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EXTRA-TERRESTRIAL LIFE

Life on Mars?

Two missions planned within the next decade are set to up the search for life on Mars, writes Jon Evans

by Jon Evans

Spotting aliens is easy in the movies. They have acid for blood and burst out of stomachs, or they can make bikes fly and have glowing fingers. In reality, detecting alien life is more complex.

For a start, at least in the short term, any attempts to detect signs of extraterrestrial life will focus on Mars, which means looking for microbes. Furthermore, any microbial life that may once have existed on Mars could now be extinct, which means trying to detect fossilised traces of life in Martian rocks. Finally, if life developed independently on Mars then it might well utilise a whole range of different organic molecules from Earth-based life; so how will we know what to look for?

These challenges have stimulated scientists to explore a range of approaches for detecting extra-terrestrial life. These novel approaches are starting to yield devices for inclusion on the next generation of missions to Mars, which have the detection of life as a key aim.

Missions so far

So far, only two missions have gone to Mars explicitly to search for signs of life. The first of these were the two Nasa *Viking* landers, which landed on Mars in 1976. Both contained a gas chromatograph (GC) linked to a mass spectrometer (MS) to detect organic molecules and were designed to conduct three different life detection experiments.

Although one of these experiments produced results that suggested life may be present, the other two experiments came up negative and the GC-MS systems failed to detect any organic molecules. This led most scientists to conclude that the *Viking* landers failed to find signs of life. But this doesn't mean that Mars doesn't contain life, because the landers' life detection equipment wasn't particularly sensitive: some claim that the *Viking* landers would have failed to detect life even if there were a million bacteria in each gramme of Martian soil.

The second life-detection mission was the *Beagle 2* lander, which was developed by the European Space Agency (ESA) and hitched a ride on its *Mars Express* spacecraft in 2003. Unfortunately, the advanced capabilities of *Beagle 2* were never exploited for analysis of martian soils because something went wrong during its entry, descent or landing, causing it to slam into the surface of Mars and never be heard from again.

Other Mars missions, including Nasa's Mars pathfinder mission in 1997 and its Mars exploration mission in 2004, were designed to reveal more about the Mars environment than to detect life. Nevertheless, these missions, particularly the Mars exploration rover mission and its two rovers — *Opportunity* and *Spirit* — helped to confirm that the conditions to support life probably had existed at some point in Mars' history.

Opportunity and *Spirit* both contained a suite of analytical instruments for investigating Martian rocks and soil, in order to determine their chemical composition. These included three different kinds of spectrometers — thermal emission, Mössbauer and X-ray — and numerous cameras and microscopes.

Using these instruments, both rovers uncovered convincing evidence that water once flowed over the surface of Mars. This evidence included physical signs that the Martian rocks have been exposed to water and the discovery of certain sulphate-rich minerals, such as jarosite, which on Earth tend to form in water. And where liquid water exists, so can life.

Following on from these findings, the search for life will increasingly move centre-stage in two future missions to Mars. The first of these is Nasa's *Mars Science Laboratory* (MSL), which is due to launch in 2009. This will deliver another rover to Mars, which will test whether its landing site has ever had, or even still has, environmental conditions favourable for microbial life.

The MSL rover will contain some of the same instruments as the *Opportunity* and *Spirit* rovers, such as an X-ray spectrometer. But it will also contain novel instruments, including an X-ray diffraction unit and a laser spectrometer.

The X-ray diffraction instrument will analyse the various minerals in Mars' rocks and should reveal more about the role played by water in the formation of those minerals. The laser spectrometer will measure the abundance of various isotopes of carbon, hydrogen, oxygen and nitrogen in the Mars atmosphere. Life on Earth preferentially uses certain isotopes, such as carbon-12 rather than carbon-13, for its metabolism. A high ratio of certain isotopes in the Mars atmosphere could therefore be evidence of life.

Nevertheless, the MSL rover has mainly been designed to detect a suitable habitat for life, rather than evidence of life itself. A specific attempt to detect traces of past or present life will have to wait for the next mission — ESA's *ExoMars* mission — which will probably launch in 2013.

