National Aeronautics and Space Administration

The Habitable Worlds Observatory

Progress, Future Plans, & Opportunities for Community participation

NASA Astrophysics Great Observatory Maturation Program (GOMAP)
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Aug 10, 2023


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Why GOMAP? Decades of research-based consensus on megaprojects

Independent Research Papers

Mission Concept Reports

GAO Report on Major Projects

SMD Internal Study on Flagship Projects

National Academy Recommendations

Challenges and Potential Solutions to Develop and Fund NASA Flagship Missions

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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.

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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

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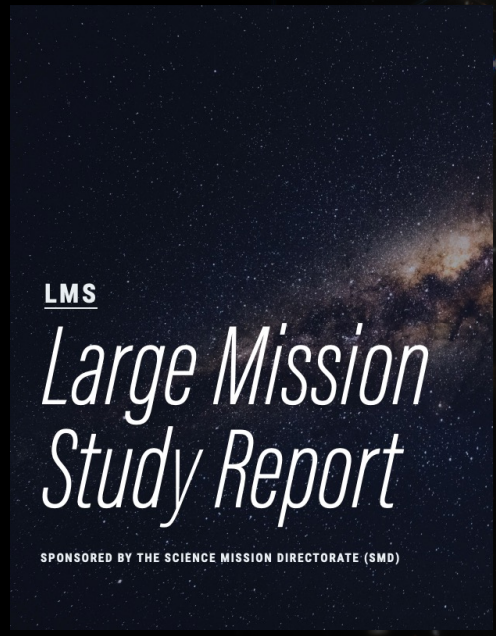
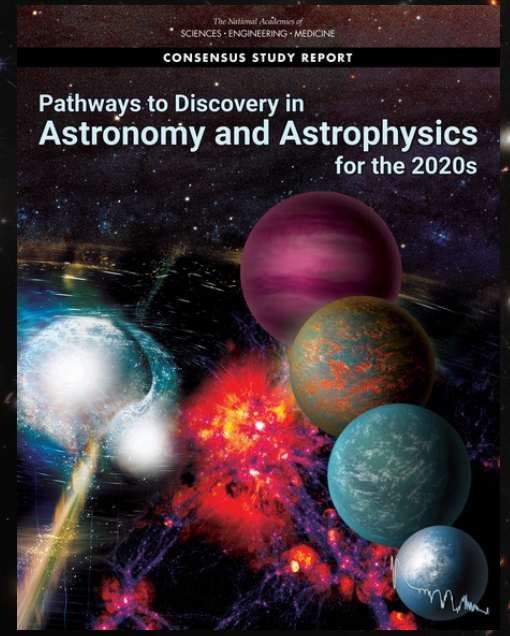
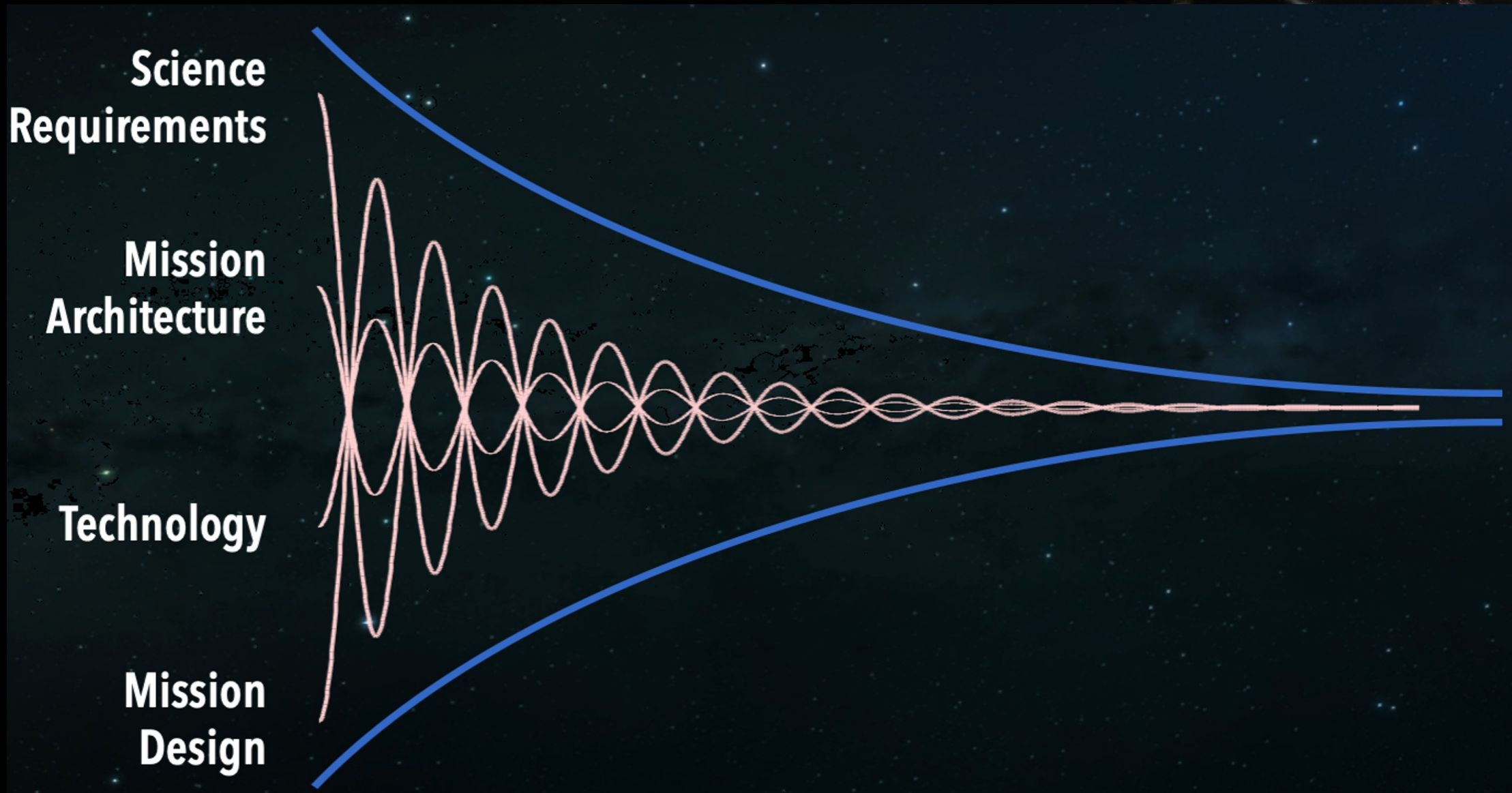


