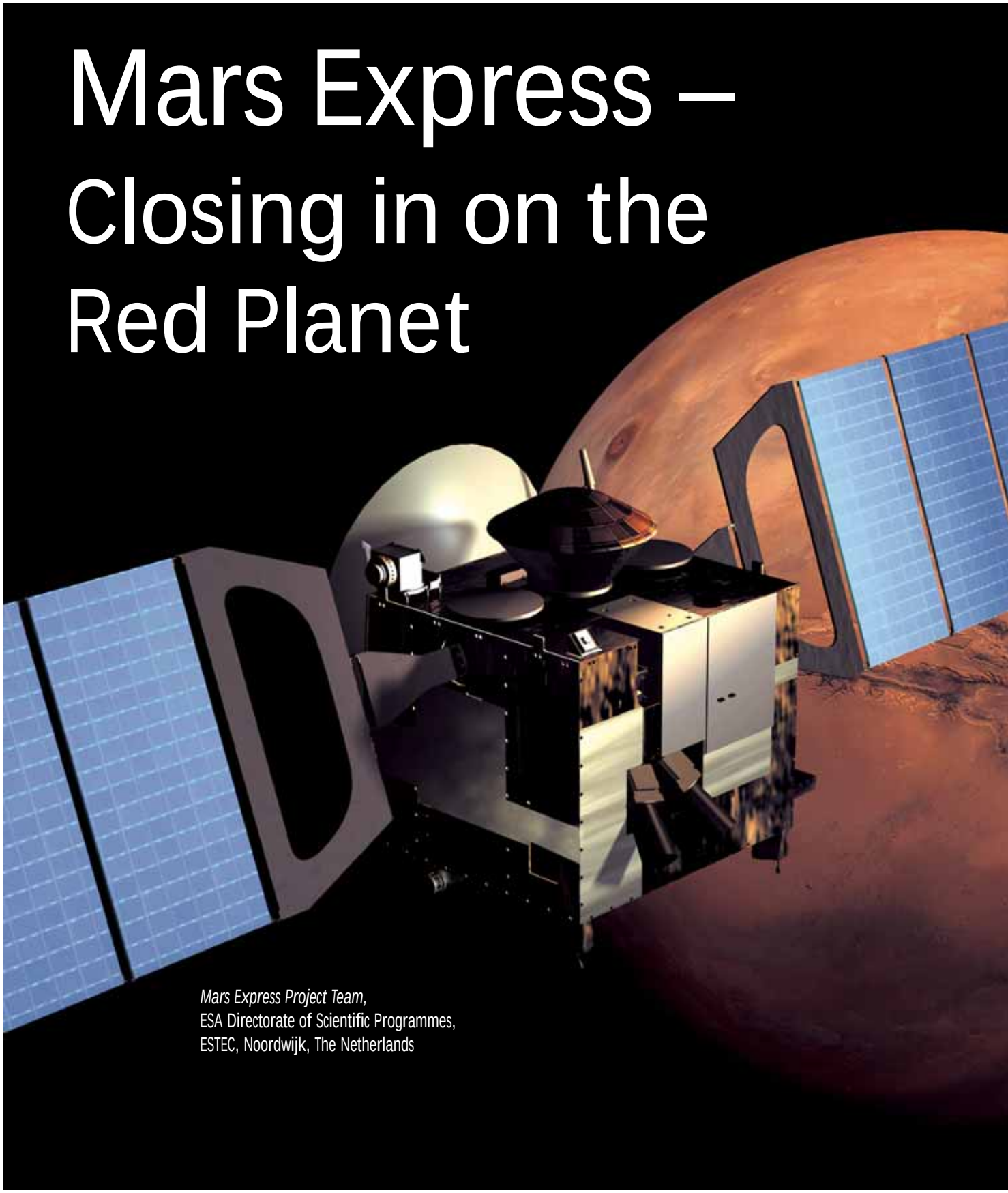
Mars Express – Closing in on the Red Planet



Mars Express Project Team,
ESA Directorate of Scientific Programmes,
ESTEC, Noordwijk, The Netherlands

Artist's impression of the Mars Express spacecraft on its way to the Red Planet

Europeans are now closer to Mars, at least metaphorically speaking. The first planetary mission managed entirely by Europe, Mars Express, is currently on its way towards the Red Planet, where it is due to arrive in December this year. The spacecraft goes into orbit around the planet, having first released a lander designed to search for Martian life!

