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THE MARS OBSERVER

How the reclusive Mike Malin changed the way that scientists view Mars.

BY ERIC HAND

It is sometimes said that Mike Malin knows Mars better than anyone else on Earth. A more verifiable statement is that Malin has seen more of Mars than anyone on Earth. His company, Malin Space Science Systems (MSSS) in San Diego, California, has designed cameras for every one of NASA's Mars-orbiting missions since Viking in 1975. Later this week, Malin will see the start of his ninth mission to the red planet, when a launch window opens on 25 November for Curiosity, the US$2.5-billion NASA rover that is carrying three of his camera systems.

Malin's devices are the eyes of the rover, the most costly and complicated Mars mission in a generation. The pictures taken by his cameras will help engineers to steer the machine; they will also be central to the scientific aim of the project: to determine whether Mars had suitable conditions for life billions of years ago.

When the images start streaming back from Curiosity, some nine months after launch, the best shots are likely to end up in Malin's hall of fame, the library inside his company's two-storey office building. A sanctuary in which the reclusive scientist can work alone, the library is strewn with copies of *Aviation Week & Space Technology*, which Malin says he has subscribed to since he was 14. In racks along the walls are poster-sized images of Mars taken from orbit. They display the wildly variegated terrain that has challenged scientists' understanding of the planet: scorched plains, dead volcanoes, mountainous dunes, chiselled canyons and the massive holes in the ground left by asteroid strikes. Everywhere he looks, Malin sees a land carved by wind, water and time. "I like these big prints," he says. "You see much more in them."

At 61, Malin no longer has the physical stamina for the geological field trips that took him to the ends of the Earth to help understand analogous Martian landforms. But he still knows how to aggressively interrogate an image. He gets down on his hands and knees and, with a magnifying glass, puts his eyes inches above a Mars image he has laid flat. “What you can do with pictures is pretty limited,” he says. “But it’s mostly limited by your imagination.”

Prickly and driven, Malin is a unique force in the world of planetary science. Almost without exception, the instruments that NASA sends to other planets come from big government research centres and leading universities. But Malin’s company of 30 people has managed to corner the market both in the cameras that get sent to Mars and the discoveries that they provide. “Here’s this little company that’s been trusted to do it,” says Phil Christensen at Arizona State University in Tempe. “It’s amazing.”

Yet Malin feels that he struggles to gain respect — and to get his cameras onto missions. And he complains that other researchers have not sufficiently adopted his vision of Mars — as a planet with layers of sedimentary rock created and sculpted by water and wind. Yet the leaders of the Curiosity mission chose its landing spot, the Gale crater, precisely because it will allow them to study the sedimentary patterns there. Anybody but Malin would see that as a vindication of his work.

THE WHOLE PICTURE

Malin’s cameras on Curiosity are sometimes overlooked amid the scientific gadgetry packed onto the 900-kilogram rover. One of those instruments is a laser that can vaporize distant rocks and, in the flash of light, look for tell-tale chemistry. Another will prepare thin samples for X-ray diffraction, a challenge even in a laboratory on Earth. Perhaps the most important instrument is the Sample Analysis at Mars, which will ingest rock samples and tease out their molecular make-up using gas chromatography and mass spectrometry in the hope of spotting an organic molecule — a sign that Mars once had a habitable environment.

The cameras are slightly more prosaic. They are much like modern digital cameras, but built to withstand the rigours of an interplanetary journey and years of dust storms and frigid temperatures on Mars’ surface. The largest of Malin’s systems are the Mastcams: two cameras on the rover’s neck that stand 2 metres off the ground and will survey the terrain. A second system, a microscopic imager fixed to the end of a robotic arm, will have sufficient resolution to see, for the first time, grains of silt. And a third, attached to the underside of the rover’s chassis, will monitor Curiosity’s descent and landing.

All these devices come from a man who once wanted to be a trombonist. Born in 1950 to a shoe-store manager and a secretary, Malin spent a large part of his teenage years obsessively practising the instrument. The extraordinary effort, he says, was triggered by a music teacher who suggested that he didn’t have the chops for it. He eventually became good enough to play with the Los Angeles Philharmonic and considered attending a conservatory. “If you ever want Mike to do something, tell him he can’t,” says Christensen. “He very much has an ‘I’ll show you’ personality.”

