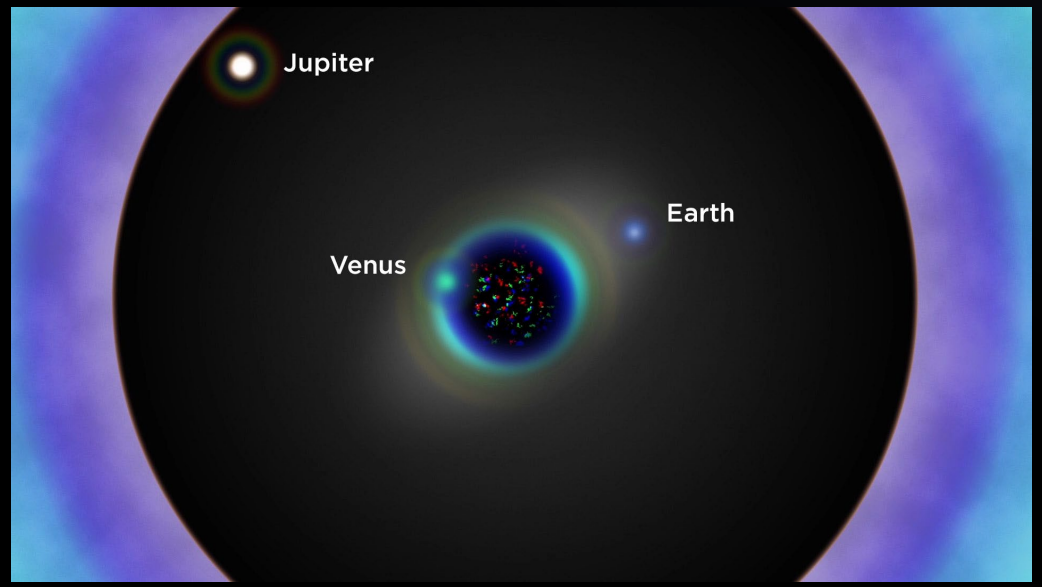
Habitable Worlds Observatory

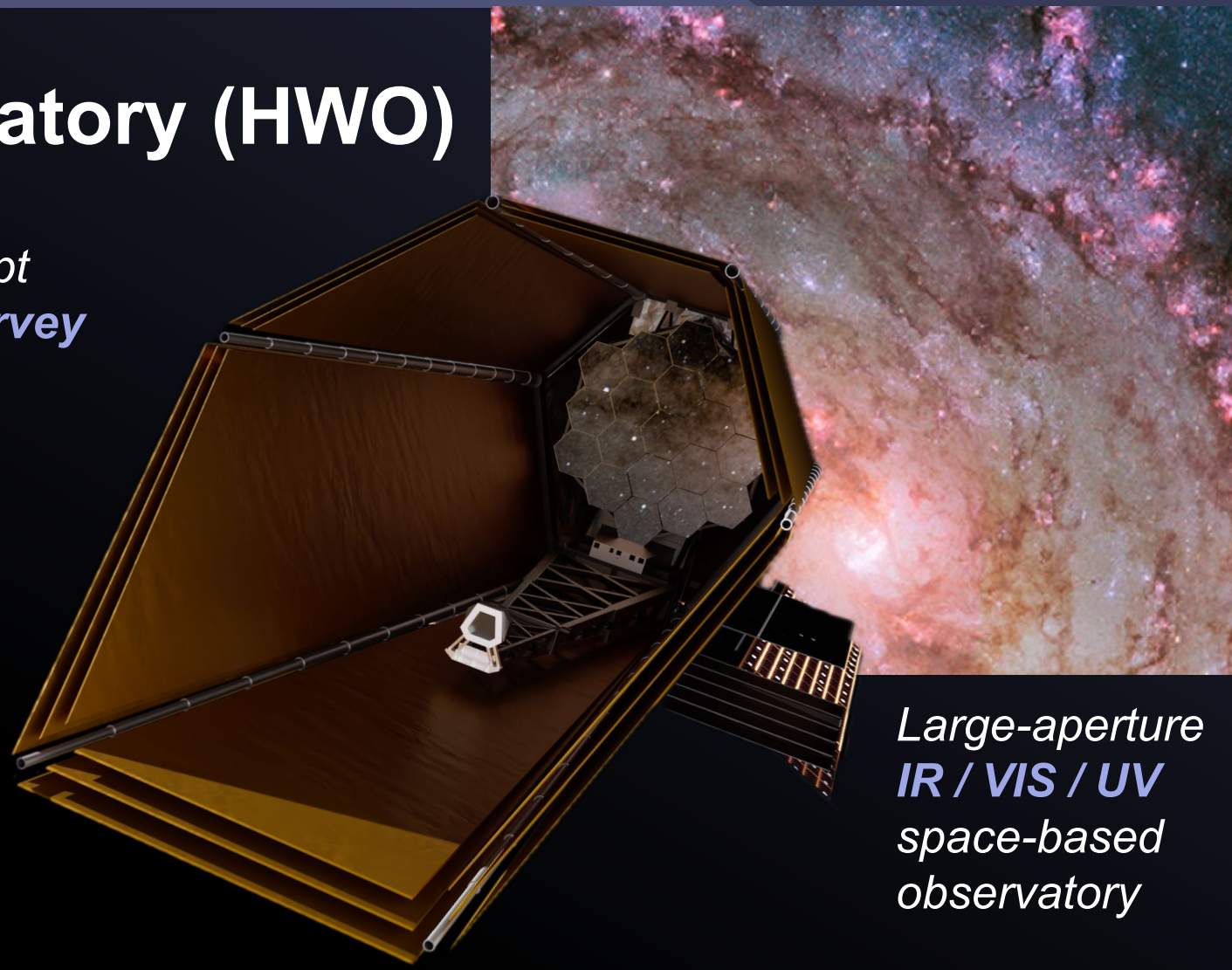
Know Thy Star, Know Thy Planet 2

Joshua Pepper
HWO Deputy Program Scientist, NASA HQ

Habitable Worlds Observatory (HWO)

*NASA **astrophysics flagship** mission concept recommended by the Astro2020 **Decadal Survey***





*Large-aperture **IR / VIS / UV** space-based observatory*

First space telescope** designed to **search for signs of life** on planets outside our solar system & will perform **transformative astrophysics

Implementing Lessons Learned for Large Missions

Independent Research Papers *Mission Concept Reports* *GAO Report on Major Projects* *NASA SMD Internal Studies* *National Academy Reports*

Challenges and Potential Solutions to Develop and Fund NASA Flagship Missions

Robert E. Bitten
The Aerospace Corporation
2310 E. El Segundo Blvd.
El Segundo, CA 90245
310-336-1917
robert.e.bitten@aero.org

Stephen A. Shinn
NASA Goddard Space Flight Center
8800 Greenbelt Road
Greenbelt, Maryland 20771
301-286-5894
stephen.a.shinn@nasa.gov

Debra L. Emmons
The Aerospace Corporation
2310 E. El Segundo Blvd.
El Segundo, CA 90245
310-418-7892
debra.l.emmons@aero.org

