

# HABITABLE WORLDS OBSERVATORY

## *TECHNOLOGY DEVELOPMENT PLAN*

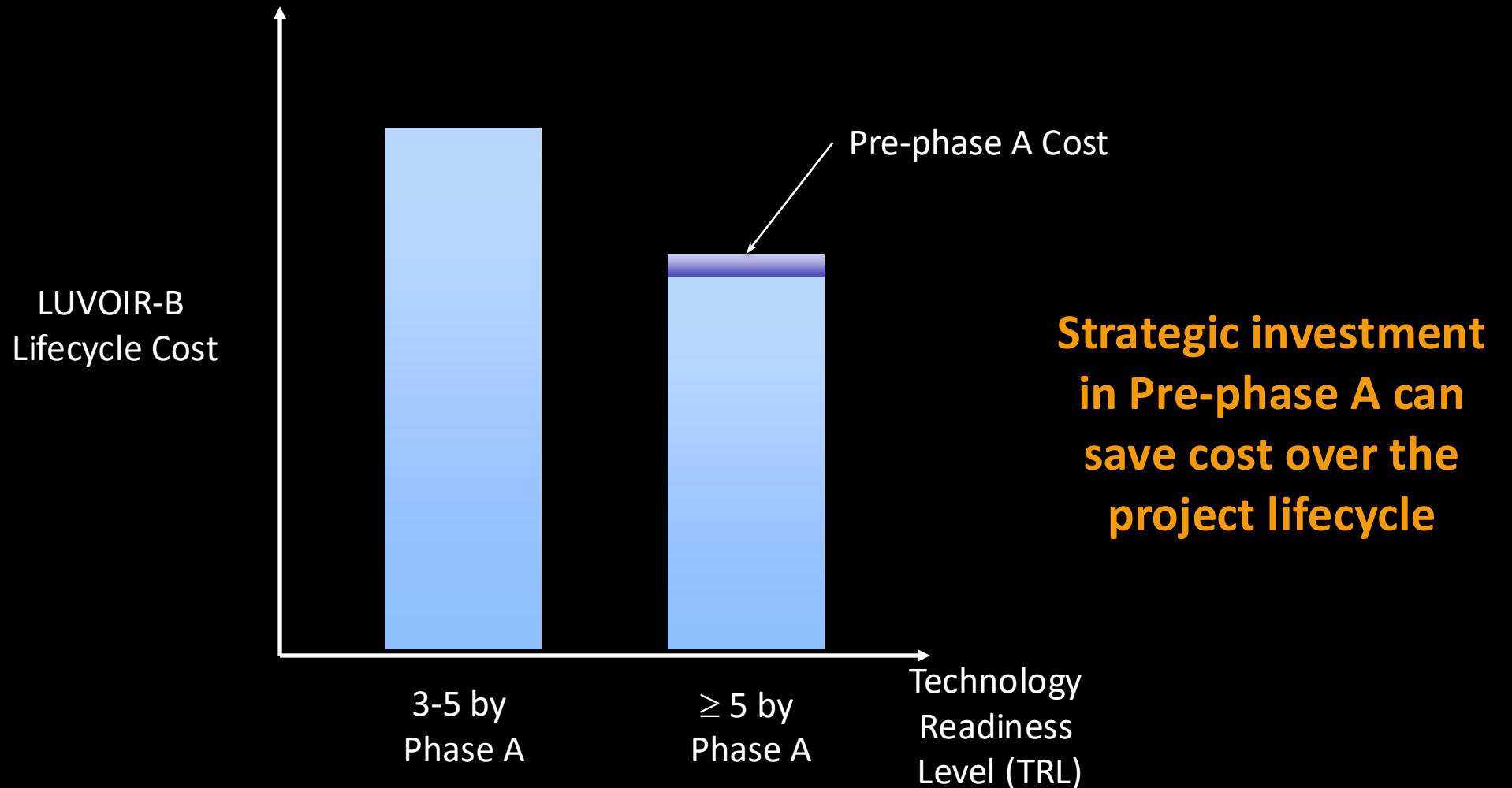
*2025 July 29*

*HWO25 – Towards the Habitable Worlds Observatory:  
Visionary Science and Transformative Technology*

*Matthew R. Bolcar (GSFC), Feng Zhao (JPL), Paul Scowen (GSFC), and many others...  
HWO Technologists*

H A B I T A B L E  
W  R L D S  
O B S E R V A T O R Y

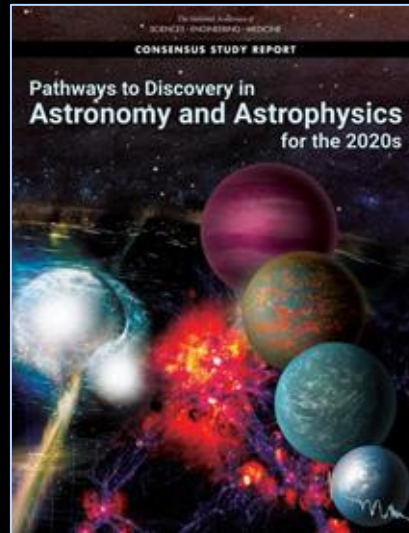
# EARLY TECHNOLOGY DEVELOPMENT SAVES MONEY



