DESTINATION SPACE!

ExoMars

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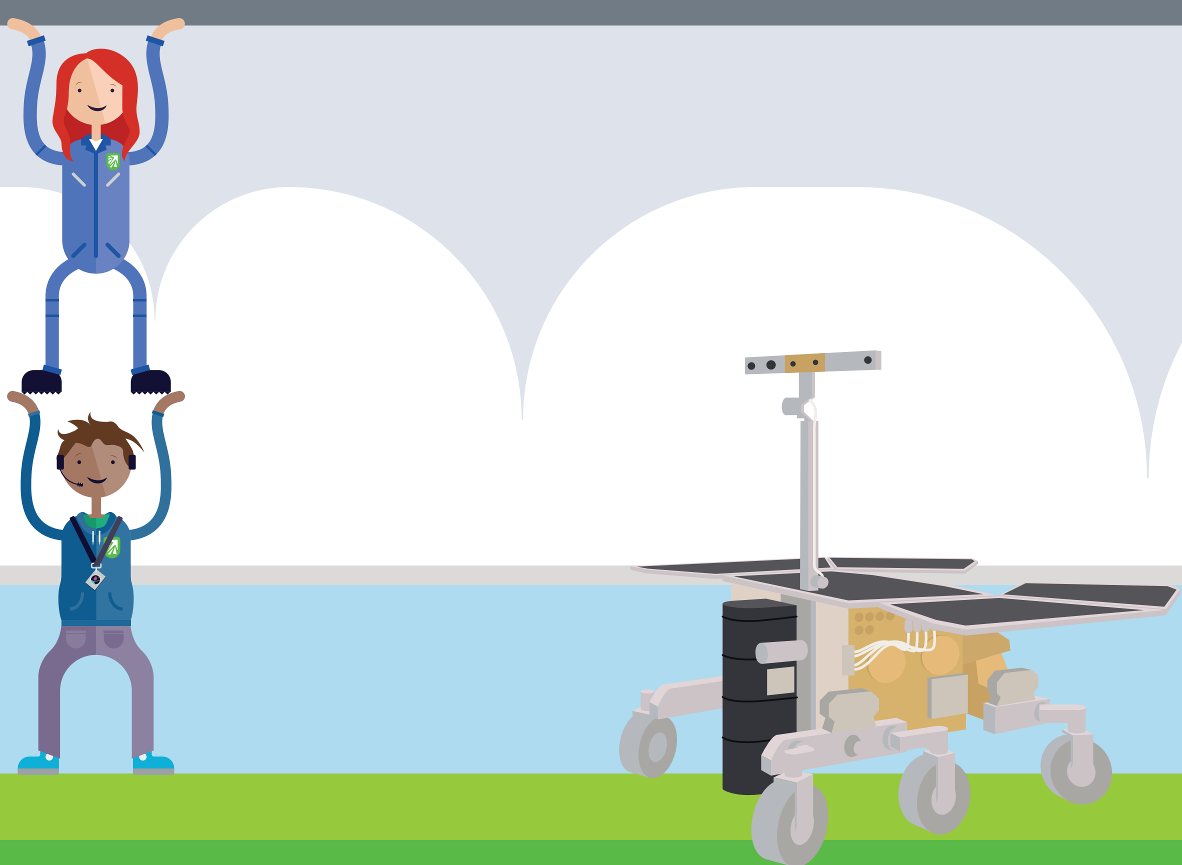

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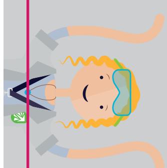
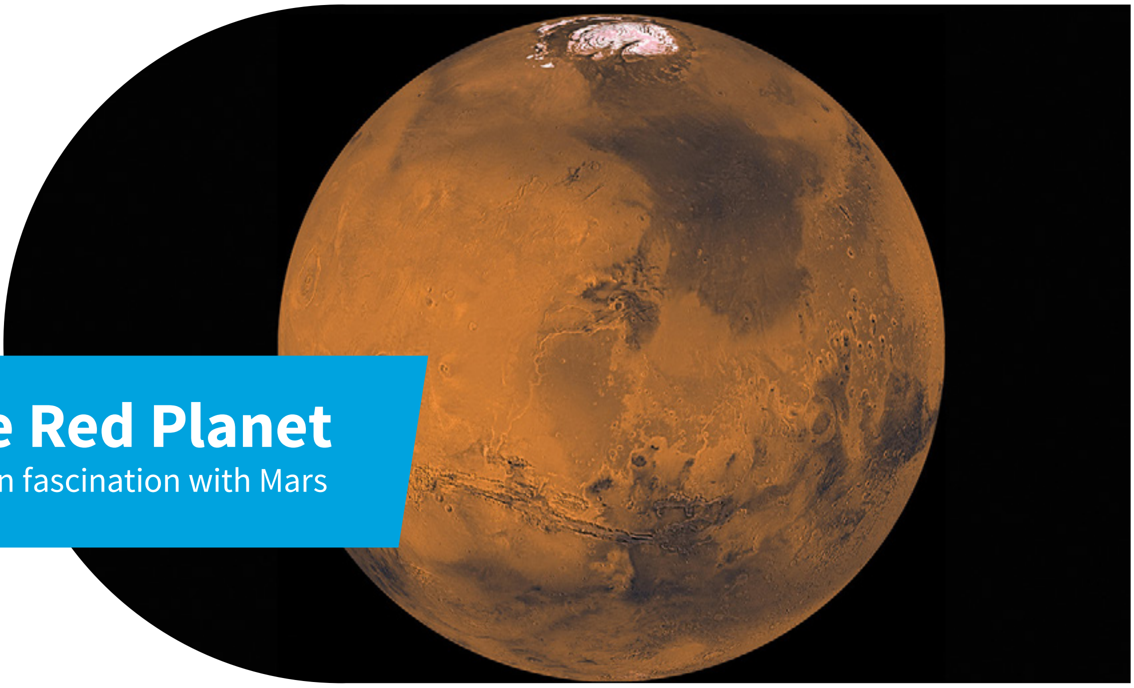




The Red Planet

Human fascination with Mars

Within our solar system, Mars is the planet we have sent the most explorative missions to in the hope of finding signs of life or conditions that would support human colonisation.

Where is Mars?

