National Aeronautics and
Space Administration

Power Up With Solar System Activities

Brought to you by NASA's Radioisotope Power Systems Program

Learn how NASA explores the extremes with out-of-this-world power systems and then build your own scale model of the solar system

For ages 8 and up

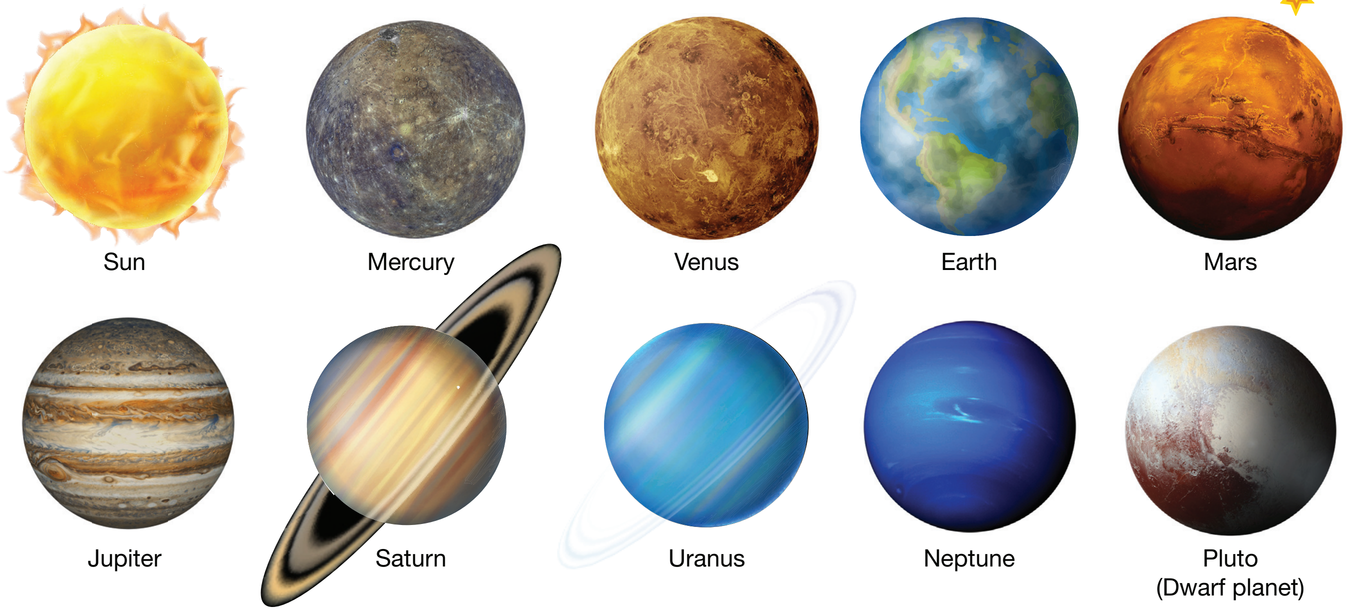
www.nasa.gov

Power Up With Solar System Activities

The Solar System Project is both educational and recreational. It is designed to give one an appreciation for the enormous size of our universe. It is challenging to design a scale model of the solar system where the same scale is used to portray not only the physical sizes of the Sun and planets, but also the distances between them. Planets are tiny in the vastness of space. Using different methods and creativity, a scale model of the solar system can be made showing the relative distances between the planets. The journey through the solar system will begin with creating our closest star, the Sun. It will continue by "traveling to, then creating" each of the planets—and beyond—unlocking some of the secrets of space, and learning why NASA uses radioisotope power systems to explore the planets, along with the harshest, darkest environments and farthest reaches of our solar system.

Our solar system is made up of eight planets and their moons, dwarf planets, millions of asteroids—most orbiting our Sun between Mars and Jupiter within the main asteroid belt—comets, and dust particles that orbit the Sun. Stars, like our Sun, generate their own light while the solar system's planets shine by reflecting the Sun's light.

The Sun is the center of our solar system. It is the closest star to the Earth, providing us with all the needed energy—light and heat—for life as we know it. The Sun is so large that over 1 million Earths would be needed to fill the same volume as the Sun.



Images shown are not to scale.

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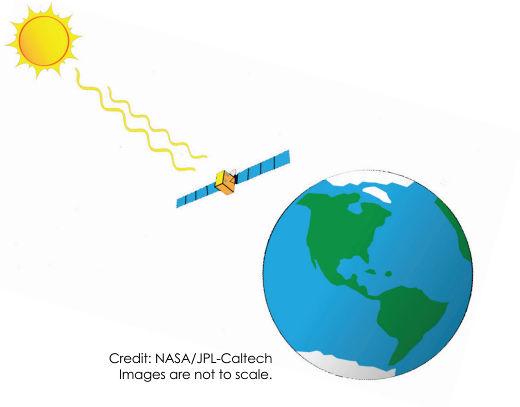
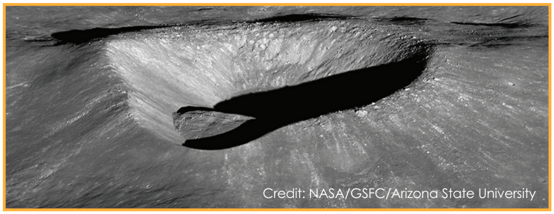
The Power to Explore the Solar System and Beyond

When NASA sends robotic spacecraft to explore the solar system, the spacecraft have computers, cameras, and other science instruments which act as our remote eyes and ears as they study the planets and teach us what they discover.

Solar power is energy from the Sun. Spacecraft that orbit Earth, called satellites, are close enough to the Sun that they can often use solar power. These spacecraft have solar panels which convert the Sun's energy into electricity that powers the spacecraft. The electricity from the solar panels charges a battery in the spacecraft. These batteries can power the spacecraft even when it moves out of direct sunlight. Solar energy has also been used to power spacecraft on Mars. NASA's Mars Exploration Rovers, Spirit and Opportunity, and Mars' Phoenix and InSight landers, all used power from solar panels.

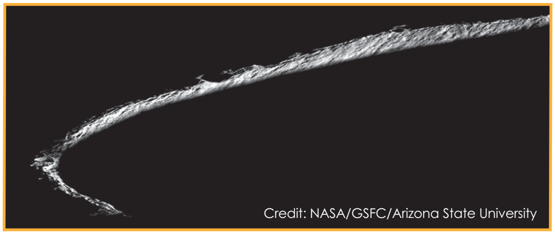


Credit: NASA/JPL-Caltech
Images are not to scale.



Credit: NASA/GSFC/Arizona State University

Ryder crater is located in the South Pole–Aitken Basin, which is the largest and possibly oldest basin on the Moon.



Credit: NASA/GSFC/Arizona State University

Shackleton Crater is an impact crater that lies at the lunar South Pole. While peaks along the crater's rim are exposed to almost continual sunlight, the interior is always in shadow.

