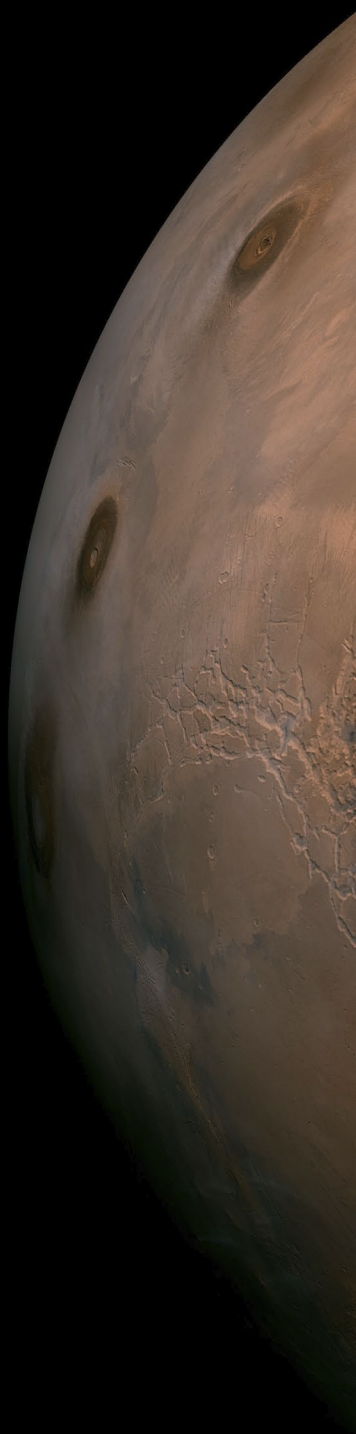
Perseverance & Ingenuity

Mars 2020 Exploration Mission Guide



"Mars tugs at the human imagination like no other planet. With a force mightier than gravity, it attracts the eye to the shimmering red presence in the clear night sky."

~ John Noble Wilford

Welcome to the Mars 2020 Exploration Mission Guide, a truly special issue of Rocket**STEM** magazine. We are devoting the entire issue to informing you about the upcoming mission to the Red Planet, which will include the first-ever interplanetary helicopter.

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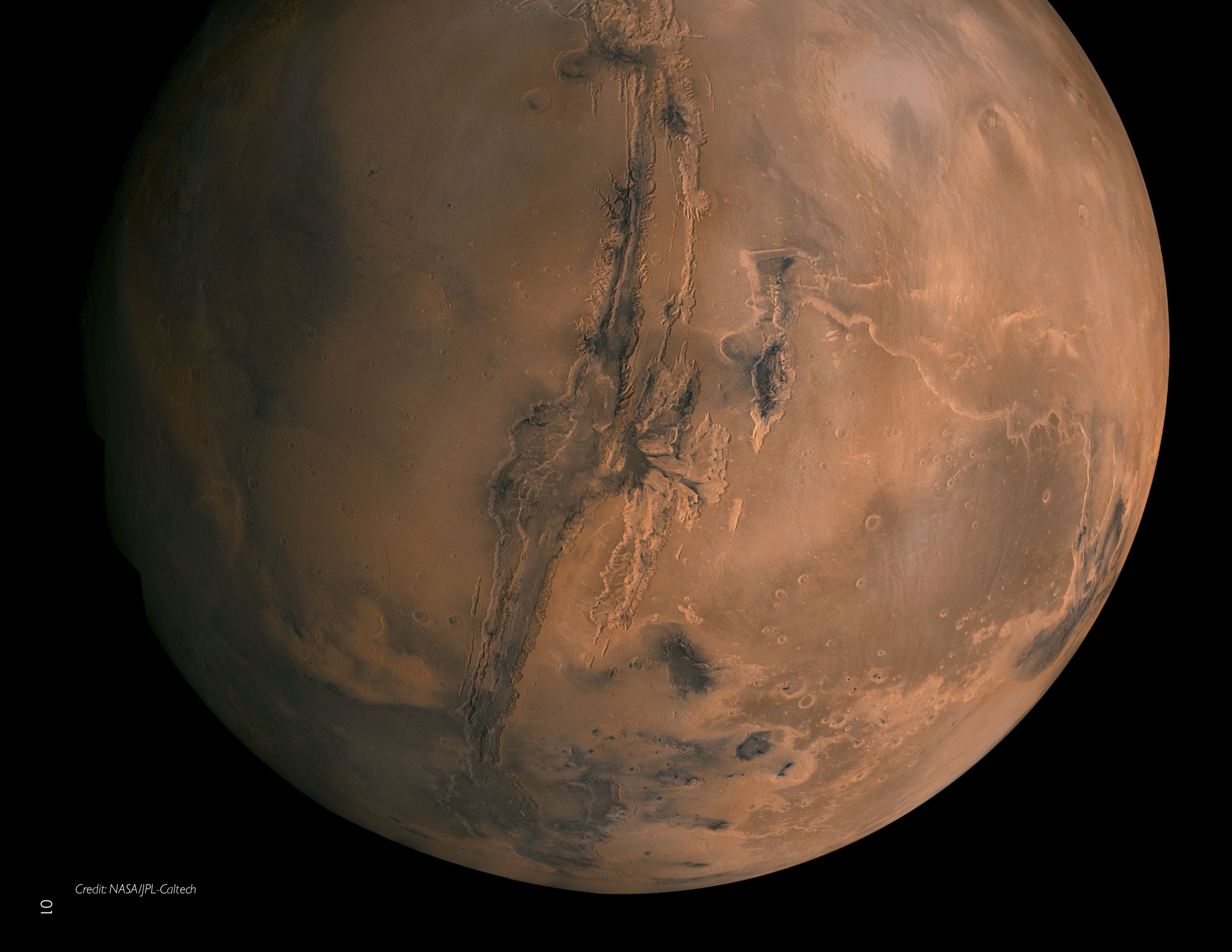
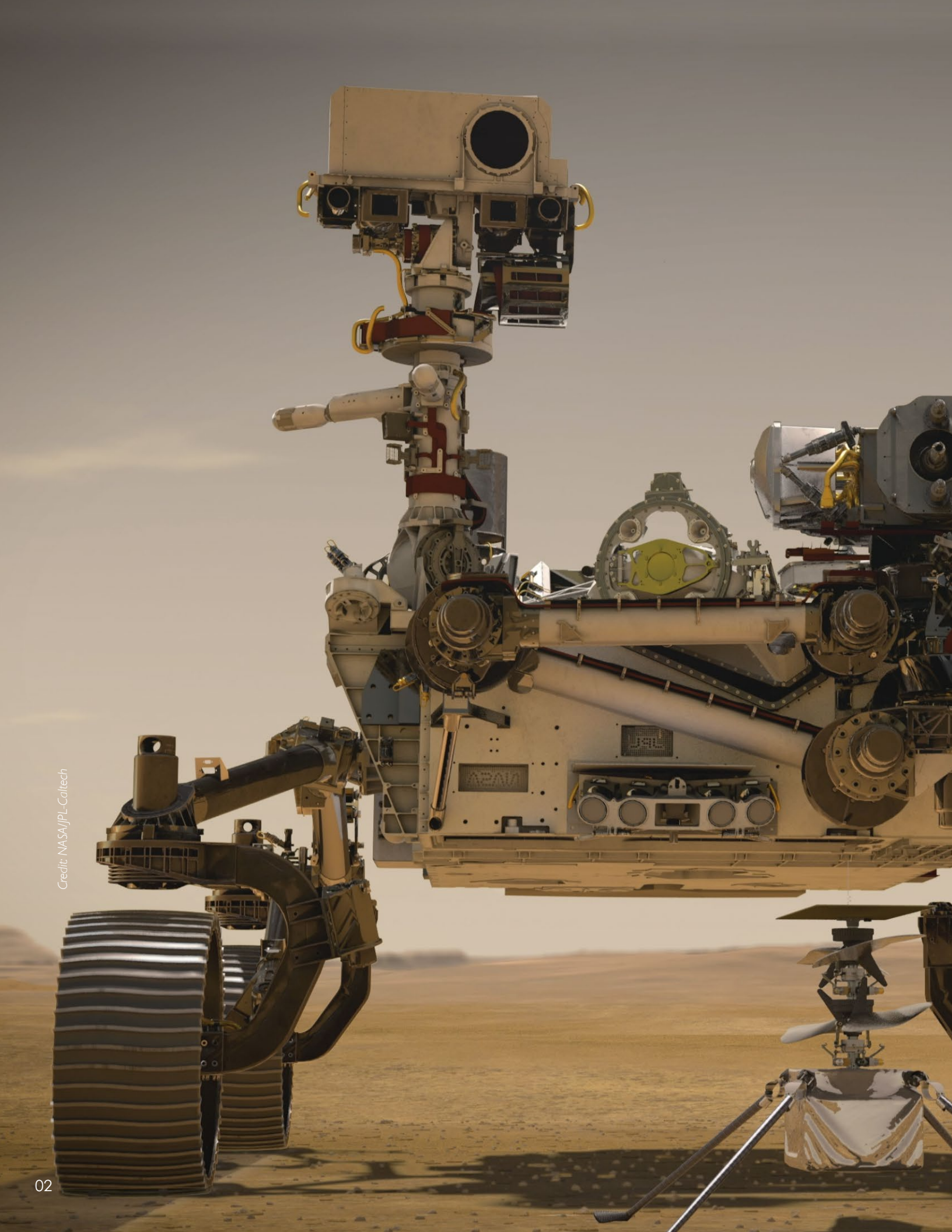


Credit: NASA/JPL-Caltech



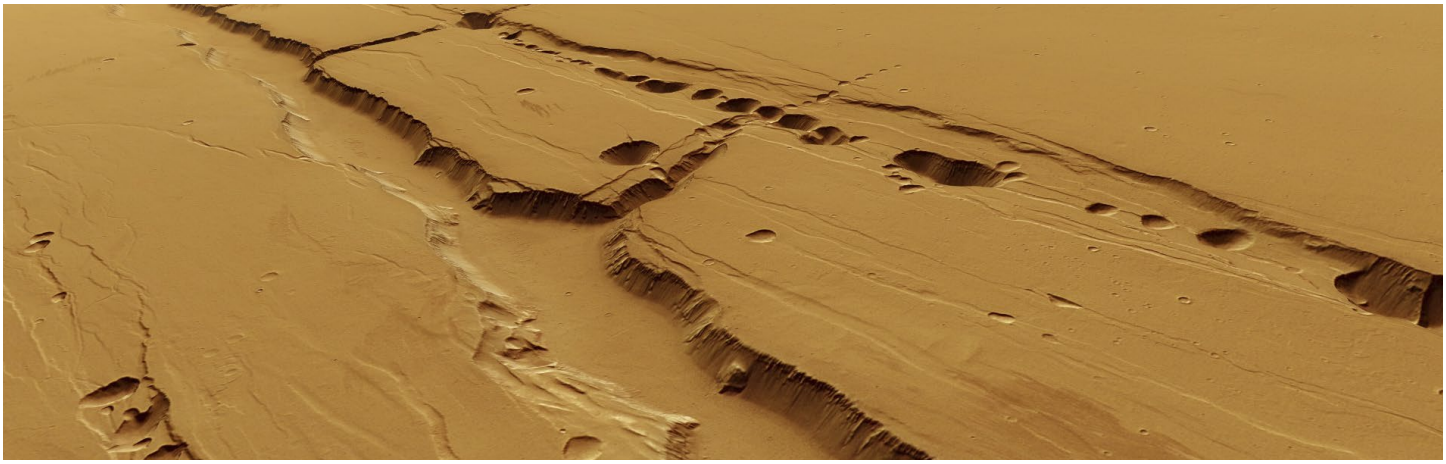
Credit: NASA/JPL-Caltech

Exploration Guide

MISSION TO MARS

ALL ABOUT MARS

Article by Lloyd Campbell



Tractus Catena on Mars. Credit: ESA/DLR/FU Berlin (G. Neukum)

The planet Mars is probably the most studied planet, other than Earth, in our solar system. Like Earth, Mars is a terrestrial planet, as opposed to a gas planet like Jupiter for example. Mars is often referred to as the Red Planet, due to the brownish-red color of its surface caused by iron oxide in the soil. You may be surprised that out of all the planets in our solar system, Mars is just the second largest planet, only eclipsing Mercury in size.

Mars has the fourth furthest orbit away from our sun. Its relative closeness to Earth makes it a popular target for astronomy buffs to view. In fact, Mars has been observed for over 3,000 years. Ancient Egyptian and Chinese astronomers' records both document observations of the red planet.

HISTORY AND MYTHOLOGY

To observers before the dawn of the telescope, Mars was nothing more than a bright light in the sky, but unlike many other lights in the sky, it wasn't always in the same place in the sky and that made it unusual and more easily noticed.

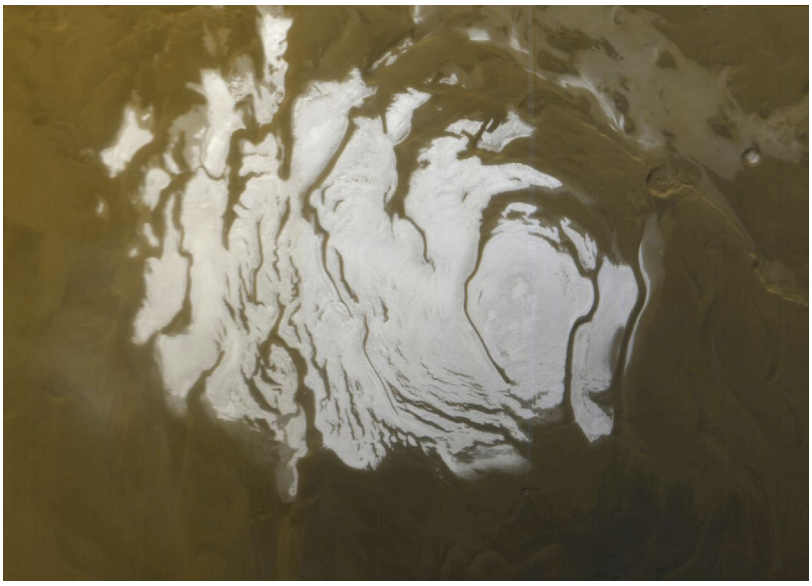
Mars gets its current name from the Roman god of war, however, it went by other names in different cultures. To the people of ancient China, it was known as the "fire star", ancient Sumerians believed that Mars was Nergal, the god of war and plague, it was referred to in Mesopotamian texts as the "star of judgment of the fate of the dead". The Greeks knew it as Ares, their god of war.

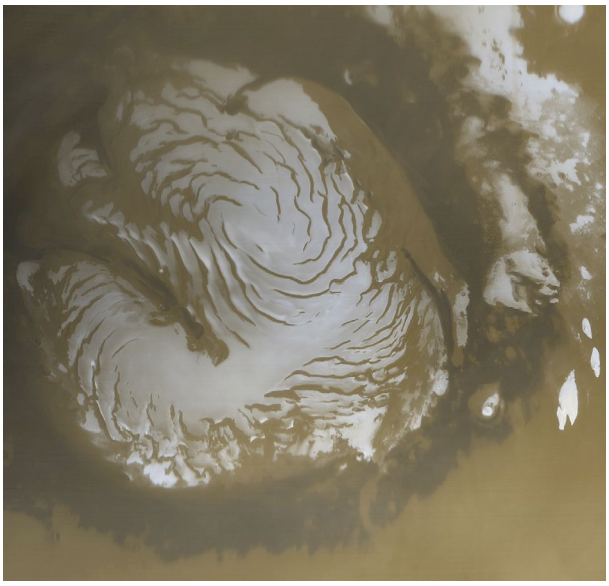
The first person to observe Mars through a telescope was Galileo Galilei in 1610.

MARS FACT SHEET

Size	0.53 Earths
Diameter	6779 Kilometers
Mass	6.42 × 1023 kg (0.151 Earths)
Gravity	0.375 that of Earth
Orbital Period (1 Martian Year)	687 Earth Days
Rotational Period (1 Martian Day)	24 hours 37 minutes
Average Surface Temperature	-81 degrees F
Atmosphere	Mainly Carbon Dioxide

COOL MARS FACTS





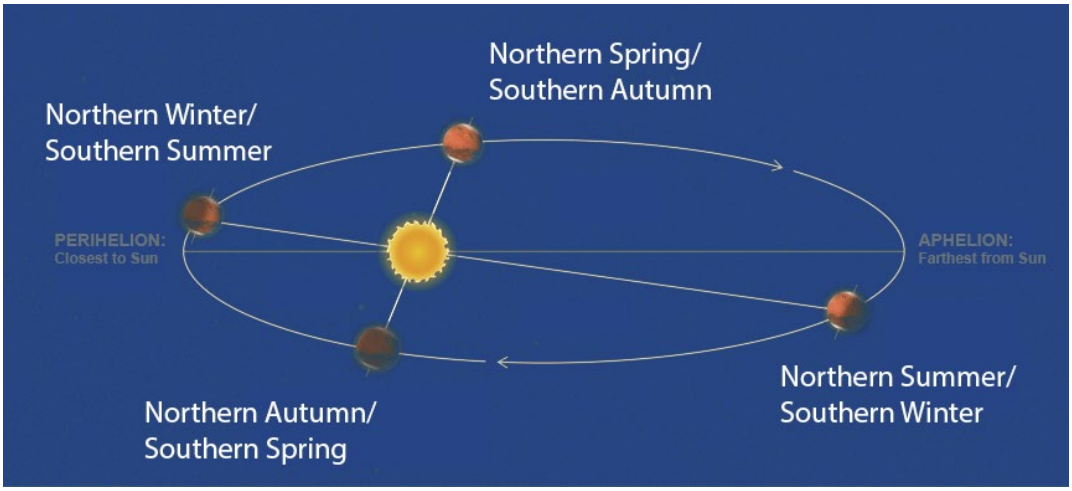
Polar frost is evident on the south polar cap of Mars (left) and the north polar cap of Mars (right) in these images from the Mars Global Surveyor orbiter. Credit: NASA/JPL/Malin Space Science Systems

MARS HAS POLAR ICE CAPS

Other than Earth, Mars is the only other planet in our solar system that has polar ice caps. The northern cap is named the Planum Boreum and the southern cap is named Planum Australe. Under both Martian ice caps, water ice has been found which helps substantiate the possibility of life having existed on the planet at some point.

MARS TAKES THE LONG WAY AROUND THE SUN

Being farther away from our Sun than Earth is means that Mars takes longer to go around the Sun than Earth does, 687 days to be exact. Its orbit is much more elliptical than Earth's orbit.



Credit: NASA/JPL-Caltech

MARS HAS SEASONS LIKE EARTH

Mars is tilted on its axis just like Earth is. Mars's axis of rotation is tilted 25.2 degrees like Earth which has an axial tilt of 23.4 degrees. This tilt is why we have seasons on Earth and Mars has seasons also. However, on Mars, those seasons last much longer because of the length of time it takes for Mars to orbit the Sun. Since the orbit of Mars is more elliptical, that is egg-shaped, than Earth's orbit is, it results in the seasons on Mars to vary in length. The shortest season on mars lasts 142 days and the longest lasts 194 days.

A DAY ON MARS SEEMS JUST ABOUT THE SAME AS A DAY ON EARTH

While Mars rotates more slowly on its axis than Earth does, a day on Mars lasts only about 41 minutes longer than a Day on Earth does. This is due to the diameter of Mars being about 3,700 miles less than the diameter of Earth.

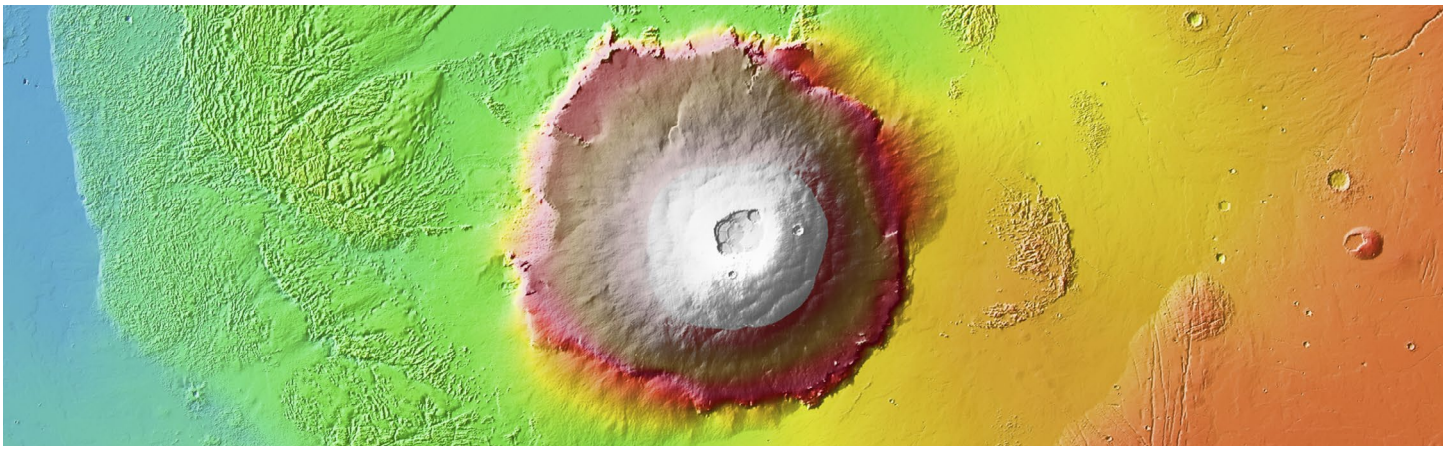
DOUBLE THE NATURAL SATELLITES

Mars has two small irregularly shaped moons named Phobos and Deimos. Like Mars, their names are derived from Roman times. According to Roman myth, Mars rode on a chariot pulled by two horses named Phobos (fear) and Deimos (panic). Phobos is the larger of the two, measuring 22.2 Km (13.8 miles) across, while Deimos is just 12.6 km (7.8 Miles. By comparison our moon is 1,737.5 km (1,079.6 mi) across. While our moon orbits at an average distance of 384,472 km (238,900 mi) from Earth, Phobos zips around just 6,000 kilometers (3,700 miles) above the Martian surface. Phobos is also getting closer to Mars, closing in at a rate of about 1.8 meters (6 feet) per century, it's expected to impact the surface of Mars in about 50 million years. It's possible that after that collision, the debris may form a ring around the planet.

Mars' moons Phobos (left) and Deimos (right) imaged by the Mars Reconnaissance Orbiter. Credit: NASA/JPL-Caltech/University of Arizona

A MOUNTAIN CLIMBERS DREAM

Mars has the tallest mountain in the solar system. Olympus Mons is a 25 km (15.5343 mi or 82021Ft) high shield volcano that formed billions of years ago. Its base is 624 km (374 mi) in diameter. The largest volcano on Earth, Mauna Loa, is 10 km (6.3 mi) high and 120 km (75 mi) across at its base.



Olympus Mons color-coded according to height from white (highest) to blue (lowest), based on images from ESA's Mars Express. Credit: ESA/DLR/FU Berlin (G. Neukum)

YOU CAN JUMP HIGHER AND FURTHER

Gravity on Mars is roughly 1/3rd (37.5%) of what it is here on Earth. That would enable you to jump higher and further than here on Earth. You could probably throw a football further than Peyton Manning too!

GETTING TO MARS IS DIFFICULT

Mars is a popular target to explore, As of July 15, 2020, a total of 45 missions have been launched, but only 26 have had some level of success. Some were lost during launch, others attempting to orbit the Red Planet, and others attempting to land on it. But those successes have supplied us with astonishing data and images from Mars. Some have astonished both us and the engineers who designed them, such as the Spirit and Opportunity rovers, which launched in 2003 and 2004 respectively on what was first thought to be short 90-day missions for the solar-powered rovers. Amazingly, the Spirit rover operated until 2010 and Opportunity operated until 2019!

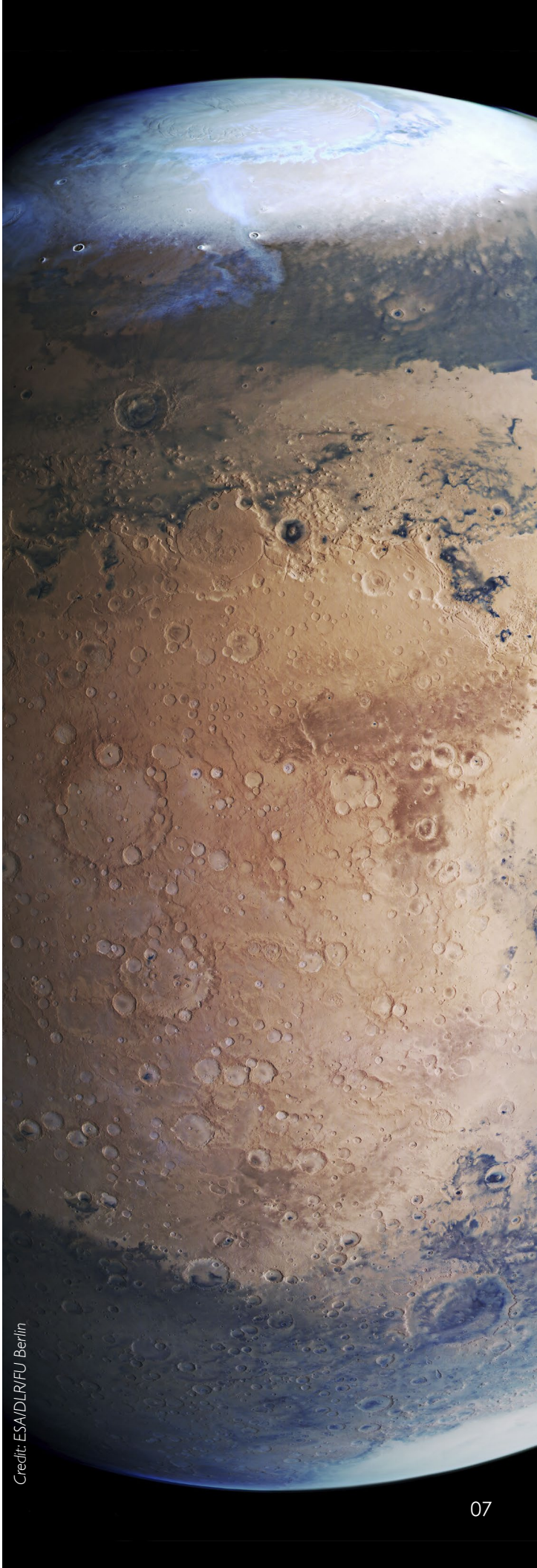
BRING YOUR FEATHER DUSTER

Dust storms on the Martian surface can be huge and can last for months, sometimes engulfing the entire planet.

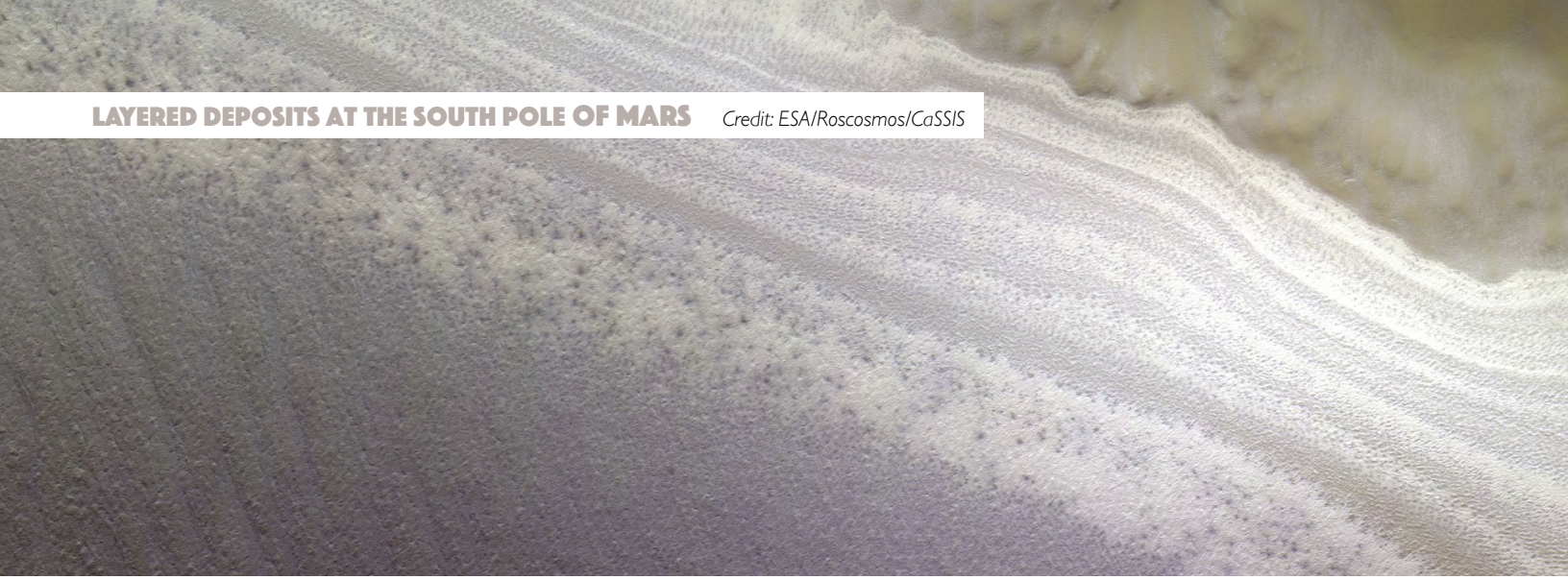
Marvin the Martian contemplates destroying the Earth. Credit: Warner Bros.

LITTLE GREEN MEN?