Mars is the fourth planet from the Sun. Our distance from Mars depends on our relative positions in orbit around the Sun. This distance ranges from 55 million kilometres away (when we are closest to Mars) to 400 million kilometres away (when we are on the opposite side of the Sun). The best time to launch a spacecraft to Mars is therefore when the two planets are near to their closest approach, which happens every 26 months.

What is it like on Mars?

The Earth goes around the Sun every 365.25 days, whereas Mars takes 687 Earth days to orbit. So one Martian year lasts two Earth years. Mars spins slightly slower than Earth, so a complete rotation of day and night lasts 24 hours and 40 minutes. This is called a 'sol'.

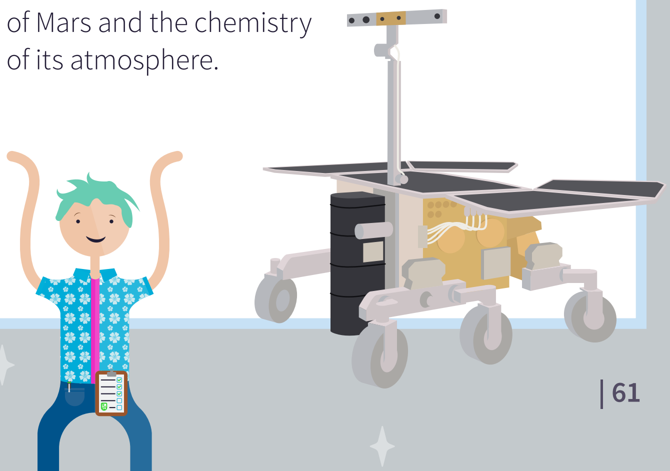
Mars is just over half the diameter of Earth, with 38% of our surface gravity. This means that you would feel much lighter on Mars.

The blood red colour of the surface of Mars, as seen from Earth, is due to rust on its' surface and is the reason that the planet is named after the Roman God of War. The two small moons of Mars are named after this god's twin sons, Phobos (fear) and Deimos (dread). There is more information about the surface of Mars and hands-on activities are included throughout this section.

The Martian atmosphere

The Martian atmosphere is about 100 times thinner than Earth's and is over 95% carbon dioxide. Mars is known for dust devils half a mile high and huge dust storms can circle the entire planet.

Between 3.8 and 4.1 billion years ago, the atmosphere of Mars was thicker, and warmer temperatures could have supported the existence of a liquid water ocean covering nearly a third of the surface. This denser atmosphere has mostly been lost to space. The mysteries surrounding the atmosphere and ancient Martian ocean may be unravelled by the James Webb Space Telescope in the future (see the previous section), with focussed detailed observation of Mars and the chemistry of its atmosphere.



Smells of Mars

What can the smells of Mars explain about the planet's past?

Can you imagine what it would smell like if you could breathe Martian air?

Mars today

Today, Mars is a cold dry world covered in a layer of very fine dust. Beneath this dust there are rocks and minerals that also exist on Earth, and which include basalt, clays and sulphate minerals. Like the Earth, Mars also has a north and a south pole, with frozen polar caps composed of water and carbon dioxide ice, and frozen water trapped below the surface, just like the coldest places on Earth do (though on Earth they are made of water ice only).

A smelly history

The geological history of Mars is generally divided into three main periods very different from each other: the Noachian, Hesperian and Amazonian. Each of these is characterised by certain conditions and chemistry and they all contribute to Mars' current composition.

The Noachian period

The Noachian lasted until 3.7 billion years ago and saw Mars continuously bombarded by asteroids and comets. The first few hundred million years of this period are also known as the Pre-Noachian, but there is no geological evidence left from this period.

During this period, Mars was a geologically active planet with a thick atmosphere that made the surface warmer than it is today, and a global magnetic field that protected it from radiation. As well as numerous volcanic eruptions which emitted gasses with the smell of rotten eggs, Mars also had rivers of water on its surface, perhaps large lakes and even an ocean!

Water combined with rocks on the surface and formed clay minerals, which would have smelled like dusty wet earth. It was during this time that microscopic life may have had a chance to emerge on the red planet, and if it did, we might have experienced a smell similar to that of dry dusty earth when it rains after a very long time, as this smell is produced by the microscopic bacteria that live in the soil.

Bottom image: Noachian Mars would have been home to numerous volcanic eruptions. Credit: Cambridge University

The Hesperian period

During the Hesperian, from 3.7 to approximately 3 billion years ago, Mars changed from being a potentially habitable planet to a frozen, arid one, where no life could survive.

Asteroid and comet impacts decreased but, as Mars began to lose its atmosphere and global magnetic field, it became colder and drier. Water froze or became trapped below the surface. During large volcanic eruptions, or when an asteroid or comet hit these areas of underground frozen water, catastrophic floods unleashed vast amounts of water back onto the surface. The chemistry of Mars changed when the large quantities of sulphur dioxide emitted by huge volcanoes combined with water to form sulphuric acid. Water became acidic and salty, and combined with rocks to form sulphate minerals which are very different from the clays that formed during the Noachian. The smell of Mars would have been less wet and earthy, but the sulphurous smell of rotten eggs would have continued to permeate the air. Did you know that sulphur is also found in vegetables like broccoli and cabbage? Perhaps the Martian air also smelled like these vegetables!

The Amazonian period

The Amazonian is the longest geological period of Mars and extends from the end of the Hesperian until the present.

Mars became a dry, cold desert, constantly bombarded by radiation. Fluvial activity decreased dramatically, although ground water may still have been released during volcanic eruptions. The freezing temperatures and lack of atmospheric pressure meant that any water exposed to the surface vaporised instantly, so Mars no longer had liquid water. Iron-rich rocks on the surface oxidised and produced iron oxide which, along with sulphur and chlorine,form part of the red dust that covers the whole planet. It is this dust that gives Mars its red-orange colour. Mars appears to have been volcanically active until 10 million years ago and it might still be today, but without water, the Martian air would have become very dry and dusty, and carry with it the smell of rotten eggs, sulphur, chlorine and dry rust.