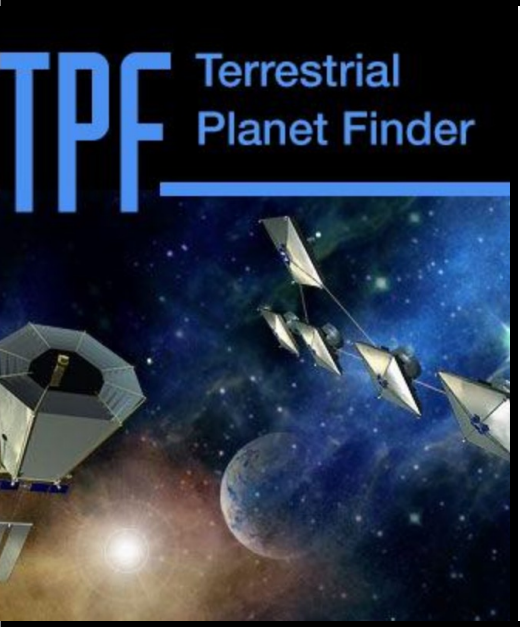
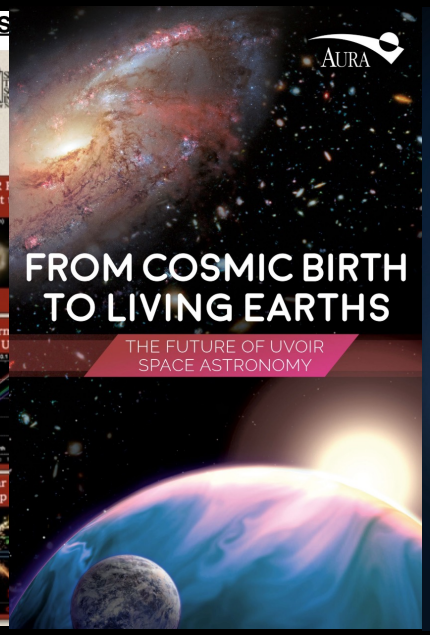
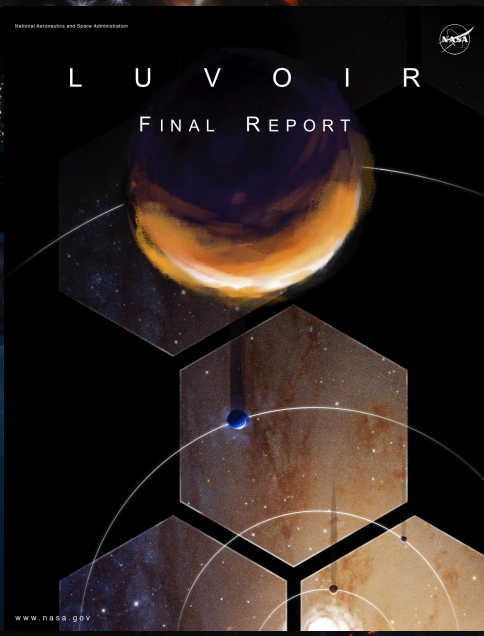


A variety of documents from internal, external, and oversight groups all point to a consistent set of problems & solutions for large/flagship projects, across sectors

Advancing the HWO Concept

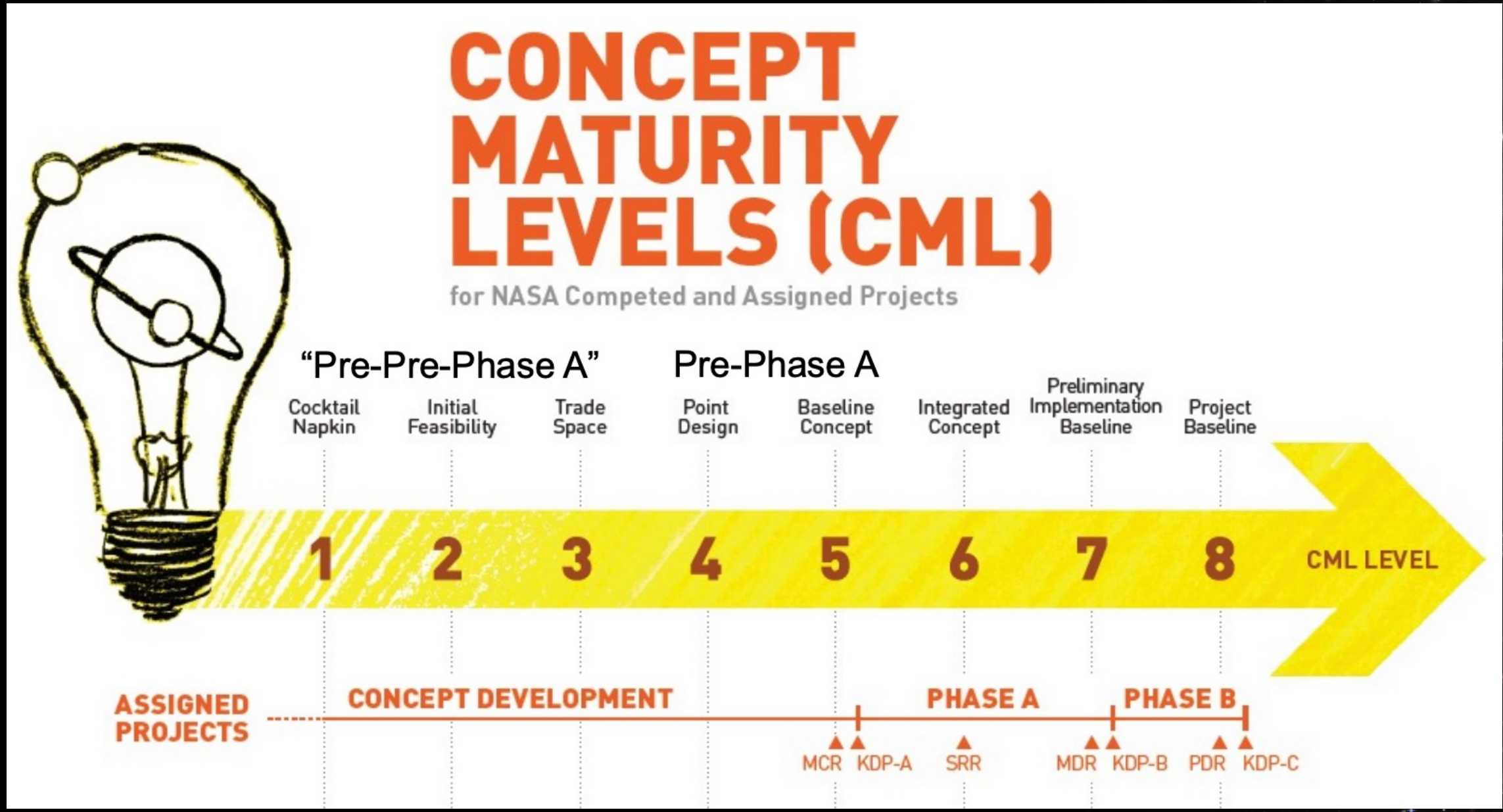


Historic Concept Studies leading up to HWO

TPF	ATLAST	HDST	HABEX	LUVOIR
				
2002-2011	2008-2015	2015	2016-2019	2016-2019

By other names, HWO-like concepts have been studied for decades

Advancing the HWO Concept



https://exoplanets.nasa.gov/internal_resources/2232_Session-2_1_Linking_Science_and_Mission_Architecture-John_Ziemer.pdf

