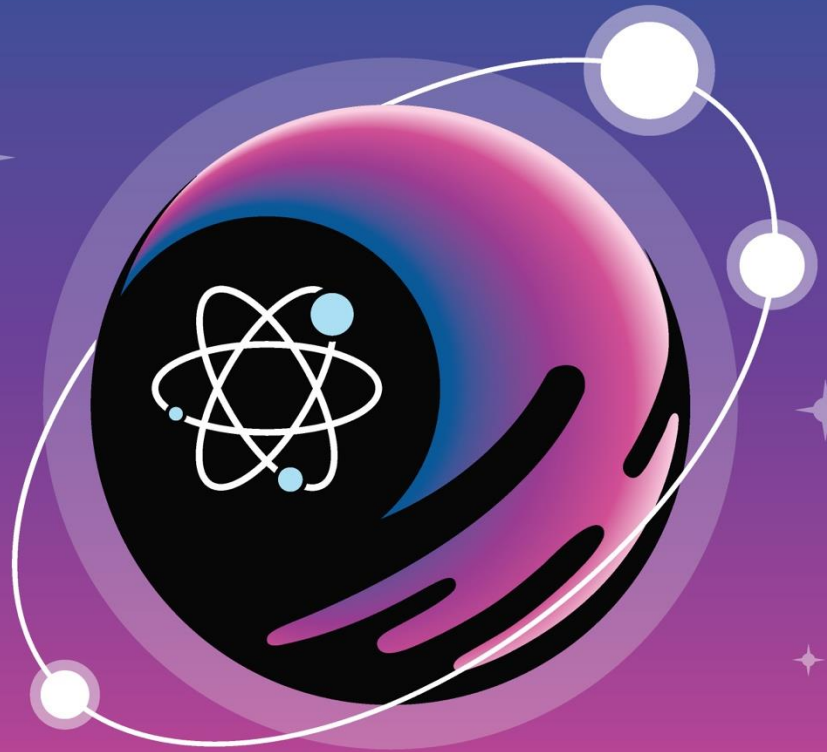


POWER TO EXPLORE

RADIOISOTOPE POWER SYSTEMS

Section 1: The Power to Explore Challenge

The Challenge

When you gaze into the night sky, the Earth's brilliant Moon often captures your attention. We are going back to the Moon to stay. However, with freezing temperatures, long lunar nights, and deep craters of the Moon that never see sunlight, we could use a special kind of power; Radioisotope Power Systems (RPS). For over 60 years, NASA has been using RPS, a type of nuclear "battery," to power spacecraft and enable them to travel to some of the harshest, darkest, coldest, and farthest reaches of our solar system. Did you know that our solar system boasts nearly 300 moons, many of which remain mysteries to us? These moons provide an incredible opportunity for discovery.

Earth's Moon Photo Credit: NASA

The Challenge

RPS has powered missions near Jupiter's moon Io, where over 400 active volcanoes were revealed; Saturn's dusty moon Titan, where it helped uncover its methane lakes, oceans, and rivers; and Pluto's moon Charon, where NASA recently discovered jagged mountains and deep canyons.

If you could plan an RPS-powered mission to any moon in our solar system, which moon would you choose to unravel its mysteries?

Pluto’s moon Charon Photo Credit: NASA

The Challenge

K-12 students, your task is to plan a mission that uses Radioisotope Power Systems (RPS) to a dark, dusty, or far away **moon** in our solar system. NASA wants to know what you plan to explore, the discoveries you hope to make, and what your special power is to help you achieve mission success.


New Horizons Photo Credit: NASA

The Challenge

Your entry should address the topics below:

- **Dark, Dusty, or Distant Mission Destination:** Tell us which moon your RPS-powered space mission will go and describe your mission goal(s). Keep in mind that your mission can either fly-by, orbit, land, or rove.
- **Radioisotope Power Systems (RPS):** Explain the importance and advantages of using RPS for this mission. How does this technology overcome the challenges of these extreme environments and destinations?
- **Your Power:** NASA missions are also powered by people–from mission planning and development to designing, launching, and operating a spacecraft. Tell us what you think your unique power is and how your special power will help you achieve mission success. Your power could be a skill, personality trait, or other personal strength that is uniquely you.

In total, your submission is limited to 275 words. You must also include a title, which will not be included in the word limit.

Prizes

Entries will be judged in three grade-level categories: K-4, 5-8, and 9-12, and the prizes are:

- 45 Semifinalists will be selected to win an RPS prize pack (15 in each category)
- 9 Finalists will receive an exclusive virtual session with a NASA RPS expert (3 in each age category) and a finalist space themed prize pack
- 3 Grand Prize Winners will receive a trip for two (student and parent chaperone) to NASA's Glenn Research Center in Cleveland, Ohio, to learn about the people and technologies that power NASA missions (1 in each age category)

Photo Credit: NASA

Watch the challenge video!

Challenge Timeline

Section 2: Radioisotope Power Systems (RPS)

Now that we know about the challenge, let’s learn a little bit about RPS to help you plan your mission.

Radioisotope Power Systems (RPS)

Many potential NASA missions would visit some of the harshest, darkest, and/or coldest locations in the solar system. What kind of energy do you think would power these missions?

