EPSC Abstracts
Vol. 11, EPSC2017-136, 2017
European Planetary Science Congress 2017

JAXA's Martian Moons eXplortaion, MMX

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Abstract

This paper describes the JAXA's Maritian Moon eXploration (MMX) mission that is under intensive study. The objective of the mission is to reveal the origin of the Martian moons, Phobos and Deimos. The goal beyond the objectives is to progress our understanding of the behavior of small bodies that delivered water from outside the snow line to the habitable zone of the solar system. The planned launch is in 2024 and various arrangements for international collaborations are moving in full-steam.

1. MMX Mission Objective and Goal

The origin of the Martian moons, Phobos and Deimos has been enigmatic. Two leading ideas are either that they are captured primordial asteroids or that they are formed by (not too gigantic) giant impacts. Detailed remote sensing observations by an orbiter may tell us the origin but analysis of returned samples enables us to step beyond revealing the origin. The goal beyond the objective is to progress our understanding of the behavior of small bodies that delivered water from outside the snow line to the habitable zone of the solar system.

The planets in the habitable zone of the solar system were born inside the snow line indicating that they were born dry. For the habitability to be switched on at all, water needs to be delivered from outside the snow line. Small bodies migrating across the boundary between the inner and the outer part of the early solar system are considered to play the role of delivery capsules of water (and organic compounds) from outside the snow line.

If the origin of Phobos is known to be captured primordial asteroid, it implies that Phobos had been one of the water delivery capsules but was captured during its journey from outside the snow line. Then detailed analysis of the samples allows us to study how the primordial materials, namely, water and organic compounds, are brought into the inner-part of the solar system. Sample analysis also allows us to unveil the migration history of the small body that behaved as a delivery capsule.

If the origin of Phobos turns out to be giant impact, samples will be composed of materials from ancient Mars and the impactor which can be a small bodey from outside the snow line. In a sense, Mars sample return is realized. Their analysis will reveal the impact size and allow us to evaluate how the initial evolution of Mars surface environment was affected by the violent satellite formation process that the small body triggered. Since the impact was likely to be of a decent scale, the nature of the impactor may be deciphered from analysis of samples that were less altered upon the impact than disabling the deciphering work.

Due to its close orbit to Mars, Phobos would have been showered by debris generated by impact events on the surface of Mars. That is, we may find samples from ancient Mars surface among samples to be collected from Phobos (even if its origin does not turn out to be giant impact). The Mars samples may span over a wide range in time and over a wide area on the surface, and may enable us to read-out the evolution history of Mars surface environment. This bonus aspect made us decide Phobos, not Deimos, as the target from which samples are returned.

2. MMX Mission Scenario and Science Instruments

The launch is planned to be in 2024 by an H-III launcher. Chemical propulsion will bring the spacecraft to Mars in one year. After Mars Oribit Insertion (MOI), orbital maneuver will put the spacecraft into a Quasi-Satellite Orbit (QSO) around Phobos. There is a variety of options for QSOs and the details are yet to be defined: The baseline QSO altitude is ~20km. From the QSOs, various remote sensing observations of Phobos will be performed, not only to characterize its surface but also to create maps based on which landing sites will be selected.

Sampling will be done as the spacecraft lands and stays on the surface for some hours. The sampling

device, a corer situated on a tip of a robotic arm, is so designed that the minimum amount of the samples is 10g and that samples from more than 2cm below the surface are acquired.

On the exit leg out of the Mars system, multiple flybys of Deimos to make remote sensing observations are situated. Close-up observations of Deimos, and that with reference to the ground-truth results from Phobos, would enable us to give strong constraint to the idea for its origin. Returning samples from both Phobos and Deimos, unfortunately, does not fit within the envelope given to the ISAS space science program.

After spending three years in the Mars system, the spacecraft will be on its return cruise to Earth. The sample recovery will be in 2029. Sample analysis effort, mostly likely involving international participation via issuance of multiple AOs, will continue for some years.

The instruments selected to be onboard the MMX spacecraft are listed below:

[Sample science]

· Sampler and Re-entry Capsule: Acquisition of more than 10g Phobos genesis samples and Earth return from Mars orbit.

[Remote-sensing observations]

· Telescopic and wide angle multiband camera : To image geologic features and for spectroscopy of hydrated and non-hydrated silicate minerals and space weathering.

· Neutron and Gamma-ray spectrometer (NGRS): For measurements of silicate and volatile components.

· Near-Infrared spectrometer (NIRS): For spectroscopy of hydrated minerals and/or organic matter

· Light detection and ranging: To measure topographic features and to construct detailed shape model

[In-situ observations]

· Circum-Martian dust monitor: For Phobos space environment theme

· Ion mass spectral analyzer : To detect degassing from possible ice inside Phobos and for Phobos space environment theme

3. International Collaboration in MMX: Hot Topics as of April 2017

Phobos has been observed by previous missions but the existing data are not necessarily in a shape that allows smooth utilization by an independent party. In order to clear this hurdle, an effort supported by NASA that will enable easy access to the requested information is in progress. While the effort is not targeting especially at JAXA's MMX, MMX will be the first to gain benefit from the effort. The products will make an early international effort of studying a possible MMX landing site possible.

In late March 2017, NASA issued an AO for investigation utilizing NGRS to be onboard MMX. The selection process will be completed before the end of 2017. The selected PI will join the Science Board of MMX which has the highest authority in making science-oriented recommendation to the MMX Project Manager.

In April 2017, JAXA and CNES signed an Implementation Agreement (IA) related to MMX. The IA states that CNES continues to study the possibility of (1) provision of "MacrOmega" (NIRS), (2) participation in the study on flight dynamics in the close proximity of Phobos, and (3) provision of a small lander (~10kg) to be deployed from the MMX spacecraft to the Phobos surface.