HWO By Astro2030

Goal:
- Successful independent assessment

Objectives:
- Ready for mission formulation
- Concept Maturity Level 5
- Technologies ≥ TRL 5
- Science Traceability Matrix finalized

Roadmaps for:
- Concept Maturity Level 8
- Technology Readiness Level ≥ 6

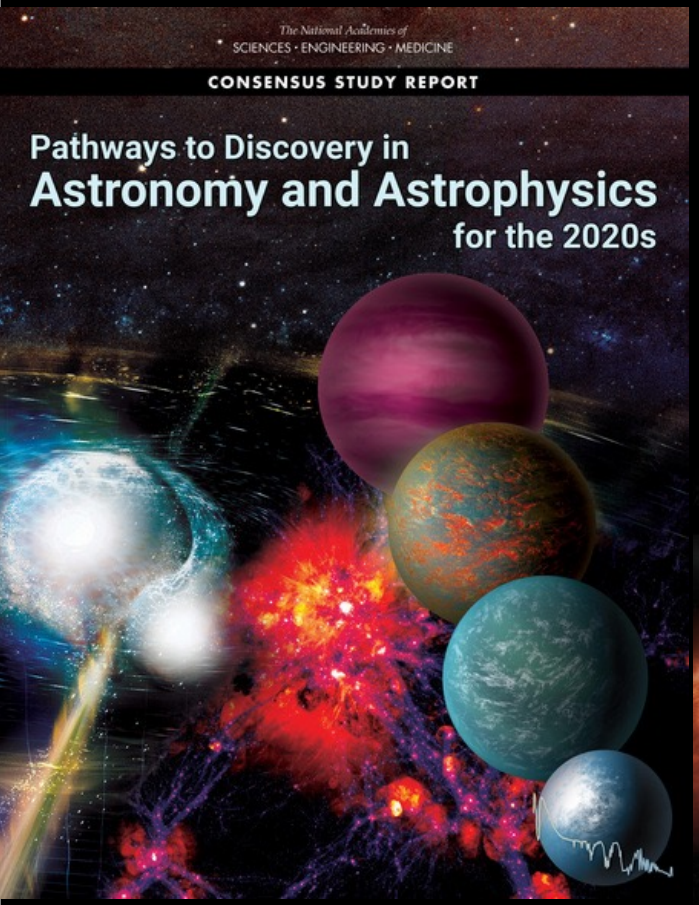
Near-Term HWO

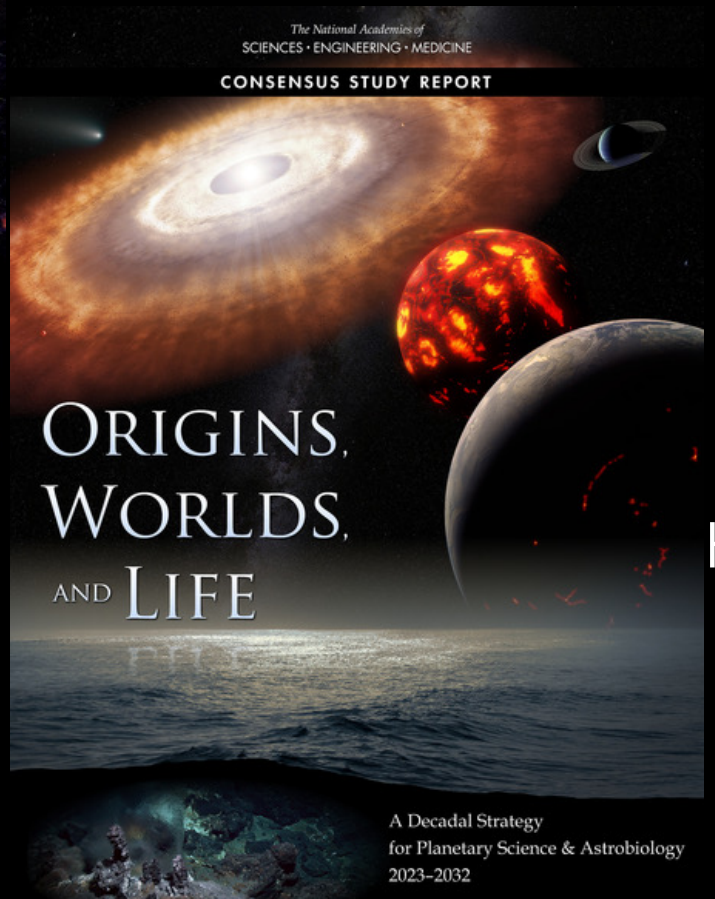
Goal:
- Efficient project ready for funding

Objectives:
- Ready for formal Pre-Phase A
- Concept Maturity Level 3
  Technologies at TRL4
- Science goals & objectives explored

Roadmaps for:
- Concept Maturity Level 5
- Technology Readiness Level ≥ 6
- Science Traceability Matrix Definition

The Science, Technology, Architecture Review Team (START)





Acting groups:

The START + Mentoring

Super START: Science Analysis

Precursor Science

Extreme Precision Radial Velocity

Responsibility:

HWO Scope

Objectives:

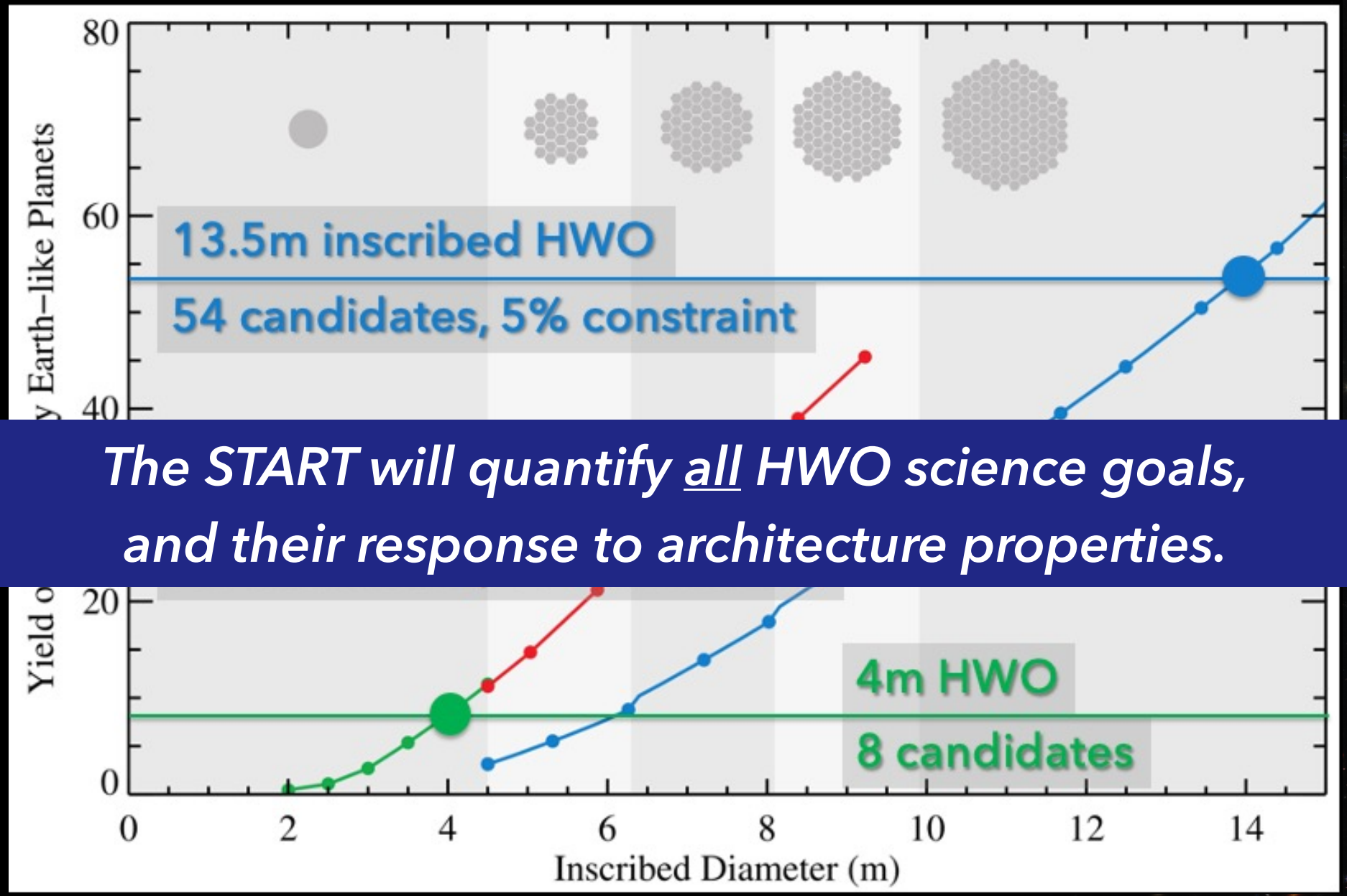
HWO Goals, Objectives, & Observations

Build in Robust Margins

Roadmap Science Traceability Matrix (STM)

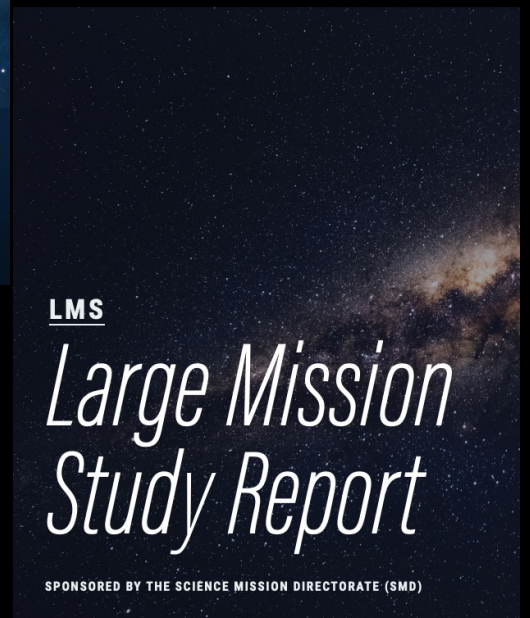
Identify Performance Breakpoints

Example of an HWO Quantified Science Goal



The START will quantify <u>all</u> HWO science goals, and their response to architecture properties.

The Technical Assessment Group (TAG)



Acting groups:

The TAG + Mentoring

Super TAG: Engineering Analysis

Aerospace Landscape Teams

Architecture Trades Teams

Responsibility:

HWO Responsiveness

Objectives:

