Enabling the Future Study of Earth-Like Worlds and the Role for Human Space Flight

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Overview

- **Strategic Plan**– use the second NRO telescope equipped with suitable aft optics and spacecraft bus services, in a joint human and astrophysics exploration bridging campaign over the coming decade. Agency fiscal constraints during this timeframe strongly indicate such a "stepping stone" merits further study.

HEO Benefits

- Technological and capability maturation on the critical path to exploring asteroids, Mars and the rest of the solar system

Science Benefits

- Post – JWST major observatory capable of conducting Decadal Survey – derived observing programs and demonstrating capabilities required for larger, more powerful telescopes suitable for investigating Earth-like worlds around other stars

Key Collaborators

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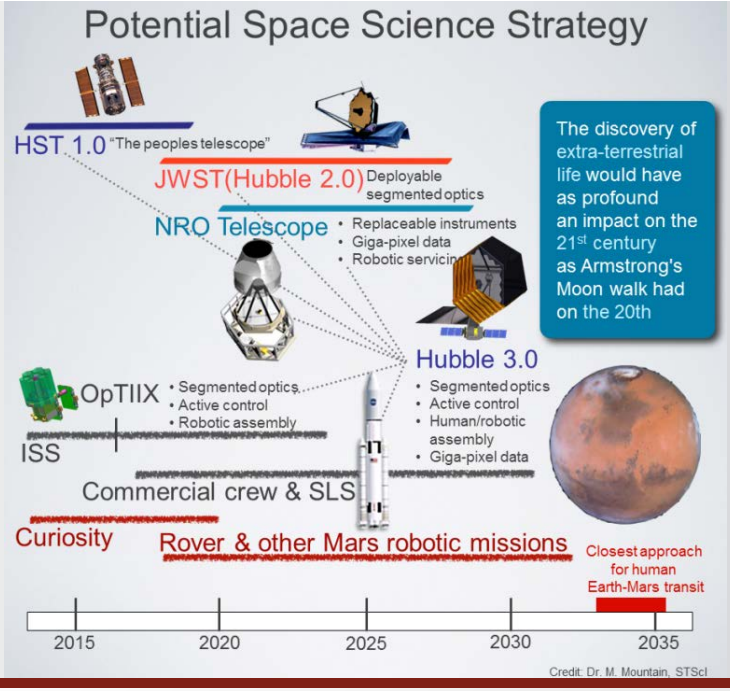
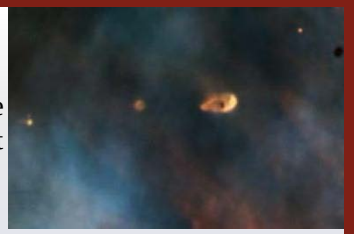
Roadmap to 20 Meter



Science

Science with a 2.4 m Space Observatory



In addition to the primary goal of building upon demonstration experiments on the ISS, a 2.4 m space telescope could be configured to carry out important scientific goals, examples of which include

- **Imaging of protoplanetary disks**
  - Spatially resolved observations of edge-on disk candidates
  - Synoptic monitoring of A proplyd in the Orion Nebula for variability due to accretion event and shadowing of illumination by inner-disk substructures.
- **Dynamics of outflows from young stars**
  - Time-domain studies of outflows from Young Stellar Objects (YSOs).
- **Fast follow-up observations of transient events.**
  - Gamma Ray Bursts. Progenitors of short, hard bursts are unknown; there are indications of rapid early decay.
- **Our Industry Partners, Lockheed Martin and Boeing, will bring their first-hand knowledge and experience with the telescope to the study team of scientists and engineers.**

Value Proposition

Use of the 2.4m NRO telescope to feed-forward needed capabilities

Needed Capabilities (✓)	NRO Telescope	16+ Meter	Mars
• Very high precision robotic assembly		✓	✓
• Image motion characterization/mitigation	✓	✓	
• Cryogenic instrumentation robotic handling	✓	✓	
• Autonomous Rendezvous and Docking (AR&D)	✓	✓	✓
• Tele-robotic servicing	✓	✓	✓
• Autonomous crew operations			✓
• Spacecraft environmental control	✓	✓	✓
• Mitigation of effects of long stays by humans	✓	✓	✓
• Segmented optics		✓	

Response to NNH13ZDA002L
Concepts for Applications of Large Space Optics

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Executive Summary

Given the likely budgetary and political environment for NASA for years into the future, science and human space flight must coordinate closely to jointly develop programs to achieve priority Agency goals. *Anything else is unlikely to survive critical budget review.*

We summarize the plausible context for combined human and astrophysics exploration in the coming decade and recommend initiating a series of design and trade studies to identify the options for best use of the NRO optic to meet the programs' simultaneous goals. Once this is completed, advanced design work on use of the NRO optical system should commence, which will be an important early step in estimating the final project cost. The design and trade studies should include (1) development of a major post-JWST observatory, (2) availability of the ISS, (3) preparation for a human mission to Mars in the mid-2030s, and (4) priority NASA long-term investments in major technologies. We outline how the NRO optics can take advantage of all four.

1. Context in the Coming Decade: Development of a Major Post-JWST Observatory

Are we alone? has been an overarching scientific goal for NASA for more than a decade. As recently as a year ago, this goal was identified by the NRC and accepted by NASA as one of only three priority objectives that would justify an extensive technology investment strategy. [See Section 4, below.]

There is no goal in modern astrophysics that is more professionally or publicly compelling than investigating Earth-like worlds. However, such a goal requires a telescope aperture approximately 16 m (or greater) (*Toward Other Planetary Systems (TOPS) Report* [B. Burke *et alia;* 1992 and subsequent work]) to study a sufficient number of candidate stars and must operate spectroscopically at visual wavelengths into the mid-infrared. This latter requires cryogenic optics and some instrumentation operating at temperatures below at least 100 K.

