Martian Moons eXploration (MMX)

Mission Overview

April 10, 2017 JAXA Tokyo Office

http://mmx.isas.jaxa.jp

Mission Goal and Objectives

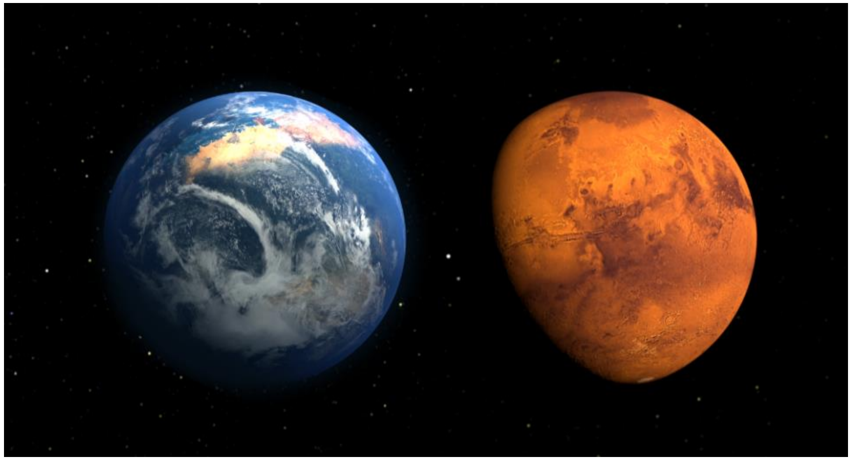
Mars Missions and their Objectives

Missions to Mars are driven by interest in its potentially habitable environment in the past. Their key questions (among many) are,

- *What is the history of the Mars surface environment?*
- *How did the atmospheric loss happen?*
- *What was driving the climate change?*

Curiosity at Gale crater

Credit: NASA, JPL-Caltech, MSSS, MAHLI

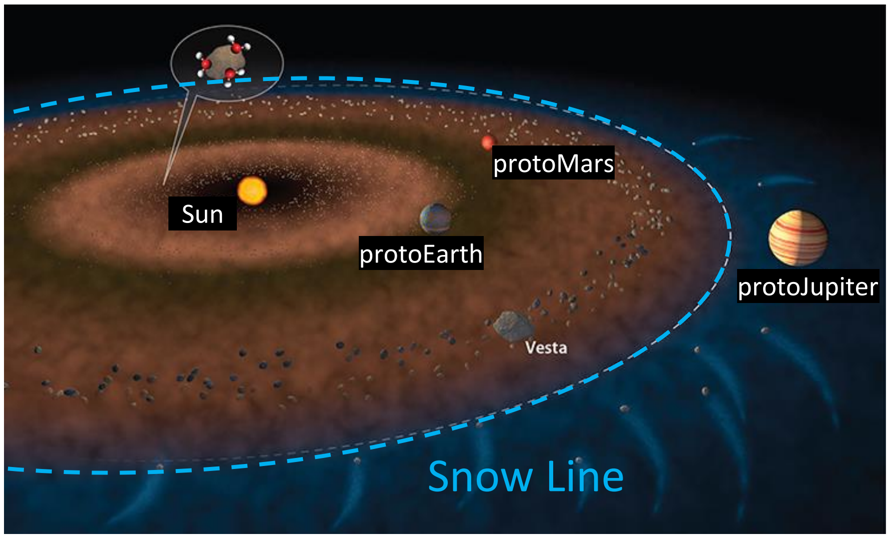


Old habitable Mars and current Mars

Credit: NASA's Goddard Space Flight Center

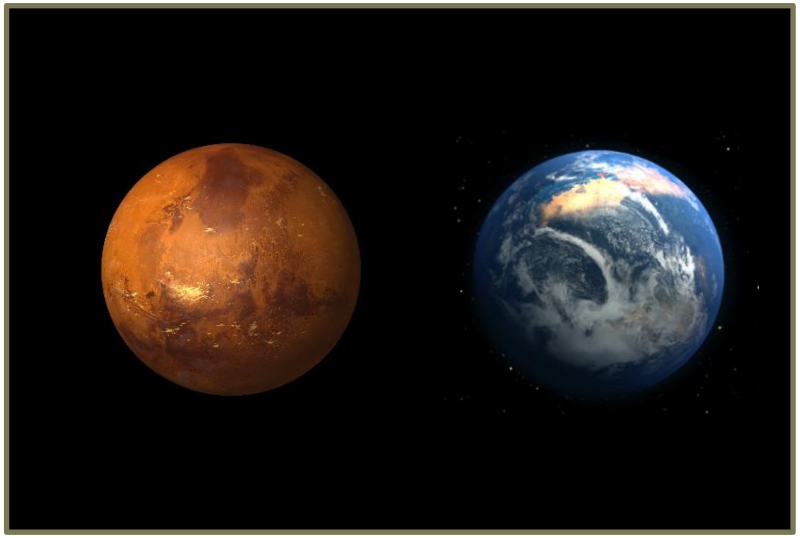
Why Water was on Mars ?

