Roman Coronagraph Instrument Update

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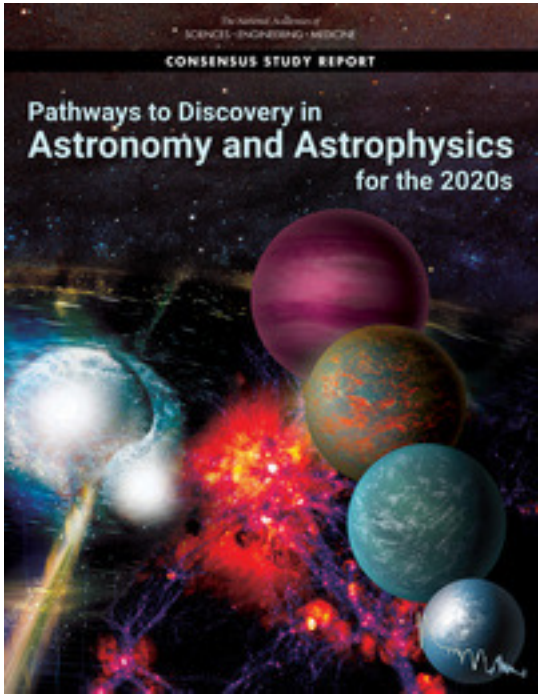
ExoPAG 25; Jan 10, 2022

Many slides borrowed from prior talks, incl. from Dominic Benford, Jeremy Kasdin, Bertrand Mennesson, …

Outline

- Intro to the Coronagraph Instrument
- Timeline and status
- Resources for the community & ROSES ‘22 opportunity

