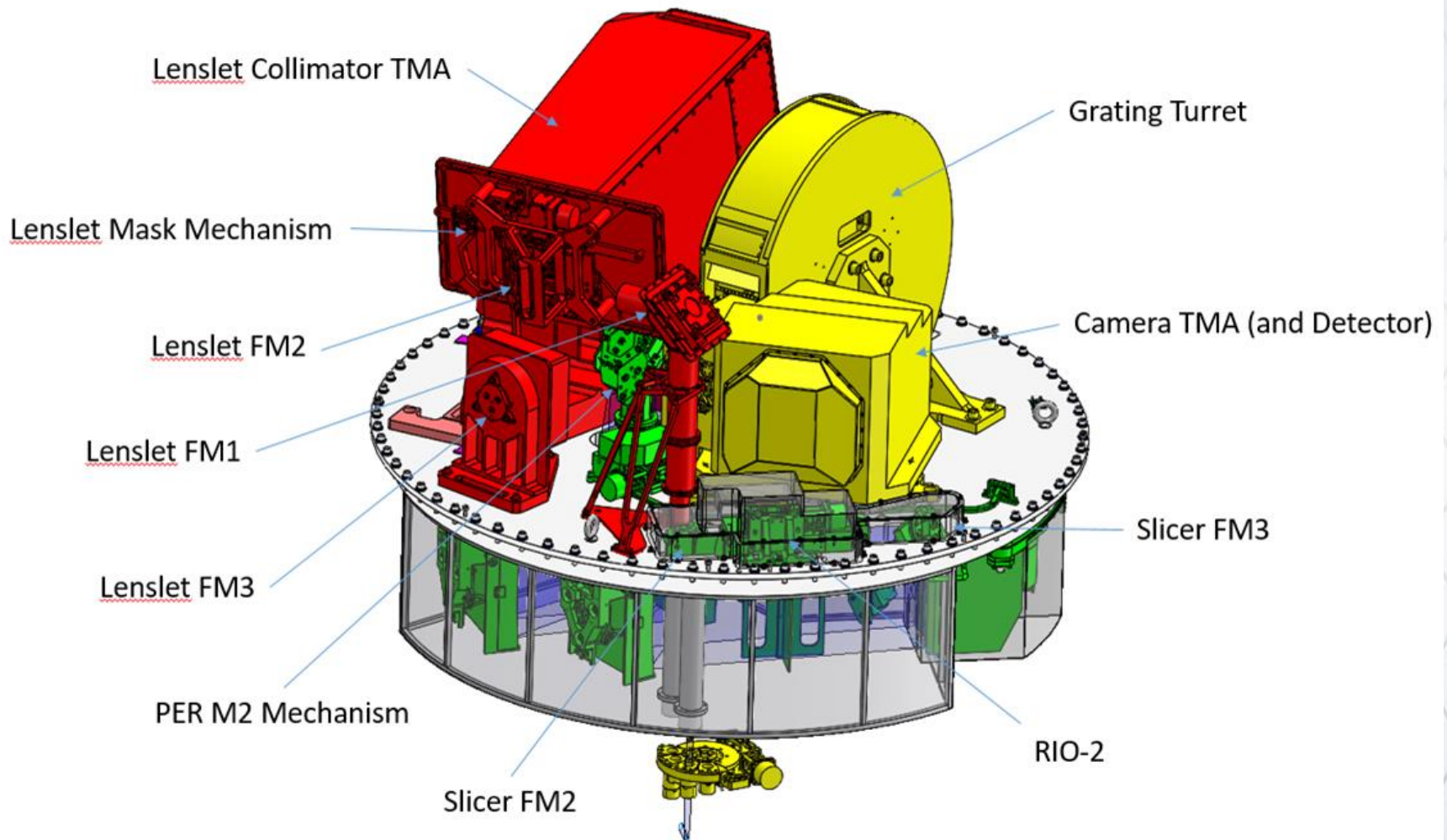


*Integral field
spectrograph*

IFS Subsystem



IFS Subsystem



Lenslet Array Mode Layout

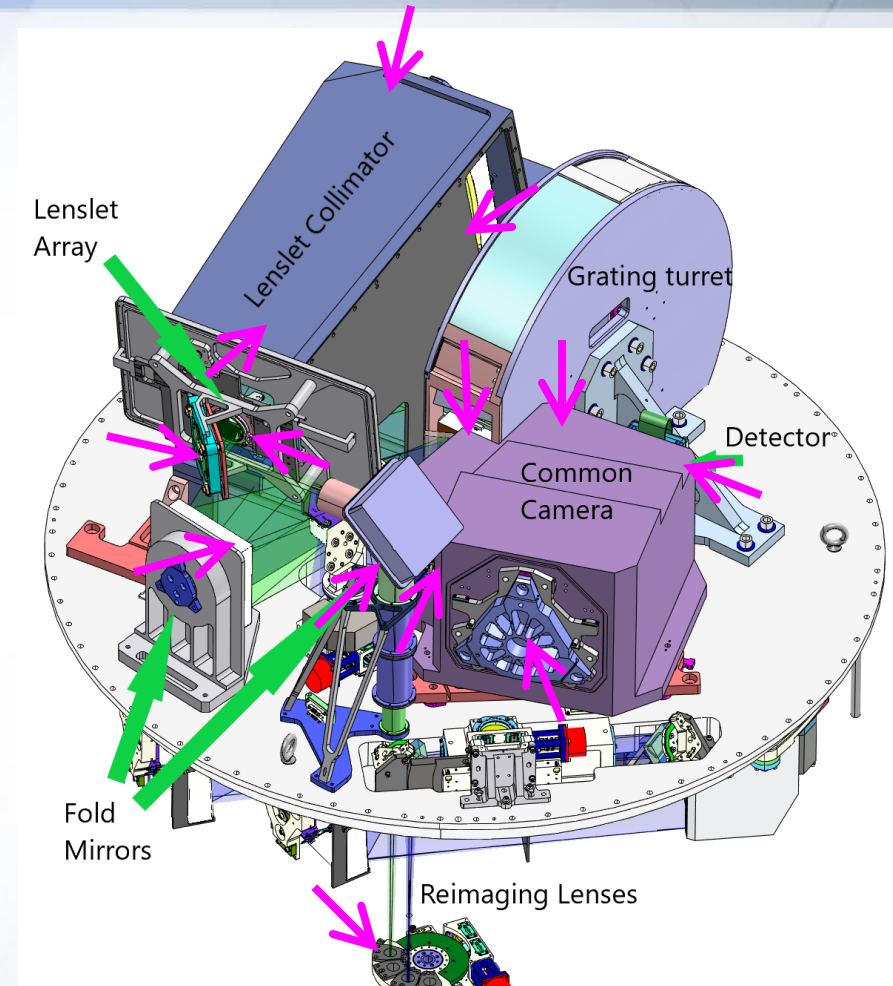
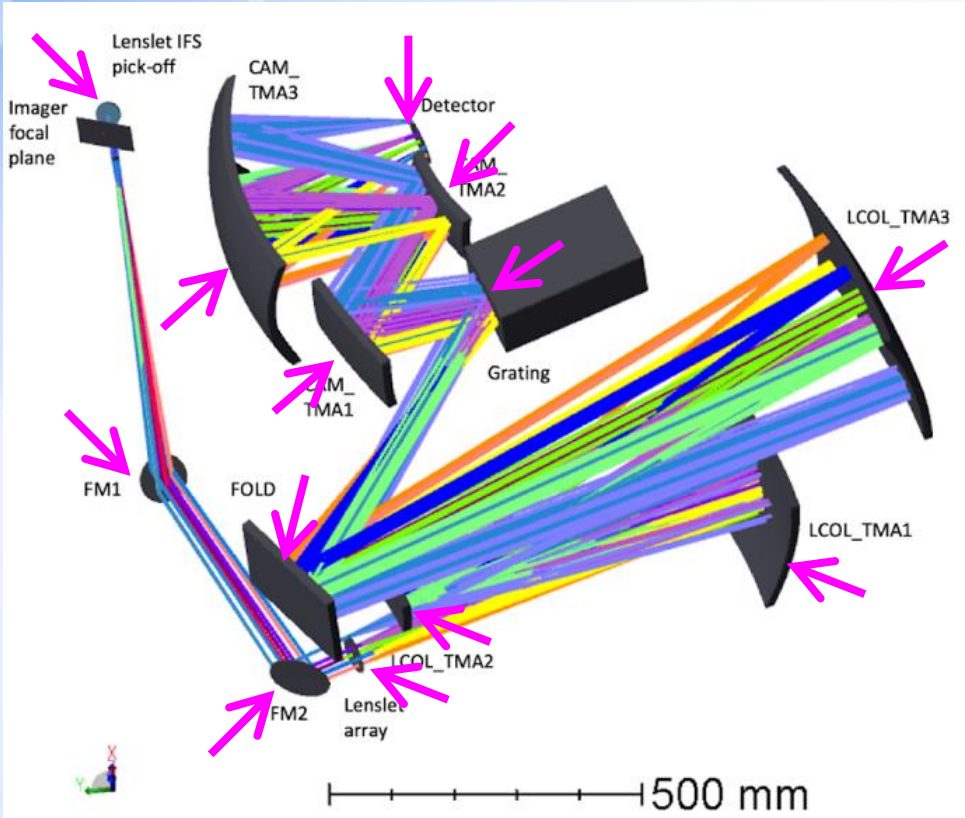
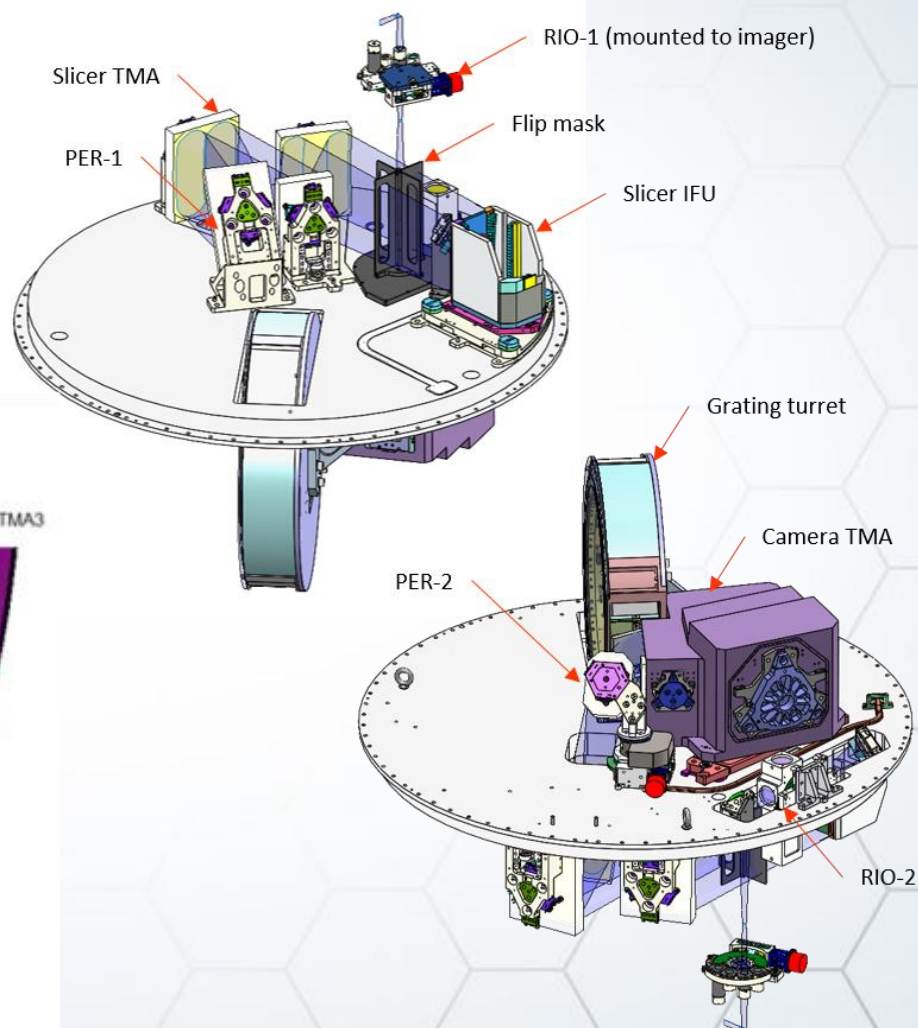
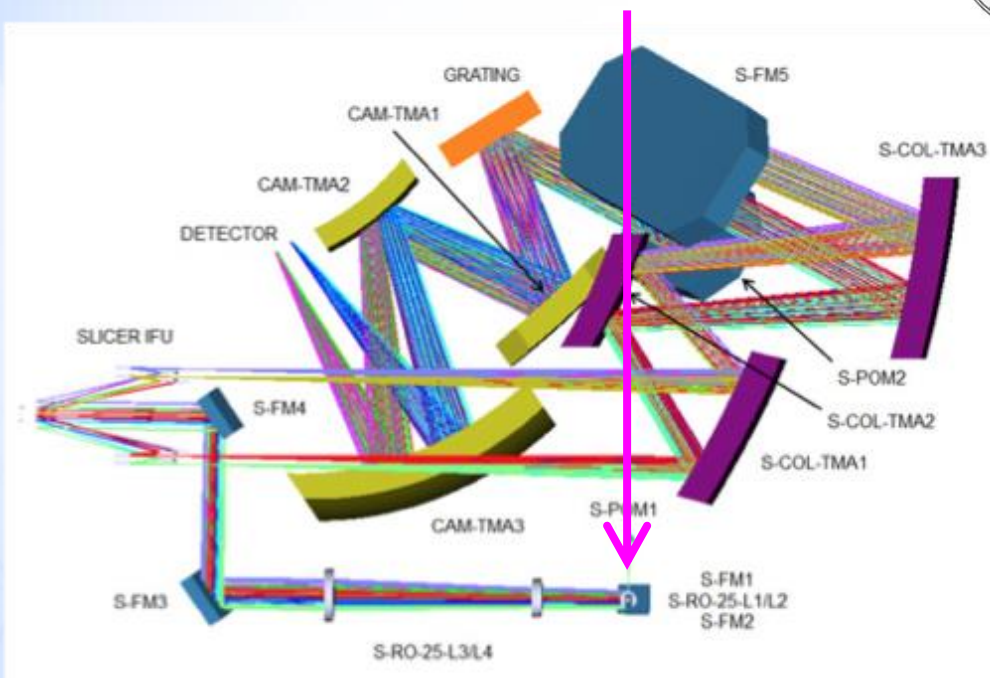
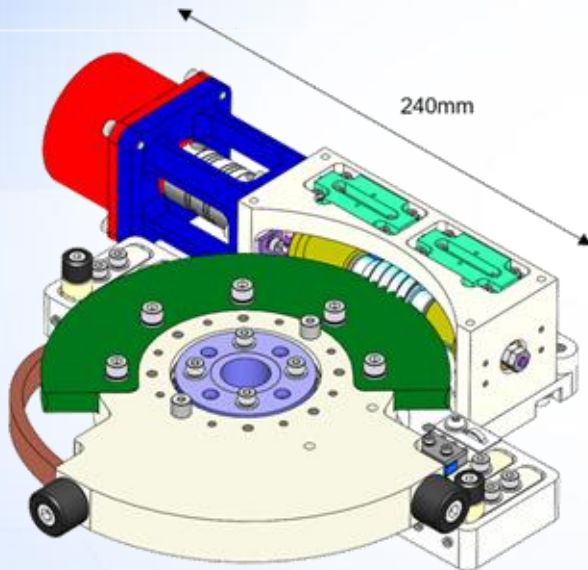


