Makeshift to Mars

The red planet has claimed many a plucky spacecraft. Richard Corfield discovers how Nasa's latest attempt hopes to overcome the odds with a different approach

It is easy to forget in these heady days of the Mars exploration rovers Spirit and Opportunity – which have exceeded their design lifetime by a factor of ten – that Mars has a long history of claiming spacecraft. In fact only half of the missions ever sent to the red planet have been successful. The rest, for one reason or another, have failed.

This month a new spacecraft will once again test the Martian odds when the Phoenix lander launches from Cape Canaveral Air Force Base in Florida, US, and tries to land close to the red planet's north pole. If successful, it will be the first craft to reach either of the Martian poles. Its mission is twofold: to search for environments suitable for past or present microbial life and to investigate the history of water in the high latitudes of Mars.

The probe carries a piece of equipment that should raise the arm hairs of any red-blooded Englishman – it is the instrument that we tried and failed to land on Mars aboard the Marie Celeste of lost Martian landers, Beagle 2. The Tega instrument (Thermal and Evolved Gas Analyser) is a mass spectrometer, able to identify organic molecules that could prove to be evidence of life on Mars.

In short

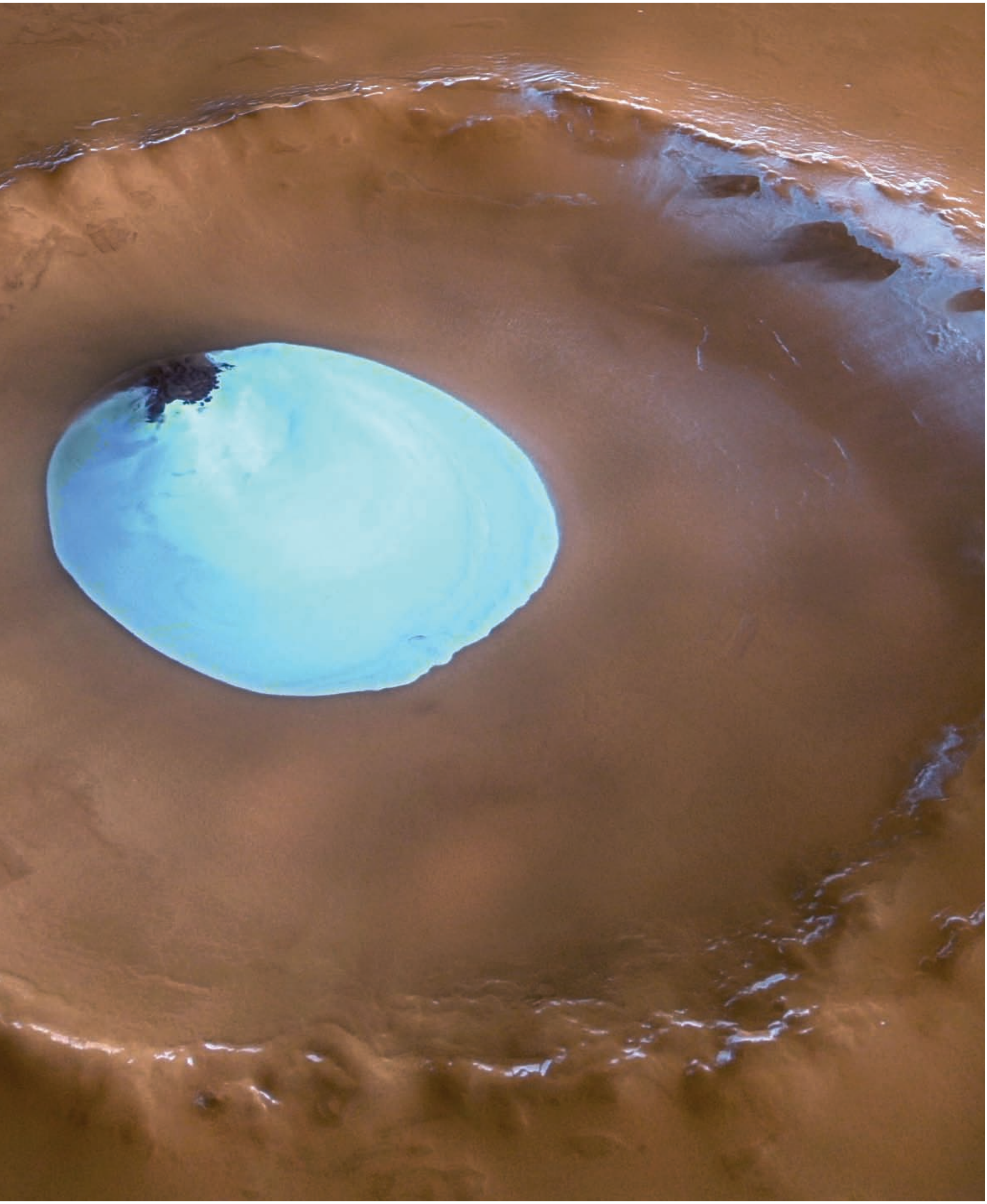
- **Nasa's latest mission to Mars, Phoenix, will be launched this month**
- **It will attempt to land near the north pole of the planet to search for evidence of water**
- **Phoenix's mass spectrometer will also test the Martian dust for compounds that may be hazardous for future astronauts**
- **The extreme conditions at the Martian north pole will eventually entomb Phoenix in ice**

