

The Habitable

Worlds Observatory:

Updates & Opportunities for Community Involvement

John O'Meara (he/his; START Co-Chair)

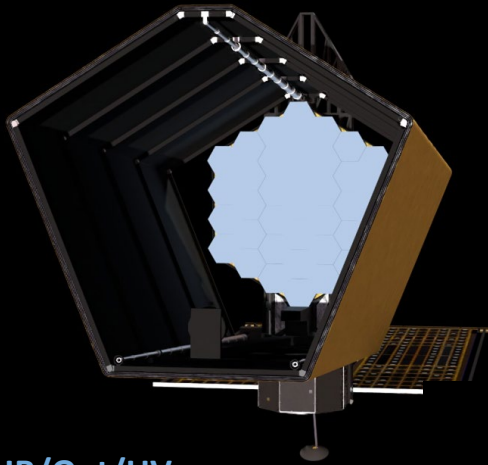
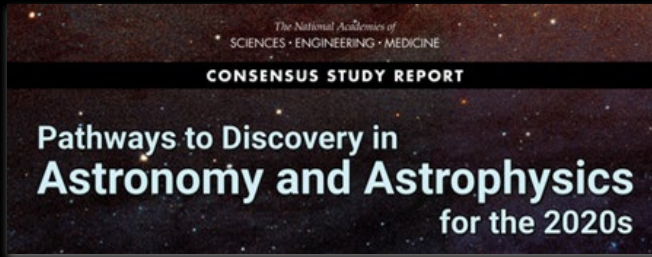
on behalf of the Great Observatory Maturation Program
(GOMAP) Integration Group (GIG), Science Architecture
Review Team (START), & Technical Assessment Group (TAG)



PhysCOS
New Orleans, LA
January 7, 2024

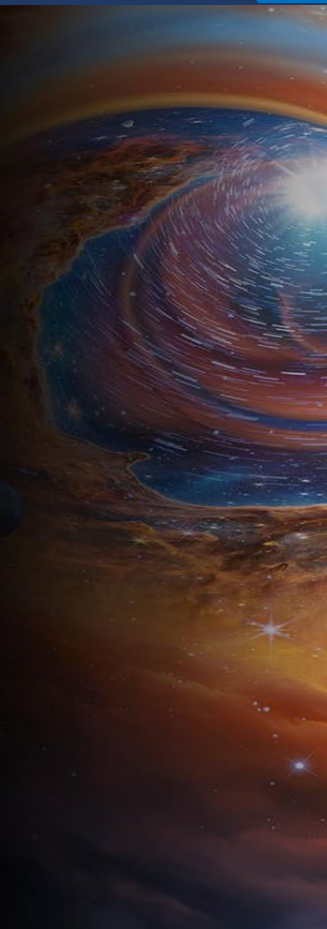
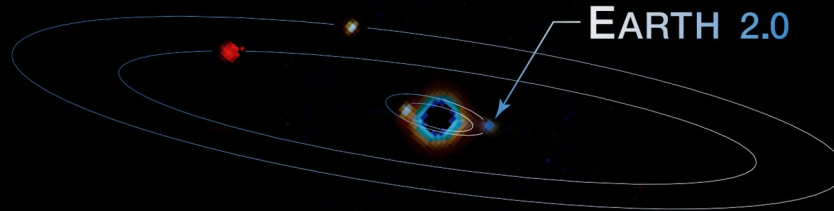
Habitable Worlds Observatory (HWO)

NASA's next flagship mission concept recommended by Astro2020 Decadal Survey



Large IR/Opt/UV observatory performing transformative astrophysics

First telescope designed specifically to search for signs of life on planets outside our solar system



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

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Abstract—Large, strategic “flagship” missions have extensive requirements that need a “challenge” environment for the National Aeronautics and Space Administration (NASA) Mission and Space Technology (M&ST) teams to meet. The Mission and Space Technology (M&ST) teams must meet the Mission Science Laboratory (MSL) and technical and programmatic challenges that lead to significant schedule delays and subsequent cost growth. Although NASA has national policies that have reduced cost growth for some “flagship” NASA science missions, NASA Flagship missions present a distinct technology risk in their requirement to provide sophisticated science or biology and exploration goals, typically under uncertainty, development, and integration. The major challenge presented by Flagship missions is that it is difficult to define in the initial phase of the mission and to set technical and programmatic milestones needed to meet performance requirements and objectives. This paper addresses the key challenges and potential solutions. The paper summarizes approaches to develop and fund Flagship missions.

