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BIOPAN and EXPOSE: Space exposure platforms for exo/astrobiological research in earth orbit with relevance for Mars exploration

Wolfgang Schulte (1), René Demets (2), Pietro Baglioni (2), Petra Rettberg (3), Ralf von Heise-Rotenburg (1), Jan Toporski (4)

(1) Kayser-Threde GmbH, Wolfratshauser Str. 48, 81379 Munich, Germany, wolfgang.schulte@kayser-threde.com, Phone: +49-89-72495-225, Fax: +49-89-72495-215; ralf.von.heise-rotenburg, Phone: +49-89-72495-341, Fax: +49-89-72495-215

(2) European Space Agency ESA/ESTEC, Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands, rene.demets@esa.int, Phone +31-71-565-5081, Fax +31-71-565-3141; pietro.baglioni@esa.in, Phone + 31-71-565-3856, Fax +31-71-565-3141

(3) German Aerospace Center (DLR e.V.), Institute of Aerospace Medicine, Linder Höhe, 51147 Köln, Germany, petra.rettberg@dlr.de, Phone +49-2203-601-4637, Fax +49-2203-61970

(4) University of Kiel, Department of Geosciences, Olshausenstrasse 40, 24098 Kiel, Germany, jtoporski@min.uni-kiel.de, Phone-+49-431-880-2901, Fax, +49-431-880-4457

Recent exobiological experiments conducted in earth orbit have indicated that biological organisms can survive in the harsh conditions of the space environment. This is not only true for the well-characterized spores of the bacterium *Bacillus subtilis*, which proved to be highly resistant to the extreme environmental conditions of space, like vacuum, ionizing radiation, energy-rich UV radiation, extreme temperatures, in laboratory as well as space experiments, but also for higher organisms like lichens, where fungi and algae live in a symbiosis. Lichens were exposed in free space during a two-week flight with ESA's space exposure platform BIOPAN in June 2005 and, while in a passive state, they withstood the space exposure without suffering detectable damage. This discovery was made with the experiment LICHENS by a Spanish experiment team led by Leopoldo Sancho from the Complutense University, Madrid, and confirmed previously published laboratory experiments in space simulation facilities.

Such experiments seem also to indicate that similar organisms might be able to survive on the much more hostile surface of Mars, as compared to earth, at least for some time. Since 1994 up to the present date (2006) 25 experiments in exo/astrobiology, radiation biology and radiation dosimetry have been conducted on four space flights with BIOPAN. Another 10 experiment proposals have now been selected to fly with the next BIOPAN mission in 2007. Some of them are considered as precursor experiments of future *in situ* astrobiology experiments on Mars.

BIOPAN is a European space exposure platform, developed for ESA by Kayser-Threde GmbH, Munich/Germany, as prime contractor to offer short-term flight opportunities (two-week flights) to the science community of exo/astrobiology research in low earth orbit. It is designed as pan-shaped experiment container that can be installed onto the outer surface of its carrier, a Russian FOTON re-entry capsule. Another facility, EXPOSE, has been conceived for longer duration flights (one year or more) on the International Space Station and shall start its maiden flight aboard the Russian external platform URM-D in mid 2007. After the space exposure the experiment samples are retrieved for post-flight analysis in the ground laboratories of the scientific investigators. Both facilities, BIOPAN and EXPOSE are primarily devoted to exo/astrobiological experiments and they can support the research into living organisms on other planets and the possibilities for transfer of life between planets. Experiments flown so far with BIOPAN include bacterial spores mixed with Martian soil analogues to test the alleged toxicity of the Martian soil while irradiated in space by solar UV at dose and wavelength levels comparable to those on Mars (experiment MARSTOX), permafrost soil samples with their embedded natural ancient bacterial spores (experiment PERMAFROST), and lichens (experiment LICHENS) and yeast (experiment YEAST) where the biological effects of low-energy protons are investigated. Other experiments relevant for exo/astrobiological research on Mars have been proposed for the next flight of BIOPAN in 2007. This is specifically testing components of the Life Marker Chip (LMC) instrument, an analytical instrument under development for ESA's ExoMars mission, dedicated to carry out *in situ* life detection experiments as part of the ExoMars rover Pasteur platform. Critical components of this instrument shall be tested in a mission scenario and in space environment, specifically the stability of the molecular components (antibodies and fluorescent dyes) as well integrity of the microarrays after space flight.

This paper describes the space exposure facilities and summarizes the sets of scientific experiments of past and future flights with emphasis on experiments that have relevance for Mars exo/astrobiology.