Image Slicer Mode Layout



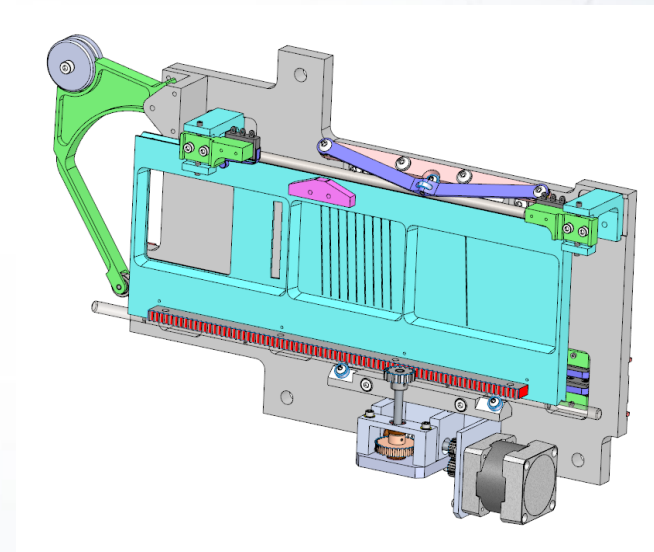
- Three mechanism types are based on heritage in UCLA and CIT.



Switching stage
(Two position)

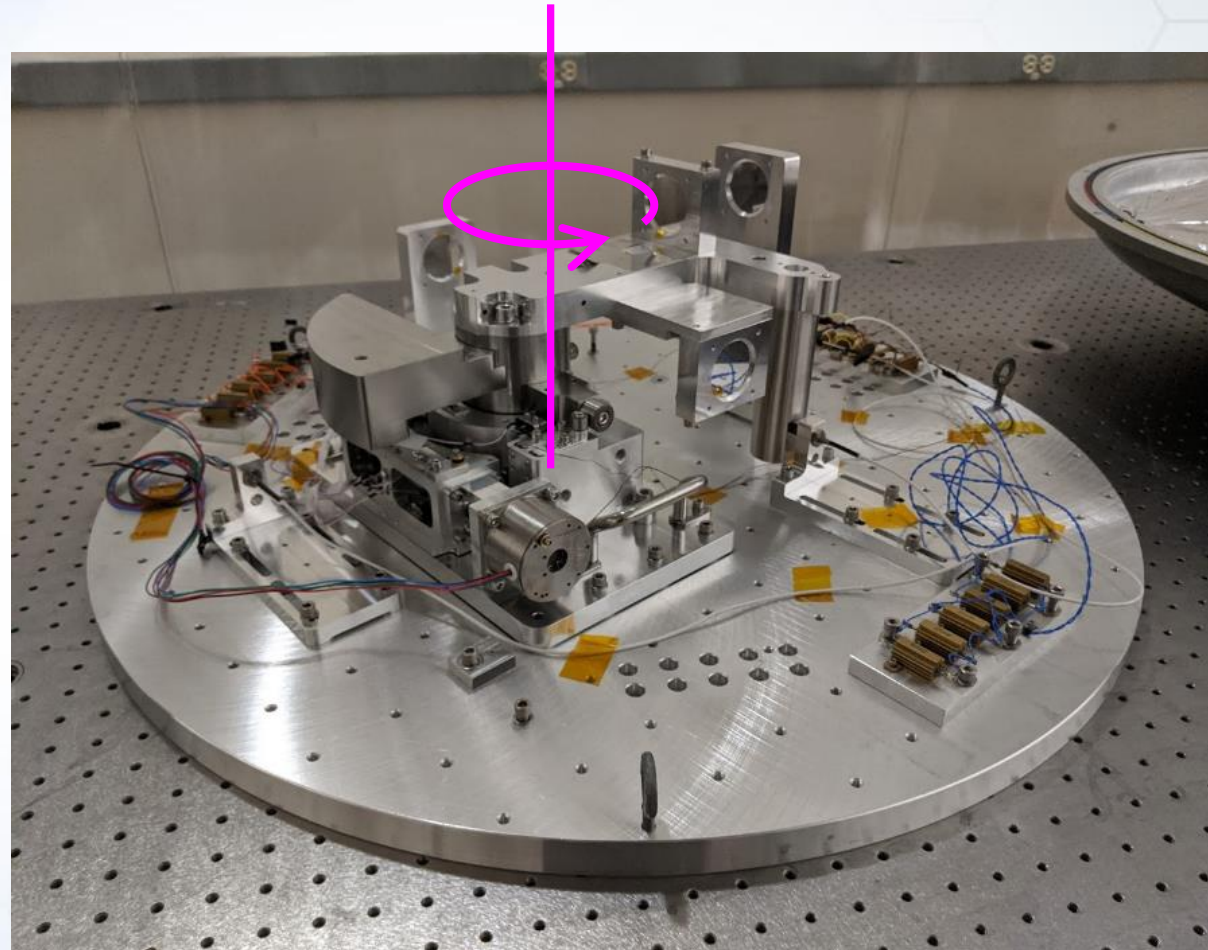
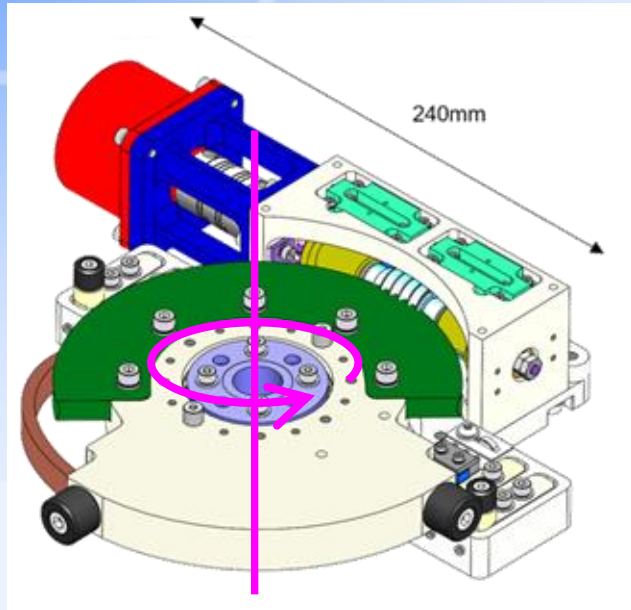


Grating turret
(rotary motion)

