Built to last

Well beyond their 'best by' dates, Spirit and Opportunity continue to collect data from the surface of Mars. By **Graham Pitcher**.

When NASA sent the Spirit and Opportunity Rovers to Mars in 2003, the plan was for the vehicles to operate for 90 days; anything more would be a bonus. But six years later, the Rovers are still working; even if one of them is currently bogged down in the equivalent of a Martian sand trap.

Bearing in mind that Mars is not the friendliest of environments for such devices to work in, what was so special about their design? Why are the Rovers still in action?

Jake Matijevic, chief engineer for the Mars Rovers with NASA's Jet Propulsion Laboratory (JPL), said there is no difference between the two vehicles. "They're identical in that they were built using the same environmental guidelines. They have the same payload and were built together."

What was the top level design contstraint? "Mobility," said Matijevic. "Basically, we created a drive system, suspension and control system, then built the vehicles based on what can effectively be done on the surface of Mars."

Beyond that are a number of other constraints, led by how much each Rover can weigh – both weigh 185kg – and the physical volume that is available in the launch platform. Finally, and just as important, the payload is determined by the way in which the Rovers would be landed on Mars – both devices were landed using an airbag structure.

The mission required vehicles that could explore a small area around their landing site and to perform some local analysis. "In a way," Matijevic continued, "the mission was a sequel to what was put together and flown in Pathfinder. There were similar sensing elements, a camera and in situ investigation equipment. It was just a matter of putting it all together on a new platform."

NASA had wanted to include sample storage, but that element dropped from the mission because there wasn't enough funding.

Matijevic said the Rovers 'decide' what to look at using input from their remote sensing instruments. "They work out what looks like an interesting target. Once in position, local instruments – such as a spectrometer and an alpha particle analyser – are deployed and work together."

These operations are controlled by a central computer. The computer in each Rover features a 32bit Rad 6000 microprocessor – a radiation hardened version of the PowerPC processor running at 20MIPS. Onboard memory includes 128byte of ram, as well as 256Mbyte of flash memory and smaller amounts of other non volatile memory, which allows the system to retain data even without power.

Once the target has been identified, the way in which it is explored has to be organised. "Decisions are made by a central sequencer," Matijevic explained. "Some instruments can work in parallel but, to a large extent, it's a matter of doing one thing and then another."

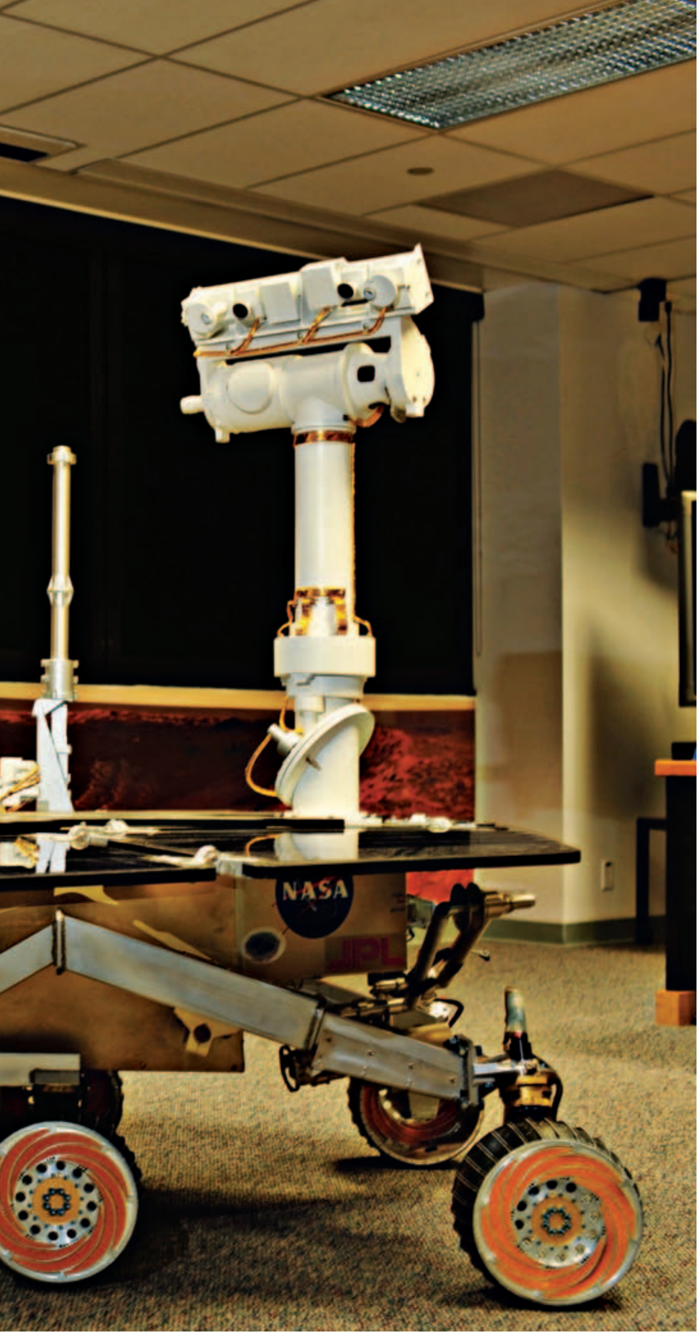
Working out what electronics could be fitted within the Rovers was determined by what Matijevic called the 'overriding' volume constraint. "The electronics have to fit amongst the other constraints and they have to be cared for; protected from the environment."