Abstract—Large, strategic "Flagship" missions have unique characteristics that lead to challenging developmental difficulties for the National Aeronautics and Space Administration (NASA). Missions such as the Hubble Space Telescope (HST), James Webb Space Telescope (JWST), and the Mars Science Laboratory (MSL) had technical and programmatic challenges that led to significant schedule delays and subsequent cost growth. Although NASA has instituted policies that have reduced cost growth for more "typical" NASA science missions, NASA Flagship missions remain a distinct challenge due to their requirement to provide unprecedented science or tackle bold exploration goals, typically while concurrently developing new technologies. The unique challenges presented by Flagship missions make it extremely difficult to fully predict cost and schedule given that the technical and programmatic advances needed to meet performance requirements are unprecedented. This paper addresses why Flagship missions are unique and proposes a new programmatic approach to develop and fund Flagship missions.

TABLE OF CONTENTS

1. DEFINITION OF FLAGSHIP MISSIONS 1
2. BENEFITS OF FLAGSHIP MISSIONS 2
3. DIFFICULTY IN ESTIMATING FLAGSHIPS 2
4. FLAGSHIP COST GROWTH 3
5. COULD COSTS HAVE BEEN ANTICIPATED? 7
6. A POTENTIAL NEW APPROACH 7
7. SUMMARY 10
ACKNOWLEDGEMENTS 10
ACRONYMS 10
REFERENCES 10
BIOGRAPHY 12