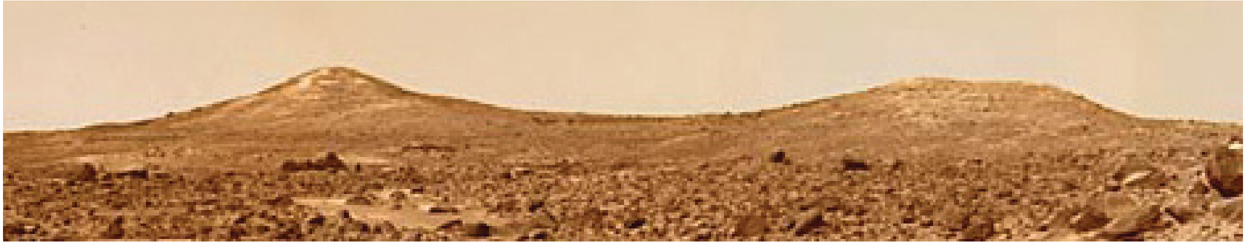
How to run this demonstration

To run the activity using the smells of Mars, you will need the metal smell tub and a well-ventilated area. Some of the smells in this activity are very strong and may be overwhelming for some participants.

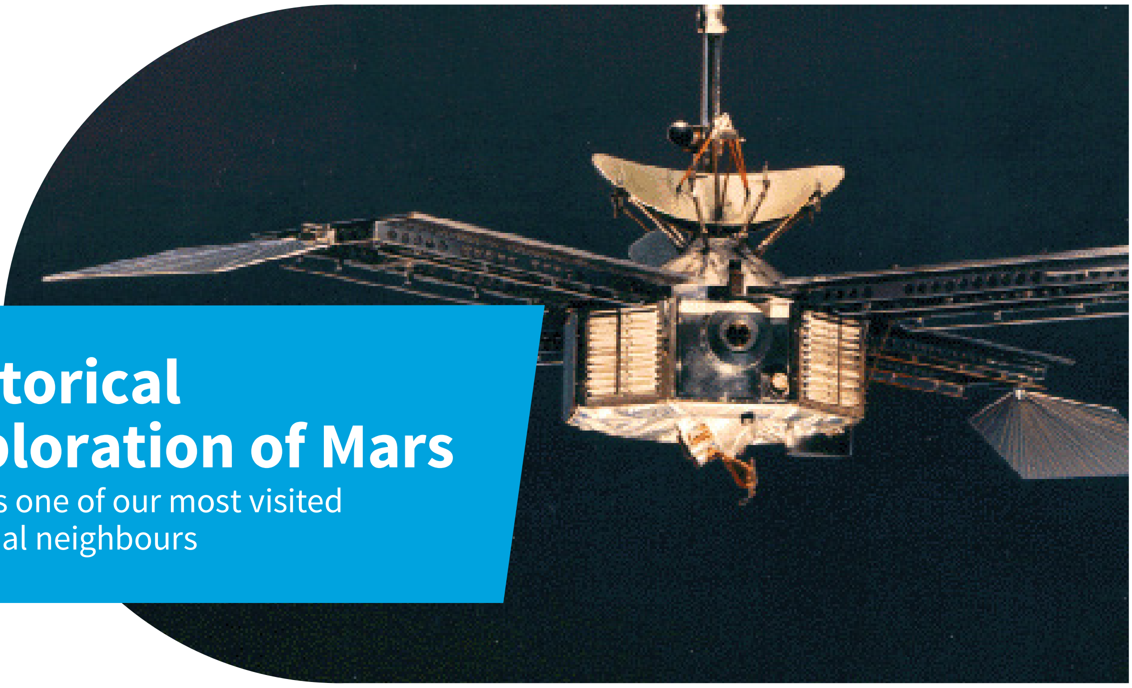
Invite the audience to smell from the aroma pot and pass it around if they wish. Encourage discussion around the different things they can smell and use these comments to discuss the chemical composition of Mars.

If relevant, refer to the different periods on Mars and how they would have all smelled pretty disctinctive. We are basically smelling back through the history of Mars in this activity.

The cotton wool in the smell containers will need to be refreshed with a drop or two of oil every couple of days (sooner with high usage) and the cotton wool inside should be changed regularly to avoid the growth of mould spores.



Bottom image: Stereo image of Mars' surface. Credit: NASA JPL



Historical exploration of Mars

Mars is one of our most visited celestial neighbours

Getting to and landing on Mars is tricky. In fact, about half of all Mars missions have failed.

Early attempts

The USA and Russia began their Mars exploration campaigns in the 1960's. Early missions were able to gather images and data after performing flybys, but with the space race and lunar landings still very fresh in people's memories both countries were eager to orbit Mars first. In 1971, both countries were able to get craft in orbit within a month of each other. The US Mariner 9 was the first, followed by the Soviet Mars 2 and 3.

These early orbiters completely changed our understanding of Mars. We were able to spend time surveying the planet for the first time. Using the thousands of images taken, we discovered many of Mars' surface features like Olympus Mons and Valles Marineris.

Touching down on the surface

The Soviet Mars 3 made even more progress by successfully landing on Mars' surface. However the transmission only lasted 14 seconds. It was the US Viking landers that gave us the first substantial in-situ analysis of Mars' surface. Both touching down in 1976, they gave us our first insights into Mars' weather and magnetic field and even conducted the first chemical analysis of Martian soil.

Roaming the red planet

Landers were an invaluable tool for planetary science, but to take exploration to the next stage in the 90's we began launching rovers to the surface of Mars to get a much broader understanding of the surface globally. In 1997, US rover Sojourner became the first human made object to drive on Mars, and since then the US has had phenomenal success with Spirit, Opportunity and Curiosity. 2020 onwards will see a new international era of Mars robotic exploration with ExoMars and a Chinese Space Agency rover planned. Once we have learnt all we can from these rovers, perhaps it will be time to send humans to Mars!

Top image: Mariner 4. Credit: NASA. Bottom image: NASA's Rover family, Soujourner, Opportunity and Curiousity. Credit: NASA

Mars globe

This 3D globe of Mars can be used to start conversations around the surface features of Mars, and links neatly into the following activity, which is a closer 3D view of Mars' surface.

Mars statistics

- Diameter: 6,779km
- Circumference: 21,344km
- Highest point: Olympus Mons, 21,229 m above datum (equivalent to sea level on Earth)
- Lowest point: Hellas Crater, 8,200 m below datum
- Mars sol (day) length: 24 hours 40 minutes
- Gravity: 38% of Earth's gravity

3D surface of Mars

A 3D relief model of the surface of Mars

This activity showcases interesting sites on Mars. A full 3D model of the complete surface of the red planet is used as a focus for conversation.