This 35-kilometre-wide Martian crater, snapped by the orbiting Mars Express probe, contains residual water ice

It's on America's tortured brow

Phoenix is well named – it is an attempt to rise from the ashes of one of the most controversial periods of Nasa's chequered history. In the spring of 1992 Dan Goldin took over as the Chief Administrator of Nasa declaring that the era of 'big space' was over and that, in future, the biggest space agency in the world would explore the planets with what he dubbed the 'faster, better, cheaper' approach. For much of the 1990s it seemed to be working, with low-budget missions such as the 1997 Pathfinder mission and its miniature Sojourner rover a spectacular success that paved the way for the hugely successful Mars Exploration Rovers still trundling the sands of Mars today.

Then, in 1998, Nasa launched Mars Surveyor 98 consisting of the Mars Climate Orbiter and the Mars Polar Lander. Their joint mission was to explore the climate of Mars and also



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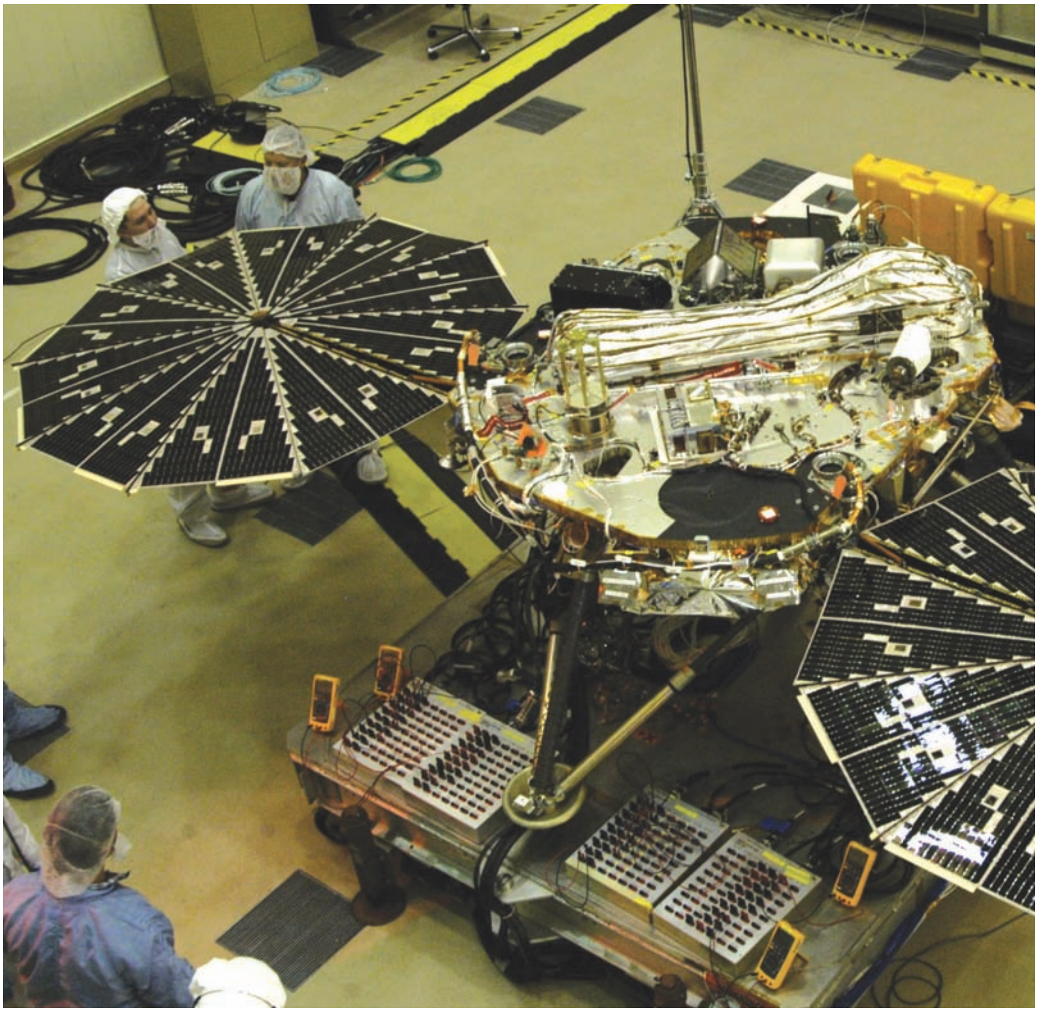


