

PLANETS Science Series

Space Hazards

Planetary Science for Out-of-School Time



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PLANETS (Planetary Learning that Advances the Nexus of Engineering, Technology, and Science) is a partnership for the development and dissemination of NASA out-of-school time curricular and educator resource modules that integrate planetary science, technology, and engineering, particularly with underrepresented audiences.



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Space Hazards

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About the *PLANETS* Science Series: Space Hazards

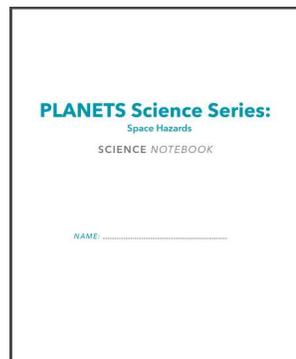
The *PLANETS* Science Series supports youth exploration in the field of planetary science by exploring the different hazards associated with the Earth and other planetary bodies as well as strategies to mitigate these hazards for exploration. This unit can be done independently, but is designed to complement the *PLANETS* Engineering is Elementary “In Good Hands: Engineering Space Gloves” activities, available at the link below:

<https://planets-stem.org/space-hazards/>

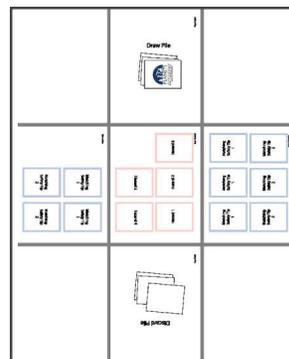
This *PLANETS* Science Series unit has several parts. All of the available materials can be downloaded for free from the *PLANETS* website.



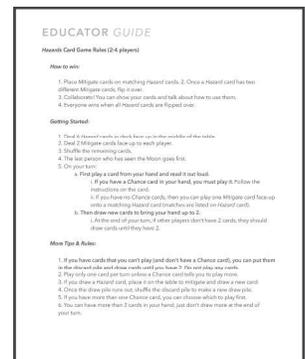
Hazards Cards
(Decks A, B, C, & D)



Science Notebook



Playmats (Safety & Mitigate Hazards)



Hazards Card Game Rules

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Learning Objectives

In the PLANETS Science Series: Space Hazards, youth will be challenged to answer the following guiding question: *What hazards are there in space exploration and how do we mitigate them?*

- » Youth will learn about hazards on Earth and the idea that humans have developed ways to mitigate some of them.
- » Youth will explore the concept that there are many hazards in space. Some hazards are the same as for the Earth, Moon, or Mars, and others are different.
- » Youth will learn that if people want to explore space, they need to mitigate hazards, and that there are multiple ways to mitigate many hazards.
- » Youth will apply their learning by selecting one of several different types of missions (i.e., humans versus robotic) for which they must mitigate different types of hazards.

Connections to Standards

The activities included in this unit support the teaching of multiple standards, including:

Next Generation Science Standards

3-ESS3-1 Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.

4-ESS3-2 Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

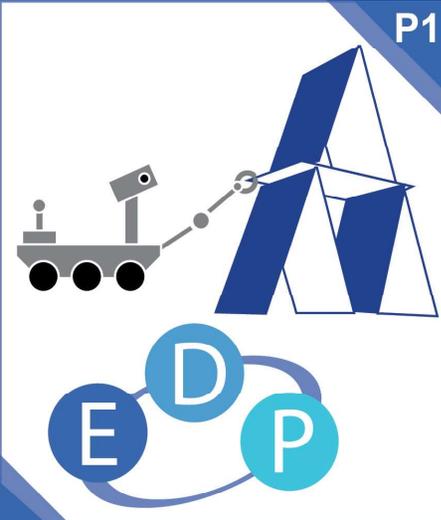
5-ESS3-1 Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.



Learning Progression - Prep Activities

These adventures introduce youth to engineering, an engineering design process (EDP), and the curricula's definition of technology.

P1



What is Engineering?
Create a Tower

Purpose

Youth engage in an engineering design challenge using an Engineering Design Process (EDP).

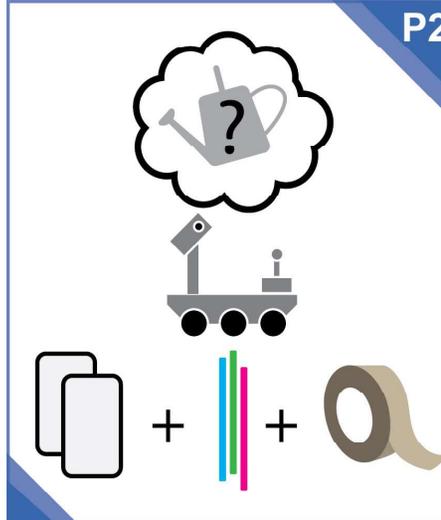
Key Take Away

We are engineers.

Engineering Reflection

Today we used an EDP to solve a problem.

P2



What is Technology?
Create a Technology

Purpose

Youth consider the definition of technology as any thing or process that humans (engineers) design to solve a problem.