# A NEW APPROACH TO DEVELOPING FLAGSHIP MISSIONS

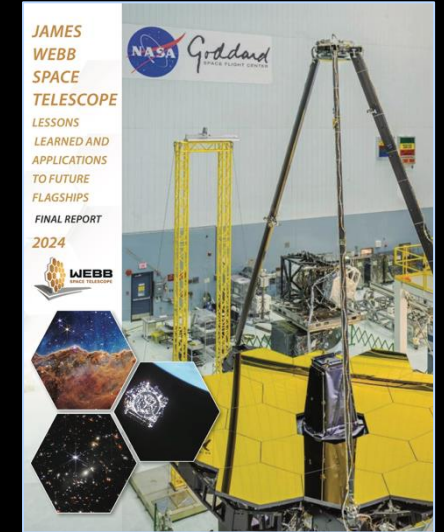


*“Recommendation: Move the current NASA TRL standard to the left for large missions...achieve TRL 6 by Mission Definition Review...”*



*“Prior to commencing mission formulation, a successful Great Observatories Mission and Technology Maturation program must be completed...”*

*“Mature the architecture and technology fully before starting the development phase...”*



**Roman Space Telescope demonstrates: When architected for success, flagship missions can deliver on cost and schedule**

# ROBUST, STRATEGICALLY EXECUTED TECHNOLOGY DEVELOPMENT...



...demonstrates technical feasibility,

...reduces overall programmatic risk,

***...and enables transformative scientific discovery with HWO.***

# WE'VE DEFINED A ROBUST, STRATEGIC TECHNOLOGY DEVELOPMENT PLAN FOR HWO



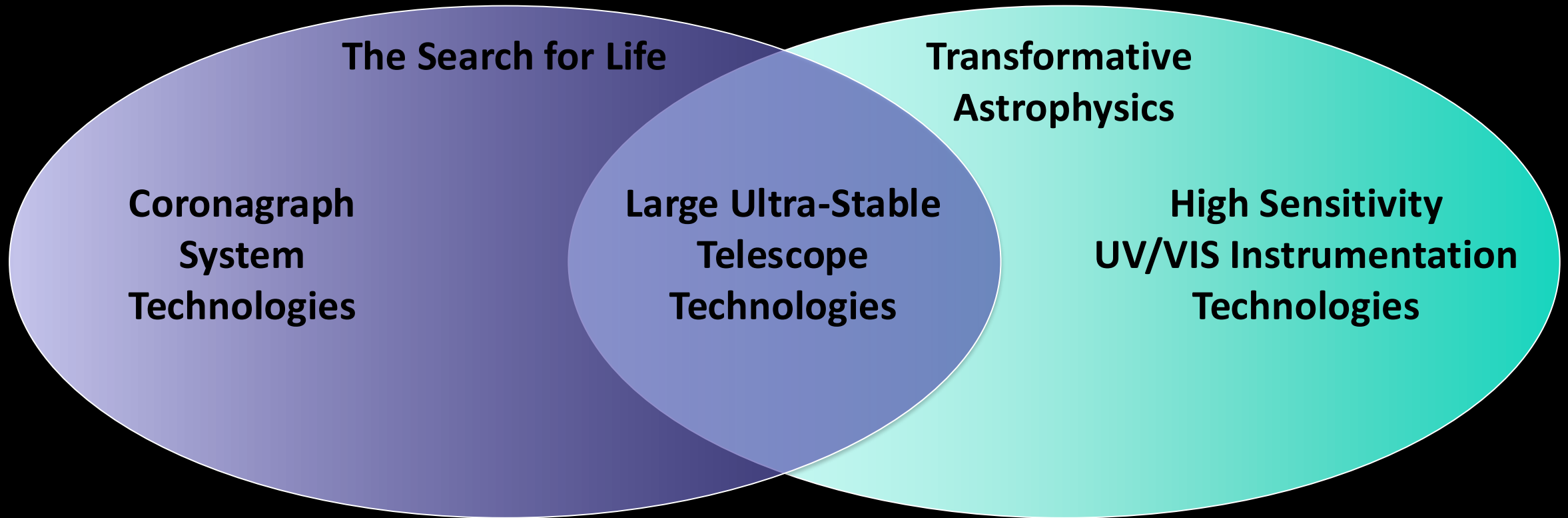
- ✓ Identified technology and engineering gaps in formulating and implementing HWO
- ✓ Defined roadmaps, milestones, and success criteria to close those gaps
- ✓ Scoped the cost, schedule, and human resources needed to implement the plan
- Poised to execute *and evolve* the plan

