Roman Space Telescope

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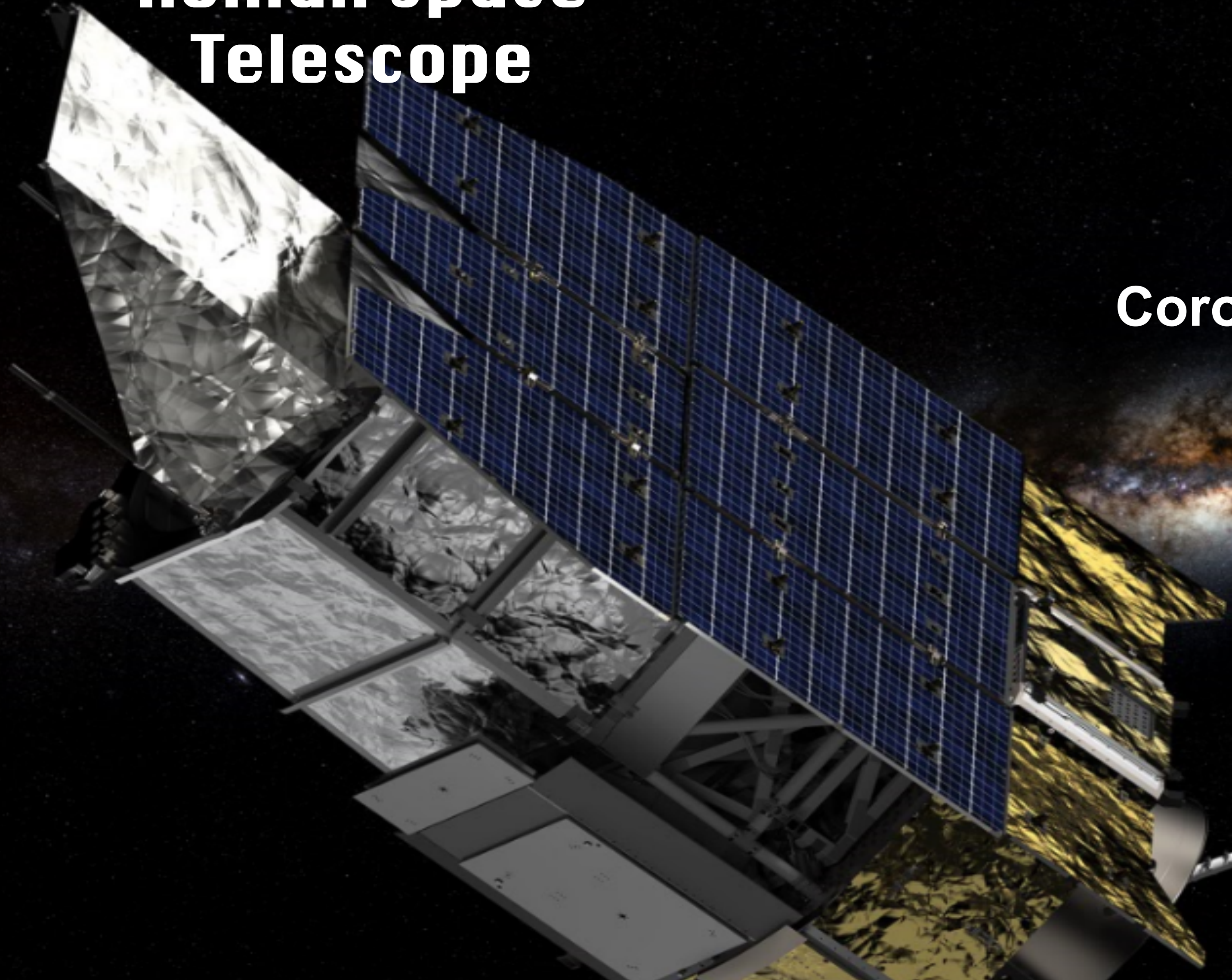

Roman Space Telescope Coronagraph Instrument (CGI) Status

Dr. Feng Zhao

Deputy Project Manager

Jet Propulsion Laboratory

California Institute of Technology

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Outline

- Recap of key coronagraph technologies
- Major events (changes) since PDR (9/2019)
- CGI baseline design and con-ops updates
- CGI technologies for future missions
- Path to CGI CDR
- Summary

Coronagraph on Key NASA Flagship Missions

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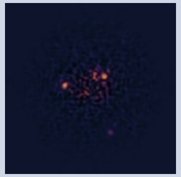
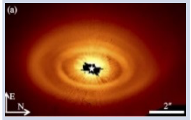
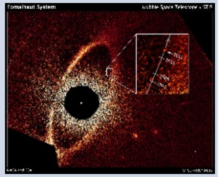
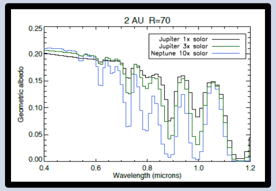
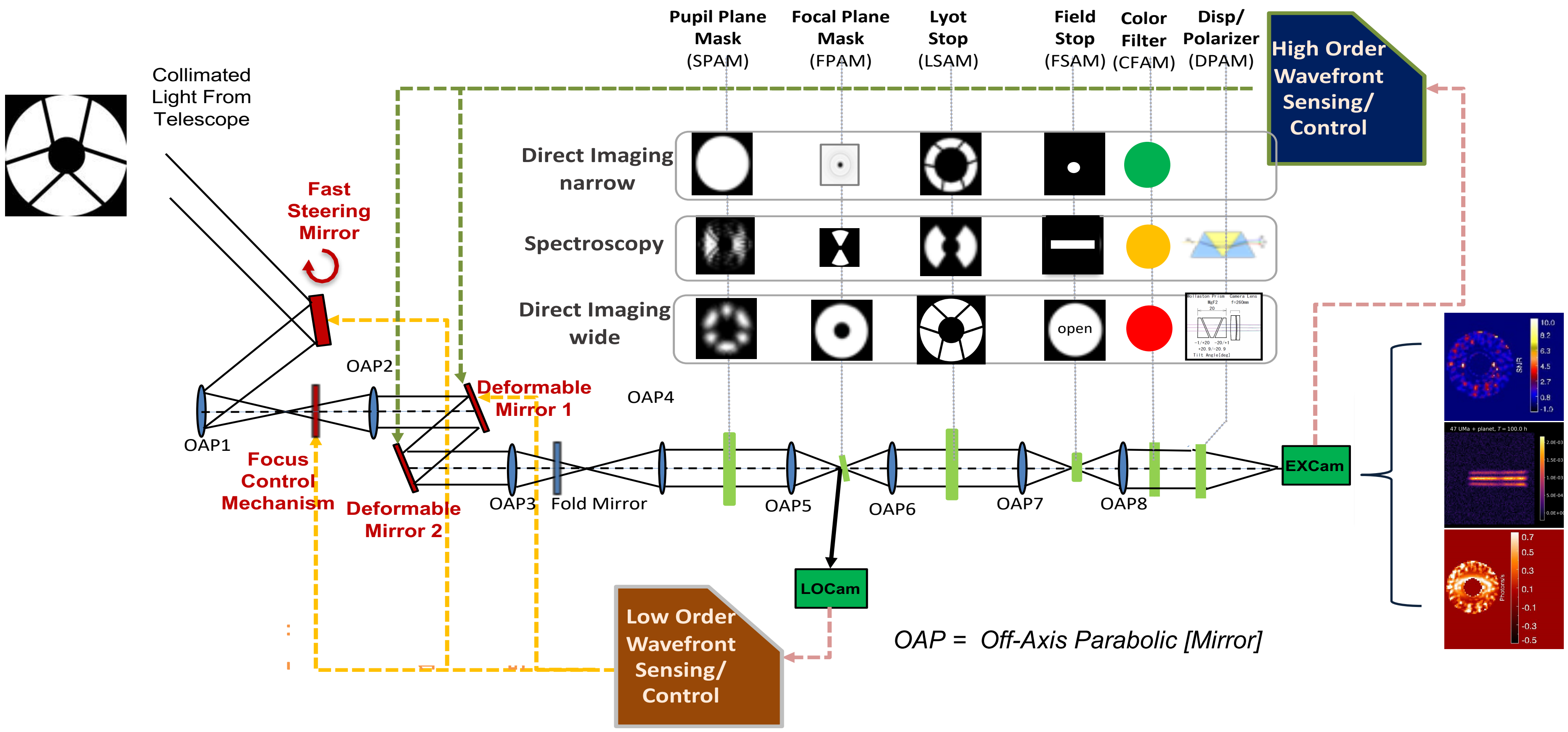
Roman Space Telescope

	Hubble			Webb			Roman
Instrument name	NICMOS	STIS	ACS	NIRCam	MIRI	NIRISS	CGI
Coronagraph type	Lyot	Lyot	Lyot	Lyot, with Gaussian apodization	1) Quadrant phase mask; 2) Lyot	Aperture Masking Interferometry	1) Hybrid Lyot 2) Shaped pupil
Contrast (raw)	1E-5	1E-5	1E-5	1E-5	1E-5	1E-4	8E--9
Contrast (proc))	1E-6	1E-6	1E-6	8E-7			8E-10
Active wavefront sensing and control	No	No	No	Yes on telescope No on Coronagraph	Yes on telescope No on Coronagraph	Yes on telescope No on Coronagraph	Yes on coronagraph No on OTA
IWA (arcsec)	0.5	0.7	0.9	1.7	0.5		0.15
Key Exo-planet science example	HR 8799 (1998) (Lafreniere et al. 2009) 	HD 141569 disk (Konishi et al. 2016) 	Fomalhaut b, (Kalas et al. 2008) 				Photometric images and Spectroscopy of mature exoplanets in nearby solar systems 

Roman CGI continues <u>space</u> coronagraphy, with addition of active wavefront sensing and control.

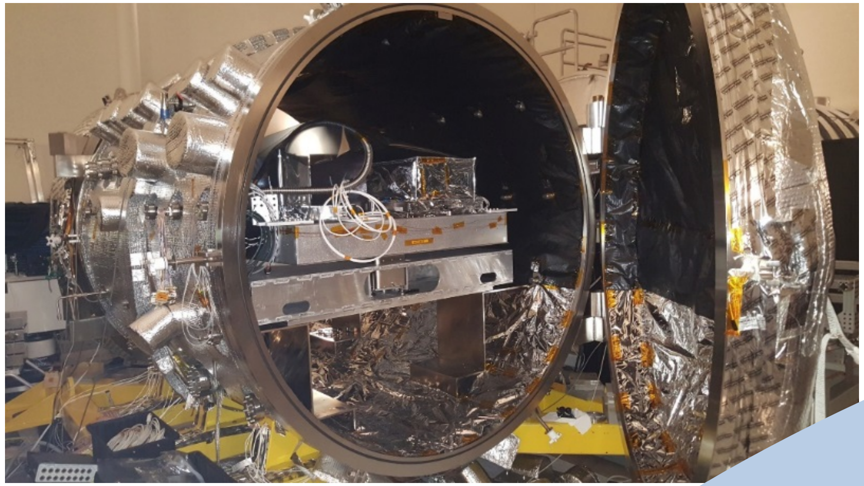
CGI Architecture

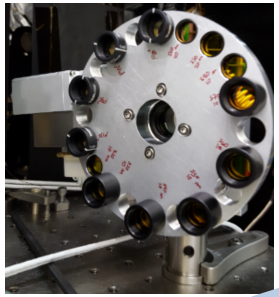
Roman Space Telescope

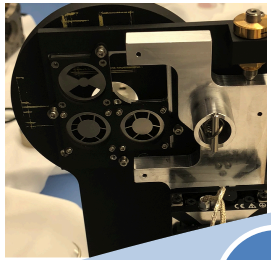


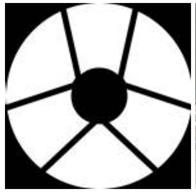
- Three observation modes implemented with three different sets of masks/filters, in respond to L1 requirements (TTR5) and objectives
- Share the same optical beam train, with two wavefront control loops to achieve high contrast (better than 1E-8)

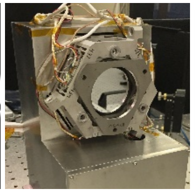
Early Investment Reduced CGI New Technology Risks to Roman Mission











Coronagraph is added to WFIRST mission. (2013)

HLC/SPC/LOWFS demonstrated separately

(2015)

WFIRST CGI Testbed built

(2016)

Broadband (10%) contrast demonstrated in dynamic environment

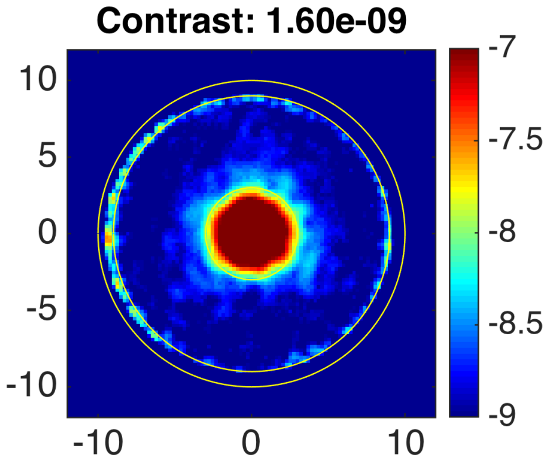
(2017, TRL-5)

