Venturing into the upper atmosphere of Venus

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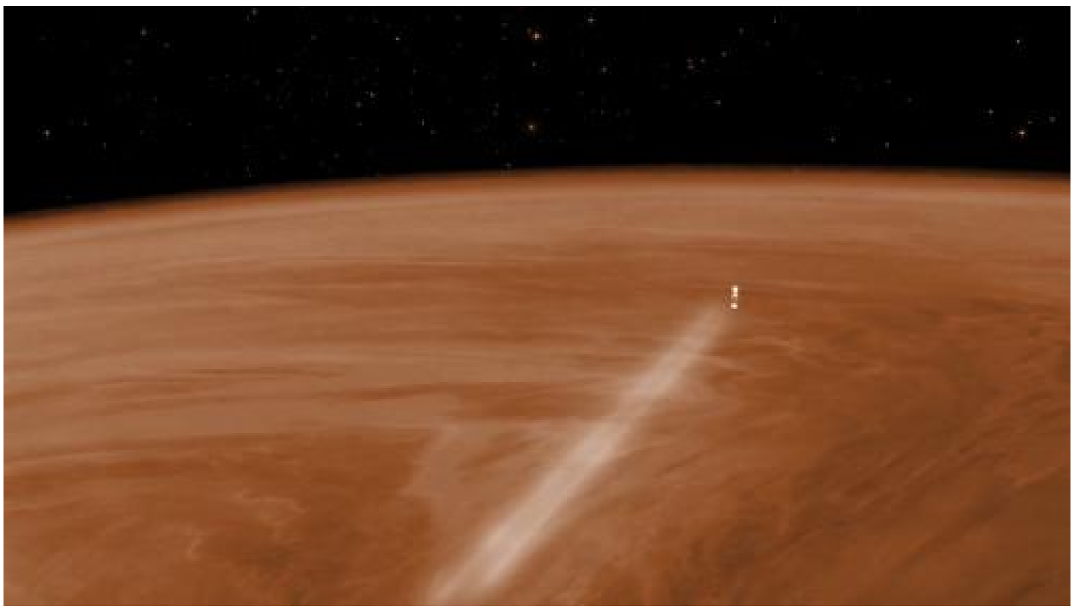

Visualisation of Venus Express during the aerobraking manoeuvre, which will see the spacecraft orbiting Venus at an altitude of around 130 km from 18 June to 11 July. In the month before, the altitude will gradually be reduced from around 200 km to 130 km. If the spacecraft survives and fuel permits, the elevation of the orbit will be raised back up to approximately 450 km, allowing operations to continue for a further few months. Eventually, however, the spacecraft will plunge back into the atmosphere and the mission will end. Credit: ESA - C. Carreau

As the end of its eight-year adventure at Venus edges ever closer, ESA scientists have been taking a calculated risk with the Venus Express spacecraft in order to carry out unique observations of the planet's rarefied outer atmosphere. First results from this aerobraking campaign were reported today at the 2014 Division for Planetary Science meeting, in Tucson, Arizona.

Currently the only spacecraft orbiting our nearest planetary neighbour, Venus Express arrived at Venus on 11 April 2006. Since then, the spacecraft has gathered a wealth of data on the planet's atmosphere and surface from its elliptical, 24-hour polar orbit.

With the spacecraft's fuel tank running low, the mission team decided to undertake several aerobraking campaigns, during which the orbiter would dip deeper than ever before into Venus' atmosphere during each pericentre passage. (Pericentre is the point of closest approach in a spacecraft's orbit around a planet.)

By gradually reducing its pericentre altitude to around 130 km, the spacecraft would be able to provide unique, detailed, in situ information about the sparse outer atmosphere, a region that is very difficult to study using remote sensing instruments.

The aerobraking campaign

Aerobraking has been used for many decades as a fuel-efficient way to slow down a spacecraft in a controlled manner. During their return flights from the Moon, the Apollo Command Modules dipped into Earth's atmosphere in order to reduce their incoming velocities. Automated spacecraft have also used this technique to cut their speed when they arrive at Mars.

One of the major problems with aerobraking is that atmospheric friction places stresses on a spacecraft's structure and causes its exterior to heat up rapidly. However, Venus Express was designed to survive modest aerobraking, in case the initial orbit insertion did not work as planned. Fortunately, this back-up procedure was never needed.

Now, near the end of its successful odyssey, the mission team had the opportunity to test and verify the spacecraft's design and aerobraking procedures without risking the overall success of the mission. For the first time, an ESA spacecraft would deliberately dip deep into a planetary atmosphere and then rise to continue operations.