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



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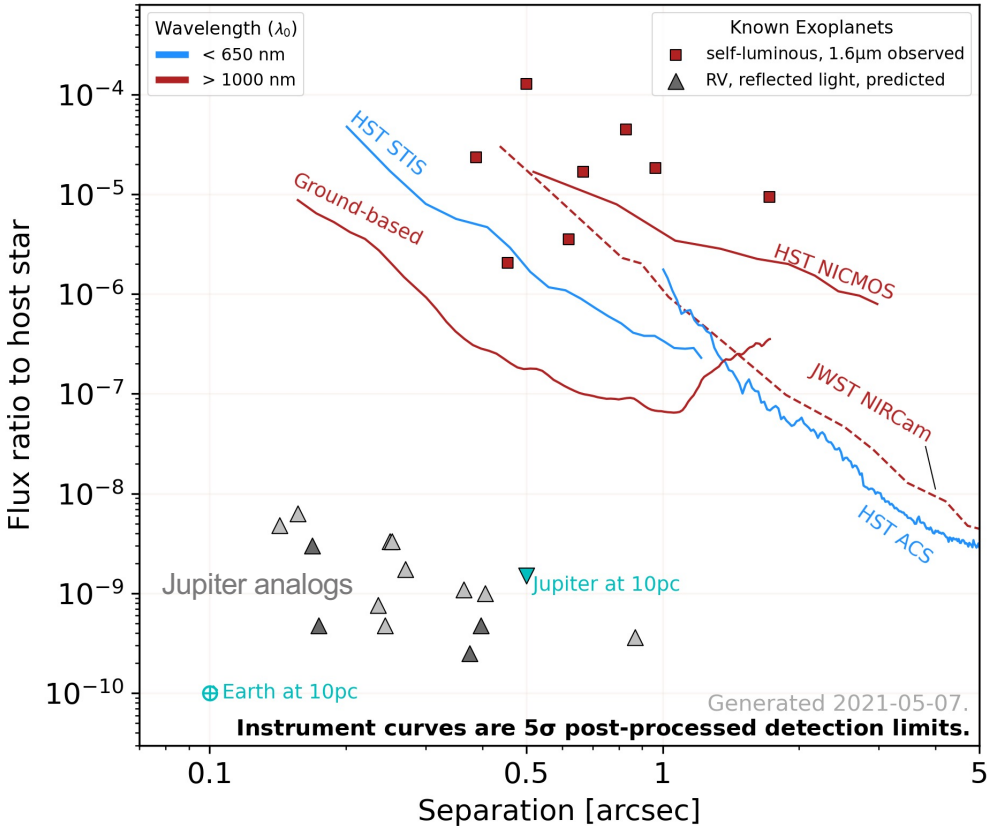
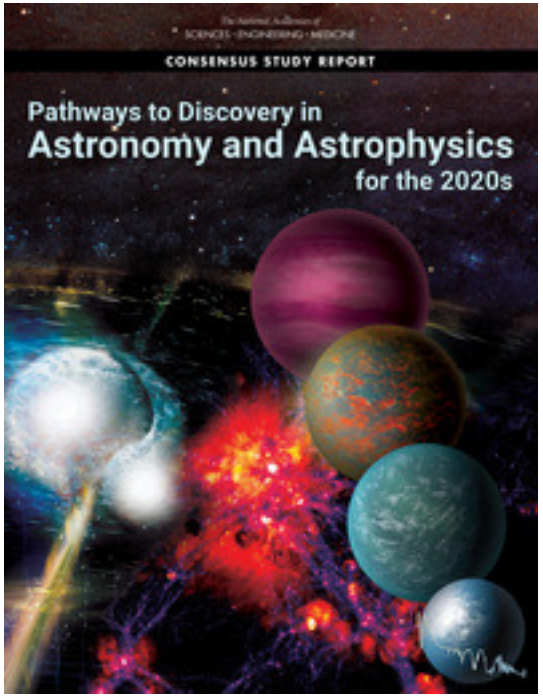
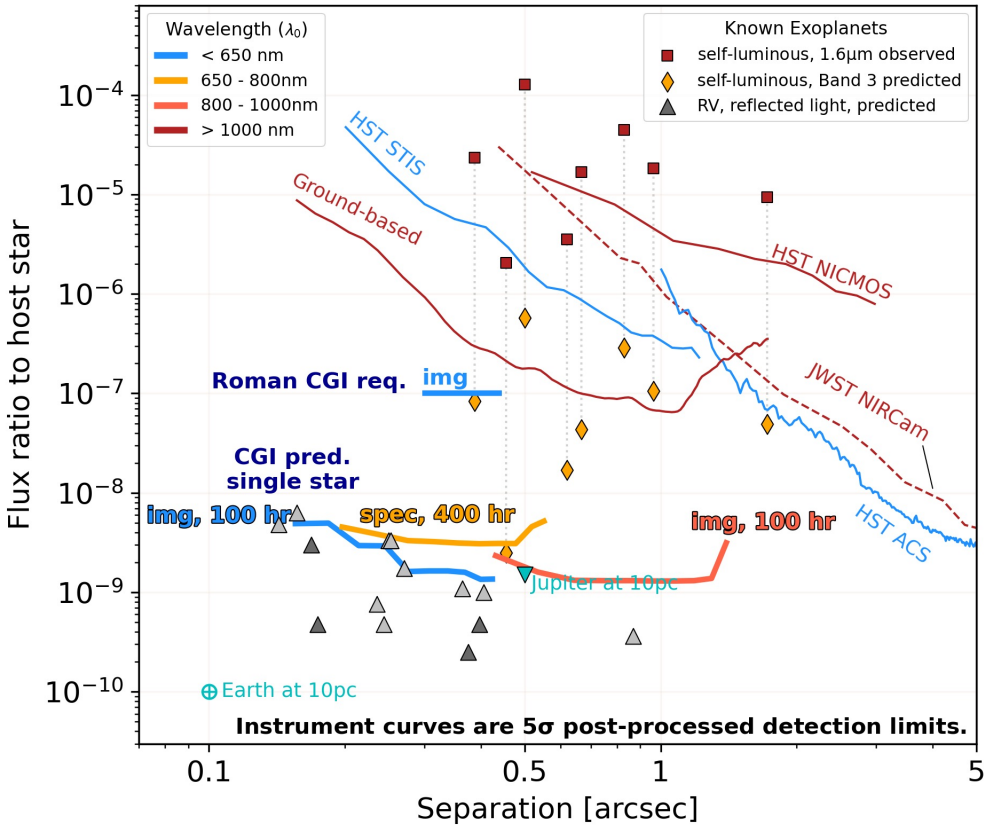




3 Primary observing modes; strongly speckle-limited at shortest wavelength



github.com/nasavbailey/DI-flux-ratio-plot/
NEW: more options for conservatism & exposure time

Exoplanet Exposure Time Calculator
https://roman.ipac.caltech.edu/sims/ETC.html

Brian Kern (JPL)
John Krist (JPL)
Bijan Nemati (UA Huntsville)
Sergi Hildebrandt-Rafels (JPL)
A.J. Riggs (JPL)
Hanying Zhou (JPL)