CGI Ground & In-Obit commissioning operations demonstrated in testbed environment

(2019)

Testbed Achieved
1.6e-9 raw contrast
550 nm, 10% BW
3 – 9 lambda/D

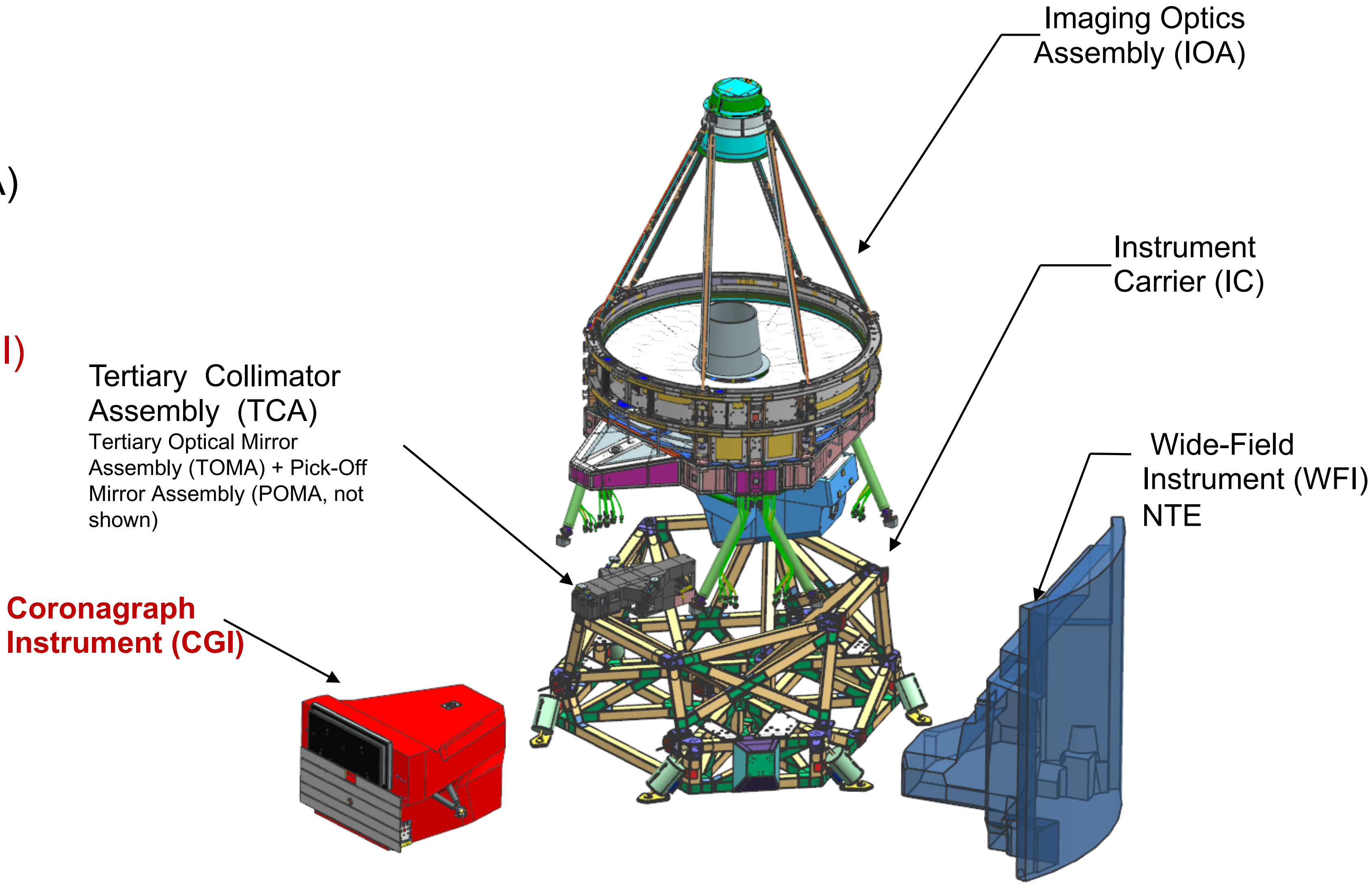
Hybrid Lyot Coronagraph



CGI has achieved required technology maturity levels for a flight project

CGI in Roman Payload

- Roman Space Telescope Payload Includes
  - Imaging Optics Assy (IOA)
  - Tertiary Collimator Assy (TCA)
  - Instrument Carrier (IC)
  - Wide Field Instrument (WFI)
  - Coronagraph Instrument (CGI)



CGI at a Glance (baseline post PDR)

- Dimension: 1.687X1.092X1.760 (m^3)
- Mass: 304Kg (CBE)
- Power: 349W Operations (CBE)
- Temperature: ~20°C optical bench

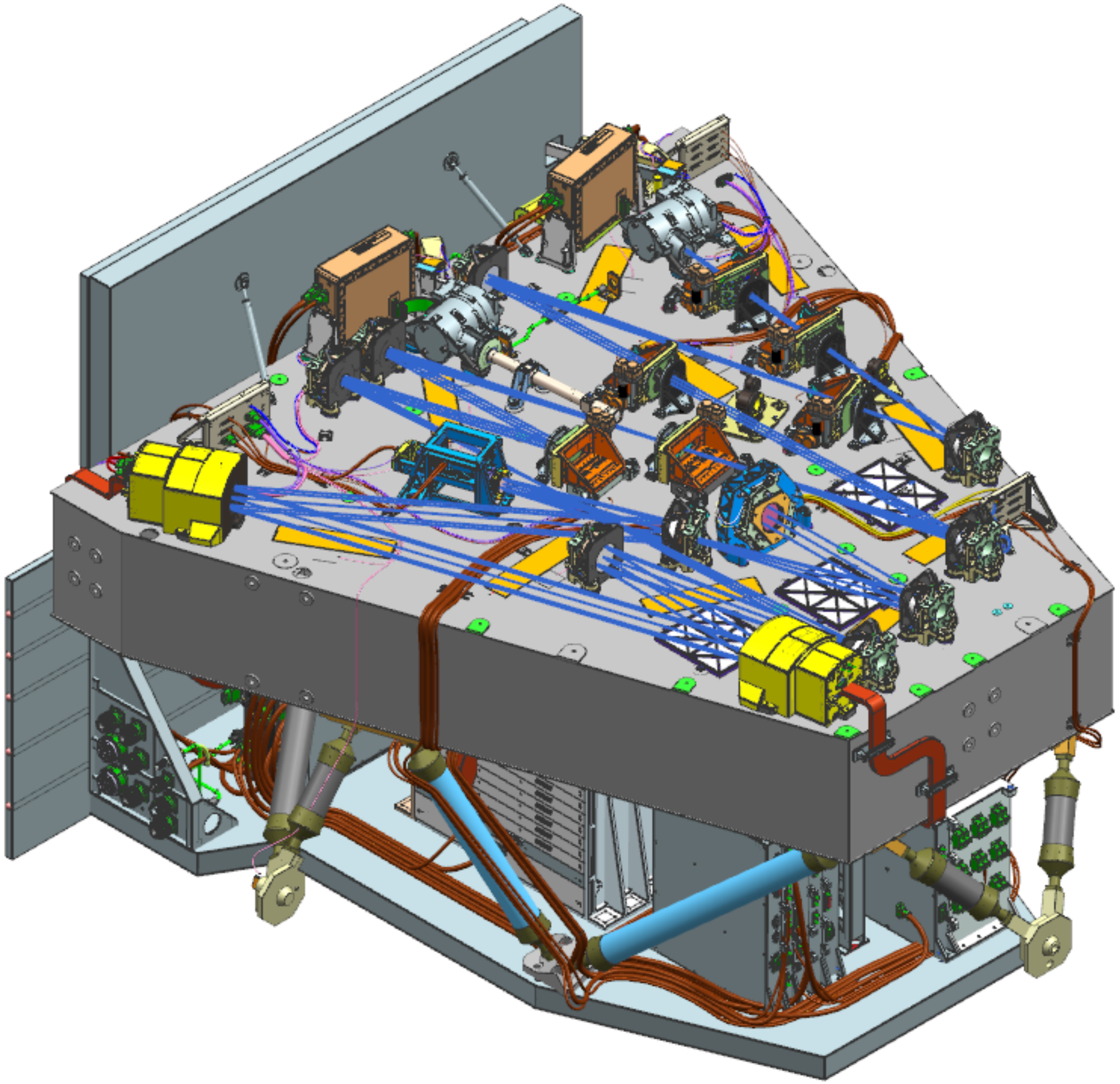
- Wavelength: 460-980nm
- Field-of-view: 20X20 arcsec max
- Pointing jitter: 0.5mas
- Prism spectrometer: R~50
- Wollaston polarizers: 0°+90°, 45°+135°
- Pupil imaging
- Phase retrieval optics

- EMCCD Camera #1: 1K X 1K pixels – Exoplanet
- EMCCD Camera #2: 50 X 50 pixels used – LOWFS
- Camera temperature: -105°C

- WPC Processor: command and data handling

- LOWFS Board (2X RTG4 FPGA): Pointing control

- Data rate: 4.6 Mbps (CBE)
- Data volume: 0.4 Tbits/day (CBE)



Major Events since PDR (9/2019)

After CGI PDR (9/2019) and WFIRST PDR (11/2019), CGI has been working with JPL and NASA to address CGI programmatic risks. There have been a number of positive steps:

- 12/2019. Per NASA Tiger Team recommendation:
  - CGI re-baselined high-order wave-front sensing and control (HOWFS/C) from “in-orbit” to “ground-in-the-loop”. This results in descope of two key electronics hardware (1) processor; (2) solid-state recorder. In addition, this change greatly simplifies the flight soft-ware.
- 2/28/2020. KDP-C, NASA agreed to:
  - Relax CGI requirement by removing CGI L1 Baseline rqmts, leaving only 1 Threshold rqmt in PLRA (TTR5 – direct imaging).
  - Reduce CGI mission life-time requirement from 5.25 years to ~1.75 years (18 months tech demo plus 3 months in-orbit check-out).
  - Remove starshade accommodation requirement for WFIRST, and put on hold starshade accommodation designs (both S/C and CGI). WFIRST will pick up the starshade accommodation design after Astro2020 decadal recommendations.
  - Re-classify CGI from risk class C to risk class D per NPR 8705.4.
  - Manage CGI directly (programmatic), CGI has its own cost cap ($334M through IOC) without HQ-UFEs
  - Maintain PDR design as allowed by CGI resources (mass, power, budget, schedule, etc.)
- 5/1/2020. CGI received additional ~40 JPL DP/FPP waivers from DTAB (Class D Technology Advisory Board)
  - More streamlined mission assurance approach is being finalized under QARTA – Quality Assurance Requirements Tailoring Agreement.

Re-cap Technical Requirements: 2-1

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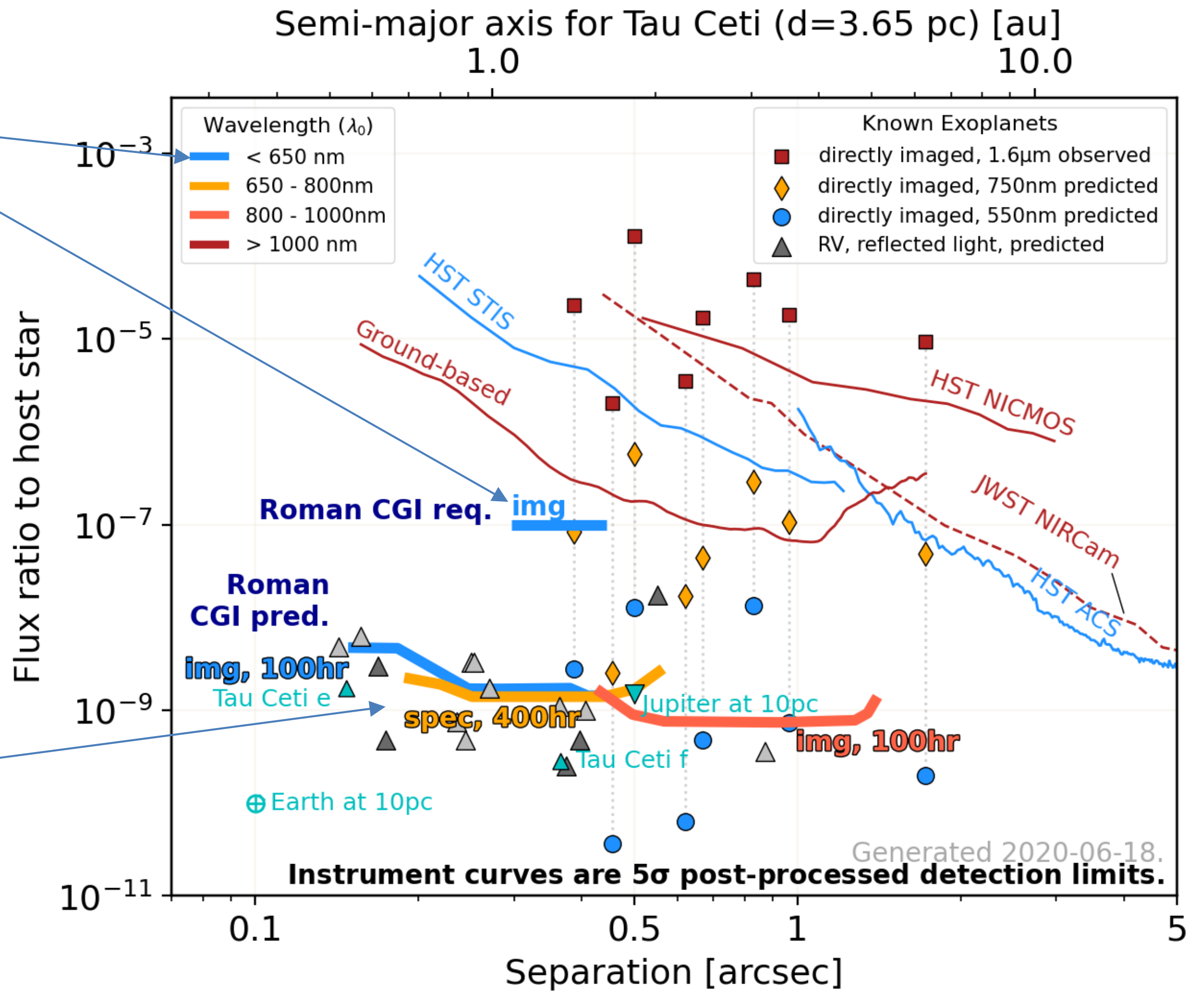
CGI TTR5 remains in PLRA (one mode)