We emphasize, in addition, that such a large-aperture observatory would be a powerful instrument for a variety of astronomical programs and, thus, of inestimable value to the world's scientific communities. Such an observatory would certainly be extremely expensive, justified only by the most important scientific priorities, although without a detailed design, it is problematic to estimate costs reliably.

We recommend use of the NRO optic to be on the path to demonstrating capabilities likely to be necessary to deploy a large-aperture space telescope capable of spectroscopically studying candidate Earth-like worlds roughly a decade later.

2. Context in the Coming Decade: Availability of the ISS

The ISS is currently planned for operation at least through 2020 with engineering certification possible for extended operations. This offers the potential for an accessible platform for development and demonstration of essential capabilities necessary to a very large optical system two or more decades into the future, as well risk reduction for the NRO optic assembly, maintenance, and operation. *We recommend an early assessment of the opportunities offered by ISS within a decade as a platform for advanced experiments and demonstration projects.*

3. Context in the Coming Decade: Preparation for a Human Mission to Mars in the Mid-2030s

The human exploration of Mars continues to be the priority long-range, horizon goal for international human space flight, with the mid-2030s – due to relative Earth-Mars orientation – as the next plausible window of opportunity for such a mission. With the mid-2030s as the target date for a Mars mission, it is revealing to consider major available activities and facilities that may be available *between now and then*.

Most recent designs for human habitation proposed for Mars will likely depart from the overall system design for ISS, which dates from the 1980s. Characteristics of ISS that can be leveraged for a Mars mission include (1) closed-loop life support, (2) rendezvous, docking, and construction, (3) advancements in EVA, and (4) management of an international program. Additional development will, however, be needed for habitable spacecraft operating beyond low Earth orbit. Characteristics of the ISS that are distinct from a mission to Mars include (1) regular re-supply, (2) abundant volume and power, (3) very different external thermal environment, (4) more modest radiation protection, and (5) extensive human involvement in maintenance.

Consequently, some type of "bridge facility" – a "stepping stone" – between ISS and the mission to Mars may be an imperative. This is analogous to the 1960s' Gemini Program, instituted to follow the Mercury Program explicitly to demonstrate capabilities necessary for travel to the Moon that the Mercury Program was not designed to achieve. It is plausible that such a "bridge facility" deployed to demonstrate key capabilities beyond LEO will also be available for additional uses within about a decade.

4. Context in the Coming Decade: Priority NASA Long-term Investments in Major Technologies

About a year ago, the NRC completed its recommended priorities for technology investments to enable human and robotic exploration. Among the highest priorities accepted by NASA were several to be developed over the coming decade relevant to future large optical systems and the capability to assemble, deploy, and upgrade them [NRC Report: *NASA Space Technology Roadmaps and Priorities* (2012)]: (1) lightweight materials; (2) instruments and sensors, including high-contrast imaging, spectroscopy, focal planes, and detectors; (3) cryogenic systems; and (4) robotic systems. Moreover, the NRC report specifically identified

as three overarching objectives for NASA, (1) to extend human activities beyond low Earth orbit, (2) explore the potential for life beyond Earth, and (3) expand understanding of the universe. *We contend that the concept and trade studies proposed for use of the NRO optic must be consistent with all three objectives identified by the NRC.*

Trade Studies and Options: Priorities for Human Spaceflight and Achieving Major Astrophysics Goals by the 2030s

In response to the RFI, we recommend beginning with a series of focused trade studies that specifically assess how the context described above for science, human space flight, the ISS, and technology priorities may be *simultaneously* applied to use effectively the NRO optic over approximately the next decade. For example, operating the NRO telescope in space beyond Earth's orbit, but still in the local vicinity within a few travel days from home, affords astronauts and robotic partners extensive opportunities to validate capabilities to enable a subsequent very large telescope. We note, in addition, that the following activities lend themselves well to opportunities for competitive participation by the academic communities, including students.

Broadening the situations in which advanced space robots deploy, assemble, repair, and upgrade complex science facilities. Modification to the Orion stack could, for example, enable teleoperations, perhaps installing cryogenic scientific instrumentation in the focal plane to extend operations well into the infrared. Such an activity has only been demonstrated via astronaut EVA.

Long-duration testing of materials and their environment. If located beyond the Van Allen Belts, the NRO telescope could enable long-duration testing of materials for radiation and micrometeorite exposure, as well as provide a platform for radiation monitoring, thus reducing our knowledge gap of radiation effects in this region.

In-situ precision measurements. Other activities that might be demonstrated with the NRO optics include *in situ* precision measurements of the jitter environment during telescope operations to greatly improve our ability to carry out diffraction-limited imaging over wide fields of regard. In addition, external occulters of various designs could be positioned in the near field of the telescope to validate concepts for high-contrast imaging of large, hot Jupiter-class objects.

Extended astronaut EVA demonstration. Depending upon the facilities being developed in free space in advance of a human mission to Mars (Section 3), very ambitious demonstration activities might be carried out that are not possible with even an upgraded Orion spacecraft. For example, a Mars or other very distant transfer habitation demonstration facility – our analogy with the role of the Gemini spacecraft – may offer more extensive robotic controls and extended astronaut EVA capabilities. This may, in turn, allow more advanced instrument and sub-system change-out and upgrade, which would need to be assessed via advanced trade studies. *That is, such a "bridging" capability will not only reduce the risk for humans and systems to Mars, but also provide the opportunity for doing world-class astrophysics post-JWST and prior to the deployment of a 16+ meter-class observatory in free space.*