The whole European space sector will then have all the more reason to celebrate. Thanks to the Mars Express mission, European engineers and scientists will have mastered not only how to land on another planet, but to do it with 'state of the art' technology, developed in a record-breaking time and at half the usual cost. This is their story.

The launch of Mars Express from Baikonur on 2 June 2003

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The Mars Express adventure began on 2 June 2003, with the spacecraft's launch by a Russian Soyuz-Fregat rocket from the Baikonur Cosmodrome in Kazakhstan. The total 'time-to-destiny' will be less than seven months, which is especially short for the long trip from Earth to Mars because ESA's engineers are participating in a game of 'planetary billiards'.

Launch opportunities to go to Mars from the Earth occur every 26 months, when the Sun, Earth and Mars form a straight line. However, because the orbits of both planets are elliptical, not all such 'oppositions' are equal. During this year's opposition, Mars and the Earth will be especially close, the closest they have been in nearly 60 000 years. The benefits for space agencies to go this year are clear – swinging from one planet to the other takes less time and fuel. It is as if this particular space trip is currently 'on sale'. This is one of the prime reasons why so many missions are visiting the Red Planet in 2003: two NASA Rovers and the Japanese Nozomi will arrive shortly after Mars Express. These new adventurers will join two other NASA orbiters, Mars Global Surveyor and Mars Odyssey, which have been on the scene since 1997 and 2001, respectively.

Mars Express is now speeding silently through interplanetary space. With its cubic structure, wrapped in its black thermal insulation and about a man's height in length, it could be seen as a giant 'space insect' with its two silver solar panels extending like wings. The lander, called Beagle 2, travels attached to one side, folded up rather like a very large pocket watch. Moving away from the Earth at an average speed of 3 kilometres per second, the spacecraft will conserve energy, doing almost nothing until about a week before its arrival at Mars. Right now there's little activity on board.

But silence and low activity are not the norm for this Mars mission. Only a few weeks ago, the ground controllers were still checking out the spacecraft configuration, as well as the post-launch survival of the seven instruments on board. Some very delicate operations took place, during which a major part of the mission was at stake. One of them was the release of the special clamps holding Beagle 2 in place during the launch.

