MARS

ONE THOUSAND ONE

EDUCATOR GUIDE

KEY

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Contributors

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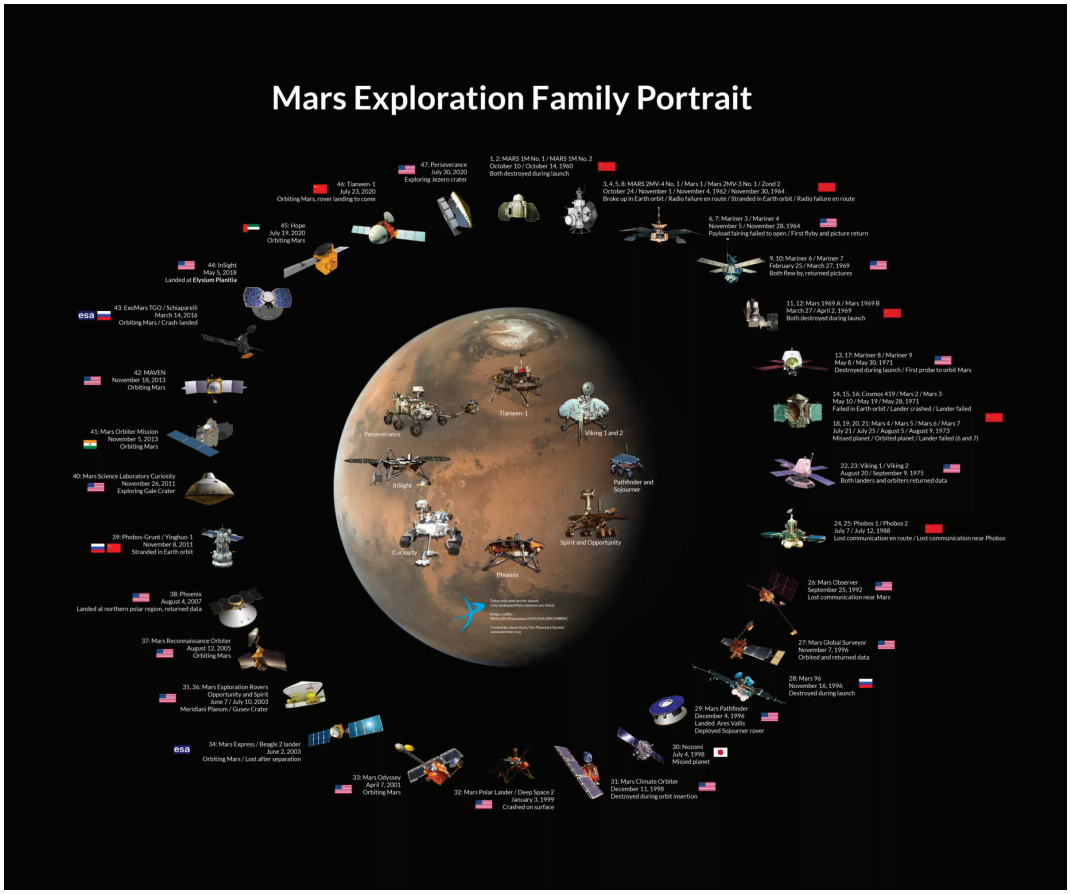
Mars Timeline

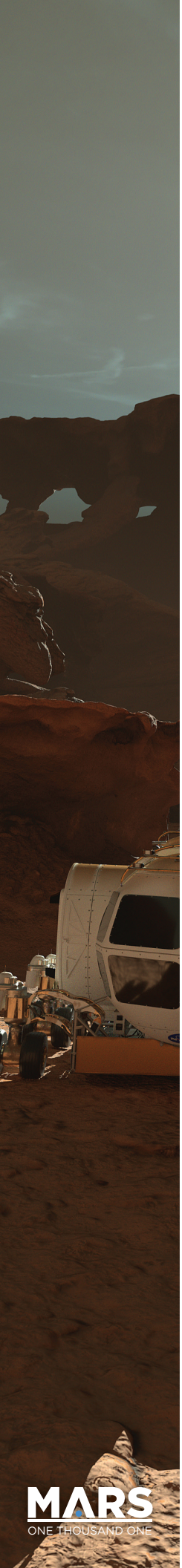
There are more spacecraft on or around Mars than any planet except Earth. Our love of the red planet has its basis in literature and mythology. In addition, if mankind is to live on another surface, Mars or the moon are most likely. After reading through the timeline, answer the questions that follow.