Nasa scientists put the finishing touches to the Phoenix lander

the potential of the poles as oases of liquid water and, possibly, life. But the Climate Orbiter was lost when it entered the atmosphere of Mars at too low an altitude and the lander was lost when the engine cut out too early.

In the first case the failure was caused by an embarrassing mismatch of imperial and metric units between the spacecraft manufacturer Lockheed Martin and the project manager, Nasa's Jet Propulsion Laboratory (JPL). In the latter case the deployment of the landing legs was so violent it triggered premature engine shutdown forty metres above the surface rather than at touchdown. In each case the problems were entirely avoidable. It became clear that faster and cheaper did not necessarily equate to better: it could just as easily mean a quicker route to egg on the face of the world's most famous space agency.

Waiting for a mission

The politically savvy Goldin knew this as well as anybody and his first action after this double whammy was to close down the next lander mission in the Mars pipeline, the Mars Surveyor Lander of 2001. Its sister mission Mars Surveyor Orbiter 2001 was rapidly renamed Mars Odyssey and, since its arrival in Mars orbit in 2001, has proved to be a spectacular success, mapping Mars and acting as the communications relay for the most successful of all Mars landers, the Mars exploration rovers (MERs) Spirit and Opportunity. But the Mars Surveyor Lander has spent the last seven years in a clean room facility in Colorado – a $100 million craft just waiting for a mission.

That mission has finally arrived. Phoenix was selected from several competing tenders in 2003, and is the first in a new series of 'scout' missions designed to augment and explore in detail crucial aspects of Nasa's overarching Mars exploration program. It is the first Mars mission to be overseen by a university rather than a Nasa contractor and is the largest single grant awarded in the University of Arizona's history.

Samples of soil and water ice will be transferred to the lander's instruments by a robotic arm which can extend 2.35 metres and which can dig a trench up to half a metre deep. The aluminium and titanium arm is equipped with tines and a back-hoe to cut through icy soil as well as a scoop camera to provide close-up, high resolution images of the Martian surface. Researchers on Earth can search within the radius of the arm for prospective samples as well as examine the rocky layers or stratigraphy of the walls of the trench as it is dug.

> 'So many hopes have been pinned on finding life on Mars – anyone who goes there now is very coy'

Space-age technology

This spacecraft also has eyes. Positioned at about the height of human eyes, these twin cameras – stereoscopic imagers similar to those that have proved so successful on the MERs – provide three dimensional imaging out to the horizon. Another camera was due to take photographs during the probe's descent to the martian surface, although a wiring problem has recently nixed that plan.

Alongside the latest technology, Phoenix also has features from a previous age of space exploration, such as landing thrusters rather than air bags. And without wheels, it is stuck wherever it lands.