Martian soil

Technically, we call the material on the surface of Mars a regolith – a layer of loose, dust-like material that is spread around the planet by regular dust storms. Unlike Earth soil, which contains a lot of organic matter, Martian regolith is composed (as far as we know so far) almost completely of mineral materials.

These include rust: oxidised iron material (giving Mars its famous orange-red colour), formed when Mars was wetter and warmer. The regolith also contains silicates, small glassy fragments called olivine, clays and perchlorates (molecules containing chlorine) which make it toxic to life as we know it.

The regolith lies upon a bedrock of basalt – a volcanic rock deposited back when Martian volcanoes such as *Olympus Mons* were still active. What lies beneath this is still up for discussion: the Curiosity rover found evidence of granite-like rock, possibly ejected by a huge meteorite impact, but recent computer simulations suggest it is more likely to be crystalised magma.

What does the 3D surface show?

The 3D Mars terrain is a relief of the planet Mars. It is a cylindrical map projection, which means that the surface is unwrapped from a sphere and laid out onto a flat surface by stretching the top and bottom. That is why the craters near the top and bottom of the model are elliptical.

The model is made to a lateral scale of 21.3km per mm, so one milimetre on the model is about the size of central London. The vertical scale on the model has been exaggerated by a factor of 20 to make the height of things easier to see, otherwise the difference between the highest and lowest points would only be 1.3mm.

The model is created using data from NASA's Mars Orbital Laser Altimeter (MOLA), which used a laser rangefinder to measure the height of the Martian surface from the Mars Global Surveyor satellite between 1997 and 2001. An image of the MOLA data set is shown on the following page. The dataset from MOLA was imported into Computer Aided Design (CAD) software and used to machine the surface model from polyurethane foam using a Computer Numerical Control (CNC) router.

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How to run the activity

Point out and discuss various points of interest on the Mars floor. You might want to include:

Olympus Mons

Olympus Mons is a shield volcano (built almost entirely of fluid lava flows) and is the biggest volcano in our solar system. The top of *Olympus Mons* is the highest point on Mars. At nearly 22km high, it is roughly two and a half times as high as Mount Everest. The base of *Olympus Mons* is approximately 600 km across, about the width of France. *Olympus Mons* was formed approximately three billion years ago.

Valles Marineris

Valles Marineris is a system of canyons which stretch almost a fifth of the way around Mars near the equator. *Valles Marineris* is more than 4,000km long, 200km wide and 7km deep. This means than it is more than ten times as long and wide as the Grand Canyon and around four times as deep.

Gale Crater

Gale Crater is a relatively small crater, around 150 km diameter, near the equator of Mars. Gale Crater was the landing site of the NASA Mars Science Laboratory Curiosity rover. Curiosity has been exploring Gale Crater for more than four years now. It has covered more than 18 km in that time, driving from its landing site near the bottom of the crater up the side of *Aeolis Mons* (Mount Sharp) in the centre.

ExoMars landing sites

The landing site for the Rosalind Franklin Rover has been chosen as *Oxia Planum.* Teams of scientists narrowed the many options down to two contenders and *Mawrth Vallis* will be the backup landing site should the first choice prove difficult.

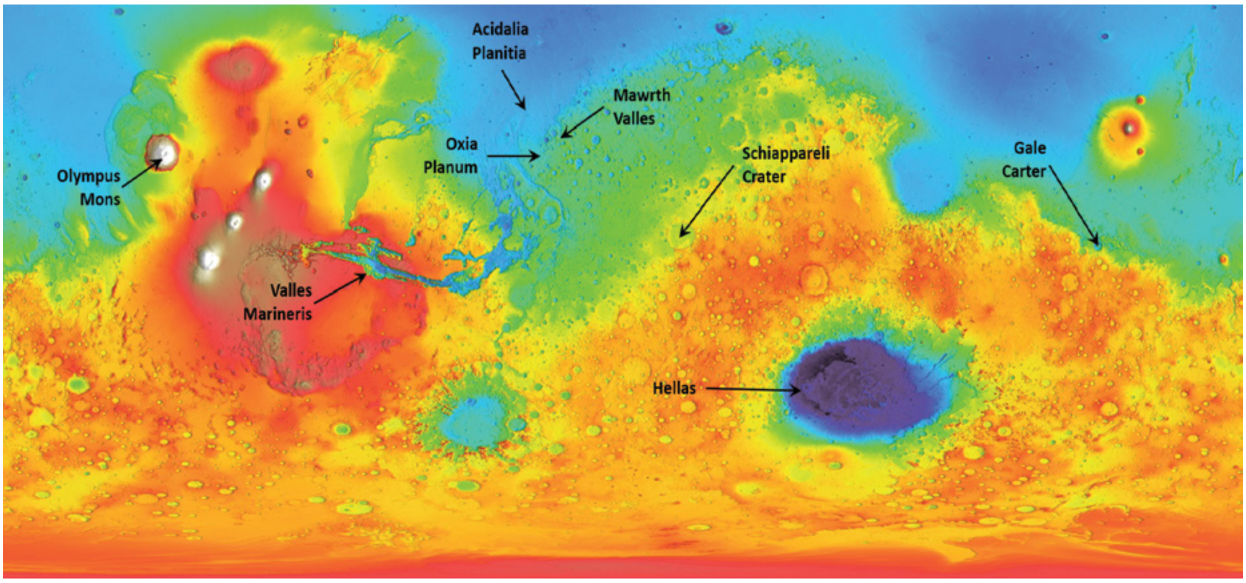
Oxia Planum contains a large area of exposed clay minerals which are nearly four billion years old. *Mawrth Vallis* is one of the oldest valleys on Mars. It contains a number of clay minerals, meaning it was wet in the past, and has lots of well-exposed sedimentary features.

Hellas

Hellas is an impact crater in the southern hemisphere of Mars. It is the largest visible impact crater known in the solar system and is more than 2,300km in diameter and 7km deep. The lowest point on the surface of Mars lies at the very bottom of *Hellas*.