The aerobraking was performed near the lowest point of the orbit by turning the lower end of the spacecraft in the direction of travel and rotating the solar panels so that they created the most atmospheric drag.

Starting on 17 May, the pericentre altitude was allowed to slowly decrease naturally from 190 km to 140 km. The orbital change was monitored in order to estimate the density of the atmosphere and the effect it would have on the spacecraft.

The orbit continued to alter under the influence of gravity, culminating in a month of 'surfing' between 131 km and 135 km above the planet's surface. Additional small thruster burns were used to lower the trajectory even further, reaching a minimum of 129.2 km on 11 July.

Although each dip into the atmosphere only slowed the orbiter's speed by about 1 m/s, the combined effect of the daily drag at these lower altitudes was so great that its orbital period was eventually reduced from 24 hours to 22 hours 20 minutes.

The duration of each pass was approximately 100 seconds and the maximum dynamic pressure achieved was more than 0.75 Newton per square metre, probably a record for a spacecraft that continued to operate in orbit.

The campaign ended on 12 July, after which a series of 15 thruster burns raised the craft's altitude again, placing it in a new orbit of 460 x 63,000 km.

Science results

"Below 155 km, the onboard accelerometers gave direct measurements of the rate of deceleration, which was directly proportional to the local atmospheric density," said Håkan Svedhem, ESA Project Scientist for Venus Express.

"This provided an excellent way to study the overall density profile and small scale density variations during each dip into the atmosphere.

"During the campaign, atmospheric density was sampled 55 times and more than 30 atmospheric profiles were gathered. To our surprise, the atmosphere appeared to be more variable than previously thought for this altitude, both from day-to-day and during each individual pericentre passage."

The data indicate that the satellite experienced extreme heating cycles, with temperatures of the solar panels increasing to about 50°C – a rise of more than 100°C – during several of the brief sweeps through the atmosphere.

The atmosphere also became about 1,000 times denser between altitudes of 165 km and 130 km, subjecting Venus Express to much higher forces and stress than during normal operations.

"We expected the density profile to be smooth," said Håkan Svedhem, "but we saw wide variations, sometimes with a steep rise, flat top and steep decline, sometimes with several peaks or a triangular shape.

"One possible explanation is that we detected atmospheric waves. These features can be caused when high speed winds travel over mountain ranges. The waves then propagate upwards. However, such waves have never before been detected at such heights - twice the altitude of the cloud deck that blankets Venus.

"Each pass took place at a similar latitude and longitude, and we are now studying the relative location of the spacecraft during its pericentre passes in relation to the ground features, to see if there is a correlation."

At the time of the campaign the low point of the orbit was located near the day-night terminator, at about 75 degrees North latitude. Some marked changes were detected as Venus Express crossed the terminator.

"Atmospheric density changed very rapidly as the spacecraft moved from daylight into darkness," said Håkan Svedhem. "It was about four times greater on the dayside than the nightside."

Two of the orbiter's scientific instruments – the magnetometer and the Analyser of Space Plasma and Energetic Atoms (ASPERA) – were also switched on during the aerobraking campaign.

Their measurements of magnetic fields and energetic particles will be analysed in the coming months and will certainly lead to new and improved models and a better understanding of the Venusian atmosphere and its environment.

Having survived its dives into the atmosphere, Venus Express is continuing a programme of more routine science observations. However, the intrepid orbiter is living on borrowed time.

"Since July the pericentre of the orbit has been naturally decreasing again, and by the end of November we shall attempt to raise it once again," said Håkan Svedhem.

"Unfortunately, we do not know how much fuel remains in its tanks, but we are intending to continue the up-down process as long as possible, until the propellant runs out.

"We have yet to decide whether we shall simply continue until we lose control, allowing it to enter the atmosphere and burn up naturally, or whether we attempt a controlled descent until it breaks up."

Either way, the tough little spacecraft will have revolutionised our knowledge of Earth's mysterious, cloud-shrouded neighbour, sending back more data than all previous missions to Venus combined.

Venus Express is Europe's first mission to Venus. It was launched from Baikonur Cosmodrome on 9 November 2005 on a Soyuz-Fregat launcher, and was inserted into Venus orbit on 11 April 2006. The payload includes a combination of spectrometers, spectro-imagers, and imagers covering a wavelength range from ultraviolet to thermal infrared, a plasma analyser and a magnetometer. Between May and July 2014, an aerobraking campaign was performed with Venus Express – the first performed by an ESA spacecraft – resulting in unique observations of the planet's rarefied outer atmosphere and a change in the spacecraft's orbital period from 24 hours to 22 hours 20 minutes.

Provided by European Space Agency

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