National Aeronautics and
Space Administration

GATEWAY: THE CISLUNAR SPRINGBOARD FOR INTERNATIONAL AND SUSTAINABLE HUMAN DEEP SPACE EXPLORATION

White Paper

ARCHITECTURE CONCEPT REVIEW 2022

INTRODUCTION

The purpose of this paper is to describe the Gateway and its contribution to how this cislunar platform supports Moon-to-Mars Objectives.

Working from both the NASA Moon-to-Mars Strategy and Objectives and an array of available Mars studies, several key characteristics of the lunar architecture have been derived, including the need for a long-duration, multi-purpose cislunar platform. That cislunar platform, orbiting the Moon in a near-rectilinear halo orbit (NRHO), is called Gateway. Gateway is a critical element of sustained deep space infrastructure; it enables the Artemis campaign, serves as a stepping-stone beyond the Earth-Moon system to Mars and establishes a U.S.-led permanent presence in cislunar space.

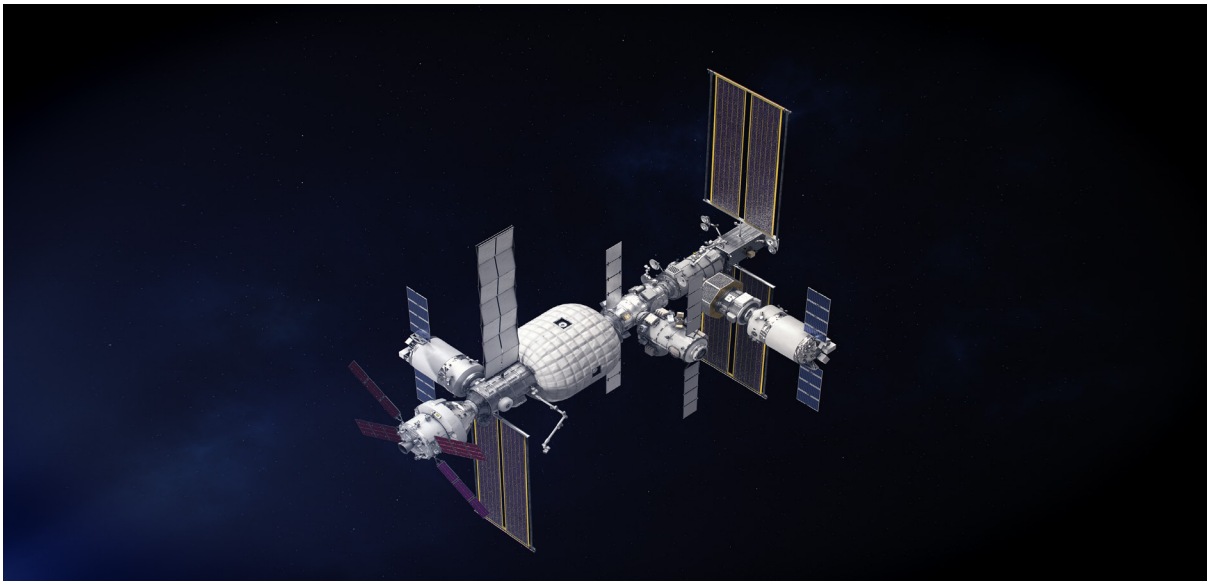

Figure 1. Illustration of the Gateway expanded capability configuration with an expanded habitation visiting vehicle.

ABOUT GATEWAY

Gateway will be a human-tended space station in orbit around the Moon and a critical part of the Artemis missions, with a mission statement of: “Creating the cislunar springboard for cooperative and sustainable human deep space exploration.” Gateway symbolizes the expansion of NASA’s human spaceflight partnerships into deep space, with international partner contributions, U.S. elements managed at multiple Centers, commercial partners, and opportunities for more, diverse partnerships and collaborations in the future. Today, all

U.S. contributions are under contract with hardware in development and being delivered for integration, and NASA's partnerships are in place with the European Space Agency (ESA), Canadian Space Agency (CSA), and Japan Aerospace Exploration Agency (JAXA). Hosted within NASA by the Johnson Space Center, the Gateway Program provides global, integrated leadership for our Gateway partners, with NASA leading research and utilization, developing integrated modular flight software and autonomy, building labs to support development and flight verification testing, performing integrated performance analyses and integrated safety, and conducting flight operations from Houston's Mission Control Center for Gateway's minimum 15-year design life.