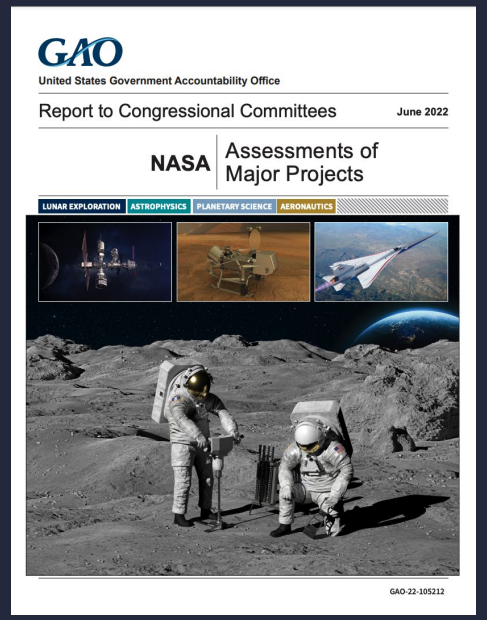
1. DEFINITION OF FLAGSHIP MISSIONS

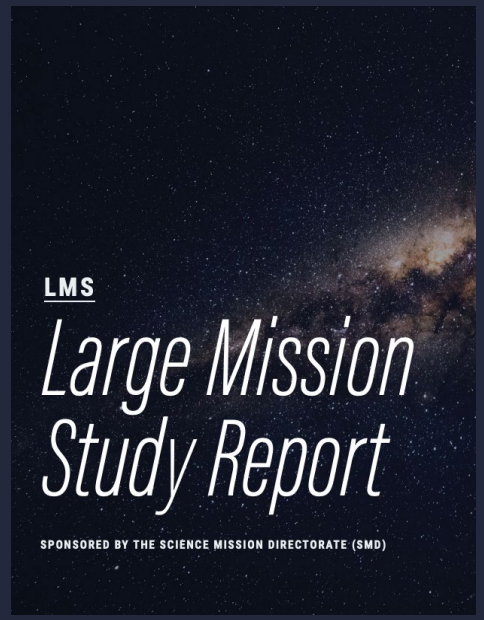
According to Miriam-Webster's Dictionary, a Flagship is: 1) the ship that carries the commander of a fleet or subdivision of a fleet and flies the commander's flag, or 2) the finest, largest, or most important one of a group of things. [1] In many ways, National Aeronautics and Space Administration (NASA) Flagship missions incorporate both of these definitions as they are the most visible because of their potential for scientific discovery and expense and are also the finest, largest, and most important of NASA's science missions. NASA Flagship missions are unprecedented in the science that they enable as they provide exquisite measurements that cannot be done otherwise and typically require new technology or advanced engineering developments to acquire the measurements.

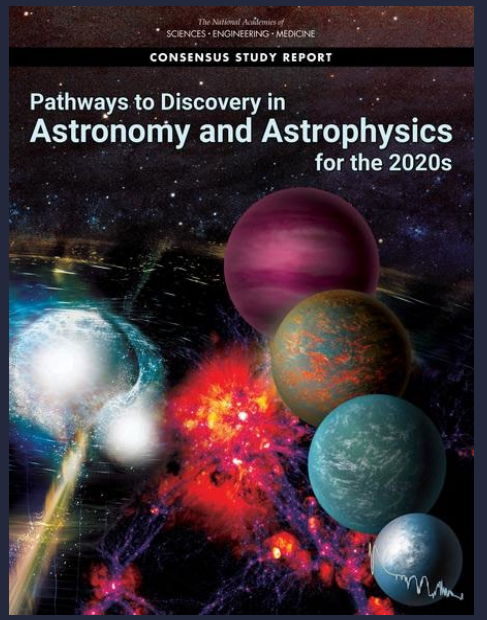
Figure 1 shows typical examples of NASA Flagship missions such as Viking, Galileo, the Hubble Space Telescope (HST), and others relative to their launch date and development cost. As shown in Figure 1, Flagship mission are typically developed on the order of every 10 years and have a cost greater than $2B fiscal year 2017. The development cost is from the start of preliminary development at the beginning of Phase B through launch and is taken from NASA historical public budget documents and then inflated to fiscal year 2017 equivalent dollars (FY17$). [2, 3] The relatively high cost of Flagship missions is due to their significant complexity with examples such as HST, as it was the largest pointable space telescope of its time, and the James Webb Space Telescope (JWST), which is larger than HST and operates at significantly colder temperatures while still meeting unprecedented stability requirements.

