

Beyond the ISS: Support for Research Campaigns on Axiom Station

*A Research Campaign White Paper Submitted to the
National Academies Space Studies Board Steering Committee for the
Decadal Survey on Biological and Physical Sciences Research in Space 2022-2032*



Authors:

Mary Lynne Dittmar, Executive Vice President, Axiom Space, 1290 Hercules Avenue, Houston, Texas 77058, USA; Ph: (832) 330-6376; Email: marylynne@axiomspace.com

Christian Maender, Director In-Space Manufacturing & Research, Axiom Space
Jana Stoudemire, Commercial Innovation Strategy Lead, Axiom Space
Jason Aspiotis, In-Space Manufacturing & Research Business Development Manager
Rachel Clemens, In-Space Manufacturing & Research Business Development Manager
Anjali Gupta, In-Space Manufacturing & Research Business Development Manager
Divya Panchanathan, In-Space Manufacturing & Research Business Development Manager
David Zuniga, In-Space Manufacturing and Research Business Development Manager
William McLamb, Lead Payload Project Manager
Luke Peeples, In-Space Innovation Associate
Erica Lefaive, Legislative Affairs Associate

Submitted: December 23, 2021

Beyond the ISS: Support for Research Campaigns on Axiom Station

Introduction

The International Space Station (ISS), in orbit for over 20 years and home to decades of space-based research in the biological and physical sciences, is approaching its end of life. Establishing a domestic commercial space station as a successor to ISS preserves the national capability to initiate or continue scientific microgravity research and, critically, enables the US to maintain leadership in space. With the recent launch of the Tiangong station by China [1], and the lessons learned from not having a transition plan after the end of the Space Shuttle Program, having an ISS replacement is a priority for NASA and the nation.

Commercial space stations are emerging as successors to the ISS to ensure continuity of human presence and research in space. Axiom Space Inc., a privately funded American company, is led by CEO Michael T. Suffredini, formerly the NASA Program Manager for the International Space Station. Axiom's leadership team draws upon decades of NASA experience in designing, building, and operating a space station managing crewed and uncrewed missions, facilitating and operating onboard research facilities, and logistics. Axiom Station, anticipated to begin assembly at the ISS in late 2024, is intended to be the cornerstone to a future 'city in space'. In addition to residential facilities for next generation space explorers, Axiom Station will provide 1) a laboratory for research and discovery, 2) a production facility for developing products that benefit from the extreme environment of space and microgravity, 3) a near-Earth platform for space-environment materials testing and validating technologies for deep-space missions, 4) a hub for transportation, logistics and services in low-Earth orbit (LEO), 5) a platform for communications, observation and national security, 6) a training ground for professional astronauts, and 7) a hub for global innovation and collaboration. This diversified offering will sustain growth of commercial infrastructure in LEO and, in turn, ensure availability of access for NASA and national interests to maintain a continuous US presence in LEO during and after the ISS lifetime.

Planned Transition From ISS to Commercial Facilities

As noted in the results in brief statement of the recent NASA Office of Inspector General Report (IG-22-005) "Given the Station's inevitable retirement and NASA's continuing need for low Earth Orbit research, the success of the Agency's Plan for Commercialization of Low Earth Orbit Development is crucial to avoid a gap in low Earth orbit access." [2] Both the IG-22-005 report and the Midterm Assessment of Implementation of the 2011 Decadal Survey on Life and Physical Sciences Research at NASA identified that LEO science research exploration will be required beyond 2024, and extended durations in microgravity, measured in years, will be required to satisfy deep space exploration research needs [8,3]. These reports also recommend expanded utilization of commercial partner capabilities to address the need for increasing cargo and crew transport, crew time availability and research on ISS. Axiom's goal is to facilitate a seamless transition of activities from the ISS to an improved and upgraded replacement,

Beyond the ISS: Support for Research Campaigns on Axiom Station

partnering with NASA and others to ensure support of biological and physical sciences as a key part of a larger operational portfolio.

Axiom Commercial Space Station Timeline

Beginning in 2020 when Axiom Space was selected by NASA to provide a habitable module to be attached to the ISS [4], the Axiom development plan utilizes a phased approach to the development of capabilities and services, as follows:

Phase 1: Private Astronaut Missions that Enable the Expansion of Research on the ISS. In May 2021, NASA and Axiom Space signed an order for the first private astronaut mission to the International Space Station (ISS) – “Ax-1” – targeted for launch in February of 2022. [5]. The mission will involve four crewmembers who will conduct approximately 25 experiments while onboard, generating critical data from studies in human research, life and physical sciences, technology demonstrations, and Earth observations that will expand applicability of microgravity research to new sectors [6]. A second 10-day mission, recently awarded by NASA, will take place in late 2022 or early 2023. [7]. Axiom Space has contracted with SpaceX for another two additional flights [8]. Ultimately Axiom plans to offer Astronaut Missions that include 10-, 30-, 60-, 90-, and 180-day missions to the ISS and Axiom Station.

