Science @Home

ROCKETS & ROVERS

Houston, we have an activity pack! Aspiring rocket scientists ages 8–11 are invited to blast off to other worlds for crafts, activities, and more.

Space is surprisingly close at just 62 miles above Earth's surface—but heading into the wild interstellar yonder requires very special equipment. Spend four days exploring the spacecraft that cruise our Solar System through guided videos, hands-on crafts, and indoor/outdoor activities.

Please note: While Science @ Home activities are designed to be conducted by kids, some little ones might need adult help with reading instructions and preparing crafts.

Day 1: Exploring the Solar System
45–60 minutes

» Solar System Scale (craft)
» Another view (activity)
» Rockets and Rovers word search (activity)

Day 2: Blast off! *45–60 minutes*

» Anatomy of a Rocket (coloring) (en español)
» Strawkets (activity) (en español)
» Hand Helicopter (activity)

Day 3: Rovers, landers and more
45–60 minutes

» Rover missions: Mars and the Moon (video)
» Anatomy of a Rover (coloring) (en español)
» Many Ways to Move (video)

Day 4: Ready for launch
60–90 minutes

» Make a Mission (activity)
» Solar System Mission Mysteries Posters (activity)
» Mission Control: Mars Rover (activity)

Kid and caregiver extension activities

» Current and upcoming missions 2021 (resource)
» Livestream planetarium shows (videos/resource)
» Curiosity Rover—Interview with Dr. Jennifer Blank (video)

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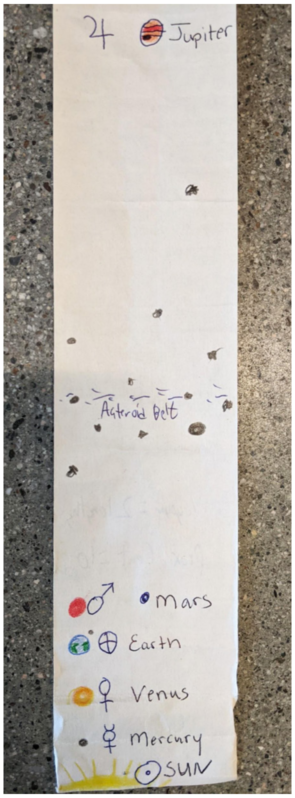


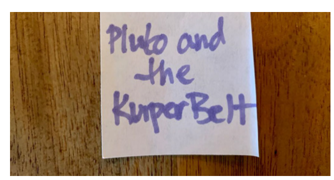
Solar System Scale

The Solar System is big. It took the *Voyager 2* spacecraft *12 years* to travel almost 3 billion miles to Neptune—even at an average cruising speed of 42,000 miles per hour! Create a scale model of our Solar System to get an idea of just how mind-bogglingly far the distances between planets really are.

Materials

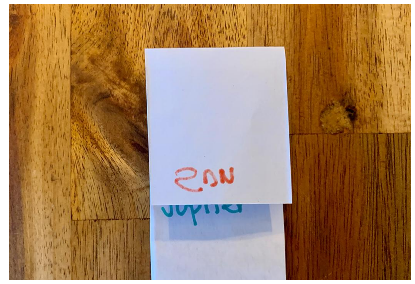
A long strip of paper, at least 3 feet long (like register or receipt paper)
Alternative: 3 feet of string or rope and masking tape
Pencil or pen
Scissors

Directions

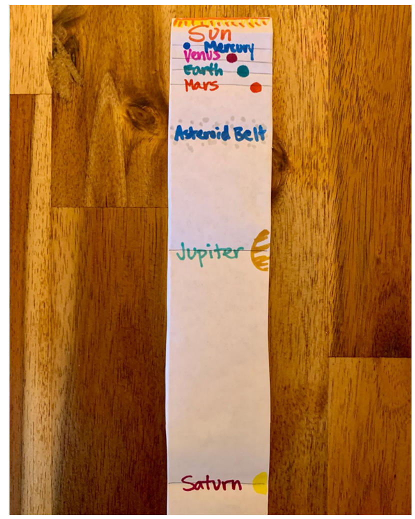


1. **Cut** the ends of the paper to make straight edges.
2. **Label** one end of the paper "Sun" and the other end "Pluto and the Kuiper Belt."
3. **Fold** the paper in half, crease it, open it up again and **mark** at the halfway point with your pencil. **Label** the mark "Uranus."
4. **Fold** the paper back in half, then in half again. **Unfold** and lay it flat.
    a. **Mark** the fold between Pluto and Uranus with your pencil and **label** it "Neptune."
    b. **Mark** the fold in between the Sun and Uranus and **label** it "Saturn."

5. **Fold** the Sun end of the paper up to meet the Saturn mark and flatten to crease it. **Unfold** and lay flat again. **Mark** at the fold between the Sun and Saturn and **label** it "Jupiter."



6. **Fold** the Sun end of the paper up to meet the Jupiter mark. **Mark** at the fold between the Sun and Jupiter and **label** it "Asteroid Belt."



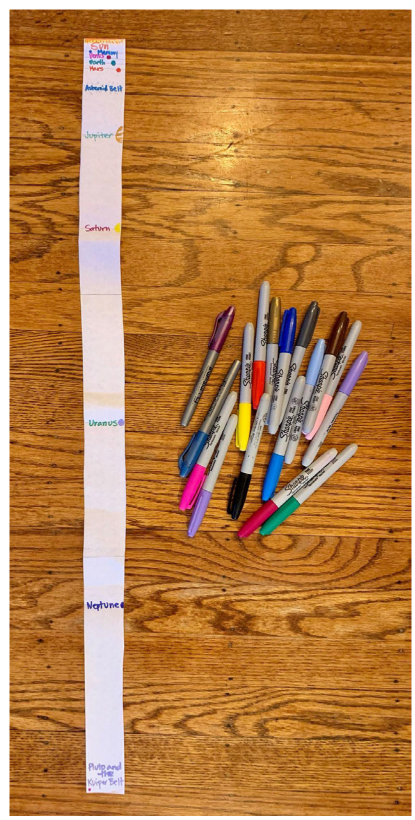
7. **Fold** the Sun end of the paper up to meet the Asteroid Belt mark and crease it. **Mark** the fold between the Sun and the Asteroid Belt and **label** it "Mars."

8. From here, folding to get precise distances may be challenging and planets are closer together. **Fold** the Sun end of the paper up to meet the Mars mark. *Leave it folded* and **fold** that section in half again. **Unfold** the tape, leaving three creases:

   a. **Mark** the crease nearest Mars and **label** it "Earth"

   b. **Mark** the crease in the middle and **label** it "Venus"

   c. **Mark** the crease closest to the Sun and **label** it "Mercury."



9. **Smooth** out your scale model and admire your work. If you want to, **decorate** your scale by drawing the planets next to their labels.

10. **Alternative method:** If you cannot find a piece of paper at least three feet long, you can also do this activity with a rope or string of the same length. Instead of marking distances with a pencil, see if a marker will be visible on your string or stick a thin piece of masking tape on the string and label it. Then follow steps 2–8.

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Thought experiments

1. The farthest humans have gone into the Solar System is to Earth's Moon. Find Earth on your model: The distance between the Earth and the Moon on your model is about the same width of the pen or pencil mark you used to indicate Earth's position. For a more precise way to show how small a distance it would be from Earth to the Moon, you would have to divide the distance from Earth to the Sun into almost 400 pieces!

2. Unmanned spacecraft take about four months to travel from Earth to Mars, while a hypothetical manned spacecraft would take at least six. (Spacecraft with humans on board travel a little slower for the astronauts' protection.) On your paper scale, locate the distance between Earth and Mars. If it takes humans six months just to travel from Earth to Mars, imagine how long it would take to reach Saturn, or even Neptune!

3. One big difference between your paper scale model and the Solar System itself is that the planets are never in a perfectly straight line like they appear here; each planet travels around the Sun at its own speed. From time to time, a few planets might appear to be in a straight line with respect to Earth or the Sun, but since the planets go at different speeds and often travel above or below the plane of the solar system, they will never line up perfectly "straight." Your paper scale model shows an approximation of their average distance from the Sun: Some planets travel a little closer or a little farther at different points in their orbit.

Another View

Why send rovers all the way to other planets or moons when we have telescopes that can see them from a distance? While telescopes teach us a lot, we can learn more about something by changing our perspective. In this activity, imagine that an alien world is right outside your door. If you were an astronomer, how would you observe it, and what tools would you use?

Materials

Pen or pencil
Paper
Binoculars or camera with a zoom feature (optional)
Electronic device with internet connection (optional)

Directions

Observe the “alien world” outside your door from different points of view as if you were an astronomer using different tools. The windows of your home are “telescopes,” and your body will become a “rover” once you head outside. Let’s start exploring!

1. View #1: Observe through a “telescope”

    a. **Find** two windows in your home that look outside at roughly the same area. *(If you do not have two windows looking outside at the same location, divide one window into two sections (top and bottom or left and right) to serve as your two windows*.

    b. **Observe** through one window for 5 minutes (try setting a timer) and **record** your observations by writing or drawing what you notice. Think about:

        i. Where do you see things?

        ii. Do things change quickly in your view, like a busy street? Or do they change slowly, like a backyard full of plants?

        iii. Are there any animals or plants? How many and what types?

        iv. What about nonliving things, likecars, rocks, or buildings?

        v. What small details do you notice?

   c. **Choose** one object you want to study closer. It could be a tree, a branch, a bush, or a crack in the sidewalk. **Observe** it for 5 more minutes and **record** what you notice or wonder about the object.

2. View #2: Observe from a different angle

   a. **Go to** the second window that also looks outside and **observe** the outdoors for another 5 minutes.

   b. **Record** your new observations on a new sheet of paper by drawing or writing what you notice. Think about:

      i. Does it look exactly the same as the first view?

      ii. Are there small or large differences in what you see?

      iii. Even if you see the same objects, can you see anything different or more clearly now?

      iv. Can you see anything that was blocked in the first view?

      v. What can't you see from this view?

   c. **Find** the object you choose to look closer at in your first view. **Observe** it for 5 more minutes and **record** any new things you notice or wonder about it.

   d. *Optional:* **Look** through binoculars or a camera with a zoom. Does it help you see things a little better? What new details can you see?

3. Reflecting on views 1 and 2

   a. **Think** about what you could and could not see from the two different windows.

      i. Were there things that blocked your view? **Record** how much of your view was blocked.

      ii. Were there new things you saw when you changed your view?

      iii. What might you be able to see or learn if you were able to be closer or look from a different angle?

4. View #3: Observe like a "rover"

    a. **Think**: How might your observations change if you were actually outside, not just looking through the window?

    b. **With an adult's permission**, go outside to the location you observed earlier. **Walk around** and **observe** for 5 minutes.

    c. **Record** your observations of your world by drawing or writing what you notice. Think about:

        i. Do you see the same animals? Plants? Nonliving things?

        ii. How about the areas you couldn't see before? Can you see them now? Are there places that you can't see now? Look back at your notes to remind yourself what you could and could not see.

    d. **Find** the object you choose to look closer at. **Observe** it for 5 more minutes and **record** any new observations or questions about the object.

        i. What small things or details do you notice that you couldn't see before?

    e. **Think**:

        i. What did you learn by changing the way you looked at the area?

        ii. What questions do you still have, and is there a way you could change your way of observing to answer them?

5. *Optional:* Observe like an "orbiter" or "satellite"

    a. **With an adult's permission** to go online, **find** your home using Google Earth or Google Maps in "satellite view."

    b. **Find** the places you observed in steps 1,2, and 4. Do you see the same things in this bird's-eye view? What is different?

    c. **Record** your observations by drawing or writing what you notice.

    d. **Look** for shadows on the Google Earth or Maps view. What do they tell you about when the picture was taken? (Hint: Note the length and direction of the shadows).

6. **Compare** the observations you've made from each of the different viewpoints (first window, second window, outside, and optional satellite view). How are they different?

Learn More:

Astronomers have learned an incredible amount about our Solar System from being able to view it up close. Until the 1970s, we could only see the outer planets like Uranus and Neptune from telescopes on or near Earth. But when the Voyager missions flew past them and sent close-up photographs back to Earth, incredible new details about these planets were revealed to us, including several new moons! Even nearby, our knowledge of our own Moon fundamentally changed when the Apollo missions landed people on its surface. Expecting to encounter steep, sharp mountains, astronauts instead found smoother, gently rolling terrain covered in a fine dust called *regolith*. Each new orbiter, lander, rover, manned mission, or simple fly-by takes us further in our quest to understand our Solar System—and beyond.