Realizing that rocky planets must have been born dry leads to the key question of different type.



Solar System in early age

Illustration by Jack Cook, Woods Hole Oceanographic Institution



ProtoMars and old habitable Mars

Credit(right): NASA's Goddard Space Flight Center

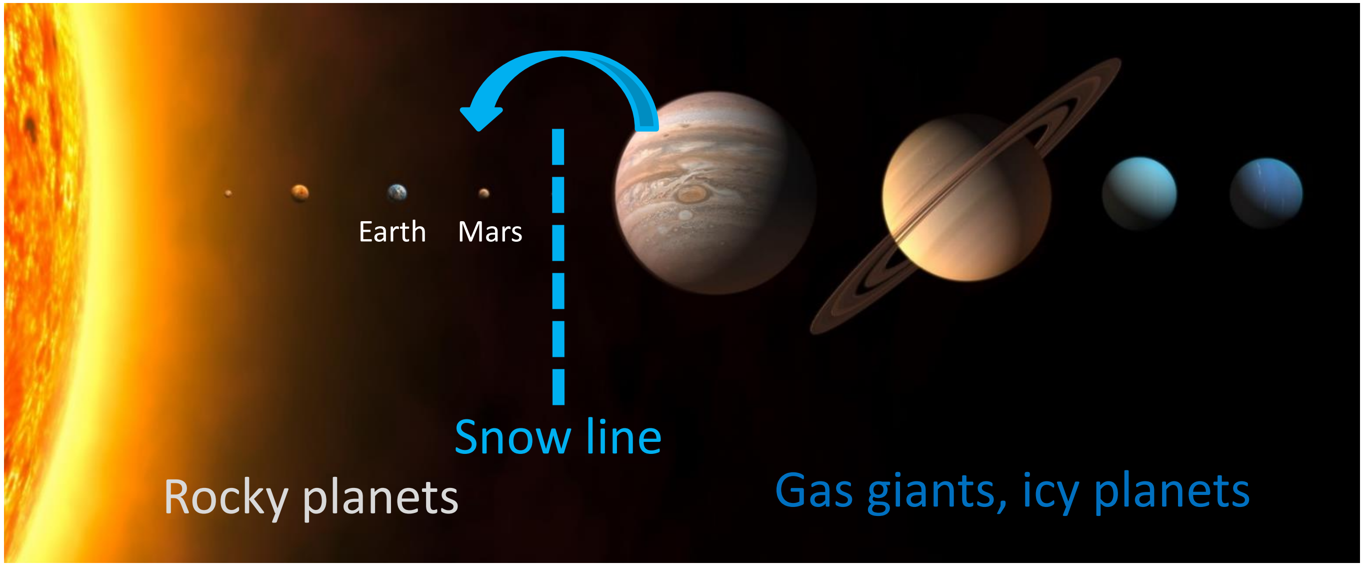
How was water delivered to Mars?

As a part of the big question:

How was water delivered to rocky planets and enabled the habitability of the solar system?

Transport across the Snow Line

- Delivery of water, volatiles, organic compounds etc. from outside the snow line entitles the rocky planet region to be habitable.
- Small bodies play the role of delivery capsules.
- Then, dynamics of small bodies around the snow line in the early solar system is the issue that needs to be understood.