Evolved Architecture Analyses

Aerospace Landscape Survey

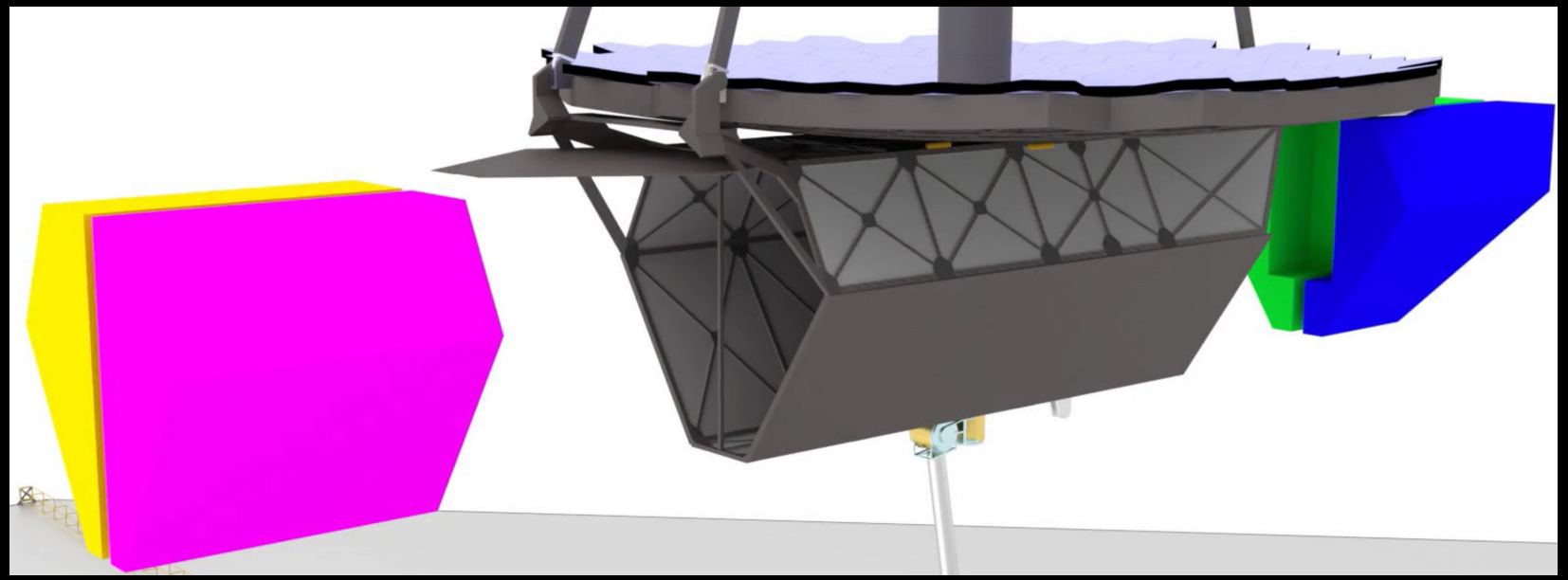
Architecture Trade Deep Dives

Build in Robust Margins

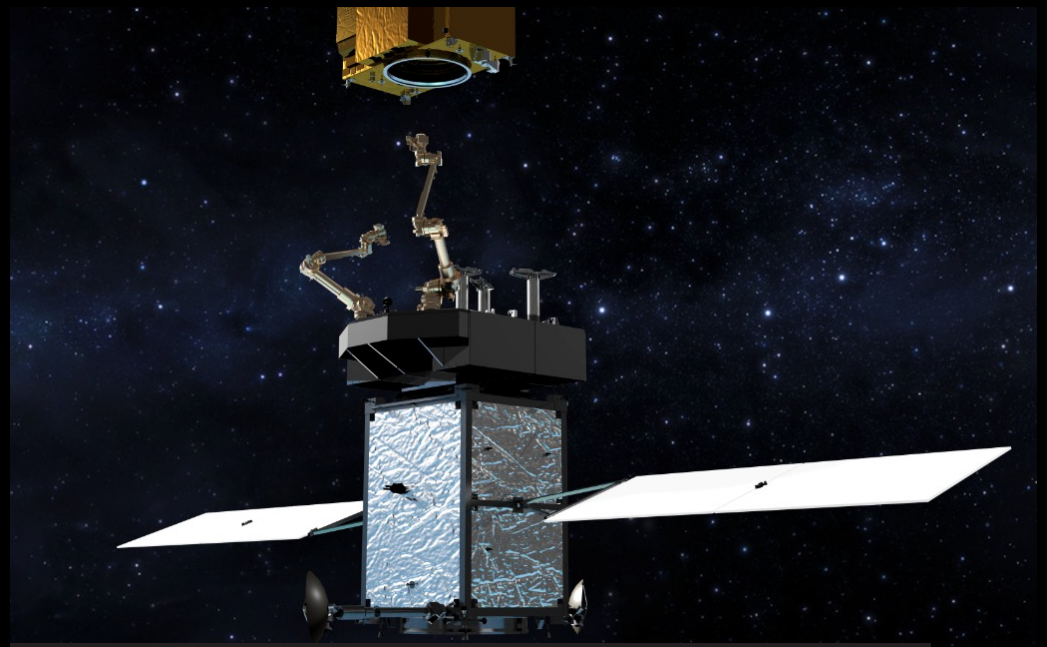
Future Architecture Trades

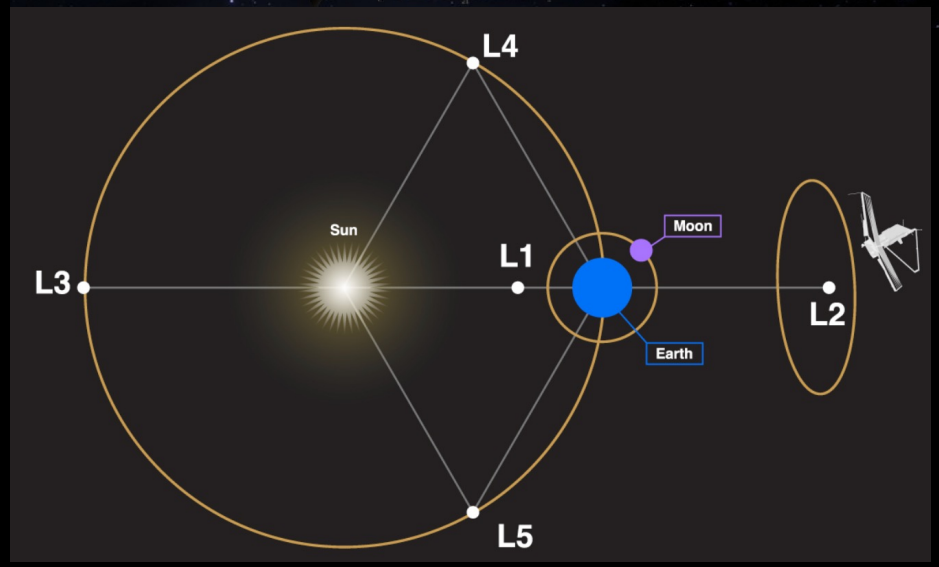
- Servicing considerations

  Design self-contained, modular instruments for ease of swapping instrument and spacecraft orbital replacement units (ORUs)



