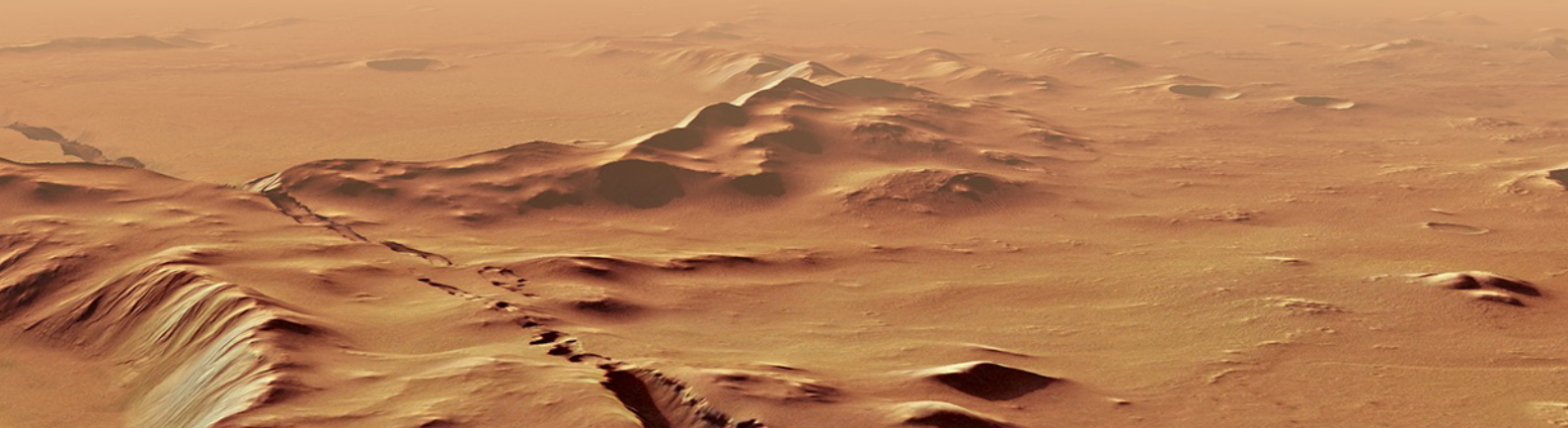
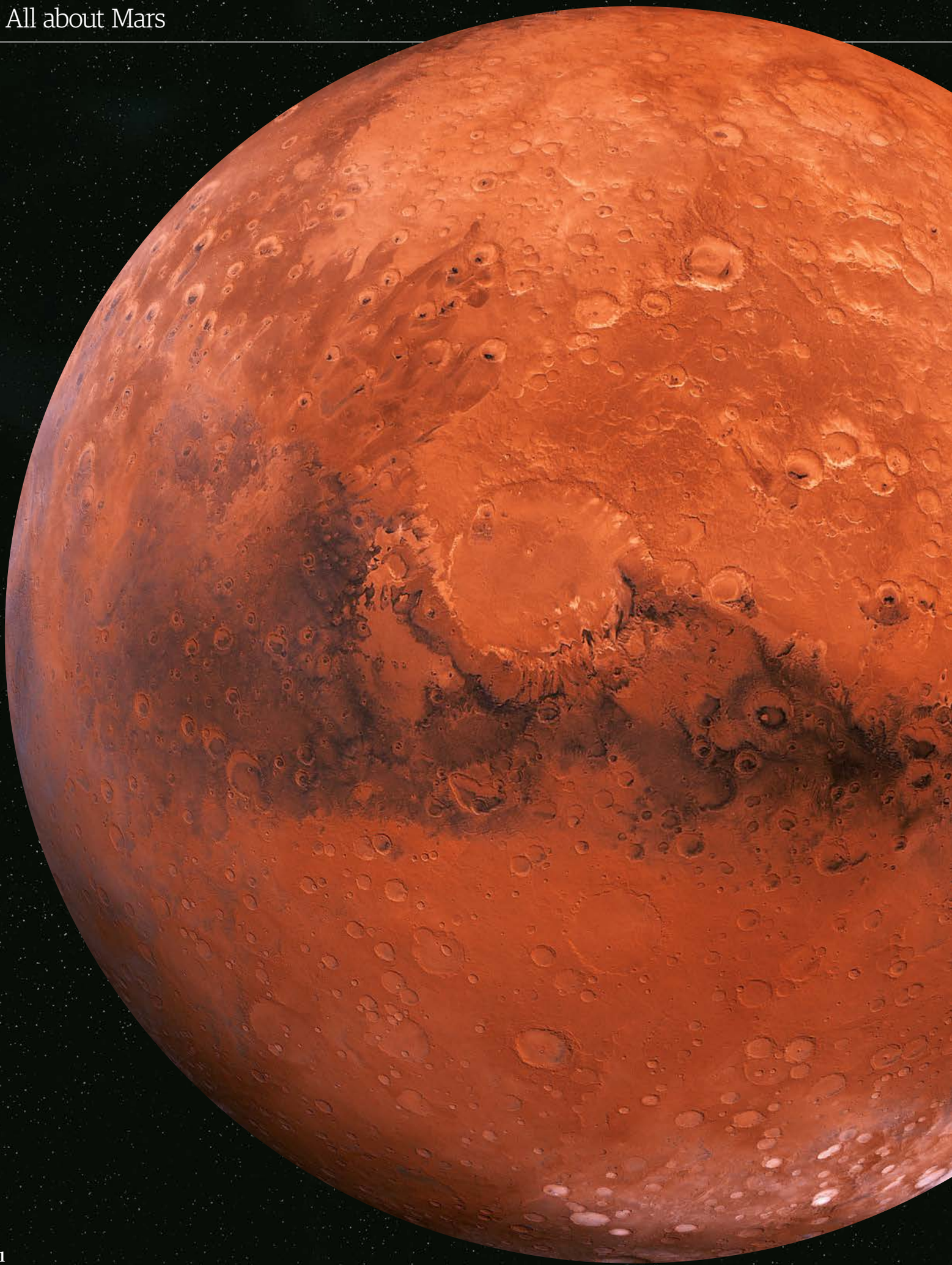
All About Space

ALL ABOUT MARS

By Shanna Freeman





All about... MARS

Written by Shanna Freeman

The fourth planet from the Sun and the seventh largest, the red and varied landscape of this once Earth-like planet has fascinated humanity since we first viewed it in the night sky. **All About Space** explores just why this planet holds such allure

Because it appears red due to the rust on its surface, Mars has long been called The Red Planet. Its 'bloody' appearance is also why it was named after the Roman god of war. But that potentially scary appearance hasn't kept us from wanting to learn more about it. Mars formed about 4.6 billion years ago, along with the other planets in the Solar System. After the initial formation, Mars was bombarded at length by meteors, which caused its heavily cratered appearance. As the planet separated into layers, molten rock in the mantle pushed through the crust, resulting in volcanic activity. The activity released a lot of heat from the core, which led it to cool down very quickly. Atmospheric water likely froze, causing flooding, but the lack of atmospheric pressure meant that water was swirled away by solar winds. Eventually Mars settled down into the dry, dusty planet we've been watching since ancient times.

