

**Terms of Reference (TOR) for the NASA Astrophysics Division
Great Observatory Maturation Program (GOMAP)
Science, Technology, Architecture Review Team (START)
For the Habitable Worlds Observatory (HWO)**

April 11, 2023

A. Background

The 2020 Astrophysics Decadal Survey, “[Pathways to Discovery in Astronomy and Astrophysics for the 2020s](#)” (hereafter [Astro2020](#)) lays out an ambitious vision for a new fleet of three multi-wavelength Future Great Observatories (FGOs) in space – the first entrant an infrared/optical/ultraviolet observatory, designed to search for life outside the Solar System and perform transformative astrophysics. Astro2020 also recommended NASA establish a “Great Observatories Mission and Technology Maturation Program” before approving a new flagship telescope for formulation.

In response, NASA is implementing Astro2020’s recommendation under the name Great Observatory Maturation Program (GOMAP). GOMAP evolves NASA’s project management strategies by applying decades of research-based consensus of past lessons learned to reduce technical/cost/schedule risk and develop large, complex astrophysics space observatories with predictable costs and schedules. Consistent with Astro2020, the first entrant into GOMAP will be the infrared/optical/ultraviolet observatory, designated the Habitable Worlds Observatory (HWO).

A future NASA pre-phase A project will make informed decisions on HWO science, technology, and architecture trades and priorities. To prepare before the establishment of a Pre-Phase A project, NASA will form and coordinate a series of groups (See Section D of this TOR) whose collective activities will perform analyses and advance HWO’s concept maturity. One of the groups being formed is the Science, Technology, Architecture Review Team (START) for HWO. The overall purpose of the START is to define HWO’s science scope based on Astro2020 and understand architecture/instrument properties and technologies that could help realize that science scope.

B. The START Activities and Deliverables

The START will quantitatively describe the relationships between Astro2020 HWO science goals and its needed observatory/instrument properties. The START will document all analyses and assessments in a final report delivered to NASA to enable future decision makers to make informed decisions. NASA and the future project will down-select to a single mission architecture and design.

The START will inform part of the decision-making by defining the high-level scope of the mission. Effectively, it will prepare information the Pre-Phase A project office can utilize in the future to develop the science goals and objectives portions of the Science Traceability Matrix (STM)^{1,2}.

The START will first identify science goals for HWO, pulling from the Astro2020 report's lists of "Science Questions" and tables of associated capabilities. The START will map these goals to HWO science objectives that are specific, feasible by HWO, and capable of being validated.

The next levels of detail in an STM define the requirements for a mission. The START will not be defining these requirements, which will be determined by NASA and the future NASA Pre-Phase A Project Office. However, those requirements are complex and coupled. To help expedite that future determination, the START will quantify relationships within HWO's complex and coupled trade space. The START will explain the observations or combinations of observations that will meet HWO science objectives. The START will quantify the relationships between HWO performance and the ability of HWO to realize its science objectives. And the START will quantify how that performance is a function of top-level architecture/instrument parameters (e.g., aperture size vs. observation time). For each science objective, the START will assess the fidelity of models needed in the future to execute those future coupled trades. The START may also identify what additional knowledge/research is needed to quantify these relationships.

B.1 The START's activities and considerations may include, but are not limited to the:

- development of one or more science concept(s) of operations (ConOps), to ensure the full set of science objectives may be achieved;
- production of "figures of merit" that demonstrate the relationship between performance and observatory parameters, and/or demonstrate significant advancements in knowledge achievable by established projects;
- identification and quantification of "break-points" in observatory performance against science objectives (i.e., scientific cliffs vs. graceful degradations);
- identification of needed science and engineering (modeling) tools, and their needed fidelity levels through the different mission phases, that need to be developed in preparation for the future Pre-Phase A Project as well as interactive science and engineering tools to engage and excite the public. Identify their desired need dates;
- production of intermediate reports and other materials so that the START activities can be shared with the public and research community; and
- consideration of potential international mission science or other contributions.

