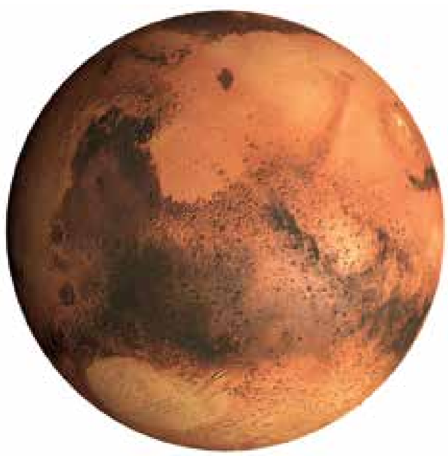
STORIES OF TOMORROW

Students Visions on the Future of Space Exploration



Mars in a nutshell

Trip to Mars

Explore Mars

Living on Mars

Assessment Tools

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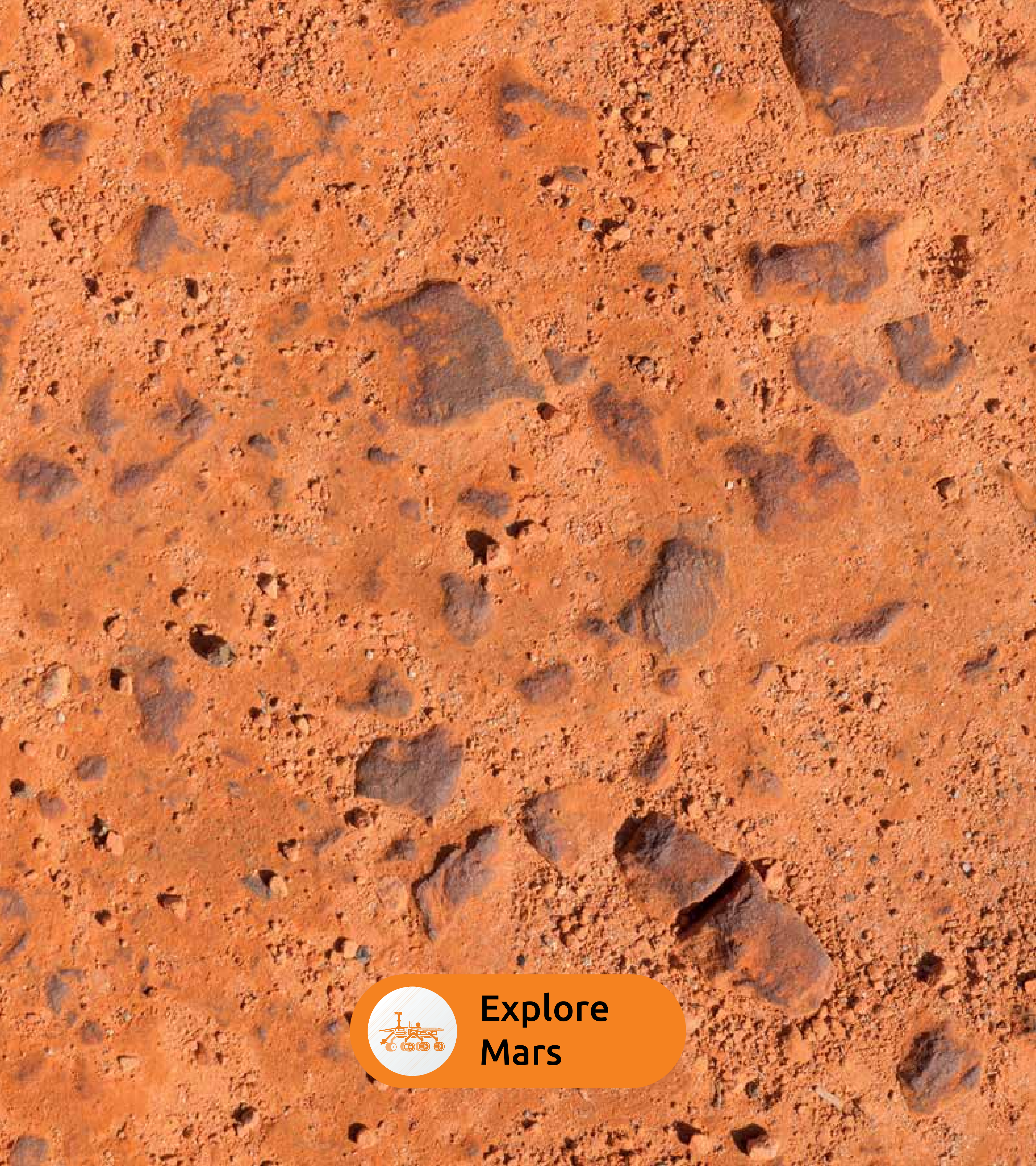
Explore
Mars