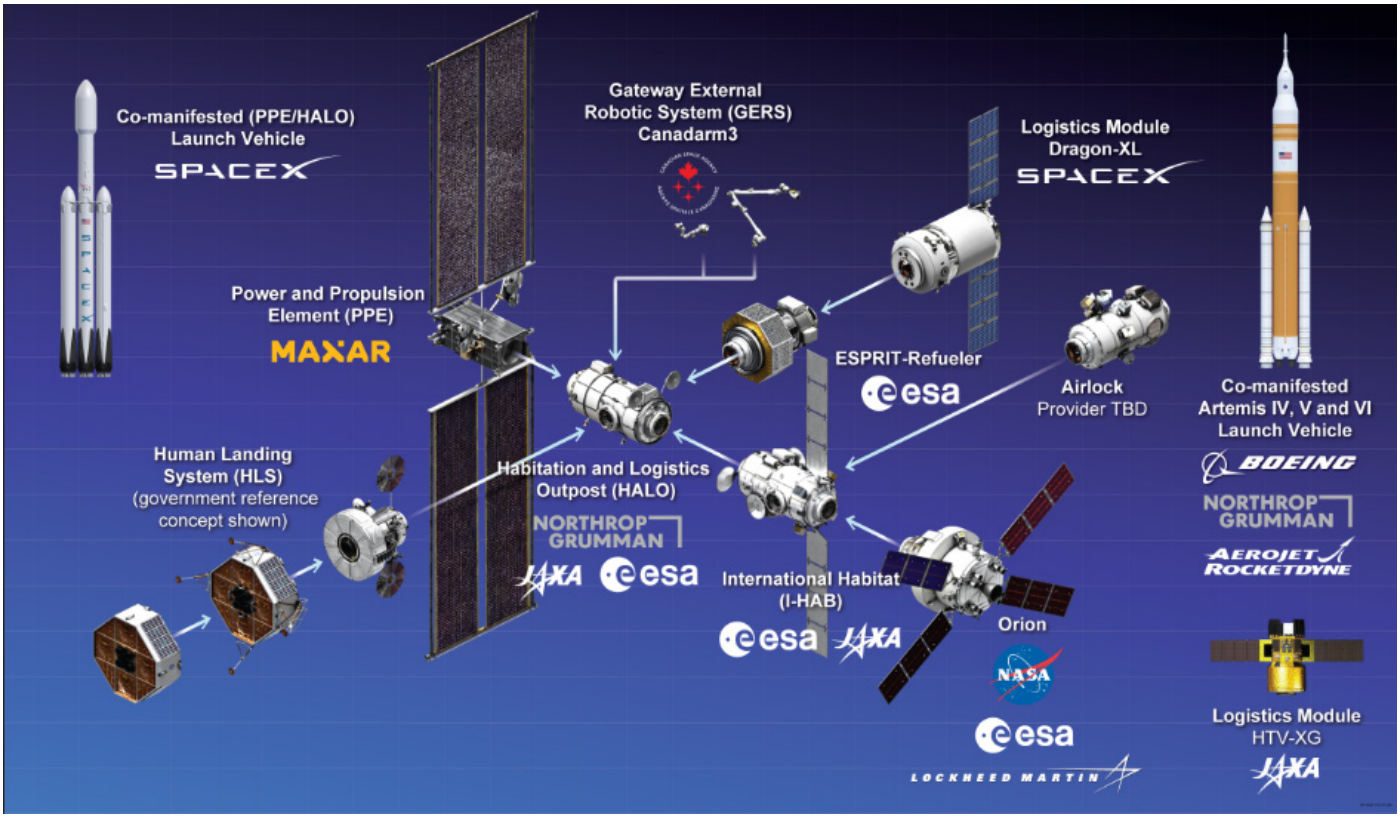

Figure 2. An expanded view of the integrated Gateway spacecraft

Gateway is an incrementally built and deployed spacecraft, providing unprecedented access to the entirety of the Moon's surface and enable sustainable lunar exploration, science, and technology development. Gateway will be instrumental in exploration of the Moon and Mars by providing the first permanent infrastructure at the Moon, serving as a staging point for lunar surface activities and Mars-forward development. Continuous deep space science and technology investigations aboard the space station will help provide insight into the environments in cislunar space.

ARCHITECTURE SELECTION: GATEWAY, THE CISLUNAR PLATFORM

The key drivers influencing the need for a long-duration cislunar platform can be summarized in distinct areas derived from the Moon to Mars Recurring Tenets, Goals, and Objectives.

Science: Gateway will be a year-round deep space laboratory with internal and external utilization capabilities, addressing key scientific questions in the Moon to Mars Objectives areas of heliophysics, human and biological science, physics and physical science, science-enabling, and applied science. For example, the first three payloads selected for Gateway will help address high priority heliophysics science and space weather questions working together to study space weather and radiation. The Gateway lunar space station will also advance understanding of physical systems and fundamental physics by utilizing the unique environment of cislunar space and NRHO. NRHO is a science-relevant orbit, providing a favorable vantage point for the Earth,

Sun, and deep space observations. Gateway's cislunar orbit provides an opportunity to make observations and measurements in the deep space environment as well as in a magnetically shielded environment, depending on the phase of the Moon's orbit. Gateway will enable the pursuit of human and biological science goals to better understand what is necessary to keep crews healthy and optimize