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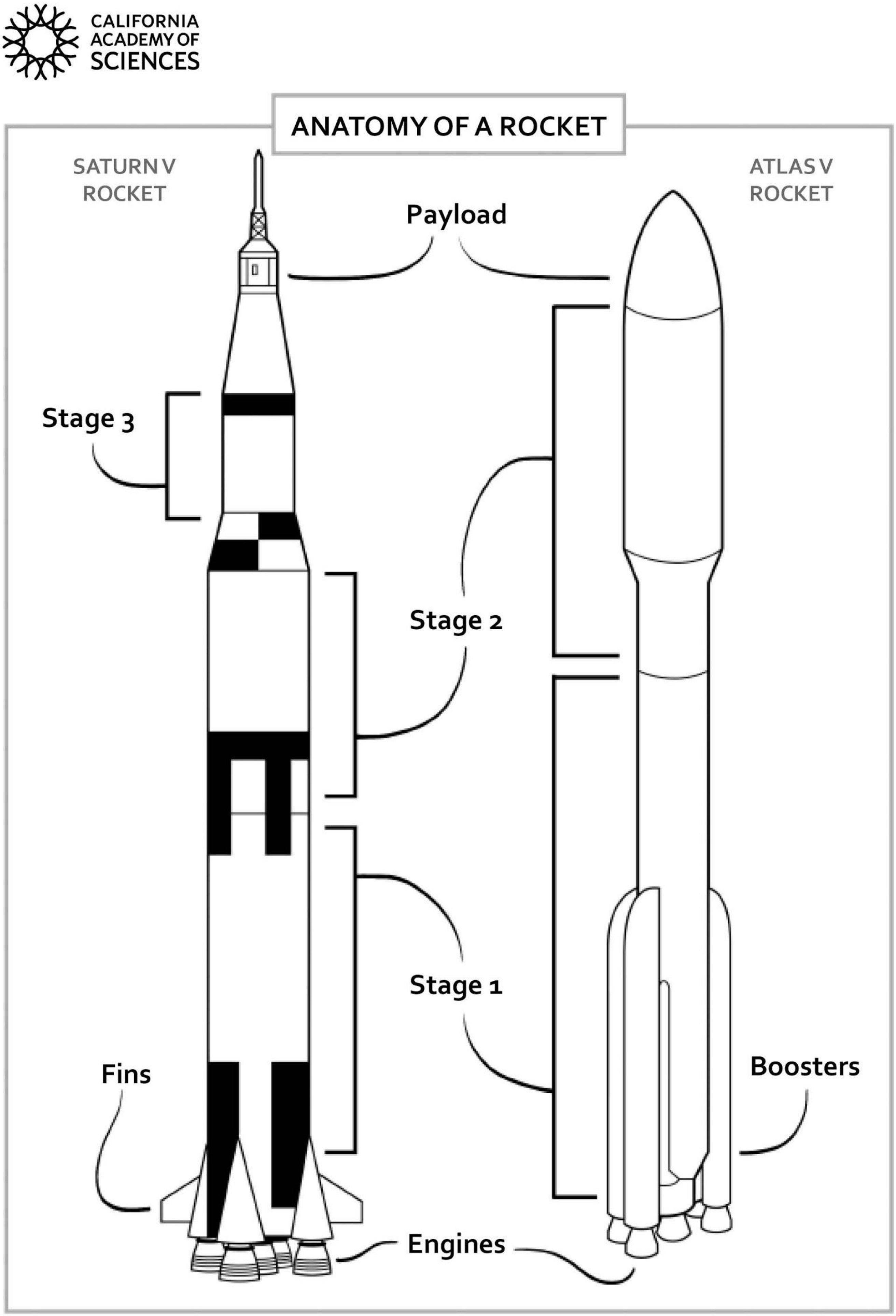
Rockets & Rovers Word Search

Need a break from searching the skies? Try searching for words instead! Looking forward, backward, down, up, and diagonally, can you find all 16 hidden astronomy terms below?

ANTENNA	ATMOSPHERE	BLAST OFF	EXPLORE
LANDING	LAUNCH PAD	MARS	MISSION
MOON	ORBIT	POWER SUPPLY	PROPULSION
ROCKET	ROVER	SOLAR SYSTEM	SURFACE

D	A	N	L	O	E	Q	T	S	W	C	D	U	F	E
V	P	T	K	Z	A	R	B	I	F	M	A	M	C	I
E	Q	B	M	O	O	N	O	B	B	Q	Q	A	Q	U
Z	T	B	R	O	G	H	O	L	L	R	F	L	L	S
A	U	X	E	R	S	X	A	A	P	R	O	Y	A	U
M	R	E	V	Q	E	P	U	Z	U	X	A	L	U	R
I	T	L	O	Y	B	N	H	S	C	N	E	P	N	F
S	L	E	R	X	C	U	Y	E	T	A	Z	P	C	F
S	H	U	K	H	X	P	K	E	R	S	M	U	H	O
I	Y	M	F	C	G	T	N	R	R	E	K	S	P	T
O	S	Q	M	L	O	N	E	A	K	H	W	R	A	S
N	T	A	T	Y	A	R	M	I	G	T	G	E	D	A
N	O	I	S	L	U	P	O	R	P	V	Z	W	P	L
S	O	L	A	R	S	Y	S	T	E	M	D	O	N	B
I	G	N	I	D	N	A	L	Z	A	B	R	P	Y	E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ANATOMY OF A ROCKET
SATURN V ROCKET
ATLAS V ROCKET
Payload
Stage 3
Stage 2
Stage 1
Fins
Boosters
Engines

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What makes a rocket?

Rockets are vehicles designed to travel out of Earth’s atmosphere and into space. They can carry rovers, satellites, supplies, astronauts, and more.

Payload: This is the cargo that's being carried into space by the rocket. It can be a satellite, telescope, supplies, or even crew for the International Space Station.

Stage 1: This is the section at the bottom of the rocket stack containing the main engines that lift the rocket off the launch pad. It is usually not powerful enough to carry the payload all the way into orbit by itself, so at least one additional stage is needed later during the flight.

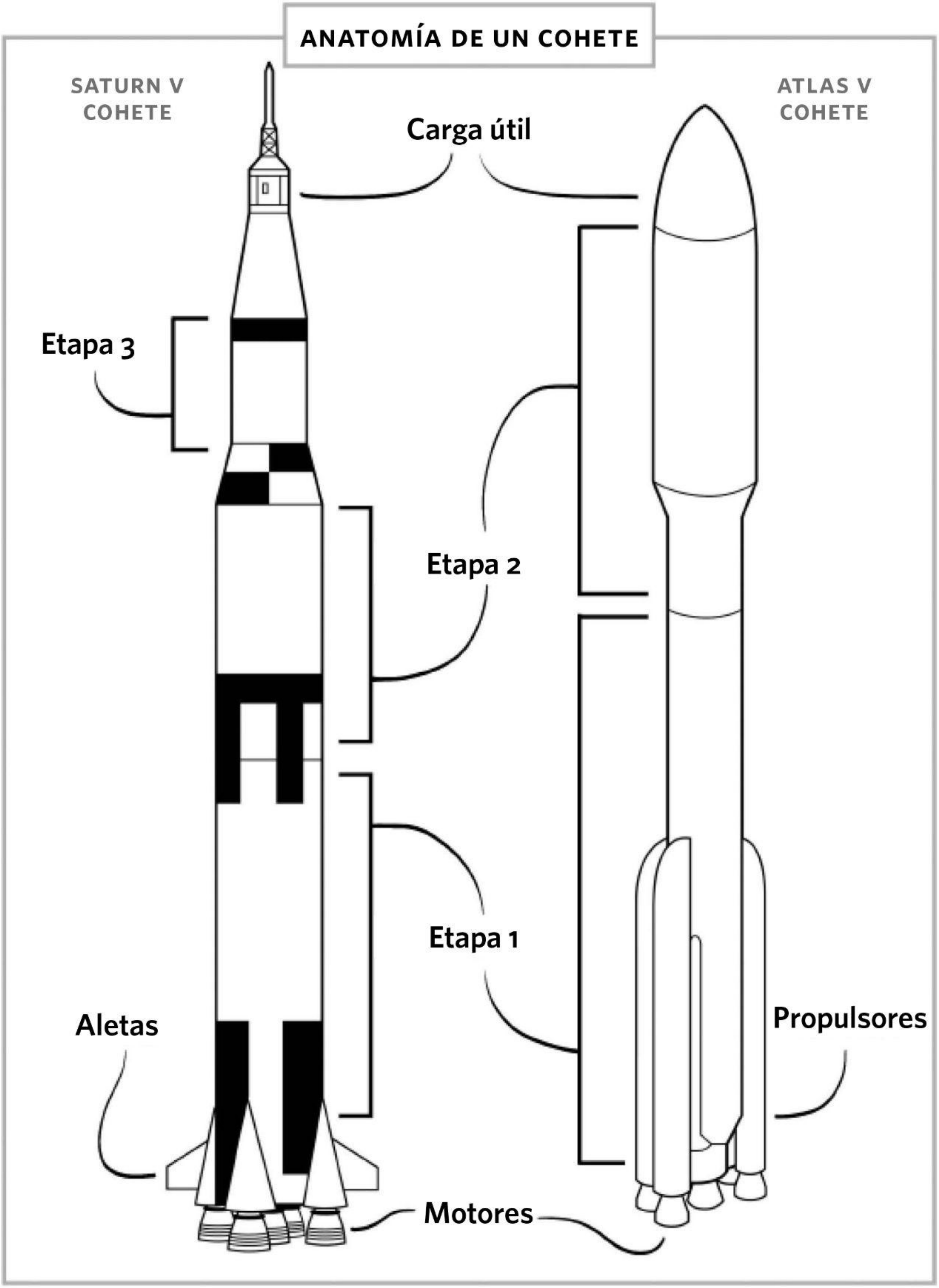
Stage 2: When the first stage has used up its fuel, the second stage sitting on top of it takes over. The rocket is now so high up that the thinner air offers less resistance, so second stage engines don't have to be as powerful as the first stage, but to make the job even easier, the empty first stage is discarded.

Stage 3: In the case of extremely massive payloads, yet another stage may be needed to get the payload into space. Usually, two or three stages get the job done—it's rare that rockets need more than three stages.

Boosters: Aside from the main engines of the first stage, some rockets use additional smaller rockets called boosters attached to the first stage to provide extra thrust to lift a payload into low Earth orbit. These are ejected after they run out of fuel.

Engines: These are at the bottom of each rocket stage and are where the fuel ignites to produce the explosive reaction that creates thrust and pushes the rocket in the opposite direction. Some engines fire only once and keep burning until their fuel is used up. Others can be throttled up and down to produce more or less thrust as needed, and can even be shut off and restarted later as needed for the mission.

Fins: Some rockets have fins for steering within Earth's atmosphere, but others don't because they can swivel their engines slightly to steer. In the particular case of the Saturn V moonrocket, the large, non-movable tail fins were meant to help the rocket stay on course in case of an in-flight emergency, which would give the crew extra time to engage the escape system. Fortunately, all the Saturn V crew launches were successful, so they never had to test the rocket in that imaginary situation.


ANATOMÍA DE UN COHETE
SATURN V
COHETE
ATLAS V
COHETE
Carga útil
Etapa 3
Etapa 2
Etapa 1
Aletas
Propulsores
Motores

¿Qué hace un cohete?

Los cohetes son vehículos diseñados para viajar fuera de la atmósfera terrestre y al espacio. Pueden transportar vehículos exploradores, satélites, suministros, astronautas y más.

Carga útil: Esta es la carga que el cohete transporta al espacio. Puede ser un satélite, telescopio, suministros o incluso tripulación para la Estación Espacial Internacional.

Etapa 1: Esta es la sección en la parte inferior de la pila de cohetes que contiene los motores principales que levantan el cohete de la plataforma de lanzamiento. Por lo general, no es lo suficientemente potente como para llevar la carga útil hasta la órbita por sí mismo, por lo que se necesita al menos una etapa adicional más adelante durante el vuelo.

Etapa 2: Cuando la primera etapa ha agotado su combustible, la segunda etapa sentada encima de ella toma el control. El cohete está ahora tan alto que el aire más delgado ofrece menos resistencia, por lo que los motores de segunda etapa no tienen que ser tan potentes como la primera etapa, sino para hacer el trabajo aún más fácil, se descarta la primera etapa vacía.

Etapa 3: En el caso de cargas útiles extremadamente masivas, se puede necesitar otra etapa para llevar la carga útil al espacio. Por lo general, dos o tres etapas hacen el trabajo, es raro que los cohetes necesiten más de tres etapas.

Propulsores: Aparte de los motores principales de la primera etapa, algunos cohetes utilizan cohetes más pequeños llamados propulsores conectados a la primera etapa para proporcionar empuje adicional para elevar una carga útil en órbita terrestre baja. Estos son expulsados después de que se quedan sin combustible.

Motores: Estos están en la parte inferior de cada etapa del cohete y son donde el combustible se enciende para producir la reacción explosiva que crea empuje y empuja el cohete en la dirección opuesta. Algunos motores disparan sólo una vez y siguen ardiendo hasta que su combustible se agote. Otros pueden ser estrangulados hacia arriba y hacia abajo para producir más o menos empuje según sea necesario, e incluso pueden ser apagados y reiniciados más tarde según sea necesario para la misión.

Aletas: Algunos cohetes tienen aletas para dirigir dentro de la atmósfera terrestre, pero otros no porque pueden girar ligeramente sus motores para dirigir. En el caso particular de moonrocket Saturn V, las grandes aletas traseras no móviles estaban destinadas a ayudar al cohete a mantenerse en curso en caso de una emergencia en vuelo, lo que daría a la tripulación tiempo adicional para activar el sistema de escape. Afortunadamente, todos los lanzamientos de la tripulación de Saturno V tuvieron éxito, por lo que nunca tuvieron que probar el cohete en esa situación imaginaria.

Strawkets

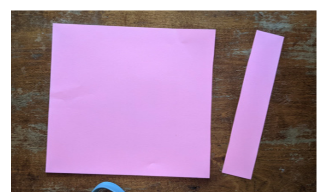
Rockets are powerful tools used to launch spacecraft, satellites, and even people into space. While your “strawket” may not make it into orbit, you’ll see the same high-powered principles in action in this activity.

Materials

Paper
Scissors
A straw
Tape
Chart (page 4)

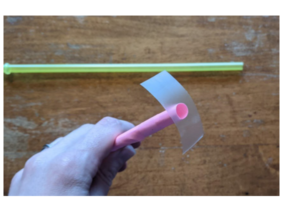
Directions

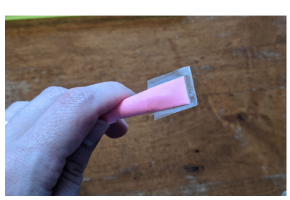
1. **Cut** a long strip off the top of a piece of paper. It should be about 1.5 inches tall, or about 3 centimeters.



2. **Wrap** your paper strip snugly around your straw. It should be tight but still able to slide. Tape the paper together so that it doesn’t unravel.

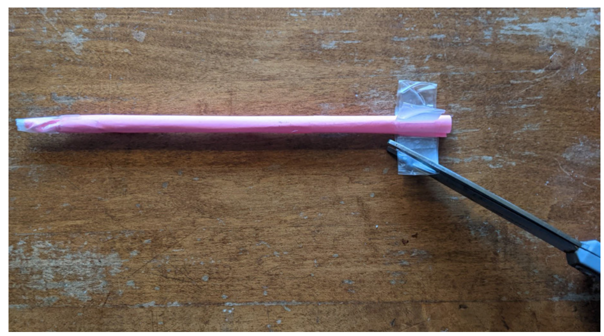
3. **Add** the nose cone. Your rocket must be sealed on the top: Tape over one end of the rolled paper to seal it, then twist the tip until pointed. Add more tape to keep it from untwisting.





4. **Add** fins by folding a piece of tape over itself as seen in the picture below. Then cut the tape into angled shapes, or experiment with your own fin designs. Try adding 1, 2, 3, or even more fins to your rocket.



