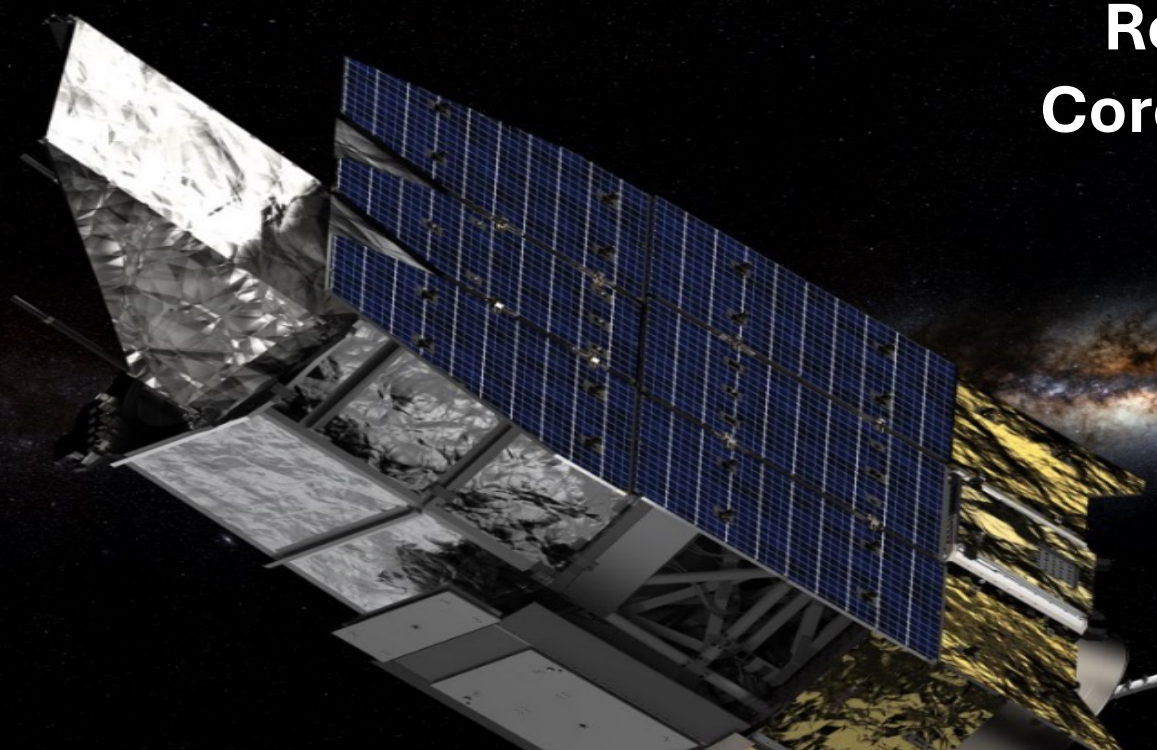
ROMAN SPACE TELESCOPE

ROMAN CORONAGRAPH

Jet Propulsion Laboratory
California Institute of Technology

Optical Alignment of the Roman Space Telescope's Coronagraph Instrument (CGI)



Brian Monacelli
Mark Colavita
Principal Optical Engineers, JPL

Jet Propulsion Laboratory,
California Institute of Technology

26 August 2024

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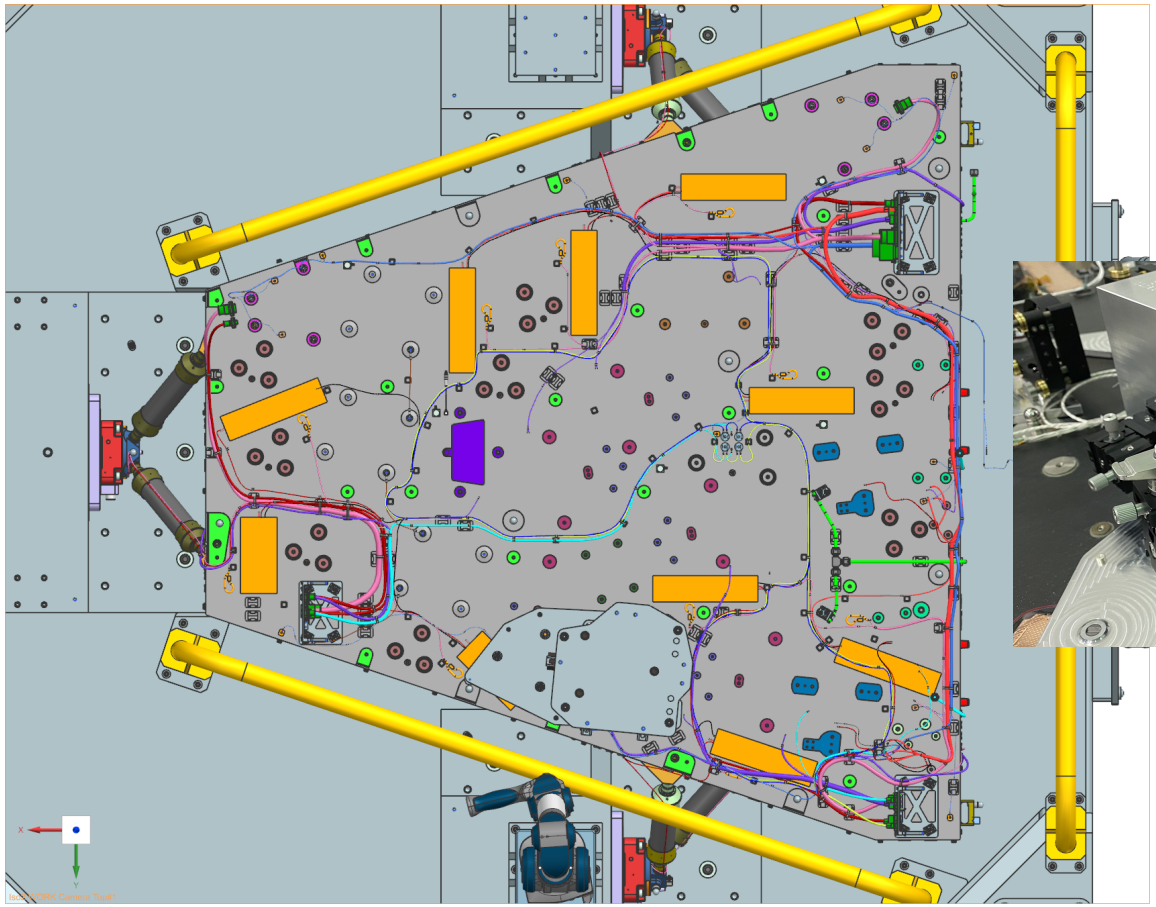
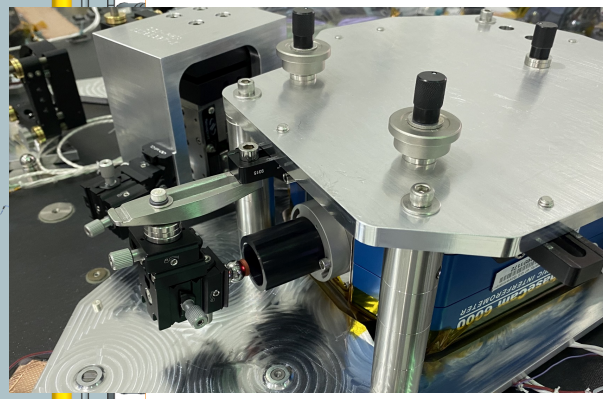
• CENTRE NATIONAL d'ÉTUDES SPATIALES • MAX PLANCK INSTITUTE FOR ASTRONOMY •