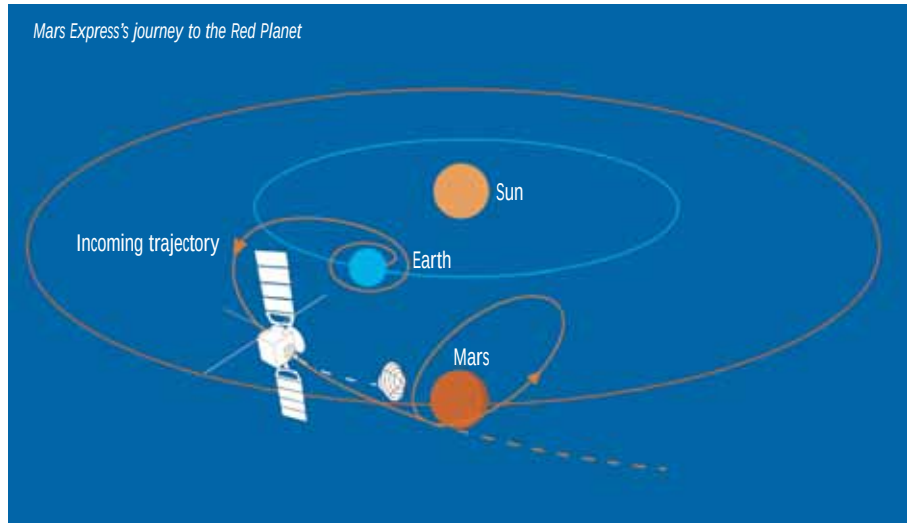


Illustration by Medialab, ©ESA 2001

"These clamps are extra means of making sure that the lander stayed perfectly attached to the spacecraft during the launch," explains Con McCarthy, Beagle 2 Principal Systems Engineer. *"Releasing them three days after the launch was a very critical operation, because if the clamps were not released correctly Beagle 2 could not be ejected on arrival at Mars, and Mars Express would go into orbit around the planet with the extra 65 kg of the lander on top."* This extra weight could have affected Mars Express operations considerably, not to mention the fact that the lander's mission would have ended before it even began.

For the Mars Express team, delicate operations like this and time pressure became routine many months before the launch. After all, this mission is not called Mars Express by chance – it has been developed quicker than any other comparable planetary mission. The design and development phase took less than four years, compared with up to six years for previous similar missions. If anything went wrong, ESA could not simply postpone the launch date. Calculations had shown that the best combination of fuel use and travel time could only be achieved by launching Mars Express in the period between 23 May and 21 June 2003. *"If we had missed the launch window, there was an 'emergency opportunity' on 28 June, with some re-arrangements in the mission. If we missed that one, we would have had to wait until 2007,"* explains Rudi Schmidt, Mars Express Project Manager.

Pioneering New Ways of Working

Mars Express has been developed quicker than any other comparable planetary mission, and at about half the cost. It took only one year to go from engineering concept to the start of development, compared to the usual five years, and it has cost 300 million Euros, compared to Rosetta's one billion Euros. What is the secret? It lies in the new managerial approach being used, which includes distributing tasks and responsibilities differently within the whole team, and the re-use of existing hardware.

Rudi Schmidt, ESA Mars Express Project Manager

Mars Express Project Manager Rudi Schmidt explains, *"Giving more responsibility to industry was a key factor. The Project Team allowed industry to take decisions faster than in the past. Also, we have enabled industry to interact directly with the launch-service provider and the scientific community. This speeds up the decision-making process and frees manpower for other tasks. Realising that all three - ESA, industry and the launch-service provider - are in the 'same boat' to Mars, we have managed to establish an excellent team spirit from the very beginning, which has helped a lot during times of high stress or technical problems."*

However, safety of the mission was never compromised. *"To ensure that quality did not suffer, we imposed a rigorous review process. We also carried out a complete test programme to ensure that we get a very reliable spacecraft. Although we had immense time pressure towards the end of the project, we did not drop any of the planned tests to save time. I call this a fast design phase followed by a thorough testing activity."*

The best way to find out how the Mars Express team dealt with their extremely tight schedule is to take a peek at their diary...

Leaving for Baikonur

"As the date for shipping the spacecraft to Baikonur draws closer, the stress and tension levels have increased dramatically, of course. Delays of minutes rather than hours, or even days, now take on a new and sometimes frightening significance," wrote John Reddy, Principle Electrical Systems Engineer for Mars Express, back in February. At that time, all development, integration and testing activities were being completed at the Toulouse facilities of Astrium, the Mars Express prime contractor. By mid March, the spacecraft had to be transported to Baikonur, almost fully integrated. *"Time waits for no man, or spacecraft,"* said Reddy.