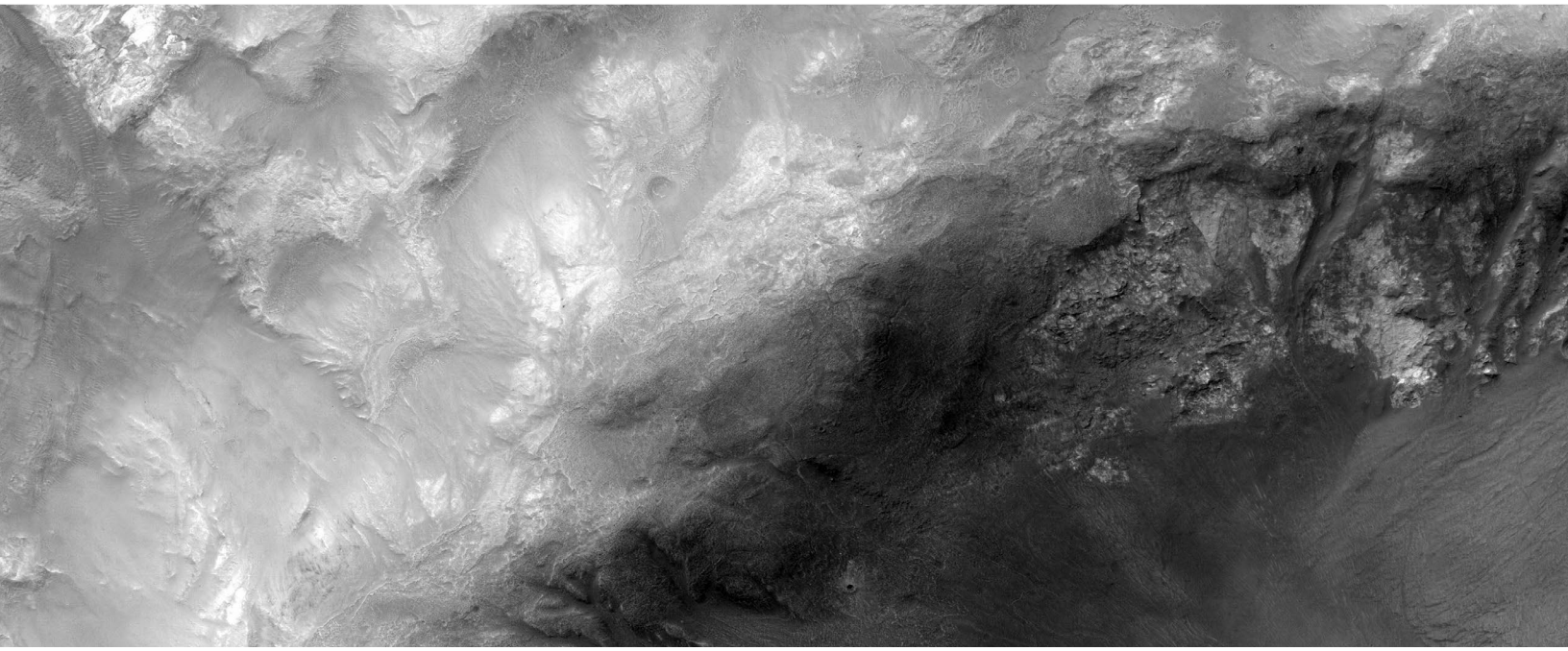
For years it was believed that life existed on Mars. An astronomer named Giovanni Schiaparelli discovered what he thought were straight lines on the surface of Mars in 1877. These lines were too straight to be naturally occurring and it was thought by some that they could only have been artificially created by some sort of intelligent life, possibly canals used for irrigation. Schiaparelli's telescopes were crude in comparison to today's and when better telescopes came out it was determined that the lines were not straight at all but just an optical illusion. Sorry, there are no little green men.



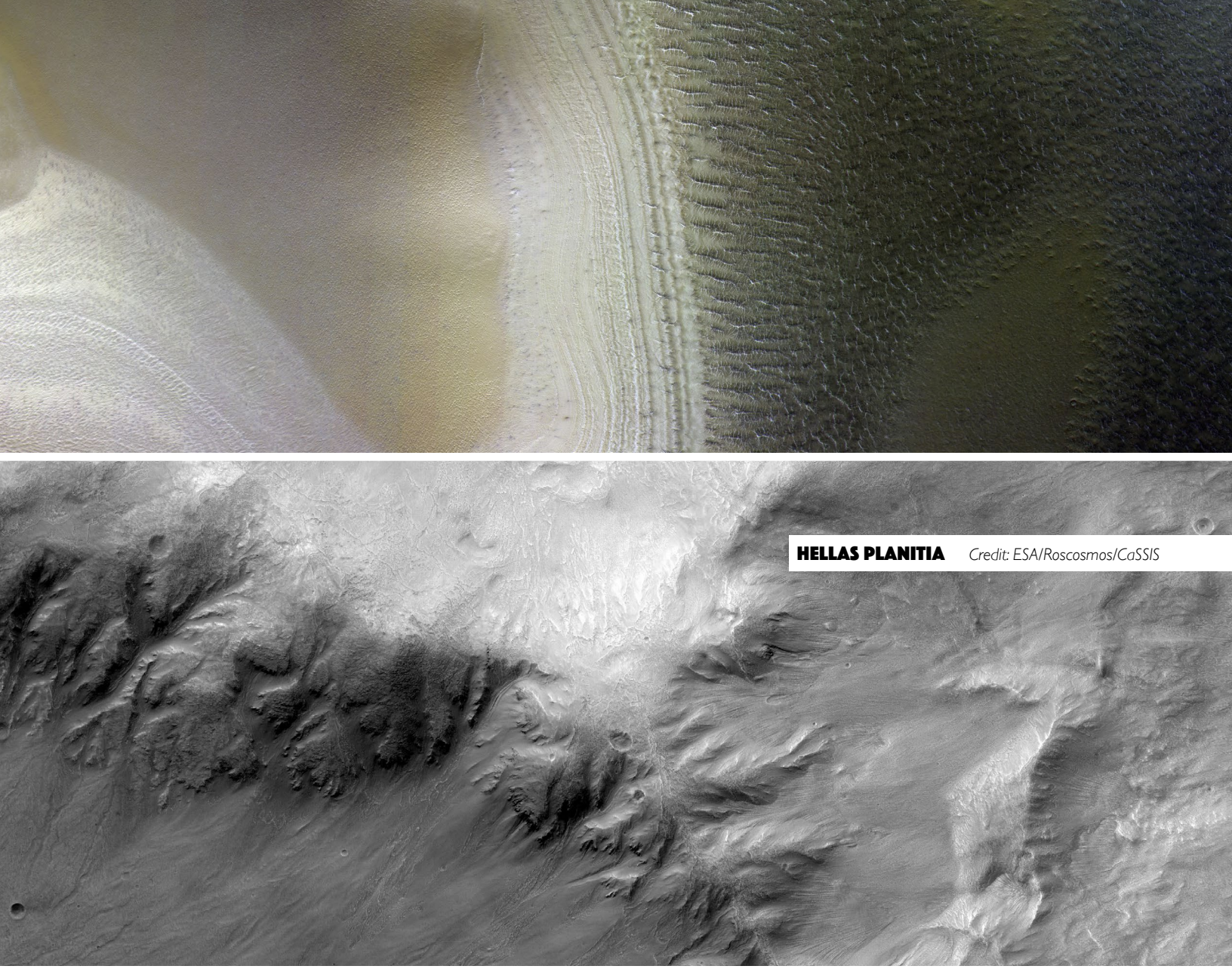
Credit: ESA/DLR/FU Berlin



LAYERED DEPOSITS AT THE SOUTH POLE OF MARS *Credit: ESA/Roscosmos/CaSSIS*



LAYERED MOUND IN JUVENTAE CHASMA *Credit: ESA/Roscosmos/CaSSIS*



HELLAS PLANITIA *Credit: ESA/Roscosmos/CaSSIS*

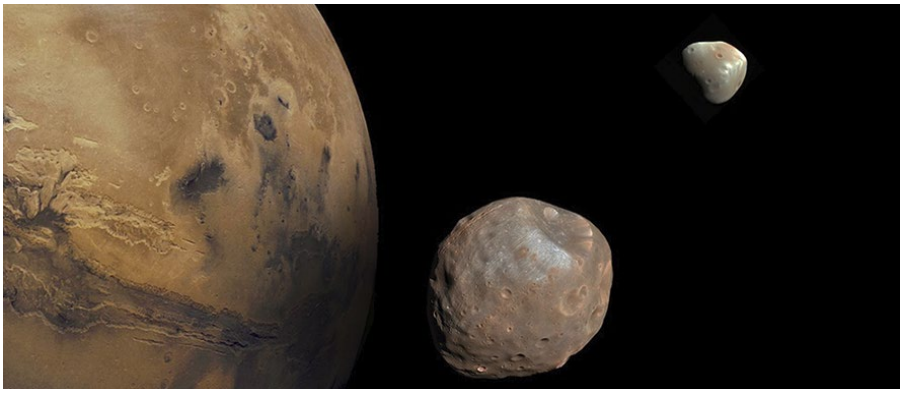
QUIZME: THE RED PLANET

Quiz authored by Avi Patel

How about a little quiz to test your knowledge about Mars? This RocketSTEM exclusive QuizMe contains 15 questions about the planet, its moons, and exploration missions.

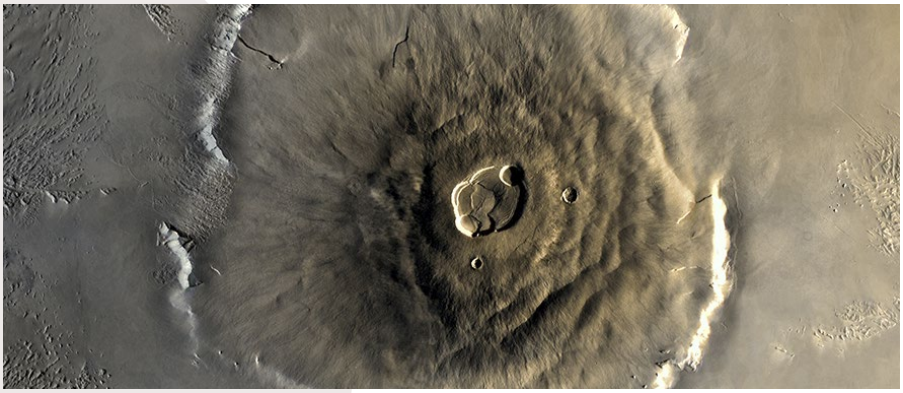
1. Mars is named after which Roman god?

A. God of Love
B. God of War
C. God of Fire
D. God of Time



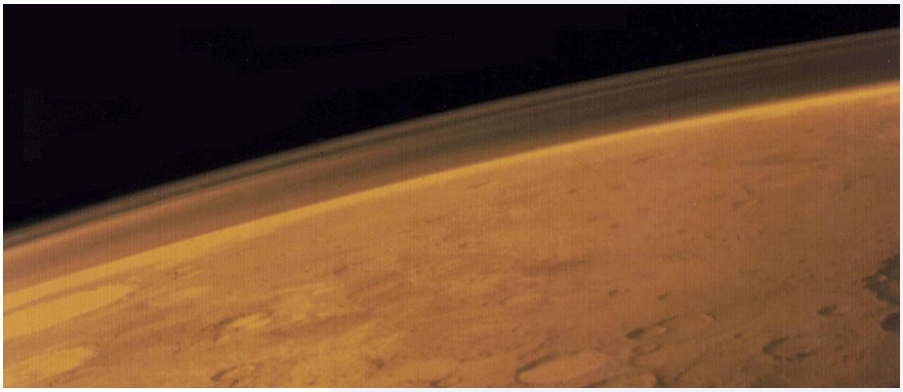
2. What are the names of Mars' two moons?

A. Phobos and Oberon
B. Callisto and Titania
C. Titania and Deimos
D. Phobos and Deimos



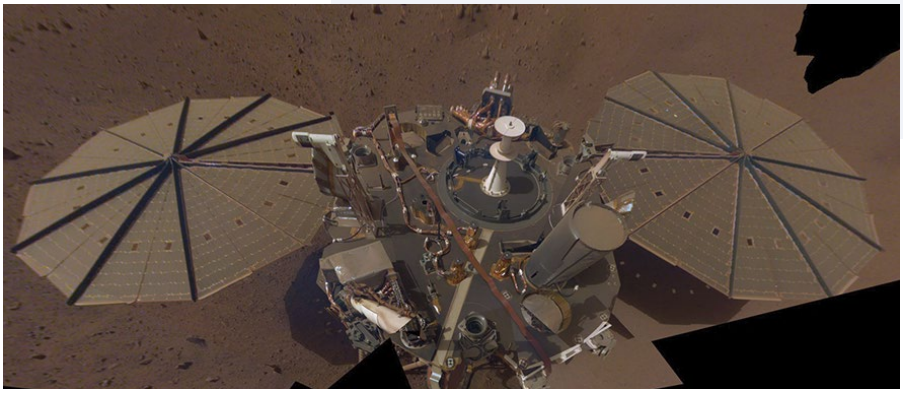
3. Olympus Mons on Mars is 5 times taller than Mount Everest on Earth?

A. True
B. False



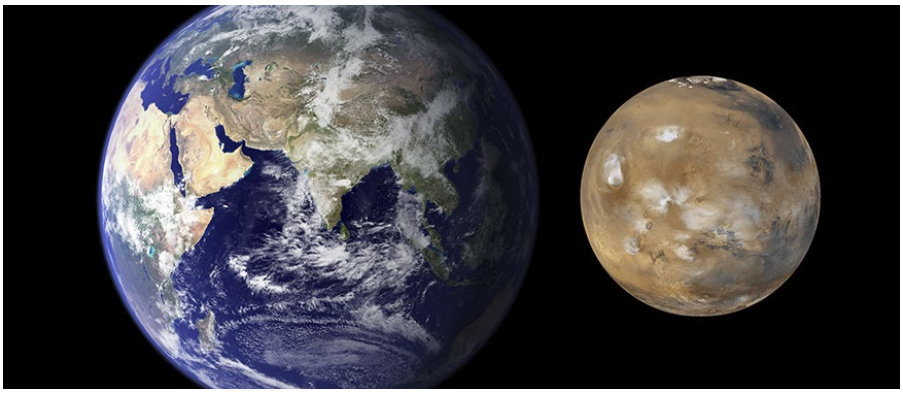
4. What are the main constituents of Mars's atmosphere?

A. Carbon Dioxide and Nitrogen
B. Oxygen and Carbon Dioxide
C. Carbon Dioxide and Methane
D. Methane and Argon



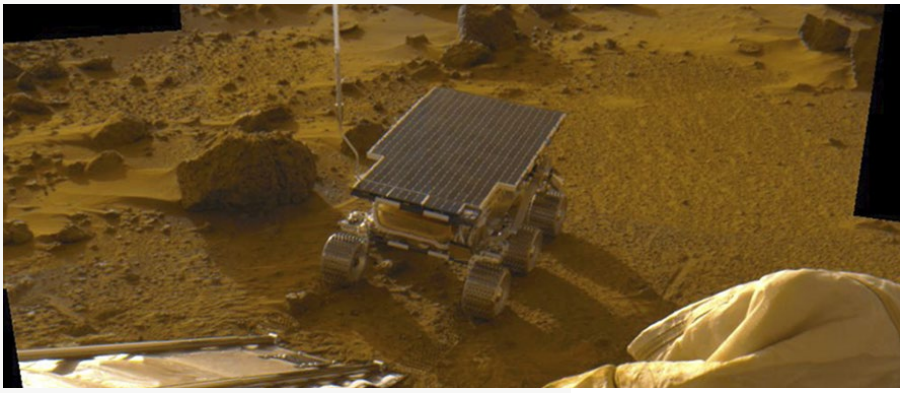
5. How many successful missions have been sent to Mars? (As of July 2020)

A. 40
B. 22
C. 18
D. 26



6. It would take over six Mars to fill up the volume of Earth?

A. True
B. False

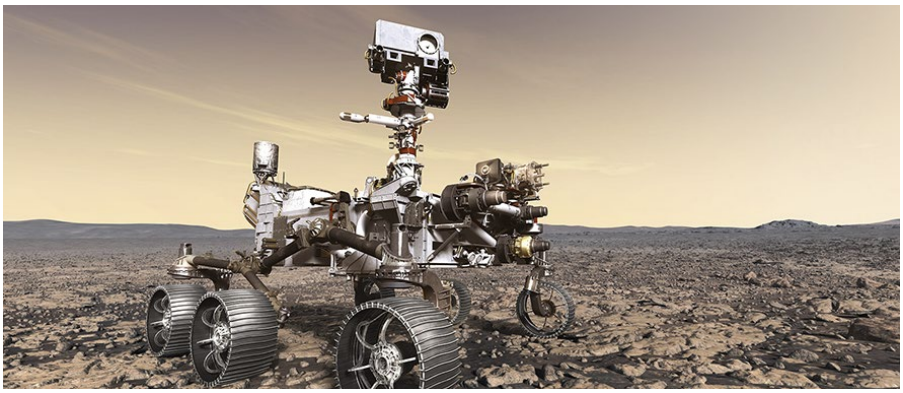


7. Which of the following was the first rover to land on Mars?

A. Curiosity
B. Sojourner
C. Opportunity
D. Exploration

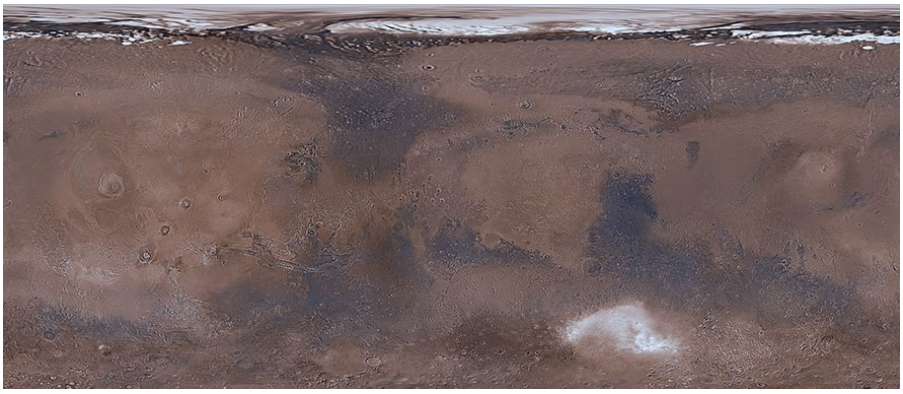
8. How long does it take Mars to complete one orbit of the Sun?

A. 687 days
B. 459 days
C. 543 days
D. 782 days



9. What is the name of NASA's Martian rover set to be launched in 2020?

A. Persistence
B. Perseverance
C. Ingenuity
D. Endurance

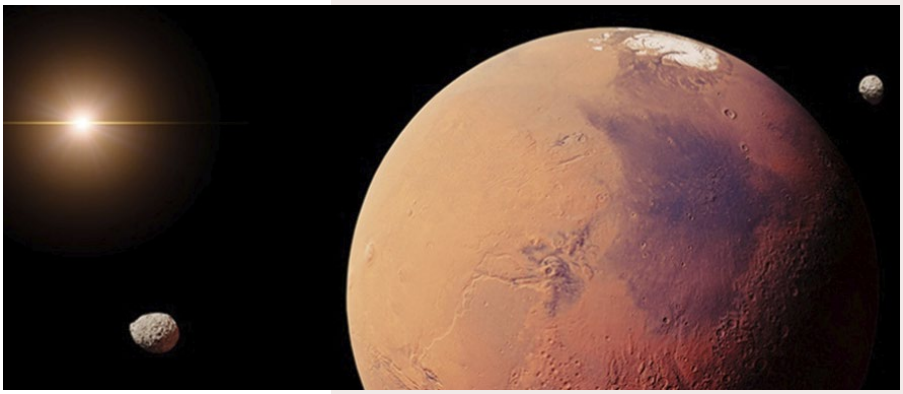


10. Which of the following is not a location on Mars?

A. Tharsis Rise
B. Elysium Mons
C. Argyre Basin
D. Valles Vikings

11. What is the average temperature on Mars?

A. 10 °C (50 °F)
B. 0 °C (32 °F)
C. -63 °C (-81 F)
D. -29 °C (-20 °F)



12. How far is Mars from the sun?

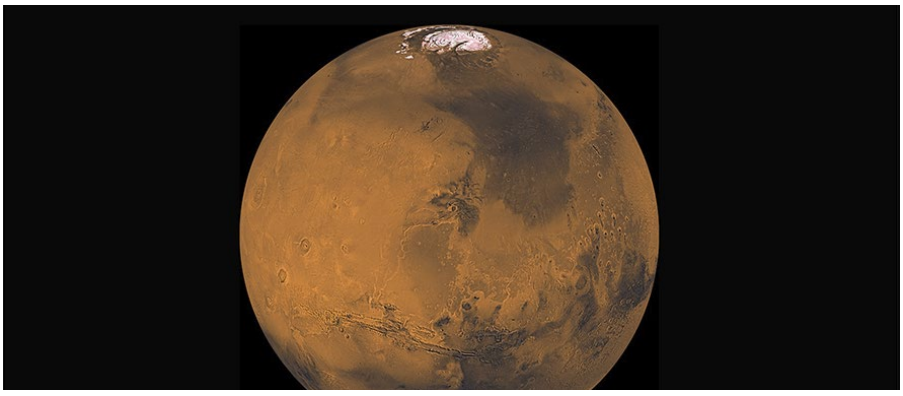
A. 228 million km (141 million mi)
B. 149 million km (92 million mi)
C. 274 million km (170 million mi)
D. 249 million km (154 million mi)

13. Mars is home to the largest dust storms in the solar system?

A. True
B. False

14. Martian sunsets are red in color?

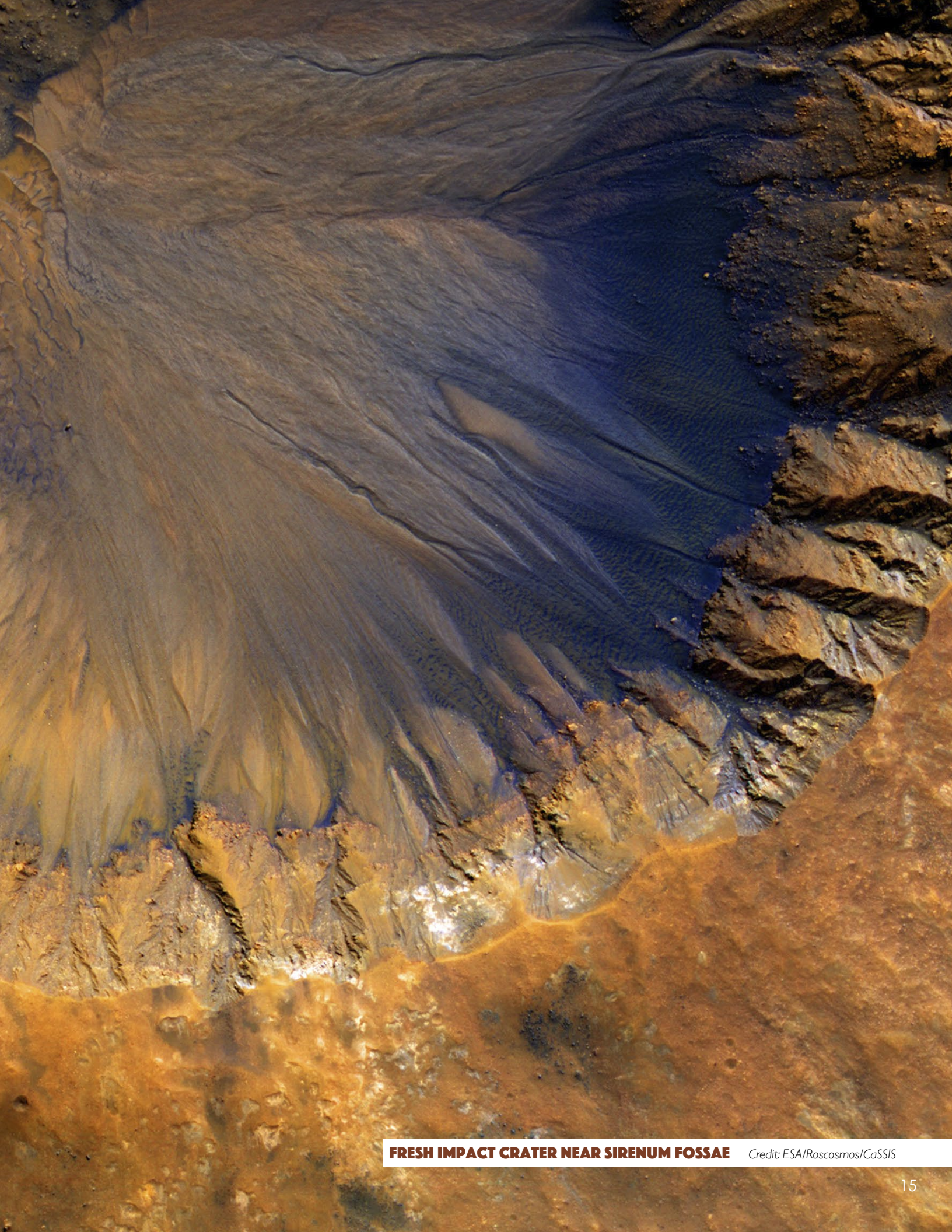
A. True
B. False



15. Fill in the blank: Mars is the _____ smallest planet in our solar system.

A. First
B. Second
C. Third
D. Fourth

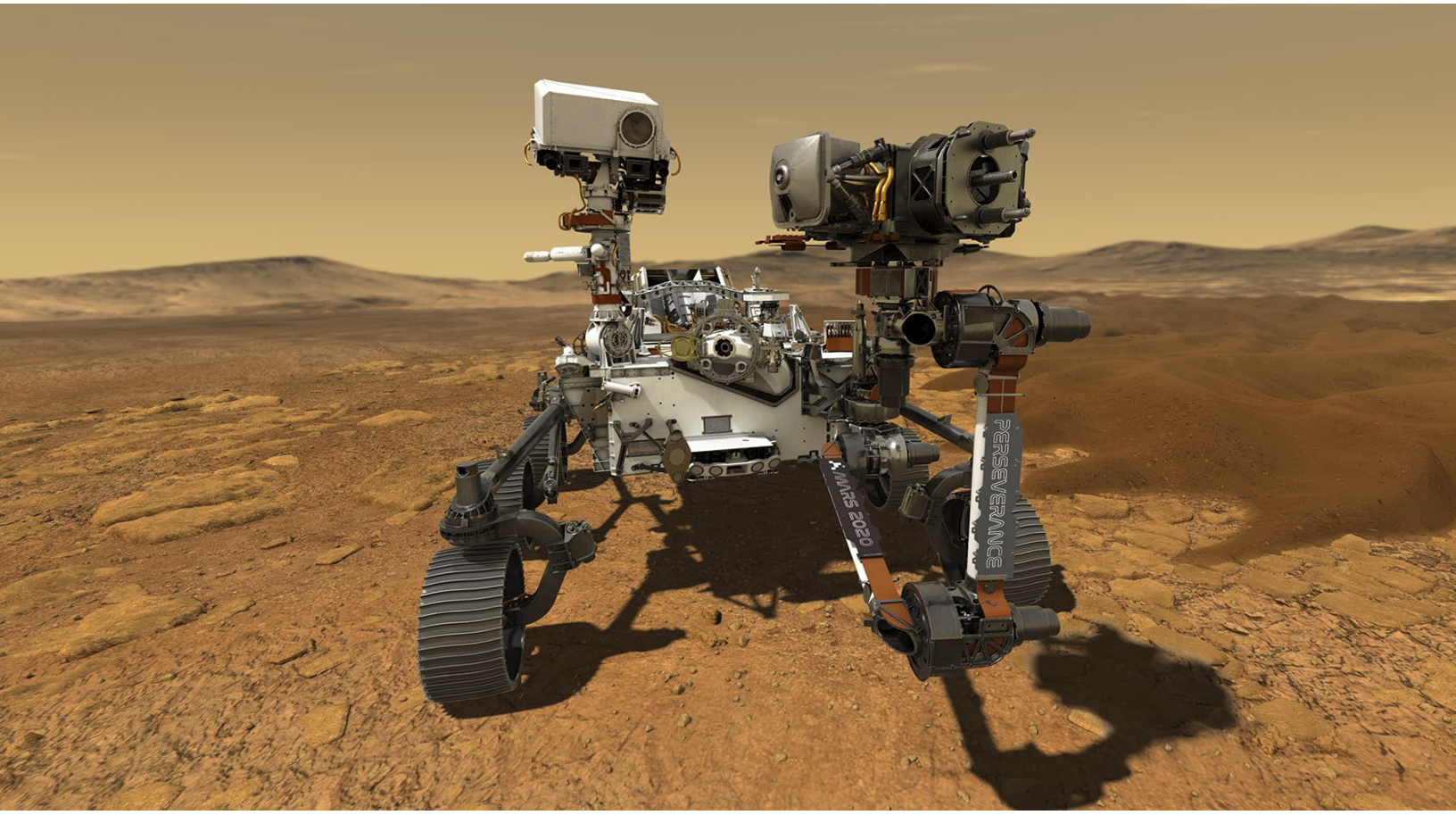
** Answer keys are placed at the back of this publication.*



FRESH IMPACT CRATER NEAR SIRENUM FOSSAE *Credit: ESA/Roscosmos/CaSSIS*

MARS 2020 MISSION OVERVIEW

Article by Ken Kremer



The Mars 2020 Perseverance mission is NASA's next mission to Mars as well as being the most complex and scientifically advanced robotic mission sent to the Red Planet.

The $2.4 Billion Mars Perseverance rover is a flagship mission dedicated to the search for signs of life beyond Earth, as part of NASA's Mars Exploration Program, a long-term effort of robotic exploration of the Red Planet.

The Perseverance Mars 2020 mission will search for signs of ancient microbial life, characterize Mars' climate and geology, collect carefully selected samples for future return to Earth, and pave the way for human exploration of the Red Planet as soon as the 2030s.

Perseverance will also ferry a separate technology experiment to the surface of Mars — a helicopter named Ingenuity, the first aircraft to fly in a controlled way on another planet.

Launch is now targeted for a launch opportunity in the July/August timeframe when Earth and Mars are aligned in good positions relative to each other for landing on Mars.

The car-sized Perseverance Mars 2020 rover is targeted for liftoff on NET 30 July 2020 aboard a United Launch Alliance (ULA) Atlas V 541 rocket from Space Launch Complex 41 on Cape Canaveral Air Force Station, Florida.

The approximately month-long launch window for the Mars 2020 Perseverance rover mission currently extends until August 15.

In this artist's concept, NASA's Ingenuity Mars Helicopter stands on the Red Planet's surface. Credit: NASA/JPL-Caltech

Such opportunities are dictated purely by celestial mechanics and only occur every 26 months when the Earth and Mars are properly aligned.

NASA's Mars 2020 Perseverance rover mission has suffered several significant delays to her launch from the Florida Space Coast to the Red Planet from the original target of July 17 due to contamination and rocket issues as well as staffing level restrictions due to the COVID-19 coronavirus pandemic.

