

Gateway Program Status and Overview

Sean Fuller^a, Emma Lehnhardt^a, Dylan Connell^a, Christina Zaid^b, Kate Halloran^c

^a National Aeronautics and Space Administration (NASA), Johnson Space Center, United States

^b MORI Associates, Johnson Space Center, Houston, TX

^c Abacus Technology Corporation, Johnson Space Center, Houston, TX

Abstract

This paper provides an overview and status of Gateway, which will be an outpost orbiting the Moon that provides vital support for a sustainable, long-term human return to the lunar surface and a steppingstone to Mars as part of the Artemis program. Gateway is a destination for deep space crew expeditions and science investigations, as well as a port for deep space transportation – for landers en route to the lunar surface or spacecraft embarking to destinations beyond the Earth-Moon system. The National Aeronautics and Space Administration (NASA) leads the Program and serves as the integrator of the spaceflight capabilities and contributions of U.S. commercial partners and international partners to develop Gateway.

This paper will provide an overview of each component of Gateway: The Power and Propulsion Element, the Habitation and Logistics Outpost; Deep Space Logistics; the International Habitation module; External Robotics System; European System Providing Refueling, Infrastructure and Telecommunications; an Airlock; and Exploration ExtraVehicular Activity (xEVA).

Expanding on the successful partnership that has provided over 20 years of continuous crew operations in low-Earth orbit on ISS, Gateway is an evolution of this extraordinary partnership that leverages the capabilities of each partner to expand humankind's sustained exploration deeper into the cosmos. Highlighting the international program with participation from multiple international partners, this paper will also provide a status of Gateway multilateral governance structure and international agreements.

Keywords: Gateway; Artemis; NRHO

Acronyms/Abbreviations

Carbon Dioxide Removal System (CDRS)
 Canadian Space Agency (CSA)
 Co-manifested vehicle (CMV)
 Deep Space Logistics (DSL)
 European Radiation Sensors Array (ERSA)
 European Space Agency (ESA)
 European System Providing Refueling, Infrastructure, and Telecommunications (ESPRIT)
 Gateway Logistics Services (GLS)
 Glenn Research Center (GRC)
 Habitation and Logistics Outpost (HALO)
 Heliophysics Environmental and Radiation Measurement Experiment Suite (HERMES)
 Internal Dosimeter Array (IDA)
 International Habitation module (I-HAB)
 International Space Station (ISS)
 Japan Aerospace Exploration Agency (JAXA)
 Johnson Space Center (JSC)
 Memoranda of Understanding (MOU)
 Near Rectilinear Halo Orbit (NRHO)
 Power and Propulsion Element (PPE)

Gateway, an essential element of NASA's Artemis missions— along with the Space Launch System (SLS) rocket, Orion spacecraft, human landing system, and surface mobility – will be a small, human tended space station orbiting the Moon to support human exploration of the lunar surface and serve as a staging point for deep space exploration. In addition to serving as a destination for astronaut expeditions and scientific research, Gateway will serve as a port for deep space transportation such as landers en route to the lunar surface or spacecraft embarking to destinations beyond the Moon, including Mars. During future Artemis missions, scientific research and technology demonstrations, including scientific experiments provided by NASA and its international partners, will be conducted year-round in the deep space environment via Gateway's unique orbit around the Moon – a Near Rectilinear Halo Orbit (NRHO). The NRHO is a six and a half day orbit that also provides distinct benefits for accessibility via a variety of launch systems and spacecraft, aggregation, low orbit maintenance costs, maneuverability, communications, and lunar surface access. [1]

1. Introduction

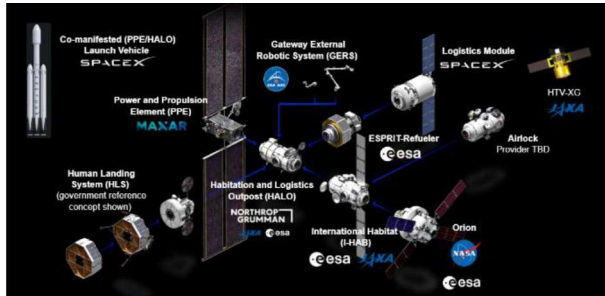


Fig. 1. Expanded view of Gateway Integrated Spacecraft, with government reference Human Landing System

This paper will provide an overview of the Gateway Program’s management and governance, international partnerships, and a status update for each of the elements of the integrated spacecraft as of September 2022.