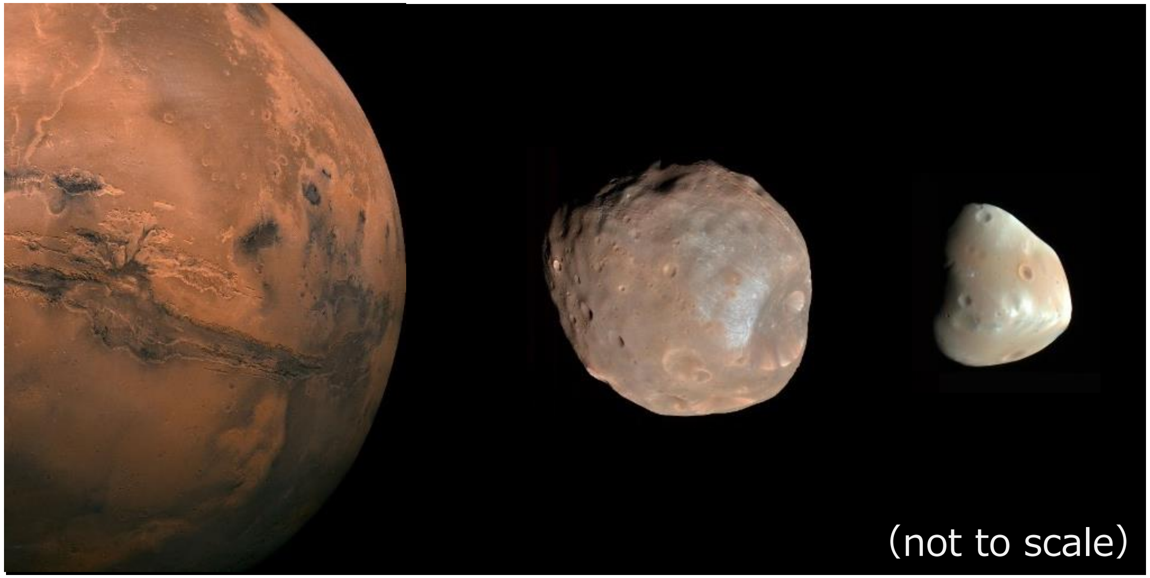


Credit: The International Astronomical Union/Martin Kornmesser

Which, among the seven objects in the inner-solar system, should we explorer to address this key question?!

Martian Moons : Minor Bodies around Mars

Mars was at the gateway position of the rocky planet region to witness the process.
Martian Moons, Phobos (diameter: 23km) and Deimos (diameter: 12km), would be categorized as asteroids if they were not in orbits around Mars.



Credit:
NASA/JPL-Caltech
University of Arizona

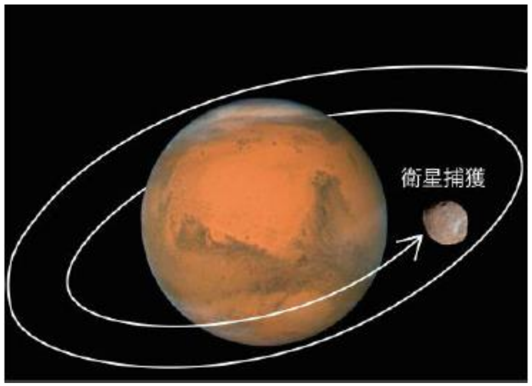
Martian Moons : Phobos and Deimos

Martian moons could have been delivery capsules of water in the early solar system.

The first step: Origin of Martian Moons

Origin of Martian Moons are not known. There are two leading hypotheses: captured primordial asteroid or giant impact.

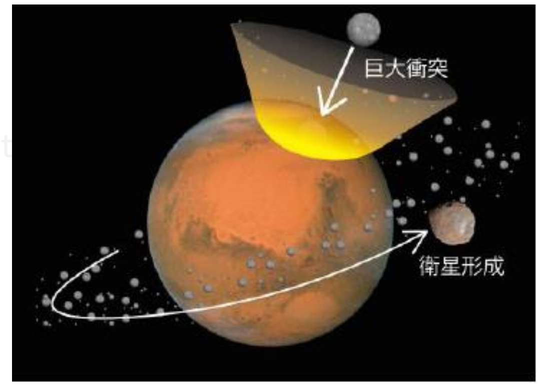
Captured Primordial Asteroid



Credit:
ELSI, Tokyo Inst. of Tech.
Hiroyuki Kurokawa

Sample analysis will characterize a capsule that was on its way to deliver water and organic compounds to the inner-solar system.