If NASA and ULA cannot launch Mars 2020 Perseverance within the narrow one-month-long window of opportunity, she will have to wait another two years until 2022 until the orbits of our Home Planet and the Red Planet align properly to enable blastoff. Such a postponement would cost $0.5 Billion additional funding and the rover would be placed in storage.

After launch Mars 2020 Perseverance begins a seven-month-long 314 million miles (505 million kilometers) interplanetary journey to the Red Planet where it will search for signs of life.

Perseverance is scheduled to touch down in an area of Mars known as Jezero Crater on Feb. 18, 2021. The crater is home to an ancient dried-up river delta and a lake that once filled it.

The one-ton rover will spend at least one Mars year (two Earth years) exploring the landing site region.

Perseverance is a robotic scientist weighing about 2,260 pounds (1,025 kilograms) and includes a robotic arm with a 99-pound (45-kilogram) turret at the end.

The rover is equipped with six advanced aluminum wheels on a rocker-bogie system.

The SUV sized rover dimensions are 10 feet (3 m) long, 9 feet (2.7 m) wide and 7 feet (2.2 m) tall with a 7 feet (2.1 meters) long robotic arm.

The rover is equipped with seven different scientific instruments and the mission includes 25 cameras – the most ever to Mars and deep space. The rover itself is equipped with 19 cameras.

The science payload has a mass of 130 pounds (59 kilograms) for seven instruments: Mastcam-Z, Mars Environmental Dynamics Analyzer (MEDA), Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE), Planetary Instrument for X-ray Lithochemistry (PIXL), Radar Imager for Mars' Subsurface Experiment (RIMFAX), Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) and SuperCam.

The solar-powered Ingenuity helicopter is a technology demonstration experiment aimed at attempting the first flight on Mars.

The four-legged Ingenuity has a mass of about 4.0 pounds (1.8 kilograms) and stands 1.6 feet or 19 inches (0.49 meters) high. It is equipped with two counter-rotating blades for lift spinning at about 2,400 rpm and two cameras.

To keep mission costs and risks as low as possible, the Mars 2020 design is based on NASA's successful Mars Science Laboratory mission architecture, including its Curiosity rover and proven landing system.

Perseverance is about 278 pounds (126 kilograms) heavier than Curiosity.

However, the suite of seven science instruments are completely new and some hardware such as the wheels have been modified based on experience with Curiosity where they suffered damage over time on the rough terrain.

The rover also carries the first Mars Helicopter – named Ingenuity on its belly. The helicopter is a technology experiment and planned as the first aircraft to fly in a controlled way on another planet.

Alexander Mather, a seventh-grade student at Lake Braddock Secondary School in Burke, Virginia named the Mars 2020 rover, while Vaneeza Rupani (right), a junior at Tuscaloosa County High School in Northport, Alabama, came up with the name for the helicopter. Credits: NASA/JPL-Caltech/NIA/Rupani Family

NAMES:

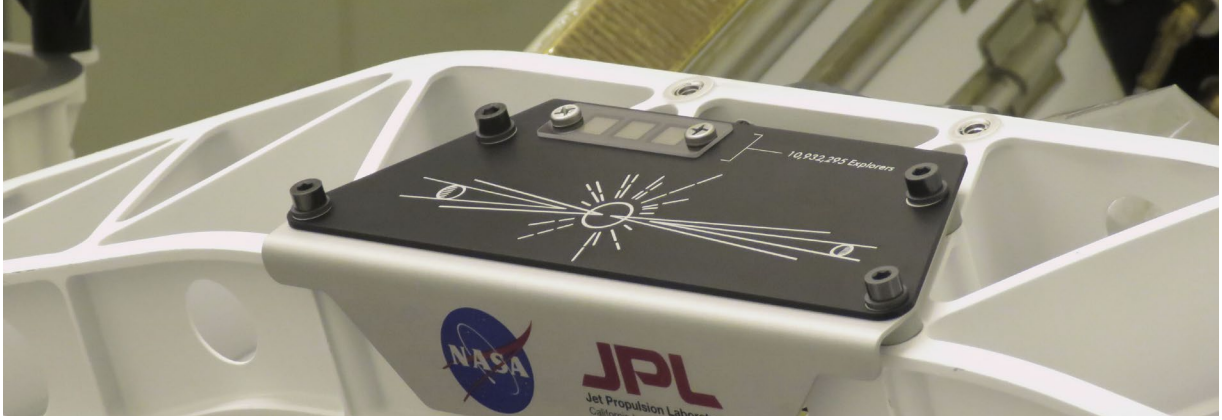
NASA conducted a "Name the Rover" contest for the Mars 2020 rover and helicopter with more than 28,000 essays submitted.

Rover: Perseverance, submitted by Alex Mather, 13, of Lake Braddock Secondary School in Burke, Virginia.

Helicopter: Ingenuity, submitted by Vaneeza Rupani, 17, of Tuscaloosa County High School in Northport, Alabama.

MICROCHIP:

The names of over 10.9 million people are stenciled by electron beam onto three fingernail-sized silicon chips as part of NASA's "Send Your Name to Mars" campaign

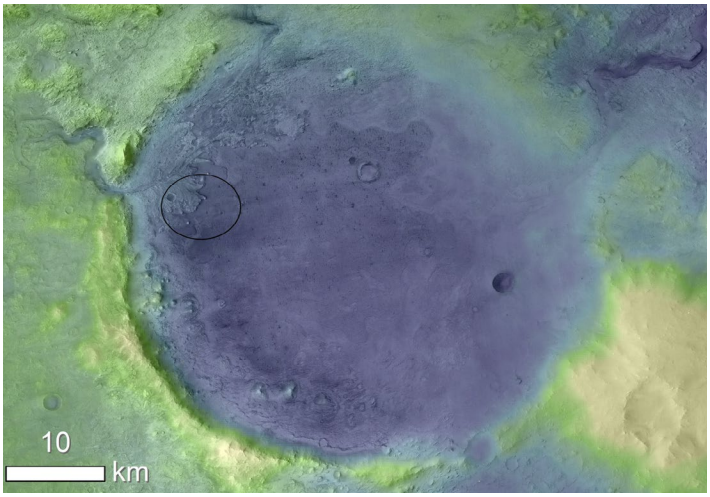


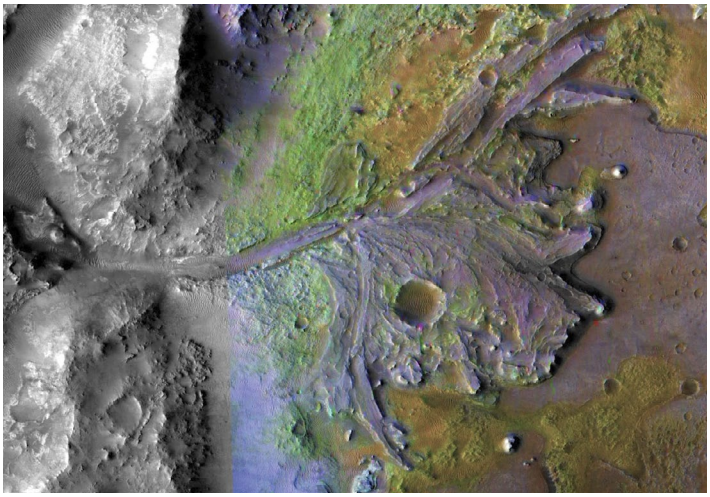
Three fingernail-sized chips affixed to the upper-left corner of this placard contain the names of 10,932,295 people. Credit NASA/JPL-Caltech

LANDING SITE:

Jezero Crater on Mars is a 28-mile-wide (45-kilometer-wide) crater on the western edge of Isidis Planitia, a giant impact basin just north of the Martian equator. The crater was a possible oasis in its distant past.

Between 3 billion and 4 billion years ago, a river there flowed into a body of water the size of Lake Tahoe, depositing sediments packed with carbonite minerals and clay. The Perseverance science team believes this ancient river delta could have collected and preserved organic molecules and other potential signs of microbial life.





These images are of Jezero Crater on Mars, the landing site for the mission. The images were created using data from NASA's Mars Global Surveyor and Mars Reconnaissance Orbiter; and the European Space Agency's Mars Express. Credit: NASA/JPL-Caltech/MSSS/JHU-APL

MARS 2020 COMPONENTS:

Based on the successful Mars Science Laboratory Curiosity design.

Cruise Stage: Configuration for travel between Earth and Mars includes an aeroshell (backshell with heat shield) in which the rover and its landing system are enclosed. Powered by solar cells equipped with thrusters.

Entry, Descent and Landing (EDL) system: Configuration for entry into the Martian atmosphere. Includes the aeroshell, parachute, descent vehicle, and structure for a skycrane maneuver that will lower the rover to the Martian surface on tethers.

Rover: 6-wheeled rover with science instruments.

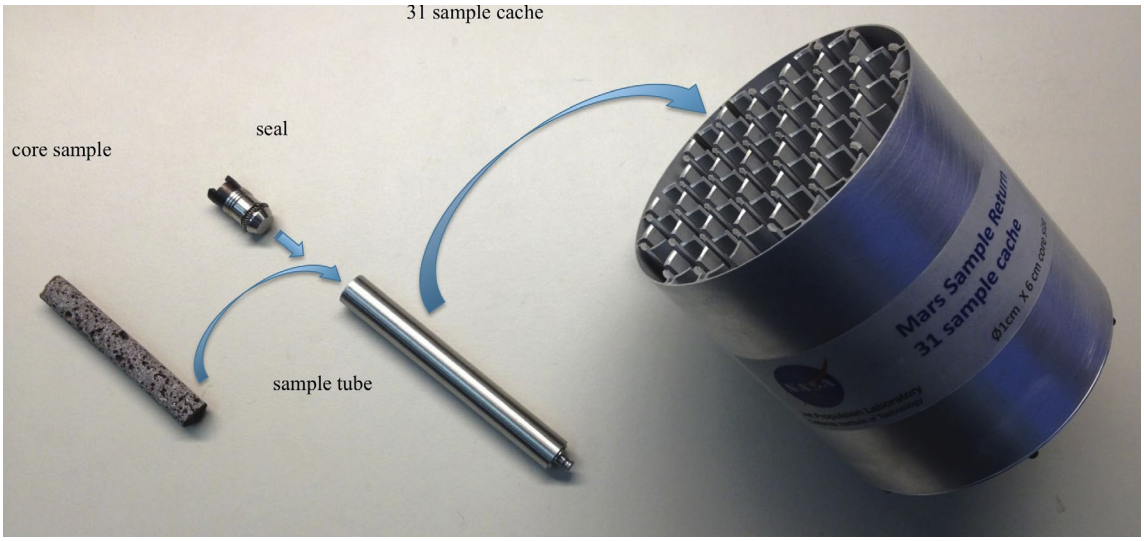
SCIENCE AND SAMPLING GOALS:

The Perseverance rover will explore the geologically diverse Jezero Crater landing site, assess it for ancient habitability, and search for sign ancient life especially in certain types of rocks that preserve signs of life over time.

The Mars Perseverance mission addresses high-priority science goals for Mars exploration, including key questions about the potential for life on Mars. The mission takes the next step by not only seeking signs of habitable conditions on Mars in the ancient past but also searching for signs of past microbial life itself.

The Mars Perseverance rover introduces a drill that can collect core samples of the most promising rocks and soils and set them aside in a "cache" on the surface of Mars.

The rover will gather a few dozen rock and soil samples and place them in sealed tubes for returned to Earth by a future NASA mission.



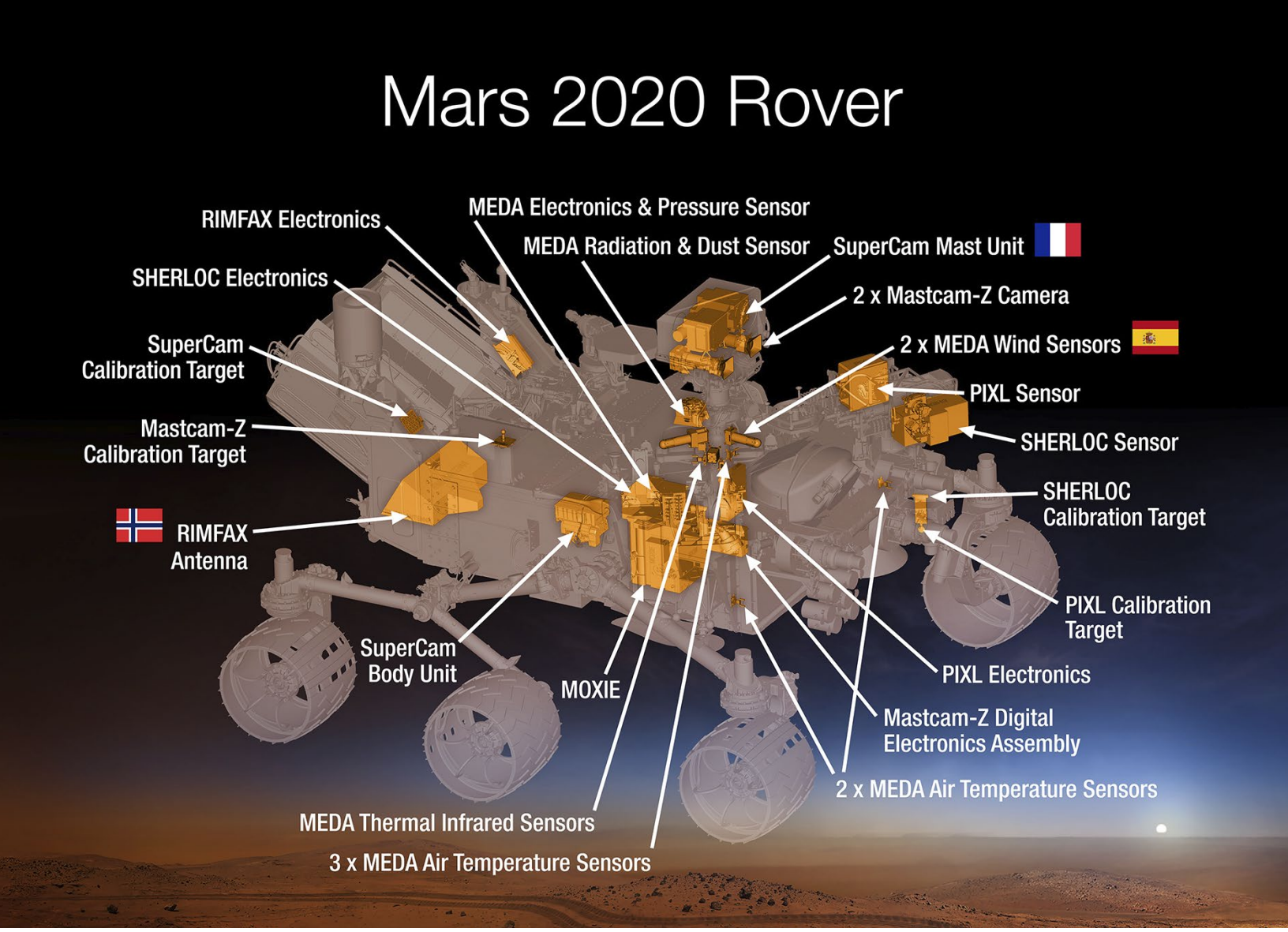
Prototype for hardware to cache core samples drilled from Martian rocks for possible future return to Earth. Credit: NASA/JPL-Caltech

The mission also provides opportunities to gather knowledge and demonstrate technologies that address the challenges of future human expeditions to Mars. These include testing a method for producing oxygen from the Martian atmosphere, identifying other resources (such as subsurface water), improving landing techniques, and characterizing weather, dust, and other potential environmental conditions that could affect future astronauts living and working on Mars.

SCIENCE INSTRUMENT PAYLOAD:

Perseverance will carry seven instruments to conduct unprecedented science and test new technology on the Red Planet. They are:

- **Mastcam-Z:** An advanced camera system with panoramic and stereoscopic imaging capability with the ability to zoom. The instrument also will determine the mineralogy of the Martian surface and assist with rover operations. The principal investigator is James Bell, Arizona State University in Tempe.
- **SuperCam:** An instrument that can provide imaging, chemical composition analysis, and mineralogy at a distance. The principal investigator is Roger Wiens, Los Alamos National Laboratory, Los Alamos, New Mexico. This instrument also has a significant contribution from the Centre National d'Etudes Spatiales, Institut de Recherche en Astrophysique et Planétologie (CNES/IRAP), France.
- **Planetary Instrument for X-ray Lithochemistry (PIXL):** An X-ray fluorescence spectrometer and high-resolution imager to map the fine-scale elemental composition of Martian surface materials. PIXL will provide capabilities that permit more detailed detection and analysis of chemical elements than ever before. The principal investigator is Abigail Allwood, NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California.



The Perseverance rover will carry seven instruments to conduct its science and exploration technology investigations. Credit: NASA/JPL-Caltech

- **Scanning Habitable Environments with Raman & Luminescence for Organics and Chemicals (SHERLOC):** A spectrometer that will provide fine-scale imaging and uses an ultraviolet (UV) laser to map mineralogy and organic compounds. SHERLOC will be the first UV Raman spectrometer to fly to the surface of Mars and will provide complementary measurements with other instruments in the payload. SHERLOC includes a high-resolution color camera for microscopic imaging of Mars' surface. The principal investigator is Luther Beegle, JPL.
- **The Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE):** A technology demonstration that will produce oxygen from Martian atmospheric carbon dioxide. If successful, MOXIE's technology could be used by future astronauts on Mars to burn rocket fuel for returning to Earth. The principal investigator is Michael Hecht, Massachusetts Institute of Technology, Cambridge, Massachusetts.
- **Mars Environmental Dynamics Analyzer (MEDA):** A set of sensors that will provide measurements of temperature, wind speed and direction, pressure, relative humidity, and dust size and shape. The principal investigator is Jose Rodriguez-Manfredi, Centro de Astrobiología, Instituto Nacional de Tecnica Aeroespacial, Spain.
- **The Radar Imager for Mars' Subsurface Experiment (RIMFAX):** A ground-penetrating radar that will provide centimeter-scale resolution of the geologic structure of the subsurface. The principal investigator is Svein-Erik Hamran, the Norwegian Defense Research Establishment, Norway.

The flight model of NASA's Ingenuity Mars Helicopter. Credit: NASA/JPL-Caltech

INGENUITY MARS HELICOPTER:

Ingenuity is a technology demonstration experiment that seeks to test a new capability for the first time – namely the first aircraft to attempt controlled flight on another planet. It is attached to the belly

Mass: about 4.0 pounds (1.8 kg). Height: 1.6 feet (0.49 meters)

Rotor system: Two pairs of counter-rotating blades, spanning 4 feet (1.2 meters) in diameter, spinning at about 2,400 rpm - about eight times as fast as a standard helicopter on Earth.

Equipped with innovative solar cells, battery, avionics, sensors, telecommunications, and other designs and algorithms.

Many components are commercial, off-the-shelf parts from the world of smartphones, including two cameras, an inertial measurement unit (measuring movement), an altimeter (measuring altitude), an inclinometer (measuring tilt angles) and computer processors.

Fuselage (body) dimensions: 0.446 feet by 0.64 feet by 0.535 feet (13.6 centimeters by 19.5 centimeters by 16.3 centimeters); four legs, each about 1.26 feet (0.384 meters) long, giving the helicopter about 0.427 feet (0.13 meters) of clearance above the ground

Power: Solar panel that charges lithium-ion batteries, providing enough energy for one 90-second flight per Martian day (about 350 watts of average power during flight)

Ingenuity is attached to the rover belly and will be deployed about two months after landing onto a flat Martian field.

Ingenuity will fly autonomously. No joystick with real time-human intervention from Earth due to communications delays across interplanetary distances.

Up to five test flight attempts are planned by the helicopter team within a 30-Martian-day (31-Earth-day) window.

CAMERAS:

19 cameras total on the rover: 9 for engineering (color); 3 for entry, descent and landing (1 black-and-white dedicated to Terrain-Relative Navigation and 2 color for public engagement and engineering reconstruction of entry, descent and landing); 2 for Mastcam-Z (color with zoom); 1 for SuperCam (color); 2 for SHERLOC (color); 1 for PIXL (black-and-white with some color capabilities); and 1 for MEDA (black-and-white)

3 cameras on the back shell: all color, all looking up to capture parachute inflation

1 camera on the descent stage: color, looking down to view the rover from above

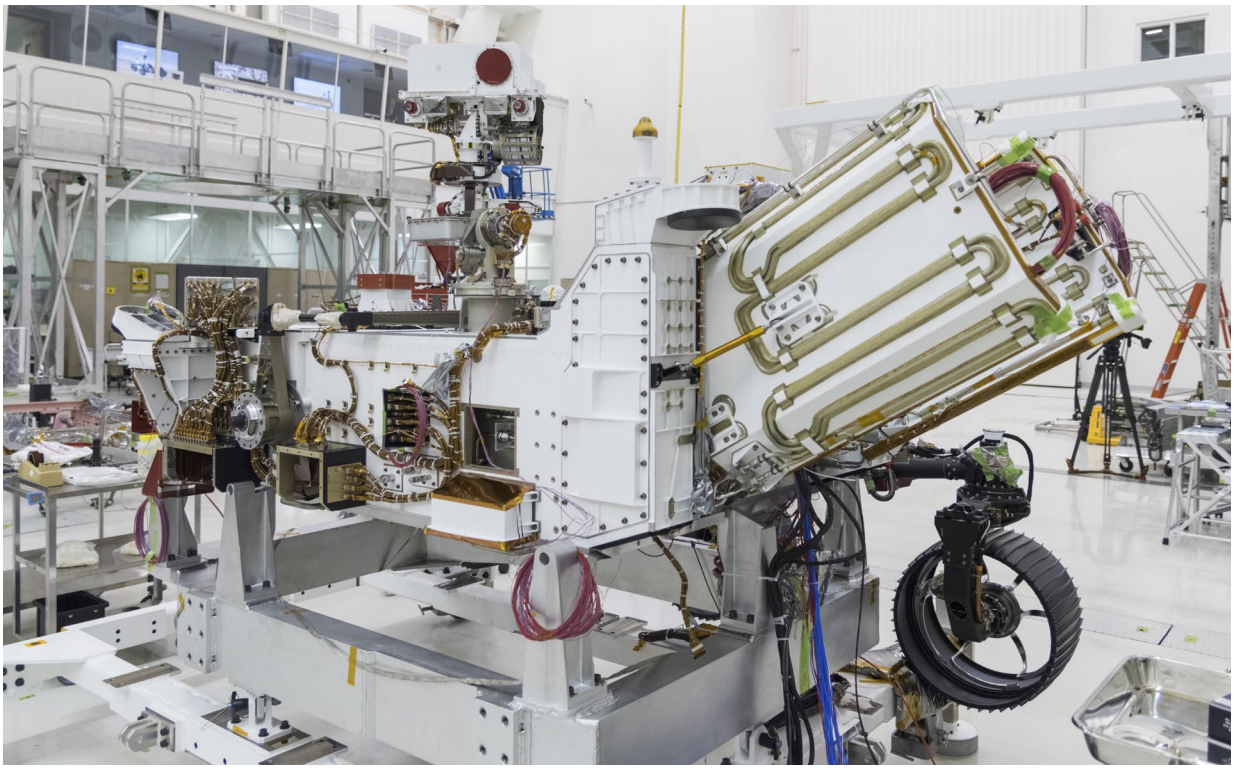
2 cameras on Ingenuity: 1 color for an oblique view for terrain images and 1 black-and-white for navigation

MICROPHONES:

1 on SuperCam and 1 on the side of the rover for public engagement and later entry, descent and landing analysis

POWER:

The power system is a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) provided by the U.S. Department of Energy with a mass of 99 pounds (45 kg) and holds 10.6 pounds (4.8 kg) of plutonium dioxide. Heat generated from the natural decay of plutonium-238 will be converted to a steady flow of about 110 watts of electricity. Two lithium-ion rechargeable batteries are available to meet the peak demands of rover activities when the demand temporarily exceeds the MMRTG's electrical output levels. Overall 14-year operational lifetime.



The electricity needed to operate the rover is provided by essentially a nuclear battery, It was inserted into the aft end of the rover between the panels with gold tubing visible at the rear, which are called heat exchangers. Credit: NASA/JPL-Caltech

Credit NASA/JPL-Caltech

Launch of the Mars Science Laboratory with the Curiosity rover atop a similar Atlas V rocket from the same launch pad at Cape Canaveral Air Force Station in Florida on Nov. 26, 2011. Credit Chase Clark

ULA ATLAS V ROCKET:

Mars 2020 liftoff is targeted for July 30, 2020, at 7: 50 a.m. ET, aboard a two-stage United Launch Alliance (ULA) Atlas V 541 rocket from Space Launch Complex 41 on Cape Canaveral Air Force Station, Florida. Procured under NASA's Launch Services Program.

The 541 configuration features a 5-meter fairing, 4 solid rocket boosters, and a single-engine Centaur upper stage.

Height: 191 feet (58 m)

Mass, fully fueled, with spacecraft on top: About 1.17 million pounds (531,000 kg)

MISSION WEBSITE:

https://mars.nasa.gov/mars2020/

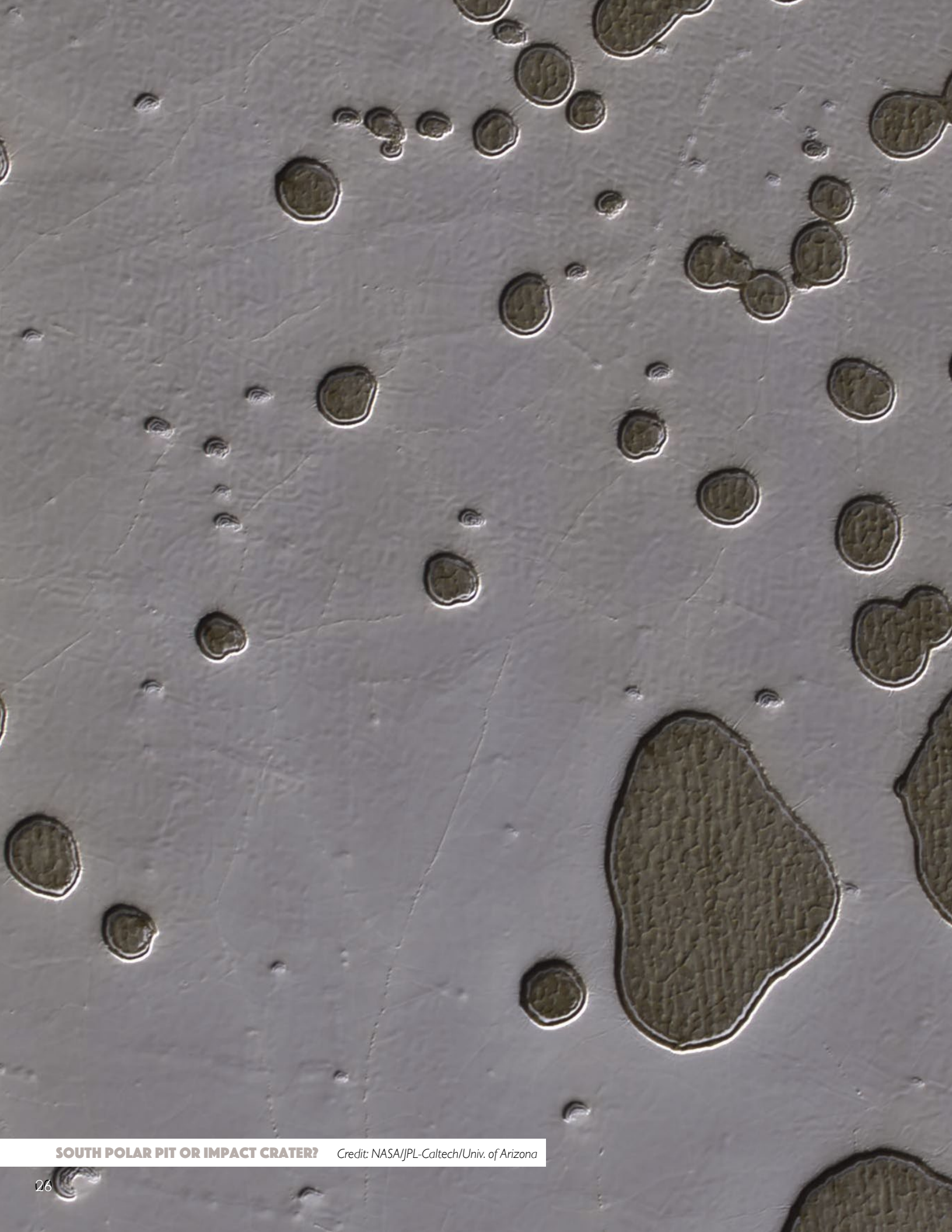
SOCIAL MEDIA:

Twitter: https://twitter.com/NASAPersevere/ @NASAPersevere

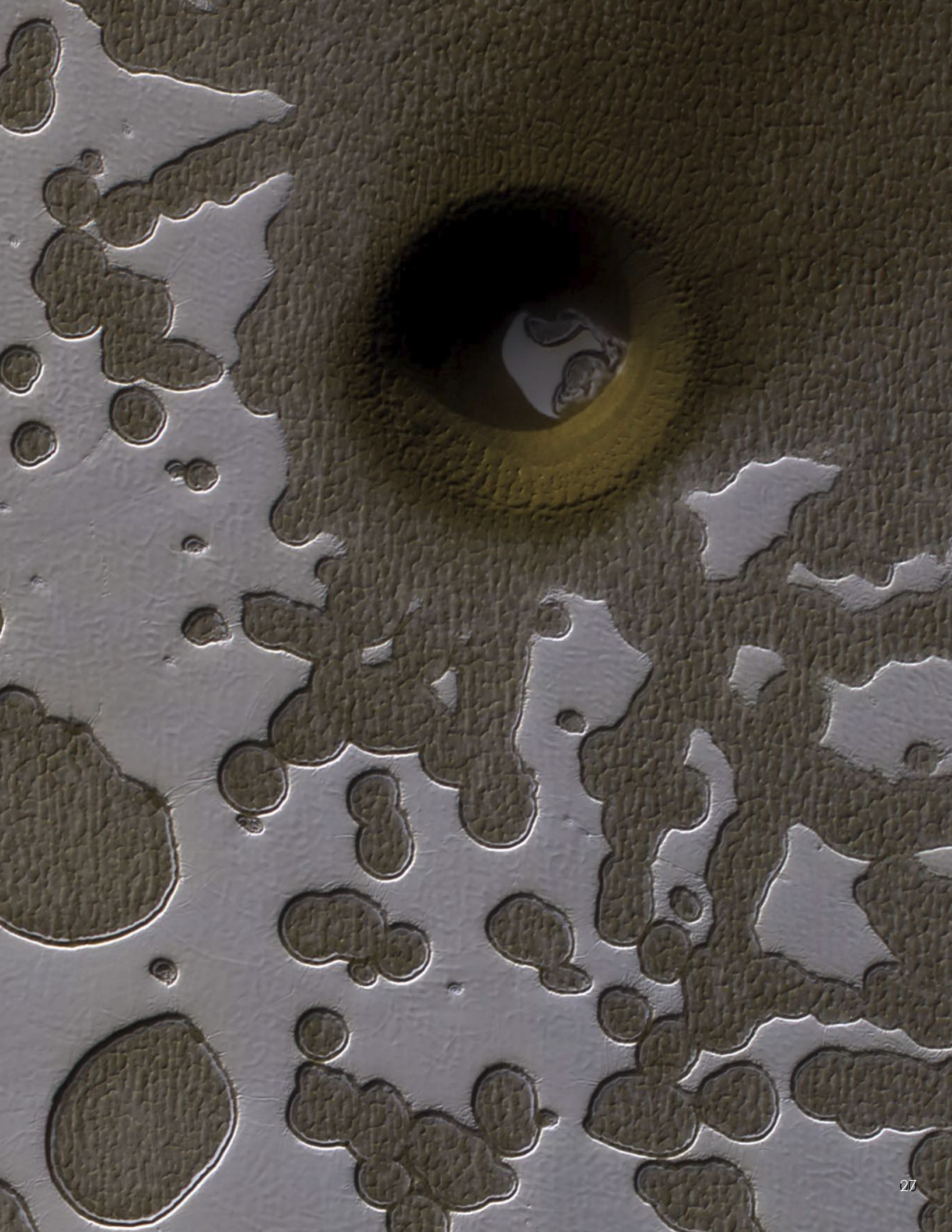
Facebook: https://www.facebook.com/NASAPersevere/

PROGRAM MANAGEMENT:

The Mars 2020 Project is managed for NASA's Science Mission Directorate, Washington, D.C., by the Jet Propulsion Laboratory (JPL), a division of Caltech in Pasadena, California.