Colorful Equatorial Gullies in Krupac Crater

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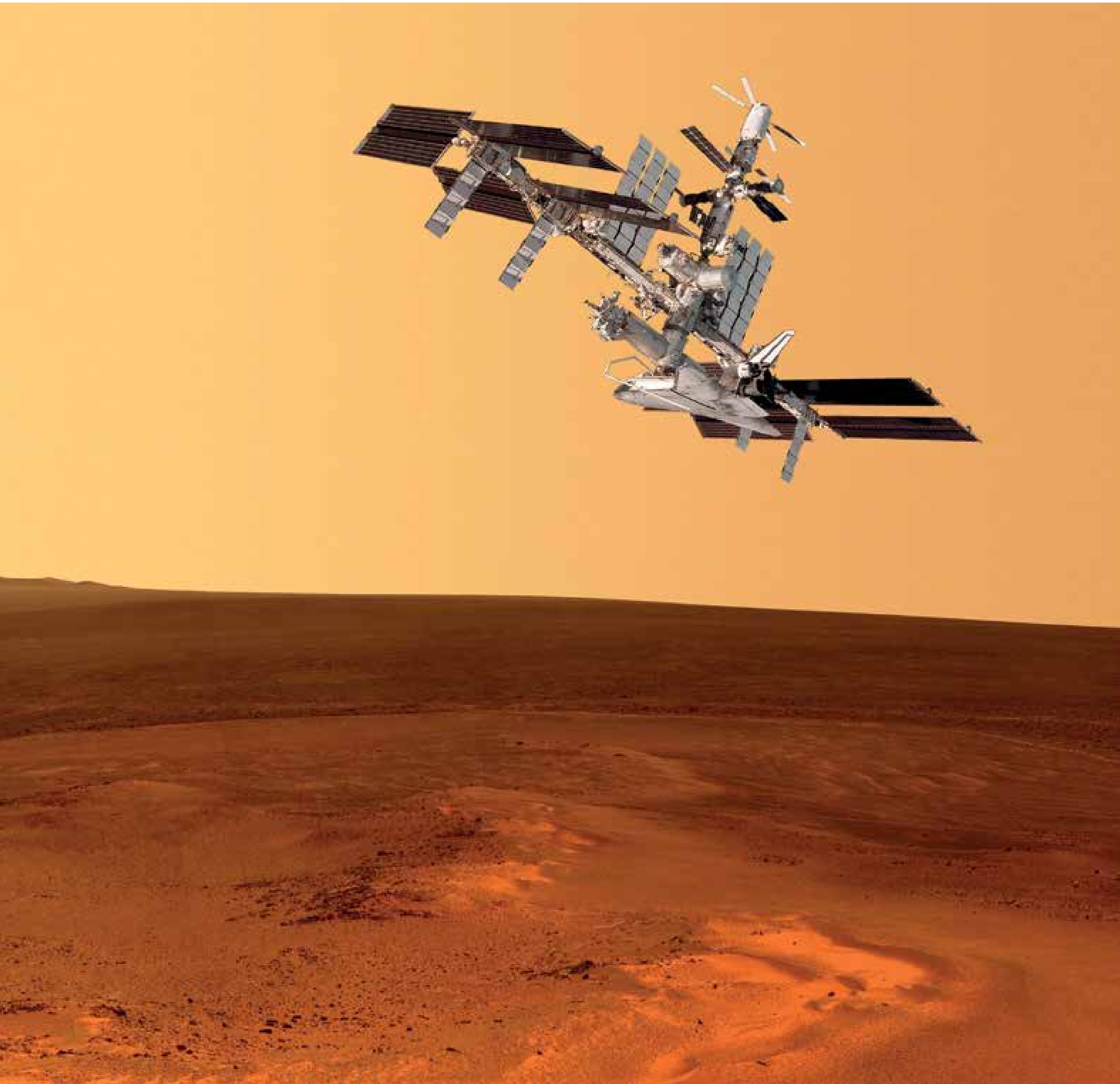
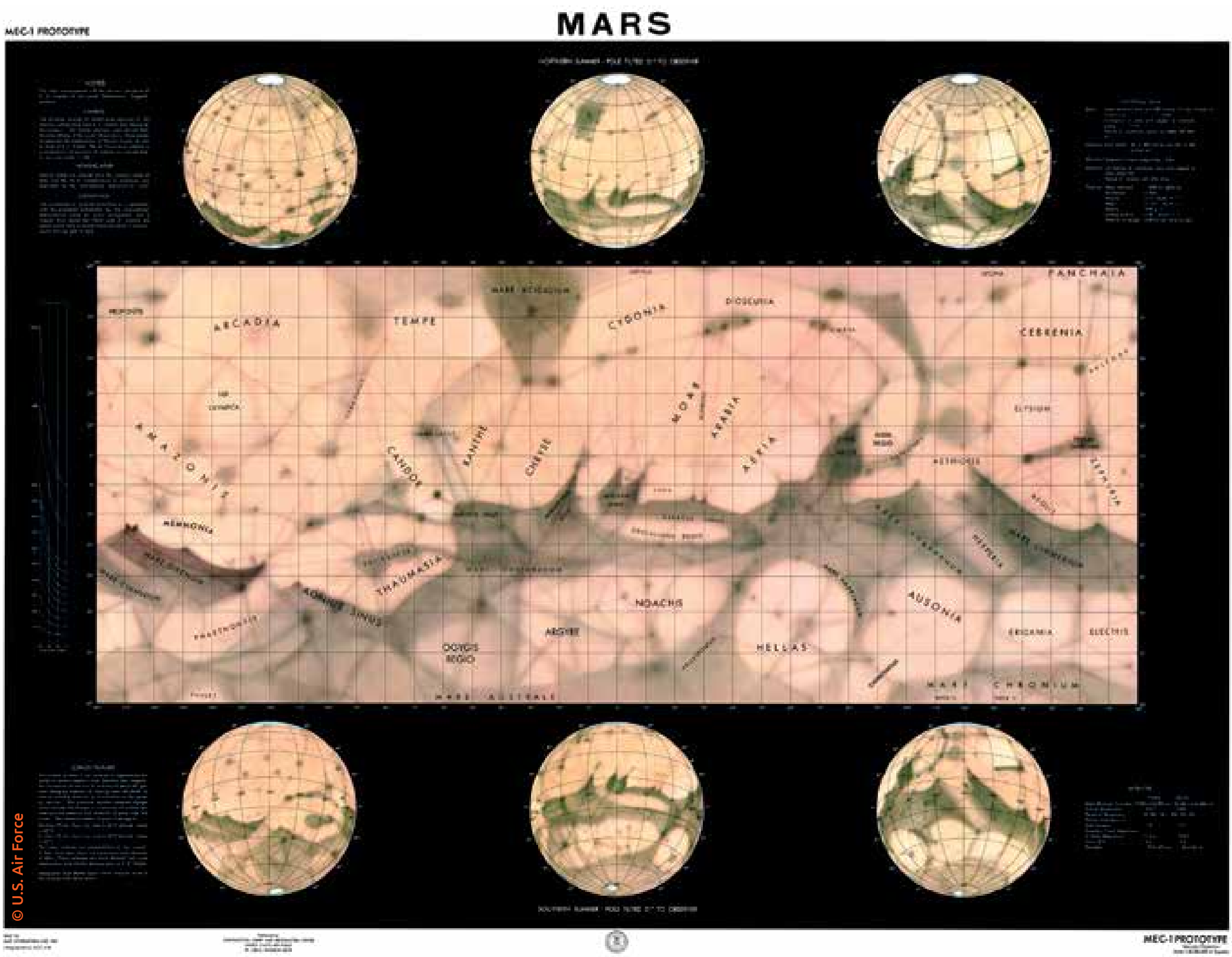