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# TECHNOLOGY NEEDS ARE INFORMED BY SCIENCE AND ARCHITECTURE



***Three Technology Tracks aligned to the system architecture.***

# TECHNOLOGY LANES FURTHER IDENTIFY INDIVIDUAL GAPS



## Coronagraph System Technologies

- Starlight Suppression
- Deformable Mirrors
- Contrast Stabilization
- Low-noise Detectors
- Spectroscopy
- Near-UV Capability
- Post-Processing

## Large Ultra-Stable Telescope Technologies

- Ultra-stable Mirrors
- Ultra-stable Structures
- Thermal Control System
- Sensing & Control
- Low-Disturbance Systems
- Deployable Systems

## High Sensitivity UV/VIS Instrumentation Technologies

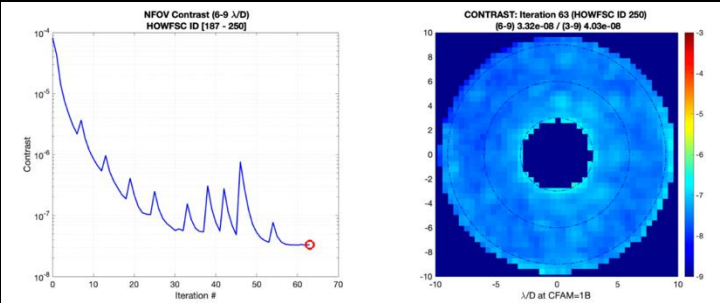
- Far-UV Mirror Coatings
- Near-UV / VIS Detectors
- Far-UV Detectors
- Multi-object / Integral  
Field Spectroscopy
- UV Gratings & Filters

***Recent progress has advanced the state-of-the-art across all tracks.***

# ROMAN CGI ESTABLISHES THE STATE-OF-THE-ART FOR HIGH-CONTRAST IMAGING

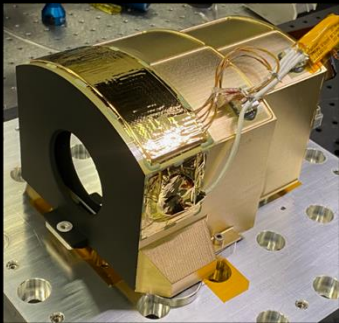


NASA/C. Gunn

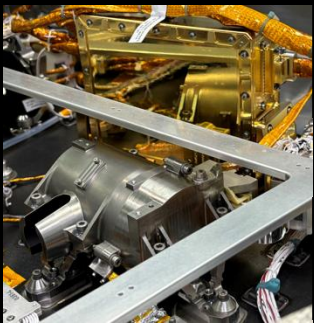


$4.0 \times 10^{-8}$   
Raw Contrast  
3-9  $\lambda/D$

48 x 48  
Deformable  
Mirror

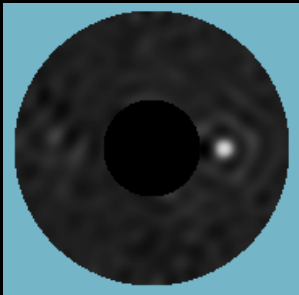


Proximity  
Electronics



Camera  
Body

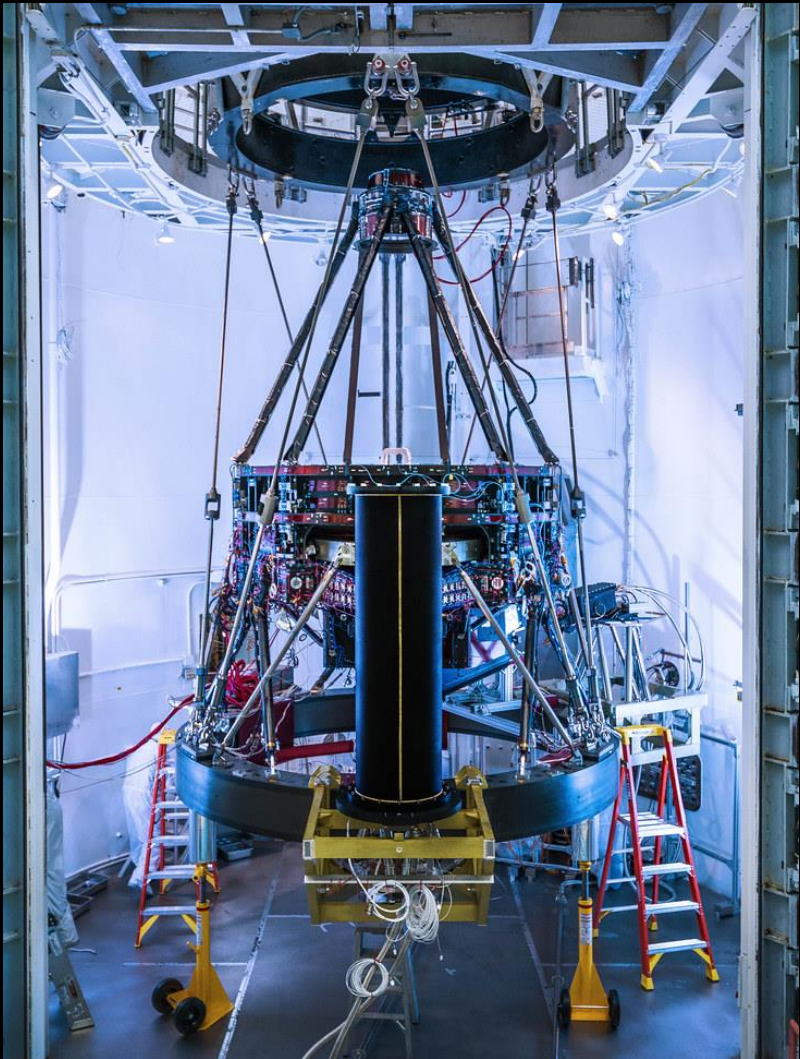
Ref Star    Target Star    Target Star - Roll