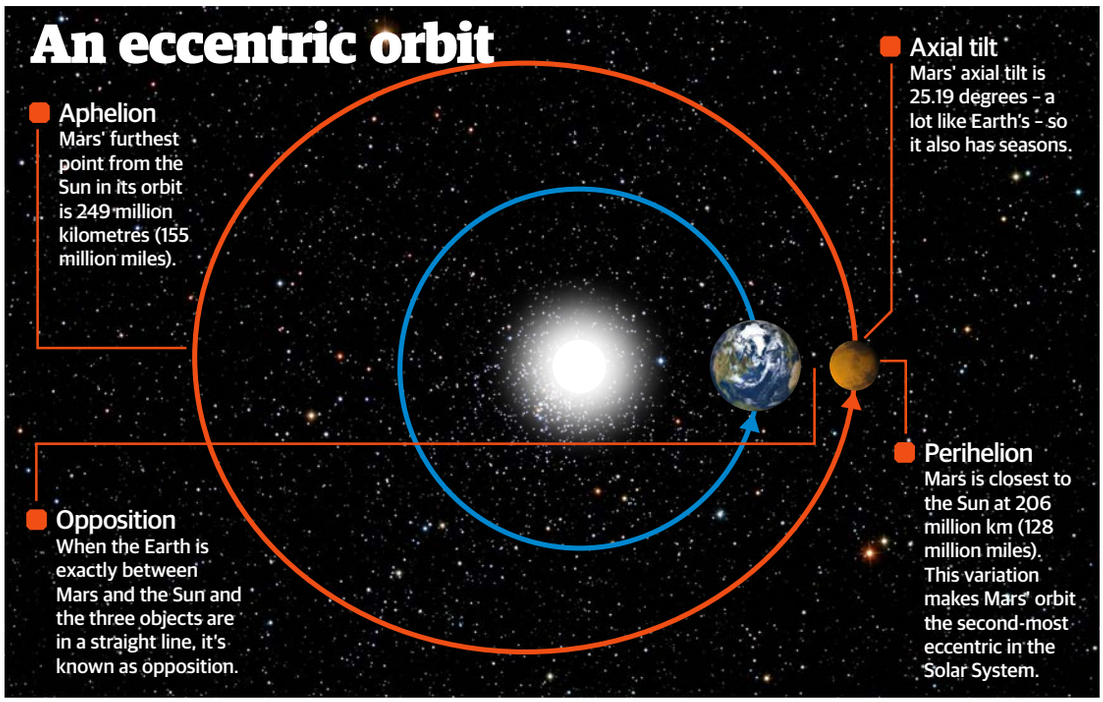
We can easily see Mars from Earth without a telescope, and it's actually easier to see when it's further away from the Earth in its orbit because our atmosphere gets in the way. We've sent lots of probes to the planet, including the recent addition of NASA's Curiosity rover. So far we've discovered that Mars is so much like the Earth, but also so very different. It is a terrestrial planet and has almost identical geographical features and a similar axial tilt (which results in seasons). It also has basically no atmosphere, no liquid water and wildly fluctuating temperatures on the surface. If there are any Martians lurking around, they have to be a hardy group - and so far they've eluded detection. Mars is red, but not all red. Although we can see the planet, we can't actually see any of its features. We do, however, see albedo features, areas of light and dark. While most of the planet is red there are also bright white areas at the poles, some upland areas, and also in the form of ice clouds. The darker spots are places where the intense wind has removed the ruddy dust to expose basaltic volcanic rock.

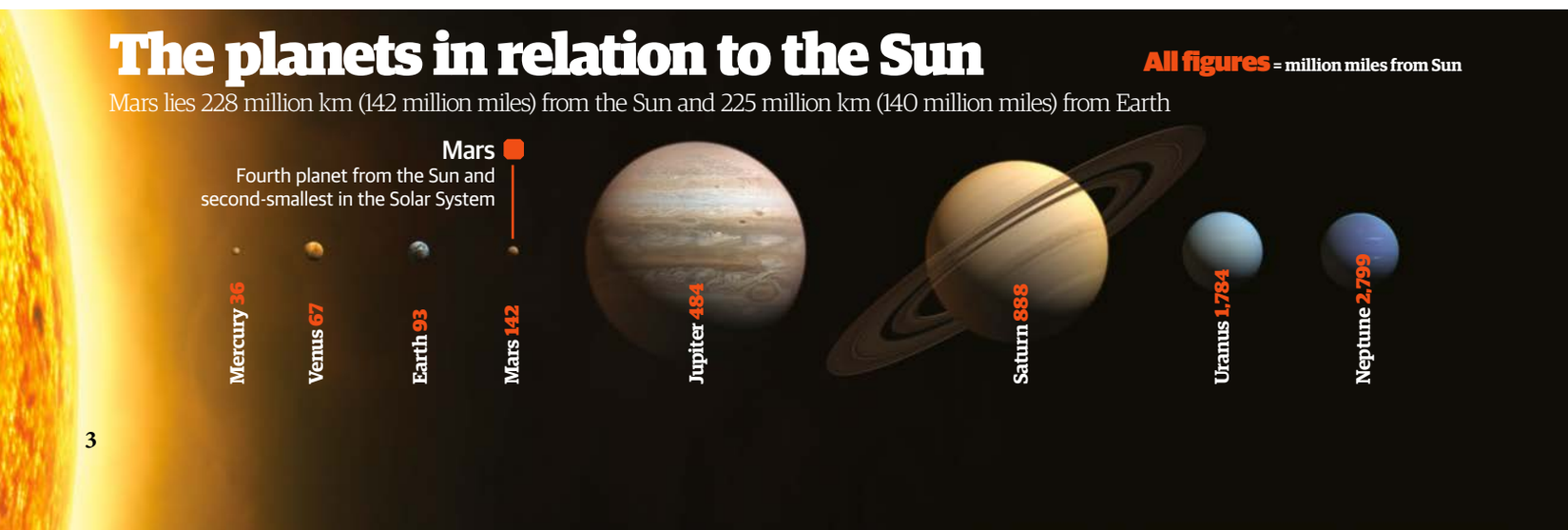
Mars is the fourth planet from the Sun in the Solar System, right between the Earth and Jupiter. Size-wise it is the second-smallest planet, behind Mercury. Despite all of the Earth comparisons, it's about half the diameter of Earth, and much less dense. In fact, its mass is about 11 per cent that of Earth's and its volume is about 15 per cent. But because there are no oceans on Mars, the smaller planet has the same amount of dry land as the Earth does.

The planet's average distance from the Sun is about 228 million kilometres (142 million miles). It takes 687 Earth days to orbit the Sun, but Mars has a very eccentric elliptical orbit. Its eccentricity is 0.09, which is the second-most eccentric in the Solar System behind Mercury (the Earth has an orbital eccentricity of 0.0167, which is almost a circle). But we believe that Mars once had a much rounder orbit - it has changed due to gravitational influences from the Sun and other planets. Rotation-wise, a Martian day is just a bit longer than an Earth day at 24 hours, 39 minutes and 35 seconds. Mars is also tilted 25.19 degrees, close to the Earth's axial tilt of 23.44 degrees. That means depending on where the planet is in its orbit around the Sun, different hemispheres will be exposed to more light - better known as seasons. They aren't seasons like we know them, which are fairly equal in length on most parts of the surface of Earth. On Mars, spring is seven months long, for example, while winter is only four. The seasons are longer because the year is longer - Mars is further away from the Sun than the Earth - but they vary because of the eccentricity of Mars' orbit.

Mars also has two natural satellites, or moons - Phobos and Deimos. Both are potato-shaped and may have been asteroids that got trapped by Mars' gravitational pull or they could have

"Because there are no oceans on Mars, it has the same amount of dry land as the Earth does"

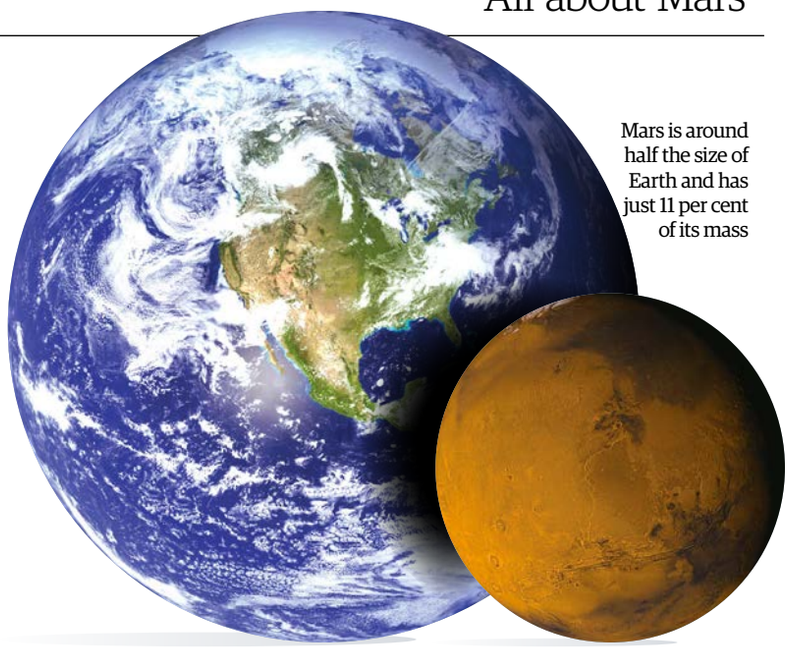




formed from material ejected from Mars during impact. The planet might also have other tiny satellites that have yet to be discovered.