The Martian

In the book and film of 'The Martian', astronaut Mark Watney is stranded on Mars when the rest of the crew are forced to evacuate. Mark spends most of his remaining time on Mars in the 'Habitat' ('the Hab') in *Acidalia Planitia*, eating potatoes and trying to survive the harsh Martian environment. Mark drives 3,200km in his electric-powered Mars Rover to Schiapparelli Crater, where he is able to escape the planet on a waiting rocket.



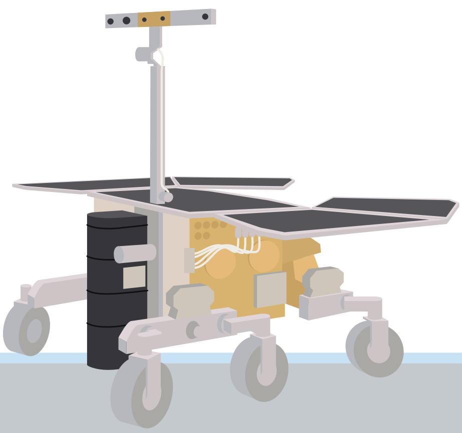
The ExoMars mission

The ExoMars programme is a collaboration between the European Space Agency and Roscosmos (the Russian space agency), to send a lander to the surface of Mars and explore beneath the surface for the first time.

Mission overview

The ExoMars mission will launch in 2020. ESA and Roscosmos teams hope to investigate the feasibility of life on Mars' surface, alongside a study of the geological and chemical environment.

The first stage of the mission was a satellite launched in 2016 called the Trace Gas Orbiter (the accompanying static Schiaparelli lander crashed). This craft will act as the communications relay for the rover, and has been analysing gases in Mars' thin atmosphere, discovering that methane appears and disappears quickly on Mars. This is interesting, as methane is a potential indicator of life (though some people suspect the gas may have come from the Curiosity rover itself).



Trace Gas Orbiter (TGO)

The Trace Gas Orbiter gathers data using four main instruments:

1 CaSSIS

The Colour and Stereo Surface Imaging Suite (CaSSIS) contains a high-resolution stereo camera (capable of resolving details of around 4.5m in size) that will be used to build up an accurate elevation model of the surface of Mars to image potential trace gas sources.

2 FREND

The Fine Resolution Epithermal Neutron Detector is a neutron detector designed to map subsurface hydrogen down to a depth of 1m. It will be able to measure the abundance of water ice and hydrated minerals, which may be useful for determining future landing sites.

3 ACS and NOMAD

The final two instruments, the Atmospheric Chemistry Suite (ACS) and Nadir and Occulation for Mars Discovery (NOMAD) contain three spectrometers designed to work together, covering a wide range of wavelengths. The spectrometers will be used to measure the composition of the Martian atmosphere, its trace gases, and to monitor its temperature determining seasonal variation.

Image: From left to right, the Trace Gas Orbiter, Schiapparelli lander and ExoMars Rover. Credit: ESA

LEGO Mars Rover

Programming your own mini-rover

This hands-on activity offers opportunities to discuss past and future Mars rover missions, including ExoMars and it's a great introduction to programming!

Operating on Mars

For current Mars rovers (including the Franklin Rover), it takes 20 minutes for a signal to reach Earth and another 20 minutes for a signal to travel back, so these rovers must be able to travel autonomously most of the time.

The test rovers and final model were all built and tested by Airbus Defence and Space at their Stevenage facility. They have also designed an innovative new navigation system for the rover.

The rover will use a sophisticated suite of cameras to analyse and map the environment around it, constructing a 3D map and generating a route itself – avoiding boulders, cliff edges, and sand dunes.

The miniature rover is built from LEGO but replicates a full-size rover in many ways. Like real Mars rovers, they have multiple parts - a power source, motors, and scientific payload - which operate together, controlled by a central computer. Programming the LEGO Mars Rover gives visitors an idea of what it is like to see rovers traverse a planet, gathering data.

Activities using the LEGO Mars Rover

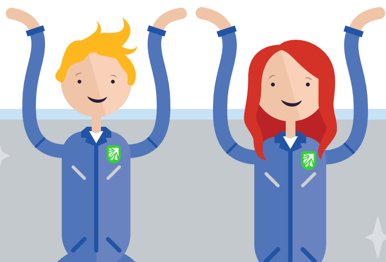
1 Drop-in driving session

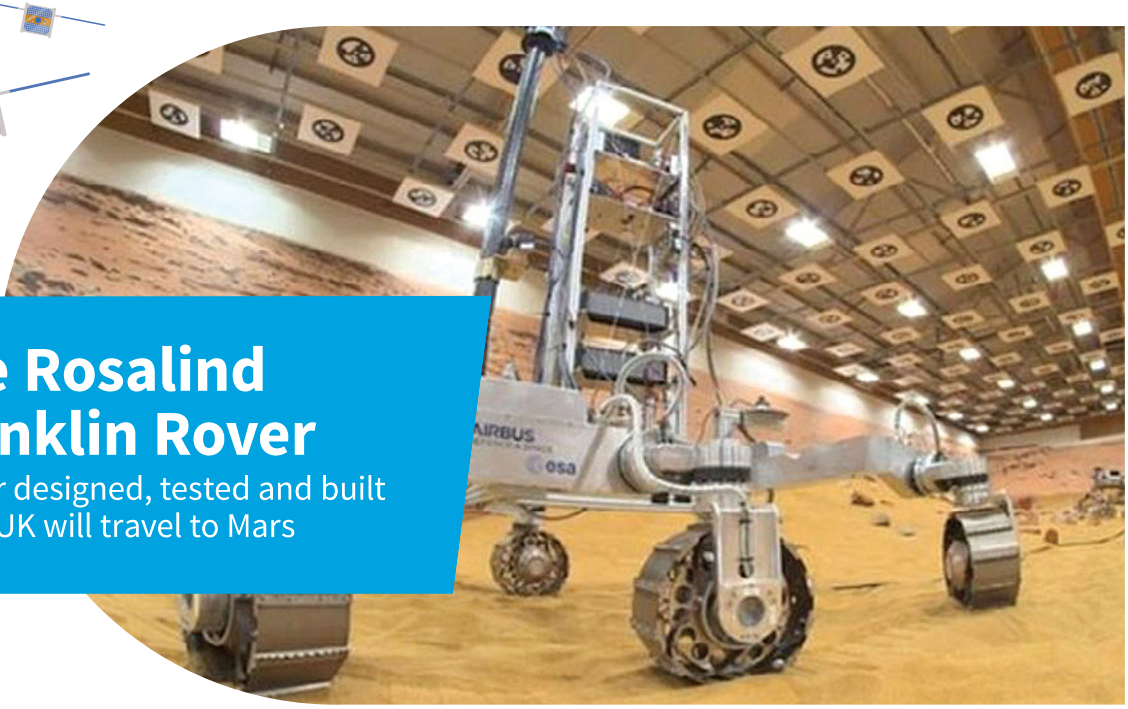
Using the rovers in this configuration requires the remote control. Plugging the controller in and running the included program allows the rover to be driven like a remote-control car. While this isn't how real rovers are controlled, it can highlight some of the difficulties. Ask visitors why you couldn't do this with a real Mars rover – the time it takes for the command to travel from Earth to Mars can be up to 24 minutes! This activity can also be done with a Bluetooth tablet.