Notes:

1. Unless otherwise noted, all of these are successful US missions.
2. Dates are the dates of the object's time on or around Mars, not its launch date. The ending date is when transmissions from Mars ended.
3. The websites given have photos.

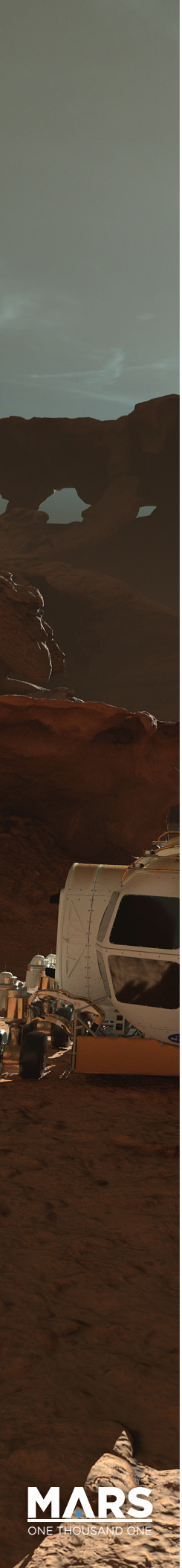


NASA/JPL/Roscosmos/JAXA/ESA/ISRO/MBRSC/Jason Davis/The Planetary Society https://www.planetary.org/space-images/the-mars-exploration-family-portrait This work is licensed under a Creative Commons Attribution-NonCommercial 3.0 Unported License. For uses not allowed by that license, contact us to request publication permission from the copyright holder.



Mars Timeline Continued

Date	Event
1965	**Mariner 4** - first flyby of Mars. https://www.jpl.nasa.gov/missions/mariner-4
1971	**Mariner 9** - first spacecraft to orbit Mars. https://photojournal.jpl.nasa.gov/spacecraft/Mariner%2B9
1976-1980	**Viking 1 and 2** - first landers to safely touch down on Mars. The twin landers looked for signs of life, sent back enough images to create a 3D image of Mars, and found evidence that water had created many features (like deltas). https://www.jpl.nasa.gov/missions/viking-2 https://www.jpl.nasa.gov/missions/viking-1
1997	**Mars Pathfinder** (lander) and **Sojourner** (rover) - analyzed rocks, computed the size of the metal core of Mars, and found water ice clouds https://www.jpl.nasa.gov/missions/mars-pathfinder-sojourner-rover
1997-2006	**Mars Global Surveyor** - the prolongation of its flight allowed it to see daily events. https://www.jpl.nasa.gov/missions/mars-global-surveyor
2001-present	**Mars Odyssey** - longest-lasting spacecraft orbiting Mars. It has helped discover the chemical make-up of Mars and has assisted two of the rovers with communications. https://www.jpl.nasa.gov/missions/mars-odyssey
2003-present	**Mars Express** - European Space Agency's (ESA). Its primary mission is to search for water below the surface of Mars. It launched a lander (**Beagle 2**) which crashed. https://www.esa.int/Science_Exploration/Space_Science/Mars_Express
2004-2018	**Spirit and Opportunity** - twin rovers launched about a month apart to explore the surface of Mars, study its geology, and find out about the history of water. https://www.jpl.nasa.gov/missions/mars-exploration-rover-spirit-mer-spirit https://www.jpl.nasa.gov/missions/mars-exploration-rover-opportunity-mer
2006-present	**Mars Reconnaissance Orbiter** - studies the surface of Mars up to 1.2 miles underground. https://www.jpl.nasa.gov/missions/mars-reconnaissance-orbiter-mro
2008	**Phoenix** lander - landed in the far north of Mars - found water ice and saw snow! https://www.jpl.nasa.gov/missions/phoenix
2012-present	**Curiosity** - rover sent to see if microbial life ever lived on Mars. https://mars.nasa.gov/msl/home/
2014-present	**Maven** - orbiter sent to study the atmosphere to help understand climate change. https://mars.nasa.gov/maven/
2014-present	**Mars Orbiter Mission** (MOM) - India's first space probe orbiting Mars https://www.isro.gov.in/pslv-c25-mars-orbiter-mission
2018-present	**InSight** - first lander to examine the interior of Mars. Its mission is to look at the makeup of the planet's core, crust, and mantle. https://mars.nasa.gov/insight/
2021-present	**Perseverance** - a rover sent to look for life and collect rock samples. Ingenuity, a helicopter, was the first powered flight on Mars. https://mars.nasa.gov/technology/helicopter/ https://mars.nasa.gov/mars2020/
2021-present	**Hope Mars Mission** - United Arab Emirates mission to orbit Mars - first Arab-Islamic mission https://emiratesmarsmission.ae/
2021-present	**Tianwen-1** - orbiter for China's first Mars mission. **Zhurong** is the rover that was launched from Tianwen-1 and is looking for water beneath the surface. https://news.cgtn.com/news/2021-04-24/China-s-first-Mars-rover-named-Zhurong--ZliGQ5pcSQ/index.html



