

Bringing Second-Generation Coronagraph Instruments to the Habitable Worlds Observatory

Garreth Ruane

Jet Propulsion Laboratory, California Institute of Technology



Jet Propulsion Laboratory
California Institute of Technology

Future Bringing ~~Second~~-Generation Coronagraph Instruments to the Habitable Worlds Observatory

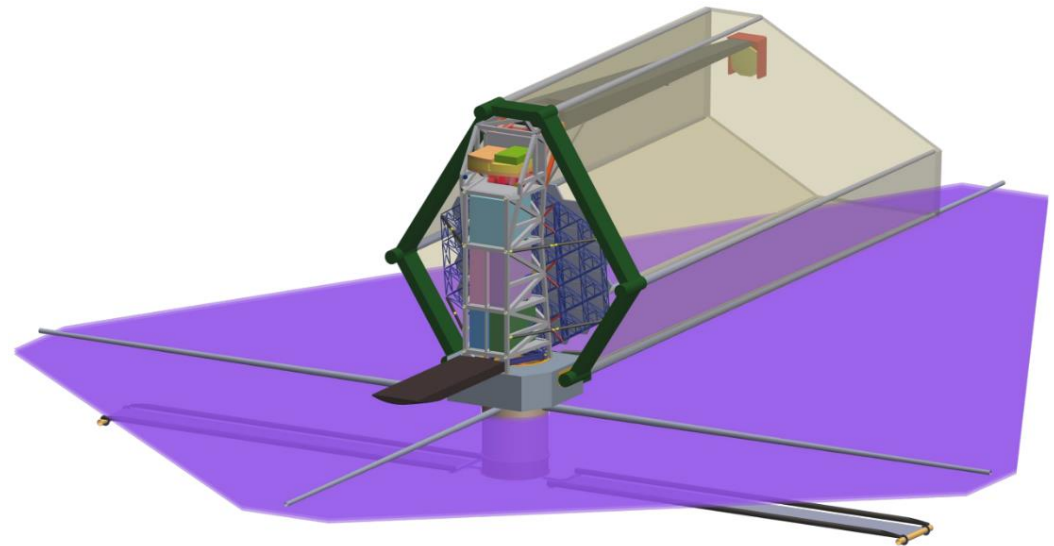
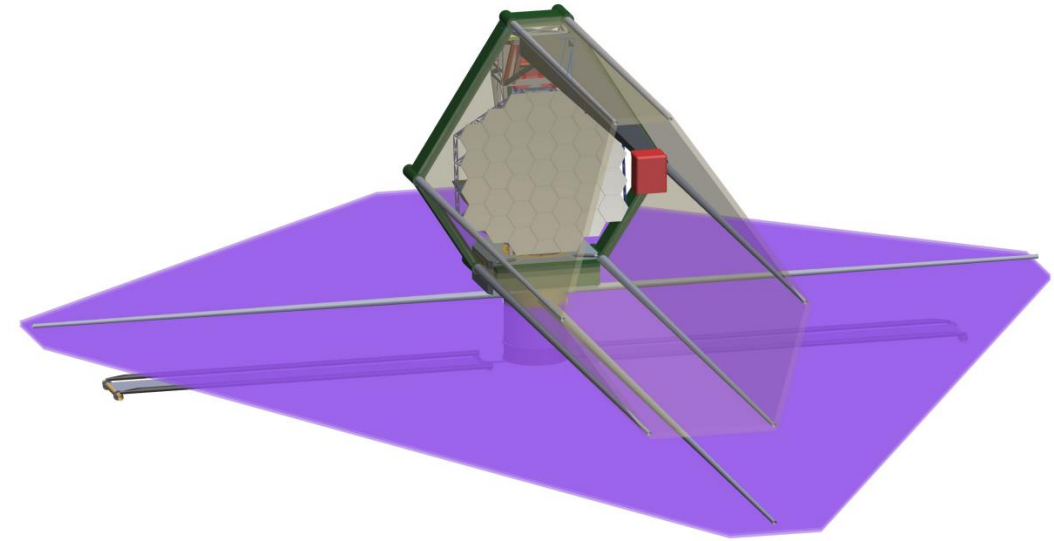
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The Habitable Worlds Observatory (HWO)