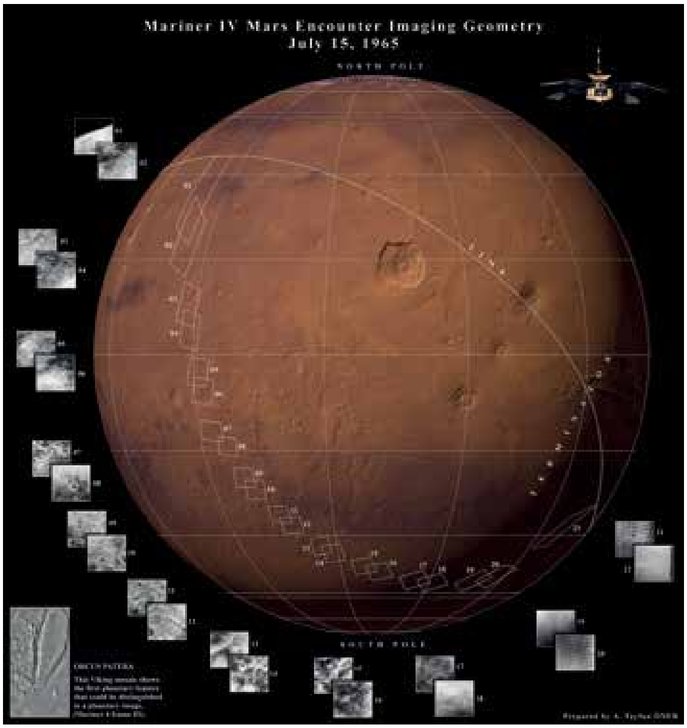
Explore and monitor Mars

The surface of Mars has been observed from Earth since the 17th century. Through the years, as the quality of telescopes improved, more and more details became discernible, and many observers produced maps that showed the distribution of bright and dark areas, that were thought at the time to correspond to continents and seas. At the end of the 19th century, some astronomers believed they were seeing on Mars dark, straight lines that were taken as signs of the existence of an evolved civilization on Mars.



© U.S. Air Force

Though this idea was not accepted by most of the scientific community, the truth is that there was no real idea of the nature of the landscape of the red planet, and the canals of Mars became part of its popular image, along with the Martians.
In 1962, the US Air Force published a map of Mars, illustrating what was then the most accepted distribution of the global features of its surface, before any close-up images became available – and something resembling the fabled canals was represented.
In fact, though there had been some early attempts to reach Mars by the USSR, it was only in 1965 that the American probe Mariner 4 flew by Mars and sent back the first detailed images of its surface. The probe only took 22 pictures, and the landscape it showed was rather Moon-like, with many craters, and no signs of canals. The idea of Mars as a life-carrying planet took a huge blow.



© NASA / Prepared by A. Tayfun Öner

Years later, in 1971, another American probe, Mariner 9, became the first to go into orbit around Mars. From that vantage point, it acquired images of the whole surface of the planet, revealing its true nature for the first time. The many discoveries included huge volcanoes and canyons, extensive dune fields, the shape of the polar caps, and large craters; but, most importantly, numerous channels were identified – except they were all dry and looked ancient.

