Press Release

September 6th, 2019

National Research and Development Agency
Japan Aerospace Exploration Agency
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Contributing to the International Planetary Protection Policy for Martian Moon Exploration

– A Japanese research team has played a leading role in setting a new international rule for planetary protection during Martian moon exploration by assessing the probability for microbial contamination of the Martian moons from Mars ejecta –

The Japan Aerospace Exploration Agency (JAXA), Chiba Institute of Technology, Tokyo Institute of Technology, The University of Tokyo, and Tokyo University of Pharmacy Life Sciences jointly conducted scientific research that assessed the microbial contamination of the Martian moons. A report on this research was accepted by the Panel on Planetary Protection (PPP) for the Committee on Space Research (COSPAR) and was approved as a recommendation to JAXA's Martian Moons eXploration (MMX) mission by the 89th COSPAR Bureau held in March 2019. This achievement is Japan's contribution to the international Planetary Protection Policy maintained by COSPAR.

The research results (2 peer-reviewed papers) were published in the electronic version of Life Sciences in Space Research on July 10th and 17th, 2019.

Gist

- When conducting space exploration, nations and organizations have to comply with a set of rules (Planetary Protection Policy).
- However, the rules for the Martian moons, Phobos and Deimos, had not been defined despite their apparent importance for future space exploration.
- The Japanese research team played a leading role in the scientific activities necessary to set new rules for the Martian moons. Specifically, the team estimated the global distribution of microorganisms on the Martian moons that may have been transported from Mars by Mars ejecta produced during gigantic meteoroid impacts on Mars in the past 5 million years. The results indicated scientifically and quantitatively that the probability that microorganisms may be included in samples collected by the MMX spacecraft on

the Martian moons is much less than the upper limit that has been agreed internationally. That is, the samples collected by the MMX mission are *safe* to bring to Earth.

- This result was approved by COSPAR, and an international agreement was obtained to conduct the MMX mission at the same level of planetary protection policy as Hayabusa2.

Background

Committee on Space Research (COSPAR) formulates and maintains a Planetary Protection Policy with associated requirements, as a reference standard for spacefaring nations and in guiding compliance with Article IX of the UN Outer Space Treaty, in order to avoid contamination of celestial bodies with organic matters and microorganisms from the Earth for future biological exploration, and to protect the Earth and its biosphere (including the Moon) from potential harmful extraterrestrial sources of contamination. All planetary missions have to implement planetary protection measures at different degrees – ranging from simple documentation to terminal sterilization of entire flight systems.*[1]

In JAXA, the Martian Moons eXploration (MMX) project is currently entertained as a next-generation sample return mission following *Hayabusa2*, based on cutting-edge technologies for exploring small objects (currently in the pre-project phase). However, the situation for the MMX mission is different from that for *Hayabusa2,* whose target body is an asteroid, since the MMX mission's target bodies are the Martian moons, which are very close to Mars; a planet that may have extant life.*[2] It is known that Martian material is transported to the Martian moons, as Mars ejecta generated by gigantic meteoroid impacts on Mars have been transported to the Earth and discovered as Martian meteorites. There is no denying the possibility that such Mars ejecta may contain Martian extant microorganisms and that these could be transported to the Martian moons. Since the COSPAR planetary protection policy did not cover the Martian moons as a target celestial body at the time, it was necessary to show that the probability that a single viable microorganism is in samples returned from the Martian moons is less than the upper limit agreed internationally, which is one millionth (1/1,000,000),*[3] in order to carry out the MMX mission in compliance with the same level of planetary protection policy as *Hayabusa2*.

Research Overview

The research team led by Prof. Kazuhisa Fujita (JAXA), Dr. Kosuke Kurosawa (Chiba Institute of Technology), Drs. Hidenori Genda and Ryuki Hyodo (Earth-Life Sciences Institute, Tokyo Institute of Technology) addressed the issue in collaboration with the University of Tokyo and Tokyo University of Pharmacy and Life Sciences.

The team examined the Martian surface history within the past 5-million years and the sterilization data for microorganisms, showing that extant viable microorganisms on the Martian moons must originate from the 10 km-sized crater called Zunil, which was formed 0.1 million years ago. Since the other craters over 10 km in diameter on Mars were much older than Zunil, microorganisms transported from these craters will already have been sterilized by intense cosmic radiation. The team investigated the fraction of Mars rocks coming to the Martian moons compared to the entire Mars ejecta produced in the Zunil-forming impact event, and the three-dimensional distribution of Martian materials accumulated on the Martian moons. The evolution of the surviving microorganisms under the radiation environments was then calculated (see Figure). Based on these results, the probability that a single viable microorganism is contained in collected samples was calculated when the corer-type sand collection system was used as planned by the MMX mission. The team demonstrated that the microbial contamination probability of samples collected on the Martian moons has a 99% probability of being below one millionth (10^{-6}) in the sampling area and the amount of samples planned by MMX even including the various uncertainties in the input parameters that were taken into account.

JAXA's report was accepted by COSPAR, and the MMX mission is now classified at the same level of planetary protection policy as Hayabusa2.

Future Prospect

The COSPAR Planetary Protection Panel has announced that this recommendation will only apply to the MMX mission but not universally for other future missions to the Martian moons. However, since the Martian moons have considerable significance as a potential base for future crewed missions to Mars, the formation of this recommendation founded on this research is expected to contribute to full-scale Mars exploration promoted through international collaboration.