Phase 2: Building the Commercial Space Station -

First Module at ISS by 2024. Axiom’s first module, the Axiom Habitat-1 (AxH1), currently being fabricated (**Figure 1**) is scheduled to berth to ISS Node 2 in 2024, ensuring continuity of access to existing ISS customers and expanded research volume and capabilities. The planned second and third modules, Axiom Habitat-2 (AxH2) in 2025 and the Axiom Research and Manufacturing Facility (AxRMF) in 2026, will further expand both crew quarters and research capacity.

Phase 3: Independent Power and Thermal Control - Detaching from ISS as a Free Flyer. The Axiom Station Power and Thermal Facility (AxPTF) will provide oversized power and heat rejection capabilities, along with a crew airlock and extravehicular activity (EVA) suits to support spacewalks for up to 3 crew at a time. The power generation system will include upgraded solar panels and modern batteries capable

of generating power for a four-module station and provide a surplus for module expansion in the future. The AxPTF with expanded environmental control and life support systems (ECLSS), storage, and payload capabilities will allow the complex to operate as an independent, free-flying commercial space station by 2028. An overview of the timeline for building the Axiom Station is provided in **Figure 2**.



Figure 1: Axiom Station docking ring fabrication by Thales Alenia Space; Earth observatory window

Beyond the ISS: Support for Research Campaigns on Axiom Station

Support for Biological and Physical Sciences

As presented by NASA Biological and Physical Sciences (BPS) Division Director, Craig Kundrot, at the Space Studies' Board Committee on Biological and Physical Sciences (CBPSS) Fall Meeting 2021, a focus on transformational research recommended by the 2011 Decadal Survey, and likely to be examined further in the 2023 Decadal Survey, will include space biology and physical sciences, as well as greater interaction with NASA's Space Technology Mission Directorates (STMD), Human Exploration and Operations Mission Directorate (HEOMD), other Government Agencies (OGA's), the ISS National Lab (ISSNL/CASIS), and expanded research conducted on governmental and commercial platforms.



Figure 2: Axiom Space timeline for construction of the Axiom Station

As presented by NASA Biological and Physical Sciences (BPS) Division Director, Craig Kundrot, at the Space Studies' Board Committee on Biological and Physical Sciences (CBPSS) Fall Meeting 2021, a focus on transformational research recommended by the 2011 Decadal Survey, and likely to be examined further in the 2023 Decadal Survey, will include space biology and physical sciences, as well as greater interaction with NASA's Space Technology Mission Directorates (STMD), Human Exploration and Operations Mission Directorate (HEOMD), other Government Agencies (OGA's), the ISS National Lab (ISSNL/CASIS), and expanded research conducted on governmental and commercial platforms.

Volume and Equipment to Support NASA Biological and Physical Science Research Needs

The AxH1 module provides approximately 75m³ in living space and pressurized volume dedicated to research and manufacturing payloads and experimentation. The living quarters will accommodate four crew members. Dedicated volume for research and manufacturing applications will allow for iterative experimentation and on orbit sample analysis. The AxH2 will offer equivalent additional crew and research capacity and will be the home to Axiom Station's Earth Observatory, offering up to 6 crew members an unparalleled view to observe and study Earth, as well as providing a platform for scientific observations requiring pressurized volume.

The AxRMF will provide approximately 133m³ of volume for state-of-the-art research and manufacturing capabilities. While continuous crew support will be available for research and pilot-scale manufacturing on the AxH1 and AxH2 modules, the semi-automated scaled manufacturing systems of the AxRMF will require only minimal crew interaction for startup, shutdown, and product recovery procedures. The launch of the AxRMF will also include a new external Axiom Robotic arm capable of supporting manipulation and operation of external research payloads for both commercial and government customers.

Capabilities to Support Biological and Physical Sciences

Objectives of the Space Biology Program include discovering how biological systems respond to the space environment, identifying the mechanisms and developing models for biological systems in space, providing mechanistic understanding to support human health, and promoting open science through GeneLab Data Systems and Life Sciences Data Archives, developing technologies to enable space flight research, and transferring the knowledge and technology of space-based research to benefit to life on

Beyond the ISS: Support for Research Campaigns on Axiom Station

Earth. Similarly, objectives of the Physical Sciences Program include investigating fundamental laws of physics, and physical processes using the space environment, identifying the underlying processes and developing models for physical systems in space, developing technology to enable spaceflight research, promote open science through Physical Science Informatics and transferring the knowledge and technology of space-based research to benefit life on Earth.