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1. DEFINITION OF FLAGSHIP MISSIONS

According to Mission-Related’s Dictionary, a Flagship is: (1) the ship that carries the commander of a fleet or (2) a mission or a fleet that first to accomplish a task. (2) The term Flagship is used to describe a mission or a fleet that is the most visible because of their potential for scientific discovery and returns and also the team, program, and most important of NASA’s science missions. NASA Flagship missions are represented in the science that they enable as they provide unique measurements that cannot be done otherwise and typically require new technology or advanced engineering developments to support 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 missions are typically developed in the early 1970s. It is noted that there is a cost greater than \$200 billion per 2017. The development cost to these types of performance development in the beginning of Phase D through launch and is taken from NASA historical public budget documents and the related to the 2017 acquisition dollars (\$17.70). (2) The relatively high cost of Flagship missions is due to their significant complexity with a long timeline of 10 to 15 years to design, build, and launch, the release of in time, and the launch. Wide Space Telescope (WST), which is larger than HST and requires of significantly colder temperatures while still meeting operational capability requirements.

Figure 1. NASA Flagship Mission Cost vs. Launch Date

TABLE 1. NASA Flagship Mission Cost vs. Launch Date

Mission	Year	Cost (\$ Billions)
Viking	1976	~100
Pioneer	1972	~10
Mariner	1969	~10
Hubble	1990	~150
Galileo	1989	~100
WST	2017	~2000

WPA-12-084-02-000001-00-0000000



GAO Report to Congressional Committees: NASA Assessments of Major Projects

United States Government Accountability Office
Report to Congressional Committees
June 2022

NASA Assessments of Major Projects

LUNAR EXPLORATION | ASTROPHYSICS | PLANETARY SCIENCE | AERONAUTICS

GAO-22-103132

LMS Large Mission Study Report

SPONSORED BY THE SCIENCE MISSION DIRECTORATE (SMD)

Pathways to Discovery in Astronomy and Astrophysics for the 2020s

THE NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE
CONSENSUS STUDY REPORT

Finding: For a decadal survey to confidently recommend implementation of a strategic mission as its highest priority, the mission’s technology and architecture need to be **developed to a level of maturity that allows a reasonable assessment of budget profile, scientific performance, and technology risk**. The mission’s cost range and development time scale must be deemed appropriate for the scientific scope.

Conclusion: Enabling subsequent decadal surveys to recommend mission implementations with sufficient knowledge of the feasibility, overall budgetary needs, and time scale requires **significant investment toward maturing large strategic mission science, technologies, and architecture in an integrated way**.

Recommendation:

The NASA Astrophysics Division should **establish a Great Observatories Mission and Technology Maturation Program**, the purpose of which is to co-develop the science, mission architecture, and technologies for NASA large strategic missions identified as high priority by decadal surveys [**First entrant: IR/O/UV observatory**]

