German Aerospace Center

Scanning the Red Planet

10 January 2011

DLR scientists have been processing data from the Mars Express HRSC camera for the last seven years

By Manuela Braun

Like a scanner in orbit, the High Resolution Stereo Camera on the European Mars Express spacecraft has been imaging the surface of the Red Planet since 10 January 2004, spotting volcanoes, trenches, wrinkle ridges and impact craters. But before we can view the surface of Mars in 3D, the photos have to be sequenced, the data has to be checked, and only then can viewable imagery be generated. This is something that the researchers at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) Institute of Planetary Research (Institut für Planetenforschung) and the Free University of Berlin (Freie Universität Berlin) have been doing for the last seven years.

Moving the PC mouse just one millimetre to the right causes a small skull icon to appear on screen in place of the mouse pointer. "This region on Mars cannot be observed by the camera during this flyover," explains Ernst Hauber from the Institute of Planetary Research. A small leftwards movement of the hand and the planning program causes the skull icon to disappear – a location has been selected along the Mars Express orbital flight path displayed for which Hauber is able to schedule observations. Since its High Resolution Stereo Camera (HRSC) acquired the first image of Mars on 10 January 2004, Mars Express has completed almost 9000 orbits. During that time, it has flown almost 450 million kilometres. Orbit by orbit, Hauber is able to view on his screen all the orbits that the spacecraft will cover over the next three months. With a few clicks, the planetary researcher is able to highlight a region and obtain useful information about it. Will it be day or night when the orbiter flies over this location? How high above the horizon will the Sun be at this time? At what angle relative to the surface of Mars will the camera be positioned?

In weekly telephone conferences with all the partners – including the European Space Agency (ESA), which controls the orbiter – he clarifies the direction in which the camera should be pointing for its next series of images. It is the aim of the DLR researchers to be the first team ever to map the entire surface of Mars at high resolution, in colour and in 3D. Although the diameter of Mars is only half that of Earth, the surface area still measures almost 150 million square kilometres, equivalent in size to all the continental landmasses on Earth combined.

Dust whirlwinds, storms and ice

Mars Express reached its destination on 25 December 2003, and the HRSC – developed at the DLR Institute of Planetary Research in Berlin – began operations on 10 January 2004. Since then, the spacecraft has been orbiting Mars, scanning its surface with no fewer than nine light-sensitive detectors arranged at different viewing angles. This enables the same location, with minimal time lag and under identical light and atmospheric conditions, to be photographed several times from an altitude of approximately 250 kilometres – the data obtained supplies scientists with information about the heights and depths of the planetary surface. Roughly two thirds of the surface of Mars has now been photographed with good quality imagery. Indeed, 40 percent of the planet has been photographed at a resolution of roughly 10 metres per pixel, achieved when the spacecraft reaches its lowest altitude of 250 kilometres above the Martian surface on its elliptical orbit. “Now, the key thing is to fill the gaps and to replace poor-quality imagery with good images," says Hauber. The scientists have until 2014 to accomplish this objective. Originally, the mission was scheduled to last for two Earth years, but ESA has extended it on four occasions.

Scientists scrutinise the quality of every single image taken. Dust whirlwinds that lift sand several kilometres up into the thin atmosphere, powerful storms in spring and autumn, and the ice-covered poles on Mars are factors that consistently make imaging conditions difficult. Decisions have to be taken regarding which of the various colour channels the camera should use for imaging, and the exposure time, the position of the Sun and the surface terrain of Mars are other factors. "We decide what is most favourable by applying a mixture of calculations and values drawn from experience," explains Hauber. The defined conditions for acquiring images are then converted by engineers into commands that are transmitted to the orbiter by ESA's European Space Operations Centre in Darmstadt.

Optimisation for the perfect picture

"There are regions on Mars that we have photographed three times and where, due to adverse weather conditions, we have three sets of poor images," explains the Experiment Data Manager, Thomas Roatsch. The spacecraft is able to save just one and a half gigabytes of data before it has to transmit its data to Earth. "A volume of data that would now effortlessly fit on any USB pen drive," says Roatsch with a grin. In the late nineties, when the camera was being made ready for its space mission which started in 2003, this was the typical memory capacity available at the time. Moreover, the antenna on the orbiter would have been unable to cope with the transmission of larger volumes of data. The data in the camera is compressed in real-time and has to be capable of withstanding the cosmic radiation in outer space, and despite these limitations, is perfectly capable of generating precise imagery of the surface of Mars. First of all, Roatsch divides up the incoming data into nine packages, corresponding to the nine different viewing angles of the detectors. Next, the data is calibrated radiometrically. This involves Roatsch correlating the quality of the 5184 pixels per image row with its neighbours and removing minor blemishes, a task familiar to every amateur photographer engaged in cleaning up digital photographs. "This process corrects what we call 'dark noise'," explains Roatsch. Finally, the precise position of the spacecraft at the moment each image was taken is assigned to every individual pixel on each photo. This is the most critical point in the production of images of Mars since, without this, it would not be possible to produce accurate maps of the Martian surface. ESA's Space Operations Centre supplies these ultra-precise details.

