EPSC Abstracts
Vol. 12, EPSC2018-1036, 2018
European Planetary Science Congress 2018

EPSC European Planetary Science Congress

Martian Moons eXploration (MMX) : an overview of its science

K. Kuramoto (1,2), Y. Kawakatsu (1), M. Fujimoto (1), J.-P. Bibring (3), H. Genda (4), T. Imamura (5), S. Kameda (6), D. Lawrence (7), K. Matsumoto (8), H. Miyamoto (5), T. Morota (9), H. Nagaoka (1), T. Nakamura (10), K. Ogawa (11), H. Otake (1), M. Ozaki (1), S. Sasaki (12), H. Senshu (13), S. Tachibana (5), N. Terada (10), T. Usui (4), K. Wada (13), S. Watanabe (9), and MMX study team
(1) Institute of Space and Astronautical Science, Japan Aero-space Exploration Agency (3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan), (2) Hokkaido University (Kita 10, Nishi 8, Kita-ku, Sapporo, Hokkaido 060-0810, Japan, keikei@ep.sci.hokudai.ac.jp), (3) IAS, Univ. Paris-Sud 11, (4) Tokyo Inst. Tech., (5) Univ. of Tokyo, (6) Rikkyo Univ., (7) APL, Johns Hopkins Univ. (8) NAOJ, (9) Nagoya Univ., (10) Tohoku Univ., (11) Kobe Univ., (12) Osaka Univ., (13) PERC, Chiba Inst. Tech.

Abstract

Martian Moons eXploration (MMX) is a round trip mission to the Martian moons, under phase-A study in ISAS/JAXA to be launched in 2024. This paper describes conceptual study results about MMX science.

Science goals and requirements

The MMX mission places two science goals; 1) To reveal the origin of the Mars' moons under debate between capture origin and giant impact origin, and then to make a progress in our understanding of planetary system formation and of primordial material transport around the border between the inner-and the outer parts of the early solar system, 2) To observe processes that have impact of the evolution of the Mars system from the new vantage point and to advance our understanding of Mars surface environmental transition.

The mission requirements extracted from the breakdown of science goals and objectives are summarized as follows: 1) Retrieval of Martian moon regolith samples and determination of the moons' origin from their laboratory analyses, 2) Close-up observations of independent proxies of the moons' origin, 3) Sample analyses and close-up observations to reveal the formation of moons' building materials and long term evolution of the moons, 4) Ibid to constrain the Mars system evolution and its elementary processes.

Sample science concepts

MMX will carry out multi-samplings from Phobos which may have compositional diversity as inferred from the existence of two end members of representative reflectance spectra. Main reasons for taking Phobos rather than Deimos as the sampling target are abundant pre-existing data that help landing site selection and the expected higher concentration of younger impact ejecta from Mars in the surface sample.

Regolith samples more than 10 g enough for detailed analyses of Phobos-indigenous materials will be collected with characterization of sampling sites in relation to bedrocks and surrounding geologic features. Isotopic, elemental and mineralogical compositions of sample particles will be examined with chronological analysis, which reveals the origin and cosmochemical nature of Phobos. If Phobos-indigenous materials are carbonaceous chondritic as favored from the reflectance spectra, capture origin is concluded. In this case, those data also tell us the birthplace and migration of Phobos precursor until the capture event had happened. If indigenous materials mostly show igneous rock textures with composition as a mixture of the Martian mantle and an exotic body, giant impact origin is concluded. In this case, samples may also tell us information on the source region of the moon-forming giant impactor, the age and processes of the giant impact event, and the physico-chemical state of primordial Martian mantle. Survey and analyses (if available) of younger materials ejected from Mars would provide us information on the evolutionary history of Mars.

Mission Instruments

For close-up observations of the Martian moons, TENGOO (Telescope camera) and OROCHI (Wide angle multi-band cameras), MacrOmega (Near IR spectrometer), MEGANE (Gamma-ray and neutron spectrometer), LIDAR (Light detection and ranging), CMDM (Circum-Martian dust monitor) and MSA (Mass spectrum analyzer) are specified as nominal science instruments. Some optional mission instruments are under discussion (rover, deployable cameras, and etc.). MacrOmega and MEGANE will be provided from CNES and NASA, respectively.

These instruments will complementarily reveal the global properties of Phobos and Deimos and search for proxies of the moons' origin, building materials and long-term evolution independently of sample analyses. For instance, high spatial resolution imaging by TENGOO will be used to search for young geologic structures on which fresh bedrock materials are exposed. Visible to near IR multispectral imaging for such structures by OROCHI and MacrOmega will constrain the mineralogical composition of bedrock with a particular focus on whether hydrous minerals exist or not, a possible proxy indicative of Phobos origin. Those instruments are also used for the landing site selection, sampling site characterization, geologic studies, and observation of Mars atmosphere.

MEGANE will also constrain averaged abundances of hydrogen and other elements such as Si, Fe, and O in surface layers across several tenths cm depth with a resolution of hemisphere-scale or better, which enables to cross-check the bedrock composition(s) estimated by sample analyses and multispectral imaging. The elemental abundance ratios such as Si/Fe are another useful proxy of satellite origin. MSA will attempt to detect ion particles originated from H_2O possibly outgassing from the moon's interior as well as the sputtered ions including metallic elements from the satellite surface. If a significant flux of H_2O-derived ion components is detected as expected for an ice-bearing Phobos, its cold origin, or capture origin is favored.

LIDAR measures the global topography of Phobos, which contributes to studies of geologic features such as grooves and craters and estimation of mass distribution inside Phobos in combination with gravity field analyses using orbital tracking and positioning data. CMDM monitors the dust particle flux around the moons, which provides basic data to understand the space weathering, gardening processes on the moon's surface, and possible dust ring formation. This helps to understand the nature of returned sample grains and the long term evolution of the surface of the Martian moons.

Mission Profile

The mission study proceeds targeting the launch in 2024. Five years round trip will be made by use of chemical propulsion system. The outward interplanetary cruise takes about 1 year by the most efficient Hohmann like transfer to arrive at Mars in 2025. MMX chooses 3 years' stay in view of more science data obtained and better condition for the landing operation. The homeward interplanetary cruise takes about 1 year as well and the spacecraft will return to the Earth in 2029.

After the Mars orbit insertion, MMX is injected into an orbit near the Phobos' orbit and approaches to Phobos by reducing the phase difference with Phobos. MMX is subsequently injected into a quasi-satellite orbit around Phobos to start its close-up observation. MMX will take successively lower quasi-satellite orbits with minimum altitude from the Phobos surface 20 km or below. From these orbits, global imaging of Mars atmosphere is also conducted.

Phobos' gravity is weak, but stronger than that of Itokawa and Ryugu, which causes differences in the approach and landing sequence from that of Hayabusa2. MMX adopts a ballistic descent to reach right above a landing site just before a final vertical descent. After the short period of hovering, the final descent is conducted by free-fall without a thruster jet to avoid sample contamination and whirling up of regolith particles.

The sampling operation time correlates with the rotation period of Phobos about 7 hours and 40 minutes; In the case without capability to hibernate in night time on the Phobos surface, the time duration of the surface stay is limited in 2.5 hours by taking 1 hour margin to the day time of Phobos. The time duration that can be allocated for the sampling operation is 1.5 hours. Taking also into account the communication delay, ~10 min is allowed for the decision of a sampling point based on the high-resolution surface image transferred to the Earth from the landing site.