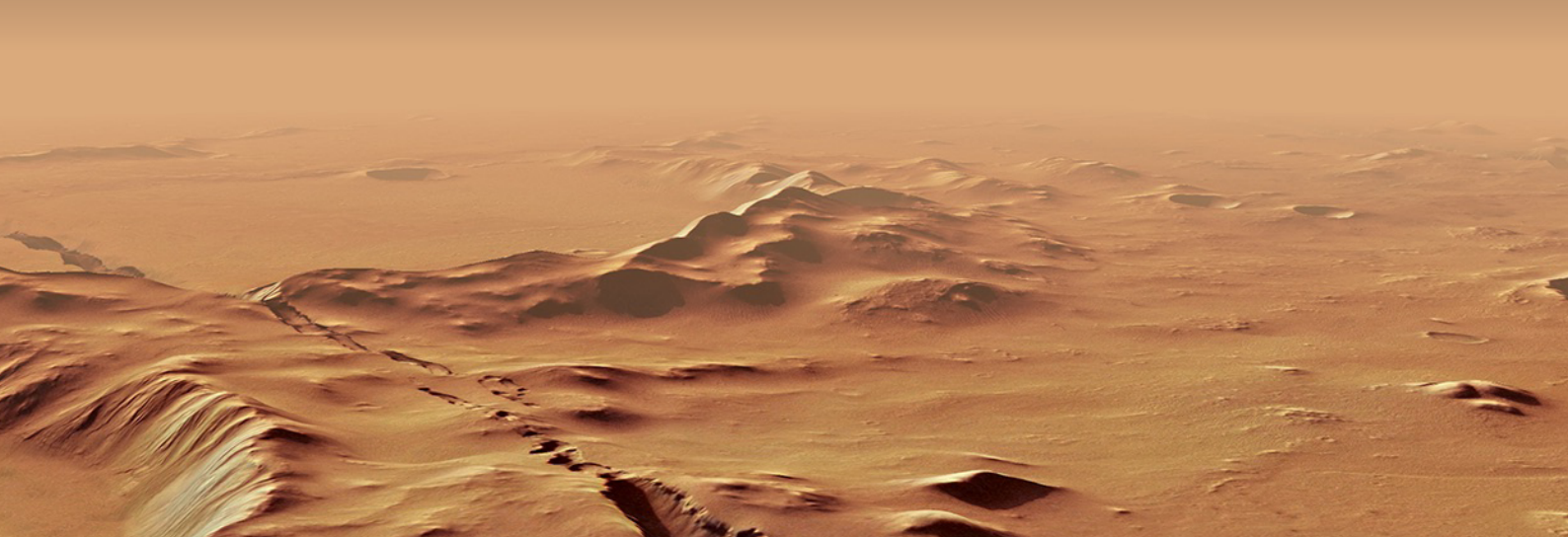
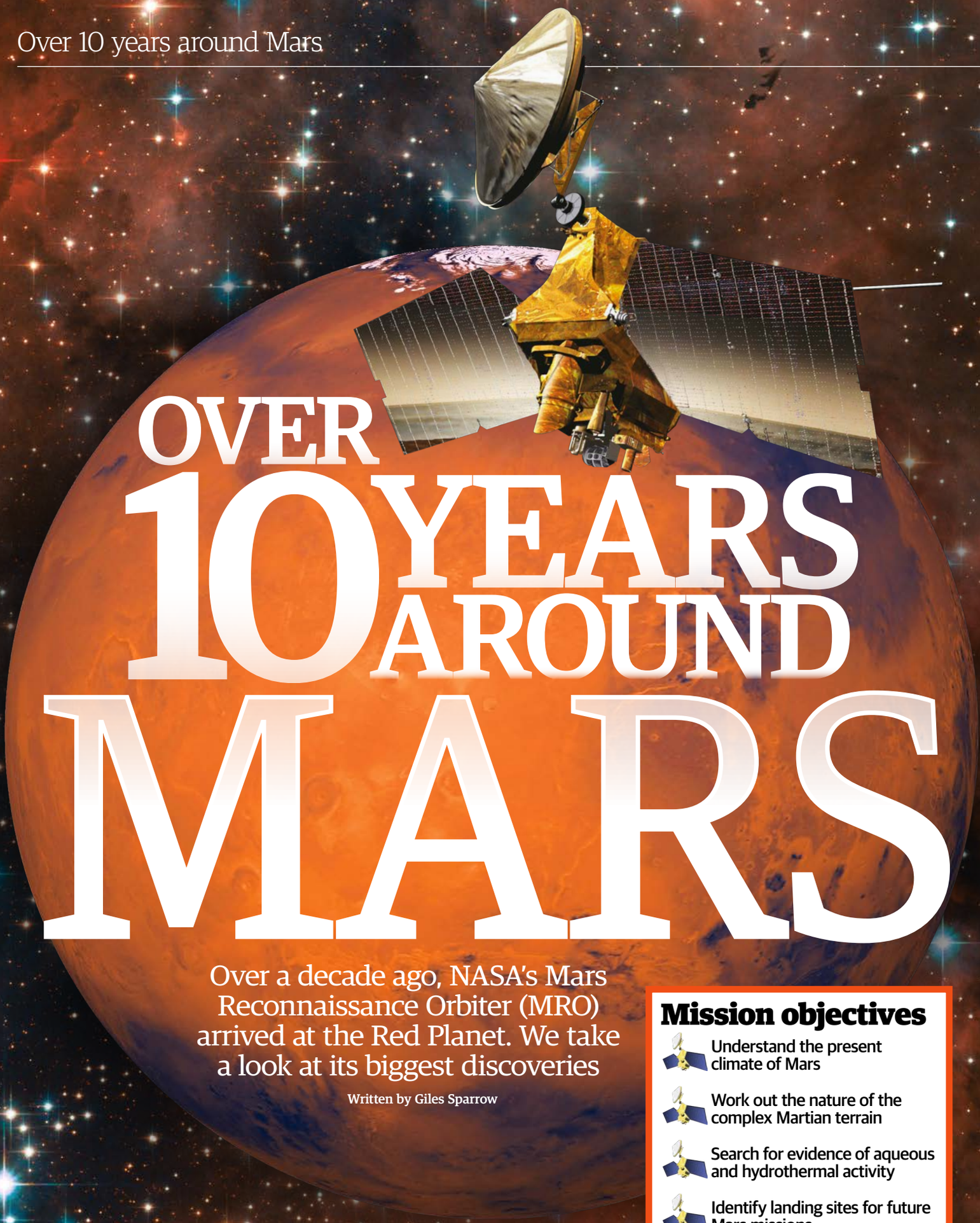
All About Space

OVER 10 YEARS AROUND MARS

By Giles Sparrow





OVER 10 YEARS AROUND MARS

Over a decade ago, NASA's Mars Reconnaissance Orbiter (MRO) arrived at the Red Planet. We take a look at its biggest discoveries

Written by Giles Sparrow

Mission objectives

- Understand the present climate of Mars
- Work out the nature of the complex Martian terrain
- Search for evidence of aqueous and hydrothermal activity
- Identify landing sites for future Mars missions
- Return data from craft on the surface during relay phase

10 March 2006

Arrival at Mars

The MRO arrives in Martian orbit, initially entering a highly elliptical orbit over the planet's poles. After initial checks, MRO begins an aerobraking manoeuvre that takes five months to complete, taking advantage of the natural brake provided by friction with the atmosphere to save thruster fuel.