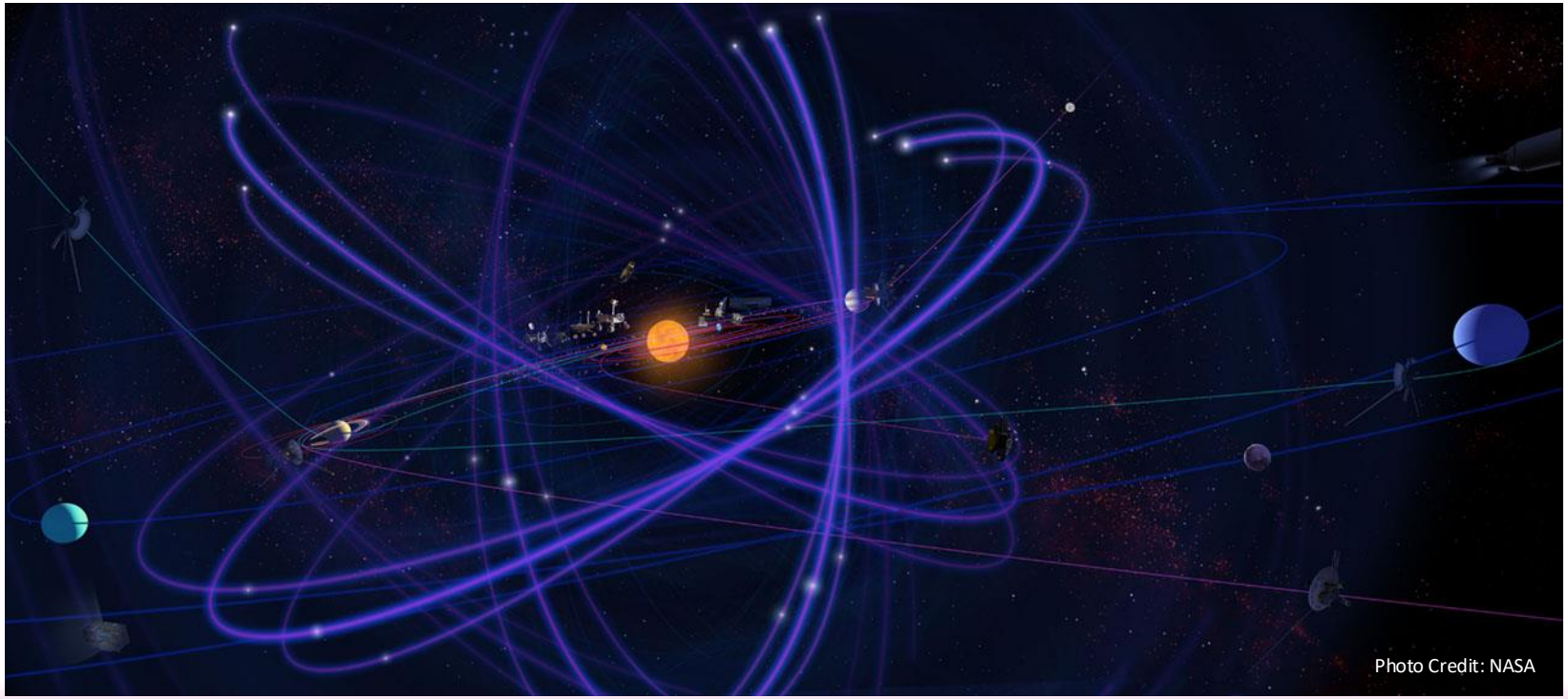
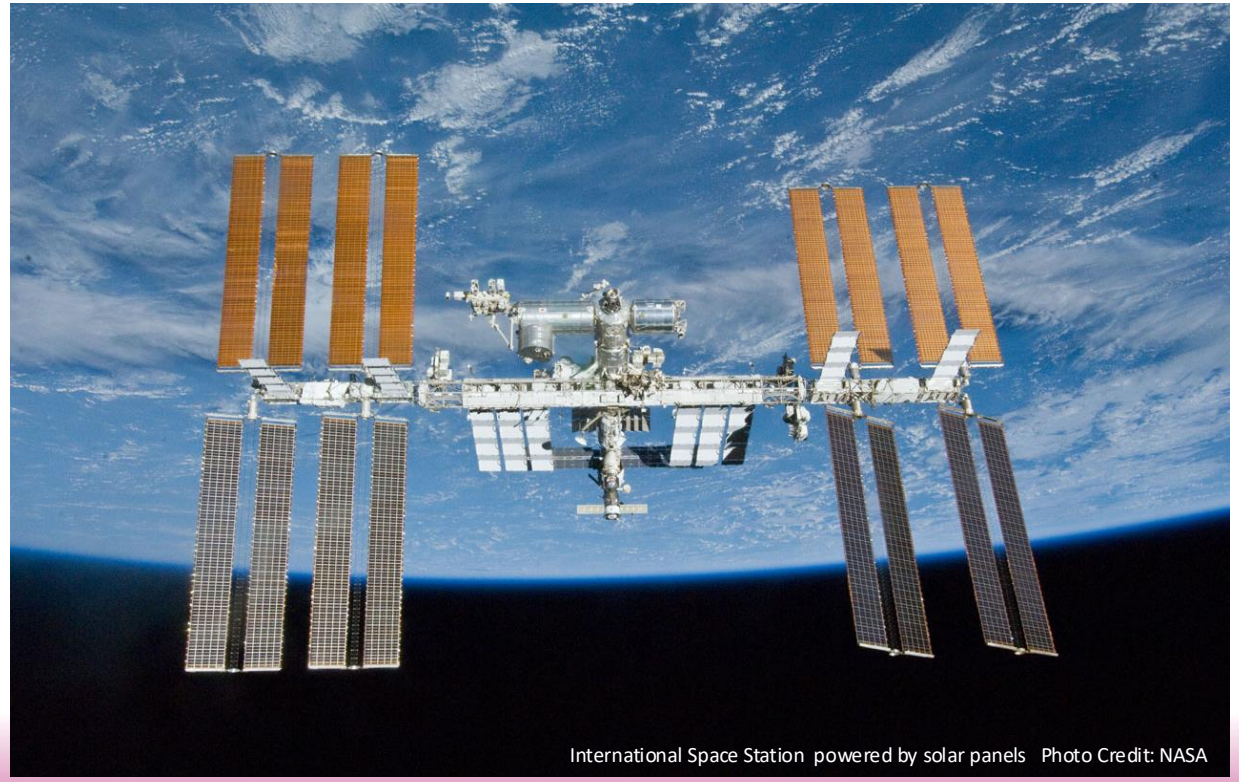


Photo Credit: NASA

Solar Energy vs. Nuclear Energy

Spacecraft require a lot of power to navigate, communicate, travel, and conduct the scientific work of the mission.

Many spacecraft can utilize solar panels to generate energy as long as there is enough sunlight to power them.

