Gateway Utilization Capabilities and Status

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Abstract

Gateway will be a space station orbiting the Moon that will enable long-term presence in deep space. As part of the National Aeronautics and Space Administration's (NASA) Artemis mission, Gateway will serve as a cornerstone of human deep space exploration and scientific discovery and a steppingstone to Mars. NASA leads the Gateway Program and serves as the integrator of spaceflight capabilities and contributions of U.S. commercial and international partners, European Space Agency (ESA), Japanese Aerospace Exploration Agency (JAXA) and the Canadian Space Agency (CSA), to develop and utilize Gateway. This paper provides an overview of the following utilization capabilities of Gateway: spacecraft overview, internal and external accommodations, resources for utilization, and vantage point for Earth, Sun, and Moon observations. Three utilization payloads have already been selected to fly on Gateway as part of the initial modules, Habitation and Logistics Outpost (HALO) and Power and Propulsion Element (PPE) modules: European Radiation Sensors Array (ERSA), Heliophysics Environmental and Radiation Measurement Experiment Suite (HERMES), and Internal Dosimeter Array (IDA). This paper will provide a short summary of each payload, the value behind conducting each payload, and share an overview of future utilization goals of Gateway.

Keywords: Gateway, Artemis, NRHO, Utilization

Acronyms/Abbreviations

Canadian Space Agency (CSA)
European Radiation Sensors Array (ERSA)
European Space Agency (ESA)
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)
National Aeronautics and Space Administration (NASA)
Near Rectilinear Halo Orbit (NRHO)
Power and Propulsion Element (PPE)
Time History of Events and Macroscale Interactions (THEMIS)

1. Introduction

After nearly fifty years, humans will be returning to the Moon. With Artemis, NASA will put the first woman and first person of color on the lunar surface. The goal of NASA's Artemis mission includes long term presence in the lunar vicinity to advance human deep space exploration and scientific discovery and to inspire of the next generation of explorers. Through collaboration with our international and commercial partners, NASA, will establish the first space station in lunar orbit, Gateway.

Gateway will enable both crew tended and autonomous research in lunar orbit and serve as a destination for Artemis astronaut expeditions, scientific research, and staging point for deep space exploration. Gateway was designed to meet the needs of researchers of today and tomorrow by providing flexible payload services. Gateway's orbit has a unique vantage point in space largely outside of the Earth's magnetosphere which means that it is an ideal place for instruments studying our Sun, also known as heliophysics research. Scientific investigations onboard Gateway will focus on research that cannot be done in low-Earth orbit, like the International Space Station (ISS) or future commercial space stations, and technology demonstrations that will enable long trips to deep space destinations. Lessons learned in the lunar vicinity through Gateway, will be used to send the first astronauts to Mars.

2. Vehicle

Gateway [1] is a multipurpose human tended space station in orbit around the Moon. It will serve as a long-term scientific hub for lunar exploration and a staging point for deep space journeys. Gateway will have habitation and research facilities, both crew and payload airlocks, external robotic capabilities, and logistics services to deliver supplies, new equipment, and research.

The first elements of Gateway (Fig. 1) that will launch on a commercial rocket are the Power and Propulsion Element (PPE) and the Habitation and

Logistics Outpost (HALO), a decision made by NASA in March 2020 [2]. Built by Maxar Technologies, PPE is a high-power 60-kilowatt solar electric propulsion spacecraft that will provide power, high-rate communications, attitude control, and orbital transfer capabilities for Gateway. Built by Northrop Grumman, HALO is the module where astronauts will live and work, conducting research while visiting Gateway. HALO will provide command and control systems for the lunar outpost, power distribution across Gateway, communication with lunar surface expeditions, and docking ports for visiting spacecraft, like NASA's Orion spacecraft, logistics resupply vehicles, and lunar landers. The HALO module will also host science investigations via internal and external payload accommodations.

