Coronagraph Instrument Update

RCF Feb 21, 2024

Vanessa Bailey
Jet Propulsion Laboratory, California Institute of Technology
on behalf of the Instrument and Community Participation Program teams

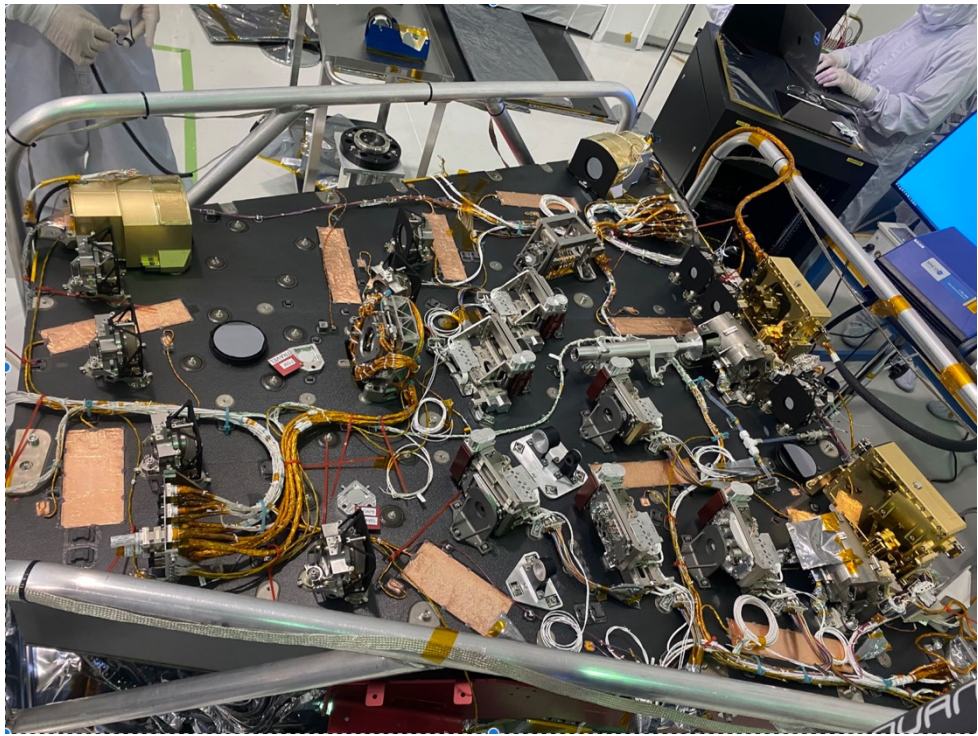
Outline

- What hasn’t changed since last time:
  - instrument designed capabilities & requirements
- What has changed:
  - integration and testing progress
  - Community Participation Program began
- What happens after delivery

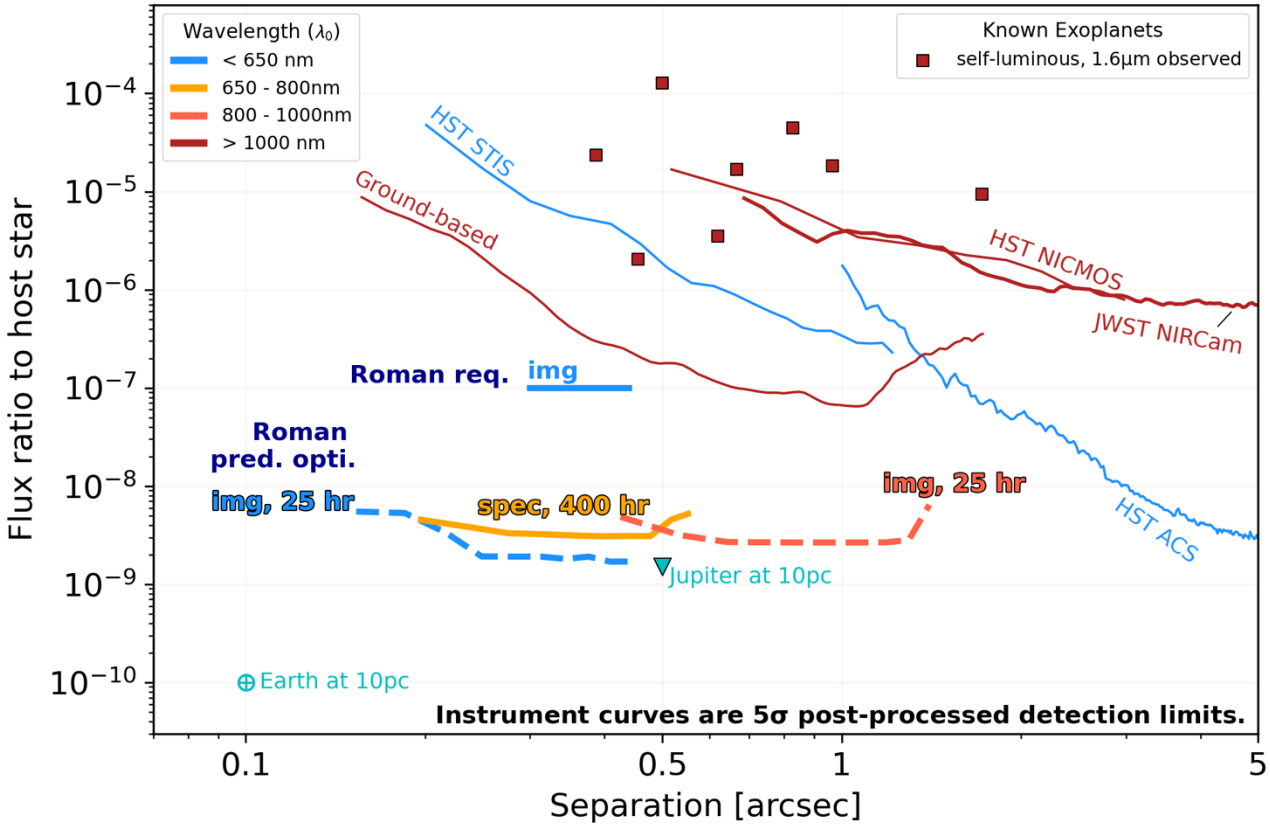
What hasn’t changed

Roman Coronagraph paves the way for HWO

- the first space-based coronagraph with active wavefront control
- a visible light “technology demonstration” instrument
  - ~550 – 875nm
  - “easy” requirement: 10^{-7} detection limit
  - Ambitious goals: few 10^{-9}
- a risk mitigation for HWO
- delivering in May
- allocated ~90 days of observing time during 1st 18 months of mission

