# The way to Mars – DLR researchers simulate the martian atmosphere

20 January 2011

To support the European ExoMars Mission to explore the Red Planet, an international project is being launched on 20 January 2011 with the aim of simulating the entry of spacecraft into the martian atmosphere. The project team is made up of German, Russian and Italian scientists and will be coordinated by the Supersonic and Hypersonic Technology Department (Überschall- und Hyperschalltechnologie) at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) Institute of Aerodynamics and Flow Technology (Institut für Aerodynamik und Strömungstechnik; IAS). Among other things, researchers are now simulating the atmosphere of Mars in a wind tunnel at the DLR's site in Cologne.

Over the last few years, there has been tremendous progress in Mars exploration. Missions such as Mars Express have significantly improved our knowledge of the Red Planet. Nevertheless, many questions remain unanswered about the nature, origins and development of our neighbouring planet. Answers to these questions can only be found on the surface of Mars. The atmosphere of Mars represents the initial hurdle in landing there safely. This is where the research group led by DLR's Ali Gülhan comes in.

**Heat during atmospheric entry**

In a similar way to spacecraft re-entering Earth's atmosphere, any spacecraft attempting to penetrate the atmosphere of Mars must be capable of withstanding incredibly high temperatures. This is why a heat-absorbent outer layer protects landing capsules and Space Shuttles. This can take the form of organic material that incinerates as the spacecraft enters the atmosphere, or it can involve the use of ceramic components.

Previous missions to Mars had only limited information about the composition of the planet's atmosphere. This made it impossible to make accurate predictions of the temperatures to be expected when entering the martian atmosphere. As a consequence, the thermal protection on these craft was designed with very generous safety margins. However, this oversized heat protection had an adverse impact on the scientific payload capacity of the spacecraft. Current research work aims to improve upon this.

**Simulated martian atmosphere**

Accurate prediction of the distribution of heat flux on the surface of the capsule as it travels through the atmosphere at hypersonic speed is essential for any fundamental improvement in the entry technology. Computer simulations are often employed to model high-temperature flows. The TAU computing process devised by DLR is also used for this kind of work. The data for these computer models is derived from wind tunnel tests in which the physical properties of the martian atmosphere are simulated. For example the martian atmosphere contains far more particulate matter than Earth’s atmosphere, and this significantly increases the erosion on the heat shield.

In Cologne, the researchers have access to a wind tunnel heated by an electric arc system, in which models can be exposed to realistic thermal loads. The system allows replication of the flow fields that will be experienced during entry into the atmosphere of Mars – complete with dust particles – and the examination of the behaviour of the heat shield material using optical as well as conventional measuring techniques. While the front of the space capsule is exposed to higher thermal loads than the rest of the spacecraft, the relatively cool and thin flow patterns on the trailing side determine the dynamic flight stability of the craft. In addition, DLR is conducting experiments in Göttingen to determine the influence of gas composition on heat flows.

The data obtained from digital simulations and wind tunnel tests is incorporated in the development of new heat shield design concepts and materials for them, and have an influence on the aerodynamic design of spacecraft.

**International and interdisciplinary**

Apart from research into flow patterns and materials, the interdisciplinary research project 'Safe and Controlled Martian Entry', SACOMAR is also tackling the problem of 'radio blackouts', where radio communication is interrupted during the entry phase. This is what project leader Ali Gülhan has to say about the potential of SACOMAR: "The project offers us an opportunity, through cooperation between researchers from different fields, to investigate the technological fundamentals of Mars atmosphere entry in detail. These research results can make a contribution to the ExoMars project being run by ESA."

This project, funded by the European Union, combines the work of German, Russian and Italian researchers with project partners from industry. DLR's partners are: the Italian Aerospace Research Centre (Centro Italiano Ricerche Aerospaziali; CIRA), Thales Alenia Space Italia, EADS Astrium GmbH, TsNIImash (Central Research Institute of Machine Building, Russia), TsAGI (Central Aerohydrodynamics Institute, Russia), IPM (Institute for Problems in Mechanics, Russia) and ITAM (Institute of Theoretical and Applied Mechanics, Russia).