Nevertheless, Malin ended up choosing space science over the arts. He did his graduate work in the early 1970s at the California Institute of Technology (Caltech) in Pasadena, and was mentored by Bob Sharp, considered by many to be the father of planetary geology. Afterwards, Malin had a stint at NASA’s Jet Propulsion Laboratory at Caltech, a place with which he continues to have a love–hate relationship. He admires the lab’s planetary missions and its starry-eyed romanticism for the cosmos. But he disliked the bureaucracy, and often butted heads with managers. “I have a personality that chafes at large institutions,” he says.

Malin ran up against similar constraints at Arizona State University, which he joined in 1979. He thrived as a researcher, making a name through his geological studies in Antarctica — an analogue for Mars. But he grew to hate the committees and collaborations that are a part of so many university jobs. Malin is not necessarily antisocial, but he does do his best work alone. Christensen recalls a time when Malin invited him over for dinner, but the only furniture in Malin’s bachelor pad was an easy chair and a television. They ate from trays in front of the television, Malin sitting in the chair and Christensen on the floor. “It never occurred to him to have more than one chair in his living room,” he says. And even though Malin now lives alone in the up-market coastal community of La Jolla, California, he doesn’t bother going to the beach.

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In the mid-1980s, NASA began talking about a flagship Mars mission, the first since Viking, to be called Mars Observer. The many instruments on the orbiter — radiometers, spectrometers and laser altimeters — were expected to revolutionize the study of the planet’s surface, atmosphere and magnetic fields. Strangely, Malin’s call for an optical imaging camera drew little support. Few, he says, saw a need for mapping at a resolution sharper than the average of 50 metres per pixel that the Viking orbiters achieved. “There was this idea that we had mapped Mars with Viking, and there was no need to map it further,” he says.

But based on his fieldwork on Earth, Malin was convinced that greater visual detail would reveal the processes that played a part in shaping the surface. It was only after a last-minute intervention from NASA headquarters that Malin was given a contract to build and operate the Mars Orbiter Camera (MOC).

But where was he actually going to build it? The answer came in 1987, when Malin won a MacArthur ‘genius’ award and used the $250,000 prize as seed money to found MSSS. There he developed a camera design for Mars Orbiter whose innovations would be copied on many subsequent missions.

Up to that point, Viking and other planetary missions had used framing cameras, which worked in the conventional way: a shutter opened and allowed light to hit an array of sensors. But Malin designed what is known as a push-broom camera. It had a permanently open aperture that funnelled light to a single line of charge-coupled devices (CCDs), at the time a new technology.

The continuous movement of the orbiting spacecraft provided the second dimension. Each time that data were read out from the line of CCDs, the spacecraft had moved forward a bit; an image was thus built up over time, one line at a time. This design eliminated the need for any moving parts, such as shutters, in the camera — always a liability on a space mission — and allowed resolutions as good as 1.5 metres per pixel.

“WHAT YOU CAN DO WITH PICTURES IS PRETTY LIMITED, BUT IT IS MOSTLY LIMITED BY YOUR IMAGINATION.”

Before the camera could prove itself, though, the mission came to an abrupt end. Just a few days before Mars Observer was supposed to enter Martian orbit in August 1993, a fuel line ruptured and the craft flew off into space. Malin suddenly had to lay off half the employees in his fledgling business. But he soon earned a second chance. A replica of the MOC became the centrepiece of the 1996 Mars Global Surveyor mission, which entered Mars orbit in 1998. And as he prepared for the deluge of data that would come from the camera, the famously individualistic Malin realized that he would need a scientific sidekick.

He found one in Ken Edgett, who was just finishing his PhD under Christensen at Arizona State University. Today, Edgett works in an office near Malin’s second-floor library. A large, laid-back man, he slouches in his office chair with his shirt untucked. At the mention of a particular Mars image, he leans into his workstation and types in an MOC number: FHA-1858. “I know this one by heart,” he says.