Nirgal Vallis, Mariner 9

Nonetheless, this pointed to the presence of water on Mars, and in 1976 a major effort was made by the USA to determine if there was (microbial) life on Mars. The Viking mission comprised two surface probes (they were not the first man-made objects on the surface of Mars, since in 1971 the USSR had its Mars 3 go down to the surface, but it did not function for long and did not send back any data) and two orbiters. These enhanced our knowledge of the global geology of the planet. But the landers had a very precise mission: to try and identify traces of life in the top layers of the Martian regolith. Scoops of the soil were collected and submitted to a number of biochemistry experiments, using reagents taken from Earth; these produced a negative result, which was at the time accepted as proof of the absence of life on Mars.

Nowadays it is considered that these results were not conclusive, and the question of life on Mars remains unanswered.

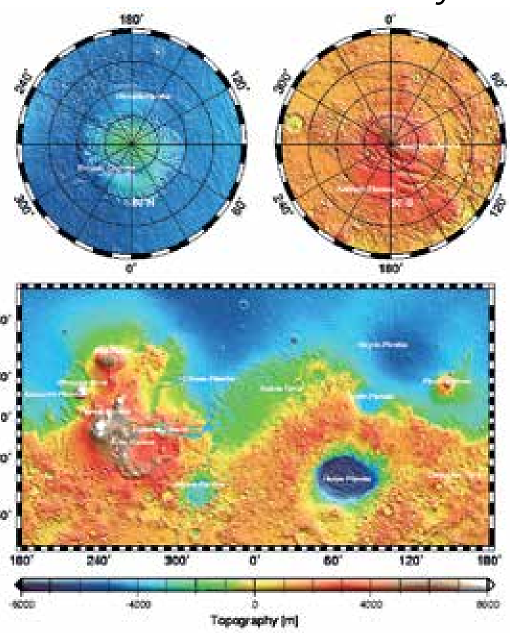
It took almost 20 years for Humanity to return to the red planet (there were some attempts in the meantime, but none met with success). Starting in 1997, a true program for the exploration of Mars became reality, with successive launches at a two-year interval. A string of automated probes has been orbiting the planet, and five robots (four rovers and one stationary) have successfully reached its surface. The motto for this program has been “Follow the water”, since water is seen as a fundamental necessity of life. However, now the focus is on the habitability of the planet, and on the preparation for future manned missions.

Our view of Mars has been changed by the huge amounts of data that a wide variety of instruments has collected. Not only has water ice been identified, but the role of liquid water in the past of the planet has been established beyond any doubt. The topography of Mars is now known with high precision. The composition and dynamics of the atmosphere are under investigation. Each and every day we have new images and other information about the Martian geology and environment.

But how did this really come about? On Earth, geological knowledge started with local and regional observations, and a global integration and understanding of the workings of our planet only came about in the second half of the 20th century. On Mars, we began by having global views (albeit with poor spatial resolution) and only now are we collecting local, small-scale observations, thanks to the work of rovers.

The first step in this global view was to determine if there were any distinctive major periods in the history of the planet. The physical characteristics of the terrains, as seen from orbit, were the basis for these divisions; one major factor was the density of impact craters in the different terrains that could be mapped. Thus, three periods were defined: the Noachian, ending 3.7 Gy ago, the Hesperian, lasting until 3.0 Gy ago, and the Amazonian – their names, following geologic tradition, came from the areas of the planet where they were first defined, following the nomenclature introduced by Schiaparelli in the late 19th century.

© NASA

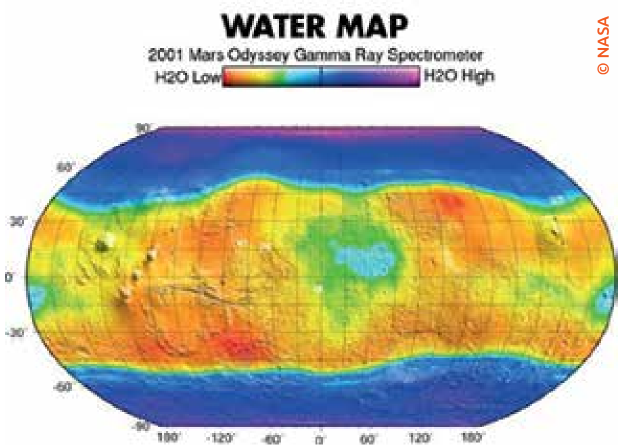


The different units that have been defined after that result from the search for geological contacts, analysis of their relations between each other, and their relation with major accidents (such as volcanoes and impact basins) – basic stratigraphic work, resulting not from field work but from the careful analysis of the images of the surface.

Furthermore, in recent years, more information has been collected about the mineralogical and lithological composition of different areas of the surface, and that information has been included in the current view of the Martian geology. The most abundant type of rock is basalt; there are extensive areas of sedimentary deposits, but the nature of the sediments is still basaltic. There is one major type of rock that is missing, and that on Earth constitutes most of the continental crust: granite. Thus, it seems that on Mars there never were conditions conducing to a differentiation and reworking of magmatic products.

Knowledge of the global topography of the planet made clear that there are major differences between the southern and northern hemispheres. The south is rugged, densely cratered, and elevated; the north is flat, low, and with less craters; and there is a huge "bubble" sitting on the equator, that corresponds to the Tharsis bulge, the area where the largest volcanoes of Mars sit. This dichotomy has existed since the early days of Mars, and its origin is still a mystery, though it could probably be due to a huge impact at the beginning of the history of the planet. One strong hypothesis is that it served as an ocean basin when Mars was young and had a thicker atmosphere, with liquid water on its surface.