Mars Timeline Continued

Questions:

1. What pattern do you notice in the mission arrival dates?

With the exception of some gaps, the arrival dates are approximately 2 years apart.

2. Why do you think that pattern occurs?

It takes about 2 years for Earth and Mars to get close enough for the missions to increase the likelihood of success for the smallest cost.

3. WNASA launched no missions to Mars from 1976-1996.
   Propose some possible explanations for this.

Answers may vary, but might include limited funding, changed political ideologies, or the perception that little scientific data was sent back from Mars

4. What does NASA propose for the future of Mars?

NASA wants to send humans to Mars in the 2030s.

5. If you were to design a mission to Mars, what would you like to learn?

Answers will vary.

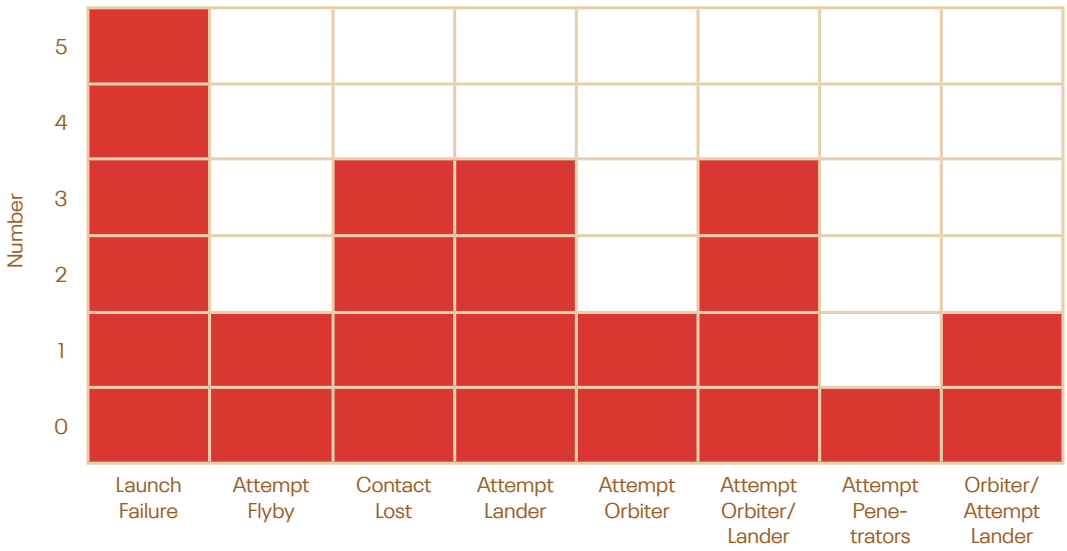
Histogram Activity of Martian Exploration

Step 1: According to NASA's Chronology of Mars exploration, there have been 26 successful missions and 24 unsuccessful missions. What percent were successful and what percent were unsuccessful? http://nssdc.gsfc.nasa.gov/planetary/chronology_mars.html

Number of Successful Missions	Percent Successful	Number of Unsuccessful Missions	Percent Unsuccessful
26	52%	24	48%

Step 2: Based on that same website, below is a table giving the cause of the failure of the unsuccessful missions. Create a histogram (bar graph) for the unsuccessful missions by cause.

Number	Cause
5	Launch failure
2	Attempted flyby
4	Contact lost
4	Attempted lander
4	Attempted orbiter/lander
2	Attempted orbiter
1	Attempted penetrators
2	Orbiter/attempted lander



Histogram Activity of Martian Exploration Continued

Step 3: Answer these questions:

1. Over time, the success rate of the missions has improved. Why do you think that is? Explain your answer.

Answers will vary, but may include that technology has improved, that practice makes perfect, etc.

