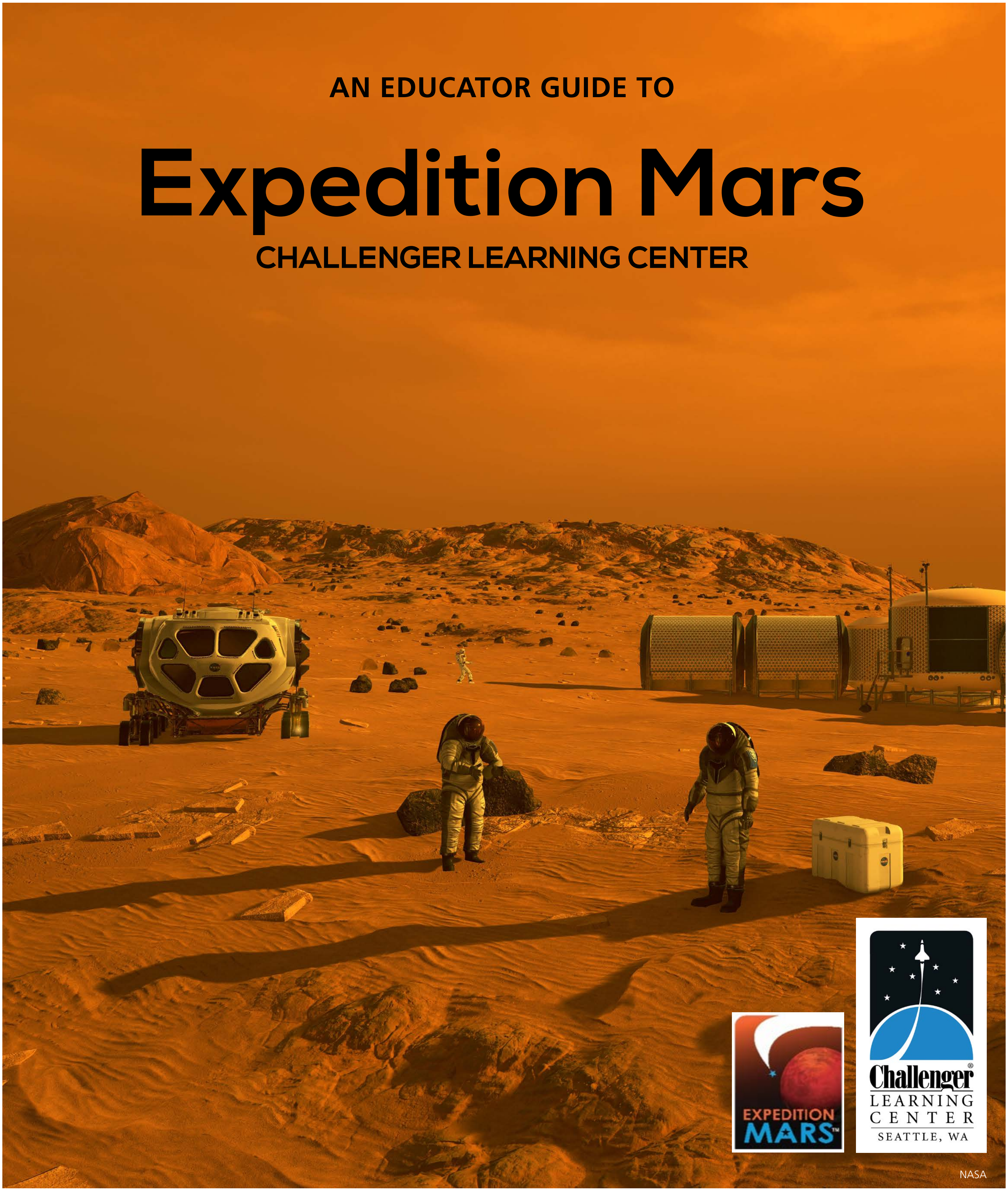
AN EDUCATOR GUIDE TO

Expedition Mars

CHALLENGER LEARNING CENTER



NASA

EXPEDITION MARS™

Challenger® LEARNING CENTER SEATTLE, WA

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UPDATED 1.2023

OVERVIEW

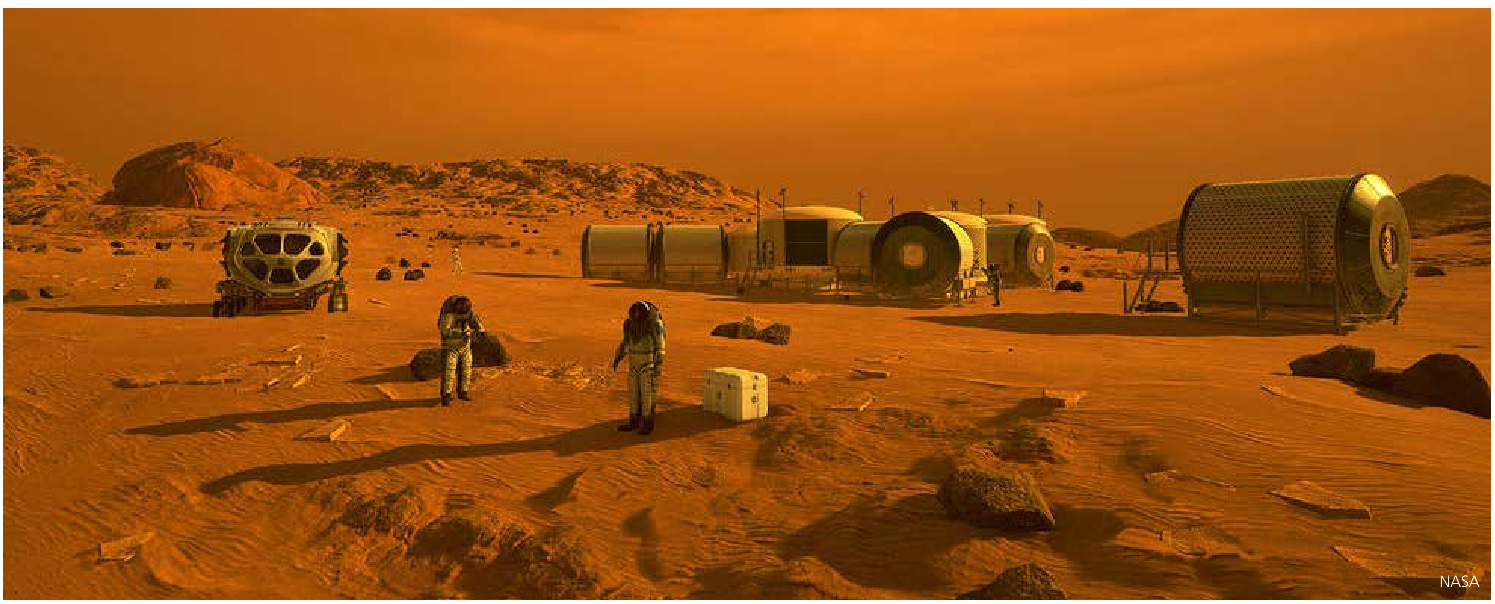
As far as we can recall, setting up a base on Mars has always been mankind's dream. Now, in the year 2076, this has become reality! Our Challenger Learning Center simulation-based learning experience will transform your students into NASA scientists and engineers with a single common purpose — the success of the mission! Essential skills including teamwork, communication, problem-solving, reading comprehension, interpreting visual information, and more will be put to the test in our mission in search of life and water on the surface of Mars.

MISSION STORYLINE

The year is 2076. A handful of facilities have been established on Mars, including a greenhouse, a mobile geological survey base, and a centralized research habitat. The primary human habitat is not on Mars, but on one of its moons, Phobos! A large Spacecraft regularly ferries astronauts and scientists between the base on Phobos and the surface of Mars. This Shuttle, or Mars Transport Vehicle (MTV) carries parts to build a remotely operated vehicle (ROV) needed to continue the search for the evidence of life and water. However, when crew members discover an imminent threat to their MTV and the Martian surface facilities, they must act quickly to save their stations, their research and their lives.

During their visit to the Challenger Learning Center, your students will be broken into 2 groups:

- **Mission Control (MC):** Located on Phobos, 9 teams of students will work on current Martian research, analyze data from the surface of Mars sent by their peers in the Mars Transport Vehicle and protect the astronauts by taking critical decisions in case of emergencies
- **Mars Transport Vehicle (MTV SC):** Flying to the surface of Mars, 9 teams of students will investigate the characteristics of minerals to discover if any were formed in water, build and program the Remote Operated Vehicle (ROV), check vital signs and radiation levels of crew members and test Oxygen levels in Martian soil.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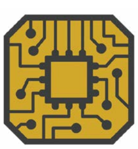
MISSION OBJECTIVES

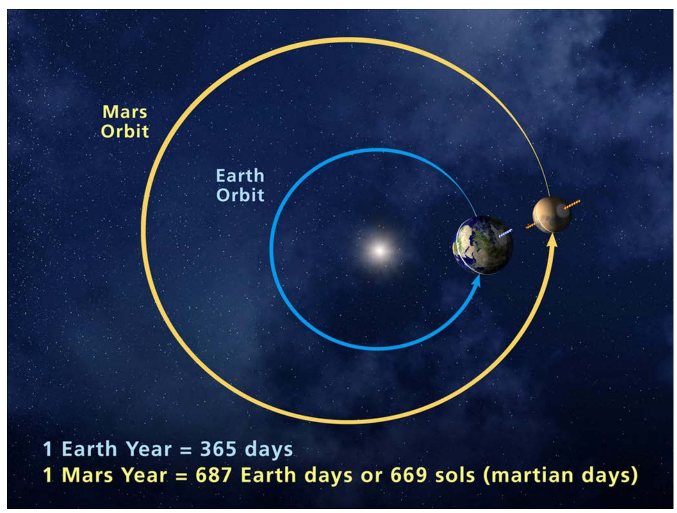
1. Students will search for evidence of life on Mars, whether fossilized or living.
2. Students will search for evidence of water by launching a ROV on Mars.
3. Students will perform their assigned tasks to ensure their mission is successful and the crew remains safe.