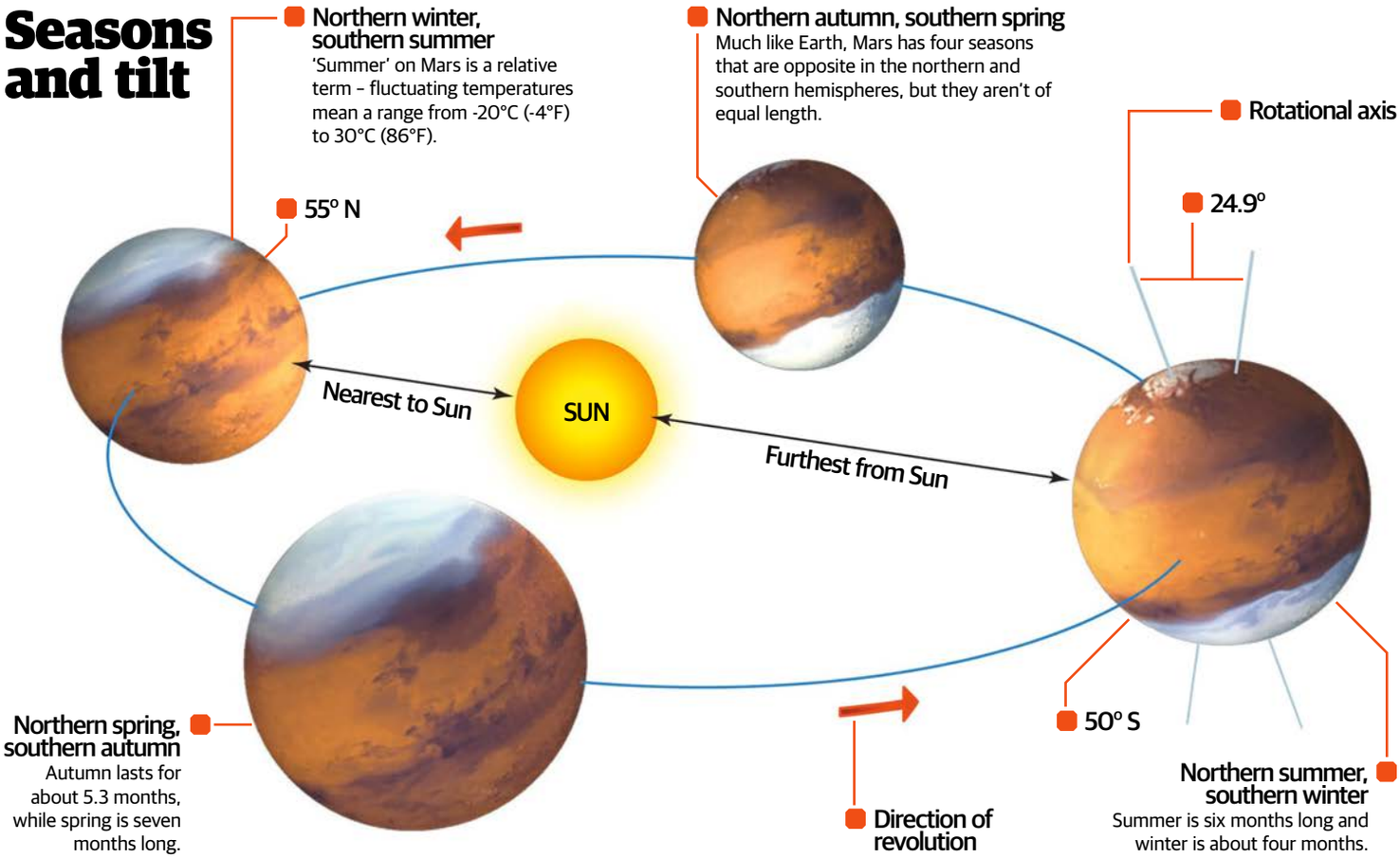
Over the years science fiction has often portrayed Mars as a sister planet to Earth and although there are many key differences - the small matter of life, for example - a true understanding can often be reached by making the right comparisons. NASA has referred to Earth as 'one of the best comparative laboratories' and the study of Mars can provide scientists with a control set for studying the potential for life beyond our world.

As mentioned, the chief of these differences is the size of the planet: Mars is a smaller world with 53 per cent the diameter and just 11 per cent the mass of Earth. The surface gravity on the Red Planet is 38 per cent that of Earth's, meaning that a human who can jump one metre (3.3 feet) on Earth could jump 2.6 metres (about nine feet) on Mars. As well as the similar land surface area the atmospheric chemistry is relatively similar especially when Earth and Mars are compared to other planets in the Solar System. Both planets have large polar ice caps made primarily of water ice, according to current thinking. Other similarities include a similar tilt in their rotational axis, which causes strong seasonal variability on the planets' surfaces.



Mars is around half the size of Earth and has just 11 per cent of its mass

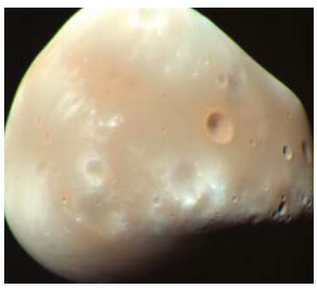
Seasons and tilt



The moons of Mars

Phobos

Phobos is the bigger of Mars' two satellites, and orbits the closest. In fact, it orbits closer to its planet than any other satellite in the Solar System. The distance from the moon to the planet is about 6,000km (3,700 miles) from the surface. Phobos has a radius of about 11km (seven miles) and is irregularly shaped and non-spherical. Its biggest feature is a large impact crater named Stickney, which has a diameter of about 9km (5.6 miles).



Deimos

Deimos is much farther from Mars than Phobos at around 23,400km (14,600 miles) away. It's also significantly smaller, with a radius of around 6km (four miles), and takes much longer to orbit Mars at 30.4 hours. Deimos, like Phobos, is not at all spherical. It has a very porous surface, and also features large craters relative to its size, with the two largest being Swift and Voltaire. Both craters are believed to be between 1 and 3km (0.6 and 1.9 miles) in diameter.

Mars inside and out

Its make-up may resemble Earth's, but Mars is a very different planet

Mars is a terrestrial, or rocky, planet – just like Earth. It also has a differentiated internal structure, meaning that there's an outer crust, a mantle and a core. However, that structure isn't exactly like the Earth's.