CGI CBE performance (three modes)

- Healthy margin ~90%
- CGI project intends to maximize the margin for the given constraints (programmatic and interfaces)

https://github.com/nasavbailey/DI-flux-ratio-plot/blob/main/documentation/flux_ratio_doc.png

Courtesy of V. Bailey

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Re-cap Technical Requirements: 2-2

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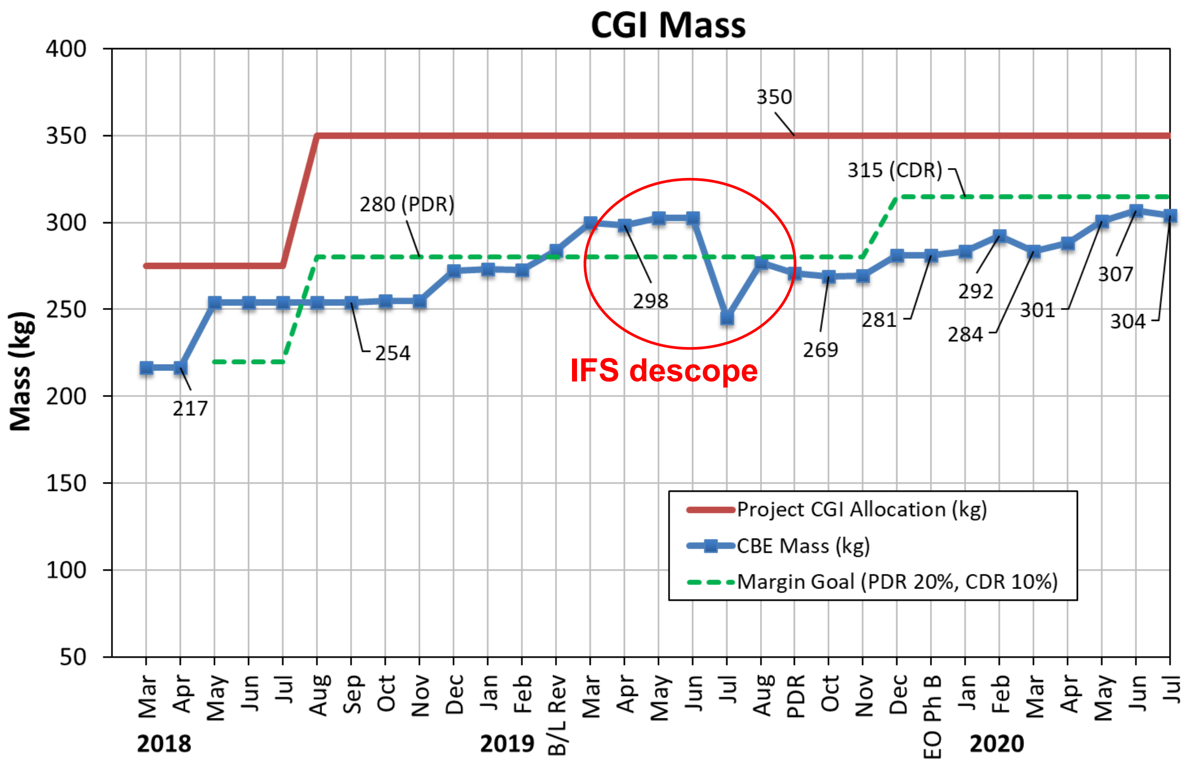
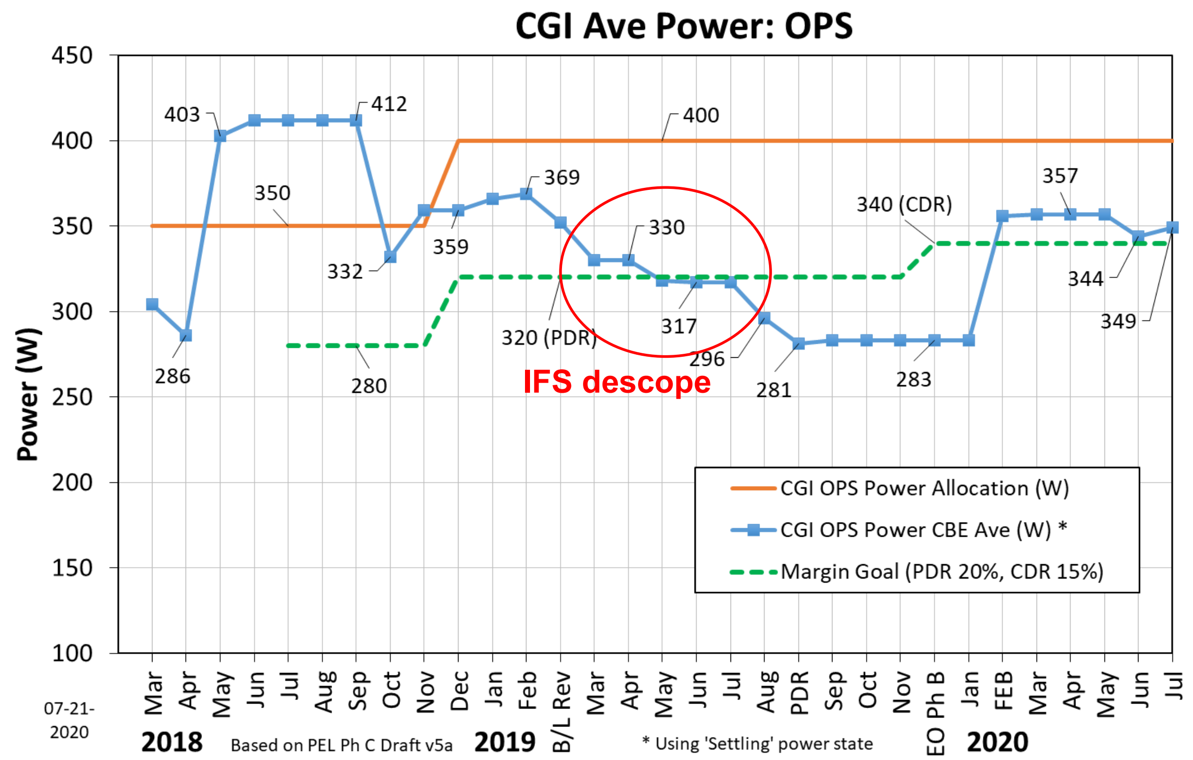
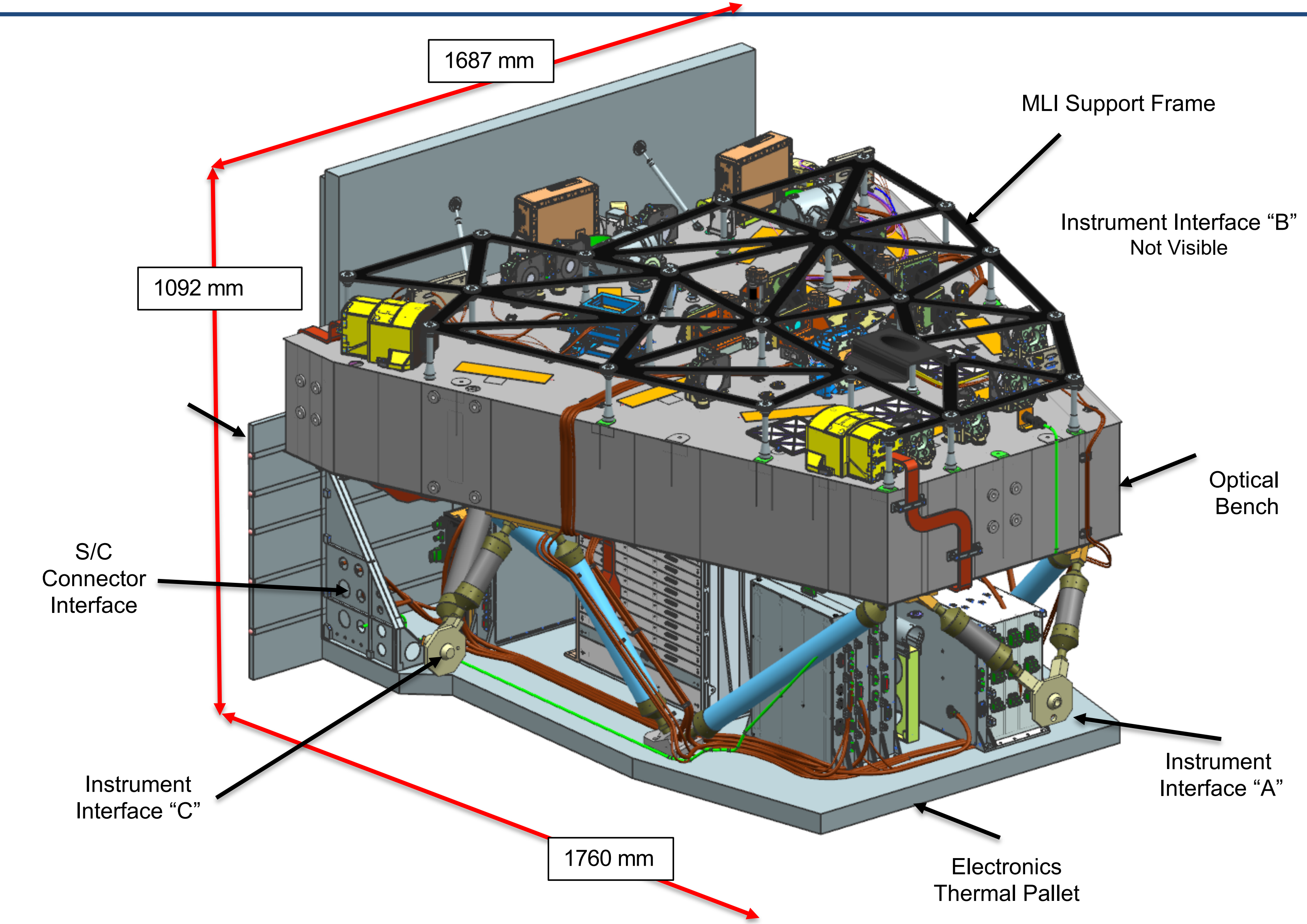




Technical resources such as mass and power often drive flight projects to simplify (de-scope) capabilities
Example: IFS descope;