2. Gateway Overview

2.1 Management and Governance

Managed from NASA’s Johnson Space Center in Houston, Texas, the Gateway Program consists of multiple elements (also called *projects* or *modules*) that are led by various NASA Centers across the United States, and by International Partners.

The Vision and Mission statements for the Gateway Program are:

- Mission: Creating the cislunar springboard for cooperative and sustainable human deep space exploration.
- Vision: A vibrant and lasting human presence in deep space.

The Gateway Program received approval for acquisition strategy from NASA Headquarters in 2018, authorization to proceed into Formulation in early 2019, and the Program Office was established at JSC in early calendar year 2019. Across the Program, multiple Gateway projects, systems, and components have finalized Preliminary Design Reviews (PDRs) and Critical Design Reviews (CDRs). The Program held its PDR for the Gateway initial capability in late summer 2022, and expects to formally conclude this PDR in fall 2022.

2.2 Objectives and Technical Parameters

The high-level objectives of Gateway are:

- Gateway shall be utilized to enable crewed missions to cislunar space including capabilities that enable surface missions
- Gateway shall provide capabilities to meet scientific requirements for lunar discovery and exploration, as well as other science objectives

- Gateway shall be utilized to enable, demonstrate and prove technologies that are enabling for lunar surface missions that feed forward to Mars as well as other deep space destinations
- NASA shall establish industry and international partnerships to develop and operate Gateway

To accomplish these objectives, high level requirements include:

- Providing habitation capability for a minimum of 30 days, with Orion attached:
- Supporting crew sizes from two to four;
- Providing a mission life of minimum 15 years;
- Using solar electric propulsion;
- Providing the capability for extravehicular activity operations outside of the vehicle;
- Operating uncrewed for up to three years;
- Providing the capability for conducting internal and external science experiments and technology demonstrations;
- Accommodating docking and undocking with crewed and uncrewed visiting vehicles; and
- Performing orbit transfers.

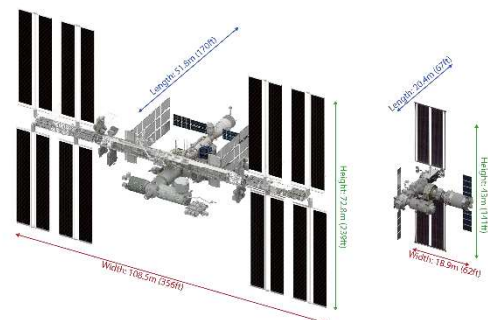


Fig. 2. Size comparison, ISS and Gateway

2.3 International Partnerships

Expanding on the successful partnership that has provided over 20 years of continuous crew operations in low-Earth orbit on ISS, Gateway is an evolution of this extraordinary partnership that leverages the capabilities of each partner. Gateway’s international partners provide important contributions to the lunar outpost, and these partnerships mark a critical part of NASA’s efforts to lead an unprecedented global coalition to the Moon, further contributing to the creation of a dynamic lunar exploration architecture. International Partners are embedded members within Gateway development team, with membership on Gateway Control Boards and technical integration embedded at all levels.

Memoranda of Understanding (MOU) provide the formal commitment between the U.S. Government and partner agencies/governments to fulfil Gateway partnership and contributions.

In October 2020, ESA signed an agreement with NASA to contribute habitation and refuelling modules, enhanced lunar communications to Gateway and two more Orion Service Modules. The ESA-provided International Habitation module, I-HAB will enhance Gateway capabilities for scientific research, life support systems and crew living quarters. These capabilities enable longer duration crewed Gateway missions. The refueling module will also include crew observation windows. The enhanced lunar communications module will be integrated with the Habitation and Logistics Outpost (HALO) module pre-launch and provide high-rate communications relay between Gateway and elements on the lunar surface.

In December 2020, Canada signed an agreement with NASA to participate in Gateway and provide advanced external robotics. The CSA-provided external robotics system includes a next-generation robotic arm, Canadarm3, for Gateway. Canadarm3 will move end-over-end to reach many parts of Gateway's exterior, where its anchoring "hand" will plug into specially designed interfaces. CSA also will provide robotic interfaces for Gateway modules, which will enable payload installation including that of the first two scientific instruments launching on the inaugural Gateway elements.