Due to the fact that every photographed location on Mars is imaged simultaneously from nine viewing angles, the data can be used to extrapolate the physical relief of Mars. Essentially, the stereo camera employs the same method as human eyes use when viewing their environment; in other words, it is 'seeing' the terrain in 3D. However, although the images of the surface are taken one row of pixels at a time, Mars Express may rotate slightly, or alter its altitude marginally, while the camera is operating. "To counteract that, we need to remove geometrical distortion from each image," says Frank Preusker from the Institute of Planetary Research. The comparison values for altitude settings are based on the readings taken by the Mars Orbiter Laser Altimeter (MOLA) that acquired extremely accurate data about the planetary surface between 1997 and 2001, on board the Mars Global Surveyor. In the next step, an initial 3D digital terrain model is calculated. "However, at this stage, the terrain model is still only a provisional one," says Preusker.

Valleys and mountains in 3D

An image on Preusker's screen appears to shimmer brightly. "The darker the colours, the better we have been able to optimise the image from Mars," he explains, and points to an area in which the image looks substantially more 'harmonious'. Time after time, Preusker uses a program to alter the camera position and viewing angle fractionally to obtain progressively better results. With each step in this process, the scientist gradually approaches the best possible version of a digital terrain model of the surface of Mars. On each strip of the landscape, recorded by the stereo camera across a width of at least 52 kilometres and down a length of several hundred kilometres, this optimisation process can take up to a day and a half. "Not all regions on Mars lend themselves ideally to this stereo camera; areas with less physical relief, such as the low plain in the northern hemisphere, with no craters or depressions, give us almost no distinctive features which we can use to align our imagery." However, despite the vast array of software-based technological support, the most critical observer remains the human eye. "We look closely at every single image and check to find what is not optimum about it," states Preusker. "Experience then helps us to decide which 'screw' we need to turn."

Step by step, precise digital maps of Mars are created in this way. To date, the HRSC team, led by Prof. Ralf Jaumann from the DLR Institute of Planetary Research, has processed 227 gigabytes of raw data into 2.7 terabytes of cartographically accurate imagery data, and 670 gigabytes into ultra-precise digital terrain models. To obtain a well-illuminated 3D image of Mars, all that is required are two colour photos, taken from different viewing angles, and superimposed with a slight overlap. It is then possible to view trenches and elevations on the Red Planet in very credible 3D using special red-green or red-blue goggles. "The important thing for research is for the surface of Mars to be depicted accurately," states Preusker. He leaves his colleagues to the task of finding out what the imagery has to tell us about Mars. "We process the pictures – then it is up to the geologists to interpret them."

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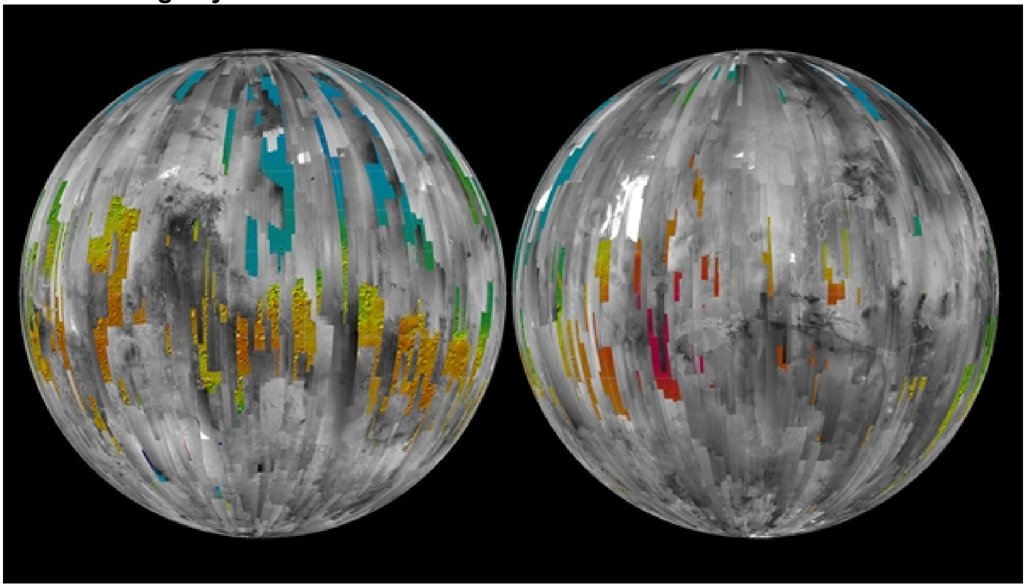
Ernst Hauber from the DLR Institute of Planetary Research

Using a planning program, planetary researcher Ernst Hauber defines which images should be acquired using the High Resolution Stereo Camera on Mars Express. It is the aim of the DLR scientists to be the first team to map the entire surface of Mars at high resolution, in colour and in 3D. Although the diameter of Mars is only half that of Earth, the surface area still measures almost 150 million square kilometres, equivalent in size to all the continental landmasses on Earth combined.