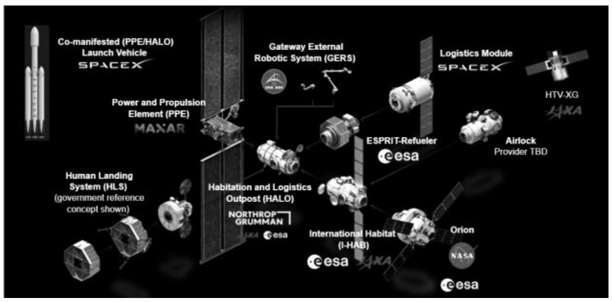

Fig. 1: Expanded view of Gateway, with government reference Human Landing System

The European Space Agency (ESA) will provide the International Habitation module (I-HAB), which will launch on another rocket and enhance Gateway's capabilities for scientific research, life support systems and living quarters. These capabilities enable longer duration crewed Gateway missions.

A logistics services delivery is expected each crewed Artemis mission to deliver cargo and other supplies to Gateway. This cargo delivery will contain all the supplies, including food, tools, and spare parts the crew needs during their mission. Launched before the crew, it will arrive and be available to them when they arrive to Gateway. The cargo delivery will also contain all the scientific instruments, research hardware, technology demonstrations, and investigations that will occur both during their stay and after they depart. After they depart, ground teams will command the logistics vehicle to undock from Gateway and will send it to a heliocentric orbit around the sun. This Sun-center orbit offers a unique platform to conduct heliophysics research after the crewed portion of the mission is complete.

Between crewed missions, Gateway will be uninhabited; however, research will continue year-round. Both internal and external scientific investigations will be enabled by both autonomous systems and some ground interaction, though much less than the typical ISS communication satellite coverage.

3. Utilization Accommodations and Resources

Gateway will provide standard interfaces for internal and external payloads including power, communication, and mechanical attachments. External payload attachment points will have robotic interfaces so that instruments can be moved around by ground controllers, which frees up crew members to perform other tasks. These payload services will enable a wide variety of Earth science, heliophysics, lunar and planetary sciences, life sciences, astrophysics, and fundamental physics investigations both inside and outside Gateway.

3.1 Internal Utilization

HALO and I-HAB will each have eight internal payload bank slots, for a total of 16, locker-based and mounted payloads (Fig. 2.). Each payload bank location will provide variable voltage power, high speed data communication, cold plate cooling, and physical attachment mechanisms. Select locations will also provide access to waste gas venting.

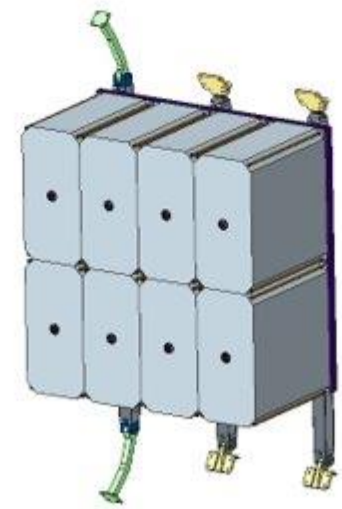
Fig. 2: Gateway payload bank concept

The Internal Dosimeter Array (IDA) will fly installed in a HALO payload bank location. Later experiments will launch on a cargo vehicle either powered or soft-stowed and be transferred and installed by Gateway crew members.

Gateway also has capability for cabin deployed instruments that require less services than payload bank experiments, which are smaller, and need to be moved inside the crew compartment. Typically, these instruments require only power and data or Wi-Fi.

3.2 External Utilization

On the outside of Gateway, the Canadian Space Agency (CSA) will provide an external robotics system, using next generation technology to create the

Canadarm3. Canadarm3 will plug into specially designed interfaces along the exterior of Gateway on one end, while the free end is used to pick up, move, and install external payloads and spare parts onto external receptacles that provide power and high-rate communication.

