Valles Marineris Explorer – using a robotic swarm to explore Mars

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Valles Marineris, the largest canyon system in the Solar System and a potential refuge for extraterrestrial life, is 7000 metres deep and stretches for some 4000 kilometres along the Martian equator. But this complex terrain of mountains, gorges, canyons and caverns can only be explored efficiently and cost-effectively using a swarm of airborne and ground units. The Valles Marineris Explorer project is jointly funded by the Space Administration of the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) and the German state of Bavaria, and involves researchers from Technische Universität Braunschweig, the DLR Institute of Communications and Navigation and Technische Universität München. Conducting simulations and practical experiments on Earth, this project aims to devise navigation solutions to enable such a robotic swarm to search for life deep in the craters and canyons of another planet.

Video: Flight over the central part of Valles Marineris

Searching for life in Valles Marineris

The Valles Marineris canyon on Mars is an interesting exploration target; the deep breaks in the Martian crust offer new insights into the geological history of the Red Planet and, possibly, prospects for finding extraterrestrial life. Spacecraft only image areas visible from orbit, so they are not suitable for finding evidence of microorganisms. Semi-autonomous rovers, which have been used on the surface for some time now, can only explore easily accessible areas with no large obstacles. "But these places are of rather limited interest in the search for extraterrestrial life on Mars. If life did develop on Mars billions of years ago, it could only have survived in protected niches, because the environmental conditions have since become hostile to life. The deep chasms in Valles Marineris represent such a biological niche. The atmospheric pressure in such places may even be high enough for pools of water to exist – the ideal habitat for

microorganisms, as we know from Earth. These places, which are hard to get to, can only be explored with any efficiency by a robotic swarm," says Oliver Funke, leader of the DLR Space Administration elements of the project.

Exploration with a robotic swarm

The key technologies for dependable position finding with a swarm of airborne devices and rovers that do not rely on an infrastructure must first be researched and tested on Earth. This has potential for other uses, such as navigation underground or during search and rescue operations in regions devastated by catastrophes. But what form might such a mission scenario take? A swarm is despatched from a base station to the target area. Upon arrival, it will need to navigate through the unknown terrain autonomously, reliably and accurately. Potential obstacles will need to be detected and bypassed or flown over. The individual elements of the robotic swarm will need to be able to locate one another in order to orientate themselves while they are exploring the target area by means of cameras, laser scanners and measuring instruments. These two tasks are being combined into a compact navigation solution, under the leadership of Technische Universität Braunschweig.

"While the airborne elements will survey large areas quickly and generate a map, the rovers will explore the mapped area and any objects of interest in detail. The orientation of the rovers will be improved by the better view from the airborne elements and the knowledge of their positional relationships. This can be extremely helpful both in the Valles Marineris on Mars and for catastrophes on Earth," says Funke, explaining the benefit of swarm navigation. Street maps quickly become useless for logistical purposes in a city devastated by an earthquake, because of the rubble. In this event, accessible routes for heavy machinery need to be found quickly.

As soon as all the swarm elements are in place, a communication network used to transmit the data acquired about difficult terrain to all the swarm elements is established. The DLR Institute of Communications and Navigation is working on the technical solutions for this swarm communication and cooperation, and is building a Mars scenario simulator. The network established by the swarm provides redundancy for the exploration and data transfer as well as in the event of failure of individual swarm elements – but if several systems fail, these faults must be compensated for. Technische Universität München is working on this challenge, as well as flight control and optical navigation.

Fast, autonomous navigation in difficult terrain

But a large number of technological challenges will need to be solved before an airborne device can be used on Mars. Due to the lack of systems such as GPS or Galileo there, an airborne device has to rely on the terrain and on a limited number of onboard sensors for navigation. "Airborne devices will need to use the data acquired immediately for flight control, so navigation must operate substantially more autonomously than with the NASA Mars rovers Spirit and Opportunity. It takes 40 minutes for a radio signal to travel from Earth to Mars and back, so remote control via telemetry is out of the question. The airborne device must therefore be capable of exploring independently," says Funke. At the moment, there are large gaps in our capabilities for exploring other planets; the partners in the Valles Marineris Explorer project are looking to close these gaps.