5. **Launch** your rocket by sliding it onto your straw and blowing out hard. Watch it fly!
6. **Reflect** after launching your rocket a few times, thinking about what kind of changes you can make to it. Can you tweak your design to make your rocket fly farther or more accurately?
7. Optional: **Print** out the chart on page 4 and **record** how far your rocket launched as you make tweaks to your design.

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Rocket design number	How far did it go?	What did you change?	Extra notes

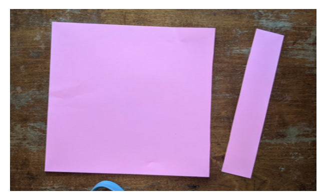
Pajilla-cohete

Cohetes son potentes herramientas utilizadas para lanzar naves espaciales, satélites e incluso personas al espacio. Si bien es posible que tu "pajilla-cohete" no entre en órbita, verás los mismos principios de alto poder en acción en esta actividad.

Materiales

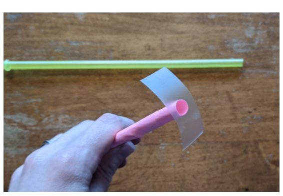
Papel
Tijeras
Cinta adhesiva
Gráfico (página 4)

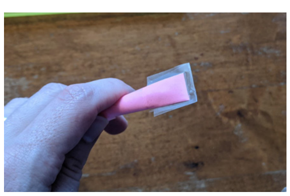
Instrucciones



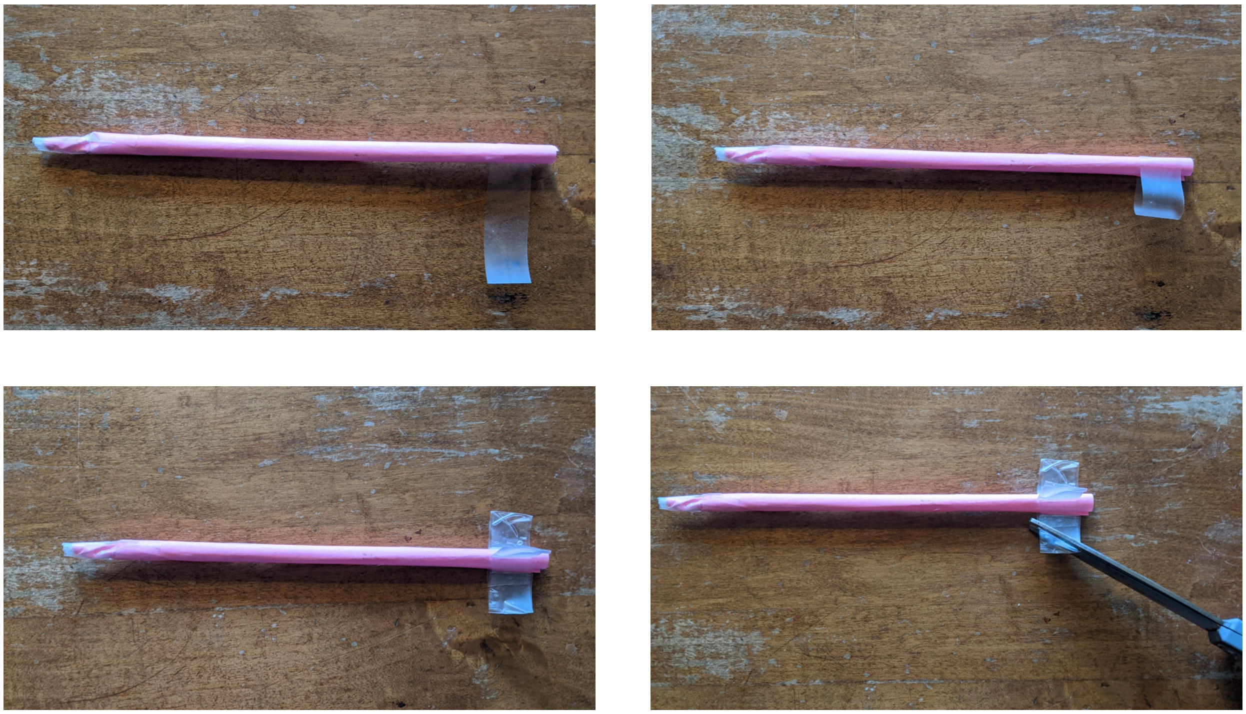
1. **Corta** una tira larga de la parte superior de un pedazo de papel. Debe ser de aproximadamente 1,5 pulgadas de alto, o unos 3 centímetros.

2. **Envuelve** tu tira de papel cómodamente alrededor de tu pajilla. Debe ser apretado, pero todavía capaz de deslizarse. Pega el papel con cinta para que no se desentrañe.
3. **Añada** la nariz del buje. El cohete debe estar sellado en la parte superior: Usa la cinta adhesiva sobre un extremo de el papel para sellar y, a continuación, girar la punta de el papel hasta que quede puntiaguda. Añada más cinta para evitar que se desenrolle.





4. **Añada** aletas doblando un trozo de cinta sobre sí mismo como se ve en la imagen de abajo. A continuación, corta la cinta en formas en ángulo, o experimenta con tus propios diseños de aletas. Intenta añadir 1, 2, 3 o incluso más aletas a tu cohete.



5. **Lanza** tu cohete deslizándose sobre tu pajilla y soplando fuerte. ¡Mira cómo vuela!

6. **Reflexiona** después de lanzar tu cohete varias veces, pensando en qué tipo de cambios puedes hacerle. ¿Puedes modificar tu diseño para que tu cohete vuele más lejos o con mayor precisión?

7. Opcional: **Imprima** el gráfico en la página 4 y **registra** hasta dónde se lanzó tu cohete mientras haces ajustes a tus diseños..

Número de diseño de cohetes	¿Hasta dónde llegó?	¿Qué ha cambiado?	Notas adicionales

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Hand Helicopter

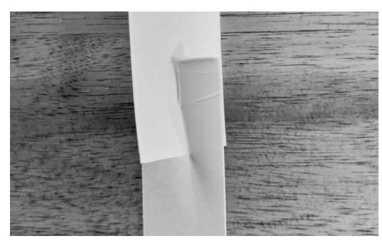
Rolling isn't the only way to get around on other planets.Some crafts move through the atmosphere of other worlds, like Ingenuity, a helicopter-style drone currently exploring Mars. Use household items to make your own flying "helicopter" rotor.

Materials

1 thick paper plate or cereal box
Scissors
Tape
A lightweight stick (pencil, chopstick, or straw)
Holepunch (optional)

Directions

1. **Cut** two 5-inch-long by 1-inch-wide strips of cardboard to make two "rotors."
2. **Cut** a half-inch slit at the top-center on both pieces of cardboard.



3. **Slide** the two cardboard strips together so the slits interlock. This will keep the cardboard strips from laying flat, which will help them move air and fly.
4. **Tape** the two cardboard strips together to make a single piece.

5. **Punch a hole** in the center of the cardboard strips where they are taped together.
6. **Push** a pencil, chopstick, or straw through the hole so that no more than half an inch pokes through, and **tape** it to the cardboard strips to secure it.

7. **Place** the stick between your palms and, pressing your palms together, quickly slide one hand forward and one hand backwards. Watch your craft fly!

Challenges

- Spin the craft faster: Does it fly higher or lower? How high could you make it go? The hand helicopter works by moving air, so if you had enough energy, it could fly VERY high. Do you think it could go into space? Why or why not?
- Try shaping the strips/rotor blades differently, bending them, or using different materials to make them. Do any of these adjustments change the way it flies?
- NASA just landed a helicopter-style drone on Mars called Ingenuity, which uses blades like your hand helicopter does. Why would we use propeller blades on Mars but not in space?

Extra fun

- Check out this video series of astronauts on the International Space Station experimenting with different toys in a weightless environment. Some toys work well, and some don't work at all!

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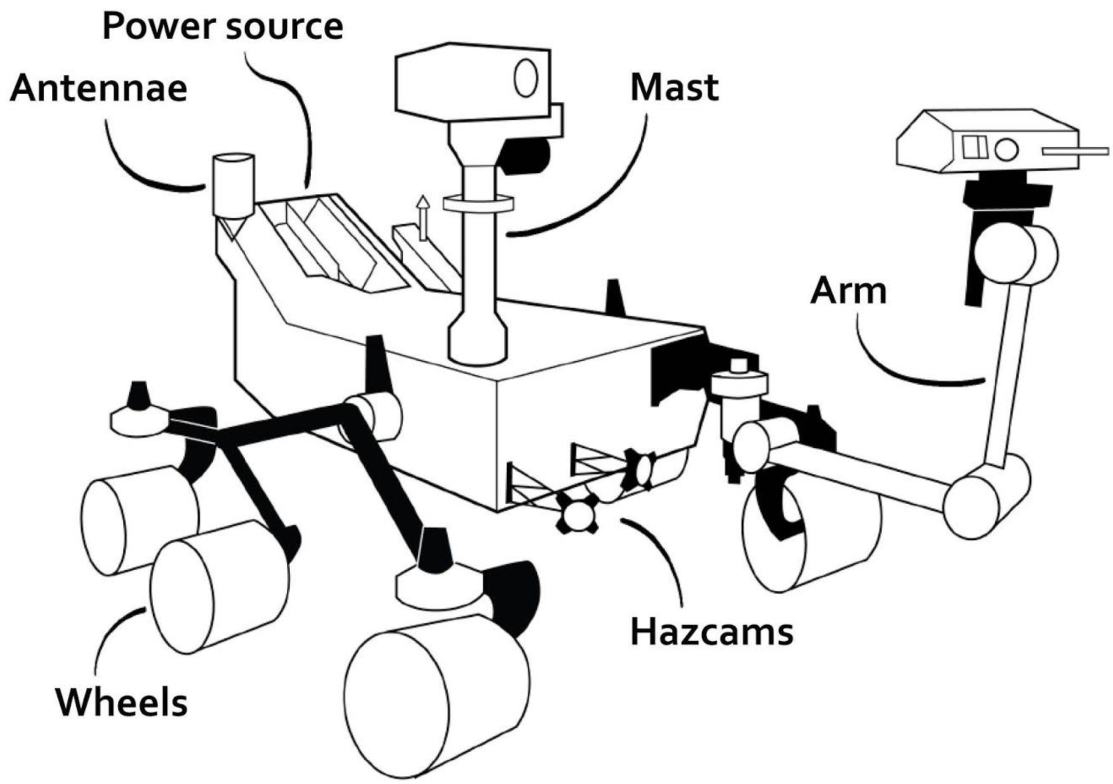
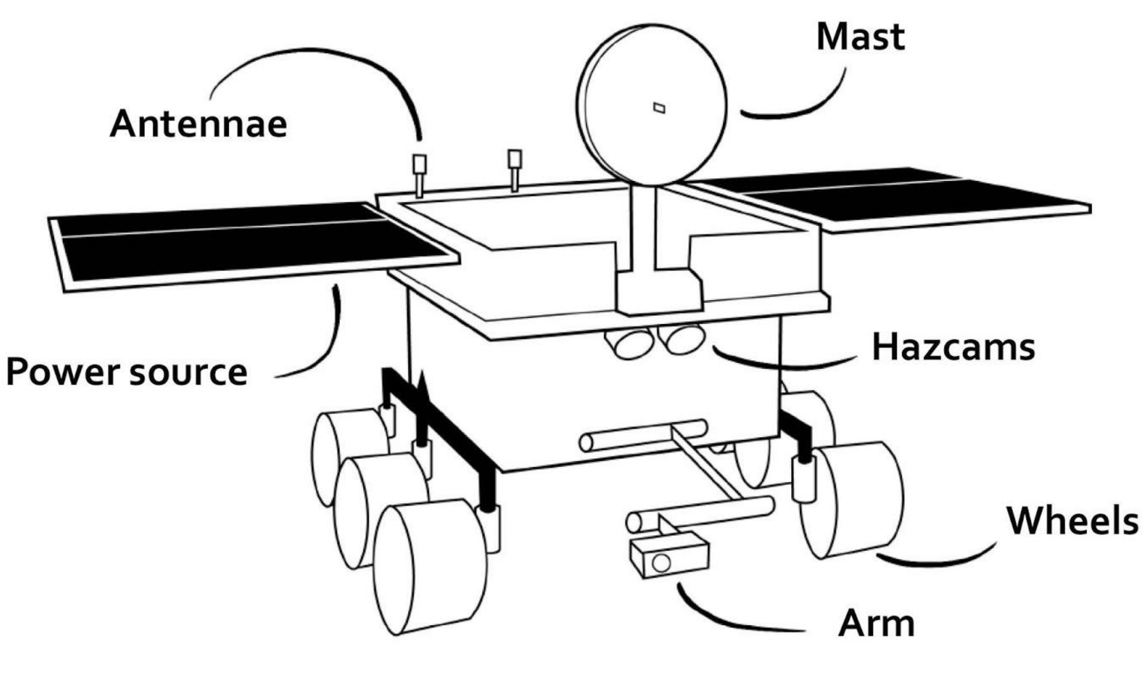
ANATOMY OF A ROVER

CURIOSITY ROVER



YUTU-2 ROVER



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What makes a rover?

Rovers travel to distant moons and planets to explore them up close and send discoveries back to Earth. They use a wide variety of tools to navigate faraway worlds on their own.

Mast: Some instruments on a rover work more effectively if they're higher up off the ground. In the case of rovers on Mars, cameras are often raised to a human eye-level to simulate the angle of view that a person standing on the surface would have.

Arm: This is a moving, jointed extension with scientific instruments at the end. Arms need to be a little farther away from the rover to perform functions like drilling rock or scooping soil.

Antennae: These enable the rover to transmit information from its instruments by radio to an orbiting relay vehicle or directly to Earth.

Hazcams: These help operators on Earth look out for obstructions or hazardous changes in the ground around a rover that might block its path or cause it to tip over or fall. The term means "hazard avoidance cameras."

Wheels: Vehicle designers may choose either treads or wheels to move the rover, depending on the terrain it's expected to cover. Treads may be better over rough ground, but wheels allow for better maneuverability.

Power source: This provides the energy that a rover and its instruments need to operate. Some rovers use solar panels to turn sunlight into electricity for power. In places where there isn't as much sunlight (due to clouds or dust storms or if they're too far away from the Sun), other rovers may depend on nuclear generators to produce power.