NASA HQ Leadership

Program Executive



Julie Crooke

Program Scientist



Megan Ansdell

Deputy Program Scientist



Josh Pepper

NASA GOMAP Website



Community START + TAG Leadership

START Co-Leads



Courtney Dressing
UC Berkeley



John O'Meara
W.M. Keck Observatory

TAG Co-Leads



Lee Feinberg
GSFC



Bertrand Mennesson
JPL

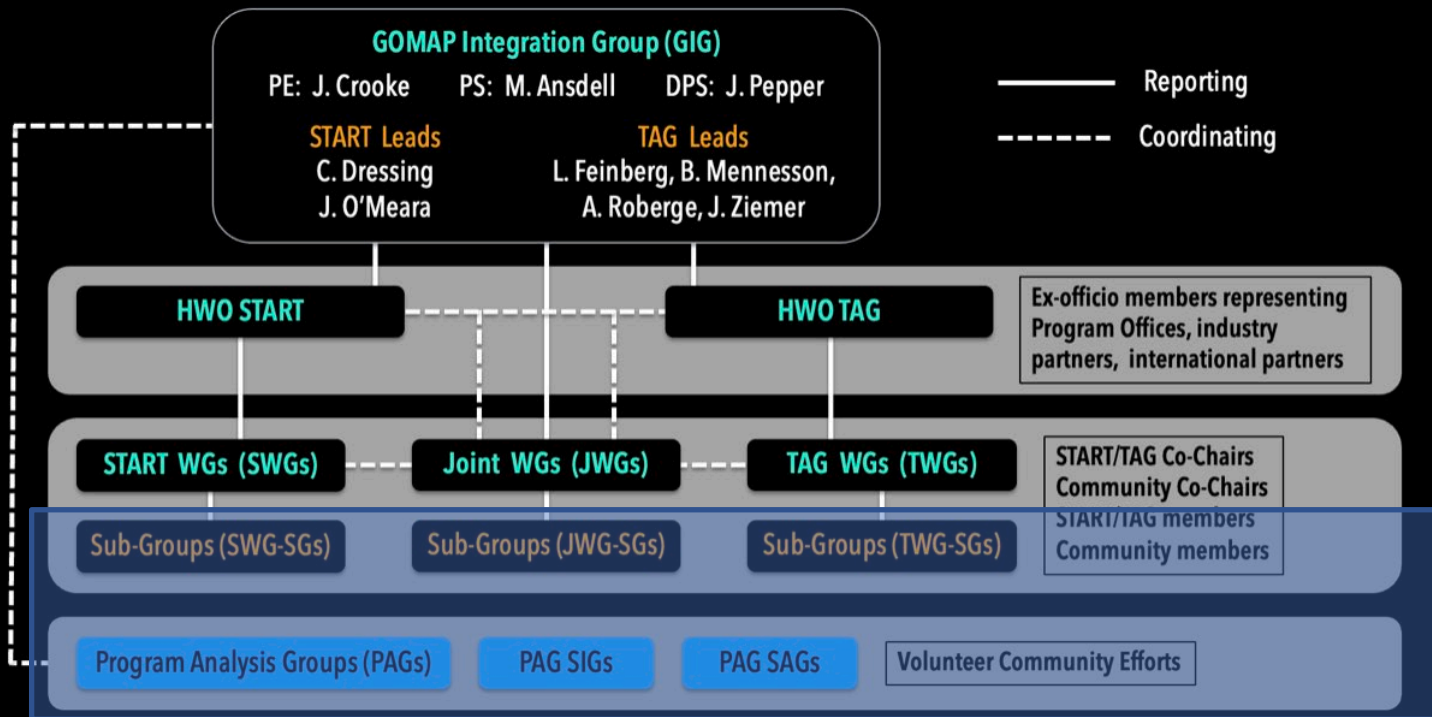


Aki Roberge
GSFC



John Ziemer
JPL

Overall Structure



The START & TAG Will Guide HWO Maturation

Science, Technology, Architecture Review Team (START)

- Quantify HWO's science objectives using Astro2020's guidance
- Outline the observatory and instrument capabilities needed to accomplish those goals.
- Develop the science goals and objectives portions of the Science Traceability Matrix.
- Assess the fidelity of models needed in the future to execute future trades.

Technical Assessment Group (TAG)

- Study architecture options.
- Identify and assess the mission architectures and technologies needed to enable those options.
- Evaluate the risks associated with those options.

