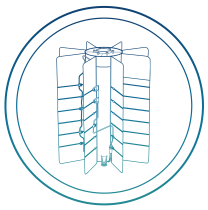
POWER TO EXPLORE CHALLENGE



SCIENCE LESSON

DIGITAL SCAVENGER HUNT

It takes a special kind of power to explore the extremes of our solar system, and NASA wants to hear how it would energize your lunar exploration dreams! But before you plan your nuclear-powered lunar base, you need to know about where you're going (the Moon), and what RPS and fission power systems can do. Follow the trail and pick up all the know-how you need on this scavenger hunt to help you design a lunar base.
The hunt is on!

FOR THE CLASSROOM

POSSIBLE APPROACH FOR THE CLASSROOM

LESSON LENGTH
~180 MINUTES

OBJECTIVE
LEARN ABOUT NUCLEAR POWER

MATERIALS
SEE BELOW

VOCABULARY

- Lunar
- Lunar South Pole
- Lunar regolith
- Apollo
- Artemis
- Nuclear energy
- Plutonium-238
- RPS
- RHU
- MMRTG
- Fission power systems
- Uranium

MATERIALS

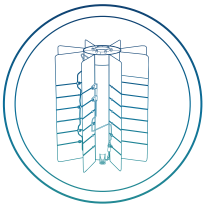
- Power to Explore Challenge Slide Deck
- Digital Scavenger Hunt Worksheet
- Device with Internet Access

PROCEDURE

In this lesson your students will participate in a digital scavenger hunt to help them learn about the Moon and nuclear power systems to complete the Power to Explore Challenge.

Download the Power to Explore Challenge Slide Deck. This slide deck gives students an overview of the challenge, the Moon, radioisotope power systems (RPS), and fission power systems. It will review the challenge details and why these systems are useful to dream up a Moon base. Feel free to customize it to suit your teaching needs.

1. Power to Explore Challenge
2. The Moon
3. Nuclear Power Systems
4. Digital Scavenger Hunt
5. Brainstorm Your Entry



SCIENCE LESSON

DIGITAL SCAVENGER HUNT

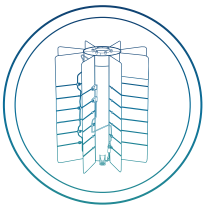
Procedure continued...

The slide deck is divided into four sections.

STUDENT ACTIVITY: DIGITAL SCAVENGER HUNT

Students use their internet sleuthing skills to track down answers to various questions about the Moon, RPS, and fission power to give them the knowledge they need to help them design their nuclear-powered lunar base for the Power to Explore Student Challenge.

1. Prep: Print or download the Digital Scavenger Hunt Worksheet for each student. Your students will use this worksheet and clickable QR codes that link to NASA websites to complete the activity.
2. Review sections 1-4 of the Power to Explore Challenge Slide Deck.
3. Set up your student or group. Students can work alone, in pairs, or in small groups for the scavenger hunt. Each student/group will need a device with internet access.
4. Students will click or scan the **QR codes** provided in the worksheet to complete the scavenger hunt. Each section contains a clickable QR code following the heading. These QR codes will take the students to handy NASA website pages where they'll find the answers to the questions in that section. Keep in mind that some of the questions may have more than one possible answer. Even better, searching for the answers will supplement their knowledge about nuclear power to prepare them for creating their challenge entry.
5. Give your students their worksheets, set a time limit, start a timer, and away they go!
6. Once they complete this activity, discuss their answers as a class and use section 5 of the Power to Explore Challenge Slide Deck to help your students brainstorm ideas for their entries.



SCIENCE LESSON

DIGITAL SCAVENGER HUNT

BACKGROUND INFORMATION

THE MOON

Our Moon is the planetary body that orbits Earth. It has 1/6th the amount of gravity as Earth and no breathable atmosphere. The Moon is full of impact craters, which are the depressions left behind after an asteroid, meteoroid, or comet collided with the Moon. These craters can be huge! For example, the Moon's South Pole-Aitken basin is the largest known impact crater in the solar system, spanning more than 1,550 miles across! The Moon does not have erupting volcanoes today, but it was once flooded with flowing lava. The Moon has signs of past volcanic activity like caves, plains, and domes made of cooled lava.

APOLLO AND ARTEMIS PROGRAMS

NASA has been to the Moon before. Apollo astronauts first set foot on the Moon on July 20, 1969. Now with the Artemis program, NASA is returning to the Moon, and this time to stay. Specifically, NASA is going to the Lunar South Pole.