Set up an area with obstacles or tasks to complete on the Mars mat. Invite visitors to come and have a go at driving the rover or turn it into a competition with points or a time trial-style leader board.

2 Programming rover paths

If more time is available, these rovers can be programmed to run through pre-determined instructions – more representative of current Mars rover operations. The system works by dragging simple instructions into a block interface. By linking multiple blocks together, a chain of instructions can be built. This makes a great activity for small groups working together to complete a simple task such as completing a figure of eight path around two obstacles.





The Rosalind Franklin Rover

A rover designed, tested and built in the UK will travel to Mars

The European Space Agency's six-wheeled Rosalind Franklin Rover is 1.5m long and 1.2m wide (not including its solar panels).

Rosalind Franklin weighs about 300kg and it is fast for a rover, able to reach up to 9mph (4m per second).

Orchestra of instruments

Rosalind Franklin's body is packed with science instruments to allow it to make the most of its active time on the surface. All of these are focussed on the search for the biosignatures of potential alien life.

The science instruments were built and will be operated by institutes and organisations in many different countries, including Switzerland, France, Norway, Germany, Italy, Russia and the UK.

What makes ExoMars special?

ExoMars will be the first rover to drill beneath the surface of Mars (to a depth of up to 2m) to access and analyse material shielded from the extreme levels of ultraviolet and cosmic radiation on the surface. This will give scientists a unique opportunity to look for signs of past or present life on Mars.

Who was Rosalind Franklin?

The ExoMars project will be the first space mission to have its lead space craft named after a woman. The Rosalind Franklin Rover is named after British chemist and X-ray crystallographer, Rosalind Elsie Franklin (1920-1958).

Franklin contributed to unravelling the double helix structure of our DNA, as well making enduring contributions to the understanding of RNA, viruses, coal and graphite.

'This name was chosen to remind us that it is in the human genes to explore. Science is in our DNA and the rover captures this spirit and carries us all to the forefront of space exploration', says ESA Director General, Jan Woerner.

Top image: ExoMars Rove. Credit: ESA.   Bottom image: Rosalind Franklin. Credit: Universal History Archive/Getty Images.

Did you know?

The LEGO rovers from the previous activity are much faster than a real Mars rover. The Rosalind Franklin Rover will have a top speed of just 5cm per second!

Panoramic Camera System (PanCam)

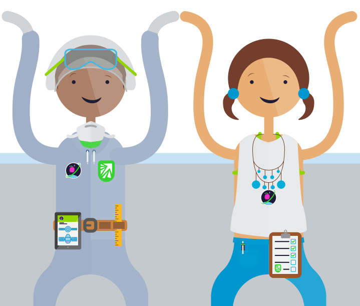
Up above the body of the rover at a height of 1.6m, the PanCam gets a great view of the Martian surface. It can rotate 360° around (perfect for panoramic images), and 180° up/down (so it can check itself out).

Development of the PanCam System was led by Professor Andrew Coates at Mullard Space Science Laboratory in Surrey.

It's called the Panoramic Camera System because it is not just one camera, but three: the two fancy ones that will take the big landscape shots, and a bonus high-resolution colour camera that will see more detail and help the rover navigate.

The main PanCam cameras will create beautiful 360° panoramas, 4000 pixels high and 24,000 pixels around. They detect visible and infra-red light, but will only see in black and white because they use CCD (Charge Coupled Device)detectors. For colour images, they combine multiple images taken using different filters - and of course they can produce stereo images!

PanCam's 11 filters' main task is to help pick out features that indicate the past presence of liquid water, and for the instrument's most exciting job of all: investigating rock textures like layers or pitting which might have been caused by life.



Ground-penetrating radar

The WISDOM (Water Ice and Subsurface Deposit Information on Mars) radar will collect data about water and rock strata 3-10m below the surface. This information will help scientists decide where it is safe and interesting to drill.

ExoMars drill

Drilling to a depth of 2m will allow Franklin to reach sediments deposited during Mars' habitable period, when there were large bodies of liquid water exposed on its surface.

At the time of writing, no mission has ever reached this depth. This is properly exciting science! However, do check out the status of NASA's InSight 'mole': it's currently stuck, but they have hopes of freeing it so it can dig down to its planned 5 m.

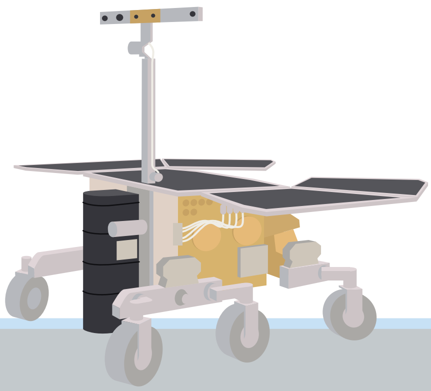
The Rosalind Franklin rover's drill will extract samples 1cm in diameter and 3cm in length, and deliver them to the Rover Payload Module for processing, a manoeuvre that can be tracked using PanCam. The samples can then be parcelled out for analysis by other instruments.

The drill arm also contains a high-resolution camera for close-up imaging of rocks, and a mini-spectrometer for investigating the borehole.