task performance during all phases of deep space missions to Mars. Specifically, the space station will enable making progress towards Earth-independent operations through applied science objectives and investigations in a number of areas, including micrometeorite flux, atmospheric weather, space weather, and dust. Gateway's external robotic interfaces, robotic arm, and science airlock will allow for payloads to fly to and be installed on the station for future investigations.

Infrastructure, Transportation, and Habitation: Gateway will be the first permanent infrastructure at the Moon. Gateway provides habitation systems for crew to live in deep space for extended durations. Early configurations provide habitation capability for up to 30 days with a crew of 2 to 4; as the Gateway expands, crew habitation duration will increase, particularly with a future Transit Habitation system docked at Gateway, which is planned to support dual roles as the eventual Mars crew transportation module and Mars analogs and lunar support missions. Gateway provides a platform and docking ports for scalability to long-term or even continuous presence, plus scalability to future Mars-class systems. Gateway will be the first to utilize high-powered solar electric propulsion on a crewed system with the capability to refuel Xenon and Reaction Control System (RCS) thrusters designed from the beginning; the capabilities of solar electric propulsion and refueling feed forward to Mars transportation objectives. This platform will necessarily need to provide the human habitation support and ability to function with reductions in crew managed reliability, maintenance, and ground intervention associated with near-Earth systems. Other relevant operational functions include robust, multi-channel Ka, X-band, and S-Band communications with over 85% coverage from assets on the surface back to earth. Finally, in a bustling cislunar commercial space economy, Gateway's flexible docking ports will accommodate rotations of arriving and departing visiting vehicles.