Giant Impact



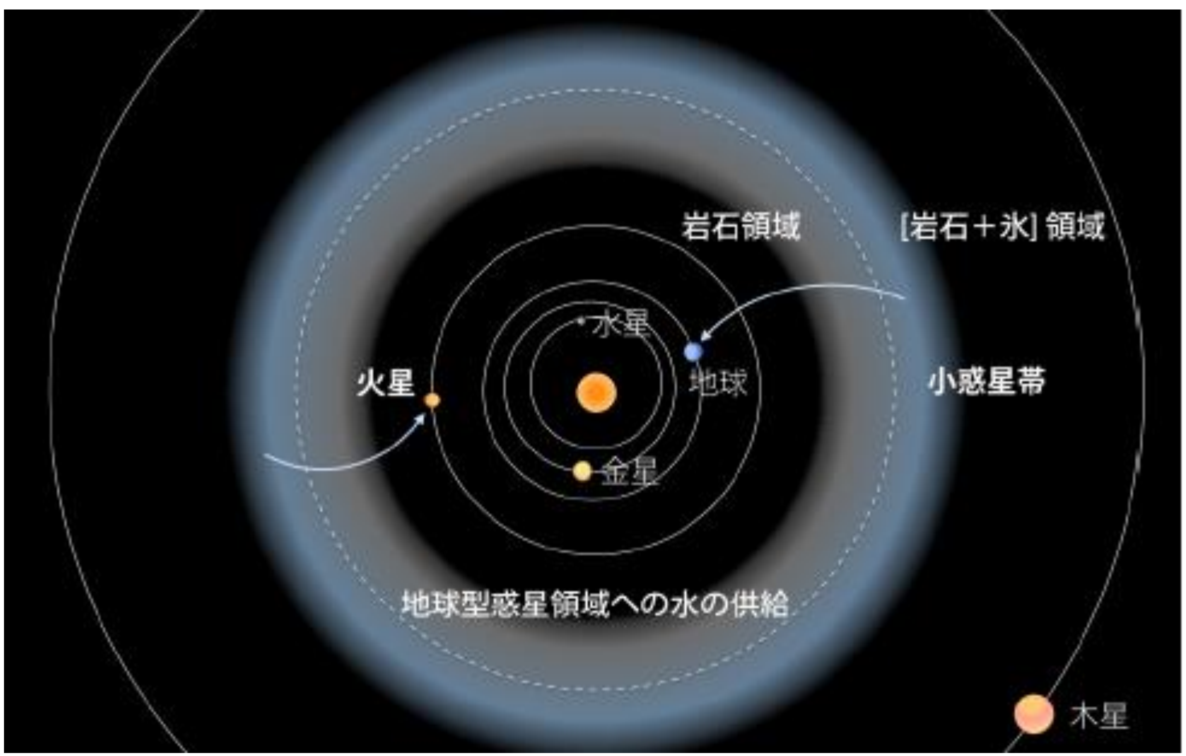
Sample analysis will reveal that the samples are mixture of Mars materials and impactor materials: Mars sample return realized! We do learn about dynamics of the small body (the impactor), too.

Martian Moons eXploration (MMX) will reveal the origin of Martian moons from the analysis of returned samples.

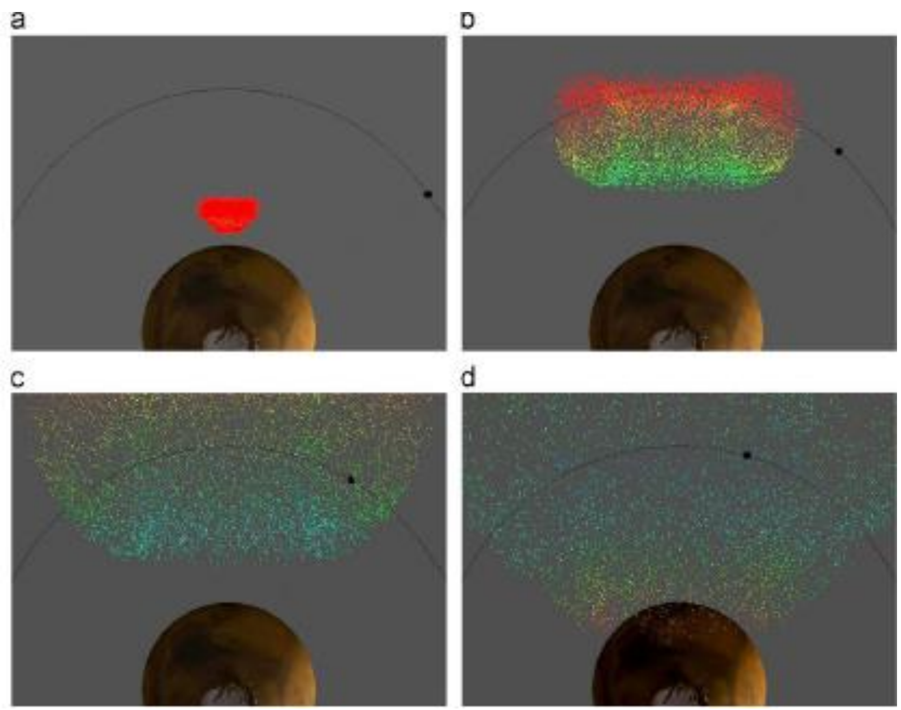
Beyond knowing the origin

- Knowing the origin is guaranteed once the sample is subject the analysis by the ground facility.
- Whichever idea found to be the case, further information related to the behavior of the Phobos-creating small body that originated outside the snow line will be obtained.

- Synergy with Hayabusa2 and OSIRIS-REx naturally expected.
- While the two asteroid missions are after the **<reservoir question>,** this mission is after the **<transport question>.**



- We will also search in the returned samples for those debris from the Mars surface that were ejected upon an impact event and implanted on the Phobos surface. When found (Mars sample return!), we will try to read-out the history of the Martian surface environment.



- SR from Phobos, not Deimos

- Difference from Martian meteorites

- *Planetary Protection* issue

Mission Objectives

Realizing that rocky planets must have been born dry leads to the key question *"How was water delivered to Mars?"*

Delivery of water, volatiles, organic compounds etc. from outside the snow line entitled the rocky planet region to be habitable.
Small bodies played the role of delivery capsules.