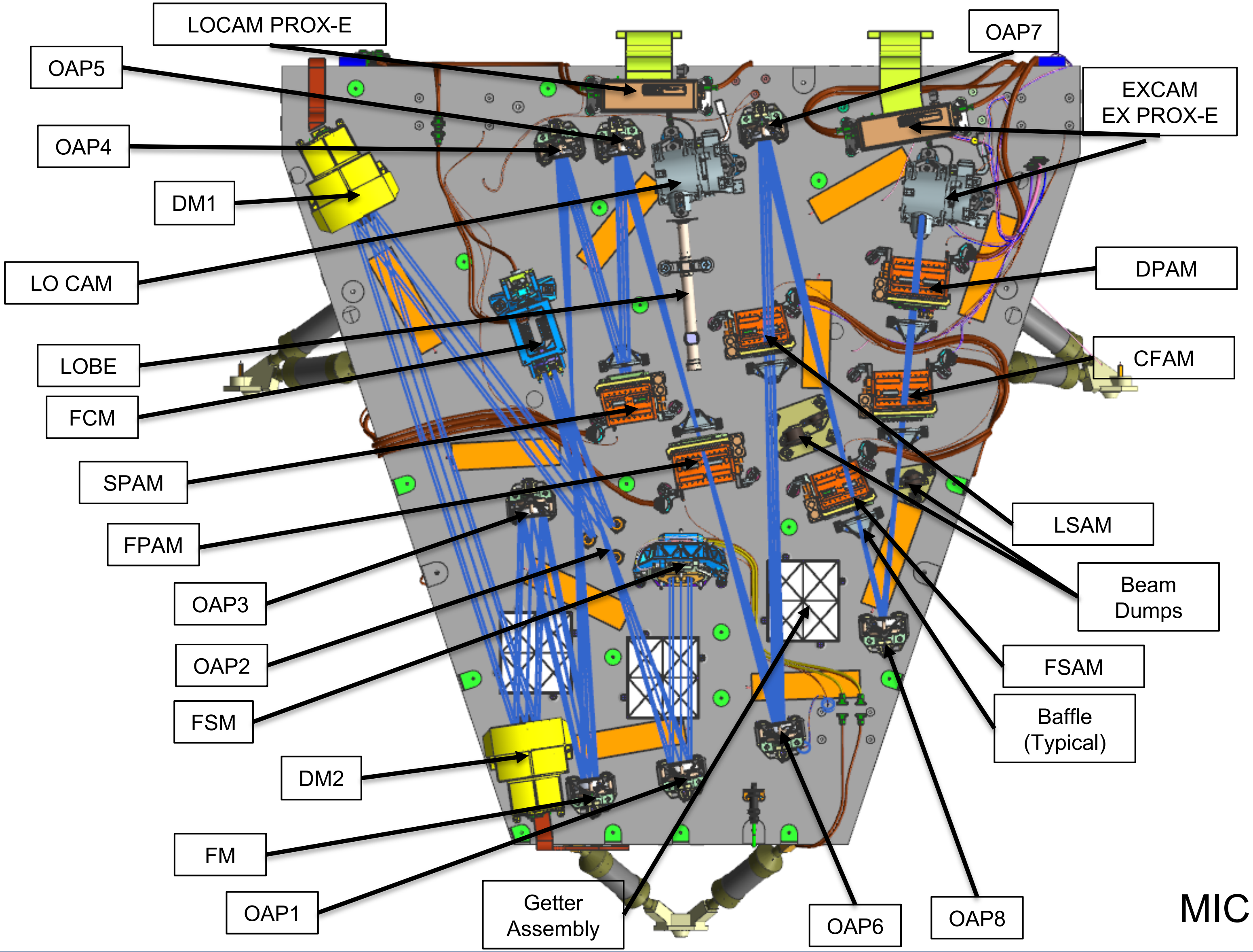
Coronagraph Instrument (CGI)



Progress highlights: Major interfaces with payload and S/C stabilized

- CGI to OTA interface: pupil finalized
- CGI to IC interface: 1st mode 35Hz agreed, load-path agreed
- CGI to S/C interface: data, timing, electrical power agreed

Optical Bench Top View with Ray Traces



<u>Progress highlights: </u>Optical Bench MICD frozen

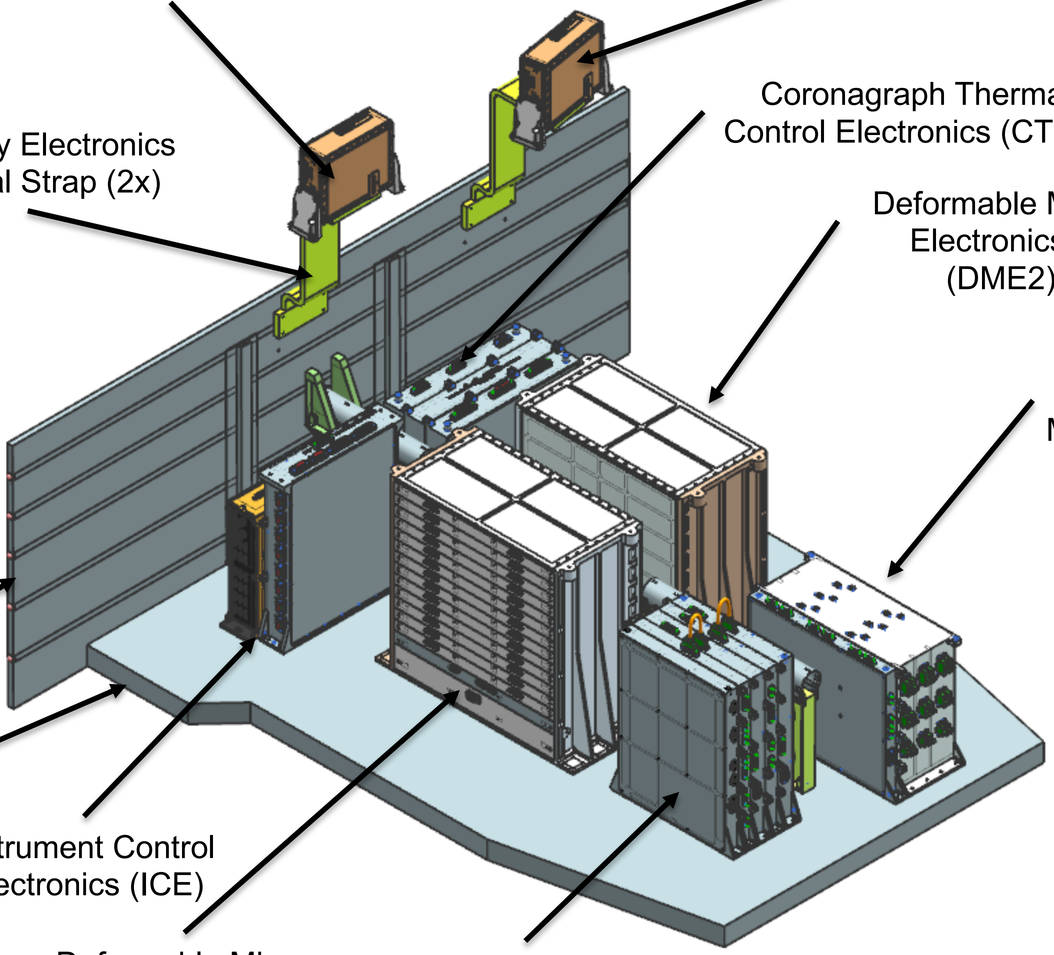
- Enables optical bench contractor (ATK) to progress on schedule
- Optical bench CDR ~10/2020
- Optical bench delivery ~10/2021

MICD: mechanical interface control document

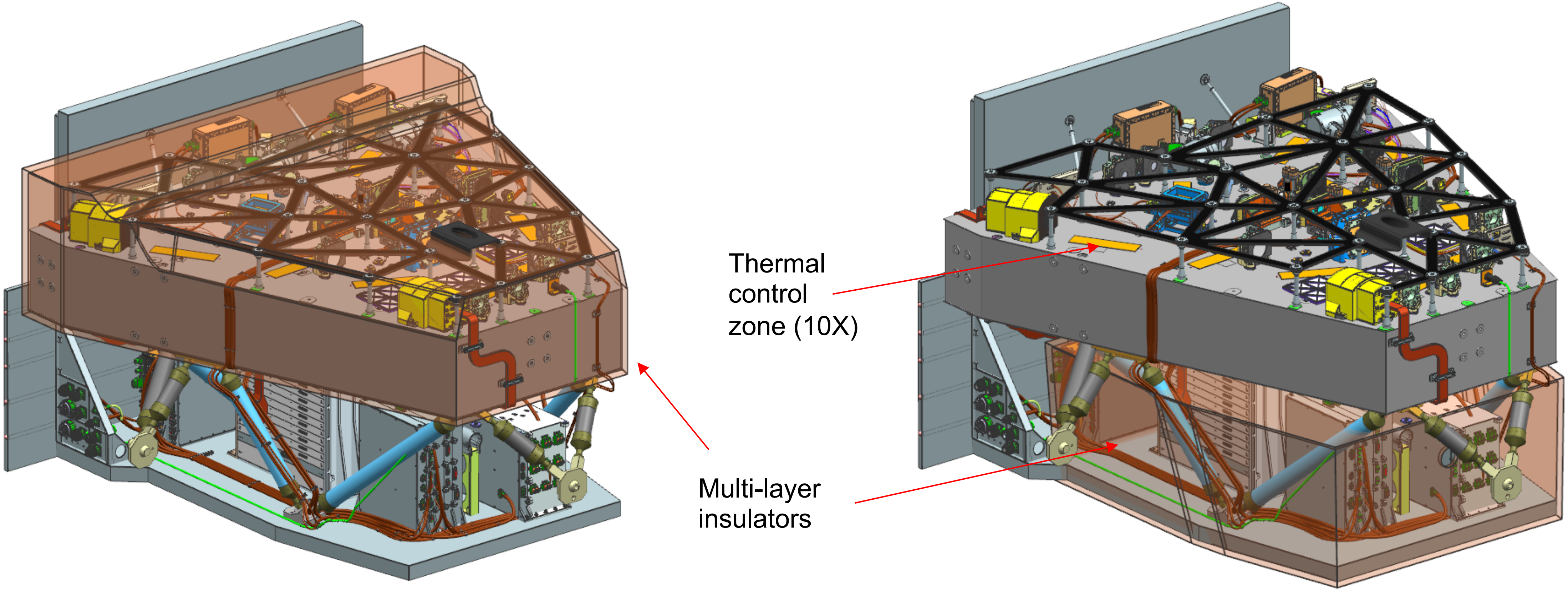
Electronics/Thermal Pallet/Warm Radiator

Progress highlights: Interface between electronics chassis and thermal pallet frozen

- Thermal radiator contract definitized recently (with Space Dynamics Lab)



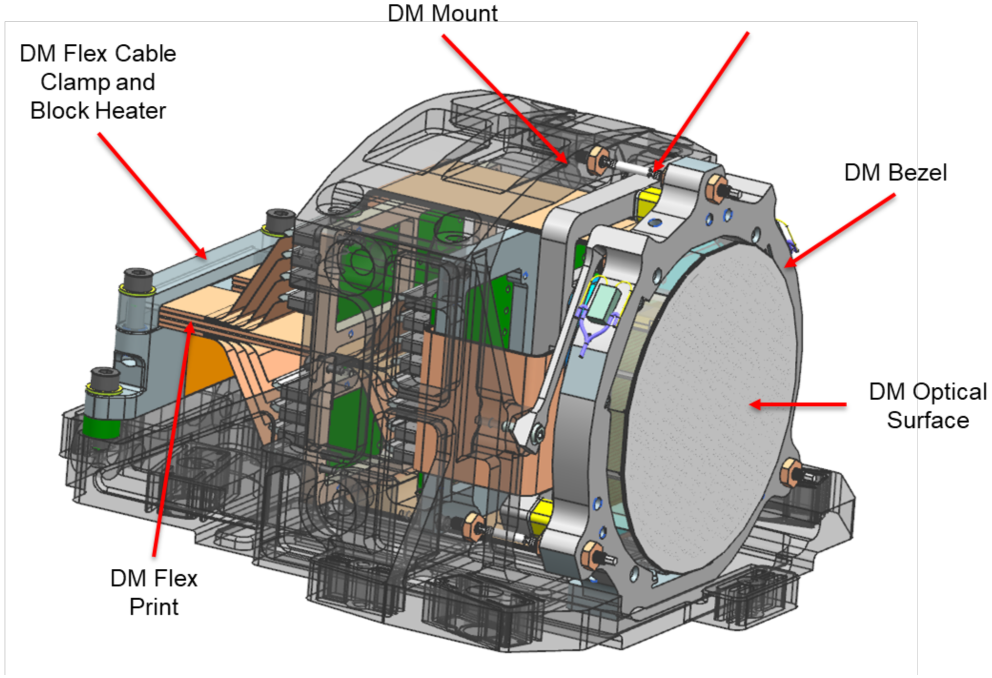
Thermal Control

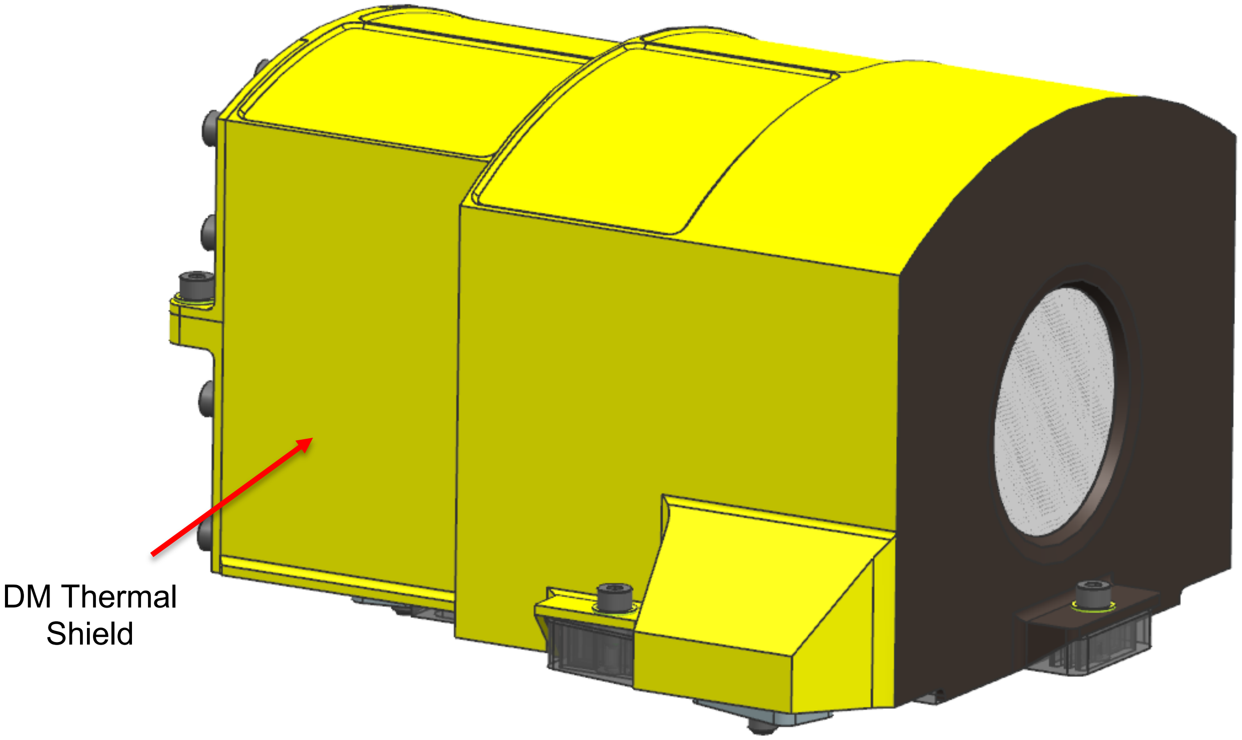


mK thermal control is crucial to speckle noise stability thus post-processing gain