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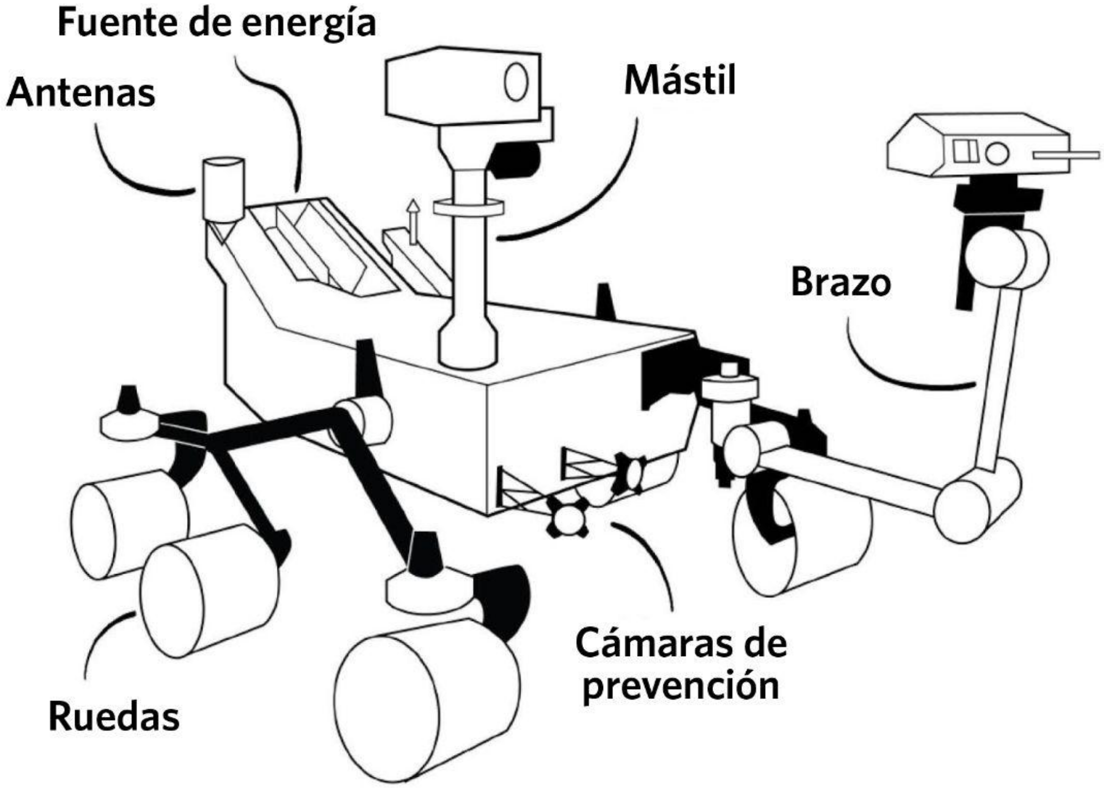
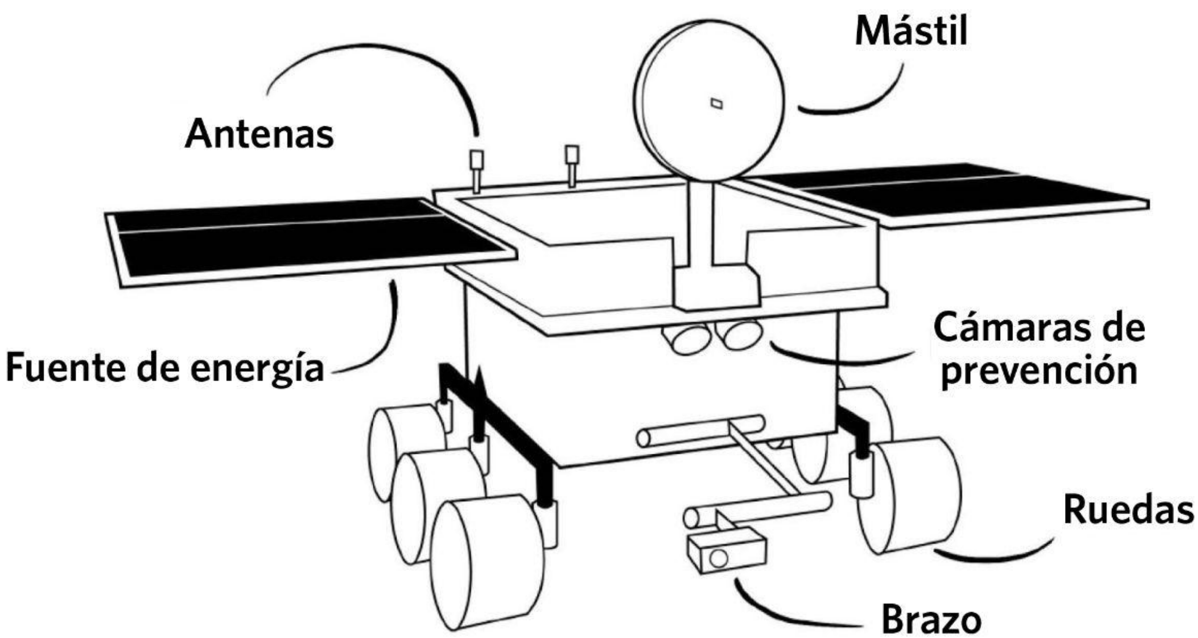
ANATOMÍA DE UN VEHÍCULO EXPLORADOR

CURIOSITY ROVER



YUTU-2 ROVER



¿Qué hace un vehículo explorador?

Los vehículos exploradores viajan a lunas y planetas distantes para explorarlos de cerca y enviar descubrimientos de vuelta a la Tierra. Utilizan una amplia variedad de herramientas para navegar por mundos lejanos por su cuenta.

Mástil: Algunos instrumentos de un vehículo explorador funcionan más eficazmente si están más arriba del suelo. En el caso de los vehículos exploradores en Marte, las cámaras a menudo se elevan a un nivel de ojos humano para simular el ángulo de visión que una persona de pie en la superficie tendría.

Brazo: Esta es una extensión en movimiento y articulada con instrumentos científicos al final. Los brazos necesitan estar un poco más lejos del vehículo explorador para realizar funciones como perforar roca o recoger tierra.

Antenas: Permiten al vehículo explorador transmitir información de sus instrumentos por radio a un vehículo de relé en órbita o directamente a la Tierra.

Cámaras de prevención: Estos ayudan a los operadores de la Tierra a buscar obstrucciones o cambios peligrosos en el suelo alrededor de un vehículo explorador que podría bloquear su camino o hacer que se vuelque o caiga. El término significa "cámaras de prevención de riesgos."

Ruedas: Dependiendo del tipo de superficie en la que se espera que esté, los diseñadores de vehículos pueden elegir bandas de rodadura o ruedas para mover el vehículo explorador. Las bandas de rodadura pueden ser mejores sobre terreno áspero, pero las ruedas permiten una mejor maniobrabilidad.

Fuente de energía: Esto proporciona la energía que un vehículo explorador y sus instrumentos necesitan para operar. Algunos vehículos exploradores utilizan paneles solares para convertir la luz solar en electricidad para la energía. En lugares donde no hay tanta luz solar (debido a nubes o tormentas de polvo o si están demasiado lejos del Sol), otros vehículos exploradores pueden depender de generadores nucleares para producir energía.

Make a Mission

Humans have been sending robotic explorers into space since the 1950's, starting with trips around our planet to expeditions all the way to the edge of the Solar System. Where would you explore if you could journey beyond Earth? In this activity, you'll design your own mission with a spacecraft, rocket, and plenty of imagination to answer questions you have about other worlds.

Materials

Planetary Explorer worksheets (pages 3–26)
Paper
Crayons or colored pencils
Solar System Mission Mysteries posters (Day 4)
Anatomy of a Rocket (Day 2) (Optional)
Anatomy of a Rover sheet (Day 3) (Optional)

Directions

1. **Choose** a moon or planet for your mission to explore. Look through the "Solar System Mission Mysteries" posters for some possible worlds and questions your mission could help answer.

2. **Fill out** the "Planetary Explorer" worksheet that matches your target world. For your mission to be successful you will need to:

   a. Decide the type of craft that will work best
   b. Choose the system that powers it
   c. Determine the kinds of scientific instruments it will use to explore the world and answer your mystery question
   d. Figure out how it will communicate with Earth
   e. Decide how it moves or propels itself
   f. Select how it will get to the surface of the world it is exploring (Entry, Descent, and Landing, or EDL)

3. **Design** and **draw** your spacecraft once you've filled out the worksheet. Be sure to include each of the features:power system, scientific instruments, communication, propulsion, and EDL, and label each part. For inspiration, use the "Anatomy of a Rover" sheet from Day 3 or look up real-life missions from NASA.

4. **Design** and **draw** a rocket that would take your craft to your chosen planet or moon. For inspiration, use the "Anatomy of a Rocket" sheet from Day 2. Label the features you are including, like payload, fins, engine, stages, and boosters.

5. **Create** a mission overview. Now that you have a target world, a mission, and a spacecraft, it is time to do a mission overview. How will you tell the story of how your spacecraft will leave Earth, go to its target location, land, explore, and send information back home? Consider making a comic, writing a short story, making a movie, drawing a picture, or using any other method that will share this information with others.

6. **Spread the word!** Talk about your mission with friends and family.

Planetary Explorer: Enceladus

Mission name:___________________________Mission chief (you):______________________________

Vital info: Enceladus is an icy moon of Saturn, much smaller than Earth's Moon. However, under its ice-crust, there is a warm and active liquid water ocean. As a small moon, Enceladus has little to no atmosphere, but has been observed spewing ice into space.

Explorer craft:

What kind of robotic explorer is the best fit for your mission? On Enceladus, there is little-to-no atmosphere but it has a rough, icy surface criss-crossed with broken icy structures caused by Saturn's tidal influence. Under the icy surface, huge amounts of liquid water exist. Circle the type craft you think will work to explore this world.

Orbiter	**Lander**	**Rover**	**Atmospheric probe**	**Submarine probe**
Goes around the target world high above the atmosphere.	Lands on the surface of the target world and remains in place.	Lands on the surface of the target world then uses limbs or wheels to move.	Travels by floating or flying through the world's atmosphere.	Swims in underwater areas. Requires liquid to move in.

Power source:

On Enceladus, the Sun is very distant, so it does not receive very much light or heat. Plus, the ice on its surface is thick enough to block sunlight from reaching its underground ocean. Circle the power source you think will work to explore this unusual moon.

Solar panels (photovoltaic cells)	**Electrochemical cells (batteries)**	**Nuclear power (radiothermal generator, or RTG)**
Solar cells get power from the Sun and don't require heavy power sources. Can only be used in places that get a lot of sunlight.	Reliable and cheap but often very heavy and do not have a long life without a way to recharge. Great for short or one-way missions.	A small amount of radioactive material like plutonium will make heat as it decays. RTGs capture that heat and turn it into electricity. Medium weight, long life but expensive and rare.

Scientific instruments:
What tools and instruments will your craft use to explore Enceladus? Think about features Enceladus has, what specific questions you want to answer, and what tools will help collect the information you need. Circle the scientific instruments you will include on your craft.

Spectrometer	**Camera**	**Magnetometer**
Tool for analyzing substances to find out what they are made of.	For taking pictures and/or video of what the craft sees.	Instrument for analyzing magnetic fields.

Arms	**Lab**	**Other**
Can hold and use a variety of tools and pick things up.	Big and heavy tools for in-depth exploration without having to return samples to Earth.	What else might your craft use to explore?

Communications:
A critical part of science is sharing the information. How will your craft's data get back to Earth? Enceladus has little gravity, so launching a rocket from the surface is not too difficult. Antennas can send information back to Earth very easily, but since Enceladus orbits Saturn very quickly and Saturn orbits the Sun, the antenna would have to be carefully aimed to reach Earth. Circle the kind of communication you will include on your craft.

High-gain antenna	**Low-gain antenna**	**Physical return to Earth**	**Orbiter relay**
Powerful high-strength antenna good for sending and receiving data, but needs to be pointed toward Earth and the Deep Space Network.	Low-frequency antenna, better for receiving information, but does not need to be pointed toward Earth.	Difficult. Your mission will need some way to blast off from the surface either to another orbiting craft or straight back to Earth.	Sends information from the surface to an orbiter around the world and then to Earth. Difficult if the craft is in a crater or canyon or under ice.

Propulsion:
If your spacecraft lands on the surface of Enceladus, how will it get around? There are many ways to move on different parts of Enceladus' surface. The same methods that allow for moving on top of the ice will not work inside the ice or under the ice in the liquid layer—so consider carefully! Circle the kind of propulsion you will include on your craft.

Wheels	Feet	Wings	Balloon
Great for rolling on hard, flat ground.	Good for climbing uneven terrain.	Good for gliding in thick atmosphere.	Low energy way to fly or float in the atmosphere.

Propellers	Jets	Swimming fins	Other
Good for steering in water or air.	Fast but high energy movement in water or air.	Slow and maneuverable through water.	How else might your craft move?

Entry/Descent/Landing (EDL):
A spacecraft that lands is only as good as its landing method! An orbiter does not need to go down to the surface of a world but most other spacecraft do. How can your spacecraft get safely to the surface of Enceladus? Circle the kind of EDL you will include on your craft.

Parachute	Rocket	Heat shield	Airbags	Other
Requires an atmosphere, challenging with larger crafts.	Good for landing in places without atmosphere, but extra fuel can be heavy.	Protects spacecraft from heat while entering an atmosphere.	Allows craft to safely bounce on the surface before the airbags deflate.	How else might your craft do EDL?

Draw or sketch what your craft might look like (as a whole or just the pieces of it):

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Planetary Explorer: Europa

Mission name:___________________________ Mission chief (you):_______________________________

Vital info: Europa is an icy moon of Jupiter, about the same size as Earth's Moon. However, similar to Enceladus, there is a liquid water ocean under its ice-crust. As a small moon, Europa has little-to-no atmosphere.

Explorer craft:
What kind of robotic explorer is the best fit for your mission? On Europa, you can expect to find little-to-no atmosphere but a rough, icy surface criss-crossed with broken icy structures due to Jupiter's tidal influence. Under the icy surface, huge amounts of liquid water exist. Circle the type craft you think will work to explore this world.

Orbiter	Lander	Rover	Atmospheric probe	Submarine probe
Goes around the target world high above the atmosphere.	Lands on the surface of the target world and remains in place.	Lands on the surface of the target world then uses limbs or wheels to move.	Travels by floating or flying through the world's atmosphere.	Swims in underwater areas. Requires liquid to move in.