Mars was at the gateway position of the rocky planet region. Phobos and Deimos are the minor bodies around Mars.
Martian moons would be related, by one way or another, to delivery capsules of water in the solar system.

Martian Moons eXploration (MMX) Mission Objectives

To reveal the origin of the Martian moons, 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.

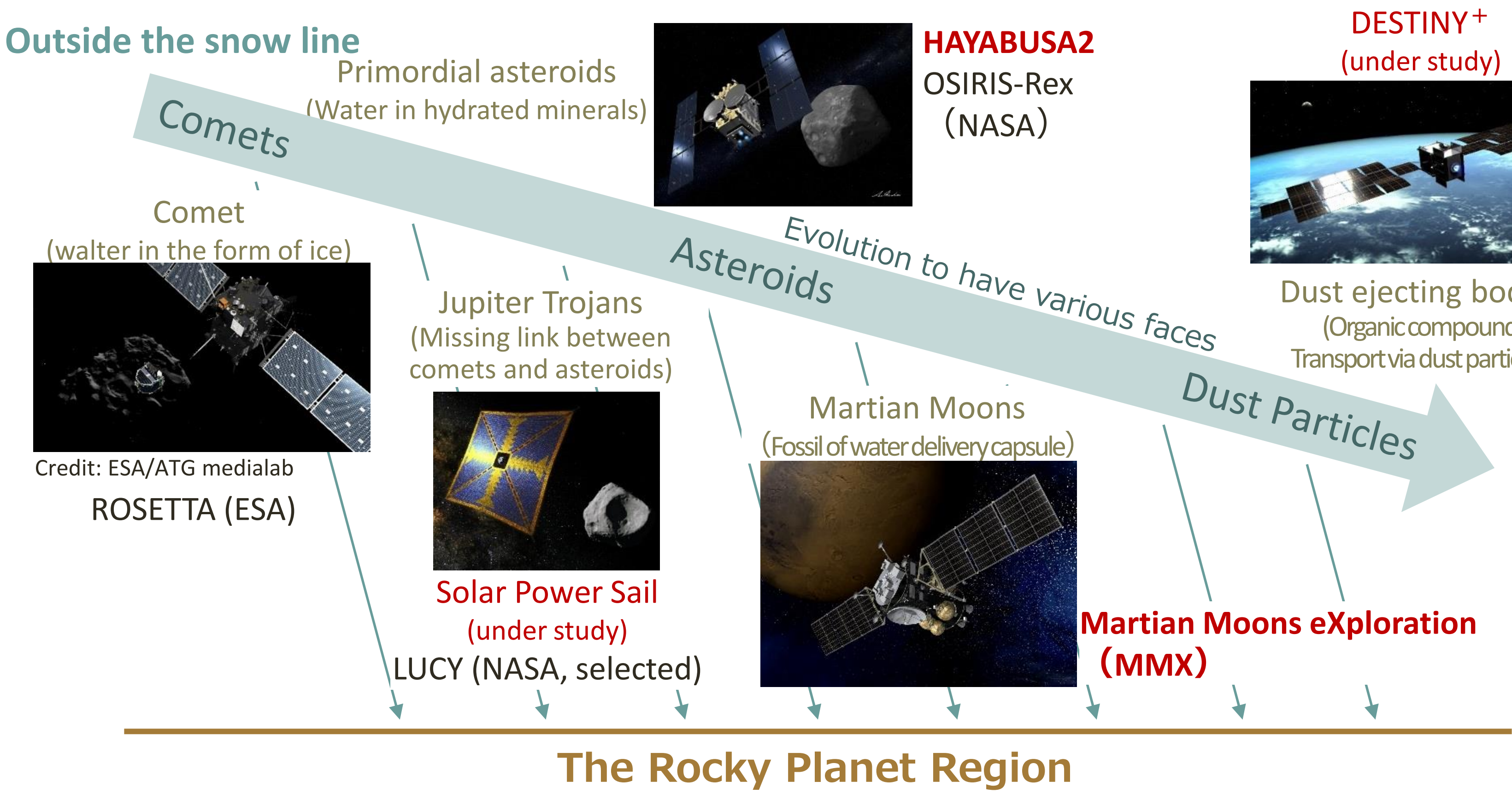
Sub-Objectives

To understand processes in circum-Martian environment and Mars atmosphere, and then to improve our views of evolutions of Martian moons as well as Mars surface environmental transition.

ISAS Minor Body Exploration Strategy

Small bodies born outside the snow line. Initially comet-like, evolved in time to show various faces. Water and organic compound delivery by these enabled the habitability of our planet. When, who and how?

ISAS addresses this question by a series of small body missions.