After Post Processing:  
Contrast Floor =  $3.94 \times 10^{-9}$

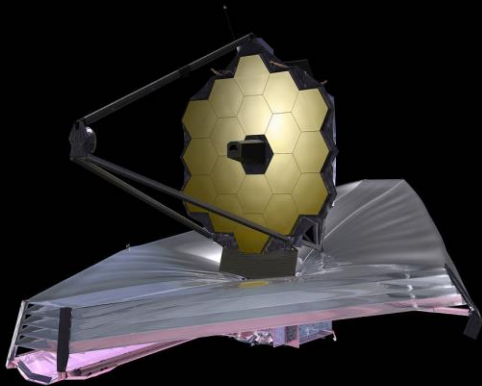
CGI/JPL

# WEBB AND ROMAN DEMONSTRATE EXCEPTIONAL STABILITY

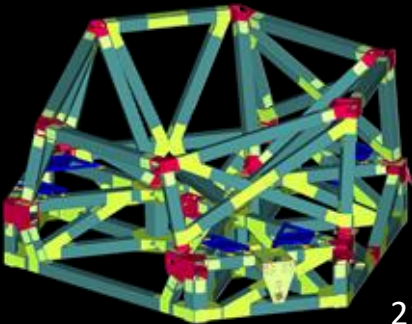


NASA/C. Gunn

Roman Telescope demonstrates 10s of picometer wavefront error stability.

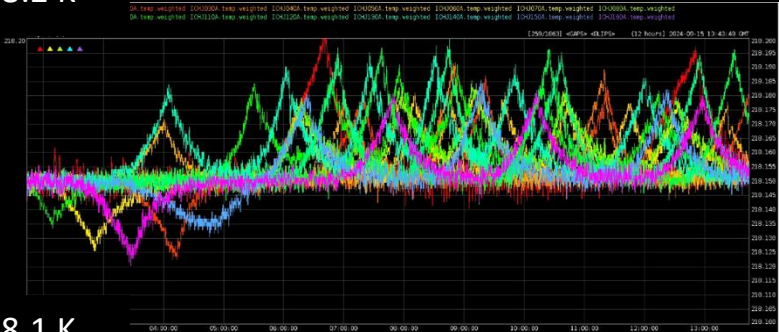


JWST exhibits extraordinary on-orbit stability.