TAG Working Groups

- **Science-Engineering Interface**
- **Systems**
 - Starlight Suppression Error Budget
 - High-Contrast Post-Processing & ConOps
 - Starshade Compatibility
 - Computational Architecture
 - Integrated Modeling (may contain ITAR/EAR material)
- **Technology (includes ITAR/EAR material)**
 - Sensing & Control
 - Mirrors
 - Coronagraphs
 - Detectors
 - Artificial Intelligence/Machine Learning
- **Servicing**

Science & Engineering Joint Working Groups

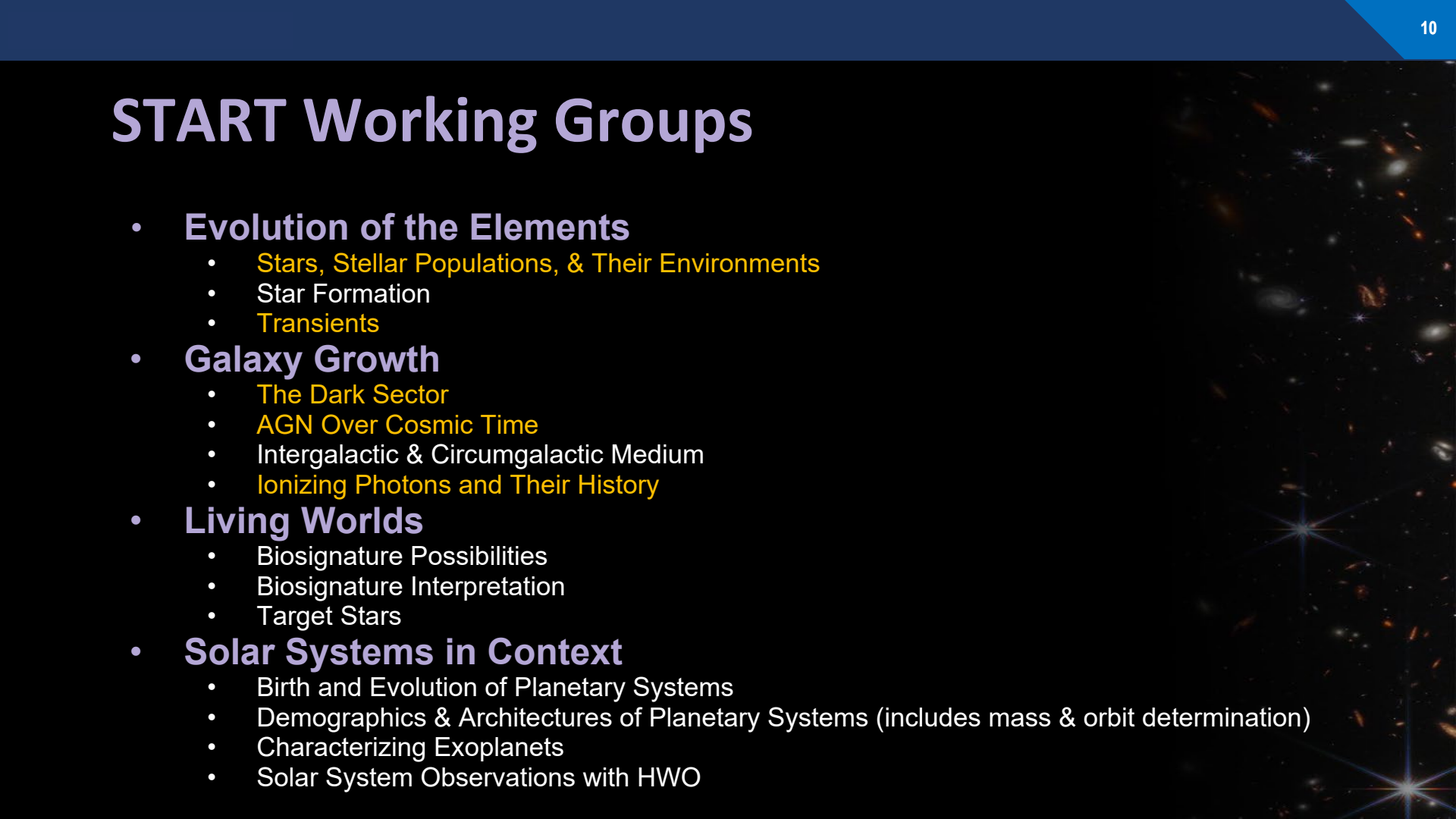
- **Comparison of Past Studies**
- **Science Case Simulation**
 - Exoplanet Direct Imaging Yields
 - Galaxy Evolution in the UV
 - Astrometry
- **Science Data Simulation**
 - High-Contrast
 - UV
 - Wide-field Imaging
- **Astronomy in the 2030s/2040s**
 - Space-based
 - Ground-based
- **Artificial Intelligence & Machine Learning**
- **GOMAP Synergies for Future Missions**

