Preface

Habitation With Gateway was published by NASA's Office of STEM Engagement as part of a series of educator guides to help middle school students reach their potential to join the next-generation STEM workforce. The activities can be used in both formal and informal education settings as well as by families for individual use. Each of these activities is aligned to national standards for science, technology, engineering, and mathematics (STEM), and the NASA messaging is current as of September 2019.

STEM Education Standards

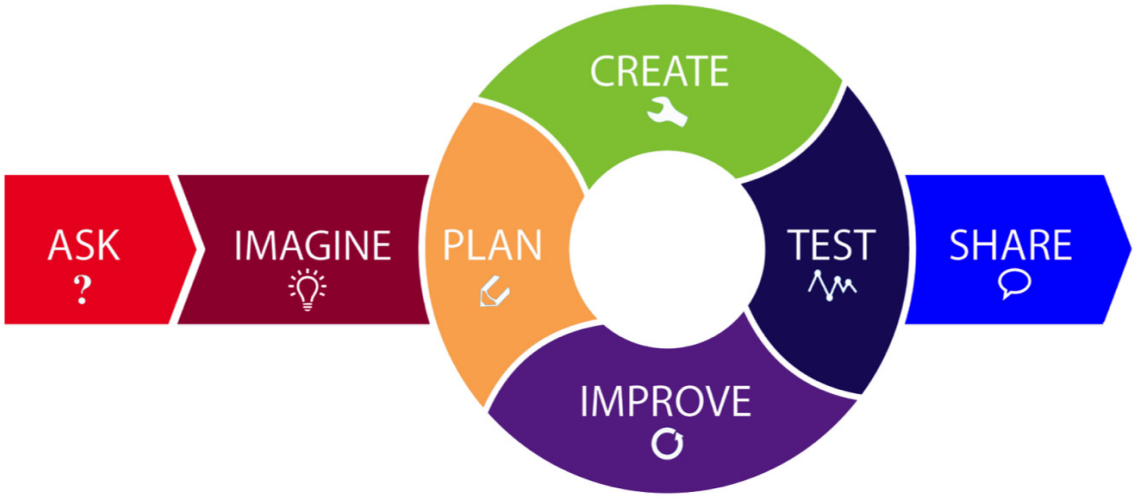
The STEM disciplines matrix shown below aligns each activity in this module to standards for teaching STEM according to four primary focus areas within each discipline. The four focus areas for science were adapted from the Next Generation Science Standards (NGSS) middle school disciplinary core ideas. The four focus areas for technology were adapted from the International Society for Technology in Education (ISTE) Standards for Students. The four focus areas for engineering were adapted from the National Science Teaching Association (NSTA) and NGSS science and engineering practices. The four focus areas for mathematics were adapted from the Common Core State Standards (CCSS) for Math middle school content standards by domain. Find additional matrices in the Appendix: STEM Standards and Practices.

Activity	STEM Disciplines															
	Science				Technology				Engineering				Math			
	NGSS Disciplinary Core Ideas				ISTE Standards for Students				NSTA and NGSS Practices				CCSS Content Standards by Domain			
	Physical Sciences	Life Sciences	Earth and Space Sciences	Engineering, Technology, and the Application of Sciences	Knowledge Constructor	Innovative Designer	Computational Thinker	Global Collaborator	Ask Questions and Define Problems	Develop and Use Models	Plan and Carry Out Investigations	Construct Explanations and Design Solutions	Ratios and Proportional Relationships	The Number System	Statistics and Probability	Geometry
Assess the Structural Integrity of a Space Module				✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	
Design and Build a Space Habitat	✓			✓		✓	✓	✓	✓	✓	✓				✓	
Experiment With Water Filtration		✓		✓	✓		✓	✓		✓					✓	✓
Test Materials for Radiation Shielding	✓				✓	✓					✓					

Engineering Design Process

The engineering design process (EDP) is crucial to mission success at NASA. The EDP is an iterative process involving a series of steps that engineers use to guide them as they solve problems. The steps outlined below can be used by student teams to solve the challenges in this activity guide. Learn more about the EDP with NASA's Educator Professional Development Collaborative at https://www.txstate-epdc.net/models-of-the-engineering-design-process/.

