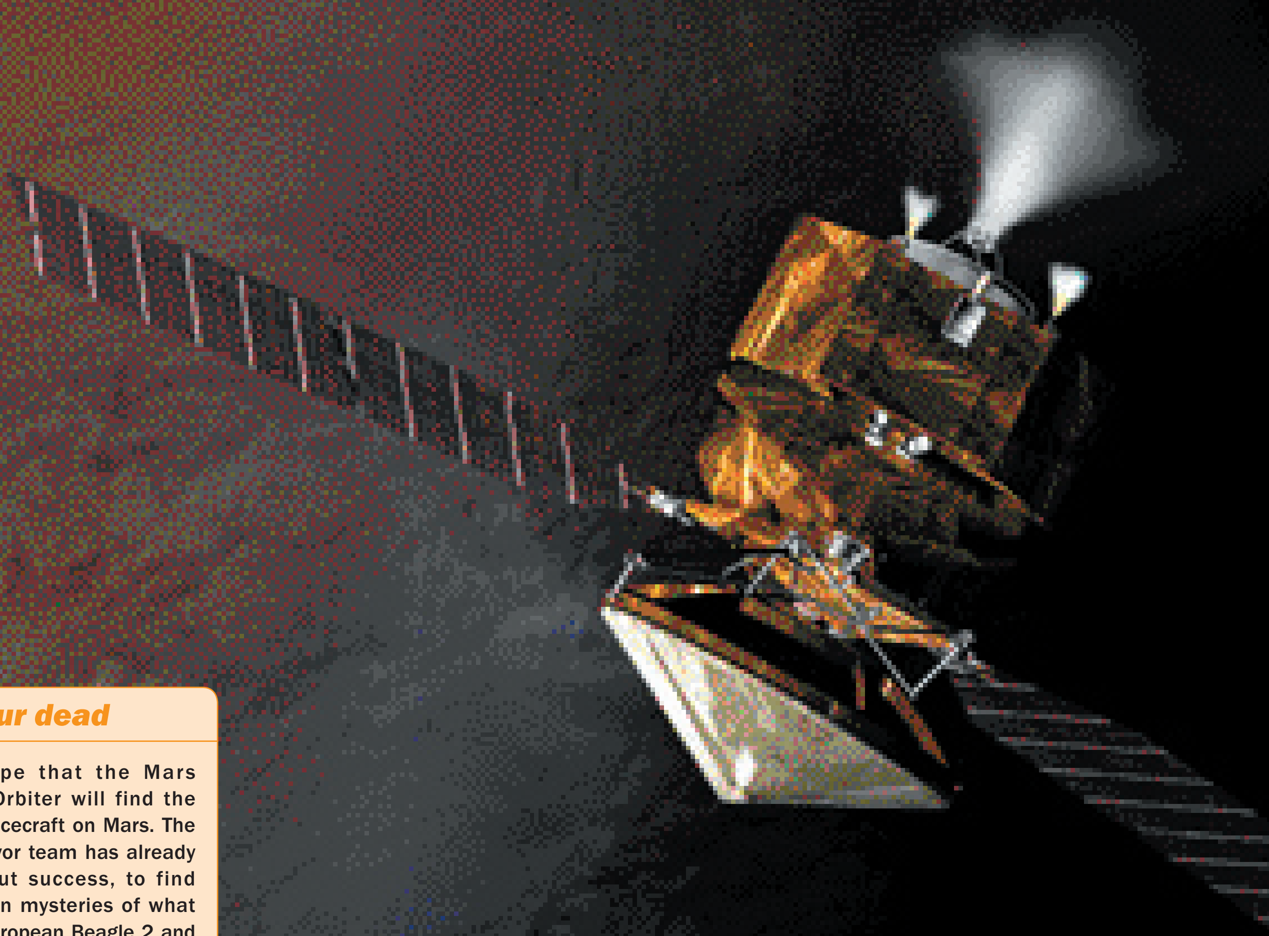
# The Martian Spy Satellite

It's big, it's bold and it promises to change the way we see Mars forever. **Donald F Robertson** takes a peek at the Mars Reconnaissance Orbiter.



The Mars Reconnaissance Orbiter will pass under the red planet's southern hemisphere upon its arrival at the planet, as seen in this artist's impression. Image courtesy: NASA.

## *Bring out your dead*

Many people hope that the Mars Reconnaissance Orbiter will find the remains of lost spacecraft on Mars. The Mars Global Surveyor team has already attempted, without success, to find answers to the twin mysteries of what happened to the European Beagle 2 and the American Mars Polar Lander. Both were lost whilst attempting to touch down on Mars. So far, there are no answers.

Although many are now looking to the HiRISE camera to find these landers, McEwen discourages the idea without dismissing it. "A huge volume of data would be needed to image all possible surface regions at full resolution. We can target specific locations that are considered higher probabilities and hope to get lucky," he says.