By the time the process is complete in early September, MRO's 112-minute orbit around Mars ranges between 250 to 316 kilometres (155 to 196 miles) above the surface. The science operations are postponed until November to avoid a communications blackout.

13 December 2006

Targeting a layered canyon

After months of aerobraking and instrument testing, one of the first targets for MRO's High Resolution Imaging Science Experiment (HiRISE) camera is an area close to the Martian north pole. Here, frozen carbon dioxide (dry ice) is laid down by winter frosts, carrying with them dust from the atmosphere.

As the upper layers of frost evaporate in spring, they leave dust behind, slowly building up a distinctive and complex layered terrain, whose inner structure is exposed around the edges of the canyons and craters.

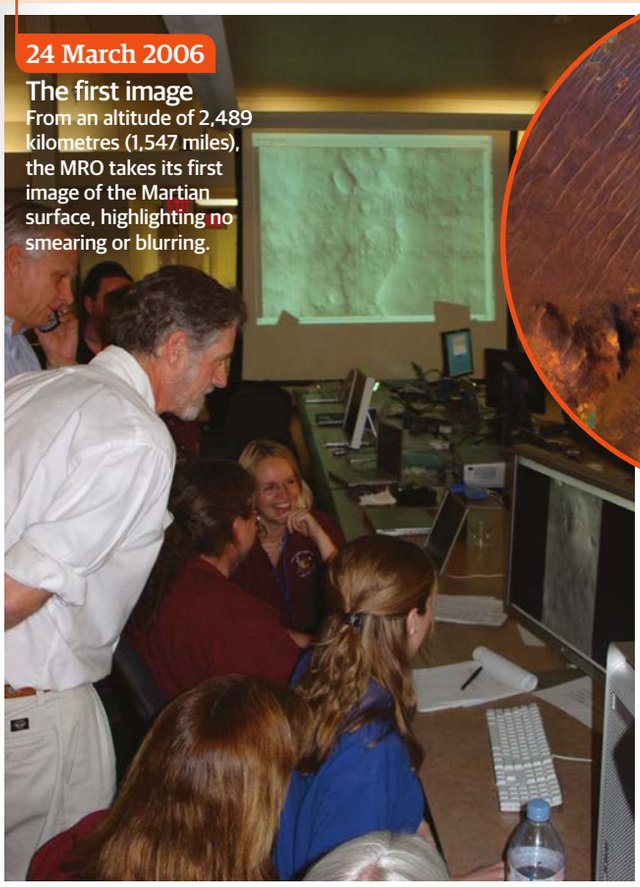
7 November 2007

Weather watch

The Mars Color Imager (MARCI) delivers wide-angle, lower-resolution images of the surface, allowing MRO to produce daily weather maps for the planet. In late 2007, MARCI captures a developing dust storm (red clouds) on the edge of the retreating north polar ice cap in Utopia Planitia.

Northern-hemisphere storms tend to remain local (this one covers 500 kilometres (310 miles) and lasts 24 hours), but those in the southern-hemisphere summer can envelope large swathes of the planet and last for weeks or even months.

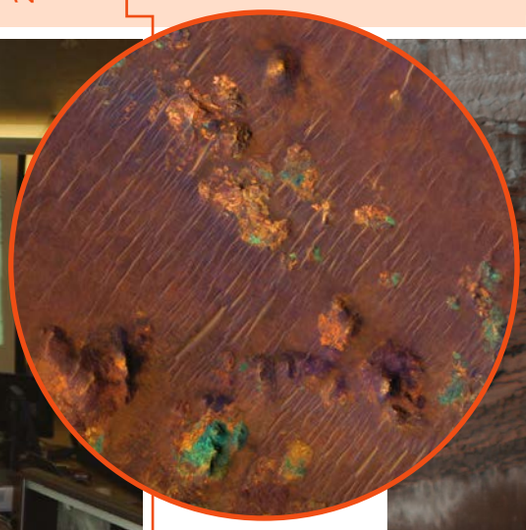
2006 2007 2008



24 March 2006

The first image

From an altitude of 2,489 kilometres (1,547 miles), the MRO takes its first image of the Martian surface, highlighting no smearing or blurring.



24 March 2007

MRO captures the Nili Fossae region

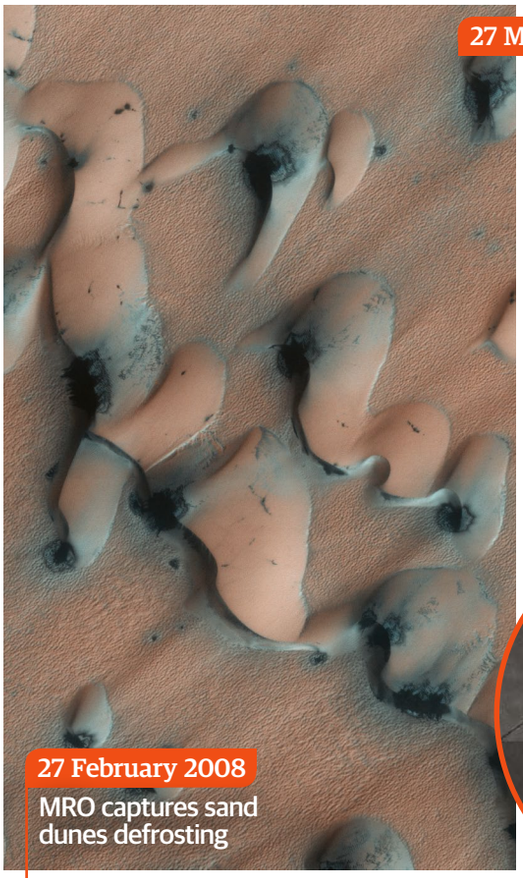
This enhanced colour image, taken by the HiRISE camera in March 2007, shows an area of the Nili Fossae region. The image is part of a series of experiments to examine more than two dozen possible landing sites for NASA's Curiosity rover.