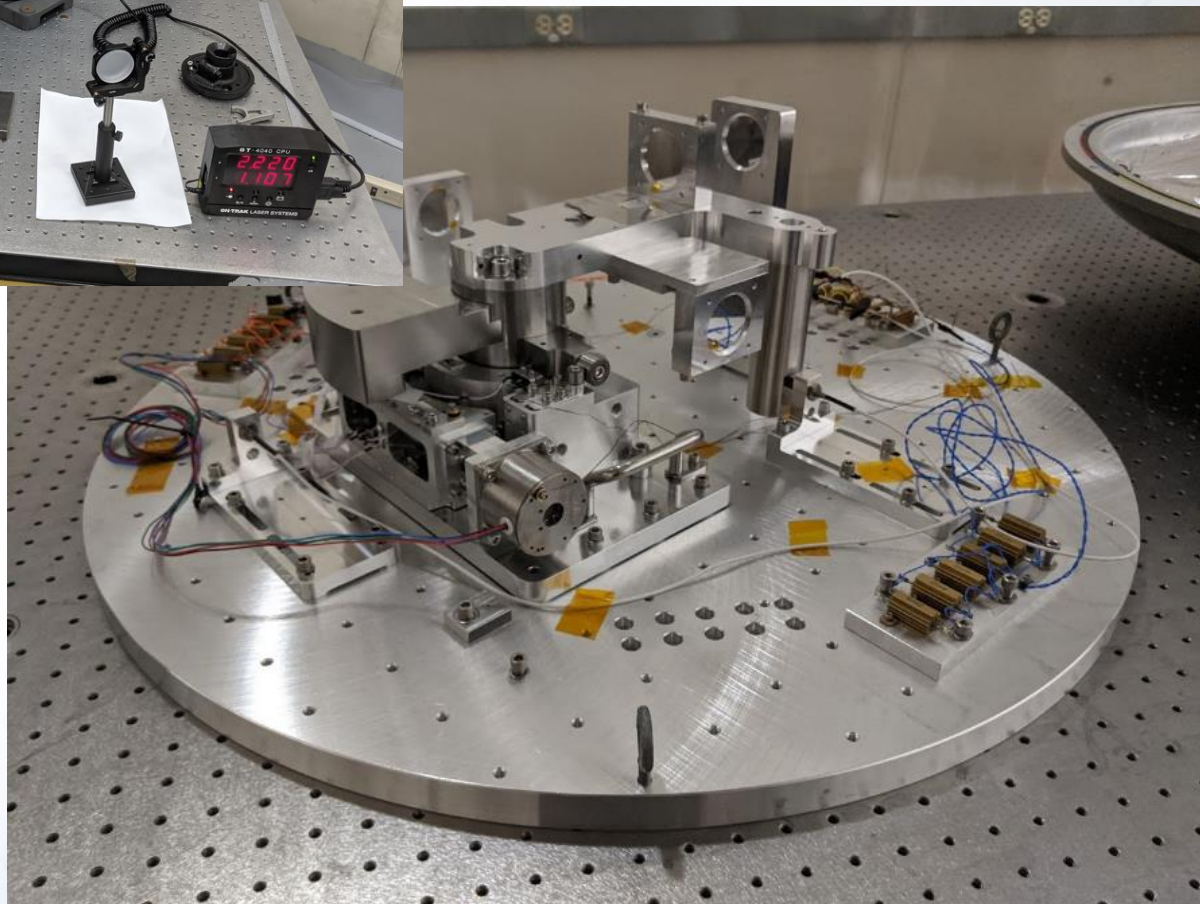
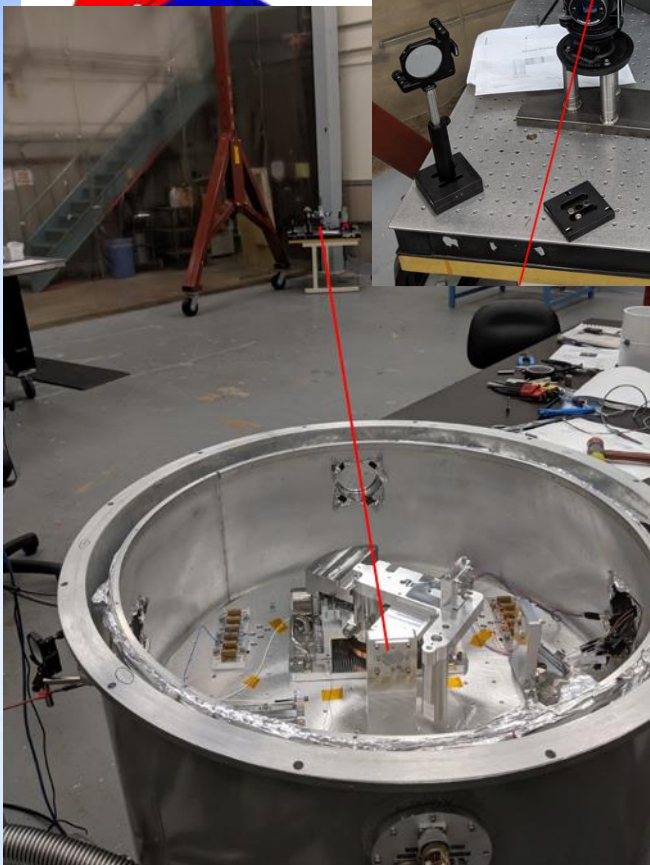
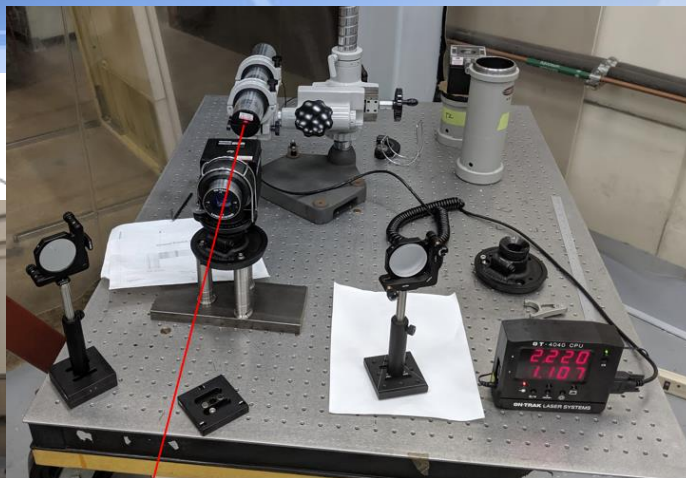


Lenslet mask slide
(Linear motion)

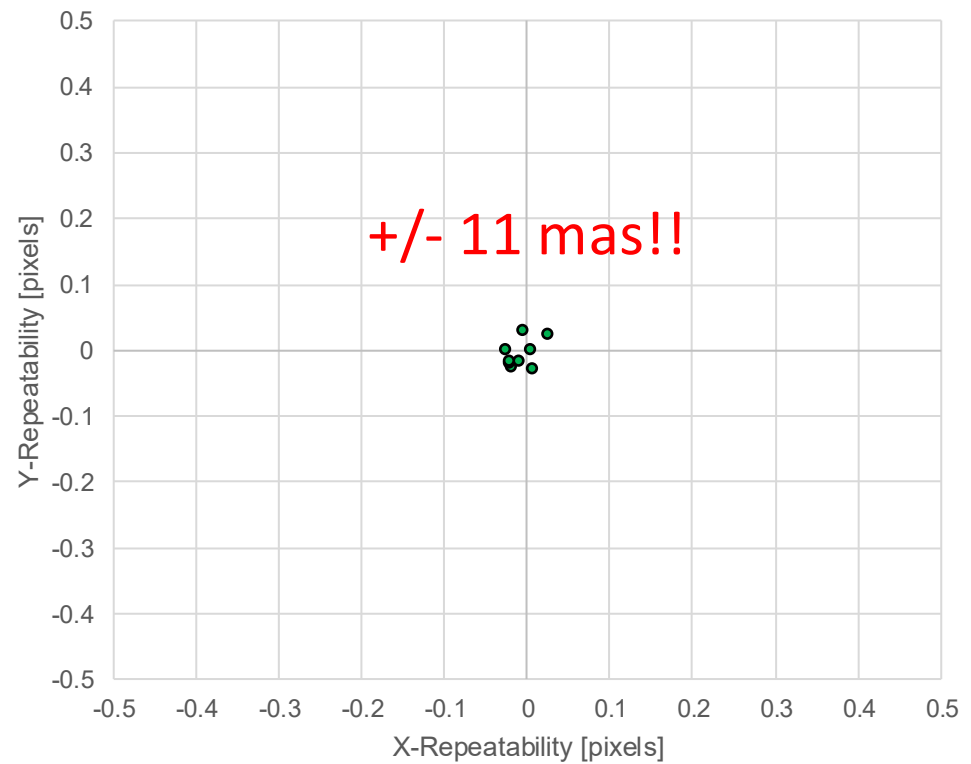
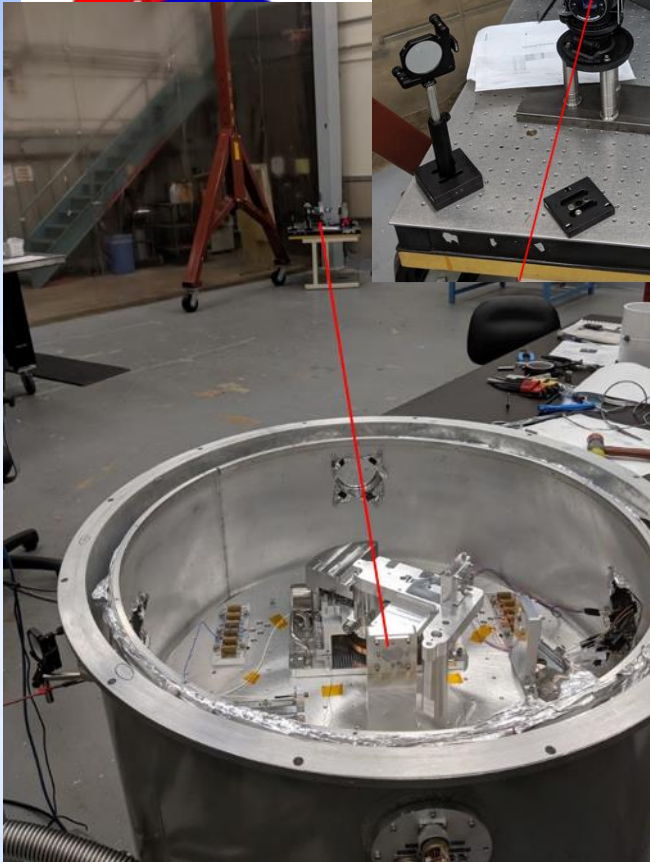
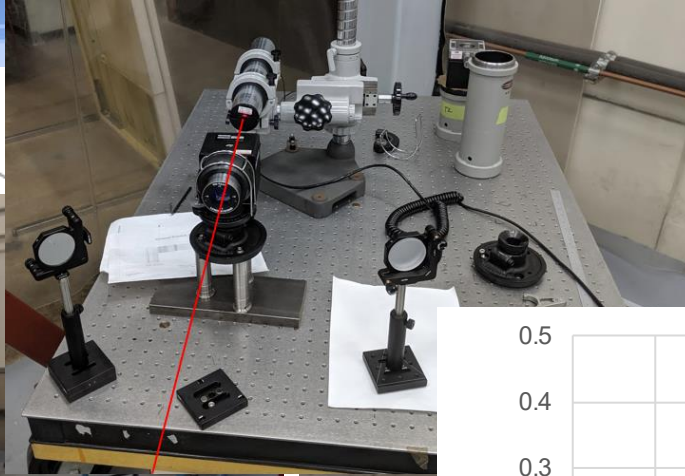
Switching stage