Figure 1. NASA Flagship Mission Cost vs. Launch Date

978-1-5386-6854-2/19$31.00 ©2019 IEEE







- ★ Co-develop the mission science, technology, and architecture
- ★ … earlier in the mission concept development phase
- ★ … to a Concept Maturity Level (CML) that allows for more robust assessments of cost, performance, risk

Decadal Survey → Big Picture Strategy

Planned in-space servicing

- Robotic servicing at Sun-Earth L2

Potential for multiple generations of instruments

Evolve technology

- Build upon current NASA investments and TRL-9 technology
- JWST segmented optical telescope system
- Roman coronagraph

Next generation rockets

- Larger telescope aperture sizes
- Leverage opportunities offered by large fairings to facilitate mass & volume trades

Build to schedule

- Mission Level 1 Requirement (e.g., Planetary mission strategy)

Robust margins

- Design with large scientific, technical, & programmatic margins

Mature technologies first

- Reduce risk by fully maturing technologies prior to the development phase

Dr. Mark Clampin, NASA Astrophysics Director, APAC presentation (slide 33) – March 29, 2023

HWO Leadership

Pre-Formulation Project Development Team will encompass a broad group, including members from the former START/TAG JPL, and other NASA Centers

NASA HQ

Program Executive

Julie Crooke

Program Scientist

Megan Ansdell

Deputy Program Scientist

Joshua Pepper

Technology Maturation Project Office (TMPO)

Principal Architect

Lee Feinberg
GSFC

Project Manager *(interim)*

J. Scott Smith
GSFC

Mission System Engineer

Mike Menzel
GSFC

Project Scientist *(interim)*

Giada Arney
GSFC

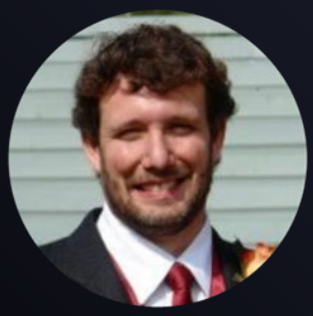
Pre-Formulation Scientist *(interim)*

Aki Roberge
GSFC

Pre-Formulation Scientist *(ex-officio)*

Bertrand Mennesson
JPL

Pre-Formulation Architect *(ex-officio)*

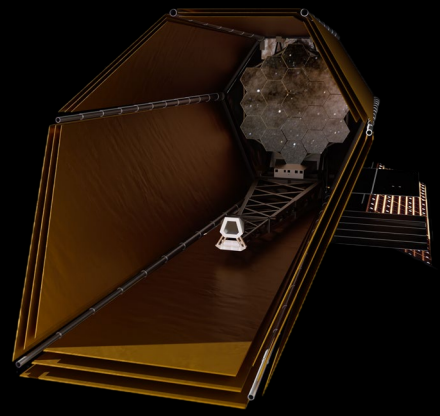


John Ziemer
JPL

HWO Preliminary Specs and Candidate Instruments

Telescope

Diameter	~6.0 m (inner)
Bandpass	~100–2500 nm



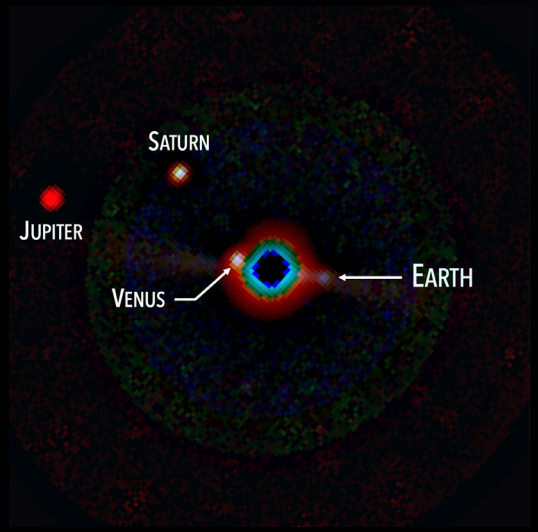
Fourth Instrument

to be defined

Coronagraph

High-contrast imaging and imaging spectroscopy

Bandpass	~200–1800 nm
Contrast	$\lesssim 1 \times 10^{-10}$
	Vis: ~140 NIR: ~70,200



High-Resolution Imager

UV/Vis and NIR imaging

Bandpass	~200–2500 nm
Field-of-View	~3’ x 2’