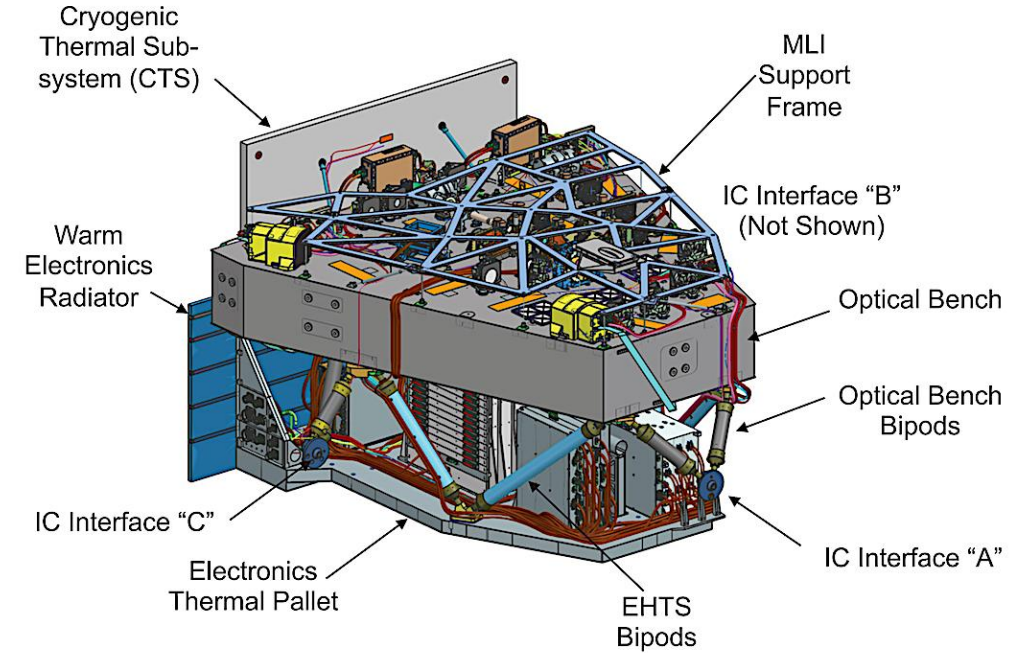
- Currently a Technology Maturation Project to support NASA's next Great Observatory focused on reaching TRL 5 on key technologies by the end the decade
- $\geq 6\text{m}$ diameter primary mirror
- Operating at Sun-Earth L2
- Designed to:
 - enable transformational UV/VIS/NIR astrophysics
 - directly image and characterize a robust sample of ~ 25 potentially habitable exoplanets
 - “be serviceable,” which is currently under study for exactly what and how that will be carried out



“EAC 5”

HWO coronagraph instruments

- HWO aims to include capability to directly observe potentially habitable planets over a broad wavelength range NUV to NIR (0.25-1.8 μ m; H₂O, O₂, O₃, and CH₄).
- Heritage from Roman CGI: a visible-only tech demo, limited contrast and capabilities; and the most complex instrument JPL has ever delivered.
- While the Roman CGI tech demo is invaluable, there is still a leap from its capabilities to the goals of HWO.
- HWO TMPO is investing in technologies that can be TRL5 by the end of the decade, which may exclude some “next generation” technology/ideas.
- A first-generation suite of coronagraph instruments on HWO may have limited performance due to technical readiness and/or risk posture.



Credit: NASA

Why plan for future-generation coronagraphs?

- A second-generation coronagraph suite may provide a unique opportunity to focus on more modest goals in a first-generation coronagraph instrument while eventually fully realizing HWO's ultimate scientific potential with reduced risk and cost.
- This second generation would build upon the lessons learned from the first generation which would be the first coronagraph instrument in space operating in the $1e-10$ contrast regime needed to directly image and spectrally characterize Earth-like exoplanets.

Examples of potential implementation phasing

Capability	First-Generation (TRL5 by end of decade)	Second-Generation (TRL5 after 2030?)
Wavelength range	1e-10 contrast restricted to visible light; limited capability in non-simultaneous UV or NIR	Better visible contrast + planet throughput; parallel NUV to NIR
Starlight suppression	Existing mask and deformable mirror technology (~2K actuators)	Advanced coronagraphs & DMs; Larger bandwidths; dual polarization; Photonic ICs
Detector sensitivity	Existing detector technologies	Photon counting NUV to NIR; cryocoolers; SN-SPDs, MKIDS, ...
Spectroscopy	Photometry; Lower resolution spectroscopy	Higher spectral resolution
Polarimetry	Limited or non-existent	Parallel/dual polarization imaging; Full stokes imaging
Fields of view	Limited inner or outer working angles; one-sided fields; localized fields on specific targets	Larger instantaneous high-contrast FOV
Multi-star systems	Limited or non-existent	Dedicated multi-star wavefront control modes

This table is notional and not based on any formal TRL assessment by HWO or otherwise

The next decadal will determine what's next for HWO

- Future-generation coronagraph instruments need technology development in the next decade to be ready in time for a servicing mission. This is not in the scope of the HWO Technology Maturation Program.
- Cost vs Architecture trade needs to be done to understand how a phased implementation of instruments may affect overall cost and risk.
- An ASTRA initiative could study what “next generation” technologies could do for future HWO instruments, including the coronagraph.
- The decadal will put this in context with other priorities and recommend the appropriate path for technology development support for future HWO instruments in the next decade.

Why start now?