Key Take Away

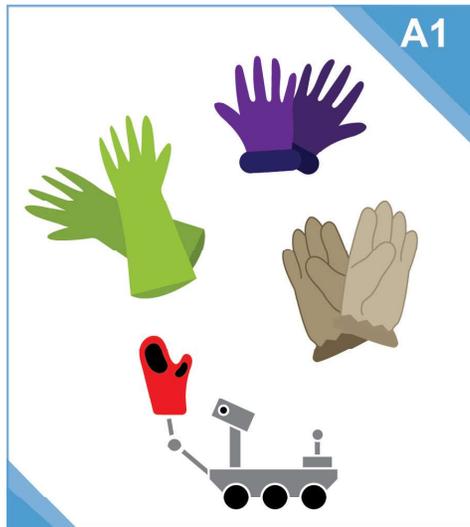
Anything designed by humans to solve problems is a technology.

Engineering Reflection

Today we asked how we can design technologies to solve everyday problems.

Learning Progression - Engineering

In these adventures, youth investigate various glove materials. They find that different materials are good for different uses and protect against different hazards.



A1

Everyday Gloves Test Gloves for Different Uses

Purpose

Youth investigate multiple glove types to determine which are better for certain tasks.

Key Take Away

We can identify which gloves are best for which uses.

Engineering Reflection

Today we asked which common household gloves are best for certain tasks. We tested them and compared the results to answer our question.



A2

Chilling Out Test Materials for Cold

Purpose

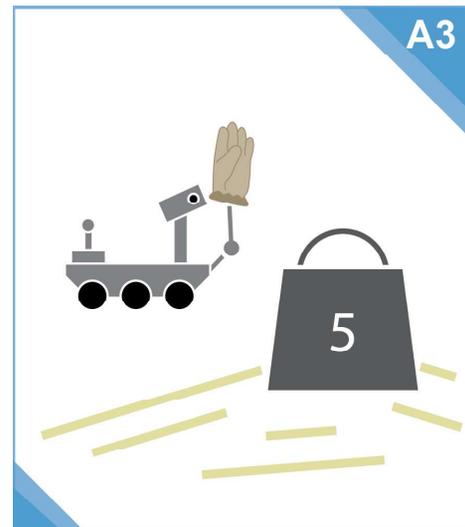
Youth explore how well different materials insulate against cold.

Key Take Away

We can identify materials to use in making a glove that protects against cold.

Engineering Reflection

Today we asked which materials are better at insulating against the cold. We tested and compared the results to answer our question.



A3

Ready for Impact Test Materials for Impact

Purpose

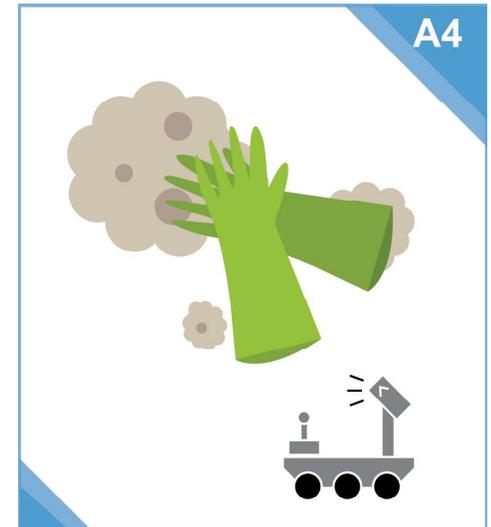
Youth explore how well different materials protect against impact.

Key Take Away

We can identify materials to use in making a glove that protects against impact.

Engineering Reflection

Today we asked which materials are better at protecting against impact. We tested and compared the results to answer our question.



A4

Dangerous Dust Test Materials for Dust

Purpose

Youth explore how different materials resist or collect dust.

Key Take Away

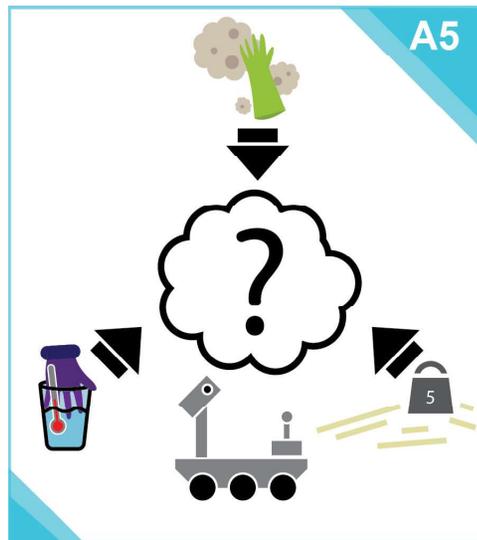
We can identify materials to use in making a glove that doesn't pick up as much dangerous dust.

Engineering Reflection

Today we asked which materials are better at not picking up dangerous dust. We tested and compared the results to answer our question.

Learning Progression - Engineering

In these adventures, youth apply what they learned in adventures 1-4 to design, improve, and share their space glove. Each is made to protect against hazards for a specific space environment.



A5

Create a Space Glove Plan, Create, Test

Purpose

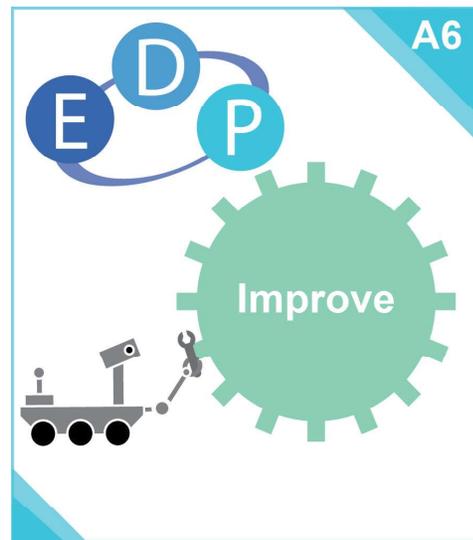
Youth apply what they learned in prior adventures to plan, create, and test a space glove designed for a space mission and its associated hazards.