2. What nations/space agencies have successfully orbited a robot around Mars?

USSR (Russia), USA, JAPAN, ESA, INDIA, UAE, CHINA

3. What nations/space agencies have successfully landed a robot on Mars?

USA, CHINA

Mars Quick Guide

In 1781, Uranus became the first planet to be discovered with a telescope. Prior to that, people only knew as much about each planet as they could see with the naked eye. Mars, known as the Red Planet because of its coloring, was named for the Roman god of war. It is the fourth planet from the Sun.

Like all planets, Mars has an elliptical orbit. An ellipse is a geometric figure that has two center points, called foci, whereas a circle has one central point.

Because the orbit is not perfectly round, Mars can be as little as 206.7 million km (128.4 million miles) or as far as 249.2 million km (154.8 million miles) from the Sun. Its average distance is 227.7 million km (141.5 million miles).

According to https://mars.nasa.gov/internal_resources/815/, depending on how close Earth and Mars are, radio signals take between 2½ minutes and 20 minutes to travel one way between the planets.

Mars and Earth have very different atmospheres.

Earth's Atmosphere	Mars's Atmosphere
Nitrogen 78%	Carbon Dioxide 95.3%
Oxygen 21%	Nitrogen 2.7%
Argon 0.9%	Argon 1.6%
Other Gases 0.1%	Other Gases 0.4%

Mars's gravity is 38% of ours and its mass is 1/10 of ours which helps to explain why its atmospheric pressure is less than 1/100th of Earth's. Mars is also much colder. Why do you think that is? On Earth, temperatures range from 56.7°C to -94.4°C or 134°F to -138°F. On Mars, however, temperatures range from 27°C to -128°C or 80°F to -199°F. Which planet has a wider temperature range?

Mars Quick Guide Continued

Here's a quick comparison of Earth and Mars.

	Earth	Mars	Notes
Diameter	40,075 km or 24,901 miles	6,780 km or 4,217 miles	About ½ the size of Earth (about twice the size of our moon)
Axis Tilt	23.43 degrees	25.19 degrees	Similar seasons, although Mars's seasons are about twice as long because its year is about twice as long
Day	23 hours, 56 minutes	24 hours, 37 minutes	
Year	365 days	687 Earth days	
Average Distance from the Sun	152 million km or 94.4 million miles	227.7 million km or 141.5 million miles	
Highest Point	Mt. Everest 8,848 meters or 29,029 feet	Olympus Mons 27,000 meters or 84,480 feet	Olympus Mons covers an area about the size of Arizona.
Deepest Canyon	Yarlung Zangbo Grand Canyon in Tibet 5,300 meters or 17,490 feet	Valles Marineris 10,000 meters or 31,680 feet	If you superimposed Valles Marineris on a map of the USA, it would run from New York City to San Francisco.
Moons	Luna, diameter: 3,475 km or 2,159.2 miles	Phobos's diameter 22.5 km or 14 miles	Phobos (meaning fear) and Deimos (meaning terror) are names for the sons of the Greek god of war, Ares

Earth, Mars, and Titan: Similarities and Differences

Step 1: For each fact below, use the following choices and place the letter that best applies to the statement in the blank provided to the left of the number.

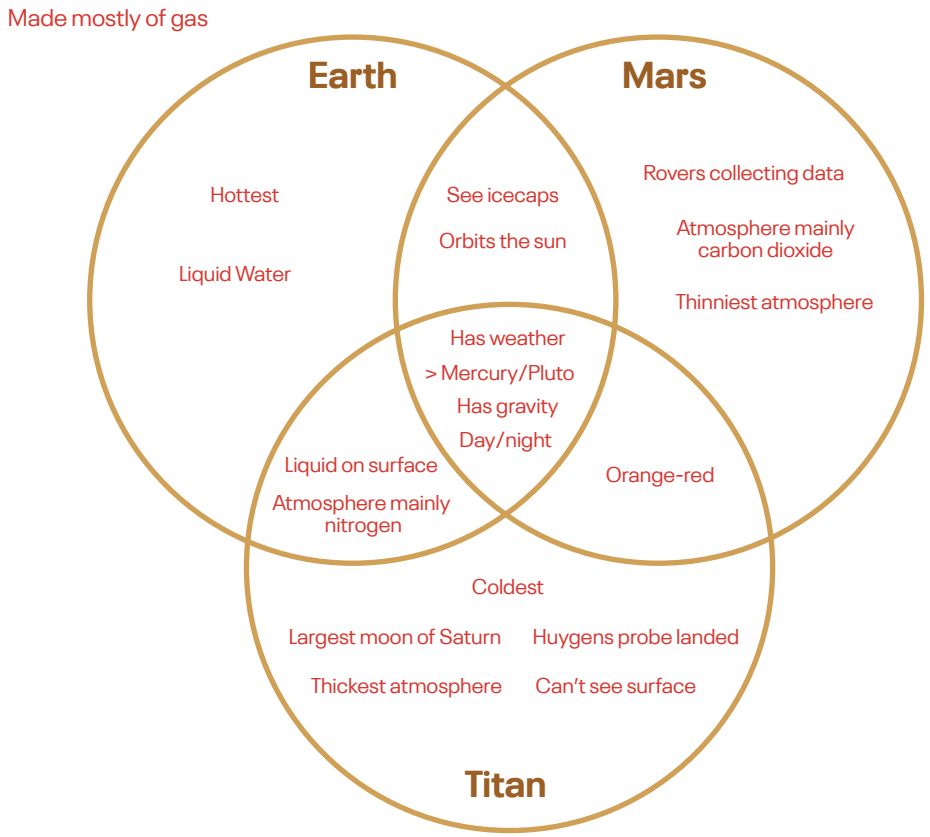
A	Earth only	**E**	Earth and Mars
B	Mars only	**F**	Mars and Titan
C	Titan only	**G**	Earth and Titan
D	All three	**H**	None of them