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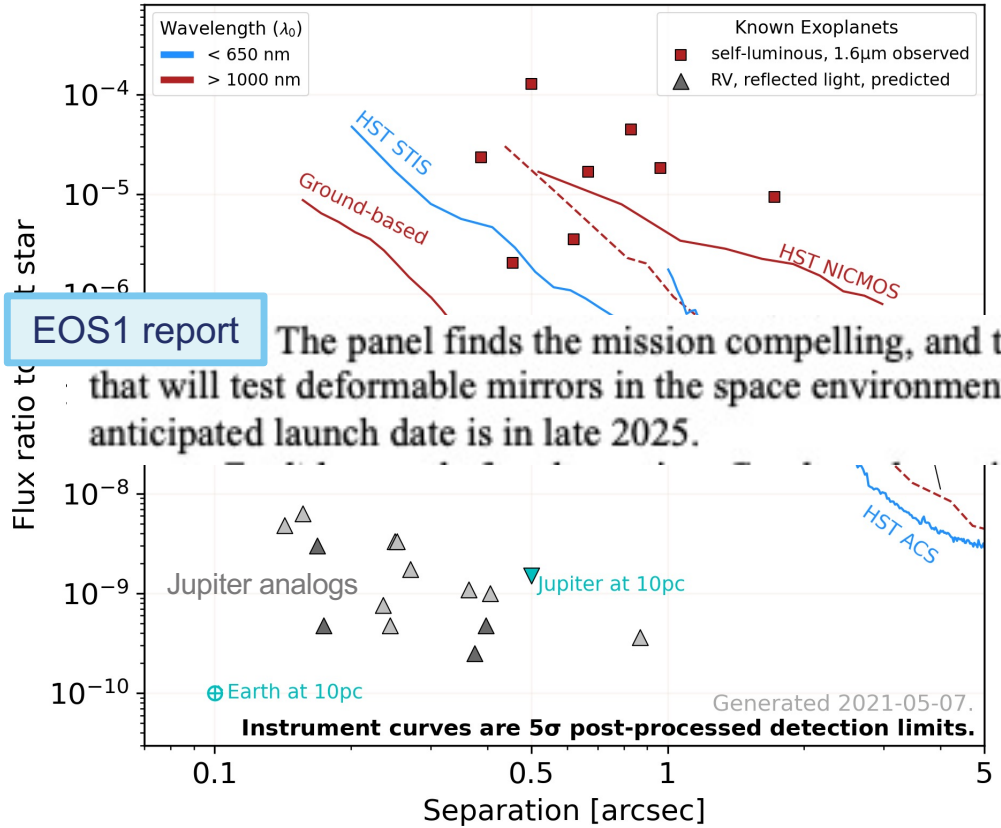
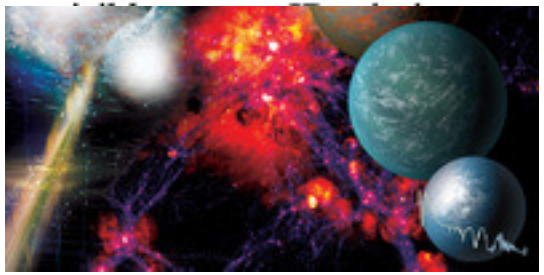


EOS1 report

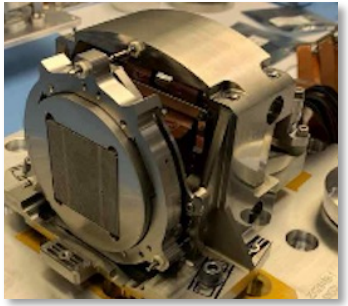
The panel finds the mission compelling, and the CGI is a useful technology demonstration that will test deformable mirrors in the space environment and also closed-loop wavefront control. The anticipated launch date is in late 2025.

Mennesson+2020, arxiv.org/abs/2008.05624



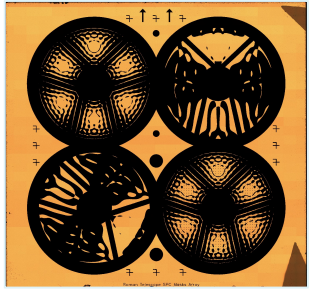
CGI will demonstrate key technologies for future missions

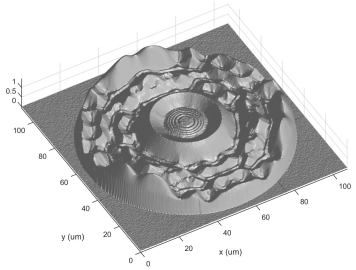
Large-format Deformable Mirrors



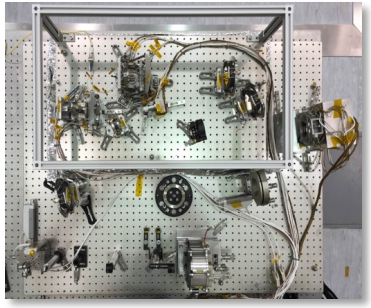
Ultra-low-noise Photon-counting EMCCDs

High-contrast Coronagraph Masks

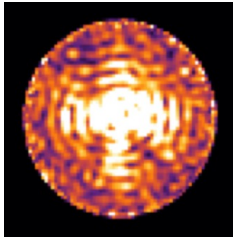


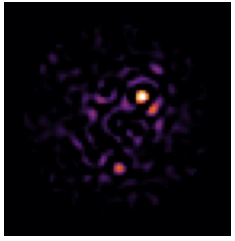


Ultra-Precise Wavefront Sensing & Control (now Ground-In-The-Loop)