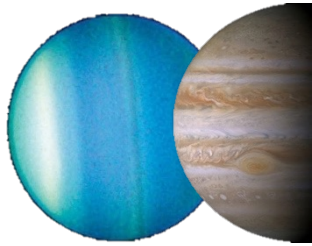


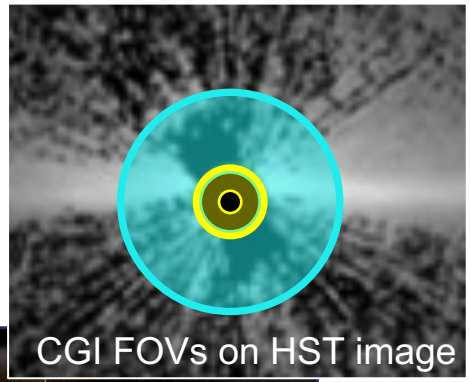
Bridges gap between massive self-luminous planets (IR) and reflected light exo-Earths (visible)

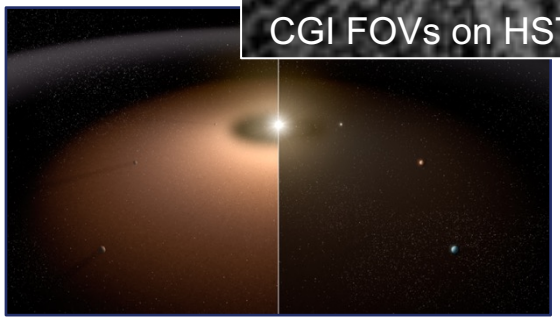


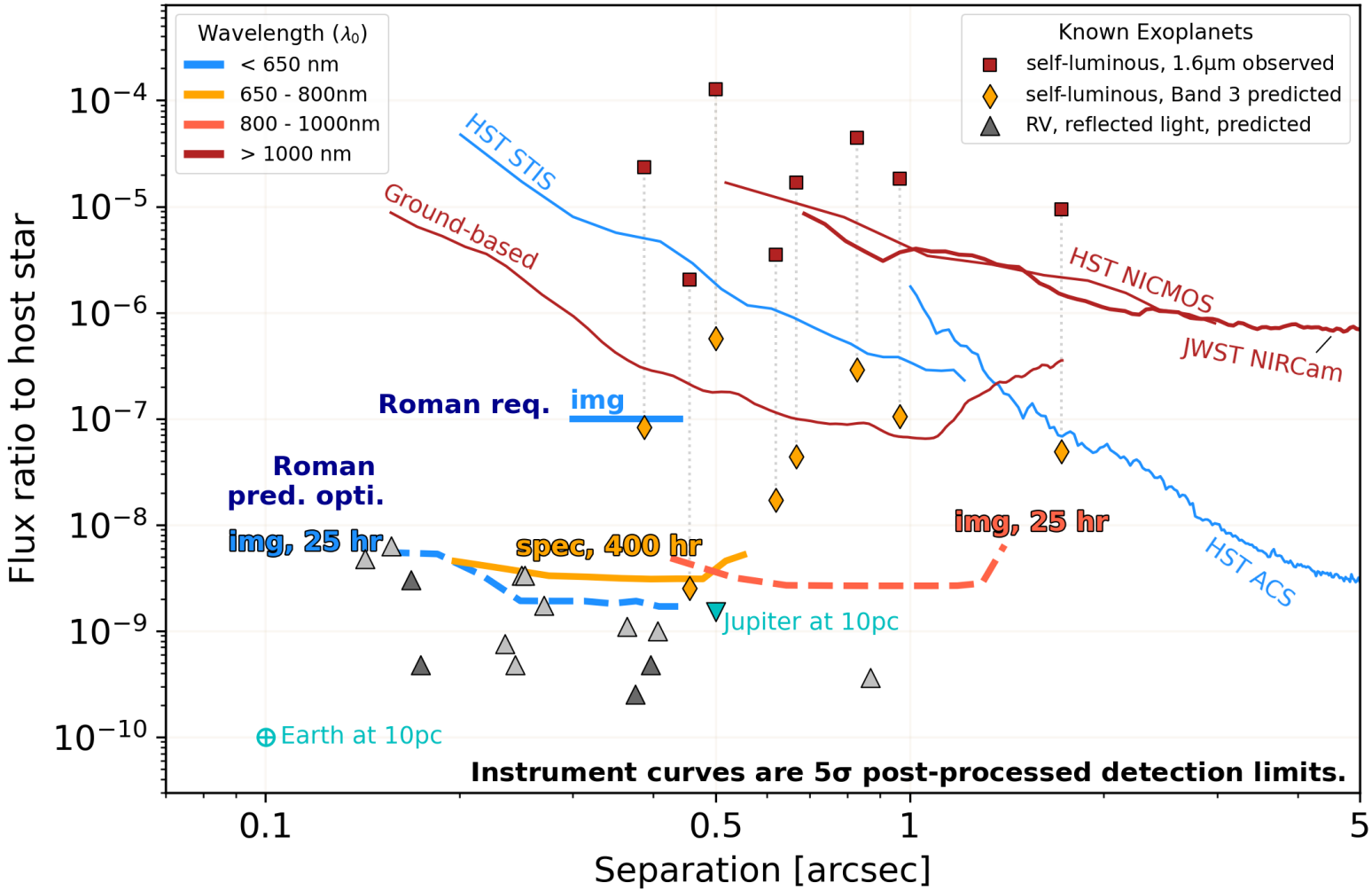
With “goal” capabilities: exciting exoplanetary system science

