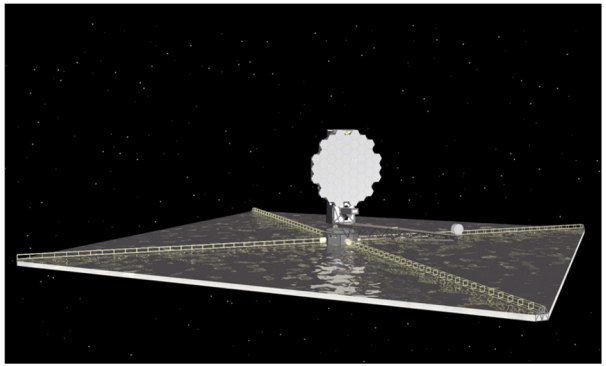
Starlight suppression with HWO

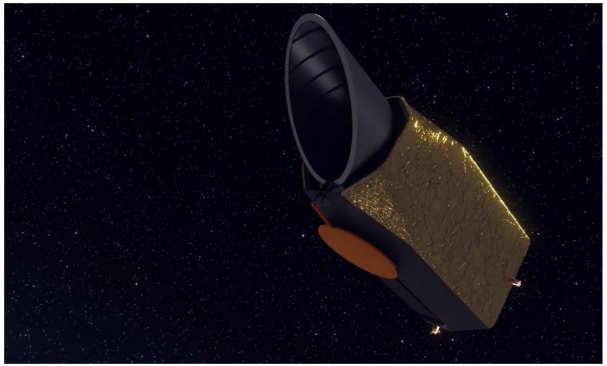
Risks, concerns and opportunities

An **incomplete** **(and probably biased)** list

Roser Juanola-Parramon and Ruslan Belikov
Starlight Suppression Workshop, August 2023