Future Architecture Trades





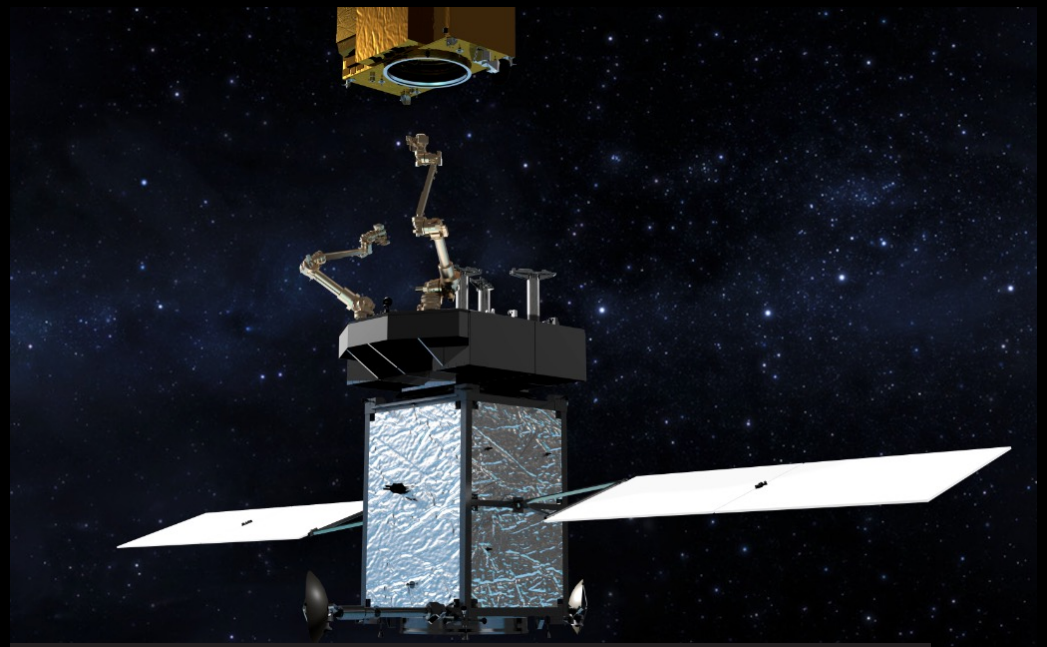
- Servicing considerations

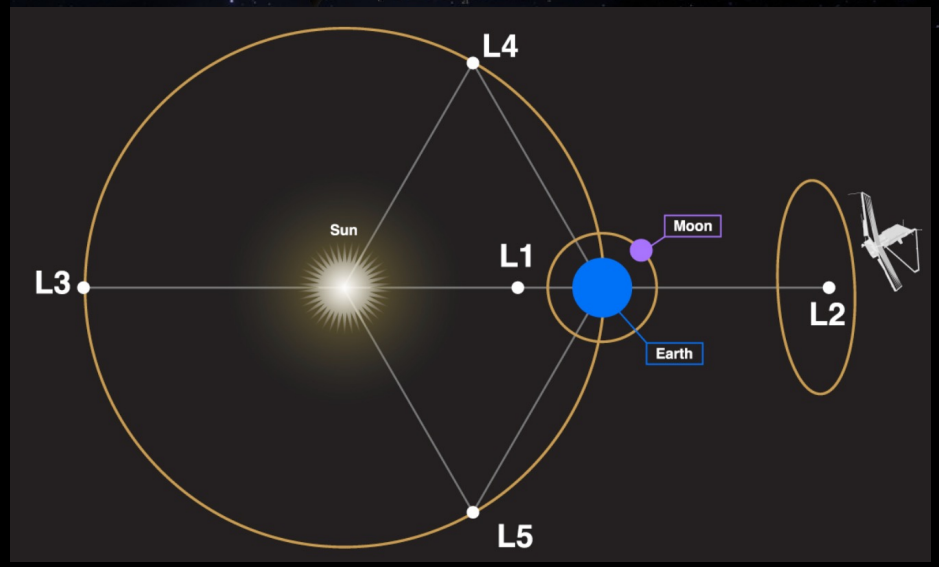
  Design self-contained, modular instruments for ease of swapping instrument and spacecraft orbital replacement units (ORUs)

- Servicing approach

  100% robotic at SEL2 or tug to cis-Lunar

Future Architecture Trades





- Servicing considerations
  - Design self-contained, modular instruments for ease of swapping instrument and spacecraft orbital replacement units (ORUs)
- Servicing approach
  - 100% robotic at SEL2 or tug to cis-Lunar

Degree of on-orbit robotic servicing autonomy

- Latency considerations vs. autonomous approach

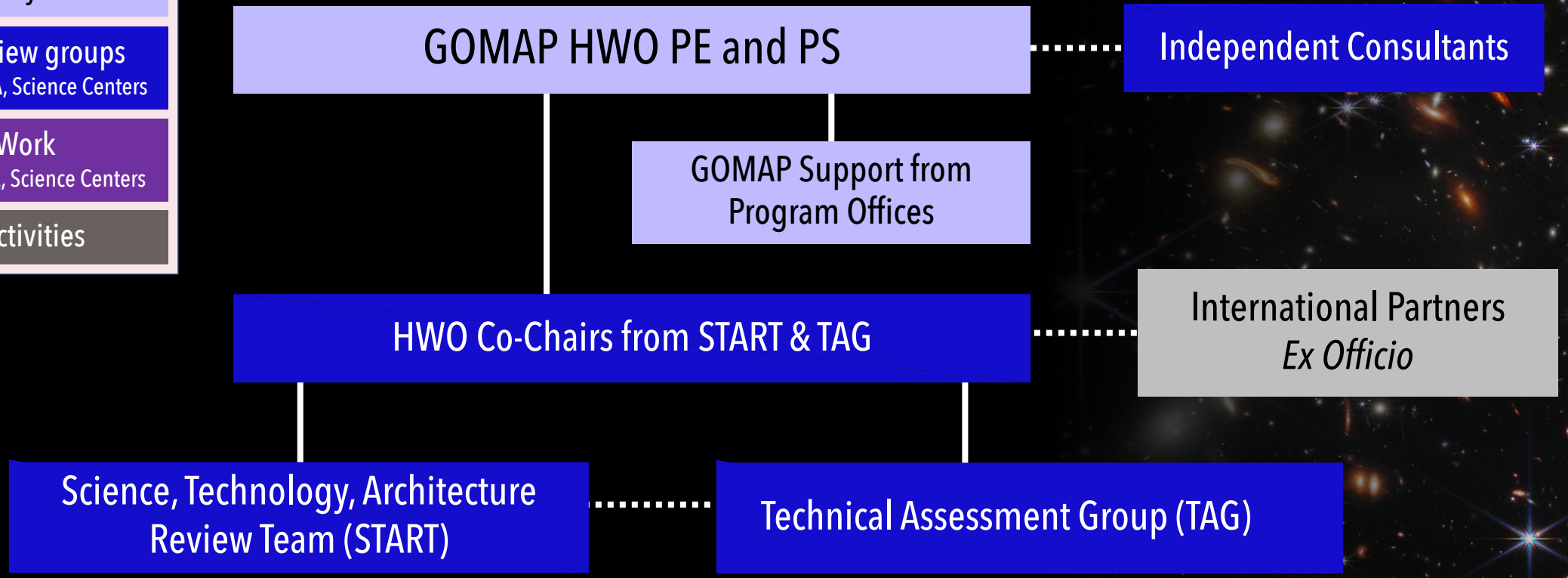
HWO Early Career Initiatives

- START/TAG members will be allowed to include their institution/research group members in technical work related to the START
- HWO mentorship program, focused on early career members from institutions not represented on the START
- HWO Early Career Community/Council for discussions within the HWO early career community, and for feedback on HWO culture from that community
- Workshop (date/location very TBD) to discuss plans for HWO workforce development
  - ”primers” on HWO science/technology
  - networking/job fair to connect people to HWO-relevant institutions
  - discussions around a welcoming, just, safe, inclusive culture for HWO

Pre- Pre-Formulation HWO Work Structure

Color Key

- HQ / PO only
- NASA formed review groups
  Industry, Academia, NASA, Science Centers
- Competed Work
  Industry, Academia, NASA, Science Centers
- Community Activities



This is a general structure that can be used for any FGO in Stages 1 & 2.