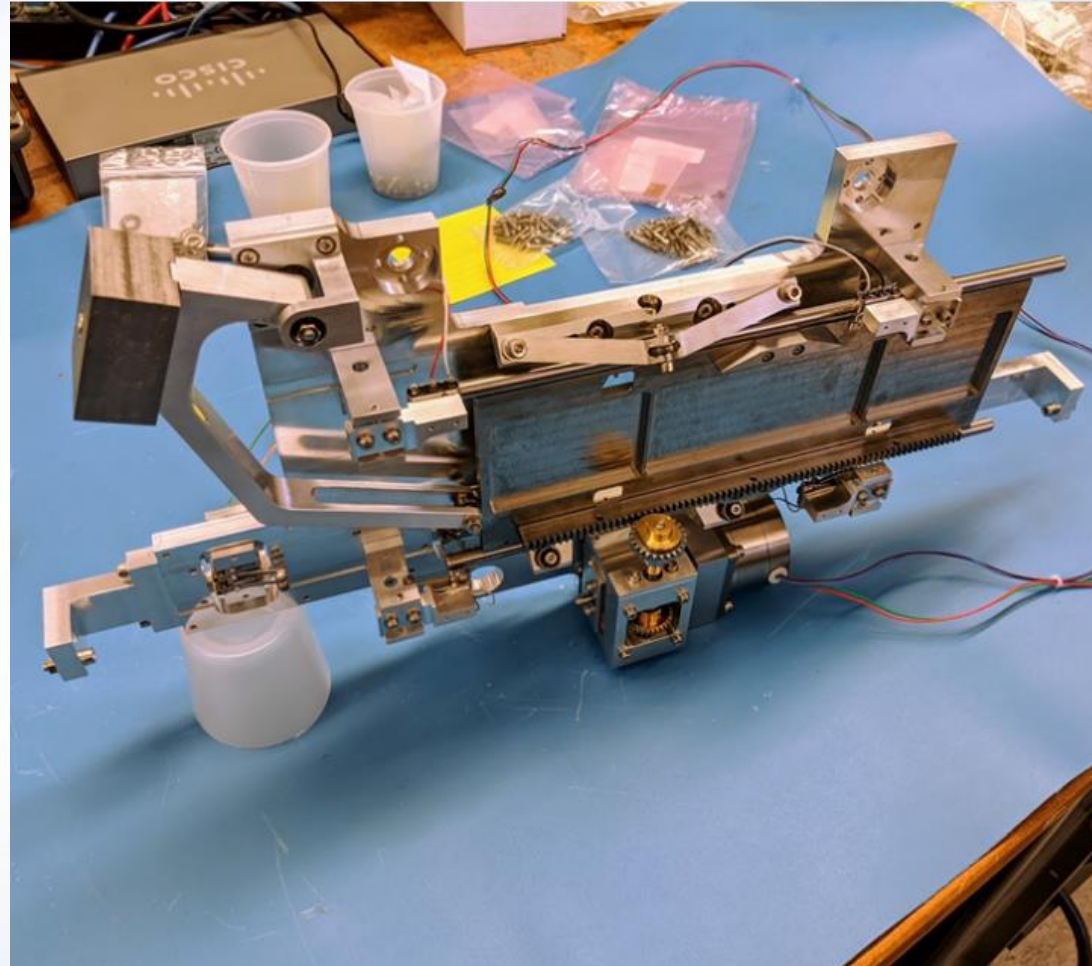
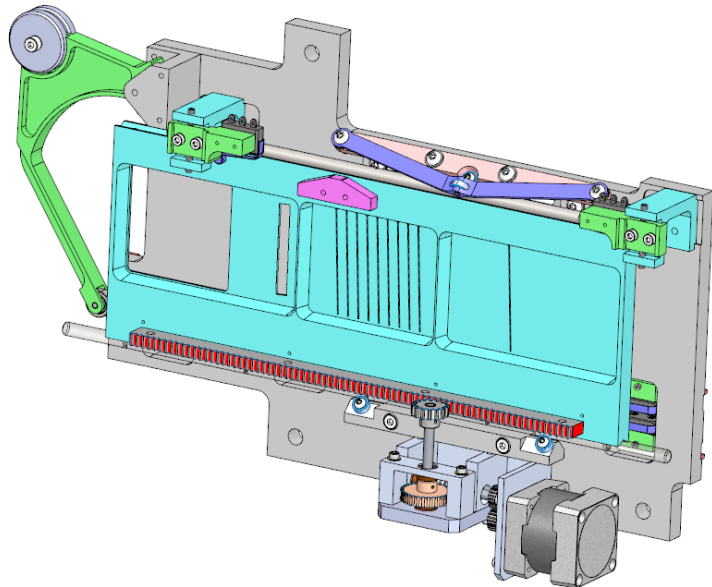
Switching stage



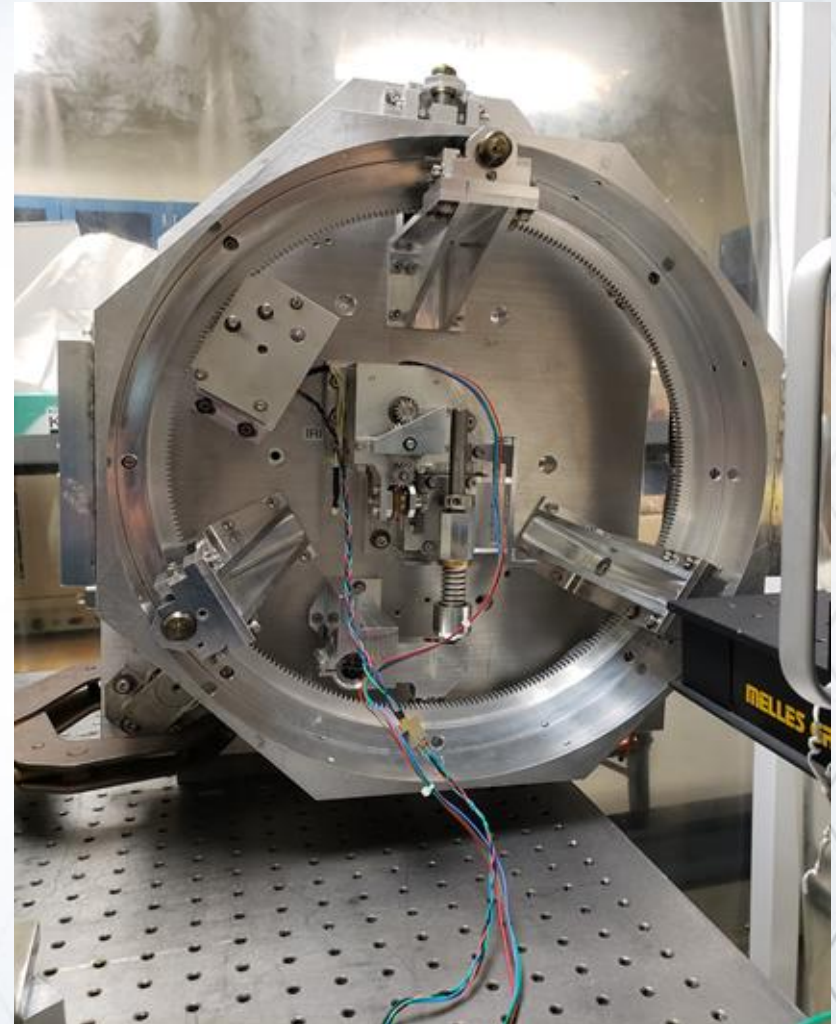
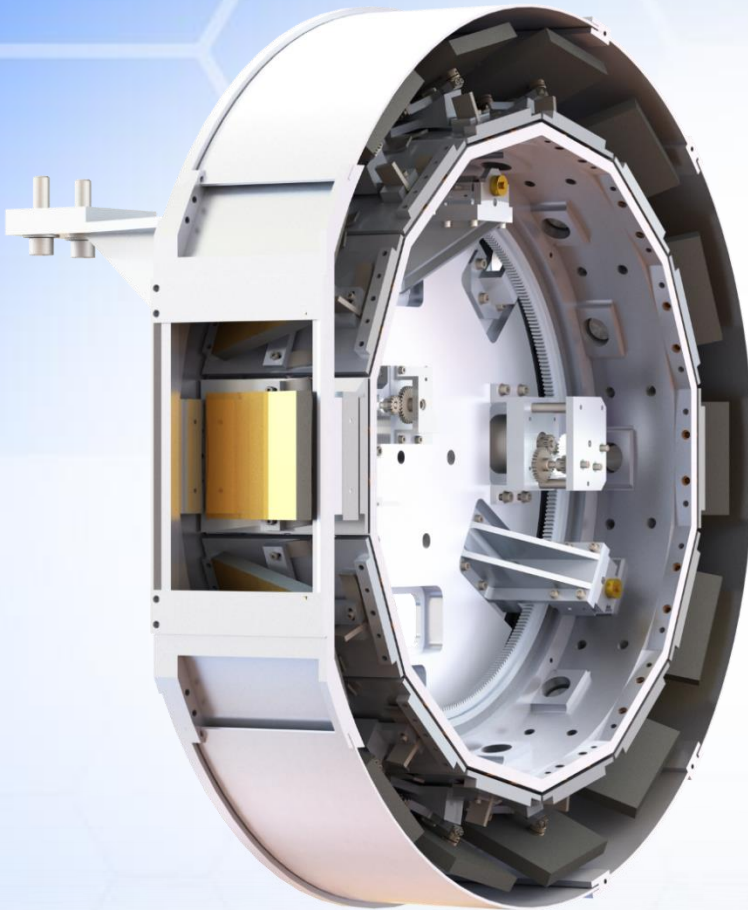
Switching stage



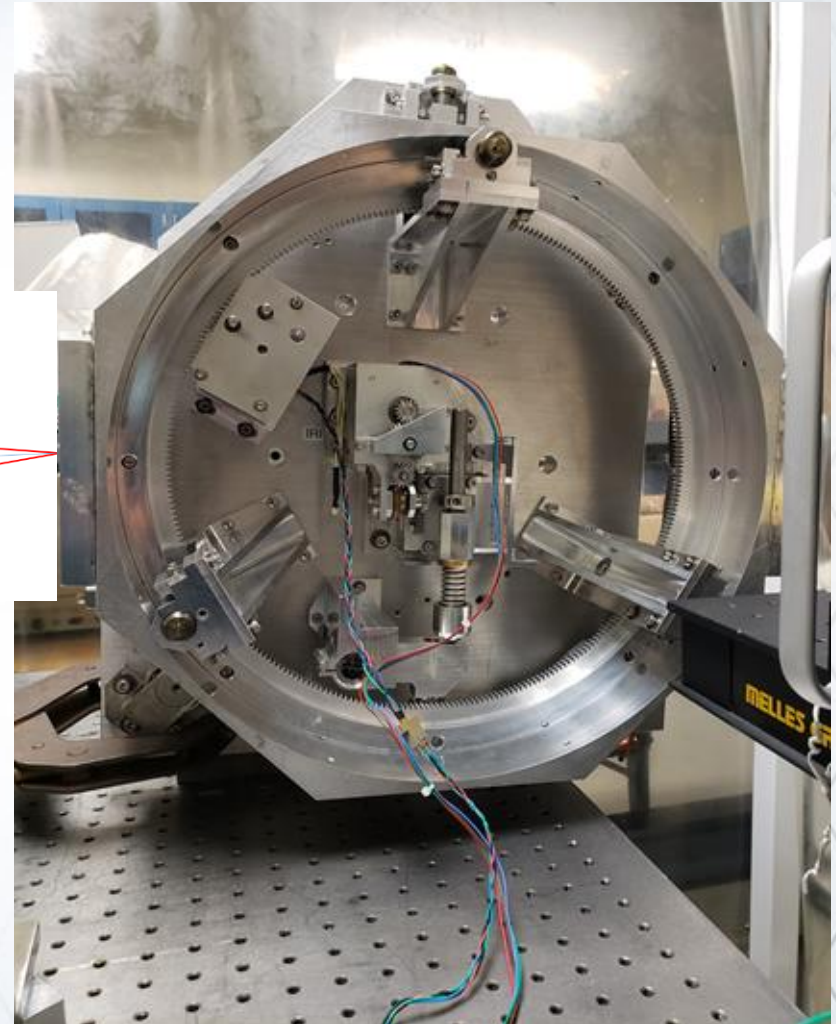
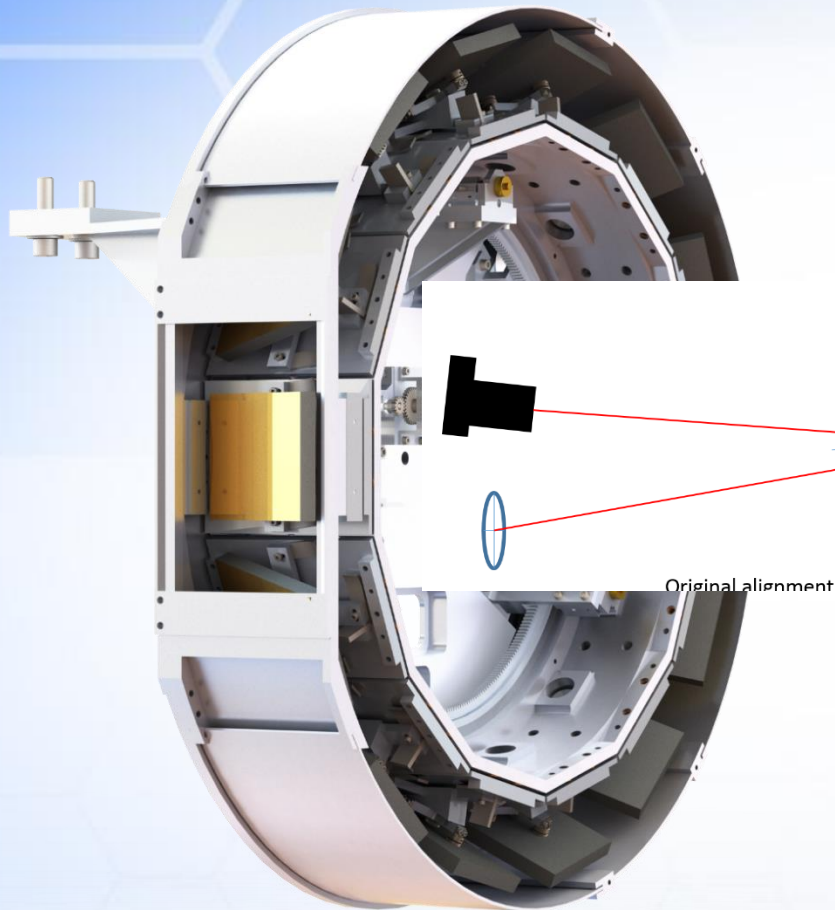
Lenslet Mask Slide Assembly