From the big picture…





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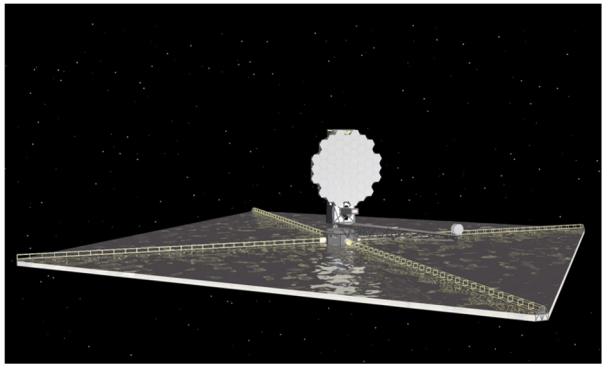
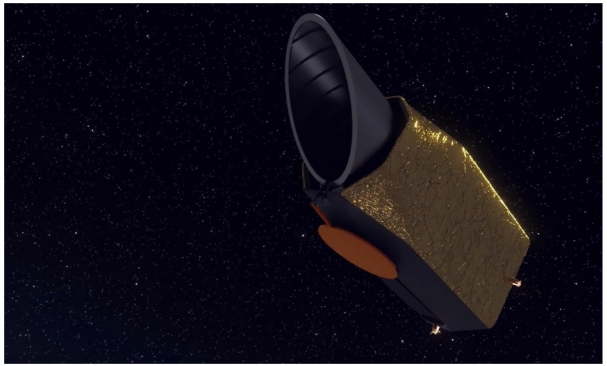
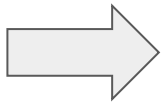
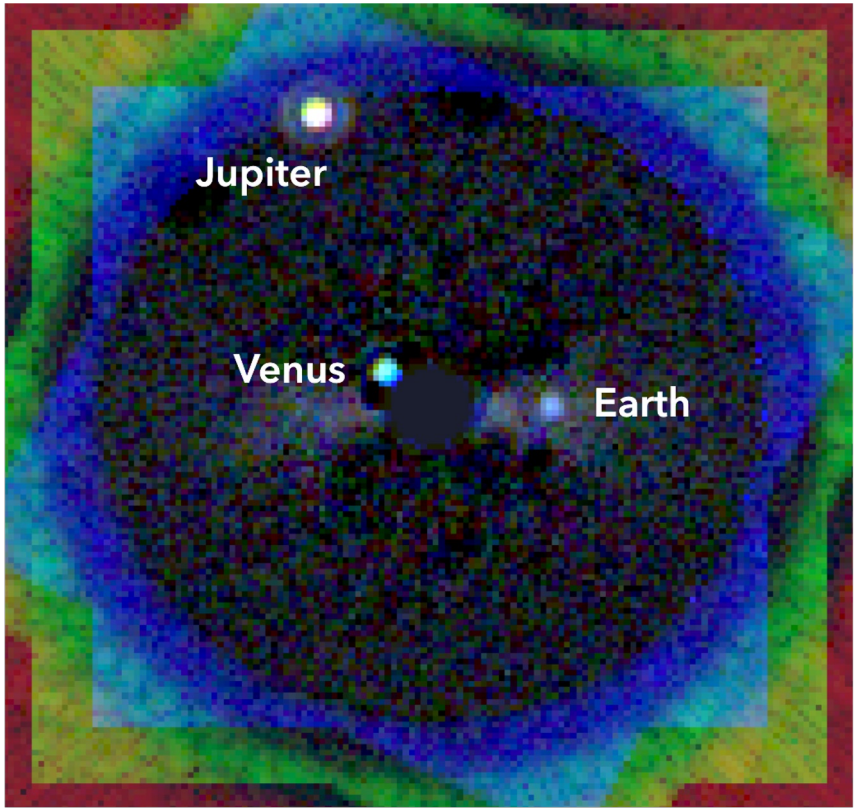
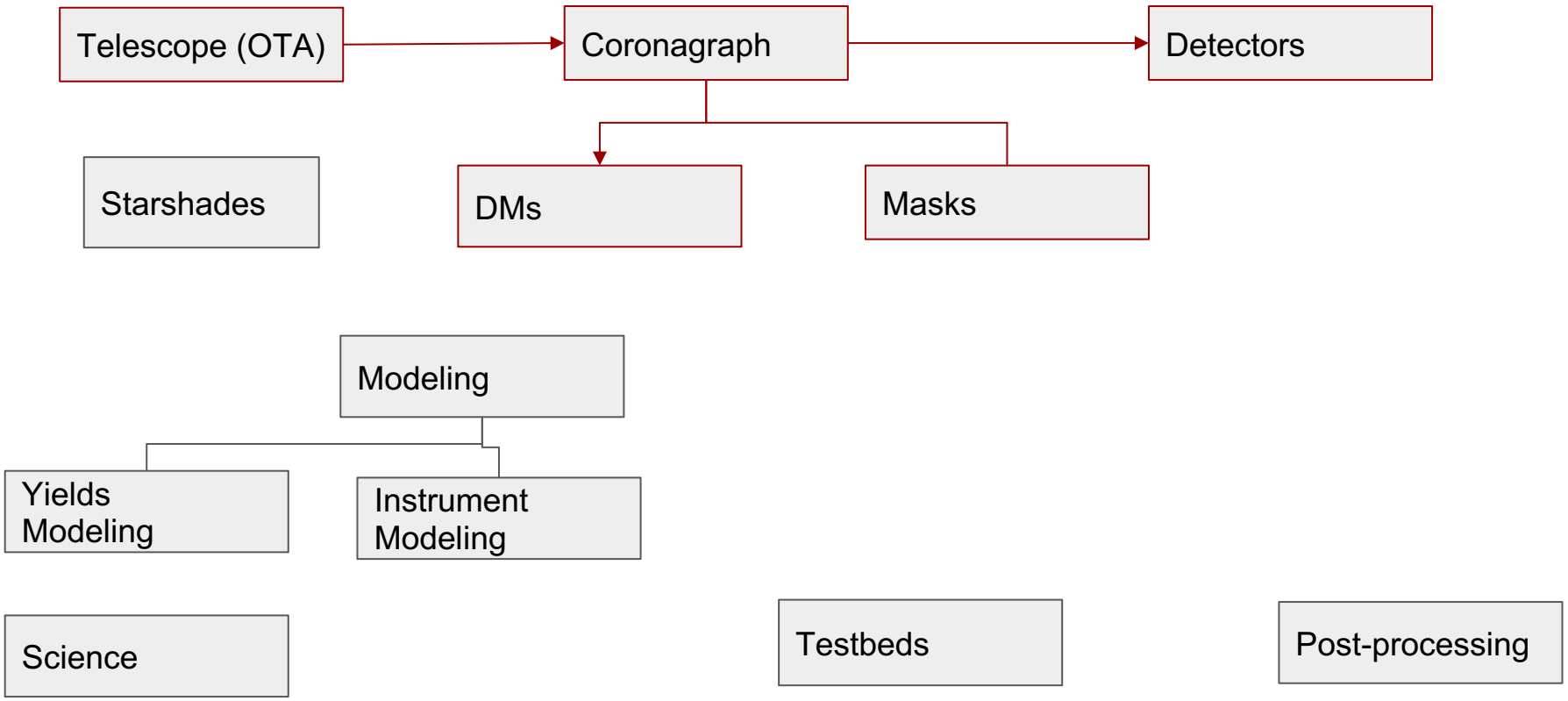