- Multi-layer insulator (MLI) to help maintain thermal stability
- Dedicated mk CTCE – Coronagraph Thermal Control Electronics
- 10 thermal control zones on the optical bench, and 2 on DMs

Deformable Mirror Assembly

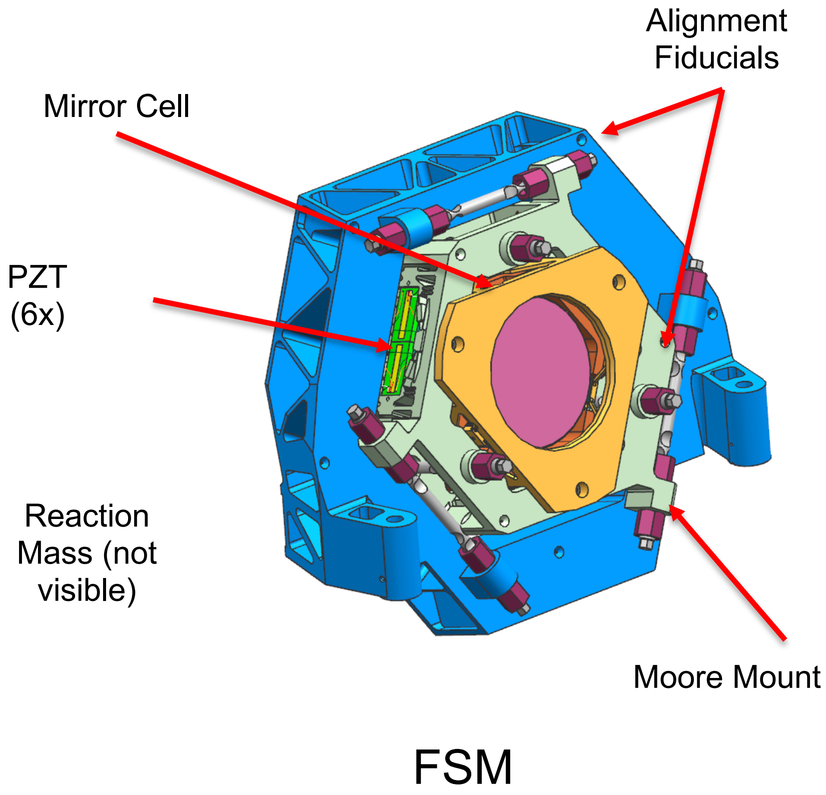


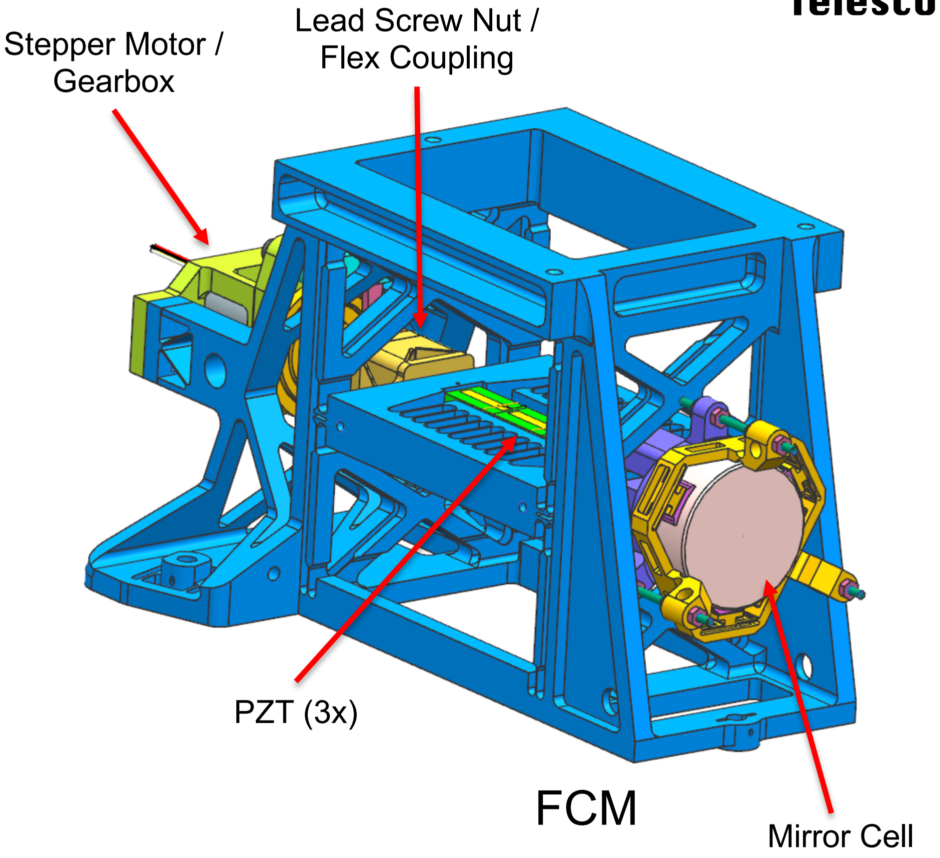


Progress high-light:

- Completed opto-mechanical peer review recently, one design accommodates all three different types of inter-connect (Fuzz button, micro-coil spring, nail pin)

Fast Steering Mirror (FSM) and Focus Control Mirror (FCM)

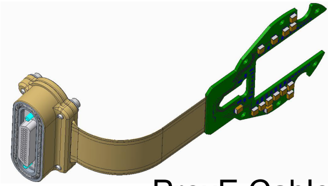




<u>Progress high-light:</u>

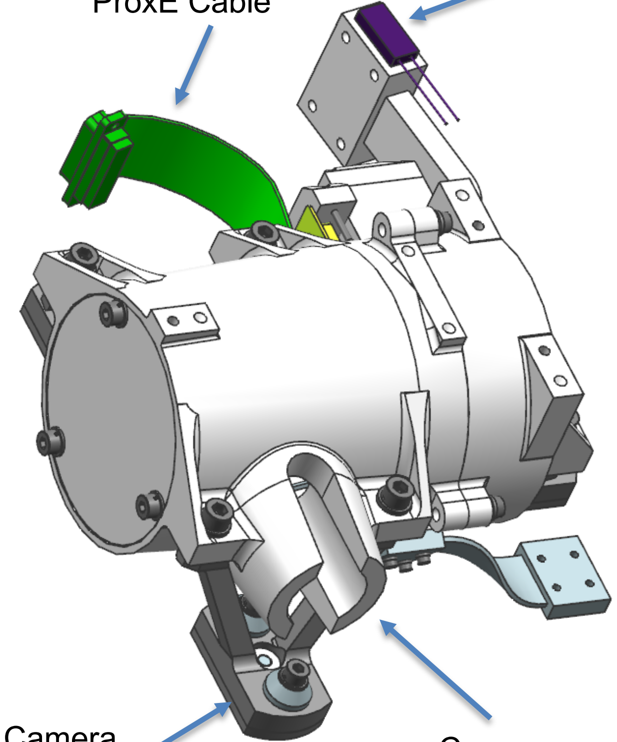
- FSM CDR passed recently; flight PZT screening completed; FSM flight model fabrication underway.
- FCM engineering development unit (EDU) fabrication underway

Camera Assembly (EX Cam, LOW Cam) and Proximity Electronics



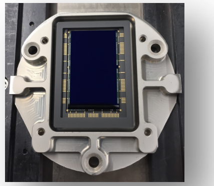
ProxE Cable

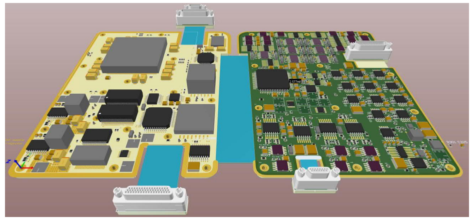
Camera Thermal Strap



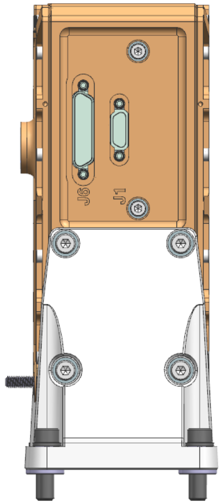
Camera Body and Mount (3X)

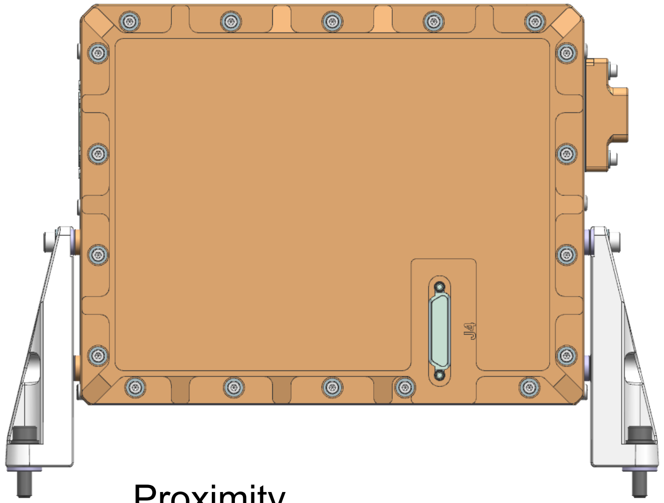
Camera Snout





Proximity Electronics board



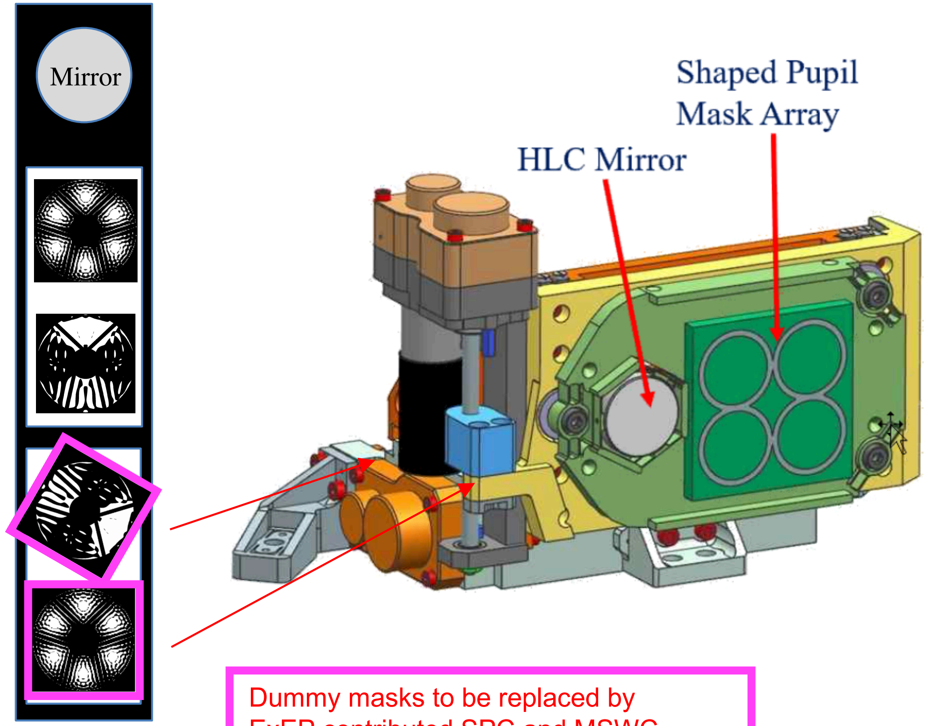


Proximity Electronics chassis

<u>Progress high-light:</u>

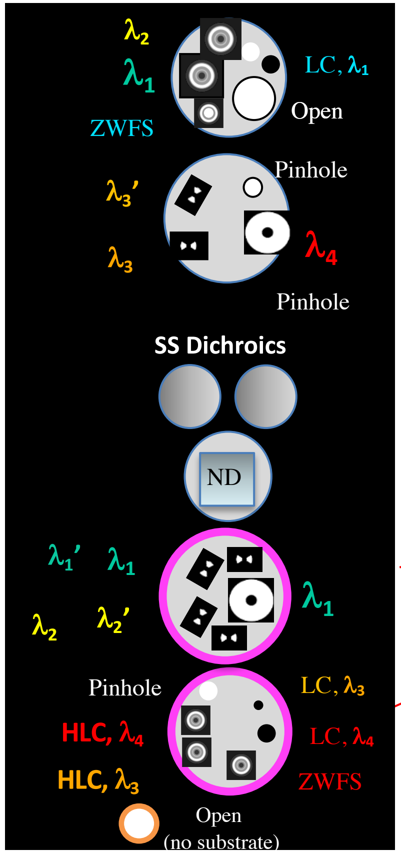
- Camera housing: Tungsten housing to maximize CGI performance over mission life (Roman 5 years)
- EMCCD (ESA contribution): Wafer batch 1 is reported 100% complete at e2v
- ABB/Nuvu making good progress on proximity electronics, EDU delivery ~10/2020