1. ASK: Identify the problem, requirements that must be met, and the constraints that must be considered.
2. IMAGINE: Brainstorm solutions and research what others have done in the past.
3. PLAN: Select and sketch a design.
4. CREATE: Build a model or a prototype.
5. TEST: Evaluate solutions by testing and collecting data.
6. IMPROVE: Refine the design.
7. SHARE: Communicate and discuss the process and solutions as a group.



Tip: In order to manage the dynamics within each team, it may be helpful to assign each student within the group a specific task, such as materials manager, design engineer, fabrication engineer, communications specialist, or team manager. Having each team member in charge of a different element of the task may reduce internal conflict within teams.

Introduction and Background

As NASA sets its sights on returning to the Moon and preparing for Mars, it is laying the foundation for human exploration deeper into the solar system by creating an orbital outpost near the Moon called the Gateway.

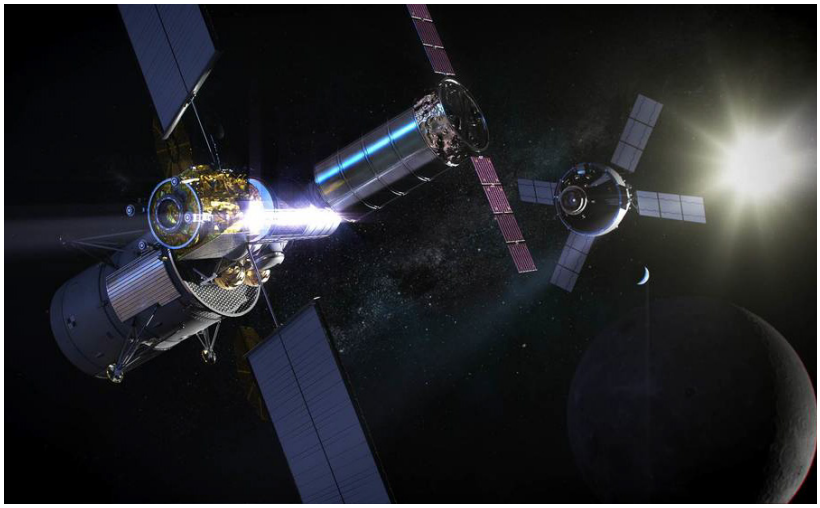


Illustration of the Gateway (left) and Orion (right). (NASA)

Some of the Gateway features include

- Lunar communications systems
- Habitation modules containing environmental control, life support, radiation protection, and safety systems
- Science and research facilities
- Cargo stowage
- Crew and science airlocks
- Robotic and autonomous systems
- Docking capabilities
- Rendezvous sensor packages

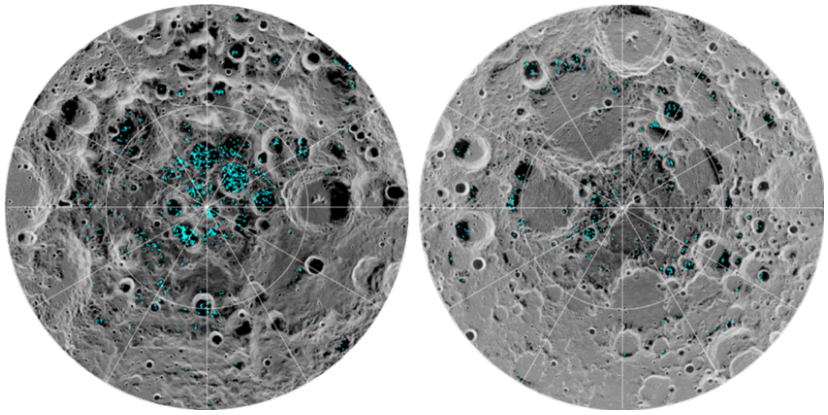
While orbiting the Moon, this spacecraft will be a temporary home and office for astronauts. The commute from Earth to the Gateway will take about 5 days and cover approximately 250,000 miles (about 400,000 kilometers). The Gateway will have living quarters, laboratories for science and research, and docking ports (physical connecting points) for visiting spacecraft. These docking ports will serve as both parking spots for the vehicles and entrances to the Gateway. The Gateway will give NASA and its partners access to more of the lunar surface than ever before, supporting both human and robotic missions.