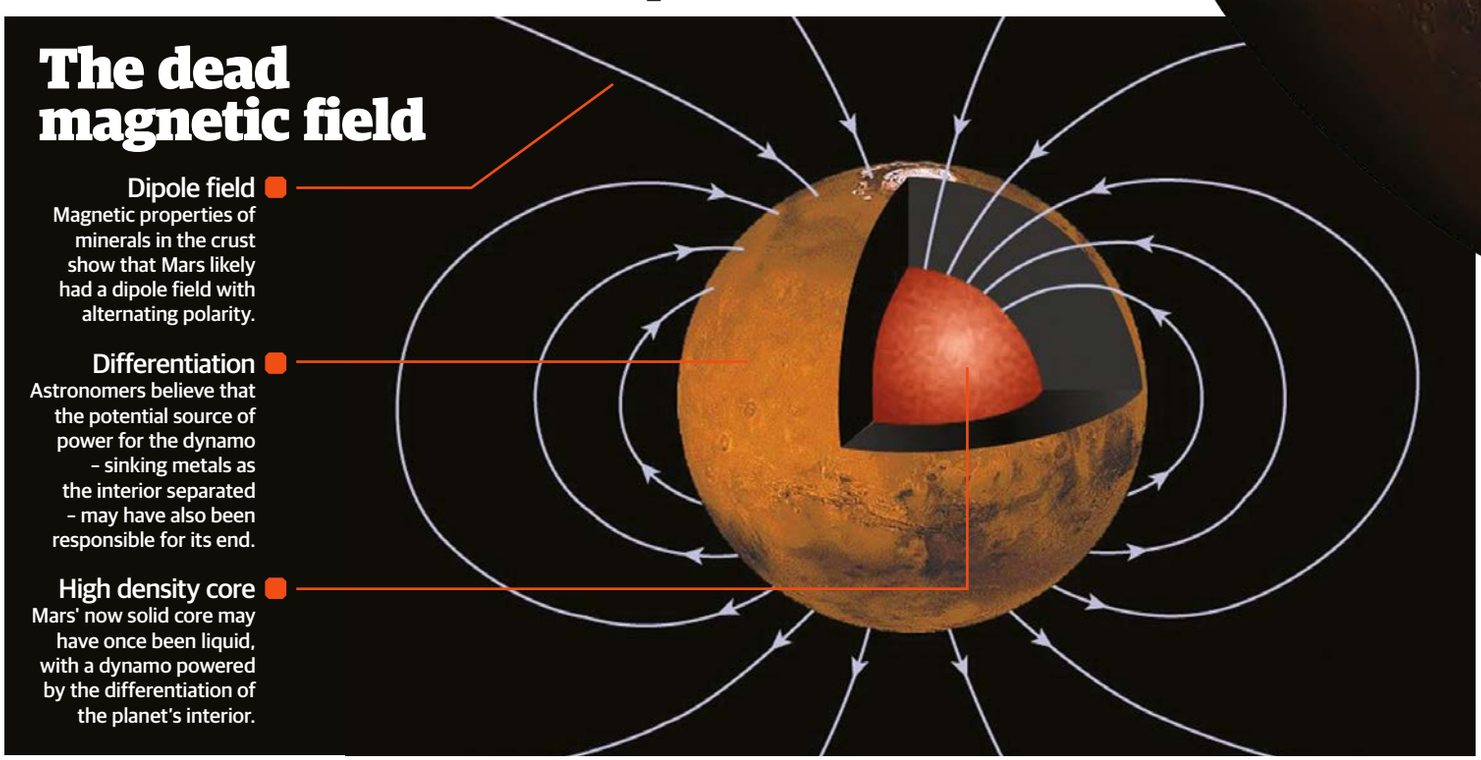
At the centre of the planet, Mars' core is believed to be between around 3,000 and 4,000 kilometres (1,850 and 2,500 miles) in diameter. It's mostly made up of iron, with nickel and traces of other elements, such as sulphur. Scientists believe that the core is mostly solid but may also contain a fluid layer. There is no magnetic field generated at the core, but Mars may have had a magnetic field in the past. There are currently areas of magnetisation at different places on the planet's surface. The differentiation process, in which heavier metals such as iron sunk through to the core while Mars was forming, may be responsible for the end of its magnetic field.

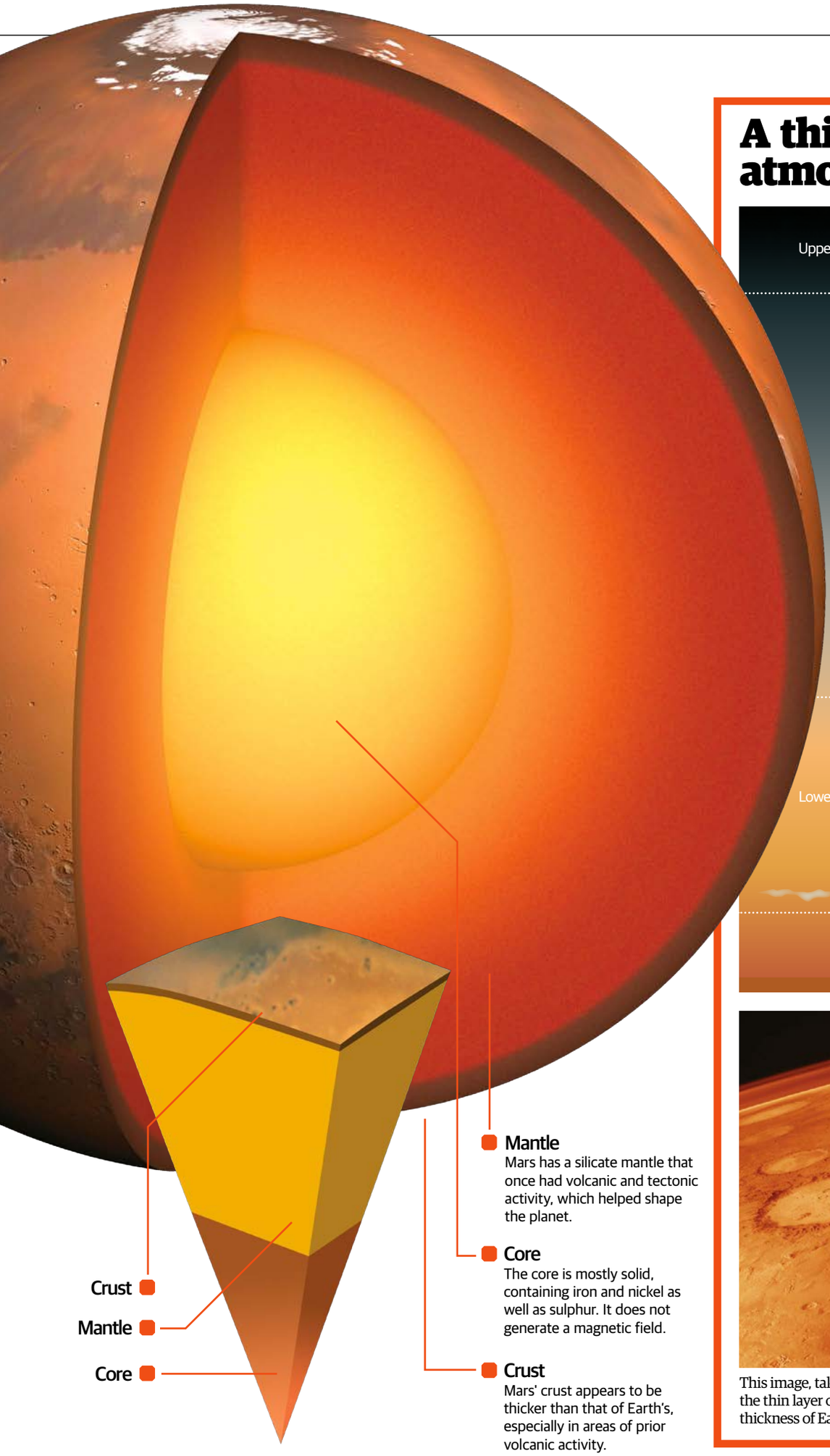
Atop the core lies Mars' silicate mantle, which is between 1,300 and 1,800 kilometres (800 and 1,100 miles) thick. Volcanic activity on the planet's surface originated here, resulting in the huge volcanoes, lava flows and other features that can be found on Mars' surface – however, the most recent volcanic activity likely took place about 2 million years ago. That may not be particularly recent by our standards, but it's fairly recent when it comes to Mars' history. These were lava flows, however; the volcanoes appear to be extinct.

Finally, there's the crust, which is about 25 to 80 kilometres (16 to 50 miles) thick. It contains oxygen, silicon, iron, calcium and other metals. The high concentrations of iron and oxygen result in rust – iron oxide – which is responsible in part for the red appearance of Mars. At its thickest the crust is more than twice as thick as the Earth's crust. The surface is covered with regolith in many places – a loose conglomerate of broken rocks, dirt and dust that sits lightly on the surface.

There isn't much atmosphere – the solar wind strips away molecules and carries them out into space. What little atmosphere is left is made up of about 95 per cent carbon dioxide, three per cent nitrogen, two per cent argon with trace gases as well.

"The solar wind strips away molecules and carries them out into space"



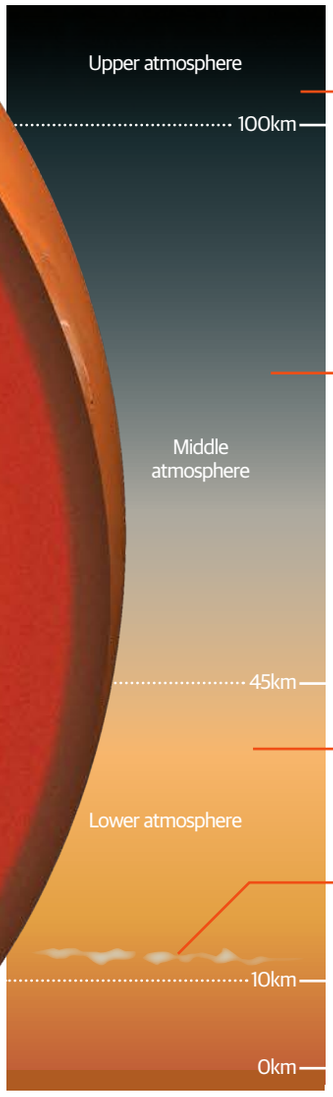


Mantle
Mars has a silicate mantle that once had volcanic and tectonic activity, which helped shape the planet.