After collecting many clues to the presence of water, its direct recognition only came in 2004, when



the OMEGA spectrometer, aboard the European probe Mars Express, identified the presence of water ice on the southern polar cap of the planet. Its presence had been also strongly hinted at by the data collected by the Gamma Ray Spectrometer of the Mars Odyssey probe, that pointed to some large concentrations of a source of hydrogen in the top layers of Martian regolith, namely in latitudes higher than 60°, both north and south, but also with some rich-areas in equatorial regions.
This shows the role of instruments other than cameras in providing information about the making of the red planet. Let us review some of the instruments that have been carried to the orbit or surface of Mars.

Cameras

Technology has greatly evolved, and the current visible imaging systems on Mars have little in common with the TV cameras that were carried by the first Mariners. There is one thing in common though: the images have to be transmitted back to Earth. The spatial resolution on the ground, that was around 5 km per pixel on the first image acquired by Mariner 4, came to a staggering 25 cm per pixel on HiRISE, the telescopic camera aboard Mars Reconnaissance Orbiter. The rover Curiosity is equipped with a sort of hand-lens, a camera (MAHLI) that can take images of targets in the tens of micrometers range, but of course those are from rock surfaces, and not the landscape.

Magnetometers

Mariner 4 carried a magnetometer to the neighborhood of Mars, and the indication was that there was no global magnetic field. However, many other probes have taken an instrument of this type to Mars; the one on Mars Global Surveyor clearly identified areas where remanent magnetism is present, and MAVEN also carries one, that plays a major role in investigating the interactions between the solar wind and the atmosphere of Mars.

Seismometers

The Viking landers carried seismometers; unfortunately, their location in the body of the probe made it impossible to collect data about any tremors of the Martian surface, since wind made the whole probe shake at times.

Altimeters

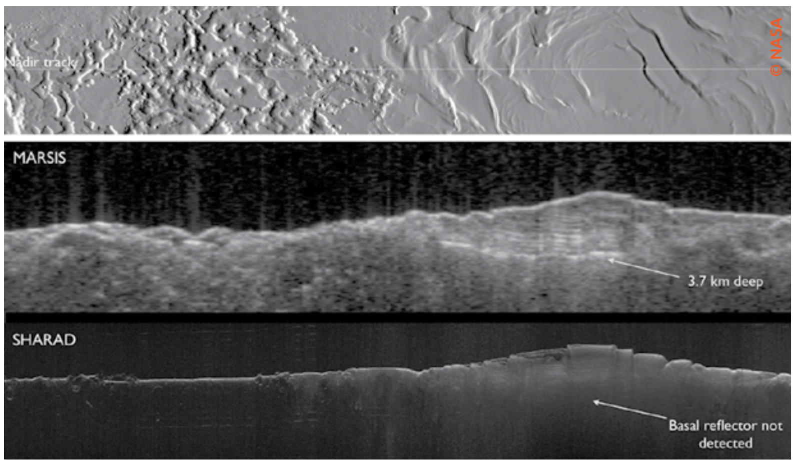
The Mars Observer Laser Altimeter (MOLA) had a second opportunity aboard the Mars Global Surveyor; it produced an extraordinary set of data that revealed the topography of Mars as never seen before.

Chemical Laboratory

The Viking landers carried a biochemistry suite, designed to try and identify metabolism within the Martian regolith. The Phoenix probe, 20 years later, also carried a chemical lab to try and identify components of the Martian soil that could point to the habitability of Mars. Thus, we can say that the sands of Mars have been sniffed and tasted by man-made instruments.

Weather station

The Phoenix probe had a full meteorological suite of instruments, that measured pressure, temperature, wind, cloud cover and a few other parameters.



Radar

There have been two radar instruments taken to the orbit of Mars; one aboard Mars Express, the other on Mars Reconnaissance Orbiter. Both have allowed us to peek under the surface of Mars, especially in the polar caps, showing us their structure.

Spectrometers

There is a wide variety of instruments that fall under this designation; though most analyse light, some take into consideration mass, or energy. Still, they are generally used to determine the composition of their targets. There have been spectrometers devoted to surface analysis, to rock analysis, to atmosphere analysis. They have provided such a huge quantity of data and discoveries

that it is impossible to list here; to mention just a few: the detection of water ice on the surface of Mars, the detection of methane in the atmosphere, the discovery of the basaltic composition of Martian rocks, and of the presence of hydrated minerals, and much more.
One instrument that has yet to make its way to Mars is a microphone. We have, so far, no record of the sound of Mars. In fact, there was one aboard the Mars Polar Lander, an American probe that did not fulfill its mission in the late 20th century. Hopefully, there will be one on the Mars2020 rover.
Currently, there are eight active probes on Mars: six in orbit, two on the surface. In 2018, another one, the American probe InSight, will hopefully reach the surface. It will, for the first time, provide much needed geophysical data about the interior of Mars, with the help of seismological detectors. It will also burrow a couple of meters into the regolith and collect data on the moisture content and heat flow. For the near future, there are a number of other planned missions, coming from the USA, Europe and Russia, but also from India, China, Japan, and the United Arab Emirates – not to mention the private efforts of companies such as SpaceX.

