MARTIAN MOONS EXPLORATION (MMX) CONCEPTUAL STUDY UPDATE.

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Introduction: Martian Moons eXploration (MMX) is a round trip mission to the Martian moons, under conceptual study in ISAS/JAXA to be launched in 2020's. Its conceptual study results have been reported in the last year's LPSC meeting with focusing on science backgrounds [1]. This paper presents the progress of conceptual study and the status of this mission.

Objectives of MMX: The main science objectives of MMX are to reveal the origin of the Martian moons under debate among primitive asteroid capture and giant impact, 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-part of the early solar system. MMX will also aim to understand physical processes in circum-Martian environment and Mars atmosphere, and then to improve our views of evolution of Martian moons as well as the surface environmental transition of Mars.

Along with the close-up observations of the two moons, MMX will carry out sampling from Phobos. The reasons for taking Phobos as the sampling target body 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. Isotopic, elemental and mineralogical compositions of sample particles will be examined with chronological analysis, which reveals the origin and cosmochemical nature of Phobos in the context of planet formation and Martian system evolution. These data also tell us the birthplace and migration of Phobos until the capture event if capture origin is the case. Alternatively, 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 will be clarified if the giant impact origin is the case. Survey and analyses (if available) of younger materials originated from Mars would provide us information on the evolutionary history of Mars. MMX will also explore Deimos with close-up observations to constrain its origin in comparison with Phobos.

Mission Instruments: A sampler system with a combination of a manipulator and corers is studied for acquisition of more than 10 g of Phobos samples from multiple sites. The manipulator has multi-degrees of freedom for its motion, enables sampling from a specified point and transferring core sample to the capsule. The corer mechanism held at the tip of the manipulator is equipped with an injection mechanism that penetrates a corer into the regolith layer > 2 cm beneath the surface. A larger return capsule is designed based on those used for the Hayabusa and Hayabusa2 missions. Because the requirement for sample collection volume of MMX is 100 times larger than Hayabusa2, the size of the sample container is enlarged for storing samples and the mechanism itself. The maximum temperature allowed during the atmospheric entry is 100 ℃ which is the same setting of the Hayabusa2 capsule.

For close-up observations of the Martian moons, TL (Telescope camera) and WAM (Wide angle multiband 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 (a small surface science package, etc.). MacrOmega and MEGANE will be provided from CNES and NASA, respectively.

Those remote-sensing instruments reveal the global properties of Phobos and Deimos precisely and aim to search for independent indicators of the moons' origin, building materials and long-term evolution, complimentarily with sample analyses. Those instruments are also used for the landing site selection, the characterization of sampling sites related to bedrocks and surrounding geologic features, and observations of Mars atmosphere.

Mission Profile: The mission study proceeds targeting the launch in 2024. A major engineering issue of the mission is large energy (Δv of 5km/s) required for a round trip to a Martian moon. Trade-off studies on the mission profile and spacecraft system resulted in 5 years trip by use of chemical propulsion system as shown in Figure 1 [2].

The outward interplanetary flight takes about 1 year by the most efficient Hohmann like transfer to arrive at Mars in 2025. Return opportunities to the Earth open in every two years, 2026 (1 year's stay) and 2028 (3 years' stay) for the departure from Mars. MMX chooses 3 years' stay in view of more science data obtained and better condition for the landing operation. The homeward interplanetary flight takes about 1 year as well, and spacecraft return to the Earth in 2029. Totally, it takes 5 years for a round-trip to Martian moons.

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 finally injected into a quasi-satellite orbit around Phobos to start its close-up observation. From this orbit, 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 planned to be conducted by free-fall without a thruster jet to avoid sample contamination and whirling up of regolith particles.

Due to the considerable time lag of communication with the Earth, an autonomous optical navigation technology is necessary to determine a relative position and velocity of the spacecraft with respect to the surface of a Martian moon for guidance and control towards a landing site. An autonomous hazard detection and avoidance technology may also be necessary to realize a safe landing.

The sampling operation time correlates with the rotation period of Phobos about 7 hours and 40 minutes; Supposing that capability to hibernate in night time on the Phobos surface is unimplemented, 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 (15 min at the shortest distance to the Earth during mission), a sequence of sampling operation is carefully being constructed. 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.

Spacecraft Overview: The requirement of large energy for a round-trip to Martian moons dominates the mission and system design. The baseline spacecraft system is in the form shown in Figure 1. The spacecraft is composed of three modules: the propulsion module, exploration module, and return module.

One notable feature of the system is the adoption of chemical propulsion system for both Mars orbit injection and escape maneuver. It minimizes the time for interplanetary transfer, and permits longer stay in the Martian system to maximize the scientific output. On the other hand, to achieve large orbit maneuver with a chemical propulsion system, large amount of propellant and multi-staged spacecraft system is necessary. The launch mass of the spacecraft is estimated to be about 3500 kg, the largest deep space explorer that ever built-in Japan.

Development of a landing system for the MMX spacecraft is a critical issue for preventing an anomalous landing, which readily causes an incident such as a mechanical rupture and a mission failure. Hence, the landing system should be designed to implement safe landings of the spacecraft.

The MMX landing system consists of three or more legs, footpads, and energy absorbers installed in the legs. A candidate to dissipate the kinetic energy is the method to utilize buckling of honeycomb cores or plastic deformation of 3D printed lattice structures. Highly reliable sensors are also installed for estimation of remaining absorbable energy and for judgment whether the spacecraft reached the surface or not.

REFERENCES: [1] Kuramoto, K. et al. (2017) LPS XLVIII abstract# 2086. [2] Kawakatsu, Y. et al. (2017) Proceedings of the 68th International Astronautical Congress, IAC-17-A3.3A.5.

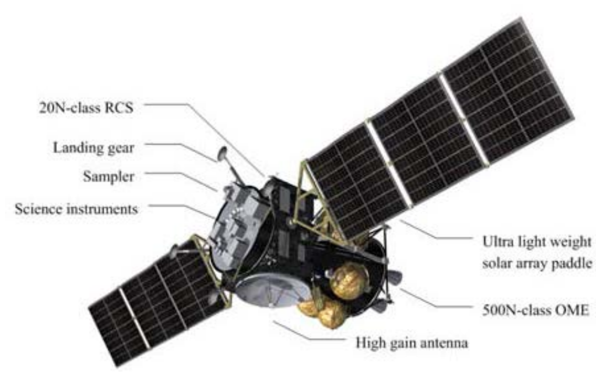

Figure 1: An example of MMX spacecraft design. Launch mass of 3500kg is composed from three stages system with the return module, exploration module and propulsion module. Nominal mission duration is 5 years.