Pasteur Instrument Suite

The Pasteur Instrument Suite contains a number of different science instruments for analysing soil samples brought up by the drill. These include:

1. MicrOmega-IR - a specialist microscope for studying soil samples before their delivery to MOMA and RLS.
2. Mars Organic Molecule Analyser (MOMA) - this detects a broad range of organic molecules and analyses them with an ion trap mass spectrometer.
3. Raman Laser Spectrometer (RLS) - for the identification of minerals and organic compounds.



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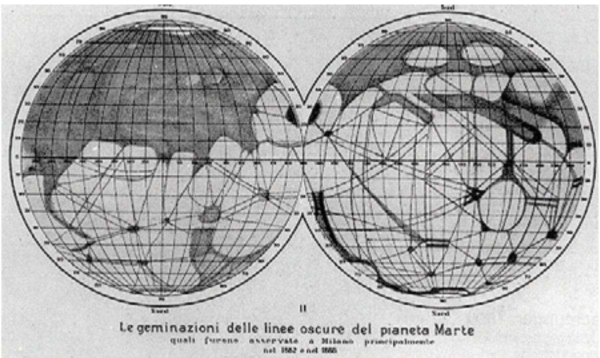
Life on Mars

Life has only ever been found on Earth, but we keep searching for it elsewhere.

Are we alone?

Humanity has always been taken with the idea of life on other worlds. From astronomer Schiaparelli and his mistakenly identified ‘canals’ to HG Wells and War of the Worlds, Mars has long been the prime focus in the search for extra-terrestrial life.



Could life survive on Mars?

The only life we know of is here on Earth. To look for life elsewhere, first we must identify the conditions here in which life can thrive and then look for those conditions elsewhere in the Solar System. At first glance, Mars doesn’t seem to fit the criteria very well. The tiny amount of possible liquid water on Mars’ surface is likely to be extremely salty and exists for only transitory periods. The atmosphere is much thinner than Earth’s and predominantly composed of carbon dioxide with no ozone layer to protect the surface from UV radiation. Additionally, Mars is cold, with an average temperature of around -60 degrees Celsius. At the moment the presence of life seems unlikely, but not impossible.

What have recent missions shown?

Recent missions to Mars have begun to change our opinions on Mars’ habitability.

In 2018 the Mars Express orbiter announced it had detected a large possible liquid water lake beneath the southern polar ice cap. The Curiosity rover has discovered ancient sediment formed 3 billion years ago containing complex carbon compounds that could have served as food for any ancient Martian microbes, and suggests a Martian surface very different to that we see today.

ExoMars’ Trace Gas Orbiter is studying methane levels that rise and fall in the atmosphere.

And as our understanding of extremophiles (organisms that can survive in the most extreme environments on Earth) improves, we can apply new parameters to searching for life on other worlds. Perhaps the first big discovery ExoMars will make will be to find evidence of at least past life on Mars.

Top image: Hoden and Ebers Crater, river delta spotted by Mars Express. Credit: ESA. Bottom image: Schiapiarelli Canal Map. Credit: Wikimedia

Investigating Mars soil

Drilling beneath the surface

The most unique element of the ExoMars mission is its drill. Capable of drilling to a depth of 2m and bringing material up to the surface, it will allow us to peek below the Martian surface.

Going deeper underground

The surface of Mars is an incredibly hostile environment. Its atmosphere is less than 1% as dense as the Earth's, which means that the heat from the Sun escapes back out into space, leaving Mars with a frosty average temperature of -63°C. Without an ozone layer, huge amounts of harmful ultraviolet radiation from the Sun reaches the planet's surface. As Mars has no planetary magnetic field, high energy charged particles called cosmic rays can bombard the surface. Mars is a freezing, arid, radiation-drenched environment, certainly not conducive to life as we know it.

For any evidence of life past or present to survive, it would need to be protected from these 'Martian death rays'.

Explorations underground on Earth have revealed a deep biosphere, a subsurface environment that is teeming with microorganisms. It is possible that below the surface, residing in Mars' extremely porous rocks, and protected from the harsh conditions by the soil and rock above, there might be a habitat just like that.

Evidence of alien life?

As the layers of rock get thicker, they can provide protection from radiation and insulation from the cold. Once these subterranean samples have been collected, they will be passed through the ExoMars rover's suite of experimental equipment. The results from these tests will give us a better understanding of what is happening on Mars. They will likely give us insights into why Mars' surface has changed and will help us to determine whether Mars has ever harboured life.

How to run the activity

In a plastic container, make an analogue for the Mars surface using damp sand. The first layer should be a dark brown sand, followed by a thin layer of black sand, then topped with a red/brown sand.

Visitors use a syringe with the end chopped off to represent their drill. Making sure the plunger is near the bottom, they push the syringe tube into the soil, giving them a 'core' of Martian soil.

They can then study this, looking through the clear walls of the syringe, while you discuss the different layers. If you happen to have a sample of basalt available, you could show this as well.

This activity can be extended by changing the pH of the soil with citric acid and bicarbonate of soda.

Survival in extremes

Can life survive in such harsh conditions

While evidence has been found to support the habitability of Mars, there are still many conditions that would make it incredibly hard for life to survive on its surface. One of these conditions is Mars' average temperature of -63°C. This can have some serious effects on the chances of life flourishing.

Chemical reactions and temperature

Living creatures fundamentally rely on chemical reactions to produce energy and the chemical compounds they need. The rates of most chemical reactions are governed by temperature, often slowing down when colder or speeding up in warmer conditions.

Using glow sticks, we can see this in action. The glowsticks rely on a reaction to produce their light. The faster this reaction occurs, the brighter the sticks will appear.

How to run the demonstration

Get two beakers and fill one with hot water from a kettle and the other with water cooled with ice (or dry ice if available).

Crack some glowsticks to start them glowing.

Split the glow sticks between the two beakers and lower the lights to observe.

What this demonstrations shows

When you crack a glow stick, hydrogen peroxide and phenyl oxalate ester react together, producing light as a by-product. The cracking noise you hear is the breaking of the barrier between these two chemicals, which then allows them to mix.

A faster rate of chemical reaction means more reactions per second and will result in a brighter glow from the glow sticks, whereas a slower reaction will mean a dimmer glow.