CURRENT AND FUTURE MISSIONS TO MARS

Name	Origin	Type	Arrival on Mars
Mars Odyssey	USA	Orbiter	2001
Mars Express	Europe	Orbiter	2003
Opportunity	USA	Rover	2004
Mars Reconnaissance Orbiter	USA	Orbiter	2006
Curiosity	USA	Rover	2012
MAVEN	USA	Orbiter	2014
Mangalyaan	India	Orbiter	2014
Trace Gas Orbiter	Europe / Russia	Orbiter	2016
InSight	USA	Lander	2018
ExoMars	Europe / Russia	Rover	2020?
Mars2020	USA	Rover	2020?
?	China	Orbiter + Rover	2020?
?	UAE	Orbiter	2020?
?	Japan	Orbiter	2020?
Mangalyaan 2	India	Orbiter + Lander	2020+

There are still many mysteries in the history of Mars, and many discoveries to be made. But let us not forget that the rate of success of the missions to the red planet still sits around 50% - Mars is a jealous guardian of its secrets…

Activities

1. Mars rover

U.S. Air Force photo by Jamie Pitcher

Replica of the Martian surface

Overview

Students design, build and test a rover for mars. Using different materials, from pasta to lego, students must design a rover that will travel down a one-meter ramp and then travel an additional one meter on a smooth, flat surface. They also play a game. In this game students execute a series of commands that will guide a human rover through a simulated Martian surface. Create a Mars landscape to go along with their rovers! Provide a variety of craft materials that may be used to draw or make a model landscape of Mars (for example, clay or Play-Doh, sand, rocks, colored and/or plain paper, markers, crayons, glitter, pipe cleaners, foil, pom-poms, tape, glue, images of Mars for a background, etc.)
(stem, design arts, hands-on experimentation, 3d design, visual arts)

Objectives

Students will:

Design, build, test and redesign their rover to make sure it is working. Experience some of the challenges of teleoperating a robotic vehicle on another planet and problem solve solutions by using a hands-on simulation.

Enjoy and be able to challenges requiring them to apply knowledge in nonroutine ways. Understand key principles and relationships within a content area and organize information in a conceptual framework. Learn, remember and recall facts relevant to an area. Learn and can apply theories relevant to a content area. Know and be able to use the language specific to a content area. Apply facts to real word situations. Be familiar with and be able to use effectively the tools and techniques specific to a content area. Evaluate, integrate and critically analyze multiple sources of information. Structure information and data in meaningful way. Formulate problems and generate hypotheses. Identify data and information needed to solve a problem. Reason and construct justifiable arguments in support of a hypothesis. Persist to solve complex problems. Collaborate with others to complete tasks and solve problems successfully.

Tools

Online exploration / Lithographs / Q&A / Fast Facts / the news / video / 3d design-printer / google mars

2. Explore mars using programming language

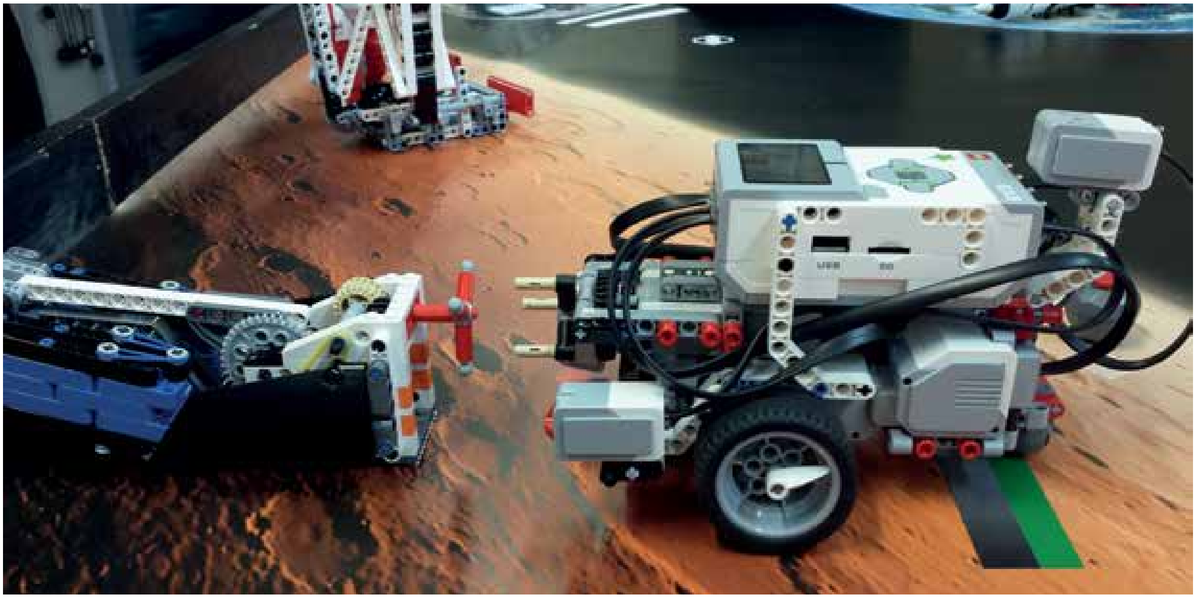
Overview

In this activity, students who have learned about Mars surface features will use their knowledge to create a Mars exploration game using the Scratch programming language. (stem)

Objectives

Students will:

Engage in computational thinking and include elements of real rover-mission planning to design their game. Understand key principles and relationships within a content area and organize information in a conceptual framework. Learn and can apply theories relevant to a content area. Apply facts to real word situations. Be familiar with and be able to use effectively the tools and techniques specific to a content area. Evaluate, integrate and critically analyze multiple sources of information. Structure information and data in meaningful way.