A New Era of Lunar Exploration

NASA scientists and engineers believe the Gateway will be the key to a new era of lunar exploration—both in orbit and on the surface of the Moon. By studying the geology of the Earth, the Moon, and Mars, and the ways in which they are similar and different from each other, scientists can learn important things about how planets and planetary systems form.

NASA also wants to use the Gateway as a science platform to look back at the Earth, observe the Sun, and get unobstructed views of the vast universe. One of the unique things about the Gateway is that NASA can move it to other orbits around the Moon to do more science in new locations.

In 2009, NASA discovered that the Moon contains millions of tons of water ice. The Gateway will be able to move to the ideal position to have astronauts descend to the lunar surface and extract the ice for use in producing water, oxygen, or hydrogen. This will assist in future missions to Mars.



Distribution of surface ice at the Moon's south pole (left) and north pole (right). (NASA)

The Gateway: A Home Base for Human Missions to the Moon and Mars

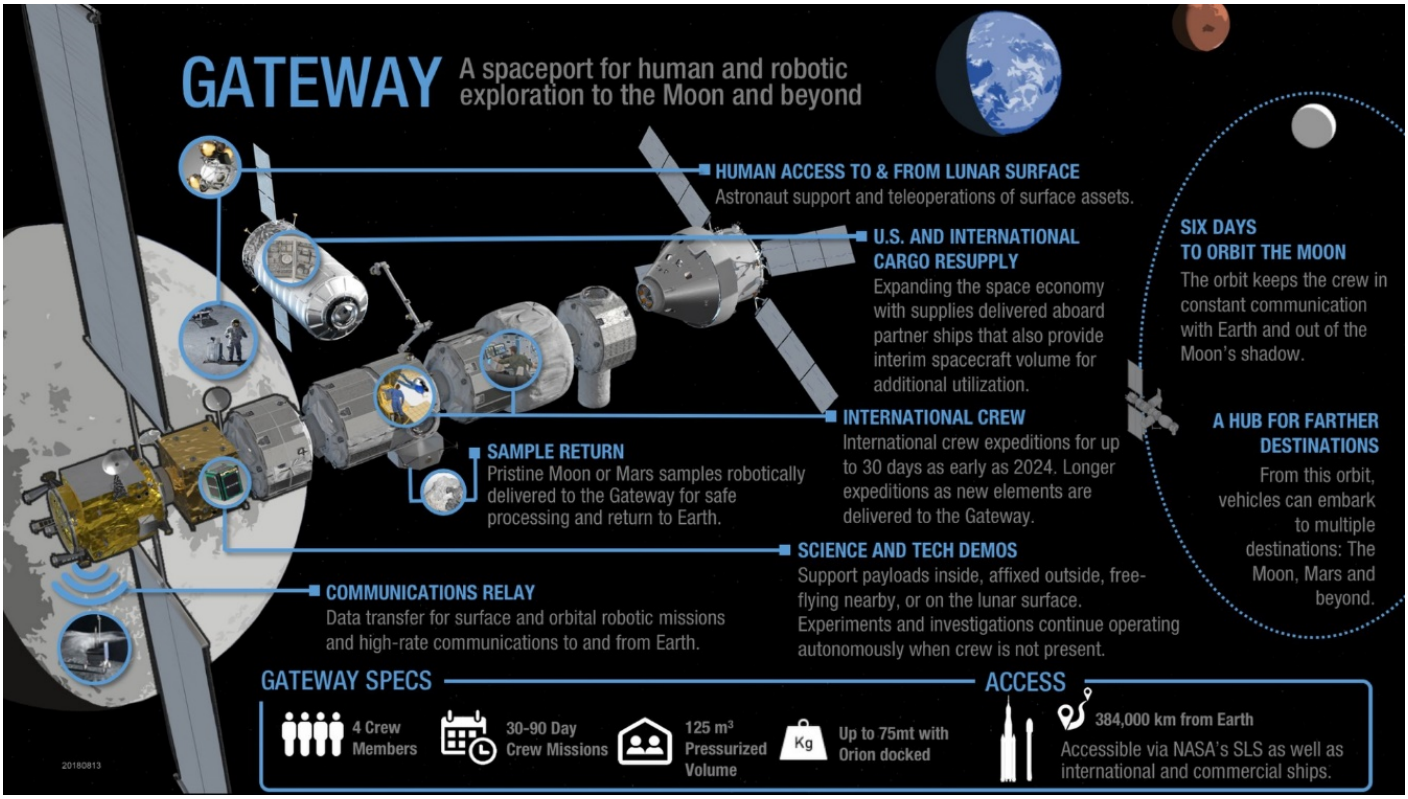
The Gateway will benefit from the years of research performed by astronauts continuously living and working on board the International Space Station since November 2000. The space station is a large spacecraft in orbit around Earth. It serves as a unique scientific platform that enables researchers from all over the world to put their talents to work on innovative experiments that could not be done anywhere else. The Gateway is similar to the space station in its design, but it will be an orbital home base for astronaut expeditions to the Moon. It will also serve as a practice ground for deep space missions—a place to train for life far away from Earth, including future human missions to Mars.