… to the ‘smaller’ pieces



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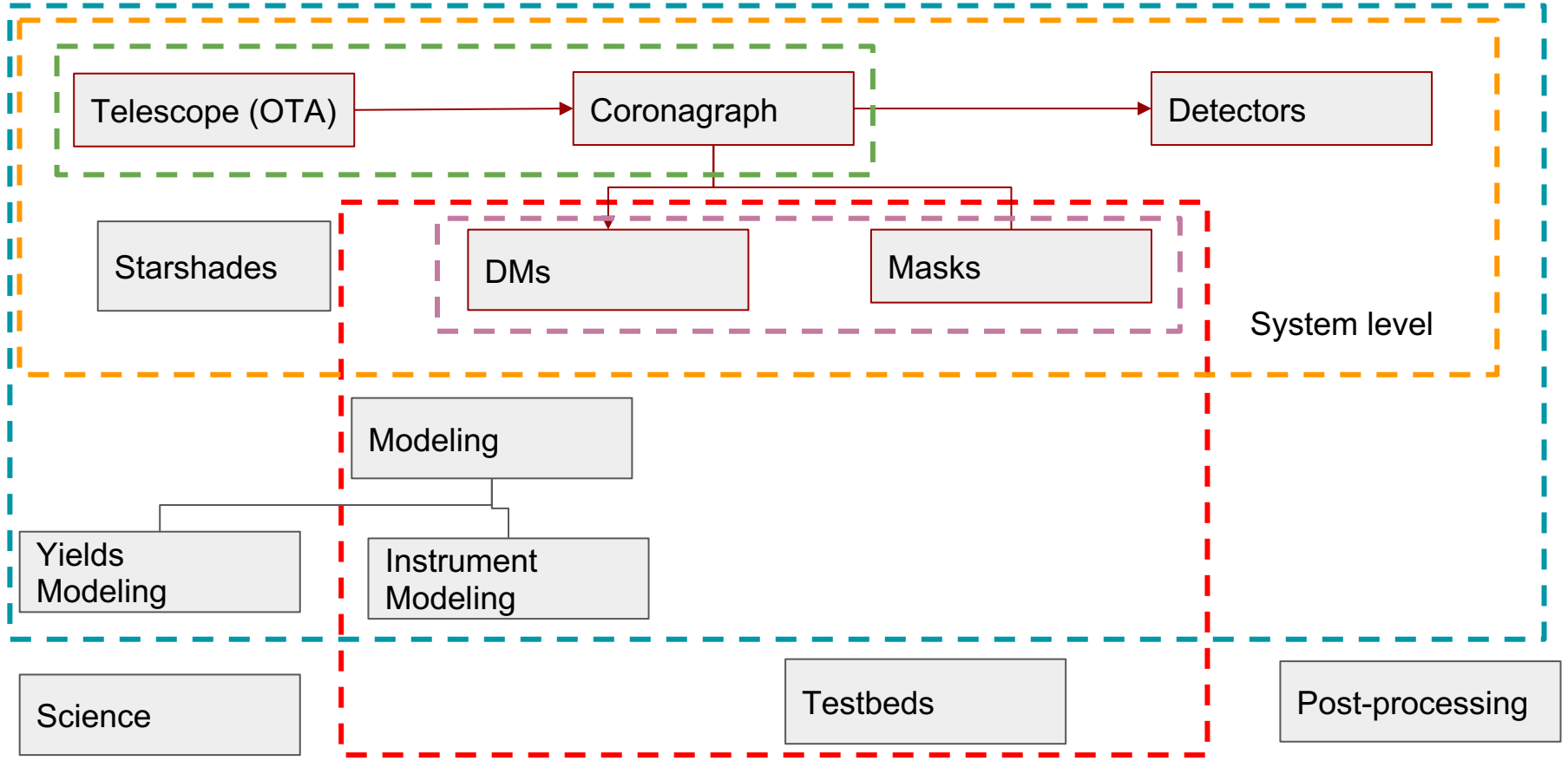
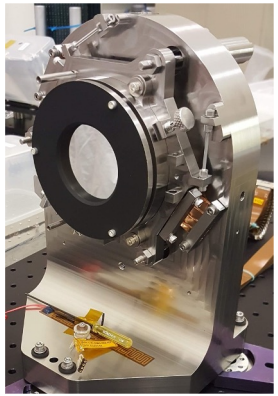
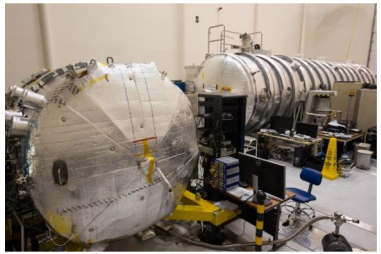