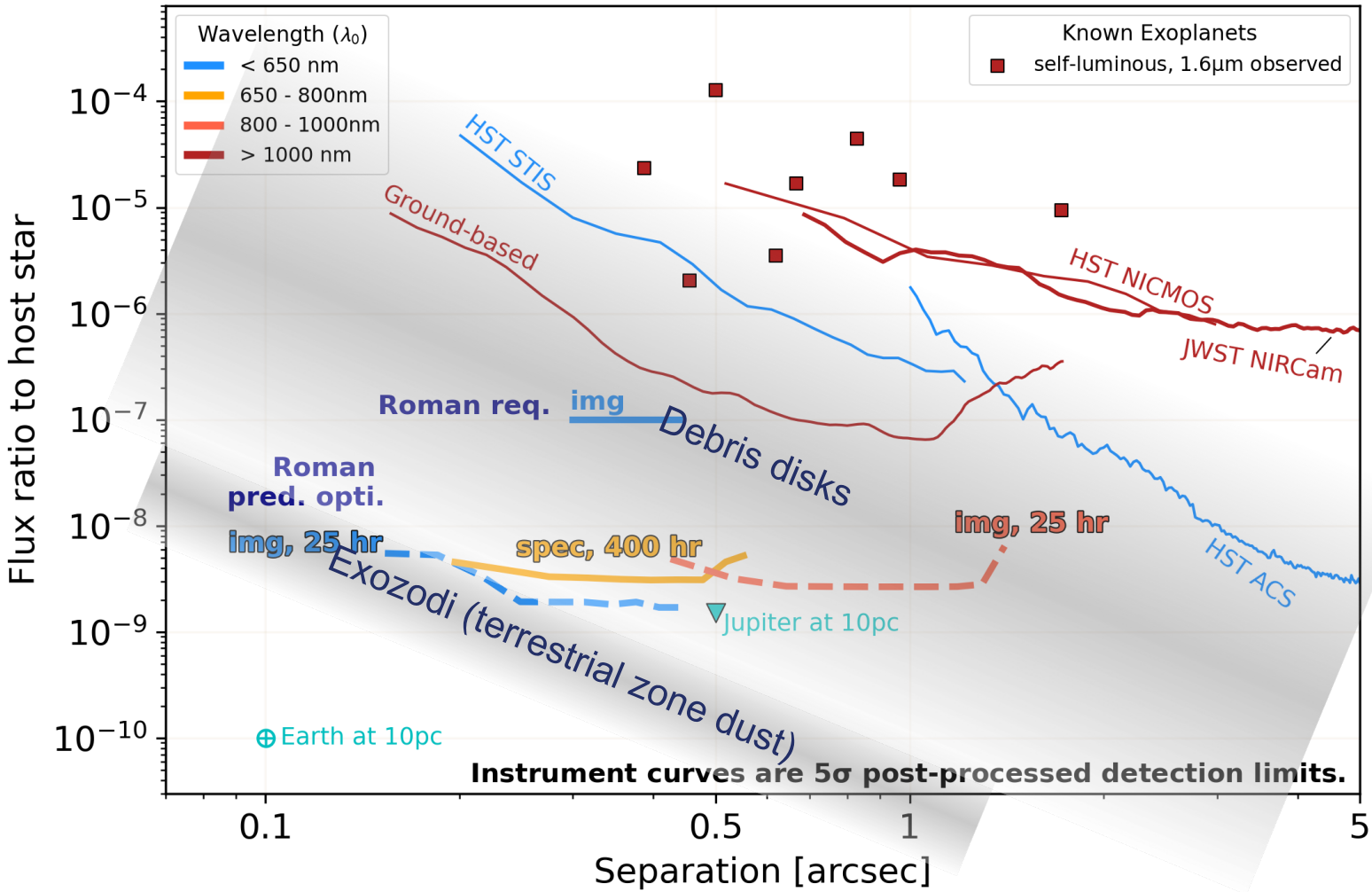
- After demonstrating our Level 1 requirement…
- Known, self-luminous planets at visible wavelengths
  - (eg: Lacy & Burrows 2020)
- Potential for first images and spectrum of true Jupiter analog
  - Known RV planet
  - (eg: Batalha+2018, Saxena+2021)
- Low surface brightness disks, improved morphology
  - (eg: Mennesson+2018)
- Potential for first visible light images of exozodi
  - (Douglas+2022)








Wavelength (λ_0)
< 650 nm
650 - 800nm
800 - 1000nm
> 1000 nm
Known Exoplanets
self-luminous, 1.6μm observed
self-luminous, Band 3 predicted
RV, reflected light, predicted
HST STIS
Ground-based
HST NICMOS
JWST NIRCam
HST ACS
Roman req. img
Roman pred. opti. img, 25 hr
spec, 400 hr
img, 25 hr
Jupiter at 10pc
⊕ Earth at 10pc
Instrument curves are 5σ post-processed detection limits.
Flux ratio to host star
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.1
0.5
1
5
Separation [arcsec]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Roman req. img
Debris disks
Roman
pred. opti.
img, 25 hr
spec, 400 hr
img, 25 hr
HST ACS
Jupiter at 10pc
Exozodi (terrestrial zone dust)
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0.1
0.5
1
5
Separation [arcsec]

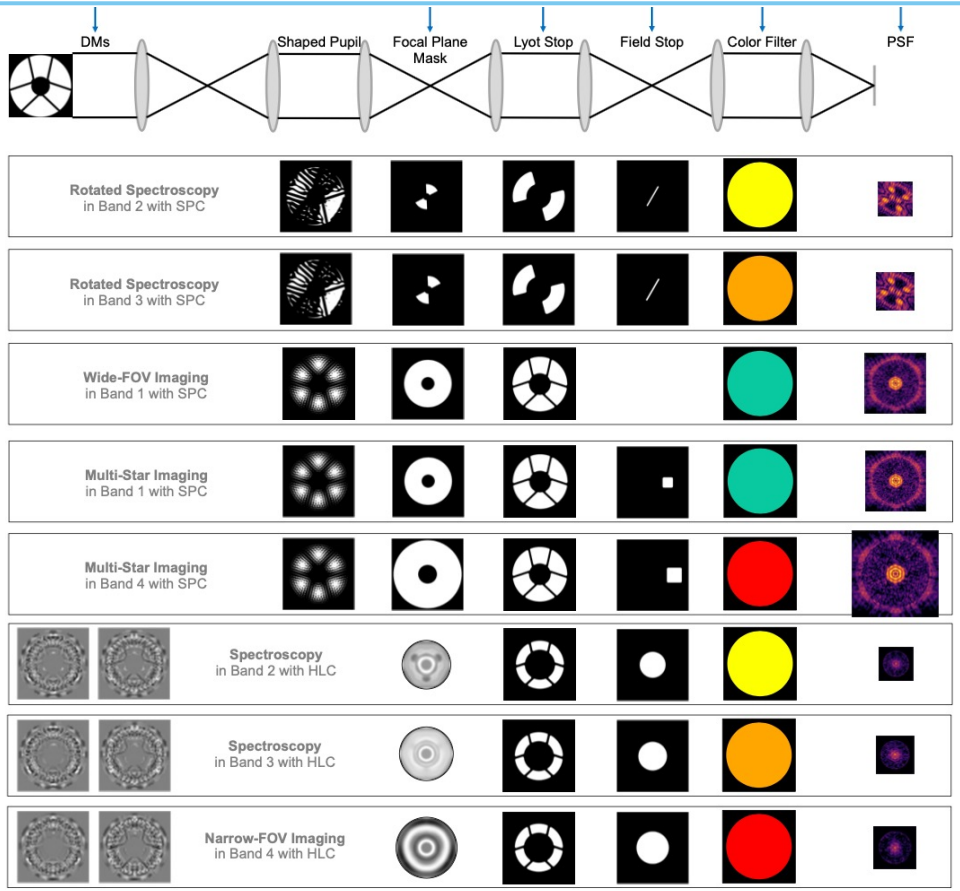
1 fully supported mode
Additional “best effort” modes: spectroscopy & polarimetry