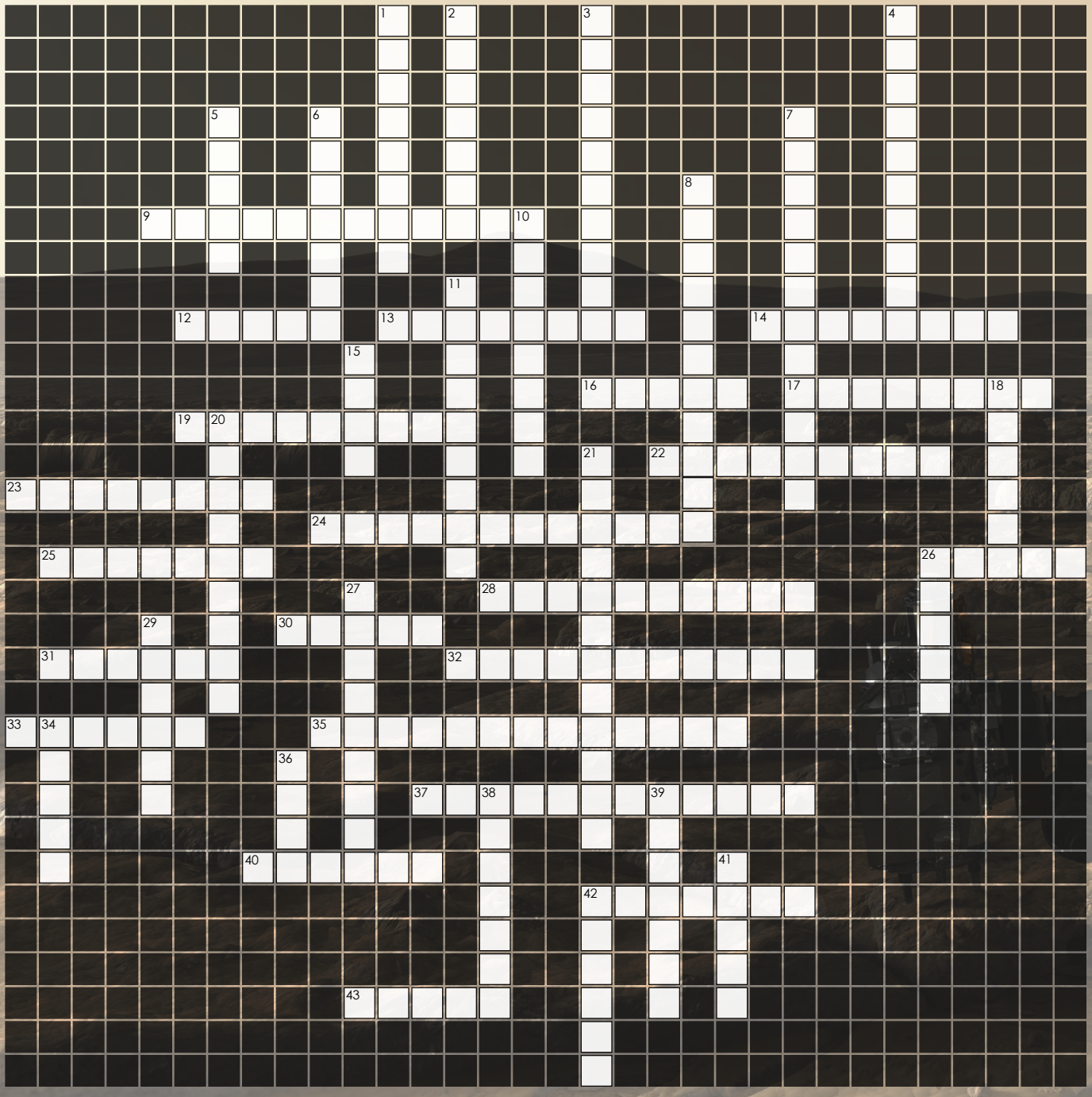


SOUTH POLAR PIT OR IMPACT CRATER? *Credit: NASA/JPL-Caltech/Univ. of Arizona*



Mission to Mars 2020 **CROSSWORD**

Mars 2020 is a NASA rover mission with a targeted launch date of July 17, 2020. The rover and its companion helicopter drone are set to land within a Martian crater on February 18, 2021. The mission will investigate the possibility of past life having existed on Mars. The rover will cache sample containers along its route for a potential future Mars sample-return mission.



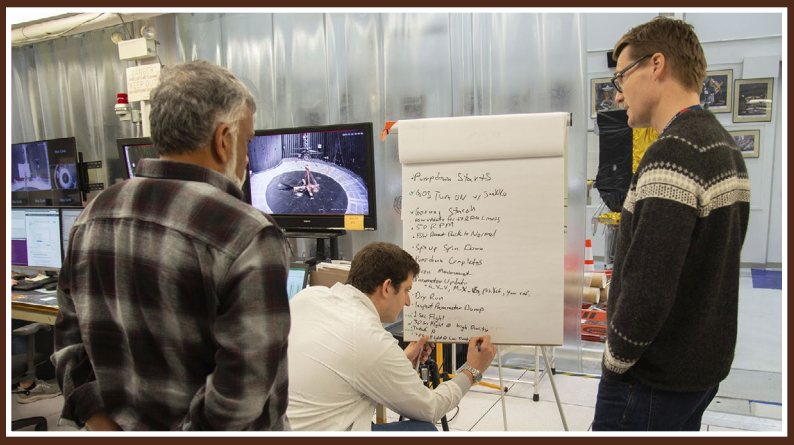
DOWN:

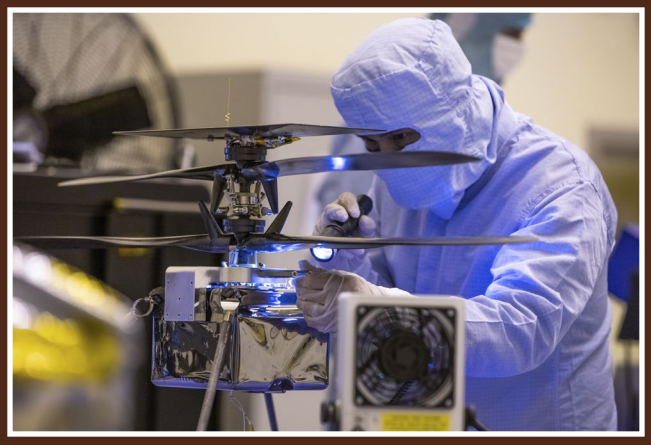
1. The electronics used to control planes, helicopters, drones, and other flying mechanisms.
2. Microorganism. Generally microscopic.
3. A chemical used to create force to move a rocket in a direction.
4. The ability for a robot to act without direct input from a human. The Mars 2020 helicopter will fly itself.
5. Acronym for Multi-Mission Radioisotope Thermoelectric Generator. Used to power the Mars 2020 rover.
6. Resistance of a body to change velocity.
7. Name of the Mars 2020 rover. Tenacity, unwillingness to give up.
8. To pollute areas or surfaces with debris or microorganisms.
10. A rocket powered raft system that will provide the last, gentle landing stage of the Mars 2020 rover.
11. A manufacturing environment free from dust and other contaminants. A room in which the Mars 2020 rover will be assembled.
15. The fourth planet in the solar system.
18. Identify the presence of something
20. Name of the helicopter riding along with the Mars 2020 rover. A quality of being clever and inventive.
21. Studies the potential for life existing and developing on planets other than Earth.
26. A detection system. Uses high-frequency waves to detect location, movement, and speed of an object.
27. An environment that life can exist or survive in. Begins with "H".
29. A synthetic fiber with high tensile strength and often used in bullet-proof vests and parachutes.
34. A Greek titan. The name of the rocket type that will launch the Mars 2020 rover.
36. Related to geology. A sample taken by boring into soil and taking a cylindrical piece for analysis.
38. A rock type typically green in color on Earth's surface. A silicate mineral that weathers easily.
39. A protective outer surface of a spacecraft to protect it from the heat of atmospheric re-entry.
41. Open source operating system. Used for the Mars 2020 helicopter computer.
42. Large bowl shaped cavity typically caused by an explosion or meteorite impact.

ACROSS:

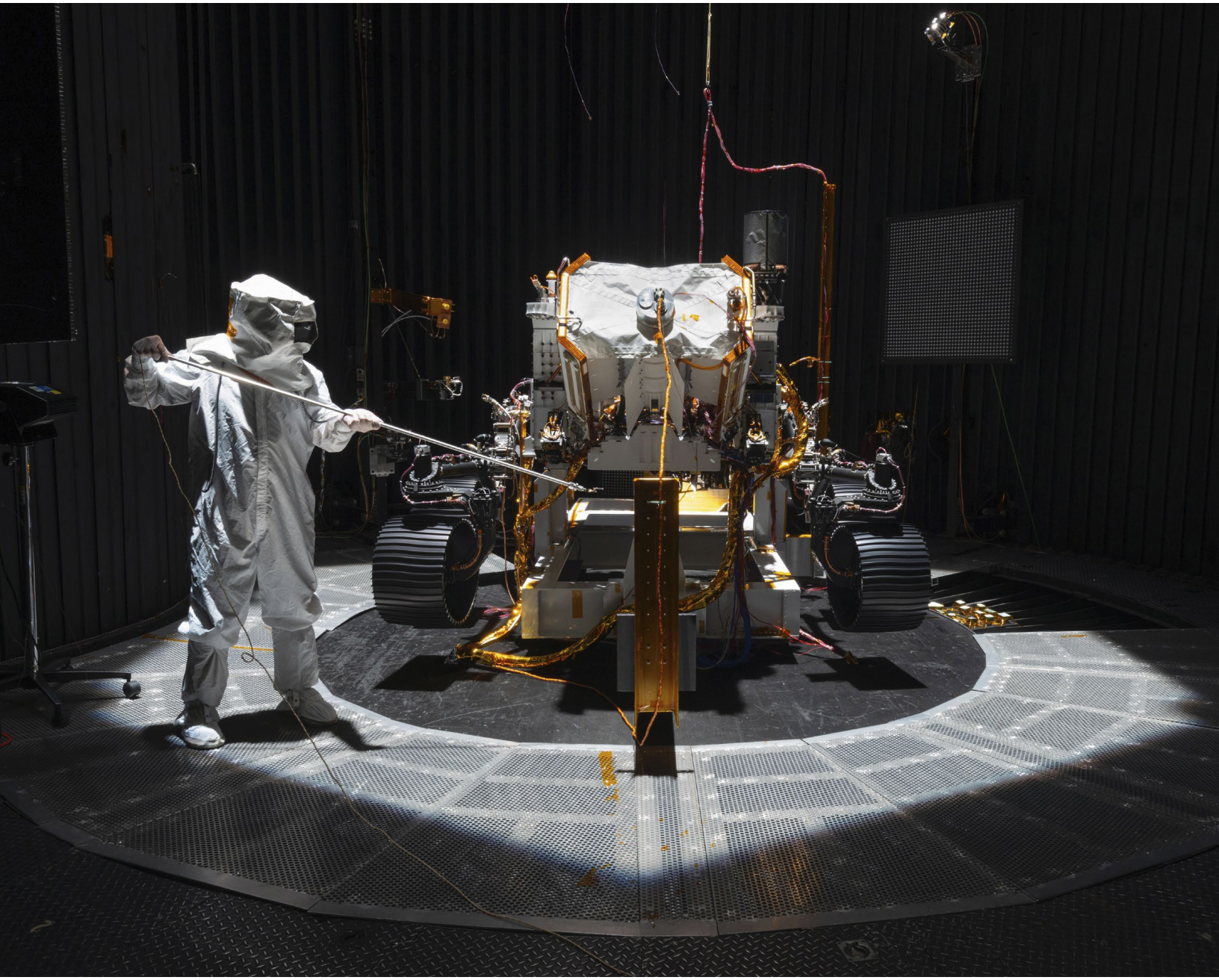
9. A rocket providing thrust opposite of the motion of vehicle.
12. Geography - triangular tract of land deposited at the mouth of river. Useful for finding biosignatures.
13. Distance gained over time in one direction. Speed.
14. Makes up ~41% of Earth's crust and is a sign of volcanism on Mars' surface. Begins with "F".
16. Acronym for Mars Oxygen ISRU Experiment, also a word for determination or nerve.
17. The height of an object relative to the ground.
19. The number of bacteria on a surface that hasn't been sterilized.
22. A cloth canopy used to slow the descent of body from free-fall.
23. Tendency of a mineral to break along planar surfaces determined by its crystal lattice.
24. An isotope that emits radiation as it decays.
25. Very old. The distant past. Life may have existed on Mars in _____ times.
26. Helicopter component. A rotating axis of radiating airfoils horizontal to the lifted body.
28. An envelope of gases surrounding a planet. Mars has a very thin one.
30. Soft, stratified sedimentary rock that can be split easily into fragile slabs. Common on Mars surface.
31. The act of a rocket moving up through the air.
32. A type of feldspar mineral that is typically transparent, glassy, and brittle. A silicate.
33. A dark, fine grained volcanic mineral. The Martian crust consists mainly of this mineral.
35. A layered rock created by cyanobacteria. Theorized to be near the Mars 2020 landing site.
37. AKA chemical or molecular fossil. Can provide scientific evidence of past or present life on a surface.
40. The crater landing site for the Mars 2020 rover. Named for a town in Bosnia and Herzegovina.
42. Along the same axis.
43. A collection of items in a secure place. The Mars 2020 rover will place samples in this.

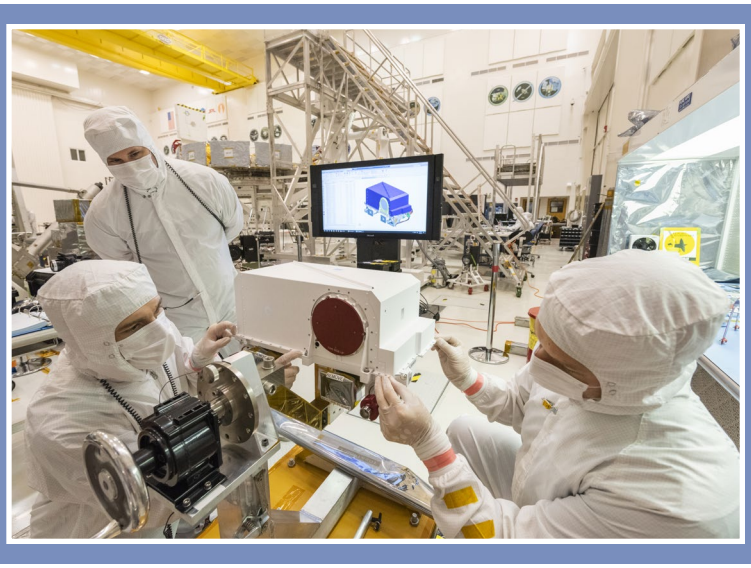
Building for MARS



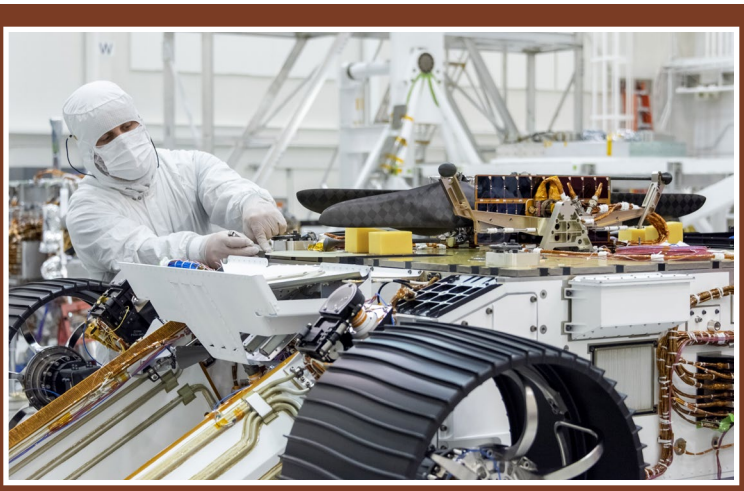


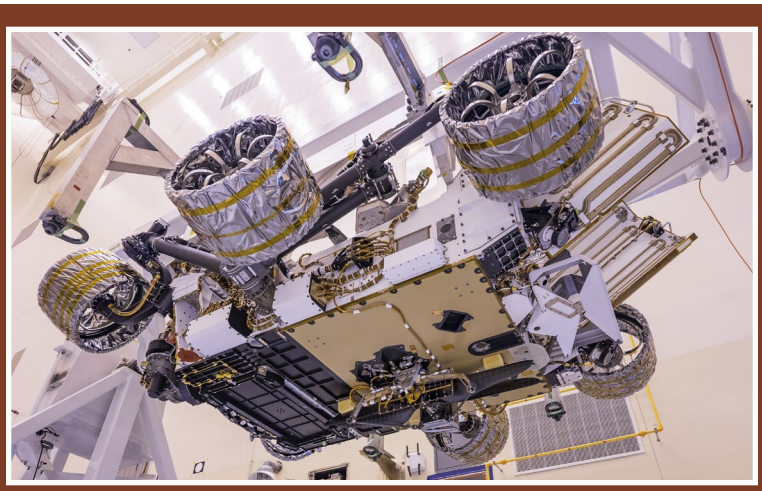
All images credit: NASA/JPL-Caltech and NASA

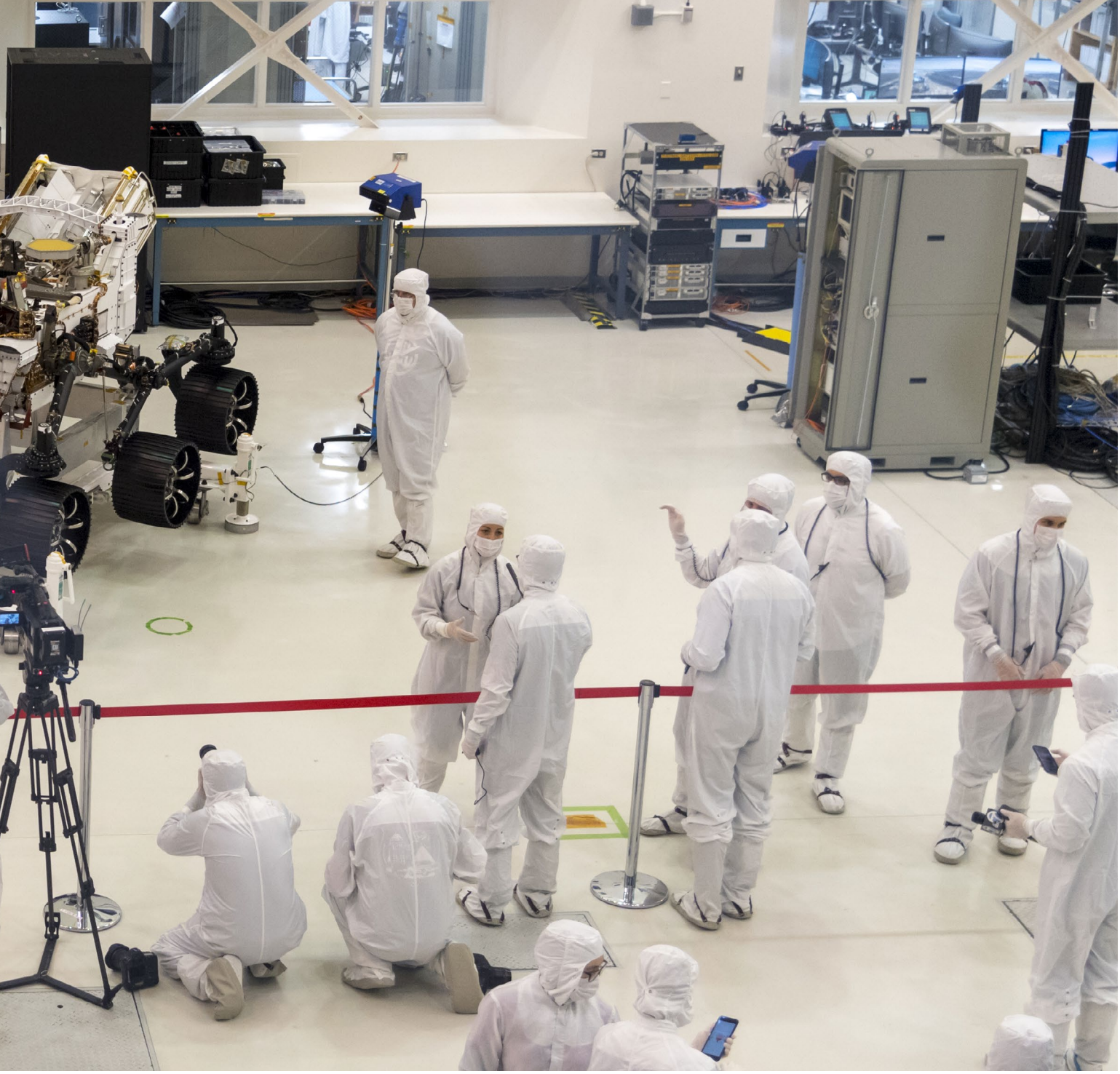


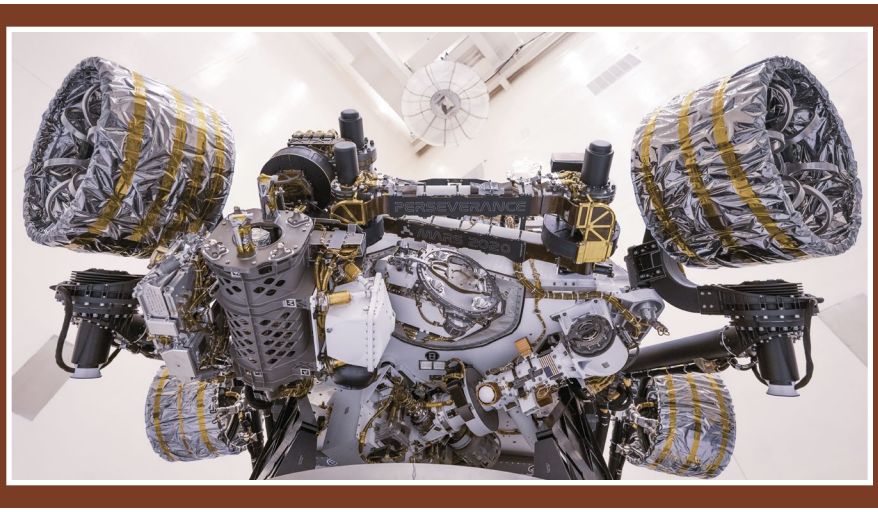


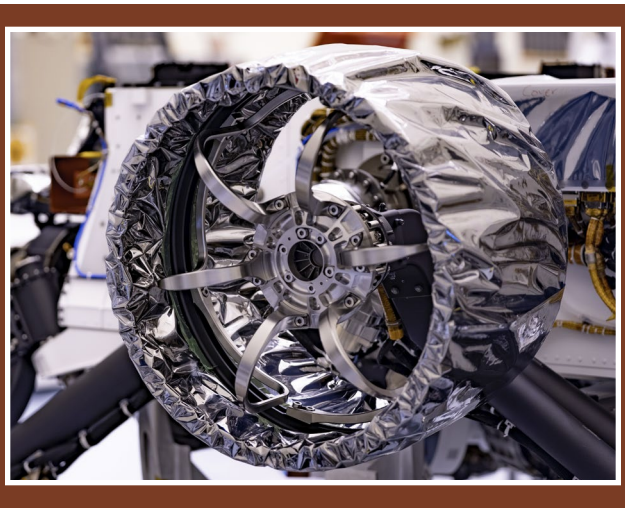

FLIGHT HARDWARE DO NOT TOUCH
FLIGHT HARDWARE DO NOT TOUCH





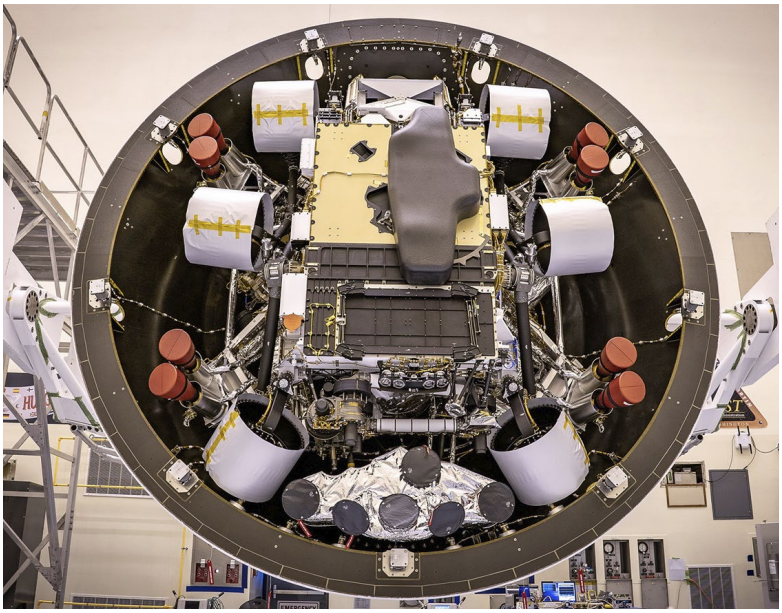


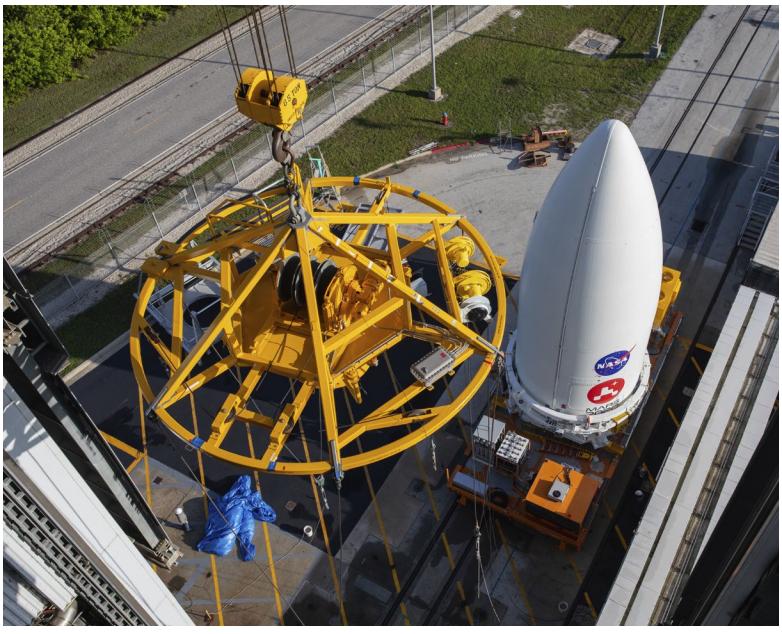

PERSEVERANCE

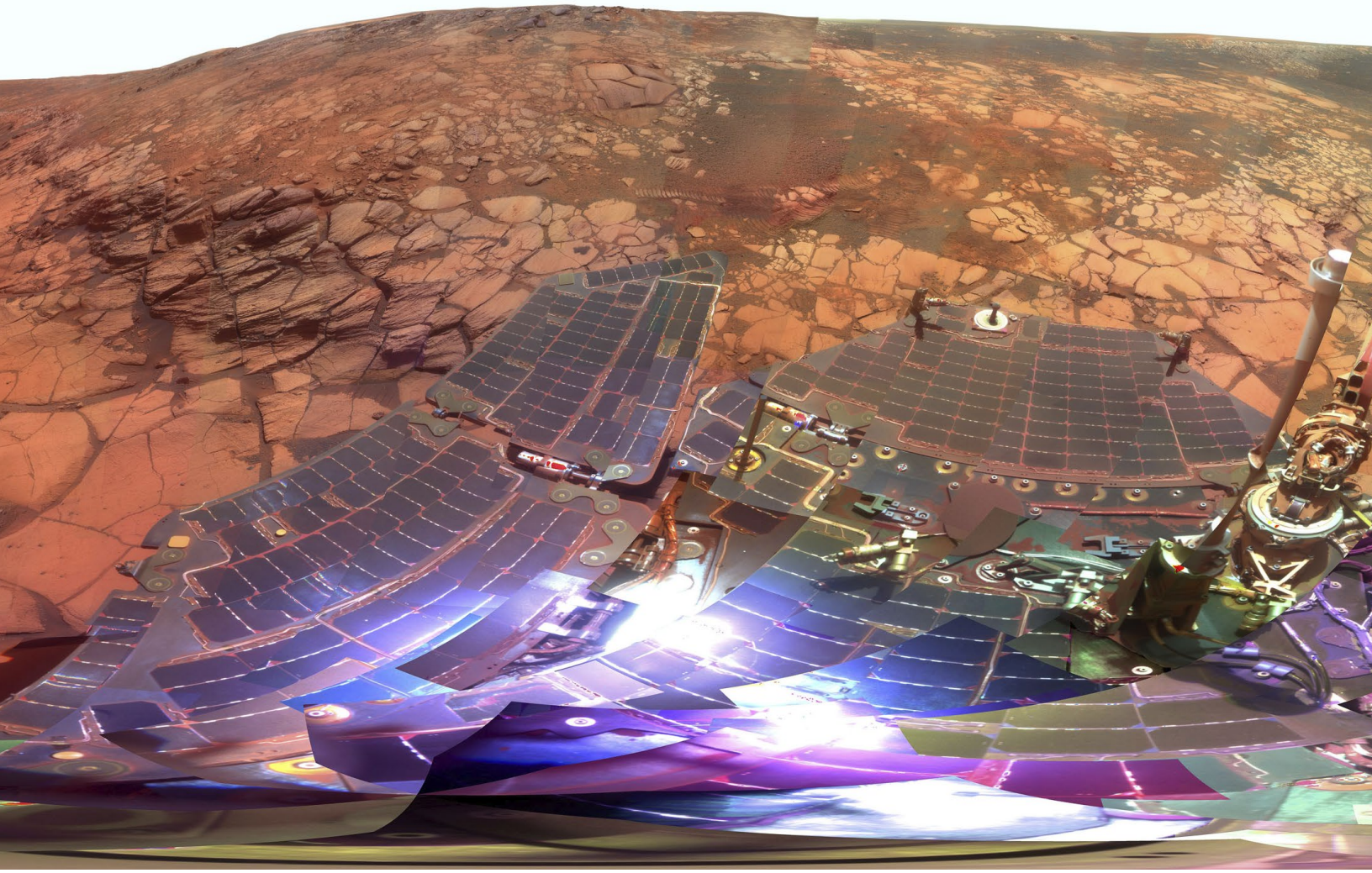



CASSINI


NORTHEAST







OPPORTUNITY'S VICTORIA CRATER PANORAMA *Credit: NASA/JPL-Caltech/Cornell University*

CURIOSITY AT JOHN KLEIN OUTCROP *Credit: NASA/JPL-Caltech/Ken Kremer/Marco Di Lorenzo*

MARS EXPLORATION HISTORICAL TIMELINE

1960s

MARSNIK 1

Failure

USSR • Oct. 10, 1960 • Flyby

Did not reach Earth orbit.