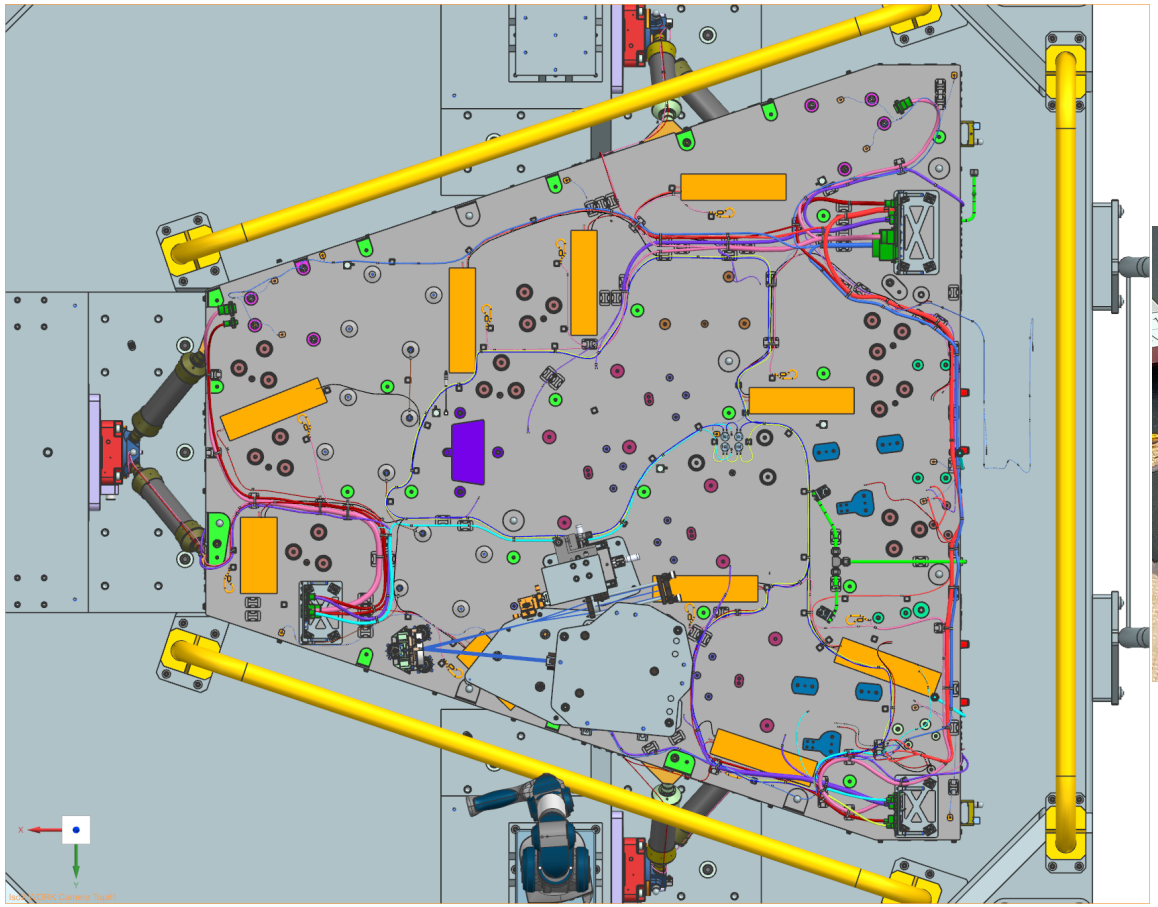
CGI Optical Alignment Sequence

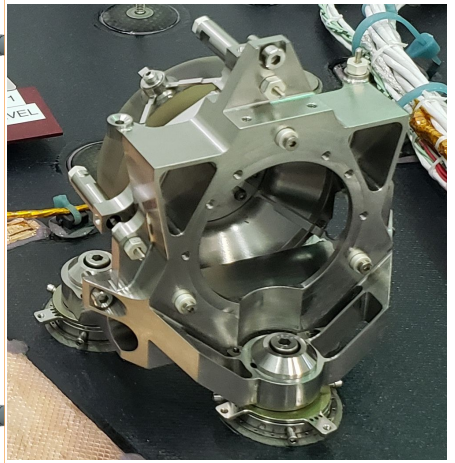
Interferometer Alignment



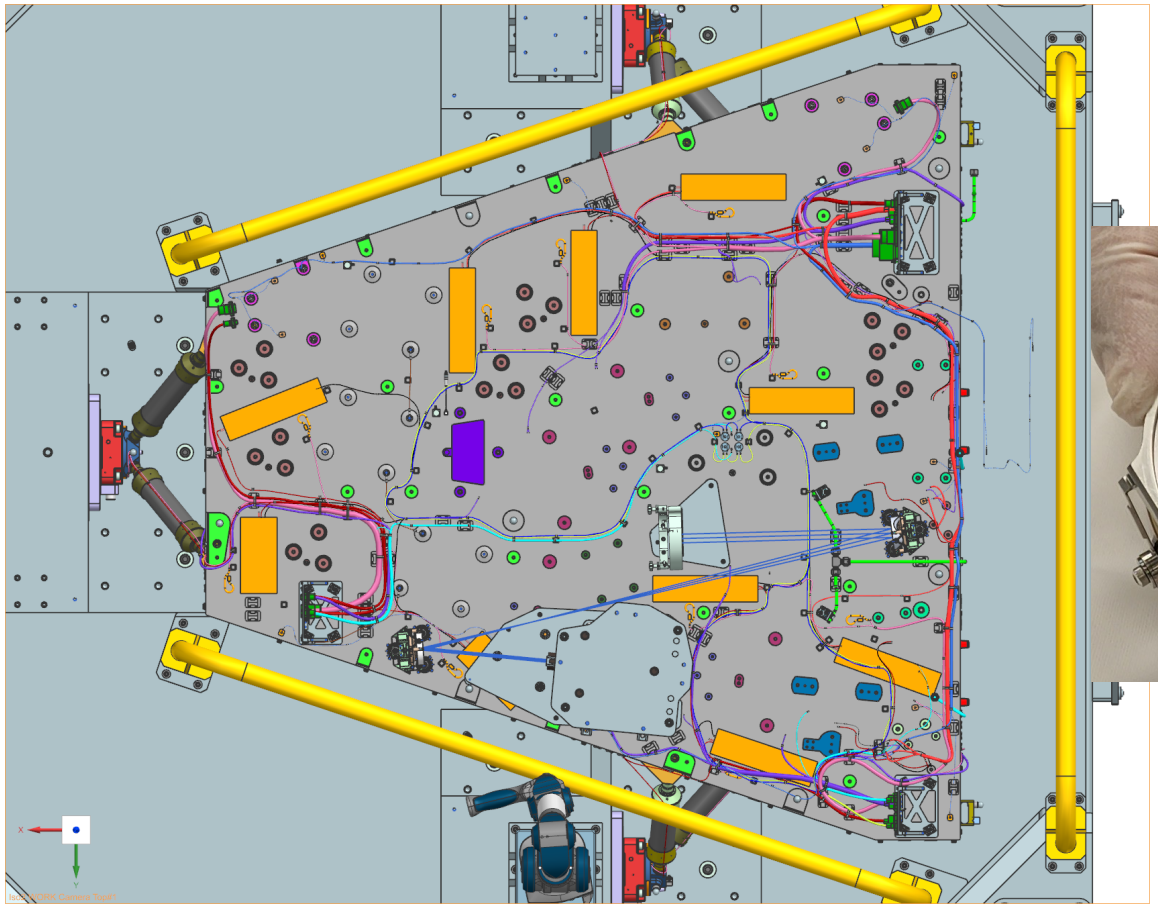


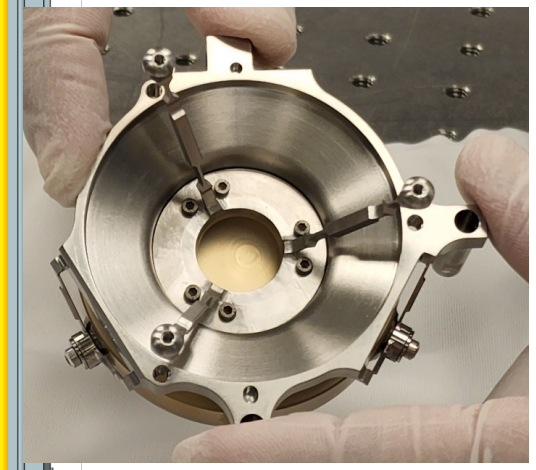
OAP8 Alignment



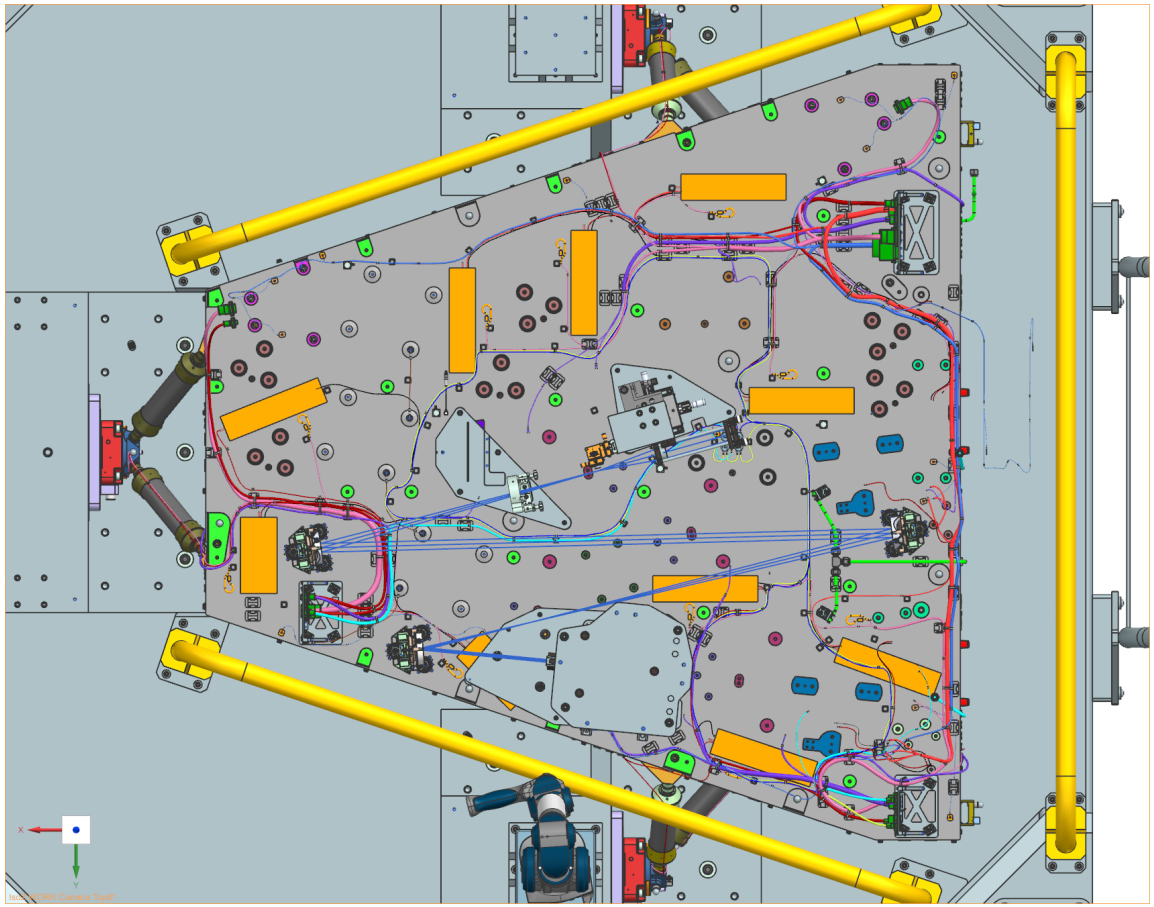


OAP7 Alignment

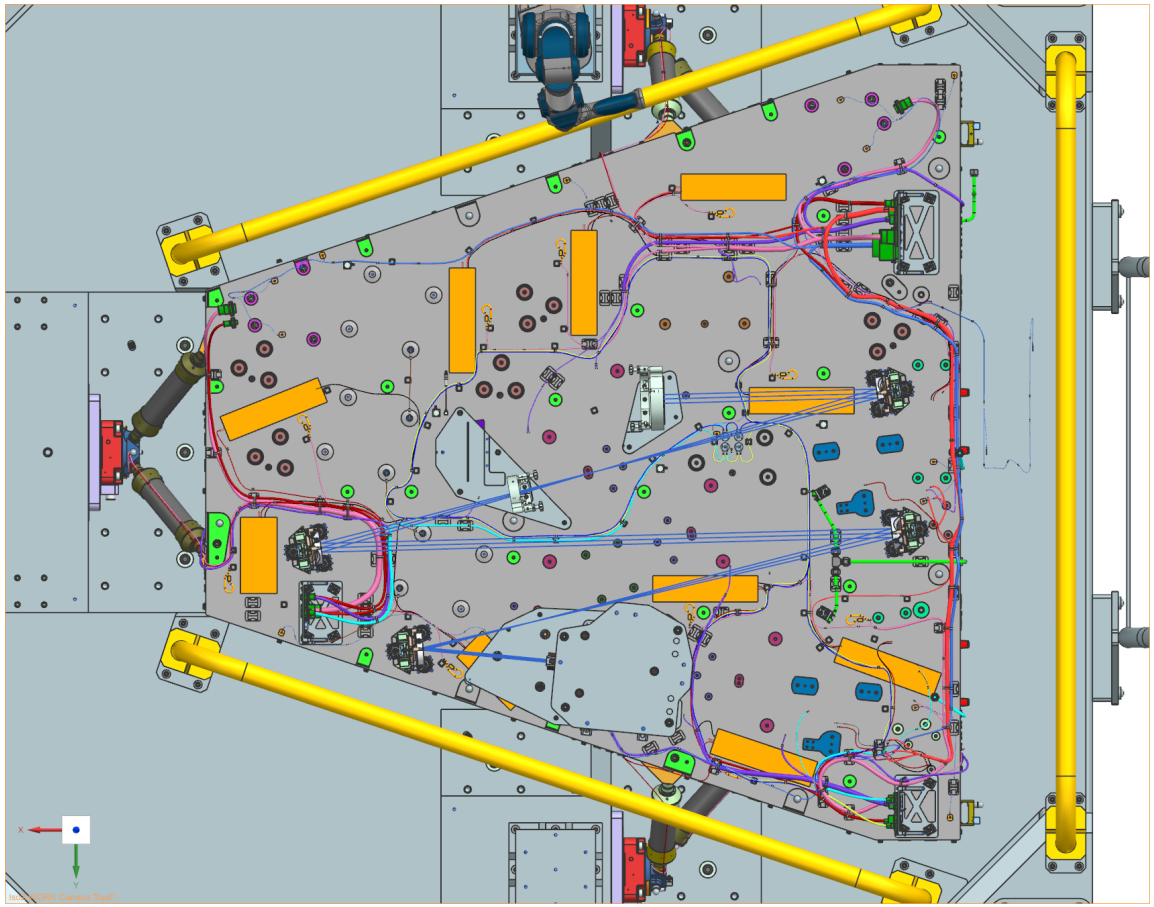




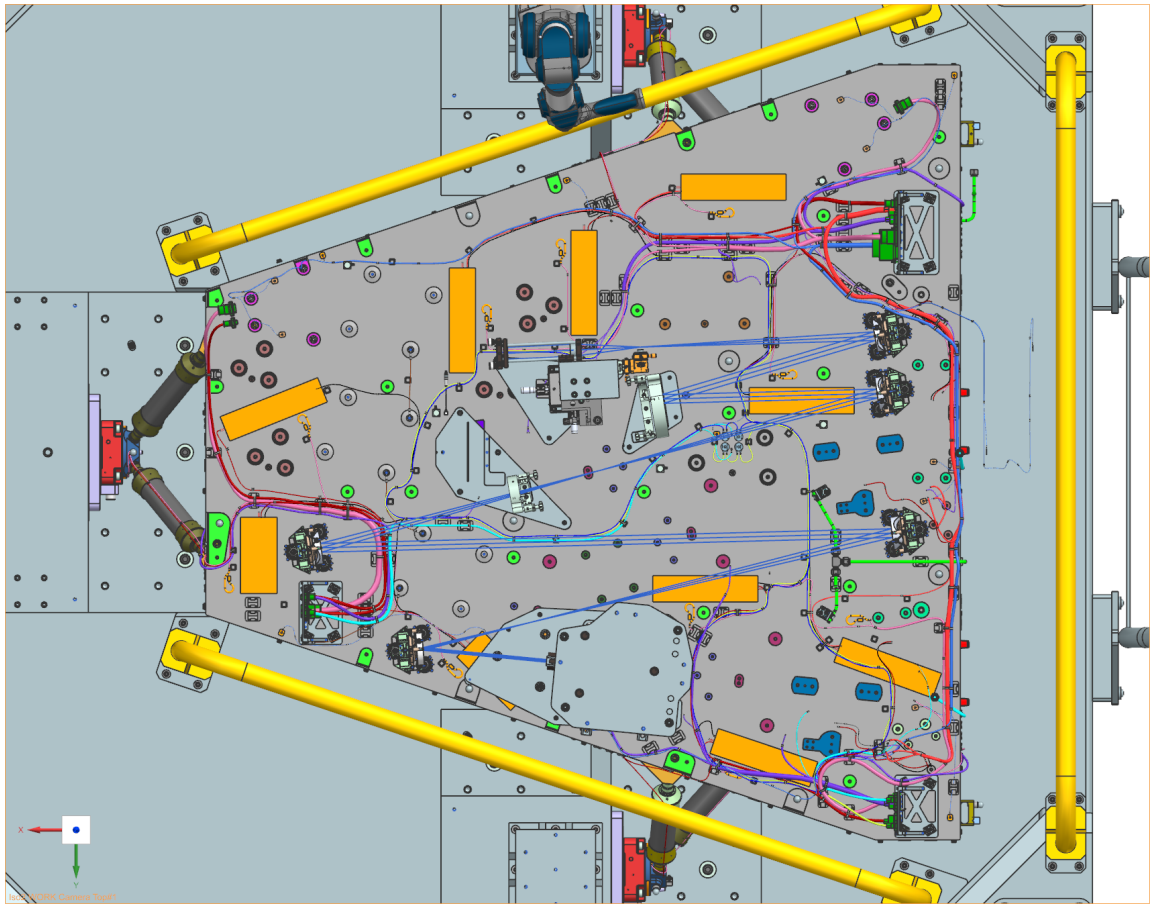
OAP6 and Surrogate FPAM Alignment



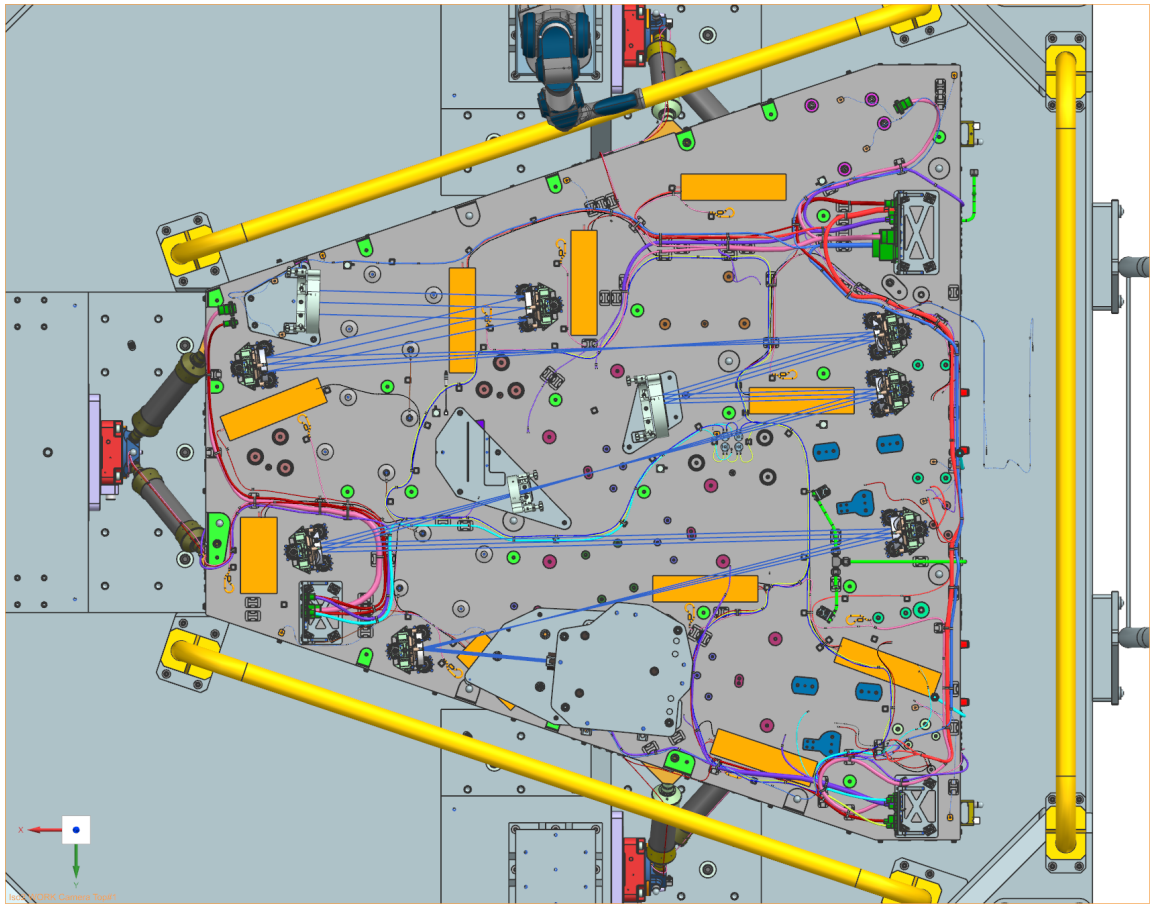
OAP5 Alignment