In December 2020, Japan finalized an agreement with NASA to provide several capabilities for Gateway's I-HAB, which will provide the heart of Gateway life support capabilities and additional space where crew will live, work, and conduct research during Artemis missions. JAXA's planned contributions include I-HAB's environmental control and life support system, batteries, thermal control, and imagery components, which will be integrated into the module by ESA prior to launch. These capabilities are critical for sustained Gateway operations during crewed and uncrewed time periods. JAXA will also be providing logistics resupply via the HTV-XG spacecraft, an evolution from the HTV and HTV-X logistics carriers that resupply ISS.

3.1 Gateway Initial Capability

The integrated PPE and HALO are the foundational elements of Gateway. In March 2020, NASA decided to integrate the two elements on Earth and launch them together.

The PPE is a high-power, 60-kilowatt solar electric propulsion spacecraft that will provide power, high-rate communications, attitude control, orbit maintenance, and orbital transfer capabilities for Gateway. The PPE is being developed and built by Maxar Technologies of

Westminster, Colorado, and is managed out of NASA's Glenn Research Center in Ohio. Maxar Technologies was awarded the contract for PPE in 2019. [2] Maxar successfully conducted a first Preliminary Design Review (PDR) in July 2021. In Spring 2022, the PPE engineering team conducted an extensive end-to-end testing campaign of PPE's advanced electric propulsion system thrusters. A Critical Design Review (CDR) is expected in 2023. [3]

HALO is where Artemis astronauts will live and conduct research while visiting Gateway. The pressurized living quarters will provide command and control systems for the lunar outpost, and docking ports for visiting spacecraft, such as NASA's Orion spacecraft, lunar landers, and logistics resupply craft. The HALO module will serve as the backbone for command and control and power distribution across Gateway and will perform other core functions, including hosting science investigations via internal and external payload accommodations and communicating with lunar surface expeditions. HALO also will enable the aggregation of additional habitable elements to expand Gateway capabilities. HALO leverages contributions from Gateway international partners for robust capabilities. Batteries provided by the Japan Aerospace Exploration Agency (JAXA) will power HALO until PPE solar arrays can be deployed and during eclipse periods. Robotic interfaces provided by the Canadian Space Agency will host payloads and provide base points for Canadarm3 robotic operations. ESA (European Space Agency) will provide a lunar communications system to enable high-data-rate communications between the lunar surface and Gateway. HALO is managed out of NASA's Johnson Space Center in Houston. Northrop Grumman of Dulles, Virginia was awarded a contract for the preliminary design of HALO in 2020, and the remaining content for HALO was finalized between NASA and Northrop Grumman through signing a contract in July 2021. [4] HALO successfully completed PDR in summer of 2021 and completed a CDR in summer 2022. Construction of Gateway's HALO module, including structural welding in Italy, is expected to conclude in the fall of 2022, followed by static loads test and proof pressure test beginning late 2022. HALO is expected to arrive to Northrop Grumman's facilities in Gilbert, Arizona in the summer of 2023, where it will begin the process of being outfitted with its various components to support future Artemis missions. [5]

In February 2021, NASA selected SpaceX to provide launch services for PPE and HALO. As of 2022, the integrated modules and referred to as the co-manifested vehicle (CMV). After integration on Earth, the CMV is targeted to launch together no earlier than November 2024 on a Falcon Heavy rocket from Launch Complex 39A at Kennedy. [6]

Some of the scientific payloads that will fly on Gateway Initial Capability have already been selected. [7, 8, 9] They include:

- The European Radiation Sensors Array (ERSA) will help provide an understanding of how to keep astronauts safe by monitoring the radiation exposure in Gateway's unique orbit.
- The Heliophysics Environmental and Radiation Measurement Experiment Suite (HERMES) is NASA's space weather instrument suite that will observe solar particles and solar wind created by the Sun.
- The ESA Internal Dosimeter Array (IDA) will include instruments provided by JAXA. Radiation measurements and data provided by the IDA will allow for the study of radiation shielding effects and improve radiation physics models for cancer, cardiovascular, and central nervous system effects, helping assess crew risk on exploration missions.