Mission Objectives (from engineering side)

A major role of the space technology divisions is to provide engineering realization to this planetary science mission. Besides, we set our own mission objectives from the engineering side in line with our mission goals to realize "further and more flexible" space exploration.

Objective : To exploit astronautics and exploration capability for our future deep space missions in the following areas.

Round trip to Martian system (Astronautics)
Large energy (Δv around 5km/s) is required for a round trip to a Martian moon.

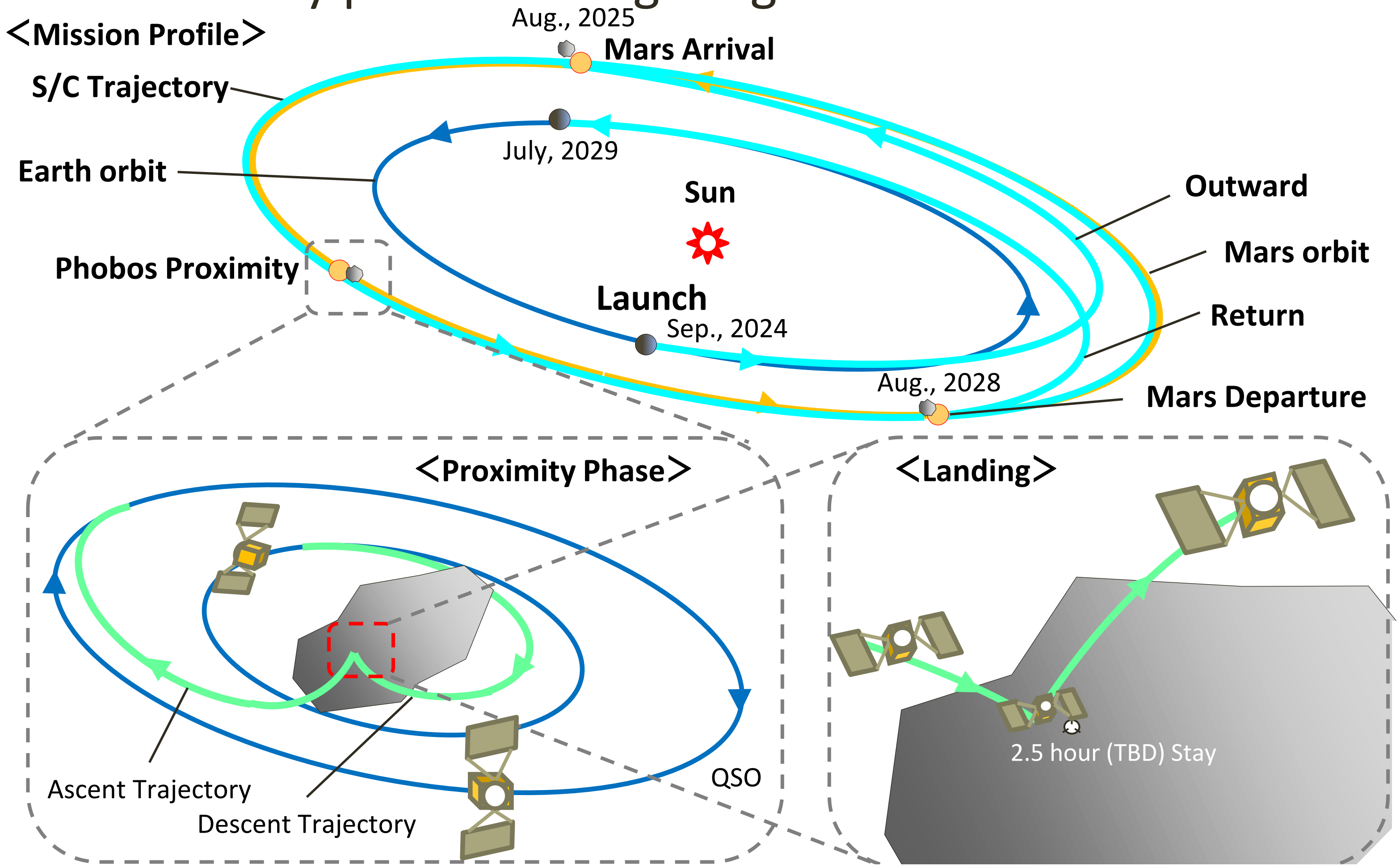
Sophisticated sample retrieval technologies (Robotics)
Higher performance (than in case of Hayabusa2) is required for sample retrieval.

High rate mission data transmission (Communication)
Performance equivalent to European and U.S. deep space missions is envisioned.

Mission Profile
Spacecraft Overview

Mission Profile

Interplanetary flight takes about 1 year for outward/homeward.
Trade-off study on the mission profile and spacecraft system results in 5 years trip by use of chemical propulsion system.
The mission study proceeds targeting the launch in JFY2024.