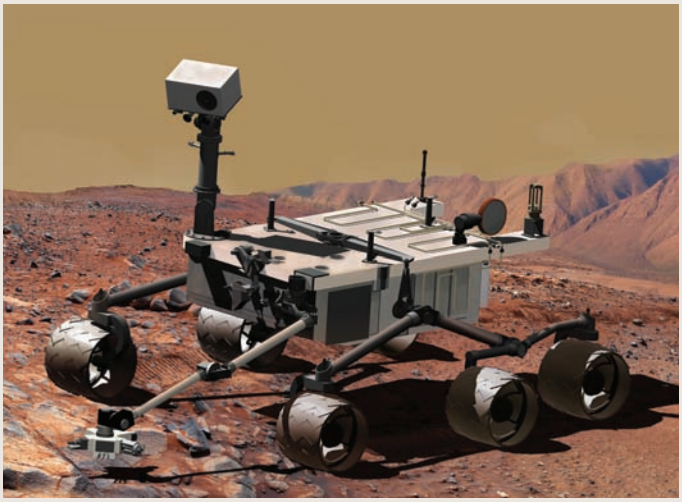
From the scientists' perspective one recognisable old-timer is the Meca instrument. As Phoenix principal investigator Peter Smith of the University of Arizona points out, this instrument was originally envisaged to support the human exploration of the red planet by analysing Martian dust for toxicity and abrasive properties. Such concerns are a direct result of the Apollo missions of the late 1960s and early 1970s. As the Apollo astronauts climbed back aboard their lunar modules they were liberally caked in black lunar dust and there was no way of removing it in the confined space of the lander. Inevitably some of this dust was inhaled.

The same problem will be unavoidable when the first human explorers land on Mars and so Nasa wants to know the composition of the dust before they risk astronauts. There are specific concerns about the possibility that Martian dust may contain heavy metals or tiny particles that might cause the inflammatory lung disease silicosis.

The abrasion of space suit fabrics by these particles is also worrying. By the time the Apollo program was drawing to its conclusion, one of the engineering findings of the extended 'J' missions – those with up to three

Mars Science Lab (MSL)

If the Phoenix mission is a curious hybrid of old and new approaches to exploring Mars, the mission planned for 2009 is the latest word. The six-wheeled MSL rover is about ten times the size of the 1997 Sojourner Rover – the size of a small car. Landing this kind of mass on the red planet cannot be accomplished using either air bags or hydrazine thrusters. The number of air bags required to land on Mars increases exponentially with mass and the MSL weighs almost 800 kg. Hydrazine thrusters mounted on the lander – despite their successes in delivering Viking and Pathfinder – are a risk because of the extreme reactivity of the fuel. Nasa thinks that it can minimise that risk using the so-called 'Skycrane' approach whereby, following parachute separation, the lander will actively manoeuvre close to its landing site and then lower the rover from the hovering skycrane for a soft landing on its wheels.



NASA / JPL

MSL is an extensive laboratory on wheels

The Mars Science Laboratory will be the most comprehensively equipped spacecraft ever to rove across the red planet. It will carry three camera systems and two sets of radiation detectors and a comprehensive suite of environmental sensors. It will also carry four mass spectrometers including one, the Sample Analysis at Mars Instrument Suite (Sam) that takes up more than half the science payload. Like the Viking GCMS Sam is a both a mass spectrometer and a gas chromatograph so that compounds can be separated before isotopic analysis. However, the most important innovation of the Sam instrument is its on–board laser for vapourising rock and soil samples whereupon the captured gas will be fed to the GC and the mass spectrometer for analysis.

EVAs (extravehicular activity) and use of lunar rovers – was that the astronauts' space suits, despite being made of supertough Teflon-coated glass fibre beta cloth, were being abraded almost to the point of unusability. Such a situation cannot be allowed for Mars exploration where missions, by definition, will have to be long-term rather than the three or four day affairs of the lunar landings.

The Meca instrument is designed to address science as well as health and engineering concerns and the Phoenix team will use it to investigate the geology, geochemistry, palaeoclimatology and exobiology of the Martian north pole. The subtle change in emphasis from manned exploration back to pure science is hinted at in the way the instrument package's name has evolved. Where once Meca stood for 'Mars Environmental Compatibility Assessment' it now stands for the more prosaic 'Microscopy, Electrochemistry and Conductivity Analyser'.

Searching for life

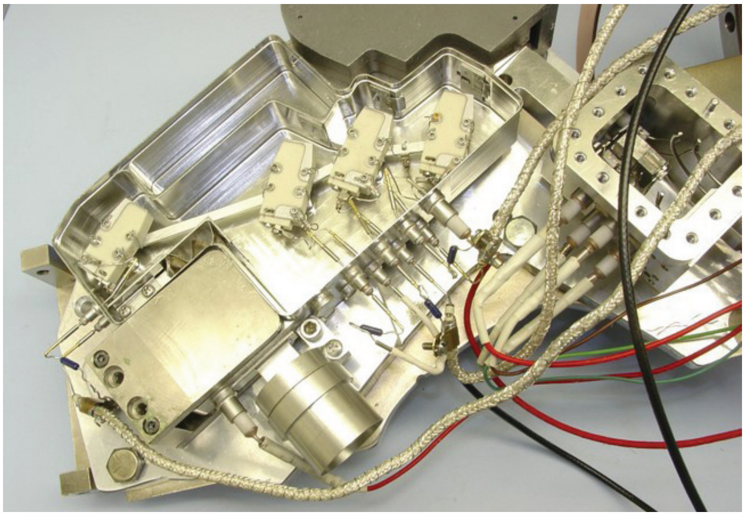
The Meca instrument package consists of two parts. One is a miniaturised wet chemistry laboratory – an 'electronic tongue' of four 35 millilitre cells that will receive samples returned by the scoop and analyse their composition using conventional wet chemistry in water brought from Earth. Each experiment takes up to 24 hours and includes reagents to test for the presence of sulfates, oxidants and, crucially, biogenic carbonates in the soil.