TEAM OBJECTIVES

	**Biology**	• Description: tests soil to determine the presence or absence of microbes; checking the Spacecraft for signs of beneficial or harmful bacteria. • Skills: following procedures, observation, graphing, drawing conclusions.
	**Robotics**	• Description: plans the path of the ROV using maps; participates in engineering the robot arm for future space missions. • Skills: spatial awareness, computational thinking, basic programming.
	**Communications**	• Description: provides communication support between Mission Control and Spacecraft; manages both events and emergencies. • Skills: reads well, assertive, calm under pressure, organized, able to multitask, leadership.
	**Geology**	• Description: examines different Martian rocks for key elements and minerals; researches and maps possible dig sites for important minerals. • Skills: strong observations abilities, hand-eye coordination, patience, follows procedure.
	**Life Support**	• Description: monitors the Environmental Control and Life Support Systems (health and safety of the crew and the Spacecraft). • Skills: reading gauges, following procedures, calm under pressure, strong observation skills.
	**Medical**	• Description: monitor the health of the crew, and run various health related tests on team members. • Skills: interacts well with others, patience for repetitive tasks.
	**Navigation**	• Description: calculates and plots the course of Spacecraft to reach Mars from Phobos and perform critical pre-flight checks. • Skills: complete multi-step math problems; strong hand-eye coordination, collaborative.
	**Rover**	• Description: builds and tests a remotely operated vehicle (ROV) to search Mars for signs of water, installing critical equipment, and retrieving data. • Skills: collaborative, perform basic math, closely follow instructions, calm under pressure.
	**Weather**	• Description: locates a missing satellite and tracks other celestial objects from across the Martian sky. • Skills: map reading and plotting, basic math, closely follow instructions, analyzing data.

MARS BACKGROUND

- **Age:** Like the rest of the planets in our solar system, Mars is believed to have formed around 4.5 billion years ago.
- **Formation:** When the solar system settled into its current layout about 4.5 billion years ago, Mars formed when gravity pulled swirling gas and dust in to become the fourth planet from the Sun.
- **Origin of the name Mars:**
  - » Mars was named by the ancient Romans for their god of war because its reddish color was reminiscent of blood. Other civilizations also named the planet for this attribute; for example, the Egyptians called it "Her Desher," meaning "the red one." Even today, it is frequently called the "Red Planet" because iron minerals in the Martian dirt oxidize, or rust, causing the surface to look red.
  - » Phobos and Deimos were discovered in 1877 by Asaph Hall and were named after the Greek mythological twin characters Phobos (fear) and Deimos (terror and dread) who accompanied their father Ares into battles. Ares, god of war, was known to the Romans as Mars.
- **Distance:**
  - » From the Sun: Mars is the fourth planet and orbit our Sun at an average distance of about 228 million km (142 million miles) or 1.52 AU.
  - » The distance between the Earth and Mars differs a lot, because Earth's orbit is smaller than Mars's. Imagine two cars on a racetrack, with the Earth on the inside and Mars on the outside. Sometimes Mars passes right next to Earth, and sometimes it's on the other side of the sun! When Mars and Earth are close, they're about 33.9 million miles (54.6 million km) apart. The farthest apart, they can be is about 249.2 million miles (401 million km). The planets pass each other every two years, which is why we have specific launch windows for new Mars spacecraft! We want to make sure that they travel the shortest distance possible.
  - » Phobos and Deimos have a relative short distance from mars making them such good Mars base locations. It might take less than a half-hour to get from one to the other!
    - · Phobos is the closest orbiting moon to any planet in the solar system, and orbits only 3,700 miles (6,000 kilometers) above the Martian surface.
    - · Deimos is much farther away, at 14,580 miles (23,460 km), but is still relatively close.
- **Size:**
  - » Mars is about half the size of Earth, at 4,196 miles (6,752 kilometers) in diameter which is about as much surface area as all of the dry land on Earth.
  - » Phobos and Deimos are extremely small, especially compared to our moon. Phobos has a diameter of 13.8 miles (22.2 kilometers), and Deimos has a diameter of 7.8 miles (12.6 kilometers).
- **Rotation:**
  - » Mars also rotates on its axis once every 24 hours and 40 minutes. So a Martian day is only 40 minutes longer than an Earth Day! But Mars takes 687 Earth days to orbit the sun, so a Mars year is almost twice as long as an Earth year!
  - » Both Phobos and Deimos have "synchronous" orbits, which means that they take as long to rotate on their axis as they do to orbit their planet. So a day on Phobos is about 7 hours and 40 minutes, and a day on Deimos is about 30 hours. This is a good amount of sunlight for machines with solar panels like rovers.
  - » Phobos is so close to Mars that it orbits the planet three times per day! And it's gradually spiraling closer and closer to the planet, and gets about 6 feet (1.8



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WATCH NOW >> Orbits of Mars Express and the Martian moons. This simulation depicts the relative orbits of Phobos, Deimos and Mars Express around the time of the flyby of Phobos on March 7th, 2010.

meters) closer every 100 years. In 50 million years, Phobos will probably either crash into Mars or break up into a rocky ring around Mars, like Saturn and the other outer planets have.

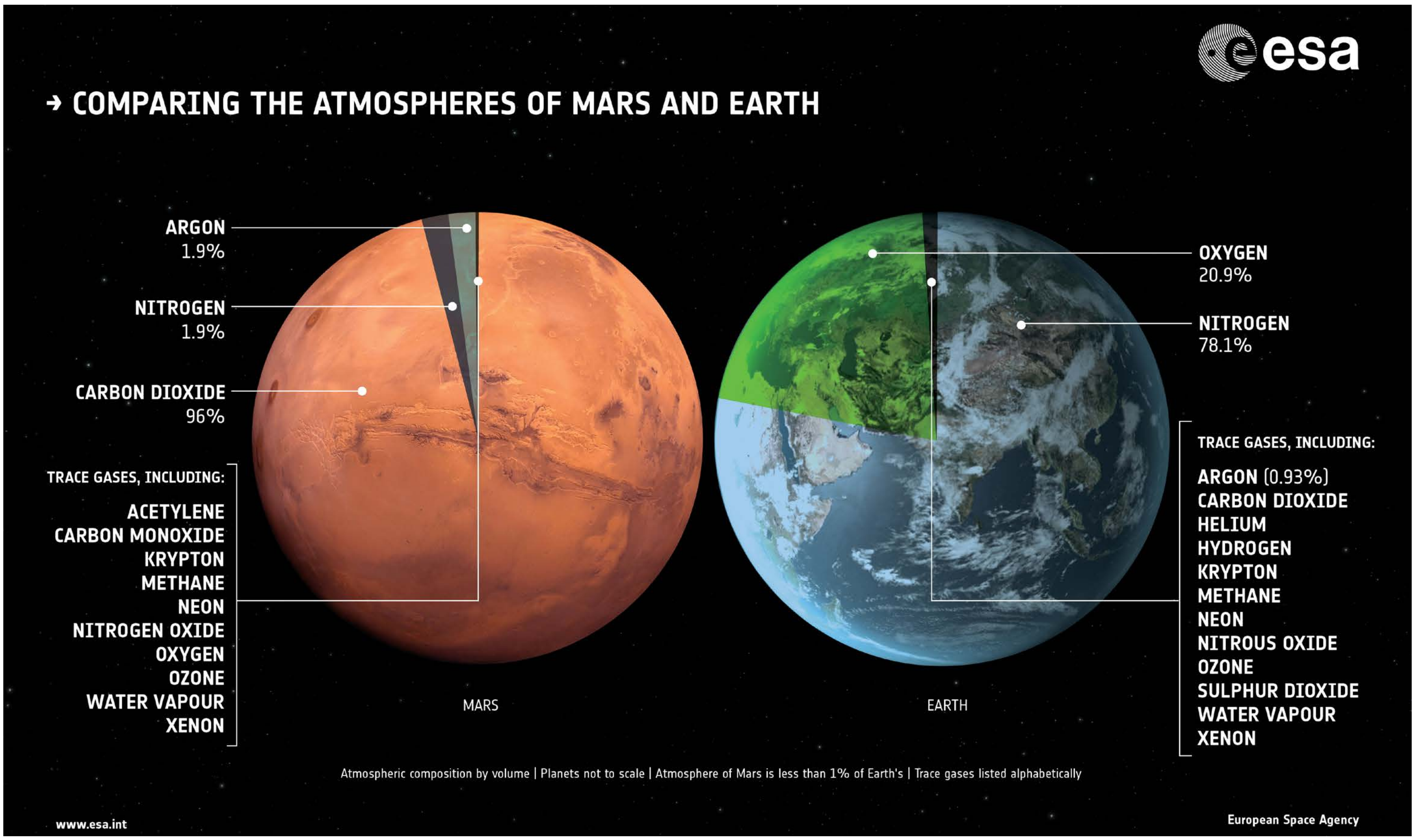
   » Deimos, on the other hand, takes 30 hours to complete one orbit, and seems relatively stable.

- **Atmosphere:**
   » Mars has a very thin atmosphere, with surface air pressure less than 1% of Earth's. No plane on Earth without a rocket engine has ever been designed to fly that high! That's why the Ingenuity helicopter is such a big deal!

   » People can't breathe the air on Mars—its atmosphere is 95% carbon dioxide and the remaining 5% are mainly composed of nitrogen and argon, with trace levels of water vapor, oxygen, carbon monoxide, hydrogen and noble gases.