Operations: Gateway will demonstrate continuous operations in a relevant deep-space environment. Gateway is also designed to aggregate elements autonomously and support incremental build-up to prepare for the eventual accumulation of systems necessary to achieve Mars capable transit systems. The operational flexibility to demonstrate managing multi-party contributions, aggregations of systems over time, and increasing complexity will be needed to address long-term Mars forward development. The ability to stage long-duration microgravity systems in deep-space or near deep-space equivalent environmental conditions provides analogous drivers to the transit conditions to and from Mars. NASA and its partners will be able to check-out systems in NRHO and conduct Mars-like analog missions closer to home and while exercising the Mars Transit Habitat docked at Gateway. Important aspects of operations include maintainability, reusability, quiescence, and autonomy. Gateway will spend the majority of its life uncrewed, which is likely for future Mars-class systems. It is imperative to advance the state of autonomous operations of human spaceflight missions, like closed-loop control and response to system anomalies, overcoming challenges with significant data latencies back to Earth, and robotics. As designed from the start, Gateway will close these critical operational gaps. Gateway is designed to operate uncrewed for up to three years. Gateway, in allowing for future upgradability in its systems, demonstrates the reconfiguration, flexibility, and adaptability that will be essential for the evolving Moon to Mars architecture.

International and Industry Partnerships: Building on the successful ISS partnership, NASA (representing the U.S. Government) has legal agreements with Canada, Japan, and ESA, with the potential to add new international participation in the future. Gateway's NASA-led components will be provided by commercial partners, enhancing the emerging lunar economy. Gateway's contracts for the first two elements, PPE and HALO, leveraged the NextSTEP Broad Area Announcement mechanisms, a public-private partnership model seeking commercial development of deep space exploration capabilities to support human spaceflight missions. These public-private partnerships are enabling companies to expand their current expertise in scale and complexity. The Gateway Logistics Services contract strategy was enabled by the strong marketplace that exists today in low-Earth orbit (LEO) for commercial resupply to the ISS. Additionally, Gateway provides a deep space technology testbed, a platform, and aggregation point for new entrants and markets in cislunar space.

Interoperability: Gateway is the first program to implement the collaboratively developed international deep space interoperability standards. Gateway's program-level requirements adhere to the nine discipline areas of these standards: avionics, communications, docking, environmental control and life support systems (ECLSS), power, rendezvous, robotics, thermal, and software.

Leveraging Low-Earth Orbit: One of the International Space Station's legacies will be Gateway. The Gateway Program's international partnerships build on ISS partnerships, and various modules and systems are evolutions of ISS capabilities. Gateway takes advantage of equipment designs like water storage and wireless access, and the testing and verifying technologies on the ISS like roll-out solar arrays, a carbon dioxide removal system, and potentially exercise equipment. Gateway will also leverage ISS derived capabilities like rendezvous and docking capabilities, and HTV-XG, a JAXA resupply vehicle based on the Japanese vehicles that resupply ISS. Gateway also feeds back into LEO commercial development, sharing requirements, interfaces, and processes with the programs and offices overseeing commercialization activities in LEO including commercial destinations and on the ISS.

Technology Development and Readiness: A cislunar platform is ideally situated to advance technologies and utilization goals. Today Gateway is advancing enabling technologies and techniques necessary for deep space exploration, like advanced solar electric propulsion, roll-out solar arrays, refueling in deep space, and autonomous robotic technologies, among other areas. Gateway is also implementing autonomous control of an integrated, multi-element spacecraft. This Vehicle System Manager software develops and demonstrates key capabilities necessary for Mars missions with long communication gaps, while implementation in the hierarchy of the Autonomous System Management Architecture demonstrates integrating and operating contributions from multiple partners and providers as an integrated spacecraft.

Access: As an aggregation and departure point, Gateway reduces the relative propulsive cost for landers to access global surface sites. Gateway's orbit is accessible by multiple launch vehicles on the market or in use by government space agencies today.

KEY TAKE-AWAYS

Gateway is a multi-purpose, long-duration cislunar platform that supports multiple Moon to Mars Recurring Tenets, Goals, and Objectives. Gateway is a critical element of sustained deep space infrastructure, enables the Artemis campaign, expands international partnerships, serves as a stepping-stone beyond the Earth-Moon system to Mars and establishes a U.S.-led permanent presence in the strategically important setting of cislunar space.

This white paper was developed as part of NASA's 2022 strategic analysis cycle to address topics of frequent discussion. For the latest white papers or other architectural documents related to human missions to the Moon and Mars, please visit: **www.nasa.gov/MoonToMarsArchitecture**.