The Gateway is much smaller than the space station. Its interior is about the size of a studio apartment, whereas the space station is larger than a six-bedroom house. Once docked, astronauts can live and work aboard the Gateway for up to 3 months at a time, conduct science experiments, and take trips to the surface of the Moon. Even without a crew present, cutting-edge robotics and computers will operate experiments inside and outside the Gateway, automatically returning data back to Earth.

NASA is looking at options for astronauts to shuttle between the Gateway and the Moon on reusable landers. Just as planes use an airport on Earth, spacecraft bound for the lunar surface or for Mars can use the Gateway to refuel, replace parts, and resupply things like food and oxygen without going home first. During months-long crew expeditions to the Gateway, this could enable multiple trips down to the lunar surface and exploration of new locations on the Moon.

Building the Gateway

NASA has already started working on the Gateway. The first major Gateway part will provide power and propulsion for the spacecraft and is targeted to launch on a private rocket in 2022. After the power and propulsion element reaches orbit and test-drives its power and communications, NASA will launch four astronauts on a Space Launch System (SLS) and Orion mission carrying two new sections that will add a small living space and initial science and operational capabilities. Each year after that, astronauts will travel to the Gateway with new parts until it is fully assembled, currently targeted for 2026.



Configurations and capabilities of the Gateway. (NASA)

NASA is planning to work with U.S. companies to build a small living and working area for the Gateway called a habitation module. The addition will leverage years of research and demonstrations under Next Space Technologies for Exploration Partnerships (NextSTEP), a public-private partnership model seeking commercial development of deep space exploration capabilities to support human space flight missions. NASA is also discussing plans with international partners to provide expanded living space, advanced robotics, transportation, and science capabilities.

NASA plans to build the Gateway with just five or six rocket launches—far fewer than the 34 launches it took to build the International Space Station. NASA's powerful SLS rocket and Orion are key to the overall assembly and operations. SLS will launch the larger components for the Gateway on flights along with Orion, and Orion will be used as a tug to deliver those components to the required orbit for assembly. Together, Orion, SLS, and the Gateway represent the core of NASA's sustainable infrastructure for human exploration.

The Importance of Water Filtration

Water, essential to sustaining life on Earth, is that much more highly prized in the unforgiving realm of space travel and habitation. Given the launch cost per pound of cargo, each gallon of water at 8.33 lb (3.78 kg) quickly adds up in cost. Likewise, ample water reserves for drinking, food preparation, and bathing would take up an inordinate amount of storage space and infrastructure, which is always at a premium on a vessel or station.