Tools
Online exploration / Lithographs / Q&A / Fast Facts / the news / google mars / programming language (scratch)

3. Touchdown to mars surface

Overview
Students will use what they know and can investigate about gravity, motion, and forces to design and build a shock-absorbing system that will protect two "astronauts" when they land. (stem/hands on/design art)

Objectives
Students will:
follow the engineering design process to design and build a shock-absorbing system out of paper, straws, and mini-marshmallows; attach their shock absorber to a cardboard platform; and improve their design based on testing results. Enjoy and be able to challenges requiring them to apply knowledge in nonroutine ways. Apply facts to real word situations. Be familiar with and be able to use effectively the tools and techniques specific to a content area. Evaluate, integrate and critically analyze multiple sources of information. Formulate

problems and generate hypotheses. Identify data and information needed to solve a problem. Reason and construct justifiable arguments in support of a hypothesis. Persist to solve complex problems.

Tools
Online exploration / Lithographs / Q&A / Fast Facts / the news / google mars

4. Parachute design

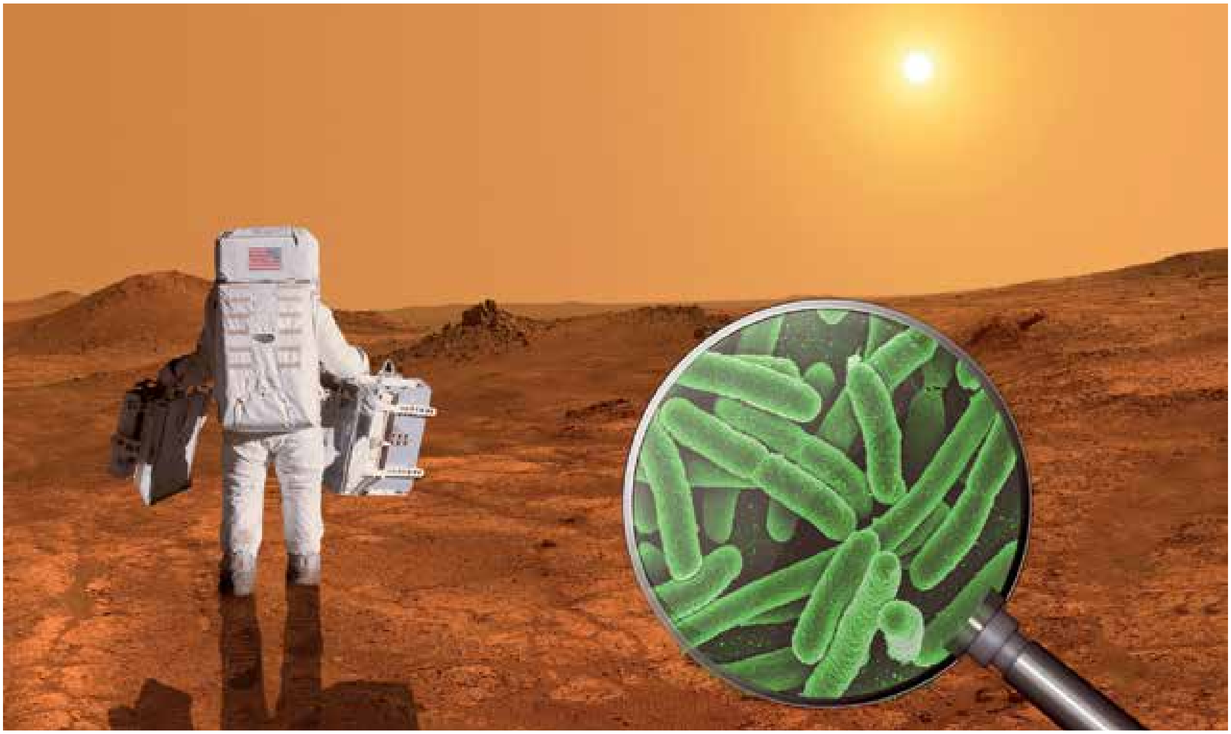
Overview
Sending larger vehicles to Mars might seem pretty far removed from the classroom, but this lesson allows you to bring it right onto students' desks! (stem/hands on/design art)

Objectives
Students will:
design and test parachute landing systems to successfully land a probe on target. After testing, students can optimize their parachutes by experimenting with different materials

and shapes for their parachute designs. Students will then retest their designs to see if the changes they made resulted in improved performance. The goal is to land a payload as slowly and softly as possible. Enjoy and be able to challenges requiring them to apply knowledge in nonroutine ways. Apply facts to real word situations. Be familiar with and be able to use effectively the tools and techniques specific to a content area. Evaluate, integrate and critically analyze multiple sources of information. Formulate problems and generate hypotheses. Identify data and information needed to solve a problem. Reason and construct justifiable arguments in support of a hypothesis. Persist to solve complex problems.