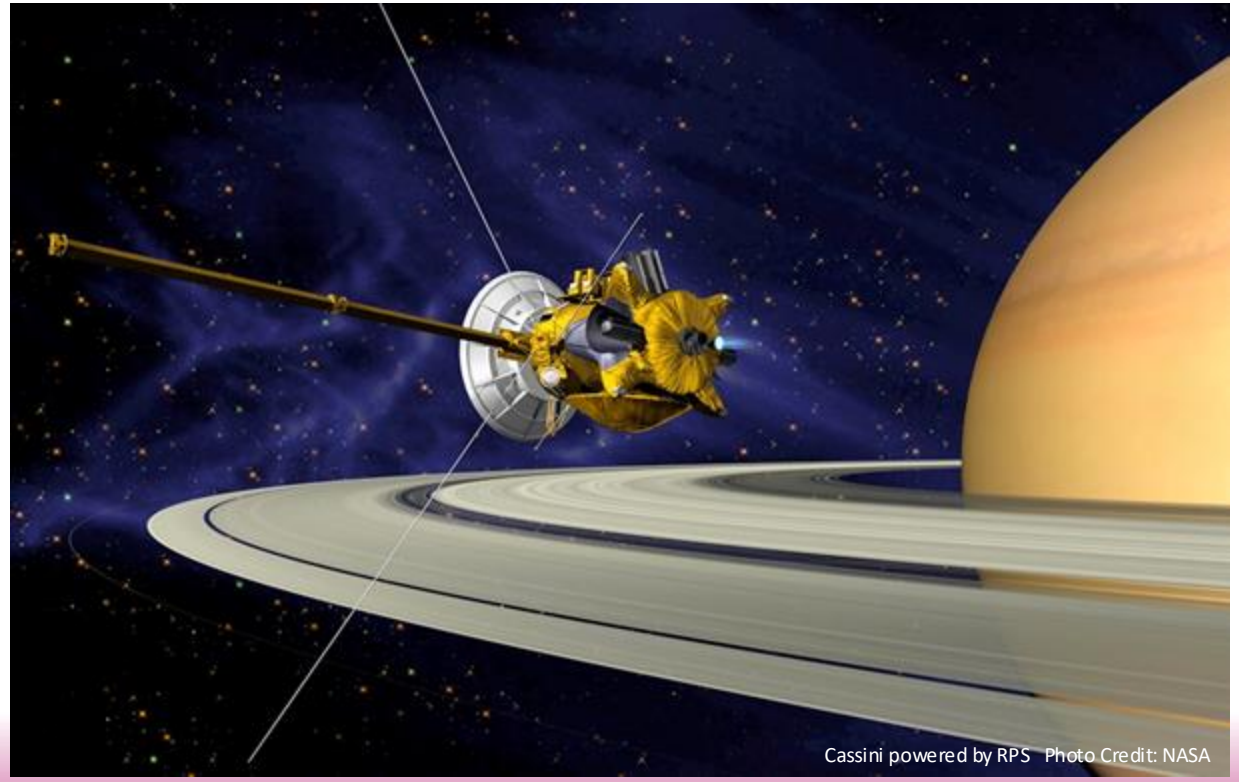


International Space Station powered by solar panels Photo Credit: NASA

Solar Energy vs. Nuclear Energy

But what about spacecraft that encounter dusty environments that block out the sunlight? Or, what about spacecraft that travel to such far distances that the sun's light is too weak to generate power for them?

When **solar energy** (energy from the sun) is not strong enough to power a spacecraft, the next option is **nuclear energy** (energy from the released nucleus of an atom).

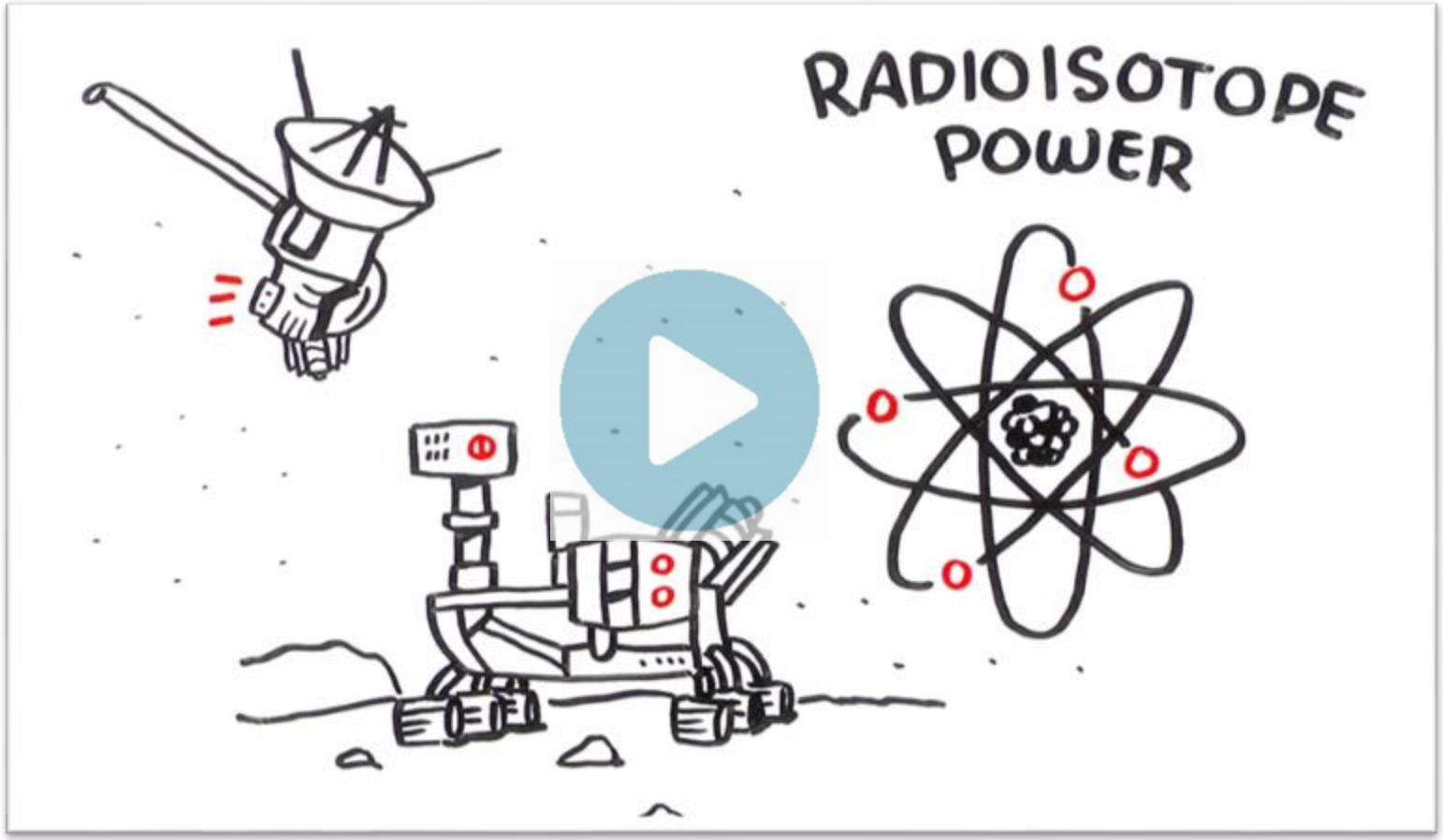


Cassini powered by RPS Photo Credit: NASA

What Is Radioisotope Power?

Radioisotope power systems—abbreviated RPS—are a type of **nuclear energy** technology that uses heat to produce electric power for operating spacecraft systems and science instruments. That heat is produced by the natural radioactive decay of **plutonium-238**.

A plutonium-238 fuel pellet glowing with the heat it produces Photo Credit: DOE



Spacecraft Power:
Learn how RPS work in this video.

Why does NASA use Radioisotope Power?

RPS are extremely reliable and dependable sources of spacecraft electrical power and useful heat energy. Let's take a look at some of the advantages of using RPS so you can consider them when planning your moon mission.