Experienced planners well know that time is merciless, however, especially when unforeseen problems show up. This is why last-minute surprises always need to be included in the schedule. In fact, this extra provision allowed the Mars Express team to cope perfectly with its own last-minute problem. *"Just before the spacecraft was due to leave Toulouse, engineers discovered a fault in one of the electronics modules,"* said Rudi Schmidt with a smile. *"Of course, it was the most difficult box to remove from the spacecraft! When you open an electronic box in a spacecraft, you can't imagine how many wires and connections there are. It's very easy to mess something up, so you must be extremely careful."*

In the end, changing the box did not create any extra problems. The team had been working with the first days of the launch window in mind; so they simply moved the launch date back by just a few days.

The launch campaign

The spacecraft, the lander and all their accoutrements, gathered into a 100-tonne cargo shipment onboard two Russian Antonov planes, arrived at Baikonur on 20 March. A two and half month launch campaign then began. Baikonur became the temporary home of more than 70 people from all over Europe, mainly from companies such as Astrium, Starsem (responsible for the launch) and Alenia (in charge of the assembly and testing programme). Work at the launch site went on for 12 hours a day, seven days a week. As the average age of the team was 40, most of them are too young to remember the excitement that surrounded the first missions to Mars in the 1960s, when people still expected to see green creatures waving to the cameras. Nevertheless, the launch team still felt the thrill of working on a mission heading for the Red Planet.

"Being here, we sometimes feel like pioneers too," wrote Don McCoy, Mars Express Assembly Integration and Verification Engineer, on 2 May. *"It's been hard work to play our part in getting Mars Express ready to go to Mars, but we are all happy to be a part of it! The schedule to get the spacecraft ready in time for the launch is very tight. There is no room for error!"*

The first weeks of the launch campaign were devoted to tests. Only when the 'all clear' was given, did the team take the final steps to get the spacecraft ready, with the installation of the thermal blankets and the solar arrays.

The Mars Express spacecraft with its solar arrays and thermal blanket installed; Beagle is visible on the right-hand side of the craft

By the end of April, the spacecraft was ready to be fuelled with propellant, a delicate process that lasted for a whole week and took place in the Hazardous Process Facility. The next step was to mount the spacecraft on Fregat, the Soyuz upper-stage rocket, and then the whole structure onto the Soyuz launcher. This 'marriage' process took place on 24 May. The whole structure was subsequently rolled out to the pad four days before launch. *"Seeing everything taking shape as scheduled was the best reward for all of us, after having put so much effort and dedication in the launch campaign,"* said Michael Witting, Mars Express Launch Campaign Manager.

When Mars Express was finally ready for launch, what could the team still do in the days before launch? The answer is rehearse, rehearse and rehearse again. *"Once the spacecraft was mounted on the rocket and sitting on the launch pad, it doesn't mean we could sit back. We still had to perform several operations to get it ready for its voyage. Mars Express is a very complex satellite and we wanted a perfect send-off. We spent about eight hours talking to it via computers to configure it,"* wrote Don McCoy.