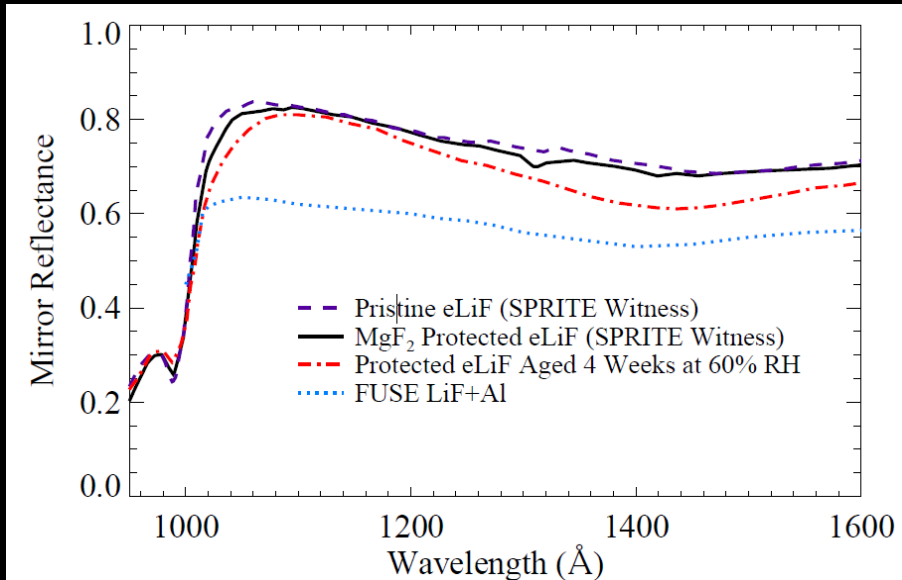
218.2 K

218.1 K

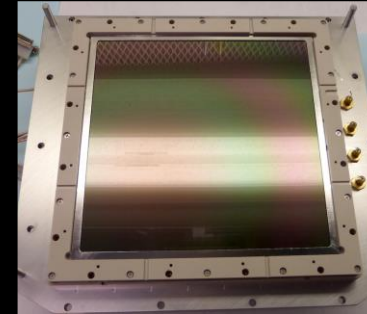


Roman Instrument Carrier achieves 10 mk stability

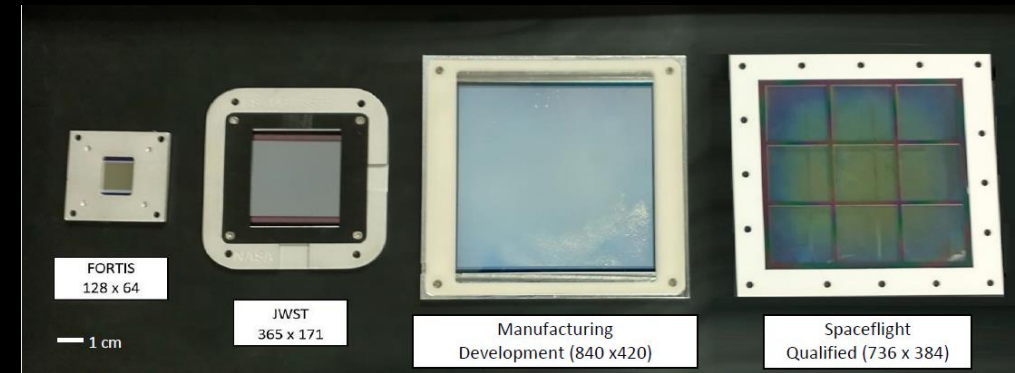
# CUBESATS AND SOUNDING ROCKETS LEAD THE WAY FOR UV INSTRUMENTATION



SPRITE CubeSat Mirror Coating



20x20 cm Micro-channel Plate for DEUCE Sounding Rocket



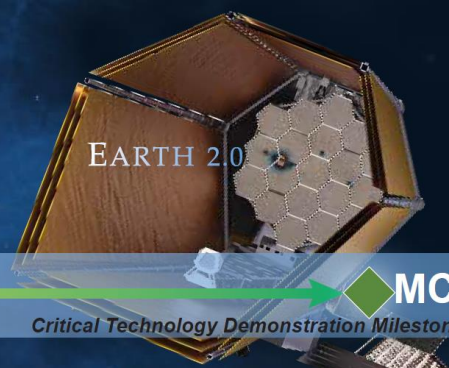
FORTIS & JWST microshutters (left)  
with next gen devices (right)

See: Tuttle, et al. 2024 for comprehensive review of state-of-the-art.

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2025

Coronagraph Testbeds Available For Use

Keck Sensing & Control Demo

Ultra-stable & System Testbeds Available For Use

Critical Technology Demonstration Milestone

MCR

## Ultra-stable Telescope System



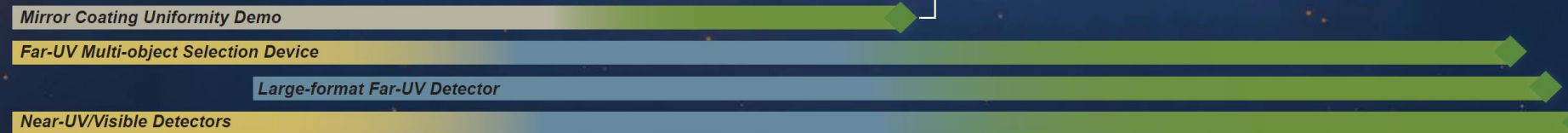
*Leverage expertise and leadership of our industry partners.*

## Coronagraph System



*Use new and existing testbeds at multiple institutions*

## High-Sensitivity UV & Instrument Technologies



*Develop through strategic directed and competed investments.*

## Emerging Technologies

- Artificial Intelligence
- Quantum Imaging and Quantum Sensors
- Photonic and Metamaterials