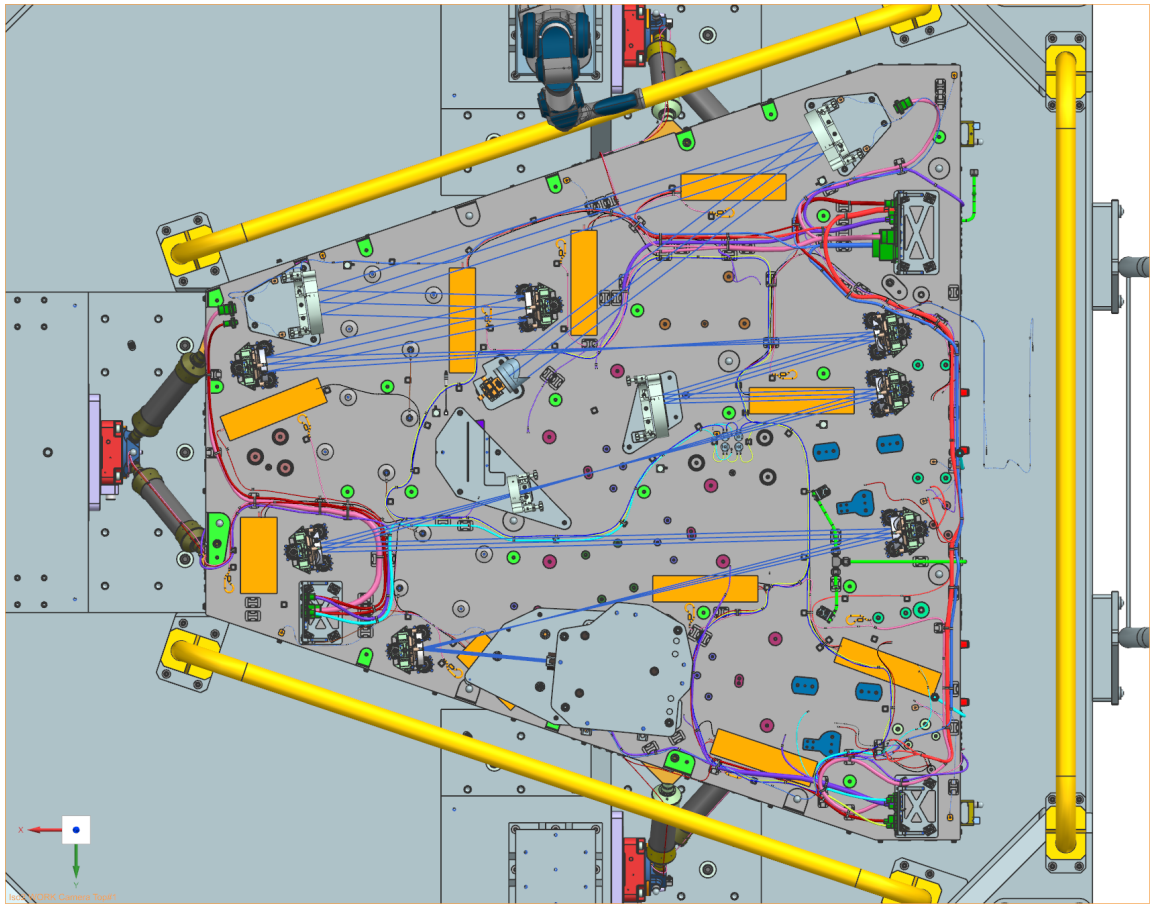
OAP4 and Surrogate SPAM Alignment



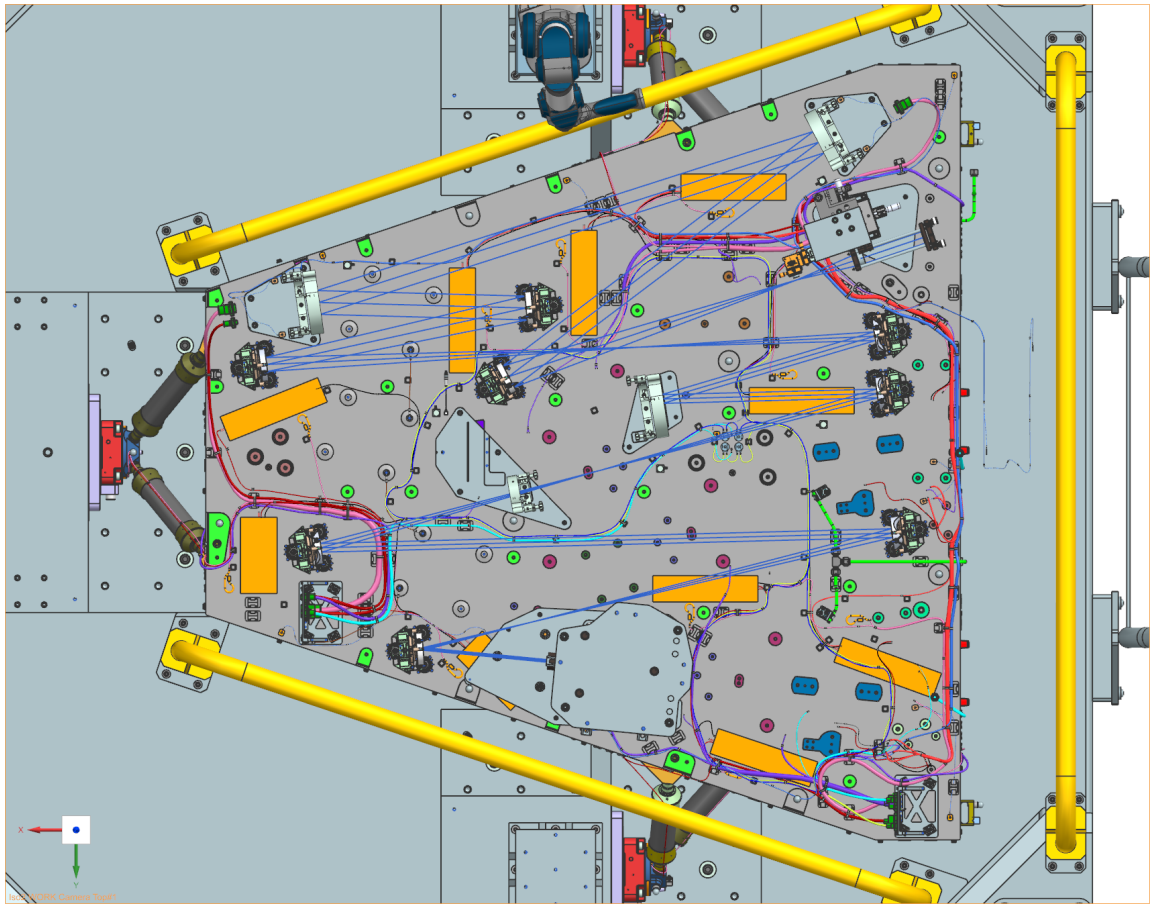
OAP3 and SFM Alignment

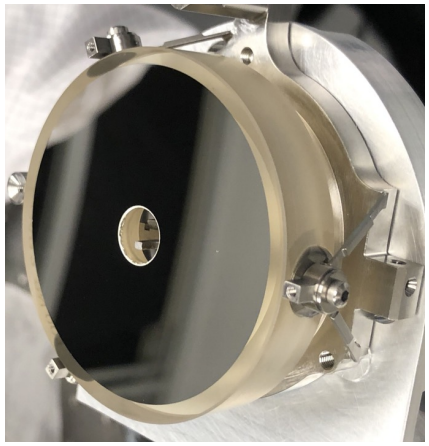


Alignment of Surrogate DMs

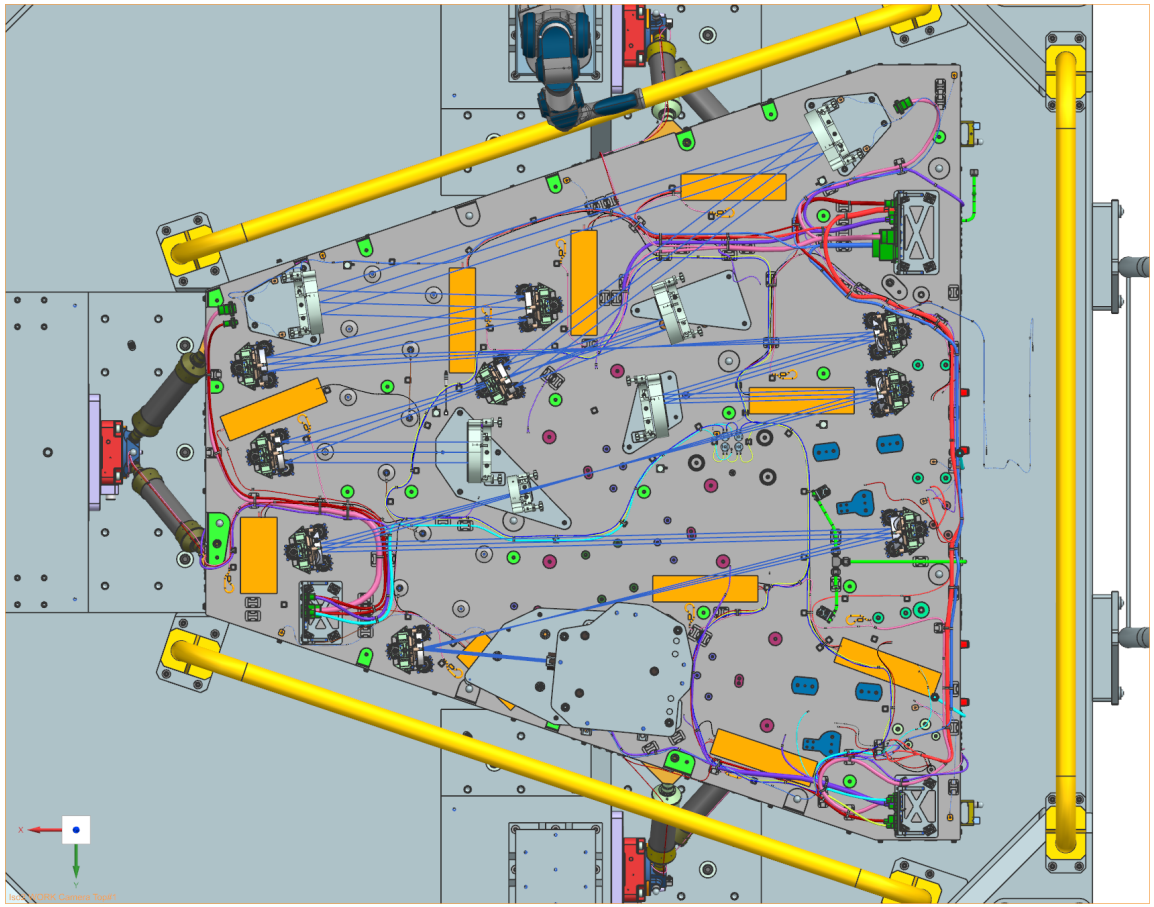


OAP2 Alignment

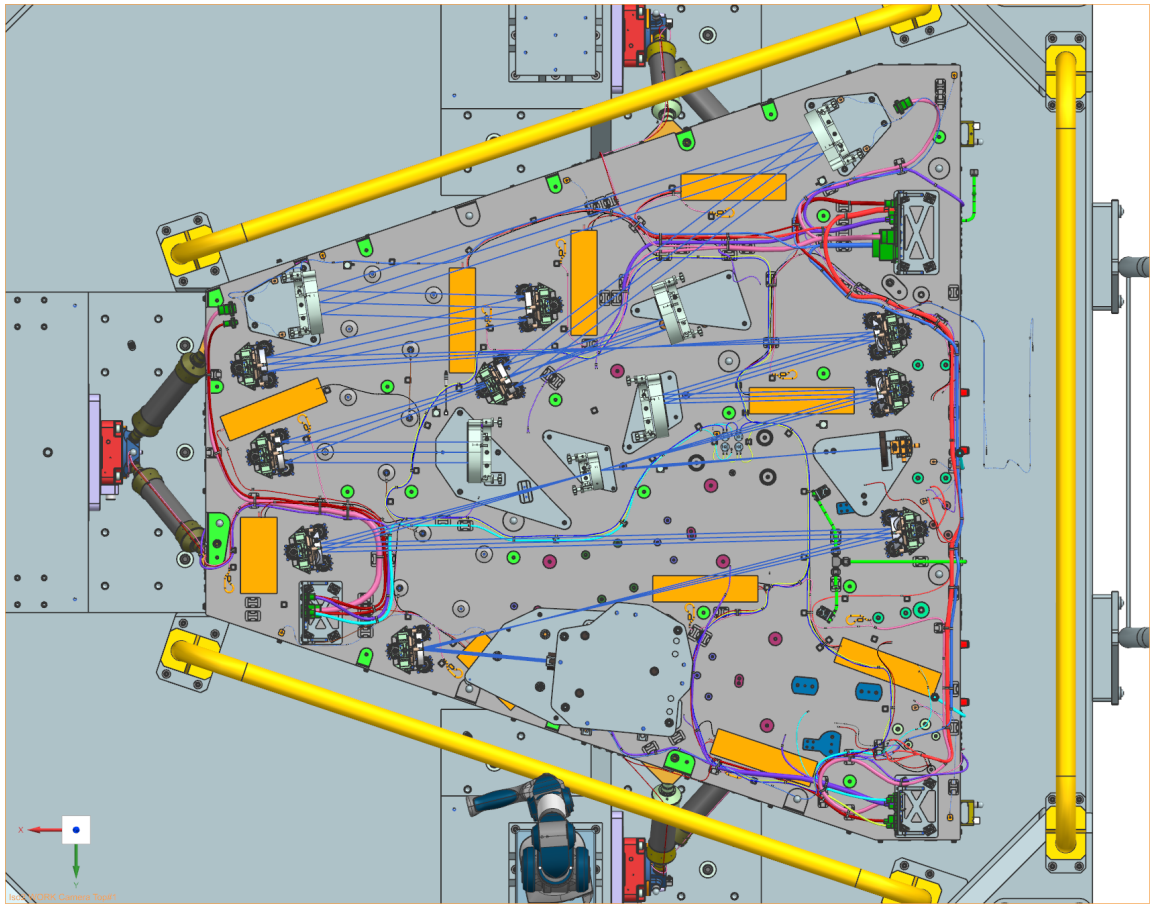




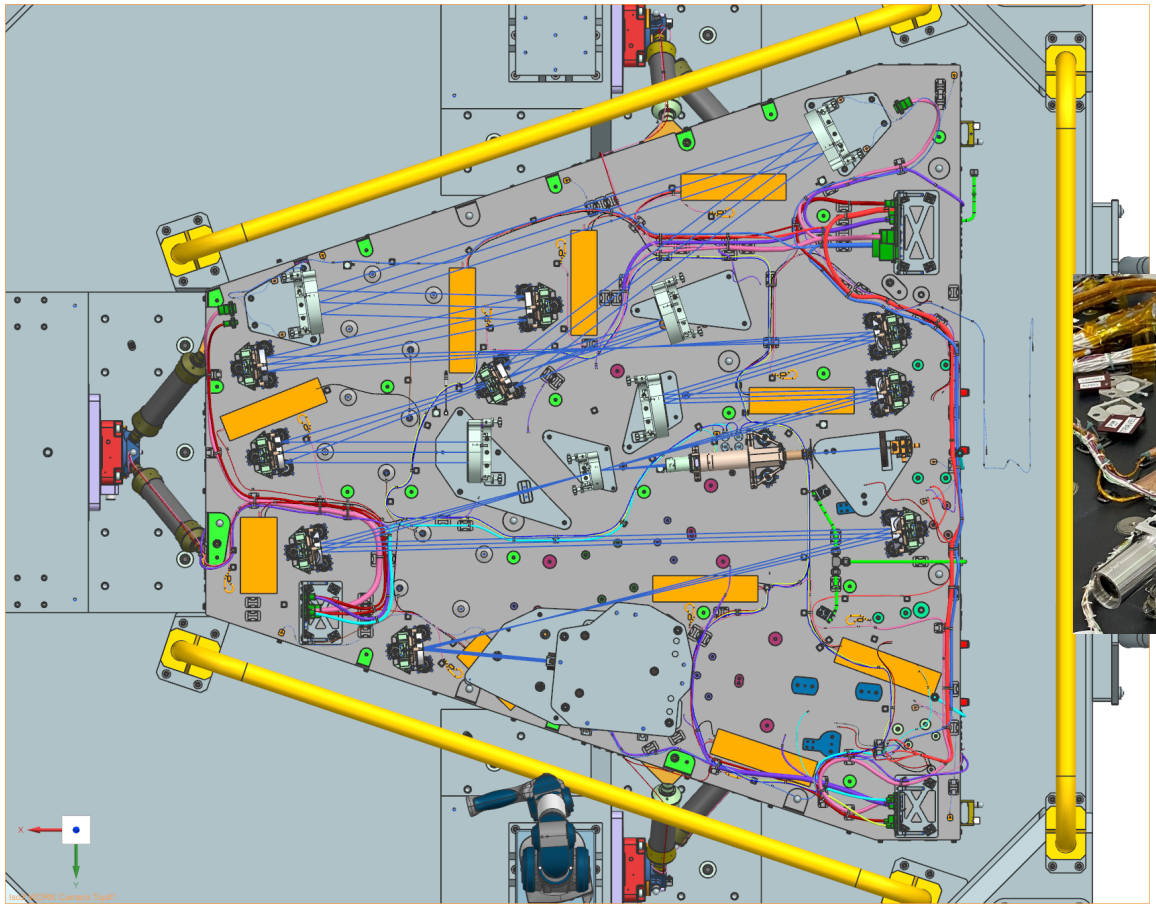
OAP1 Alignment

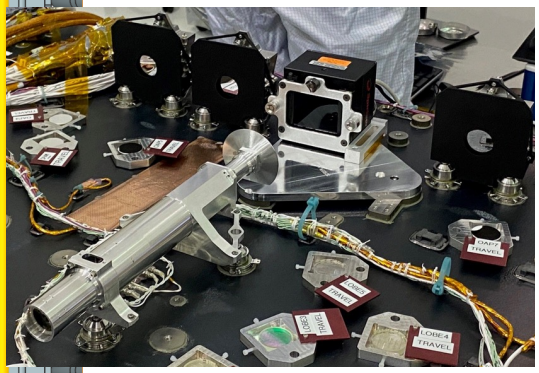


Surrogate FPAM Relocation

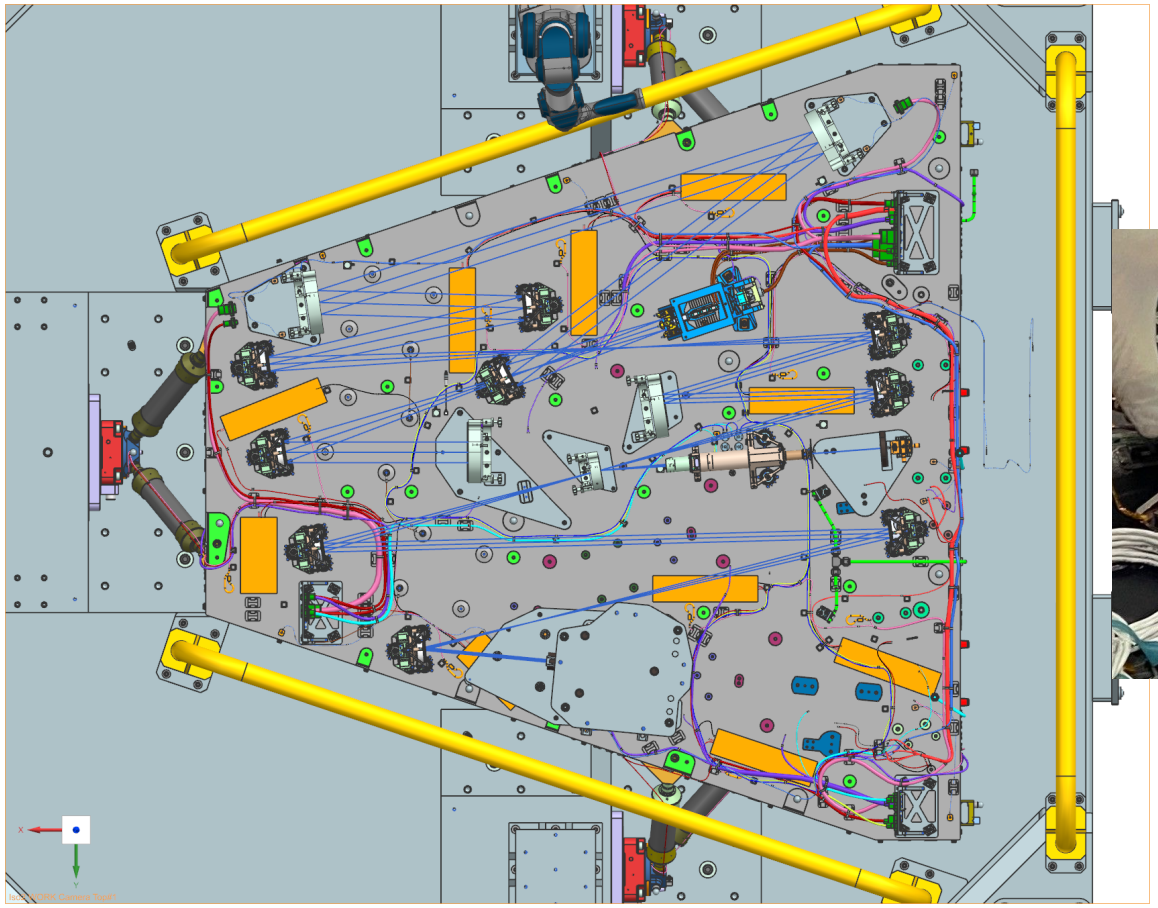