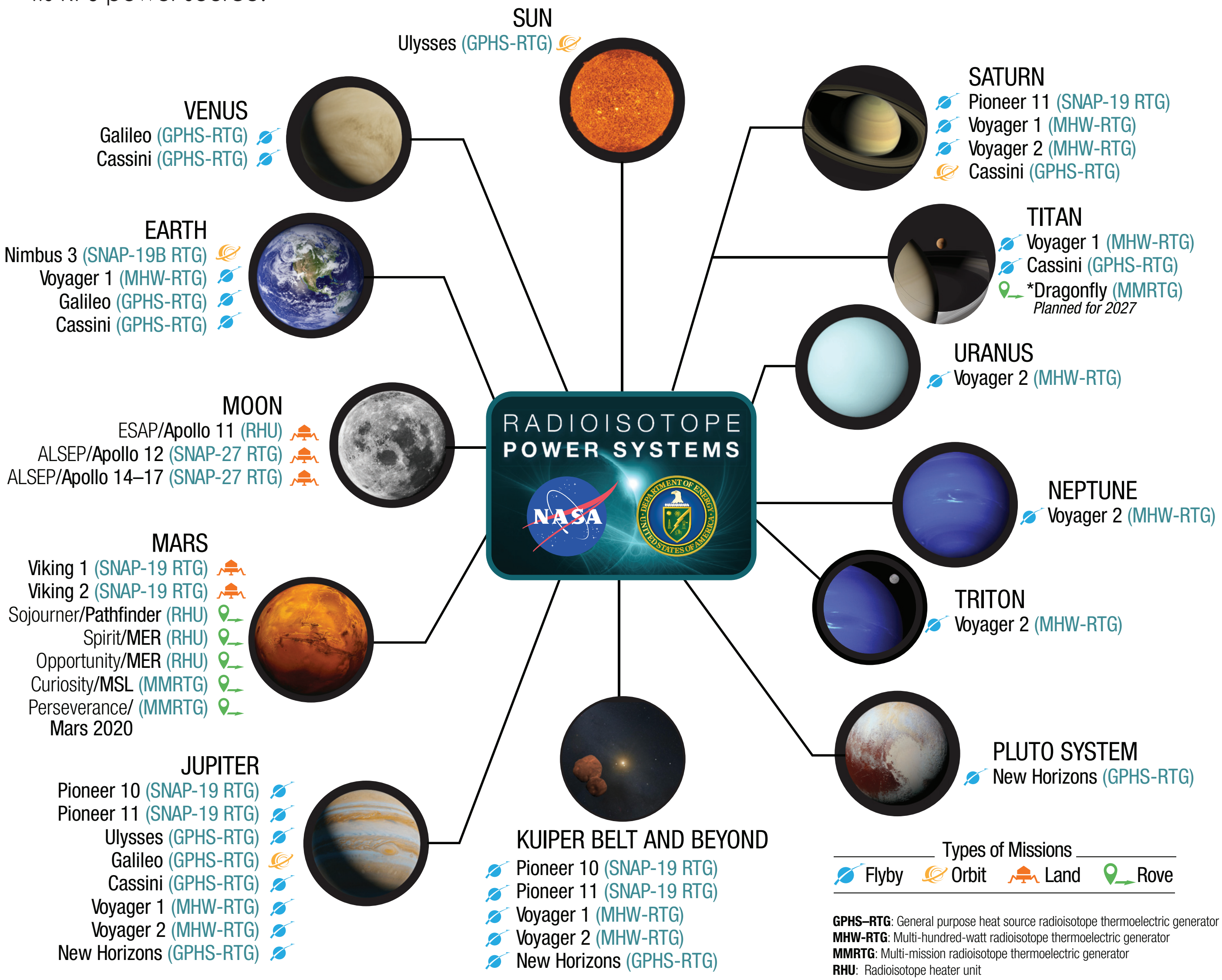
However, solar power does not work for all spacecraft. One reason is that as spacecraft travel farther from the Sun, solar power becomes less efficient. Solar-powered explorers may also be limited by a planet's weather and seasons, and harsh radiation (a type of energy). They might not have the energy to be able to explore dark, dusty environments, such as craters on the Moon.

In addition to solar power, NASA uses radioisotope thermoelectric generators (RTGs) to turn heat into electricity. RTGs are lightweight, compact spacecraft power systems that provide electrical power using heat from the natural radioactive decay of plutonium dioxide. RTGs are used on NASA missions where other options, such as solar power, are impractical or incapable of providing the power that a mission may need to accomplish its scientific or operational goals.

RTGs operate continuously over long-duration space missions, independent of changes in sunlight, temperature, or surface conditions like thick clouds or dust. In addition, RTGs can be used to provide useful additional heat to keep spacecraft components and systems warm. The U.S. has flown 31 missions with RTGs over the past 60 years.

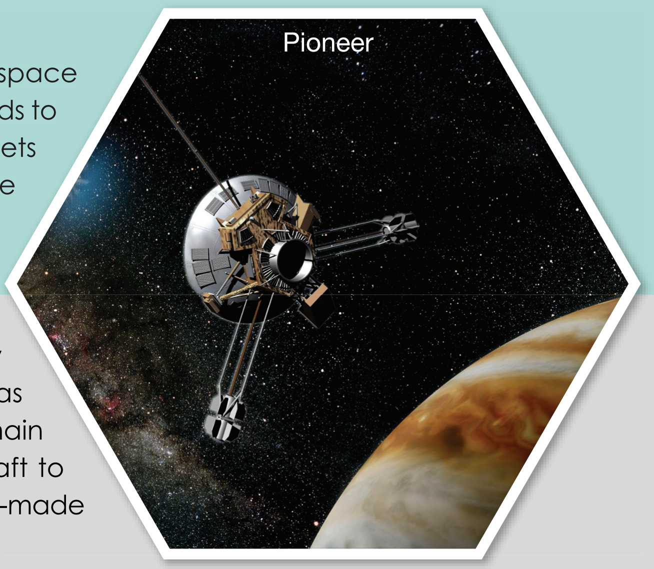
The Power to Explore—Proud Past, Strong Future

NASA's RPS program works in partnership with the Department of Energy to deliver power systems and technology for science missions to some of the most distant, dustiest, darkest, and harshest environments in the solar system. RPS have enabled the missions listed below. The name of each mission is followed by its RPS power source.



Power to Explore—Spacecraft

Choosing between solar and radioisotope power for a space mission has everything to do with where a spacecraft needs to operate and what the mission must accomplish when it gets there. Radioisotope power is used only when it will enable or significantly add to the ability of a mission to meet its science goals.



Pioneer 10, NASA's first mission to explore the outer planets, was the first spacecraft to use electrical power supplied by four radioisotope thermoelectric generators (RTGs). It was the first spacecraft to fly beyond Mars, fly through the main asteroid belt, and fly by Jupiter. It was the first spacecraft to cross into interstellar space, becoming the first human-made object to go beyond Neptune.

NASA's Pioneer 11, a sister spacecraft to Pioneer 10, was the first spacecraft to study Saturn up close and the second spacecraft to cross into interstellar space.

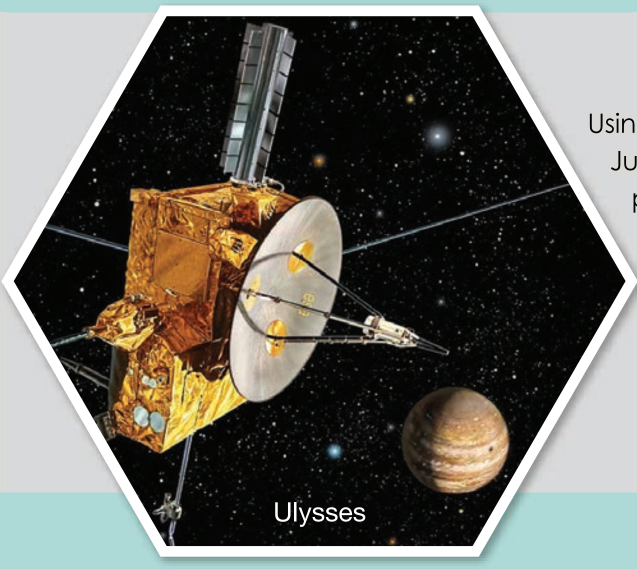
Galileo, using RTGs, was the first spacecraft to examine Jupiter and its moons for an extended period. Circling the solar system's most giant planet for 8 years, Galileo beamed back a string of discoveries to Earth.

The New Horizons spacecraft flew by Pluto and took the only close-up images we have of Pluto and its moon, Charon. It went on to fly by Arrakoth, an object in the very distant Kuiper Belt.

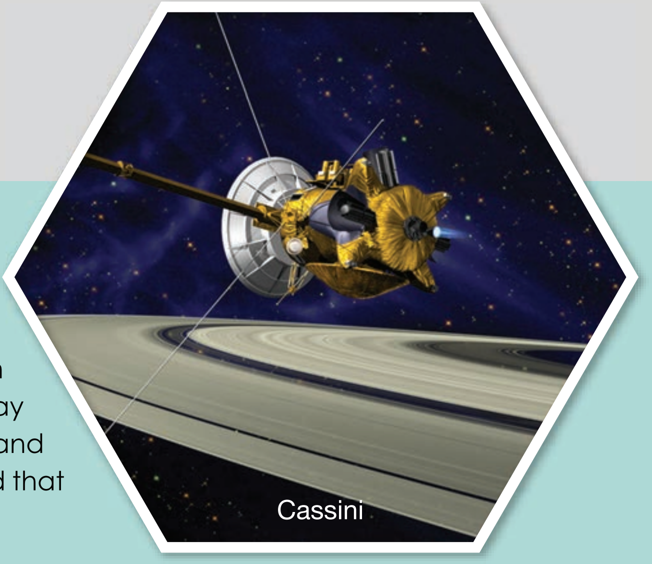
Power to Explore—Spacecraft

NASA's two Voyager spacecraft have traveled farther and have been traveling longer than any other human-made object. They are both are still sending back information to scientists after more than 45 years in space! Each spacecraft's electrical power is supplied by three radioisotope thermoelectric generators (RTGs). Voyager 1 flew by Jupiter and Saturn, and is now in interstellar space, the space between the stars. Voyager 2 flew by Jupiter, Saturn, Uranus, and Neptune. Voyager 2 is also in interstellar space.