3.2 *Deep Space Logistics and Gateway Logistics Services*

As astronauts prepare for missions to the lunar surface, they will need deliveries of critical pressurized and unpressurized cargo, science experiments, and supplies. The Kennedy Space Center manages the Deep Space Logistics (DSL) project office, which includes management of Gateway Logistics Services (GLS) contract.

In March 2020, NASA selected SpaceX of Hawthorne, California, as the first U.S. commercial provider under Gateway Logistics Services contract. [10] SpaceX and the DSL team are currently conducting special studies in advance of providing authority to proceed for the first GLS mission.

3.3 *I-HAB and ESPRIT*

The European Space Agency (ESA) will contribute habitation and refueling to Gateway. The I-HAB will enhance Gateway capabilities for scientific research, life support systems and crew living quarters, which will enable longer duration crewed Gateway missions. The Japan Aerospace Exploration Agency (JAXA) plans to provide several capabilities for Gateway's I-HAB, including I-HAB's environmental control and life support systems, batteries, thermal control, and imagery components, which will be integrated into the module by ESA prior to launch. Gateway's I-HAB module will utilize similar life support systems to those currently on the ISS. As a technology risk mitigation, a scaled version of the JAXA developed Gateway CO₂ removal system (CDRS) will be flown and demonstrated on ISS. This tech demo will help validate the CDRS design and flush out any issues prior to launching the CDRS in I-HAB

where crews will depend on it for longer duration stays at Gateway.

The ESPRIT, or European System Providing Refueling, Infrastructure, and Telecommunications, provides additional fuel capacity to resupply PPE, windows, and enhanced lunar communications. These capabilities are realized in two components, the HALO Lunar Communications System (HLCS) which is integrated and launched with HALO and the ESPRIT Refueling Module which is a separate module that will be docked to HALO on a future mission.

ESA is under contract with Thales Alenia Space for both the I-HAB and ESPRIT modules. [11] I-HAB completed its PDR in Fall 2021 with primary structure fabrication underway.

ESA recently provided a design modification to ERM adding capability to launch with 1.5MT of cargo and volume for 6.5m³ of on-orbit stowage. The module size grew to 3m in diameter with refueling ring located around the pressurized habitable compartment. In the summer of 2022 ESA conducted a delta SRR to review these changes.

Gateway refueling of Xenon and bi-propellant from ERM storage tanks to the PPE tanks will be utilizing new technologies. Development of the refueling system has been advancing with breadboard testing of the integrated ERM-HALO-PPE fueling system occurring in the summer of 2022.

3.4 *Gateway External Robotics System*

The Canadian Space Agency (CSA) will provide an advanced Gateway external robotics system (GERS), which includes a next-generation robotic arm, or Canadarm3. Canadarm3 will move end-over-end to reach many parts of Gateway's exterior. Canadarm3 will be used to conduct maintenance, to berth and inspect vehicles, and install science payloads. In addition, CSA will also provide Gateway external robotic interfaces (GERI) across the Gateway modules. Robotic interfaces on PPE and HALO host the ERSA and HERMES payloads enabling early utilization. The GERI PDR was complete summer of 2022. MacDonald, Dettwiler and Associates Ltd. (MDA) was selected by CSA for both the Canadarm3 and external robotic interfaces. [12, 13] Canadarm3 completed System Requirements Review in January 2022 and is progressing toward a PDR in 2023. Canadarm3 will be delivered to Gateway via a Gateway logistics flight supporting the Artemis V mission.

3.5 *Airlock*

The Gateway integrated spacecraft will also need an Airlock. The Gateway airlock module will support both crewed spacewalks and a science airlock to transfer scientific experiments and Gateway hardware between the pressurized cabin and the exterior of Gateway.

Canadarm3 will be an integral part of the science airlock operations moving the hardware into and out of the science airlock and deploying/retrieving around Gateway.

As of August 2022, NASA is in discussion with a potential new NASA Gateway international partner to contribute to the Gateway Airlock. Ongoing conversations are occurring to determine the international provider who will provide contributions to the airlock.

4. Summary

In summary, Gateway will provide unprecedented access to the Moon and enable sustainable exploration to the lunar surface and beyond. *Gateway symbolizes the expansion of NASA's international and commercial partnerships into deep space.* Significant progress is underway around the world toward establishing humanity's first permanent outpost in orbit around the Moon.

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