Band	λ_{center}	BW	Mode	FOV radius	FOV Coverage	Pol?	Coronagraph Mask Type	Support
1	**575 nm**	**10%**	**Narrow FOV Imaging**	**0.14” – 0.45”**	**360°**	**Y ****	**Hybrid Lyot**	**Req’d**
2	**660 nm**	17%	Slit + R~50 Prism Spectroscopy	0.17” – 0.52”	2 x 65°	-	Shaped Pupil	Best Effort
3	**730 nm**	17%	Slit + R~50 Prism Spectroscopy	0.18” – 0.55”	2 x 65°	-	Shaped Pupil	Best Effort
4	**825 nm**	11%	“Wide” FOV Imaging	0.45” – 1.4”	360°	Y	Shaped Pupil	Best Effort

“Best effort” modes will not be end-to-end performance tested prior to delivery & do not have guaranteed support on-orbit.

** Polarimetry in Band 1 is ‘best effort’

Unsupported “contributed” mask configurations



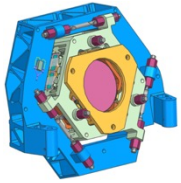
Additional masks contributed by NASA’s Exoplanet Exploration Program to fill empty slots in mechanisms.

No funding for on-sky commissioning identified at this time. Analogous to HST/STIS Bar5??

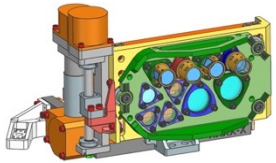
Not shown: unsupported “low-contrast” classical Lyot spots (analogous to HST) for very wide FOV imaging (~1-3.5”)

For complete list of masks see Riggs+ SPIE O&P 2021

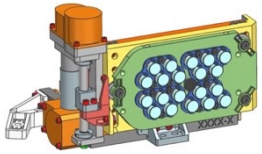
Light path



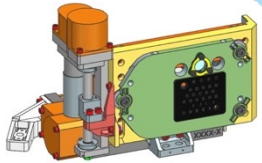
FSM: Fast Steering Mirror



DPAM: Prisms & Lenses

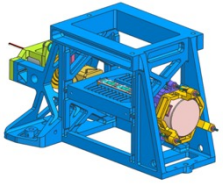


CFAM: Color Filters

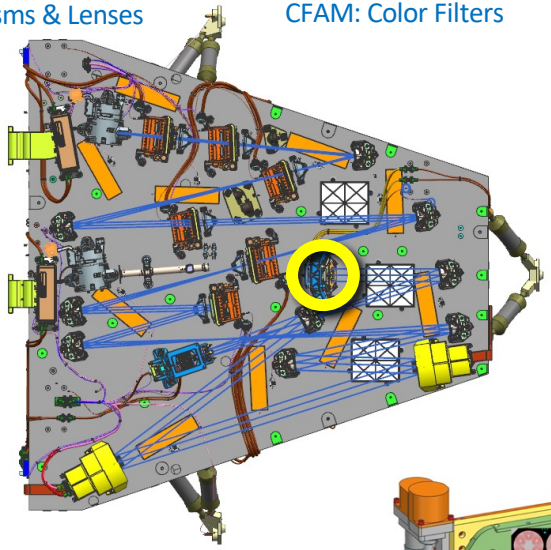


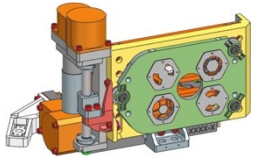
FSAM: Field Stops & Slits

- Used in control loops
- Used in setting up modes

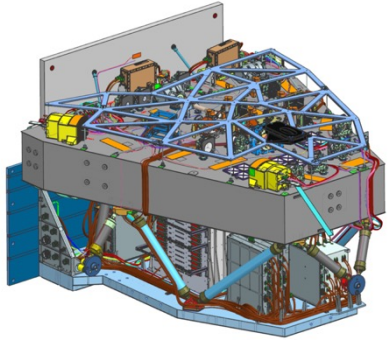


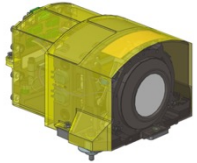
FCM: Focus Control Mirror



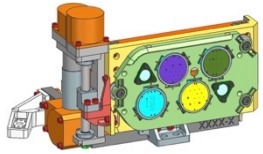


LSAM: Lyot Stops

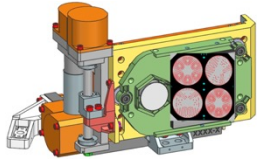




DM (2x): Deformable Mirror



FPAM: Focal Plane Masks

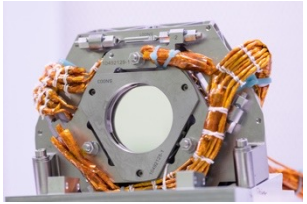


SPAM: Shaped Pupil Masks

What has changed?

As-built

- Used in control loops
- Used in setting up modes



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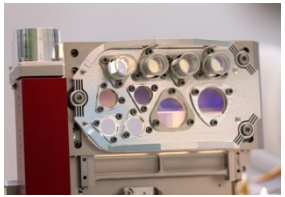

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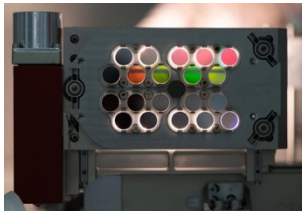

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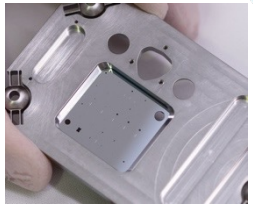