Cassini powered by RPS Photo Credit: NASA

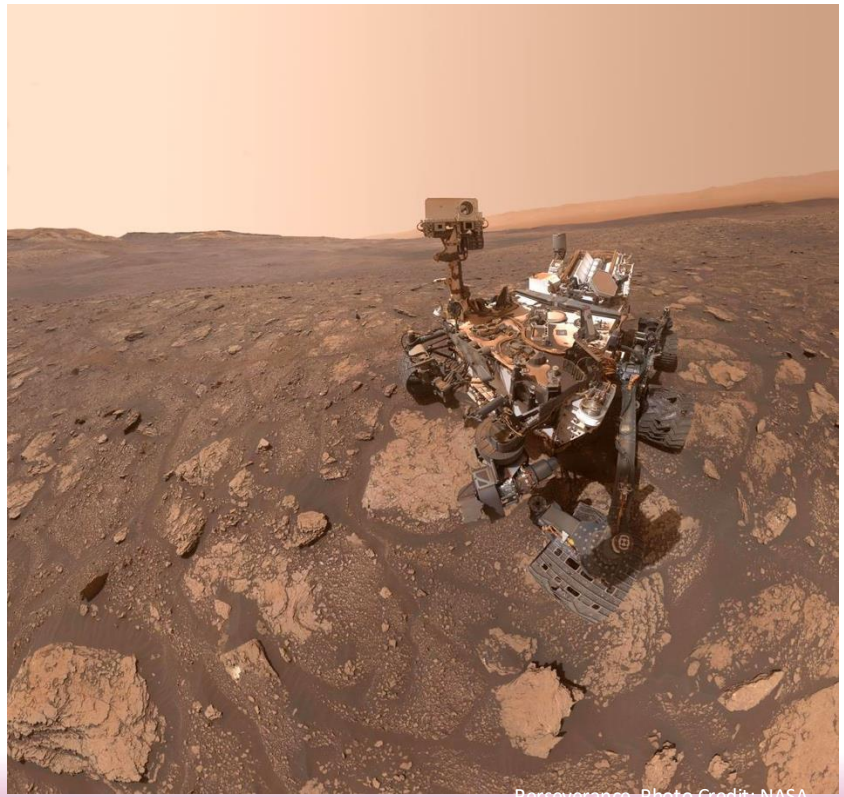
RPS can be used in dark environments

No light, no problem! RPS does not need light to function. Because of this, it can be used to travel to places like Saturn or Pluto. Saturn's available sunlight is only one hundredth, or one percent, of what we receive at Earth, and Pluto's is only six hundredths of a percent of the amount available at Earth. Since RPS does not rely on solar arrays it can give spacecraft the power it needs to go to faraway places, or in deep craters with little available sunlight.

Kuiper Belt Object Photo Credit: NASA

RPS can withstand dusty environments

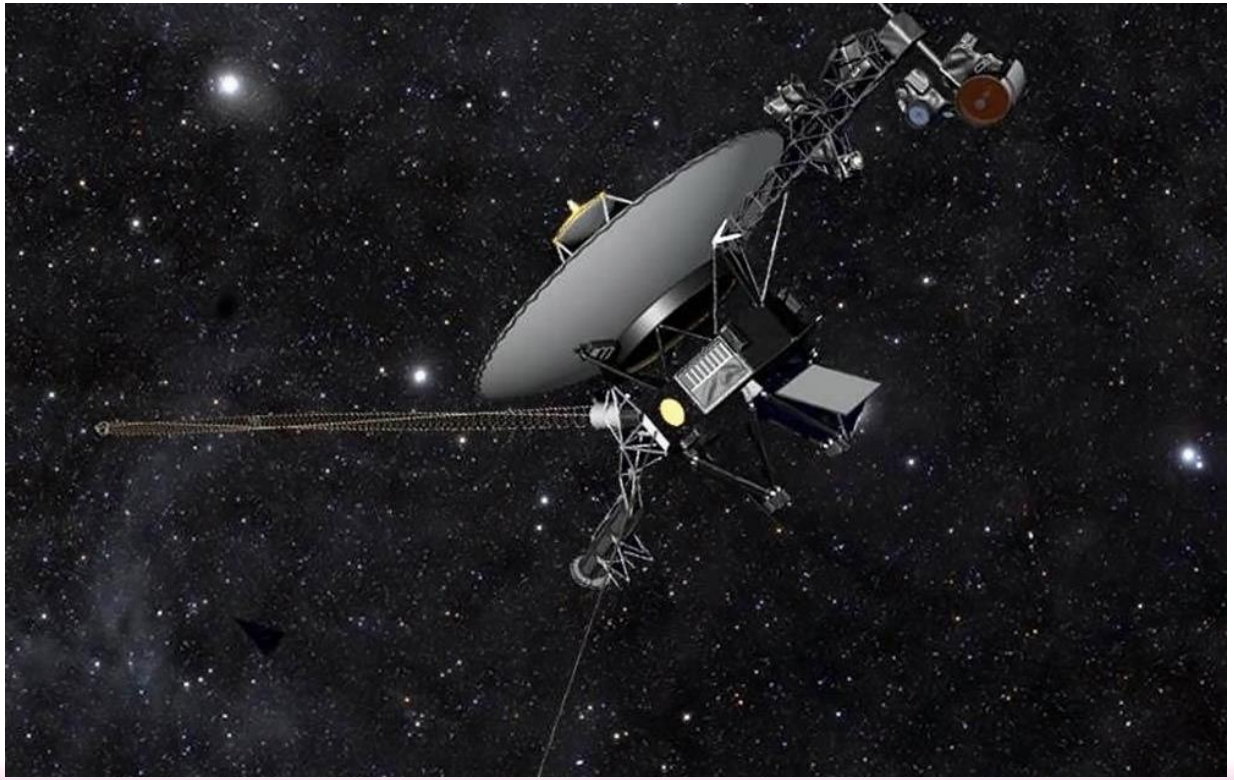
Dust storms are a regular occurrence on Mars which could cover solar panels making them unable to produce power. Fortunately, NASA's rovers PERSEVERANCE and CURIOSITY have RPS systems that can keep them going even when the environment gets dusty.



Perseverance Photo Credit: NASA

RPS can be used on far away missions

RPS enables far away missions. Going the distance takes time. NASA's RPS-powered VOYAGER twin spacecraft launched over 45 years ago and are over 14.6 billion miles away and they continue to return valuable data to scientists on Earth. Thanks to RPS, the Voyager spacecraft have visited Jupiter, Saturn, Uranus, and Neptune and are currently exploring interstellar space.



Voyager powered by RPS Photo Credit: NASA/JPL-Caltech

RPS offers longevity

RPS offers 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!