Power source:
The Sun is very far from Europa so it does not receive much light or heat. Europa's ice is thick enough to block sunlight from the underground ocean. Circle the power source you think will work to explore it.

Solar panels (photovoltaic cells)	Electrochemical cells (batteries)	Nuclear power (radiothermal generator, or RTG)
Solar cells get power from the Sun and don't require heavy power sources. Can only be used in places that get a lot of sunlight.	Reliable and cheap but often very heavy and do not have a long life without a way to recharge. Great for short or one-way missions.	A small amount of radioactive material like plutonium will make heat as it decays. RTGs capture that heat and turn it into electricity. Medium weight, long life but expensive and rare.

Scientific instruments:
What tools and instruments will your craft use to explore Europa? Think about features Europa has, what specific questions you want to answer, and what tools will help collect the information you need. Circle the scientific instruments you will include on your craft.

Spectrometer	**Camera**	**Magnetometer**
Tool for analyzing substances to find out what they are made of.	For taking pictures and/or video of what the craft sees.	Instrument for analyzing magnetic fields.

Arms	**Lab**	**Other**
Can hold and use a variety of tools and pick things up.	Big and heavy tools for in-depth exploration without having to return samples to Earth.	What else might your craft use to explore?

Communications:
A critical part of science is sharing the information. How will your craft's data get back to Earth? Europa is a relatively large moon, but launching a rocket from the surface is not too difficult. Antennas can send information back to Earth very easily, but since Europa orbits Jupiter very quickly as Jupiter orbits the Sun, the antenna would have to be carefully aimed to reach Earth. Circle the kind of communication you will include on your craft.

High-gain antenna	**Low-gain antenna**	**Physical return to Earth**	**Orbiter relay**
Powerful high-strength antenna good for sending and receiving data, but needs to be pointed toward Earth and the Deep Space Network.	Low-frequency antenna, better for receiving information, but does not need to be pointed toward Earth.	Difficult. Your mission will need some way to blast off from the surface either to another orbiting craft or straight back to Earth.	Sends information from the surface to an orbiter around the world and then to Earth. Difficult if the craft is in a crater or canyon or under ice.

Propulsion:

If your spacecraft lands on the surface of Europa, how will it get around? There are many ways to move on different parts of Europa's surface. The same methods that allow for moving on top of the ice will not work inside the ice or under the ice in the liquid layer—so consider carefully! Circle the kind of propulsion you will include on your craft.

Wheels	Feet	Wings	Balloon
Great for rolling on hard, flat ground.	Good for climbing uneven terrain.	Good for gliding in thick atmosphere.	Low energy way to fly or float in the atmosphere.

Propellers	Jets	Swimming fins	Other
Good for steering in water or air.	Fast but high energy movement in water or air.	Slow and maneuverable through water.	How else might your craft move?

Entry/Descent/Landing (EDL):

A spacecraft that lands is only as good as its landing method! An orbiter does not need to go down to the surface of a world but most other spacecraft do. How can your spacecraft get safely to the surface of Europa? Circle the kind of EDL you will include on your craft.

Parachute	Rocket	Heat shield	Airbags	Other
Requires an atmosphere, challenging with larger crafts.	Good for landing in places without atmosphere, but extra fuel can be heavy.	Protects spacecraft from heat while entering an atmosphere.	Allows craft to safely bounce on the surface before the airbags deflate.	How else might your craft do EDL?

Draw or sketch what your craft might look like (as a whole or just the pieces of it):

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Planetary Explorer: Mars

Mission name:____________________________ Mission chief (you):______________________________

Vital info: Mars is a small, rocky planet with a very thin atmosphere and less gravity than Earth. Famous for its reddish color, it is covered in mountains, valleys, and what seem to be ancient dried-up shorelines and flowsites from water that flowed on its surface a very long time ago.

Explorer craft:
What kind of robotic explorer is the best fit for your mission? Mars Is a small, rocky world with mountains and craters and a thin atmosphere. Some flying atmospheric craft will need a specialized design for flying on Mars. Circle the type craft you think will work to explore this world.

Orbiter	**Lander**	**Rover**	**Atmospheric probe**
Goes around the target world high above the atmosphere.	Lands on the surface of the target world and remains in place.	Lands on the surface of the target world then uses limbs or wheels to move.	Travels by floating or flying through the world's atmosphere.

Power source:
Different crafts doing different tasks will require different amounts of energy. For example, is it more important for your mission that your craft travel miles across the surface, or that it continues to explore for a long time? Circle the power source you think will work to explore it.

Solar panels (photovoltaic cells)	**Electrochemical cells (batteries)**	**Nuclear power (radiothermal generator, or RTG)**
Solar cells get power from the Sun and don't require heavy power sources. Can only be used in places that get a lot of sunlight.	Reliable and cheap but often very heavy and do not have a long life without a way to recharge. Great for short or one-way missions.	A small amount of radioactive material like plutonium will make heat as it decays. RTGs capture that heat and turn it into electricity. Medium weight, long life but expensive and rare.

Scientific instruments:
What tools and instruments will your craft use to explore Mars? Think about the features Mars has, what specific questions you want to answer, and what tools will help collect the information you need. Circle the scientific instruments you will include on your craft.

Spectrometer	**Camera**	**Magnetometer**
Tool for analyzing substances to find out what they are made of.	For taking pictures and/or video of what the craft sees.	Instrument for analyzing magnetic fields.

Arms	**Lab**	**Other**
Can hold and use a variety of tools and pick things up.	Big and heavy tools for in-depth exploration without having to return samples to Earth.	What else might your craft use to explore?

Communications:
A critical part of science is sharing the information. How will your craft's data get back to Earth? Mars has some gravity, so launching a rocket from the surface may have some challenges. Antennas can send information back to Earth very easily, but would have to be carefully aimed and timed. Circle the kind of communication you will include on your craft.

High-gain antenna	**Low-gain antenna**	**Physical return to Earth**	**Orbiter relay**
Powerful high-strength antenna good for sending and receiving data, but needs to be pointed toward Earth and the Deep Space Network.	Low-frequency antenna, better for receiving information, but does not need to be pointed toward Earth.	Difficult. Your mission will need some way to blast off from the surface either to another orbiting craft or straight back to Earth.	Sends information from the surface to an orbiter around the world and then to Earth. Difficult if the craft is in a crater or canyon or under ice.

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Propulsion:
If your spacecraft lands on the surface of Mars, how will it move around on the rocky surface or through the thin atmosphere? Circle the kind of propulsion you will include on your craft.

Wheels	**Feet**	**Wings**	**Balloon**
Great for rolling on hard, flat ground.	Good for climbing uneven terrain.	Good for gliding in thick atmosphere.	Low energy way to fly or float in the atmosphere.

Propellers	**Jets**	**Other**
Good for steering in water or air.	Fast but high energy movement in water or air.	How else might your craft move?

Entry/Descent/Landing (EDL):
A spacecraft that lands is only as good as its landing method! An orbiter does not need to go down to the surface of a world but most other spacecraft do. How can your spacecraft get safely to the surface of Mars? Circle the kind of EDL you will include on your craft.

Parachute	**Rocket**	**Heat shield**	**Airbags**	**Other**
Requires an atmosphere, challenging with larger crafts.	Good for landing in places without atmosphere, but extra fuel can be heavy.	Protects spacecraft from heat while entering an atmosphere.	Allows craft to safely bounce on the surface before the airbags deflate.	How else might your craft do EDL?

Draw or sketch what your craft might look like (as a whole or just the pieces of it):

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Planetary Explorer: Mercury

Mission name:_____________________________ Mission chief (you):_______________________________

Vital Info: Mercury is the smallest planet in the Solar System and the closest to the Sun. It is rocky with almost no atmosphere and much less gravity than Earth. It is thought to have ice deposits hiding in the shadows of craters at the polar regions.

Explorer craft:
What kind of robotic explorer is the best fit for your mission? Since Mercury is so close to the Sun, any mission destined for the Mercurian surface needs to focus on specialised landing methods as well as ways of protecting itself from the Sun if it lands on the sunlit side to collect solar power. Even orbiters would need protection so close to the Sun. Circle the type craft you think will work to explore this world.

Orbiter	**Lander**	**Rover**
Goes around the target world high above the atmosphere.	Lands on the surface of the target world and remains in place.	Lands on the surface of the target world then uses limbs or wheels to move.

Power source:
Light from the Sun is abundant on one side of Mercury, but not the other. The intense light on one side also makes for a very hot, very dangerous environment for a spacecraft, so it will need extra protection. Circle the power source you think will work to explore it.

Solar panels (photovoltaic cells)	**Electrochemical cells (batteries)**	**Nuclear power (radiothermal generator, or RTG)**
Solar cells get power from the Sun and don’t require heavy power sources. Can only be used in places that get a lot of sunlight.	Reliable and cheap but often very heavy and do not have a long life without a way to recharge. Great for short or one-way missions.	A small amount of radioactive material like plutonium will make heat as it decays. RTGs capture that heat and turn it into electricity. Medium weight, long life but expensive and rare.

Scientific instruments:
What tools and instruments will your craft use to explore Mercury? Think about the features Mercury has, what specific questions you want to answer, and what tools will help collect the information you need. Circle the scientific instruments you will include on your craft.

Spectrometer	**Camera**	**Magnetometer**
Tool for analyzing substances to find out what they are made of.	For taking pictures and/or video of what the craft sees.	Instrument for analyzing magnetic fields.

Arms	**Lab**	**Other**
Can hold and use a variety of tools and pick things up.	Big and heavy tools for in-depth exploration without having to return samples to Earth.	What else might your craft use to explore?

Communications:
A critical part of science is sharing the information. How will your craft's data get back to Earth? From Earth's perspective, Mercury is sometimes on the opposite side of the Sun or very close to the Sun, so antennas would have to be carefully aimed and timed to reach Earth. However, Mercury has little gravity, so launching a rocket from the surface is not too difficult. Circle the kind of communication you will include on your craft.

High-gain antenna	**Low-gain antenna**	**Physical return to Earth**	**Orbiter relay**
Powerful high-strength antenna good for sending and receiving data, but needs to be pointed toward Earth and the Deep Space Network.	Low-frequency antenna, better for receiving information, but does not need to be pointed toward Earth.	Difficult. Your mission will need some way to blast off from the surface either to another orbiting craft or straight back to Earth.	Sends information from the surface to an orbiter around the world and then to Earth. Difficult if the craft is in a crater or canyon or under ice.

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Propulsion:

If your spacecraft lands on the surface of Mercury, how will it get around? Since Mercury has no atmosphere, some features like wings and parachutes won't work, but the planet's hard and rocky surface would work well for ground-based movement. Circle the kind of propulsion you will include on your craft.

Wheels	**Feet**	**Roll**	**Other**
Great for rolling on hard, flat ground.	Good for climbing uneven terrain.	The entire craft rolls across flat ground.	How else might your craft move?

Entry/Descent/Landing (EDL):

A spacecraft that lands is only as good as its landing method! An orbiter does not need to go down to the surface of a world but most other spacecraft do. To land on Mercury, you will need to use rockets or airbags,, since parachutes and wings are useless without an atmosphere. Luckily, gravity is much lower closer to the surface of Mercury, so landings are a little easier. Circle the kind of EDL you will include on your craft.

Parachute	**Rocket**	**Heat shield**	**Airbags**	**Other**
Requires an atmosphere, challenging with larger crafts.	Good for landing in places without atmosphere, but extra fuel can be heavy.	Protects spacecraft from heat while entering an atmosphere.	Allows craft to safely bounce on the surface before the airbags deflate.	How else might your craft do EDL?

Draw or sketch what your craft might look like (as a whole or just the pieces of it):

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Planetary Explorer: Miranda

Mission name:______________________________ Mission chief (you):____________________________

Vital info: Miranda is one of Uranus' moons. It is so small that it is not a perfect sphere, and has very little gravitational pull and no atmosphere. Miranda is made of a mix of water ice and rock and appears to have amazingly varied surface terrains, with ridges, craters, and mountains seemingly squished together.

Explorer craft:
What kind of robotic explorer is the best fit for your mission? Miranda has a rocky and icy surface, but no atmosphere. Circle the type craft you think will work to explore this world.

Orbiter	**Lander**	**Rover**
Goes around the target world high above the atmosphere.	Lands on the surface of the target world and remains in place.	Lands on the surface of the target world then uses limbs or wheels to move.

Power source:
Orbiting Uranus, Miranda is extremely far from the Sun and receives very little light and heat. Circle the power source you think will work to explore it.

Solar panels (photovoltaic cells)	**Electrochemical cells (batteries)**	**Nuclear power (radiothermal generator, or RTG)**
Solar cells get power from the Sun and don't require heavy power sources. Can only be used in places that get a lot of sunlight.	Reliable and cheap but often very heavy and do not have a long life without a way to recharge. Great for short or one-way missions.	A small amount of radioactive material like plutonium will make heat as it decays. RTGs capture that heat and turn it into electricity. Medium weight, long life but expensive and rare.

Scientific instruments:
What tools and instruments will your craft use to explore Miranda? Think about its features, what specific questions you want to answer, and what tools will help collect the information you need. Circle the scientific instruments you will include on your craft.

Spectrometer	**Camera**	**Magnetometer**
Tool for analyzing substances to find out what they are made of.	For taking pictures and/or video of what the craft sees.	Instrument for analyzing magnetic fields.

Arms	**Lab**	**Other**
Can hold and use a variety of tools and pick things up.	Big and heavy tools for in-depth exploration without having to return samples to Earth.	What else might your craft use to explore?

Communications:
A critical part of science is sharing the information. How will your craft's data get back to Earth? With such minimal gravity, launching a rocket from Miranda may not be too difficult. Antennas can send information back to Earth very easily, but since Miranda orbits Uranus very quickly and Uranus orbits the Sun, the antenna would have to be carefully aimed to reach Earth. Circle the kind of communication you will include on your craft.

High-gain antenna	**Low-gain antenna**	**Physical return to Earth**	**Orbiter relay**
Powerful high-strength antenna good for sending and receiving data, but needs to be pointed toward Earth and the Deep Space Network.	Low-frequency antenna, better for receiving information, but does not need to be pointed toward Earth.	Difficult. Your mission will need some way to blast off from the surface either to another orbiting craft or straight back to Earth.	Sends information from the surface to an orbiter around the world and then to Earth. Difficult if the craft is in a crater or canyon or under ice.