For example, given the statement, "It has an atmosphere."; you'd respond, "D", applies to all three (Earth, Mars and Titan), since all three have an atmosphere of some sort.

G 1. It has liquid on its surface now.
G 2. It has an atmosphere composed mostly of nitrogen.
D 3. It has gravity.
C 4. It is the largest moon of Saturn.
C 5. It has the thickest atmosphere.
B 6. It has rovers like Curiosity collecting data on its surface.
E 7. You can see its icecaps.
B 8. It has the thinnest atmosphere.
D 9. It is larger than Mercury and Pluto.
C 10. It was landed on by the Huygens probe in January 2005.
A 11. It is the hottest of the three.
C 12. It is the coldest of the three.
A 13. There is evidence of liquid water on its surface
B 14. Carbon dioxide is the major gas in its atmosphere.
D 15. It has weather.
H 16. It is made mostly of gas.
E 17. It orbits the Sun.
D 18. It has day and night caused by rotation on its axis.
F 19. When seen from space, it is an orange-red color.
C 20. We cannot see its surface from space in visible light.

Earth, Mars, and Titan: Similarities and Differences Continued

Step Two: Develop a three-way Venn diagram that describes the answers obtained above.



Step Three: Based on your answers above, which is more similar to Earth: Mars or Titan? Explain your choice.

Based on this information alone, students may answer either way as long as they justify their reasoning.

Going to Mars

1. Do you want to go to Mars? Create a T Chart. On one side, put what you would miss if you went to Mars. On the other side, put what benefits you would gain if you went to Mars. Remember, you will be gone for a minimum of 4 years. Then write a good paragraph explaining whether or not you would like to go to Mars.

2. Whether or not you want to go to Mars, plan what you would take with you. You are very limited in the amount of space allotted to you personally. You may take no more than 1 cubic meter or 27 cubic feet (a box that is 1x1x1 meter or 3x3x3 feet). The container does not have to be the same dimension on each side, but must take up no additional space). You need to include your clothes, music, books, hobby supplies, etc.

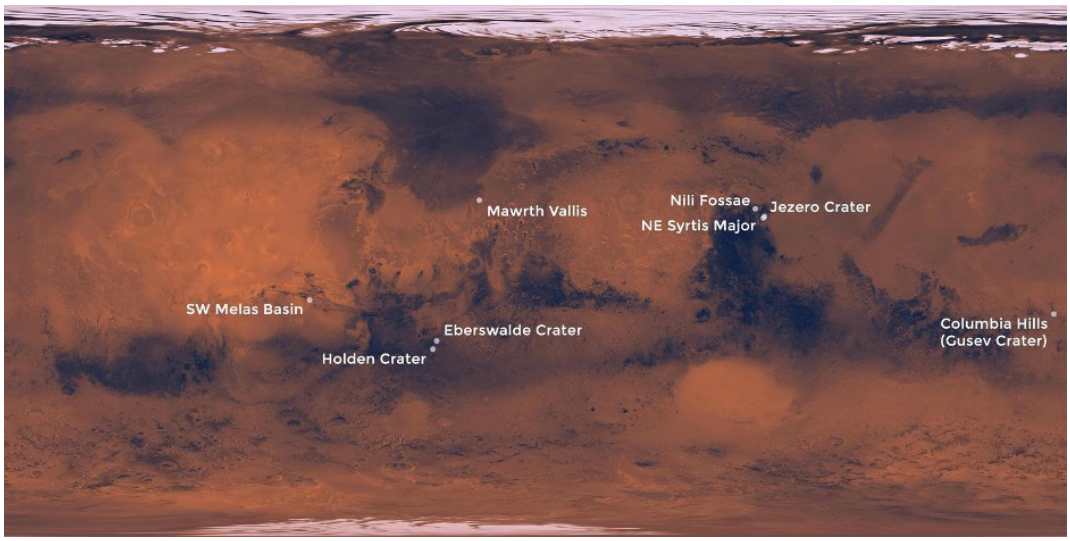
3. If you could choose the name of the rocket that would take you (or others) to Mars, what would it be? What is the meaning of the name? Why did you choose that name? What are 2 other names that could be used? Explain why you think they might be good names.