SPAM: Shaped Pupil Alignment Mechanism
FPAM: Focal Plane Alignment Mechanism

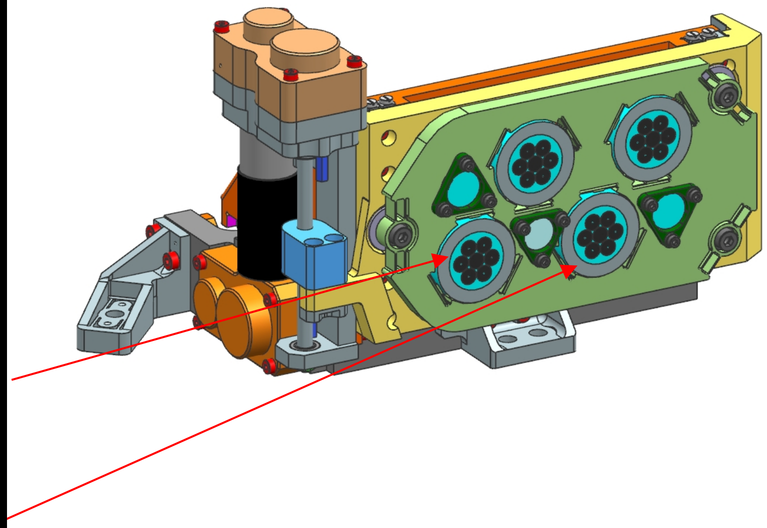


Dummy masks to be replaced by ExEP contributed SPC and MSWC masks

SPAM



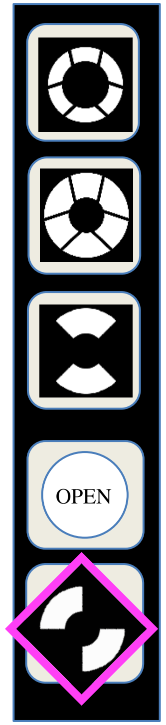
Pink box = ExEP contributed

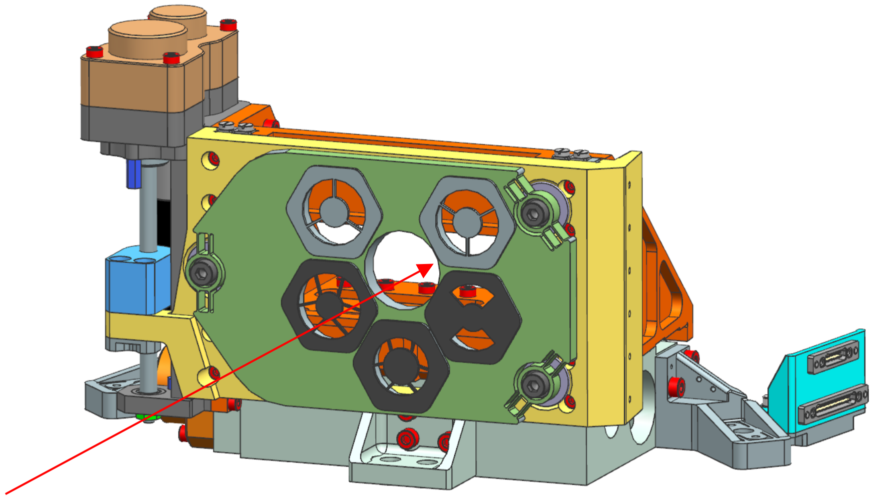


Dummy masks to be replaced by ExEP contributed HLC and ZWFS masks

FPAM

LSAM: Lyot Stop Alignment Mechanism
FSAM: Field Stop Alignment Mechanism

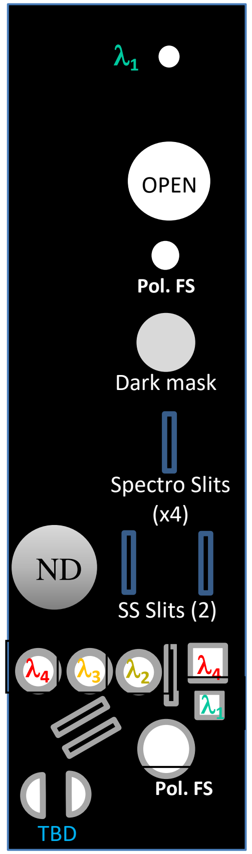




Dummy masks to be replaced by ExEP contributed Lyot stop

(CAD Drawing to be updated for 4 masks)

LSAM



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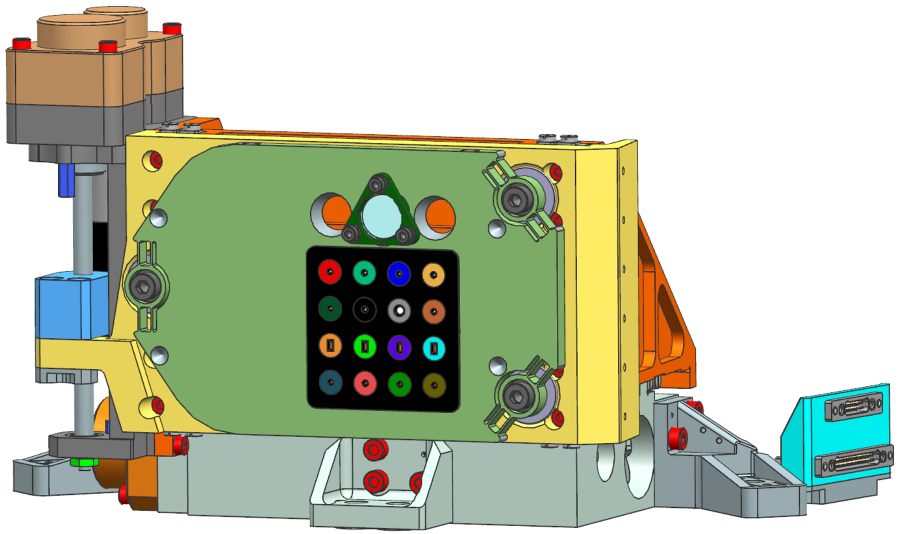
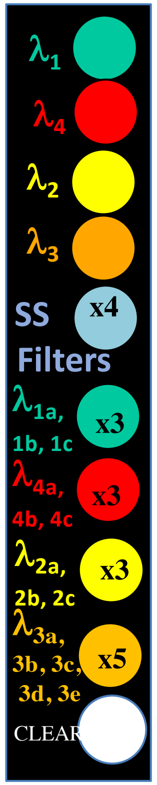
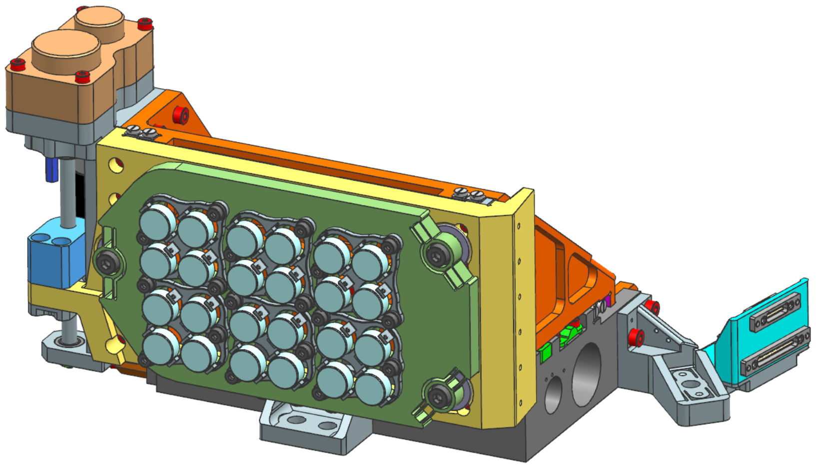


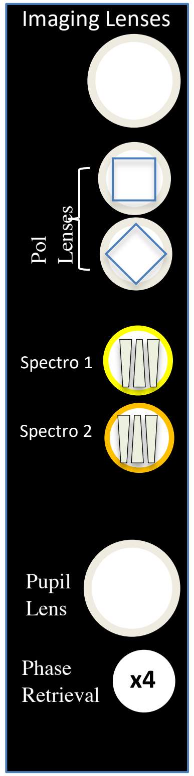
FSAM

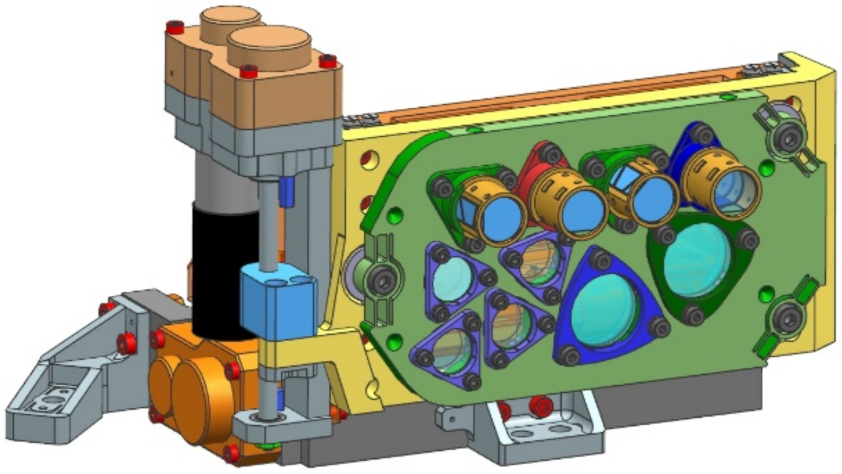
CFAM: Color Filter Alignment Mechanism
DPAM: Dispersion Polarizing Alignment Mechanism





CFAM





DPAM

ExEP Contribution Summary

Mechanism	Substrate WAS	Substrate IS
SPAM	Baseline SPC mask	Baseline SPC mask
	Mirror	Mirror
	Spare/Blank →	Contributed SPC mask
	Spare/Blank	Spare/Blank

Mechanism	Substrate WAS	Substrate IS
FPAM	Baseline Band 1/2	Baseline Band 1/2
	Baseline Band 3/4	Baseline Band 3/4
	Starshade Dichroic 1	Starshade Dichroic 1
	Starshade Dichroic 2	Starshade Dichroic 2
	Neutral Density Filter	Neutral Density Filter
	Spare/Blank →	Contributed Band 1/2
	Spare/Blank →	Contributed Band 3/4

Mechanism	Substrate WAS	Substrate IS
LSAM	Baseline HLC stop	Baseline HLC stop
	Baseline SPC bowtie stop	Baseline SPC bowtie stop
	Baseline SPC wide stop	Baseline SPC wide stop
	Open	Open
	Spare/Blank →	Contributed SPC bowtie stop
	Spare/Blank	Spare/Blank

Mechanism	Substrate WAS	Substrate IS
FSAM	Neutral Density Filter	Neutral Density Filter
	Field stops substrate	Field stops substrate

(no change)

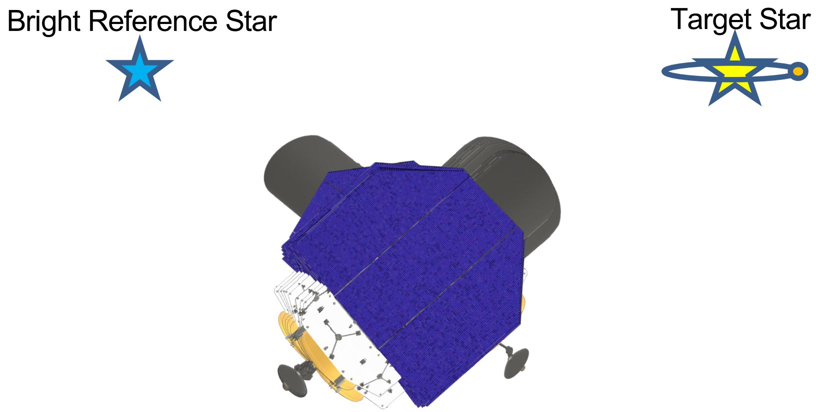
The Exoplanet Exploration Program is currently funding contributed hardware as well as corresponding technology maturation efforts as needed.