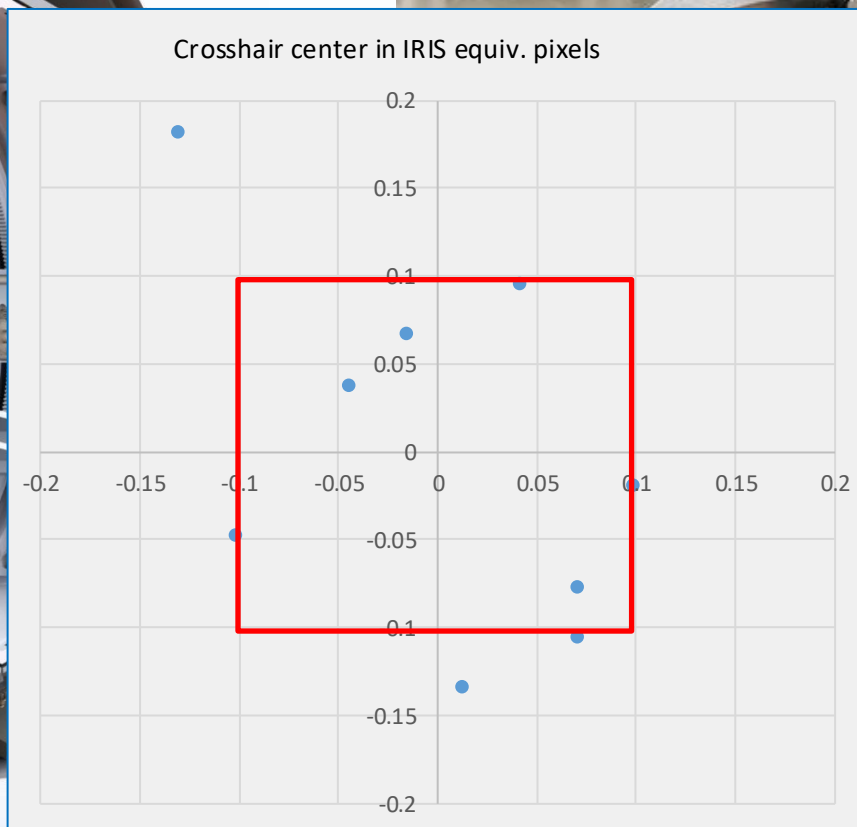
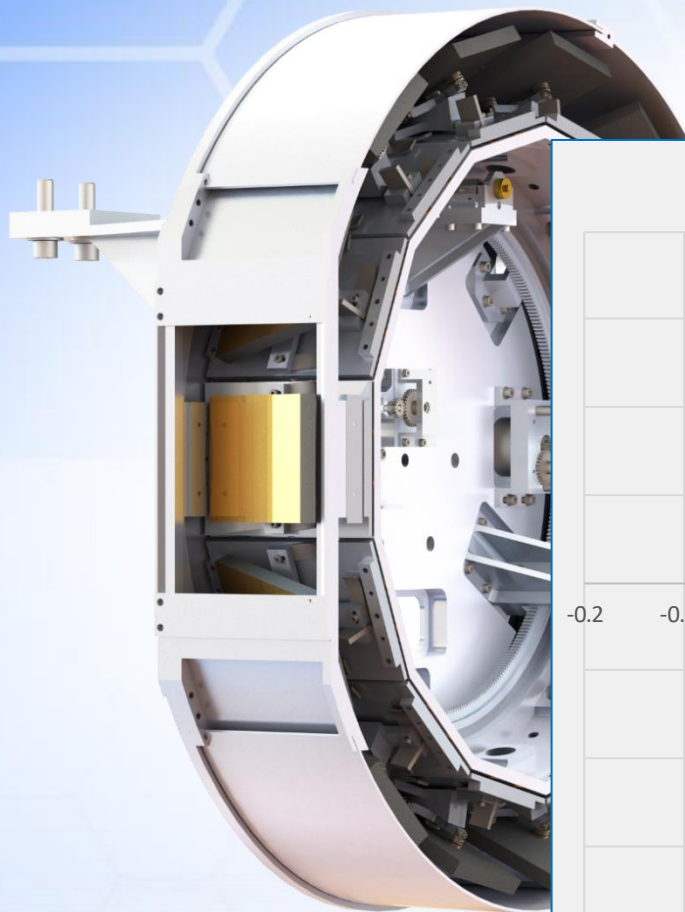
Grating Turret Assembly



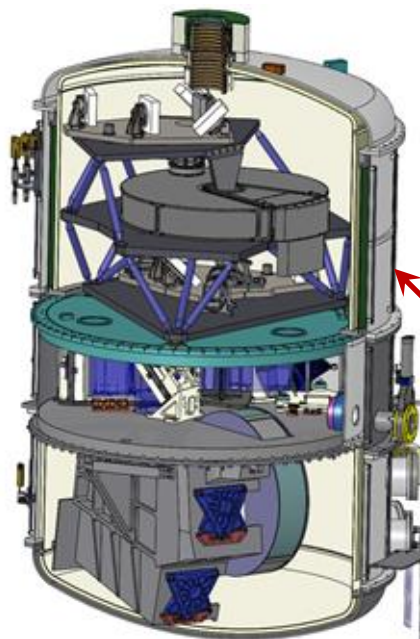
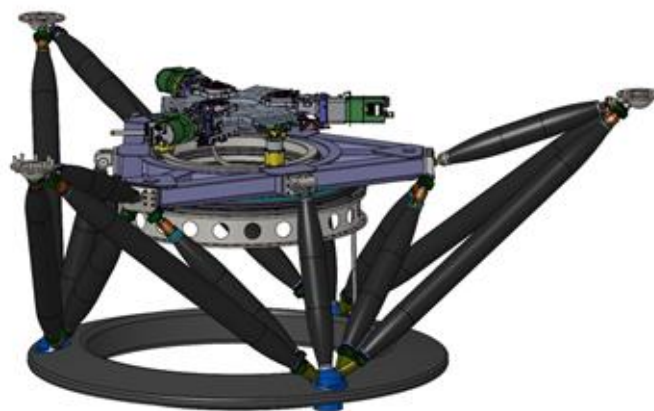
Grating Turret Assembly