Data Post-Processing





All hardware now at TRL ≥ 6

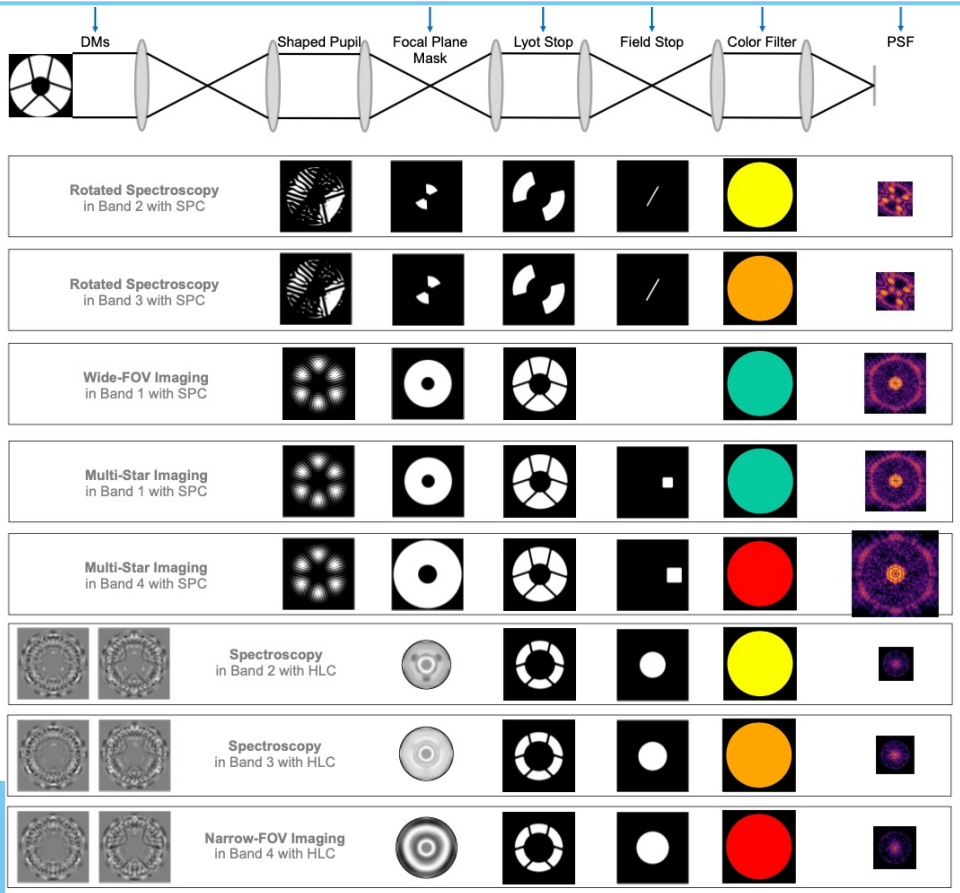
Primary Observing Modes
One required, others “best effort”

Band	λ_{center}	BW	Mode	FOV radius	FOV Coverage	Pol.	Coronagraph Mask Type	Req’d
1	575 nm	10%	Narrow FOV Imaging	0.14” – 0.45”	360°	Y	Hybrid Lyot	Y
2	660nm	15%	Slit + R~50 Prism Spectroscopy	0.17” – 0.52”	2 x 65°	-	Shaped Pupil	-
3	730 nm	15%	Slit + R~50 Prism Spectroscopy	0.18” – 0.55”	2 x 65°	-	Shaped Pupil	-
4	825 nm	10%	“Wide” FOV Imaging	0.45” – 1.4”	360°	Y	Shaped Pupil	-

Only Band 1 + Hybrid Lyot coronagraph will be end-to-end high-contrast ground-tested.
Bands 2, 3, 4 are “best effort,” with assembly-level testing, but not end-to-end performance testing.

Complete list of filters available at https://roman.ipac.caltech.edu/sims/Param_db.html
Can’t mix & match coronagraph mask w/ any filter; must be sub-band

Unsupported mask configurations



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

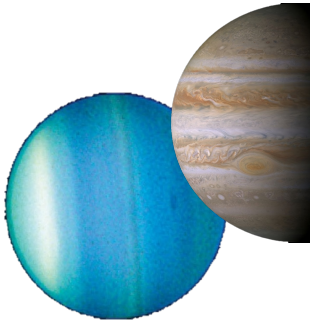
No funding for on-sky commissioning identified at this time. Analogous to HST/STIS Bar5.