60+ science filters & grism

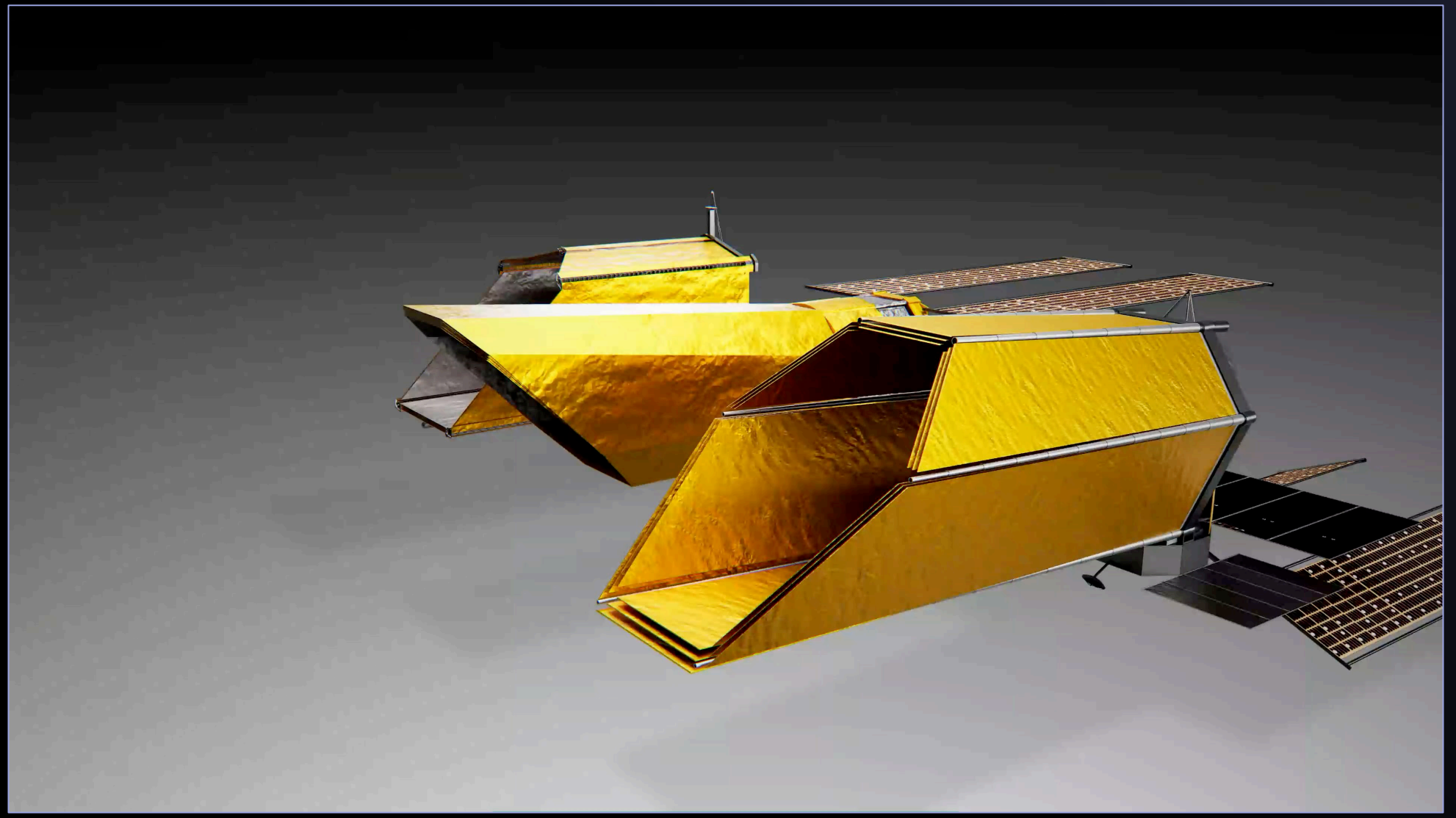
High-precision astrometry?

UV Multi-Object Spectrograph

UV/Vis multi-object spectroscopy and FUV imaging

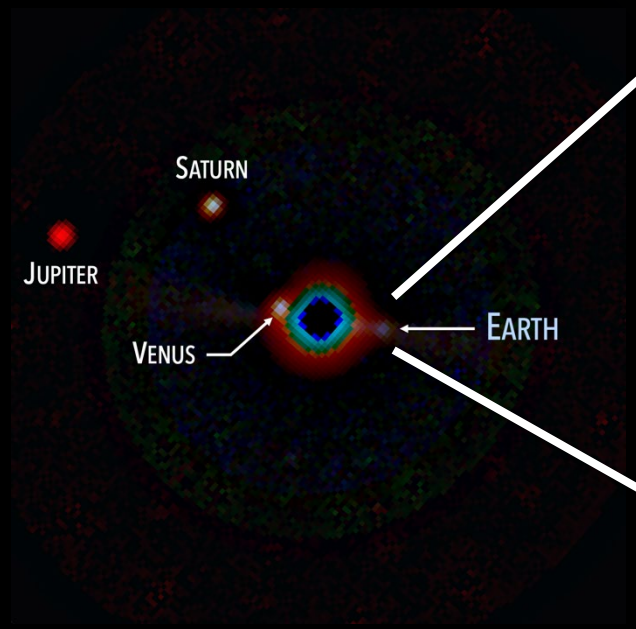
Bandpass	~100–1000 nm
Field-of-View	~2’ x 2’
Apertures	~840 x 420
	~500–60,000