   » This atmospheric pressure is too low for liquid water to exist on the surface of Mars, but Mars once had a much thicker atmosphere. Over time, Mars's atmosphere has been stripped away by solar winds.

   » Neither Phobos nor Deimos have an atmosphere.

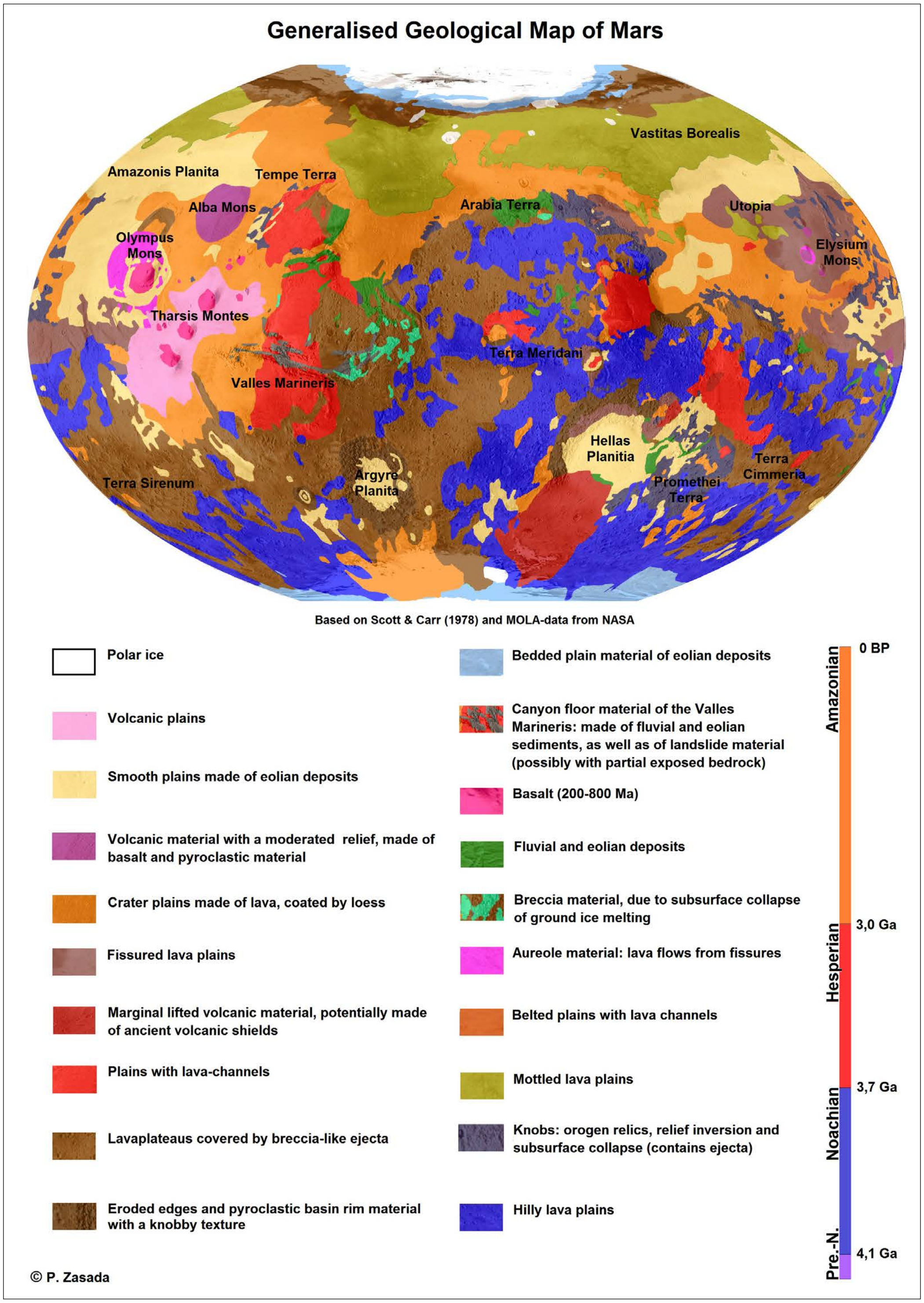


ESA

- **Temperature:**
  - » Mars is further away from the sun than Earth is, which a much thinner atmosphere, so it's quite cold! On average, the temperature on Mars is about -80° Fahrenheit (-60° Celsius). On a summer day near the equator, it may get up to 70° F (20° C), but on a winter day near the pole's temperatures can get down to -195° F (-125° C).
  - » Phobos and Deimos are also very cold, with average temperatures around -40° F (also -40° C.) This ranges from 25° Fahrenheit (-4° C) on the sunlit sides of the moon, and -170° F (-112° C) on the shadowed sides.
- **Gravity:**
  - » Because Mars is so much smaller than the Earth, and also less dense, it has1/3rd Earth's gravity! If you weigh 150 pounds on Earth, you'd weigh 50 pounds on Mars.
  - » Phobos and Deimos are so small that they don't have enough mass or gravity to pull themselves into a spherical shape. This makes them both roughly potato-shaped but also easy to take off from as it does not require much energy.

	Earth	**Mars**
Average Distance from Sun	93 million miles (150 million km)	142 million miles (230 million km)
Length of Year	365 Days	687 Days
Diameter	7,926 miles (13,000 km)	4,220 miles (7,000 km)
Gravity	3x that of Mars	1/3 of Earth
Average Temperature	57℉ (14 ℃)	-80℉ (-63 ℃)
Atmosphere	78% N, 21% O_2	98% CO_2

- **Geology:**
  - » Surface: Mars is a "terrestrial" planet, which means that its surface is very rocky, and has been altered by volcanoes, impacts, winds, crustal movement and chemical reactions.
    - · Crust is between 6 and 30 miles (10 to 50 kilometers) deep and made of iron, magnesium, aluminum, calcium, and potassium.
    - · Mars' red color comes from the iron oxide in the soil. The iron in the soil has been exposed to the carbon dioxide in the atmosphere for such a long time that it has actually rusted. However, this rusty layer is only a few inches deep in most places and if you were to scrape away the Martian soil, you would find a gray planet.
    - · Martian soil is very fine, like a powdery dust. Even though Martian winds are not very strong, it's easy for them to pick up this dust and carry it in massive dust storms that can cover the planet.



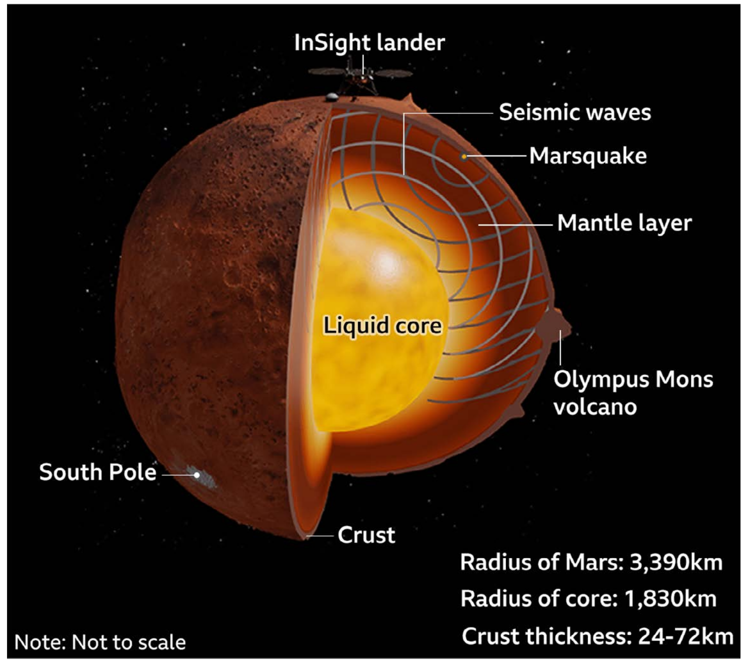
PATRICK ZASADA - VSWD WISS. KOLLOQ (20.9.2013) ABSTRACT

» **Interior:** Mars isn't very geologically active anymore.

· Mars' dense core is probably between 930 and 1,300 miles (1,500 to 2,100 kilometers) in radius. It's made of iron, nickel, and sulfur. It does not spin like the Earth's does. This means that Mars does not have a very strong magnetosphere or magnetic field for protection against the solar wind!

· Surrounding the core is a rocky mantle between 770 and 1,170 miles (1,240 to 1,880 kilometers) thick.

The interior layers of Mars

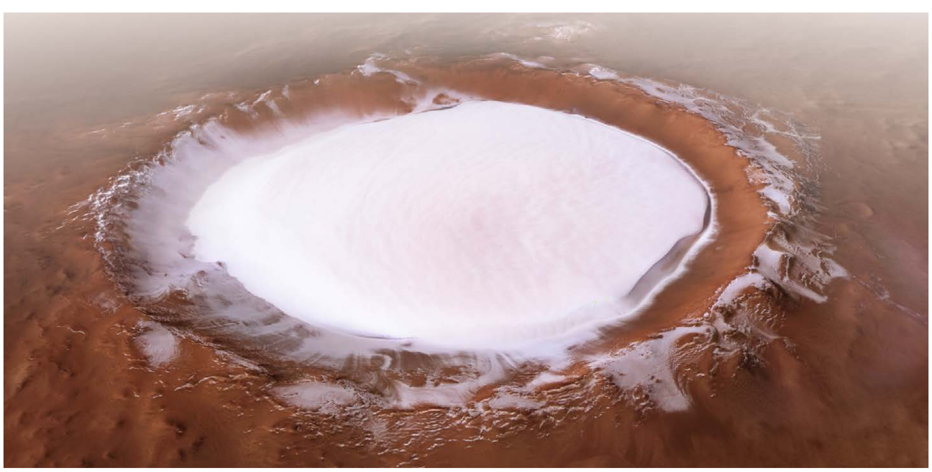


Source: S.Cottaar/P.Koelemeijer/J.Winterbourne/NASA

WATCH NOW >> Video of what might a Mars have looked like billions of years ago with rover's landing sites.