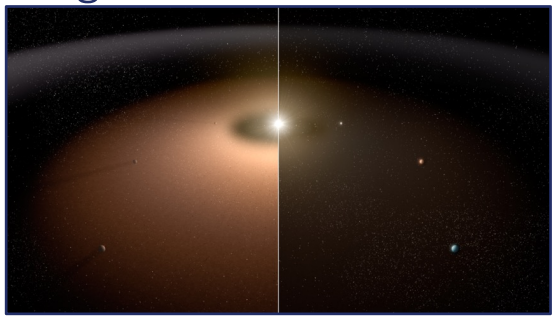
Not shown: unsupported "low-contrast" classical Lyot spots (analogous to HST) for very wide FOV imaging (~1-3.5")

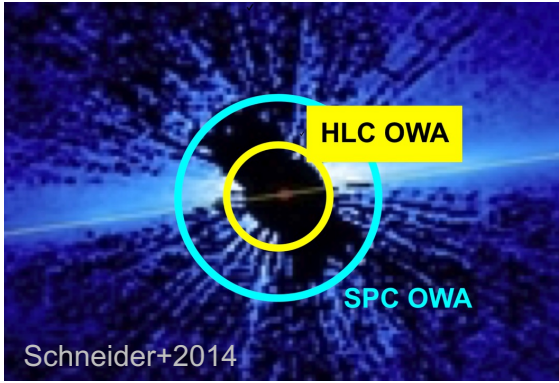
For complete list of masks see Riggs+ SPIE O&P 2021

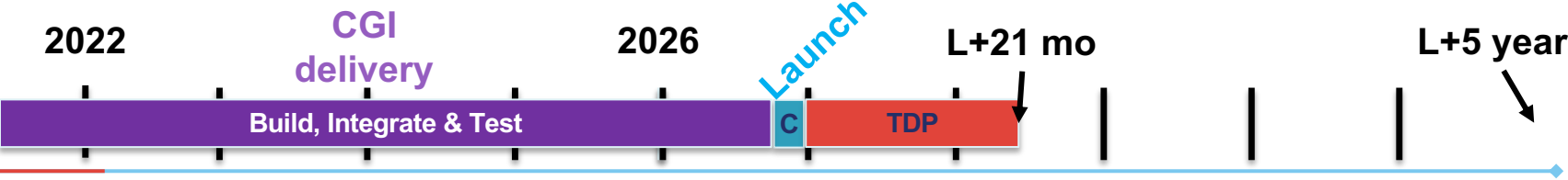
Capable of exciting exoplanetary system science

- Characterize known, self-luminous planets at visible wavelengths
  - (eg: Lacy & Burrows 2020)
- Potential for first images of true Jupiter analog
  - (eg: Batalha+2018, Saxena+2021)
- Low surface brightness disks, improved morphology
  - (eg: Mennesson+2018)
- Potential for first visible light images of exozodi
  - (Douglas+2022)









Apr 2021: Passed Instrument Critical Design Review

Dec 2023: Instrument delivery to payload integration & test (delayed for COVID impacts)

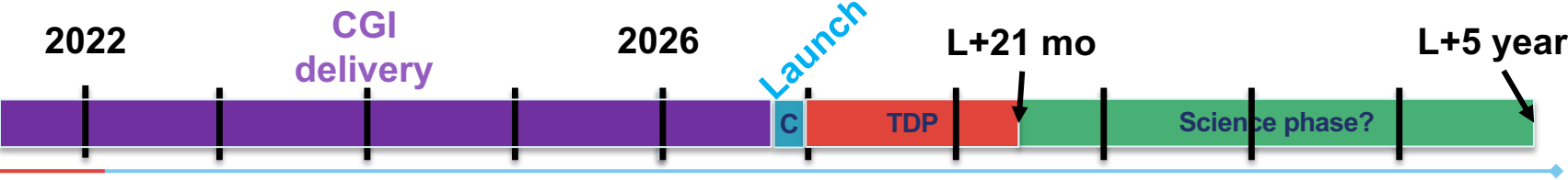
Launch: goal of late 2026; no later than May 2027 (delayed for COVID impacts)

Commissioning Phase

- 450 hr in first 90 days after launch

Coronagraph Instrument Technology Demonstration Phase (TDP)

- **~2200 hr (3 months) baselined** in next 1.5 years of mission



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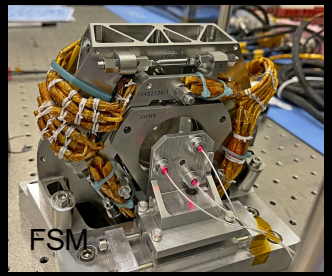
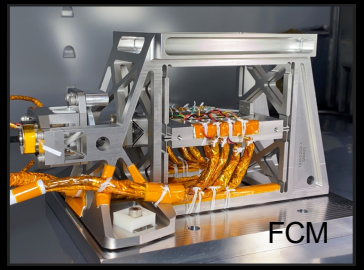
If TDP successful, potential add'l science phase