Voyager


Ulysses

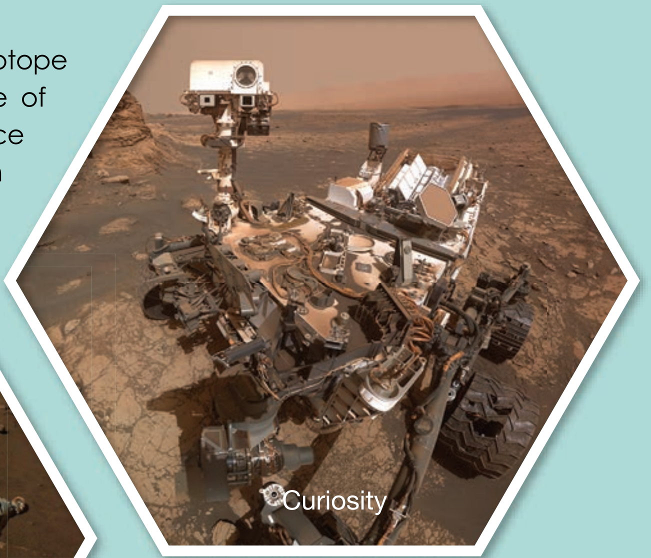
Using RTGs, Ulysses completed three rendezvous with Jupiter between 1992 and 2008, utilizing the giant planet's gravity to accomplish three passages over the Sun's north and south poles.


Cassini

Cassini used RTGs to orbit Saturn for 13 years and study Saturn and its rings and moons. It took 7 years to get from Earth to Saturn, flying by Venus, Earth, and Jupiter on its way out to Saturn. Cassini discovered some of Saturn's rings and moons that had never been seen before, and discovered that some of Saturn's moons are geologically active.

Power to Explore—Spacecraft

The Curiosity and Perseverance rovers are using radioisotope thermoelectric generators (RTGs) to explore the surface of Mars. Curiosity found evidence of past water on the surface of Mars. Perseverance is collecting samples of the Martian surface that will be returned to Earth on a future mission.



Curiosity

Perseverance

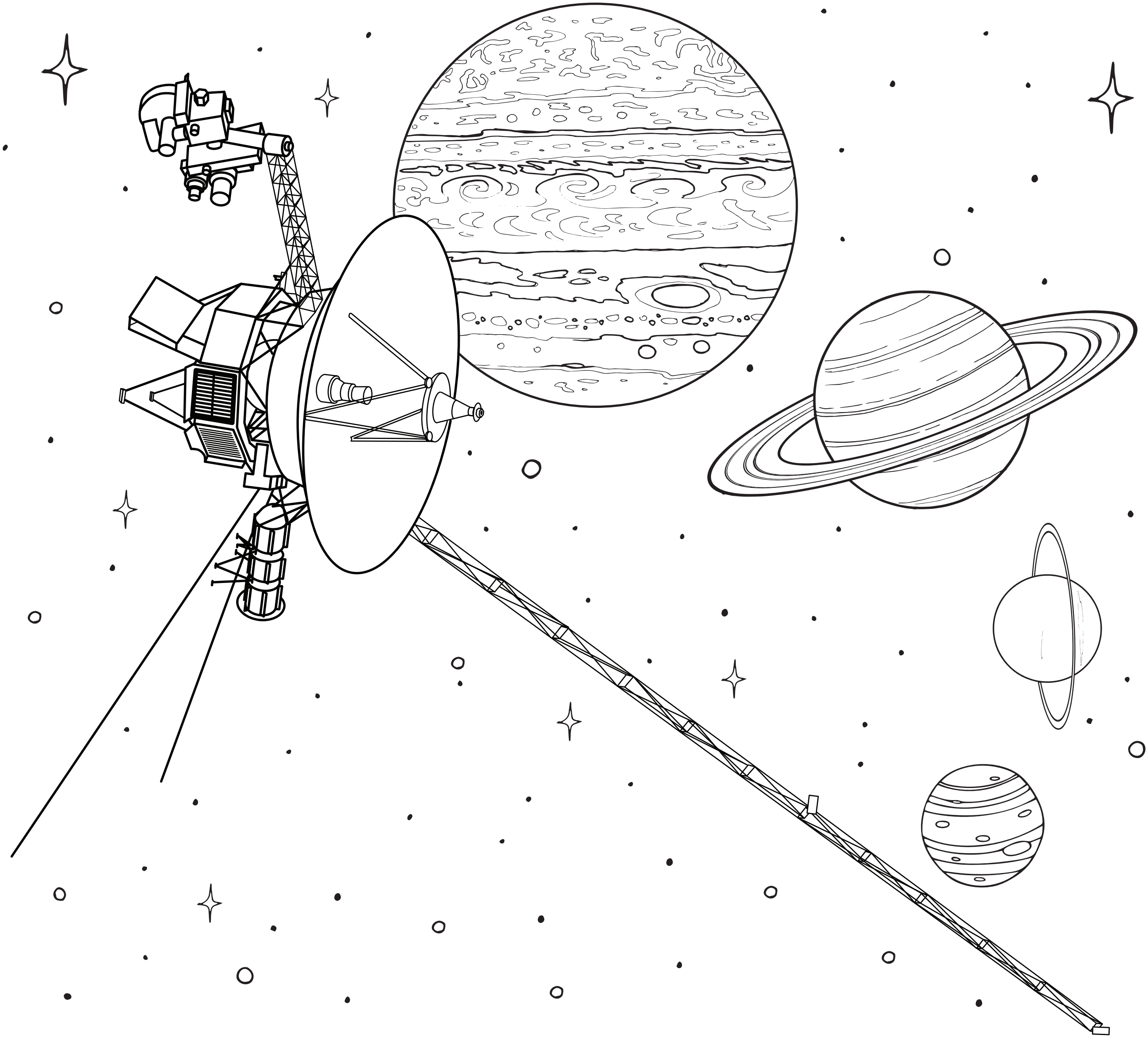
Basic power for the Viking Lander was provided by two RTGs. The use of these generators represented a major milestone in the development of long-lived, highly reliable isotope power systems for space use by NASA.

The generators provided a long-lived source of electricity and heat on Mars, where sunlight is half as strong as on Earth, and is non-existent during the Martian night, when temperatures can drop as low as –120 °C (–184 °F).

Viking Lander

Voyager 1 and 2

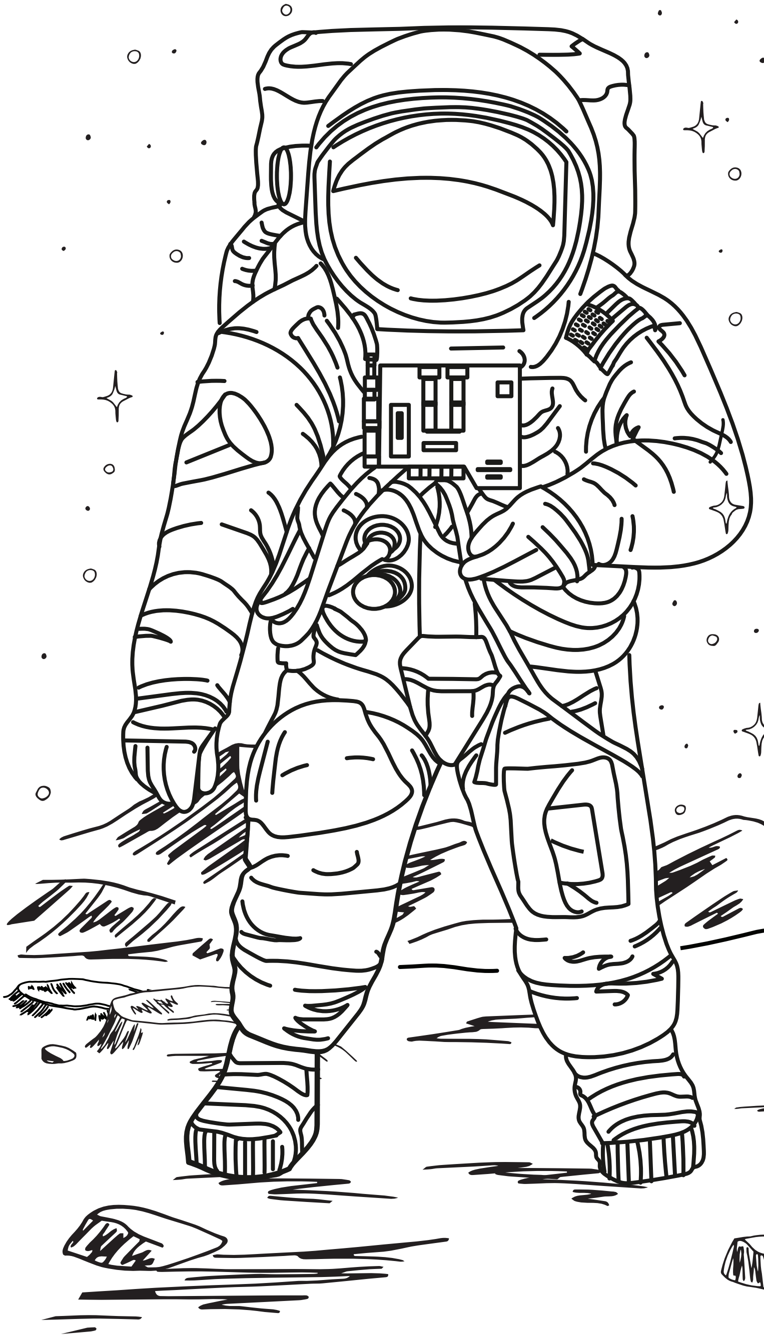
Between them, Voyager 1 and 2 have explored all the giant outer planets of our solar system, 48 of their moons, and the unique systems of rings and magnetic fields those planets possess.