Key Take Away

We can engineer a glove that protects us from certain space hazards and can be used to perform mission tasks.

Engineering Reflection

Today we used data from prior investigations to imagine, create and test a space glove for use in a space environment.



A6

Improve a Space Glove Improve a Technology

Purpose

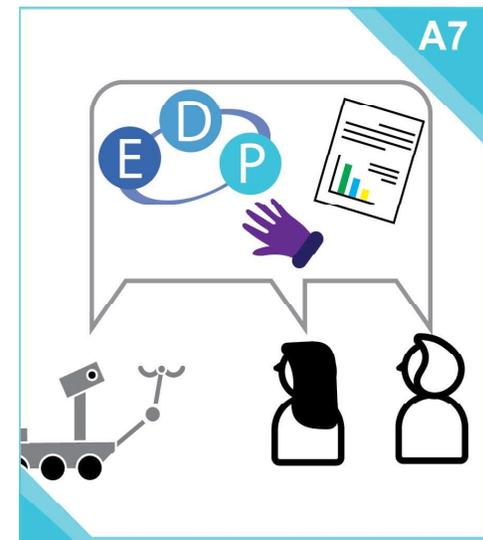
Youth improve their glove for more agility, strength, or to better protect against the hazards of their space environment.

Key Take Away

We can improve technologies we have designed.

Engineering Reflection

Today we improved our space glove. Mistakes help engineers learn and then improve technology.



A7

Engineering Showcase Communicate Results

Purpose

Youth prepare presentations to communicate their space glove design to others.

Key Take Away

We can communicate how we designed our space glove using an EDP.

Engineering Reflection

Today we communicated our space glove technology and how we used an EDP to design it.

Learning Progression - Science

In these adventures, youth explore hazards on earth and in space and how we mitigate them. Youth present hazards and mitigations for a specific mission.



S1

Everyday Hazards Everyday Hazards Card Game

Purpose

Through a card game, youth are introduced to these concepts: hazards are dangers and mitigation is a way to lessen the danger.

Key Take Away

There are many everyday hazards and many ways we can mitigate or protect ourselves against them.

Science Reflection

Today we explored everyday hazards and different strategies that humans have developed to mitigate them so they aren't so dangerous.



S2

Hazards on Earth Earth Hazards Card Game

Purpose

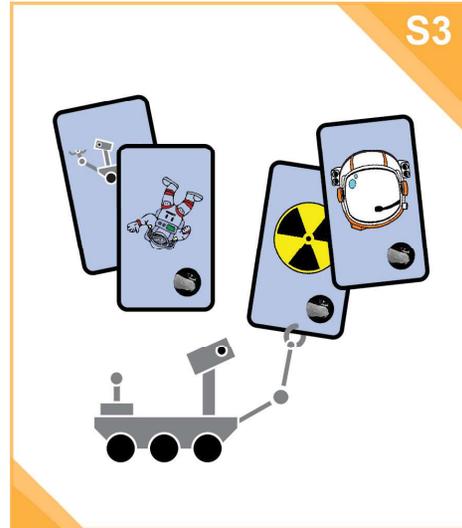
Youth are introduced to natural hazards as dangers and mitigation on Earth through a card matching game.

Key Take Away

There are natural hazards on Earth and humans have developed ways to mitigate some of them

Science Reflection

Today we learned about different natural hazards on Earth and different strategies that humans have developed to mitigate them.



S3

Hazards in Space Space Hazards Card Game

Purpose

Youth explore different hazards and mitigations in space and learn that some are the same as they are on Earth.

Key Take Away

There are many hazards in space and ways to mitigate them. Some are the same as for the Earth, Moon, or Mars, and others are different.

Science Reflection

Today we learned about different hazards in space and different strategies that humans have developed to mitigate them.



S4

Mitigate Hazards For Your Mission

Purpose

Youth investigate the hazards and mitigations that apply to a specific mission and learn that they are different for human versus robotic missions.

Key Take Away

If people want to explore space, they need to mitigate hazards. Different types of missions require different hazard mitigations.

Science Reflection

Today we explored how we can use information and technology to keep astronauts and equipment safe while exploring space.

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Unit Overview

In this unit, youth will learn:

- » Youth will learn about hazards on Earth and the idea that humans have developed ways to mitigate some of them.
- » Youth will explore the concept that there are many hazards in space. Some hazards are the same as for the Earth, Moon, or Mars, and others are different.
- » Youth will learn that if people want to explore space, they need to mitigate hazards, and that there are multiple ways to mitigate many hazards.
- » Youth will apply their learning by selecting one of several different types of missions (i.e., humans versus robotic) for which they must mitigate different types of hazards.

In these activities, youth will learn about hazards on Earth and in space and different strategies humans have developed to mitigate them. This builds on the concepts of engineering space gloves to account for different hazards in different planetary environments in the Engineering Adventures unit, *In Good Hands: Engineering Space Gloves*. Youth will also explore chance factors that either help (research and collaboration) or complicate (loss of power or communication) hazard mitigation. In the final activity, youth will put together all they have learned to make a presentation as Health and Safety Officers for an upcoming NASA mission.