Joint Working Groups

- **Diversity, Equity, Inclusion, & Accessibility**
- **Mentorship**
 - *The mentorship working group will initially be part of the DEIA working group.*
- **Communications**



START Working Groups

- **Evolution of the Elements**
 - Stars, Stellar Populations, & Their Environments
 - Star Formation
 - Transients
 - **Galaxy Growth**
 - The Dark Sector
 - AGN Over Cosmic Time
 - Intergalactic & Circumgalactic Medium
 - Ionizing Photons and Their History
 - **Living Worlds**
 - Biosignature Possibilities
 - Biosignature Interpretation
 - Target Stars
 - **Solar Systems in Context**
 - Birth and Evolution of Planetary Systems
 - Demographics & Architectures of Planetary Systems (includes mass & orbit determination)
 - Characterizing Exoplanets
 - Solar System Observations with HWO
- 

PhysCOS WGs of Interest

Uncovering the Drivers of Galaxy Growth

Description: Study how galaxies, constituents, and their environments evolve over the history of the HWO-observable universe.

Sub-Groups:

- *AGN over cosmic time:* Studying the central engines of galaxies and their impacts on galaxy evolution in imaging and spectroscopy as at multiple scales
- *Ionizing photons and their history:* Understanding the galaxies and their stars that drove reionization by observing their analogues at lower redshift in the UVOIR
- *The dark sector:* Exploring the nature of dark matter and dark energy via their impacts on galaxies and large-scale structure

PhysCOS WGs of Interest

Following the Evolution of the Elements Over Cosmic Time

Description: Trace the rise of the periodic table via studies of the formation, distribution, and evolution of stars, and their deaths.

Sub-Groups:

- *Stars, stellar populations, and their environments:* UVOIR spectroscopy and imaging of stars from individuals in the Milky way, to populations in the Local Group, to stellar clusters across the universe
- *Transients:* Studies of supernovae, merger-driven stellar and stellar remnant explosions, and sources of gravitational wave events

Getting Involved with HWO Working Groups

- See the HWO website for descriptions of each working group.
- Fill out the application form (link on HWO website).
- Contact the GIG (see slide 4) if you have any questions.
- Application Components:
 - Name
 - Institution (“self” is fine for those without formal affiliations)
 - Career Stage
 - Citizenship (required only for subgroups dealing with ITAR/EAR material)
 - Check boxes of groups you would like to join or co-chair
 - For potential co-chairs:
 - Blurb about interest and research background
 - Summary of leadership experience

NASA GOMAP Website



<https://science.nasa.gov/astrophysics/programs/habitable-worlds-observatory/>

What will the WGs do?

The START SG participants will begin with a definition of the key science cases, their objectives, and their observables to define the scientific figures of merit. These will be passed to the TAG for incorporation into modeling and analysis, and the process may iterate

TAG WG participants will develop codes & models to analyze various HWO architecture options, as well as track technology needs and develop roadmaps for technology maturation.