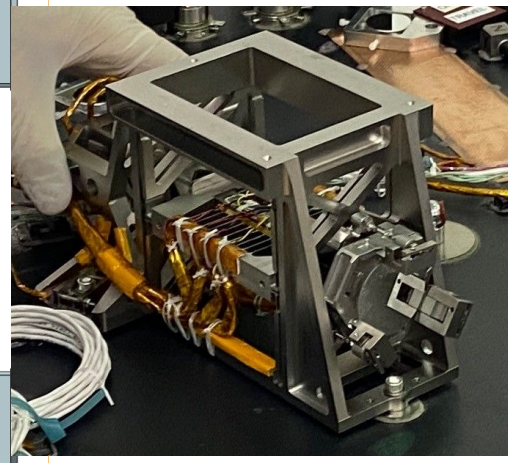
Initial LOBE Alignment



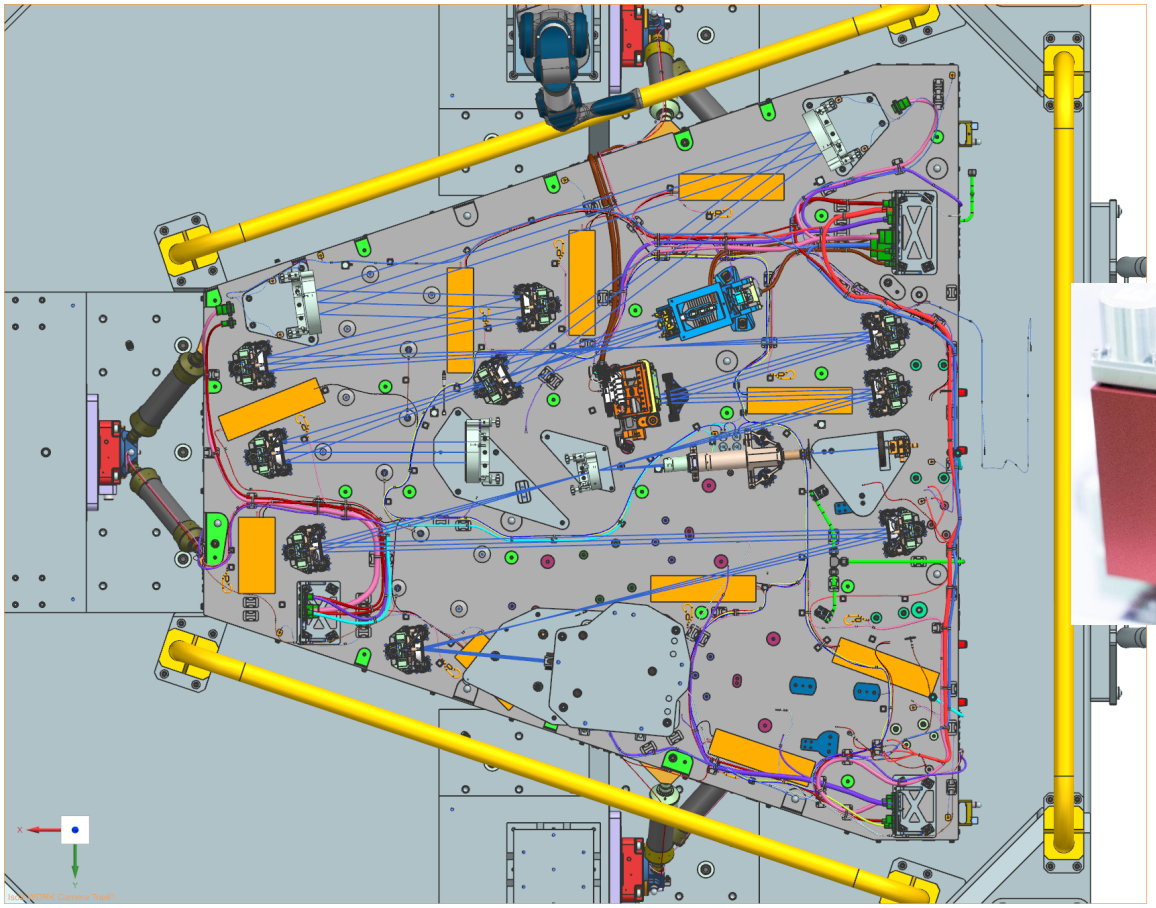


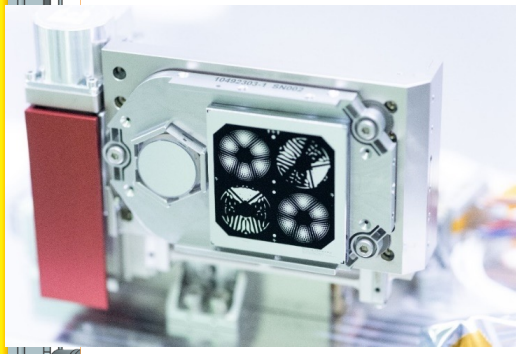
FCM Integration and Alignment



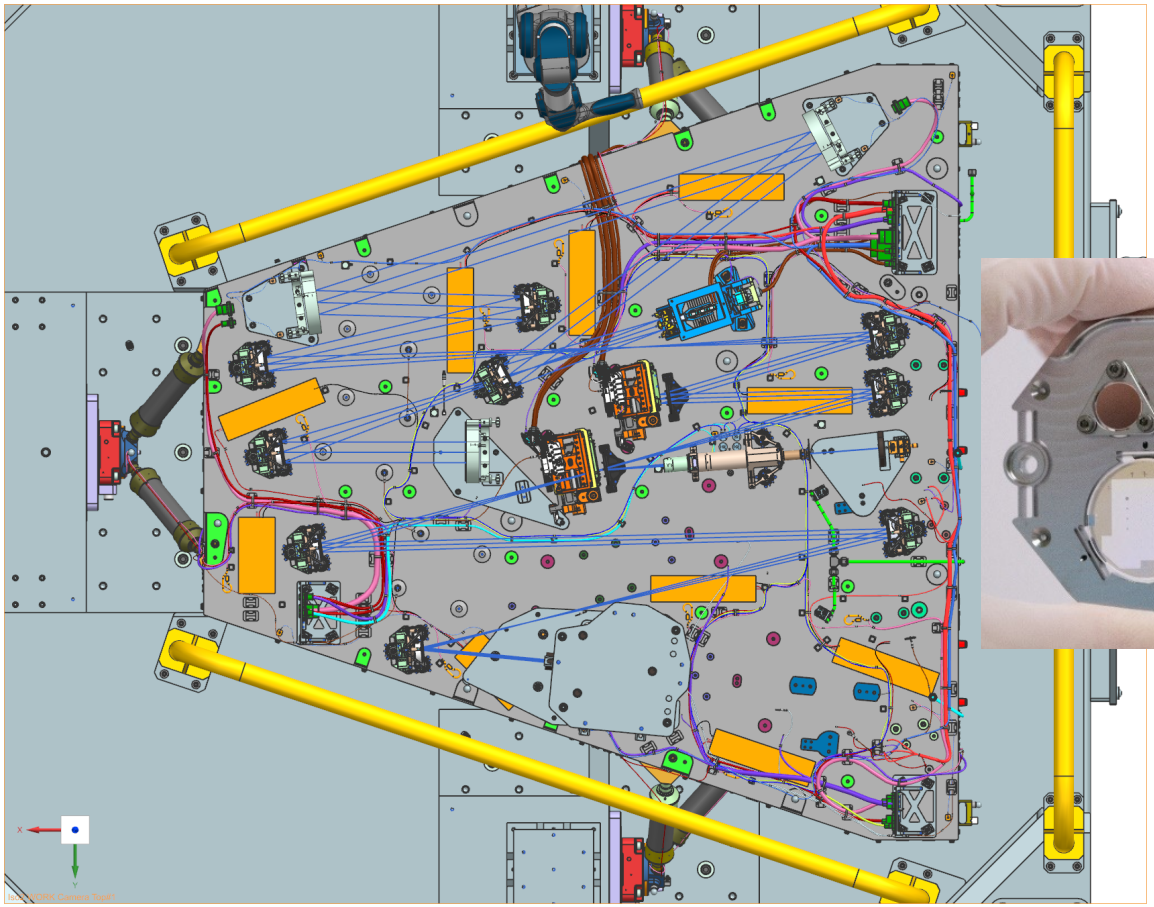


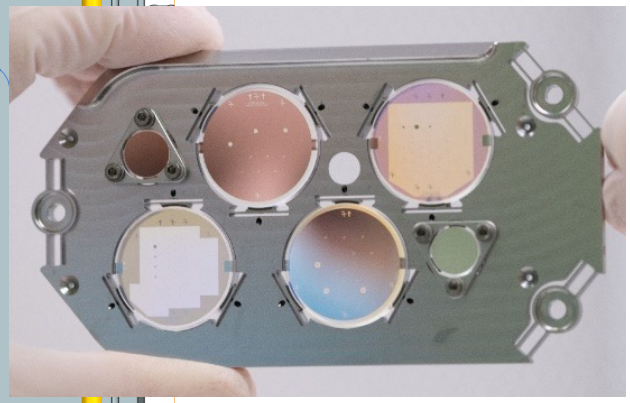
SPAM Integration and Alignment



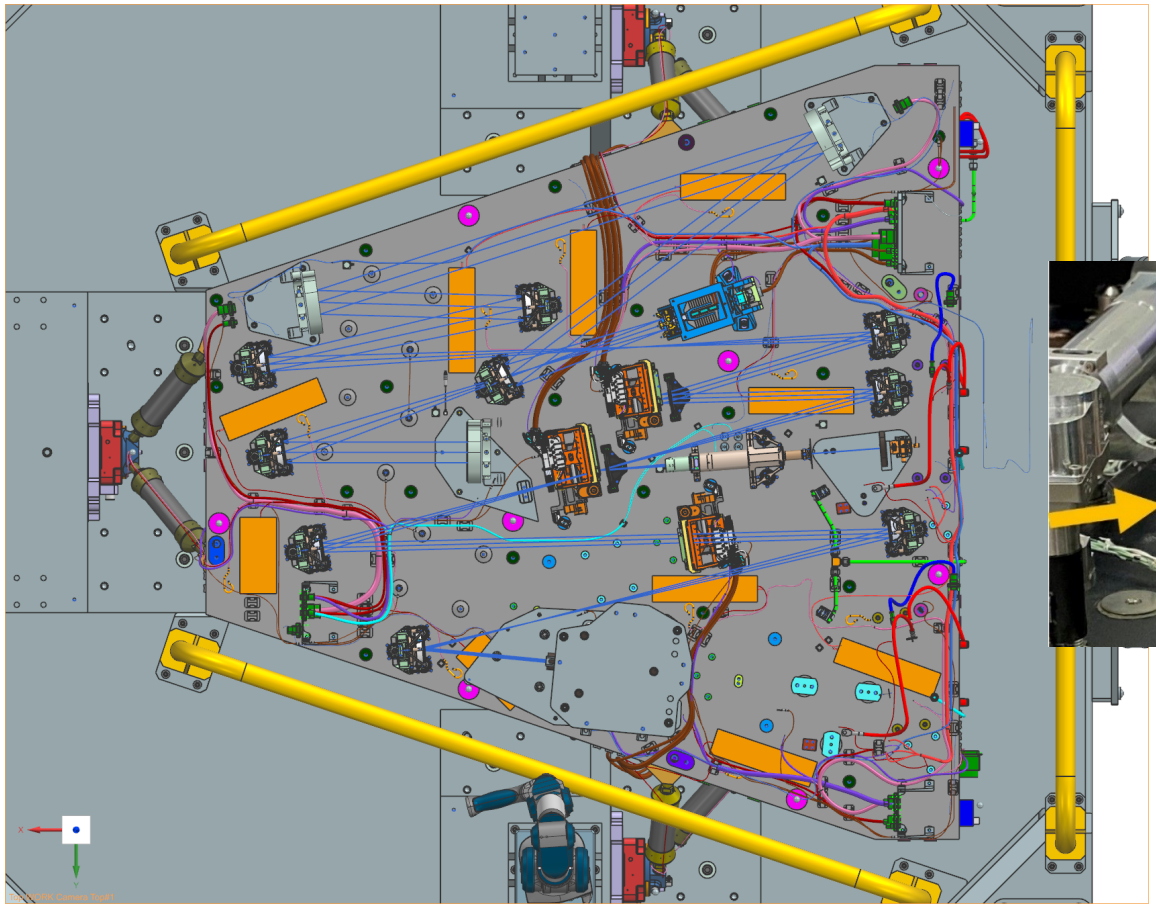


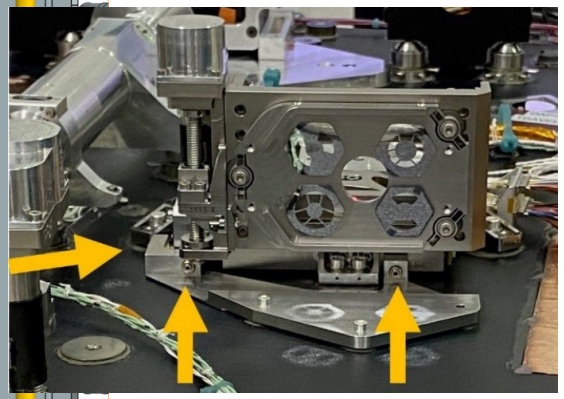
FPAM Integration and Alignment



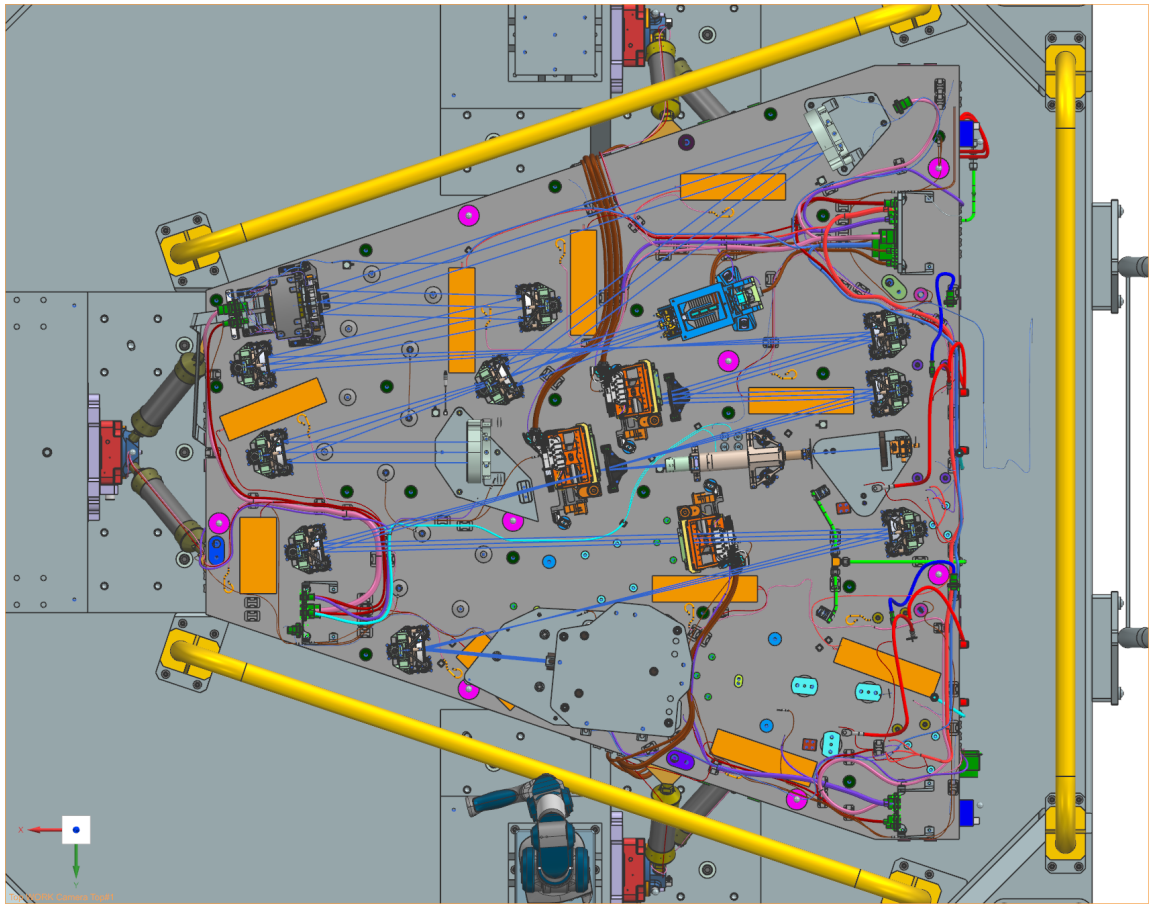