Water rationing and recycling are an essential part of daily life and operations on the International Space Station and will be equally important on the Gateway. In space, where Earth's natural life support system is missing, these spaceports must provide abundant power, clean water, and breathable air at the right temperature and humidity for the duration of human habitation and with virtually no waste. NASA's Environmental Control and Life Support System (ECLSS), under continued monitoring by the Marshall Space Flight Center, helps astronauts use and reuse their precious supplies of water on the space station.

The ECLSS Water Recovery System (WRS) reclaims wastewater from humans and lab animals in the form of breath condensate (from exhaling), urine, hygiene and washing, and other wastewater streams. On Earth, biological wastewater is physically filtered by granular soil and purified as microbes in the soil break down urea, converting it to a form that plants can absorb and use to build new

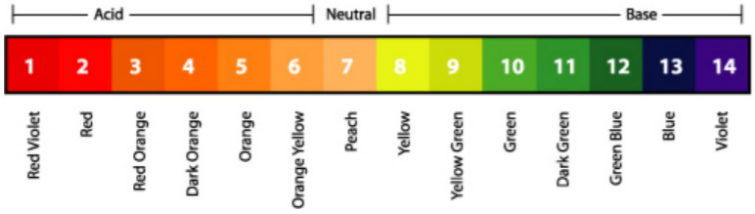
tissue. Wastewater also evaporates and returns as fresh rainwater—a natural form of distillation. WRS water purification machines on the space station mimic these processes, though without microbes or the scale of Earth's natural system.

The astronaut crew that will be onboard Gateway will need a system similar to WRS to efficiently recycle wastewater and reduce the need to provide the resource via resupply. Without this capability, the Gateway would not be able to support the needs of the crew during missions of up to 3 months, and resupply is not even an option for the long-duration space travel planned for future missions to Mars.

The Gateway will use filtration and temperature sterilization to ensure the water is safe to drink. During this process, water is checked often to ensure it meets water quality requirements, and it is monitored closely for bacteria, pollutants, and proper pH level. The pH scale ranges from 0 to 14 and is a tool used by scientists to measure the strength of an acid or base. Proper pH balance of 7 is important to a human body.

Public water systems must meet a pH level of 6.5 to 8.5. The space station water is required to be within the range of 6.0 to 8.5, and the same will likely be required for the Gateway. The recycled water that comes from this process is sterile, so there is no odor or bad taste.

pH COLOR CHART



pH SCALE

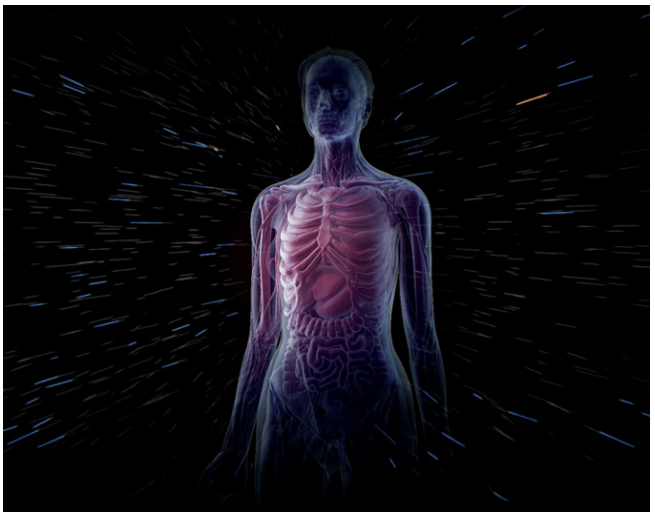
Measure	Type	Examples
Below 7	Acid	Citrus juices such as lemon, orange, or lime Sodas such as cola
7	Neutral	Pure, clean water
Above 7	Base	Toothpaste, baking soda

pH color chart (left) and pH scale (right).