To design the observatory to accommodate the first, second, and future generations, there needs to be a concerted effort to:

- Plan the instrument replacement/modification missions at least conceptually
- Define servicing compatibility requirements for the instruments
- Design the first generation AND future generation instruments in parallel with the serviceable observatory
- Develop the technologies that enable future generation instruments in parallel
- Better understand the cost/architecture trade space

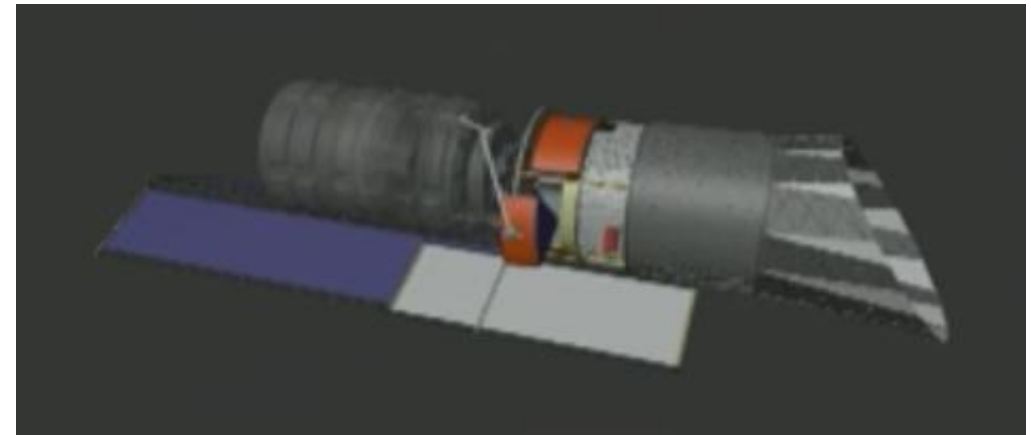
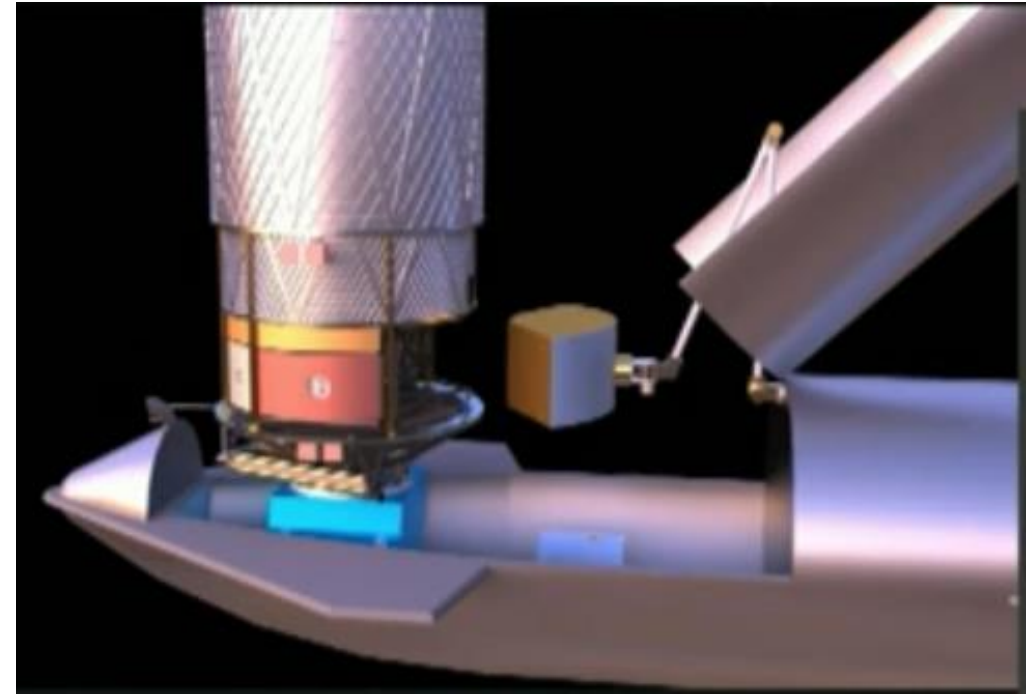
Many open questions and uncertainties ...

HWO servicing concepts

- Serviceability is being treated as a high-level requirement for HWO.
- Publicly available information sources:
 - 2024 "Pioneering Sustainable Observatories" workshop highlighted how in-space servicing could provide a programmatic structure to maximize HWO's scientific return.
 - "Servicing Space Observatories" by John Grunsfeld. Presented at HWO25 conference.

Themes

- Technology exists
- Requirements and costing for servicing and future instrumentation is key
- Picometer stability may open a new technology need



Stills from animations in "Servicing Space Observatories" by John Grunsfeld.
Provided by NASA Goddard.

Take aways

- We cannot wait until HWO's observatory design is locked in to plan its servicing mission(s) and future-generation instrumentation.
- Proactively developing first-generation, future-generation, and servicing concepts may mitigate technical risk.
- Future-generation coronagraph instruments need technology development in the next decade to be ready in time for a servicing mission (not in scope!).
- An ASTRA initiative should study what “next generation” technologies could do for future HWO instruments, including the coronagraph.
- Cost vs Architecture trade needs to be done now to understand how a phased implementation of instruments may affect overall cost and risk.
- Don't forget that $1e-10$ contrast is very hard. Characterizing large numbers of exo-Earths is even harder.