The upgraded tools and expanded physical volume available on Axiom Station will provide opportunities to accelerate leading edge research toward exploration goals and benefit to life on Earth. Axiom welcomes input from the scientific community regarding capabilities that will advance research and stimulate innovation in methodology, with a particular focus on transformational science. We are working with several industry partners on development of onboard capabilities, some which are publicly shared in general terms and include:

- Flexible passive and active payload accommodations that are reconfigurable on orbit
- Updated research facilities and data management systems (relative to ISS)
- Provisions for commercially provided equipment and ease of transfer from terrestrial to in-space operations
- External payload facilities'
- On-orbit analytics and advanced infomatics
- Edge computing capabilities
- AI/ML

Existing & Potential New Research Synergies with other U.S. Government Agencies

The Axiom Station provides a platform to continue expanding existing NASA and ISSNL initiatives with the National Institutes of Health (NIH), National Science Foundation (NSF), Department of Defense (DoD) and Department of Energy, and others, through additional Axiom Private Astronaut Missions where funded researchers can be trained to conduct experiments on orbit, as well as expanded research volume and capabilities.

Collaboration - Across Science Divisions & with Commercial/International Partners

The additional Axiom Station volume and crew facilitate greater collaboration with NASA BPS with Science Technology Mission Directorate (STMD) including the Zero Boil Off Tank Experiments (ZBOT), Lunar in situ research utilization (ISRU), Human Research Program (HRP) animal, plant, microbiological, and human analog model systems research, Advanced Exploration Systems (AES) ECLSS Crew Health and Performance Systems Capability, combustion/fire safety and two-phase flows for water recovery and thermal management advancement initiatives being further reviewed by the committee for the Decadal survey.

Beyond the ISS: Support for Research Campaigns on Axiom Station

Additionally, Axiom's ability to support professional astronaut missions that expand opportunities for science and human health research will foster international partnerships from other space-faring nations who seek to collaborate with NASA on exploration and LEO commercialization opportunities.

A Seamless Transition

The additional volume Axiom Station will add to LEO for both research and habitation beginning in 2024 provides opportunities not only to advance the pace of research but also ensure continuity of some existing research programs already in LEO, after ISS end of life. Axiom will make research capabilities available as the station is being built, providing several years of research support prior to completion and detachment of the Axiom Station from the ISS. Axiom Station can also augment NASA's human exploration research in preparation for Artemis and future Mars missions.

Summary

The Axiom Station provides foundational in-space infrastructure that will not only sustain U.S. leadership in human spaceflight and space exploration, but also provides a tangible, near-term platform to support and accelerate microgravity research goals. Functionality designed to address commercial customer needs including more rapid access to flights, streamlined processes for quick access to microgravity labs, and state-of-the-art capabilities providing on orbit analysis and iterative experimentation during a single mission have the potential to significantly advance NASA's life and physical sciences BPS objectives, health research and technology demonstrations, and to facilitate partnership across NASA Science Mission Directorate (SMD) divisions, international space agency partners and other government agencies. Axiom is committed to provide strong support for NASA biological and physical science initiatives utilizing commercial capabilities to establish a new standard of operations in LEO in the coming decade.

¹ Jones, A. (2021). China's Tiangong Space Station. *Space.com* (24 August 24), <https://www.space.com/tiangong-space-station> (accessed 6 November 2021).

² NASA Office of Inspector General (2021). NASA's Management of the International Space Station and Efforts to Commercialize Low Earth Orbit. IG-22-005 (30 Nov), <https://oig.nasa.gov/docs/IG-22-005.pdf> (accessed 17 December 2021).

³ National Academies of Sciences, Engineering, and Medicines (2018). A Midterm Assessment of Implementation of the Decadal Survey on Life and Physical Sciences Research at NASA, <https://doi.org/10.17226/24966> (accessed 17 December 2021).

⁴ NASA (2020). NASA Selects First Commercial Destination Module for International Space Station Press release (28 Feb), <https://www.nasa.gov/press-release/nasa-selects-first-commercial-destination-module-for-international-space-station> (accessed 26 November 2021).

⁵ NASA (2021). NASA, Axiom Agree to First Private Astronaut Mission on Space Station. Press release (21 May). <https://www.nasa.gov/press-release/nasa-axiom-agree-to-first-private-astronaut-mission-on-space-station> (accessed 17 December 2021).

Beyond the ISS: Support for Research Campaigns on Axiom Station

⁶ Axiom Space (2021). Axiom Space reveals robust microgravity portfolio for first-ever private mission to visit International Space Station. (17 Nov), <https://www.axiomspace.com/press-kit-ax1-research> (accessed 20 December 2021).

⁷ Record-holding astronaut Peggy Whitson and mission pilot John Shoffner to lead Axiom Space's Ax-2 mission to enable new research in space. Press release (25 May), (<https://www.axiomspace.com/press-release/ax2>) (accessed 17 December 2021).

⁸ Axiom Space (2021). Axiom Space signs blockbuster deal with SpaceX to fly three additional private crew missions to ISS through 2023. Press release (2 Jun), <https://www.axiomspace.com/press-release/axiom-spacex-deal> (accessed 17 December 2021).