Propulsion:
If your spacecraft lands on the surface of Miranda, how will it get around? There is no atmosphere to fly in and the surface of Miranda has many steep and jagged edges. Circle the kind of propulsion you will include on your craft.

Wheels	**Feet**	**Roll**	**Other**
Great for rolling on hard, flat ground.	Good for climbing uneven terrain.	The entire craft rolls across flat ground.	How else might your craft move?

Entry/Descent/Landing (EDL):
A spacecraft that lands is only as good as its landing method! An orbiter does not need to go down to the surface of a world but most other spacecraft do. How can your spacecraft get safely to the surface of Miranda? Circle the kind of EDL you will include on your craft.

Parachute	**Rocket**	**Heat shield**	**Airbags**	**Other**
Requires an atmosphere, challenging with larger crafts.	Good for landing in places without atmosphere, but extra fuel can be heavy.	Protects spacecraft from heat while entering an atmosphere.	Allows craft to safely bounce on the surface before the airbags deflate.	How else might your craft do EDL?

Draw or sketch what your craft might look like (as a whole or just the pieces of it):

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Planetary Explorer: the Moon

Mission name:______________________________ Mission chief (you):_____________________________

Vital info: The Moon is a small, rocky world that orbits planet Earth. With no atmosphere and much less gravity than Earth, it is the only place beyond Earth that has been visited by human beings. It is covered in craters, mountains, and even ancient lava flows and is thought to have ice deposits below its dusty surface.

Explorer craft:
What kind of robotic explorer is the best fit for your mission? The Moon is a rocky and airless environment with much less gravitational pull than Earth. Circle the type craft you think will work to explore this world.

Orbiter	**Lander**	**Rover**
Goes around the target world high above the atmosphere.	Lands on the surface of the target world and remains in place.	Lands on the surface of the target world then uses limbs or wheels to move.

Power source:
Any one location on the surface of the Moon will have two weeks of light and heat followed by two weeks of darkness and cold. How will you power and keep your rover working under these conditions? Circle the power source you think will work to explore it.

Solar panels (photovoltaic cells)	**Electrochemical cells (batteries)**	**Nuclear power (radiothermal generator, or RTG)**
Solar cells get power from the Sun and don't require heavy power sources. Can only be used in places that get a lot of sunlight.	Reliable and cheap but often very heavy and do not have a long life without a way to recharge. Great for short or one-way missions.	A small amount of radioactive material like plutonium will make heat as it decays. RTGs capture that heat and turn it into electricity. Medium weight, long life but expensive and rare.

Scientific instruments:
What tools and instruments will your craft use to explore the Moon? Think about the features the Moon has (rocks, craters, valleys, etc.), what specific questions you want to answer, and what tools will help collect the information you need. Circle the scientific instruments you will include on your craft.

Spectrometer	**Camera**	**Magnetometer**
Tool for analyzing substances to find out what they are made of.	For taking pictures and/or video of what the craft sees.	Instrument for analyzing magnetic fields.

Arms	**Lab**	**Other**
Can hold and use a variety of tools and pick things up.	Big and heavy tools for in-depth exploration without having to return samples to Earth.	What else might your craft use to explore?

Communications:
A critical part of science is sharing the information. How will your craft's data get back to Earth? Since the Moon orbits Earth quite closely, and the same side always faces Earth, communication can take a variety of forms. However, if your mission lands at the poles or the Far Side of the Moon, your spacecraft might need some assistance. Circle the kind of communication you will include on your craft.

High-gain antenna	**Low-gain antenna**	**Physical return to Earth**	**Orbiter relay**
Powerful high-strength antenna good for sending and receiving data, but needs to be pointed toward Earth and the Deep Space Network.	Low-frequency antenna, better for receiving information, but does not need to be pointed toward Earth.	Difficult. Your mission will need some way to blast off from the surface either to another orbiting craft or straight back to Earth.	Sends information from the surface to an orbiter around the world and then to Earth. Difficult if the craft is in a crater or canyon or under ice.

Propulsion:

If your spacecraft lands on the surface of the Moon, how will it get around? Since the Moon is a rocky world, traveling along the surface can take a variety of forms—but without oceans or atmosphere, wings and jets might not be the best option. Circle the kind of propulsion you will include on your craft.

Wheels	**Feet**	**Roll**	**Other**
Great for rolling on hard, flat ground.	Good for climbing uneven terrain.	The entire craft rolls across flat ground.	How else might your craft move?

Entry/Descent/Landing (EDL):

A spacecraft that lands is only as good as its landing method! An orbiter does not need to go down to the surface of a world but most other spacecraft do. How can your spacecraft get safely to the surface of the Moon? Circle the kind of EDL you will include for your craft.

Parachute	**Rocket**	**Heat shield**	**Airbags**	**Other**
Requires an atmosphere, challenging with larger crafts.	Good for landing in places without atmosphere, but extra fuel can be heavy.	Protects spacecraft from heat while entering an atmosphere.	Allows craft to safely bounce on the surface before the airbags deflate.	How else might your craft do EDL?

Draw or sketch what your craft might look like (as a whole or just the pieces of it):

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Planetary Explorer: Titan

Mission name:______________________________ Mission chief (you):_____________________________

Vital info: Titan is a large, rocky moon of Saturn. In many ways, it is the most Earth-like place in the Solar System. It has a thick atmosphere—the only moon that does—made of nitrogen (the same dominant gas as Earth's atmosphere), a solid surface with liquid oceans, and even clouds, rain, and liquid lakes. The big difference? Titan is so far from the Sun and so cold that its liquids are not made of water, but methane!

Explorer craft:
What kind of robotic explorer is the best fit for your mission? Titan is a large world with a thick atmosphere made of nitrogen (the same dominant gas as Earth's atmosphere) and a rocky surface with mountains, valleys, and liquid oceans. Circle the type craft you think will work to explore this world.

Orbiter	**Lander**	**Rover**	**Atmospheric probe**	**Submarine probe**
Goes around the target world high above the atmosphere.	Lands on the surface of the target world and remains in place.	Lands on the surface of the target world then uses limbs or wheels to move.	Travels by floating or flying through the world's atmosphere.	Swims in underwater areas. Requires liquid to move in.

Power source:
Powering a spacecraft on Titan poses an interesting challenge. Titan orbits Saturn, very far from the Sun, and its thick haze can block sunlight, making solar panels a difficult option. Circle the power source you think will work to explore it.

Solar panels (photovoltaic cells)	**Electrochemical cells (batteries)**	**Nuclear power (radiothermal generator, or RTG)**
Solar cells get power from the Sun and don't require heavy power sources. Can only be used in places that get a lot of sunlight.	Reliable and cheap but often very heavy and do not have a long life without a way to recharge. Great for short or one-way missions.	A small amount of radioactive material like plutonium will make heat as it decays. RTGs capture that heat and turn it into electricity. Medium weight, long life but expensive and rare.

Scientific instruments:
What tools and instruments will your craft use to explore Titan? Think about the features Titan has, what part you want to explore, the specific questions you want to answer, and what tools will help collect the information you need. Circle the scientific instruments you will include on your craft.

Spectrometer	**Camera**	**Magnetometer**
Tool for analyzing substances to find out what they are made of.	For taking pictures and/or video of what the craft sees.	Instrument for analyzing magnetic fields.

Arms	**Lab**	**Other**
Can hold and use a variety of tools and pick things up.	Big and heavy tools for in-depth exploration without having to return samples to Earth.	What else might your craft use to explore?

Communications:
A critical part of science is sharing the information. How will your craft's data get back to Earth? Titan is a very large moon, but launching a rocket from the surface is not too difficult. Antennas can send information back to Earth very easily, but since Titan orbits Saturn and Saturn orbits the Sun, they will have to be very carefully amined and timed. Circle the kind of communication you will include on your craft.

High-gain antenna	**Low-gain antenna**	**Physical return to Earth**	**Orbiter relay**
Powerful high-strength antenna good for sending and receiving data, but needs to be pointed toward Earth and the Deep Space Network.	Low-frequency antenna, better for receiving information, but does not need to be pointed toward Earth.	Difficult. Your mission will need some way to blast off from the surface either to another orbiting craft or straight back to Earth.	Sends information from the surface to an orbiter around the world and then to Earth. Difficult if the craft is in a crater or canyon or under ice.

Propulsion:
If your mission is designed to land on the surface or atmosphere of Titan, how will it move? Titan's thick atmosphere could provide a great opportunity for a flying spacecraft, and its cold oceans could provide options for liquid mobility methods as well. Circle the kind of propulsion you will include on your craft.

Wheels	**Feet**	**Wings**	**Balloon**
Great for rolling on hard, flat ground.	Good for climbing uneven terrain.	Good for gliding in thick atmosphere.	Low energy way to fly or float in the atmosphere.

Propellers	**Jets**	**Swimming fins**	**Other**
Good for steering in water or air.	Fast but high energy movement in water or air.	Slow and maneuverable through water.	How else might your craft move?

Entry/Descent/Landing (EDL):
A spacecraft that lands is only as good as its landing method! An orbiter does not need to go down to the surface of a world but most other spacecraft do. How can your spacecraft get safely to the surface or atmosphere of Titan? Circle the kind of EDL you will include on your craft.

Parachute	**Rocket**	**Heat shield**	**Airbags**	**Other**
Requires an atmosphere, challenging with larger crafts.	Good for landing in places without atmosphere, but extra fuel can be heavy.	Protects spacecraft from heat while entering an atmosphere.	Allows craft to safely bounce on the surface before the airbags deflate.	How else might your craft do EDL?

Draw or sketch what your craft might look like (as a whole or just the pieces of it):

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Planetary Explorer: Venus

Mission name:______________________________ Mission chief (you):______________________________

Vital info: Venus is an Earth-sized, rocky planet with Earth-like gravity and a very thick atmosphere that blocks light from reaching the surface. Its atmosphere is made of gases poisonous to humans, creates high pressures, and traps so much heat that is hotter than Mercury even though it is farther from the Sun.

Explorer craft:
What kind of robotic explorer is the best fit for your mission? Venus has a rocky surface and a thick atmosphere, but that atmosphere can block many spacecrafts' views of the surface from orbit, and heat and pressure have crushed and melted past landers on the planet's surface. Circle the type craft you think will work to explore this world.

Orbiter	Lander	Rover	Atmospheric probe
Goes around the target world high above the atmosphere.	Lands on the surface of the target world and remains in place.	Lands on the surface of the target world then uses limbs or wheels to move.	Travels by floating or flying through the world's atmosphere.

Power source:
Sunlight can be scarce on the surface of Venus due to its thick, cloudy sky, but may work for orbiters or some atmospheric probes since Venus is close to the Sun. Circle the power source you think will work to explore it.

Solar panels (photovoltaic cells)	Electrochemical cells (batteries)	Nuclear power (radiothermal generator, or RTG)
Solar cells get power from the Sun and don't require heavy power sources. Can only be used in places that get a lot of sunlight.	Reliable and cheap but often very heavy and do not have a long life without a way to recharge. Great for short or one-way missions.	A small amount of radioactive material like plutonium will make heat as it decays. RTGs capture that heat and turn it into electricity. Medium weight, long life but expensive and rare.

Scientific instruments:
What tools and instruments will your craft use to explore Venus? Think about Venus' features, what part of the planet your craft is exploring, what specific questions you want to answer, and what tools will help collect the information you need. Circle the scientific instruments you will include on your craft.

Spectrometer	**Camera**	**Magnetometer**
Tool for analyzing substances to find out what they are made of.	For taking pictures and/or video of what the craft sees.	Instrument for analyzing magnetic fields.

Arms	**Lab**	**Other**
Can hold and use a variety of tools and pick things up.	Big and heavy tools for in-depth exploration without having to return samples to Earth.	What else might your craft use to explore?

Communications:
A critical part of science is sharing the information. How will your craft's data get back to Earth? Venus' thick atmosphere poses a challenge to sending data back to Earth from the surface. Circle the kind of communication you will include on your craft.

High-gain antenna	**Low-gain antenna**	**Physical return to Earth**	**Orbiter relay**
Powerful high-strength antenna good for sending and receiving data, but needs to be pointed toward Earth and the Deep Space Network.	Low-frequency antenna, better for receiving information, but does not need to be pointed toward Earth.	Difficult. Your mission will need some way to blast off from the surface either to another orbiting craft or straight back to Earth.	Sends information from the surface to an orbiter around the world and then to Earth. Difficult if the craft is in a crater or canyon or under ice.

Propulsion:
If your spacecraft lands on the surface or atmosphere of Venus, how will it move? Circle the kind of propulsion you will include on your craft.

Wheels	**Feet**	**Wings**	**Balloon**
Great for rolling on hard, flat ground.	Good for climbing uneven terrain.	Good for gliding in thick atmosphere.	Low energy way to fly or float in the atmosphere.

Propellers	**Jets**	**Swimming fins**	**Other**
Good for steering in water or air.	Fast but high energy movement in water or air.	Slow and maneuverable through water.	How else might your craft move?

Entry/Descent/Landing (EDL):
A spacecraft that lands is only as good as its landing method! An orbiter does not need to go down to the surface of a world but most other spacecraft do. Landing on the surface of Venus through its turbulent atmosphere is something that has only been accomplished a few times. How can you protect your spacecraft on its way down to the surface? Circle the kind of EDL you will include on your craft.

Parachute	**Rocket**	**Heat shield**	**Airbags**	**Other**
Requires an atmosphere, challenging with larger crafts.	Good for landing in places without atmosphere, but extra fuel can be heavy.	Protects spacecraft from heat while entering an atmosphere.	Allows craft to safely bounce on the surface before the airbags deflate.	How else might your craft do EDL?

Draw or sketch what your craft might look like (as a whole or just the pieces of it):

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Solar System Mission Mysteries Posters

Our Solar System is filled with mysterious loactions and features, from underground lakes to unbreathable atmospheres. Take a look through the following seven posters of planets and moons, each with their own curious feature highlighted. Do any of them capture your curiosity or imagination? Choose one to think more deeply about. What might it be like to visit that world? What might you need to prepare a mission there? Continue on to the “Planetary Explorers” worksheets in the “Make a Mission” activity to plan your exploration of one or more worlds.