Grating Turret Assembly

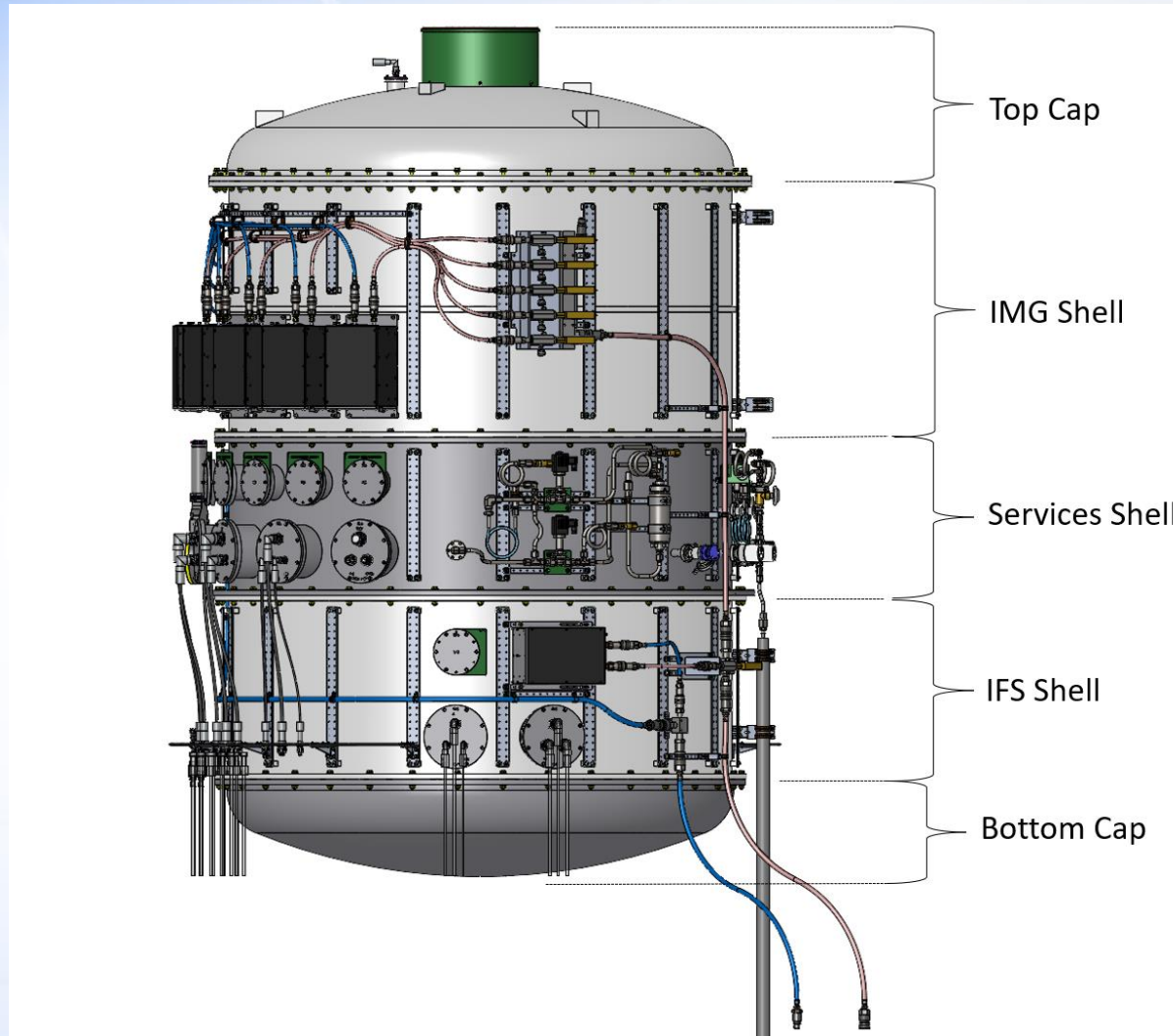


InfraRed Imaging Spectrograph

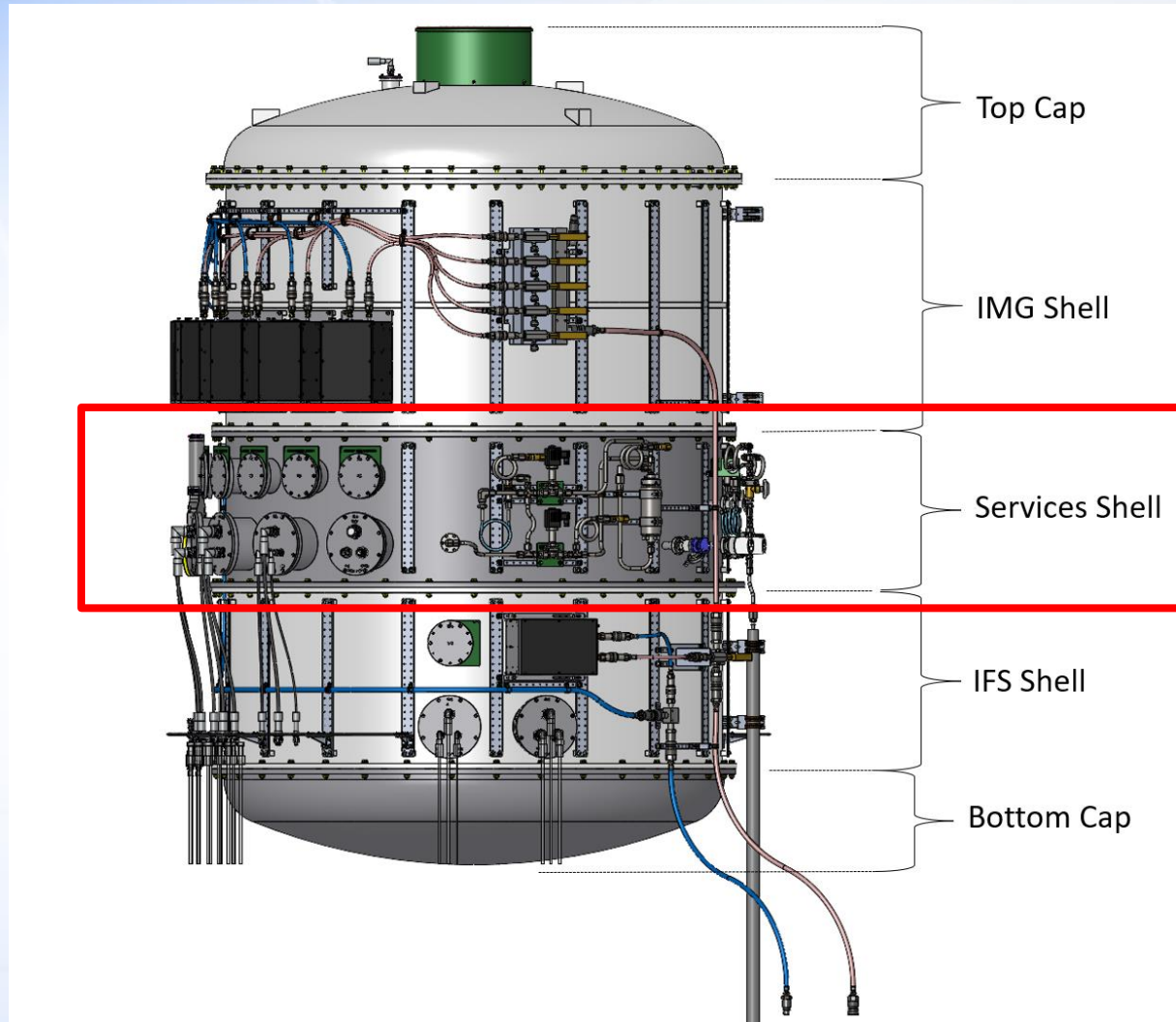


Cryostat

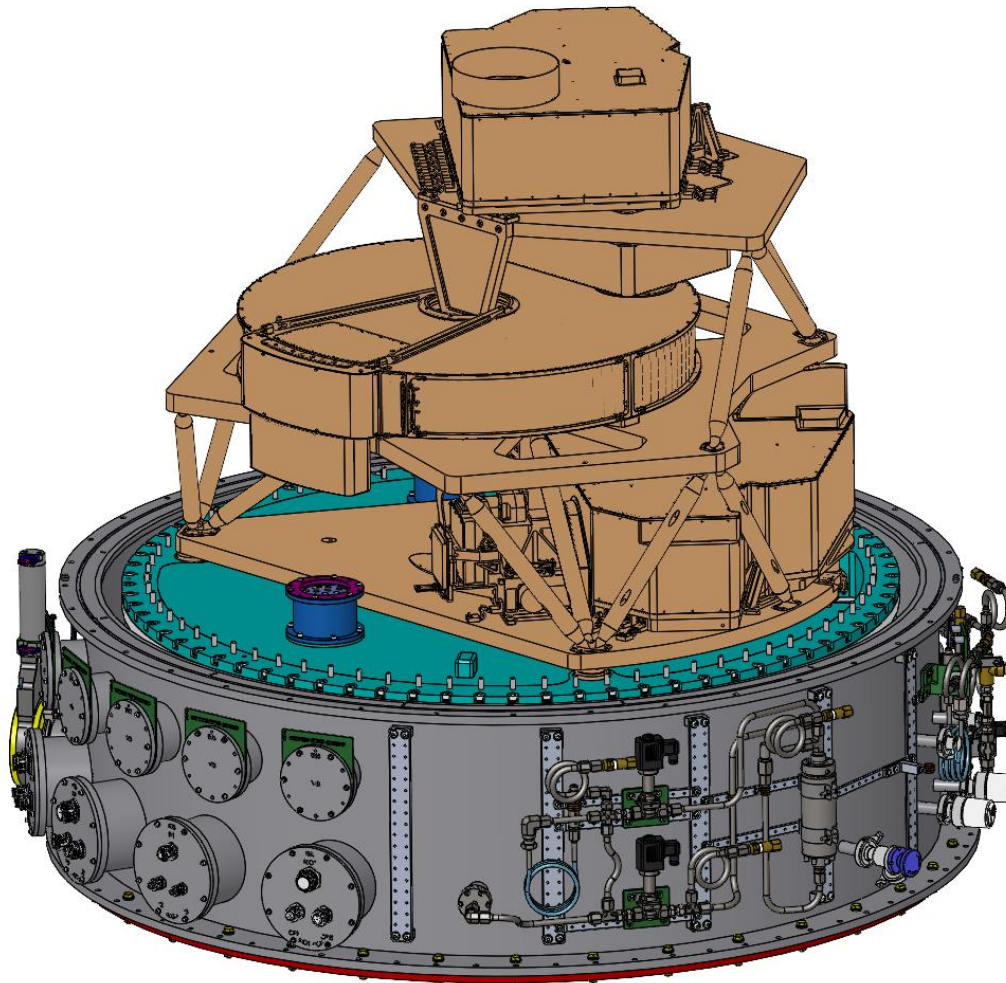
Science Cryostat Subsystem



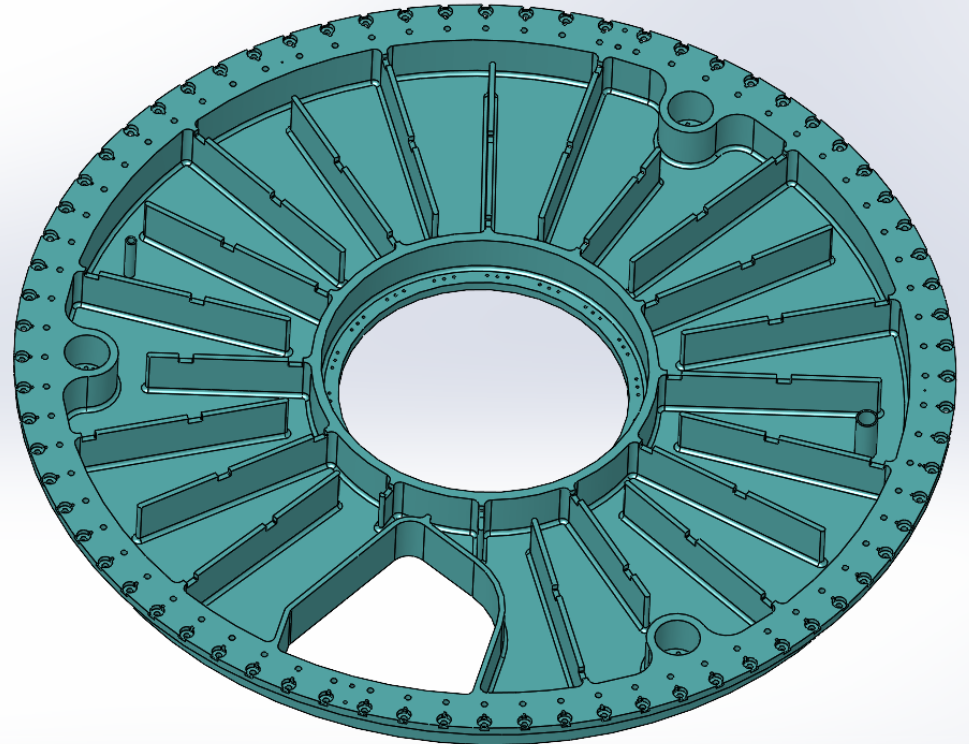
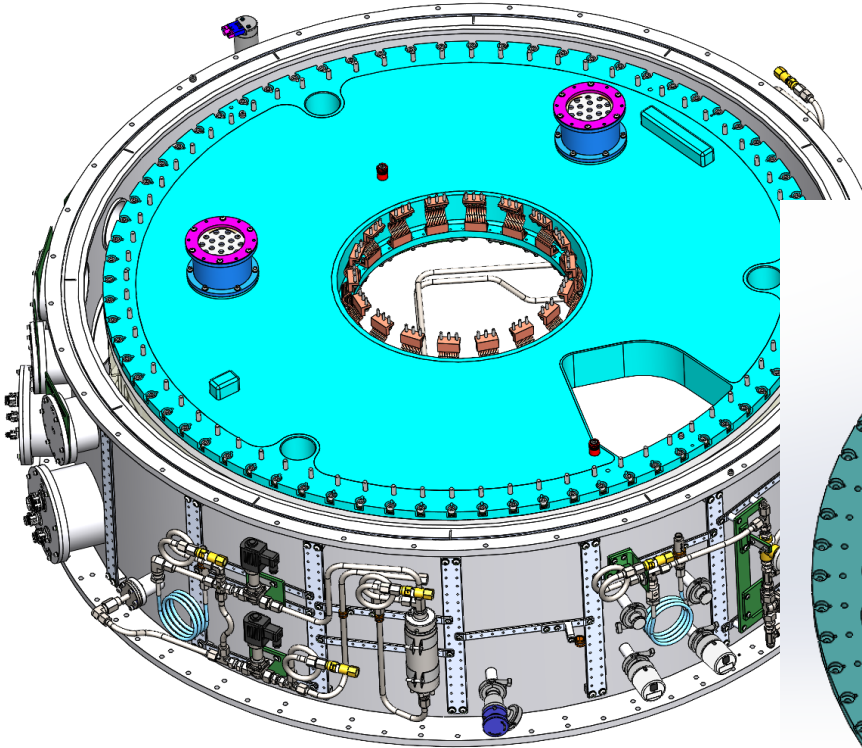
Science Cryostat Subsystem