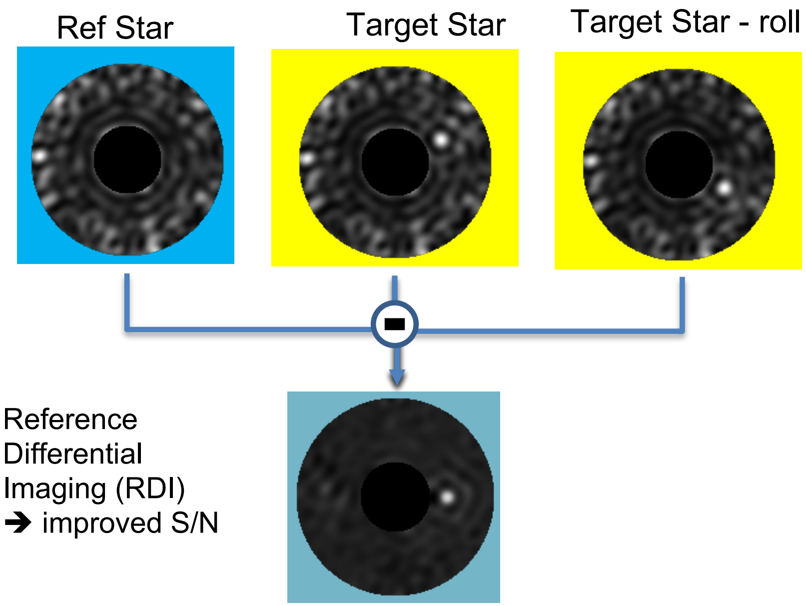
- Algorithms development
- Testbed demonstrations

CGI has no additional performance requirements for these contributions.
=> **No additional programmatic risk to CGI.**

Courtesy of Vanessa Bailey.

L1 Requirements Demonstration – Operations Optimization



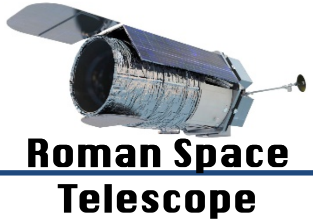


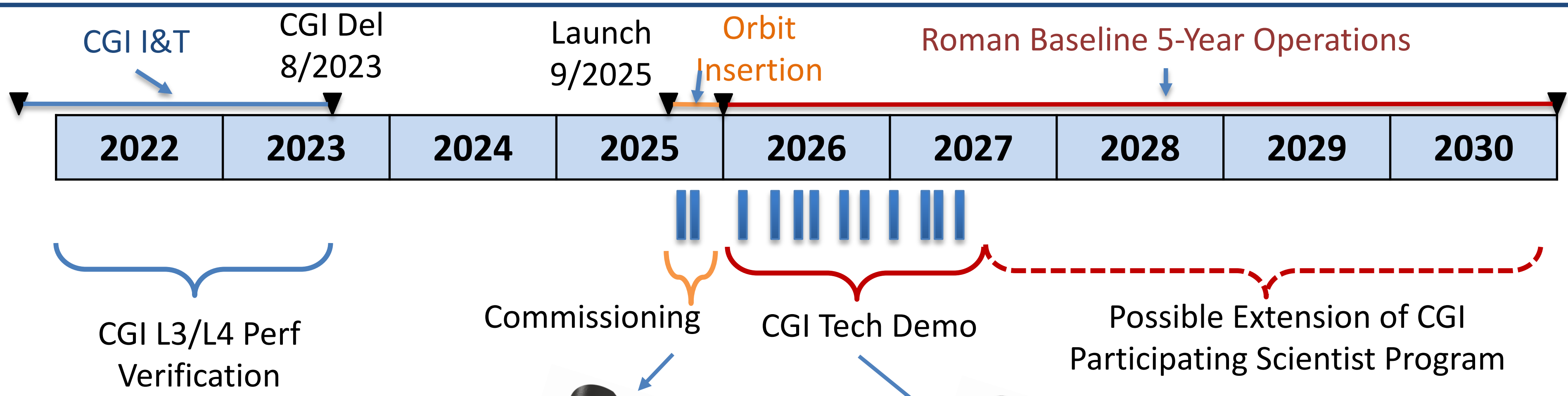
Reference Differential Imaging (RDI) ➔ improved S/N

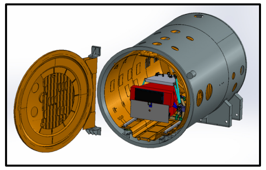
Courtesy of J. Krist

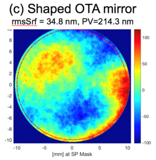
Need both active wavefront control and optimized in-orbit operations to meet L1 requirements

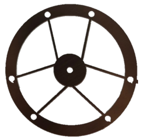
CGI Operations (dark-hole digging)

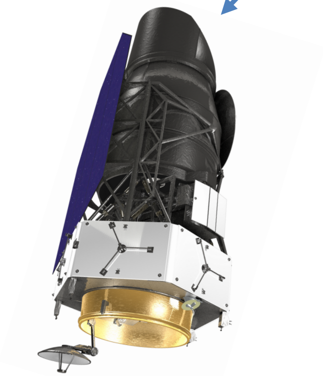


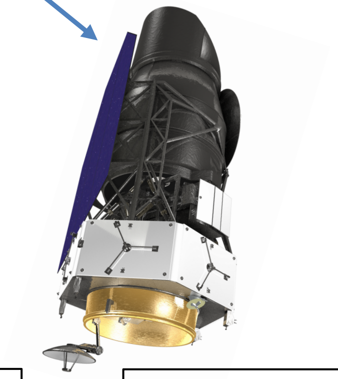










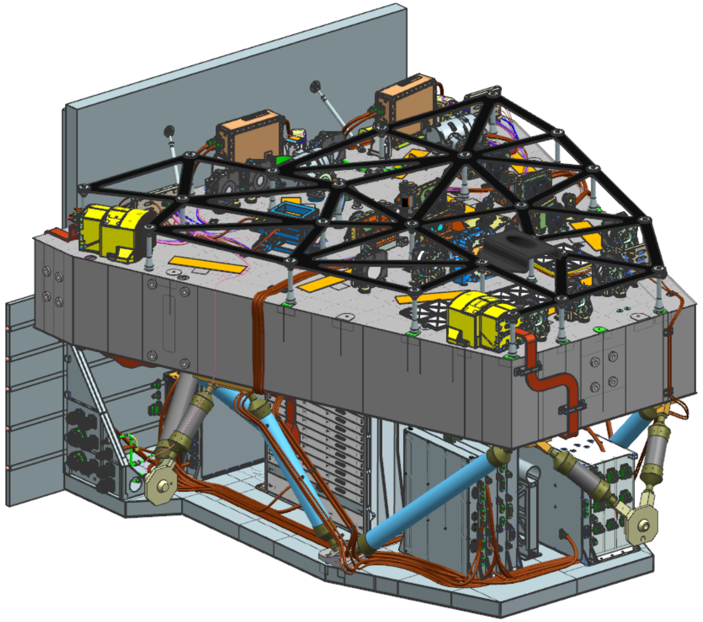


Configuration:
- CGI +
- CGI Verification Source (CVS):
  - Simulated pupil
  - Simulated wavefront error
- Pin-hole + broadband laser to simulate star

Configuration:
- Roman with CGI
- During orbit insertion to L2
- Bright reference stars

Configuration:
- Roman with CGI
- At L2
- Bright reference stars
- Target stars (with planets, disks)
- Differential imaging

Roman CGI as the Exo-Earth Imaging Coronagraph Tech Demo



- In many areas, meeting the requirements for CGI puts us in the regime of performance for the next generation, Earth detecting coronagraphs.

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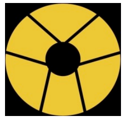
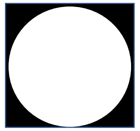
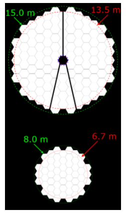
Top Level Mission Parameters Compared

Roman Space Telescope

Top Level Characteristics	Roman CGI (CBEs)	HabEx Required (VVC6)	LUVOIR Required A: APLC B: VVC6
IWA (in lambda/D)	3 (HLC at 575 nm SPC at 730 nm)	3.1 (at 500 nm)	A: 4.0 B: 3.5 (both at 500 nm)
Flux Ratio Detection Limit at IWA	10^-8 (10σ)	10^-10 (10σ)	10^-10 (10σ)
Spectral Bandwidth	10% (HLC) 15% (SPC)	20%	20%
Spectral Resolution	50 (SPC)	70	140 (VIS IFS); 70 (NIR IFS); 200 (NIR Single Point Source)
Multiplanet Spectroscopy Capability	No	Yes	Yes
Polarimetric Capability	Yes, 4 linear states, 2 at a time	Yes	Yes
Entrance Pupil			
Aperture type	on-axis 2.4m monolith with 6 struts	off-axis 4m monolith	A: on-axis segmented 13.5 m inscribed diameter B: off-axis segmented 6.7 m inscribed diameter
Primary Obscuration (linear fraction)	28%	0	A: 8% B: 0
F/#	1.3	2.5	A: 1.3 B: 2.73

Value as a Technology Demonstrator

Roman CGI compared to future missions:

- CGI more stringent than future missions (green)
- CGI in family with future missions (blue)
- CGI easier than future missions (red)

Courtesy of B. Mennesson, et al.

Deformable Mirrors

Roman Space Telescope

Deformable Mirrors (DM)	Roman CGI (CBEs)	HabEx Required (VVC6)	LUVOIR Required A: APLC B: VVC6
Number of actuators	48 x 48	64 x 64	A: 128 x 128 B: 64 x 64
Number of DMs per coronagraph channel	2	2	2
DM stroke range (μm)	> 0.5	> 0.5	> 0.5
DM stroke resolution (pm)	7.5	2.5	1.9

Value as a Technology Demonstrator

Roman CGI compared to future missions:

CGI more stringent than future missions

CGI in family with future missions

CGI easier than future missions

Courtesy of B. Mennesson, et al.

Low Flux Detection

Roman Space Telescope

Low Flux Detection	Roman CGI (CBEs)	HabEx Required (VVC6)	LUVOIR Required A: APLC B: VVC6
Photon counting	Y	Y	Y
Point source flux / PSF core broad-band imaging, (e-/s)	0.14 (HLC around 575 nm)	0.01	0.06 (A)
Point source flux / PSF core per spectral bin, (e-/s)	0.027 (SPC around 730 nm)	0.0004	0.0008 (A)
Detector Format	1024 x 1024 (imaging and spectroscopy)	1024 x 1024 (imaging) 2048 x 2048 (IFS)	1024 x 1024 (imaging) 4096 x 4096 (IFS)
dQE at 550nm	0.5	> 0.56	0.72 (CBE)
Effective Read Noise, e- (after EM gain)	0.015	< 0.1 (CBE: 0)	0 (CBE)
Dark Current (e-/pix/s)	1.3x 10-4	< 4 x 10-4 (CBE: 3 x 10-5)	3 x 10-5 (CBE)
Clock-induced Charge (e-/pix/read)	0.005	< 6 x 10-2 (CBE: 1.3 x 10-3)	1.3 x 10-3 (CBE)
Lifetime at specified detector parameters	5 years	> 5 years	> 5 years

Value as a Technology Demonstrator

Roman CGI compared to future missions:

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Courtesy of B. Mennesson, et al.

Wavefront Sensing and Control

Wavefront Sensing and Control	Roman CGI (CBEs)	HabEx Required (VVC6)	LUVOIR Required A: APLC B: VVC6
Low Order Wavefront Sensing and Control	Yes (up to Z11)	Yes	Yes
Pointing jitter after correction (mas rms per axis)	0.35 for V = 5 0.20 for V < 3	< 0.3	< 0.3
Residual Defocus (pm) drift after correction	3 (OS9 temporal rms)	< 1315	A: < 33, B: < 7
Residual Astigmatism (pm) drift after correction	3 (OS9 temporal rms)	< 157	A: < 50 B: < 14
Residual Coma (pm) drift after correction	2 (OS9 temporal rms)	< 94	A: < 1 B: < 8
Residual Spherical (pm) drift after correction	2 (OS9 temporal rms)	< 76	A: < 2 B: < 4
High order wavefront drift in pm after any correction	5 (OS9 temporal rms)	< 5	< 5
Laser Metrology	No	Yes (M1-M2-M3)	Yes (6 per M1 segment-M2-M3)

Value as a Technology Demonstrator

Roman CGI vs. HabEx and easier of LUVIOR A/B

- CGI more stringent than future missions (green)
- CGI in family with future missions (blue)
- CGI easier than future missions (red)

Courtesy of B. Mennesson, et al.