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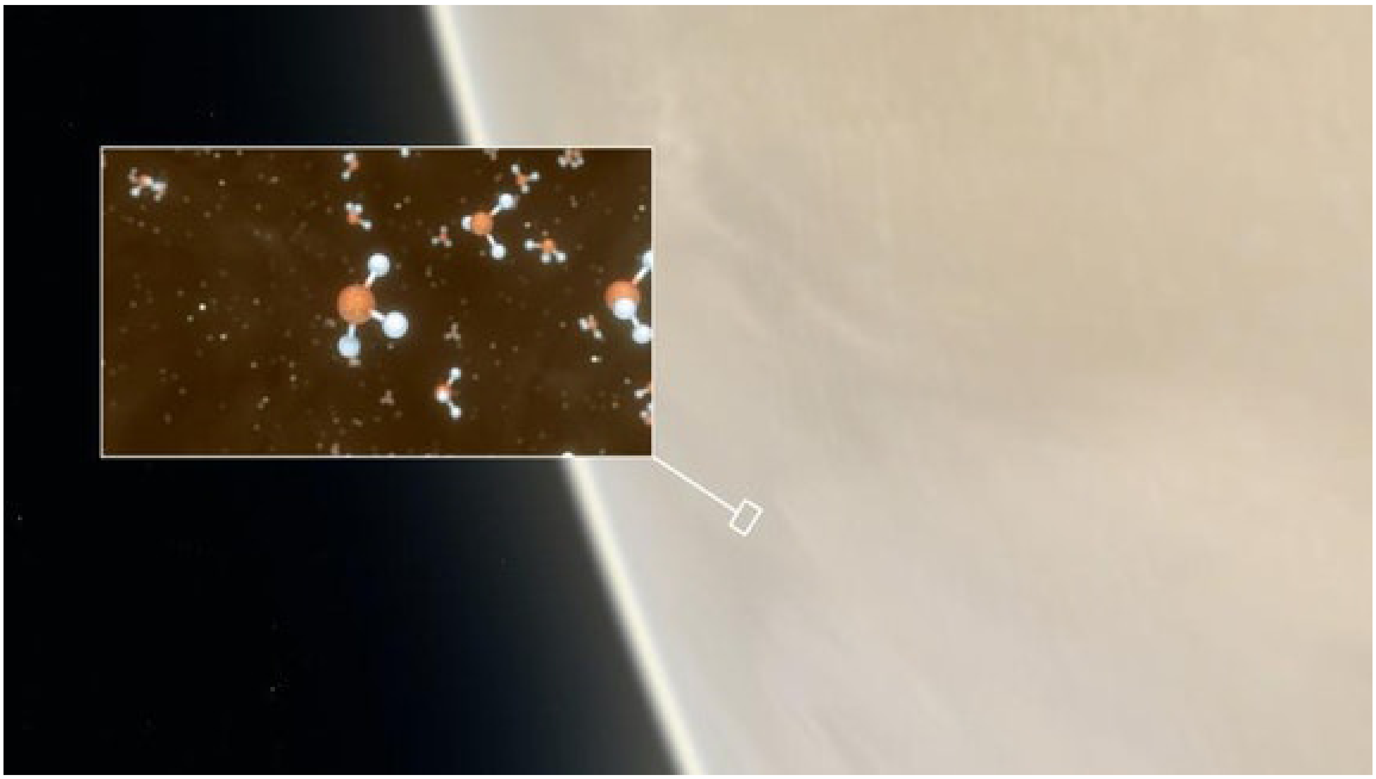
Target Acquired:

Venus: Mysterious Molecule



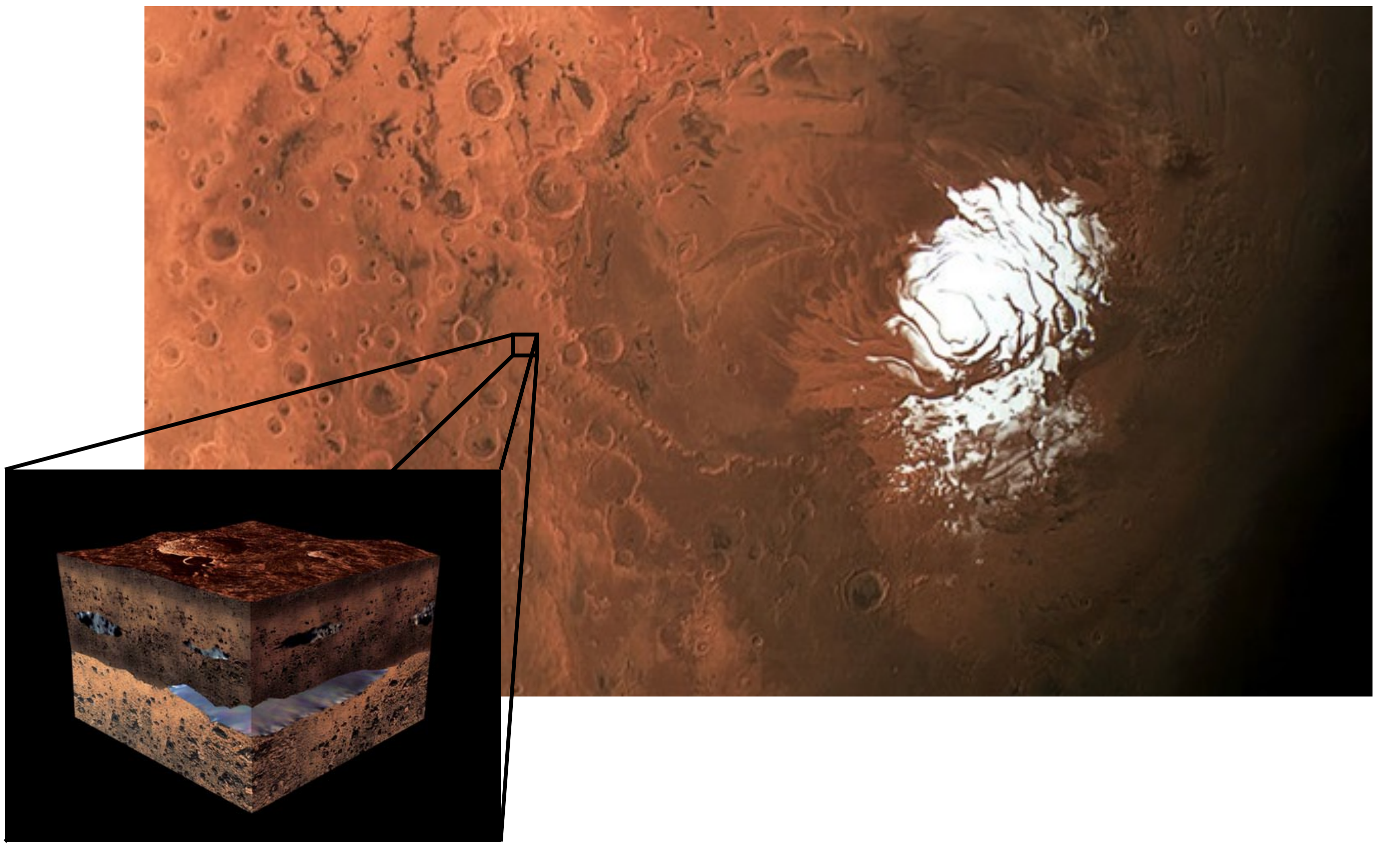
Venus is too hot for life as we know it to live on the surface, but higher up in the air where it is cooler, life might thrive. In fact, when scientists look at the color of some of Venus's clouds, they see a special molecule called phosphene that often comes from living things!

Your mission, should you choose to accept it, is to design a mission to explore Venus's clouds and find out where all the phosphene is coming from.

Image by ESO/M. Kornmesser/L. Calçada & NASA/JPL/Caltech

Target Acquired:

Underground Lakes on Mars



A very long time ago, **Mars** used to look like Earth, with oceans and a warm atmosphere. But today, the surface is as dry as a desert. However, scientists have recently made an exciting discovery: there are lakes of water trapped deep beneath layers of rock and dust under Mars's surface!

Your mission, should you choose to accept it, is to design a mission to get down to those underground lakes and find out what they're like.

Mars Cutout illustration by Medialab, ESA 2001 / Mars South Pole by ESA/DLR/FU Berlin/CC BY-SA

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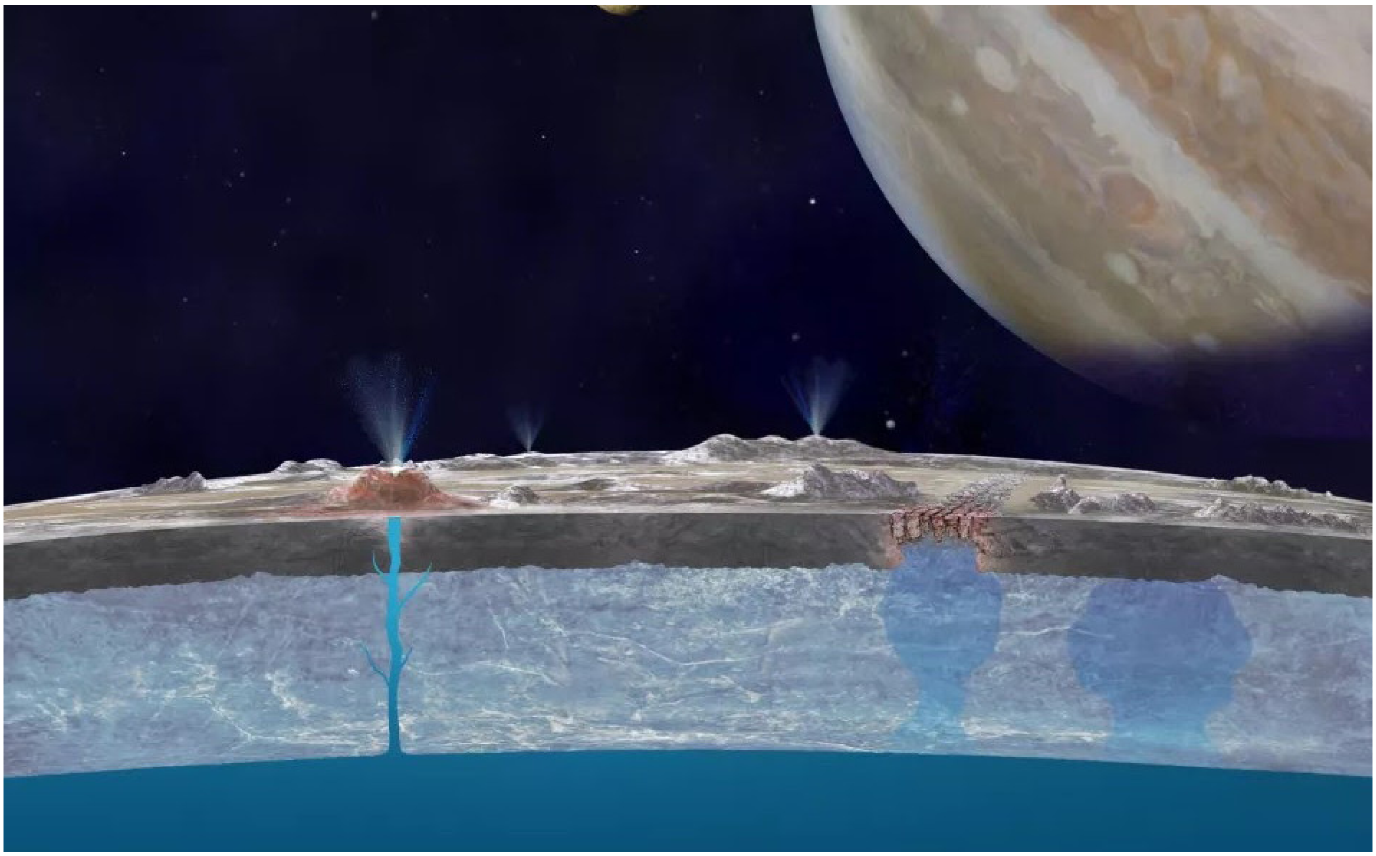
Target Acquired:

Europa's Trapped Ocean



Europa is one of the largest moons of Jupiter. Unlike our Moon, Europa is covered in a thick layer of ice. Trapped under that ice is more water than there is on planet Earth! That ocean is kept warm by magma bubbling up from deep within the small moon.

Your mission, should you choose to accept it, is to design a mission to learn more about that trapped ocean under Europa's surface.