Pioneer 10 and 11

Pioneer was the first to fly beyond Mars' orbit, through the asteroid belt, and close to Jupiter. During the passage by Jupiter, Pioneer 10 obtained the first close-up images of the planet, charted Jupiter's intense radiation belts, located the planet's magnetic field, and discovered that Jupiter is predominantly a gas planet. Long before and after flying by Jupiter, Pioneer 10 transmitted data on the magnetic fields, energetic particle radiation, and dust populations in interplanetary space. Pioneer 11 was the first mission to explore Saturn and the second spacecraft in humanity's early studies of the outer solar system.

Apollo Lunar Surface Experiment Package (ALSEP)



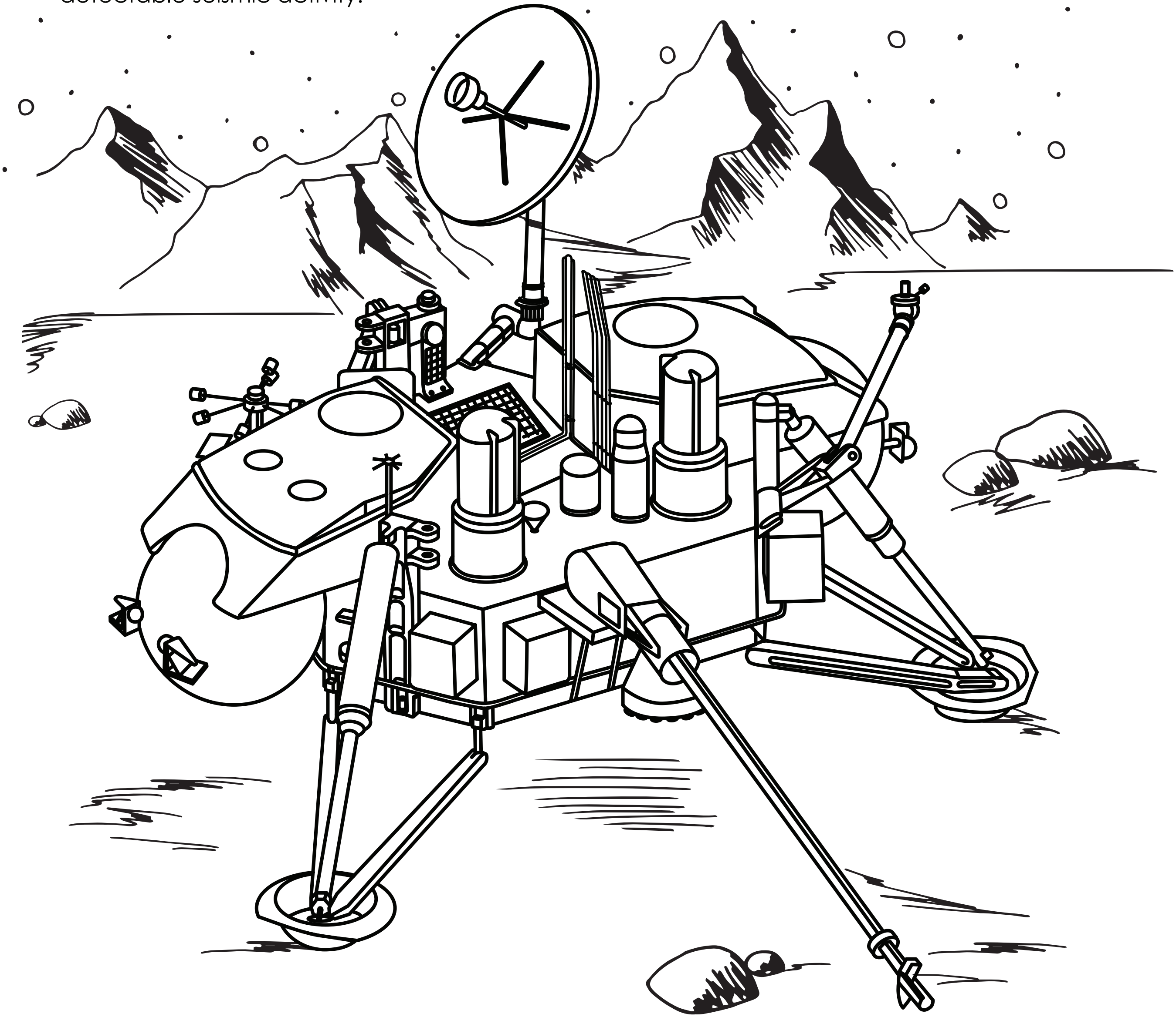
The goal of NASA's Apollo program was to land humans on the Moon and bring them safely back to Earth. Six of the missions achieved this goal.

ALSEP was 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. Designed for a life of one year (Apollo 17 was designed for two), they ended up working for up to 8 years.

The ALSEP system, first flown on the Apollo 12 mission, consisted of a Central Station with a communications package with leads running out to the instruments placed around it. Its power was supplied by a SNAP–27 model radioisotope thermoelectric generator (RTG).

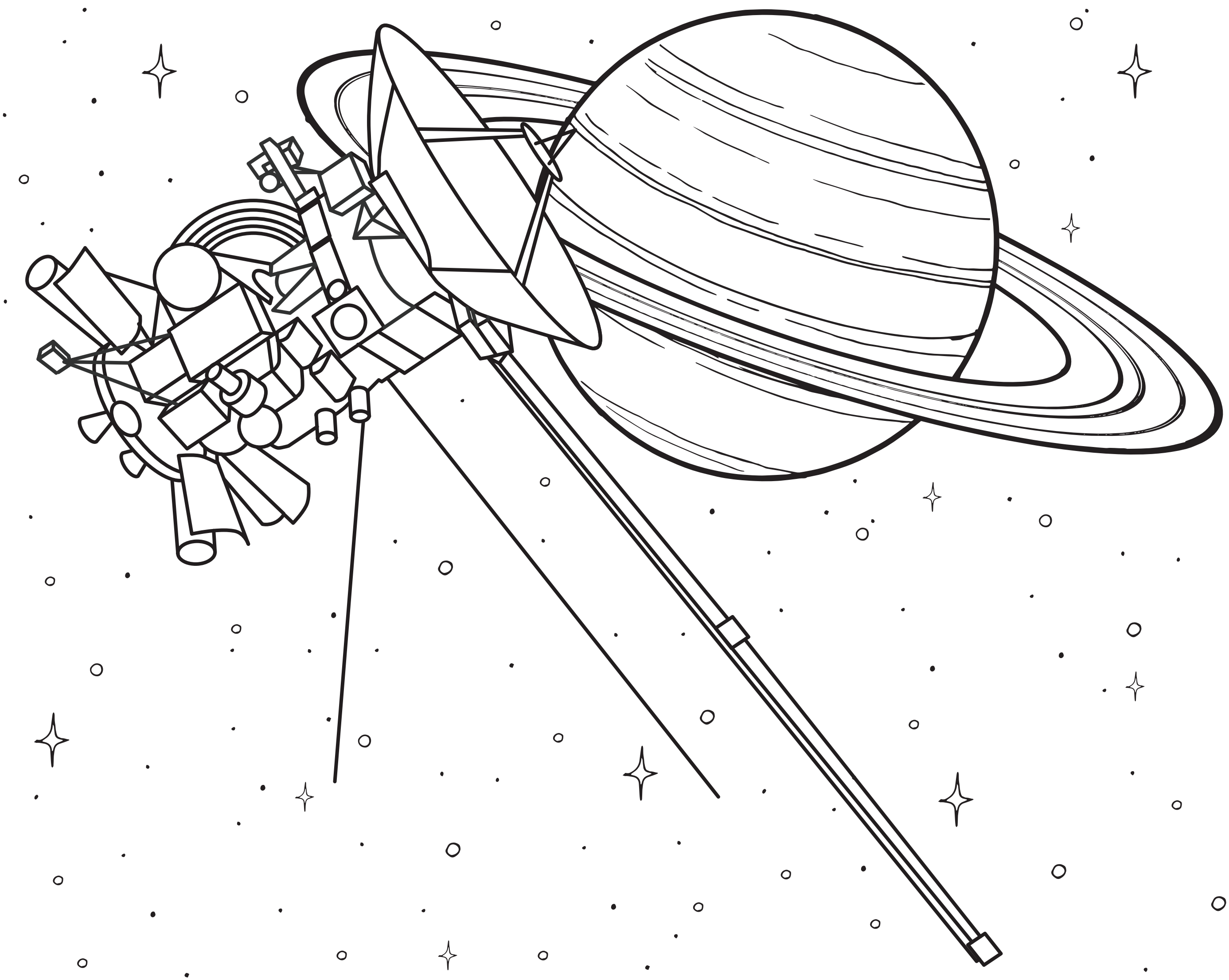
Viking Lander

Viking 1 was the first successful mission to land on Mars. The four Viking spacecraft provided numerous new insights into the nature and history of Mars, producing a vivid overall picture of a cold weathered surface with reddish volcanic soil under a thin, dry carbon dioxide atmosphere, clear evidence for the existence of ancient river beds and vast floods, and no detectable seismic activity.