Workers inspect one of Mars Reconnaissance Orbiter's solar panels. Image courtesy: NASA.

**Seven** months after its August 2005 launch, NASA's Mars Reconnaissance Orbiter(MRO) will surf its way into orbit around Mars. At a hefty 2,180 kilograms, the spacecraft is no lightweight and is the first spacecraft designed from the ground up for aerobraking – using the atmospheric drag of a planet to slow down a spacecraft, modifying the probe's orbit. Get it wrong and the spacecraft will burn up as it plunges to the surface of the planet.

Despite the risks, MRO will spend about six months dipping into the upper atmosphere to lower its initially elliptical orbit, the solar arrays reaching two hundred degrees Celsius. The science mission will then finally start in November 2006, when the craft will be in a 320- by 255-kilometre orbit, with the low point over the south pole. The first picture could redefine our image of Mars.

The reason is that MRO is nothing short of a spy satellite, equipped with a huge telescope and camera assembly, called the High Resolution Imaging Science Experiment, or HiRISE camera. To put it in perspective, if there were trees on Mars (and no one thinks there are!) HiRISE would provide detailed images of each individual specimen.

## Going up

The HiRISE camera is a Cassegrain telescope with a mirror 0.5 metre in diameter. It's the largest ever sent to Mars, or to any other planet, for that matter. With a resolution of twenty-five to thirty-two centimetres per pixel, scientists will be able to identify objects on Mars about one metre across. They can combine pictures from different angles to create three-dimensional stereo views.

Dr Virginia Gulick is the scientist planning studies of fluvial and hydrothermal processes from NASA's Ames Research Center near San Francisco. According to her, HiRISE will be as big an improvement over the current Mars Observer as the Mars Observer was over Viking. A HiRISE photo of Mars will be like floating only a few hundred metres above the planet's surface with mountains thousands of metres tall and canyons similarly deep.

Superlatives are all very well but, looking in great detail at a few small areas, of something as large and complex as a whole world, presents serious problems. For all its observational power, the Mars Reconnaissance Orbiter's primary camera will be limited by two factors.

The first is the number of pictures that can be taken during the single Martian year (two Earth years) mission. Even though data will flow to scientists on Earth faster than ever before, it will still take four to forty-eight hours to return each full-sized 20,000 by 40,000 pixel image, depending on the compression used and the distance to Earth. These constraints will limit the primary mission to just ten thousand pictures, of which only some three thousand will be full sized.

Secondly, each picture will cover a very small part of the planet. Only one-tenth of one percent of the planet will be imaged at the best resolution, and only about one percent will be photographed at 1.2 metres per pixel or better. The Mars Reconnaissance Orbiter will explore a few locales on Mars with incredible detail, but it will also ignore most of a world with as much surface area as all the continents on Earth.

Project scientists are aware of these issues. The HiRISE optics are designed for relatively wide angled photos, six kilometres wide on the surface. In reality, HiRISE won't see just one tree-sized boulder, it will see a small region full of such objects. So a context camera will take moderate resolution photos with a thirty-kilometre width surrounding each HiRISE image, letting scientists see the lie of the land. According to HiRISE Principal Investigator, Dr Alfred S. McEwen, even these images, at six metres per pixel, would be considered "high resolution on most spacecraft."

A third camera, the Compact Reconnaissance Imaging Spectrometer for Mars, or CRISM, is sensitive to certain chemicals and minerals likely to have been left behind when water evaporates. It will look for evidence of hot springs and for the salt deposits on ancient lakebeds in the bottom of craters and other low-lying areas.

Dr Scott Murchie, Principal Investigator for CRISM and Supervisor of the Planetary Surfaces and Atmospheres section of Johns

Hopkins University's Applied Physics Laboratory, told *Astronomy Now*, "It is our plan for every HiRISE image to be accompanied by a CRISM observation with one-hundred metres resolution in seventy spectral bands – what we call a 'ride-along' image." These will provide the mineralogical context for each detailed HiRISE image. Only areas deemed to have the highest scientific priority will get the full 544 spectral band observation at fifteen-metre resolution.

**Photos like this one of Elysium Mons from the Mars Global Surveyor could look as old fashioned as sepia, when Mars Reconnaissance Orbiter starts work. Image courtesy: NASA/JPL/Arizona State University.**

## What lies beneath?

Another instrument called the Italian Shallow Subsurface Radar will directly map the interfaces between rock and any frozen or liquid water present within a kilometre of the surface. To be detected, an aquifer would need to be at least three hundred metres to three kilometres across. Other experiments will probe the atmosphere and test new technologies for future missions to Mars, e.g., autonomous navigation using positions of the two Martian moons.