In Activity 1, “Everyday Hazards,” youth learn about the concept of hazards and the idea that humans have developed ways to mitigate them. Youth act out hazards and safety tips in a form of charades and match appropriate safety tips with their respective hazards in a collaborative card game. Youth also learn the definition of the word “mitigate” and are introduced to the idea that there are careers focused on hazard mitigation.

Activity 1 Guiding Questions

- » What are some examples of everyday hazards?
- » What are some safety tips that help address these hazards?
- » What does the word “mitigate” mean?
- » What does a Health and Safety Officer do?

For example, safety hazards like tripping and crossing the street can be mitigated by

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watching where you are going. Food allergies and cold or flu germs can be mitigated by medicine and washing your hands.

In Activity 2, “Earth Hazards” youth explore hazards on Earth and the idea that humans have developed ways to mitigate some of them. Youth match appropriate mitigation strategies with their hazards in a collaborative card game. Youth also learn in the card game that chance events and human collaboration also play a role in hazard mitigation.

Activity 2 Guiding Questions

- » What are some examples of natural hazards?
- » What are some things people could do to mitigate hazards?

For example, Earth hazards like volcano, flood, wildfire, and extreme weather can be mitigated by a variety of things like evacuating (getting out of there) whereas something like drought can only be mitigated by preparing ahead of time. Collaboration via teamwork, friendly neighbors, and research can help mitigate hazards. Things like climate change and being unprepared make it more difficult to mitigate hazards.

In Activity 3, “Space Hazards” youth explore that hazards also exist in space and that some are the same as they are on Earth and some are different. Youth also learn about hazards that are the same or different between the Moon, Mars, and asteroids. Humans have also developed ways to mitigate some space hazards. Youth match mitigation strategies with hazards in the same collaborative card game as activity 1, but with different cards.

Activity 3 Guiding Questions

- » What are some of the hazards that NASA missions must mitigate in space in order to explore?
- » What are some things NASA has done or people could do to mitigate these hazards?
- » Do you think different places in space have different hazards?

For example, space hazards like micro impacts and radiation can be mitigated by things like shielding. Growing plants can help with the hazards of not having enough air (oxygen) or food. Having no air, poison (toxic) soil and scratchy soil (regolith) can all be mitigated with a space suit. Collaboration via teamwork, re-supply, and research can help mitigate hazards.



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Things like the loss of communication or power make it more difficult to mitigate hazards.

In Activity 4, groups combine the information they have learned in the previous activities and present what hazards, mitigation strategies, and other factors NASA needs to consider and employ for one of four mission options. The missions youth are considering are both human and robotic. They launch on Earth, and visit the Moon, Mars, or asteroids.

Activity 4 Guiding Questions

- » Which hazards do you think are the most / least likely for your particular mission?
- » Which do you think are the most and least dangerous?
- » Which mitigations do you think are the easiest, most cost effective, or apply to the most hazards?

A launch in Florida would have to take hazards like extreme weather and flooding into account, and mitigate these by doing things like preparing supplies; whereas, astronauts visiting the Moon would have to deal with hazards like scratchy soil (regolith), low gravity, and no food, water, or air, and apply the appropriate mitigations like space suits, vitamins, food, and exercise. Both of these missions have to address extreme temperatures (too hot / too cold) and mitigate this with things like insulation (layer up / thicker walls).

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Space Hazards

Reference to concepts on the hazard cards are highlighted in blue text and bolded to make information for subsequent activities easier to find. Also check out the vocabulary section on page 29.

Hazards on Earth

Lava flows, ash and gases, and other volcanic hazards

Some of the primary hazards from volcanoes are lava flows, ash, and toxic gases. Ground movement from volcanoes can also trigger landslides, which could dam rivers and cause flooding.

Lava flows occur when molten rock erupts to the surface and flows like a river of hot liquid rock. Lava flows can range from small and gentle to large and fast-moving. Lava flows burn, knock down, and bury anything in their way. There is little that can be done to stop them because they are so hot and dense: the best thing is to just get out of the way.

Volcanic ash occurs in explosive volcanic eruptions. It is not the same as the ash from a fire, which is made of burned wood or leaves. **Volcanic ash** is made of tiny shards of rock and glass, which makes it extremely dangerous to breathe or get in your eyes. Large eruptions can send huge amounts of ash into the air, which then rains down on the surrounding area or is carried downwind. Not only is the ash dangerous to people and animals, it is very heavy when it builds up, and like a very large snowfall can block roads and crush buildings. Ash can also kill crops and other plants if enough falls on them. Ash in the atmosphere can damage airplane engines and disrupt air travel.

Most volcanic eruptions also involve toxic gases, including gases like carbon dioxide, sulfur dioxide, hydrogen sulfide, and several types of acid. Carbon dioxide is heavier than air, so it can collect in low places and suffocate humans or animals. Hydrogen sulfide, which can smell like rotten eggs, is very toxic if there's a lot of it. Sulfur dioxide is also toxic to breathe and can also interact with water in the atmosphere or a lake to form sulfuric acid. Acid can



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come directly out of a volcano or it can mix with water in clouds and become acid rain or fog. This acid can mix with lake or pond water and turn the water acidic for fish and other animals in the water. Scientists who work near active volcanoes usually have to wear protective masks with filters to remove toxic gases from the air they breathe.