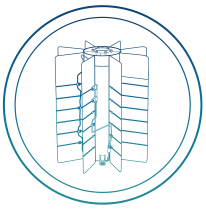
LUNAR SOUTH POLE

The Lunar South Pole region offers unique opportunities for exploration, scientific discovery, and establishing a long-term human presence. Studying this part of the Moon could help scientists answer important questions about the history of the Moon, Earth, and our solar system.

OPPORTUNITIES ON THE LUNAR SOUTH POLE

- **Scientific Discovery:** The final Apollo Moon mission was in 1972. Scientists have been investigating lunar samples and data from the Apollo missions ever since, but it also led to many new questions. Lunar scientists look forward to using new research equipment to support new investigations at the Lunar South Pole. Lunar scientists hope to: obtain new samples to examine the Moon's composition and uncover more evidence of how the Moon formed, continue to investigate the origins of water and its behavior, use portable seismometers to study moonquakes, and so much more!

- **Learning to Live off the Land:** Bringing everything from Earth is hard. Instead, NASA wants to prioritize using what they find where they are, which is called In-Situ Resource Utilization (ISRU). Some natural materials on the Moon could one day help support future exploration. But first, we need to find out what is there and how to use it.



SCIENCE LESSON

DIGITAL SCAVENGER HUNT

Background Information continued...

- **Harvesting Water Ice:** NASA has found evidence of water ice at the lunar south pole. The Lunar South Pole region features craters that are unique in that sunlight does not reach their interior. These permanently shadowed regions on the Moon preserve water ice and other frozen materials dating from the early solar system. Scientists are still learning where that ice is, how much exists, and how difficult it will be to collect. If we can collect it and clean it, the water could be used to make oxygen, produce materials for rocket fuel, or provide drinkable water for astronauts.

- **Lunar Regolith:** The Moon is covered in lunar regolith (lunar soil). While it may look like regular dirt, it's not at all like earth-based garden soil. Regolith is sharp, rough, and made of a combination of broken rock and fine dust. And since it is everywhere, engineers are testing ways to dig, move, and use lunar regolith to make protective mounds/hills and even produce oxygen. NASA and industry are also testing ways to build with lunar regolith by 3D-printing large-scale habitats or landing pads.

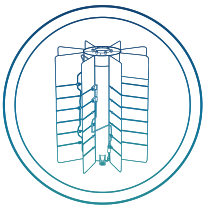
CHALLENGES ON THE LUNAR SOUTH POLE

Building an enduring human presence on the Moon means designing for extremes. There is no air to breathe, rugged terrain, long periods of darkness, cold temperatures, radiation, and lunar dust.

- **Rugged Terrain:** The Lunar South Pole region is rugged. Steep slopes, ridges, deep craters, and rocks shape nearly every part of the landscape. Some of the region's most interesting scientific destinations are among the most difficult to reach. Detailed mapping and robotic exploration will help NASA identify safe landing areas, determine where habitats and other structures can be placed, and plan how astronauts and robots will move across the Moon's surface.

- **Darkness:** Near the Moon's South Pole, the Sun never climbs high. It skims along the horizon and casts long shadows. Some high ridges get sunlight much of the time, while the floors of deep craters never see the Sun at all. Even the sunniest spots have periods of darkness. Reliable power becomes especially important in dark, shadowed places.

- **Environmental Conditions:** The Moon has almost no atmosphere. There is no air to breathe, and nothing overhead to block radiation in the same way that our atmosphere and magnetic field protect us here on Earth. On the Moon, astronauts must bring their own air, and they must live inside protected habitats shielded from radiation. Also, the lunar surface experiences extreme temperatures. With almost no air to spread heat around, temperature depends only on sunlight. Sunlit areas can be much warmer, while some permanently shadowed craters drop to about -334°F (-203°C), among the coldest places in the solar system.



SCIENCE LESSON

DIGITAL SCAVENGER HUNT

Background Information continued...

- **Lunar Dust:** Apollo astronauts experienced firsthand how easily lunar dust can cling, scratch, jam, and cover equipment. Managing lunar dust will be an important part of sustaining reliable operations on the Moon for longer periods of time. Moon dust is sharp, clingy and everywhere. With no wind or water to wear it smooth, lunar dust stays jagged, sticks to spacesuits and gets into machines. It can also coat solar panels, making them less effective.

SOLAR ENERGY VS. NUCLEAR ENERGY

Solar energy (energy from the sun) can be used if there is enough sunlight to power solar panels. In dark, dusty conditions, nuclear energy (energy released from the nucleus of an atom) is the best option for providing continual power. On the Moon, nuclear power systems will work during long lunar nights, in permanently dark craters with water ice, and in dusty conditions. Yes, solar energy can be used on the Moon in areas of constant sunlight, but for this challenge, we are focused solely on nuclear energy.