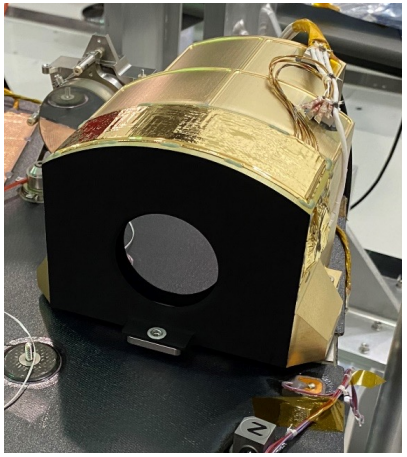
LSAM Integration and Alignment



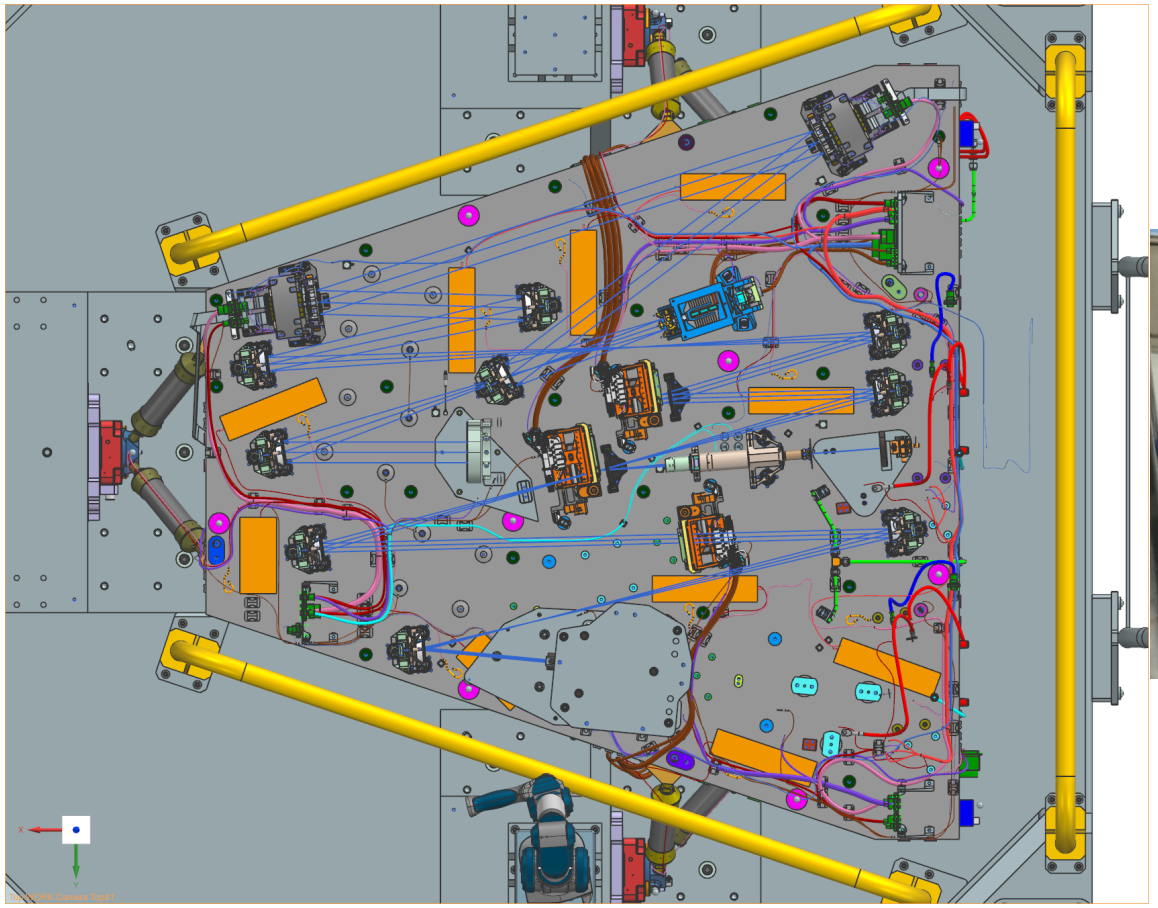


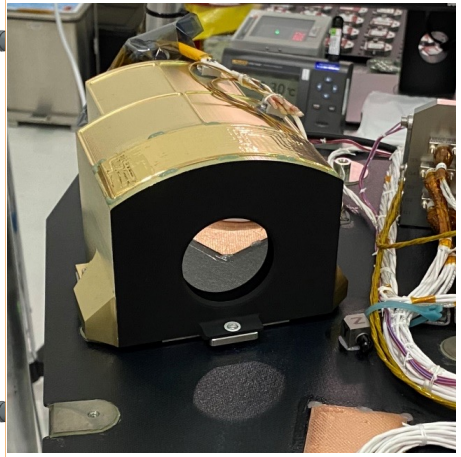
DM2 Integration and Alignment



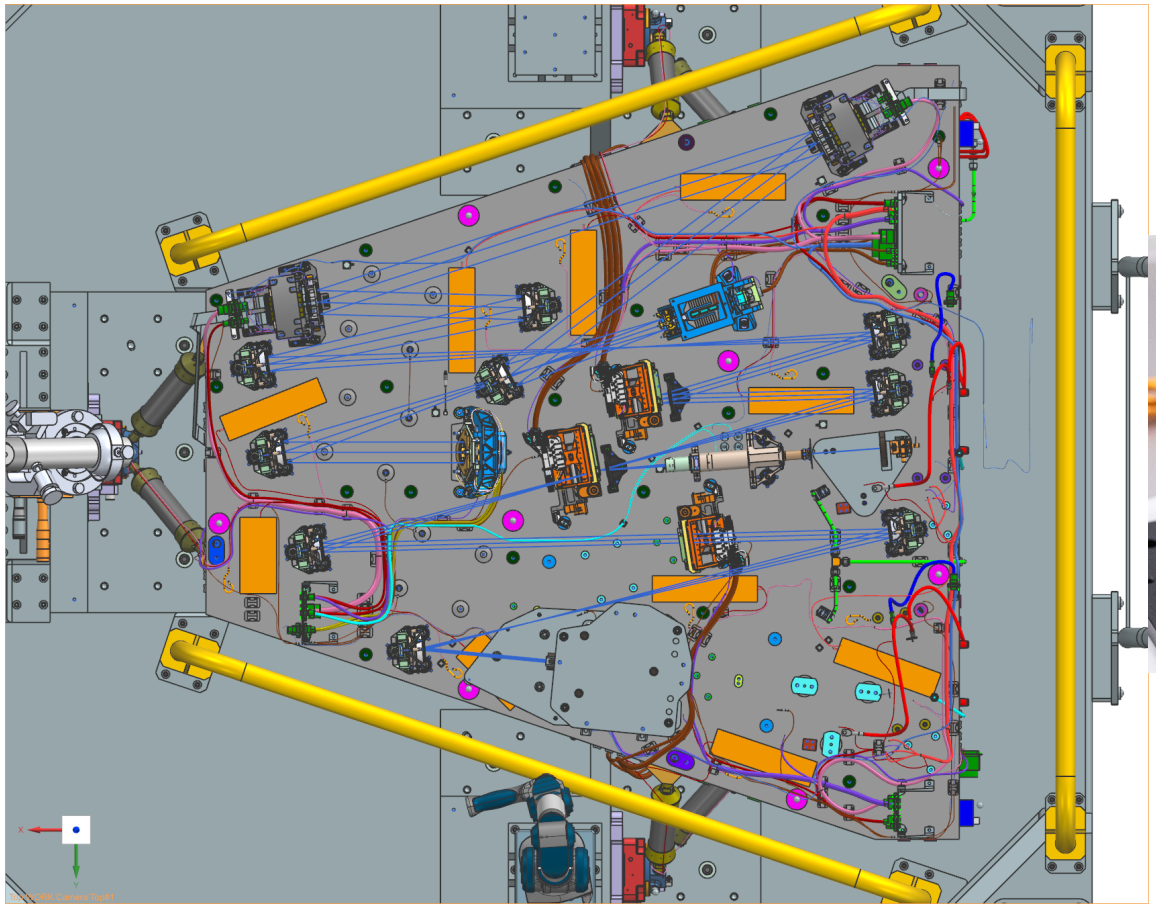


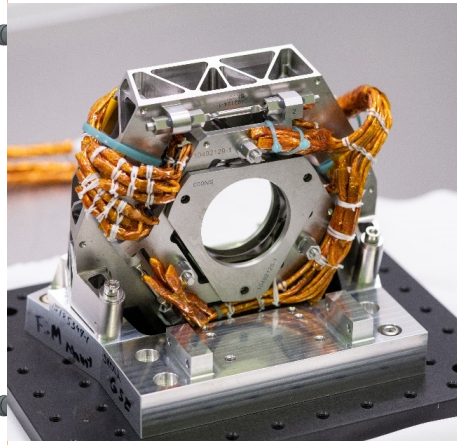
DM1 Integration and Alignment



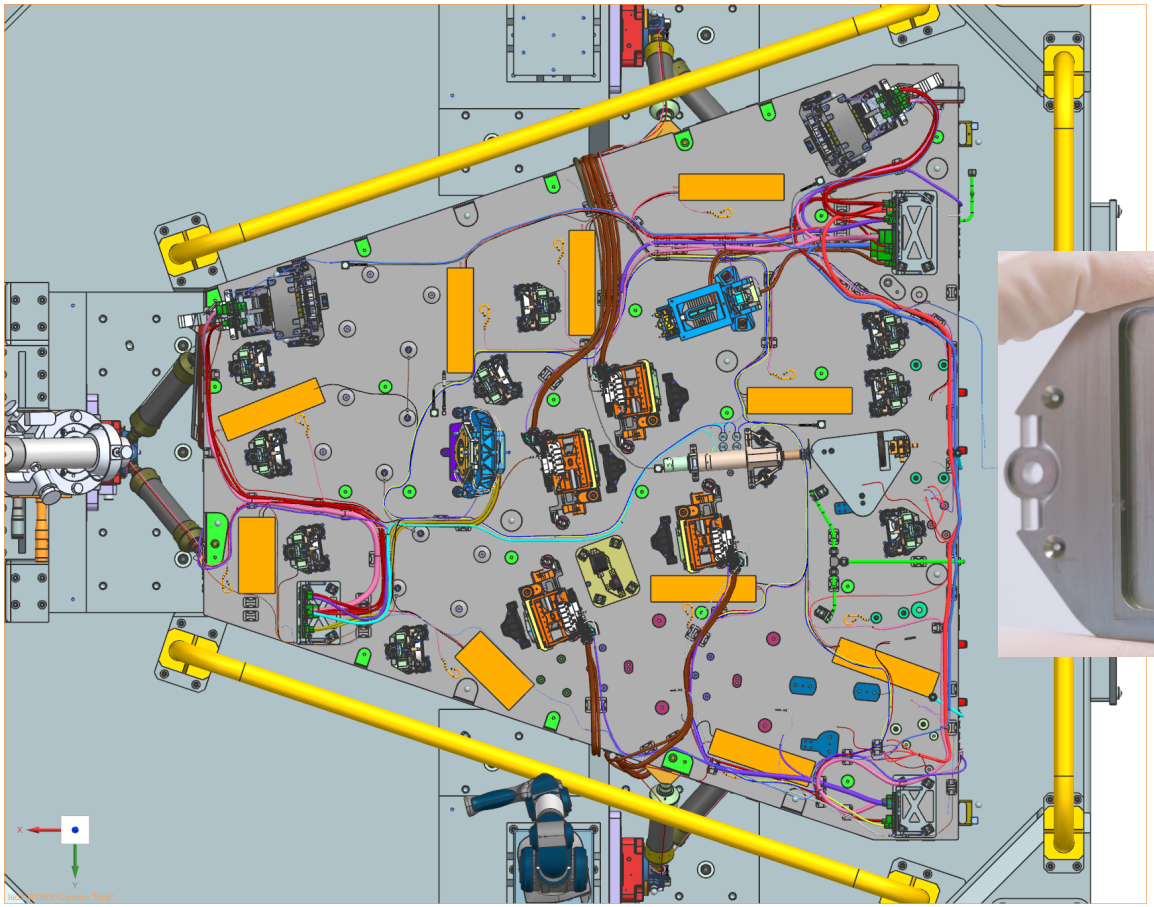


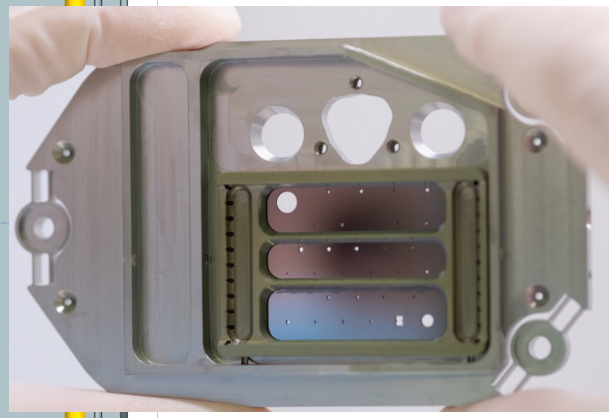
FSM Integration and Alignment



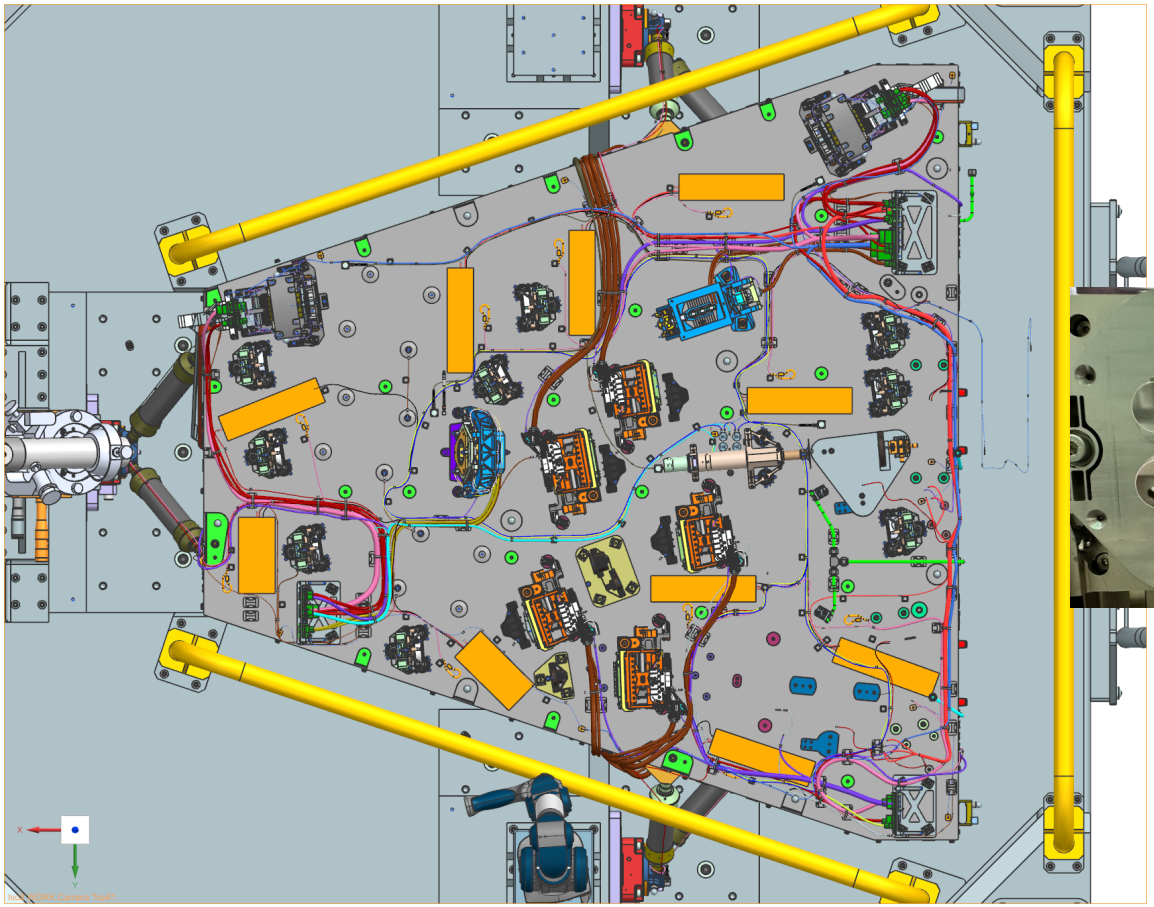


FSAM Integration and Alignment