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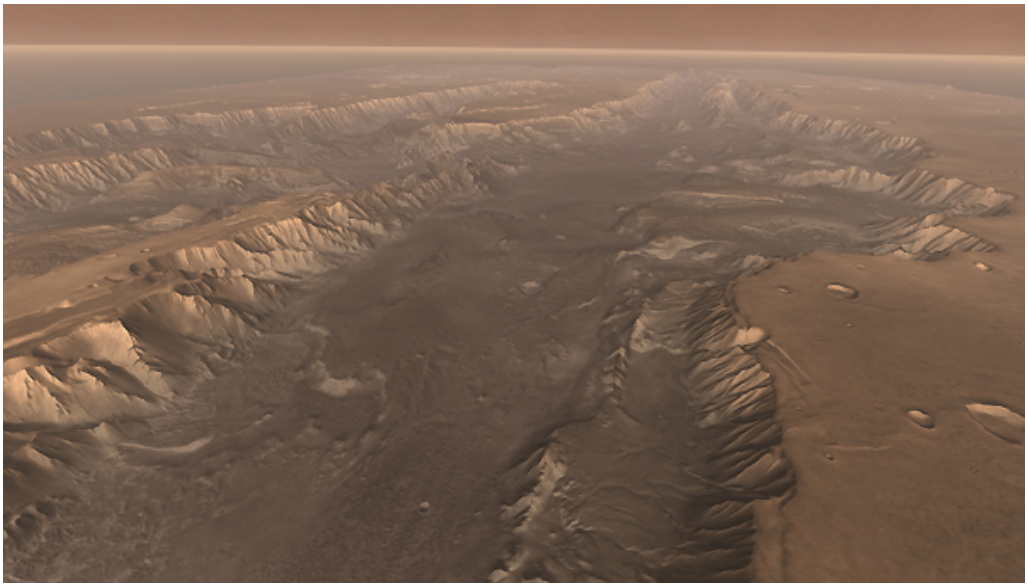
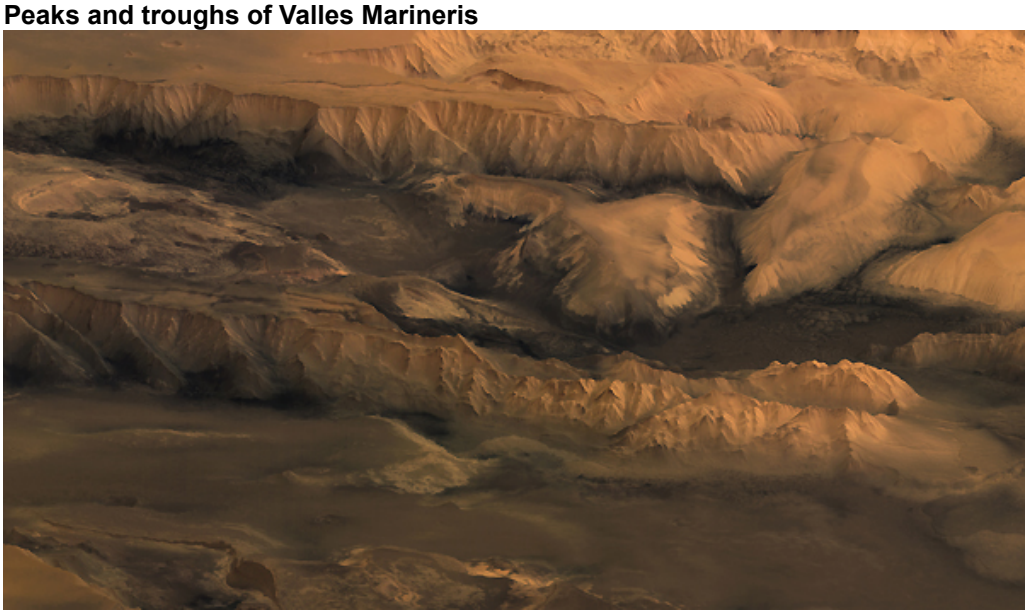
The enormous Valles Marineris



Perspective view of the enormous Valles Marineris canyon on Mars.