There will be two external payload receptacles on PPE, one on HALO, and four on I-HAB, plus more on the airlock module. All locations will offer the same interface and services, but each will have unique viewing areas.

Two external payloads will launch with initial Gateway elements: the Heliophysics Environmental and Radiation Measurement Experiment Suite (HERMES) and European Radiation Sensors Array (ERSA). Future instruments will arrive on a cargo vehicle and be robotically transferred by ground controllers operating Candarm3.

3.3 Autonomy

Since Gateway will be uninhabited for long periods of time and in the deep space lunar vicinity, communication with satellites will occur less frequently than on ISS, Gateway's systems and payloads are being designed for autonomy. Gateway will operate with crew on board for up to 30 days with Orion attached. The experiments conducted using Gateway's initial payloads and future instruments will be continuous, advancing scientific discovery in a deep space environment.

3.4 Airlock

Gateway will have an airlock module that supports both crewed spacewalks as well a science airlock to transfer scientific instruments or other Gateway hardware between the pressurized cabin and exterior of Gateway. Canadarm3 will be an integral part of the science airlock operations moving end over end to transfer the hardware into and out of the science airlock and deploying or retrieving items around Gateway. As of August 2022, conversations are underway as the Gateway Program pursues potential International Partnerships to contribute to the Airlock.

4. Gateway Vantage Point

Gateway will travel in a Near Rectilinear Halo Orbit (NRHO) around the Moon [3]. This multibody orbit has many benefits to Artemis missions. It allows easy access from Earth orbit with existing launch vehicles, while also serving as an effective staging point for deep space exploration. The NRHO enables broader access to the surface of the Moon, enabling many different destinations for lunar exploration missions. Because the NRHO is a nearly stable orbit that naturally balances the gravity of the Earth and the Moon, Gateway's orbit maintenance costs are low.

NRHO geometry allows a continuous line-of-sight to Earth, which allows the spacecraft to send data directly to Earth-based antennas. This geometry simplifies the communications path since a relay satellite is not necessary. Gateway will rely on a network of Earth-based antennas around the globe for communications. Gateway can also serve as a relay hub from Earth to the far side of the Moon. Gateway's unique orbit also has scientific benefits. During one NRHO orbit around the Moon, which takes approximately seven days, Gateway will spend about a quarter of time inside the Earth's magnetotail, where it receives protection from the Earth's magnetic field. Most of the time, Gateway's orbit will allow researchers direct measurements of the solar wind and the sun's radiation. Before Gateway, heliophysics researchers would have to build both the spacecraft capable of journeys outside the Earth's magnetotail and the instruments to study the Sun. Soon those researchers will have a platform to perform their investigations.

5. Current Payloads

Three payloads were selected to fly with the initial Gateway elements, PPE and HALO, two external and one internal, and all three focusing on radiation from the Sun that occurs in deep space. These instruments will help scientists better understand how to plan for space weather and outbursts of the Sun on future missions to the Moon and Mars. Radiation affects not just the crew members health but also vehicle systems and electronics, so understanding and planning for unpredictable space weather will be crucial to long duration deep space missions.

5.1 HERMES

The Heliophysics Environmental and Radiation Measurement, or HERMES, instrument (Fig. 3.) will operate on the exterior of Gateway and study the nearby magnetic field, protons, electrons, ions, and lower-energy electrons of the solar wind [4,5]. Along with two similar instruments orbiting the Moon on Time History of Events and Macroscale Interactions (THEMIS) spacecraft, HERMES will provide simultaneous measurements allowing researchers to study how solar winds change over time. Serving as the first space weather monitoring platform on a crewed space station, HERMES is being built by NASA and managed by the Goddard Space Flight Center.