Core
The core is mostly solid, containing iron and nickel as well as sulphur. It does not generate a magnetic field.

Crust
Mars' crust appears to be thicker than that of Earth's, especially in areas of prior volcanic activity.

A thin atmosphere

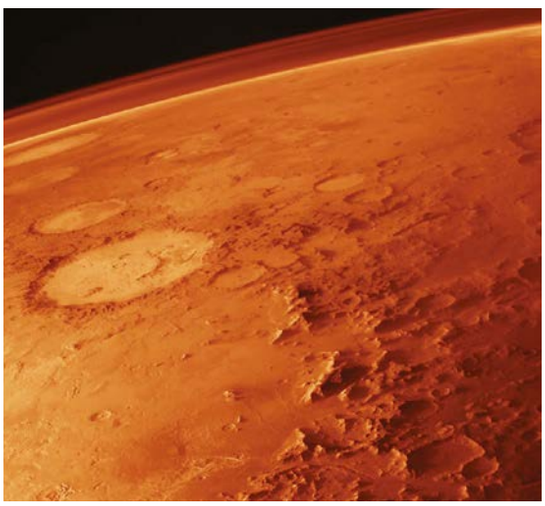


Upper atmosphere
Also known as the thermosphere, this layer is heated by the Sun. The lack of a magnetic field means that the gases separate out into space.

Middle atmosphere
In the middle atmosphere, the Martian jet stream swirls the surface dust and gives the sky its orange colour.

Lower atmosphere
The atmosphere contains 95 per cent carbon dioxide, three per cent nitrogen, two per cent argon and traces of elements such as methane.

Thin ice clouds
Strong winds sweeping off Mars' polar ice caps, along with atmospheric sublimation of carbon dioxide, help create these thin ice clouds.



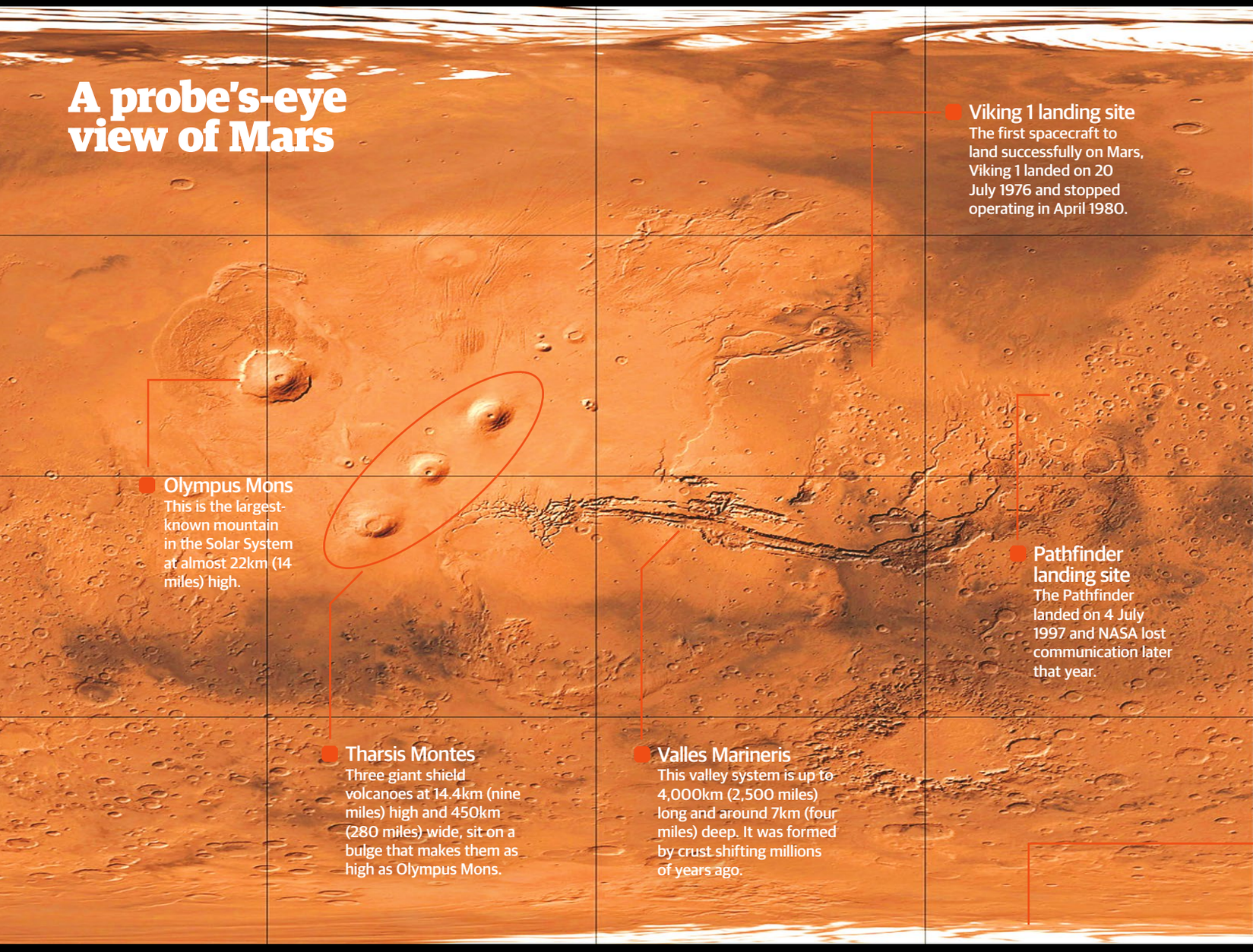
This image, taken by the Viking Orbiter from low orbit, shows the thin layer of Mars' atmosphere - less than one per cent the thickness of Earth's atmosphere

On the surface

Mars has a lot of geographical similarities with Earth, but there's a reason why we haven't found life there... yet

Thanks to the many images sent back from various probes, we know that Mars has a lot of interesting geographical features. The biggest one is that Mars has incredibly different northern and southern hemispheres. Most of the northern hemisphere is lower in elevation than the southern one (up to six kilometres or four miles lower). It also has far fewer impact craters, and is much smoother and uniform all over. Finally, the crust on the northern hemisphere appears to be much thinner than the southern hemisphere's. While astronomers aren't sure of the reasons behind this dichotomy, it involves the three main forces that have influenced the planet's surface: volcanic activity, tectonics and impacts.

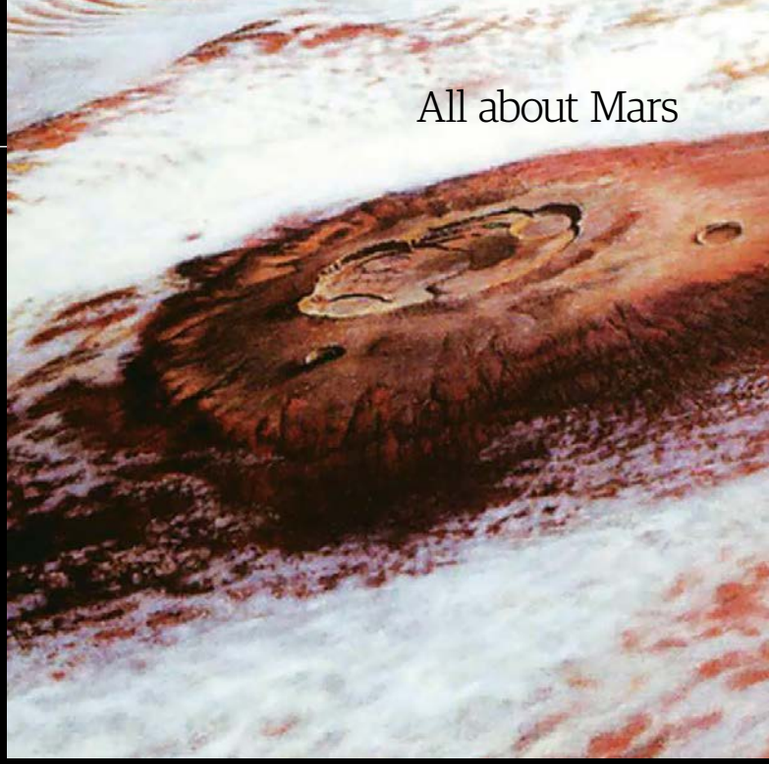
Some of the most striking features on Mars' surface are its mountains – which are all inactive volcanoes. The western edge of the southern hemisphere contains two different areas – the Tharsis bulge and the Elysium volcanic complex – each of which contain several volcanoes. The Tharsis bulge covers about 25 per cent of the planet's surface and lies seven to ten kilometres (four to six miles) above it. This includes Mons Olympus, a shield volcano that is the largest mountain in the Solar System. Up until a few years ago, scientists were sure that Mars didn't have plate tectonics like Earth. Then we discovered that there are in fact tectonics at work. Not only do features like steep cliffs and the flat walls of canyons show faults at work, but so do the fact that Mars' volcanoes are concentrated in two different areas. The huge valley system known as the Valles Marineris is the deepest in the Solar System and takes up a quarter of the