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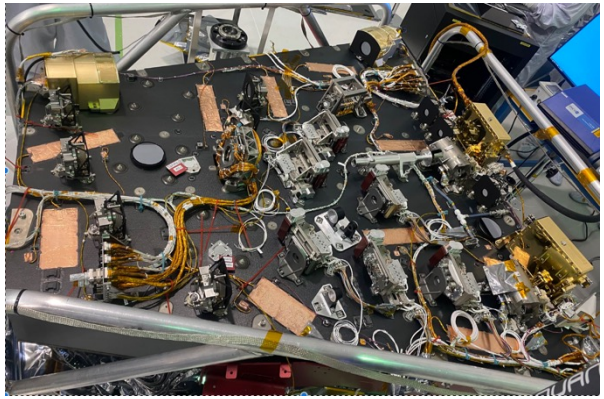
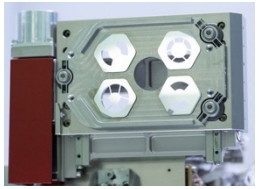
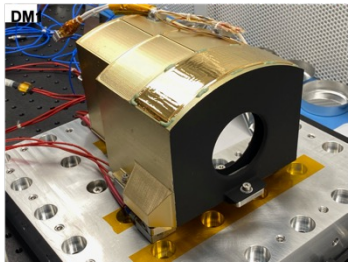




LSAM: Lyot Stops

Electron-Multiplying CCDs (2x)



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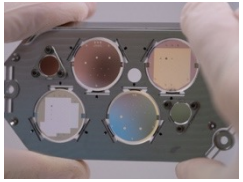

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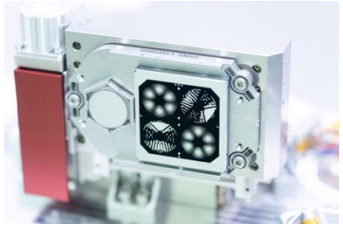
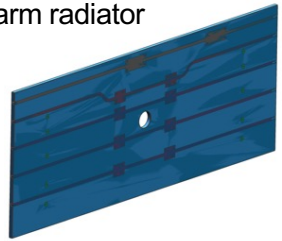
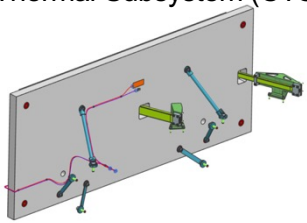


SPAM: Shaped Pupil Masks

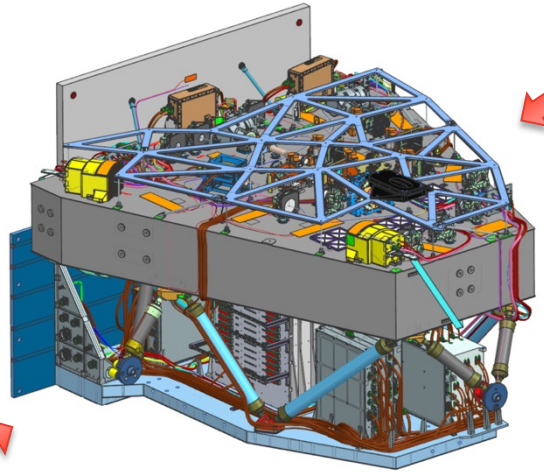
Cryogenic Thermal Subsystem (CTS)

Warm radiator

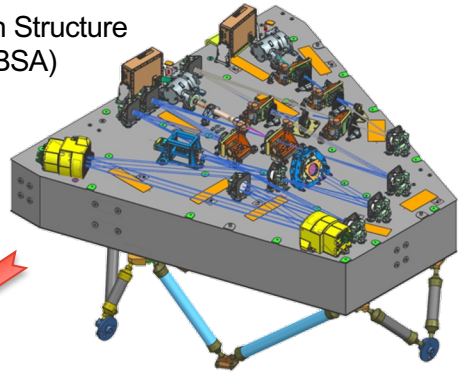


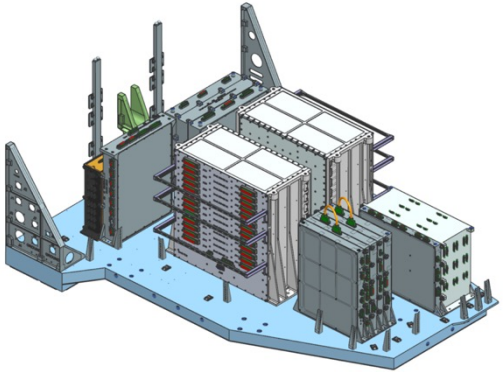


CGI Assembly



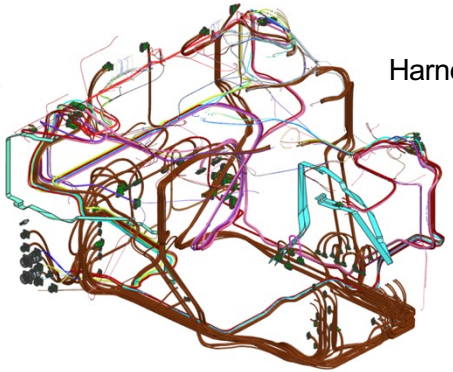
Optical Bench Structure Assembly (OBSA)





Thermal Pallet and Electronics

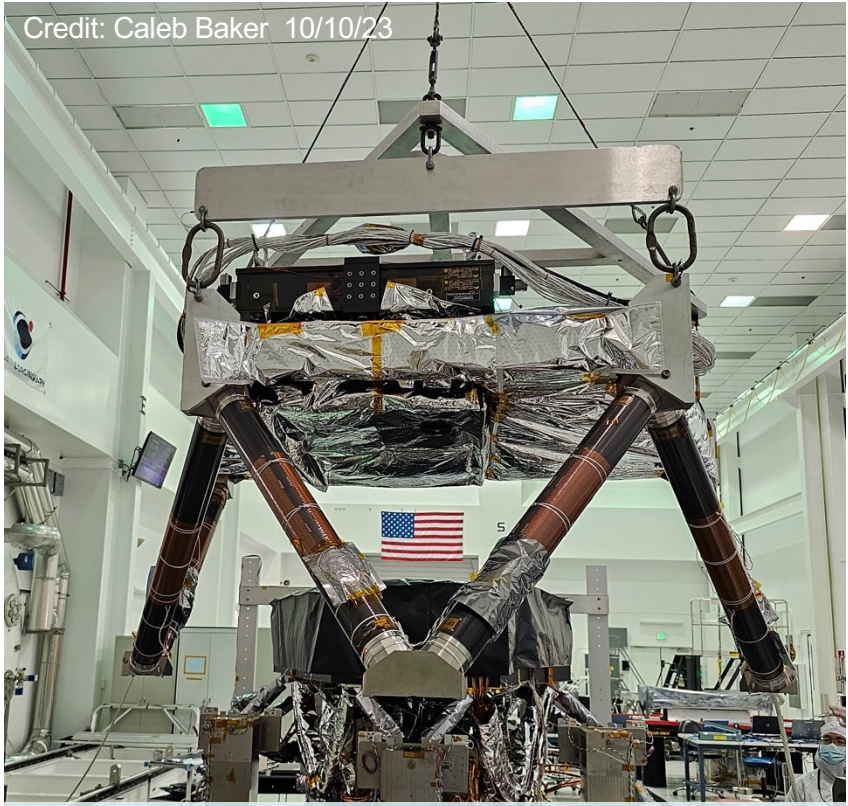
Harness




Source Simulator
Optical Bench
Electronics Pallet

Fall 2023: Full Functional Testing

- Test **functionality** of as-built instrument *in air*
- Test both hardware and software-hardware interactions
- Exercise test procedures that will be used in later in thermal vacuum chamber (TVAC) tests