<https://volcanoes.usgs.gov/vhp/gas.html>

Temperature changes with and without an atmosphere (Too hot/ too cold)

Heat is transferred by three main processes: conduction, radiation, and convection. Conduction is when something hot is in physical contact with something cold, and the heat flows to the cold object to equalize their temperatures. Radiation is when something hot loses energy by emitting radiation, or light. Convection occurs when air near a hot object heats up, becomes less dense than its surroundings and flows away, taking the heat with it. Convection needs air or liquid to transfer heat, so in space where there is no air, convection cannot occur. Even when there is air, such as inside a space station, convection is caused by hot air rising. If everything is weightless, hot air cannot rise.

Without convection, anything that sits out in the sunlight in space gets extremely hot because there is no air to carry the heat away, and radiation and conduction can't keep up. Likewise, it means that anything that is in the shade in space gets extremely cold: radiation and conduction slowly remove all of the heat, and there is no air to deliver more heat. Since conduction is so ineffective at transferring heat it is possible for the same object (such as a moon rock, a spacecraft, or an astronaut's space suit) to get extremely hot on the sunlit side and extremely cold on the shadowed side. For example, the international space station would be about 250 degrees F (121 C) on its sunlit side and -250 degrees F (-157 C) in the shade without careful thermal design to keep its internal temperature safe.

https://science.nasa.gov/science-news/science-at-nasa/2001/ast21mar_1/

Climate Change

Climate change is the change in the Earth's long-term (decades to centuries) global temperature and climate patterns. A rapid increase in carbon dioxide in the atmosphere

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is currently causing the planet to warm up by trapping more of the Sun's heat. The Earth's climate system is very complex and deeply interconnected, so even a small change in temperature can have a wide range of effects on different parts of the world. Increased temperatures (**too hot**) are causing the polar ice caps and many glaciers to melt, which leads to rising sea levels and changes in ocean currents. Warmer ocean temperatures feed more frequent and more powerful hurricanes and **extreme weather**. Warmer oceans also are devastating to sea life. For example, some studies estimate that more than 90% of coral reefs will be dead by 2050, even if humans stop producing carbon dioxide (CO₂) today. Other parts of the world are experiencing severe **droughts**, which lead to crop shortages, **wildfires**, and **dust storms**. Others are experience more incidences of **flooding**. Increased temperatures at the poles may also destabilize atmospheric currents, causing more severe winters and winter storms (**too cold**) in the mid-latitudes and warmer temperatures at the poles. While climate change may impact weather events, weather and climate are not the same thing. Weather is the state of the atmosphere at a certain time and place with respect to its temperature, humidity, cloud cover, wind, or precipitation. As an analogy, weather is like the clothes you are wearing right now; climate is like all the clothes you have in your closet.

Hazards related to Extreme Weather

Extreme weather refers to strong storms such as hurricanes and blizzards, and dangerous weather phenomena such as tornadoes and lightning. These hazards are all driven by the interactions between the Earth's atmosphere and heat from the Sun. As more heat gets trapped in Earth's atmosphere, weather becomes more extreme - storms produce more rain, stronger winds, and more lightning. Stronger storms also produce more tornados when conditions are right. Hurricanes increase in strength due to surface water temperature increases: the heat energy from the water increases the energy of the storm and increases the evaporation, putting more moisture into the atmosphere. Warmer, moister air creates bigger, stronger hurricanes.

Hazards related to Geology

Geologic hazards include **volcanoes**, **earthquakes**, landslides, and tsunami. These hazards are driven by the Earth's internal energy, rather than the Sun's energy. Because they occur in response to processes inside the Earth, they are harder to predict than hazards that occur in



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the Earth's atmosphere. Some geologic hazards like volcanoes, landslides and earthquake aftershocks have a probability of occurrence that can be calculated based on historical conditions. Volcanoes generate certain types of earthquakes before eruption and some swell up due to pressure building inside. Scientists are studying Marsquakes and Moonquakes to try to understand ground shaking on other planetary bodies, and what those can tell us about their interiors.

Hazards in Space

Space Radiation

Radiation is energy in the form of light waves or particles. Many types of radiation are harmless, but high energy radiation, called "ionizing" radiation, is dangerous because it has enough energy to break chemical bonds in animal cells. This is dangerous for two reasons: if a lot of cells are damaged all at once, it can cause radiation sickness, which begins with vomiting, followed by more severe symptoms or even death depending on how much radiation damage occurred. Ionizing radiation damage can lead to cancer later in life as the cell malfunctions when it tries to divide and replicate.

In space, astronauts are at risk from two main types of radiation: galactic cosmic rays and solar flare particles. Galactic cosmic rays are the nuclei of heavy atoms moving at nearly the speed of light. They are produced by distant, extremely high energy processes like supernovae or black holes. When a cosmic ray hits something, like an astronaut or a spacecraft, it breaks apart and forms a shower of high-energy particles and leaves a path of ionized atoms in its path. Cosmic rays can easily penetrate through spacecraft or space suits, but can be stopped by shielding such as lead, concrete, or soil on a planetary surface, or by thick enough layers of specific types of plastic or tanks of water on spacecraft.