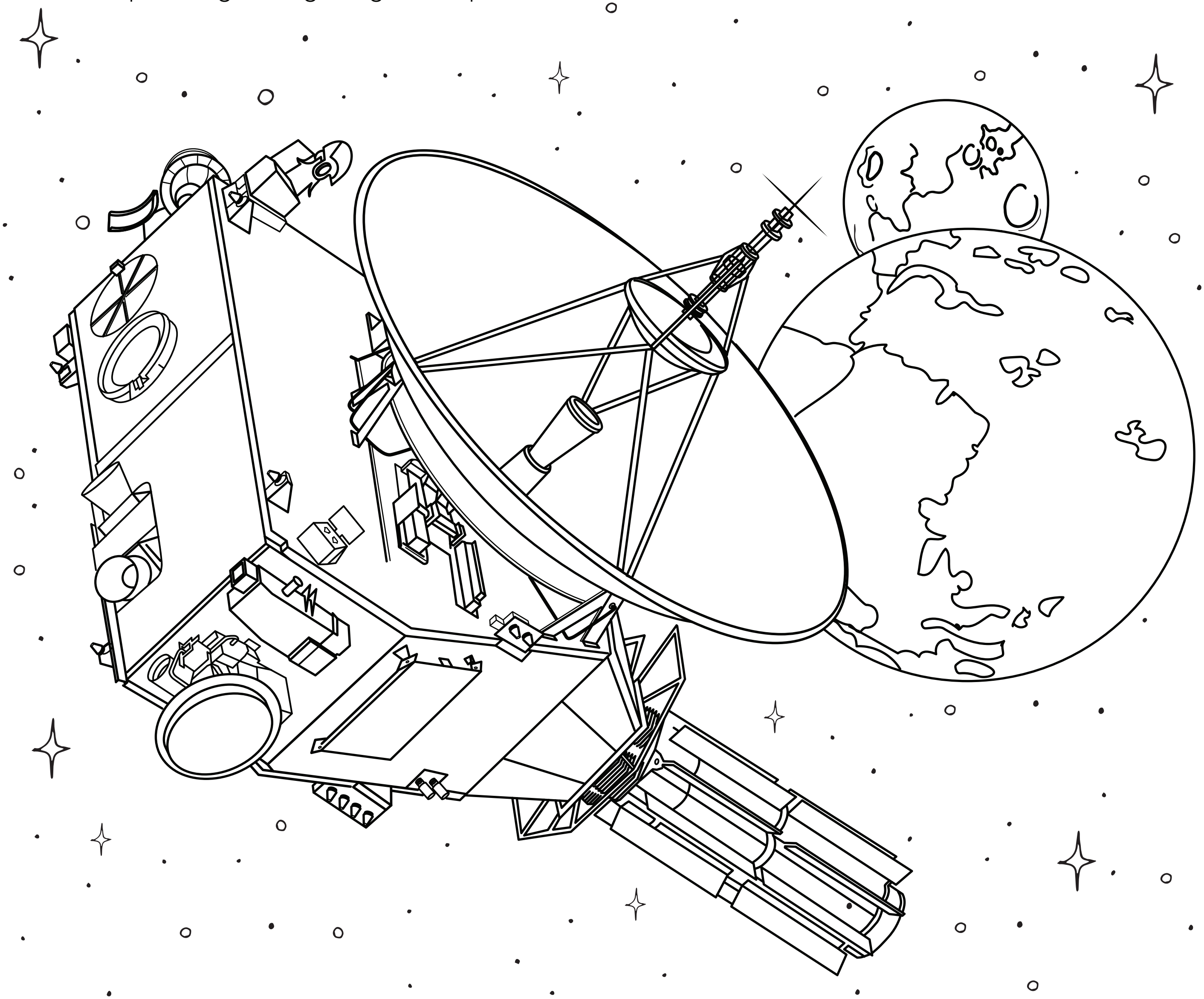
Cassini

After successfully completing the first in-depth, up-close study of Saturn and its realm from orbit, Cassini embarked upon two extended missions to follow up on the many discoveries made during its primary 4-year mission. Among the most surprising discoveries were geysers erupting on Enceladus and the dynamic effects of it and other moons on Saturn's rings. Cassini also mapped Saturn's largest moon, Titan, using radar to peer beneath its dense, hazy atmosphere.



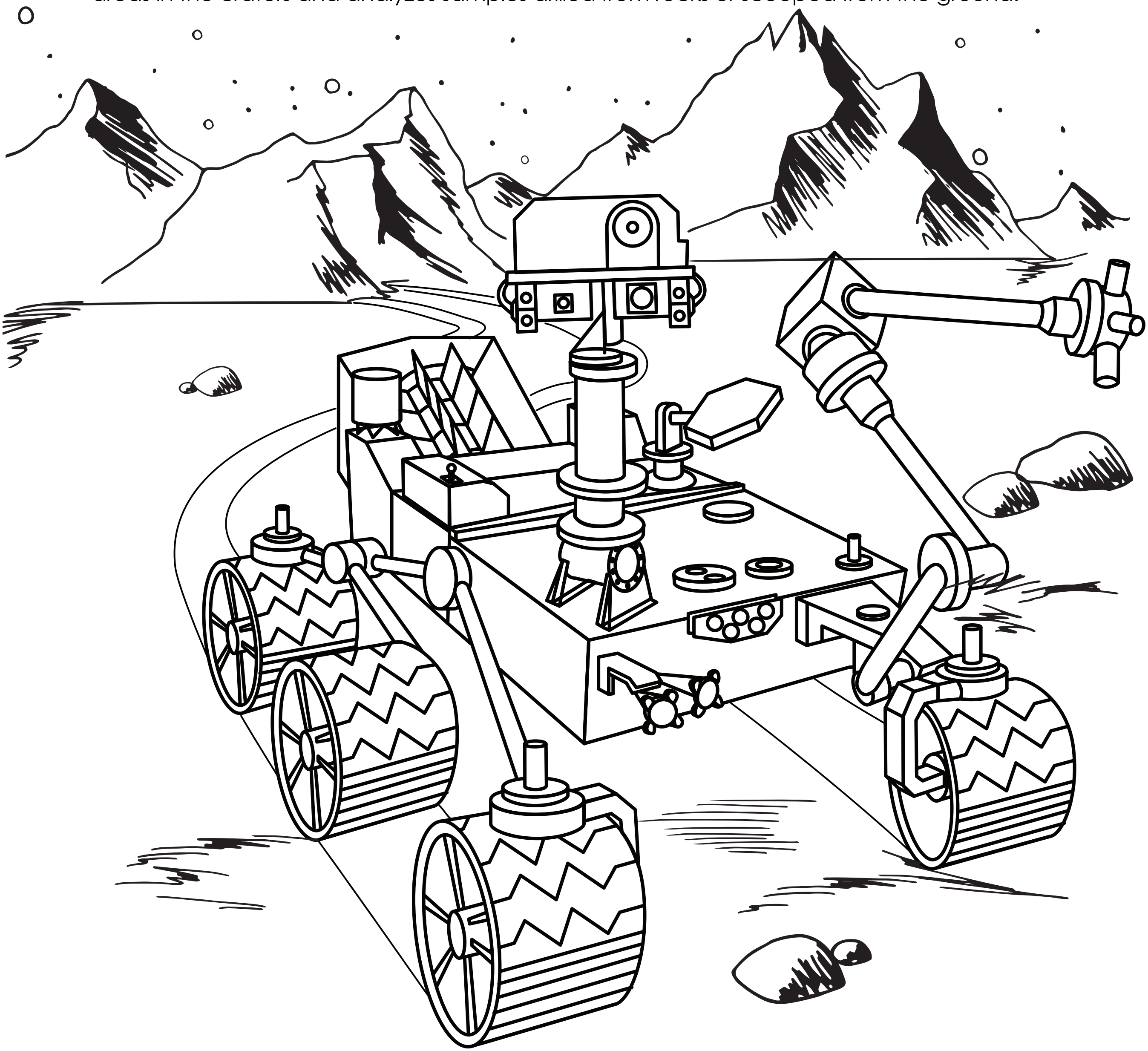
New Horizons

New Horizons made the first close-up observations of Pluto and its giant moon Charon and other smaller moons of the Pluto system. On the way to Pluto, New Horizons completed a study of the Jupiter system taking pictures of the planet and its moons and detected clumps in Jupiter's rings and lightning near its poles.