Used carefully, an ultra-high resolution camera like HiRISE will tell scientists a lot. For example, at the Martian poles, the Mars Global Surveyor currently in orbit is seeing "layering down to the limit of resolution," said Dr Ken Herkenhoff of the United States Geological Survey Astrogeology Team and the scientist in charge of the Mars Reconnaissance Orbiter's polar geology observations.

Focusing in on the smallest layers, the HiRISE camera may "help us address some embarrassingly simple questions. For example, what is the typical timescale of layer deposition – a day? a year? a thousand years? Do they record Martian climate variations, like ice ages on Earth? If so, can we relate the stratigraphy to theories about changes in Mars' axis of rotation?" In each case, detailed observations of the fine layers can tell scientists about global processes.

"Variations in the amount of dust in the ice cause the layering, but we don't know how much dust nor how it is distributed," added Herkenhoff. To determine that, "the topography of the surface of the layered deposits must be known. HiRISE stereo observations will allow us to derive accurate topography."

HiRISE's ability to see the humble boulder in unprecedented detail should help answer many long-standing questions about Mars. For example, are the northern planes the ancient bottom of a vast ocean, as some scientists believe? According to a paper by McEwen and others, a gentle, fine-grained ocean deposit should have only the occasional ice-rafted boulder. If large numbers of rounded boulders were found, that would imply relatively violent deposition in mudflows or floods. On the other hand, if HiRISE sees boulders mixed with dunes, that would indicate the dunes were created under flowing water rather than by wind. Boulders deposited in glacial moraines should be clearly visible to HiRISE.

Meanwhile, CRISM will be using its infrared spectroscopic images to search for hints of recent volcanic activity on Mars. Volcanism usually involves gases that condense out onto the surface. Could CRSIM see these? Murchie says yes. "Volcanic gases do yield condensates and reaction products detectable by CRISM, especially sulphates." But he suggests a better strategy for detecting very recent volcanism using his instrument: "Most materials on Mars have a dust coating, but really fresh lava would be distinguished by [the absence] of the spectral signature of Martian dust." However, in the Martian context, 'recent' is usually applied to deposits that could be thousands to millions of years old and CRISM would detect relatively dust-free deposits only months or years old. So, identification of million-year-old lava flows would rely mostly on the morphology and lack of craters as determined by HiRISE and the Context Imager, according to Murchie.

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## Martian bugs?

Evidence for very early life on Earth comes from fossilized microbial mats, the remains of colonies of single-celled organisms. When NASA's Opportunity Rover found the apparent remains of a large body of standing salt water, scientists realised the possibility of colonies on early Mars.

On Earth, fossilized microbial mats can be quite large. Asked whether CRISM could detect them on Mars, Murchie said, "There are several kinds of minerals associated with microbial colonies that CRISM could detect, including carbonates and ferric oxides. We can detect as a patch features as small as thirty-eight metres across. Even smaller occurrences of minerals can be detected – but not spatially resolved – by their 'diluted' spectral signature."

Murchie added that his instrument could also detect "other minerals indicative of aqueous environments where such colonies could occur including clays, sulphates, and nitrates." So that answer appears to be: maybe.

## Myopic Mars craft?

The Mars Reconnaissance Orbiter is a large and complex spacecraft undertaking a difficult mission. That brings up another risk when sending complex instruments far from Earthly repair people. The HiRISE camera was built by the same institution that built the blurred Deep Impact camera. Asked if the same problem might crop up at Mars, McEwen explained, "HiRISE operates at room temperature rather than –130 degrees C like the Deep Impact camera. It has been much easier to calibrate and focus. HiRISE also has a focus mechanism with far more margin for error than we expect to need."

A bigger limit on camera performance will be the stability achieved by the spacecraft. The solar arrays and, if need be, the high-gain antenna may be paused during picture taking, before they resume tracking of the Sun and Earth.