(written above is an example, and could change in the future)

Mission scenario

(1) Mars orbit insertion

(2) Transfer to a quasi-satellite orbit around Phobos for close-up observations

(3) Landing and sampling from Phobos

(4) Transfer to Deimos for multi-flyby observations (or from a quasi-satellite orbit).

(5) In-situ space observations and Mars remote sensing observations for Mars atmospheric science themes while the spacecraft is within the Mars gravitational sphere.

(6) Departure from Mars and return to Earth

(7) Recovery of samples and initial analysis

- Model payload:

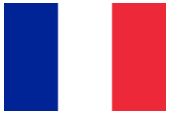
A list of instruments that meets all the mission requirements.

[sample science]

- **Sampler**: Acquisition of more than 10g Phobos genesis samples

[remote sensing]

- **Visible camera**: To image geologic features
- **Near-IR spectrometer**: For spectroscopy of mineralogical signatures and for Mars atmospheric observations



- **Neutron/Gamma-ray spectrometer**: For elemental composition measurements

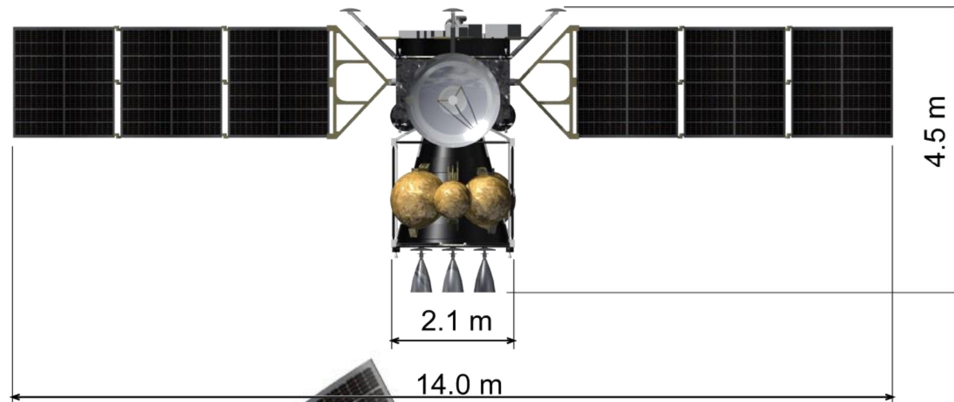
- **LIDAR**: To construct a shape model

[in-situ observations]

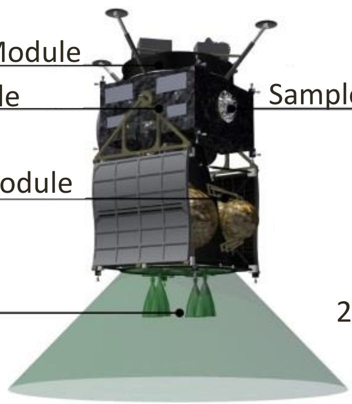
- **Ion mass spectrometer**: To detect degassing from possible ice inside Phobos
- **Dust counter**: For Phobos space environment theme
- **LIBS <optional>**: local elemental abundance measurements upon landing

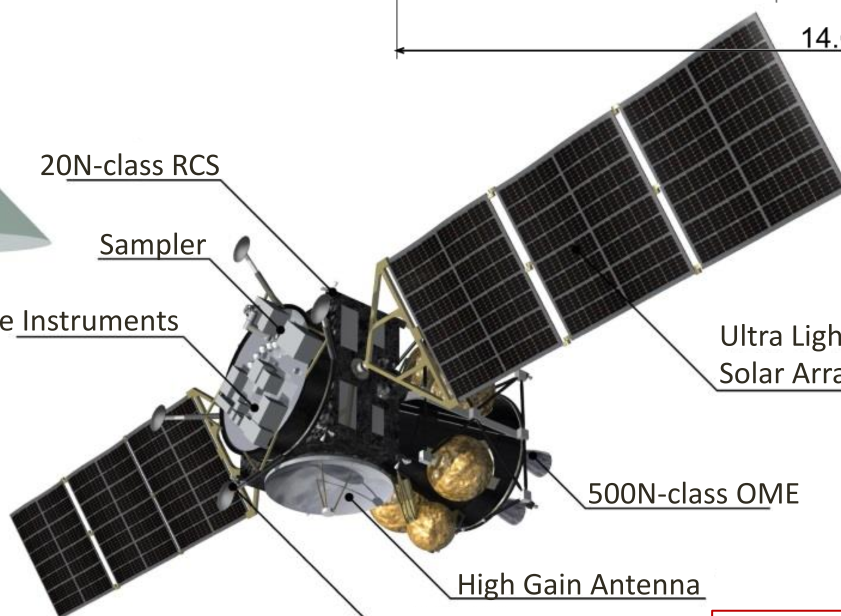
Spacecraft Configuration

Wide range trade-off study has been done in pre-Phase A study, and spacecraft system's configuration and major specification are defined preliminarily.