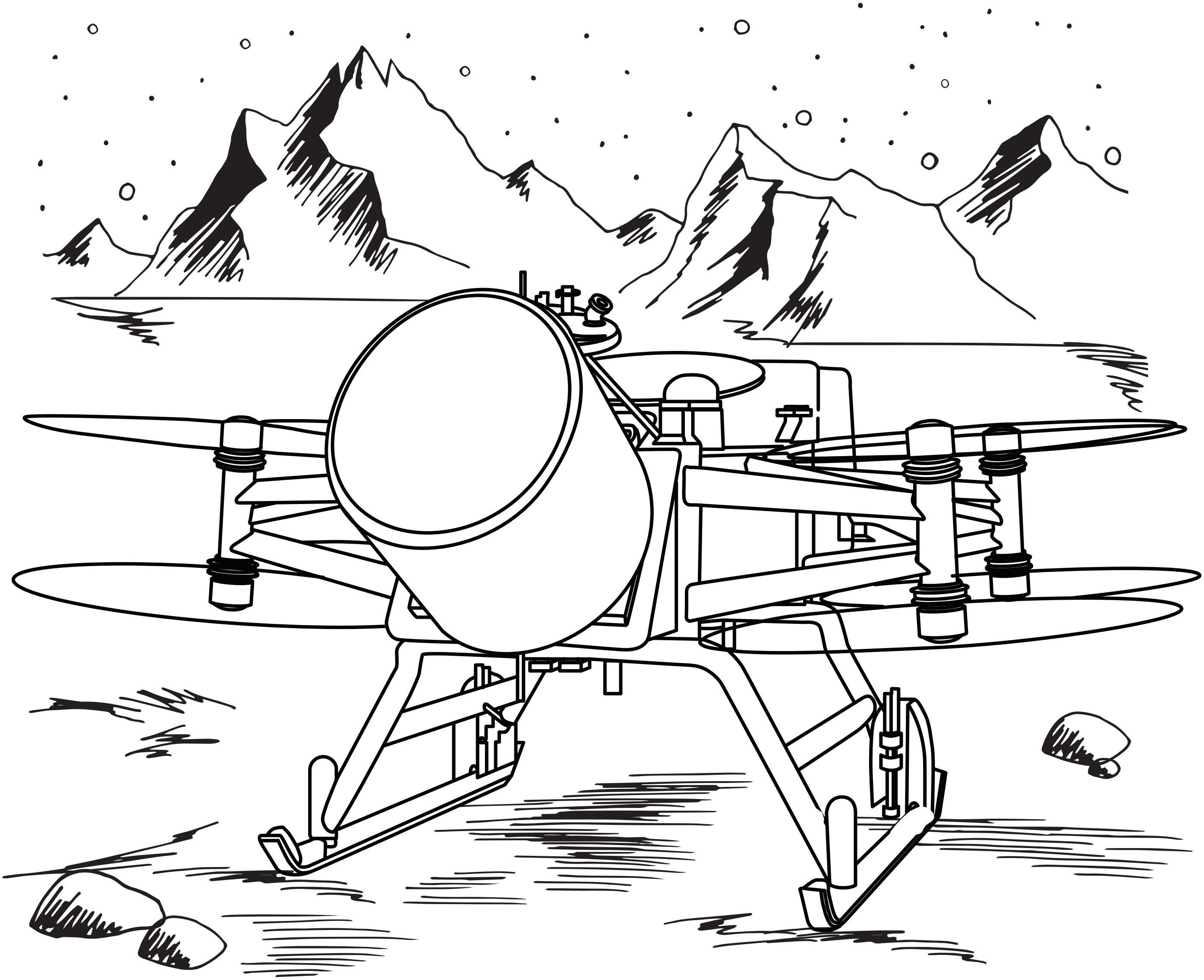
Curiosity

Curiosity met its major objective of finding evidence of a past environment well suited to supporting microbial life on Mars. The rover studies the geology and environment of selected areas in the craters and analyzes samples drilled from rocks or scooped from the ground.



Dragonfly

NASA's next destination in the solar system is the unique, richly organic world Titan. Advancing the search for the building blocks of life, the Dragonfly mission will fly multiple ventures to sample and examine sites around Saturn's icy moon. Dragonfly will use a large lithium-ion battery as its power source, which is designed to be recharged by a multi-mission radioisotope thermoelectric generator (MMRTG) between flights.



Power to Explore—Puzzle Fun

Solve the anagrams. Use the circled letters from the words and unscramble them to complete the answer to the puzzle. Each circled letter is used only once.

SCISINA	◯ _ _ _ ◯ _ _
YRAEVGO	_ _ _ _ _ _ ◯
EIPNORE	◯ _ _ _ _ ◯ _
OPAOLL	_ _ _ _ _ _
LELOGIA	_ ◯ _ _ _ _ _
SYESSLU	_ _ _ ◯ _ _ _
COISUYRIT	◯ _ ◯ _ ◯ _ _ ◯ _
AFYOLRGDN	_ _ ◯ _ _ _ ◯ _ _
GVKNII	_ _ _ _ _ _
RNEOWSZOINH	_ _ _ _ ◯ _ _ _ _ _ _
AEERVEPERSCN	_ _ _ _ _ _ _ _ _ _ ◯ _

Radioisotope thermoelectric generators produce the power to enable *these* to explore our solar system and beyond.

_ _ B _ _ _ _   _ _ _ _ _ _ _ _ _ T

Find the words in the puzzle. Words can go in any direction and can share letters as they cross over each other.

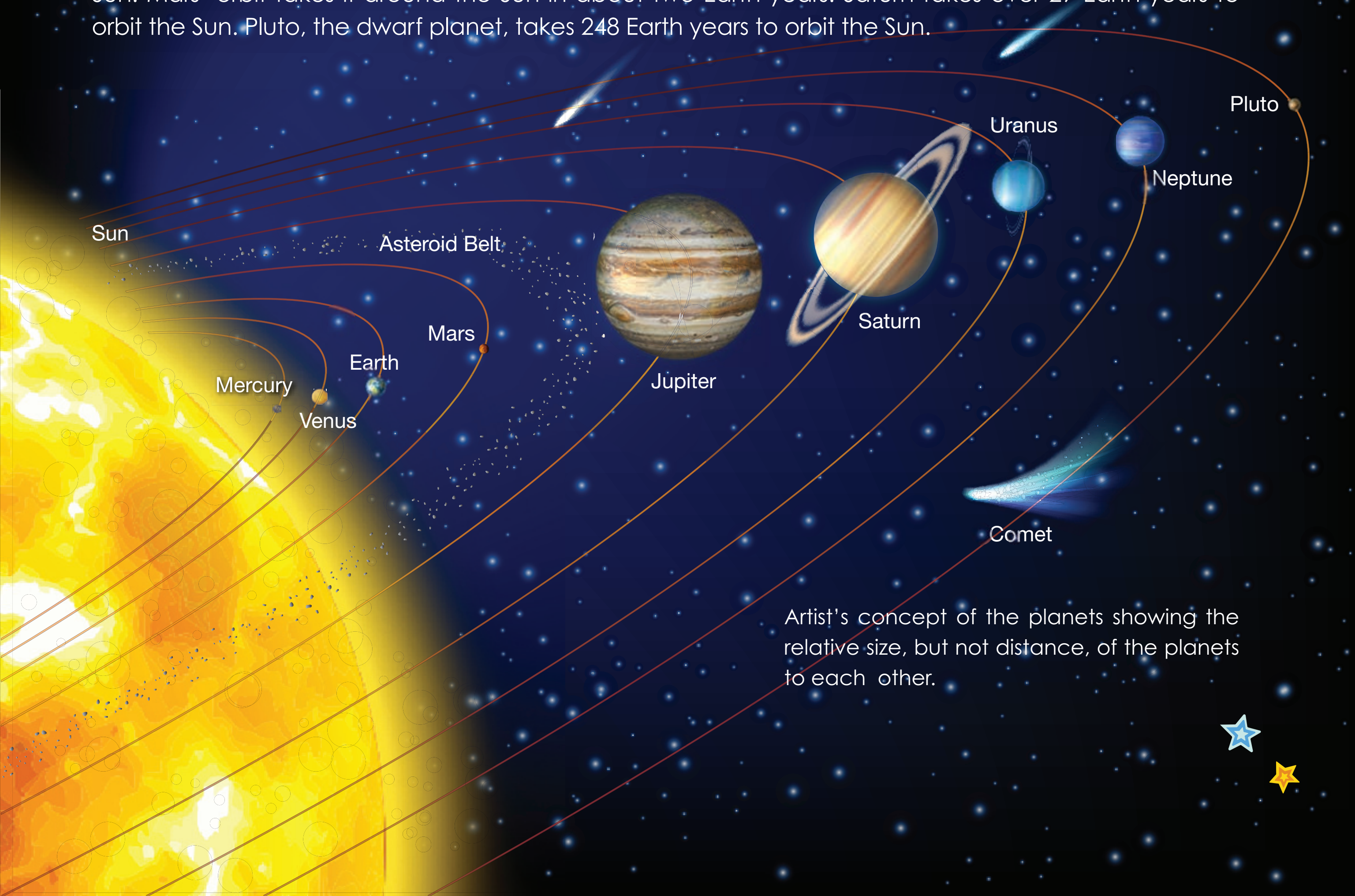
APOLLO	NEW HORIZONS
BATTERY	PERSEVERANCE
CASSINI	PIONEER
CURIOSITY	PLUTO
DRAGONFLY	SATURN
EARTH	SOLAR SYSTEM
GALILEO	SPACECRAFT
HEAT	STARS
JUPITER	SUN
MARS	ULYSSES
MERCURY	URANUS
MISSION	VENUS
MOON	VIKING
NEPTUNE	VOYAGER