MARSNIK 2

Failure

USSR • Oct. 14, 1960 • Flyby

Did not reach Earth orbit.

SPUTNIK 22

Failure

USSR • Oct. 24, 1962 • Flyby

Achieved Earth orbit only.

MARS 1

Failure

USSR • Nov. 1, 1962 • Flyby

Radio failed at 65.9 million miles (106 million km).

SPUTNIK 24

Failure

USSR • Nov. 4, 1962 •Flyby

Achieved Earth orbit only.

MARINER 3

Failure

United States • Nov. 5, 1964 • Flyby

Shroud failed to jettison.

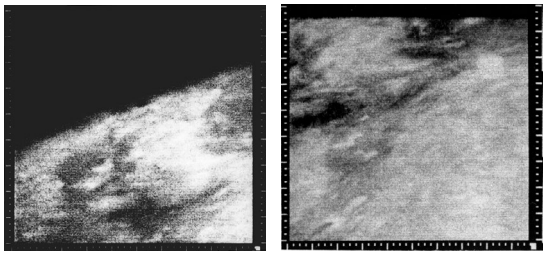
MARINER 4

Success

United States • Nov. 28, 1964 • Flyby

First successful flyby July 14, 1965; returned 21 photos.

First close-up images of Mars as captured during flyby of Mariner 4.



ZOND 2

Failure

USSR • Nov. 30, 1964 • Flyby

Passed Mars but radio failed, returned no planetary data.

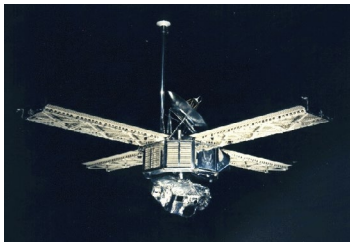
MARINER 6

Success

United States • Feb. 24, 1969 • Flyby

Successful flyby July 31, 1969; returned 75 photos.

Mariner 6 spacecraft

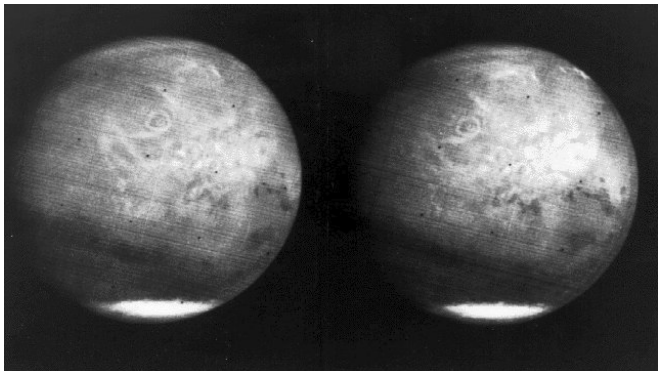


MARINER 7

Success

United States • March 27, 1969 • Flyby

Successful flyby Aug. 5, 1969; returned 126 photos.



Full disc views of Mars imaged by Mariner 7 during approach in 1969.

MARS 1969A

Failure

USSR • March 27, 1969 • Orbiter

Did not reach Earth orbit.

MARS 1969B

Failure

USSR • April 2, 1969 • Orbiter

Failed during launch.

MARINER 8

Failure

United States • May 8, 1971 • Orbiter

Failed during launch.

KOSMOS 419

Failure

USSR • May 10, 1971 • Lander

Achieved Earth orbit only.

MARS 2

Partial Success

USSR • May 19, 1971 • Orbiter & lander

Arrived Nov. 27, 1971; orbiter returned data and images; lander burned up due to steep entry.

MARS 3

Partial Success

USSR • May 28, 1971 • Orbiter, lander and rover

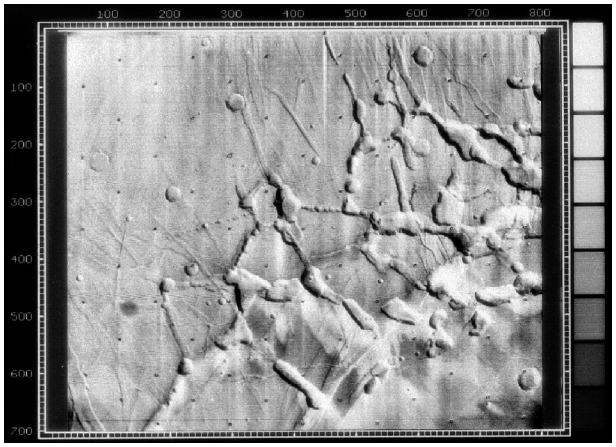
Arrived Dec. 3, 1971; orbiter returned data and images; lander operated on surface for 20 seconds.

MARINER 9

Success

United States • May 30, 1971 • Orbiter

Operated in orbit Nov. 13, 1971 to Oct. 27, 1972, returned 7,329 photos.



Mariner 9's view of the "labyrinth" at the western end of Vallis Marineris.

MARS 4

Partial Success

USSR • July 21, 1973 • Orbiter

Flew past Mars Feb. 10, 1974 and collected some data, but did not achieve Mars orbit.

MARS 5

Partial Success

USSR • July 25, 1973 • Orbiter

Arrived Feb. 12, 1974, lasted a few days.

MARS 6

Partial Success

USSR • Aug. 5, 1973 • Flyby module & lander

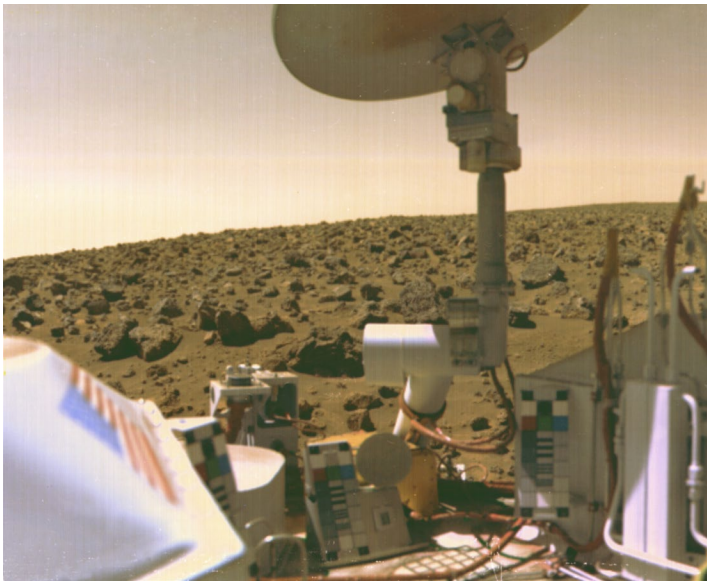
Arrived March 12, 1974, lander failed due to fast impact; flyby module returned data

MARS 7

Failure

USSR • Aug. 9, 1973 • Flyby module & lander

Arrived March 9, 1974, lander missed the planet.



Viking 2's image of Mars Utopian Plain.

VIKING 1

Success

United States • Aug. 20, 1975 • Orbiter & lander

Entered orbit June 19, 1976, and operated until Aug. 7, 1980; landed July 20, 1976, and operated until Nov. 11, 1982.

VIKING 2

Success

United States • Sept. 9, 1975 • Orbiter & lander

Entered orbit Aug. 7, 1976, and operated until July 25, 1978; landed Sept. 3, 1976, and operated until April 11, 1980; combined, the Viking orbiters and landers returned more than 50,000 photos.

1980s

PHOBOS 1

Failure

USSR • July 7, 1988 • Mars orbiter & Phobos lander

Lost August 1988 en route to Mars.

PHOBOS 2

Partial Success

USSR • July 12, 1988 • Mars orbiter & Phobos lander

Entered orbit, lost contact March 1989 near Phobos.

1990s

MARS OBSERVER

Failure

United States • Sept. 25, 1992 • Orbiter

Lost just before Mars arrival Aug. 21, 1993.

MARS GLOBAL SURVEYOR

Success

United States • Nov. 7, 1996 • Orbiter

Arrived Sept. 12, 1997; mapped in high detail through January 2000, completed its third extended mission in September 2006, and last communicated Nov. 2, 2006.

Spanning s a region of about 1,500 m (4,921 ft) across, this Mars Global Surveyor image shows gullies on the walls of Newton Basin in Sirenum Terra.

MARS 96

Failure

Russia • Jan. 16, 1996 • Orbiter, two landers & two penetrators

Launch vehicle failed.

Sojourner takes a measurement of the Yogi Rock.

MARS PATHFINDER (SOJOURNER)

Success

United States • Dec. 4, 1996 • Lander & rover

Landed July 4, 1997, completed prime mission and began extended mission Aug. 3, 1997, and last communicated on Sept. 27, 1997.

NOZOMI

Failure

Japan • July 4, 1998 • Orbiter

Failed to enter orbit December 2003.

MARS CLIMATE ORBITER

Failure

United States • Dec. 11, 1998 • Orbiter

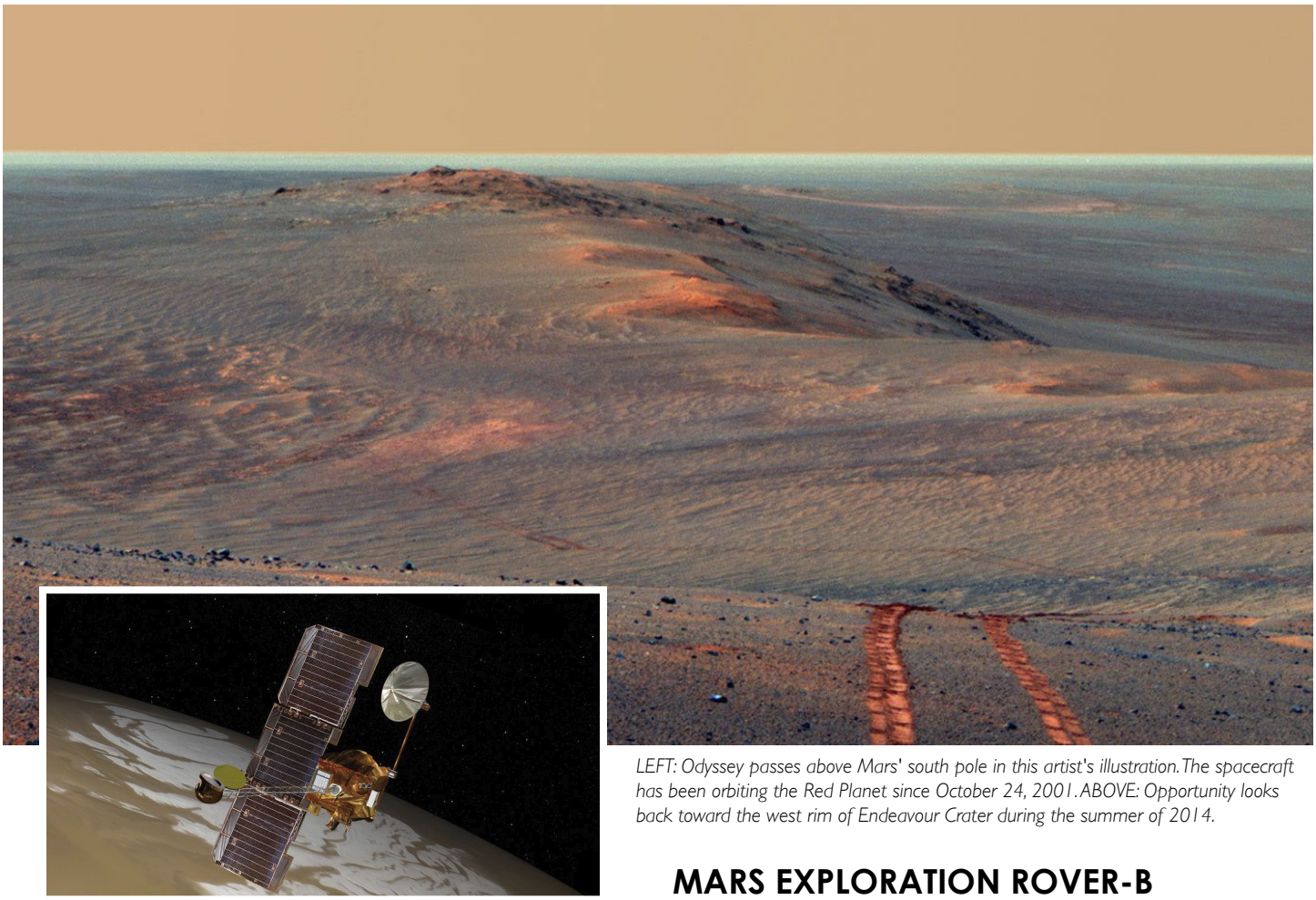
Lost upon arrival Sept. 23, 1999.

MARS POLAR LANDER/DEEP SPACE 2

Failure

United States • Jan. 3, 1999 • Lander & two penetrators

Lost on arrival Dec. 3, 1999.



LEFT: Odyssey passes above Mars' south pole in this artist's illustration. The spacecraft has been orbiting the Red Planet since October 24, 2001. ABOVE: Opportunity looks back toward the west rim of Endeavour Crater during the summer of 2014.

MARS ODYSSEY

Success

United States • March 7, 2001 • Orbiter

Entered orbit Oct. 24, 2001, completed prime mission Aug. 24, 2004, currently conducting extended mission of science collection and communication relay.

MARS EXPRESS/BEAGLE 2

Partial Success

Europe • June 2, 2003 • Orbiter & lander

Orbiter completed prime mission November 2005, currently in extended mission; lander lost on arrival Dec. 25, 2003.

MARS EXPLORATION ROVER-A (SPIRIT)

Success

United States • June 10, 2003 • Rover

Landed Jan. 4, 2004 for three-month prime mission inside Gusev Crater, completed several extended missions, last communicated March 22, 2010, mission declared complete May 25, 2011.

MARS EXPLORATION ROVER-B (OPPORTUNITY)

Success

United States • July 7, 2003 • Rover

Landed Jan. 25, 2004 for three-month prime mission in Meridiani Planum region, completed several extended missions, last communicated June 10, 2018, mission declared complete on Feb. 13, 2019.

MARS RECONNAISSANCE ORBITER

Success

United States • Aug. 12, 2005 • Orbiter

Entered orbit March 12, 2006, completed prime mission 9/26/10, currently conducting extended mission of science collection and communication relay.

PHOENIX MARS LANDER

Success

United States • Aug. 4, 2007 • Lander

Landed May 25, 2008, completed prime mission and began extended mission Aug. 26, 2008, last communicated Nov. 2, 2008.

This composite image looking toward the higher regions of Mount Sharp was taken on September 9, 2015, by NASA's Curiosity rover.

PHOBOS-GRUNT/YINGHUO 1

Failure

Russia/China • Nov. 8, 2011 • Phobos lander with sample return & Mars orbiter

Achieved Earth orbit only.

MARS SCIENCE LABORATORY (CURIOSITY ROVER)

Success

United States • Nov. 26, 2011 • Rover

Landed Aug. 6, 2012, completed prime mission, currently conducting extended science mission.

MARS ORBITER MISSION (MANGALYAAN)

Success

India • Nov. 5, 2013 • Orbiter

Entered orbit Sept. 14, 2014, completed prime mission, currently conducting extended mission.

MARS ATMOSPHERE AND VOLATILE EVOLUTION MISSION (MAVEN)

Success

United States • Nov. 18, 2013 • Orbiter;

Entered orbit Sept. 21, 2014; completed prime mission, currently conducting extended science mission.

EXOMARS 2016 (TRACE GAS ORBITER AND SCHIAPARELLI MODULE)

Partial Success

Europe • March 14, 2016 • Orbiter & landing-demonstration module

Entered orbit Oct. 19, 2016, currently conducting prime mission; unsuccessful Mars impact of Schiaparelli module Oct. 19, 2016.

INSIGHT LANDER

Success

United States • May 5, 2018 • Lander

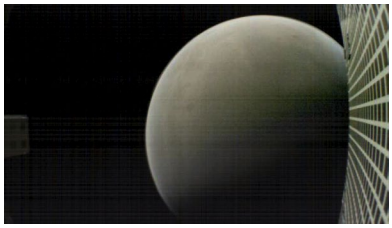
Landed Nov. 26, 2018, currently conducting prime mission at Elysium Planitia.

MARCO

Success

United States • May 5, 2018 • Two-CubeSat providing data relay for InSight Lander.

Flew by Mars and completed relay Nov. 26, 2018, concluded operations Feb. 2, 2020.



View of Mars from MarCO-B during its flyby in late 2018.

The United Arab Emirate's Hope orbiter is shown with its solar panels fully deployed before final preparations for its launch this summer.

EMIRATES HOPE MISSION

United Arab Emirates • NET July 19, 2020 • Orbiter

MARS 2020

United States • NET July 30, 2020 • Rover

TIANWEN 1

China • NET July/August 2020 • Orbiter, lander & rover

EXOMARS 2022

Europe/Russia • 2022 • Lander & rover

MARS TERA-HERTZ EXPLORER

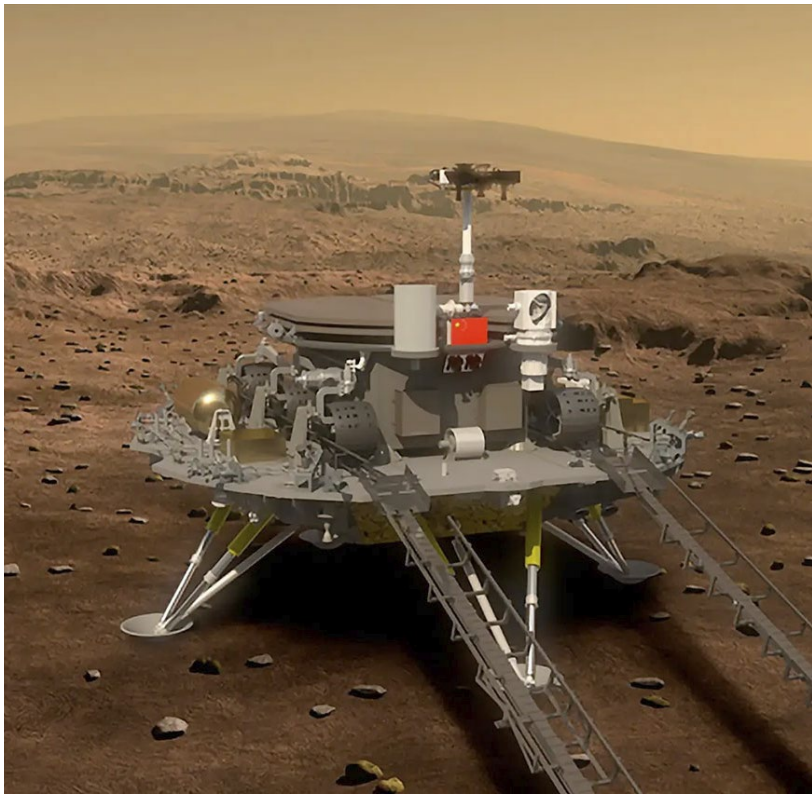
Japan • 2022 • Orbiter & lander

MARS ORBITER MISSION 2

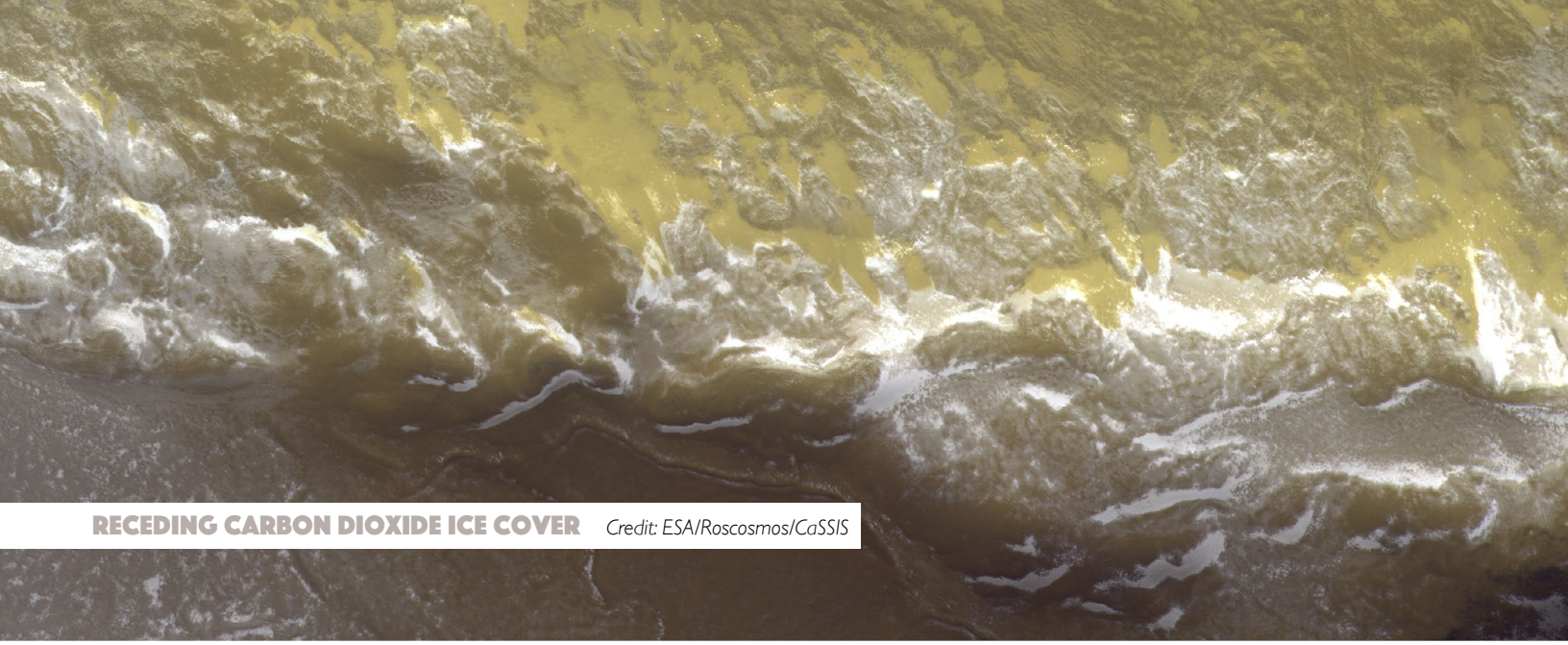
India • July 16, NET 2022 • Orbiter, possibly lander & rover

MARTIAN MOONS EXPLORATION

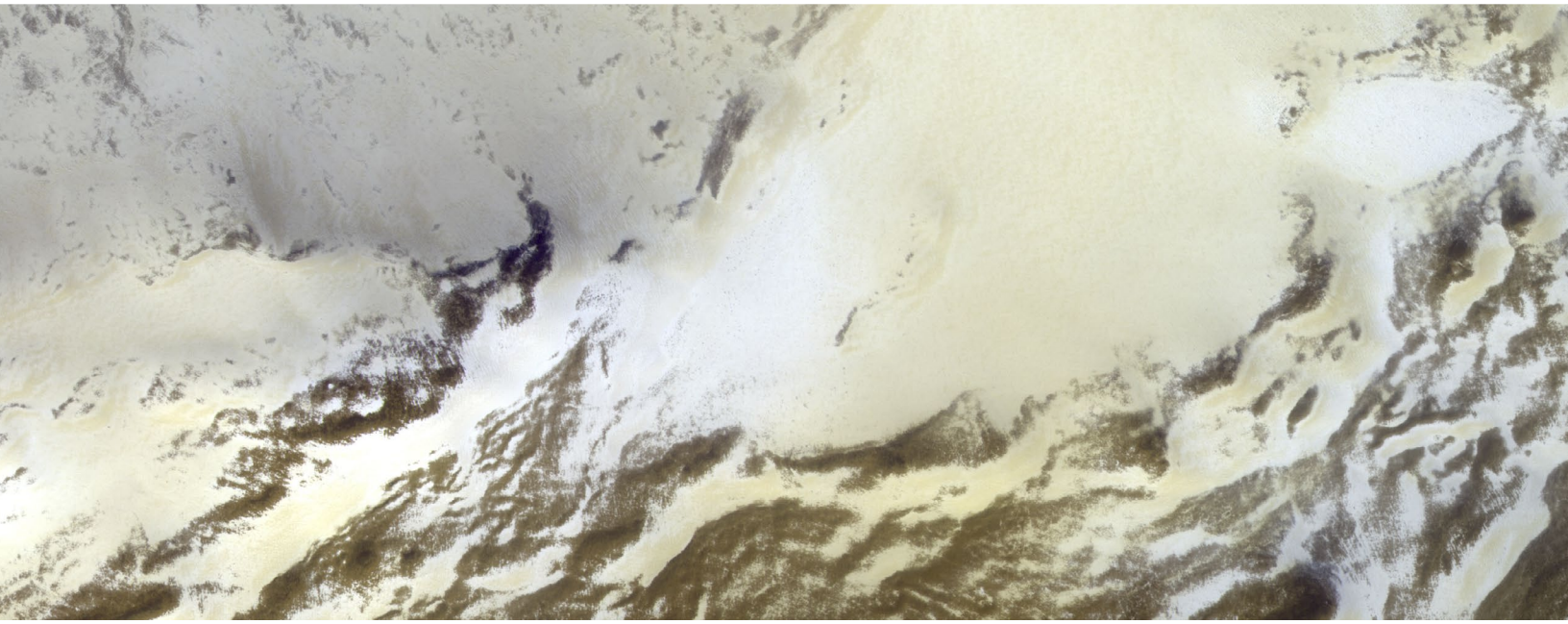
Japan • NET 2024 • Orbiter, Phobos lander & sample return back to Earth

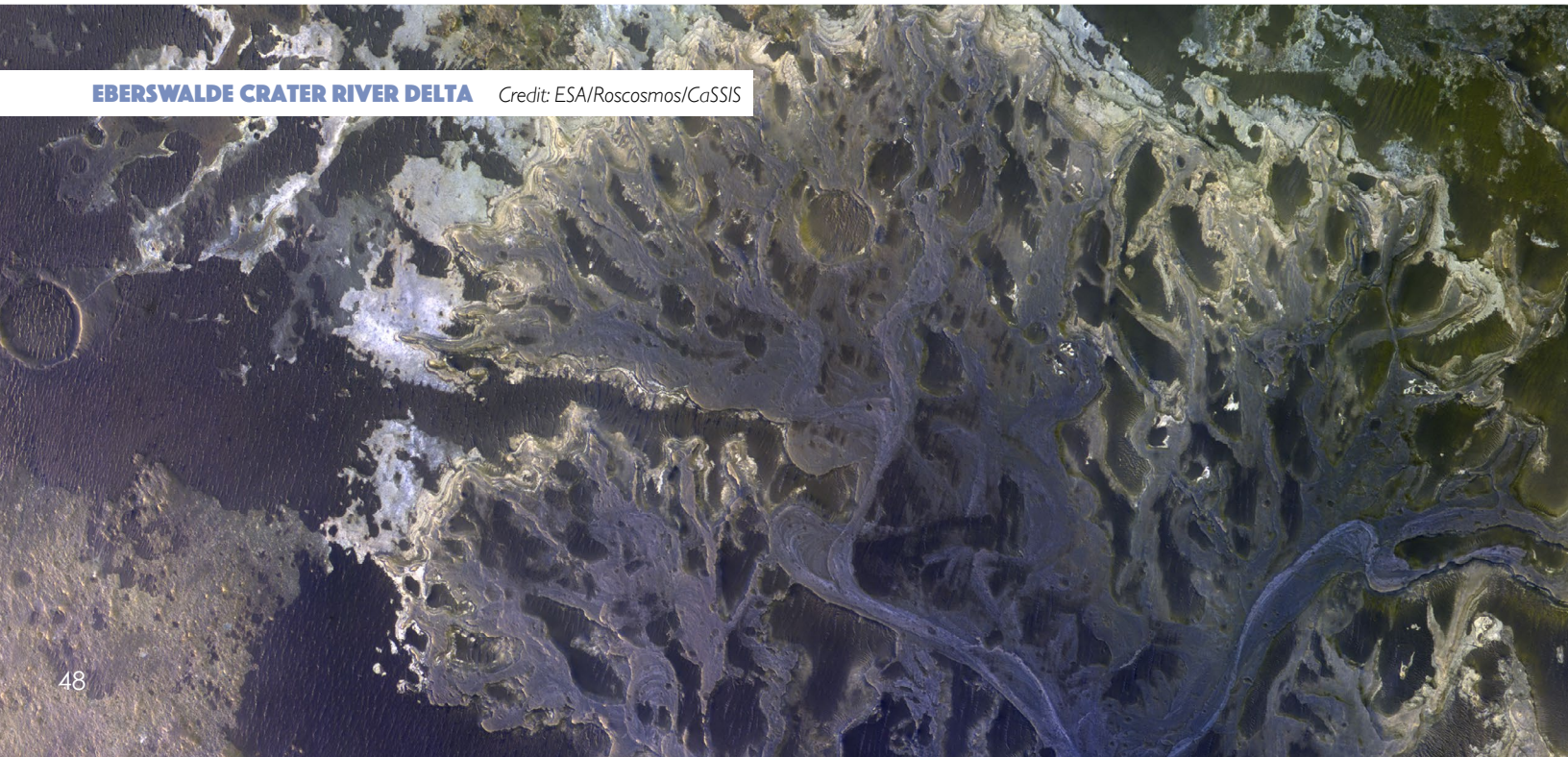


Artist's illustration of China's Tianwen 1 lander deploying its rover on Mars.