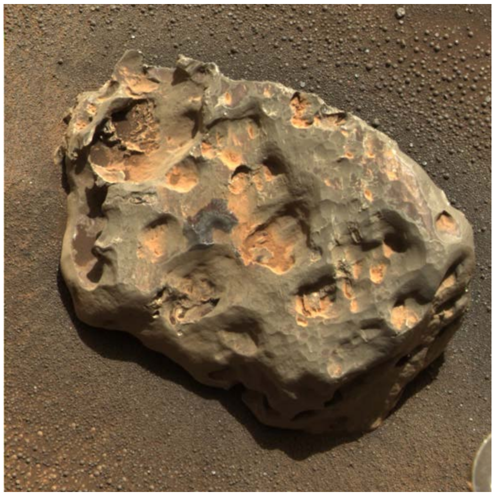
MARS FACTS

- Is there water on Mars?
- Rovers have found evidence of many types of rock that can only be formed in water, which leads scientists to believe that there was once a lot of water on Mars and a thicker atmosphere!
- Mars is home to some of the largest volcanoes in the solar system!
  » Do not worry, scientists have never recorded an active volcano eruption on the surface of Mars, but it is home to Olympus Mons. This volcano is the height of three Mount Everests stacked on top of each other, and is as wide as a mid-sized American state!
  » Mars is also home to a large canyon called the Valles Marineris, which may have been formed by water, ancient geologic activity, or both! It is more than 2,000 miles (3,000 kilometers) long, 370 miles (600 kilometers) wide and 5 miles (8 kilometers) deep.
  » NASA's InSight lander has recorded over 500 quakes to date! 2 types of marsquakes have been noticed. One is more "Earth like" quake were waves travel more directly through the planet, while the "Moon-like" quake tend to be more scattered
- Like other places in our solar system with very little atmosphere, Mars also has its fair share of impact craters from passing asteroids!

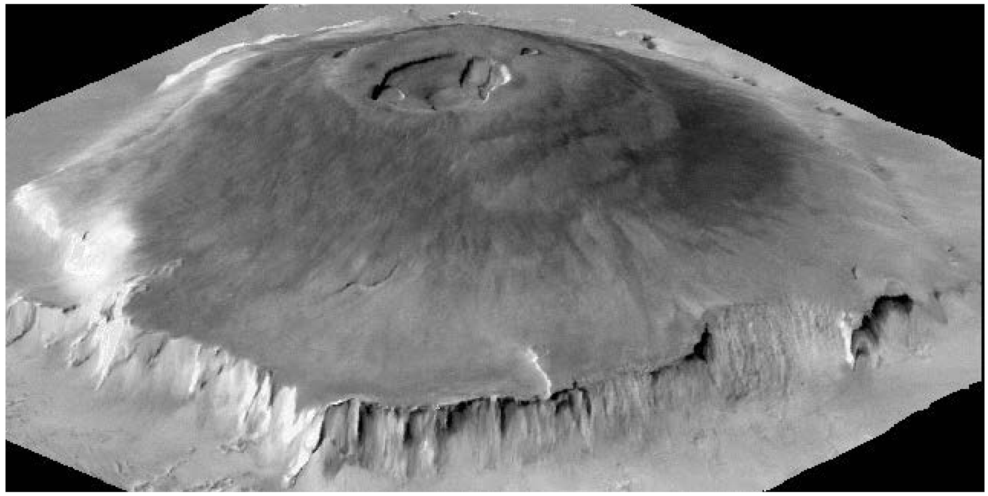


Korolev crater is 82 kilometres across and found in the northern lowlands of Mars. It is an especially well-preserved example of a martian crater and is filled not by snow but ice, with its centre hosting a mound of water ice some 1.8 kilometres thick all year round. (Credit: ESA/DLR/FU Berlin)

Valles Marineris Credit: NASA/JPL-Caltech



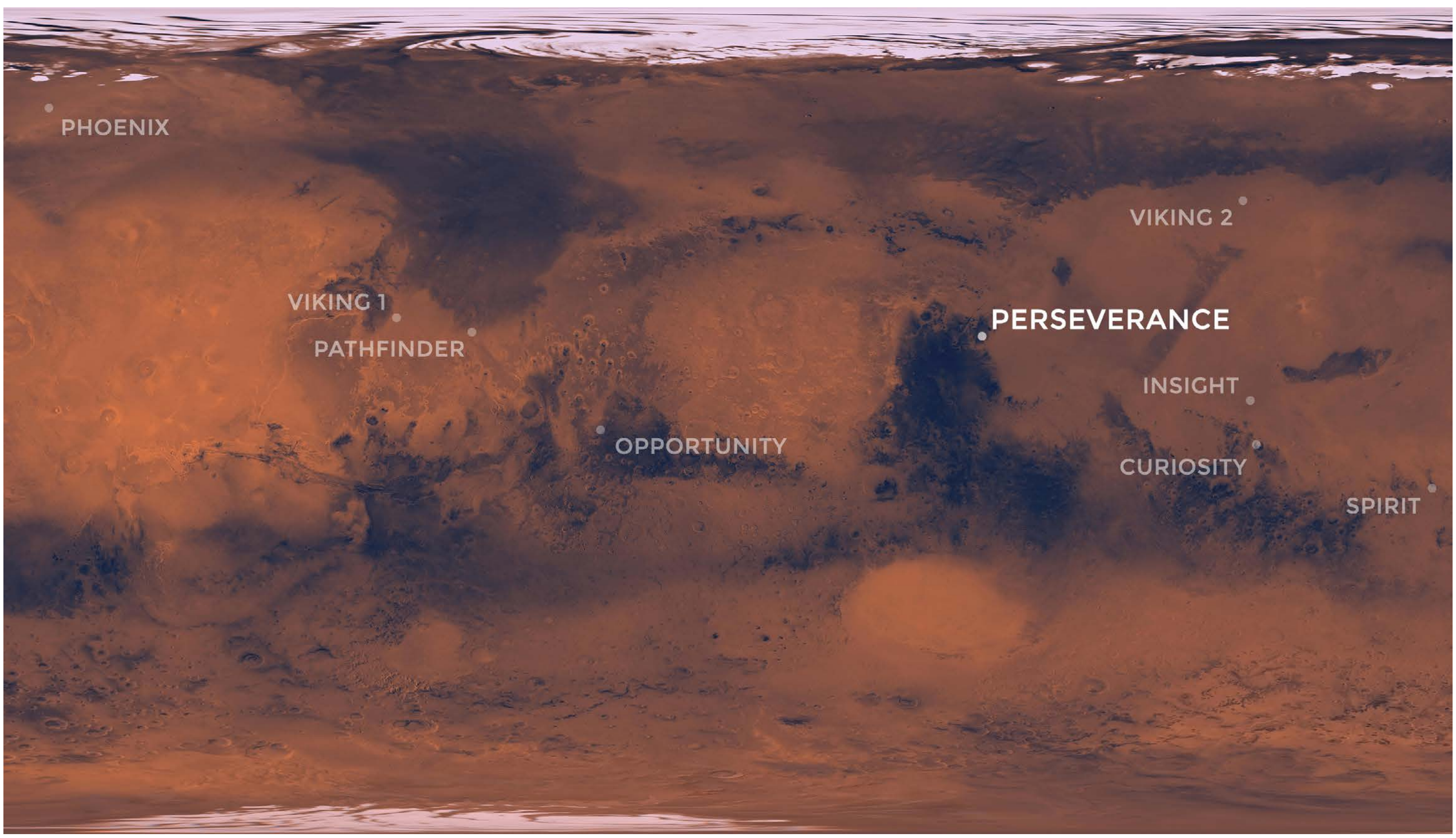
Opportunity found an iron meteorite on Mars, the first meteorite of any type ever identified on another planet. (NASA/JPL-Caltech/Cornell)



Olympus Mons Credit: NASA

EXPLORATION OF MARS CHRONOLOGY *(abbreviated)*

Exploring Mars is a difficult and dangerous feat, and even though most missions seem pretty successful nowadays, over half of all missions sent to Mars since the first in 1960 have failed. Here are just a few of the spacecraft that made it and some of their accomplishments:



This map of the Red Planet shows Jezero Crater, where NASA's Mars 2020 rover is scheduled to land in February 2021. Also included are the locations where all of NASA's other successful Mars missions touched down. (NASA/JPL-Caltech)

Mariner 4. (NASA/JPL-Caltech)

Mariner 4

USA, Flyby | Nov. 28, 1964 to Dec. 20, 1967

The first robotic instrument to successfully visit Mars, which provided 22 close-up photos of the surface of Mars and confirmed a thin carbon dioxide atmosphere. *Mariner 6, 7*, and *9* would go on to take many more pictures of Mars and its moons, orbit the planet, and identify potential water features.

Viking 1. (NASA/JPL-Caltech)

Viking 1 and Viking 2

USA, Orbiters/Landers | Aug. 20, 1975 to Aug. 7, 1980

These two orbiter/lander teams provided detailed color panorama views of Martian terrain, monitored Martian weather, and mapped the surface with over 52,000 images. They were also the first to search for evidence of micro-organisms, and the results of these experiments are still being studied and debated today.