PSP – Participating Scientist Program

- PSP = Participating Scientist Program (to be changed to Community Participation Program)
- Kick-off ~May 2021, continuing through Phase E
- ~10 external scientists from partner countries and US institutions.
  - US team members to be competed via open call in late 2020
- Work with Coronagraph Technology Center (CTC) at JPL in tech demo preparation and operations. Add value by complementing the technologist/engineering experience of JPL staff on CTC:
  - Lead by CGI Technologist (CTC)
  - Assist analysis of image data from I&T
  - Maintain target database, advise observation planning
  - Simulate, process, and interpret astrophysics observations
    - Simulated datasets for performance analysis and community engagement
    - Flux- and wavelength-calibrated spectra
    - High-precision astrometry
    - Polarimetry calibration and interpretation
  - Research alternative wavefront sensing and control algorithms
  - Engage broader astronomy community
  - Publish science and technology results from tech demo phase

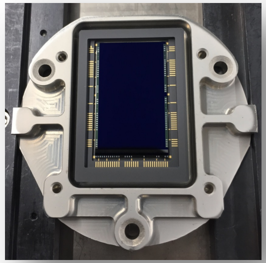
CGI International Contributions -- Update

Jet Propulsion Laboratory
California Institute of Technology

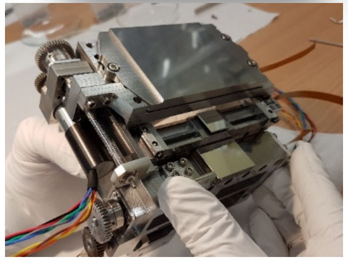
Roman Space Telescope

Four international partners with contributions:

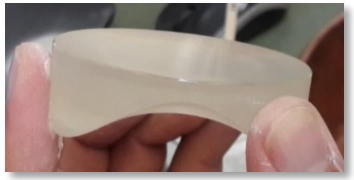
- EMCCD from e2v/ESA
  - No major changes since PDR, COVID impact is minimum:
    - Wafer batch #1 completed on schedule
    - Wafer batch #2 ~46% complete
- Precision Alignment Mechanisms (PAMs) from MPIA:
  - Changes since PDR: DLR co-funding lost due to budget re-prioritization at DLR; NASA agreed to replace the lost DLR funding, MPIA on contract with JPL since 12/2019. Progress continues without impact due to DLR funding situation
- Off-axis parabolas (OAPs) from LAM/CNES:
  - Changes since PDR: found four of the eight OAPs not suited for LAM's approach (stress polishing). NASA agreed to fund US vendor (II-VI Optical Systems) to polish these four (#1, #2, #3, #8) using traditional approach to mitigate schedule and technical risks.
- Polarization Optics from JAXA:
  - No major changes since PDR, some COVID schedule impacts:
    - Polarization prisms and lenses experience COVID schedule impact. Working to buy from US vendor (non-rad-hard) optics for EDU development. Flight units schedule being worked.
    - Mask substrates (Si for SPC, and Fused Silica for HLC) batch #1 delivered to JPL on 7/31/2020, just in time for flight mask fab. Batch #2 schedule for late 10/2020 as backups.



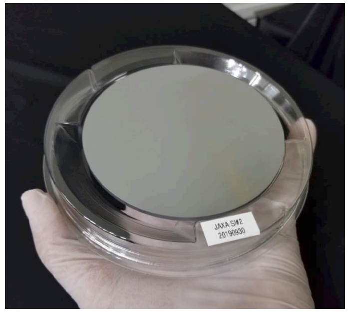
EMCCD (3X)



PAM (6X)

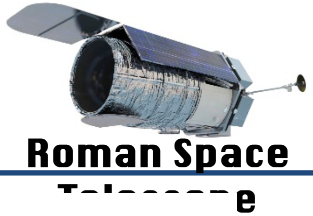


OAP (8X)

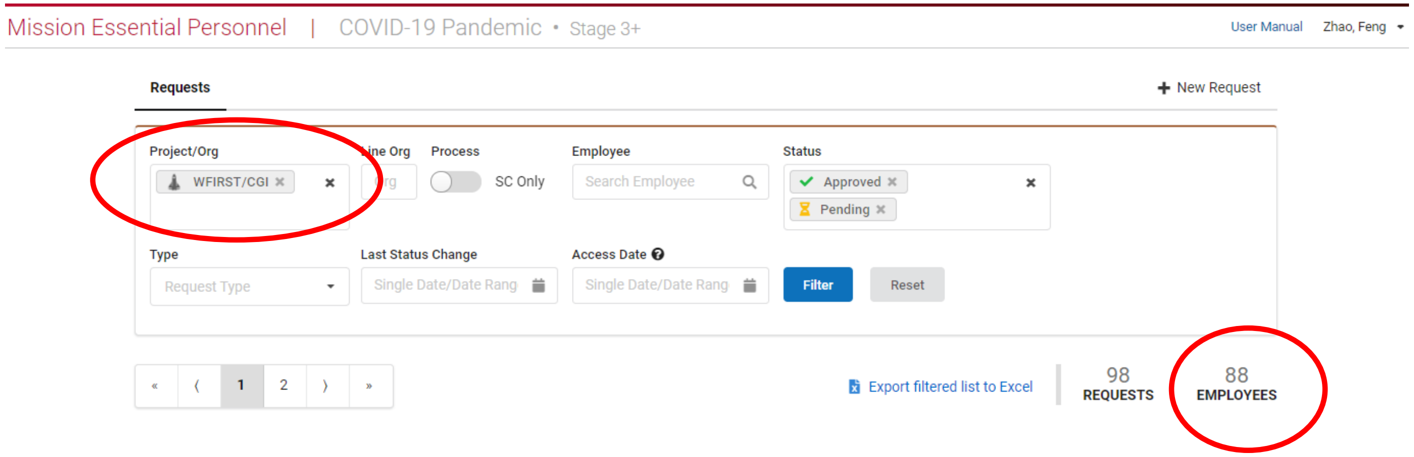


Mask substrates & polarization prisms

CGI continues making progress during COVID-19



- CGI staff working from home since 3/17/2020
- JPL has approved ~25 CGI critical tasks, with ~88 CGI "Mission Essential" personnel to return to lab since 4/2020
  - (1) DM TRL-6 development; (2) electronics; (3) camera; (4) mask fab and testing; (4) mechanisms; (5) Performance testbed; (6) parts qualifications.
- All services such as mechanical fab, e-fab, environmental test labs, analytical labs, etc. are open to support CGI for limited capacities



COVID Restart Activity Tracking

Actions

ID	Project	Task	Description	Location/Facility	FTE/Day	Requested Start	Current NET
11	WFIRST/CGI	DM	DM Interconnect	B103-108 (Hybrid lab)	1	4/20/2020	4/20/2020
20	WFIRST/CGI	Avionics EDU	DME PCD	B306; B183	5	5/4/2020	5/4/2020
21	WFIRST/CGI	Avionics EDU	DME PCD	B306; B183	5	5/4/2020	5/4/2020
22	WFIRST/CGI	Avionics EDU	DME PCD	B306; B183	5	5/4/2020	5/4/2020
23	WFIRST/CGI	Avionics EDU	DME PCD	B306; B183	5	5/4/2020	5/4/2020
24	WFIRST/CGI	Avionics EDU	DME PCD	B306; B183	5	5/4/2020	5/4/2020
25	WFIRST/CGI	Avionics EDU	DME PCD	B306; B183	5	5/4/2020	5/4/2020
26	WFIRST/CGI	Avionics EDU	DME PCD	B306; B183	5	5/4/2020	5/4/2020
43	WFIRST/CGI	Camera	Camera characterization	B300-151	2	5/4/2020	5/4/2020
44	WFIRST/CGI	Camera	DM soldering & camera packaging	B103-108	1	5/11/2020	5/11/2020
45	WFIRST/CGI	Camera	Camera lab setup & PQV	B300-110	2	6/1/2020	6/1/2020
46	WFIRST/CGI	Camera	Camera lab setup & PQV	B300-110	2	6/1/2020	6/1/2020
47	WFIRST/CGI	Mechanisms	PZT, mechanism parts	B103; B158; B300-ATL	2	5/4/2020	5/4/2020
50	WFIRST/CGI	Mech Fab	FSM life test and EMCCD installation	B318-highbay	2	5/11/2020	5/11/2020
57	WFIRST/CGI	MDL	DM metalization & mask fab at MDL	B302-MDL	2	5/11/2020	5/11/2020
58	WFIRST/CGI	MDL	DM metalization & mask fab at MDL	B302-MDL	2	5/11/2020	5/11/2020
59	WFIRST/CGI	Mech Fab	FSM life test and EMCCD installation	B318-highbay	2	5/11/2020	5/11/2020
84	WFIRST/CGI	Controls	EDU mask testing	B318-highbay	2	6/15/2020	6/15/2020
103	WFIRST/CGI	DM	UPDATED 7/16 personnel updated. DM TRL-6 (transition from #11, #57) and module rework	B306-120; B183; ETL	4	5/26/2020	5/26/2020
104	WFIRST/CGI	Parts evaluation, qualification	Radiation, upgrade screen,	B300	2	6/1/2020	6/1/2020
106	WFIRST/CGI	Active Optics	FSM and FCM EDU integration and test	B318-highbay	2	6/22/2020	6/22/2020
108	WFIRST/CGI	Harness	EDU harness fab, assembly and test		2	7/20/2020	7/6/2020
213	WFIRST/CGI	CGI EGSE	On-lab Access Request -- Addition of lab space to Tasks #22-#26	B183-104	2	6/15/2020	6/15/2020
306	WFIRST/CGI	CGI DME MGSE Fabrication & Assembly	fabrication of MGSE components and assembly of the final products to their specified configurations to support CGI Deformable Mirror Electronics (DME)	B171-310	1	7/6/2020	7/6/2020
399	WFIRST/CGI	Camera I&T, thermal strap	Bonding of PRTs and Heaters to the thermal strap for use in the EDU Camera.	B125-122, B144, B300-132	2	7/20/2020	7/20/2020

Approved CGI critical tasks on-lab

Path to CDR

- Due to COVID impact, CGI CDR has been rescheduled from 2/2021 to 4/2021.
  - Different degrees of supply chain COVID impacts across the board
- Maintain 8/2023 CGI delivery, by taking 2 months out of I&T schedule (dropping two months of testing for two modes)
- DM TRL-6 interconnect demonstration ~ 11/2020
  - Currently carry three different methods for risk reduction (1) 2nd generation fuzz button, (2) micro coil springs, (3) nail pins
  - Down select to one approach ~ end of 8/2020 after risk mitigation studies
  - Focus on one type for 11/2020 demonstration
- Prior to CGI CDR, we expect to complete all element/assembly-level CDRs (9/2020 – 2/2021)
- FY21 budget risk and COVID impact

Summary

- CGI is making solid progress toward CDR (4/2021)
  - DM interconnect TRL-6 technology maturation ~ 11/2020
  - External interfaces stabilized: CGI to OTA, IC, and S/C
  - Internal interfaces frozen: Optical bench, electronics thermal pallet, etc.
  - Next steps: complete all the detailed designs, release ALL drawings by CDR
- Maintain an acceptable risk posture
  - KDP-C requirement relaxations to CGI, off-ramps to protect CGI schedule and budget, Tiger Team recommendations for simplifications
  - ExEP contribution of additional masks without increasing CGI programmatic risks
- CGI continues coronagraphy in space on NASA flagship missions, demonstrating key technologies for future earth 2.0 imaging missions

Back-up charts

Acronyms

- CAD Computer Aided Design
- Cam Camera
- CF Color Filter
- CFAM Color Filter Alignment Mechanism
- CFWM Color Filter Wheel Mechanism (aka Color Filter Alignment Mechanism)
- CGI Coronagraph Instrument
- ~~CSAM Camera Selector Alignment Mechanism~~
- CTCE Coronagraph Thermal Control Electronics
- DI Direct Image
- ~~DICam Direct Imaging Camera~~
- DM Deformable Mirror (by Xinetics)
- DME Deformable Mirror Electronics
- DPAM Dispersion Polarizing Alignment Mechanism
- EXCam Exoplanetary systems Camera
- FM Folding Mirror
- FCM Focus Control Mirror
- FPA Focal Plane Array
- FPAM Focal Plane Alignment Mechanism
- FPM Focal Plane Mask
- FS Field Stop
- FSAM Field Stop Alignment Mechanism
- FSM Fast Steering Mirror
- IC Instrument Carrier
- ICE Instrument Control Electronics

- ~~IFS Integral Field Spectrometer (PISCES at GFSC)~~
- ~~IFSCam Integral Field Spectrometer Camera~~
- ISE Instrument Support Electronics
- LOBE LOWFS Optical Barrel Element
- LOCam Low Order [Wave Front Sensing] Camera
- LOWFS Low Order Wave Front Sensing
- LS Lyot Stop
- LSAM Lyot Stop Alignment Mechanism
- MLI Multi-Layer Insulation
- NTE Not To Exceed
- PAM Precision Alignment Mechanism
- PAME Precision Alignment Mechanism Electronics
- PZ or PZT Piezoelectrics
- PRT Platinum Resistance Thermometer
- SPAM Shaped Pupil Alignment Mechanism
- WFI Wide Field Instrument
- WFIRST Wide Field Infrared Survey Telescope
- OBSA Optical Bench Structure Assembly
- SMR Spherical Mounted Reflector