'Phoenix will test Martian dust for heavy metals or tiny particles that could pose health risks for future astronauts'

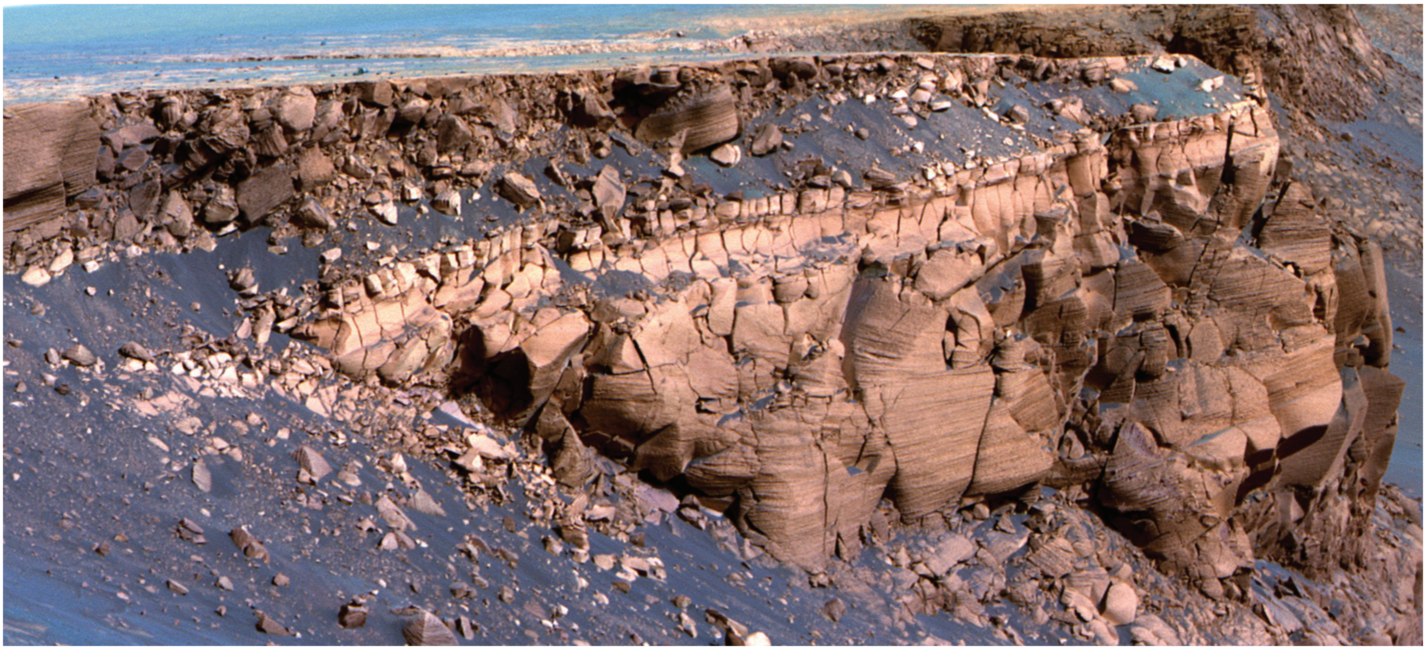
The second half of the Meca device is an atomic force microscope. Complementing the wet chemistry laboratory aboard the spacecraft, this instrument will use a combination of coloured and UV LEDs to create a small-scale topographic map of soil and water-ice grains retrieved by the robotic arm. Detection of any hydrous or clay minerals in the soil will be strong evidence for the presence of liquid water at the Martian poles. Particles from 1 millimetre down to 10 microns can be imaged, making this the most powerful microscope ever sent to Mars.