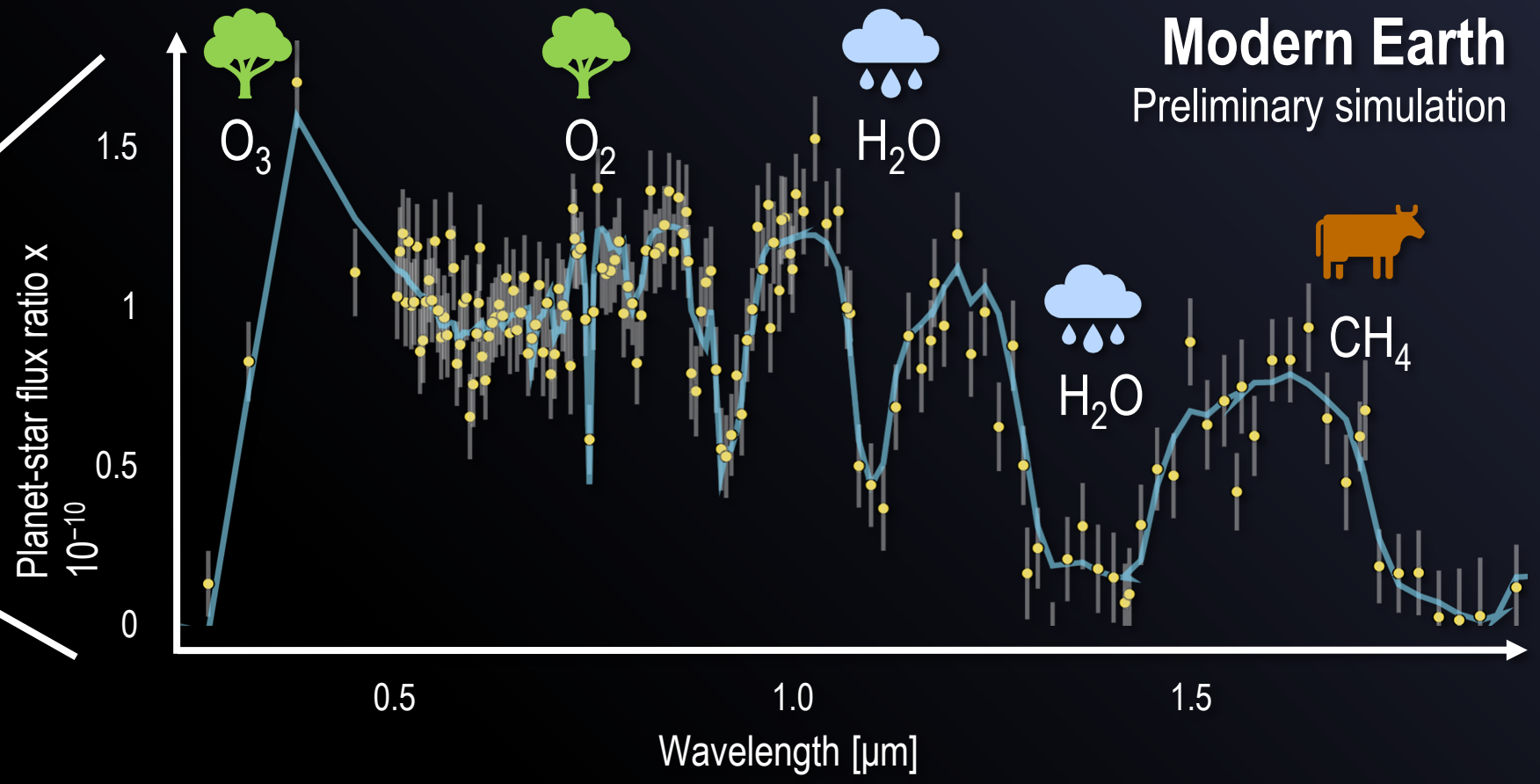
Exploring the Engineering Trade Space



Credit: Lustig-Yaeger (JHU-APL), Robinson (NAU), Arney (NASA GSFC)