Matijevic: "We almost never have a chance to design from scratch. Instead, we use tried and tested components."

This was done by building an insulated core box with heating ability, creating an environment – an acceptable temperature range – within which the electronics can function. "This required a lot of 'give and take' with the initial sizing," Matijevic recalled, "to allow what you think will be the end requirement."

Other design issues included how to wire up individual components and where to put the support electronics. "As we went through the design phase," he continued, "we kept checking to see if we met not only mass and volume constraints, but also those of power. Once you get through the critical design evaluation, you have an idea of what can be built and where it can fit."

The Rovers were created in three



Photographs: David Butow

Jake Matijevic, chief engineer for the Mars Rovers at NASA's Jet Propulsion Laboratory, with a model of the craft in one of the Rover control rooms.

years. "That's a very intensive period," Matijevic noted, "where all the pieces have to be put together."

Interestingly, the Rovers featured a lot of previously designed electronics. "We often select from components that have already been built and used," he observed. "For example, the computer was built for the Pathfinder mission in the 1990s."

Then there's the question of the general support electronics. Surprisingly, this comes in the format of VME boards housed in a card cage. With the high levels of vibration involved in a rocket launch and a controlled, but hard, landing on Mars, one might think that board might come loose.

And Matijevic pointed out that, as far as possible, it's a COTS operation. "The precise configuration is specialised and there's quite a bit of building support equipment," he noted. "It's a leap of faith in some senses, but we're tweaking designs that have been used in previous systems. Flying VME cages had been done, so the design was available and adaptable."

It's also interesting to discover that redundancy is not always an issue. "Most of the Rover's systems are, surprisingly, single string," Matijevic said. "We had a lengthy debate about where redundancy would be acceptable, but the decision was that, for a three month mission, saving mass was more important."

The Rovers are solar powered. Both have strings of GaAs panels, producing at best, said Matijevic, 1kWhr from a day's exposure. "We went through a process in which we tried to understand what the mission performance would be during the different Martian seasons. We thought there was a reasonable chance that the Rovers would have enough energy to get through their 90 day mission and be good for another three months after that. But we didn't know what it would be like to go through a full Martian year. Over time, dust accummulates on the solar panels, which reduces energy production. Even using conservative assumptions, we thought the system wouldn't be producing enough energy after six months."

Power is stored in lithium ion batteries: a crucial improvement over previous approaches. Matijevic said: "It was a new technology at the time and had shown good charge/discharge characteristics. It has proved very robust and is one of the reasons why the mission has lasted. The batteries are still capable of charging and discharging."

Communications are another element picked up from Pathfinder. The Rovers can 'talk' directly with Earth using X band communications. "We put the antenna on a kind of paddle," Matijevic continued, "allowing a full range of coverage, regardless of the vehicle's tilt and orientation." This is supplemented by a uhf system that relays data to satellites in Mars orbit, which then transmit to Earth. "We didn't have an opportunity to try out the uhf system before launch," he said. "But everything worked fine when they got to Mars."

"We're taking advantage of the heritage of other systems with similar functions and similar parts. We're somewhat driven by time, which means we almost never have a chance to design from scratch. Instead, we use tried and tested components," Matijevic concluded.