Credit: ESA/DLR/FU Berlin (G. Neukum).

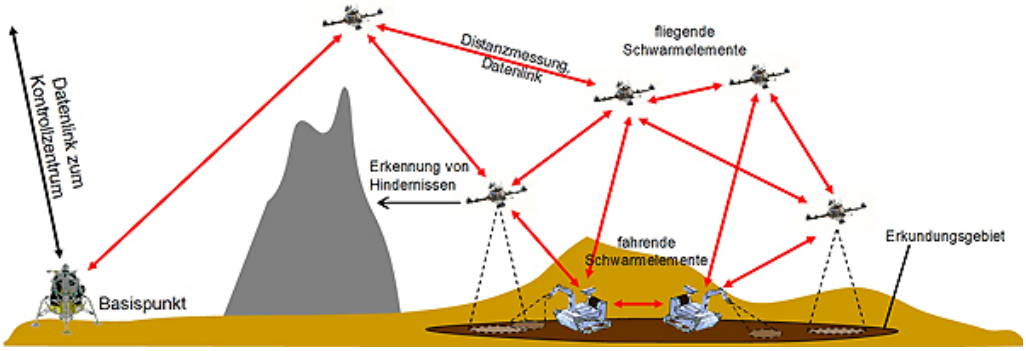
Peaks and troughs of Valles Marineris



View from an imaginary point above the adjacent highland across the central Valles Marineris from south to north. The three central valleys – Melas Chasma, Candor Chasma and Ophir Chasma, each around 200 kilometres wide – can be seen running parallel to one another. Candor Chasma is visible in the foreground, with Ophir Chasma behind. The steep cliffs in the background and the centre of the image are around 5000 metres high and show traces of intensive erosion; the remnants of massive landslides can be seen at the foot of the cliff wall. It is unclear how this massive structure was formed.

Credit: ESA/DLR/FU Berlin (G. Neukum).

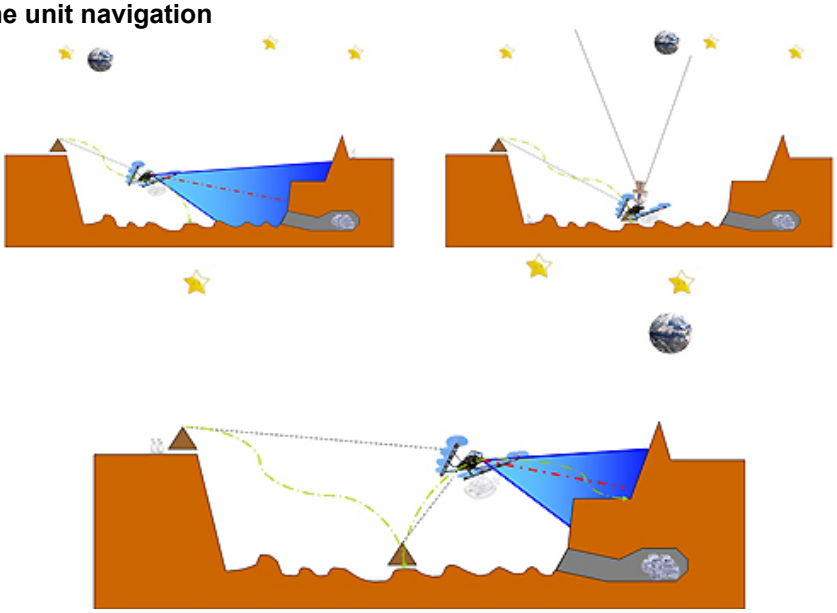
Navigation with a robotic swarm



Individual swarm elements communicate and share the latest data on the terrain with one another. A ground station then forwards all relevant data to Earth.

Credit: DLR.

Airborne unit navigation



Schematic representation of the navigation of an airborne unit as it searches for life in Valles Marineris.

Credit: DLR.

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