Exploring Mars in low Earth orbit

July 31 2014, by Aaron L. Gronstal

The Expose-R2 experment on the outside of the Zvezda module of the International Space Station (ISS). Credit: DLR

In their quest to understand life's potential beyond Earth, astrobiologists study how organisms might survive in numerous environments, from the surface of Mars to the ice-covered oceans of Jupiter's moon, Europa. For now, Earth is our only example of an inhabited planet, and studying the limits of habitability on Earth is a major component of astrobiology research. For this reason, scientists collect data from places on our planet where life is pushed to the absolute limits of adaptability, from the Antarctic to the Arctic, and from smoldering thermal vents to highly acidic rivers.

But locations like the Antarctic Dry Valleys or deep-sea vents in the Pacific aren't the only places in which astrobiologists study life as we know it. Low Earth orbit provides an opportunity to observe Earth-life in the harsh conditions of space.

In the early hours of July 24th, 2014, a new astrobiology experiment began its journey from the Baikonur Cosmodrome in Kazakhstan to the International Space Station (ISS). BIOMEX (Biology and Mars Experiment) launched onboard a Russian Progress cargo spacecraft and is one of four experiments that make up the EXPOSE-R2 facility, which will be mounted on the exterior of the ISS Zvezda module. Just six hours after launch, the cargo ship successfully docked with the ISS.

Life on the Station

BIOMEX contains twelve different experimental packages that are designed to help determine life's potential on Mars. The Institute of Planetary Research at the German Aerospace Center (DLR) is coordinating BIOMEX, but the project involves 25 participating institutions from around the world.

BIOMEX contains numerous chambers that are filled with biomolecules and organisms that include bacteria, archaea, algae, fungi, lichens and mosses. Replicate samples spread across the compartments are subjected to a range of environmental conditions. Some samples of each biomolecule or organism are embedded in a simulant Mars soil (ranging from just a single layer of soil to multiple layers), and other samples are left on their own to face the space environment without protection.

Various filters are also being used on the sample chambers to test exposure to different levels of radiation. By doing this, scientists are able to simulate the solar radiation present at the martian surface. Some of the sample chambers are even pumped full of a simulated Mars

atmosphere that is rich in carbon dioxide and pressurized to replicate conditions on Mars.

"To gain real insights into the behavior of biomolecules within a martian environment, we have to check the different parameters we might encounter on Mars," explained Dr. Jean-Pierre Paul de Vera of the German Aerospace Center (DLR) and the principle investigator for BIOMEX. "This means we will approach—as much as possible on the ISS—martian conditions, including extreme temperature regimes, martian atmosphere by using Mars-like gases in the compartments of EXPOSE-R2, and the radiation regime, which we can never simulate in the labs on Earth."

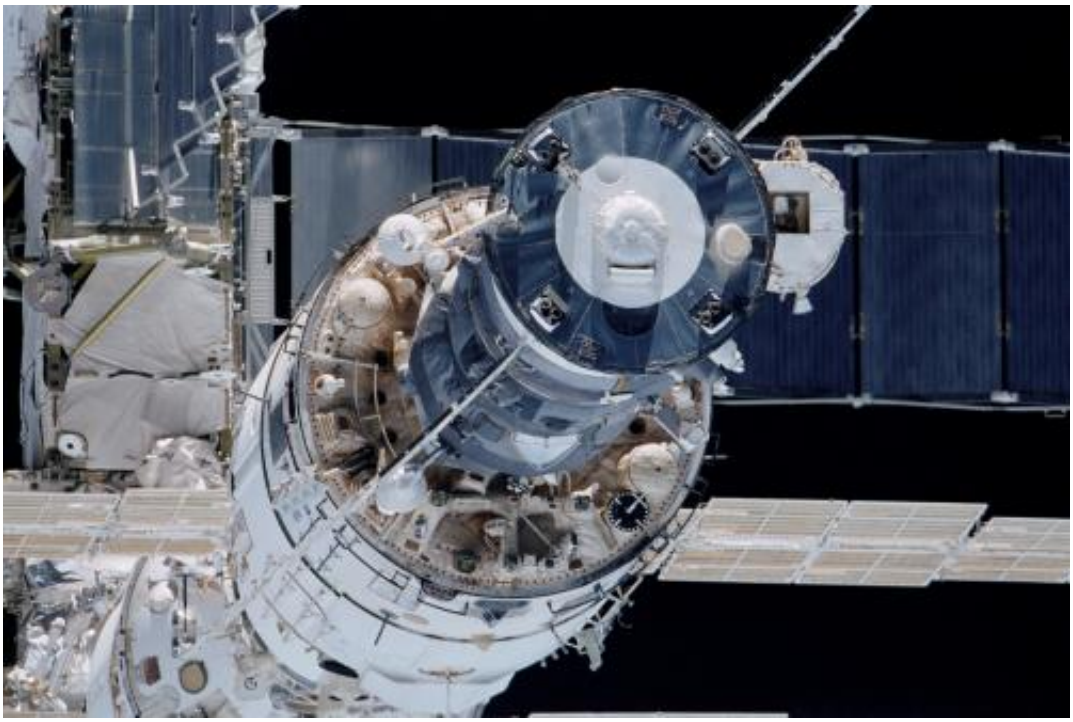
The samples will spend up to one and a half years outside the space station, and the organisms inside will be monitored with temperature sensors and dosimeters, which monitor radiation exposure. The goal is to see how exposure to these varied environmental pressures affects the survival of the organisms and the stability of important cellular components like membrane lipids, pigments, proteins and DNA.

The results of BIOMEX will help astrobiologists understand whether or not these biological materials can cope with conditions in the space environment and on Mars, and if being buried in martian soil might aid in their survival.