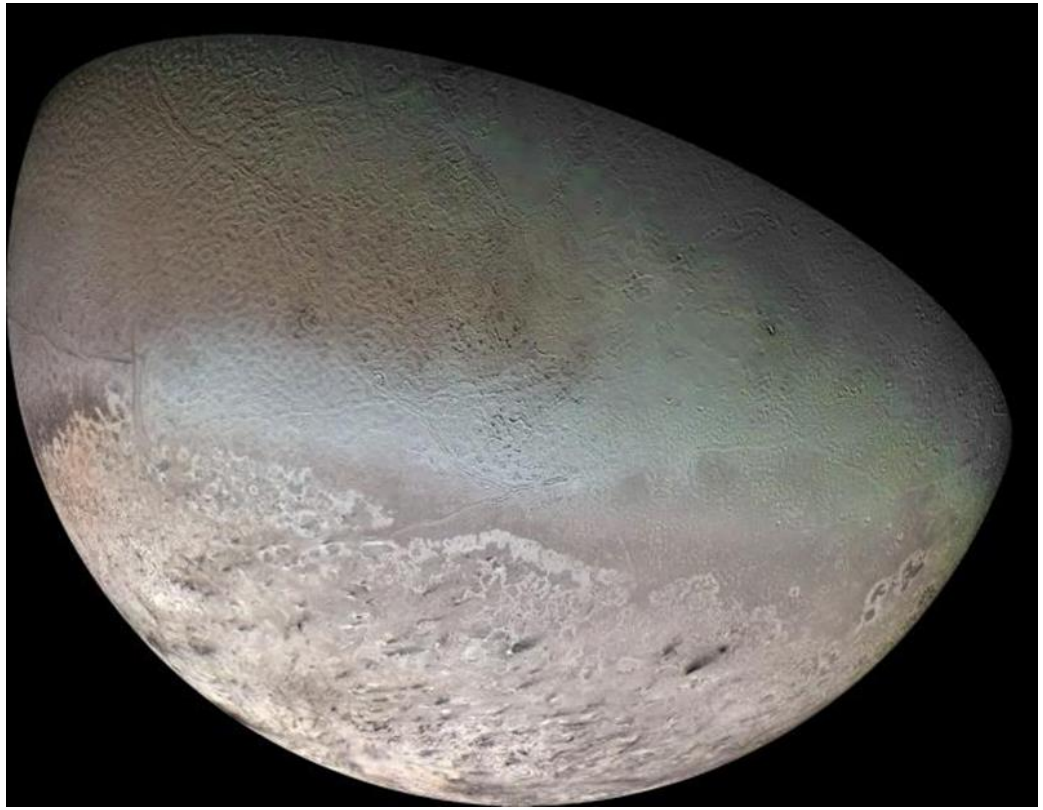


Photo Credit: NASA/JPL-Caltech

RPS are rugged

RPS are mighty! These systems are very rugged which allows them to function in extreme environments. In the future, radioisotope power systems could continue to support missions to extreme environments in our solar system like the liquid lakes of Saturn's moon Titan or the rings and moons of the giant ice planet Uranus.

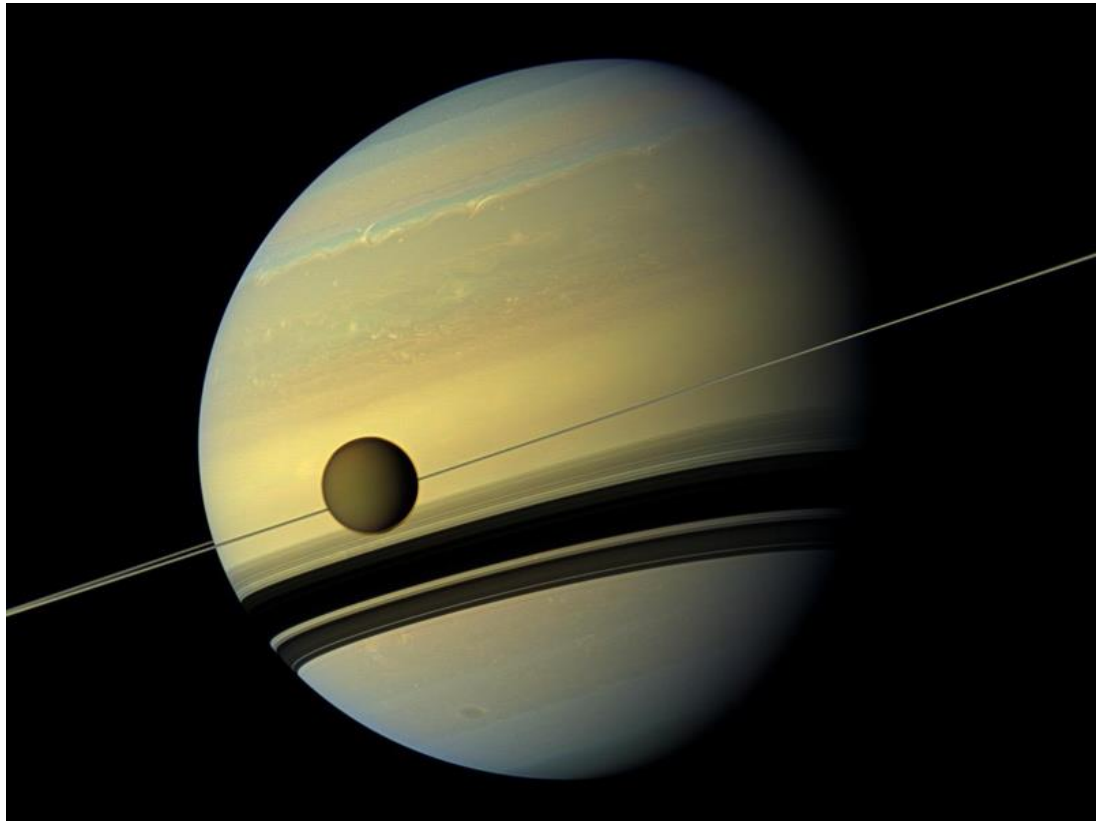


Photo Credit: NASA/JPL-Caltech

RPS are heat producing

The excess heat produced by some radioisotope power systems can be used to enable spacecraft instruments and onboard systems to continue to operate effectively in extremely cold environments. In addition, Radioisotope Heater Units (RHUs) can be used for additional thermal control, especially on solar-powered spacecraft, such as the Spirit and Opportunity rovers that explored Mars.

Radioisotope Heater Unit

RPS Missions

RPS have enabled NASA's exploration of the solar system since the Apollo era of the late 1960s. They have been employed to power crafts that are moving through - and now beyond - our solar system, collecting data and samples, giving us valuable information that we've never been able to access before.

Apollo 15 Photo Credit: NASA

RPS Missions

RPS are used in powering four different types of missions:

- **Flyby** – Flybys are used to get a quick glimpse of a planetary object. A flyby spacecraft will travel close to the object it is observing and collect data from it, like when Voyager 1 & 2 flew by Jupiter and discovered its rings and the volcano on its moon Io. Flybys can survey, take pictures, study magnetic fields, and much more!

- **Orbit** – Orbiters can study a planet for a long time, map it out, study its moons in detail, and detect changes over time, like weather patterns. A spacecraft that orbits will travel to a distant planet and then decelerate at the right moment to get captured in orbit and observe the planet while orbiting it. The Cassini spacecraft that orbited Saturn for 13 years had a magnetometer, a spectrometer, a fields and particles instrument, and cameras that could see in infrared, ultraviolet, and visible light.

RPS Missions

- **Land** – A lander spacecraft makes physical contact with the surface of its destination, stays where it is, and does all its functions in the place where it lands. Landers can also include scientific equipment like cameras, robotic arms, sensors, and much more. Much of what we understand about the moon's interior comes from the Apollo Lunar Surface Experiments Package, a collection of scientific instruments powered by RPS that monitored the environment at each Apollo landing site.

- **Rove** – A rover has the added value of letting you land somewhere safe and then travel somewhere more interesting! Rovers can move around, explore, collect samples, and transmit data back to Earth. Perseverance and Curiosity are currently exploring and collecting valuable information on Mars. NASA's Dragonfly mission will consist of a rotorcraft (multi-rotor vehicle) that will fly to dozens of locations on Saturn's moon, Titian searching for the building blocks of life.