Like MSL, *ExoMars* will land a rover on the surface of Mars, possessing a suite of scientific instruments known as the Pasteur payload. Some of these instruments will be the same as those on previous Mars missions, including a GC-MS, a Mössbauer spectrometer and an X-ray diffraction instrument, but others will be novel. These include a Raman spectrometer to detect organic molecules in Martian rocks and two instruments designed specifically to detect signs of life. Another novel capability will include the use of a portable drilling device to get up to 2m below the surface. This capability is critical because the harsh environment as well as radiation may sterilise the top metre of surface soil.

One of these instruments is known as Urey: Mars Organic and Oxidant Detector (after Harold Urey, one of the pioneers of astrochemistry) and was developed by a joint US-European team led by Jeffrey Bada from the University of California at San Diego, together with Frank Grunthaner and coworkers at Nasa's Jet Propulsion Laboratory, Richard Mathies at University of California at Berkeley, Pascale Ehrenfreund at Leiden University, Mark Sephton at Imperial College London, Aaron Zent and coworkers at Nasa-Ames, and a number of other European and US collaborators.

This instrument will primarily search for amino acids, which make up the proteins that are a ubiquitous part of life on earth as well as nucleobases and other organic amines. Unlike other biomolecules, such as DNA, amino acids are hardy and can probably survive for thousands of years in Martian soil. In addition, amino acids are chiral molecules, meaning that they can exist in two mirror-image versions, although life on Earth tends to favour using left-handed (rather than right-handed) versions. Thus, although amino acids can be produced by non-biological processes, finding an excess of either left- or right-handed amino acids on Mars will be good evidence of past or present life.

Urey consists of three related lab-on-a-chip instruments: the Mars organic detector (MOD), the Mars organic analyser and the Mars oxidant instrument. The MOD will heat Martian soil samples and/or aqueous extracts from a subcritical water extraction system to vapourise any organic molecules that may be present. This vapour will condense onto a cold finger coated with a fluorescent dye that binds solely to amino acids. Any detected amino acids or other organics are then transferred to the MOA, where they are separated by capillary electrophoresis in a separation buffer containing cyclodextrin compounds, which can separate amino acids based on chirality.

Urey also has the capability of analysing the environment and soils for acids and oxidants with microarrays of thin film sensors in the MOI component. This will enable researchers to study the chemical environment of any organics that are found on or below the surface to understand why or how these organics have been modified or degraded in the harsh Martian environment.

Mars-like environments

The researchers have tested the Urey instruments in California's Panoche Valley and the Atacama Desert in Chile, which is the driest desert in the world. 'It is unquestionably the most inhospitable and most Mars-like environment on the face of the Earth,' says Mathies. 'But we were able to successfully run the instruments there and detect amino acids at concentrations as low as parts per trillion.' This sensitivity is critical for life detection because it is a 1000-fold better than that deployed on *Viking*.

Despite its sensitivity, however, this instrument still assumes that life on Mars utilises amino acids and that might not be the case. So the Pasteur payload will also contain another life-detection instrument looking for a greater variety of organic molecules.

This instrument is called the life marker chip (LMC) and is being developed by an international team jointly led by David Cullen at Cranfield University and Mark Sims at Leicester University, both in the UK. The LMC is an antibody array that consists of around 100 antibody 'spots', with 25 different types of antibody on each array. The Pasteur payload will contain around 40 individual arrays, made up of two or three different versions.

In total, therefore, the arrays will house 50–75 different antibodies, each of which will bind specifically to a different organic molecule. The idea is that samples of Martian soil will be passed over the arrays, which will generate a signal whenever an antibody in the array captures its target organic molecule.

According to Cullen, the LMC will test for four different kinds of organic molecules: non-biological organic molecules, such as the simple amino acids found in meteorites; markers of past life, such as fossilised membrane molecules; markers of current life, such as enzymes and metabolites; and markers of terrestrial contamination. In addition, it will look for unusual distributions in the detected organic molecules.

'If Martian life evolved completely separately from Earth life, we can look for any unexpected distribution of complex organic molecules that we cannot explain by non-biological processes,' says Cullen. These kinds of unexpected distributions would then be a strong indication of life, even if that life doesn't use exactly the same biomolecules as life on Earth.

Both these instruments have been included in the provisional list of Pasteur instruments, but a decision on the final payload will not be made until the end of the year. 'I do anticipate, however, that given the exobiology focus of the *ExoMars* mission, the relevant instruments will be confirmed,' says Piero Messina from ESA.

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