In the hot water, the chemicals in the glow sticks are gaining thermal energy from the hot water and so the particles move faster. There are more collisions per second and the collisions have more energy, resulting in more reactions. This is why they glow more brightly.

In the cold water, thermal energy transfers from the glow stick into the water, causing the chemical particles to have less kinetic (moving) energy, so there are fewer reactions per second resulting in a dimmer glow.

Did you know?

Recent studies suggest that the lowest temperature life can survive at on Earth is -20°C, but some specialised organisms like tardigrades can go into a state of hibernation if exposed to extreme conditions and have even survived exposure to the vacuum of space!

Challenges of landing on Mars

Our desire to explore draws us to Mars, but getting there, and in particular touching down on the surface, is incredibly difficult.

The journey to Mars

The first challenge of landing on Mars is getting there. At times, Mars can be a massive 400 million kilometres from the planet Earth. This means that launch windows are limited to their close approaches. This falls roughly every two years. However, even at their closest, any spacecraft would have to cover over 54 million kilometres. To cover this distance takes most spacecraft around nine months, during which time the spacecraft is in deep space and must survive extreme conditions of temperature and radiation.

The descent to Mars' surface

Once your craft has arrived at Mars, it can begin the EDL procedure (Entry, Descent and Landing). Entry of Mars' atmosphere presents some unique difficulties, due to its thin nature. Traditionally, on the Earth, we would use the thick atmosphere to provide a resistive medium to slow a spacecraft to speeds that can then be dealt with using parachutes, which also rely on a thick atmosphere to provide drag.

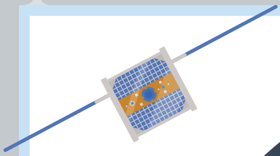
Due to the thinner atmosphere, a Mars-bound spacecraft must pass through a much longer distance to slow down to a safe speed, and parachutes must be much bigger to land spacecraft safely. The larger a rover is, the bigger the parachutes need to be.

With the current crop of Mars rovers, the limits of parachutes have been reached. NASA's most recent rover, Curiosity, and the next rover from Europe and Russia, ExoMars, are so large they require assistance from retro rockets to ensure that the craft is slowed sufficiently to land safely. These 1.27 billion Euro rovers are lowered from beneath a rocket-fired platform on a sky crane. These methods are especially nerve-wracking, as they only work in Mars' reduced gravity, so they can't be fully tested on Earth.

Did you know?

The EDL phase of a Mars rover's journey is so dangerous that mission controllers refer to it as the seven minutes of terror!

Image: An artists's impression of Curiosity Skycrane upon landing. Credit: NASA



Mars VR

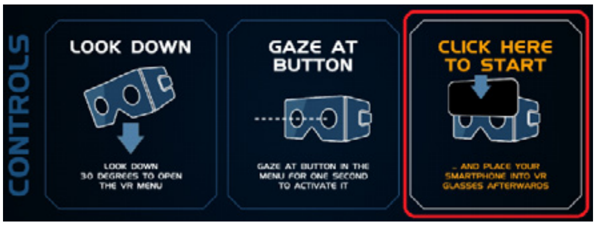
Walk around the Curiosity rover

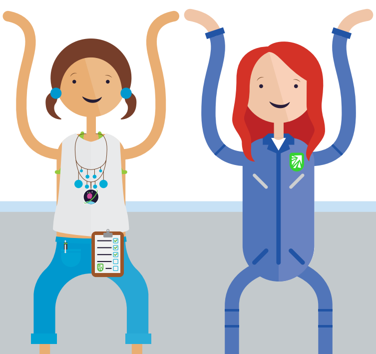
With an android smart phone and VR headset, visitors can walk around the Curiosity rover and Mars, as well as explore the solar system, International Space Station and more, with the free Solar System Scope VR app.

Setting it up

Before the phone is placed in the headset, it will need to be set up. When you launch the app, choose the 'with VR glasses' option. On the following screen select the 'Without VR button – gaze' option. This will allow people to control navigation by moving their head, rather than using an external control option.

Once selected, an information screen comes up explaining the basics of navigation. Click on the 'click here to start' icon and place the phone in the headset.





What you can do

When you first start the app you will be in a solar system view. You can navigate around by looking in the direction you want to go.

Planet distances are not to scale in this app.

To go to Mars, or any of the other options, tip your head down 30° to bring up the menu. Move the blue pointer over the binocular icon to bring up your six exploration options.

Move the pointer to the Curiosity rover to travel to Mars.

You can look around the rover by moving your head, and you can move, step by step, by moving the pointer to the forwards or backwards arrow.

Why not explore the ISS while you are at it?

The future of Mars exploration

Visiting the neighbours

Humans have always been fascinated with Mars. With its interesting geological history, atmosphere and water, not only is Mars one of the most likely places to find alien life, but also the best place to set up an interplanetary base.

A succession of robotic landers and orbiters have been exploring on our behalf, investigating Mars' present and history, surveying resources and providing information vital to the planning of future crewed missions to the planet.

Plans for visiting the red planet

The US plans to send astronauts to Mars in the 2030s, building on technologies developed during its Artemis missions, which intend to land a mixed-sex crew on the Moon in 2024.

SpaceX have ambitions towards permanent settlement of Mars. They plan to start unmanned missions in 2022 to deliver materials for the construction of a refuelling base, before landing humans by 2024.

Why go to Mars?

A large part of the drive is from the heart. To be able to share in someone's experience of setting foot on our first new world would be incredibly inspiring: a culturally significant event for all humanity.

Most plans for setting up a Mars base involve having robots and humans working together. Robots cope well with the extreme environment, while humans are great at innovating, dealing with unexpected situations and making tricky judgement calls.

Some people think we should learn how to live on Mars in case something terrible happens to Earth. Others want to mine it for valuable materials, or visit as tourists.

Second thoughts

Not everyone thinks we should go.

Styling long-term habitation of Mars as 'colonisation efforts intending to exploit Mars' natural resources' evokes memories of violent land-grabs and genocide from our own history and is why many prefer the term 'settlement'.

Suggestions of terraforming the planet (changing its environment) may remind us of our inability to maintain the climate on Earth.

And if there was alien life, could we harm them by introducing new species or changing their environment? Or might they harm us?

Image: The prototype Z-1 spacesuit for Mars exploration is designed for mobility. Credit: NASA