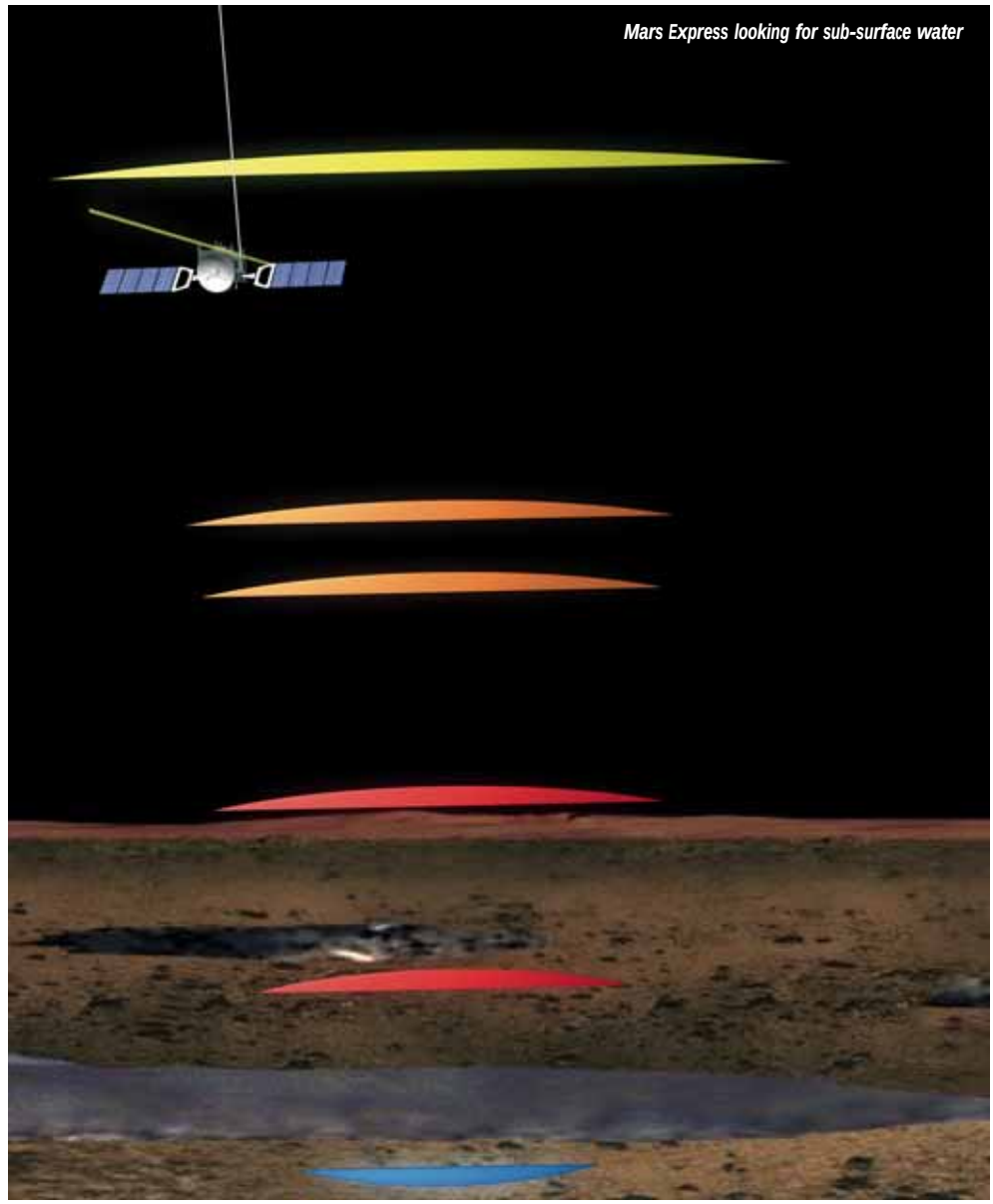
The future

Of course the most interesting part of the mission is not yet written in any diary. Full activity on board the spacecraft will resume six days before arrival at Mars with the ejection of the lander. That operation will also be one of the 'hold-your-breath' type. Beagle 2 must land on a region called Isidis Planitia, a flat sedimentary basin straddling the northern plains and the southern highlands of Mars. The landing area has the shape of a large ellipse, 300 kilometres long and 150 kilometres wide. But Beagle 2, which weights only 65 kilograms, is too light to carry a steering mechanism, and it will be unable to receive commands from Earth. So, how will it manage to land where planned? The answer is simple: engineers have calculated very precisely where and at what speed Beagle 2 has to be ejected from the Mars Express orbiter. Putting theory into practice, however, won't be as simple. The operations leading up to Beagle 2's release will take two days, and engineers regard it as one of the most complex phases of the whole mission.