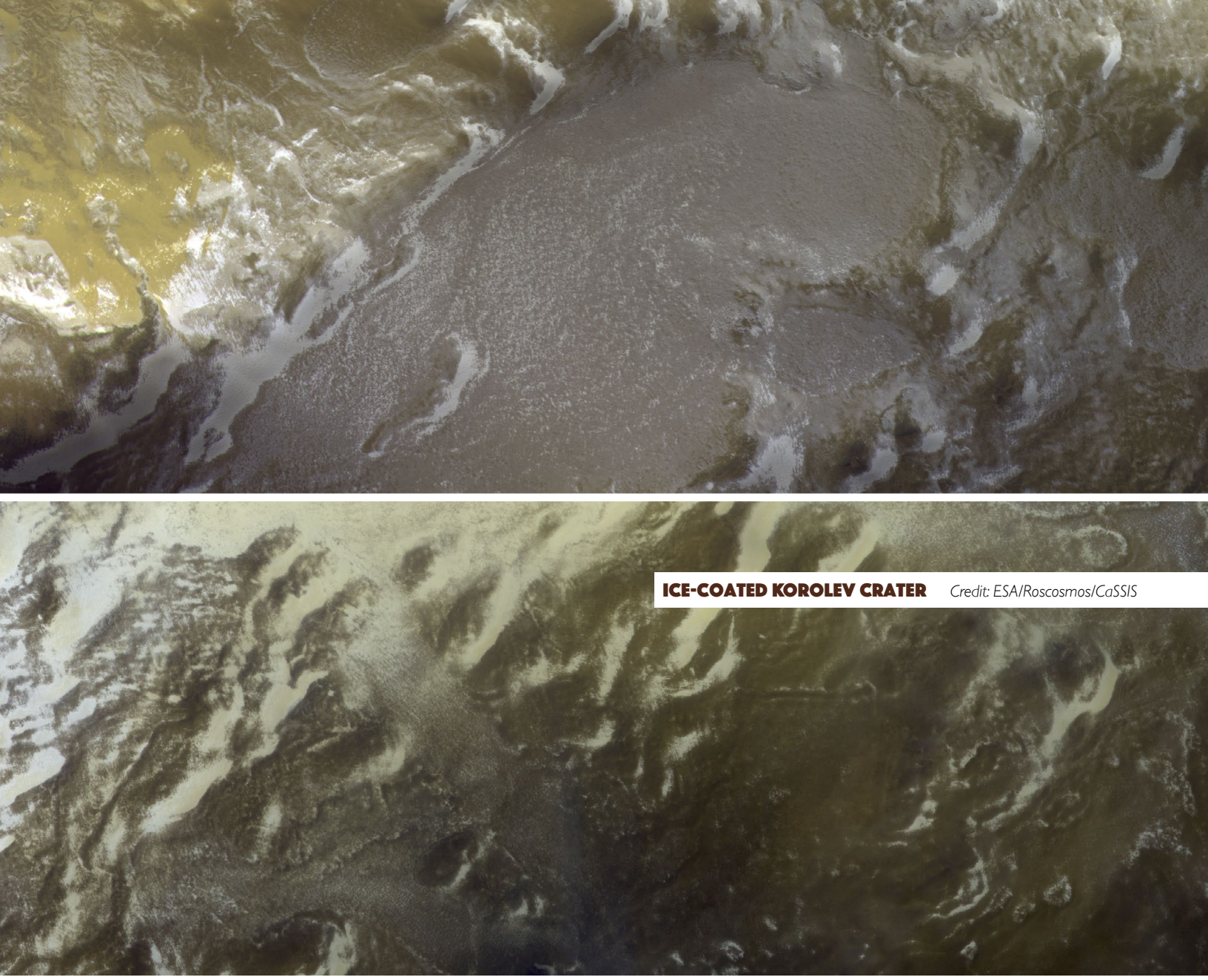


RECEDING CARBON DIOXIDE ICE COVER *Credit: ESA/Roscosmos/CaSSIS*





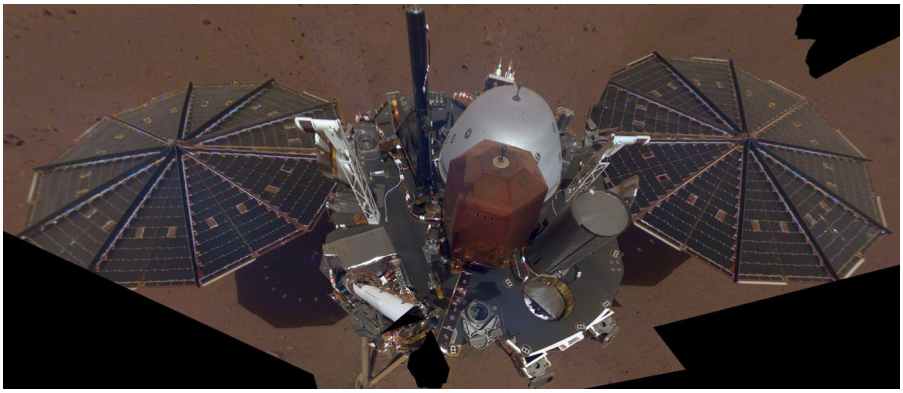
EBERSWALDE CRATER RIVER DELTA *Credit: ESA/Roscosmos/CaSSIS*



ICE-COATED KOROLEV CRATER *Credit: ESA/Roscosmos/CaSSIS*

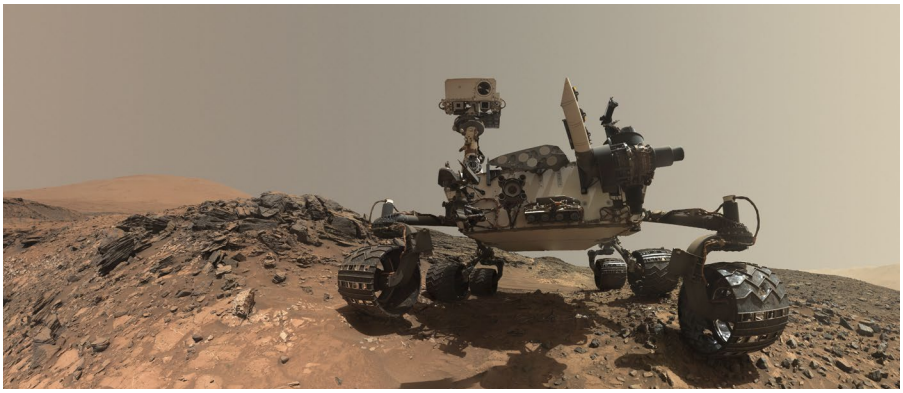
QUIZME: EXPLORING MARS

Quiz authored by Sherry Valare



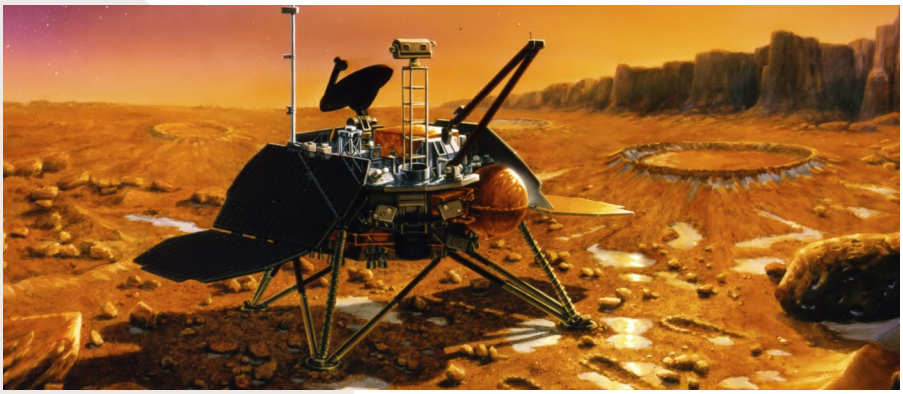
1. The letters in the acronym "InSight" stand for:

A. Intelligent Night Seeking in the Greatest cHronological Terraces
B. Inner Seated Internal Geological Heat Tiles
C. Interior exploration using Seismic Investigations, Geodesy & Heat Transport
D. Idle negated Standing Igneous Geo tHermal Timing



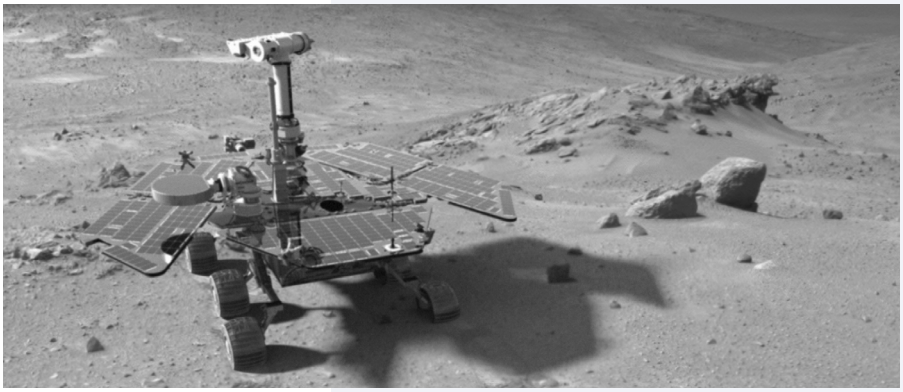
2. What unique mechanism was used to land the Curiosity rover on Mars?

A. Rocket landing
B. Parachute and sky crane
C. Airbag dropped on the surface
D. Capsule using reverse thrusters



3. The Mars Polar Lander/Deep Space 2 mission was lost upon its arrival at Mars. Had it been successful, the spacecraft would have landed near the edge of the planet's southern polar cap to dig for _____ with a robotic arm.

A. Granite
B. Diamonds
C. Fossils
D. Water Ice

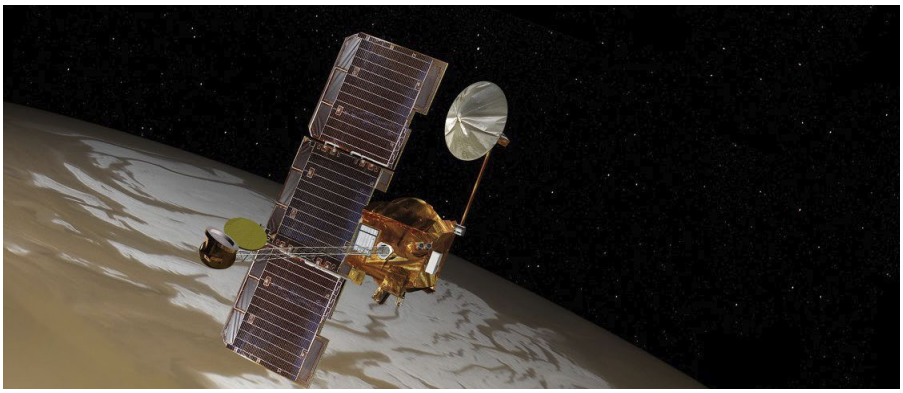


4. In January, 2004, the Mars Exploration Rover mission landed two rovers on the surface of Mars to observe the atmosphere and conduct field geology. The names of the two rovers were?

A. Spirit and Opportunity
B. Freedom and Curiosity
C. Delta and Gamma
D. Tom and Jerry

5. The MAVEN (Mars Atmospheric and Volatile EvolutioN) spacecraft is the first to ever make direct measurements of the _____.

A. Microbes on the surface
B. Martian atmosphere
C. Water ice
D. Fault lines

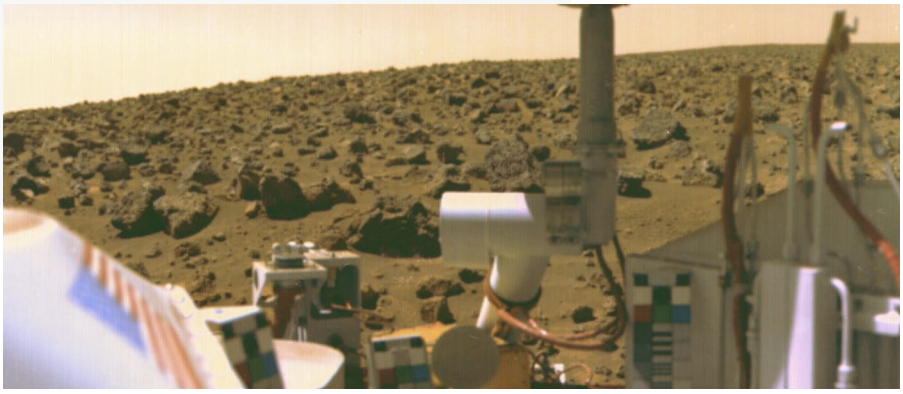


6. The longest-lasting spacecraft at Mars is the Mars Odyssey mission, launched in 2001. Is the orbiter's extended operations still continuing to take place in 2020?

A. True
B. False

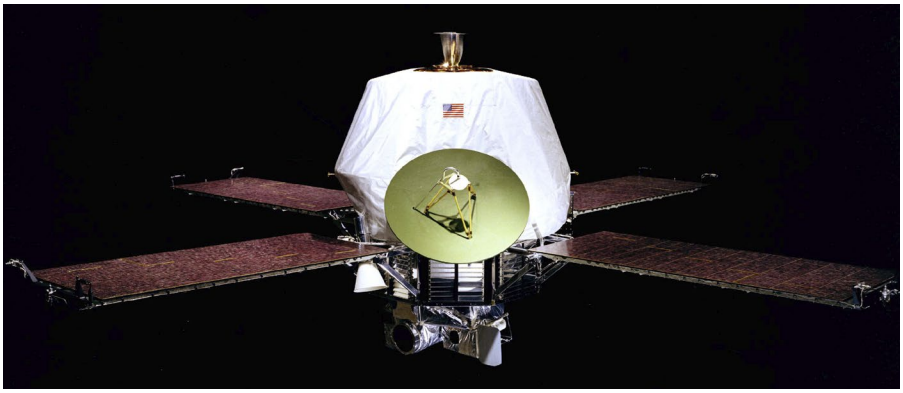
7. The most powerful camera sent on a planetary mission, flew on which mission?

A. Curiosity
B. InSight
C. Polar Lander
D. Reconnaisance Orbiter



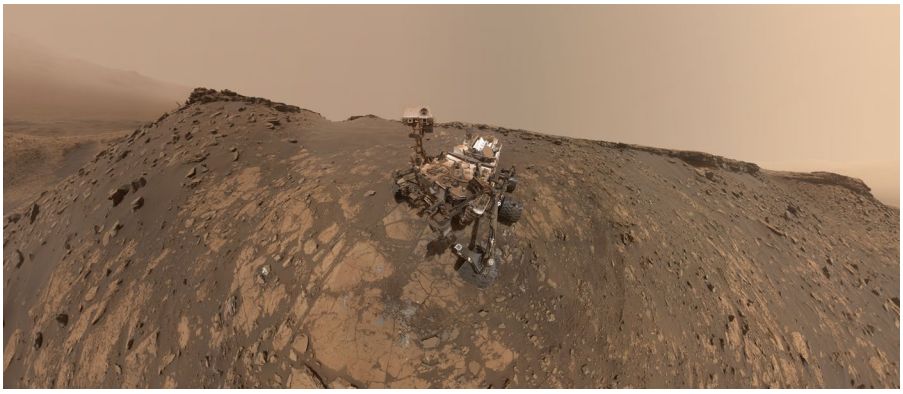
8. The first U.S. mission to land a spacecraft on Mars and return images of the planet's surface was _____ .

A. Mariner Project
B. Viking Project
C. X-Files Project
D. Pathfinder Project



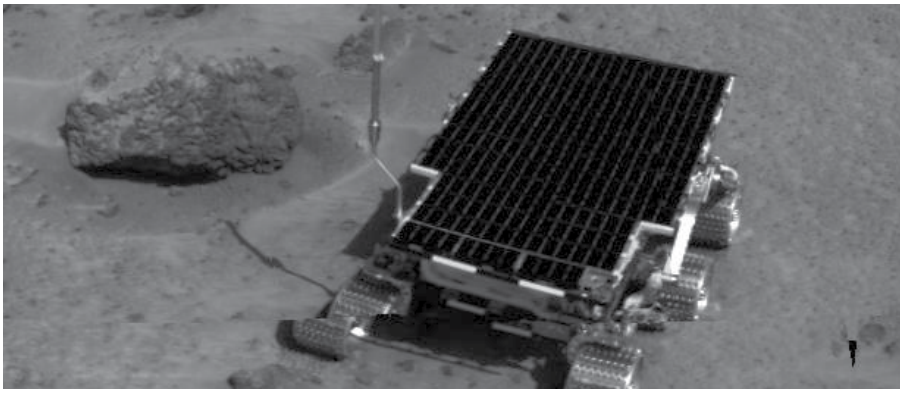
9. NASA's JPL (Jet Propulsion Laboratory) designed and built how many Mariner spacecraft to explore the inner solar system, between 1962 and 1973?

A. 3
B. 7
C. 10
D. 15



10. This "selfie" was taken by which rover at the Hutton Drill Site on Mars?

A. Opportunity
B. Curiosity
C. InSight
D. Pathfinder

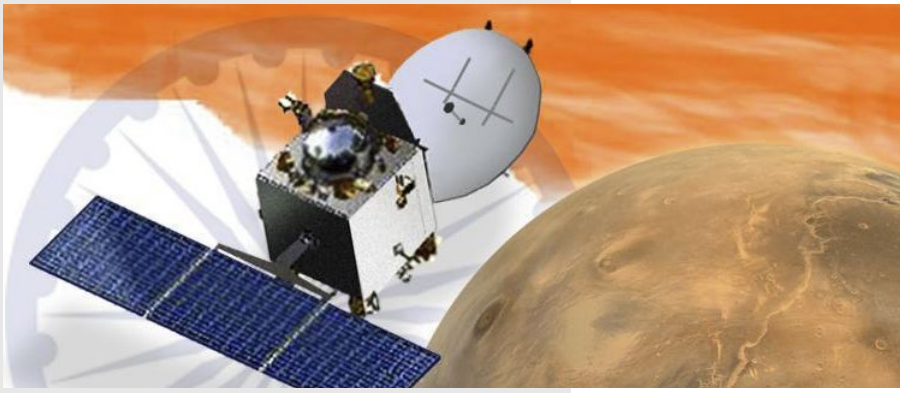


11. On July 4, 1997, the Mars Pathfinder mission landed on Mars. The name of the rover on board was what?

A. Truth
B. Sojourner
C. Starfinder
D. Vulcan

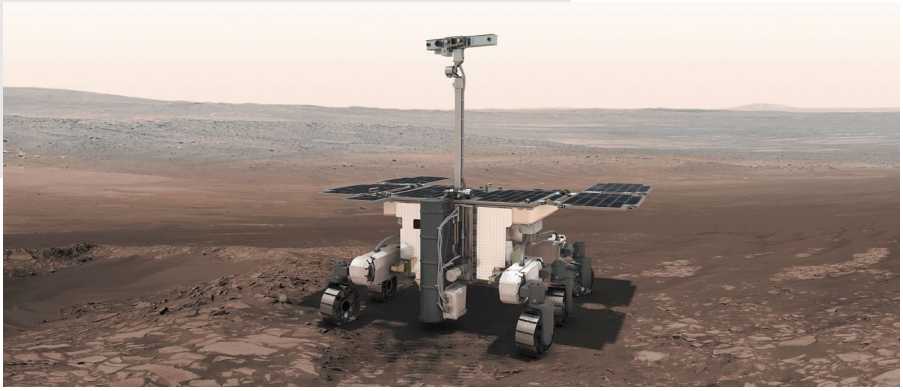
12. The separate Martian landing locations for the Spirit and Opportunity rovers were Gusev Crater and Meridiani Planum. These sites were targeted since they showed evidence of being affected by what?

A. Liquid water
B. Earthquakes
C. Hurricanes
D. Gravity



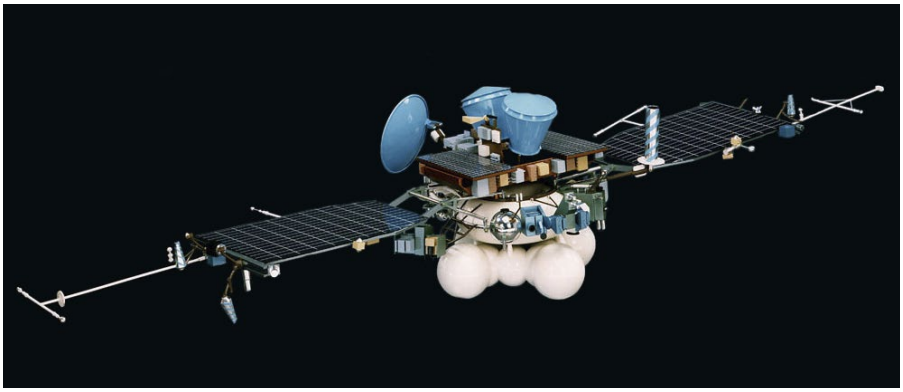
13. India is the fourth nation to successfully send a spacecraft to Mars. What was the name of the mission?

A. MOTT
B. MASS
C. MAMM
D. MOM



14. What is the name of the joint European/Russian mission slated for 2022?

A. ExOTeRRa
B. ExoPlanets
C. ExoMars
D. ExOMeter



15. The _____ mission, was an ambitious Russian mission launched in the 1990s, to investigate the evolution of the Martian atmosphere, its surface, and its interior.

A. Mars 1
B. Mars 30
C. Mars 55
D. Mars 96

VICTORIA CRATER *Credit: NASA/JPL/University of Arizona*

Artist's illustration of **INGENUITY** flying through the skies of Mars.

Image credits: NASA/JPL-Caltech

MAKE A PAPER MARS HELICOPTER

NASA's Perseverance Mars rover, launching in July 2020, will carry the first helicopter to the surface of Mars! This helicopter has to be super lightweight to fly on Mars. It also needs large blades that can rotate really fast so it can generate enough lift to overcome the gravity of the Red Planet and lift off the ground.

In this NASA/JPL-Caltech activity project, you 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, you will experiment with the design of your helicopter to see what works best.

WATCH THE TUTORIAL

In this episode of Learning Space, you'll learn how to build a paper helicopter, then see if you can improve the design like NASA engineers did when making the first helicopter for Mars. | Watch on YouTube

See below for materials and step-by-step instructions. For more video tutorials and activities like this one, visit Learning Space.

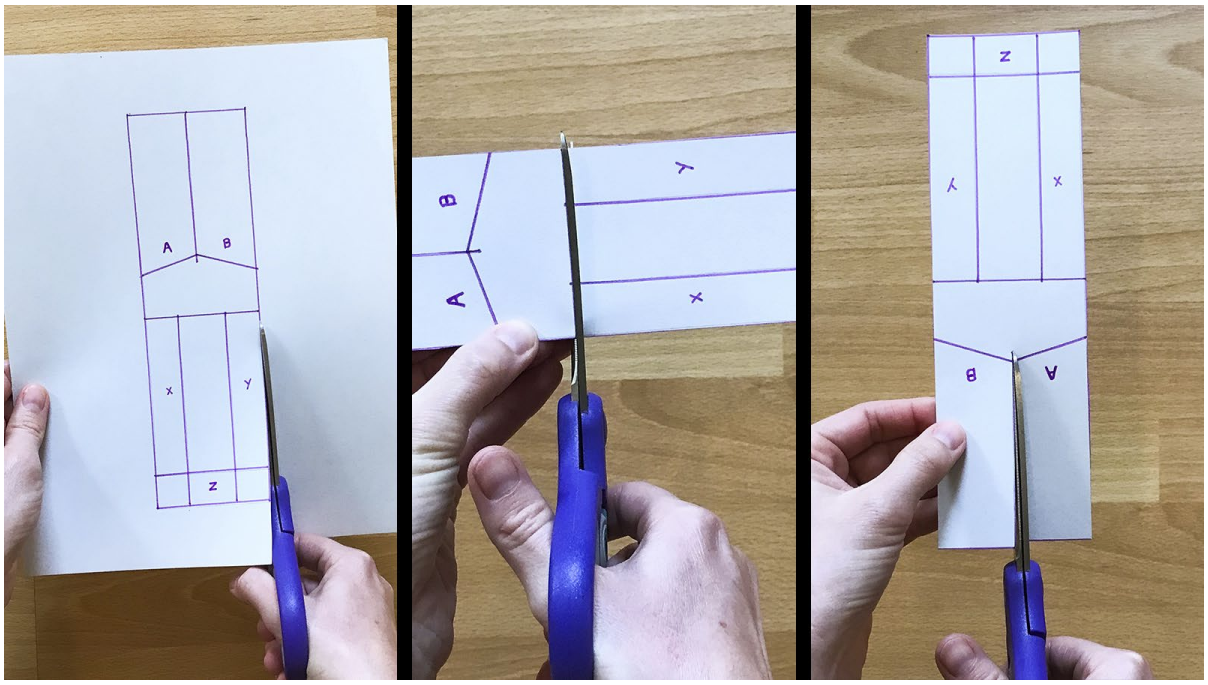
MATERIALS

- ◯ Plain paper OR a copy of the template – Download PDF
- ◯ Scissors
- ◯ Measuring tape
- ◯ Pencil
- ◯ (Optional) 3-meter (10-foot) length of lightweight ribbon or smartphone camera

** Don't worry if you don't have all of the materials. Get creative and substitute materials with what you have! It's all part of the design process.*

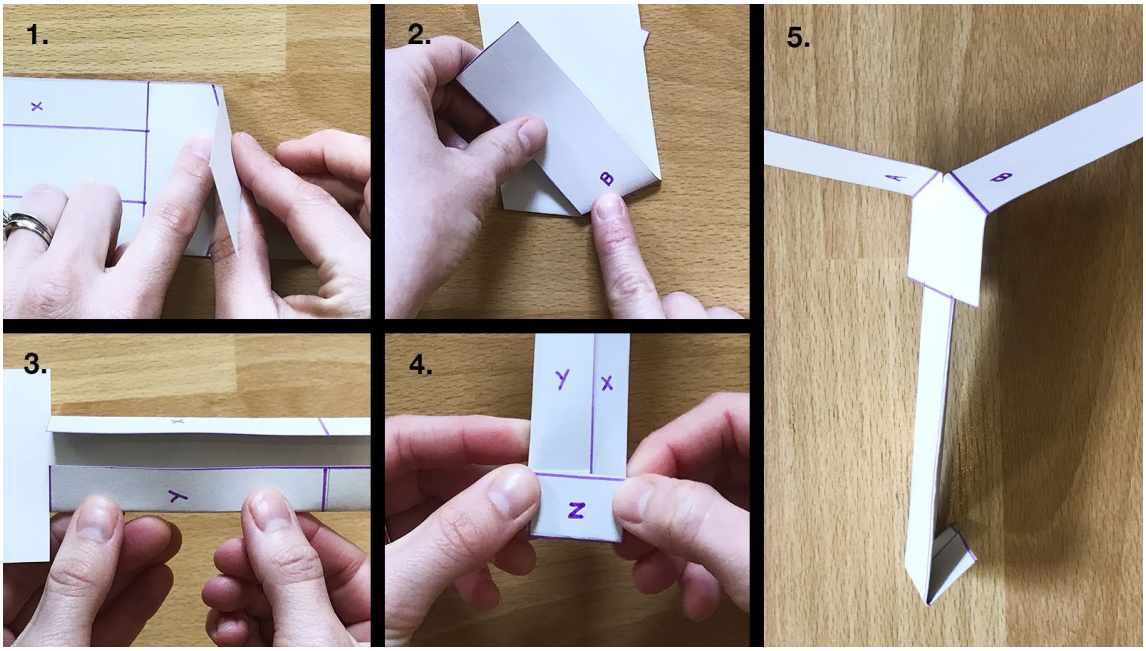
1. CUT OUT THE HELICOPTER

Cut along the dashed lines of the template. If you're using plain paper, make a sketch of the helicopter solid and dashed lines as a guide.



2. FOLD ALONG THE SOLID LINES

The propeller blades, A and B, should be folded in opposite directions along the solid lines. The X and Y panels fold toward the center, and Z is folded upward to give the body of the helicopter rigidity and lower its center of gravity for more stable flight.