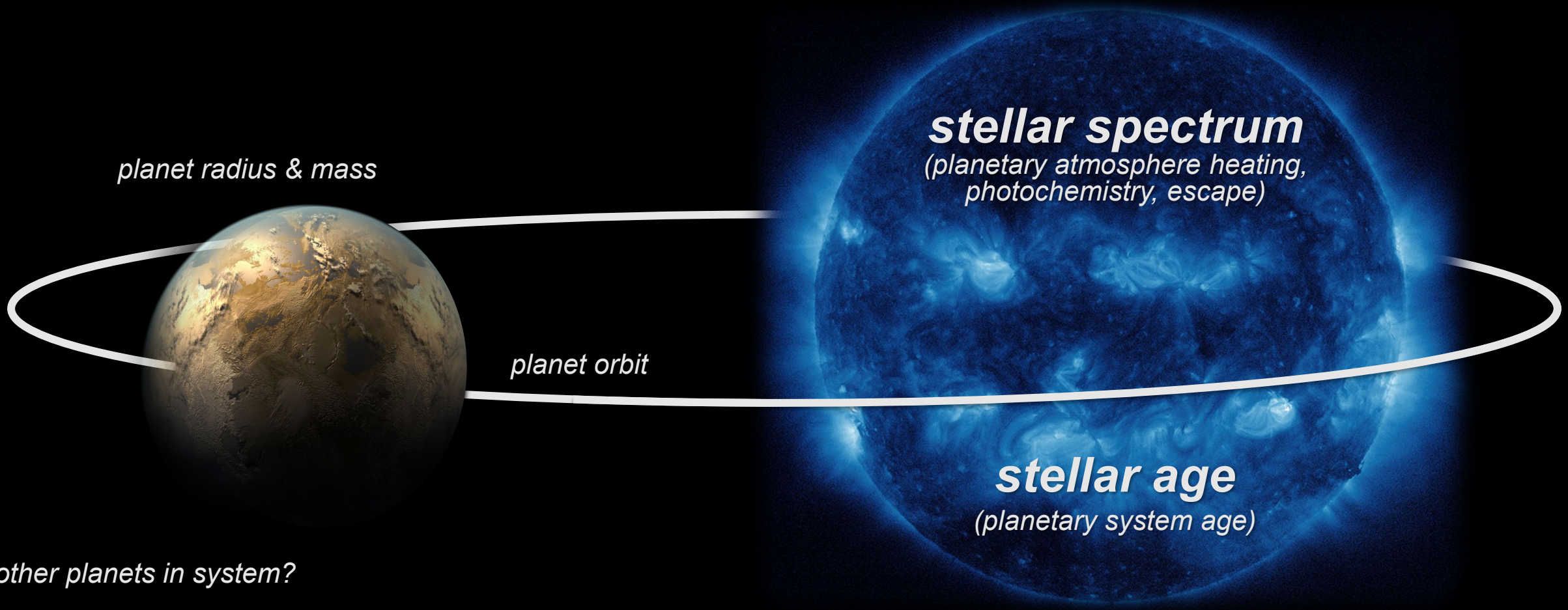
Searching for Global Biospheres





HWO will directly image ~25+ Earth-sized exoplanets in the Habitable Zones around Sun-like stars, suppressing starlight by factors of ~10 billion to obtain exoplanet atmosphere spectra covering multiple potential biosignatures

“Know Thy Star”