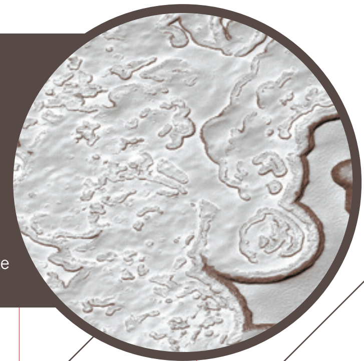
That image changed everything in Mars science, Edgett says. It

FOCUS ON MARS

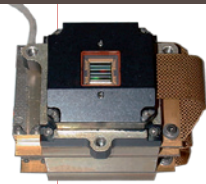
Michael Malin and his company, Malin Space Science Systems (MSSS), have built cameras for nearly all missions to Mars since the Viking programme in the 1970s.

NOVEMBER 1996
The Mars Global Surveyor spacecraft takes off with the Mars Orbiter Camera (MOC), a near clone of the imager on the failed Mars Observer. MOC operated from 1997 to 2006, taking more than 240,000 images.

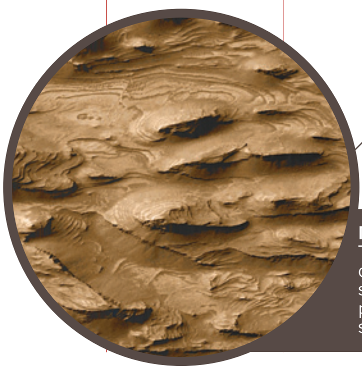
FEBRUARY 2000
A MOC image of the south polar region reveals pits and other signs of erosion in the frozen carbon dioxide ice cap. The Swiss-cheese pattern indicates that Mars is undergoing climate change.



APRIL 2001
Mars Odyssey launches, carrying the MSSS-built visible imager, part of a dual camera that captures both thermal and visible wavelengths.

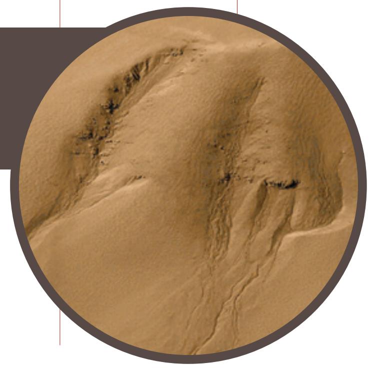


1996 1997 1998 1999 2000 2001 2002 2003



MARCH 1999
The MOC discovers layered deposits at Candor Chasma, suggesting that sedimentary processes were important in shaping the Martian surface.

SEPTEMBER 1999
The MOC discovers gullies on the wall of a crater, leading to the controversial suggestion that liquid water may still be active on Mars.



MSSS (MOC); NASA/JPL-CALTECH/MSSS (MARS IMAGES); NASA/JPL/ARIZONA STATE UNIV. (IMAGER)

showed a region, called Candor Chasma, that had been carved into notched canyons and ziggurat-like steps[1] (see 'Focus on Mars'). The terracing had an enormous implication: these were once layers of sediment, probably laid down by water. And to get so many layers, water must have been at work for millions of years. It was the first solid evidence of a water-sculpted Mars.

The picture soon ended up on the cover of *Science*. It was one of four such covers for Malin and the MOC team, highlighting papers that touched on everything from the possibility of near-surface water flowing in large gullies today[2], to the ever-changing Swiss cheese of frozen carbon dioxide at the poles that indicates ongoing climate change[3]. The MOC images also revealed the substantial sedimentary layering within a mysterious mound at the centre of the 154-kilometre-wide Gale crater — evidence that would eventually lead researchers to choose that site as the target for the Curiosity rover.

All those discoveries vindicated Malin, and his long push to get something like the MOC to fly. "It really changed our views of the planet," says Jim Bell, a geologist at Arizona State University who is the principal investigator for the cameras on Spirit and Opportunity, small rovers that landed on Mars in 2004. "It set the tone and the goals for the Mars programme that we're still pursuing today."