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Mars Global Surveyor

USA, Orbiter | Nov. 7, 1996 to Nov. 2, 2006

A global mapping mission that examined the whole planet, including its atmospheric layers. This helped multiple future orbiter and rover missions, and was in its third mission extension when it finally went into safe mode.

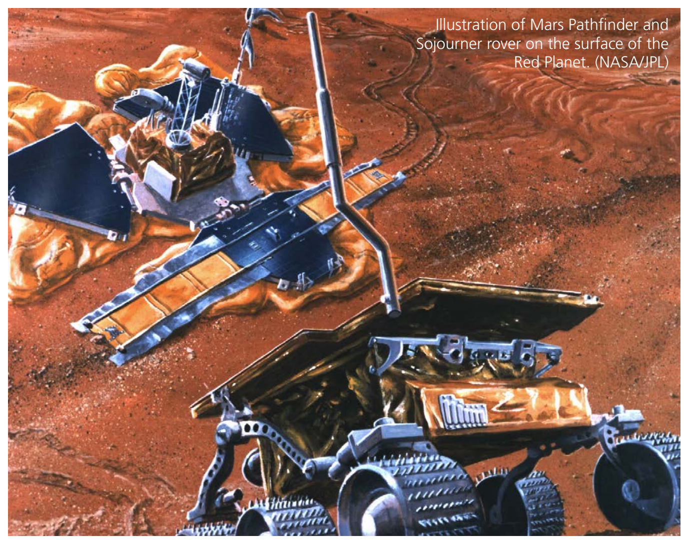
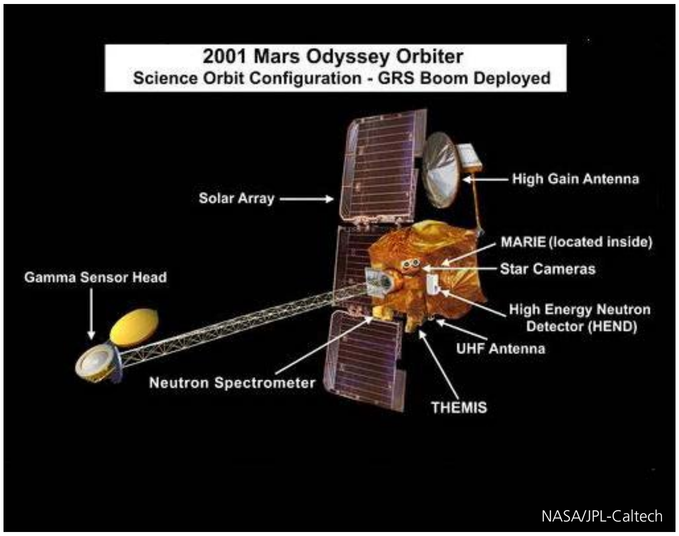


Illustration of Mars Pathfinder and Sojourner rover on the surface of the Red Planet. (NASA/JPL)

Mars Pathfinder and Sojourner

USA, Lander/Rover | Dec. 4, 1996 to Nov. 4, 1997

Pathfinder lander sent more than 16,500 pictures, made 8.5 million measurements of atmospheric pressure, temperature, and wind speed, and helped scientists form theories about a warmer, wetter Mars of the past. *Sojourner* rover was the first rover outside of the Earth-Moon system, and was the size of a small microwave. It took several rock samples, confirmed past volcanic activity, and proved that Mars rovers could be operated remotely.

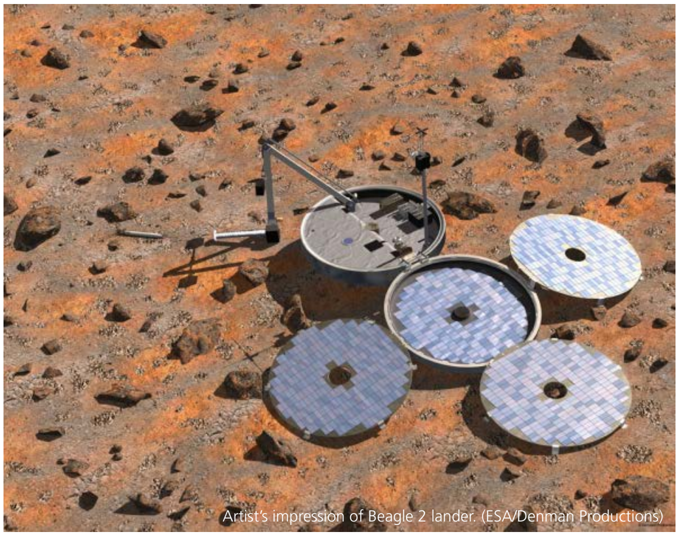


NASA/JPL-Caltech

2001 Mars Odyssey

USA, Orbiter | April 7, 2001 to Present

The longest surviving and continually spacecraft around a planet other than Earth. *Odyssey* mission is to look for evidence of past or present water and ice and study the planet's geology and radiation. It was also the primary relay for surface landers and rovers to Earth, all the way through the *Curiosity* mission.



Artist's impression of Beagle 2 lander. (ESA/Denman Productions)

Mars Express and Beagle 2

Europe, Orbiter/Lander | June 2, 2003 to Present

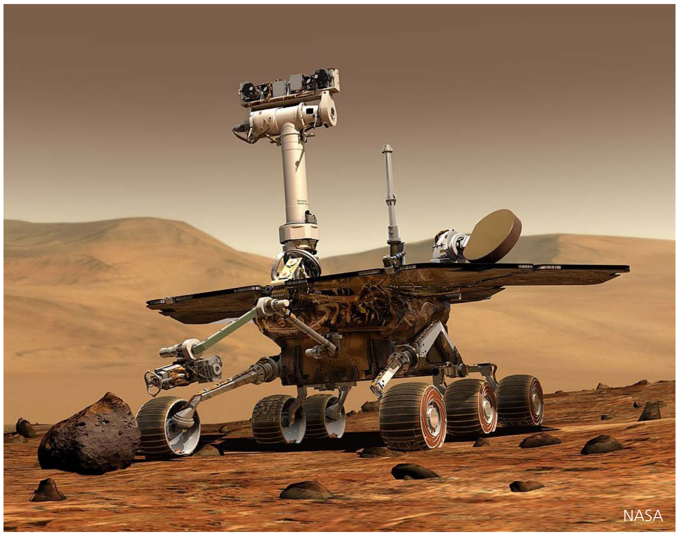
Mars *Express* is the second longest surviving and continually operating spacecraft around another planet, after Mars *Odyssey.* It has provided high resolution images, mapped minerals, used radar to probe the Martian subsurface, and studied the interaction between Mars' atmosphere and outer space. Unfortunately, the *Beagle 2* lander failed to fully deploy.

NASA

Spirit

USA, Rover | June 10, 2003 to March 22, 2010

Part of the Mars Exploration Rover mission with *Opportunity,* this rover was akin to a traveling geologist. It was meant to last 90 Marian days, but wound up exploring Gusev crater for 7 years covering 4.8 miles. *Spirit* analyzed plenty of rocks that could only be found in water such as hematite, and challenged teams on Earth to creatively maneuver from a distance.



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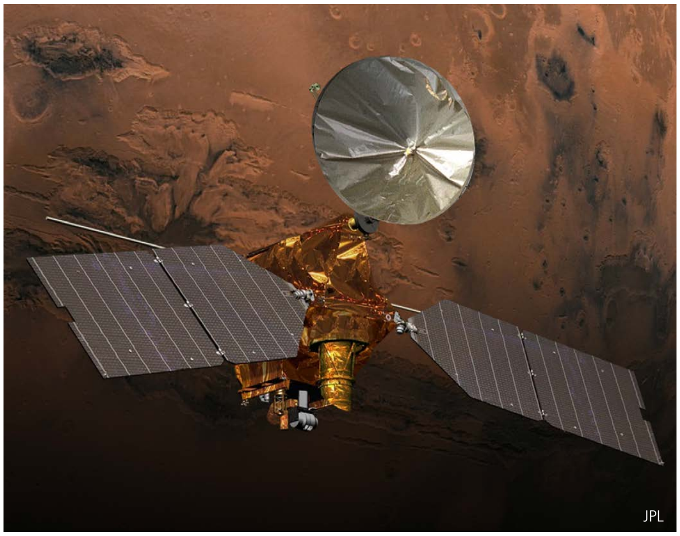
Opportunity

USA, Rover | June 7, 2003 to June 10, 2018

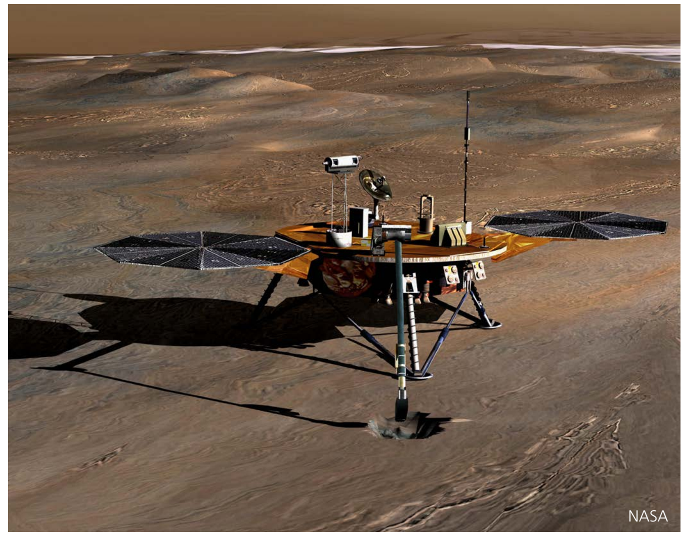
Opportunity touched down on the opposite side of the planet on Meridiani Planum and operated for 13 years driving a grand total of 28 miles. *Opportunity* was one of JPL's most successful missions, driving from one crater to another, making unprecedented descents, observing many rocks such as meteorites, and posing its own engineering challenges. It operated for 13 years—the current record for Mars rovers.