19 February 2008

Capturing an avalanche

When MRO revisits the layered terrain at the north polar cap in the Martian spring, scientists hope to study the way in which carbon dioxide frosts evaporate from underlying sand dunes.

It comes as something of a surprise, however, when an image from HiRISE ends up capturing no fewer than four separate avalanches thundering down a layered cliff face more than 700 metres (2,296 feet) tall. Further observations confirm that similar avalanches recur in Martian spring – they are probably triggered when blocks of dust-laden dry ice collapse as frozen carbon dioxide slowly thaws.



27 February 2008

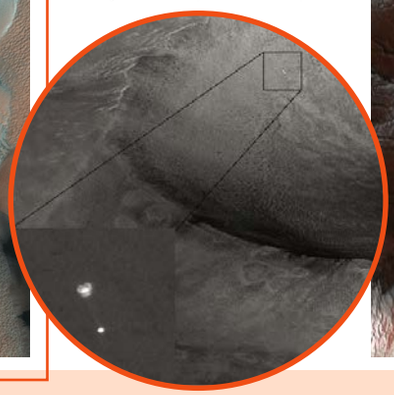
MRO captures sand dunes defrosting

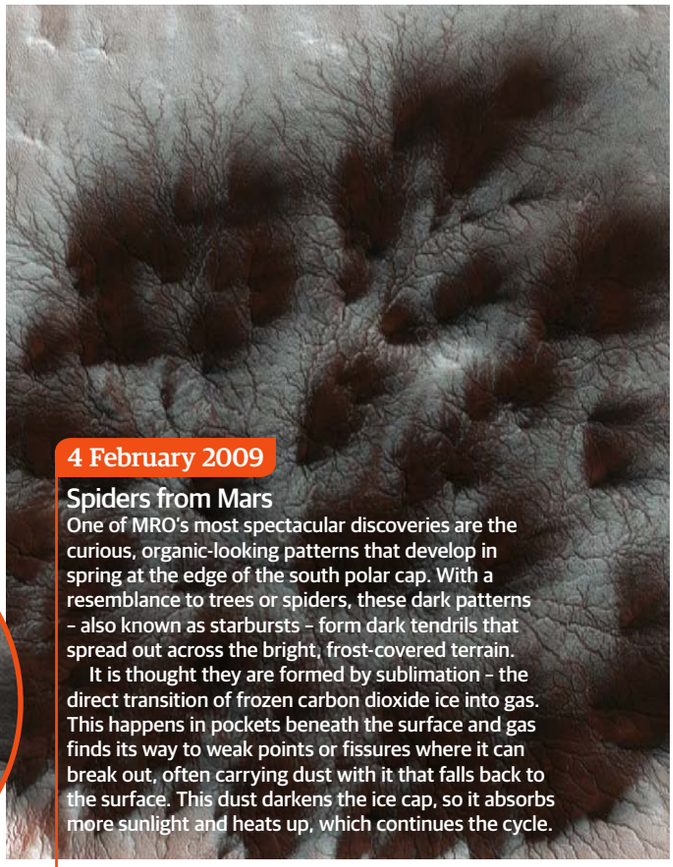
27 May 2008

Flight of the Phoenix

Throughout its time of operation at Mars, the MRO has been used in conjunction with several other spacecraft, helping to identify potentially interesting landing sites for rovers, making observations to supplement those from other orbiters, and tracking other missions once they have reached the surface.

In 2008, MRO uses its HiRISE to capture one such mission on its final descent to the Martian surface. The Phoenix Lander is shown here at an altitude of about 13 kilometres (eight miles), shortly after its parachute opens.





4 February 2009

Spiders from Mars

One of MRO's most spectacular discoveries are the curious, organic-looking patterns that develop in spring at the edge of the south polar cap. With a resemblance to trees or spiders, these dark patterns – also known as starbursts – form dark tendrils that spread out across the bright, frost-covered terrain.

It is thought they are formed by sublimation – the direct transition of frozen carbon dioxide ice into gas. This happens in pockets beneath the surface and gas finds its way to weak points or fissures where it can break out, often carrying dust with it that falls back to the surface. This dust darkens the ice cap, so it absorbs more sunlight and heats up, which continues the cycle.

2008

2009

23 March 2008

Phobos flyby

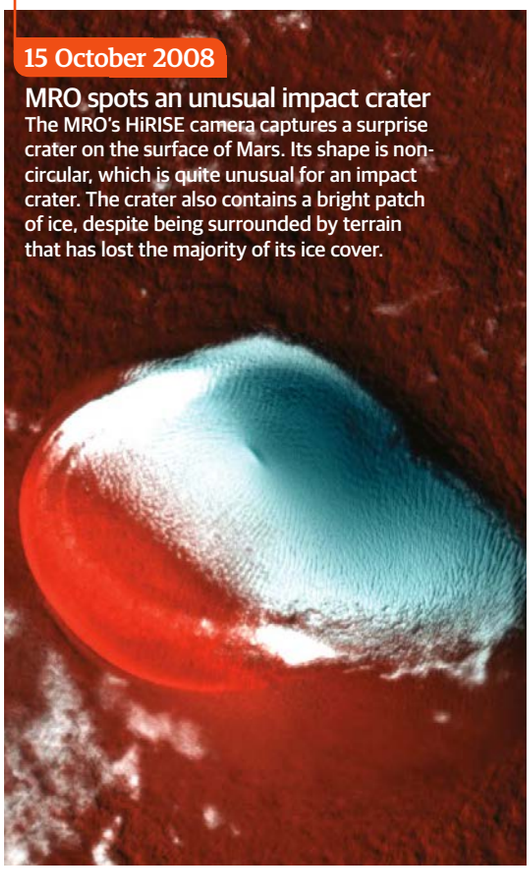
The MRO team turn the HiRISE camera away from Mars to image its two satellites, Phobos and Deimos, at the highest resolution yet obtained. The larger of the two moons, Phobos, orbits closer to Mars, circling the planet once every seven hours and 40 minutes.