The sun is constantly producing radiation, both the kind that is essential for life on Earth (light and heat), and higher energy radiation in the form of x-rays and particles. The particles emitted by the sun are mostly protons, electrons, and helium nuclei, and are sometimes referred to as the "solar wind". Solar flares are explosions on the surface of the sun that release a burst of x-rays and high-energy particles. X-rays travel at the speed of light and can reach astronauts in minutes, but the particles are slower and can take several days to reach

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astronauts, giving enough time to seek shelter. These particles are easier to stop than cosmic rays but can still be harmful to astronauts who are not adequately shielded.

<https://www.nasa.gov/analog/nsrl/why-space-radiation-matters>

Weightlessness (Low gravity)

It is a misconception that there is no gravity in space: The force of Earth's gravity at the altitude of the space station is only slightly lower than the gravity that we feel at the surface. The difference is that the space station is essentially in free-fall around the Earth, so that the force of gravity (weight) cannot be felt. On planets or other bodies that are smaller than the Earth, gravity is actually weaker, so even on the surface an astronaut will feel lighter. The moon has about 1/6th the gravity of the Earth and Mars has about 1/3rd. Asteroids are much smaller than the moon, and an astronaut would feel nearly weightless.

The human body relies on gravity to function properly. The stress of weight on our bones and muscles tells the body to strengthen them, and the blood pressure difference between our feet and our heads tells our body how much blood we need and how strong our heart needs to be. In a weightless or low-gravity environment, the human body lacks these cues, so the body begins to break down bone, muscle, and blood that it thinks it no longer needs.

Astronauts have specialized exercise equipment that they can use while in orbit to simulate the effects of gravity on the body and encourage the body to maintain healthy levels of bone, muscle, and blood. Vitamins can help to replace the calcium and other minerals lost due to weightlessness.

Even with these mitigations, astronauts who have been off of Earth for a long time take months to fully recover once they are back on Earth.

Micro-Impacts

A **micro-impact** occurs when a small particle moving at a very high-speed hits a spacecraft or space suit. These particles can be natural micro-meteoroids such as the dust from a comet, or artificial particles such as small pieces of spacecraft or flecks of paint. Objects in



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orbit, or in transit between planets, are moving extremely fast: thousands of miles per hour. If they run into other objects that are not moving, or that are going that fast in a different direction, the collision can be very dangerous even if the particles are very small. A large grain of sand moving at orbital velocity has an energy comparable to a bullet fired from a gun. Micro-impacts can punch holes in spacecraft or space suits, often with no warning. The best way to protect against this hazard is to design spacecraft with shielding. Thin layers of metal, with some space between them, have been used as **shielding** on spacecraft for many years. A small impact might puncture through the first layer, but in the process, it breaks up into even smaller particles. These particles impact the next layer and are either stopped or break up even more as they pass through. After several layers, the particles are stopped before they reach the sensitive part of the spacecraft. This sort of shielding works for large spacecraft or space stations but is not practical for space suits.

Toxic (“poison”) soil on Mars

The soil on Mars contains chemicals called perchlorates. These chemicals are salts containing a chlorine atom bonded to four oxygen atoms. They are highly soluble in water and are only found in extremely dry climates. Perchlorate is toxic to humans, interfering with the functioning of the thyroid, so astronauts will need to avoid contact with martian soil and dust. Perchlorate is also very chemically reactive, so it can be processed to produce oxygen or as a component of rocket fuel.

Regolith (“scratchy soil”) on the Moon and asteroids

The surface of airless bodies like the Moon and asteroids are covered with a powdery soil called “regolith” formed by billions of years of large and small impacts pulverizing the rocks. Much like volcanic ash, regolith is composed of microscopic shards of glass and rock, making it dangerous for astronauts to inhale. Air filters inside the spacecraft or habitat could help mitigate this hazard by removing regolith dust from the air.

Space Junk

Space junk is human-made debris in orbit, ranging from small pieces and fragments to entire broken spacecraft. Because orbital velocities are so high, colliding with space junk could be disastrous, and the orbits of more than 18,000 pieces of large debris are tracked.

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Smaller debris cannot be tracked and is much more common.

For large pieces of space junk, if there is any chance that the object might collide with the space station, the space station's orbit is slightly modified using small maneuvering thrusters until the danger of collision is over. Since the orbits for these larger objects are well known, a small correction to the space station's orbit ahead of time can allow it to avoid collision.

Using Local Resources (Use what is around)

One of the biggest challenges faced by space missions is that it is difficult and expensive to launch a lot of material from the Earth's surface into space. Missions to the surface of other planets may be able to process materials found on the surface to produce useful resources like water, oxygen, metals, building materials, and rocket fuel. Doing this allows missions to launch with less mass and "live off the land" once they arrive at their destination. Martian soil is toxic due to the presence of perchlorate ions, but these may be used to generate rocket fuel or oxygen, so extracting resources from the soil can also get rid of the toxic chemicals in it! Water may be one of the most valuable resources to find in the solar system. It can be used for drinking, food preparation, cleaning, and it can be chemically separated into oxygen for breathing and hydrogen for fuel. The good news is that water can be found in many places throughout the solar system. The challenges are that it is often present as ice, it is sometimes located deep below the surface and hard to get to, and it may be contaminated. Thus, finding water in the solar system, extracting it and purifying it for use, combined with methods for reusing and recycling it, are some of the more important challenges facing human exploration of the solar system.