Tools
Online exploration / Lithographs / Q&A / Fast Facts / the news / google mars

5. Looking for life
Overview
Students follow the scientific method and looking for life on mars. (science)



Objectives

Students will:

use research to develop an operational definition of life and then use the fundamental criteria for life to examine simulated extraterrestrial soil samples for signs of life. Enjoy and be able to challenges requiring them to apply knowledge in nonroutine ways. Understand key principles and relationships within a content area and organize information in a conceptual framework. Apply facts to real word situations. Structure information and data in meaningful way. Formulate problems and generate hypotheses. Be familiar with and be able to use effectively the tools and techniques specific to a content area. Evaluate, integrate and critically analyze multiple sources of information. Formulate problems and generate hypotheses. Identify data and information needed to solve a problem. Reason and construct justifiable arguments in support of a hypothesis. Persist to solve complex problems.

Tools

Online exploration / Q&A / the news

6. What can craters tell us about mars?

Overview

Students learn some basic concepts about craters on Mars using three investigative techniques: image interpretation, modeling, and Mars-Earth comparisons.
(stem, design arts, hands-on experimentation, 3d design)

Objectives

Students will:

examine images of Martian craters and speculate about what caused them. Next, they model the formation of an impact crater by dropping objects into a tray of powder. They examine the effects of each impact and the features each impact creates. Students re-examine the images of the Martian craters to see if their modeling experience gives them additional insights. They create hypotheses to try to explain a feature not seen in their models, a mud-flow-like ejecta blanket. Students write a plan to test one of the hypotheses and carry out their investigation. Finally, students apply their modeling experiences by making several inferences. Interpret images of craters. Compare craters on Mars and Earth. Model geologic processes. Design and conducting a Mars-related investigation. Collect and interpret data from a classroom experiment. Draw conclusions and make inferences.

Tools

Online exploration / Lithographs / Graphic Organizers / Q&A

STORIES OF TOMORROW

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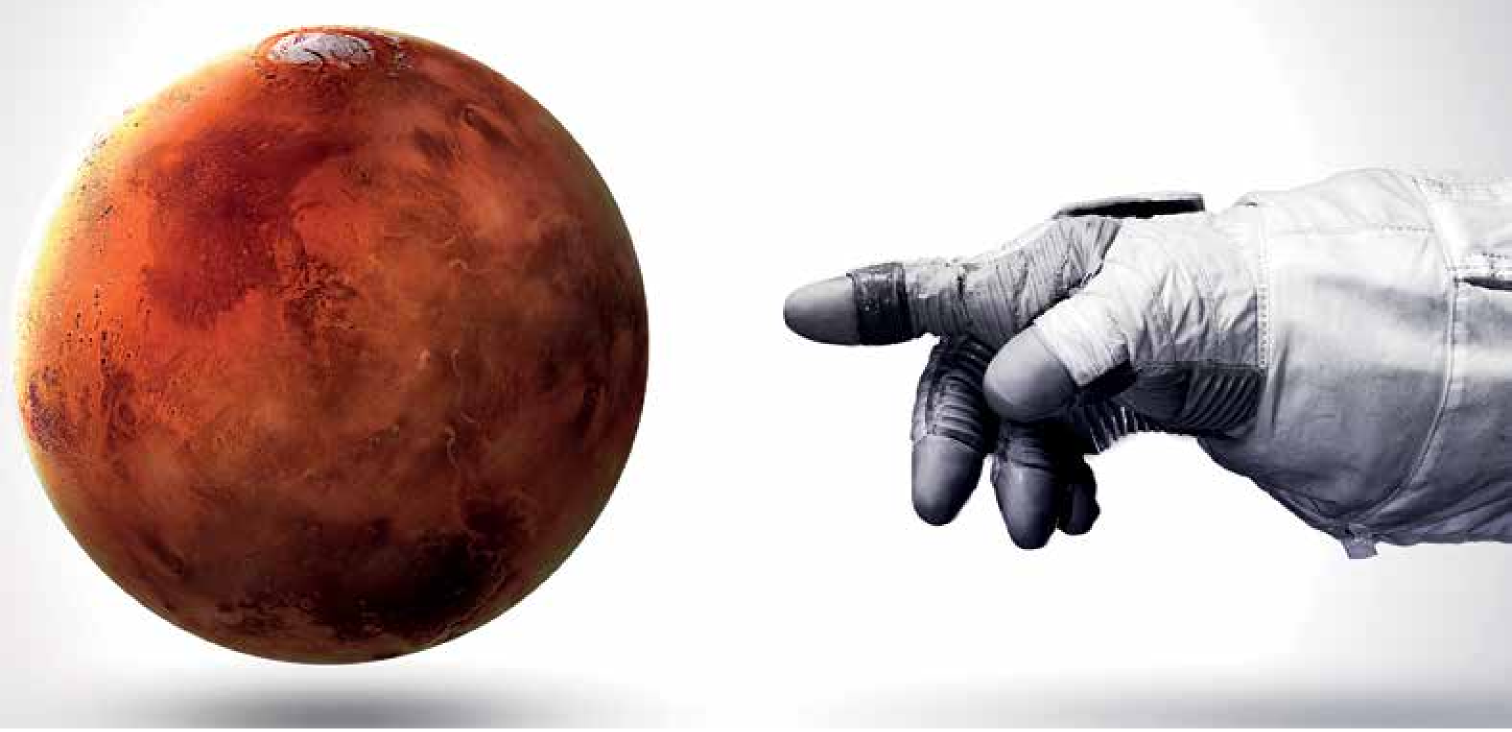

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