Risks and concerns



- **Coronagraph instrument level**
  - 1e-10 contrast has not been demonstrated yet in the lab
  - DMs:
    - There is no DM device today that can meet the expected HWO wavefront control requirements
    - DMs are the key coronagraph component to achieve the required contrast
    - Lead times can be half a decade to develop and test a new wavefront control device.
    - **Need**: DM technology investment EARLY
  - Coronagraph masks:
    - Coronagraph mask design is challenging, and characterization is required
  - At the moment, deepest demonstrations are for monolithic apertures, followed by obstructed, segmented, and finally obstructed+segmented.



- **Testbeds**
  - Lab demos are in visible band, and UV coronagraphy is more challenging
  - DM quantification error: The minimum step of the actuator is a contrast limitation
  - Mask design and fabrication: occulter ghost
  - Environment can be unstable: testbed jitter
  - Unknown issues: persistence effect from the detector
  - **Need**: coordination across institutions. Directed funding, stable, experienced operator workforce

Risks and concerns

- **Telescope level**
  - **Need:** Further understanding of system sensitivity and stability
  - Coating uniformity requirements across individual segments are unknown
  - Micro-meteoroid impacts (baffle requirement, which adds complexity and affects stability)
  - Deviating from what is known: utilize ‘lessons learned’ early on
  - **Need:** use architecture evaluations derived from modeling and simulation to develop error budgets and specs.

- **System level**
  - Wavefront sensing and control has yet to be demonstrated at a system level
  - HWO-required combination of contrast, bandwidth, IWA has not yet been demonstrated
  - Observatory stability and coronagraph instrument performance are inextricably coupled
  - **Need:** to formalize interplay between observatory stability, coronagraph masks, and DMs
  - **Need**: Novel payloads should use extra margins to avoid painful descopes, and keep key trades open as long as possible