Launch Configuration





On-Orbit Configuration

Launch Mass : 3400kg

Three stages system.

Return module:	1350kg
Exploration module:	150kg
Propulsion module:	1900kg

Mission Duration : 5 years

(written above is an example, and could change in the future)

Options under consideration

The major ones:

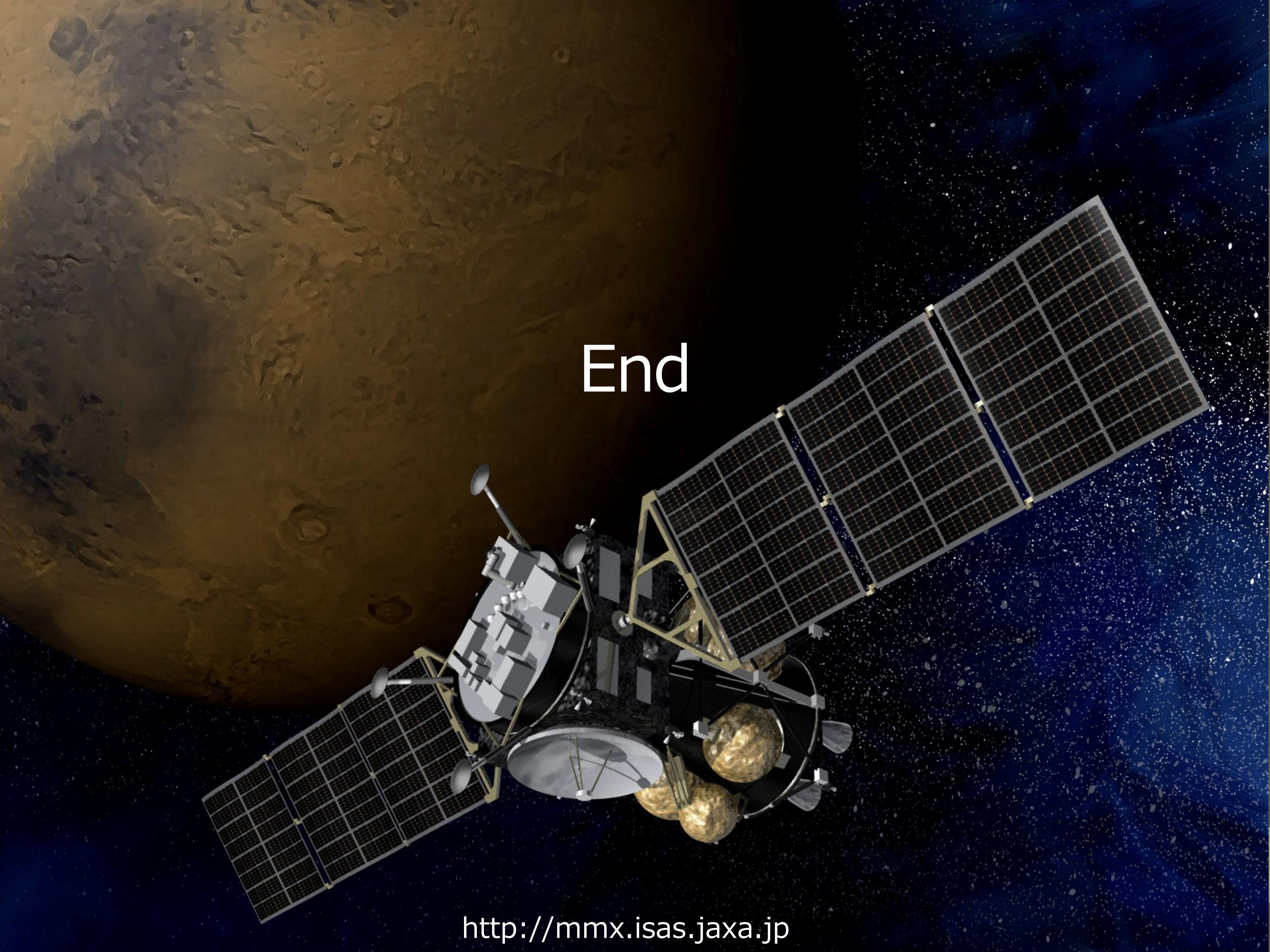
- A small lander to be deployed upon landing on Phobos
- Battery for overnight survival upon landing on Phobos
- The number of low altitude orbits around Phobos
- Flyby vs rendezvous of Deimos

The question of distributing the mass resources (lander mass, battery mass, fuel mass) to which science target:

more detailed Phobos info

or

somewhat better info on Deimos.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