B.2 The START Deliverables:

The HWO START final report should include assessments, evaluations, and discussions of activities described above as well as:

¹ <https://science.nasa.gov/science-pink/s3fs-public/atoms/files/PI%20Launchpad--STM--JLeisner%20210615.pdf>

² https://science.nasa.gov/science-pink/s3fs-public/atoms/files/Launchpad_Session3_STM_18Nov2019_smf_final.pdf

- analysis results from science and technical activities;
- a complete list of open assessments or analyses that the START was not able to perform, either because of a lack of time, resources, or other limitations;
- a roadmap to enable future quantification of those unaddressed relationships;
- open-source publication of tools used to produce these relationships, including documentation for those tools; and
- assessment of the level of fidelity of models needed in the future to execute trades.

Further details about the START activities & deliverables are described in Appendix A of this TOR.

B.3 The START Resources:

Many of these activities will be aided by the work of prior mission concept studies and prior NASA astrophysics roadmap activities. In particular, the 2013 Astrophysics Roadmap, “Enduring Quests Daring Visions: NASA Astrophysics in the Next Three Decades”³ laid the groundwork and sentiment of the community that led to the community endorsing the study of the Habitable Exoplanet Observatory (HabEx), Large UltraViolet Optical InfraRed (LUVOIR), Lynx, and Origins mission concept studies⁴ who all developed comprehensive science cases, complete with STM’s. Given that the HabEx and LUVOIR studies were inputs to the Astro2020 report that prioritized HWO, the products from these teams should be considered critical input to the START.

The START’s activities will also be informed by current and future working groups (Section D), industry studies, and lessons learned studies^{5,6,7,8}, among others. Thus, participating in the START will be one of many ways for community members to engage in formulating HWO. These paths will include but will not be limited to technology maturation competitions, targeted research and analysis studies, and community-formed groups such as the Astrophysics Program Analysis Groups (PAGs), Science Interest Groups (SIGs), and Science Analysis Groups (SAGs). For the relationship of these activities to the START, see Section D of this TOR.

GOMAP – including the HWO START– will be conducted consistent with the NASA Astrophysics Statement of Principles related to diversity, equity, inclusion and accessibility⁹. All of the START members will be required to sign an agreement to abide by the NASA APD

³ https://science.nasa.gov/science-red/s3fs-public/atoms/files/secure-Astrophysics_Roadmap_2013.pdf

⁴ <https://science.nasa.gov/astrophysics/2020-decadal-survey-planning/large-missions-history-and-foundational-information>

⁵ https://science.nasa.gov/science-red/s3fs-public/atoms/files/SMD_LMS_eBook_report2.pdf

⁶ https://asd.gsfc.nasa.gov/luvoir/reports/LUVOIR_FinalReport_2019-08-26.pdf (Chapter 12)

⁷ R. E. Bitten, S. A. Shinn and D. L. Emmons, "Challenges and Potential Solutions to Develop and Fund NASA Flagship Missions," *2019 IEEE Aerospace Conference*, 2019, pp. 1-13, doi: 10.1109/AERO.2019.8741920.

⁸ F. Bordi, D. L. Emmons, M. Clampin, S. A. Shinn, R. E. Bitten, “Establishing a resilient flagships science program”, Proc. SPIE 11443, Space Telescopes and Instrumentation 2020: Optical, Infrared, and Millimeter Wave, 114437I (13 December 2020)

⁹ <https://science.nasa.gov/science-red/s3fs-public/atoms/files/NASA%20Astrophysics%20Statement%20of%20Principles%20Nov2022.pdf>

NASA Astrophysics Statement of Principles: [go.nasa.gov/3Kwn07s](https://www.nasa.gov/3Kwn07s)

Statement of Principles, and attendees at the START meetings will be expected to also abide by those principles.