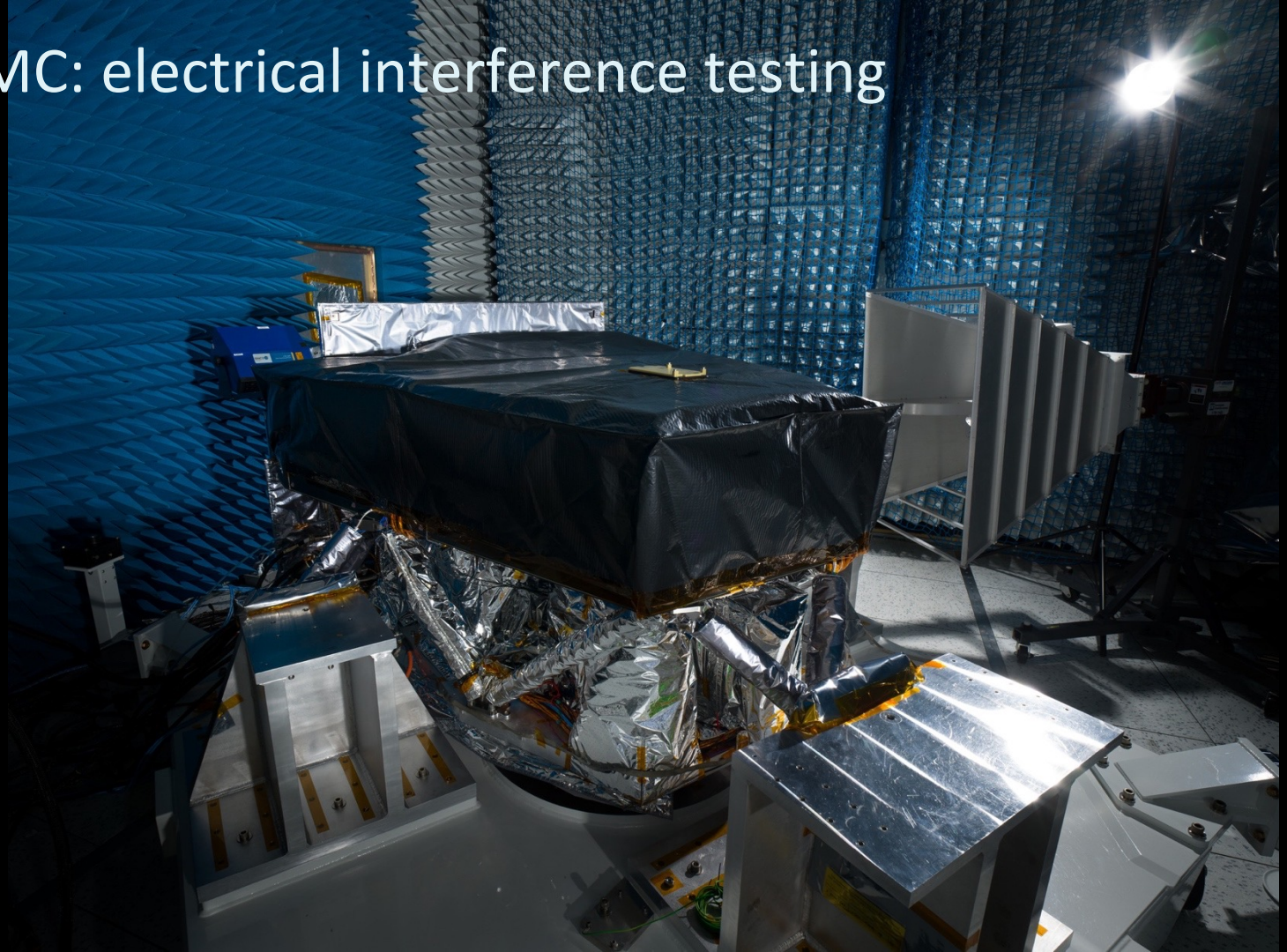
Installing the source simulator


CAUTION
EXIT

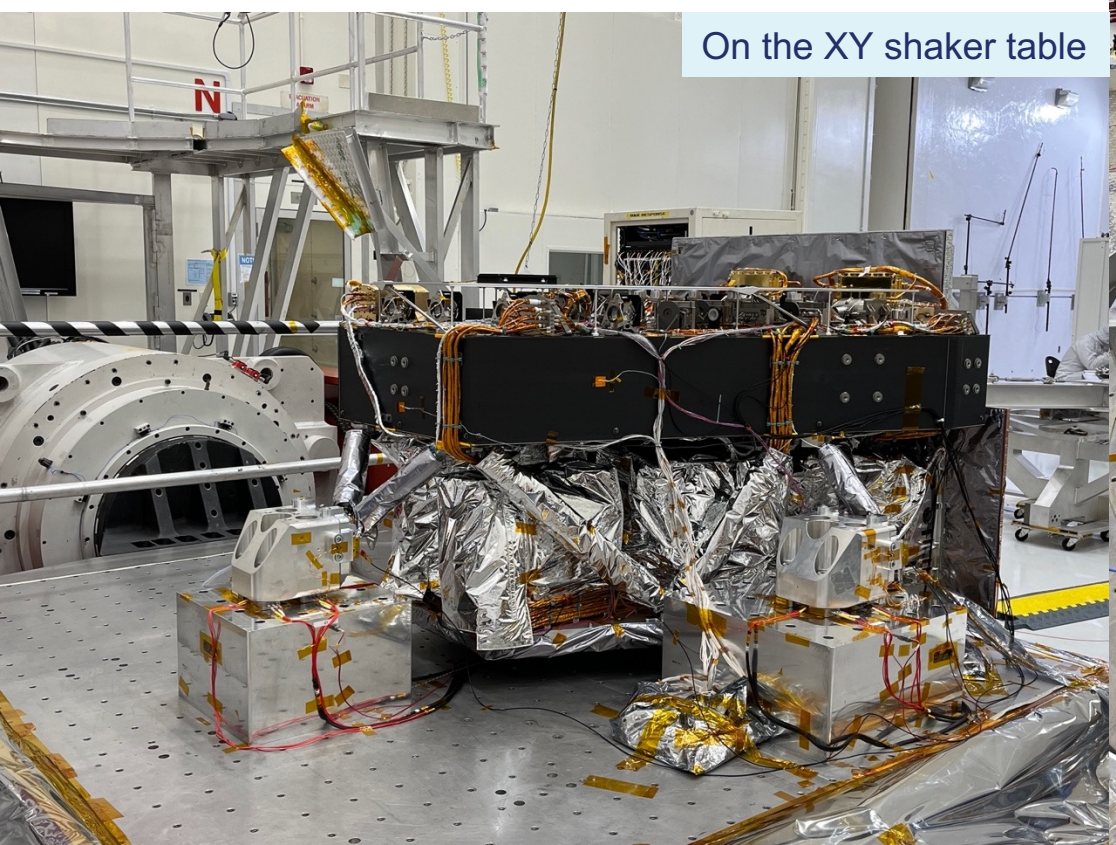
”First light” during full functional test