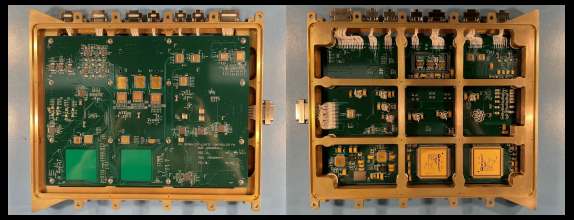
- ~10% (OOM) of remainder of 5 year mission
- Commission unofficial observing modes (add'l mask+filter combo's)
- Support community engagement in science and technology
- Not guaranteed: would require additional resources

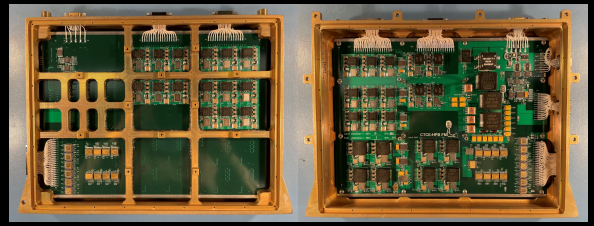
Flight Hardware

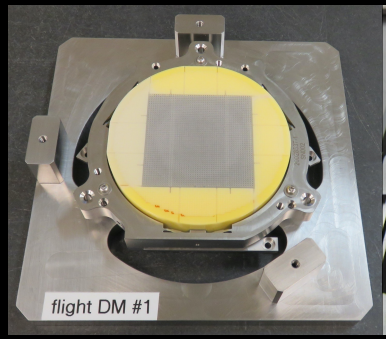
From CL#21-6276

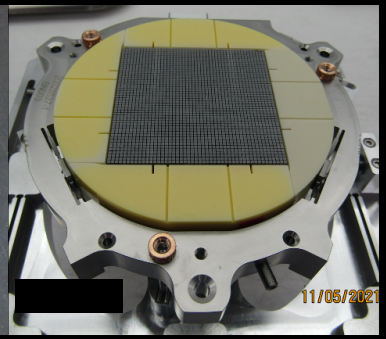


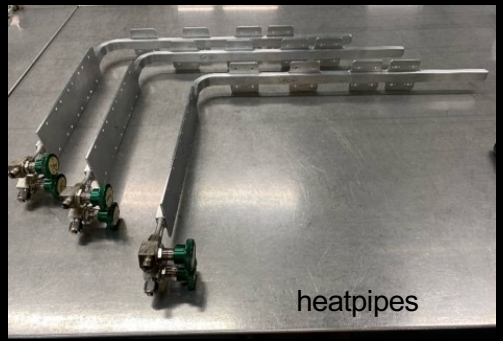


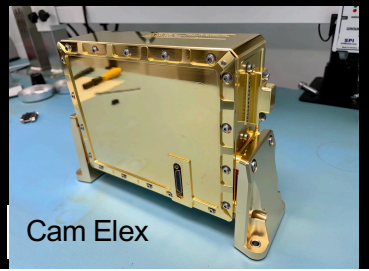


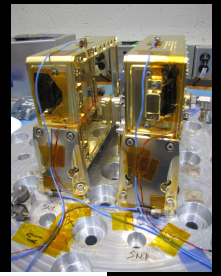




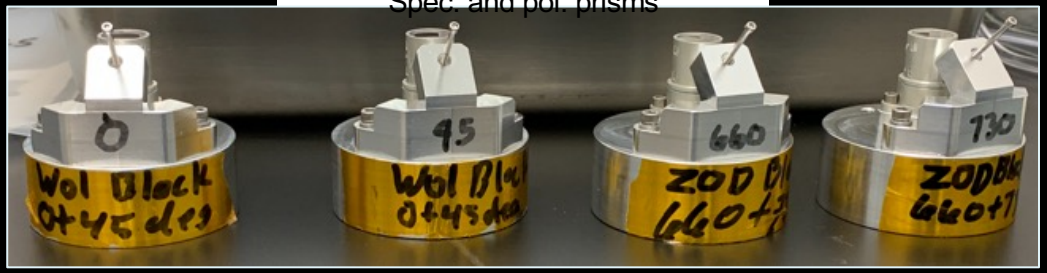




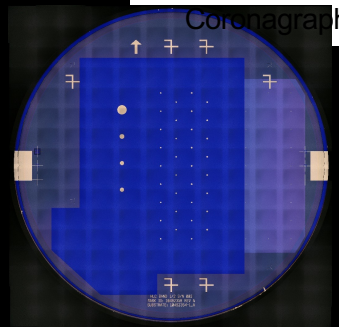


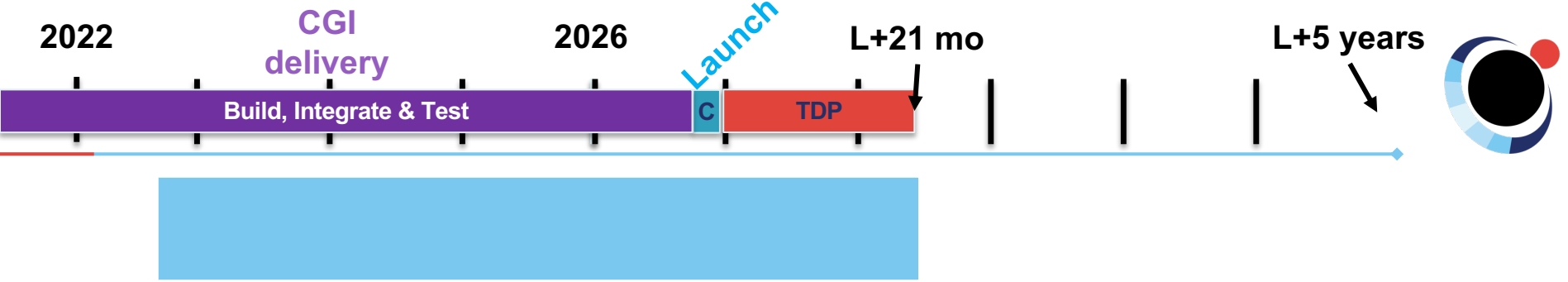


Spec. and pol. prisms



Coronagraph masks and stops





- Community teams, with members from US and all partner agencies.
- Work closely with Coronagraph Project in tech-demo preparation and operations. Add value by complementing the expertise of JPL and IPAC Science Support Center (SSC) Project staff.
  - CPP members are Coronagraph team members, not only end users
  - Potential examples: Target/observation preparatory work; image simulations; data analysis tools; wavefront sensing and control strategies; …
- Definitive list of need areas and proposal guidelines will be released in ROSES 2022 call

Community Information

- October & November ‘21 Coronagraph Information Sessions
  - https://roman.ipac.caltech.edu/mtgs/Roman_CGI_workshop.html