Not that Malin sought the limelight or found comfort in the recognition. He had to be dragged to press conferences, and cajoled into releasing data and writing up papers. He also demanded an unusual amount of control. With the MOC, Malin and Edgett personally chose the targets for nearly half of the 243,227 images it took. Because the MOC swivelled independently, the two researchers did not have to worry about any other instrument on the Mars Global Surveyor spacecraft. But on Curiosity, Malin's mast cameras will serve as the eyes for the other instruments. He will have to balance pursuing his own scientific goals with doing the reconnaissance needed to guide the sampling by the other instruments.

Some are worried that Malin and Edgett will find it hard to defer to the needs of others. "These are guys who like to do it their way," says Christensen. "They're not necessarily team players."

The members of Curiosity's science team will need to work together if they are to crack the mystery at the centre of the Gale crater: a 5-kilometre-tall mountain of stacked sediments that reaches above the crater's rim. At some point, a massive amount of material must have filled the crater and buried it completely. Then erosive forces must have stripped most of the sediment away, leaving only the mound behind.

Curiosity is supposed to find out how sediment got into the hole, and how it got out. The working hypothesis is water and wind, acting over immense stretches of time. Researchers judge that the oldest sediments at the bottom were deposited 3.8 billion years ago, when Mars was thought to be warm and wet, and that the rock at the top of the mound represents a vastly different era some 200 million to 300 million years later, when Mars was growing colder and dryer[4].

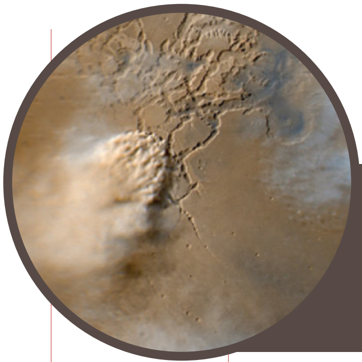
As it climbs upwards from the bottom of the mound, the rover will provide geologists with an unparallelled opportunity to study Martian history up close. By comparison, the Opportunity rover has traversed just 100 metres of strata in its nearly six years of exploration, according to John Grotzinger, Curiosity's project scientist at Caltech. "That is the gift of Gale," he says. "You know you're going to get a walk through time."

Although no one is willing to admit it, all on the team secretly hope that the rover, lasting a decade or more with its nuclear power source, could somehow make it to the top. A panoramic image taken from that vantage would surely be one for the ages — and yet it would be a bittersweet achievement for the man whose cameras would capture it. For although almost all the instruments on Curiosity are big steps up in capability from the sensors on Spirit and Opportunity, the Mastcams offer only an incremental improvement. That is not the way Malin had wanted the story to go.

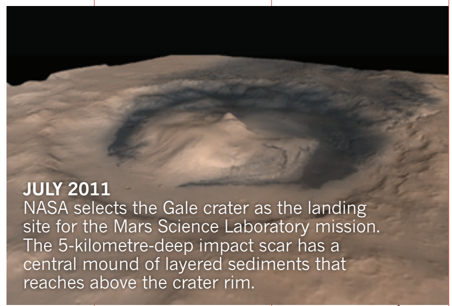
LOST FOCUS

Mike Ravine enters a storage room at the MSSS offices, flicks on the lights and considers two plastic boxes. He unlocks them and opens their lids — but does not touch the cameras inside, "The only time I've ever not delivered something was that," he says, stabbing his finger at the cameras. "It's disturbing to have been so close."

The advanced-projects manager at MSSS, Ravine is another employee



DECEMBER 2008
A second MSSS-built camera on the Mars Reconnaissance Orbiter, the Mars Color Imager, has monitored planet-wide weather patterns and captured the thick churning clouds of dust that sometimes rise out of canyons.



JULY 2011
NASA selects the Gale crater as the landing site for the Mars Science Laboratory mission. The 5-kilometre-deep impact scar has a central mound of layered sediments that reaches above the crater rim.