Mars Reconnaissance Orbiter

USA, Orbiter | August 12, 2005 to Present

With a mission to "follow the water", this orbiter was designed to observe the climate, atmosphere, and seasons on Mars, search for signs of water past and present, map geologic forces shaping the surface, and provide data and relay support for ground missions back to Earth. It has played a key role in finding landing sites for *Phoenix, Curiosity, InSight,* and *Perseverance.*



Phoenix

USA, Lander | Aug. 4, 2007 to Nov. 2, 2008

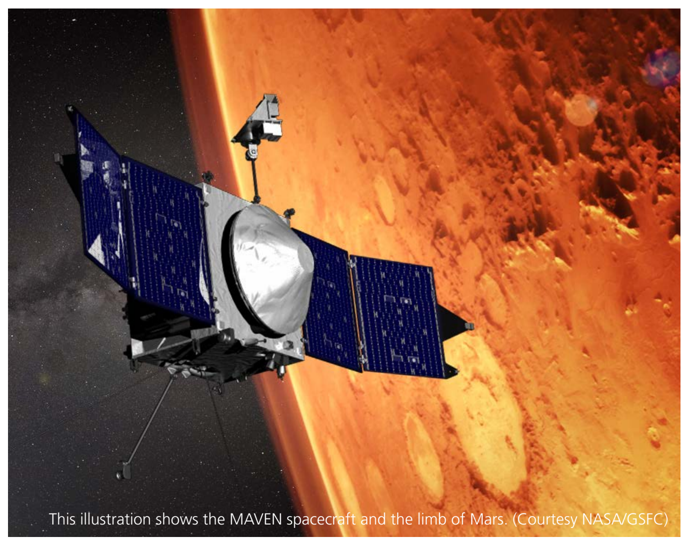
Sent near Mars's north polar ice cap, *Phoenix's* mission was to look learn more about Mars's past climate and potential habitability. It observed signs of water ice sublimating in the soil, and did additional tests on soil salt and acidity

NASA's *Curiosity* rover took this selfie on Oct. 11, 2019, the 2,553rd Martian day, or sol, of its mission. The rover drilled twice in this location, which is nicknamed "Glen Etive." (NASA/JPL-Caltech/MSSS)

Mars Science Laboratory Curiosity

USA, Rover | Nov. 26, 2011 to Present

A mobile lab the size of an SUV, the *Curiosity* rover successfully landed using a revolutionary sky-genie system. It has been roving Mars since 2012, and has discovered evidence of persistent liquid water in Mars's past, chemistry that could have once supported life, organic carbon, present and active methane, and more. Powered by a nuclear battery, it has traveled 15.5 miles as of April 2021, and has the potential to travel much farther.

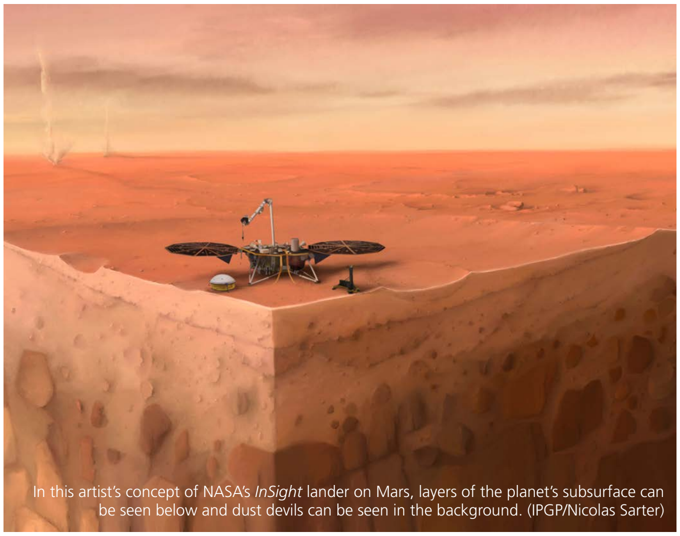


This illustration shows the MAVEN spacecraft and the limb of Mars. (Courtesy NASA/GSFC)

MAVEN

USA, Orbiter | Nov. 18, 2013 to Present

MAVEN is short for "Mars Atmospheric and Volatile EvolutioN." Its mission is to obtain critical measurements of the Martian atmosphere to further understand the planet's dramatic climate changes through history.



In this artist's concept of NASA's *InSight* lander on Mars, layers of the planet's subsurface can be seen below and dust devils can be seen in the background. (IPGP/Nicolas Sarter)

InSight

USA, Lander/Flyby | May 5, 2018 to Present

InSight is short for "Interior Exploration using Seismic Investigations, Geodesy and Heat Transport". It is designed to study the deep interior of Mars and the evolutionary process of terrestrial planets by monitoring for seismic activity and heat, and has returned the first sounds of Martian wind and data from several Marsquakes.

This illustration depicts Mars Helicopter *Ingenuity* during a test flight on Mars. *Ingenuity* was taken to the Red Planet strapped to the belly of the *Perseverance* rover (seen in the background) (NASA/JPL-Caltech)

Perserverance and Ingenuity

USA, Rover/Helicopter | July 23, 2020 to Present

This mission features the first powered flight on another planet by helicopter Ingenuity. *Perseverance* is another large-build rover based off of the *Curiosity* design, and is designed to perform astrobiology, and will eventually attempt to cache samples for a future Mars-return mission.

STANDARDS

During this mission, the teams are exposed to the following Next Generation Science Standards (NGSS) and Common Core State Standards (CCSS):

GEOLOGY (GEO) TEAM

- **NGSS**
  - » MS-SEP: Ask questions to clarify evidence of an argument.
  - » MS-SEP: Construct a scientific explanation based on valid and reliable evidence obtained from sources.
- **CCSS**
  - » RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
  - » RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.
  - » MP2: Reason abstractly and quantitatively.

NAVIGATION (NAV) TEAM

- **NGSS**
  - » MS-PS2-2: Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- **CCSS**
  - » RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.
  - » RST.6-8.9: Draw evidence from informational texts to support analysis, reflection, and research.
  - » MP2: Reason abstractly and quantitatively.

COMMUNICATIONS (COM) TEAM

- **NGSS**
  - » MS-SEP: Analyze and interpret data to determine similarities and differences in findings.
- **CCSS**
  - » L.6.6: Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases; gather vocabulary knowledge when considering a word or phrase important to comprehension or expression.
  - » SL.6.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
  - » MP6: Attend to precision.

REMOTELY OPERATED VEHICLE (ROV) TEAM

- **NGSS**
  - » MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
  - » MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- **CCSS**
  - » RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.
  - » SL6.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

WEATHER (WX) TEAM

- **NGSS**
  - » MS-ESS2-5: Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.
- **CCSS**
  - » SL6.2: Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.
  - » SL6.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
  - » MP2: Reason abstractly and quantitatively.

ROBOTICS (BOT) TEAM

- **NGSS**
  - » MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
  - » MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **CCSS**
  - » RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.
  - » RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
  - » MP2: Reason abstractly and quantitatively.

BIOLOGY (BIO) TEAM

- **NGSS**
  - » MS-SEP .6-8: Ask questions to clarify evidence of an argument.
  - » MS-SEP .6-8: Construct a scientific explanation based on valid and reliable evidence obtained from sources.
- **CCSS**
  - » RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
  - » WHST.6-8.9: Draw evidence from informational texts to support analysis, reflection, and research.

MEDICAL (MED) TEAM

- **NGSS**
  - » MS-SEP.6-8: Analyze and interpret data to determine similarities and differences in findings.
  - » MS-SEP.6-8: Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation.
- **CCSS**
  - » L.6-8.6: Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases; gather vocabulary knowledge when considering a word or phrase important to comprehension or expression.
  - » RI.6.7: Integrate information presented in different media formats as well as in words to develop a coherent understanding of a topic or issue.
  - » RST.6.8.3: Follow precisely a multi-step procedure when carrying out experiments, taking measurements, or performing technical tasks.
  - » SL.6.2: Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it.
  - » MP1: Make sense of problems and persevere in solving them.
  - » MP6: Attend to precision.

LIFE SUPPORT (LS) TEAM

- **NGSS**
  - » MS-SEP.6-8: Construct a scientific explanation based on valid and reliable evidence obtained from sources
- **CCSS**
  - » RST.6.8.3: Follow precisely a multi-step procedure when carrying out experiments, taking measurements, or performing technical tasks.
  - » WHST.6-8.9: Draw evidence from informational texts to support analysis, reflection, and research.
  - » MP6: Attend to precision.

POST-MISSION CHALLENGE: (approx. 3 or 4 class periods)

[OPTIONAL POST-MISSION ACTIVITY FOR GRADES 4+]

Students' complete activities and demonstrate their knowledge by producing a NASA Spotlite animated video that will help others change what they think about one of two Mars misconceptions.

STUDENT PROCEDURE

1. Working in teams, identify criteria for the animated video:

Components of a NASA Spotlite Video	INTRO NASA Spotlite	ENGAGE Misconception	EXPLORE Demonstration	OUTRO Credits
	• Start with the NASA Spotlite logo. • Add a video title. • Include the topic of the video.	• Use a situation that presents a question to address the misconception • Use dialogue between characters	• Demonstration or experiment to confront the misconception. • Ask viewers to complete a "Try This" or "Your Turn" activity.	• Cite resources used for works created by others. • Add NASA Spotlite logo.

1. Select one of the **two misconceptions** below:

MISCONCEPTION 1

Mars is red because it is hot.