S	S	N	O	I	S	S	I	M	S	M	O	I	N	S	V
P	O	P	L	H	S	V	D	S	Z	C	C	F	S	H	M
J	J	E	E	S	I	A	U	S	Q	A	S	D	N	O	R
U	C	A	L	K	L	N	T	Q	H	S	E	B	O	S	E
T	T	E	I	I	E	Q	R	U	C	S	S	N	Z	T	T
F	U	N	F	V	L	T	A	U	R	I	S	P	I	A	I
A	G	R	P	L	J	A	R	P	F	N	Y	L	R	R	P
R	E	Q	A	I	H	I	G	S	O	I	L	U	O	S	U
C	Y	L	F	N	O	G	A	R	D	L	U	T	H	S	J
E	U	S	D	S	U	N	K	C	E	F	L	O	W	U	T
C	L	B	I	J	K	S	E	S	R	A	M	O	E	N	C
A	X	T	I	P	E	R	S	E	V	E	R	A	N	C	E
P	Y	R	E	G	A	Y	O	V	R	J	V	T	Y	U	I
S	S	O	L	A	R	S	Y	S	T	E	M	U	H	I	C
M	S	N	E	P	T	U	N	E	Y	R	U	C	R	E	M
S	M	S	J	B	B	A	T	T	E	R	Y	D	W	Y	Q

The Planets and Their Orbits

All the planets orbit around the Sun in the same counterclockwise direction. The period of revolution is how long it takes a planet to make one trip around the Sun. The planets also rotate, or turn on their axes, as they travel around the Sun. Earth rotates on its axis once every 24 hours, or one Earth day. The rotation of three planets is "retrograde" (opposite the planet's orbit). The period of rotation is the time it takes a planet to turn completely around once.

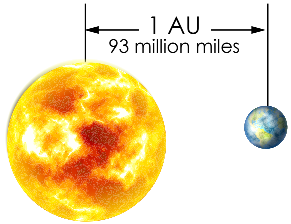
In space, the planets' positions are constantly changing as they revolve around the Sun. They do not actually align, as shown below, because each planet orbits the Sun at different speeds. It takes Mercury only 88 Earth days to orbit the Sun. It takes the Earth 365 days, or one Earth year, to orbit the Sun. Mars' orbit takes it around the Sun in about two Earth years. Saturn takes over 29 Earth years to orbit the Sun. Pluto, the dwarf planet, takes 248 Earth years to orbit the Sun.



Artist's concept of the planets showing the relative size, but not distance, of the planets to each other.

The Solar System Scaled

The solar system is so big that it is measured in special units, called astronomical units, or AU. One AU is the distance between the Sun and the Earth, which is about 93 million miles. With 1 foot representing 1 AU, in about 40 feet you can create a solar system that is about one trillion times smaller than the actual solar system. Scaled distances are approximate.

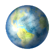


Sun
Actual Size: 864,000 mi (1,391,000 km) in diameter

Mercury
Actual Size: 3,000 mi (4,900 km) diameter
Average distance from Sun: 0.4 AU
Scaled distance from Sun: 5 in. = 36 million miles away

Venus
Actual Size: 7,500 mi (12,100 km) diameter
Average distance from Sun: 0.7 AU
Scaled distance from Sun: 9 in. = 67 million miles away

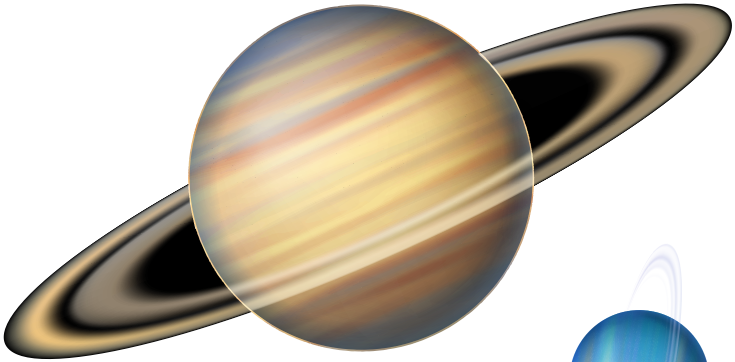
Earth
Actual Size: 7,900 mi (12,800 km) diameter
Average distance from Sun: 1.0 AU
Scaled distance from Sun: 12 in. = 93 million miles away



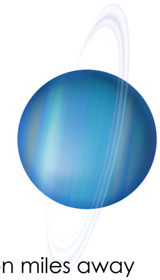
Mars
Actual Size: 4,200 mi (6,800 km) diameter
Average distance from Sun: 1.5 AU
Scaled distance from Sun: 18 in. = 142 million miles away

Jupiter
Actual Size: 88,800 mi (143,000 km) diameter
Average distance from Sun: 5.2 AU
Scaled distance from Sun: 60 in. = 484 million miles away

Saturn
Actual Size: 75,000 mi (120,500 km) diameter
Average distance from Sun: 9.5 AU
Scaled distance from Sun: 10 ft = 890 million miles away



Uranus
Actual Size: 31,800 mi (51,100 km) diameter
Average distance from Sun: 19.0 AU
Scaled distance from Sun: 20 ft = 1,785 million miles away



Neptune
Actual Size: 30,800 mi (49,500 km) diameter
Average distance from Sun: 30.0 AU
Scaled distance from Sun: 30 ft = 2,793 million miles away

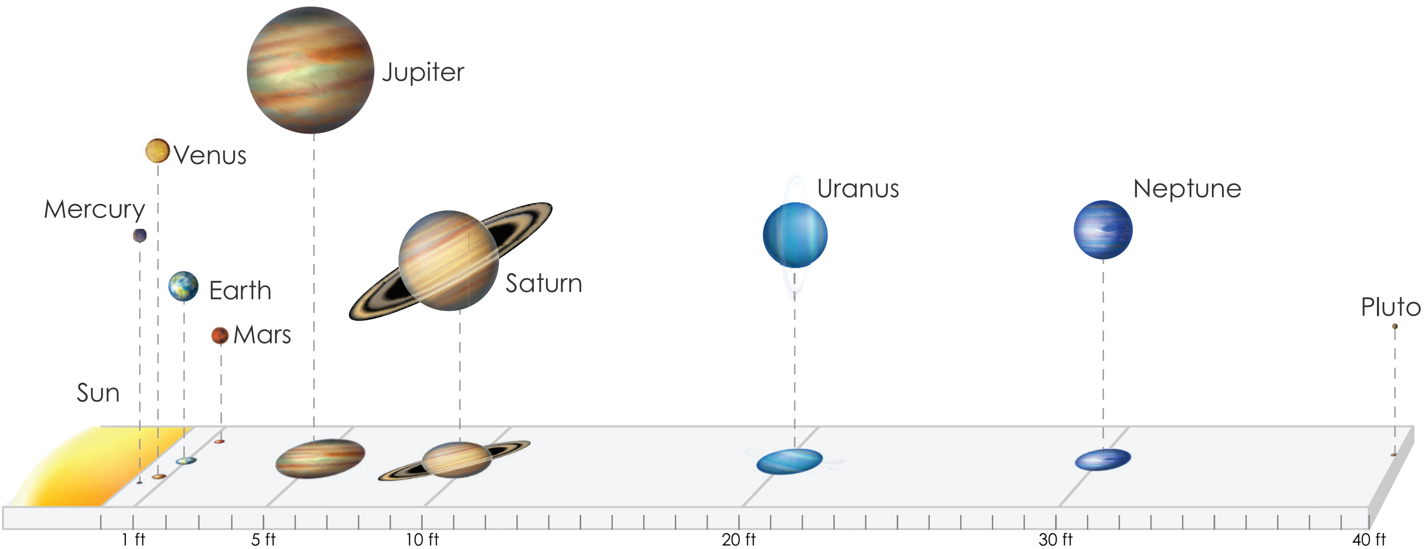
Pluto (dwarf planet)
Actual Size: 1,477 mi (2,370 km) diameter
Average distance from Sun: 40.0 AU
Scaled distance from Sun: 40 ft = 3,670 million miles away

Note: Scaled sizes and distances are approximate.