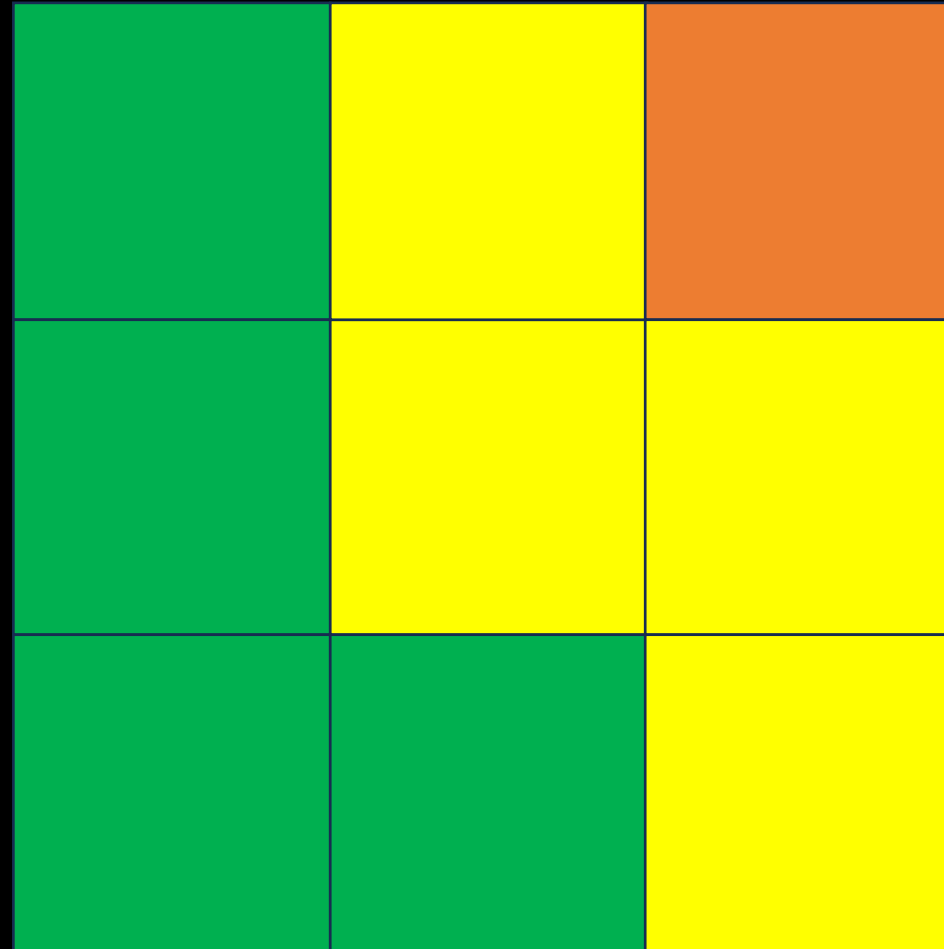
Currently Funded	Development / Fabrication
Design and Analysis	Characterization / Demonstration

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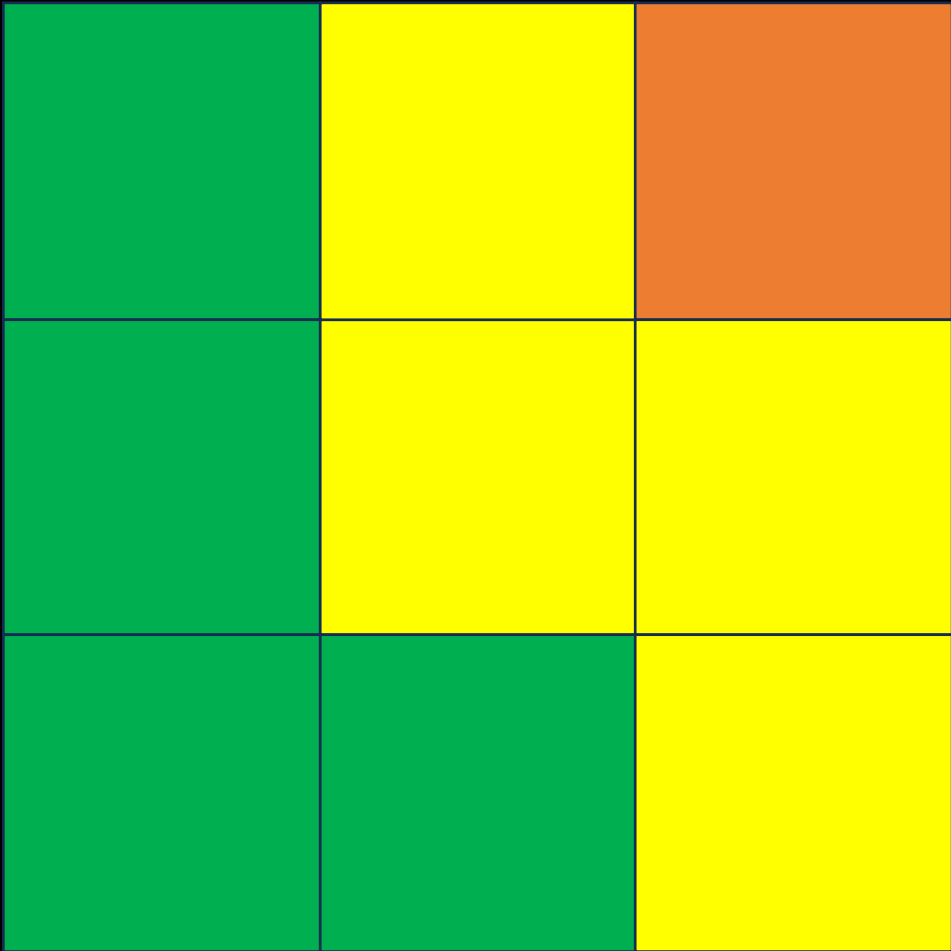
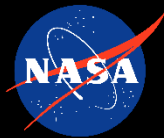