Growing plants in space

Plants need many things to grow: soil, nutrients, sunlight, water, oxygen, many of which we take for granted on Earth because plants have evolved to growing in the environment provided by Earth (atmosphere, rain, soil type, soil nutrients, Earth gravity, etc.). In a weightless environment like the space station, astronauts use specially designed soils to wick water to the plants roots without drowning them, and gentle fans to circulate the air. Hydroponic systems are also an option, replacing soil with circulating water. Full-spectrum lights stand in for the sun to provide plants with energy and to tell them which direction to grow. Interestingly,



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weightlessness is not as much of a problem as scientists anticipated: as long as the environment is healthy for them, they can grow in zero-g.

On Mars, plants would have to be grown in climate-controlled greenhouses, and the soil would have to be made safe by removing toxins and adding organic material. In many ways, it would be similar to growing plants on the space station, but the presence of gravity would make some things simpler.

<https://www.theatlantic.com/science/archive/2019/01/plants-flowers-international-space-station-moon-mars/581491/>

<https://www.popsci.com/nasa-growing-food-in-space/>

Space Suits and Suitports

Space suits are designed by engineers to protect astronauts from many hazards. Check out this video to learn more about Space Suits and how they are designed for hazards: <https://www.nasa.gov/feature/nasa-spacesuit-development>. A suitport is a specialized door to a spacecraft or habitat, where the back of an astronaut's space suit attaches directly to the door. This allows the astronaut to enter and exit the space suit through the suit's back panel, without ever having to bring the suit inside. Using a suitport cuts down on the amount of dust and soil that are tracked into the living space, helping to mitigate the hazards of regolith, toxic soil, and dust.



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NASA photo of a practice rover on Earth that has suitports that astronauts use to enter and exit the rover. The astronaut leaves the rover by stepping into the suit from the inside, then sealing off the port as they leave in the suit. Notice how the space suit stays outside at all times, limiting the amount of contamination inside the rover.

Dust Storms

Dust storms happen when strong winds blow over dry, dusty land, lifting the dust into the air and forming a huge cloud of dust. This dust can block out sunlight and make it difficult to see, and dust can clog mechanical devices and hurt the lungs and eyes of people or animals. On Earth, dust storms are most common in the deserts, especially the Sahara desert. Dust storms on Earth are usually local or regional: hundreds of kilometers wide at most. Dust storms on Mars are quite common since the whole planet is a dry, dusty desert. Mars has local and regional dust storms, but sometimes when the conditions are right, dust storms on Mars can grow to cover the entire planet. A planet-wide dust storm in 2018 blocked out the sun on Mars for weeks and ended the Opportunity rover mission. The solar powered rover could not function in the darkness of the dust storm.

Hazards Faced by Robots (Use a Robot Instead)

Robots are used in space exploration because they can be built to withstand conditions that humans could not, and because a robot does not need to return to Earth at the end of its mission. Even though robots can survive where humans cannot, they still face hazards when exploring the solar system. In many cases, the hazards are similar to those faced by humans, but only certain pieces of the robot are sensitive. For example, some parts of a robot can be exposed to extremely low or high temperatures or levels of radiation with no problem as long as key components are protected. One of the key hazards that affects humans but has almost no effect on robots is the vacuum of space. Robots don't need air to breathe and with proper engineering are almost unaffected by vacuum.

Robots don't need to worry about resources such as food, water, or air, but they have their own resources that they need to survive and function. The main resource that robots use is energy. Robots get their energy from batteries, solar panels, or radioisotope power sources.



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For missions where the robot doesn't need to survive for a long time, such as a Venus lander or an atmospheric probe on Jupiter, which will be destroyed by heat and pressure after a couple of hours, just a battery is enough. For longer duration missions, solar panels or radioisotope power sources are used to recharge the batteries. Solar panels work better for missions closer to the sun, but if sunlight is blocked for any reasons, such as by a dust storm on Mars, solar powered robots cannot function. Beyond Mars, the sun is so faint that solar panels need to be huge to provide enough energy, so missions to Mars and beyond often use radioisotope power.

Radioisotope power uses the heat generated by the decay of plutonium to generate heat, which is then turned into electricity to charge the robot's batteries. It is not nuclear fusion or fission, it is a much smaller and more stable (but weaker) source of power. Radioisotope power lasts for a long time, but it slowly decreases at a set rate determined by how quickly the plutonium breaks down into less radioactive materials, so missions that last a long time have less and less power.

Other resources that robots depend on are fuel and coolant. Orbiting and flyby spacecraft use rockets to adjust their direction and maintain stable orbits. Doing this uses rocket fuel. NASA engineers are very good at maneuvering spacecraft using as little fuel as possible, but it does eventually run out. Some scientific instruments need to be kept extremely cold and use coolant such as liquid helium. When the coolant runs out, the instrument doesn't work as well.

Temperature is another hazard for robots. Robots can handle much more extreme temperatures than humans, but they still need to be carefully engineered to make sure that key components such as the batteries and computers don't fail due to hot or cold temperatures. Very cold temperatures can also make it harder for moving parts on robots to function. For example, the robotic arm on the Curiosity rover on Mars needs to be heated up before it is used, which drains energy from the rover's batteries (this is why the arm is rarely used at night: it takes more energy to use when it is colder).

Moving parts in general are a hazard for robots. Since a robot cannot heal like a person, moving parts tend to wear out and break over time, and can become contaminated by dust or soil. For orbiting spacecraft, they often used spinning wheels as gyroscopes to adjust

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which way they are pointing without spending rocket fuel. These “reaction wheels” can break over time. It is not usually possible to send a repair mission, so once something breaks, engineers have to find a way to work around it or accept that the spacecraft can no longer do some things.