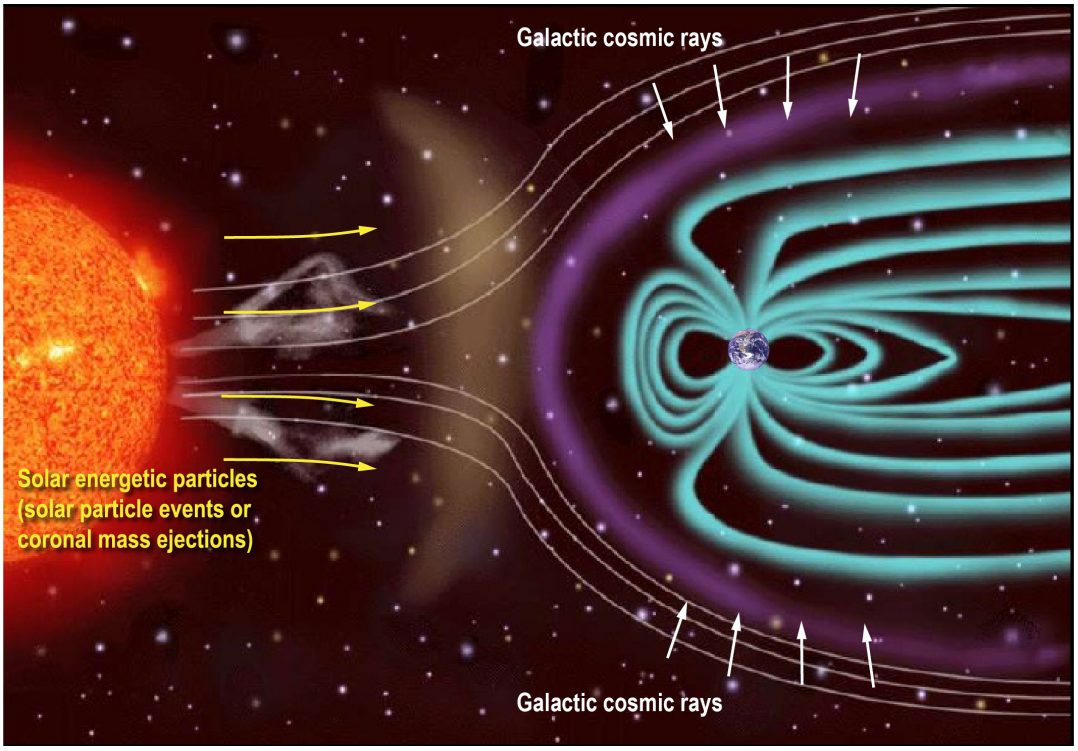
New Challenges Ahead: Radiation Shielding

Designing the Gateway presents engineers with new challenges in keeping astronauts safe and healthy while in space and after they return. As astronauts venture to interplanetary space, they will be exposed to higher levels of cosmic radiation from the Sun and galactic cosmic rays. This is called ionizing radiation because it has enough energy to knock electrons out of atoms or molecules, creating ions. Through these interactions, radiation disrupts cellular functions within the body, resulting in damage to the nervous system and producing symptoms such as nausea and fatigue. Long-term effects could include increased risks of cancer and cardiac disease.

Earth's atmosphere and magnetosphere—the magnetic field generated by the Earth's spinning iron core—are important because they provide shielding from most of the harmful high-energy particles. On Earth, galactic cosmic radiation is intercepted by oxygen and nitrogen molecules in the atmosphere before it reaches the surface, so it is of little danger to humans. As seen in the illustration below, most of the high-energy particles from the Sun are deflected around the Earth by its magnetosphere, which extends far beyond the atmosphere.