Demonstration and Experimenting Ideas:

1. WETA - Reading Rockets Activity 1: Why is Mars Red? (Lab Instructions

- **Visit Resources**

Rust - The Crust That Makes Stuff Bust

- **Resource PDF**

MISCONCEPTION 2

All planets have one moon.

Demonstration and Experimenting Ideas:

1. NASA Solar System Simulator

- Resource: **https://space.jpl.nasa.gov/**

2. NASA Eyes on the Solar System

- Resource: **https://eyes.nasa.gov/**

2. Increase your knowledge by completing activities.
3. Develop an interesting storyline.
4. Write a script for the animated video.
5. Film. Edit. Produce.
6. **Submit** videos to NASA eClips™ for review.*

**Exemplary animated videos will be added to the NASA eClips website under Student Productions.*

EXTENSION ACTIVITY: Build the First Mars Community

[OPTIONAL EXTENSION ACTIVITY FOR GRADES 5+]

Going to Mars is definitely not easy! The travel alone can take up to 6 months and, when the first human crew goes to Mars, they will be staying for at least several years. In this project, students assume the role of NASA aerospace engineers using the engineering design process for creating and designing the first sustainable Mars Habitat to host the Mars Crew!

Using an Augmented Reality App and research briefs from NASA, students will explore the possibilities and challenges of establishing a permanent base on Mars as it requires a variety of building modules and equipment to provide services to the inhabitants such as food, fuel, water, energy, and oxygen.

OBJECTIVES

Students will be learning about the different modules that are a part of a Mars habitat using augmented reality and design their own Mars Habitat for that can sustain the First Mars Crew for long periods of time. Essential questions to think about:

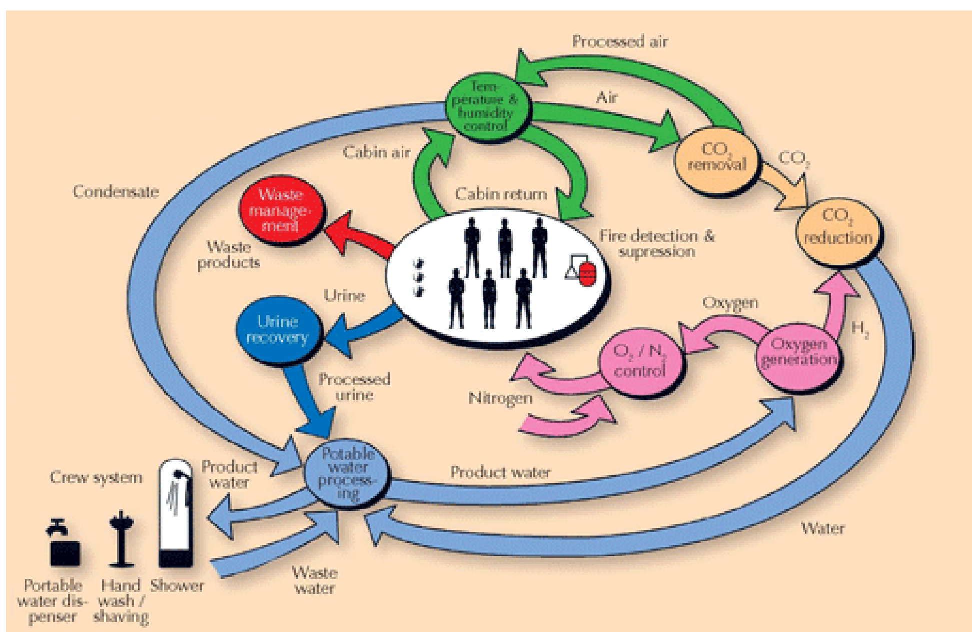
- *What elements need to be included in the design of a Mars habitat to ensure safety and sustainability?*
- *What resources are needed to sustain human life inside a habitat on Mars?*

LEARNING GOALS

- Assess and explain the risks/rewards of a Mars colonization
- Identify the physical characteristics of Mars, including the location, climate, geographical features, atmosphere, and surface
- Identify and understand what a new Martian colony would need for human survival
- Draw evidence from literary or informational texts to support analysis, reflection, and research
- Design and create ideas based on research.

BACKGROUND

Since its creation in 1958, NASA has engaged in the exploration of space. However, after the Apollo Missions of the late 1960's and early 1970's, crewed space exploration was limited to low Earth orbit (LEO) destinations. Today NASA's goals include exploration of four destinations: cis-lunar space, near Earth asteroids (NEA's), the Moon, and, finally, Mars. Travel to these destinations will take humanity farther into space than it has ever been, and each destination will provide unique opportunities for scientific discovery.



The flow of recyclable resources on board the ISS. (Courtesy of NASA)

Mars is a very different environment than Earth. The atmospheric pressure, gravity, temperature, soil composition, and availability of water are vastly different than Earth planetary conditions. However, there are some important similarities between the two planets! Their daily photo-period (i.e. day length) is similar, and while available liquid water is scarce, water is present on Mars, usually in the form of ice. In many ways current Martian conditions are similar to some of the most extreme environments on Earth (e.g., Antarctica), and similar to what many scientists believe primitive Earth soil and atmospheric chemistry were like. These similarities have led scientists to question whether it might be possible to alter Martian planetary conditions to make them more hospitable to humans. Once astronauts arrived on Mars, it would be necessary to manufacture much of what they need on site (in-situ) and being able to produce food and generate oxygen on Mars would greatly increase the feasibility of a crewed Mars mission.

Mars habitats must contend with surface conditions that include almost no oxygen in the air, extreme cold, low pressure, and high radiation. To contend with these constraints, architects have worked to understand the right balance between in-situ (already on Mars) and ex-situ (brought from Earth) materials and construction as it currently cost about 17 000 USD to lift 1 kg to the International Space Station (ISS)!

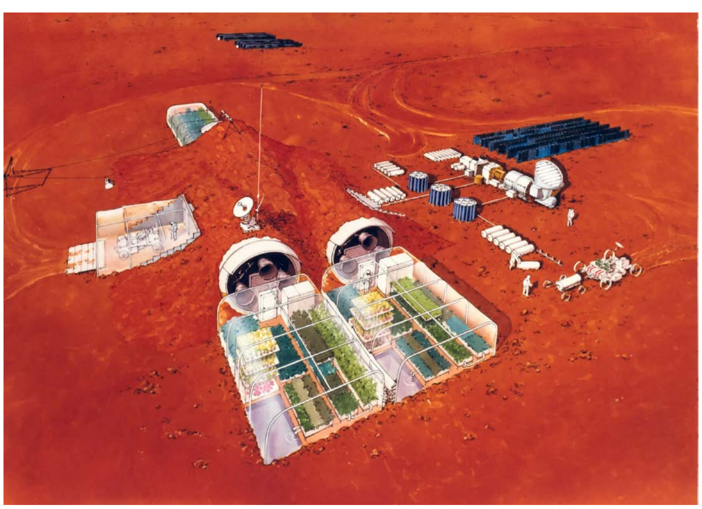
In early 2015, NASA outlined a conceptual plan for a three stage Mars habitat design and construction award program. The first stage called for a design. The next stage requested plans for construction technology that used discarded spacecraft components. The third stage involved building a habitat using 3D printing technology! In May 2019, NASA announced that the top winner of the 3D Printed Habitat Challenge was from AI SpaceFactory, with an entry called "MARSHA."

MARSHA site on Mars. (NASA/AI SpaceFactory)

Illustration of the MARSHA interior. (NASA/AI SpaceFactory)

On the MARSHA example, the unique vertically oriented, egg-like shape maintains a small footprint, to handle Mars internal atmospheric pressure and thermal stresses. For the comfort of the crew, each level has at least 1 window, which, together, cover the full 360-degree panorama. Indirect natural light from the large water-filled skylight and intermittent windows floods the interior while still keeping the crew safe from harmful solar and cosmic radiation. Circadian lighting, designed to recreate Earthly light, is employed to maximize crew health.

Other examples of Mars habitats:



Artist's concept of living quarters covered with soil to shield the crew from the sun's radiation. The extended base has greenhouse and a pressurized work facility where full spacesuits would not be required. (NASA/CASE FOR MARS)

A Mars habitat is often conceived as part of an ensemble of Mars base and infrastructure technologies. Some examples include Mars EVA suits, Mars rover, aircraft, landers, storage tanks, communication structures, mining, and Mars-movers. (TEAM SEARCH+/APIS C)

MATERIALS NEEDED

- Tablet/iPhone/Smart Phone with a camera
- Mars Community Builder App:
  - » Google/Android products: **https://play.google.com/store/apps/details?id=com.pixeldustudios.marsbuilder&hl=en_US&gl=US**
  - » Apple products: **https://apps.apple.com/us/app/mars-community-builder-ar/id1457257128**
- **Mars Habitat 7 Trigger Cards** (see attachments)
- **Research Briefs** (see attachments)
- **Mars Habitat Research Sheet** (see attachments)
- **Considerations for Designing a Space Habitat One-Sheet** (for teacher; see attachments)

VOCABULARY

- **Constraint:** restricting or limiting circumstances.
- **Design Process**: a step-by-step process that scientists, engineers, architects, and other designers utilize when creating a new product, structure, material, etc. Steps in the design process:
  1. Identify the problems
  2. Gather information
  3. Generate design ideas
  4. Build your design
  5. Test out/reflect on your design and evaluate what is working and what is not.
     - » If it worked exactly how you wanted it to, fantastic! Go to step 6.
     - » If it didn't work perfectly, consider going back and reevaluating your design ideas, create a new design or modify your existing one, and test it out again. Repeat this process as many times as you want and/or need.
  6. Share your results.
- **Ex situ:** Latin fort "away from the natural location."
- **In situ:** Latin for "in its original place."
- **Radiation:** Energy given off as particles or waves. The Earth's atmosphere protects human tissue from many kinds of radiation. Outside of the atmosphere, the tissue of astronauts is vulnerable to radiation damage.
- **Regolith:** Layer of loose solid material covering the bedrock of a planet.