Tools for the Future

While the samples in BIOMEX are attached to the outside of the station, scientists on Earth will be working with replicate samples in the lab. Here they will simulate martian conditions as best they can in the controlled environment of the laboratory and monitor the Earth-bound samples with a number of instruments.

At the completion of the experiment, BIOMEX samples will be returned to Earth



View of a Progress vehicle connected to the Zvezda module of the ISS. The Zvezda Service Module was the first fully Russian contribution to the International Space Station. The module provides station living quarters, life support systems, electrical power distribution, data processing systems, flight control systems and propulsion systems. Credit: NASA

where scientists will take a close look at the results. In the laboratory, they will examine the stability of biomolecules after they have been exposed to the conditions in low Earth orbit. This includes studying the signatures they leave behind in the sample chambers, which could be useful on future life-detection missions on Mars.

"BIOMEX is investigating the capacity of instruments to detect selected

biosignatures (pigments, membrane composites, lipids etc.) in a Mars-like environment before and after space experiments, and also during Mars simulations in the lab," de Vera told Astrobiology Magazine.

The set of spectroscopic instruments they are using on Earth are similar to those currently being eyed for Mars missions in the near future. They include Raman, IR and UV/VIS spectroscopes. Initial tests in the lab have already turned up some interesting results. Studies at the German Aerospace Center in Cologne and Berlin indicate that biosignatures are altered by temperature and radiation. This causes their appearance to differ from the signatures we normally observe in Earth conditions.

Beyond Astrobiology

Data from BIOMEX could also have some important applications beyond the realm of astrobiology according to Dr. de Vera. Studying how biosignatures survive in a simulated Mars regolith might have lessons for archaeology experts on Earth who are looking for radiation-independent (e.g. not carbon 14-dating) methods to study ancient wooden objects. In particular, the thermogravimetric methodology, which is used by de Vera and his team to test the bounded and remaining water in BIOMEX samples after they have faced the conditions of space, is of special interest for archaeologists.

Raman spectroscopy is also a technique that is growing in prominence for biological studies in numerous fields.

"Raman spectroscopy is used more and more in microbiology, pharmacology and medicine," said de Vera. "The Robert Koch institute in Berlin, which is cooperating with us, uses this method (coupled with other methods) to characterize microorganisms that can be harmful to health, and they have to be detected very fast to find out if there could be a risk of an epidemic."

The studies of biofilms in space could have some interesting implications for the health of astronauts and humans on Earth. On Earth, biofilms are used in some health drinks to trigger the immune system. Studying biofilms in space can help determine whether or not these drinks might be safe for astronauts to consume in orbit, or if the space environment will cause biofilm cultures to rapidly mutate in such a way as to become harmful for consumption.

"Desiccation [removal of water] and radiation protection is also a very important issue," noted de Vera. "Studies on the exposed samples might give more information about how the most resistant microorganisms are able to shield themselves efficiently, and which substances are responsible for their resistance. The cosmetic and food industries are interested in these results."

In fact, the Fraunhofer Institute IZI for Cell Therapy and Immunology in Potsdam, Germany is already working with two of the organisms that de Vera and his team are studying. One is a highly resistant cyanobacteria, and the other is a green algae. Thanks to BIOMEX, these organisms now have a home in low Earth orbit, clinging to the outside of the International Space Station.

Further Afield with BIOMEX

The Mars Simulation Facility Laboratory. Credit: DLR

BIOMEX will help astrobiologists understand the potential for habitability on Mars. If life ever originated on Mars, and if that life operated under the same biological principles as on Earth, could those organisms have adapted to survive on Mars in the present day?

By exploring this question, BIOMEX could help shape the future of Mars exploration, providing guidelines for where robotic explorers might search for signs of life on present-day Mars or signs of ancient life preserved in the regolith.

"With the data obtained by the selected biomolecules as potential biosignatures and which are exposed to the Mars-like conditions in space, we are building up a database that might have significant

relevance for future exploration missions to Mars," said de Vera. "This database might serve as back-up, or a systematically generated reference list that takes into account the martian environmental conditions that might influence the signatures of minerals, and possible fossils or biomolecules from potential extant life forms."

EXPOSE-R2

BIOMEX is one of four experiments in the Expose-R2 facility. Two of the additional studies are also providing data that could be useful to astrobiologists:

BOSS (Biofilm Organisms Surfing Space), led by Dr. Petra Rettberg of the DLR in Cologne. BOSS will study the different ways in which exposure to the space environment affects single-celled plankton and microorganisms that form biofilms.

"We want to know what effects UV radiation will have on cell structure and biofilms in space conditions, and the differences between biolfilm and non-biofilm forming organisms," said Charles Cockell of the University of Edinburgh, whose lab provided some of the biological samples for both BIOMEX and BOSS. "They will help us understand how organisms can be made to be robust against extreme space conditions."

It is thought that organisms capable of forming biofilms may be more successful in protecting themselves from harsh environmental conditions. The ability to produce biofilms may have been important in the early stages of life's evolution on Earth, when conditions on our planet were very different than today.

PSS (Photochemistry on the Space Station), led by Prof. Dr. Hervé Cottin from Laboratoire Interuniversitaire des Systèmes Atmosphériques

(LISA) UMR CNRS in Créteil Paris. Organic compounds and mixtures in both solid and gas form will be exposed to the space environment. The results of PSS will provide information about organic chemistry and the potential formation of prebiotic molecules in the space environment. Scientists can use this information to understand how radiation in space triggers reactions that lead to the formation of these molecules, some of which could have been materials in the origin of life as we know it. The data will also help determine how organic compounds are affected by solar radiation on planets or small bodies that do not have a dense atmosphere to shield their surfaces.

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