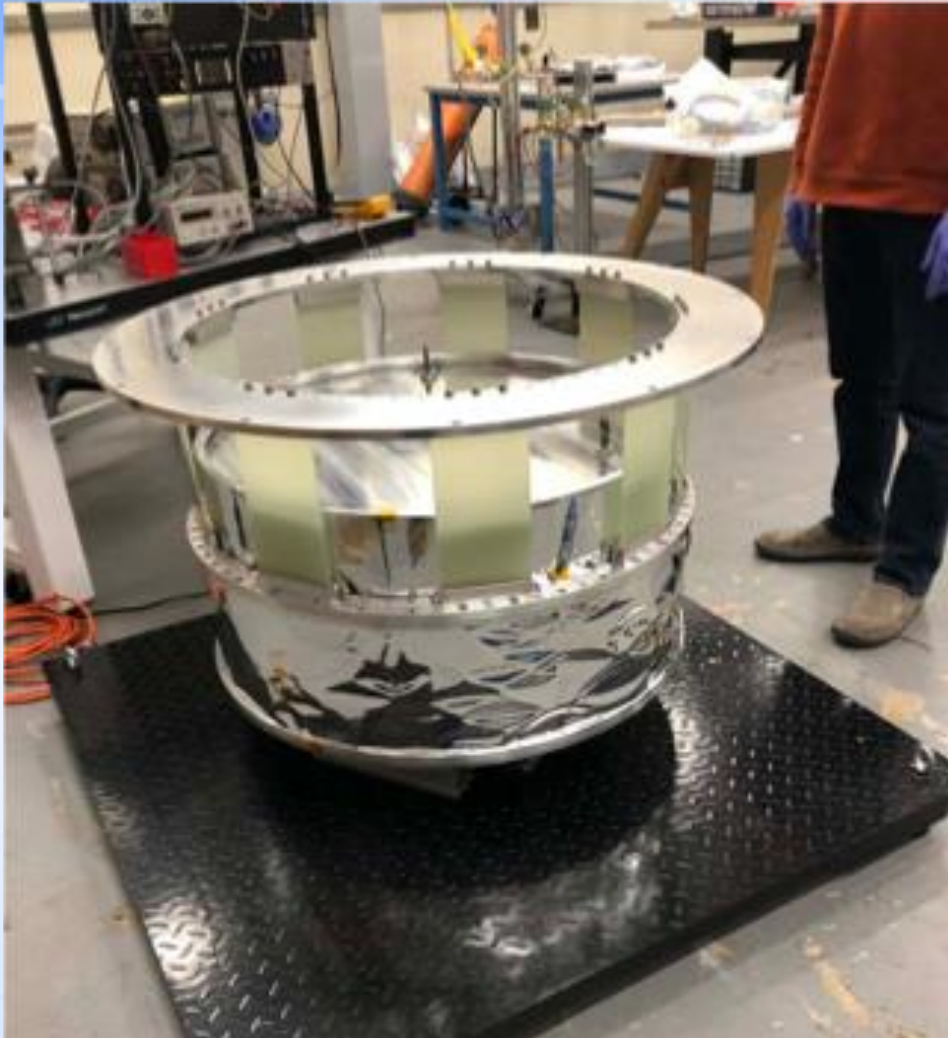
Imager Subsystem on the Service Shell

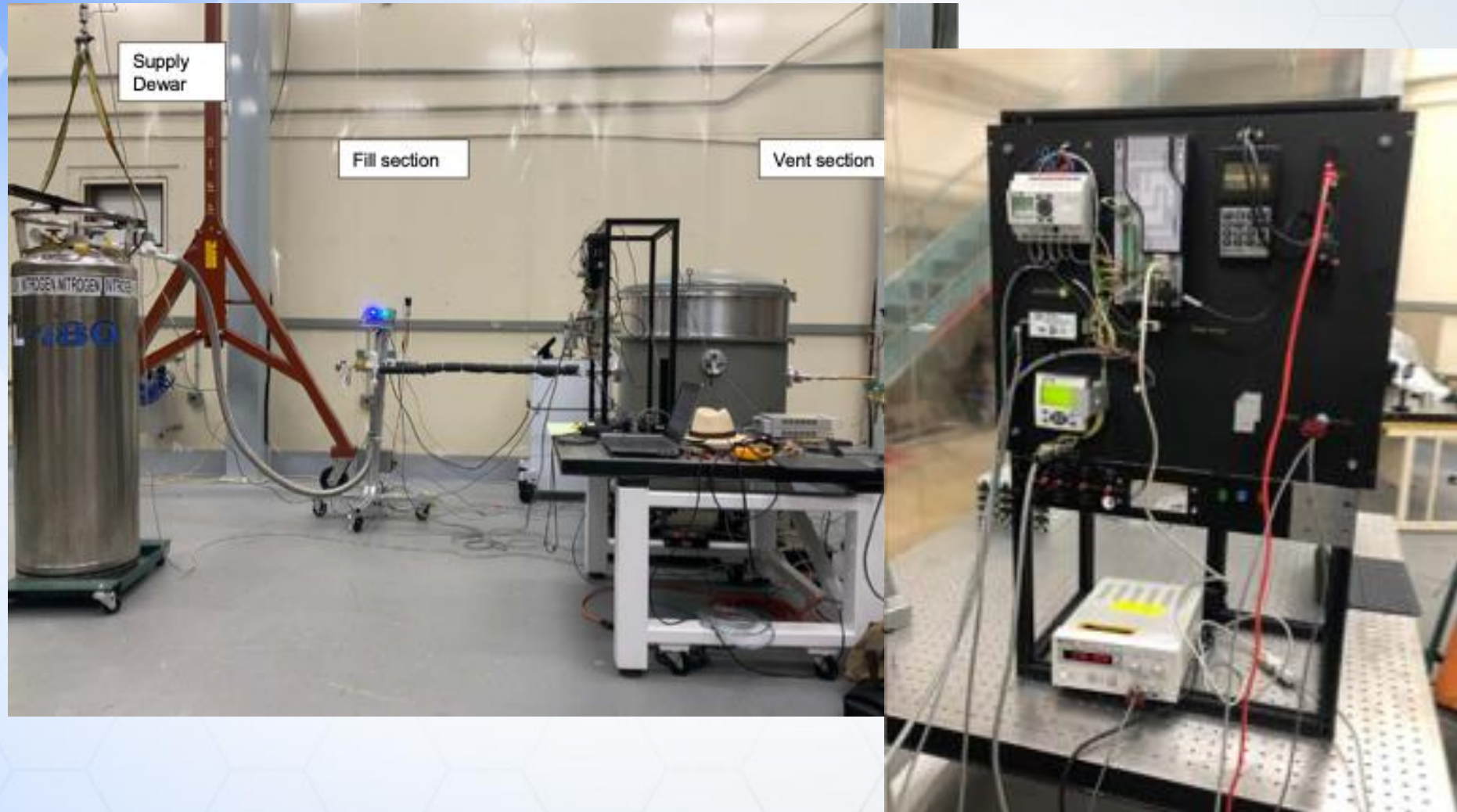


Cold Plate Assembly

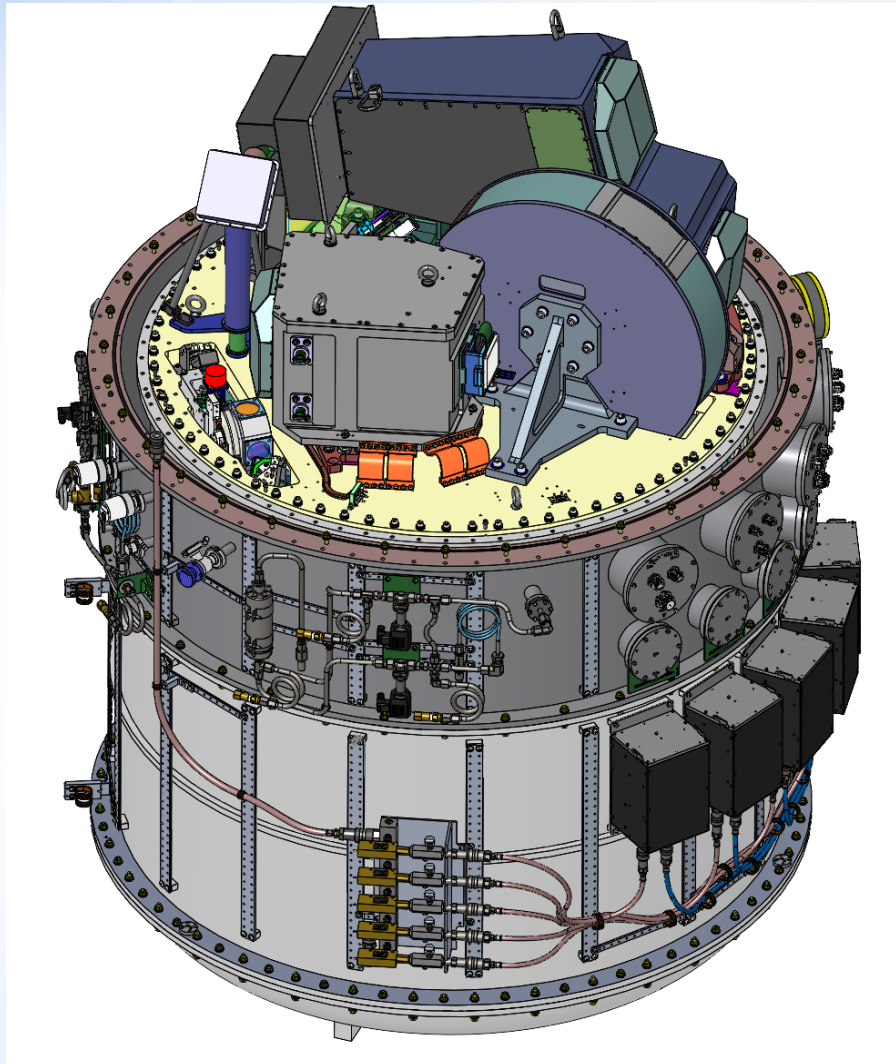


1/2 Scale Prototyped Cold Plate

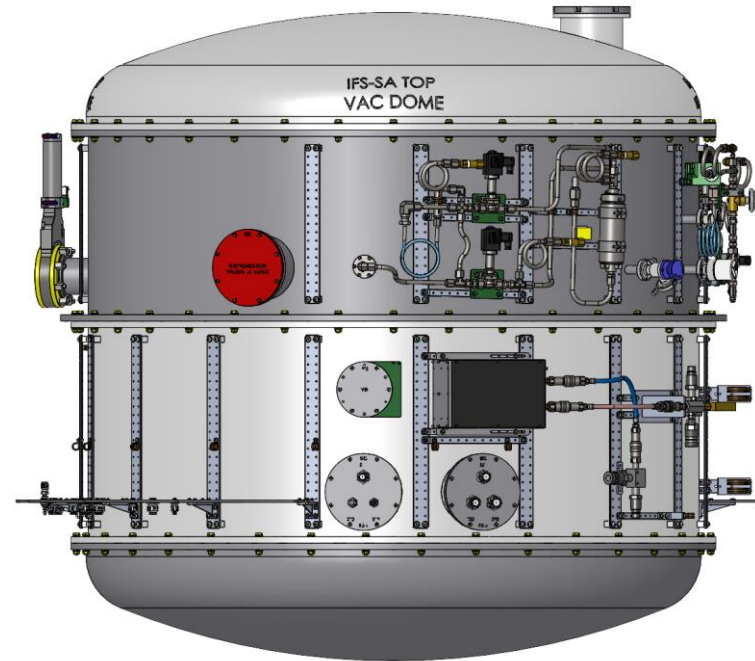
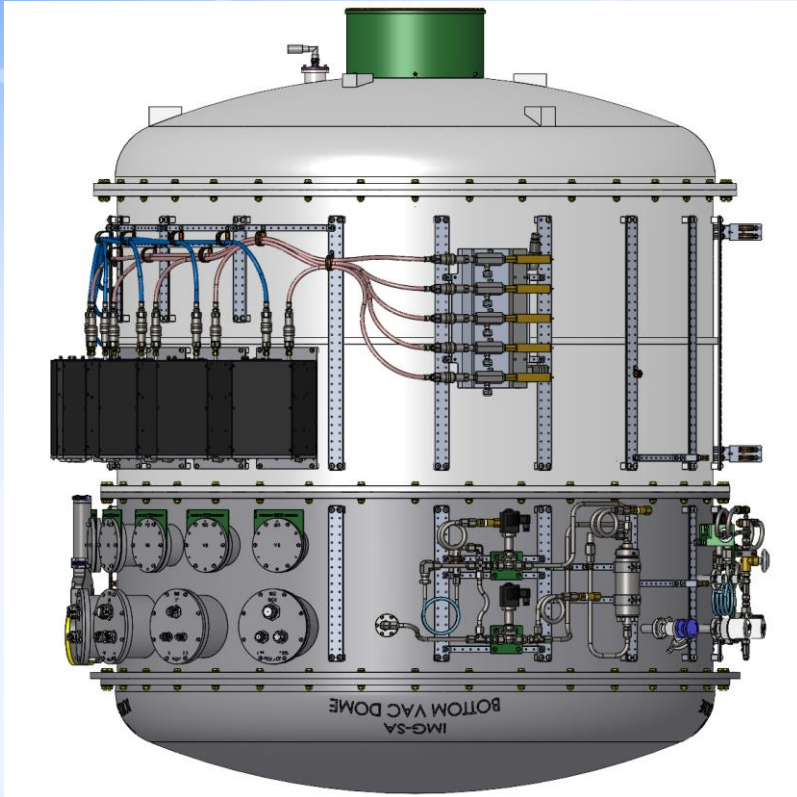