Image by NASA/JPL-Caltech

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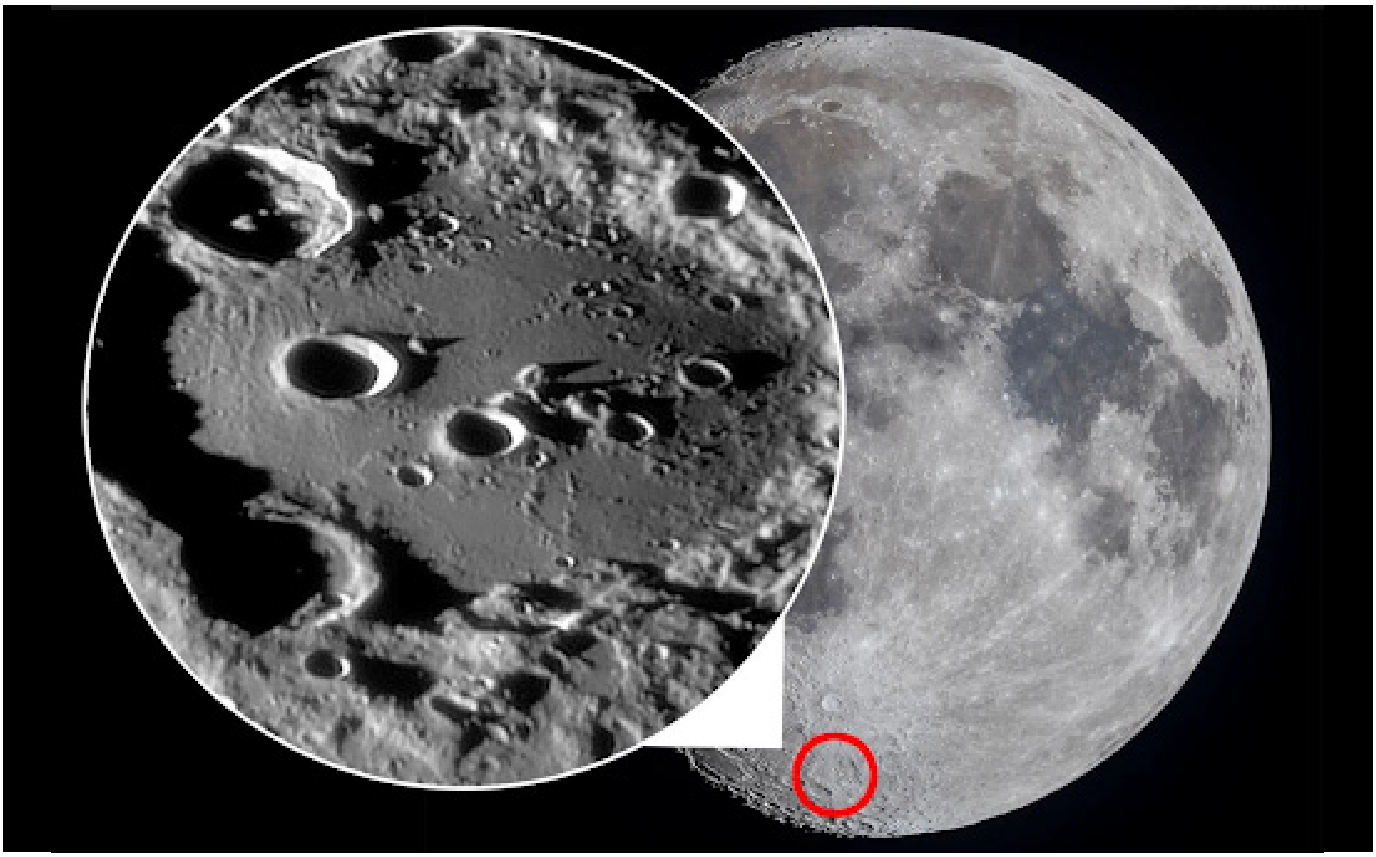
Target Acquired:

Ice Shadows on the Moon



The surface of the **Moon** is 100 times dryer than the Sahara desert, and yet, we have found ice in shadows at its south pole. Humans need water to survive, so finding ice on the Moon would be a big help for astronauts: instead of wouldn't bringing it themselves, they'd just have to find it, melt it, and purify it.

Your mission, should you choose to accept it, is to design a mission to find and map the location of ice on the Moon's surface.

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Target Acquired:

Titan: Strange Atmosphere

Titan is Saturn's largest moon, and the only moon in the solar system with a stable atmosphere. Unlike Earth's atmosphere, however, the gases on Titan are not breathable. They also block our view of Titan's surface. With the help of radar, scientists have found that there is liquid on Titan's surface!

Your mission, should you choose to accept it, is to design a mission to travel to Titan and explore this strange atmosphere, and the surface that lies below.

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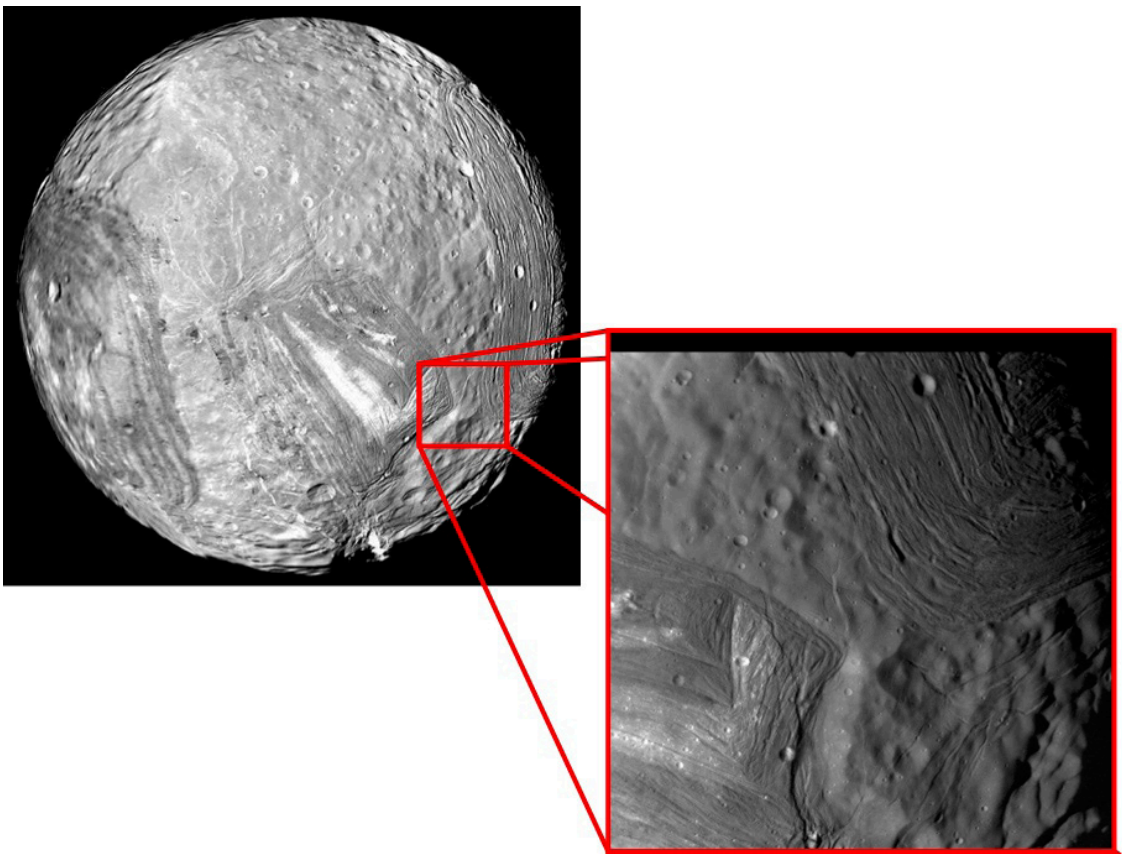
Target Acquired:

Mountains on Miranda?



Miranda, one of Uranus's moons, is one of the strangest places in the Solar System. The only close look we've had was when Voyager 2 flew by in 1986 — but it still left scientists with lots of questions. It appears to have several kinds of terrain, including ridges, craters, and mountains.

Your mission, should you choose to accept it, is to design a mission to travel to this small moon and get a better sense of what the ground is like and why it's all jumbled up.

Miranda by NASA/JPL-Caltech/Kevin M. Gill, CC BY-SA 2.0

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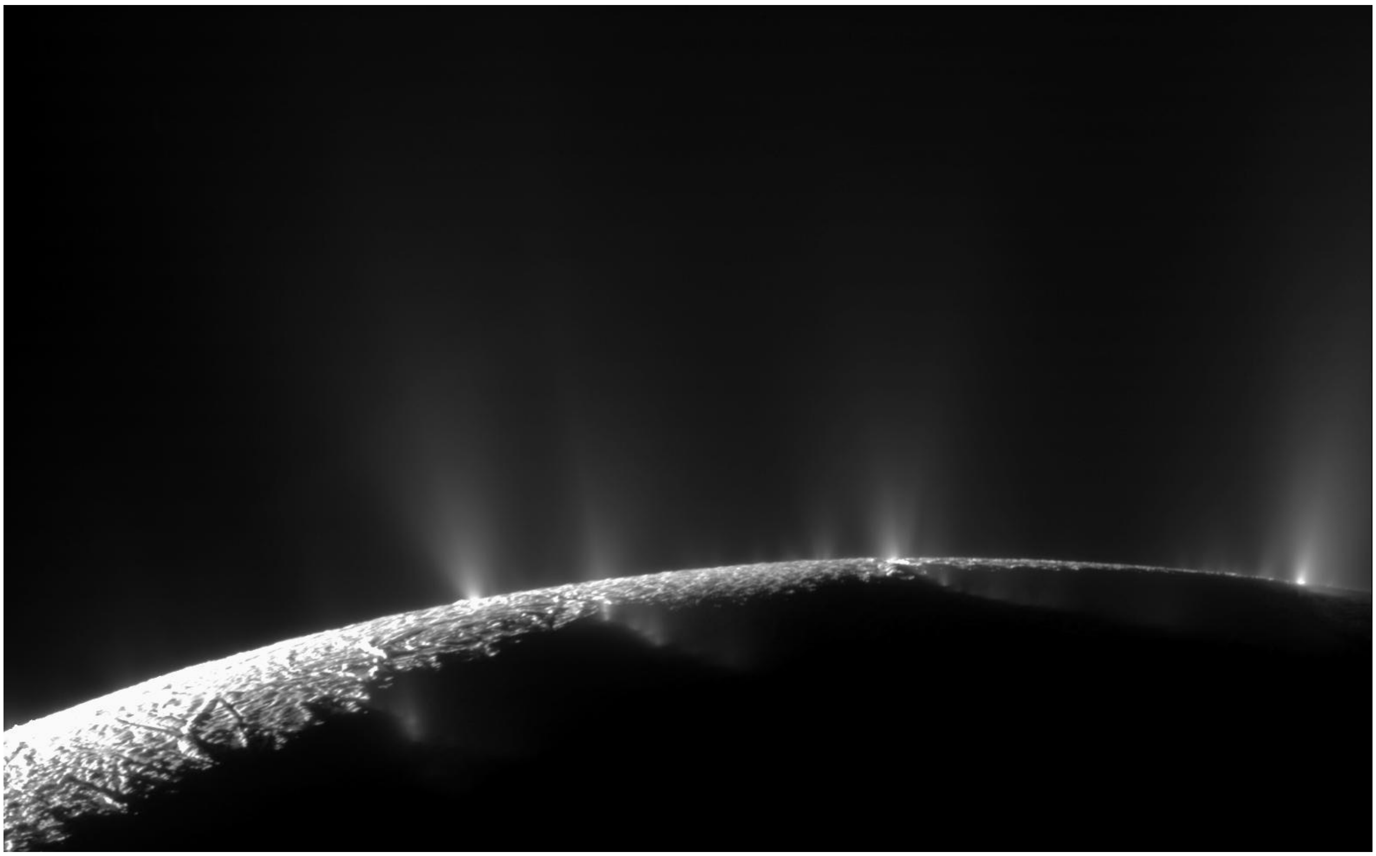
Target Acquired:

Geysers on Enceladus



Enceladus is a moon in orbit around Saturn. The spacecraft Cassini flew over the top and spotted something bizarre happening on its surface: Geysers! A liquid is being launched high up away from the surface.

Your mission, should you choose to accept it, is to design a mission to find out if the liquid launching up off the surface is pure water or if there is something else hiding beneath the surface.

Image byNASA/JPL/Space Science Institute

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Mission Control: Mars Rover

You're in the driver's seat of an imaginary Mars mission! Using your surroundings, your imagination, and the help of another person, you will simulate the complex process of moving a rover on a different planet.

Materials

A partner to act as your "rover"
A room or area with lots of open space to move around
A toy or object that your partner will retrieve for "study"
A piece of paper and writing tool for listing steps
A blindfold to cover your eyes

Directions

1. **Create** a safe game space to be the surface of Mars for your rover to explore:
   a. **Pick** an indoor or outdoor space at least 10 feet by 10 feet. Make sure the area is clear of stairs, low tables, or anything that would hurt if your blindfolded rover ran into it.
   b. **Add** safe obstacles to your imaginary Mars scene. A pillow might be a flat rock, a chair might be a crystal formation.
2. **Pick** a toy or object that the rover will study. **Place** the object somewhere in the space, and decide a starting place, or "landing site," for your rover.
3. **Plan** your rover's mission. What task will it accomplish? Try having the rover:
   a. make its way to the object
   b. pick it up
   c. return it to the starting position

4. **Write** the step-by-step instructions you will give to your rover in order for them to successfully complete their mission. Rovers are incredibly powerful and precise tools, but they can't think for themselves—scientists have to plan out their rovers' missions very carefully in advance, long before the rovers are even on the planet they're studying! To simulate this, here are examples of actions your rover might take before it starts moving:

    a. Take 5 steps forward
    b. Turn to the right
    c. Walk for 2 seconds
    d. Turn 30 degrees clockwise
    e. Reach down in front of you
    f. Feel around for the object
    g. Turn around entirely
    h. Crawl, step, or jump

5. **Place** a blindfold on your rover and **position** them at your chosen starting point

6. **Read** out the steps you prepared, in order, for the rover to complete. Scientists practice their commands many times, and change their instructions until it works. If your rover didn't successfully get the object and return to the starting spot, change your instructions and try again! What can you do to make your instructions more effective?

7. **Challenges**: Once you have completed a mission successfully, try:
    a. placing 2 objects in the scene to retrieve and grabbing them both in 1 mission!
    b. adding "tools" like salad tongs, big spoons, or lengths of rope.
    c. timing how long it takes to complete a mission. How quickly can you do it?
    d. completing a mission without having to correct any instructions.

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Current and Upcoming Space Missions (2021)

Stay up-to-date on the latest Solar System news with these online resources about current missions to the Moon, Mars, and Venus, as well as upcoming rocket launches.

Upcoming launches

» **NASA**
Upcoming NASA launches and returns
nasa.gov/launchschedule

» **Space Coast Launch Schedule**
Upcoming rocket launches (mostly NASA) from Florida
spacecoastlaunches.com

» **Spaceflightnow.com**
A regularly updated listing of **planned orbital missions** from spaceports around the globe. Dates and times are given in Greenwich Mean Time. "NET" stands for "no earlier than." "TBD" means "to be determined." Recent updates appear in red type.
spaceflightnow.com/launch-schedule

» **Spaceflight Insider**
Launch schedule for 2021
spaceflightinsider.com/launch-schedule

» **SpaceX**
SpaceX launches only
(Dragon, Starlink, Starship)
spacex.com/launches

Current Moon and planetary missions

» **Mars 2020**
Perseverance rover and Ingenuity helicopter
mars.nasa.gov/mars2020

» **Perseverance**
Perseverance rover Facebook page
facebook.com/NASAPersevere

» **Curiosity**
Curiosity rover Facebook page
facebook.com/MarsCuriosity

» **Emirates Mars Mission**
Hope Orbiter
emiratesmarsmission.ae

» **China National Space Agency**
Various missions, including Tianwen-1 (Mars Rover Mission) and Yutu ("Jade Rabbit") rovers on the Moon
www.cnsa.gov.cn/english

» **European Space Agency**
Various missions, including Venus and Mars orbiters
esa.int