Pre- Pre-Formulation HWO Work Structure

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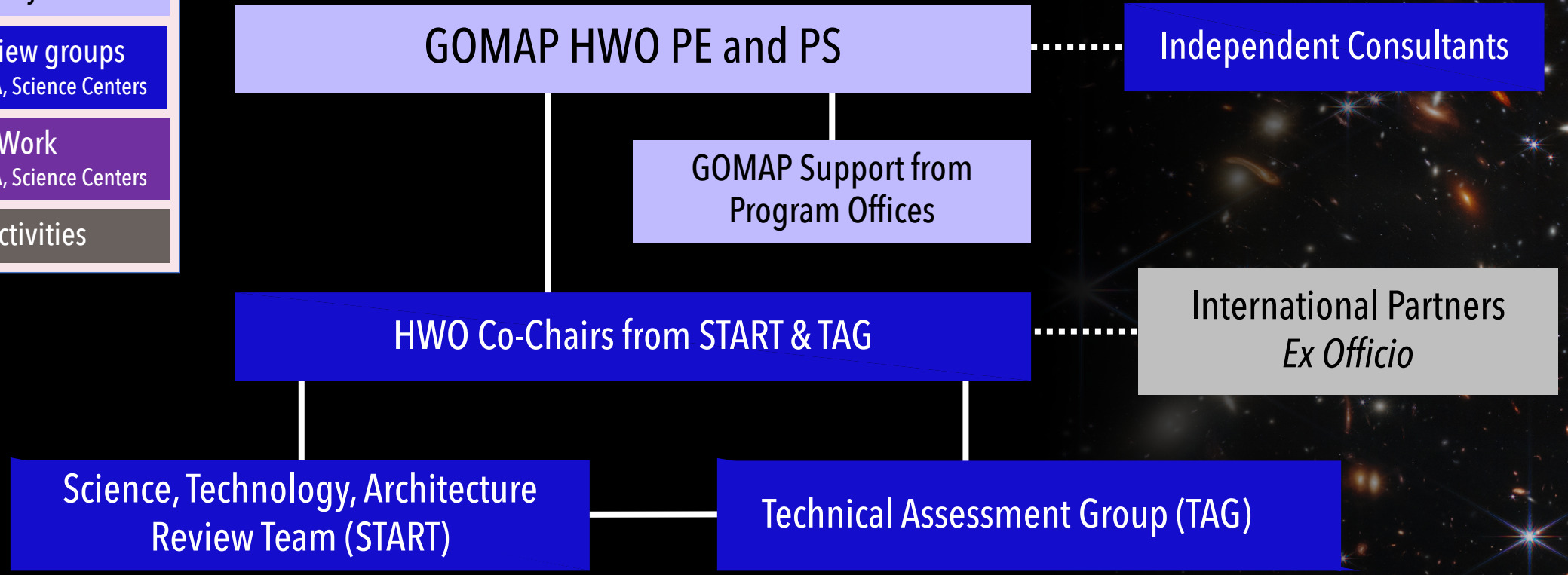
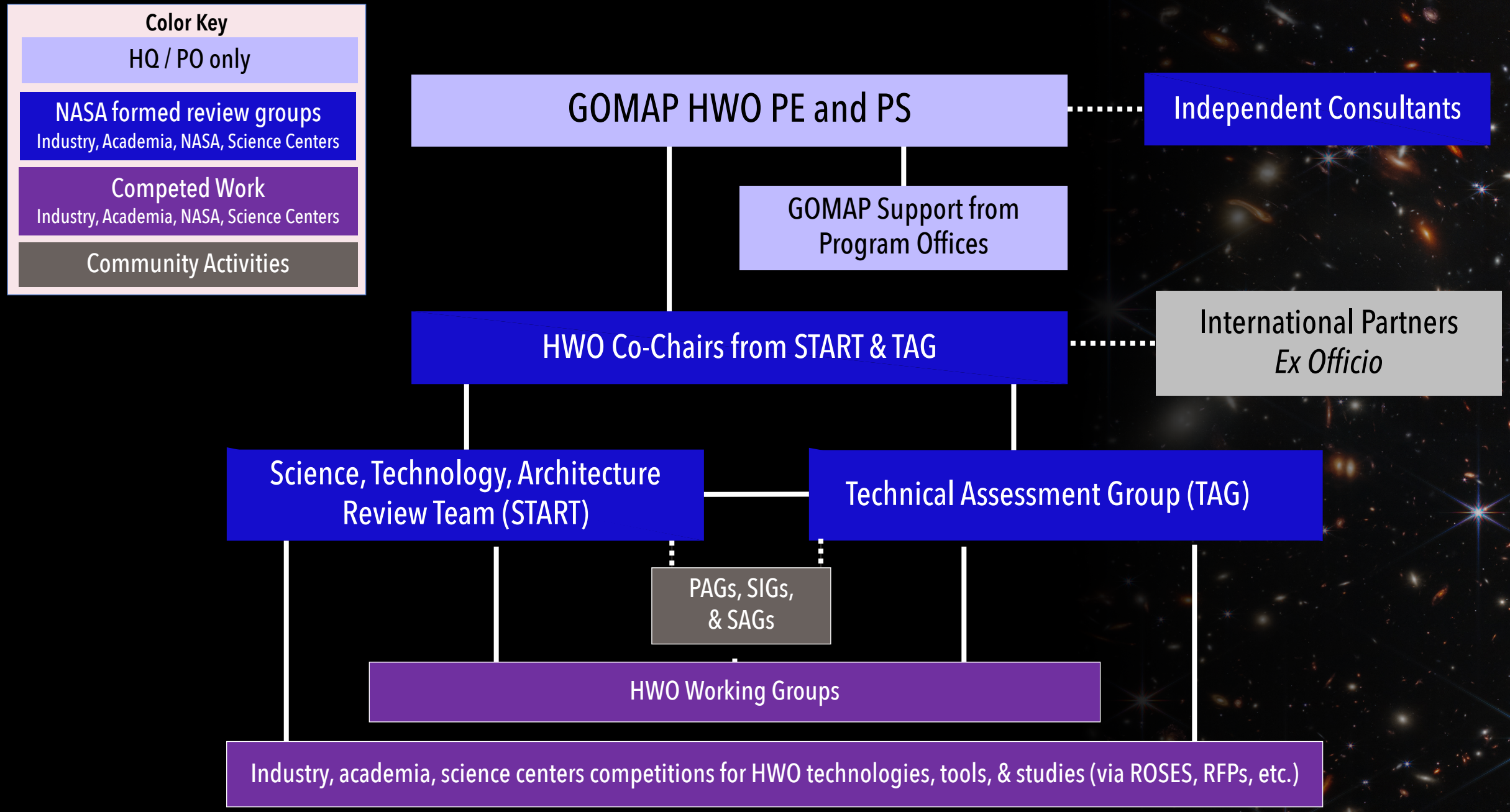
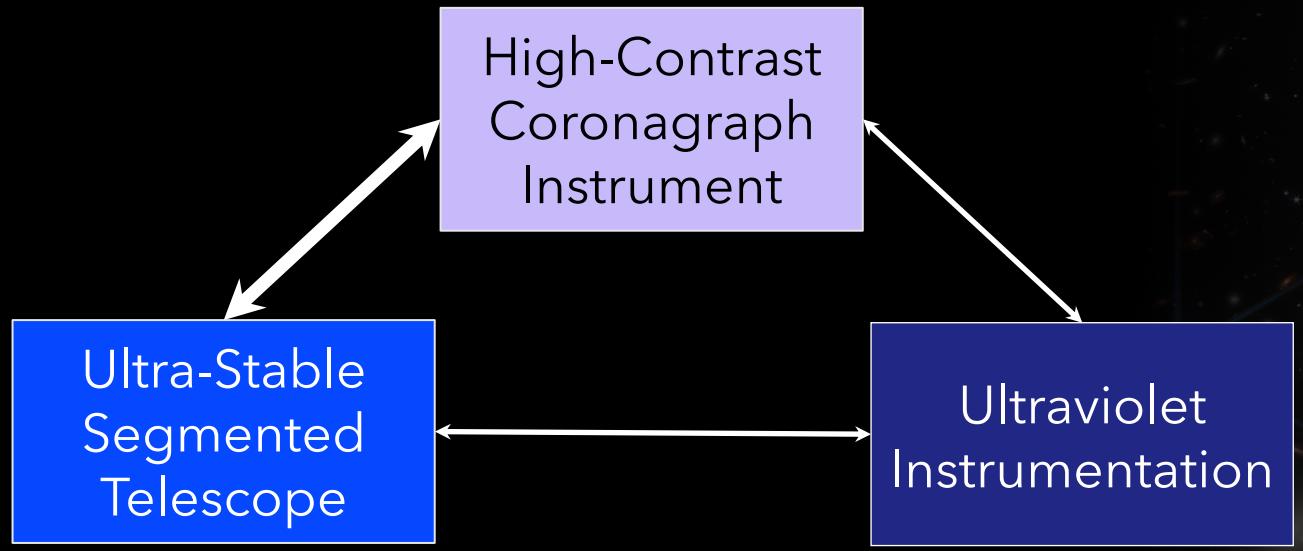