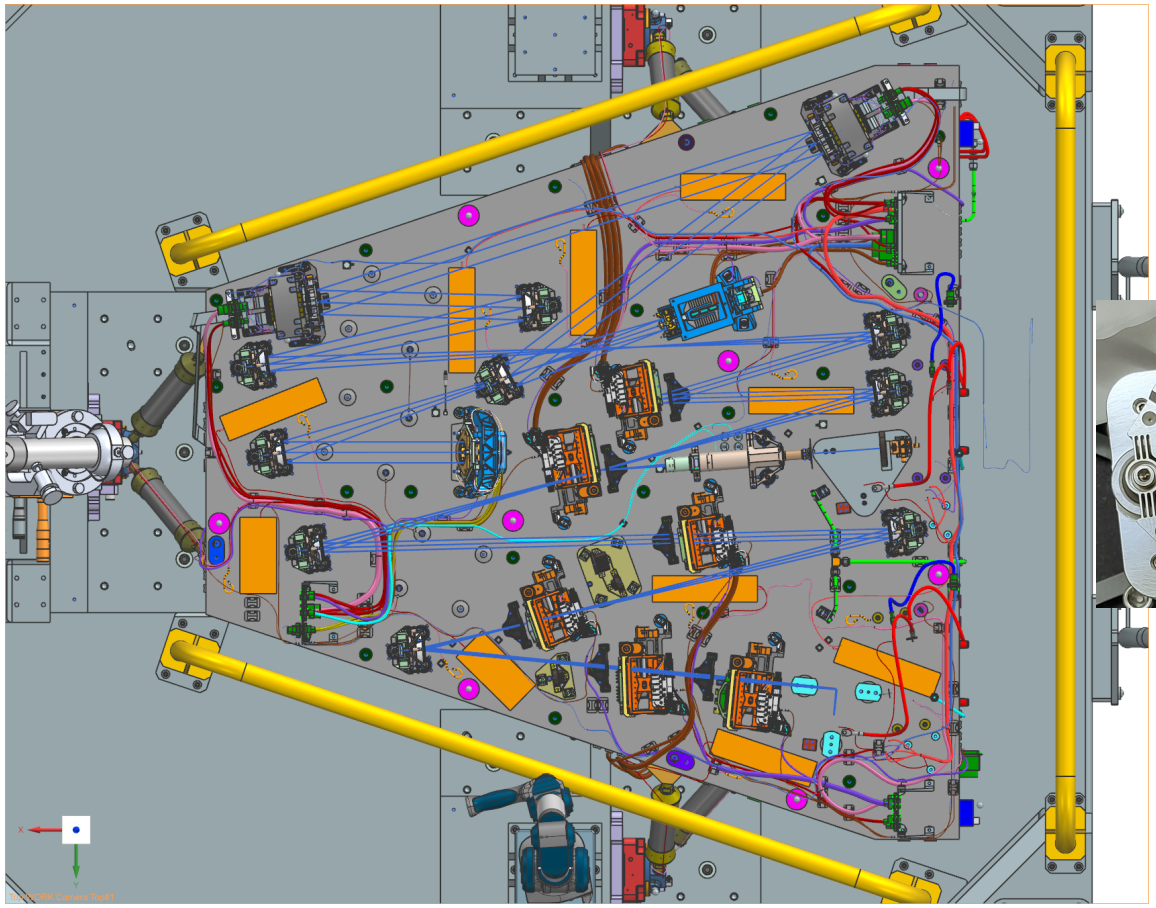


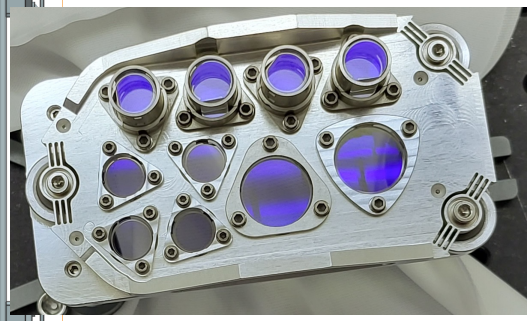


CFAM Integration and Alignment

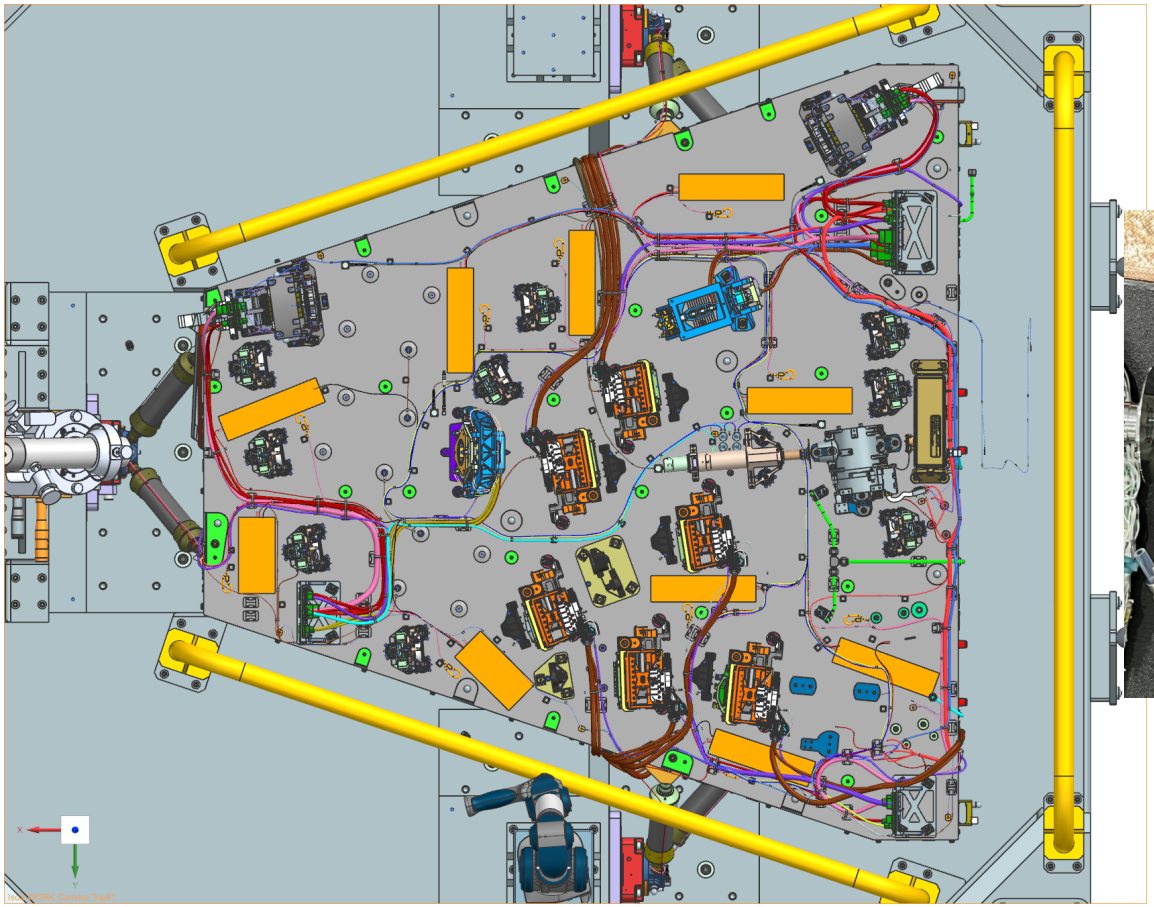


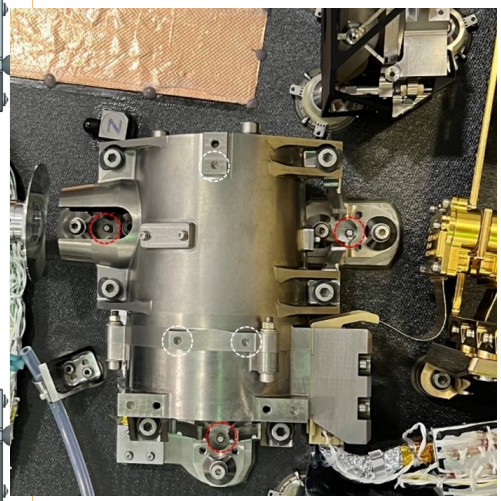
DPAM Integration and Alignment



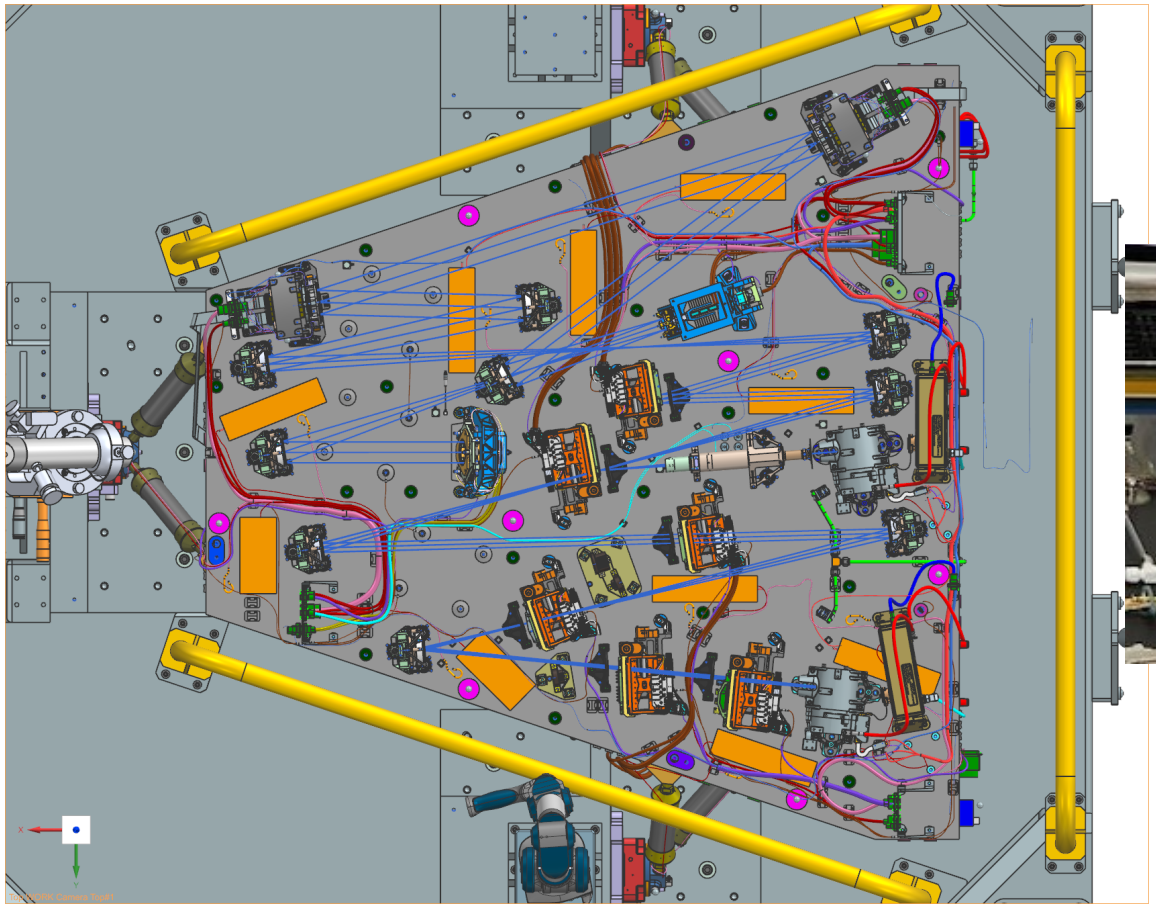


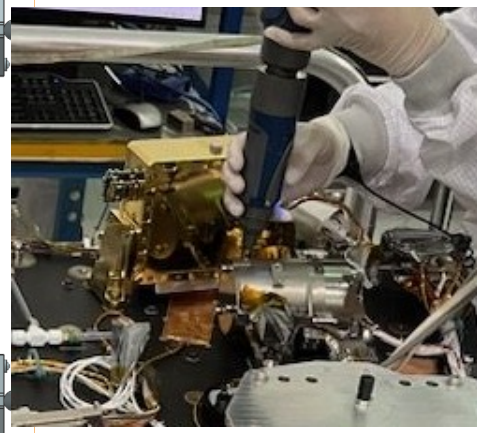
LOCam Integration and Alignment





ExCam Integration and Alignment





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End-to-end WFE of CGI Static Optics