Where we are at

- First Face-to-Face meeting in October/November, 2023
- Second Face-to-Face meeting planned for March, 2024
- Bi-weekly START/TAG telecons
- Additional telecons for START or TAG only
- Many, many more telecons to come as WGs spin up



NASA Astrophysics Division Statement of Principles



All participants in GOMAP-HWO activities must adhere to the APD Statement of Principles

American Astronomical Society (AAS) Code of Ethics



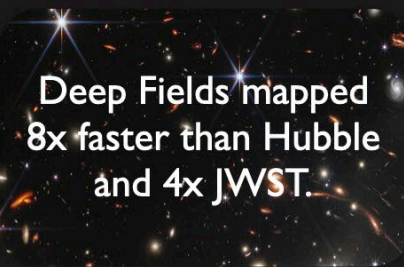
The AAS Code of Ethics is required to be followed under the APD Statement of Principles

Reporting Protocol

Follow the procedures in the APD Statement of Principles and contact the HWO GIG

Use institutional reporting channels, as appropriate

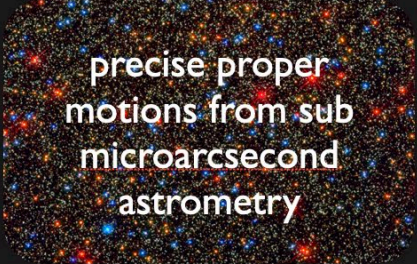
NASA-funded individuals have access to NASA programs (Ombuds, Anti-Harassment, ODEO) and a facilitator to help navigate the various options



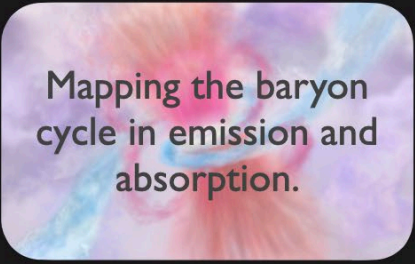
Deep Fields mapped
8x faster than Hubble
and 4x JWST.



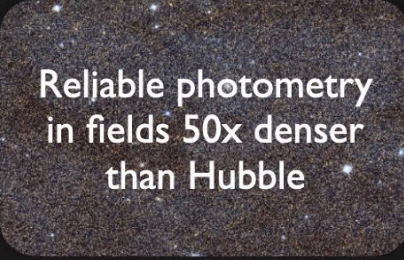
1.4 million individual
shutters for intensive
UV spectroscopy



precise proper
motions from sub
microarcsecond
astrometry



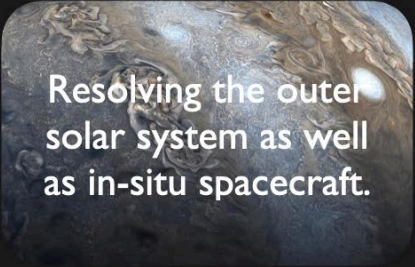
Mapping the baryon
cycle in emission and
absorption.




Reliable photometry
in fields 50x denser
than Hubble

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

Transformative Astrophysics Capabilities




Resolving the outer
solar system as well
as in-situ spacecraft.



Seeing all the building
blocks of galaxies

HST HWO



28th magnitude point
sources in an hour.

Your idea here.