Tega is the other main analytical instrument. It is a combination of eight tiny ovens (each about the size of a ballpoint pen) hooked up to a mass spectrometer that will look for a variety of isotopes including carbon, oxygen, nitrogen and hydrogen. The ability to look for carbon isotopes is central to the search for life – be it extant or extinct – because photosynthesis splits carbon into its isotopes. On Earth, the light carbon isotope ^{12}C is preferentially incorporated into organic material leaving the surrounding crystalline matrix enriched in the heavy carbon isotope, ^{13}C. If Tega detects material isotopically depleted in ^{12}C (with high levels of ^{13}C) it will be strong evidence of the presence of life on Mars.

NASA / UNIVERSITY OF ARIZONA



Tega – Phoenix's mass spectrometer



Rocky layers on the Martian surface carry evidence of the planet's watery history

Of course, the whole concept centres on the idea that life on Mars will be based around the chemistry of carbon, a concept that has underpinned Nasa's life exploration policy since the 1950s. Although the two legendary Viking landers of the 1970s also carried mass spectrometers, they found no evidence for any organic material on Mars. With the other three experiments producing highly equivocal results the Viking landers – despite a price tag of over a billion dollars – added almost nothing to the question of whether there was ever life on Mars.

Peter Smith points to two flaws of the Viking missions – one in design and the other in their mission profile. 'The Viking ovens did not get hot enough,' he observes, 'the kerogens [matter within sedimentary rocks] that are the most likely repositories of organic material will not vapourise below 500°C, and that was the maximum rated temperature of the Viking ovens.' By contrast the ovens that Phoenix carries will reach 1000°C, easily hot enough to vapourise any hidebound hydrocarbons that the Phoenix scoop feeds into the mass spectrometer's maw. The other problem Smith identifies was simply that the Vikings 'landed in the wrong place.'

It's a fair point: data from the orbiting Mars Global Surveyor and the European Space Agency's (ESA's) Mars Express tell us that Mars almost certainly had water billions of years ago, as well as in its more recent geological past. So the Phoenix mission will look for water in the most likely places – the poles. No matter that Mars is an arid, desert planet with a temperature profile that makes the Antarctic look like Biarritz; there is the very strong suspicion that if water exists it is at the poles, probably as water ice but possibly sublimating to vapour during the Martian summer. But that simply was not known at the time the Viking landers were sent to Mars, and so, as Smith says, they landed in the wrong place. Extending that reasoning to the more modern era of Mars exploration suggests that even if Beagle 2 had set down safely in Isidis Planitia her own mass spectrometer may well have drawn a blank.

Cautious new mission

And so Phoenix is going to Mars with the latest kit to investigate life. But it is not going to search for life – the real emphasis is subtly different. As Smith points out, it is going to Mars to find out if life could exist, rather than if it is there. This slight reluctance to grasp the biological nettle is probably related to the many failures that have accompanied the search for life on Mars. So many hopes and expectations have been pinned on finding life on Mars, from the canals of Schiaparelli and Lowell to the Viking landers, the Mars Polar Lander and the ill-fated voyage of Beagle 2, that anyone who goes to Mars now is very coy. The best that can be expected these days is the mission profile that Phoenix is following – to find out if life could exist on Mars.

'Even if Beagle 2 had set down safely in Isidis Planitia, her own mass spectrometer may well have drawn a blank'

Is this too cautious? What if Phoenix's miniscule mass spectrometer does find depleted carbon? Will that evidence be definitive, or only suggestive? Any discoveries will probably be closer to the latter, which explains why more sophisticated life-hunting missions are currently in the pipeline (see box, p47).

An icy tomb

For all the sophistication of Phoenix it will be no match for the prevailing environmental conditions at the north pole of Mars. Eventually the solar panels that will unfurl like Chinese fans will be unable to power the back-hoe that will yank chunks out of the Martian permafrost. Then the craft's other instruments will take precedence – most particularly the meteorological station that has been contributed by the Canadian Space Agency to give us our first view of the weather at Mars' north pole.

But eventually this too will fail when the planet slides back into the iron grip of the Martian winter. Soon after that, plucky Phoenix will find herself entombed in six metres of ice, the first ice-maiden of Mars, beyond even the rescue of the clever engineers of JPL. After that she will become dormant, like her Viking and Pathfinder predecessors; her job done but waiting for the day when the astronauts she blazed the trail for come to dig her from the sands of Mars.

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