RPS Missions

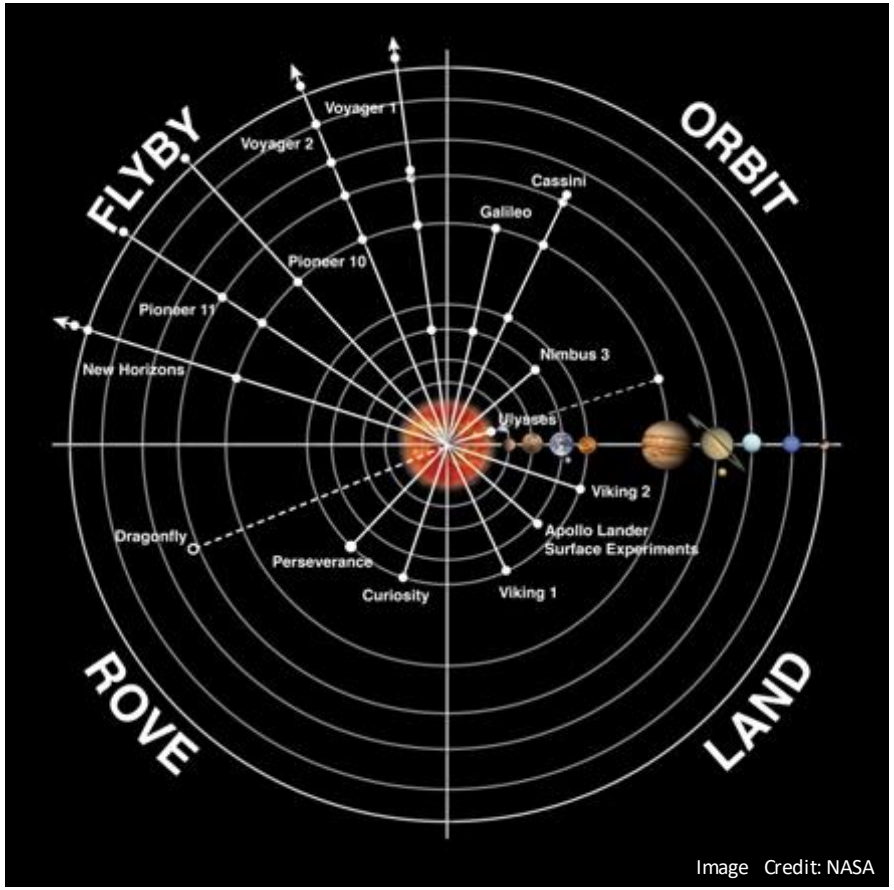


Image Credit: NASA

For more information about RPS-powered missions, click here.

Section 3: Learn About RPS Scavenger Hunt

Welcome to the RPS Scavenger Hunt. It is time to use your internet sleuthing skills to track down the answers to 20 questions about Radioisotope Power Systems, which will give you the knowledge to help you design your RPS-powered mission.

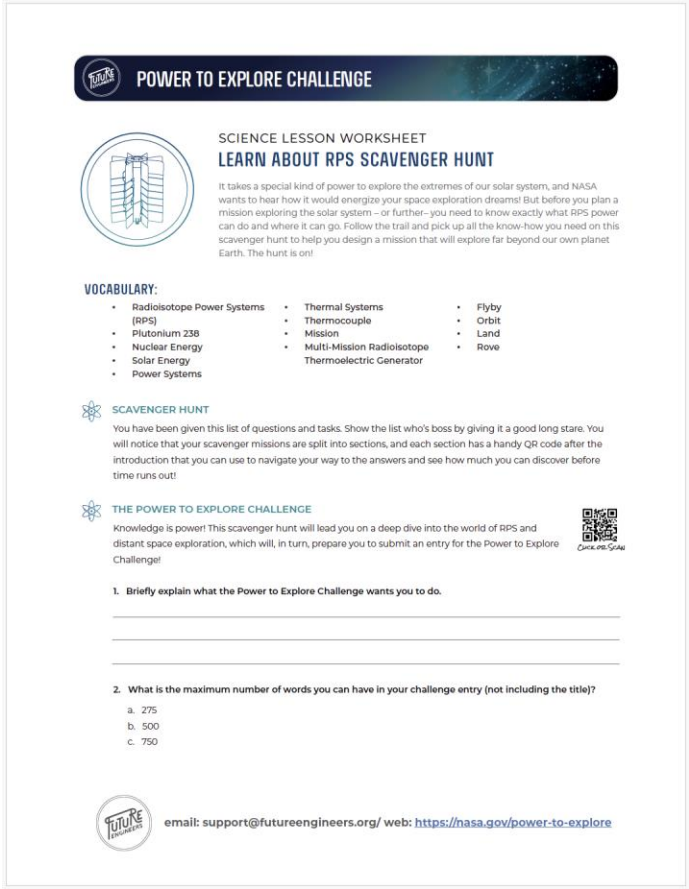
You will need the “Learn about RPS Scavenger Hunt” worksheet and access to the internet!

Scavenger Hunt Procedure

The worksheet is split into the following sections:

- **THE POWER TO EXPLORE CHALLENGE**
- **RADIOISOTOPE POWER SYSTEMS (RPS)**
- **PLUTONIUM-238**
- **MISSIONS AND MISSION GOALS**
- **FUTURE EXPLORATION**
- **BONUS QUESTION**

At the beginning of each section, you'll find a QR code. These QR codes can be clicked or scanned and lead to NASA website pages, where you'll find the answers to the questions in that section. The only section that does not contain a link is the **bonus question**.



POWER TO EXPLORE CHALLENGE

SCIENCE LESSON WORKSHEET

LEARN ABOUT RPS 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 space exploration dreams! But before you plan a mission exploring the solar system – or further– you need to know exactly what RPS power can do and where it can go. Follow the trail and pick up all the know-how you need on this scavenger hunt to help you design a mission that will explore far beyond our own planet Earth. The hunt is on!

VOCABULARY:

- Radioisotope Power Systems (RPS)
- Plutonium 238
- Nuclear Energy
- Solar Energy
- Power Systems
- Thermal Systems
- Thermocouple
- Mission
- Multi-Mission Radioisotope Thermoelectric Generator
- Flyby
- Orbit
- Land
- Rove

SCAVENGER HUNT

You have been given this list of questions and tasks. Show the list who's boss by giving it a good long stare. You will notice that your scavenger missions are split into sections, and each section has a handy QR code after the introduction that you can use to navigate your way to the answers and see how much you can discover before time runs out!

THE POWER TO EXPLORE CHALLENGE

Knowledge is power! This scavenger hunt will lead you on a deep dive into the world of RPS and distant space exploration, which will, in turn, prepare you to submit an entry for the Power to Explore Challenge!

1. Briefly explain what the Power to Explore Challenge wants you to do.

2. What is the maximum number of words you can have in your challenge entry (not including the title)?
   a. 275
   b. 500
   c. 750

email: support@futureengineers.org/ web: https://nasa.gov/power-to-explore

Scavenger Hunt Checklist

Do you have your worksheet?

Do you have a device with internet access?

Got something to fill in the answers?

Then you are ready; the hunt is on! Good luck, and remember, everything you discover can help you come up with your challenge entry.

Section 4: Scavenger Hunt Answers

Let’s see how you did!