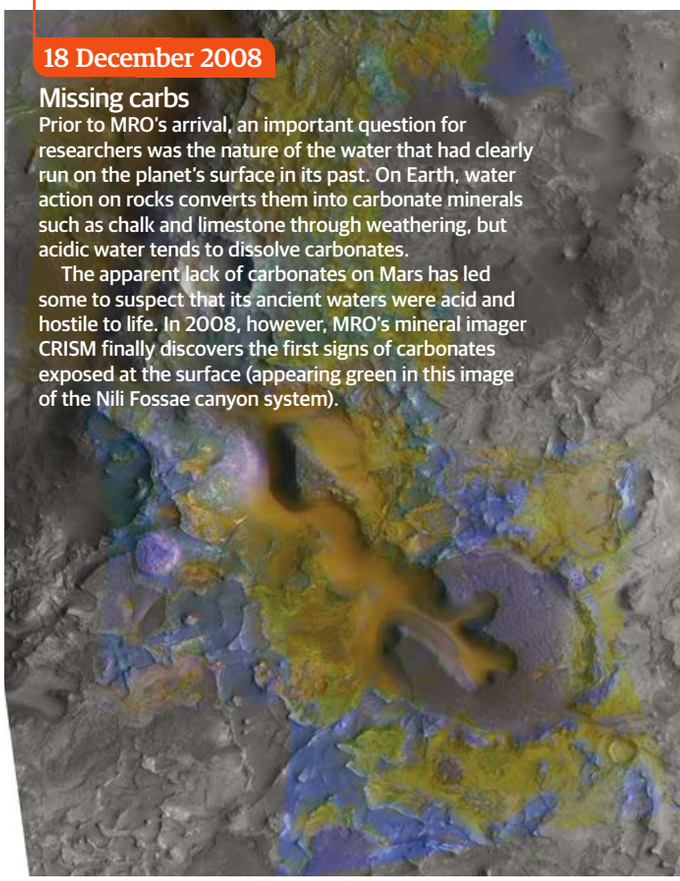
Seen in this image from 6,800 kilometres (4,200 miles), the potato-shaped moon's most prominent feature is a crater called Stickney. The curious grooves that appear to radiate from the crater and run parallel with the moon's longer axis are thought to be stress fractures, caused as Martian tidal forces push and pull on the satellite.

15 October 2008

MRO spots an unusual impact crater

The MRO's HiRISE camera captures a surprise crater on the surface of Mars. Its shape is non-circular, which is quite unusual for an impact crater. The crater also contains a bright patch of ice, despite being surrounded by terrain that has lost the majority of its ice cover.





18 December 2008

Missing carbs

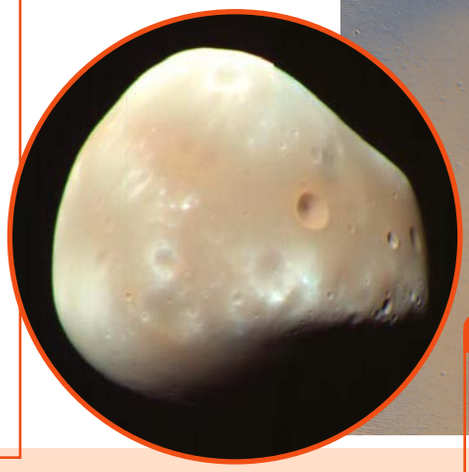
Prior to MRO's arrival, an important question for researchers was the nature of the water that had clearly run on the planet's surface in its past. On Earth, water action on rocks converts them into carbonate minerals such as chalk and limestone through weathering, but acidic water tends to dissolve carbonates.

The apparent lack of carbonates on Mars has led some to suspect that its ancient waters were acid and hostile to life. In 2008, however, MRO's mineral imager CRISM finally discovers the first signs of carbonates exposed at the surface (appearing green in this image of the Nili Fossae canyon system).

21 February 2009

Martian Moon Deimos in high resolution

The smaller of Mars' moons, Deimos, is captured by the HiRISE camera onboard the MRO in February 2009. The moon is around 12 kilometres (7.5 miles) across and has a smooth surface, apart from dents created by the most recent impact craters.