planet's circumference. It's also a plate boundary, with horizontal movement along the plates. With just one known fault as opposed to many on Earth, some believe that Mars' tectonic system is much younger.

Impact craters and basins are prevalent in Mars' southern hemisphere. The Hellas basin is the largest of these at 1,800 kilometres (1,100 miles) in diameter. The largest basins are believed to date back to a period of heavy bombardment about 3.8 billion years ago. They show evidence of erosion and also contain a lot of regolith, or soil deposits. The smaller craters are younger, and look a lot like the Moon's impact craters.

Mars has many different types of craters thanks to erosion, deposits and volcanic activity. They also contain ejecta blankets – flows formed in the soil after an impact melts ice under the planet's surface. Mars is believed to have ice underneath its surface – and there are also ice caps at the poles, the amount of which changes depending on the seasons. Because Mars has a similar tilt to the Earth, it does have four seasons – they're just longer and of varied lengths. Temperatures can get as low as minus 143 degrees Celsius (minus 225 degrees Fahrenheit) at the ice caps in the winter. The ice beneath the surface freezes and melts depending on the temperature. The atmospheric pressure on Mars is much lower than the Earth's, and it's so thin that there is very little to block the surface from the Sun's heat. There are ice clouds, probably caused when the wind kicks up dust, while one of the Red Planet's biggest weather features is dust storms, which can last up to a month.



Despite its thin atmosphere, Mars does have a layer of ice-water clouds, although the blanket lies below the planet's tallest volcano, Olympus Mons. A wave cloud due to ripples in the atmosphere is also visible

North pole
Mars' north pole contains about a third of the ice found in the Earth's Greenland ice sheet.

Viking 2 landing site
NASA's Viking 2 landed here on 3 September 1976 and operated until 11 April 1980.

Hellas Planitia
The largest visible impact crater in the Solar System is around 2,300km (1,400 miles) in diameter and 7.2km (4.4 miles) deep.

Spirit rover landing site
NASA's Spirit rover landed on 4 January 2004 and became stuck in soft soil on 1 May 2009. Communication was lost in 2010 and NASA officially ended the mission in 2011.

South pole
The south pole contains enough ice to cover the surface of the planet in a liquid layer up to 11m (36ft) deep.

Olympus Mons

Polar ice caps

Canyons, craters and deserts

Mars is home to some of the largest planetary features in the Solar System

Olympus Mons
Olympus Mons is the tallest known mountain in the Solar System at 22km (14 miles) high. It's more than twice the size of Mount Everest and is an extinct volcano.

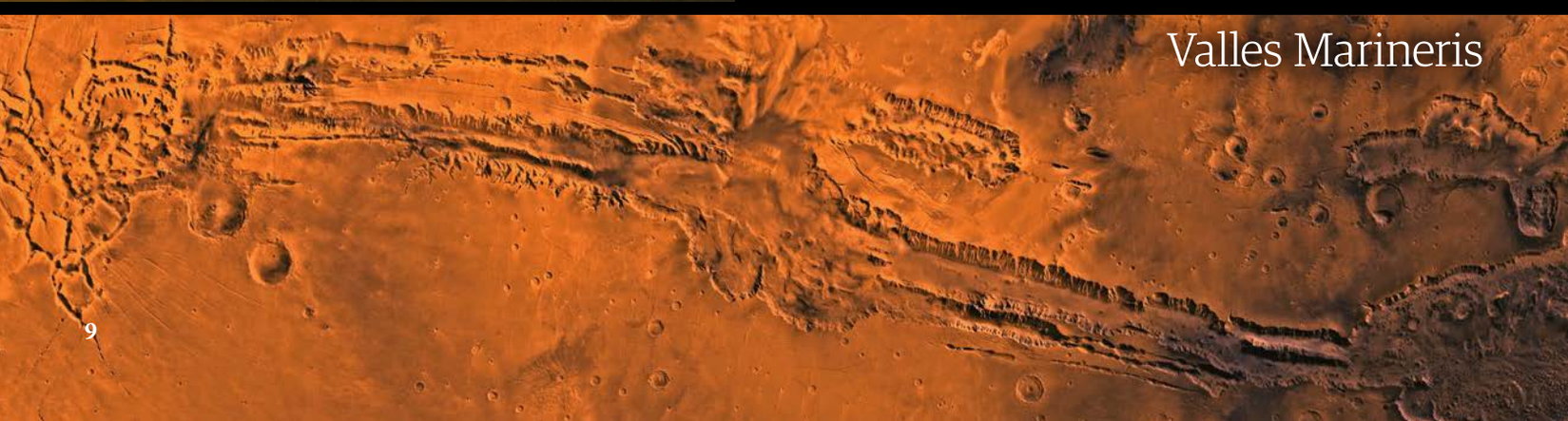
Polar ice caps
This polar ice cap on the southern end of Mars grows and wanes each year depending on the season. It is made up of both water ice and dry ice (frozen carbon dioxide).

Valles Marineris
Valles Marineris is a system of canyons located along the equator of Mars and covers almost 25 per cent of the planet's circumference. It is around 7km (four miles) deep, 200km (124 miles) wide and 4,000km (2,500 miles) long. On Earth, that would be the distance between New York and Los Angeles.

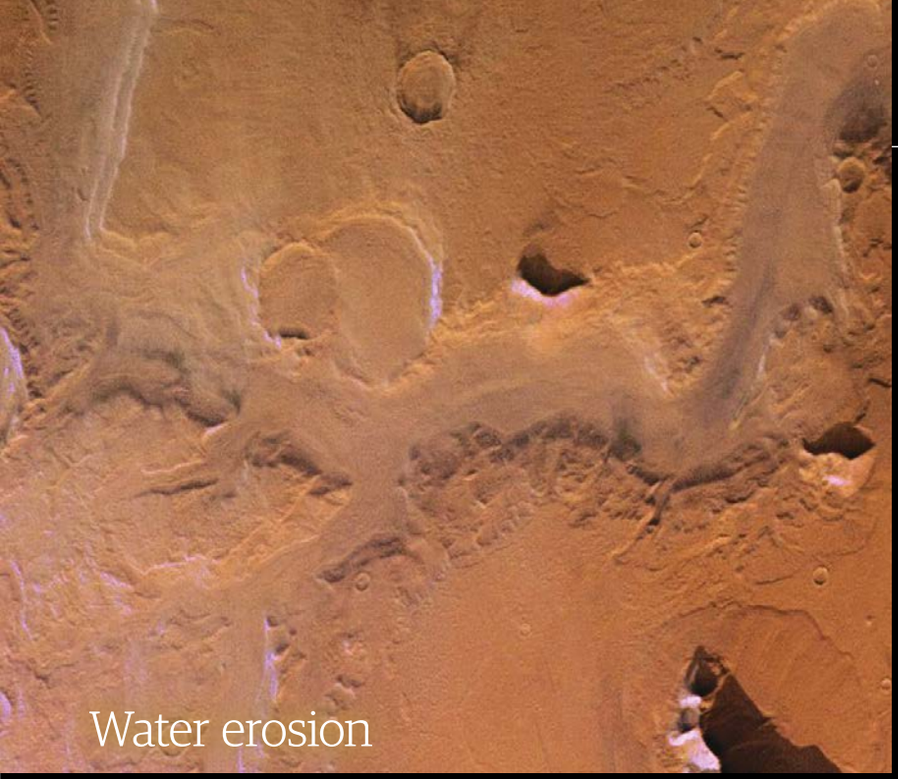
Water erosion
Reull Vallis is one of the valleys on Mars that look as if they may have been carved out by water movement. Many of these valleys contain grooves on their floors that may be rich in ice.