Going to Mars Continued

4. What supplies/equipment would you need to have on Mars before you or other humans get there? Why?

5. What will you or other people actually do on Mars? Why are these activities important?

Landing Site Selection



https://mars.nasa.gov/resources/landing-sites-under-consideration-for-the-mars-2020-rover/

The Perseverance rover is, of course, safely on the surface of Mars.

Perseverance sent back this image, a remnant from the river delta in Jezero Crater, in March 2021
https://mars.nasa.gov/resources/25695/perseverance-view-of-the-delta-in-jezero-crater/

Landing Site Selection Continued

Back in 2015, NASA scientists and engineers were hot on the question of where to land a rover on Mars in 2021. Eight landing sites made the semifinals.

Use this website to answer the first two questions below.
https://mars.nasa.gov/mars2020/timeline/prelaunch/landing-site-selection/

Questions:

1. What are two main questions that scientists and engineers have to answer?

Students will pick two of the following:
- Can the Mars 2020 rover achieve all of the mission's scientific objectives at this site?
- Does the area show signs in the rock record that it once had the right environmental conditions to support past microbial life?
- Does the area have a variety of rocks and "soils" (regolith), including those from an ancient time when Mars could have supported life?
- Did different geologic and environmental processes, including interactions with water, alter these rocks through time?
- Are the rock types at the site able to preserve physical, chemical, mineral, or molecular signs of past life?
- Is the potential high for scientists to make fundamental discoveries with the samples cached by the rover, if potentially returned to Earth someday?
- Does the landing site have water resources (water ice and/or water-bearing minerals) that the rover could study to understand their potential use by future human explorers?
- Can the rover land and travel from place to place without facing significant hazards posed by the terrain?

2. What features do all of the final 3 candidate landing sites share?

All indicated that they had liquid water there at one time.

3. Why did NASA choose to fly the helicopter Ingenuity on Mars?

Answers will vary, but might include any of the following. By flying a helicopter on Mars, future powered flight missions will be possible. The terrain is rocky, so having a scout for the rovers will prove beneficial. The helicopter can look at sites impossible for a rover, like the sides of cliffs.

4. Upload and describe 5 images from the website https://mars.nasa.gov/mars2020/multimedia/images/ that Perseverance or Ingenuity have taken so far that tell the story of Jezero crater.

As long as the student has uploaded 5 images and described them, they should be deemed correct.

5. Which of the science objectives criteria does your chosen site meet? In what ways? NASA's science objectives are found here: https://mars.nasa.gov/mars2020/mission/science/objectives/

There are four objectives. Students should tell how their landing site does or does not meet each objective.
a. The first objective, geology, is to study the rocks and landscape to better understand the area's history.
b. The second objective, astrobiology, is to determine whether there has been life in the area or if the area is suitable for life in the future.
c. The third objective, sample caching, is to collect samples of the geologic diversity and to store the samples for later retrieval.
d. The fourth objective, preparing for humans, is to collect information that will help to determine if the site is sustainable for human life.

Landing Site Selection Continued

Next consider sending another rover to Mars.