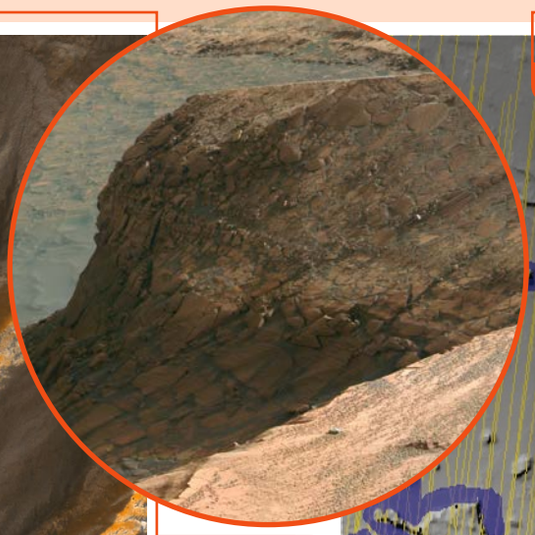
14 July 2009

Snapping Victoria Crater at Meridiani Planum

2010

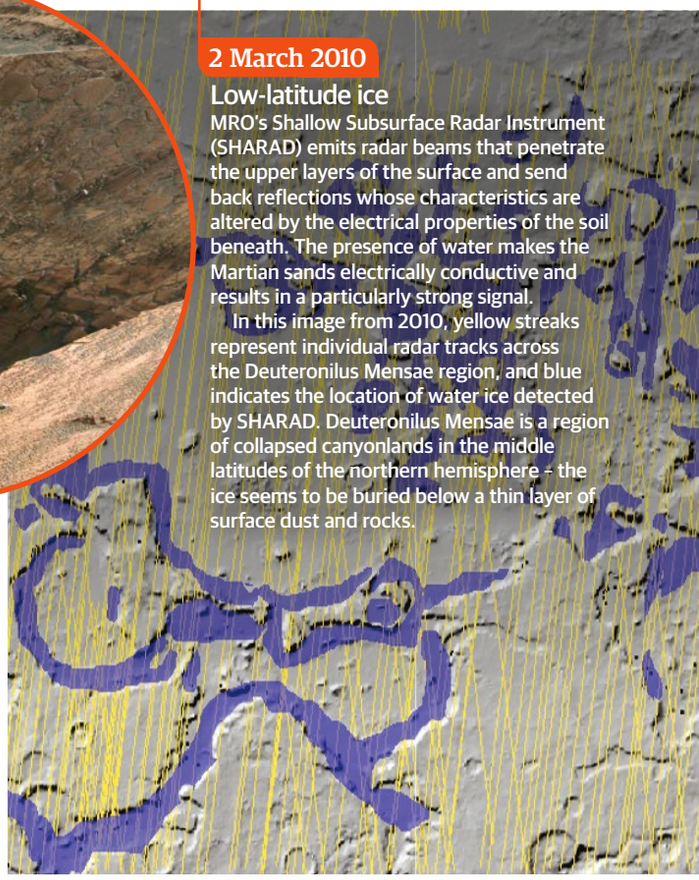
14 July 2009

Crater Edge in Terra Sirenum



14 July 2009

View of Cape Verde from Cape St. Mary in mid-afternoon, in false colour



2 March 2010

Low-latitude ice

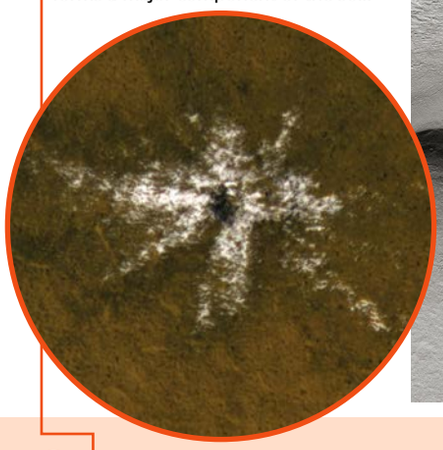
MRO's Shallow Subsurface Radar Instrument (SHARAD) emits radar beams that penetrate the upper layers of the surface and send back reflections whose characteristics are altered by the electrical properties of the soil beneath. The presence of water makes the Martian sands electrically conductive and results in a particularly strong signal.

In this image from 2010, yellow streaks represent individual radar tracks across the Deuteronilus Mensae region, and blue indicates the location of water ice detected by SHARAD. Deuteronilus Mensae is a region of collapsed canyonlands in the middle latitudes of the northern hemisphere – the ice seems to be buried below a thin layer of surface dust and rocks.

19 May 2010

Craters of ice

The 'Red Planet' owes its nickname to the rusty Martian sands that cover its surface – but this HiRISE image in May 2010 reveals just how thin that surface layer really is. A small ten-metre (32.8-foot) crater formed here after the area was last photographed in March 2008, and has pierced straight through the red soil to hit an underlying layer of ice, blasting snowy 'ejecta' across the surrounding terrain (colours have been processed to highlight the contrast). The crater is at mid-northern latitudes, where MRO observations suggest ice forms a major component of the soil.



13 September 2010

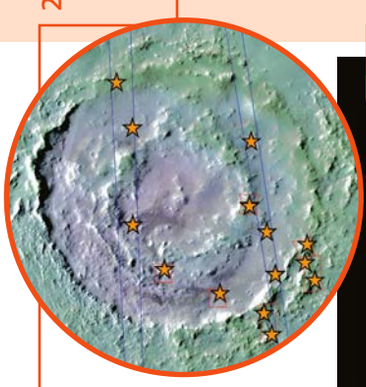
Martian glaciers

Shortly after MRO began imaging the surface, scientists began to notice features that were most likely created by glaciers – slow-moving rivers of ice that reshape the landscape as they move from higher altitudes to lower altitudes.

In 2010, however, HiRISE captures a glacier that is still very present today – a flow of ice from an elevated mountain valley down to an eroded 'snout' on the level plain below. The surface of the glacier is covered in boulders up to three metres (9.8 feet) across that have been carved out of the valley walls. There are thought to be many more glaciers like it across Mars, often hidden beneath the red dust.

2010

2011



25 June 2010

Mars' wet north

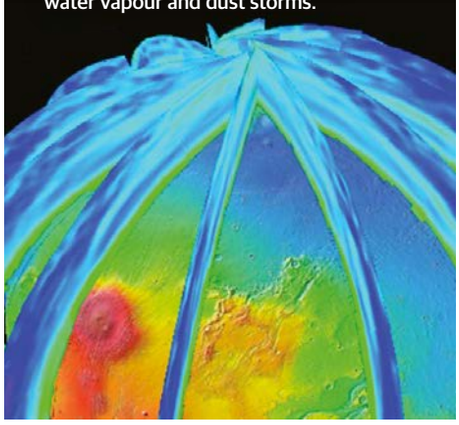
Ancient hydrated minerals had already been found in the southern highlands but the northern plains seemed to have a disappointingly dry history. Using the CRISM spectrometer, researchers target several craters and identify multiple signatures from hydrated, clay-like minerals (such as those shown here at Lyot Crater). The crater seems to have punctured through the overlying dry soil to expose an ancient layer below, revealing evidence that watery and hospitable conditions were once global, perhaps 4 billion years ago.

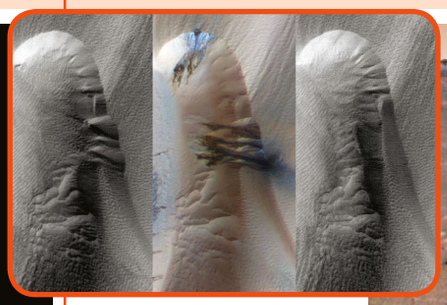
20 August 2010

Mapping the atmosphere

MRO's Mars Climate Sounder (MCS) studies the atmosphere by viewing sections through air above the horizon at a variety of wavelengths.

This MCS image shows curtain-like profiles of the atmosphere above the northern hemisphere, based on 13 orbits' worth of observations. Colour coding indicates different temperatures in the atmosphere ranging from -70°C (-94°F) in green, to a chilling -150°C (-238°F) in purple. MCS can also detect water ice clouds, accumulations of water vapour and dust storms.





3 February 2011

Changing dunes

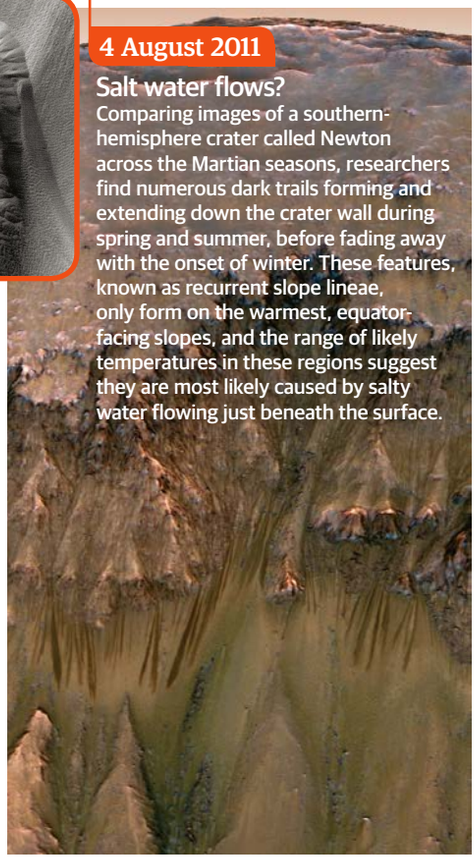
The vast dune sea known as the Vastitas Borealis surrounds the Martian north pole just beneath the polar cap, and was long assumed to be in a state of permanent deep-freeze.