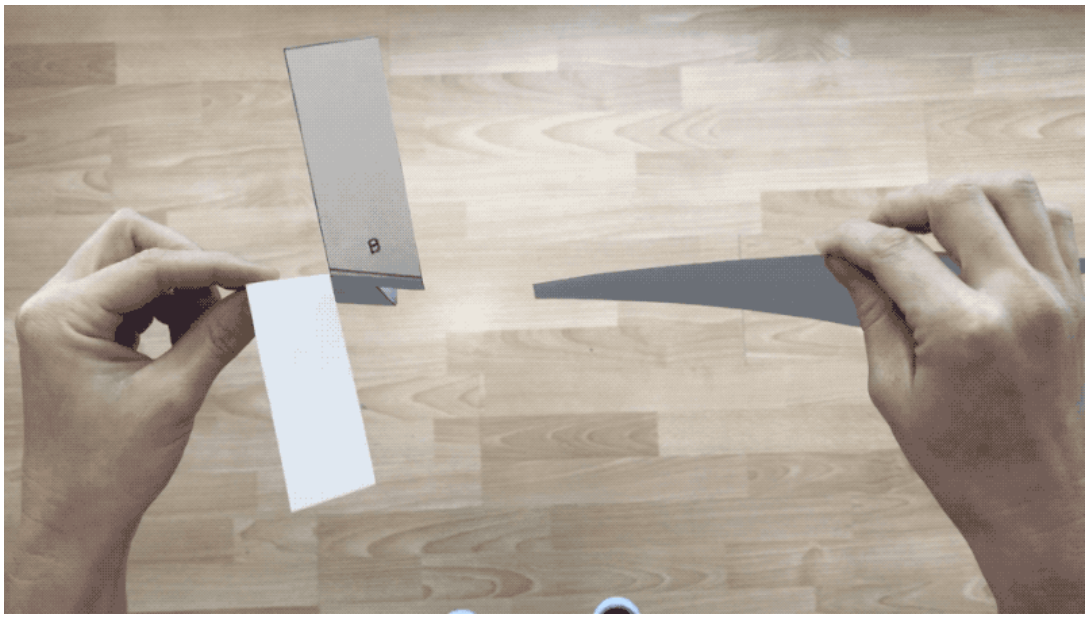


3. DO A TEST FLIGHT

Stand up and hold the helicopter by its body. Raise it as high in the air as you can. Now, drop it. What do you observe? Which way do the blades turn? Drop the helicopter from a higher spot. (Climb a few stairs or stand on a step stool.) How does the performance change?

4. COMPARE

Grab an unfolded piece of paper the same size as the one used to make the helicopter. Drop it at the same time as the helicopter. Which falls faster? Wad up the piece of paper into a ball. Drop this paper ball at the same time as the helicopter. Which falls faster? Can you guess why? Hint: It has something to do with air resistance.



5. EXPERIMENT

Make one change to your helicopter. Try folding the bottom up one more fold, or shortening or changing the shape of the blades. How does the performance of your helicopter change? Why? Can you figure out a way to make your helicopter blades turn faster or slower?

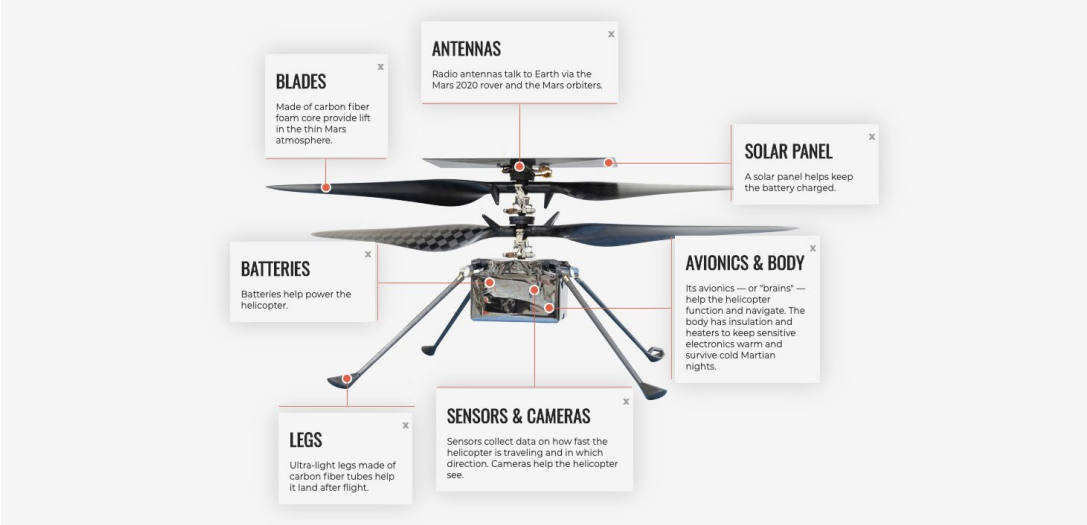
6. MAKE A NEW MODEL

To make the Mars helicopter, NASA engineers had to build and test multiple designs to find something that could get enough lift from the Red Planet's thin atmosphere.

Lift is a force that is generated when the slightly angled moving blades of the helicopter encounter air particles. This increases the air pressure on the bottom of the blades. And the increased air pressure forces the blades and the entire helicopter up into the air. When there are fewer air particles in the atmosphere, less lift is generated. Mars' atmosphere has only 1% of the particles of Earth's atmosphere. This means that blades that generate enough lift on Earth won't work on Mars.

To generate enough lift for the Mars helicopter, engineers gave it two sets of enormous blades that are 4 feet (1.2 meters) across and rotate about 10 times as fast as those of helicopters on Earth.

Think about how you want to improve the performance of your helicopter and make another one that is different from your first. 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"?

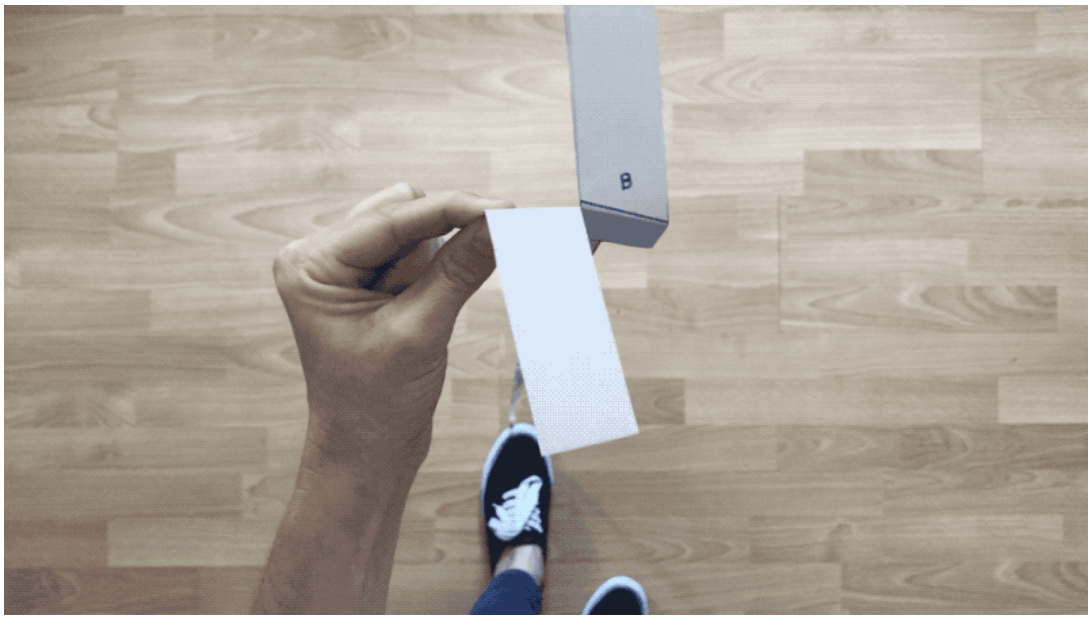


7. REVERSE IT

Notice which way your helicopter blades turn. Is it clockwise or counterclockwise? Is this consistent for all of your helicopters? What is a single change you can make to your helicopters to make them spin in the opposite direction?

8. COUNT THE ROTATIONS

Measure the height of your shoulder and write this down. Choose your best-performing helicopter and drop it from shoulder height. Count the number of rotations it makes before landing. If counting the rotations is difficult because of the speed, either record a video of the drop and play it back in slow motion or attach a straightened ribbon to the bottom of the helicopter body. You can count the twists in the ribbon after it lands. Record this number next to the drop height.



9. REPEAT

What would happen if you dropped the helicopter from a lower height? Repeat the measuring, dropping and counting from a lower height.

10. PREDICT

How many times would the helicopter rotate if you dropped it from a taller height? Measure a taller height, and then predict the number of rotations your helicopter will make.

11. TEST YOUR PREDICTION

Drop your helicopter from the taller height and see how close your prediction was. Try again from other heights and see if you can make better predictions each time!

EXPLORE MORE

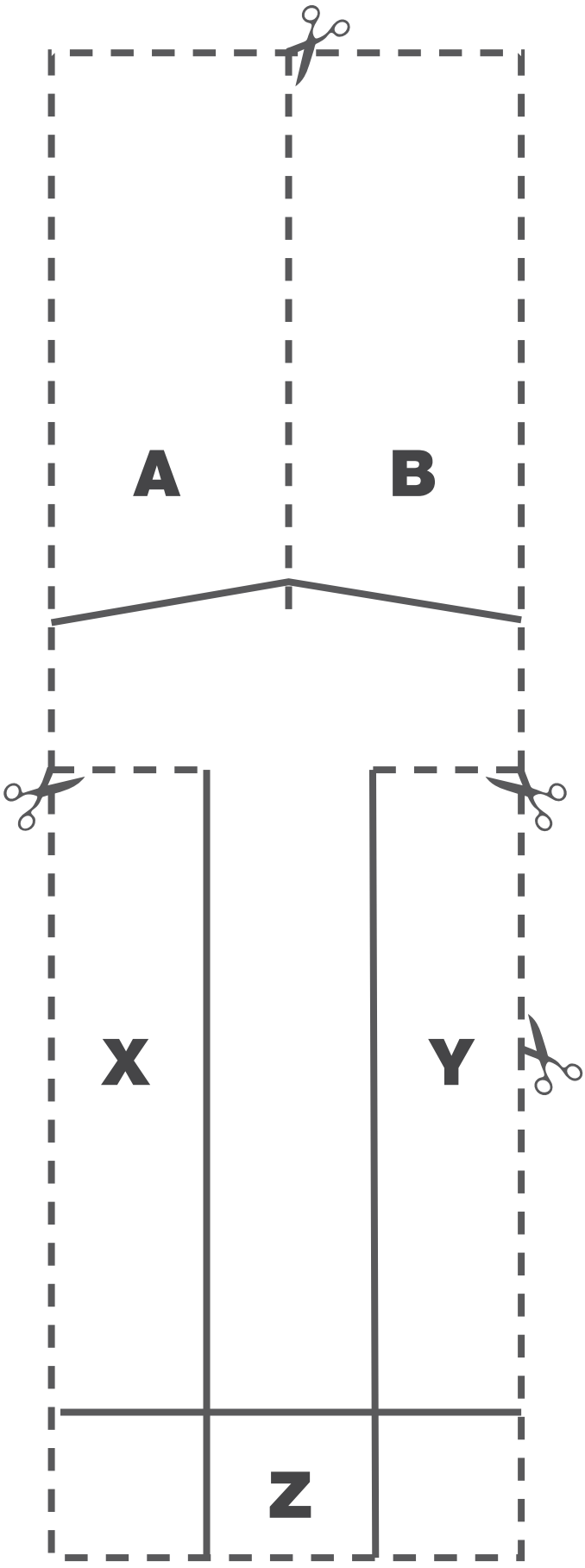
Explore the wonder of space exploration from home but visiting these NASA educational websites.

NASA Space Place

NASA STEM at Home for Students

10 Things to Do With NASA at Home

Standards-aligned lessons for educators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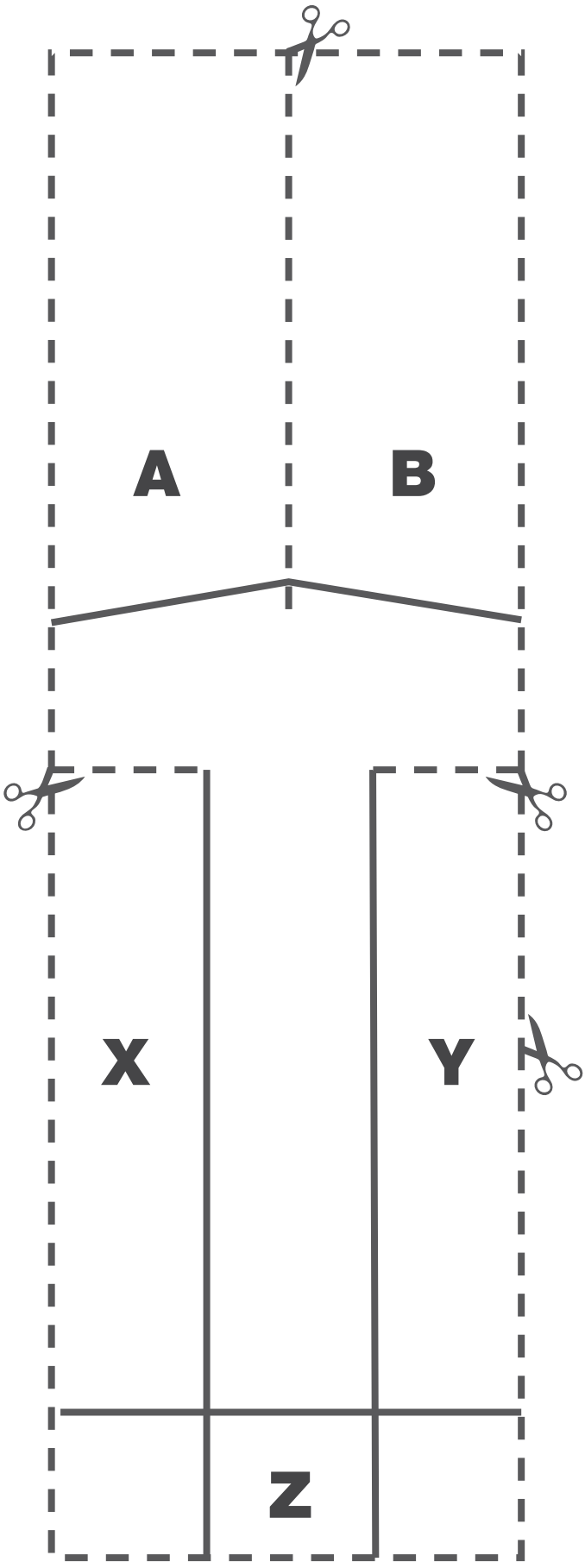
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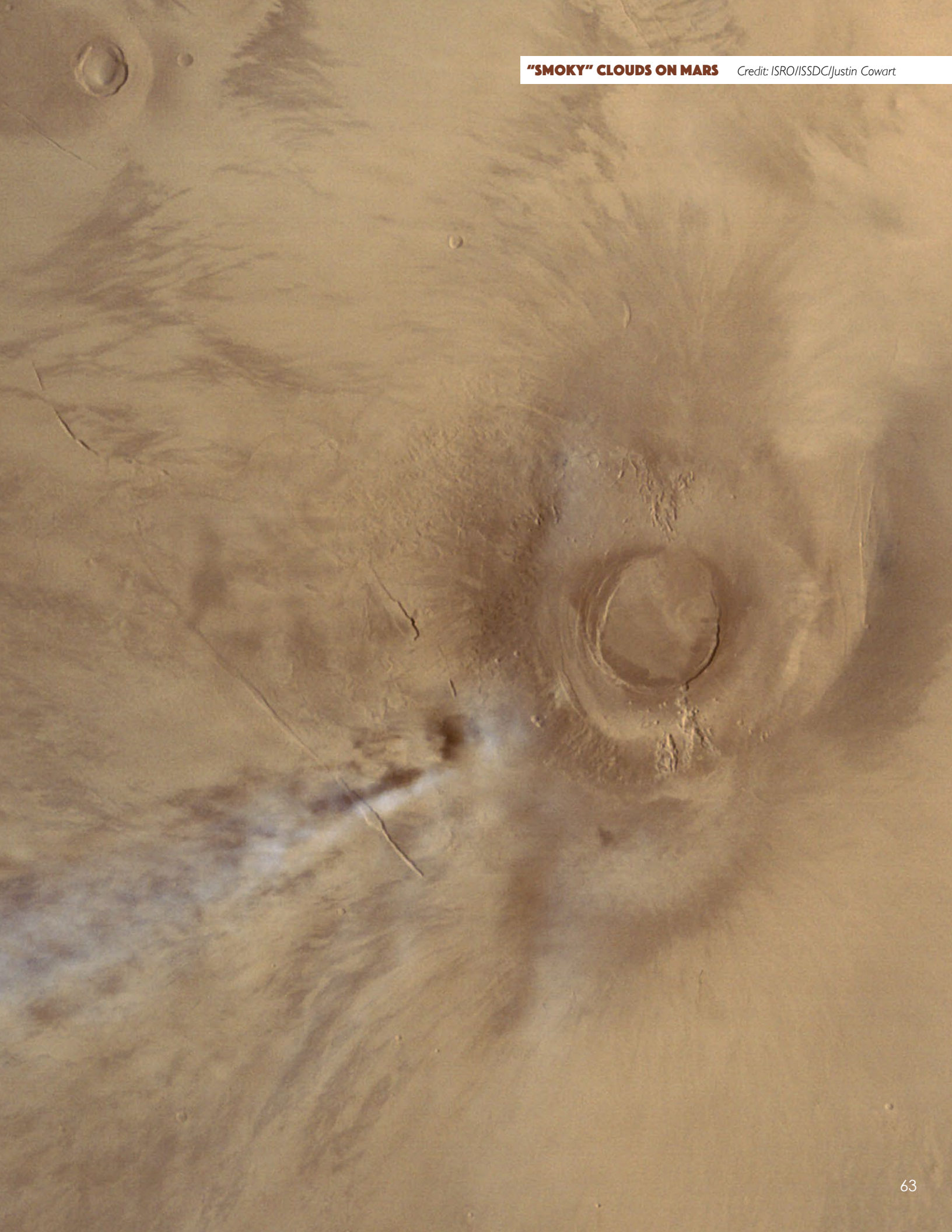


"SMOKY" CLOUDS ON MARS *Credit: ISRO/ISSDC/Justin Cowart*

Helo, Mars!

Objective

Apply trigonometric ratios to the NASA Mars Helicopter Scout so that flight data such as climb angle and average speed can be calculated given initial flight parameters.

Vocabulary

- **Slope:** The angle the rille wall makes to the horizontal.
- **Above Ground Level (AGL):** The altitude as measured from the local area.
- **Altitude:** The height that an object is in the air.
- **Average Speed:** The Round Trip Distance divided by the Travel Time Climb.
- **Angle:** The angle formed between the rover and the FTP.
- **Distance to FTP:** The distance from the rover to a point above and downrange of the rover.
- **Flight Time Capacity:** The amount of time that is available to fly.
- **Fly–To–Point (FTP):** A point above the Martian surface.
- **Ground Distance:** The downrange distance from a rover.
- **Hover Time:** The amount of time spent in a stationary position above the ground.
- **Round Trip Distance:** The distance from the rover to the FTP and back to the rover.
- **Travel Time:** The time it takes to fly a certain distance.

Narrative

Roving on Mars is a great way to get from point A to point B, with scientists back on Earth always looking for interesting places for the rovers to go visit and analyze. However, sometimes finding the next spot to visit can be a daunting task since scientists have to rely on satellite imagery to find compelling places to visit. But even these satellite images are not that detailed; it follows that a closer inspection of the places is always more desirable.

In the same way that a ship on the ocean has a Crow's Nest where the crew can see further, getting to higher ground allows for greater vision of the rover on Mars. But how on Mars can one get to a higher place to see further?

Several solutions present themselves, but each solution is not noteworthy. For example, a tower can be erected from the rover, but the complexity and the mass penalty is probably too much. It would be nice if we could scout the area ahead of the rover, and survey without weighing too much. The reason is because an increase in mass equals to an increase in the amount of propellant needed just to get off the ground.

For a more in-depth treatment of this high school project by Joe Maness & Rich Holtzin visit www.stemfortheclassroom.org.

Analysis

Enter the Mars Helicopter Scout (MHS). This little and ultra light weight flying machine can take off from the rover and fly out to a distance that the rover cannot see. It has solar panels on the top of the machine, and has two counter–rotating rotors that generate lift in the thin Martian air. The best part? The entire helicopter has a mass of only one kilogram!

The MHS is activated, and is sent instructions to go to a certain Fly–To–Point (FTP) away and above the rover. The helicopter lifts off and flies to the FTP, hovers, and takes images of the terrain that the rover cannot see. Afterwards, the MHS flies back to the rover where it shuts itself down and uses the solar panels to recharge its batteries. Nice!

The MHS has around 3 minutes (180 seconds) of flight time capacity, and has a maximum altitude of 120

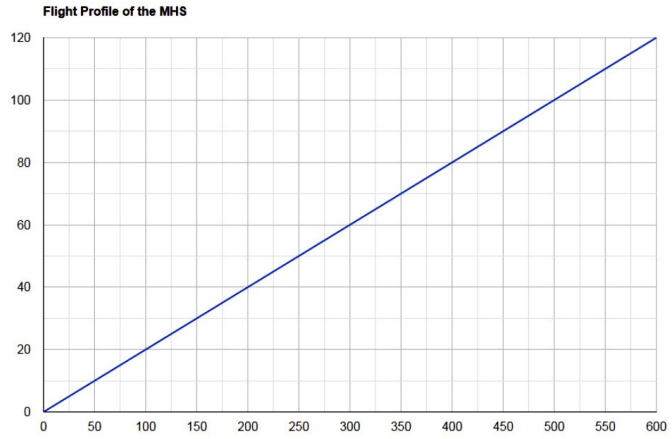
Original illustration by Meha Magesh

meters AGL with a maximum Ground Distance of 600 meters downrange from the rover. These numbers will serve as our constraints for the MHS app.

Scientists on Earth feed the MHS its flight information, and off it goes. The information given to the MHS consists of three parts:

1. Desired Altitude (in meters AGL)
2. Desired Ground Distance away from the rover (in meters)
3. Desired Hover Time (in seconds)

The Rover and FTP form a right triangle, which can be solved easily using trigonometric and triangle identities!



The maximum flight path capability of the MHS, with a maximum downrange distance of 600 meters and a maximum altitude of 120 meters AGL (Graph is NOT drawn to scale). Credit: S.T.E.M. For the Classroom

We can use the Pythagorean Theorem to find the Distance to the FTP, which is the hypotenuse of the right triangle. The tangent ratio is used to determine the climb angle (in degrees). The Travel Time becomes the Flight Time Capacity minus the Hover Time. We can then use that information to calculate the average speed of the MHS.

- $Distance\ to\ FTP = \sqrt{(Ground\ Distance)^2 + (Altitude)^2}$
- $Round\ Trip\ Distance = 2(Distance\ to\ FTP)$
- $Climb\ Angle = tan^{-1}\left(\frac{Altitude\ AGL}{Ground\ Distance}\right)$
- $Travel\ Time = Flight\ Time\ Capacity - Hover\ Time$
- $Average\ Speed = \frac{Round\ Trip\ Distance}{Travel\ Time}$

Example

Scientists on Earth want the MHS to go to a FTP that is 400 meters downrange with an altitude of 100 meters AGL, and a hover time of 60 seconds so that the MHS can take a image of the rover. Find the Round Trip Distance, Climb Angle, and Average Speed of the MHS.

$$Distance\ to\ FTP = \sqrt{(Ground\ Distance)^2 + (Altitude)^2}$$

$$= \sqrt{(400)^2 + (100)^2}$$

$$= \sqrt{160000 + 10000}$$

$$= \sqrt{170000}$$

$$= 412\ meters$$

$$Round\ Trip\ Distance = 2(Distance\ to\ FTP)$$

$$= 2(412)$$

$$= 825\ meters$$

$$Climb\ Angle = tan^{-1}\left(\frac{Altitude\ AGL}{Ground\ Distance}\right)$$

$$= tan^{-1}\left(\frac{100}{400}\right)$$

$$= 14°$$

$$Travel\ Time = Flight\ Time\ Capacity - Hover\ Time$$

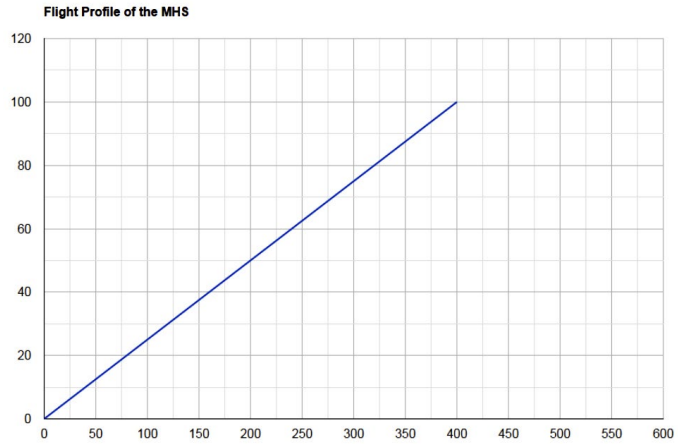
$$= 180 - 60$$

$$= 120\ s$$

$$Average\ Speed = \frac{Round\ Trip\ Distance}{Travel\ Time}$$

$$= \frac{825}{120}$$

$$= 6.87\ m/s$$



Flight path of the MHS. (Graph is NOT drawn to scale). Credit: S.T.E.M. For the Classroom

With initial conditions of 400 meters downrange, an altitude of 100 meters AGL, and a 60 second hover time, the MHS will fly a Round Trip distance of 825 meters with a Climb Angle of 14 degrees from the horizon and an Average Speed of almost seven meters per second.

Guided practice

The MHS science team back on Earth wants to image a rock formation ahead of the Mars rover. They wish to fly several sorties. Find the Round Trip Distance, Climb Angle, and Average Speed of the MHS given the different initial flight parameters.

1. Downrange: 50 m; Altitude: 120 m AGL; Hover Time: 60 s
2. Downrange: 150 m; Altitude: 75 m AGL; Hover Time: 45 s
3. Downrange: 320 m; Altitude: 45 m AGL; Hover Time: 35 s
4. Downrange: 550 m; Altitude: 50 m AGL; Hover Time: 30 s
5. Downrange: 400 m; Altitude: 45 m AGL; Hover Time: 35 s

Artwork

Draw a picture of the MHS in its brief flight over the Martian surface in search of interesting places to record as the Earth shines brightly in the sky overhead.

R.A.F.T. writing

- **Role:** Teacher/Instructor/Master
- **Audience:** 8th Graders
- **Format:** Step–By–Step Instructions
- **Topic:** How to calculate the Distance to the FTP by solving for the hypotenuse of a right triangle given the lengths of the two other sides.

Discussion topics

- What is your visual picture of the surface of Mars?
- Do you agree or disagree with the notion of funding explorations to other planets?
- What kind of noise do you think the MHS makes while flying in the Martian atmosphere?
- How is the MHS similar to drones used on Earth? How is it different?
- Could a version of the MHS be used on other planets?
- If you could somehow hop aboard the MHS, describe what you would see.

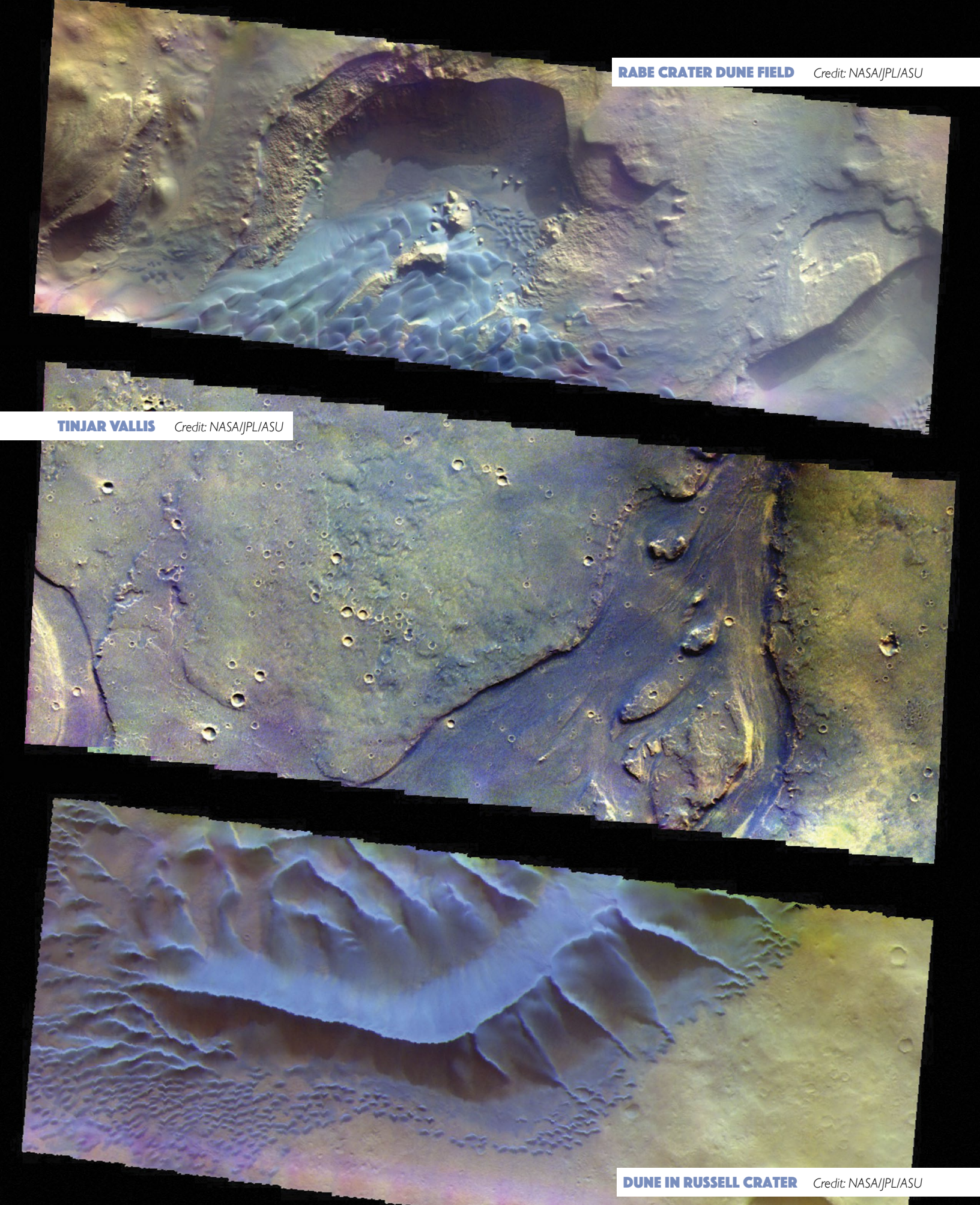
Conclusion

The Mars Helicopter Scout can fly from its perch on a rover and travel ahead to find captivating places for it to visit. The MHS will certainly make it easier for scientists to "see" further than the rover which is limited in its vision due to being so close to the ground.