  - Overviews of instrument, observation cases, constraints, simulation tools
  - Recordings & slides posted
- Public tools for image simulation, exposure time estimates, wavefront sensing/control
  - https://roman.ipac.caltech.edu/sims/Code.html
  - https://roman.ipac.caltech.edu/sims/ETC.html
  - Observing Scenario 11 coming Jan/Feb
- Macintosh and Turnbull SIT pages: papers, codes
  - https://romancgi.sioslab.com/
  - https://www.exoplanetdatachallenge.com/SIT
- Coming soon: “one stop shop” page on IPAC Roman site linking to all key resources

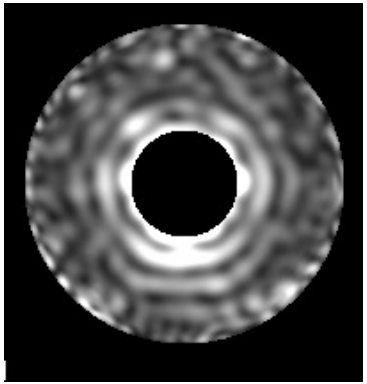
Summary

- The best way to pave the way for future missions is to go beyond requirements and observe challenging targets
  - Expect 100-1000x improvement in contrast in visible
  - Could take first reflected-light image of an exoplanet & exozodi
  - New parameter space in circumstellar disks & self-luminous young planets
- Building flight hardware
  - Deliver instrument Dec 2023
- Resources for potential CPP proposers and interested users at roman.ipac.caltech.edu

Observing Scenarios (OS#): Realistic simulated datasets

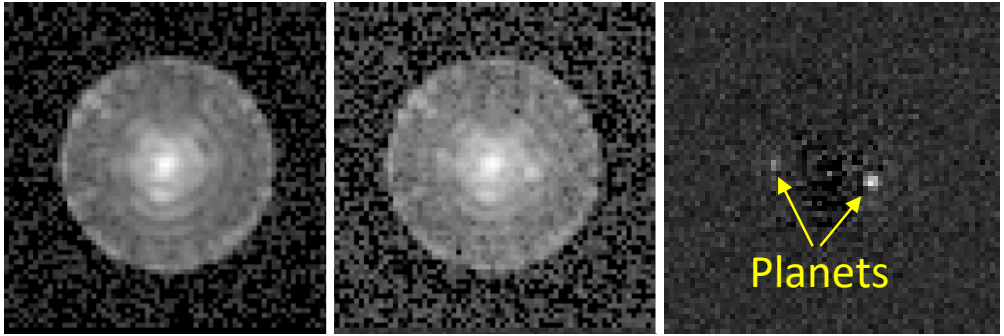
- Observing scenario includes slews to/from target & reference stars
- Thermal (solar incidence) and structural finite element modeling of telescope and instrument
- Dynamic modeling (vibration from reaction wheels)
- Low-order wavefront sensing & correction modeling
- Optical diffraction modeling produces speckle field time series