Credit: NASA

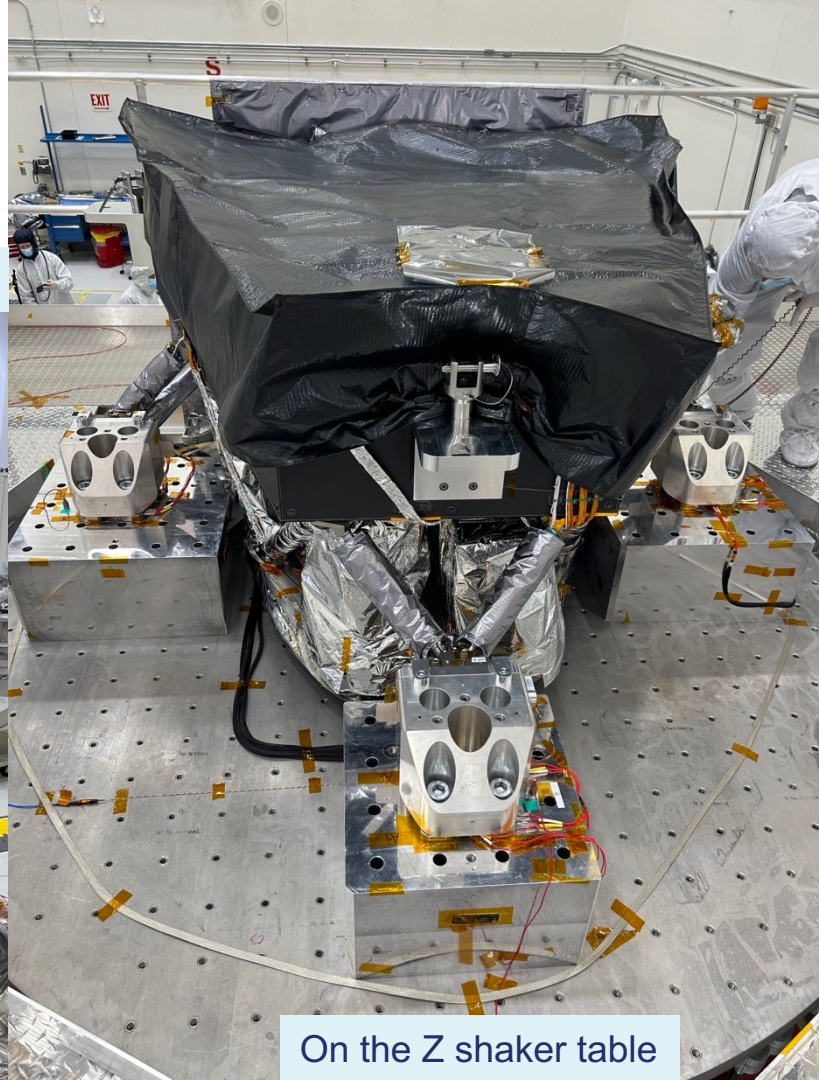
EMI/EMC: electrical interference testing