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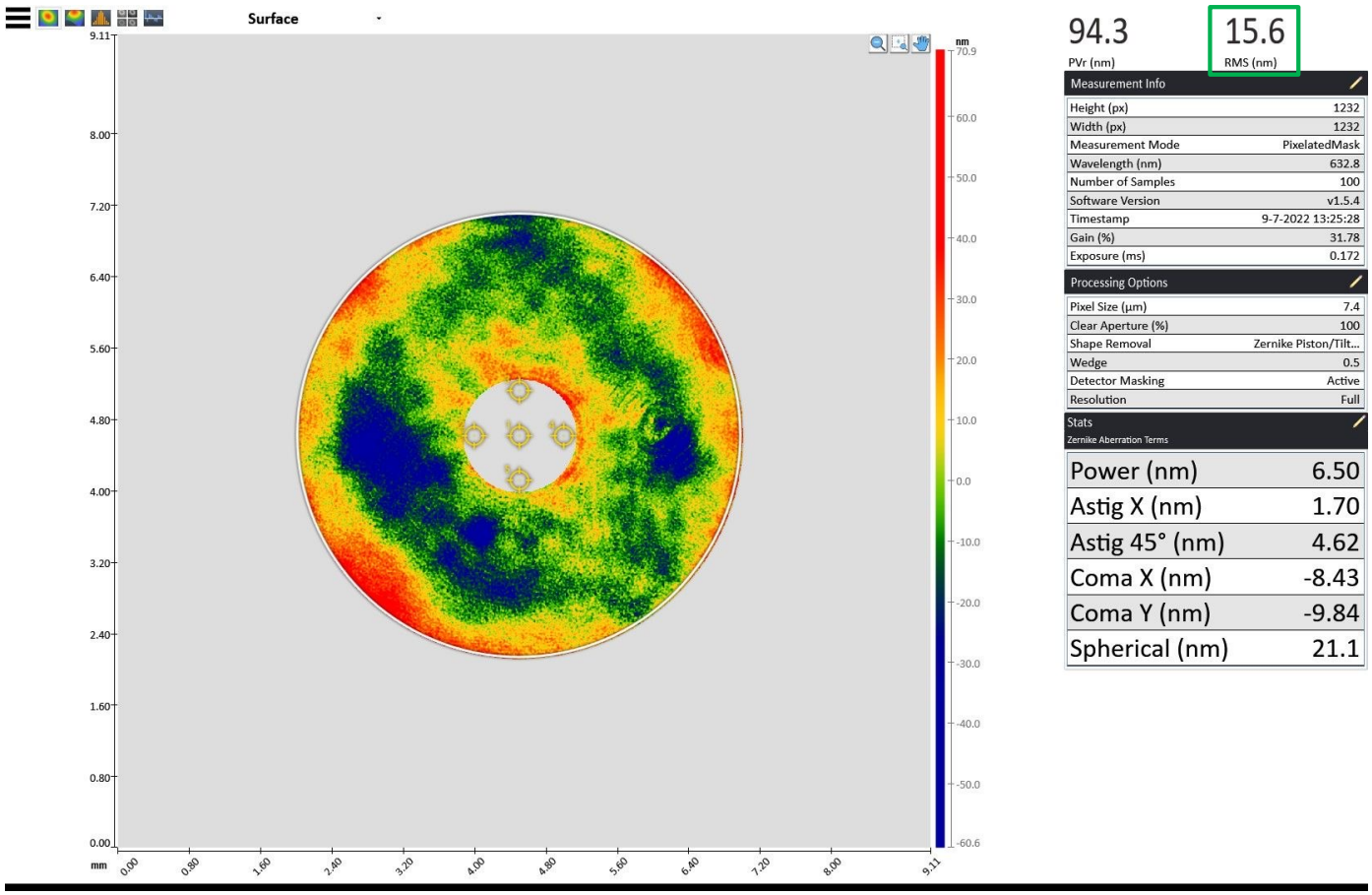


94.3
PVr (nm)

15.6
RMS (nm)

Measurement Info	
Height (px)	1232
Width (px)	1232
Measurement Mode	PixelatedMask
Wavelength (nm)	632.8
Number of Samples	100
Software Version	v1.5.4
Timestamp	9-7-2022 13:25:28
Gain (%)	31.78
Exposure (ms)	0.172

Processing Options	
Pixel Size (µm)	7.4
Clear Aperture (%)	100
Shape Removal	Zernike Piston/Tilt...
Wedge	0.5
Detector Masking	Active
Resolution	Full

Stats
Zernike Aberration Terms

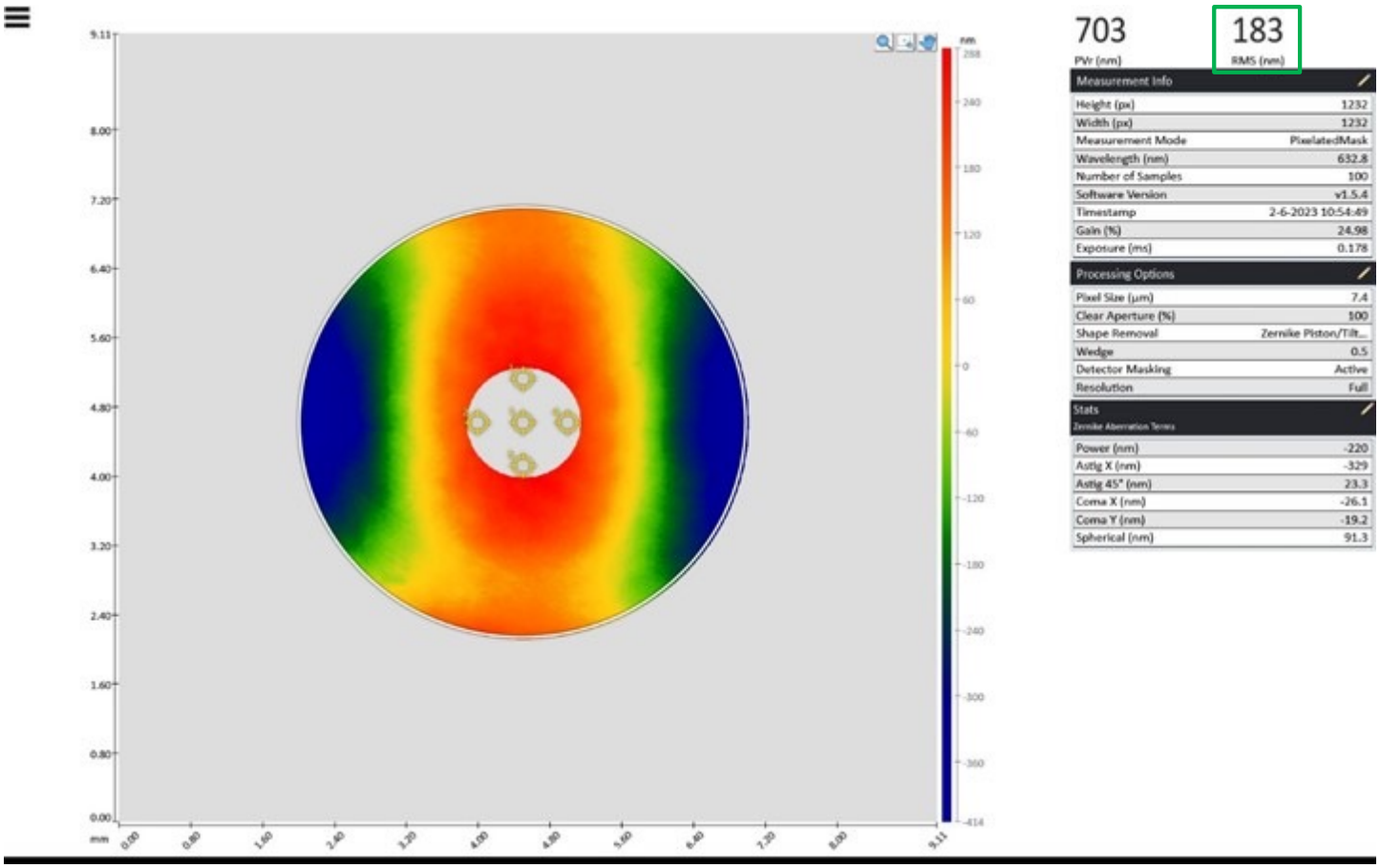
Power (nm)	6.50
Astig X (nm)	1.70
Astig 45° (nm)	4.62
Coma X (nm)	-8.43
Coma Y (nm)	-9.84
Spherical (nm)	21.1

CGI DM Optical Alignment Objectives

1. Replace surrogate DMs with flight DMs
2. Align DM actuator grids to OBSA Coordinate System
3. Align pupils to coincide
4. Register DM actuators

Measurement of each objective was iterated as alignment improved

End-to-end WFE with Inherent DM Aberrations

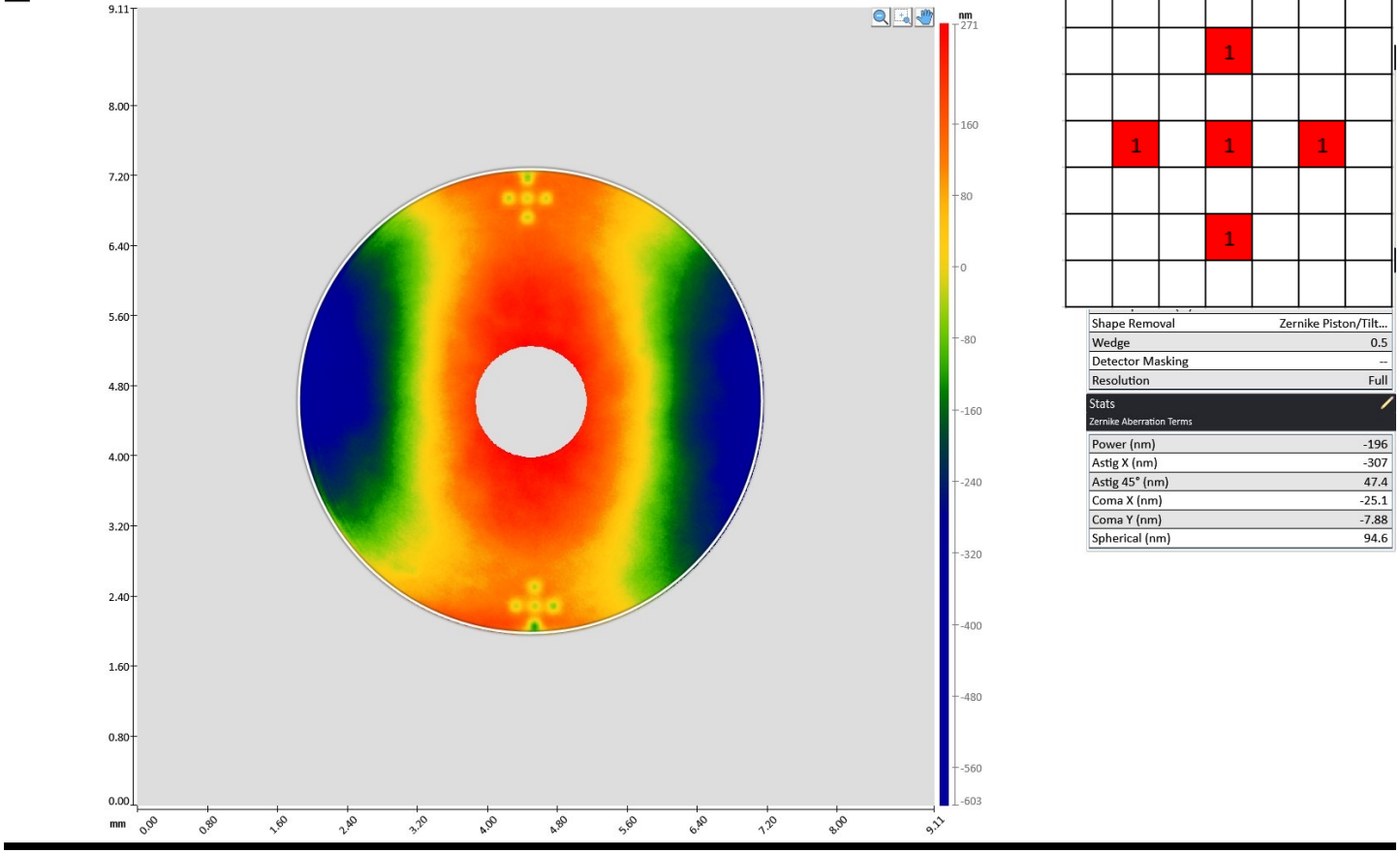


CGI DM Optical Alignment Objectives

1. Replace surrogate DMs with flight DMs
2. Align DM actuator grids to OBSA Coordinate System
3. Align pupils to coincide
4. Register DM actuators
5. Realign OAP mirrors to compensate innate DM aberrations and minimize end-to-end WFE

Measurement of each objective was iterated as alignment improved

DM1 pokes

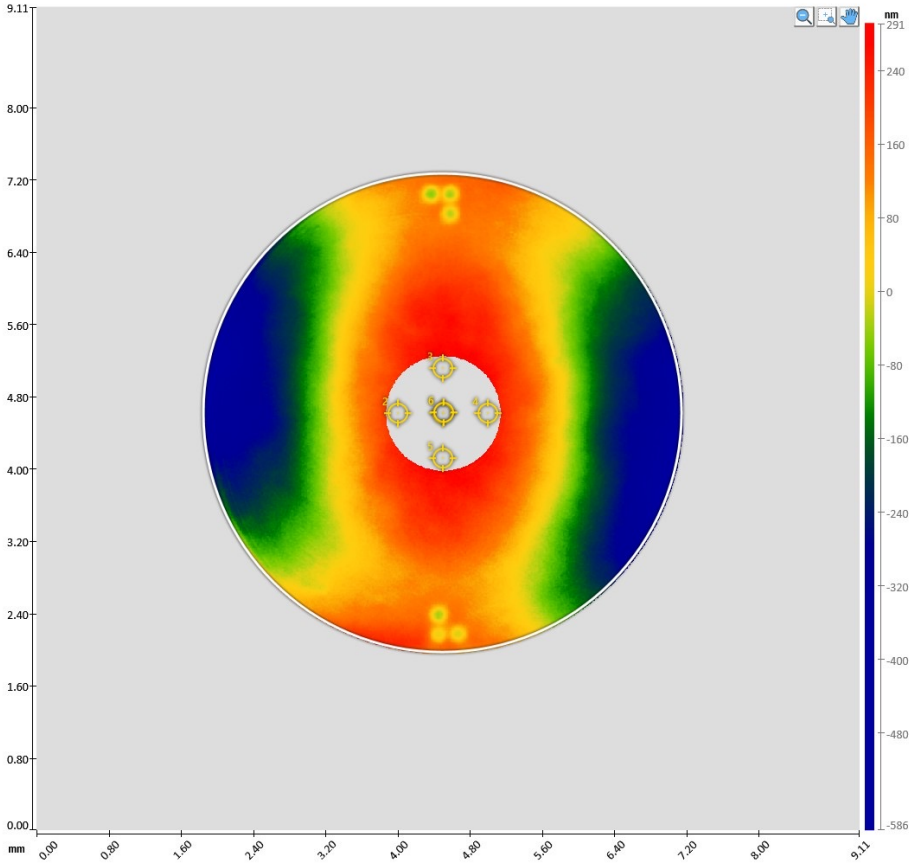


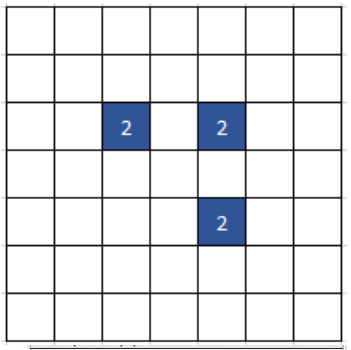
Shape Removal	Zernike Piston/Tilt...
Wedge	0.5
Detector Masking	--
Resolution	Full

Stats
Zernike Aberration Terms

Power (nm)	-196
Astig X (nm)	-307
Astig 45° (nm)	47.4
Coma X (nm)	-25.1
Coma Y (nm)	-7.88
Spherical (nm)	94.6