Radiation is hazardous to robots as well. They can withstand a lot more than a human, but the computers inside of robots need to be designed so that they do not fail when they are hit with a charged particle. Radiation can also damage the silicon detectors used by cameras on spacecraft, so over time the images degrade in quality.

Landers and rovers also have to worry about hazards on the surface. The landing site has to be chosen so that the robot can touch down safely. Engineers on Earth have to choose a safe path for rovers every time they drive, avoiding obstacles like boulders and cliffs, as well as hazards like loose sand that can trap a rover.



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Vocabulary

Apollo Missions: The Apollo Program was a series of space missions designed to land humans on the Moon and bring them safely back to Earth. It was mostly active from the 1960s - 1970s. We're still analyzing data and samples from the Apollo missions!

Asteroid: A rock orbiting the Sun that's too small to be a dwarf planet and does not have a tail of gas and dust like a comet. The size of asteroids ranges from 1,000 km to dust particles.

Blizzard: A heavy snow storm with high winds.

Climate: The aggregate of weather conditions prevailing in a particular area, or globally, over a long period of time (decades, centuries, or thousands of years).

Climate Change: The changing conditions of all of Earth's atmosphere mostly caused by rising amounts of greenhouse gases.

Drone: An aircraft or vehicle that does not have a pilot. They're usually controlled with a remote control. Also called unoccupied aerial systems, or UAS.

Drought: A long time of unusually low rainfall, leading to a shortage of water.

Dust storm: A strong wind storm that carries a lot of dust into the air.

Earthquake: Ground shaking in the Earth's surface caused by a sudden shock. Earthquakes are primarily caused by movements in Earth's tectonic plates.

Filter: A material or device that removes things you don't want to be there from a liquid or gas.

Flood: An overflow of water that submerges land that is usually dry, often caused by extreme weather events such as heavy rain, hurricanes, or melting snow. Flood waters can

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be partially controlled by placing sandbags to protect buildings and roadways.

Fire Suppression: An engineered system that puts out fires.

Gravity: The force that attracts objects toward the center of the Earth, or towards any other object with mass (such as a planet, moon, or asteroid).

Greenhouse Gases: Gases that trap heat by letting sunlight into the atmosphere, but not letting heat out of the atmosphere.

Hazard: A danger. In this activity, an extreme event that occurs naturally and can cause harm to humans.

Health and Safety Officer: A person who makes sure everyone has a safe working environment.

Hurricane: A large, strong storm with very strong winds and lots of rain.

Impact: An explosion caused by an asteroid or comet crashing into the surface of a planet. When a planet has an atmosphere, smaller objects burn up before reaching the ground. Larger objects may explode in midair or create a small crater, causing damage locally. Very large objects are less common but their impacts can devastate an entire region or even the whole planet.

Insulation: Materials that prevent heat from moving across them. A jacket is insulation that prevents heat from leaving the body; a refrigerator has insulation that prevents heat from getting into the cold interior.

International Space Station: A habitable spacecraft in low Earth orbit where astronauts from all over the world live and conduct science and engineering experiments.



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Landslide: A large movement of rocks and dirt down a slope.

Mitigate: To make less severe, serious, or painful.

NASA: The National Aeronautics and Space Administration. The US Government's organization for space exploration and planetary science research.

Planetary Science: The study of planets, moons, asteroids, and other objects in the solar system.

Radiation: Energy that moves from one place to another in the form of waves (like radio waves or visible light) or subatomic particles. Some radiation is bad even in small amounts like gamma rays. Some can hurt you if you are exposed for a long time, like ultraviolet rays (which is what causes sunburn). Some radiation is beneficial like when we use a microwave to heat food or radio waves to listen to music in the car.

Regolith: Broken up rocks, like sand or gravel, on top of bedrock. Regolith is often found on the surface of planets or moons that have little or no atmosphere. Sometimes called soil on other planets or moons.

Rover: A vehicle sent to another planet or moon to explore by sending pictures and data back to Earth.

Shielding: A material that protects the inside from danger. Shields can protect against things like small impacts, radiation, and dust.

Spacecraft: A vehicle designed to travel in space.

Tornado: A very quickly spinning column of air with extremely high winds.

Toxic soil: Dirt and rock that is dangerous to breathe, eat, or grow plants in.

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Training: Teaching a person a skill or type of behavior.

Tsunami: A large, fast-moving sea wave. Tsunamis can be caused by earthquakes, underwater landslides, volcanic eruptions, or asteroid impacts.

Weather: The state of the atmosphere at a certain place and a certain short time period (minutes to hours to days) with respect to its temperature, humidity, cloud cover, wind, or precipitation.

Wildfire: An uncontrolled fire of plants and trees in a rural area. Wildfires can burn down houses, farms, and other buildings if they are not controlled.



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Materials List

Unit Materials List

Quantity	Item
1 per youth	Science Notebook
1 per youth	Pencils
1 roll	Clear tape (for prep)
1	Safety <i>Hazards</i> Playmat
1	Safety <i>Hazards</i> cards (Deck A)
1 per group of 4	Mitigate <i>Hazards</i> Playmat
1 per group of 4	<i>PLANETS Hazards</i> cards (Decks B, C, and D)
1 per group of 4	<i>Hazards</i> Card Game Rules