6. Put the "Key Questions for Deciding on the Mars 2020 Rover's landing Site" in order of their importance to you in deciding on your landing site selection and explain your reasoning. https://mars.nasa.gov/mars2020/timeline/prelaunch/landing-site-selection/

Students should put these statements in an order of their choosing and explain their reasoning
- Can the Mars 2020 rover achieve all of the mission's scientific objectives at this site?
- Does the area show signs in the rock record that it once had the right environmental conditions to support past microbial life?
- Does the area have a variety of rocks and "soils" (regolith), including those from an ancient time when Mars could have supported life?
- Did different geologic and environmental processes, including interactions with water, alter these rocks through time?
- Are the rock types at the site able to preserve physical, chemical, mineral, or molecular signs of past life?
- Is the potential high for scientists to make fundamental discoveries with the samples cached by the rover, if potentially returned to Earth someday?
- Does the landing site have water resources (water ice and/or water-bearing minerals) that the rover could study to understand their potential use by future human explorers?
- Can the rover land and travel from place to place without facing significant hazards posed by the terrain?

7. Assuming that NASA keeps the remaining seven sites under consideration for future Mars missions, which one would you choose to send a rover to in the future? Use the following website to research the remaining possibilities. Do not include the Jerezo Crater as this is the one that NASA has already sent Perseverance to. https://mars.nasa.gov/mars2020/timeline/prelaunch/landing-site-selection/eight-potential-sites/

Answers will vary. Look for logical arguments

8. Pictures, please! What makes your selected site so appealing visually? When in the landing site selection meeting for Apollo XV, Commander Dave Scott pointed out that "one should be aware of grandeur". With that in mind, make the case for your site and include at least three interesting images! Use the search feature of the NASA photojournal site, and type in the name of your feature in the top search box https://photojournal.jpl.nasa.gov/Help/PIADetQuery.html

Answers will vary, but students should upload at least 3 pictures and explain why their site should be chosen.

Finally, think about a human mission to Mars.

9. What criteria would be important for a human mission landing on Mars?

Most of the same criteria identified in question 6 apply, with the possible addition of radiation protection/shielding and a nearby supply of frozen or underground liquid water.

10. Based on the criteria you selected in question 9, would the landing site you chose be a good one for human explorers? Why or why not?

Answers will vary. Look for logical arguments.

Extension: Using what you've learned in this investigation, can you identify another good landing site for humans?

Ice as a Mineral

Mars has a great deal of surface ice, which human explorers will probably harvest to use as a ready supply of water.

Practical Note: The properties of ice change rapidly at room temperature. Leave the ice in the freezer as long as possible.

Safety Note: When doing this lab, please wear safety glasses, especially when hammering!

Part One: Field Hardness Test:

Hardness is defined as resistance to scratching.

Materials: Refrigerated butter pat, frozen nail, frozen OLD penny (prior to 1980, so there is no zinc in the penny), unpolished fingernail (still attached to one's finger), block of Ice (bigger is better).

Step 1: Fill a large baggie 2/3 full of water (>1 Liter), then freeze it 48 hours prior to beginning this activity. Put the penny and the nail in the freezer at the same time.

Step 2: Hypothesize which materials will scratch the ice by writing "yes" or "no" in the table below. Note: The numbers next to each tool indicate their hardness on Moh's Hardness Scale.

Refrigerated Butter (1)	Fingernail (2)	Frozen Penny (3)	Frozen Nail (5)
NO	NO	YES	YES

Step 3: Assemble the test materials. Try to scratch the ice with each test material (butter, nail, penny, fingernail).

Step 4: Fill in the data sheet below by writing "yes" or "no" to indicate if each of the tools scratched the ice. Note: The numbers next to each tool indicate their hardness on Moh's Hardness Scale.

Items	Notes (include whether or not you were correct in your hypotheses)
Refrigerated butter (1)	NO
Unpolished Fingernail (2)	NO
Frozen Penny (3)	YES
Frozen Nail (5)	YES

Ice as a Mineral Continued

Part Two: Answer the Following Questions

1. Based on the data, what is the range of the hardness of ice near its melting point? That is, the range is between the highest number that does not scratch the ice and the lowest number that does scratch the ice.

Between 2 and 3

2. The ice you are using is around 0°C. If the ice were -100°C, would the ice be harder or softer? Explain your answer.

Ice should be harder, but not much, since the basic structure of the ice remains water.

3. What mineral on Moh's hardness scale most closely matches ice?

Gypsum (2) or Calcite (3).

Part Three: Fracture vs. Cleavage

Hit the ice with a hammer **(goggles on)** and immediately observe the fragments.

1. Do the fragments break along smooth, even lines (cleavage), or are the breaks uneven like broken glass (fracture)?

The fragments fracture. Note that the edges will dull rapidly as the ice melts.