The integration of Mars Express into the launcher's fairing

Ejection of Beagle 2 from the Mars Express spacecraft

The Beagle 2 landing sequence


Mars Express looking for sub-surface water

"Beagle 2 is fixed to the spacecraft with a spin-up and eject device," explains Rudi Schmidt. *"This device will be released by firing a pyrotechnic charge six days prior to Mars arrival. This will give Beagle 2 a certain forward speed - about 0.5 metres per second - and a rotation at the same time. The rotation has pretty much the same effect as with a child's spinning top. It stabilises Beagle 2 while it flies towards its landing site on the surface."*

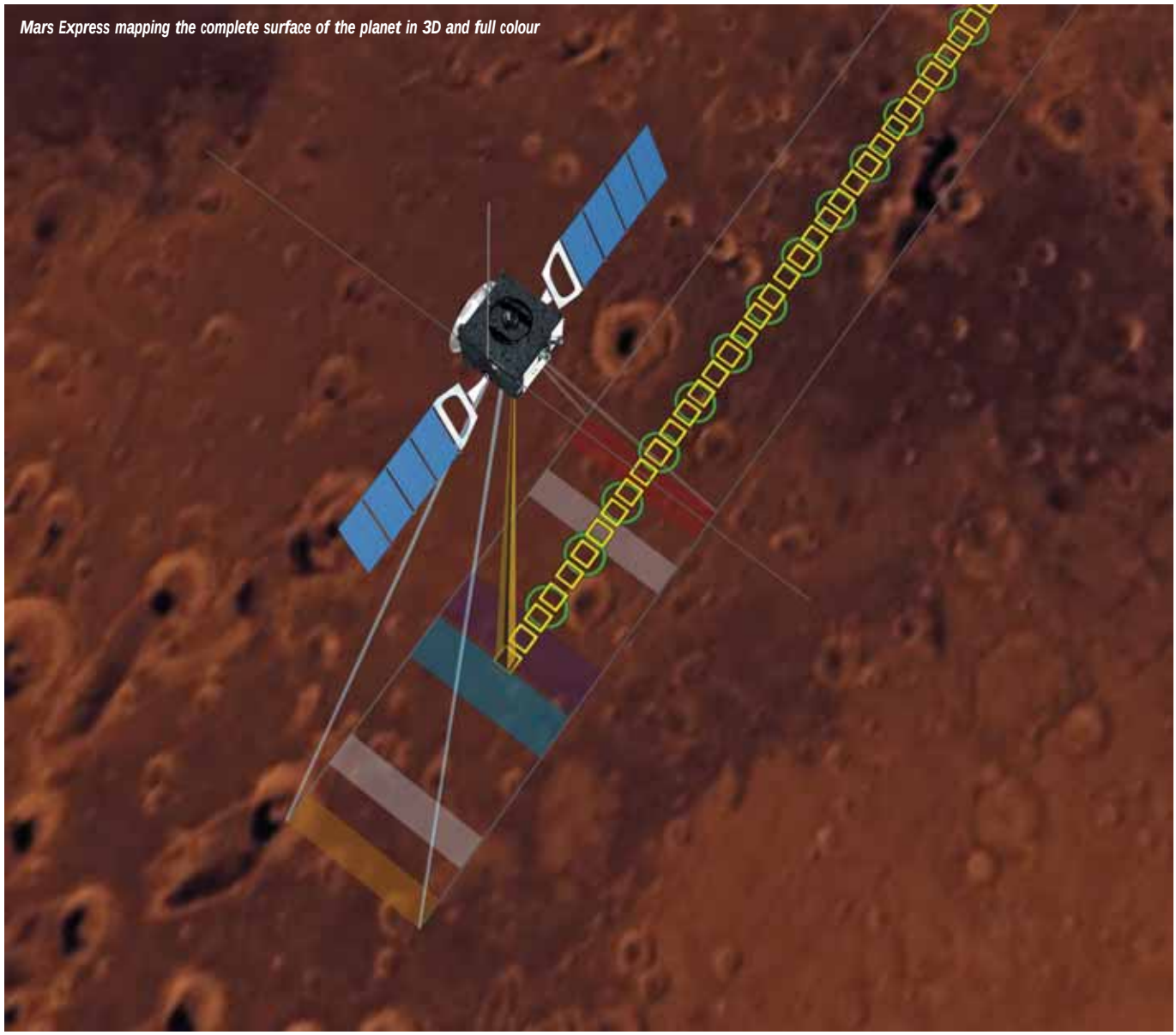
The mechanism and its operation is complicated. A lot of testing has gone into ensuring that it reliably releases Beagle 2 from the orbiter. Mission controllers at the European Space Operations Centre (ESOC), in Darmstadt, Germany, have been training for months with simulators that resemble sophisticated computer games. However, a failure when in orbit around Mars will cost you much more than a few points!