Making Your Scaled Solar System—The Chalk Walk

The materials needed are sidewalk chalk, a tape measure or smartphone measuring app, and about 40 feet of sidewalk. Using the scale 1 foot = 1 AU, from the previous page, start by drawing the Sun in yellow chalk. Then, using your tape measure or smartphone measuring app, draw Mercury approximately 5 inches away from the Sun, Venus 9 inches away, and Earth 12 inches (1 foot) away. Use the same scale to measure and draw the remaining planets all the way out to Pluto, the dwarf planet, being 40 feet away from the Sun at the end of your solar system.

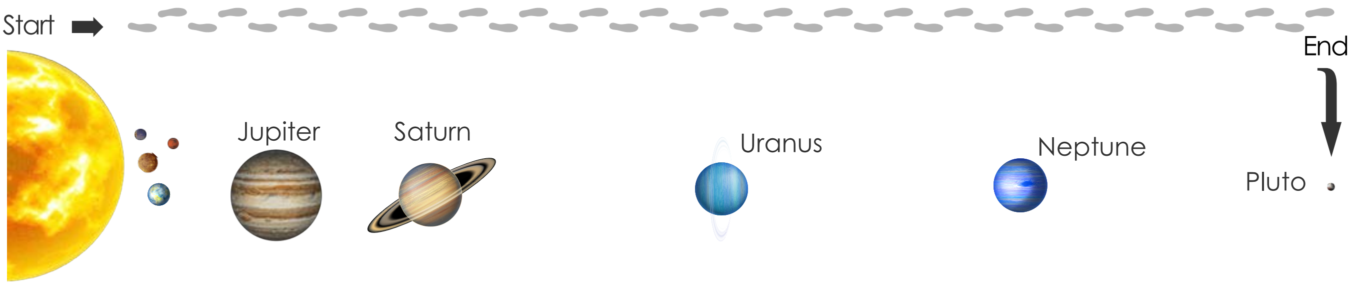
You can draw all your planets along a single straight line from the Sun. If you have enough space, consider drawing them at their correct distance in different spots around the Sun to represent their orbits.



The Solar System Step

Another creative way to measure your solar system distance is by counting steps. Start by tracing out the Sun in yellow chalk. Walk 40 steps, to the end of your solar system, and draw Pluto.

Walk back ten steps and draw Neptune. Walk back ten more steps and draw Uranus, and back ten more steps towards the Sun and draw Saturn. Use the distances on the previous page to complete your solar system, where 1 step is equal to 1 AU.



Be sure to write the names of the planets and the actual distances they are from the Sun. This is a great way to visualize the scale of the solar system and get a feel for where the planets are.

Also, be sure to draw the relative sizes of the planets, as close as possible, for a more accurate sidewalk chalk model. For example, Jupiter should be a lot bigger than Mercury and Venus.

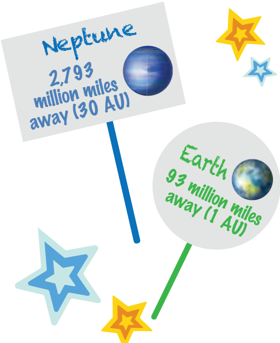
Make it a fun learning experience.

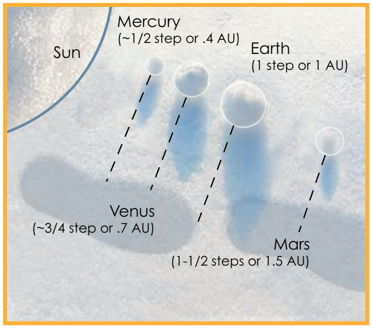
The "Snowlar System"

If it is snowy where you live, you can build a "snowlar system"—a solar system made of snow. If you have access to a sidewalk, you can line up all the planets along the edge. If you are on a playground or have a larger space, you can spread out your solar system and space the planets on their orbits at the right distance from the Sun. Use the scale of 1 step is equal to 1 AU.

Start by making a giant snowball or mound of snow to represent the Sun. Take one step away from the Sun to start your measurements. Make a very small snowball representing Mercury and place it about 1/2 step away from the Sun. Make a snowball about twice the size as Mercury representing Venus and place it about 3/4 step away from your Sun. Make another snowball for the Earth, a bit larger than the Venus snowball, and place your Earth snowball about 1 step, or 1 AU from the Sun. Make a smaller snowball to represent Mars, which is about half the size of Earth. Take another step from the Sun and place Mars approximately 1-1/2 steps away from the Sun. Take 5 steps from the Sun and make a very large snowball for Jupiter. You can make several tiny snowballs and place them between Jupiter and Mars to represent the asteroid belt. Take 5 steps from Jupiter and make a large, but smaller than Jupiter, snowball for Saturn. You can make rings out of snow or draw lines in the snow to represent the rings around Saturn. Take 10 steps from Saturn and make a big snowball for Uranus, then take 10 more steps and make another big snowball for Neptune. If you have the space and want to include the dwarf planet Pluto in your snowlar system, take another 10 steps and make a tiny snowball for Pluto.

Have fun and think of creative ways to write the names of the planets and their actual distances from the Sun in your snowlar system.





Other Fun Ideas

After you create your solar system, you can add any spacecraft you just learned about, which use RTGs as their power system. You can print and color the images in this guide or draw your own versions of them. You can attach them to craft sticks and put them in the ground on or near the planets they study.

You can make this a seasonal activity. In the fall, you can make planet pumpkins of various sizes, and place them at their planetary distances.

In the spring, you could use plastic eggs or color eggs to look like the planets, and hide them (or put them in plain sight) at relative distances from a central location like a house, church, or schoolyard. Post a scale (1 step = 1 AU, for example) for your solar system to provide a clue as to how far away to look for the eggs. Be creative and have fun learning about the solar system.

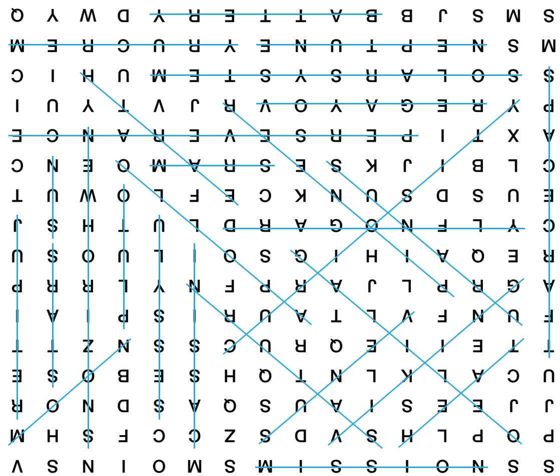
To find out where planets are currently located,
visit https://solarsystem.nasa.gov and click on the orbiting planets at the top of the page.

Power to Explore—Puzzle Fun Answers

CASSINI
CURIOSITY
VOYAGER
DRAGONFLY
PIONEER
VIKING
APOLLO
NEW HORIZONS
GALILEO
PERSEVERANCE
ULYSSES

Radioisotope thermoelectric generators produce the power to enable these to explore our solar system and beyond.

ROBOTIC SPACECRAFT



SHARE YOUR SOLAR SYSTEM!

You have created a replica of our solar system showing the relative distances between the planets.

Share your solar system model with NASA! Snap a picture or video of your solar system and post it on Facebook, Twitter, and Instagram using the hashtag #NASASolarSystem. Be sure to get your parents' or guardians' permission before sharing your snaps online—or ask if they can post it for you.

NASA NASA @NASA #NASA

RADIOISOTOPE
POWER SYSTEMS PROGRAM

For more information on how NASA uses radioisotope power to explore the solar system, visit https://rps.nasa.gov.