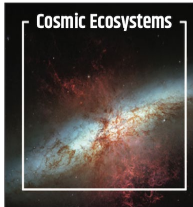
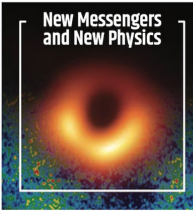
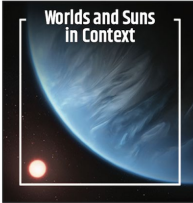
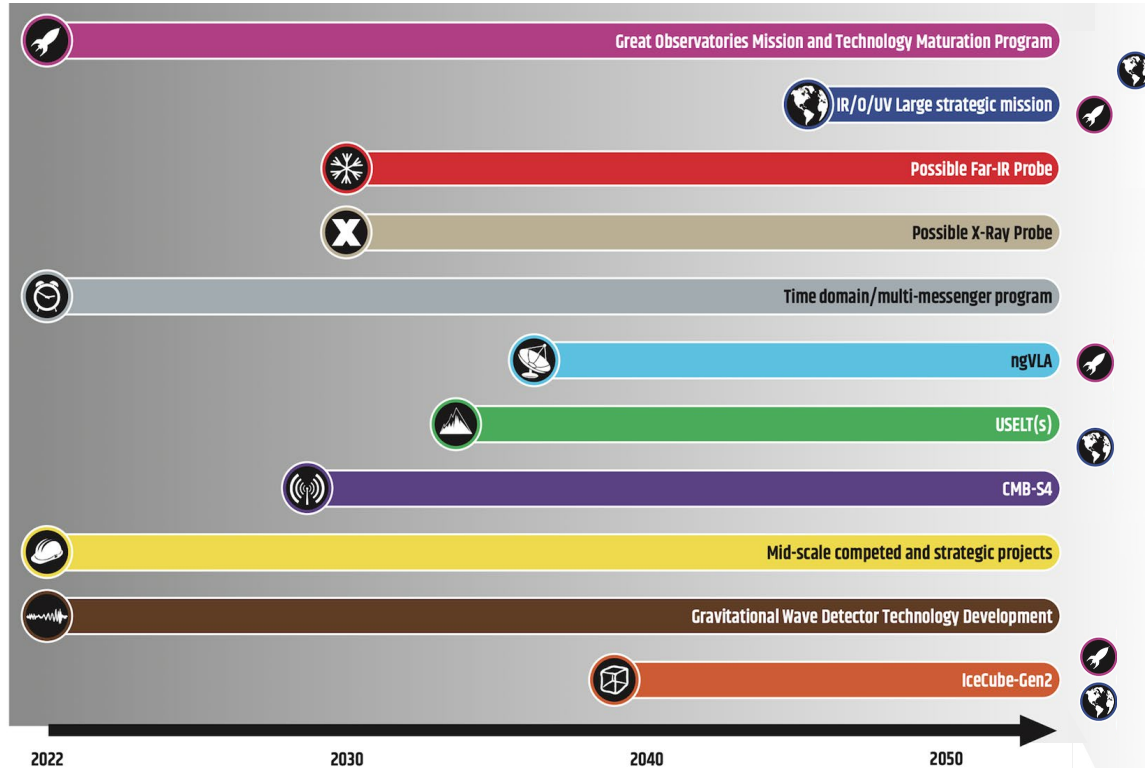
Servicing to achieve
leaps in instrument
capabilities

“The **same large aperture telescope that can identify Earth analogs** would be equally transformative for general astrophysics...”

“...would inherit the scientific power of **HST, but...1-2 orders of magnitude** leaps in sensitivity and performance...”

“...capable of **achieving breakthrough discoveries across nearly all of astrophysics** ...one of the most scientifically versatile astronomical telescopes ever flown...”

“...will **directly address two-thirds of the 24 key science questions** identified in Chapter 2 and will contribute towards answering many of the others.”



Astro2020's 3 Science Themes + Recommended Activities

12:45pm CT: GOMAP-HWO Background

NASA HQ Update

The Story of Life in the Universe

1:15pm CT: HWO Working Groups

START & TAG Working Group Overview

Call for community-wide involvement

Sign-up Here!



2:15pm CT: ROSES Precursor Science Program

Lightning talks from ROSES-2022 selections

Submit to ROSES-2023 call

2:41pm CT: HWO Technology

Roadmap Team Reports

Industry Studies



Mandatory NOI due 3/29

Full proposals due 4/26

Contact Doris Daou

Doris.Daou@nasa.gov

Zoom Link

<https://berkeley.zoom.us/j/98889522047?pwd=Y29aaXBoWVZrWjVVOdnJaVFJDdFRWQT09>

Meeting ID: 988 8952 2047

Passcode: HWOaas

HWO at AAS

Joint PAG 1/7 3pm

HWO at NASA booth, all meeting

NASA Townhall 1/8 12:45pm

Stellar Spectra for modeling exoplanetary atmospheres 1/8 6pm

NN-EXPLORE EPRV Initiative 1/9 9am

Science Drivers for UV in the gap years 1/9 9am, 1/9 1:30pm

HWO Splinter 1/10 12:30pm

Yield modeling tools 1/11 9am