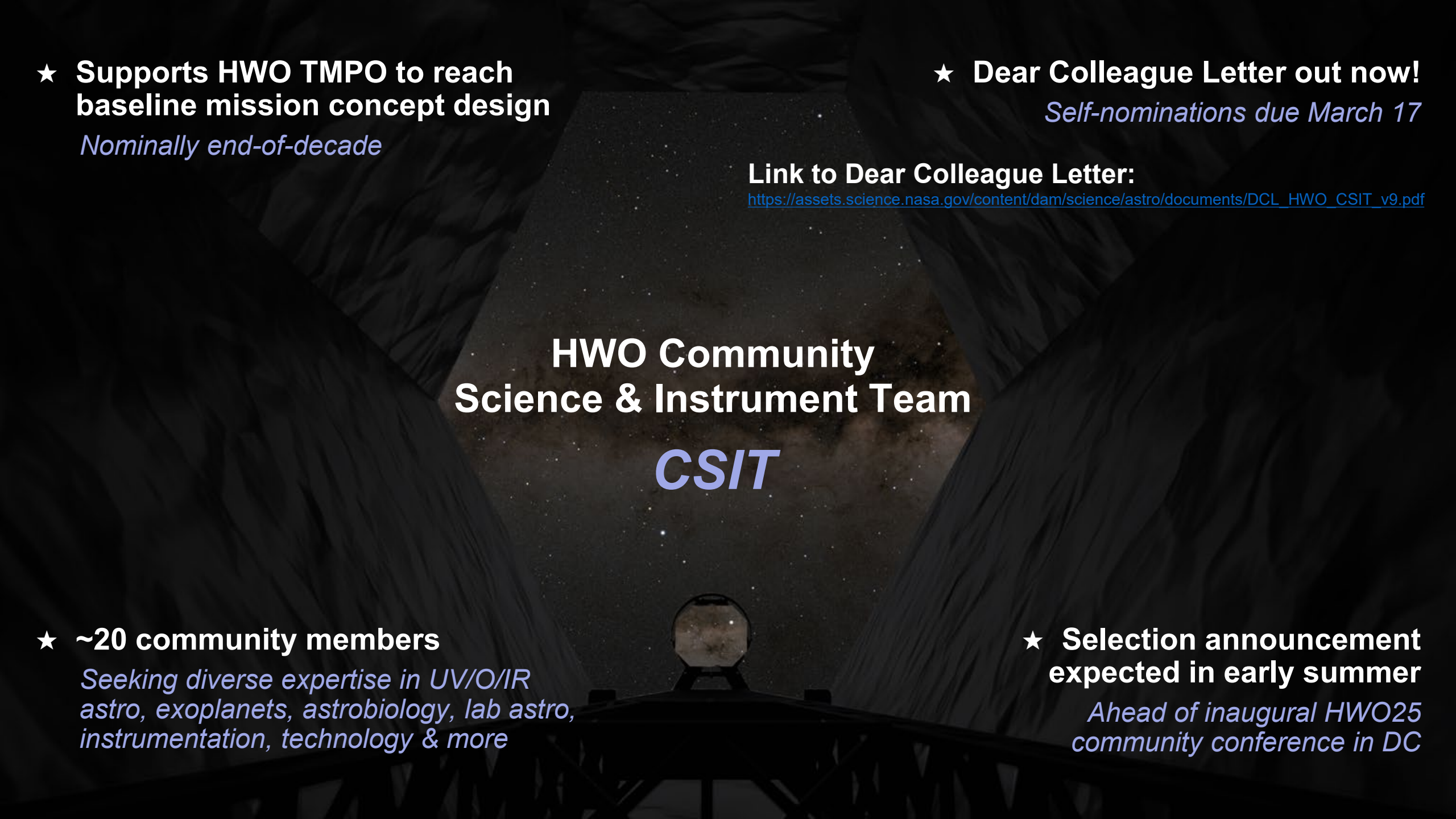
Knowing the stars for the HWO search for life

Are these good target stars for a direct imaging search for HZ terrestrials?

- Stellar types
- Ability to detect small HZ planets (distance, stellar brightness, zodi)
- Other planets / stars in the system
- Ability to measure the planet properties (stellar activity, rotation)

What stellar properties will inform our interpretation of the exoplanets, especially biosignatures?

- Bulk system properties (age, overall dynamics)
- Stellar properties that affect planet property measurability (everything?)



★ **Supports HWO TMPO to reach baseline mission concept design**

Nominally end-of-decade

★ **Dear Colleague Letter out now!**

Self-nominations due March 17

Link to Dear Colleague Letter:
https://assets.science.nasa.gov/content/dam/science/astro/documents/DCL_HWO_CSIT_v9.pdf

HWO Community Science & Instrument Team

CSIT

★ **~20 community members**

Seeking diverse expertise in UV/O/IR astro, exoplanets, astrobiology, lab astro, instrumentation, technology & more

★ **Selection announcement expected in early summer**

Ahead of inaugural HWO25 community conference in DC

HWO Community Science & Instrument Team (CSIT)

★ CSIT Activities

- *Execute scientific studies to support baseline concept definition*
- *Analyze potential science instruments*
- *Provide input to HWO TMPO's technology development plans*
- *Serve as ambassadors for broader sci/tech communities*

★ CSIT Selection Process

- *Self-nomination packages due March 17, 2025*
- *Independent reviewers evaluate based on specified criteria*
- *Selections announcement planned for summer 2025*

★ CIST Timeline

- *Activities begin summer 2025*
- *Continue until Mission Concept Review (nominally end of decade)*
- *Members may be rotated/added*

HWO25 | JULY 28 – 31, 2025

Towards the HABITABLE WORLDS OBSERVATORY

VISIONARY SCIENCE AND TRANSFORMATIONAL TECHNOLOGY

JOHNS HOPKINS BLOOMBERG CENTER, WASHINGTON DC

ABSTRACTS DUE FRIDAY, FEBRUARY 21

PRELIMINARY PROGRAM
ANNOUNCED MARCH-APRIL

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

JOHNS HOPKINS UNIVERSITY

NExScI