2004 2005 2006 2007 2008 2009 2010 2011

AUGUST 2005
The Mars Reconnaissance Orbiter spacecraft launches with the MSSS-built Context Camera, a wide-angle imager that has mapped more than two-thirds of the planet at a resolution of 6 metres per pixel.

NOVEMBER 2011
The Mars Science Laboratory mission is scheduled to launch, carrying the rover Curiosity with three cameras built by MSSS.

MSSS (CONTEXT CAMERA); NASA/JPL-CALTECH-MSSS (MARS IMAGES); NASA/JPL-CALTECH (CURIOSITY)

cut from the Malin cloth: clever, driven and a bit combustible. As well as working for MSSS, Ravine has launched an Internet start-up company, produced a movie and cultivated Hollywood contacts including the director James Cameron, whom he convinced to join the Curiosity camera team. They planned to develop twin 'zoom' cameras, which could switch rapidly between wide-angle panoramas and narrow, high-resolution close-ups. With high-definition and near-video capabilities on the cameras, Cameron would make three-dimensional movies for the public.

But with Curiosity running over budget in 2007, NASA demanded that the mission trim \$39 million from its instrument packages. The zoom cams had to be scrapped, even though Malin says that they were neither over budget nor behind schedule. Malin's team quickly designed two cheaper, fixed-focus cameras instead, one with a wide field of view, and one a narrow.

Ravine had one last chance to rescue the zoom cams when problems with the rover's motors forced NASA to delay the mission's launch from 2009 to 2011. He and Cameron flew to Washington to see NASA administrator Charles Bolden and convinced him to put the zooms back.

But by then, time was too short. There were problems with the alignment of the lenses and Malin's team could not fix them quickly enough. In March 2011, with most of the rover assembled and ready to go, NASA ordered the conventional cameras to be put on. Malin is still full of regret. He wonders how it would have gone had his team been able to work on the zoom cams all along. "They should never have been de-scoped," he says.

In February, just a few weeks before NASA shelved the zoom cameras for good, Malin had a heart attack. He'd already had one, two decades ago, and a stroke six years ago. But neither deterred him from long days and nights of work.

This time was different. Malin needed a quadruple bypass. As he recovered from surgery, his absence at the office was palpable. His employees — the closest thing Malin has to a family — wondered about their future.

Six months later, Malin is back, tethered to an iPhone that reminds him to take his medicine. Doctors have told him to curtail his workaholic hours. But on this September day at the office, Malin is as intense as ever. He enters an empty, cavernous room about the size of a basketball court, and offers a glimpse of his vision for the future of Mars exploration.

MARS ON EARTH

"As a kid I thought I'd be the first person on Mars," he says. "That ain't gonna happen." Instead, he wants to bring Mars to Earth, or at least to use his cameras to give people a feel for the richness of another world. Malin paces off a circle in his empty room, winking at an imaginary point in the centre to mimic the snapshots he would like his Mastcams to take on Mars. In this painstaking way, he would build a three-dimensional data set of a rock or other object of interest to scientists. Then, with the help of a virtual-reality helmet, Malin could recreate the view back in this room in San Diego. Geologists could peer in close, look behind a rock, or even explore it virtually using the rover's arm. And, ever the business man, Malin says that people might pay for the virtual trip to Gale crater. "Basically, you'd walk around — and you'd be on Mars!" he says.

Malin has told some of his colleagues about the idea. Although they've offered murmurs of support, he knows that it will be up to him to make things happen. It will certainly be tougher without the zoom cameras or the full support of an Oscar-winning director. But never count Malin out. It took him years to convince his colleagues of the importance of a sedimentary Mars — and now they're sending a multibillion-dollar rover to the largest mound of stacked sediment in the Solar System.

Standing in the vacant room, Malin surveys the space. But you know that, in his mind, it's already a Martian landscape. "It's not real to people because they don't see it," he says. "I'm going to make it real." ■

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Eric Hand *covers physical sciences for* Nature *in Washington DC.*

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3. Malin, M. C., Caplinger, M. A. & Davis, S. D. *Science* **294,** 2146–2148 (2001).
4. Thomson, B. J. *et al. Icarus* **214,** 413–432 (2011).