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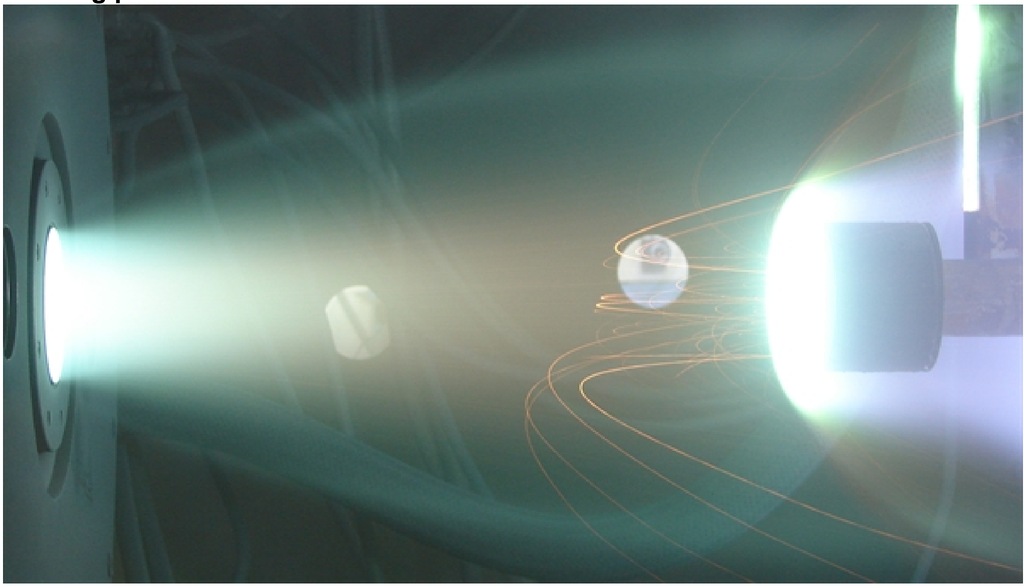
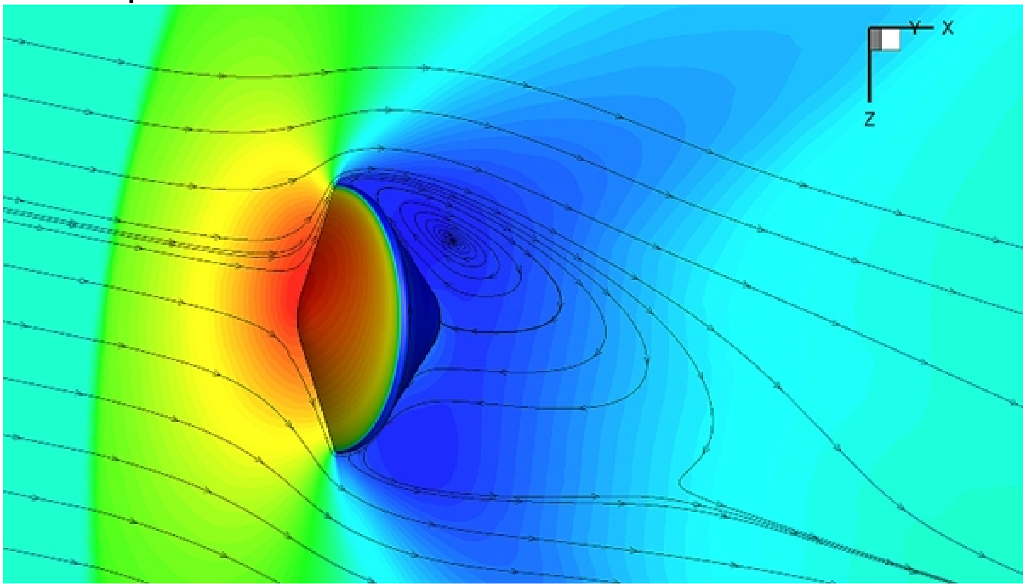
### Glowing particles in the arc-heated wind tunnel



The data for these digital computer models is derived from wind tunnel tests in which the main physical properties of the martian atmosphere are simulated. For example, the atmosphere of Mars contains a higher concentration of particulate matter than the atmosphere of Earth, meaning that greater resistance to erosion is required.

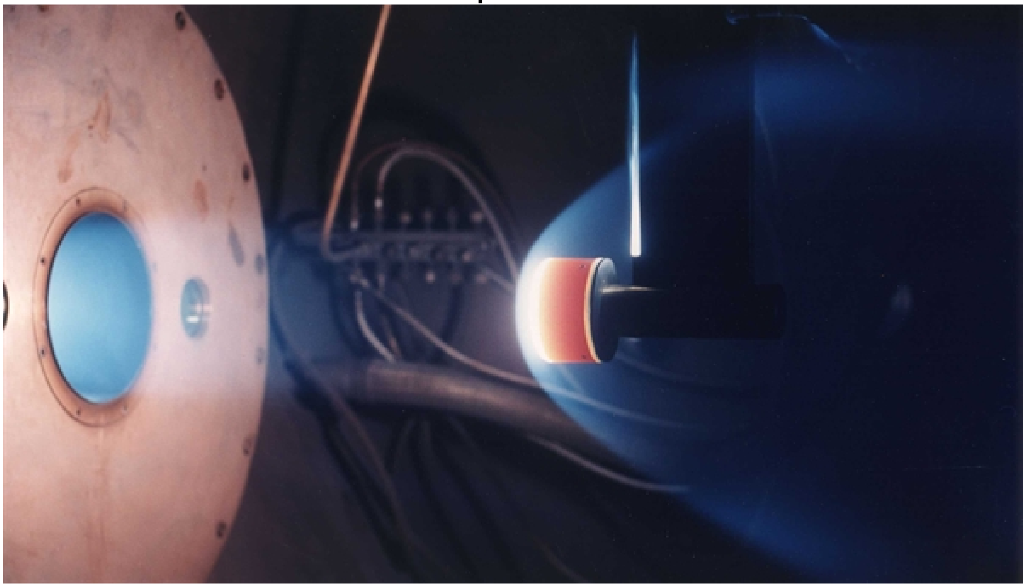
**Computer simulation of the flow characteristics of hot gases during entry into the atmosphere**




An accurate prediction of the distribution of heat flux on the surface of the capsule as it travels through the atmosphere at hypersonic speed is essential for any fundamental improvement in entry technology. Computer simulations are often employed to model high-temperature flows. The data for these computer models are derived from wind tunnel tests in which the physical properties of the martian atmosphere are simulated.



**A model in a simulated martian atmosphere**



In Cologne, the researchers have access to a wind tunnel heated by an electric arc system, in which models can be exposed to realistic thermal loads. Optical and electronic metrology systems are used to examine the flow characteristics of the hot gases and the local thermal loads being experienced by individual sections of the model. Space capsules enter the atmosphere with their unstreamlined undersides facing in the direction of travel. This gives rise to a shock wave at high temperatures, while the gases flowing past the sides of the capsule are significantly cooler as they pass the other end of the capsule.