Pre- Pre-Formulation HWO Work Structure



Three Technology Development Systems



GOMAP will mature each of the technologies at the **system** level

Technology systems are coupled, must be developed in parallel with cross-validation

NASA ROSES solicitation: System-Level Segmented Telescope Design

HWO Technology Development through NASA ROSES Solicitation

Ultra-Stable Large Telescope Research and Analysis – Technology Maturation (ULTRA-TM)

Technology Maturation for Astrophysics Space Telescopes (TechMAST)

https://science.nasa.gov/researchers/sara/grant-solicitations/roses-2017/amendment-50-release-d15-system-level-segmented-telescope-design

GOMAP/HWO Groups – How To Get Involved

Community Activities

- Program Analysis Groups
  - Science Analysis Groups
  - Science Interest Groups
- START meetings (likely to be open)
- HWO Workshops, TIMS, and Seminar-Series

NASA-Formed Groups

- The Science, Technology, Architecture Review Team (START)
- The Technical Assessment Group (TAG)
- Technology Road-mapping Groups (FY23)
- Science Yields and Metrics Teams (FY23)
- Mentorship program (details TBD)

Competed Calls

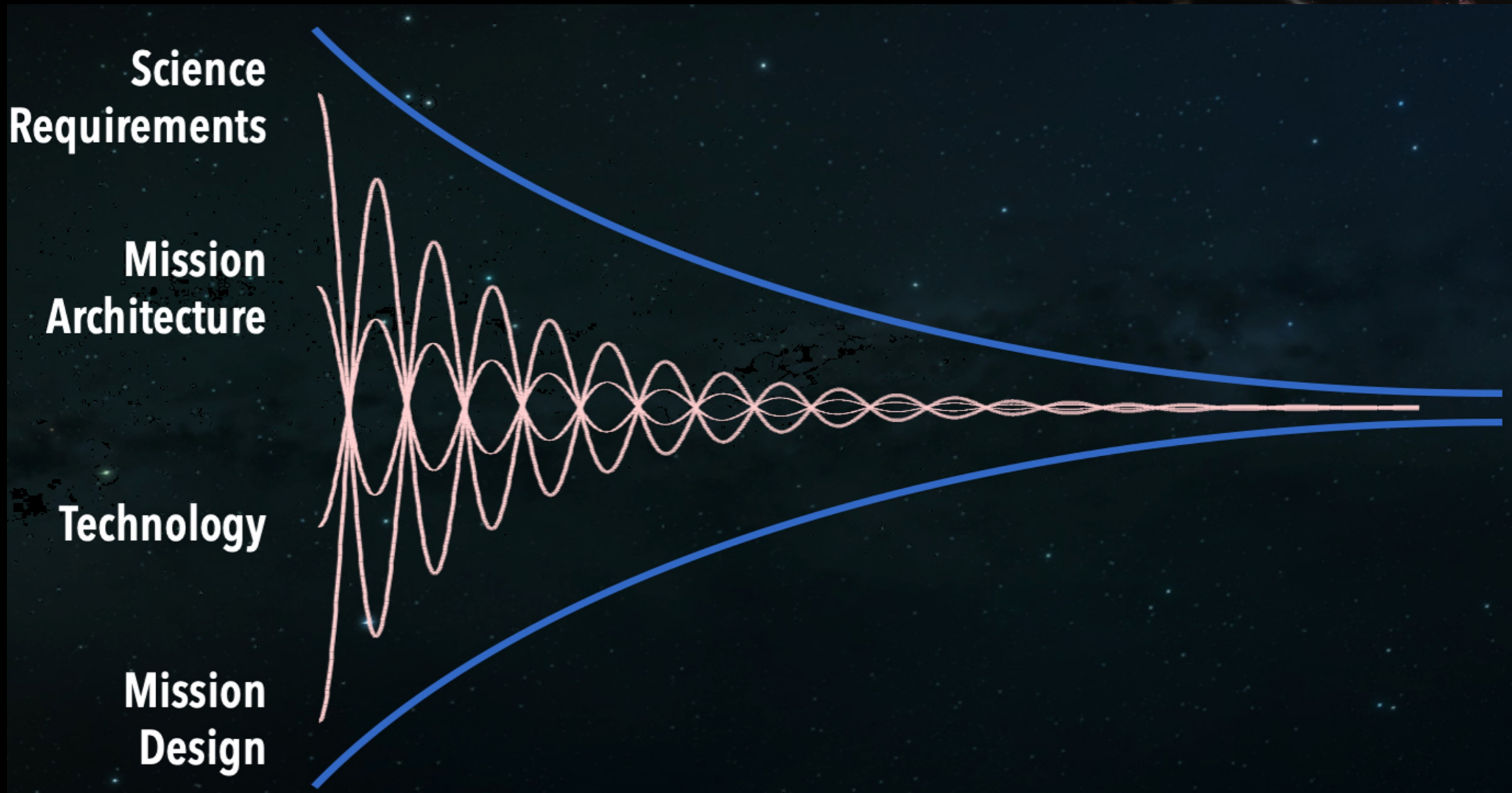
- Astrophysics Decadal Survey Precursor Science (ROSES)
- EPRV Foundation Science (ROSES)
- Strategic Astrophysics Technologies (ROSES)
- Future Technology calls (ROSES)
- Future Architecture Deep Dives & Aerospace Landscape calls (TBD)

A successful flagship starts long-term work ***before*** staffing ramps up…

Establishing this work isn't the same as shifting Phase A early

This critical step between Pre- Pre-Phase A through Phase A involves government, science community, industry, and partners to coordinate efforts, refine HWO's definition, and ***prescribe how to proceed in Phase A***

Closing thoughts for the START/TAG



Questions and more information

NASA Astrophysics Statement of Principles:
go.nasa.gov/3Kwn07s

NASA GOMAP website:
go.nasa.gov/4107ZzC

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