However, this set of HiRISE images showing the area across two Martian years (roughly four Earth years) shows substantial erosion has taken place around the rim of a steep-edged dune. The changes are partially due to the seasonal accumulation and evaporation of carbon dioxide frost from the atmosphere, but are also affected by strong winds that shift the Martian sands and quickly wipe away signs of previous landslips.

4 August 2011

Salt water flows?

Comparing images of a southern-hemisphere crater called Newton across the Martian seasons, researchers find numerous dark trails forming and extending down the crater wall during spring and summer, before fading away with the onset of winter. These features, known as recurrent slope lineae, only form on the warmest, equator-facing slopes, and the range of likely temperatures in these regions suggest they are most likely caused by salty water flowing just beneath the surface.



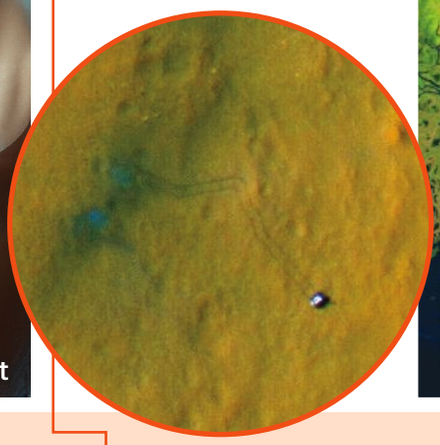
1 April 2012

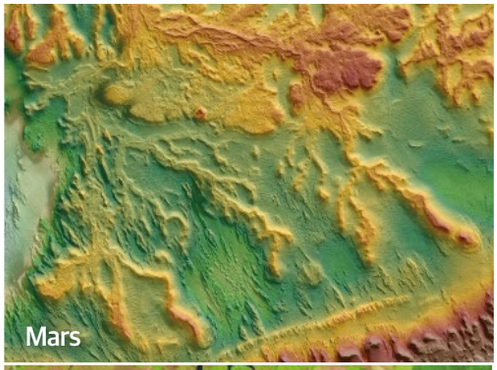
Martian dunes covered in frost

6 September 2012

Tracking Curiosity

Prior to the arrival of NASA's Curiosity rover on Mars in 2012, MRO plays a key role in gathering data about its landing site in Gale Crater. As with Phoenix in 2008, the HiRISE camera tracks the probe during its descent, and it has been used to monitor the rover's progress intermittently throughout the rest of Curiosity's mission. The spacecraft's rockets blow away the red surface dust during the "sky crane" descent stage to the Martian surface, revealing the darker iron-rich rock beneath, which can be seen in the centre of the photograph.





16 July 2013

A coastal delta?

Scientists have long speculated that the northern plains were once covered in a shallow ocean. In 2013, using HiRISE images of the Aeolis Dorsa region (which sits between the northern and southern hemisphere), researchers create an elevation map and find a series of inverted ridges fanning out as they run downhill – a structure similar to how river deltas flow into Earth's seas. It's the strongest evidence yet that the ocean theory is correct.

2012

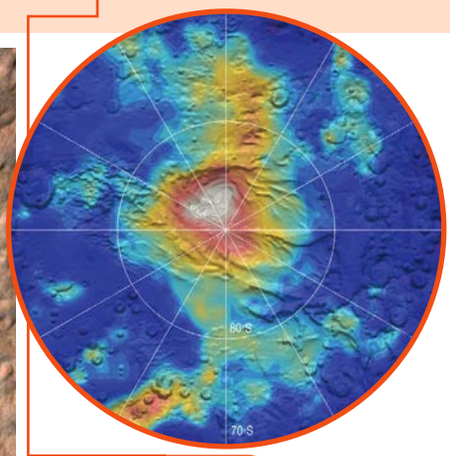
2013

16 February 2012

Twister on the move

The existence of dust devils on the Martian surface had been suspected since the 1970s, but MRO surprises everyone by delivering stunning images of these tornado-like whirlwinds in action. This relatively small-scale dust devil is about 30-metres (98-foot) wide and 800-metres (2,624-foot) high – others can grow much larger.

Dust devils scour the Martian surface clear of dust, frequently leaving scribble-like dark trails where they expose the underlying bedrock. They are thought to form in the same way as Earth's dust devils, when a pocket of warm air is trapped at the surface by overlying cold air and is then finally allowed to rise, creating a spinning updraft.



11 September 2012

Winter wonderland

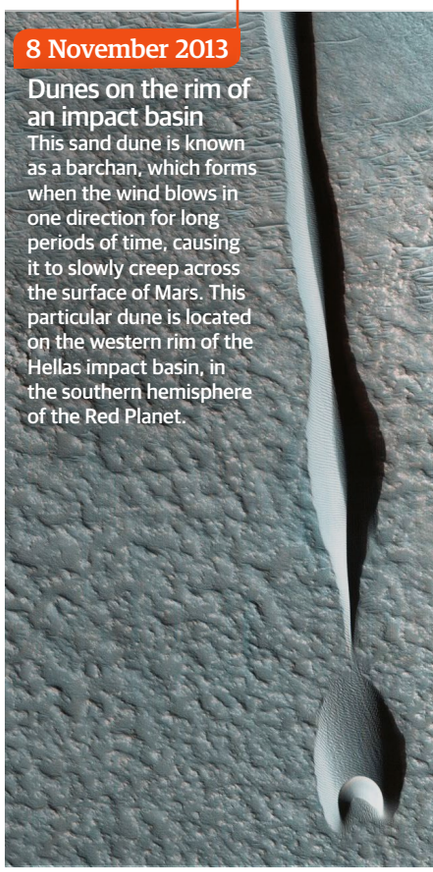
During the southern-hemisphere winter of 2006 to 2007, the MRO uses its Mars Climate Sounder to study cloud formations over the south polar ice cap.

In 2012, a team of scientists announce a new analysis of this data, confirming the presence of a huge carbon dioxide snow cloud, some 500 kilometres (310 miles) across, hovering over the south pole. The cloud, made of frozen "dry ice" crystals, would deposit snow on the ground in the right conditions, perhaps explaining how the south pole grows from a small residual ice cap that persists through summer, to an extensive snowcap covering a large amount of the southern hemisphere.

8 November 2013

Dunes on the rim of an impact basin

This sand dune is known as a barchan, which forms when the wind blows in one direction for long periods of time, causing it to slowly creep across the surface of Mars. This particular dune is located on the western rim of the Hellas impact basin, in the southern hemisphere of the Red Planet.