1. **Briefly explain what the Power to Explore Challenge wants you to do.**

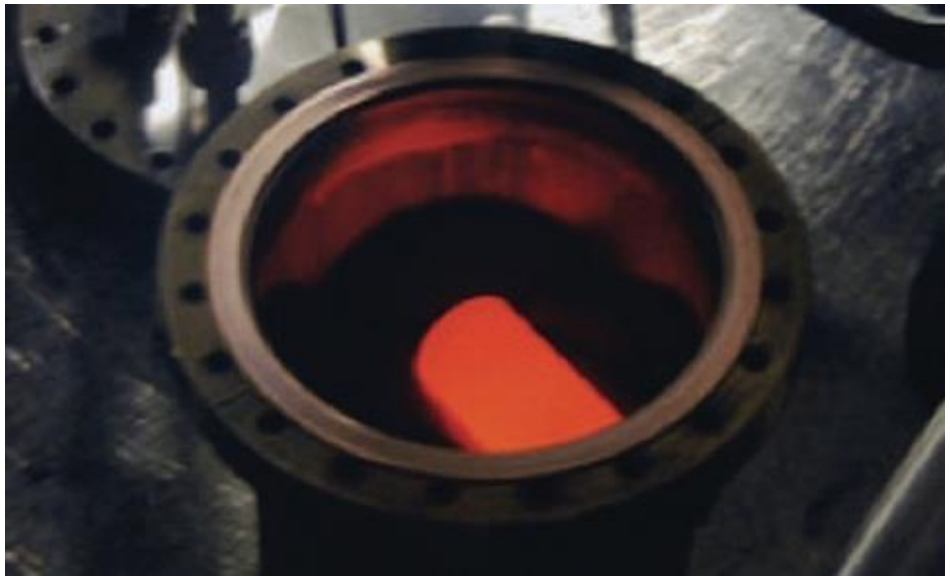
- Research radioisotope power systems, which is a type of nuclear "battery," and then dream up a new RPS-powered space mission to a moon in our solar system. Please write about:
  - Where you would go on your mission and describe your mission goal(s).
  - Also, describe a special human power you have that will contribute to the success of your mission goal(s).

2. **What is the maximum number of words you can have in your challenge entry (not including the title)?**

a. 275
b. 500
c. 750

3. **Where does the heat for RPS come from?**

   The heat is produced by the natural radioactive decay of plutonium-238.



4. **Approximately how long has RPS technology been used in the U.S. space program?**

   a. Since 2011
   b. Over 40 years
   c. Since 1958
   d. Over 60 years

5. **How sharp are your eyes? Find these paragraphs and fill in the missing words.**

RPS offer several important benefits. They are ___compact___, rugged and provide reliable power in harsh environments where ___solar___arrays are not practical. For example, Saturn is about ten times farther from the sun than Earth, and the available sunlight there is only one hundredth, or one percent, of what we receive at Earth. At___Pluto___, the available sunlight is only six hundredths of a percent of the amount available at Earth. The ability to utilize radioisotope power is important for missions to these and other incredibly distant destinations, as the size of solar arrays required at such distances is impractically large with current technology.

RPS 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.

In addition, some of 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 the future, radioisotope power systems could continue to support missions to some of the most extreme environments in the___solar system___, probing the secrets of Jupiter's ocean moon Europa, floating in the ___liquid lakes___of Saturn's moon Titan or touring the rings and moons of the ice giant planet ___Uranus___. With this vital technological capability, the possibilities for exploration and discovery are limited only by our imaginations.

6. **Match the acronym to the full name.**

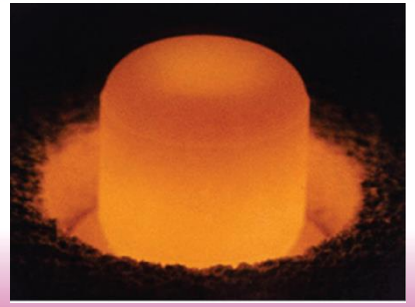
RTG	Radioisotope Thermoelectric Generator
DOE	Department of Energy
MMRTG	Multi-Mission Radioisotope Thermoelectric Generator
RHU	Radioisotope Heating Unit
RPS	Radioisotope Powered Systems

PLUTONIUM-238

Plutonium-238 is the radioisotope of choice for RPS! It has proven to be a very dependable and safe heat source on more than two dozen U.S. space missions. Let's find out more about how it can help you in designing your mission.

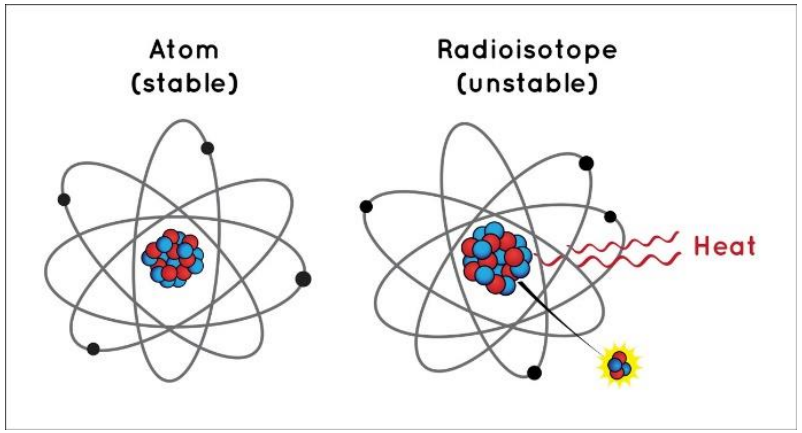
CLICK OR SCAN

7. **Take a screenshot or draw a picture of a pellet of plutonium-238.**



8. **To be suitable for space missions, a radioisotope must meet a list of specific criteria. Plutonium-238 meets all of them! Name two of these criteria.**

- Exist in an insoluble form and/or otherwise not be readily absorbed into the body in the unlikely event of a launch accident
- Exist in a form such that it presents no or minimal chemical toxicity when taken into the body
- Have relatively low neutron, beta, and gamma radiation emissions, so as to not adversely affect spacecraft instruments or require excessively massive shielding
- Be stable at high temperatures, so its characteristics remain essentially unchanged over many years
- Have a long enough half-life (at least 15 to 100 years), so that it can generate for many years sufficient heat for transformation into electricity
- Have a high-power density, so a small amount of it can generate a substantial amount of heat

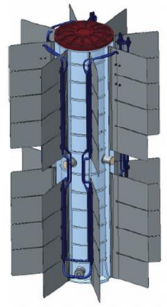


9. **Radioisotopes are measured by the rate at which they decay. This is known as the half-life.**

a. What is the half-life of plutonium-238? 87-88 years

b. Why is plutonium-238 ideal for long-lived space missions? Because it is a long-lived source of heat that can be converted to power or electricity that can be used for the mission

10. Look at the pictures below and answers the questions that follow.



a. What are these devices called, and what is their abbreviation? *(Hint: One is a Next gen- _____ and the other is an Multi-Mission_____)*

Next Gen-RTG and Multi-Mission Radioisotope Thermoelectric Generator (MMRTG)
RTGs or RPS

b. What do these devices do?