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# PRIORITIZING GAPS HELPS FOCUS LIMITED RESOURCES

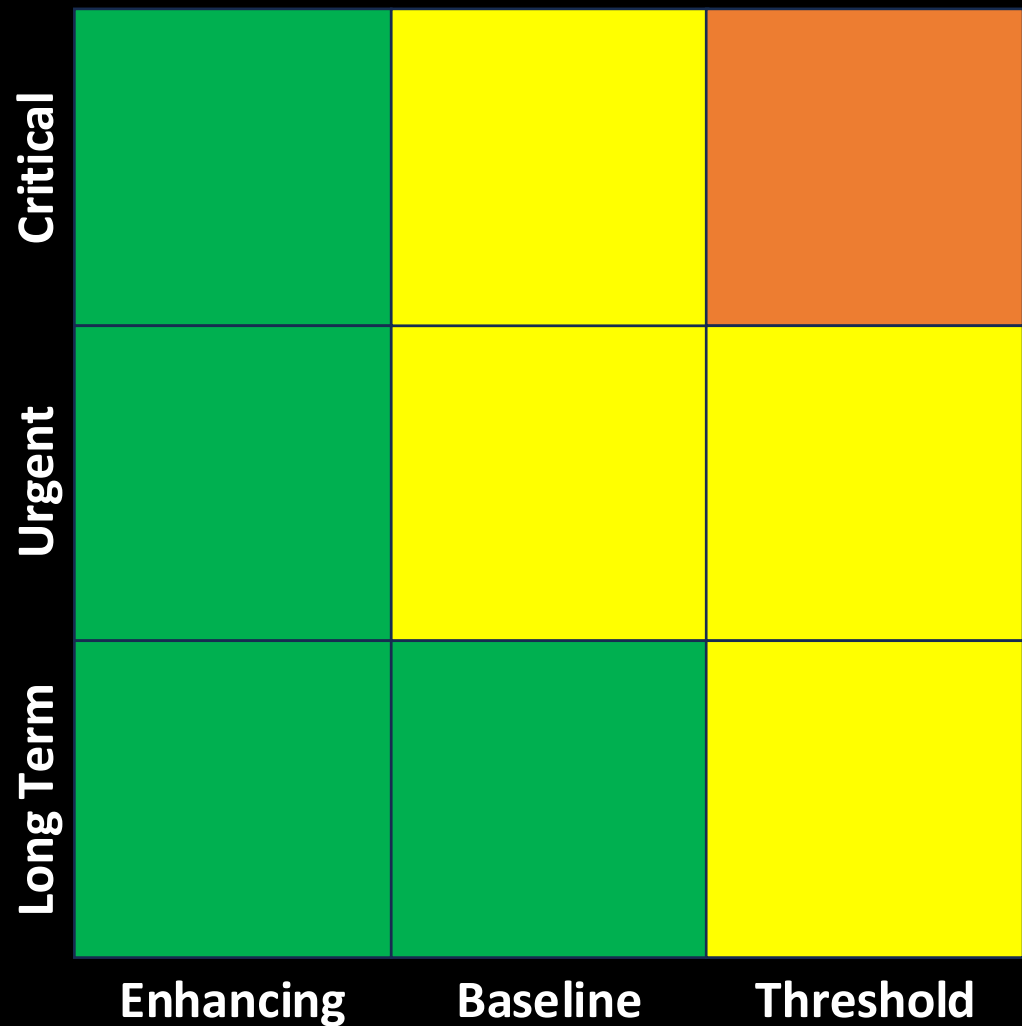


# PRIORITIZING GAPS HELPS FOCUS LIMITED RESOURCES



*Ranks how enabling  
the technology is to  
HWO Mission*

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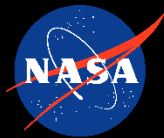


*Ranks how urgently  
the technology needs  
to be demonstrated to  
inform the HWO  
design.*



Critical	T19		T1, T2, T8, T11
Urgent	T22, T23	T7, E15, E16, T17	T3, T4, E6, E9, E10, T14
Long Term	T20, T21	E18	E5, T12, E13
	Enhancing	Baseline	Threshold

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Critical	Urgent	Long Term	Enhancing	Baseline	Threshold
			T19		T1, T2, T8, T11
			T22, T23	T7, E15, E16, T17	T3, T4, E6, E9, E10, T14
			T20, T21	E18	E5, T12, E13

Contrast, Contrast Stability,  
Ultra-stable Mirrors,  
Sensing & Control

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Critical Urgent Long Term	Enhancing	Baseline	Threshold
	T19		T1, T2, T8, T11
	T22, T23	T7, E15, E16, T17	T3, T4, E6, E9, E10, T14
Long Term	T20, T21	E18	E5, T12, E13

Other Coronagraph &  
Ultra-stable Telescope  
Technologies  
*Plus*  
Far-UV Coatings

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Critical Urgent Long Term	Enhancing	T19		T1, T2, T8, T11
		T22, T23	T7, E15, E16, T17	T3, T4, E6, E9, E10, T14
		T20, T21	E18	E5, T12, E13
		Enhancing	Baseline	Threshold