DM2 pokes



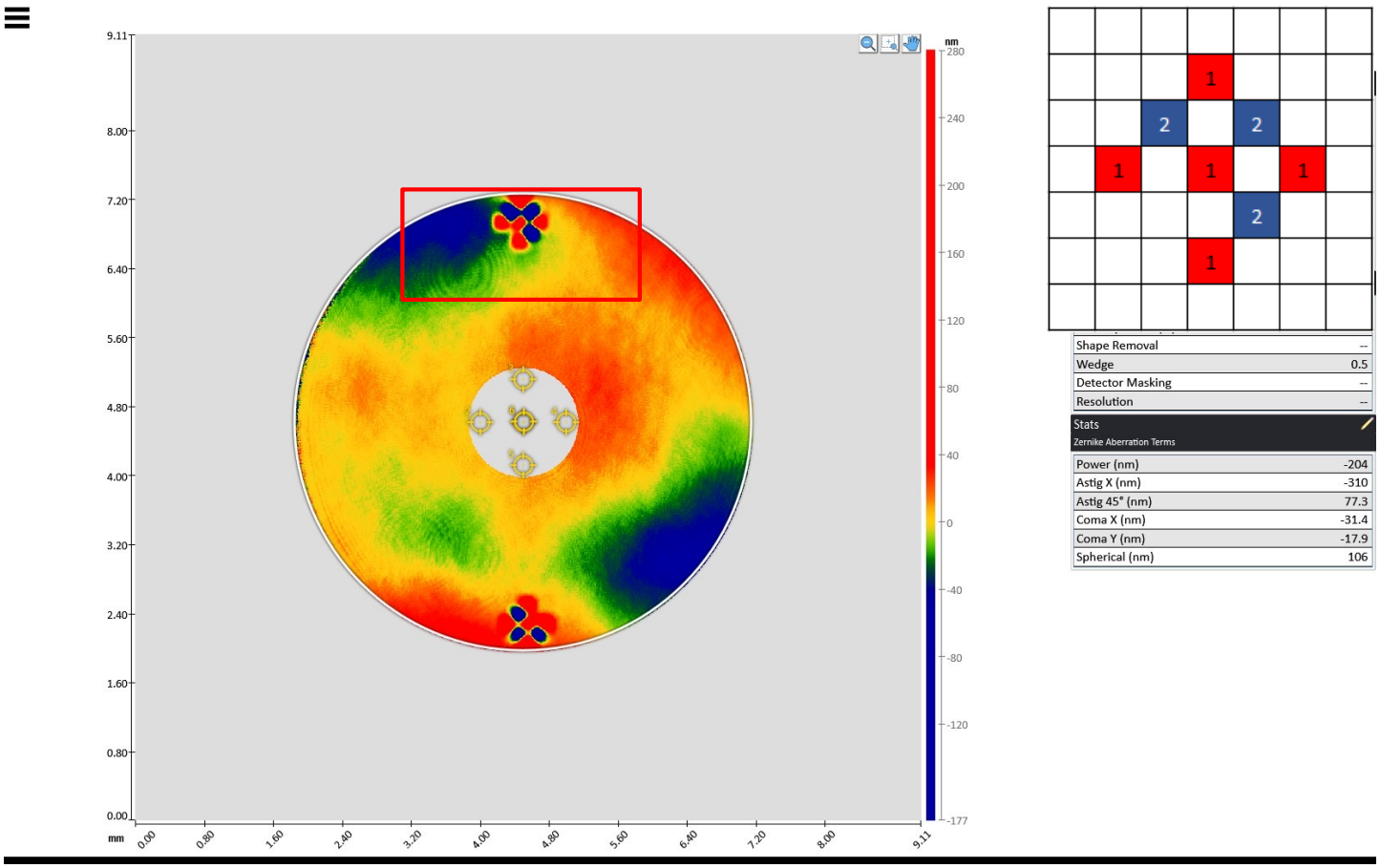


Shape Removal	Zernike Piston/Tilt...
Wedge	0.5
Detector Masking	--
Resolution	Full

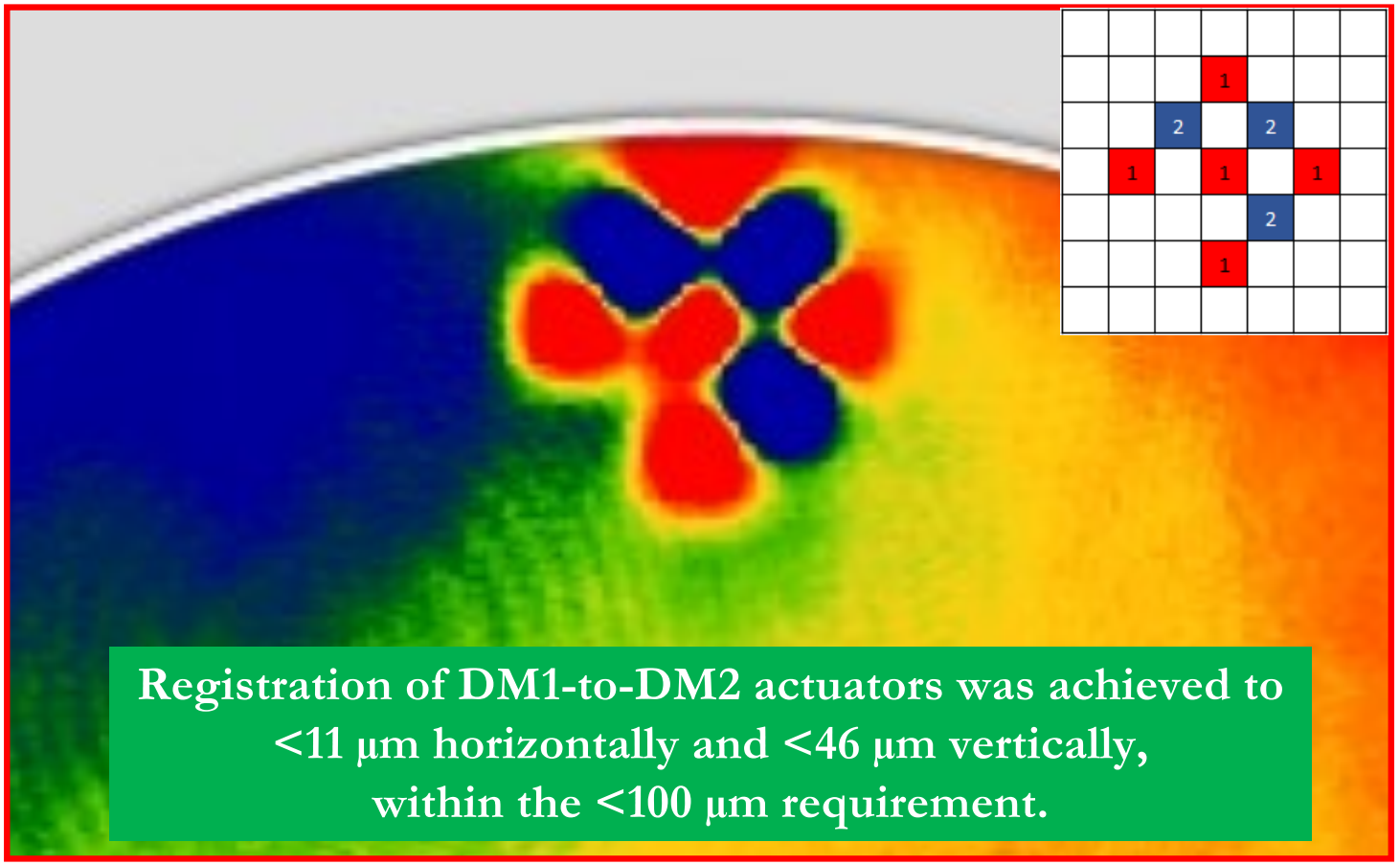
Stats
Zernike Aberration Terms

Power (nm)	-204
Astig X (nm)	-310
Astig 45° (nm)	77.3
Coma X (nm)	-31.4
Coma Y (nm)	-17.9
Spherical (nm)	106

Register laterally DM2 to DM1 via pokes (difference interferogram)

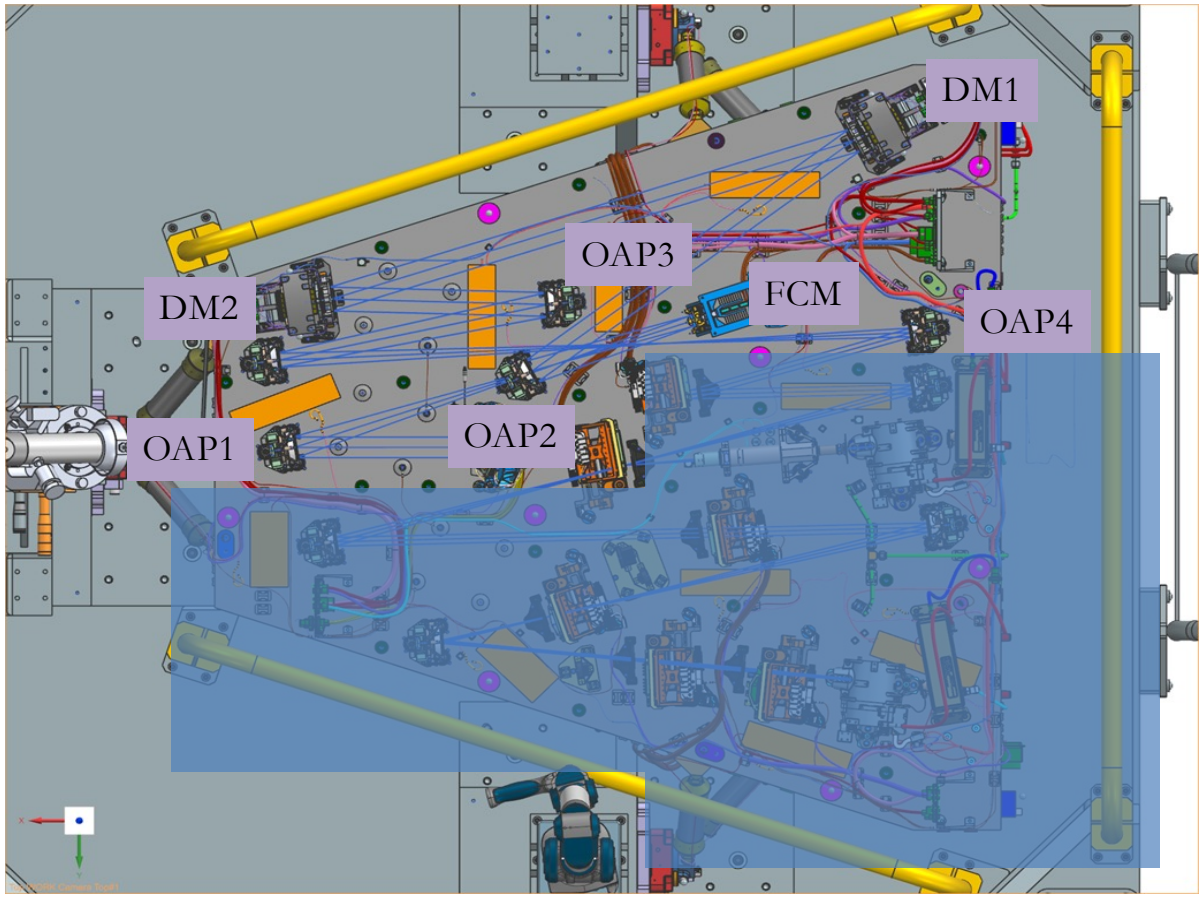


Register laterally DM2 to DM1 via pokes (difference interferogram)



Registration of DM1-to-DM2 actuators was achieved to <11 μm horizontally and <46 μm vertically, within the <100 μm requirement.

Optics Used for DM Aberration-compensation Alignment



Optics realigned

Optics not moved

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Final end-to-end WFE minimized by realigning OAP mirrors 1, 2, 3, and 4

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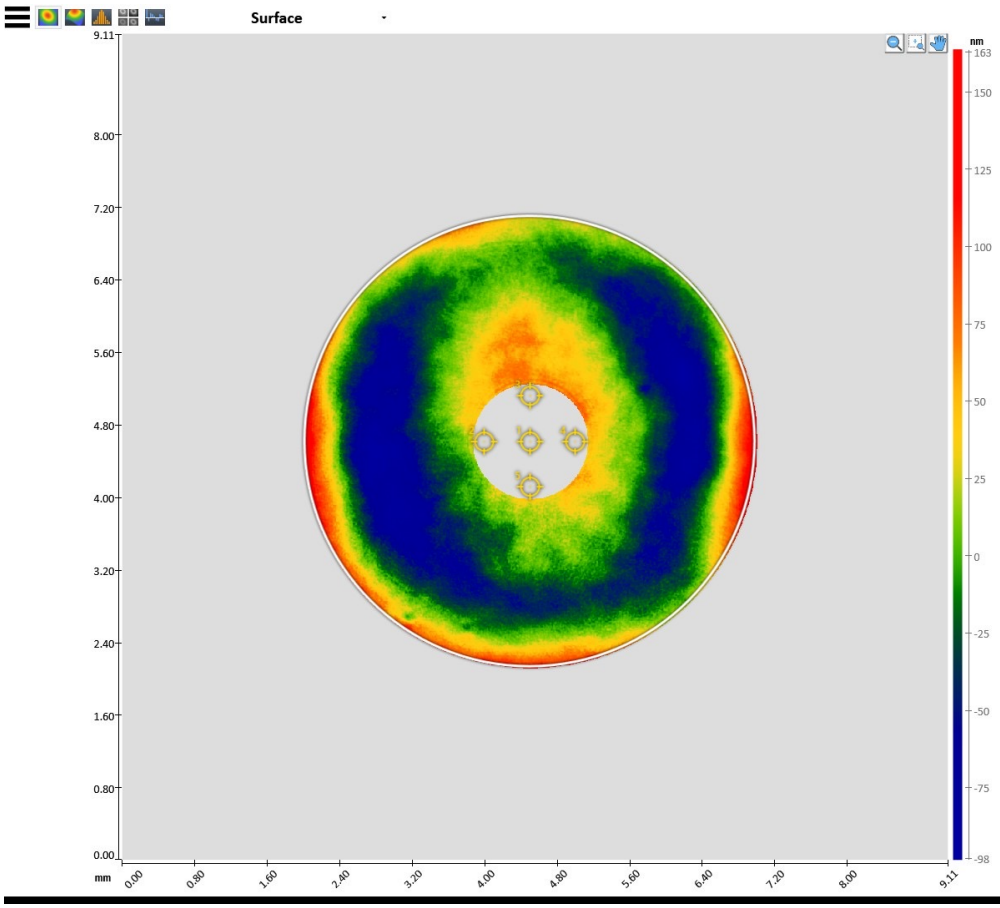


248
PVr (nm)

44.4
RMS (nm)

Measurement Info	
Height (px)	1232
Width (px)	1232
Measurement Mode	PixelatedMask
Wavelength (nm)	632.8
Number of Samples	100
Software Version	v1.5.4
Timestamp	2-14-2023 13:41:44
Gain (%)	24.98
Exposure (ms)	0.178

Processing Options	
Pixel Size (µm)	7.4
Clear Aperture (%)	100
Shape Removal	Zernike Piston/Tilt...
Wedge	0.5
Detector Masking	Active
Resolution	Full

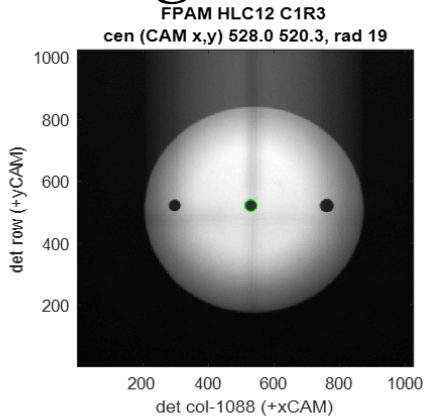
Stats
Zernike Aberration Terms

Power (nm)	-0.675
Astig X (nm)	-5.65
Astig 45° (nm)	-5.08
Coma X (nm)	-17.9
Coma Y (nm)	-34.0
Spherical (nm)	86.6

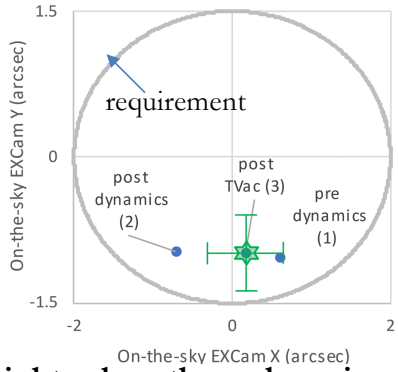
Measured WFE of 44.4 nm RMS before phase-flattening of DMs

CGI Alignment Checks through Environmental Testing

- Critical CGI alignment metrics were measured before and after environmental tests, and after delivery to Goddard
  - An alignment telescope was aligned to the OBSA coordinate system via fiducials on the CGI and the CGI Instrument Carrier
  - Measured boresight and pupil stability, as well as checking close clearances in the CGI beam train
- Results: minor changes through environments; no change after delivery
  - Final values comply with our interface requirements with Roman



Example raw boresight measurement data



Boresight values through environments

Changes small between tests

All values meet requirements