For further information on prior reports, the Dear Colleague Letter, and other supporting information and documentation, please visit the NASA Astrophysics GOMAP webpage: <https://science.nasa.gov/astrophysics/programs/gomap>

C. The START Membership, Interactions, and Funding

The START will consist of approximately 15-20 members including the co-chairs, to perform the analyses and assessments described in this TOR.

C.1 The START Members:

The HWO START comprises recognized subject matter experts (SMEs) in UV, visible, and NIR space science including cosmic origins, physics of the cosmos, exoplanetary, and Solar System science for large space telescopes, systems engineering, technology, and mission architectures.

The START will consist of members with a diversity of experiences and backgrounds, including members with different demographics, cultures, career stages, and geographically with members from diverse types of institutions among others, consistent with NASA's core value of inclusion (See Section E of this TOR).

C.2 The START Co-Chairs:

The START will be led by Co-Chairs. The Co-Chairs will coordinate and integrate all of the START activities. The Co-Chairs are ultimately responsible for delivering a final report capturing the relevant and enabling information. Co-Chairs must have relevant experience in science, engineering, and/or space-based technical implementation. No more than one of the Co-Chairs will be from any single institution, including NASA. The Co-Chairs report/communicate directly to and take direction from the NASA Headquarters (HQ) GOMAP Program Scientist (PS), Shawn Domagal-Goldman.

The responsibilities of the START Co-Chairs include:

- coordinate the START activities among and including directly with the START members; the community PAGs, SIGs, and SAGs; the pre-cursor science principle investigators (PIs), as well as with the NASA HQ PE and PS with other potential groups that may form in the future, etc.
- establish meeting agendas;
- lead meeting discussions;
- communicate status to the NASA Headquarters GOMAP PE and PS; and
- In coordination with the NASA HQ GOMAP PE and PS, coordinate external communications transparently to relay status to the public and the astronomical and aerospace communities.

The START members must be “U.S. Persons” as defined in ITAR¹⁰. “U.S. Persons” includes U.S. citizens or U.S. permanent residents at U.S.-based research and academic institutions, NASA centers, government laboratories, industry, FFRDCs, and from private individuals.

C.3 Community Interactions:

The START members may consult subject matter experts from the general science and engineering communities and/or other affiliated institutions. The START will continuously and directly interact with the community through participating in workshops, conferences, and other meetings. The START will incorporate community work supporting the maturation of the Habitable Worlds Observatory.

C.4 Support for the START:

Members of the START are expected to participate in quarterly hybrid (preferably in-person) START meetings and more frequent remote videocons (on a to-be-determined cadence). Honoraria will be provided commensurate to the commitment level. Additional support will be available for detailed assessments and analyses identified by members of the START. Logistical and travel support will also be provided for the START members.

C.5 International Ex Officio Representatives:

International space agencies expressing interest in participating in HWO may participate in the START with the approval of the NASA Astrophysics Division Director. International representatives are appointed by participating international space agencies. They represent their space agency’s perspectives for ideas and coordinating activities.

C.6 The START membership Length of Service:

The START will be formed in Summer 2023 and continue to operate until HWO receives formulation authorization and a Pre-Phase A Project office is created, or until otherwise terminated by the NASA Astrophysics Division Director. The START activities may last roughly between 18 months up to 3 years. START membership will be adjusted over time depending on programmatic needs and individual circumstances. All membership changes will be approved by NASA. In the event new members are needed, a new call will be released.

D. Relationship to Other GOMAP Activities:

The START will be conducting this work in parallel with other groups working to help prepare other aspects of HWO for the Pre-Phase A Project Office. In order to ensure coordination of these efforts, the START should receive reports from and report-out to these groups. Below is a list of the groups that have been created (or are in the process of being created) at the time of this Dear Colleague Letter and Terms of Reference. We anticipate these groups’ efforts will be coordinated with the START, via NASA’s Astrophysics Division (APD), GOMAP Program Executive and Program Scientist, the Astrophysics Program Offices (POs), and their respective Astrophysics Division Program Office PEs and PSs.