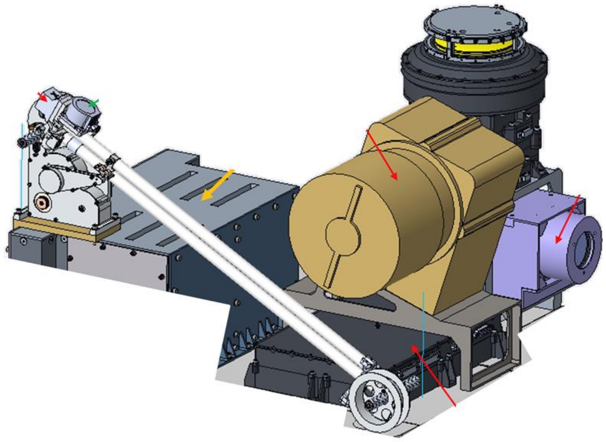

Fig. 3: Heliophysics Environmental and Radiation Measurement Experiment Suite, HERMES, instrument

5.2 ERSA

European Radiation Sensors Array (ERSA) is an ESA developed instrument (Fig. 4), also external to Gateway, studying the solar winds and radiation [4,5]. A suite of instruments will study cosmic rays, neutrons, ions, ionizing radiation, and magnetic fields. In addition to data useful to study crew members health, ERSA's ionizing radiation instrument will provide data to keep electronics in space healthy too. Ionizing radiation on electronics can cause brief spikes in voltage, which can cause short-circuits and potential damage. ERSA is being developed and managed by ESA.

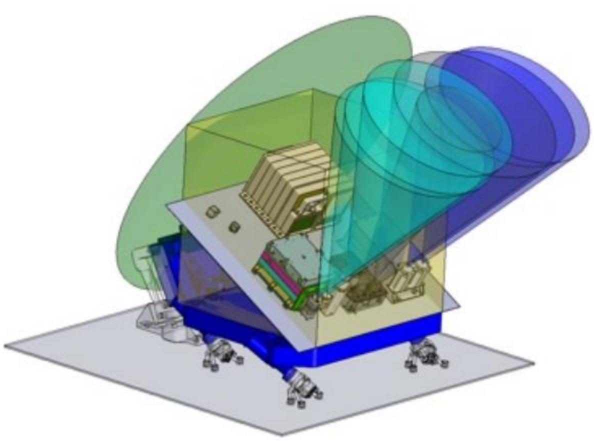

Fig. 4: European Radiation Sensors Array, ERSA, instrument

5.3 IDA

The internal radiation instrument, IDA (Fig. 5), that will be integrated and launched in the HALO, is led by ESA with contributions from the Japan Aerospace Exploration Agency (JAXA) [4,5]. It will study how well the Gateway vehicle shields the habitable volume from radiation. IDA data will be compared to the external data from ERSA and HERMES and will be used to assess crew risk of cancer, and radiation effects on the cardiovascular and nervous systems.

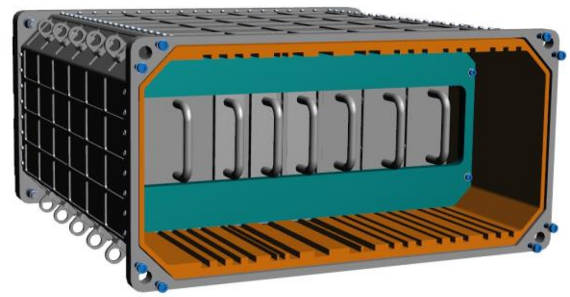

Fig. 5: Internal Dosimeter Array, IDA

6. Future Utilization

The internal and external payload accommodations outlined in this paper and the unique vantage point in deep space not offered at low earth orbit destinations, highlights the role Gateway plans in enabling research and exploration in a deep space environment. Many different types of research are possible at Gateway, including Earth science, heliophysics, lunar and planetary sciences, life sciences, astrophysics, fundamental physics investigations, and technology demonstrations for Mars. Additionally, Gateway allows opportunities for education, outreach, and public engagement that will serve to inspire the Artemis generation of explorers.

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