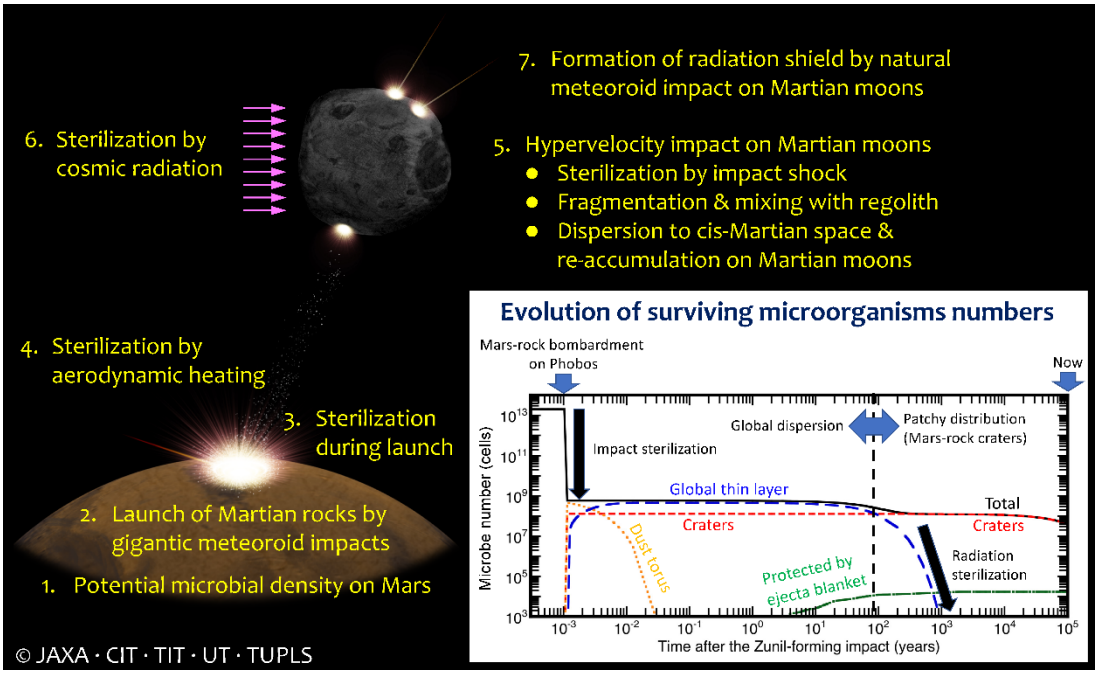

Figure: A schematic diagram of the time sequence from the Zunil-forming impact event to the present, and various processes related to the number of surviving microorganisms considered in the study. The team estimated the number density of potentially-living microorganisms on present-day Mars based on the number densities of microbes at analog sites on the Earth in Antarctica, where there are regions of permafrost. The team conducted a series of three-dimensional impact simulations to reproduce the Zunil-forming impact event and analytically calculated the orbital evolutions of each ejecta particle in the cis-Martian space. This combined calculation provided the total transported mass of Mars rocks to the Martian moons. The team then considered the sterilization of microorganisms due to both collisions with the moons based on data pertaining to the most resistant microbes found on Earth. The inset of the figure shows the time variation of the total number of surviving microorganisms on Phobos. Finally, the team calculated the probability that living microorganisms are collected together with the sand on Martian moons.

*1 During past deep space explorations performed in Japan, obligations under the COSPAR planetary protection policy were implemented by individual projects by adopting design standards in compliance with the COSPAR planetary protection policy and associated requirements, and by forming an international agreement at the COSPAR planetary protection panel. Considering the recent increase in space exploration missions in Japan, JAXA newly established a planetary protection organization in December 2018 and issued JAXA's planetary protection policy and the associated standards to systematically work on planetary protection issues. JAXA is now organizationally committed to steadily complying with the COSPAR planetary protection policy.

*2 Although Viking conducted by NASA in the 1970s did not detect any Martian microorganisms, there is no denying the

possibility that microorganisms of 1 billion (10^9) cells or less per 1 kg of Martian soils, which was the detection limit of the life-detection instruments used at that time, might exist on Mars. In fact, it is widely understood that the life detection instrument used for Viking cannot detect any microorganism under the microbial density in the Atacama Desert or Antarctica.

*3 If the probability that the collected samples contain viable microorganisms exceeds the upper limit of one millionth, the planetary protection policy called *Restricted Earth Return* applies. At present, no spacecraft has been launched with this policy applied, since a completely different implementation of the planetary protection requirements compared with past missions will be required for spacecraft design, operation, and handling of samples after returning to the Earth. Future Mars sample return and manned Mars missions will be conducted in this framework. The number of *one millionth* (1/1000,000) is an international standard for regarding risks as virtually zero, and is widely used in the water quality standards of the World Health Organization (WHO) and the quality standards of the US Food and Drug Administration (FDA), for example.

Published Papers

Fujita, K., K. Kurosawa, H. Genda, R. Hyodo, S. Matsuyama, A. Yamagishi, T. Mikouchi, and T. Niihara, Assessment of the probability of microbial contamination for sample return from Martian moons I: Departure of microbes from Martian surface, Life Sciences in Space Research, https://doi.org/10.1016/j.lssr.2019.07.009, 2019.

Kurosawa, K., H. Genda, R. Hyodo, A. Yamagishi, T. Mikouchi, T. Niihara, S. Matsuyama and K. Fujita, Assessment of the probability of microbial contamination for sample return from Martian moons II: The fate of microbes on Martian moons, Life Sciences in Space Research, https://doi.org/10.1016/j.lssr.2019.07.006, 2019.

This research is supported by JSPS KAKENHI grant numbers JP17H03486, JP17H01176, JP17H02990, JP17H01175, JP17K18812, JP17J01269, JP18HH04464, JP18K13600, and JP19H00726, and by the Astrobiology Center of the National Institute of Natural Sciences, NINS (AB301018).