¹⁰ “U.S. Persons” as defined in ITAR is explained at <https://oiiir.hq.nasa.gov/nasaacp/Webbrfg/tsld018.htm>

NASA APD has an existing Research Opportunities in Space and Earth Sciences (ROSES) solicitation related to HWO, the “Astrophysics Decadal Survey Precursor Science.” This will fund research “... *on science investigations that will reduce future Great Observatory mission risk and inform mission designs and trades when those activities begin.*” This work is being supported across all three flagship-level observatories recommended by Astro2020. The START should ask for reports on the progress from these teams doing research specifically relevant to HWO science goals and objectives. As part of this, the START should provide opportunities for those relevant teams to present to the START and coordinate optimal paths.

NASA’s Exoplanet Exploration, Physics of the Cosmos, and Cosmic Origins Program Offices have created and are facilitating community-led Technology Roadmap Working Groups, whose goal is to develop technology development roadmaps for HWO. These roadmaps will be a plan to strategically mature key technologies early to reduce the risk of late technology development creating cost and schedule overruns on the future project. The GOMAP PE, PS, and the START should receive reports directly from these teams on their progress. Additionally, the START should inform these groups and the GOMAP PE and PS if any of its findings could have an impact on technology development roadmaps. While the START may interact with the Program Offices, the START reports directly to the NASA HQ GOMAP PS. While there is no required interaction of the START with the Program Offices, the Program Chief Scientists and Program Chief Technologists may serve *ex officio* on the START as their time permits.

NASA APD and its program offices receive input from three Program Analysis Groups (PAGs): the Exoplanet Program Analysis Group (ExoPAG), the Cosmic Origins Program Analysis Group (COPAG), and the Physics of the Cosmos Program Analysis Group (PhysPAG). The PAGs self-determine what Science Interest Groups (SIGs) and Science Analysis Groups (SAGs) are conducted for each respective PAG. This may include activities related to GOMAP and HWO. To ensure coordination and avoid duplication of efforts, the START will ensure it has representation at PAG meetings, and the START will invite the PAGs to present potentially relevant SAG/SIG activities for discussion and coordination.

Other groups will also be created in the future with specific GOMAP responsibilities. As those are created, the APD GOMAP PE and PS will inform the START’s co-chairs of these new groups in case coordination with them is required.

E. Inclusion, Diversity, Equity, and Accessibility (IDEA):

Astro2020 provided State of the Profession and Societal Impacts (SoPSI) recommendations. Consistent with those recommendations, and recognizing the scale of HWO as a multi-generational flagship mission, NASA plans to establish a GOMAP SoPSI working group that will create a plan for incorporating Astro2020 SoPSI recommendations in a manner consistent with NASA Science Mission Directorate (SMD’s) strategic priorities for IDEA¹¹ and NASA’s Policy Statement on Diversity, Equity, Inclusion, and Accessibility for NASA’s Workforce and

¹¹ <https://science.nasa.gov/about-us/idea>

Workplaces¹². At a minimum and subject to the guidance of that working group, the START will include a mentorship program¹³ that will provide career development, immersion, and networking opportunities for the next generation of HWO experts. That program will be defined once selections are made; Successful START applicants will act as mentors.

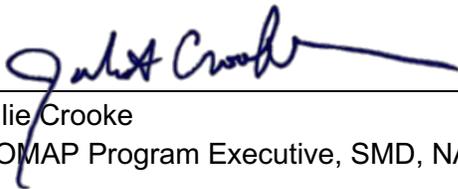
F. Organizational Conflict of Interest

The START members avoid conflicts of interest by limiting the START activities to be consistent with only gathering factual information, assessing, reviewing, analyzing, documenting, and making the final report public for transparency. The START will not make any decisions, prioritizations, recommendations, or give advice. The START's fact gathering, analysis, and documentation will be submitted to NASA.