NUCLEAR POWER SYSTEMS

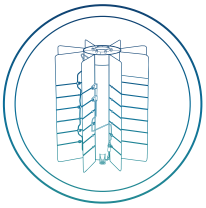
NASA uses nuclear energy in areas where solar energy is absent, limited, or impractical. Nuclear energy can be used to generate electrical power, provide useful heat, or both. Nuclear power systems are always “ON” and don’t need to be recharged. A Radioisotope Power System (RPS) is a small but mighty type of nuclear technology that relies on the natural heat of plutonium-238. RPS technologies include Multi-Mission Radioisotope Thermoelectric Generators (MMRTGs) and Radioisotope Heater Units (RHUs). Fission power systems generate plentiful energy on demand through the collision of neutrons and uranium atoms that produce a controlled chain reaction to create heat that is converted into electricity.

MULTI-MISSION RADIOISOTOPE THERMOELECTRIC GENERATOR (MMRTG)

A Multi-Mission Radioisotope Thermoelectric Generator, or MMRTG, generates small amounts of electricity. It is the perfect, ultra-reliable power system for remote observation equipment or robotic explorers and is currently used to power the Mars Curiosity and Perseverance rovers.

WHAT IS A THERMOCOUPLE?

The principle of a thermocouple involves two plates; each made of a different metal that conducts electricity. Joining these two plates to form a closed electrical circuit while keeping the two junctions at different temperatures produces an electric current.



SCIENCE LESSON

DIGITAL SCAVENGER HUNT

Background Information continued...

RADIOISOTOPE HEATER UNIT (RHU)

A Radioisotope Heater Unit (RHU) generates heat. It won't provide electricity, but it will help space technologies that need to stay warm or survive cold lunar nights.

PLUTONIUM-238

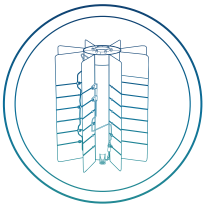
The fuel in an RPS is plutonium-238 (Pu-238). It is not the type of plutonium used for nuclear weapons and would not work as fuel in a nuclear reactor. As it decays, plutonium-238 emits alpha particles which can be shielded by material as thin as a piece of paper. This decay happens because each atom of plutonium-238 has 144 neutrons but only 94 protons. Over time the atoms shed their extra neutrons to stabilize themselves, releasing heat.

FISSION POWER SYSTEMS

Space reactor systems are being developed to meet the growing demand for power in space can be more powerful—able to generate plentiful energy on demand. They use a process called nuclear fission, in which neutrons collide with uranium atoms, causing them to split and release energy. This creates a controlled chain reaction that produces heat, which is then converted into electricity. Fission power systems are a type of space reactor that will generate great amounts of energy by converting the heat to electricity. Large fission systems on Earth can power entire cities, but what could these smaller reactors power on the Moon? This technology would make an ideal, robust energy source for living, working, and building things on the Moon.

URANIUM-235

Fission power systems use uranium—an extremely energy- dense material—to produce heat and generate electricity. Even a small amount of uranium could produce enough energy to power a whole school.



SCIENCE LESSON

DIGITAL SCAVENGER HUNT

Background Information continued...

WHAT ARE THE ADVANTAGES OF USING NUCLEAR POWER?

Nuclear Power Can Be Used in Dark Environments.
No light, no problem! Nuclear power does not need light to function. Because of this, a lunar base could operate continuously throughout long, dark lunar nights, or in deep craters on our Moon with little available sunlight or that are in permanent darkness.

Nuclear Power Can Withstand Dusty Environments.
Dust storms are a regular occurrence on the Earth's Moon, which is covered with dust and rocks. Lunar dust could cover solar panels, decreasing their power generation. Fortunately, nuclear power can keep going even when the environment gets dusty, like NASA's rovers Perseverance and Curiosity, which have RPS systems that enable them to explore Mars' dusty surface.

Nuclear Power Offers Longevity.
RPS and fission power systems offer the key advantage of operating continuously over long-duration space missions, largely independent of changes in sunlight, temperature, charged particle radiation, or surface conditions like thick clouds or dust. Because it uses the heat from the natural radioactive decay, it can keep producing power for decades!

Nuclear Power is Heat Producing.
The excess heat produced by some radioisotope power systems can be used to enable spacecraft instruments and on-board systems to continue to operate effectively in extremely cold environments. In addition, small radioisotope heater units (RHUs) can be used for additional thermal control.