Part Four: Extension Activity

Repeat these tests on a block of dry ice (frozen carbon dioxide) - available at many grocery chains or other establishments. **Note: you MUST handle dry ice with gloves.**

Dry ice has a hardness of about 2, so the data table would look the same, except that an unpolished fingernail might scratch the dry ice.

Hydroponics

You may want to use https://www.nasa.gov/mission_pages/station/research/10-074.html to research growing plants in space.

Hydroponics is a way to grow plants without soil. There are a few things you need:

- **Water** - with a pH level around 6–6.5.
- **Oxygen** - Most plants get oxygen from the soil surrounding the roots. Without soil, you will need to leave space between the roots and the water so that the plants can get oxygen from the air or you need to oxygenate the container with an air pump.
- **Root Support** - Roots need something to hold on to like peat moss or coconut fiber. Don't use sand, which might become compacted, or gravel which won't retain moisture.
- **Nutrients** - Plants need nutrients which they usually get from the soil, but you can add the nutrients to the water you use. Look up what nutrients your plants will need.
- **Light** - either natural or artificial.

According to https://astrobotany.com/plants-grown-in-space/, the following plants have been grown in space. After looking over the list, answer the questions that follow.

Year	Type (Research, Sustenance, Ornamental)	Plant Name	Spacecraft
1973	Sustenance	Rice	Skylab
1982	Research	Arabidopsis thaliana (thale cress)	Soviet Salyut 7
1995	Sustenance	Wheat	MIR
1997	Research	Brassica rapa (includes turnip and bok choy	MIR
1999	Research	Ceratopteris richardii (triangle water fern)	Columbia
2002	Sustenance	Tomato	ISS
2002	Sustenance	Spinach	ISS
2002	Sustenance	Pepper	ISS
2010	Sustenance	Mizuna Lettuce	ISS
2012	Sustenance	Zucchini	ISS (grown in a Ziplock plastic sandwich bag)
2012	Sustenance	Sunflower	ISS
2015	Sustenance	Red Romaine Lettuce	ISS
2016	Ornamental	Zinnia	ISS
2018	Research	Brachypodium distachyon (purple false brome)	ISS
2018	Sustenance	Broccoli	ISS
2019	Research	Cotton	Chang'e-4 (on the surface of the moon)
2020	Sustenance	Radish	ISS

Hydroponics Continued

1. Rank the type of plant (research, sustenance, ornamental) in order of importance. Why have each type been grown?

Answers will vary.

2. Which plant did you expect to see on the table that was there? Which plant surprised you the most? Explain your answer.

Answers will vary.

3. Which plant would you like to see grown in space? Why?

Answers will vary.

4. Why are scientists looking at growing plants hydroponically on Mars?

Because hydroponics allows for more control of the growth process and targeting resources will minimize waste.

5. Think about the purpose of plants. They provide us with many needed things. What do you think the first plants grown on Mars should be? Be specific. Why did you choose those plants?

Answers will vary, but should include mention of oxygen production and nutrients gained.

Selected Resources

Below is a list of resources you may want to use to extend or co-teach your lessons. There are both fiction and nonfiction works listed. As always, before sharing any of these resources with your students, preview them. Some contain mature language/ideas/visuals.

Books

Welcome to Mars: Making a Home on the Red Planet (nonfiction) by Buzz Aldrin & Marianne Dyson
Curiosity: The Story of a Mars Rover (nonfiction children's book) by Markus Motum
The Martian Chronicles (fiction) by Ray Bradbury
Stranger in a Strange Land (fiction) by Robert Heinlein
John Carter of Mars series (fiction) by Edgar Rice Burroughs
The Fated Sky (fiction) by Mary Robinette Kowal
Before Mars (fiction) by Emma Newman
Mission To Mars (nonfiction) by Buzz Aldrin
The Martian (fiction) by Andy Weir
The Case for Mars (nonfiction) by Robert Zubrin

Films & TV

The Martian
The Right Stuff
Apollo 13
Gravity
Mars Attacks!
The Simpsons: Deep Space Homer

Music

Blue Telescope by John Hiatt
Theme from Mission Impossible composed by Lalo Schifrin
Variations on Twinkle, Twinkle Little Star
OK Computer by Radiohead
Space Oddity by Davie Bowie
Is There Life on Mars? by David Bowie
Don't Stop Me Now by Queen
Rocket Man by Elton John

TED Talk

How We'll Live on Mars by Stephen Petranek

TikTok

NASA's Perseverance Rover
Perseverance Rover
First Sounds from Mars

Bibliogaraphy

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https://www.planetary.org/space-images/the-mars-exploration-family-portrait
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