Eventually, humans are going to have helicopters flying on Mars. Pretty amazing. One can only imagine what they will they think of next.

Guided practice answer key

1.	Round Trip Distance = 260 m	Climb Angle =	67°	Average Speed =	2.17 m/s
2.	Round Trip Distance = 335 m	Climb Angle =	27°	Average Speed =	2.48 m/s
3.	Round Trip Distance = 646 m	Climb Angle =	8°	Average Speed =	4.46 m/s
4.	Round Trip Distance = 1,105 m	Climb Angle =	5°	Average Speed =	7.36 m/s
5.	Round Trip Distance = 805 m	Climb Angle =	6°	Average Speed =	5.55 m/s



RABE CRATER DUNE FIELD *Credit: NASA/JPL/ASU*

TINJAR VALLIS *Credit: NASA/JPL/ASU*

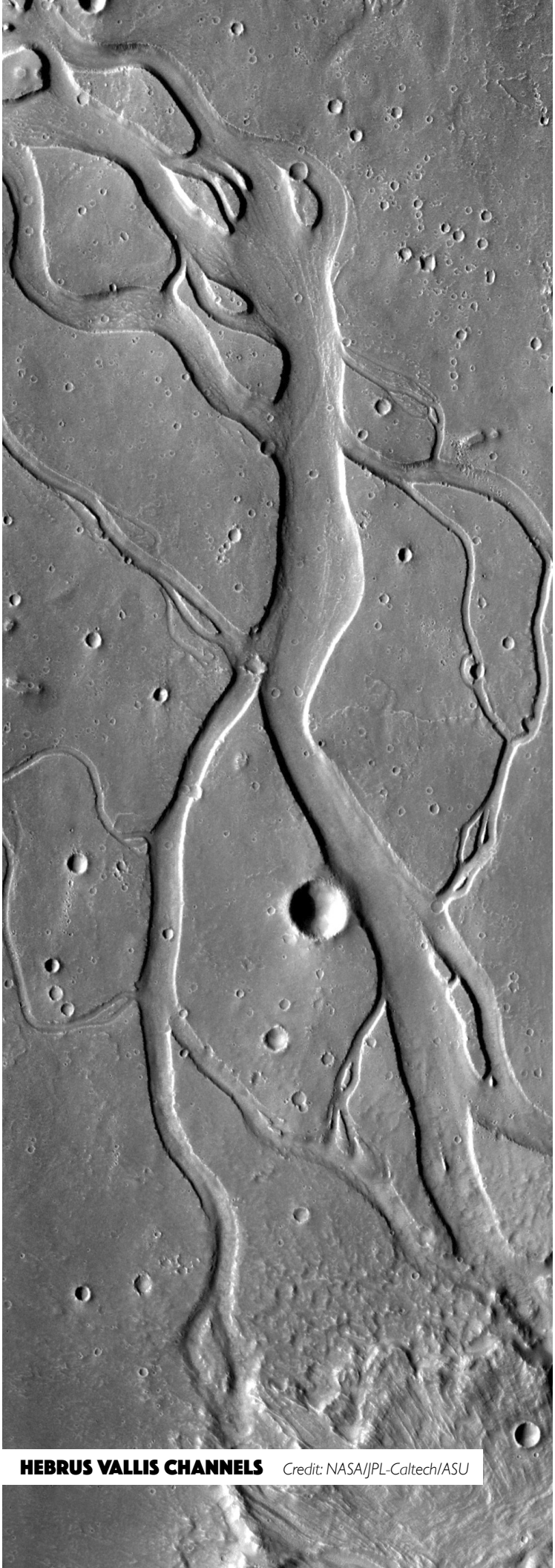
DUNE IN RUSSELL CRATER *Credit: NASA/JPL/ASU*

Mars Exploration **WORD SEARCH**

The Red Planet has been studied throughout human history. The very first mission to Mars was sent in 1960, while the first probe landed in 1971. We've hidden 36 words related to Mars exploration below. They may be placed horizontal, vertical, or even diagonal. Good luck!

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

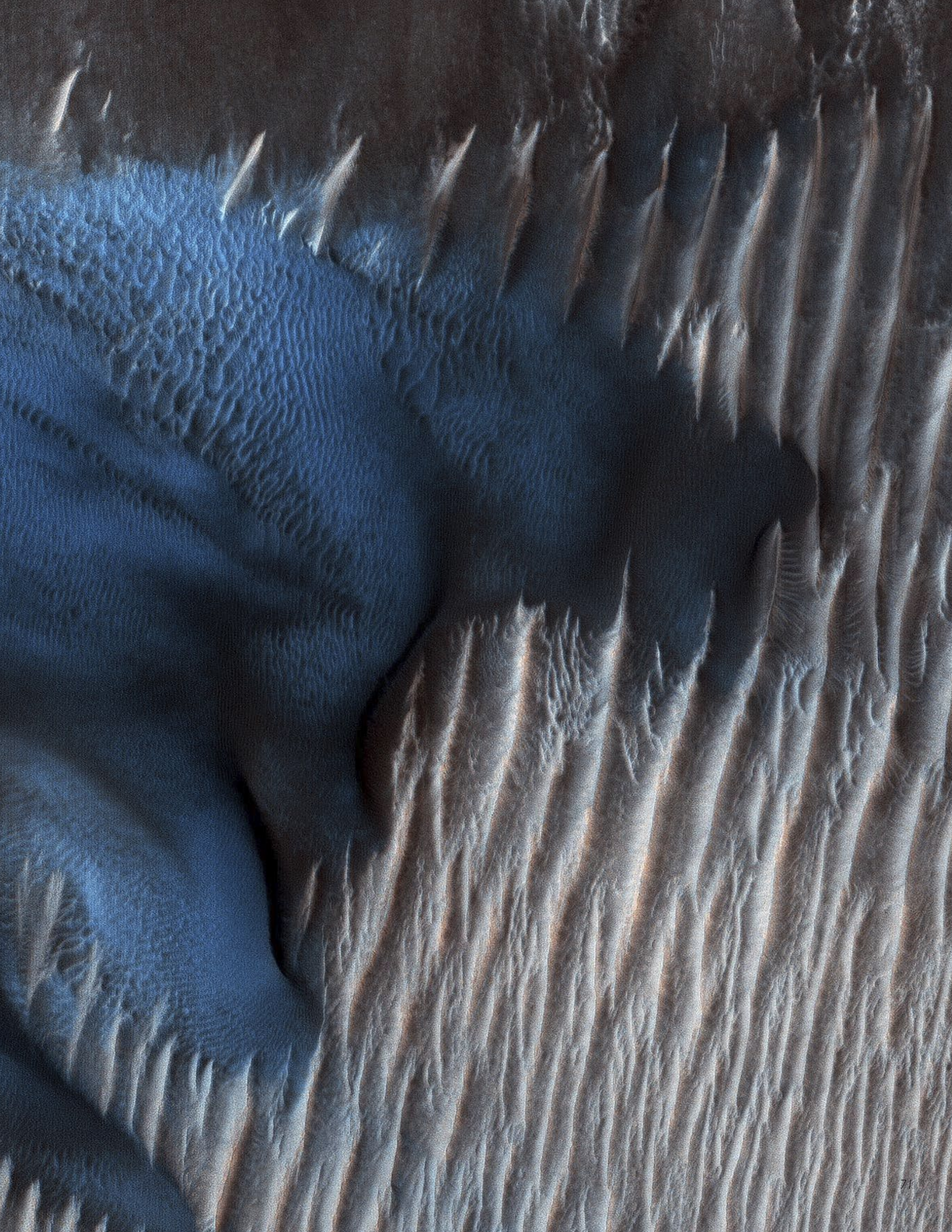
ALDRIN MARS CYCLER
ARGYRE BASIN
BEAGLE
CURIOSITY
DEIMOS
ELYSIUM MONS
EXOMARS
EXPRESS
FOBOS-GRUNT
GALACTIC GHOUL
GLOBAL SURVEYOR
HOPE
INSIGHT
KOSMOS
MARCO
MARINER
MARS DIRECT
MAVEN
ODYSSEY
OLYMPUS MONS
OPPORTUNITY
PATHFINDER
PERSEVERANCE
PHOBOS
PHOENIX
RECONNAISSANCE
ROSALIND FRANKLIN
SCHIAPARELLI
SOJOURNER
SPIRIT
TEMPE TERRA
THARSIS RISE
VASTITAS BOREALIS
VIKING
WERNHER VON BRAUN
WILLY LEY



HEBRUS VALLIS CHANNELS *Credit: NASA/JPL-Caltech/ASU*

VALLEYS AND RIDGES *Credit: ESA/DLR/FU Berlin*

DUNE INSIDE LYOT CRATER *Credit: NASA/JPL-Caltech/Univ. of Arizona*



Red Planet **QUIZME** Answer Key

Question No. 1 Answer: **B**

Mars is the Roman god of Love. The Romans had named this planet "Mars" mainly because of its reddish color which was reminiscent of blood and war. Interestingly, Mars's moon - Phobos and Deimos - were named after a Roman myth where Mars, the god of war, was riding a chariot pulled by two horses named Phobos and Deimos.

Question No. 2 Answer: **D**

Phobos and Deimos are two moons of Mars. However, they are much smaller than our moon at only 22.2 km and 12.6 km in diameter respectively. Phobos and Deimos were named after two mythological creatures meaning panic/fear and terror/dread. Oberon and Titania are moons on Uranus and Callisto is a moon on Jupiter.

Question No. 3 Answer: **False**

Olympus Mons is only about 2.5 times the height of Mount Everest. In fact, Olympus Mons is about 25 km high while Mount Everest is only about 9 km high. Even though the hotspot below Olympus Mons cooled down, Olympus Mons still holds the record of the largest volcano in the solar system.

Question No. 4 Answer: **A**

Carbon Dioxide and Nitrogen are the main constituents of Mars's atmosphere. Carbon Dioxide accounts for 96% of the planet's atmosphere while Nitrogen accounts for 1.9% of the planet's atmosphere. Nevertheless, the atmosphere of Mars is still much thinner than the atmosphere of Earth.

Question No. 5 Answer: **C**

Out of the 56 total Mars missions to this date, only 26 of them were successful. In general, missions to Mars have always been a very difficult task. The missions to Mars started back in the 1960s and they still continue to this day. However, they still come with great risk and uncertainty.

Question No. 6 Answer: **True**

This statement is true. The volume of Mars is roughly equal to the volume of 0.151 Earths. Therefore, you could easily fit a little more than six Mars into one Earth. In comparison, the diameter or Mars is 6779 km while the diameter of Earth is 12742 km.

Question No. 7 Answer: **B**

Sojourner, named after a women's rights activist, was the first wheeled vehicle to be deployed on Mars. This was the first step taken for more detailed observations on the surface of Mars. The rover had landed on July 4th of 1997 in the Ares Vallis region of Mars.

Question No. 8 Answer: **A**

The orbital period of Mars is 687 days which is just shy of two Earth years. This is mainly due to the fact that the orbital radius of mars and its distance from the sun is much greater than those of Earth. This is why the seasons on Mars last roughly six months compared to the seasons on Earth which only last three months.

Question No. 9 Answer: **B**

Perseverance is the name of the Martian rover that is set to be launched from Earth in July 2020. It is expected to touch down on Mars on February 2021 near the Jezero crater. Ingenuity will also be launched at this time, but it is a small robotic helicopter. Endurance and Persistence were not real Mars rover launched.

Question No. 10 Answer: **D**

The Tharsis Rise, Elysium Mons and Argyre Basin are all geographical locations on the Martian surface. However, the Valles Vikings does not exist. The name is actually Valles Marineris which is a system of canyons that run along the Tharsis Region. This region is also home to some of the largest canyons in the solar system.

Question No. 11 Answer: **C**

The average temperature throughout the surface of Mars is -63 °C which is quite low when compared to the average temperature on the surface of Earth at 14 °C. The temperatures on the surface of Mars can reach a high of 20 °C in the Summer near the equator and -150 °C in the Winter near the poles.

Question No. 12 Answer: **A**

Mars is approximately 228 million kilometers from the sun which is one and a half times the distance from Earth to the sun. This is roughly equal to 1.5 AU (astronomical units). Based on this distance, it takes around 13 minutes for light to travel from the sun to Mars.

Question No. 13 Answer: **True**

That statement is true. Due to large amount of fine dust particles and necessary atmospheric conditions for wind, dust storms are fairly common on Mars. However, these dust storms are intense which can reach upwards to 110 kmh and last for a couple od days. Sometimes, the dust storms are so intense that they can cover the entire planet for weeks.

Question No. 14 Answer: **False**

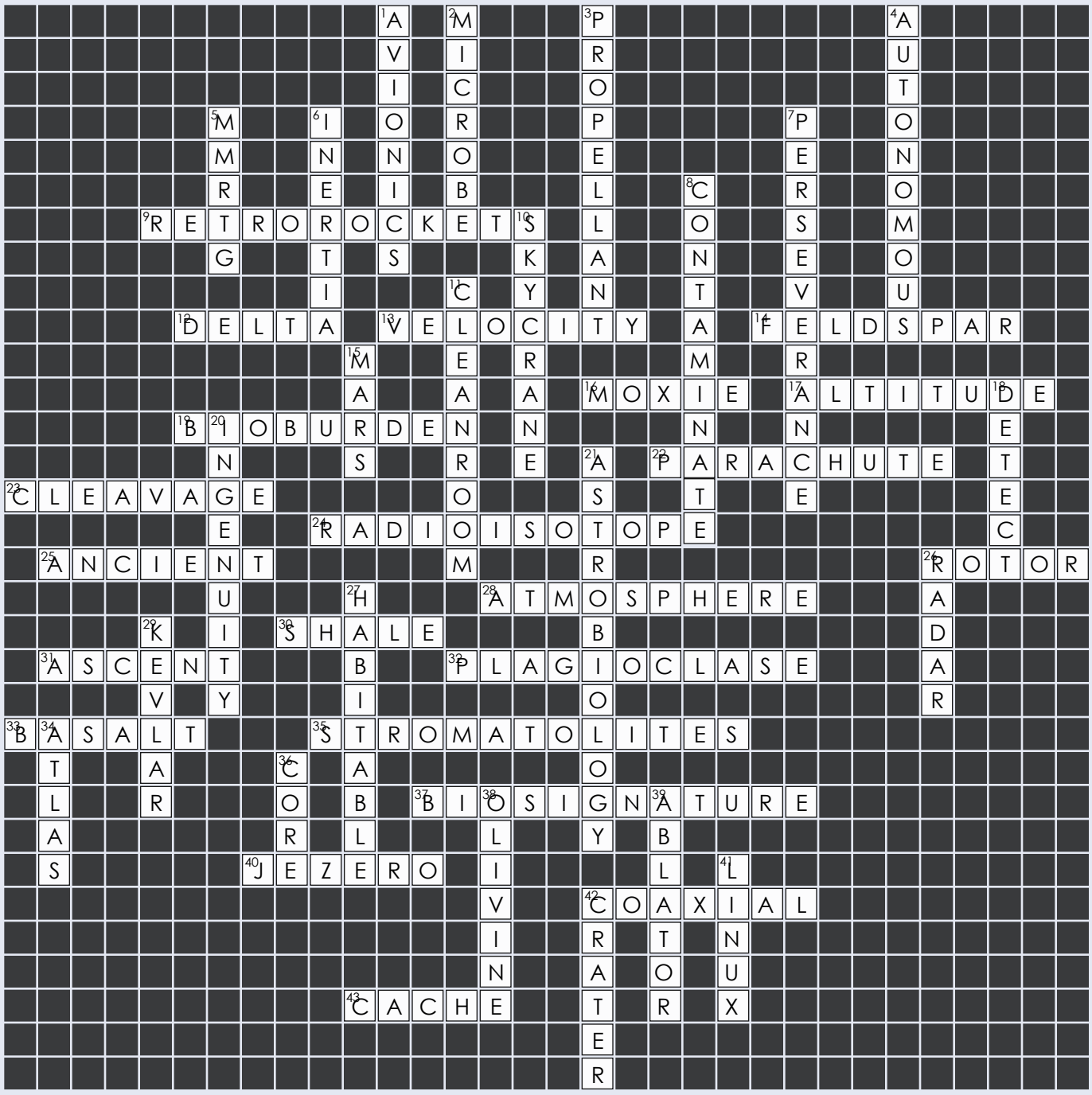
Although the Martian daytime sky is red, their sunsets are quite different. In fact, the blue Martian sunsets actually originate from the fact that the blue light penetrates the atmosphere slightly more efficiently. Unlike the bright and vivid sunsets on Earth, the sunsets on Mars are dull and somber.

Question No. 15 Answer: **False**

Mars is the second smallest planet in our solar system followed by Mercury, and it is fourth in order from the sun. It is the last rocky planet in the from the sun and comes right before the asteroid belt. Mars has a volume of 1.6 x 1011 km3 which is roughly equal to 0.151 Earths.

Mars 2020 **CROSSWORD** Answer Key

Mars 2020 is a NASA rover mission with a targeted launch date of July 17, 2020. The rover and its companion helicopter drone are set to land within a Martian crater on February 18, 2021. The mission will investigate the possibility of past life having existed on Mars. The rover will cache sample containers along its route for a potential future Mars sample-return mission.



Exploring Mars **QUIZME** Answer Key

Question No. 1 Answer: **C**

The InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport, is the first Mars lander which will conduct intensive studies on Mars inner composition - the crust, mantle, and core. This will also answer important questions about how the rocky planets in our Solar System, as well as rocky exoplanets, were formed.

Question No. 2 Answer: **B**

Curiosity had an exciting landing followed by people all around the world. The rover was part of the MSL mission, whose goal is to determine if microbial life was capable of being supported by either recent or past environments.

Question No. 3 Answer: **D**

The Mars Polar Lander was also carrying two small probes (Deep Space 2), that were supposed to test new technologies by impacting the surface of Mars. Both the lander, and the probes, were lost when they arrived on Dec. 3, 1999.

Question No. 4 Answer: **A**

The first scientific goal for the Mars rovers, Spirit and Opportunity, was to hunt down and study the characteristics of rocks and soil on Mars, looking for evidence of past water activity. Combined, the rovers have sent out hundreds of thousands of high-resolution photos of the Martian terrain.

Question No. 5 Answer: **B**

The Mars Atmosphere and Volatile Evolution mission (MAVEN) launched Nov. 18, 2013, to explore Mars' upper atmosphere, ionosphere, and its interactions with the Sun and the solar wind. Scientists hope to attain a more concise idea of what Mars may have looked like in the past, and to learn more about Mars' atmosphere and climate, liquid water, and planetary habitability, over time.

Question No. 6 Answer: **True**

The Mars Odyssey mission launched out of Cape Canaveral, Florida, aboard a Delta II rocket, on Oct. 24, 2001, to study and globally map the elemental composition of the surface of Mars. It currently remains in operation.

Question No. 7 Answer: **D**

The most powerful camera sent on a planetary mission flew on the Mars Reconnaissance Orbiter. The camera has the ability to capture objects as small as a dinner table, on the surface of Mars. Armed with this visual aid, MRO has been able to guide the journeys of surface landers and rovers, and help them avoid obstacles that could jeopardize their safety.

Question No. 8 Answer: **B**

The Viking Project was the first U.S. mission to land a spacecraft safely on Mars, and then return images of its surface. The mission consisted of two identical spacecraft, each with a lander and orbiter, which flew together. After each pair would enter Mars' orbit, they separated allowing the landers to descend to the surface.

Question No. 9 Answer: **C**

NASA's Jet Propulsion Laboratory designed and built a set of 10 small robotic explorers, named Mariner, between 1962 and 1973, to explore the inner solar system. The spacecraft were to visit the planets Venus, Mars, and Mercury, then return to Venus and Mars for additional observations. Each Mariner spacecraft completed its mission in under a year or two, except one, which lasted three years.

Question No. 10 Answer: **B**

This isn't your average selfie! Curiosity took this photo using the Mars Hand Lens Imager (MAHLI) camera, on the end of its robotic arm. A total of 86 individual images were taken and stitched together into the panorama you see here.

Question No. 11 Answer: **B**

The Mars Pathfinder mission consisted of a lander and a rover. The lander was formally named the Carl Sagan Memorial Station after its successful touchdown on the surface of Mars. The rover, Sojourner, was named after American civil rights crusader, Sojourner Truth. Both pieces of equipment outlived their design lives. Over its lifetime, the mission returned 2.3 billion bits of information, which included 16,500 images from the lander and 550 images from the rover.

Question No. 12 Answer: **A**

Spirit and Opportunity were targeted to land on sites on opposite sides of Mars because of the possibility of liquid water existing at those areas, in Mars' past. Meridiani Planum, Opportunity's landing site, was chosen because there was possibly a former lake in a giant impact crater there. Spirit was sent to Gusev Crater, where the existence of mineral deposits made the case for the possibility of water in the past.

Question No. 13 Answer: **D**

On Nov. 5, 2013, India launched its first mission to the Red Planet to test key technologies for interplanetary exploration and to study the Martian surface and atmosphere from orbit. The Mars Orbiter Mission (MOM) is also sometimes referred to as Mangalyaan, a Sanskrit term for Mars craft.

Question No. 14 Answer: **C**

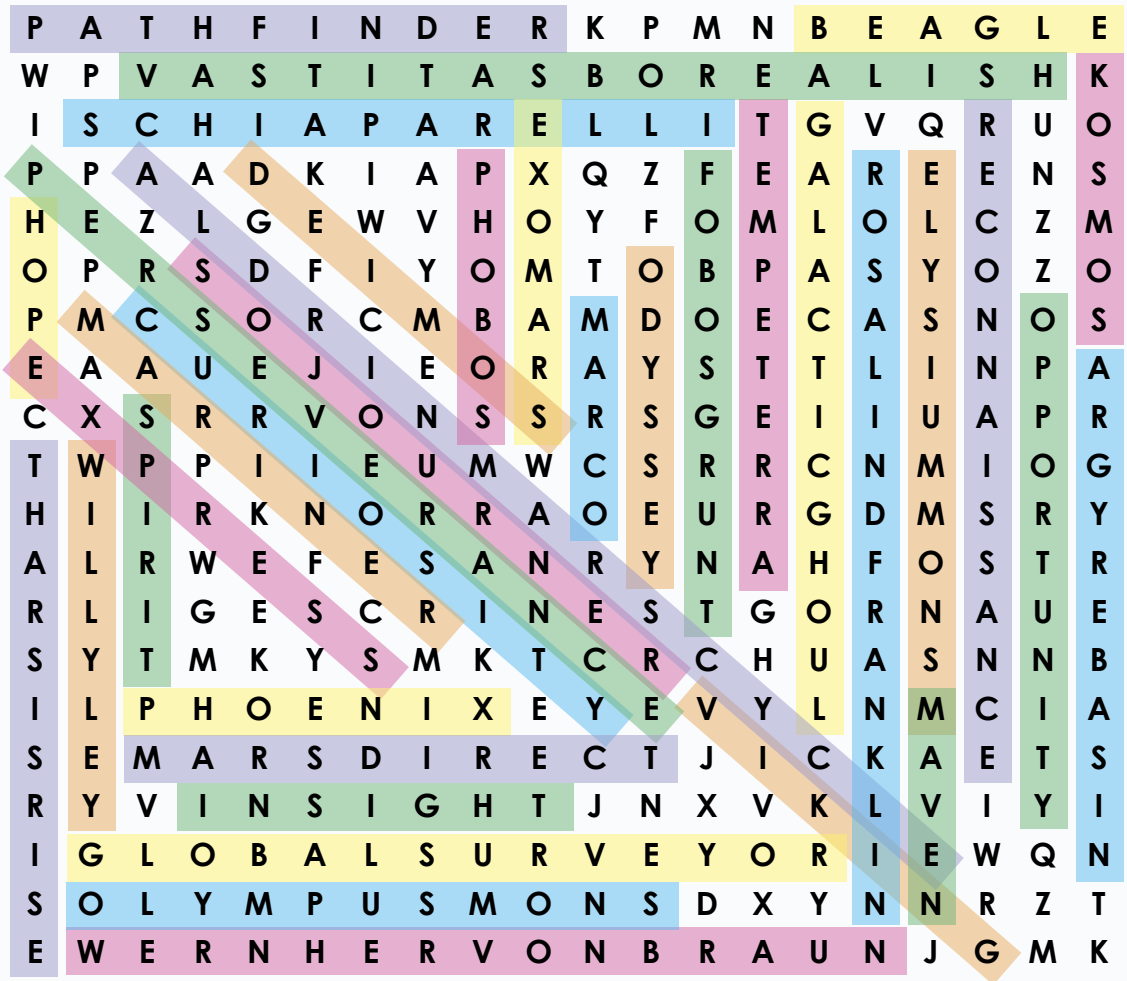
ExoMars will send a European rover, Rosalind Franklin, and a Russian surface platform, Kazachok, to the surface of Mars. The primary objective is to land the rover at a site with high potential for finding well-preserved organic material, particularly from the very early history of the planet. The drill is designed to extract samples from various depths, down to a maximum of two meters.

Question No. 15 Answer: **D**

Mars 96 included an orbiter (with more than 20 science instruments), two landers (each with seven instruments), and two penetrators (with 10 instruments each). Several European countries had major science instruments aboard. Germany, France, and Finland alone spent more than $200 million on the mission. The mission failed when the second stage of the rocket cut off extremely early.

Mars Exploration **ANSWER KEY**

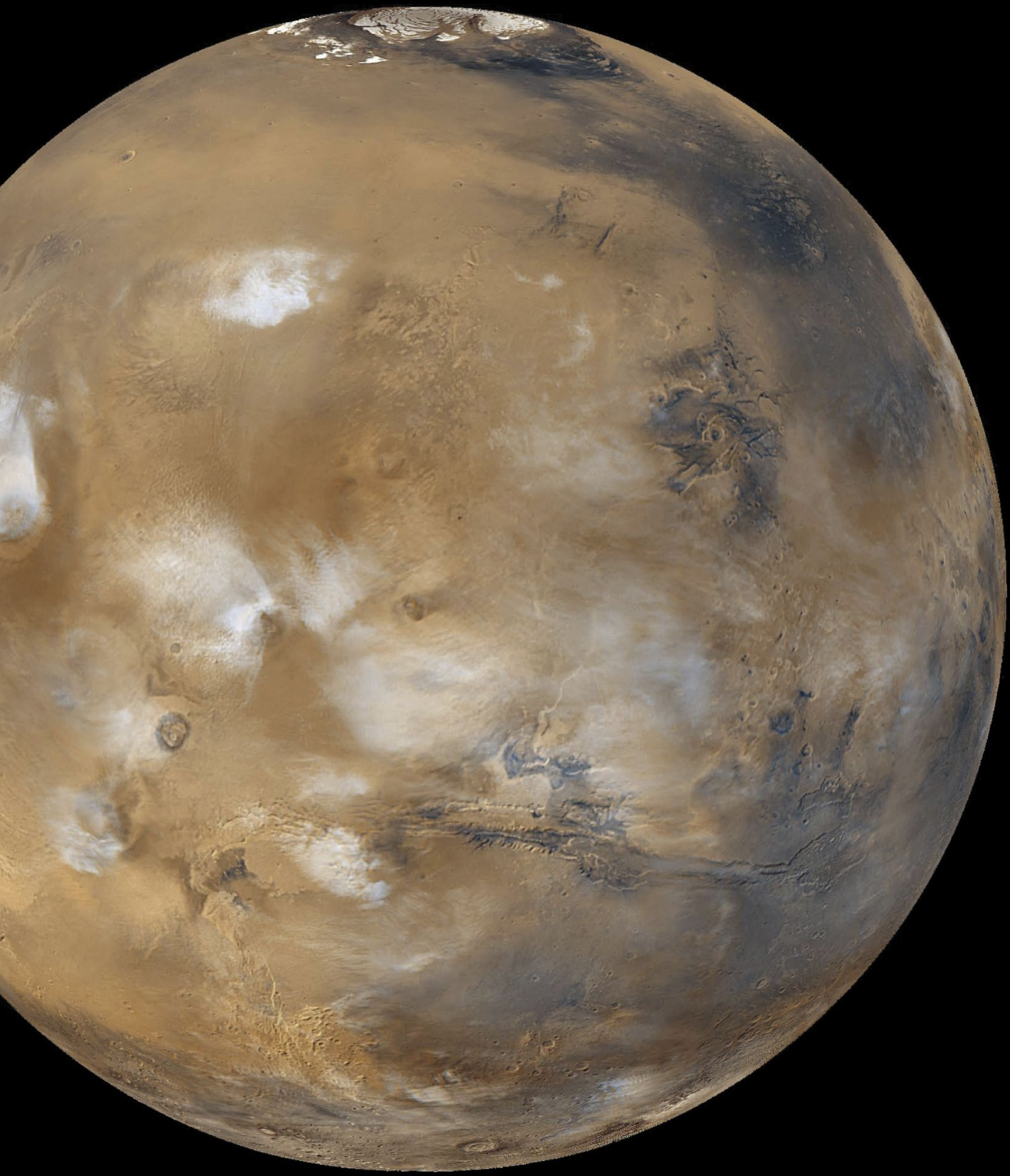
The Red Planet has been studied throughout human history. The very first mission to Mars was sent in 1960, while the first probe landed in 1971. We've hidden 36 words related to Mars exploration below. They may be placed horizontal, vertical, or even diagonal. Good luck!



ALDRIN MARS CYCLER
ARGYRE BASIN
BEAGLE
CURIOSITY
DEIMOS
ELYSIUM MONS
EXOMARS
EXPRESS
FOBOS-GRUNT
GALACTIC GHOUL
GLOBAL SURVEYOR
HOPE
INSIGHT
KOSMOS
MARCO
MARINER
MARS DIRECT
MAVEN
ODYSSEY
OLYMPUS MONS
OPPORTUNITY
PATHFINDER
PERSEVERANCE
PHOBOS
PHOENIX
RECONNAISSANCE
ROSALIND FRANKLIN
SCHIAPARELLI
SOJOURNER
SPIRIT
TEMPE TERRA
THARSIS RISE
VASTITAS BOREALIS
VIKING
WERNHER VON BRAUN
WILLY LEY

“I haven’t a clue
if there is life on
other planets,
but I’d be charmed
if we found
a unicellular
organism on Mars.
It would change
our whole concept
of life on Earth.”

~ Tommy Lee Jones



Credit: NASA/JPL-Caltech

Creatted by RocketSTEM *for all future Martian settlers.*