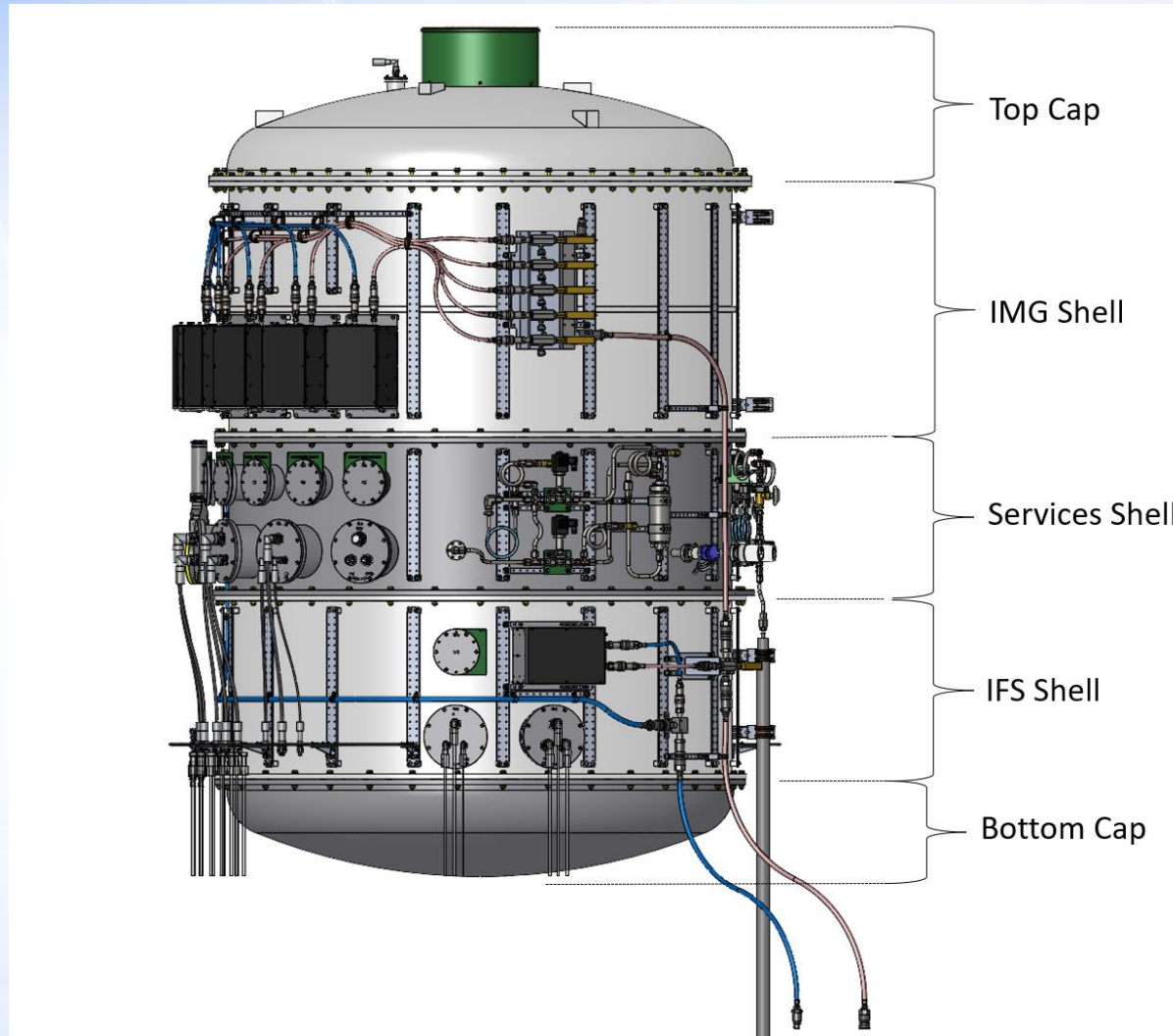
IFS Subsystem on the Service Shell



Imager and IFS Standalone Cryostats



Science Cryostat Subsystem



- Liger shares the data reduction system with IRIS.

Algorithm	Real Time Processing		Offline Processing	
	Imager	IFS	Imager	IFS
Generate master dark	x	x	x	x
Generate master flat	x	x	x	x
Dark subtraction	x	x	x	x
Correct detector artifacts	x	x	x	x
Remove cosmic rays			x	x
Flat fielding	x	x	x	x
Spectral extraction		x		x
Wavelength calibration		x		x
Cube assembly		x		x
Scaled sky-subtraction	x	x	x	x
Residual ADC				x
Telluric correction				x
Field distortion correction			x	
Flux calibration			x	x
Mosaic/Combine science			x	x

- ◆ Following will be publicly available
 - ◇ Pipeline
 - ◇ Raw frames
 - ◇ Reduced frames
 - ◇ Calibration frames
 - ◇ Calibration data (e.g., for PSF-R)
 - ◆ WFS data (TBD)
 - ◆ Telemetry data (TBD)

System level analyses

System-level Analyses

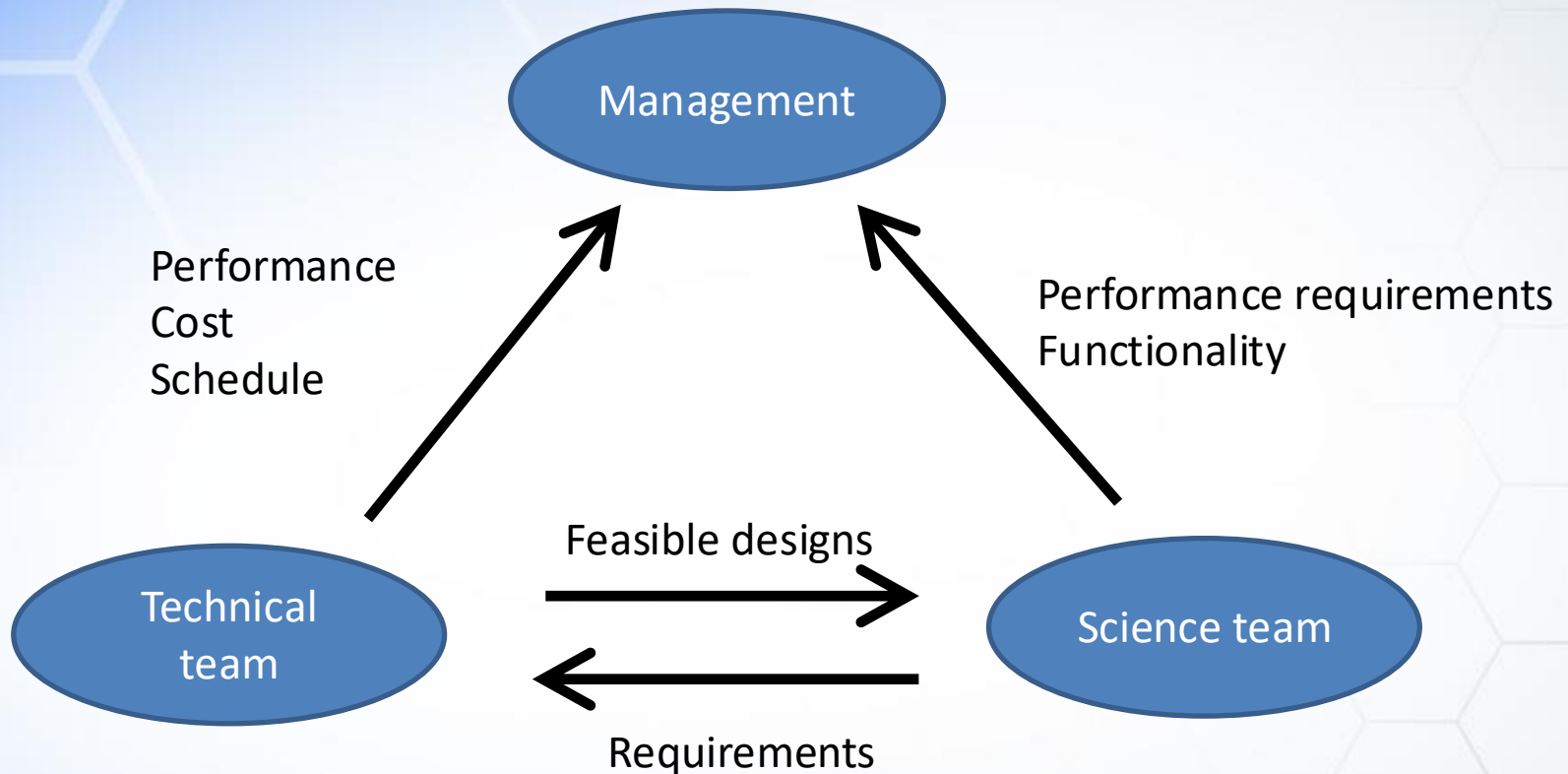
- ◆ Wavefront error budget (Tanaka et al. 2026)
- ◆ Throughput budget
- ◆ Stray light analysis
- ◆ Structural Thermal Optical Performance (STOP) analysis (Shimizu et al. 2026)
- ◆ Vibration analysis

Final words and Summary

Future works

- ◆ Demonstration of super accurate distortion correction with a curved focal surface.
- ◆ Simulating scientific impacts of detector persistence
- ◆ Astrometry simulator development
- ◆ CCD operation for pupil viewing camera
- ◆ ADC prism alignment at cryogenic temperature
- ◆ Detector characterization and ODGW development
- ◆ Verification of the IRIS imager performances

Please contact me if you are interested
in the instrumentation



Please contact me if you are interested
in joining the IRIS science team

Summary

- While there are remaining works to be done, major parts of IRIS completed the final design phase and are ready for fabrication.

Summary

<i>Capatibility mode</i>	<i>Spatial sampling</i>	<i>Field of view (arcsec)</i>	<i>Resolution (l/dl)</i>	<i>Bandpass¹</i>
<i>Imager</i>				
	4 mas	34 x 34	Set by filter	BB and NB
<i>Slicer IFS</i>				
<i>88x45</i>	50 mas	4.4 x 2.25	4,000, 8,000	20%, 10%
<i>Spaxels</i>	25 mas	2.2 x 1.125	4,000, 8,000	20%, 10%
<i>Lenslet IFS</i>				
<i>112x128</i>	9 mas	1.01 x 1.15	4,000, 8,000	5%, 2.5%
<i>Spaxels</i>	4 mas	0.45 x 0.51	4,000, 8,000	5%, 2.5%
<i>Lenslet IFS</i>				
<i>16x128</i>	9 mas	0.144 x 1.15	8,000 - 10,000	20%
<i>Spaxels</i>	4 mas	0.064 x 0.51	8,000 - 10,000	20%

***1: Maximum of 60 filters can be installed.**

Acknowledgments

The TMT Project gratefully acknowledges the support of the TMT collaborating institutions. They are the California Institute of Technology, the University of California, the National Astronomical Observatory of Japan, the National Astronomical Observatories of China and their consortium partners, the Department of Science and Technology of India and their supported institutes, and the National Research Council of Canada. This work was supported as well by the Gordon and Betty Moore Foundation, the Canada Foundation for Innovation, the Ontario Ministry of Research and Innovation, the Natural Sciences and Engineering Research Council of Canada, the British Columbia Knowledge Development Fund, the Association of Canadian Universities for Research in Astronomy (ACURA), the Association of Universities for Research in Astronomy (AURA), the U.S. National Science Foundation, the National Institutes of Natural Sciences of Japan, and the Department of Atomic Energy of India.