26 February 2014

Icy revelations

MRO's high-resolution cameras have discovered many unsuspected features on Mars, including unusual terraced craters like this one. At first glance, its bulls eye structure makes it look as though a second meteorite has struck the exact centre of an earlier crater, but the reality is rather different.

Terraced craters form when an impact penetrates through layers of material that have different strengths – in this case, a relatively weak sheet of ice just below the surface has been hollowed out to form the crater's wide outer walls, while the much tougher rock beneath has only been excavated at the point of impact itself.

16 January 2015

The spacecraft locates the Beagle 2 lander

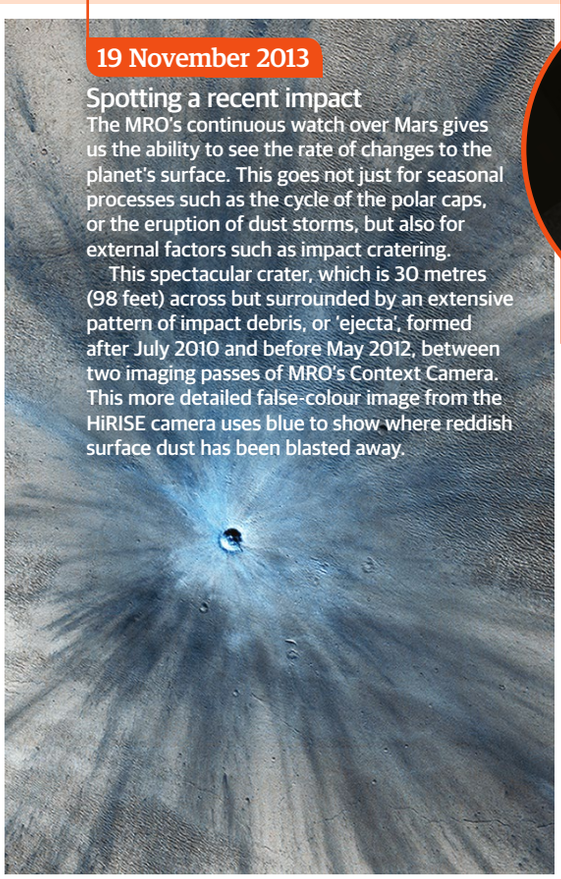
Beagle 2, a lander released by the Mars Express Orbiter on Christmas Day in 2003, is uncovered by MRO with its solar arrays partially deployed on the surface of Mars.

17 May 2015

MRO snaps a "Hollywood movie site"

Using the HiRISE camera, the Mars Reconnaissance Orbiter snaps the region Acidalia Planitia, which is featured in the best-selling novel and movie, *The Martian*.

2013 2014 2015

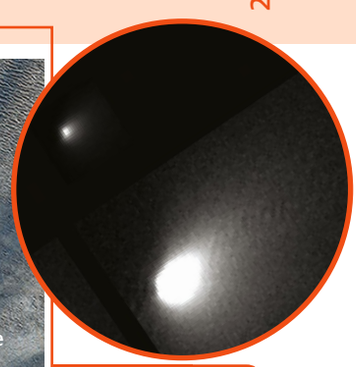


19 November 2013

Spotting a recent impact

The MRO's continuous watch over Mars gives us the ability to see the rate of changes to the planet's surface. This goes not just for seasonal processes such as the cycle of the polar caps, or the eruption of dust storms, but also for external factors such as impact cratering.

This spectacular crater, which is 30 metres (98 feet) across but surrounded by an extensive pattern of impact debris, or 'ejecta', formed after July 2010 and before May 2012, between two imaging passes of MRO's Context Camera. This more detailed false-colour image from the HiRISE camera uses blue to show where reddish surface dust has been blasted away.

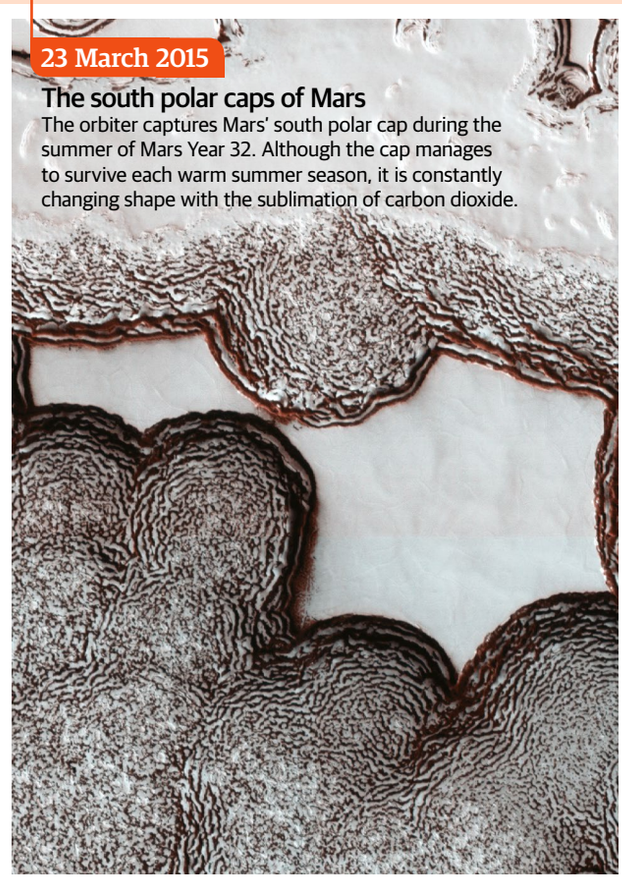


19 October 2014

Watching a comet flyby

In late 2014, space agencies take precautions with MRO and their other Mars orbiters as the recently discovered Comet Siding Spring makes an unusually close approach to the Red Planet.

When the comet was first discovered, it was thought to be on a possible collision course with Mars – with the potential to create a new crater several kilometres or miles across. In the end, however, Siding Spring passes within 140,000 kilometres (86,992 miles) of Mars – about one-third of the distance from the Earth to the Moon.



23 March 2015

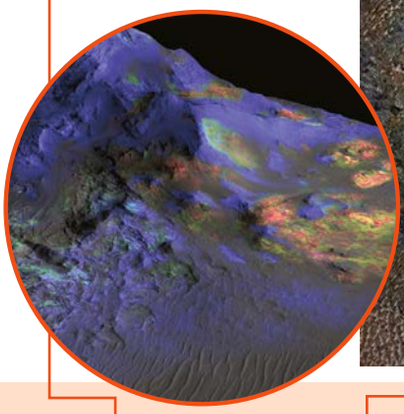
The south polar caps of Mars

The orbiter captures Mars' south polar cap during the summer of Mars Year 32. Although the cap manages to survive each warm summer season, it is constantly changing shape with the sublimation of carbon dioxide.