After ejecting the lander, the Mars Express orbiter will be on a collision course with the planet. Three days before arrival, therefore, ground controllers must manoeuvre the spacecraft onto the right trajectory. They will also reduce its speed by 1.3 kilometres per second to allow the planet's gravity to 'capture' Mars Express and put it into Mars orbit. Several manoeuvres will still have to be performed to get the spacecraft into its final operational orbit. The latter is highly elliptical, taking Mars Express from within just 260 kilometres of the Martian surface, to more than 11 000 kilometres away from it at its furthest point.

In the meantime, while the orbiter is still getting into its chosen orbit around Mars, Beagle 2 will have already touched down on the planet's surface. The landing will also be a very complicated and challenging operation, given that the lander will enter the Martian atmosphere at a speed of several thousand kilometres per hour. Friction with the planet's atmosphere will slow it down to about 1600 kilometres an hour, at which point parachutes will be deployed. Just before it reaches the surface, large gas-filled bags will inflate to protect the lander as it bounces. Once the lander comes to a halt, the bags will be ejected and scientific operations can begin.

One of the reasons why Isidis Planitia was chosen is that it is not too rocky to preclude a safe landing, but rocky enough to be interesting for the experiments. Isidis Planitia has few steep slopes, it is not too dusty, and its elevation is low enough to provide enough atmospheric depth to allow the parachutes to brake the lander's descent in the thin Martian atmosphere.

After landing, Beagle 2 will begin emitting a 'beeping' signal, which will be picked up by the Jodrell Bank radio telescope in England. Arrival of this 'life sign' from Beagle will tell the engineers that it has landed successfully. Several 'overflights' by Mars Express and NASA's Mars Odyssey will be needed to determine its exact position. One or two days after the landing, and once the outer case has been opened and the solar panels unfurled, Beagle will start making observations. The Payload Adjustable Workbench (PAW) at the end of the robotic arm, where most of



Mars Express mapping the complete surface of the planet in 3D and full colour

the instruments are located, will unfold and rotate to give its two stereo cameras a panoramic view. With the help of these and other images, rocks and soil samples will be selected and analysed in detail.

In the meantime, the orbiter will be imaging the entire planet at very high resolution in 3D and in full colour. It will also scan the subsurface with a radar altimeter, looking for water and ice, and map the mineral composition of the surface with great accuracy.

Then it will be the turn of the scientists. Data from the orbiter will be returned to Earth via the 35-metre dish at New Norcia, near Perth, Australia. From there, they will be sent to ESOC and then to the instrument scientific teams. Data from the lander will also be relayed via the orbiter, except for some periods when NASA's Mars Odyssey will pick up Beagle 2 data and send them to Earth. This will happen during the first 10 days after the landing, when Mars Express and Beagle won't be able to 'see' each other.

So what will Mars Express and Beagle 2 discover? Maybe water, maybe life... *"In any event we will get the most thorough view of the planet ever, which is of fundamental importance"*, says Agustin Chicarro, ESA's Mars Express Project Scientist. *"In the global international effort to explore Mars, Mars Express is a key mission, since it will provide the framework within which all further Martian observations will be understood."*

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