Sand dunes
Regolith - a mix of soil, sand, dust and broken rocks - has drifted into dunes on Mars' surface. We once thought they were stationary, but observations have shown that the dunes actually move due to prevailing winds.

Hellas Basin
The Hellas Basin is one of the biggest impact craters in the Solar System. At 2,300km (1,400 miles) in diameter, it is wider than the state of Texas.

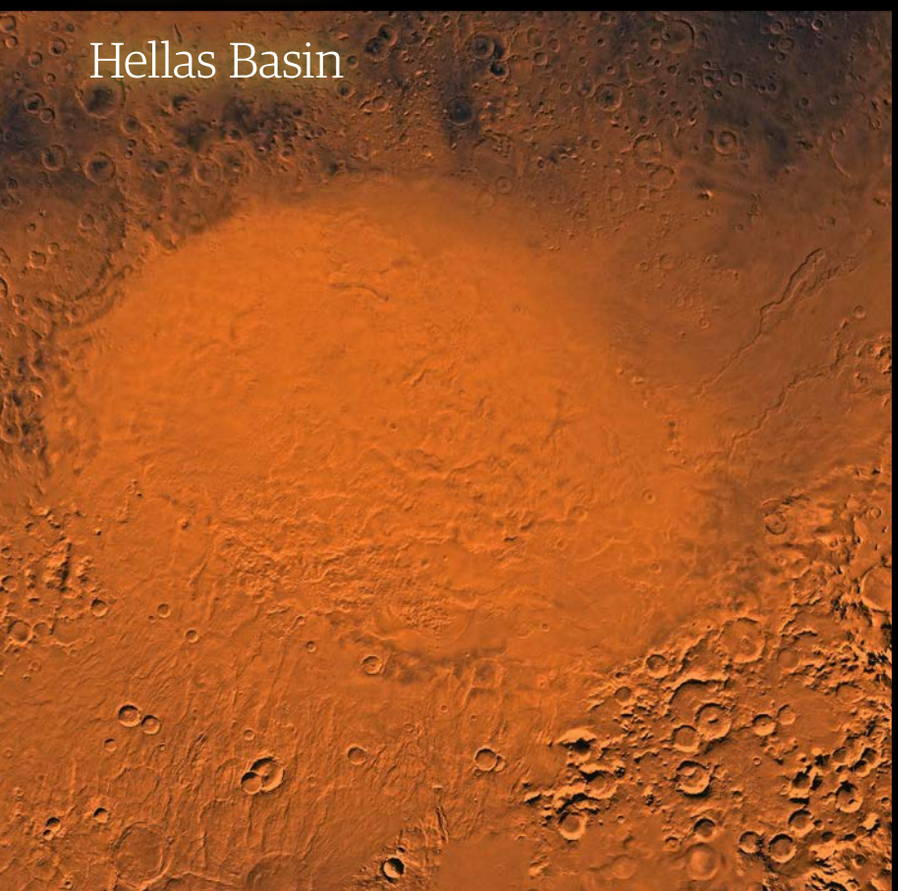


Valles Marineris



Water erosion

Sand dunes



Hellas Basin

Mars by numbers

Fantastic figures and surprising statistics about the Red Planet

2,300km

The diameter of Mars' Hellas Basin is the same as the diameter of Pluto

2

Mars has two known satellites: the moons of Phobos and Deimos

271 years and 221 days

How long it would take you to get to Mars from Earth if you could drive there in a car at 97km/h (60mph)

14.5

Travelling at a speed of 14.5 miles per second compared to the Earth's 18.5 miles per second, Mars is slower to orbit the Sun

687 Earth days

A year on Mars is 687 Earth days, while a day on Mars is equivalent to 1.026 Earth days

37.5%

Gravity on Mars as a percentage of Earth's. If you could visit, you could jump three times as high as you can on our planet

Exploring Mars

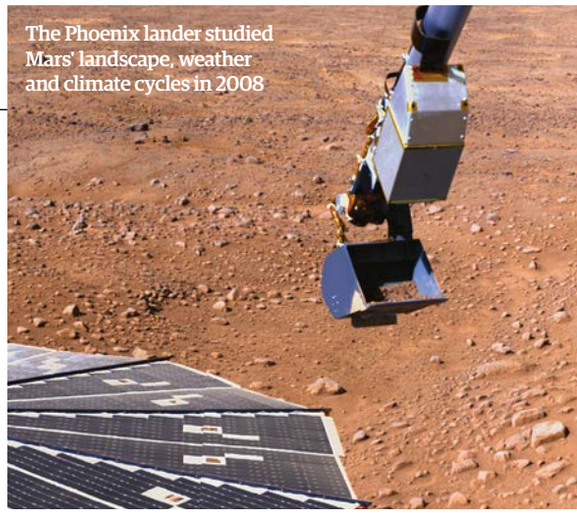
The failure rate in shooting for Mars is high

The Soviet Union, not the United States, was the first country to attempt a Mars exploration – but it was unsuccessful. The Mars 1M was just the first of many failed attempts to visit Mars. Since that first attempt in 1960, 43 different spacecraft have tried and only 14 of them completed their missions. Mars 1M had a launch failure, but other probes have been the victims of communication problems, computer malfunctions and even the planet itself. It's been so difficult to get to Mars that some have dubbed the challenge the "Martian curse", and one journalist in the United States jokingly said that there must be a "Galactic Ghoul" hindering our exploration efforts. So why has it proved so difficult to get there? It takes a spacecraft about seven months on average to travel the 225 million kilometres (140 million miles) to Mars. Once it reaches the planet, if the orbiter has a lander then it must successfully separate and have the lander touch down gracefully on the surface. And Mars can be unpredictable. Things like dust storms and soft soil have impeded landers, for example. But we do have to remember that most of total failures were early in our space exploration history. While there have been some memorable recent failures, including the 1999 Mars Climate Orbiter, which was pure human error. In that case, a contractor used imperial units instead of metric, which caused the probe's rocket to shut down early and send it crashing into the planet.

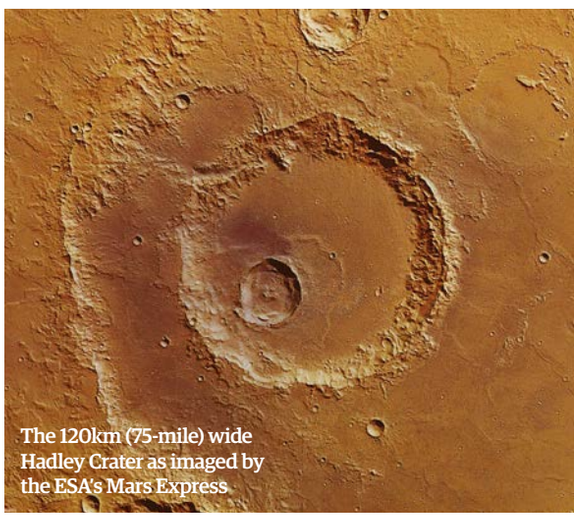
Currently there are three orbiters around Mars: the Mars Odyssey and Mars Reconnaissance Orbiter, both from NASA, and the European Space Agency's Mars Express. Sadly after 14 years on the surface, the Opportunity rover was announced inactive when it became swept up in a dust storm in June 2018 but, with Curiosity studying the terrain, humaniity continues to explore the red

MSL launches atop a Atlas V rocket on 26 November 2011

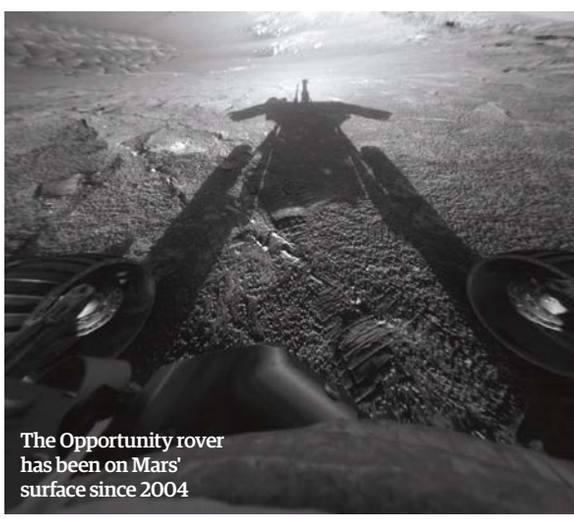
> "It takes a spacecraft about seven months to travel the 225 million kilometres to Mars"