They convert the natural decay heat of plutonium-238 into electricity.

c. Unscramble this anagram of an unlikely superhero to reveal the device's name that converts heat into electricity. *(Hint: The name of the device is one word)*

HERO CLUMP TOE

THERMOCOUPLE

11. RPS use spacecraft that are designed for flyby, orbit, land, or rove missions. You will need to decide what your mission will be and what your spacecraft will do. Use the RPS missions page and NASA image "Flyby, Orbit, Rove, and Land" to answer the multiple-choice questions below.

What kind of missions were Voyager 1 and Voyager 2?

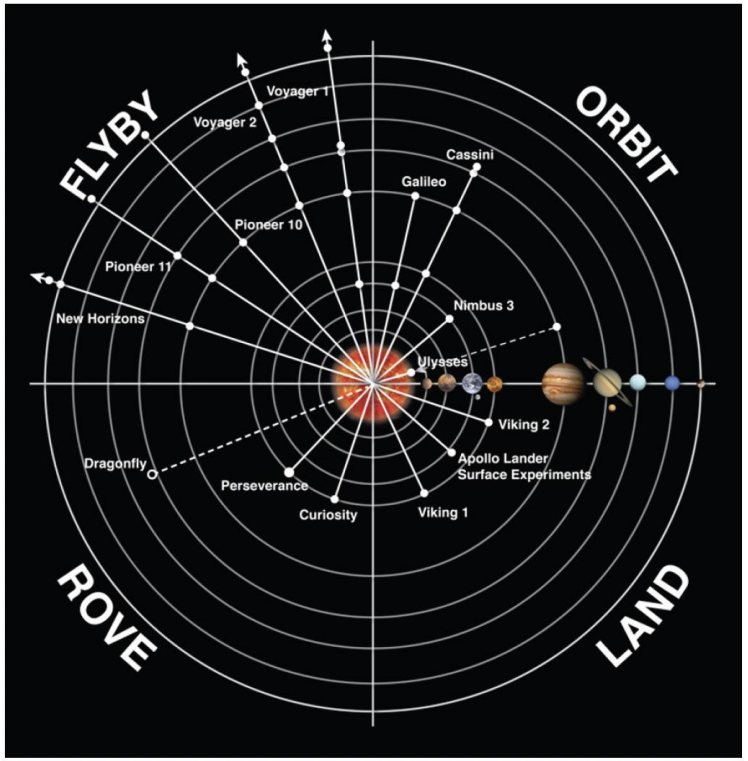
a. Flyby
b. Orbit
c. Land
d. Rove

Galileo was the first spacecraft to orbit and study what planet?

a. Mars
b. Jupiter
c. Neptune
d. The Moon

NASA's Viking mission to mars was composed of two pairs of spacecraft - Viking 1 and Viking 2 - each consisting of an orbiter and lander. This was the first mission to land on what planet?

a. Mars
b. Jupiter
c. Neptune
d. The Moon



12. Use the picture below and the RPS Missions link to answer the following questions.

(Hint: On the mission page, click on "Past Missions.")

Click or Scan

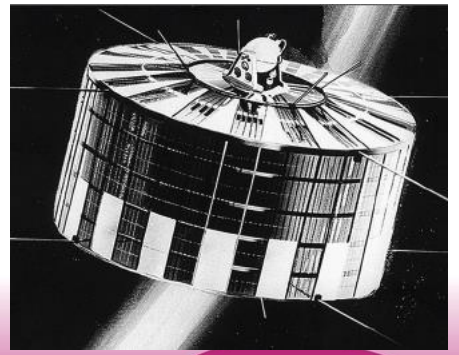
a. Name this crewed mission (one with astronauts) that used RPS.

Apollo 12

b. What did RPS power on this crewed mission?

ALSEP (Apollo Lunar Surface Experiment Package), a collection of geophysical instruments designed to continue to monitor the environment of each Apollo landing site for a period of at least a year after the astronauts had departed. ASLEP ended up working for up to 8 years!

13. RPS sounds like new technology, but we've been using it for over 60 years. Screenshot or quickly sketch the first space object to use an RPS. No points for artistic skills, but you do get unlimited glory if you can also name it and provide the date it launched.



Name of the first space object to use RPS: TRANSIT IV-A

Date Launched: June 29, 1961

14. Which is the most recent piece of NASA technology to use an MMRTG?

(Hint, it launched in 2020. Click this link to find out where the MMRTG is located.)

PERSEVERANCE

15. Ulysses is the spacecraft named after an intrepid adventurer from ancient times. Ulysses was launched in 1990 with very specific mission goals and ten instruments; what did those instruments measure?

The sun's fields and particles, and its ultraviolet, X-ray, and gamma radiation.

16. Name the twin rovers that use both solar power and RPS.

Spirit and Opportunity

17. Name the two longest-running active missions using RTGs and the dates they were launched.

Voyager 1 September 5, 1977
Voyager 2 August 20, 1977

18. This piece of text is located somewhere in the Missions pages. Use your hawk-sharp eyes to find it and fill in the blanks!

> The **Mars 2020** "Perseverance" rover is conducting geological assessments of its landing site on Mars; Perseverance is determining the __habitability___ of the environment, searching for signs of__ancient Martian life__, and assessing natural resources and ___hazards__for future__human explorers___.

19. Sometimes spacecraft carry a friendly hitchhiker. Can you name the orbiter that dropped off the European Huygens probe on one of Saturn's moons? And which moon was it?

Cassini. Titan.

FUTURE EXPLORATION

NASA is always looking to the future! Find out what's in store next for RPS.

20. Dragonfly, which is set to launch in 2028 is the next mission with plans to use an MMRTG. Part of NASA's New Frontiers program, Dragonfly is an octocopter designed to do what?

Dragonfly is an octocopter designed to explore and collect samples on Saturn's largest moon, Titan, an ocean world with a dense, hazy atmosphere.

Image Credit: NASA

BONUS QUESTION

Every NASA mission is a massive achievement, a unique testament to what humankind can accomplish with collaboration and an unquenchable thirst to discover what lies beyond our planet. NASA's groundbreaking work ignites a global passion for space exploration, generation after generation. We want to know what has inspired you.

21. What is your favorite NASA RPS-powered mission, and why?

Any answer referencing an RPS mission is correct.

Congratulations! You've completed the scavenger hunt; now you're ready to brainstorm your entry ideas.

Remember that you will need to include:

- **Dark, Dusty, or Distant Mission Destination:** Tell us which moon in our solar system you RPS-powered mission will go and describe your mission goal(s). Keep in mind that your mission can either flyby, orbit, land, or rove.

- **Radioisotope Power Systems (RPS):** Explain the importance and advantages of using RPS for this mission. How does this technology overcome the challenges of these extreme environments and destinations?

- **Your Power:** NASA missions are also powered by people–from mission planning and development to designing, launching, and operating a spacecraft. Tell us what you think your unique power is and how your special power will help you achieve mission success. Your power could be a skill, personality trait, or other personal strength that is uniquely you.

Go to the BRAINSTORMING section of the challenge website to help you home in on your entry idea.