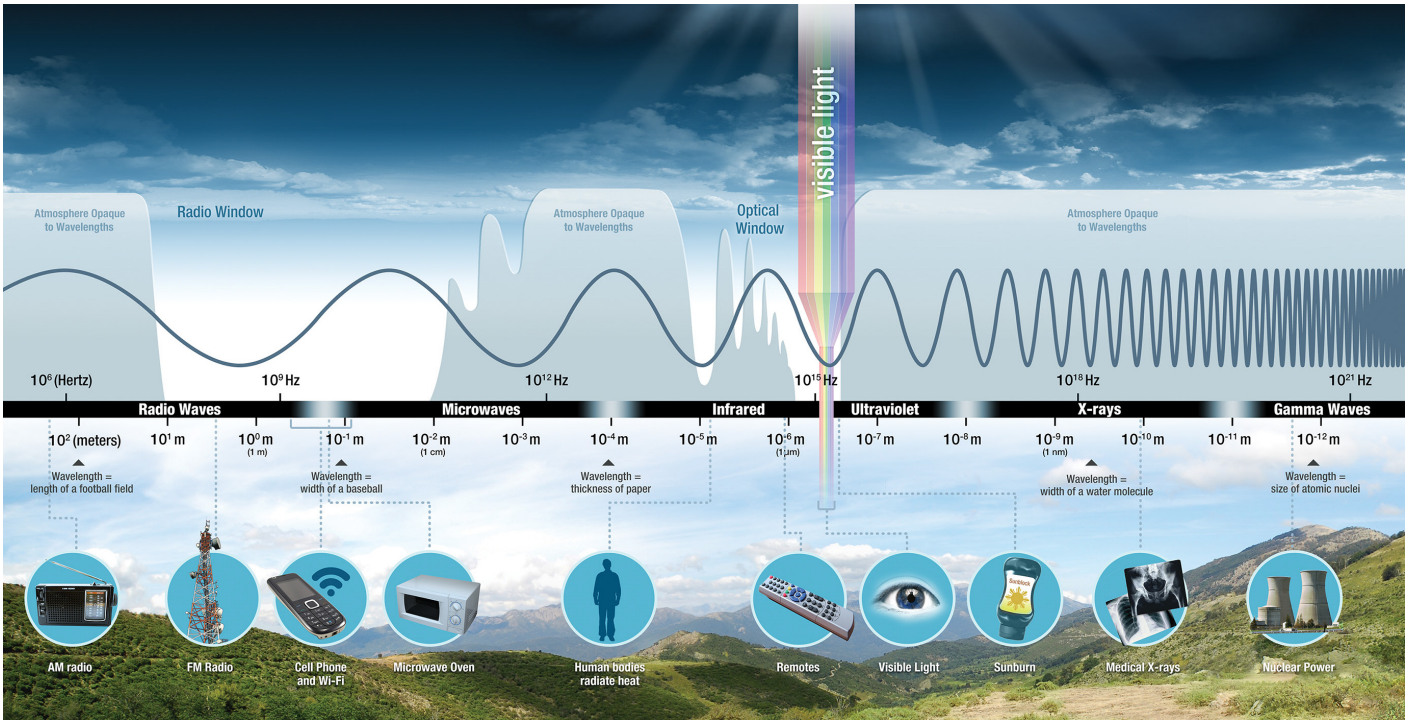


Space radiation is made up of protons and all the elements on the periodic table. It enters the human body at energies approaching the speed of light and can damage deoxyribonucleic acid (DNA). (NASA)



Sources of ionizing radiation in interplanetary space. (NASA)

One form of radiation from the Sun that can have a negative impact for humans on Earth is ultraviolet (UV) radiation. UV radiation is a type of light that is invisible to the human eye because its wavelength is too short to detect. UV light is classified into three groups according to its wavelength. UVA and UVB travel through the atmosphere and can reach the Earth's surface. They cause sunburns and can lead to skin cancer. UVC is extremely dangerous, but it is completely absorbed by the ozone layer and does not reach the surface of the Earth.



Electromagnetic spectrum. (NASA)

Habitation With Gateway

The International Space Station has been hosting astronauts for the last two decades for extended stays as long as a year in length, but it has remained in low Earth orbit—just outside the atmosphere but still within the protective boundary of the Earth's magnetosphere. In contrast, the Gateway will be placed in orbit around the Moon, far from the protection of Earth's atmosphere and magnetosphere. To protect astronauts and sensitive equipment from long-term exposure to increased levels of radiation while aboard the Gateway, scientists and engineers must come up with new methods and technologies for shielding them against high-energy charged particles of galactic cosmic rays, solar particle events, and secondary protons and neutrons.