Vibe testing:
Simulating the vibration environment of rocket launch



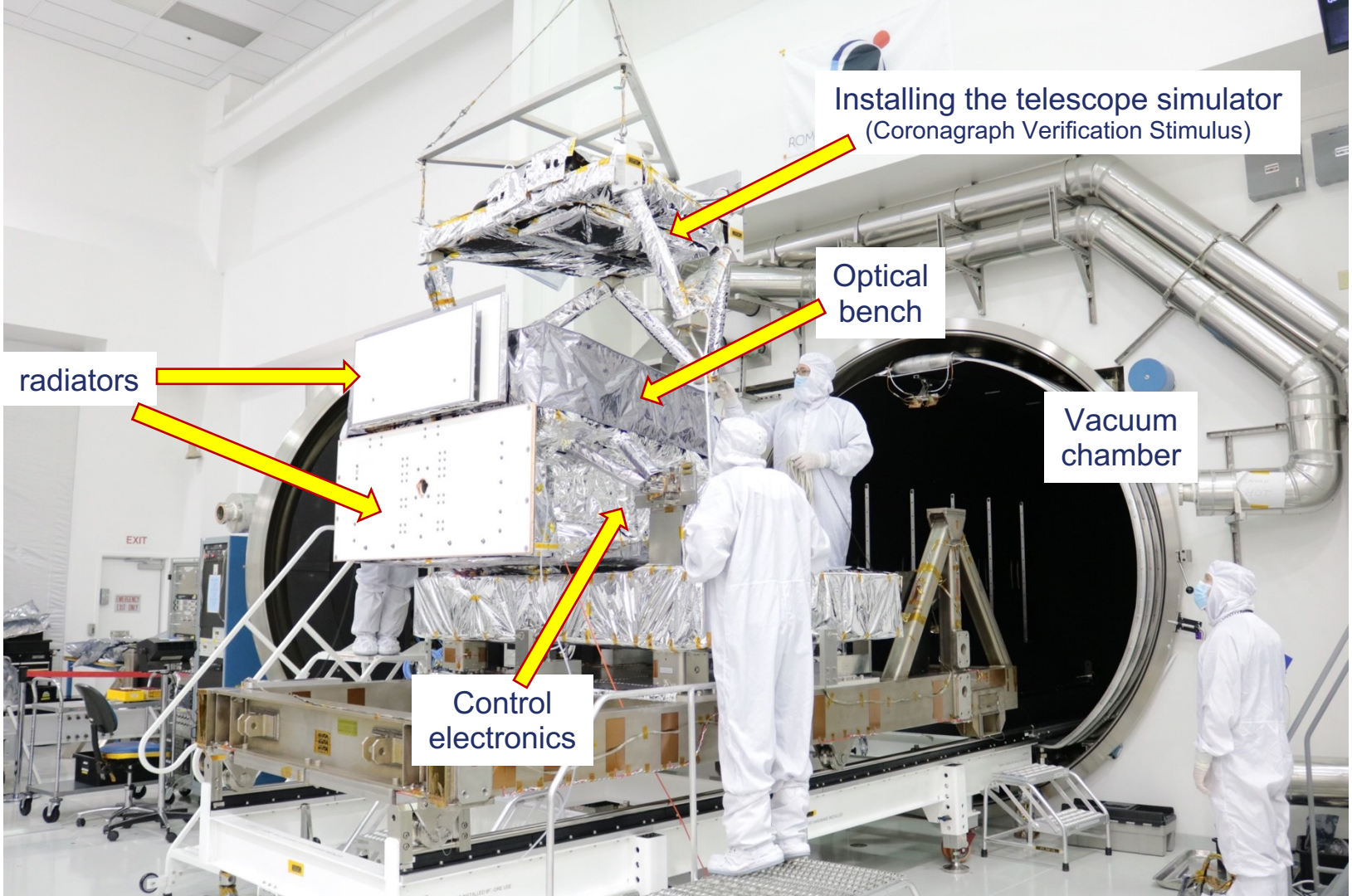
On the XY shaker table



On the Z shaker table

JPL Transpo Gang delivered us safe & sound back to the clean room


ROMAN CORONAGRAPH
EXIT


Installing the telescope simulator
(Coronagraph Verification Stimulus)
Optical bench
radiators
Vacuum chamber
Control electronics

Now: limited functional tests before closing the chamber door

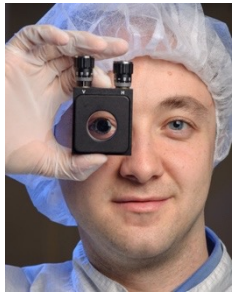
Thermal Vacuum Testing (TVAC) & delivery

- “Run for the record” performance tests in a space-like environment
  - Benefits of TVAC: Cold detectors, no air turbulence, thermal stability
- Door closes next week, then 24/7 through mid-April
- Activities:
  - Watch paint dry (literally), recheck alignment, calibrate detectors, flatten wavefront, test star acquisition, dig dark hole, run test observation to monitor stability over few hour timescales, …
- Delivery to GSFC scheduled in mid-May

What’s next? Preparing to observe

Coronagraph Community Participation Program PIs

Dmitry Savransky
Cornell
Inaugural co-chair



Rus Belikov
Ames

Beth Biller
ESA

Oliver Krause
MPIA

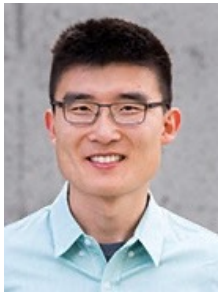
Max Millar-Blanchaer
UCSB

Naoshi Murakami
JAXA

Laurent Pueyo
STScI

Ty Robinson
Univ of Az

Arthur Vigan
CNES



Jason Wang
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Schuyler Wolff
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Community Participation Program Members

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Lisa Altinier
Ramya Anche
Lee Armus
Vanessa Bailey
Pierre Baudoz
Ruslan Belikov
Eduardo Bendek
Beth Biller
Sarah Blunt
Ellis Bogat
Wolfgang Brandner
Oscar Carrion-Gonzalez
Benjamin Charnay
Gaël Chauvin
Amanda Chavez
Elodie Choquet
Robert De Rosa
John Debes
David Doelman
Ewan Douglas
Markus Feldt
Jessica Gersh-Range
Julien Girard
Alexandra Greenbaum
Tyler Groff
Samantha Hasler
Sergi Hildebrant Rafels
Justin Hom
James Ingalls
Satoshi Itoh
Emmanuel Joliet
Stephen Kane
N. Jeremy Kasdin
Hajime Kawahara
Yui Kawashima
Tim Koch
Oliver Krause
John Krist
Masayuki Kuzuhara
Zhexing Li
John Livingston
Jorge Llop Sayson
Patrick Lowrance
Kevin Ludwick
Bruce Macintosh
Eric Mamajek
Mark Marley
Johan Mazoyer
Bertrand Mennesson
Max Millar-Blanchaer
Shota Miyazaki
Sarah Moran
Naoshi Murakami
Tsutsumi Nagai
Bijan Nemati
Jun Nishikawa
Malachi Noel
Emiel Por
Axel Potier
Laurent Pueyo
Susan Redmond
Jason Rhodes
Tyler Robinson
Matthias Samland
Dmitry Savransky
Jürgen Schreiber
Dan Sirbu
Frans Snik
Jennifer Sobeck
Remi Soummer
Karl Stapelfeldt
Takahiro Sumi
Aoi Takahashi
Motohide Tamura
Taichi Uyama
Arthur Vigan
Jason Wang
Schuyler Wolff
Cynthia Wong
Michele Woodland
Hibiki Yama
Toru Yamada
Marie Ygouf
Kenta Yoneta
Robert Zellem
Hanying Zhou
Neil Zimmerman

CPP + PS Responsibilities

- Data Processing Pipeline
- Observation Planning
  - Target database, precursor observations
  - Internal tools for generating observation plans
- Image & observation simulations
- Best effort: Preparing for beyond-requirements observations
  - Prepare for commissioning, and operations of the primary and goal observing modes
  - Research *potential* alternative high-order wavefront sensing and control algorithms

- **Stay tuned: Opportunities for broader community input are in development**

More info at https://roman.gsfc.nasa.gov/science/roses.html

Timeline

- Completed: full functional, EMI/EMC, & vibe tests
- Feb - April: TVAC Tests
- May: Instrument delivery to GSFC
- now – launch: prepare for observations
  - Stay tuned for future engagement opportunities
- After launch: ~90 days baselined early in mission