EDUCATOR PROCEDURES

1. Introduce the design challenge and its two main objectives.
2. Identify the problem/research:
   - Have students read the five **Research Briefs** that are highlighting components that need to be incorporated in the Mars habitat design to meet the needs of NASA. Distribute the **Mars Habitat Research Sheet** so they can take notes.
3. Brainstorm on solutions with the class: reflect about our lives on Earth (what do we need to survive, be productive and happy?) and what is essential for survival in space?
   - Use the **Considerations for Designing a Space Habitat** one-sheet to facilitate the discussion.
4. Show students two videos: **Mars Habitat Example** and **Mars Ice House** to start brainstorming ideas.

5. Introduce the students to the **Mars Community Builder App.** This interactive experience allows users to learn about Mars and take part in a step-by-step building process that could one day be used to help make an interplanetary community a reality. The App requires the use of **Mars Habitat Trigger Cards:** Mars Planet, Habitat Lander, Greenhouse, Recreation Module, Water Tanks, Communications Center, and Earth Return Vehicle. *(The Trigger Cards do not need to be printed, an electronic copy works just fine.)*
6. Have students sketch, build or write a paragraph about their Mars Habitat with indication of what materials they are going to use and the layout of their base.

STUDENT PROCEDURES

1. Research/Identify the problem:
    - Read the five **Research Briefs** highlighting the components that need to be incorporated in the Mars habitat design to meet the needs of NASA. Take notes in the **Mars Habitat Research Sheet.**
2. Brainstorm Solutions/Reflect: *What do we need to survive on Earth? What is essential to survive in space? What are the constraints of having a colony/astronauts crew on Mars?*
3. Show students two videos: **Mars Habitat Example** and **Mars Ice House** to start brainstorming ideas.
4. Explore a virtual Mars Habitat using the augmented reality App, **Mars Community Builder!** Using the App and the Engineering Process, start thinking about how you would like to build your base.
    - What materials? What shape? Where on Mars?
    - What Rooms/Facilities? And why these choices? Think about the astronaut's comfort!
    - Think about how the astronauts will move on the surface of Mars. What vehicles could they use?
5. Sketch or write a paragraph about your Mars Habitat indicating what materials you are going to use.

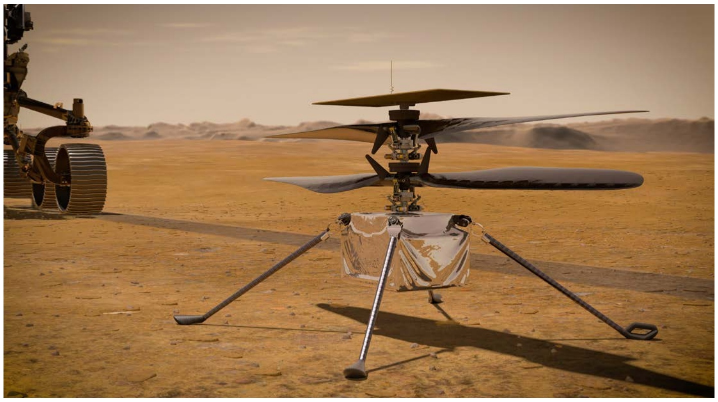
STANDARDS

- **Common Core Standards (CCSS)**
    - » CCSS.ELA-Literacy.RI.5.7: Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.
    - » CCSS.ELA-Literacy.RI.5.9: Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.
    - » CCSS.ELA-Literacy.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.
    - » CCSS.ELA-Literacy.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
    - » CCSS.ELA-Literacy.RST.6-8.4: Determine the meaning of symbols, key terms, and other domain specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.
    - » CCSS.ELA-Literacy.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually.
    - » CCSS.ELA-Literacy.RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.
    - » CCSS.ELA-LITERACY.SL.6.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
    - » CCSS.ELA-LITERACY.SL.6.2: Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.

- **Next Generation Science Standards (NGSS)**
  - » 3-5-ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
  - » MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
  - » MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
  - » MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
  - » MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

EXTENSION ACTIVITY: Testing Mars Helicopters

[OPTIONAL EXTENSION ACTIVITY FOR GRADES 5+]



NASA/JPL-Caltech

NASA's Perseverance Mars rover launched in July 2020, carrying the first helicopter to the surface of Mars! This helicopter has to be lightweight and have large blades to fly on Mars. These large blades rotate so quickly that they generate enough lift to overcome the gravity of the Red Planet and lift off the ground.

In this project, students will build a paper helicopter. Then, just as NASA engineers had to try out different versions of the Mars helicopter before coming up with a final design, students will experiment with the design of their helicopters to see what works best.

LEARNING GOALS

- Learn and understand how a helicopter can fly.
- Record Data based on experimentation.
- Using the design process to create prototypes.
- Draw evidence from data and observations.

BACKGROUND

In July 2020, NASA launched the Perseverance rover to Mars. Traveling along with Perseverance is Ingenuity, the first helicopter designed to fly on Mars.

Ingenuity performed it's first test flight on April 19,2021 and continued to test itself over the next few days. For its first flight, Ingenuity hovered a few feet above the ground for about 20 to 30 seconds, made a turn, and landed. The very first powered flight in the extremely thin atmosphere of Mars! Ingenuity has been tested, and now the team will attempt additional experimental flights over a farther distance and at a greater altitude. Ingenuity's performance during these experimental flights will help inform decisions about the future use of small helicopters for Mars exploration.

Designing a helicopter to fly on Mars was no small task. The Mars atmosphere is only 1% the density of Earth's atmosphere, so generating enough lift to overcome the gravity of Mars is a challenge. The helicopter had to be lightweight with extremely fast rotors to be able to generate enough lift. Though a full outdoor test couldn't be done on Earth, engineers were able to simulate conditions on Mars inside a test chamber at NASA's Jet Propulsion Laboratory in Southern California. To do this, they offset Earth's

gravity by attaching tethers to the helicopter that support about 62% of its weight. Then, they performed flight tests inside a vacuum chamber that pumped out approximately 99% of the air, leaving a very thin atmosphere. Months of design, testing, redesign, and retesting went into the development of the Ingenuity Mars helicopter.

In this activity, your students will experiment with simple paper helicopter designs, engaging in the engineering design process that NASA engineers use every day.

VOCABULARY

- **Lift:** A force that keeps aircraft in the air, usually produced by wings or rotors.
- **Rotors:** The spinning blades of a helicopter

MATERIALS

- **Helicopter Instructions and Templates** (see attachments; have multiple copies of template on hand)
- Scissors
- Measuring Tape
- Pencil
- Ribbon, or string

EDUCATOR PROCEDURES

1. Ask students to consider how a helicopter flies. Elements of their description might include fast-moving, horizontal, rotary blades. Explain that the rotary blades are slightly angled so they can push against the air and lift the helicopter off the ground.
2. Explain that a helicopter moves so much air with its large, fast-moving blades, that the force of the blades against the air can overcome the weight of the helicopter and push it up off the ground. The helicopter is working against the force of gravity—which is constantly pulling the helicopter down toward the ground—and generating an upward force called "lift" by rotating its blades through the air. When the force of lift is greater than the force of gravity, the helicopter rises from the ground and flies.
3. Ask students if a helicopter might fly differently on the Moon or Mars and why. Note: The Moon doesn't have an atmosphere in which to generate enough lift to fly. Mars has a very thin atmosphere that is able to support a small helicopter with very fast-moving blades. NASA's Mars Ingenuity helicopter tested whether this was feasible, as it was not known for certain.
4. *Ingenuity* is a technology demonstration. In other words, the goal is to see whether it can fly on the Red Planet and study how the design could be improved for a future Mars helicopter.
5. Explain to students that they will now experiment with building a paper helicopter and try to create the best design.

STUDENT PROCEDURES

1. Create your first prototype helicopter.
   - » Cut the solid lines on the paper helicopter template. Have students fold the propeller blades, in opposite directions along the dashed lines.
2. Do a test flight by standing up, holding the helicopter by its body, raising it as high in the air as you can and dropping it.
   - » *What do you observe? Which way do the blades turn?* Drop the helicopter from a higher spot. *How does the performance change?*
3. Make one change to your helicopter and do another drop. Try to change a lot of different aspects, and see how the changes affect the flight of the helicopter.
   - » How could you improve the performance of their helicopter and make another one that is different from their first. You could use a different kind of paper or make a much smaller or much larger one.
   - » *How big of a helicopter can you make that will still work? How small of a helicopter can you make? How do helicopters with different blade sizes compare in performance? What size works best? How do you define "best performance"?*
4. Drop one of your helicopters and try to count how many times the blades rotate. It's impossible! *How might you solve the problem of counting rotations?*
   - » If you access to a slow-motion video proceed in that direction. Other students can attach a straight ribbon to the bottom of their helicopter, stand on the end of the ribbon to hold it securely in place on the floor and drop their helicopter as before. Once the helicopter comes to rest on the ground, have them count the twists in the ribbon to determine how many rotations their helicopter made.

DISCUSSION/WRAP UP

- *Which helicopters reach the ground sooner: those that rotate faster or slower?*
- *How does the speed of rotation affect the flight of a real helicopter? How might this be important when designing a helicopter for Mars?*
- *How was your experience designing and testing a paper helicopter similar to how NASA engineers designed and tested the Ingenuity Mars helicopter?*

STANDARDS

Next Generation Science Standards

- K-2-ETS1-3: Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.
- 3-PS2-1: Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.
- 3-PS2-2: Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.
- 3-5-ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.