OS9 Speckle Field Time Series
(includes model uncertainty factors)



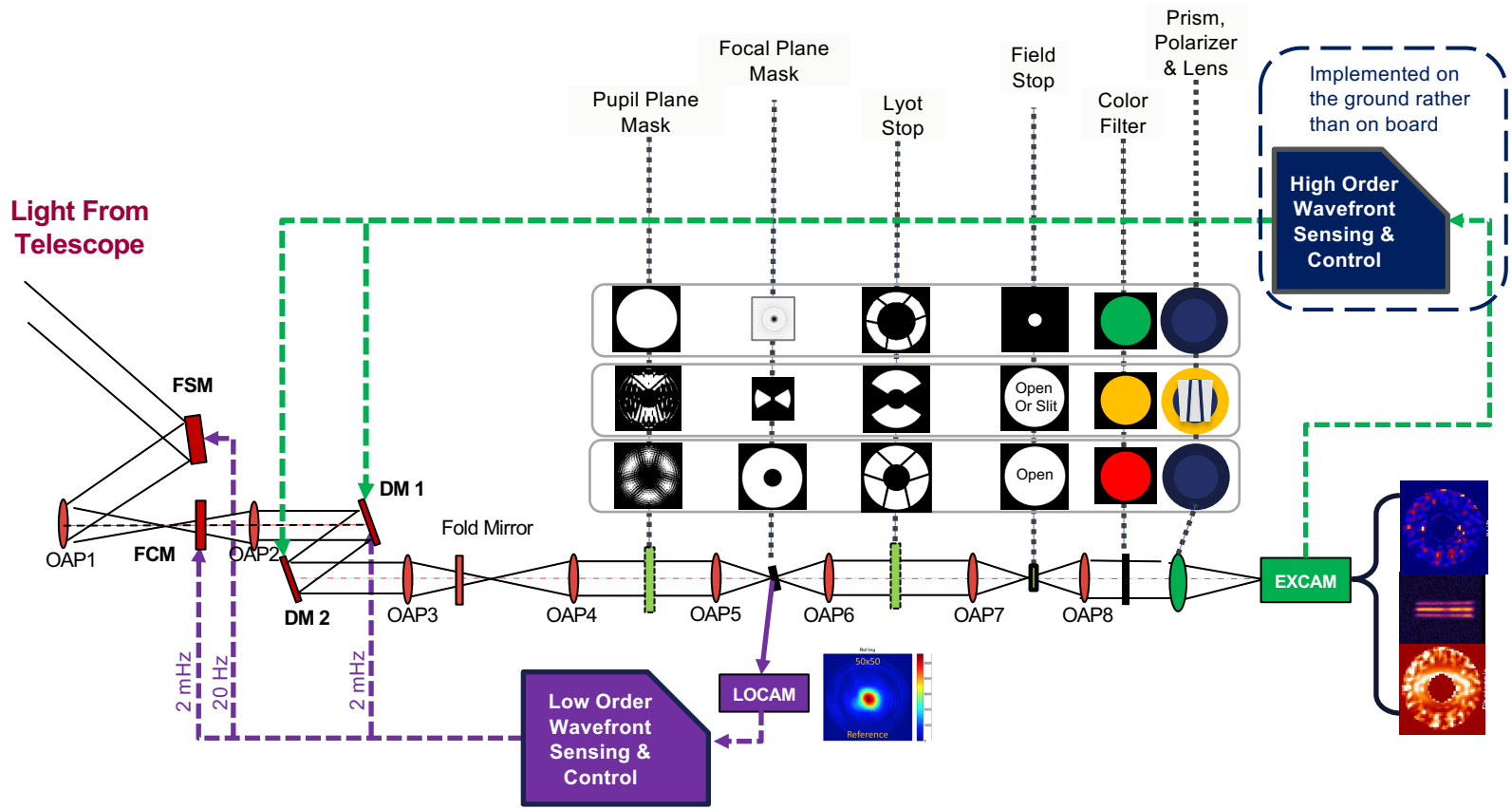
Summed Images

Reference star | Target star | Target - ref



- https://roman.ipac.caltech.edu
- OS9 is the latest scenario
- OS11 will be released Jan/Feb & will incorporate “ground-in-the-loop” wavefront sensing/control.
- OS11 will be the last OS

Key technologies work together as a system to deliver high performance



OAP = Off-Axis Parabolic [Mirror]