Concurrence:



Shawn Domagal-Goldman
GOMAP Program Scientist, SMD, NASA HQ



Julie Crooke
GOMAP Program Executive, SMD, NASA HQ

Eric P. Smith
Astrophysics Division Chief Scientist, SMD, NASA HQ

Approval:

Mark Clampin
Astrophysics Division Director, SMD, NASA HQ

¹²

https://www.nasa.gov/sites/default/files/atoms/files/2022_administrator_policy_statement_on_deia_at_nasa_tagged.pdf

¹³ Acknowledging there are dozens of different types of mentoring activity options. Examples include: <https://www.togetherplatform.com/blog/15-mentorship-program-ideas>

Appendix A: Additional Activities & Deliverables

Further Detailed Example Activities

More example activities of the GOMAP HWO START and HQ members are described below. These are not exhaustive lists, nor are they intended to be prescriptive, and the scope of these might change due to unanticipated circumstances.

Detailed Example START Activities:

- START: Communicate with the NASA Headquarters GOMAP Leadership Team on a TBD cadence.
- START Co-Chairs: Review and assess that all science objectives (quantitative and qualitative) have been identified/synthesized from the Astro2020 Report for HWO. Ensure a complete and accurate list.
- START: Identify and develop a list of enabling HWO-specific precursor science investigations and their needed timing and timeline.
- START: Identify the activities best suited for the external community members (i.e., PAGs, etc.) that will not be conducted by START.
- START: Report out to the public and stakeholders coordinated with HQ.
- START: Identify Candidate Science Instruments
 - START: Identify comprehensive list of candidate science instrument capabilities to fulfill each identified science objective.
 - START: Quantitatively assess each instrument's measurement capability needs (precisions, accuracies, etc.) to achieve each science objective.
- The START may consider the following activities while evaluating Astro2020 HWO science as well as architecture "response metrics" for various architectures.
 - Identify astrophysical parameters that are still undetermined/unknown.
 - Determine each parameter's needed accuracy, if known.
 - Identify options for how to achieve, quantify, assess, bound, and determine them.
 - Identify obstacles to achieving known quantities
 - Assess each parameter's impact on achieving the relevant science objectives.
 - Assess the needed timeline of achieving the knowledge and nature of each parameter.
- The START should address modeling tools:
 - Identify needed scientific and engineering modeling tools for the mission and their needed levels of fidelity as the mission matures and timing.
 - Identify interactive web-based (website) science and engineering tools for the public.
 - Identify potential options for developing tools, i.e., industry, academia, students, etc.
 - Identify inputs needed to develop science tools.
 - Define needed Science Evaluation Tools (SET), activities, and their needed timing.

- Identify science metrics that the SET(s) will use to assess mission architecture options.

HQ Activities Related to START:

- HQ: Establish plans for GOMAP based on past flagship lessons observed/learned, including from the Large Mission Study. Maintain this list and ensure past lessons are applied to the mission planning as well as all cross-discipline coordinated activities.
- HQ: Document the assumptions, assessments, and applied lessons to reviews of the GOMAP activities.
- HQ: Identify and suggest IDEA plans and develop methods for weaving IDEA into all aspects of GOMAP including:
 - Creation of GOMAP/IDEA Working Group to inform and decide on “best practices” for the future project
 - Identifying long-term SME areas that are ripe for establishing more senior mentors and more junior mentees,
 - Assess needed numbers of SMEs in the future for critical disciplines,
 - Suggest methods to establish a push-pull relationship between under-served communities and NASA to continually improve IDEA throughout all GOMAP activities.
- HQ: Develop integrated programmatic, science, mission architecture, and technology strategies.
- Select members and co-chairs for START
- Ensure connection between START activities and other GOMAP activities, communicate with co-chairs when new GOMAP activities are created

Combined HQ/START activities:

- HQ, POs, START: Develop science communication strategies and materials including content, platforms, etc.
- Uphold IDEA standards outlined in the NASA APD Statement of Principles at the individual level
- Communicate across GOMAP activities, as facilitated via NASA APD
- HQ, POs, START: Identify and track activities for which progress was not made or was slow due to a lack of time or resources