Mars coverage by HRSC



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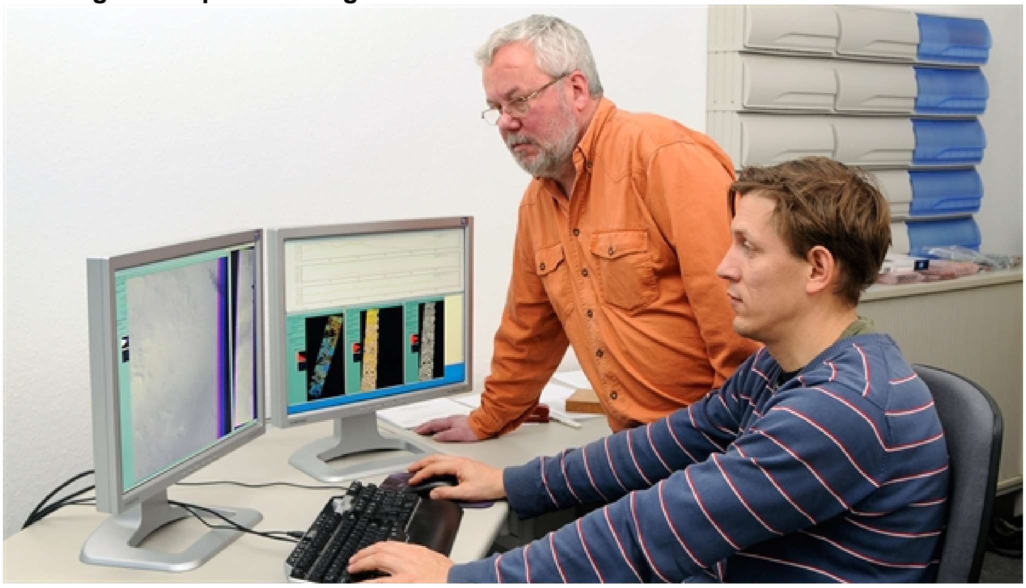
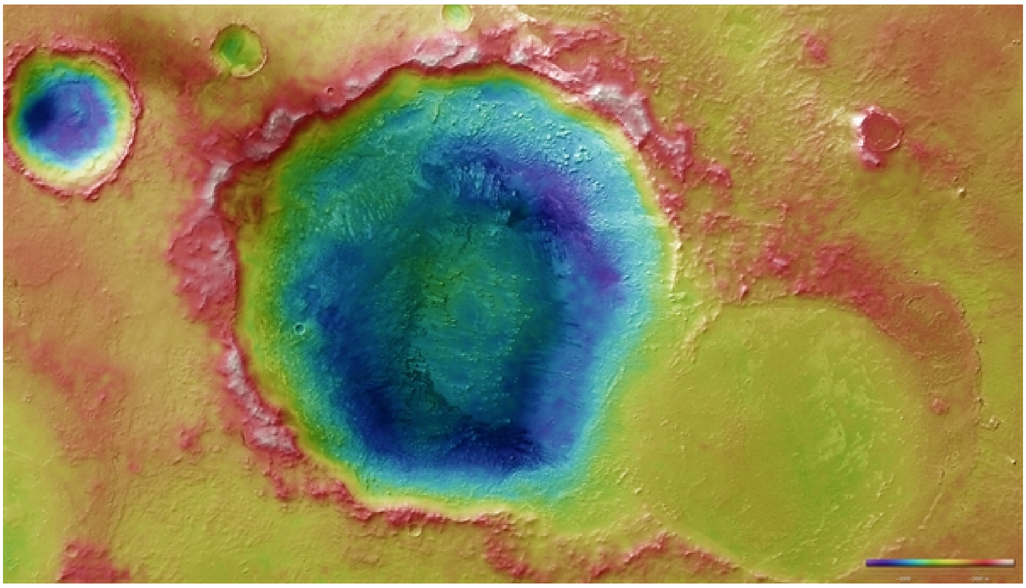
Working on the perfect image



Before the observer can view the surface of Mars in 3D, the data from the stereo camera needs to be checked and processed. Thomas Roatsch (standing) and Frank Preusker are on the team that has been working on this project since the first image of Mars was acquired seven years ago. To date, the HRSC team has processed 227 gigabytes of raw data into 2.7 terabytes of cartographically accurate imagery data, and 670 gigabytes into ultra-precise digital terrain models.

Elevation of the Meridiani



Elevation of the Meridiani Planum, located at the northern edge of the Southern Highlands of Mars. The region is located at about 2°N,352°E and lies between the Tharsis volcanic region to the west and the low-lying Hellas Planitia impact basin to the southeast. Meridiani Planum spans 127 x 63 kilometres, equivalent to an area of roughly 8000 square kilometres, about the size of Cyprus. This image was created using a Digital Terrain Model obtained from the High Resolution Stereo Camera on the European Space Agency's Mars Express spacecraft. Elevation data is colour-coded: purple indicates the lowest-lying regions and beige the higher elevations. The scale is in metres. Copyright note: As a joint undertaking by DLR, ESA and FU Berlin, the Mars Express HRSC images are published under a Creative Commons licence since December 2014: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO. This licence will also apply to all HRSC images released to date.

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