Risks and concerns

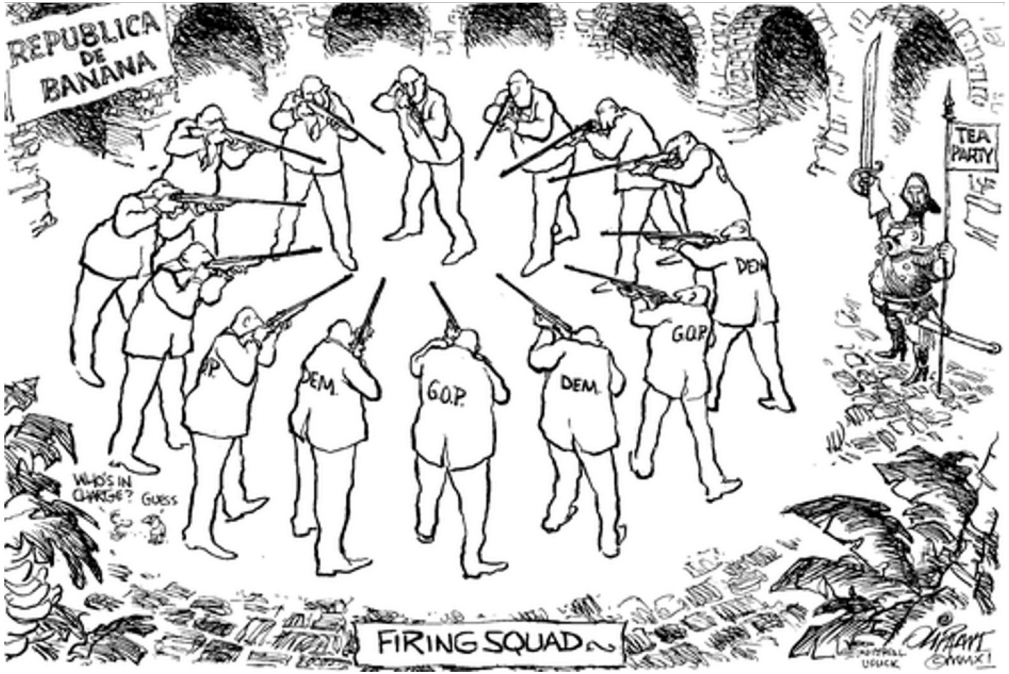
- **Starshades**
  - Full scale demo challenging (does not benefit from Roman CGI heritage as much as coronagraph)
  - Not demonstrated in the UV or NIR, only vis
  - Requires fuel, long slew times -> lower blind search science yield
  - Concerns: edge scatter, micrometeorite impacts, diffuse starlight, contamination (increases solar scatter); optical performance demo & models validated only at subscale, and part of band
  - **Need**: Improving fidelity of demonstrations. Demos for larger size would build further confidence.

- **Instrument modeling**
  - Full end-to-end models take a long time.
  - **Need** an analytical / semi-analytical / streamlined models for rapid turnarounds during trades
  - Need: close the loop with testbeds to validate models

- **Science**
  - Coronagraph performance is complex and trade space is coupled
  - **Need:** DRMs and uniform assumptions to avoid biases in yields
  - Should do wavelength optimization – can increase yields by 50%

	Top Risk / Concern	Top Opportunity
Telescope	Stability (also, UV coatings)	Can relax telescope stability requirements by making instrument more robust (esp. by by WFC, calibrations)
Coronagraph	1e-10 contrast has not been demonstrated in the lab (although can potentially relax this requirement)	Improvements in efficiency can mitigate telescope and science risks Photonic chips are a promising emerging technology
DMs / WFC	No DM device today that can meet the expected HWO wavefront control requirements	Early investments allow better testbed progress (and are necessary for that)
Detectors	Detector noise for spectroscopy (esp. in UV)	Energy-resolving detectors improve yield, automatically provide spectra
Modeling	Models not validated below 1e-9 Full end-to-end models take a long time to run	Investments in even better modeling: will allow reducing MUFs and thus lower mission cost; more rapid progress in testbeds
Testbeds	Getting to 1e-10 requires mitigation of many limiting factors simultaneously	Directed funding, stable experienced workforce is key to accelerating testbed progress
Starshades	Full-scale demo is challenging (does not benefit from CGI heritage)	Starshade enables better spectral characterization; backup/add-on
Science	We don't know what the science landscape is going to be in 20 years (and making sure HWO is competitive with ground in 2040)	By building the best observatory we can, we can be well-prepared to answer those questions
Programmatic	GOMAP funding is not yet available Unclear requirements; locking decisions too early	Invest in early and thorough trade studies, (analyzing specific requirements without worrying yet that they could be wrong)
System-level	Analyzing sub-systems separately rather than a system; Coronagraph performance is complex and trade space is coupled	Relax telescope requirements and cost by making instrument more powerful
Political	Getting everyone to agree	

Chas Beichman's assessment of our community, circa 2009



The opposite of a simple truth is a falsehood,

but the opposite of a great truth may be another great truth

– Niels Bohr

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Political	~~Getting everyone to agree~~	Diversity of opinions, managed properly, leads to a better mission