UV/VIS Detectors,  
Gratings, Filters, and  
Spectroscopy  
*Plus*  
NUV High-Contrast  
Capability

# PRIORITIZING GAPS HELPS FOCUS LIMITED RESOURCES



Superconducting Detectors	Critical   Urgent   Long Term	T19		T1, T2, T8, T11
Photonics		T22, T23	T7, E15, E16, T17	T3, T4, E6, E9, E10, T14
Artificial Intelligence		T20, T21	E18	E5, T12, E13
Quantum Sensors				
Meta Surfaces				
		Enhancing	Baseline	Threshold

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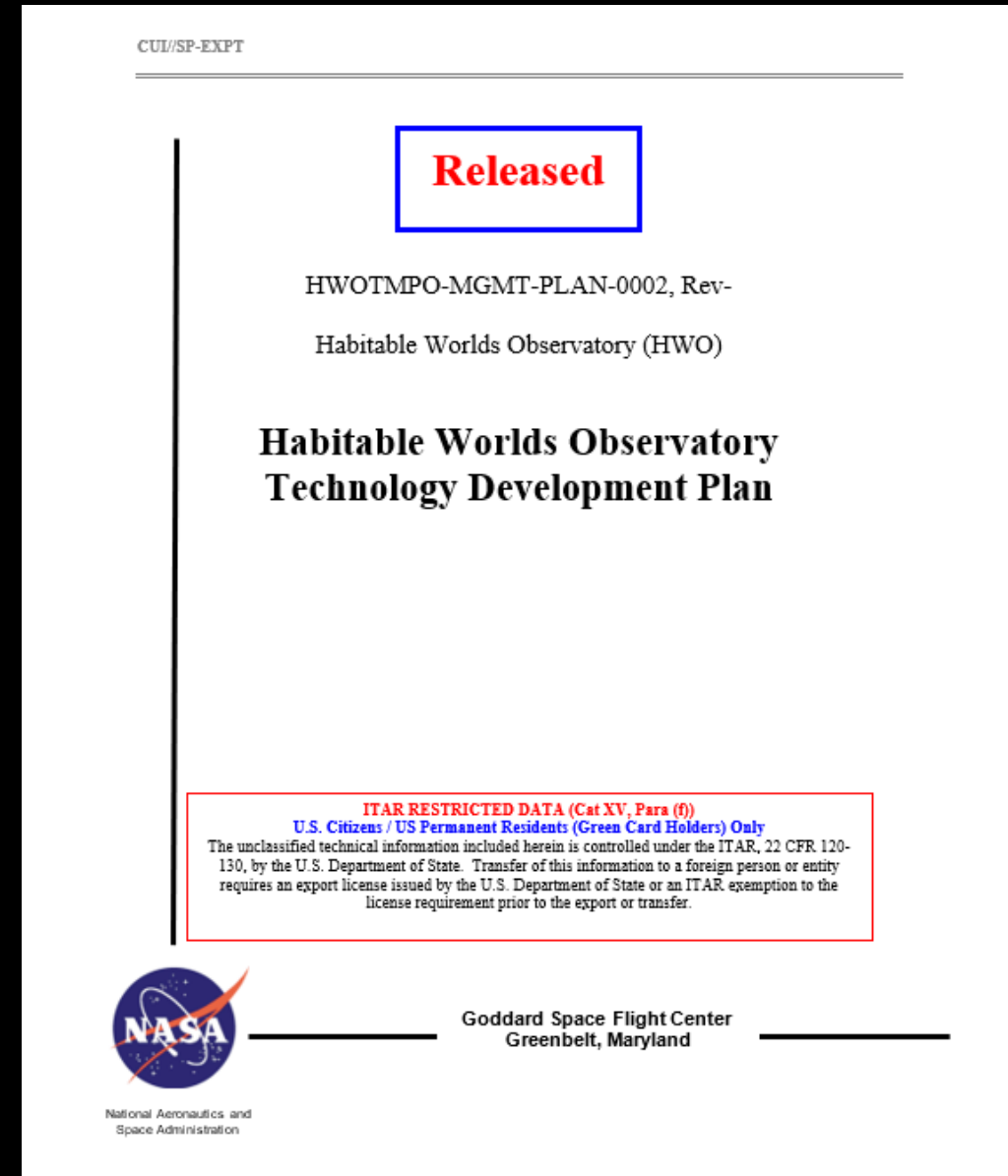
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# OUR TECHNOLOGY DEVELOPMENT PLAN HAS BEEN DELIVERED TO NASA HQ

110 pages detailing the process, state-of-the-art, and path forward

Public version is being prepared as a SPIE  
*JATIS* Special Issue article

Internal version will be a “living document”  
that will evolve with our plan





*Our Technology Plan is in place.*

*We have a risk-based process to evolve that plan in response to challenges.*

*Our critical technologies continue to advance  
to enable HWO's transformative scientific discovery.*