The Phoenix lander studied Mars' landscape, weather and climate cycles in 2008

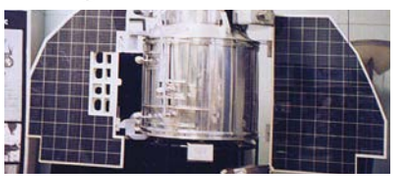


The 120km (75-mile) wide Hadley Crater as imaged by the ESA's Mars Express



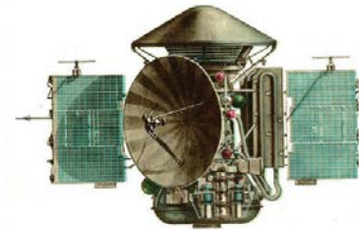
The Opportunity rover has been on Mars' surface since 2004

Major missions



Mars 1M
Oct 1960
These Soviet missions were the first in the quest to explore Mars. Mars 1M No 1 experienced a launch failure on 10 October 1960. Mars 1M No 2 met the same fate.

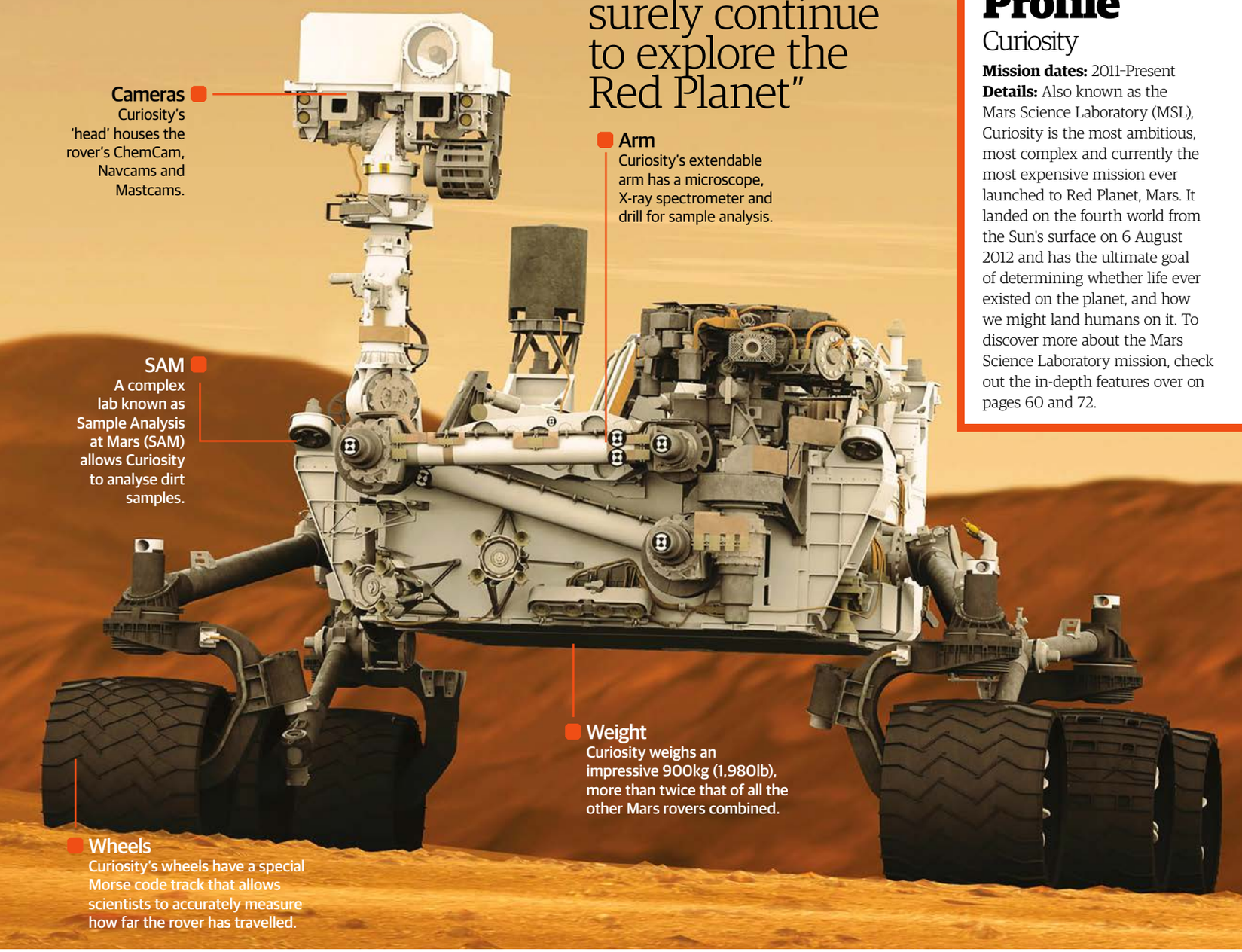
Mariner 4
28 Nov 1964-21 Dec 1967
Mariner 4 performed the first flyby and returned the first colour images of Mars. These were also the first images taken of another planet from deep space.



Mars 2 & 3
19 May 1971-22 Aug 1972
The Soviet-built Mars 2 became the first spacecraft to land – or rather crash – into the surface of the planet. Mars 3 had a soft landing on 2 December 1971.

Viking 1 & 2
20 Aug 1975-13 Nov 1982
Viking 1 landed softly and fully completed its mission. It also held the record for longest Mars mission until the Opportunity rover.

"Despite the high failure rate, we'll surely continue to explore the Red Planet"



Cameras
Curiosity's 'head' houses the rover's ChemCam, Navcams and Mastcams.

Arm
Curiosity's extendable arm has a microscope, X-ray spectrometer and drill for sample analysis.

SAM
A complex lab known as Sample Analysis at Mars (SAM) allows Curiosity to analyse dirt samples.

Weight
Curiosity weighs an impressive 900kg (1,980lb), more than twice that of all the other Mars rovers combined.

Wheels
Curiosity's wheels have a special Morse code track that allows scientists to accurately measure how far the rover has travelled.

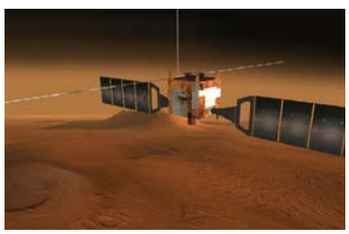
Mission Profile

Curiosity

Mission dates: 2011-Present
Details: Also known as the Mars Science Laboratory (MSL), Curiosity is the most ambitious, most complex and currently the most expensive mission ever launched to Red Planet, Mars. It landed on the fourth world from the Sun's surface on 6 August 2012 and has the ultimate goal of determining whether life ever existed on the planet, and how we might land humans on it. To discover more about the Mars Science Laboratory mission, check out the in-depth features over on pages 60 and 72.

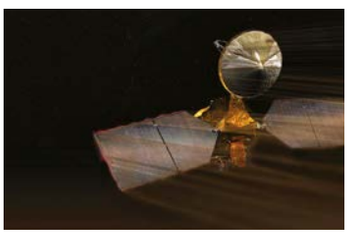
Mars Polar Lander
3 Jan 1999-3 Dec 1999

The Mars Polar Lander was meant to perform soil and climatology studies on Mars, but NASA lost communication with it and it's believed it crashed.



Mars Express Orbiter
2 Jun 2003-present

The ESA's first planetary mission consisted of the Beagle 2 lander and the Mars Express Orbiter, with the latter still operational today.



Beagle 2
2 Jun 2003-19 Dec 2003

The Beagle 2 lander was lost six days before it was due to enter the Martian atmosphere. Attempts were made to contact it, but these ended in failure.

Opportunity
7 Jul 2003-10 Jun 2018

Opportunity was a rover launched shortly after its twin, Spirit, by NASA. It was still going strong up until 2018, when a dust storm silenced it.