

Gateway Program Status and Overview

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Abstract

This paper provides an overview and status of the 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 the Gateway.

This paper will provide an overview of each component of the 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, the 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 the Gateway multilateral governance structure and international agreements.

Keywords: Gateway; Artemis; NRHO

Acronyms/Abbreviations

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

system – will be a small space station orbiting the Moon that will support human exploration of the lunar surface as well as serve as a staging point for deep space exploration. In addition to serving as a destination for astronaut expeditions and scientific research, the 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 the Gateway's unique orbit around the Moon – a Near Rectilinear Halo Orbit (NRHO). NRHO is a highly elliptical seven-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

The Gateway, a critical component of NASA's Artemis program – along with the Space Launch System (SLS) rocket, Orion spacecraft, and human landing

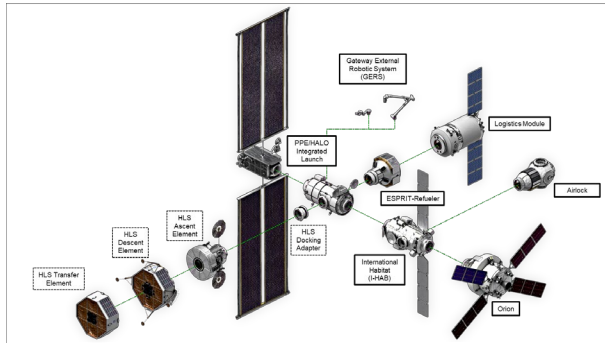


Fig. 1. Expanded view of the Gateway Integrated Spacecraft, with government reference Human Landing System

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 2021.

2. Gateway Overview

2.1 Management and Governance

Managed from the NASA 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. The Gateway Program is still currently in the Formulation phase, and in April 2021 received approval to proceed into the next stages of development through a NASA decisional gate called Key Decision Point-0. Across the Program, multiple Gateway projects, systems, and components are currently finalizing Preliminary Design Reviews (PDRs). The Program will hold a synchronization review to evaluate progress and technical maturity in early calendar year 2022.

2.2 Objectives and Technical Parameters

The high level objectives of the Gateway are:

- The Gateway shall be utilized to enable crewed missions to cislunar space including capabilities that enable surface missions

- The Gateway shall provide capabilities to meet scientific requirements for lunar discovery and exploration, as well as other science objectives
- The 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 the Gateway

To accomplish these objectives, high level requirements include:

- Providing habitation capability for a minimum of 30 days;
- Supporting crew sizes from two to four;
- Providing a mission life of at least 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.

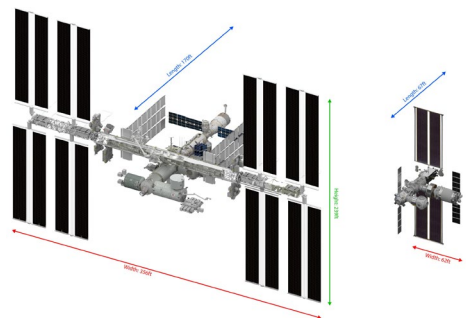


Fig. 2. Size comparison, ISS and Gateway

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, the 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 the 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 the 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 the 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 the 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 the 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.

3.1 Gateway Initial Capability

The integrated PPE and HALO will be the foundational elements of the 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 the 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 and is on track for a Critical Design Review (CDR) in 2022. [3]

HALO is where astronauts will live and conduct research while visiting the 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 the 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 is also on track for a CDR in 2022. [5]

In February 2021, NASA selected SpaceX to provide launch services for PPE and HALO. After integration on Earth, the PPE and HALO are targeted to launch together no earlier than November 2024 on a Falcon Heavy rocket from Launch Complex 39A at Kennedy. [6]

Some of the preliminary scientific payloads that will fly on the 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 the Gateway Logistics Services (GLS) contract.

In March 2020, NASA selected SpaceX of Hawthorne, California, as the first U.S. commercial provider under the 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 the 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 the Gateway's I-HAB, including 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.

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] The next major milestone for I-HAB is the completion of PDR in fall 2021.

3.4 Gateway External Robotics System

The Canadian Space Agency (CSA) will provide an advanced external robotics system, which includes a

next-generation robotic arm, or Canadarm3. Canadarm3 will move end-over-end to reach many parts of the 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 external robotic interfaces for Gateway modules.

MacDonald, Dettwiler and Associates Ltd. (MDA) was selected by CSA for both the Canadarm3 and external robotic interfaces. [12, 13] The next major milestone for the Canadarm3 is a System Requirements Review in fall 2021.

3.5 Airlock

The Gateway integrated spacecraft will also need an Airlock. The Gateway airlock module will support both crewed spacewalks as well 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 September 2021, the Gateway Program is pursuing potential International Partnerships to contribute the Gateway Airlock.

4. Summary

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

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