8 June 2015

Glassy debris found

When meteorites hit a planet, the shock waves heat and compress the surface, often fusing sandy grains together to create glass. Impact glass is common on Earth but is hard to detect on Mars as its spectral signature is indistinct. In 2015, researchers find a way to prove that glass is widespread around many meteorite craters, such as Alga, the glass shown here in green. Impact glass can preserve traces of organic chemistry on Earth, so could assist in the search for life on Mars.



2 September 2015

Mars' lost atmosphere

After MRO's confirmation of carbonate minerals on Mars in 2008, the hunt was on to discover larger deposits. The weathering process that creates carbonates also locks away carbon dioxide from the atmosphere, and so weathering could have played a significant role in thinning the Martian atmosphere. In 2015, scientists identify the largest carbonate region so far in Nili Fossae – exposed carbonates are coloured green in this composite of CRISM data and a HiRISE image. The presence of large carbonate deposits supports the idea that ancient surface water was amenable to the development of life.

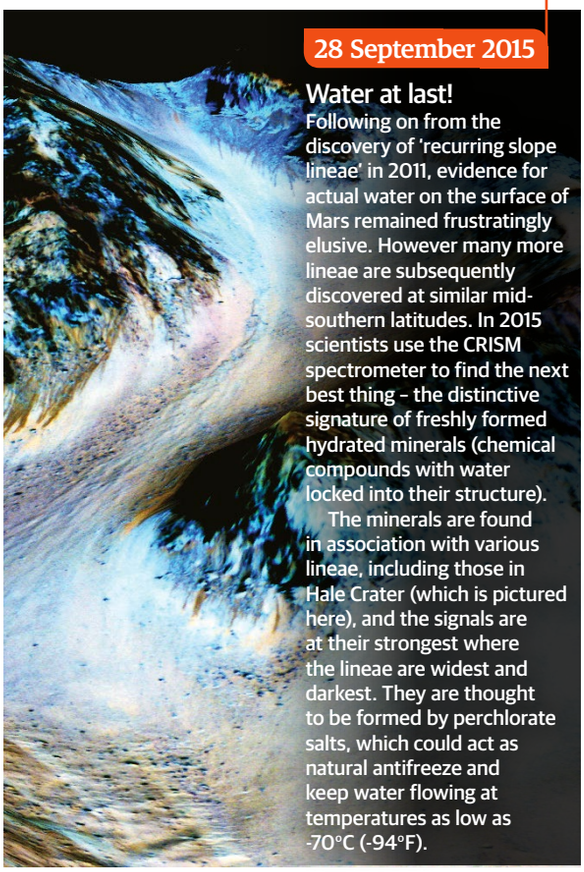
29 March 2017

50,000 orbits completed

In its 50,000 orbits of Mars the MRO took 90,000 images covering around 99% of the planet (as shown in the picture) and it has observed more than 60% of Mars more than once, gathering over 300TB of scientific data.

2016

2017

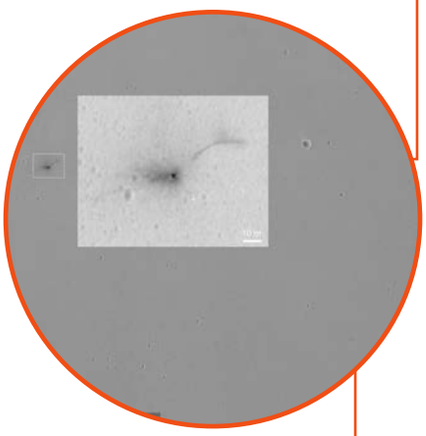


28 September 2015

Water at last!

Following on from the discovery of 'recurring slope lineae' in 2011, evidence for actual water on the surface of Mars remained frustratingly elusive. However many more lineae are subsequently discovered at similar mid-southern latitudes. In 2015 scientists use the CRISM spectrometer to find the next best thing – the distinctive signature of freshly formed hydrated minerals (chemical compounds with water locked into their structure).

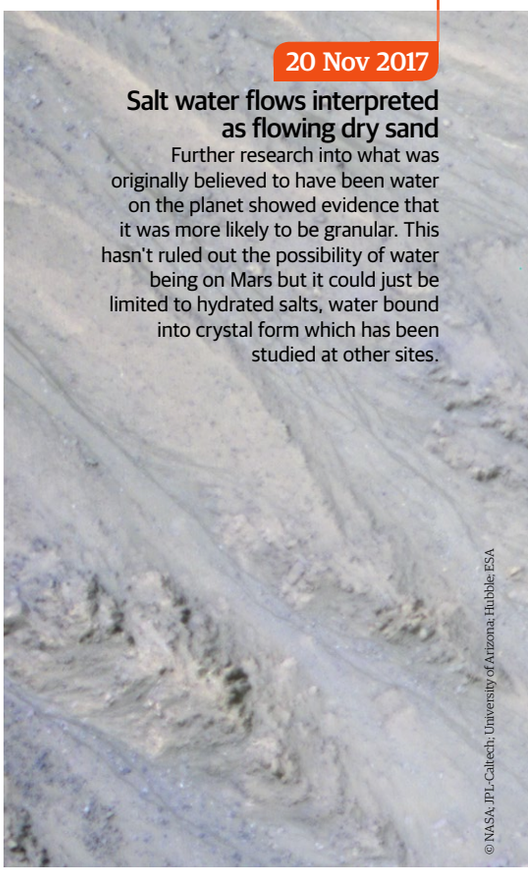
The minerals are found in association with various lineae, including those in Hale Crater (which is pictured here), and the signals are at their strongest where the lineae are widest and darkest. They are thought to be formed by perchlorate salts, which could act as natural antifreeze and keep water flowing at temperatures as low as -70°C (-94°F).



21 Oct 2016

Schiaparelli's crash site found

The Schiaparelli test lander was a joint mission by the Russian space agency and European Space Agency built to test landing technology for Mars whilst also launching the Trace Gas Orbiter in orbit around the planet. On 19 October 2016 the lander crashed on the surface of the planet, leaving three impact sites. The MRO's Context Camera captured its first image of the impact sites: the lander itself, its heat shield and its parachute along with the back shell.



20 Nov 2017

Salt water flows interpreted as flowing dry sand

Further research into what was originally believed to have been water on the planet showed evidence that it was more likely to be granular. This hasn't ruled out the possibility of water being on Mars but it could just be limited to hydrated salts, water bound into crystal form which has been studied at other sites.