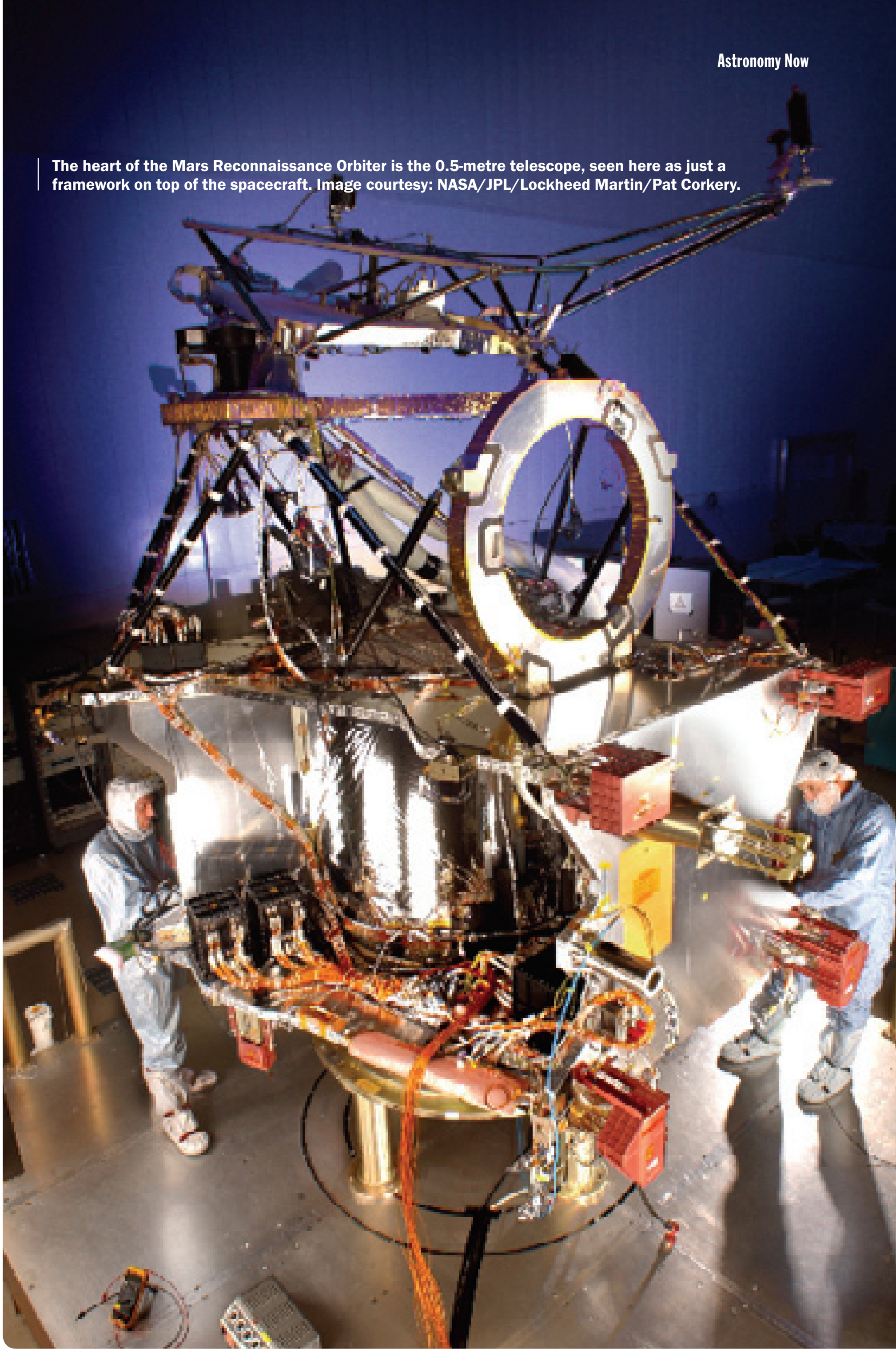
Herkenhoff, in addition to his role as a polar scientist, is the lead scientist involved in calibrating the camera. Since the telescope and its large mirror are being built in Earth's gravity, being launched out of that gravity could significantly distort the ultra-sensitive instrument. "We cannot adjust the shape of the mirror," says Herkenhoff. Instead, the camera will observe the star clusters Omega-Centauri, M-11 and the Pleiades during flight to measure the exact geometry of the optics. "We will build a computer model of the camera that includes any distortions and use that to remove the effects from the images using image processing software."

This is not unusual, according to Herkenhoff, who says, "All optical systems have some level of distortion, requiring that the images be re-projected to remove it. This step will be part of the processing that will take raw HiRISE images and project them onto a topographic model of the Martian surface."

When asked whether the resolution could be increased by lowering the spacecraft's orbit, McEwen stated that the atmosphere and planetary protection regulations, to prevent any terrestrial microbes on the spacecraft from reaching the Martian surface alive, preclude lowering the orbit. However he added, "We could increase resolution in the down-track direction by using the same type of roll manoeuvre used by the Mars Global Surveyor to point at one location as the spacecraft passes by overhead". The roll along track slows down the motion of the camera's field-of-view across the surface by about one-third, allowing the camera to acquire three times as much data for a given area along the spacecraft's path over the surface.

Practically, that will not make the surface resolution three times better, but it can result in pictures that are approximately fifty percent sharper and with a better signal-to-noise ratio, according to McEwen.

So, would McEwen like to send an even larger camera into orbit around Mars to see still more detail? "There is no theoretical limit – unless it is so big that it blocks the Sun and shades the planet you are trying to image," he jokes. "The bigger the better."



The heart of the Mars Reconnaissance Orbiter is the 0.5-metre telescope, seen here as just a framework on top of the spacecraft. Image courtesy: NASA/JPL/Lockheed Martin/Pat Corkery.

*Donald F Robertson is a freelance space industry journalist based in San Francisco.*