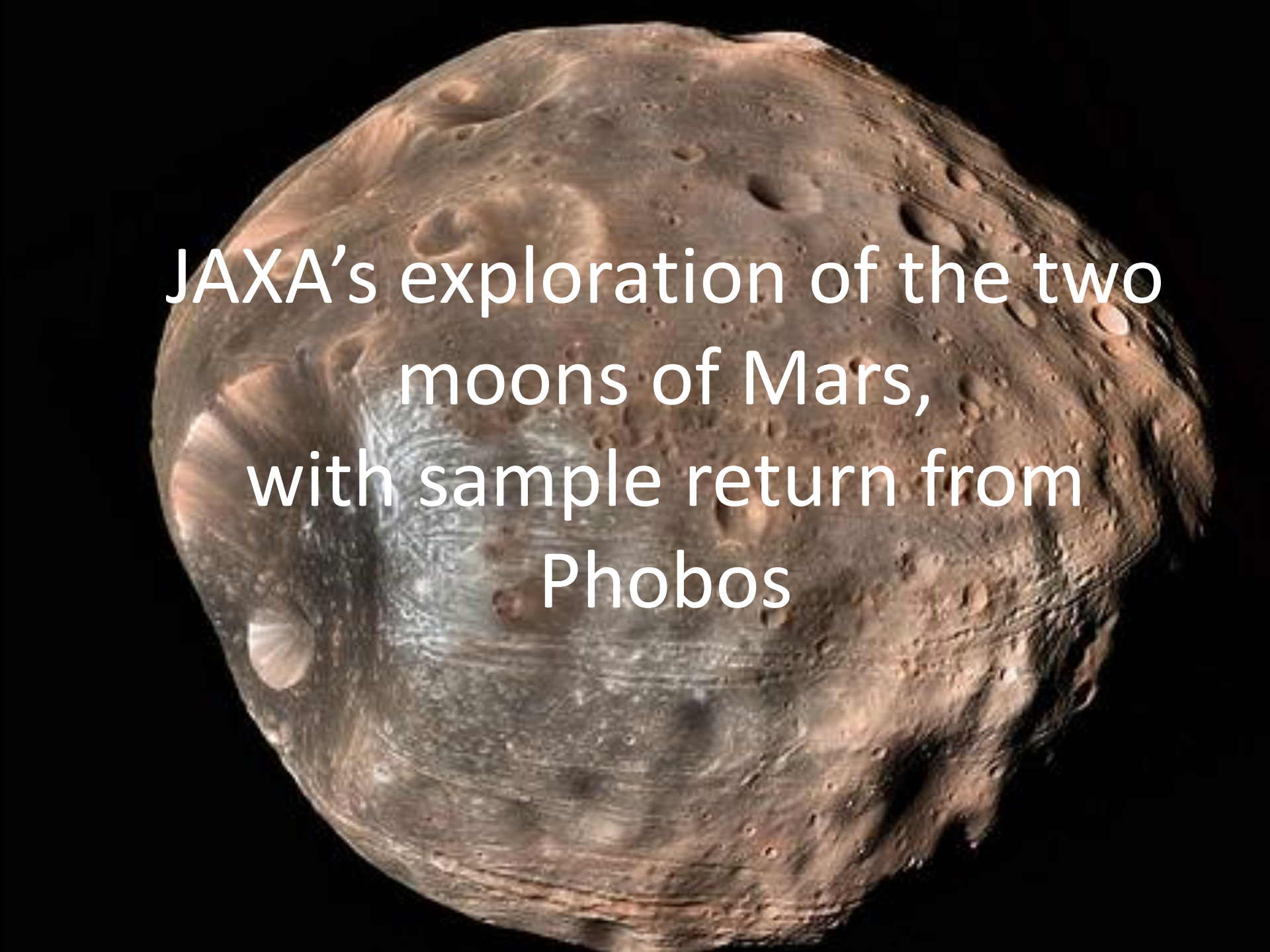
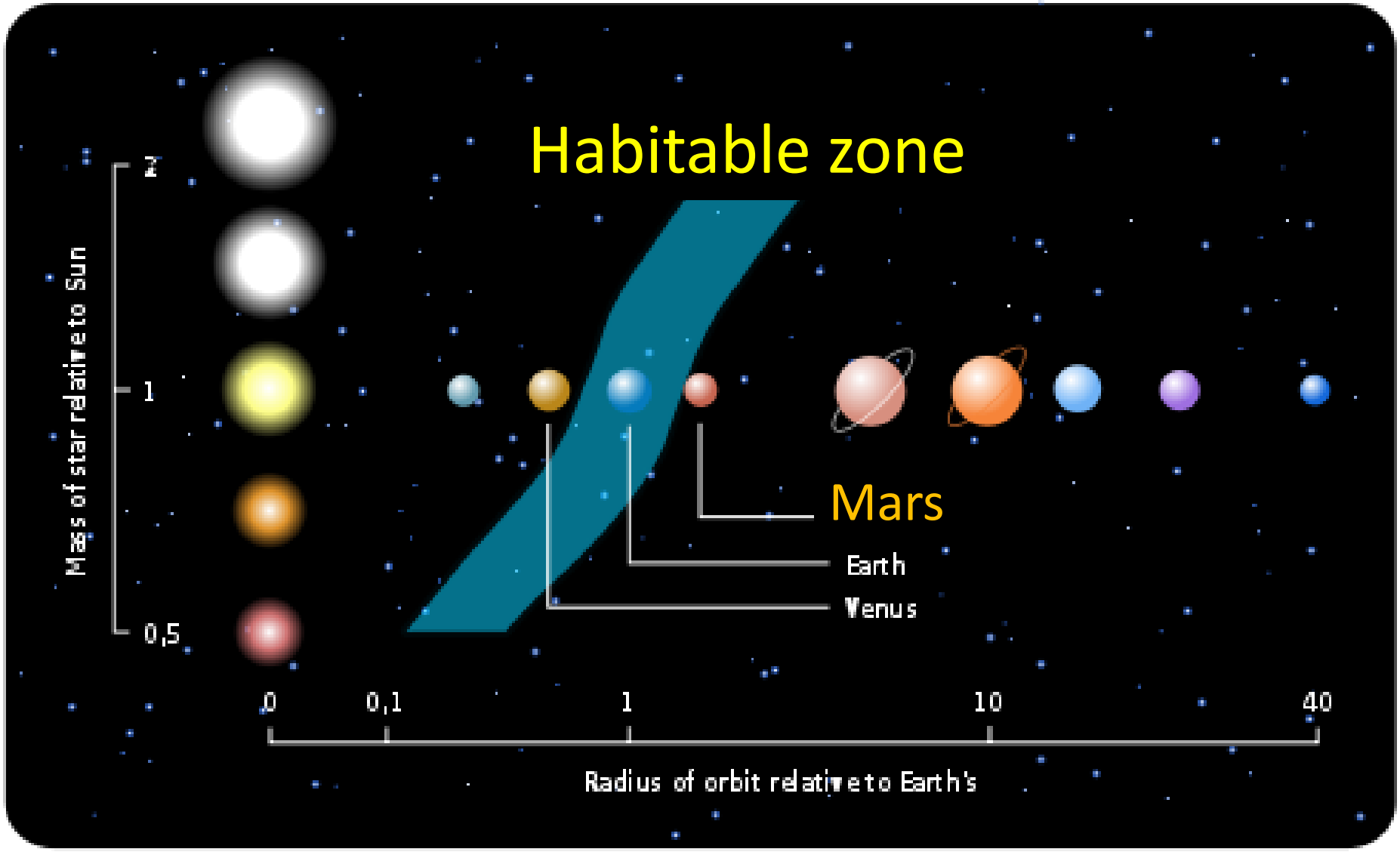

JAXA’s exploration of the two moons of Mars,
with sample return from Phobos

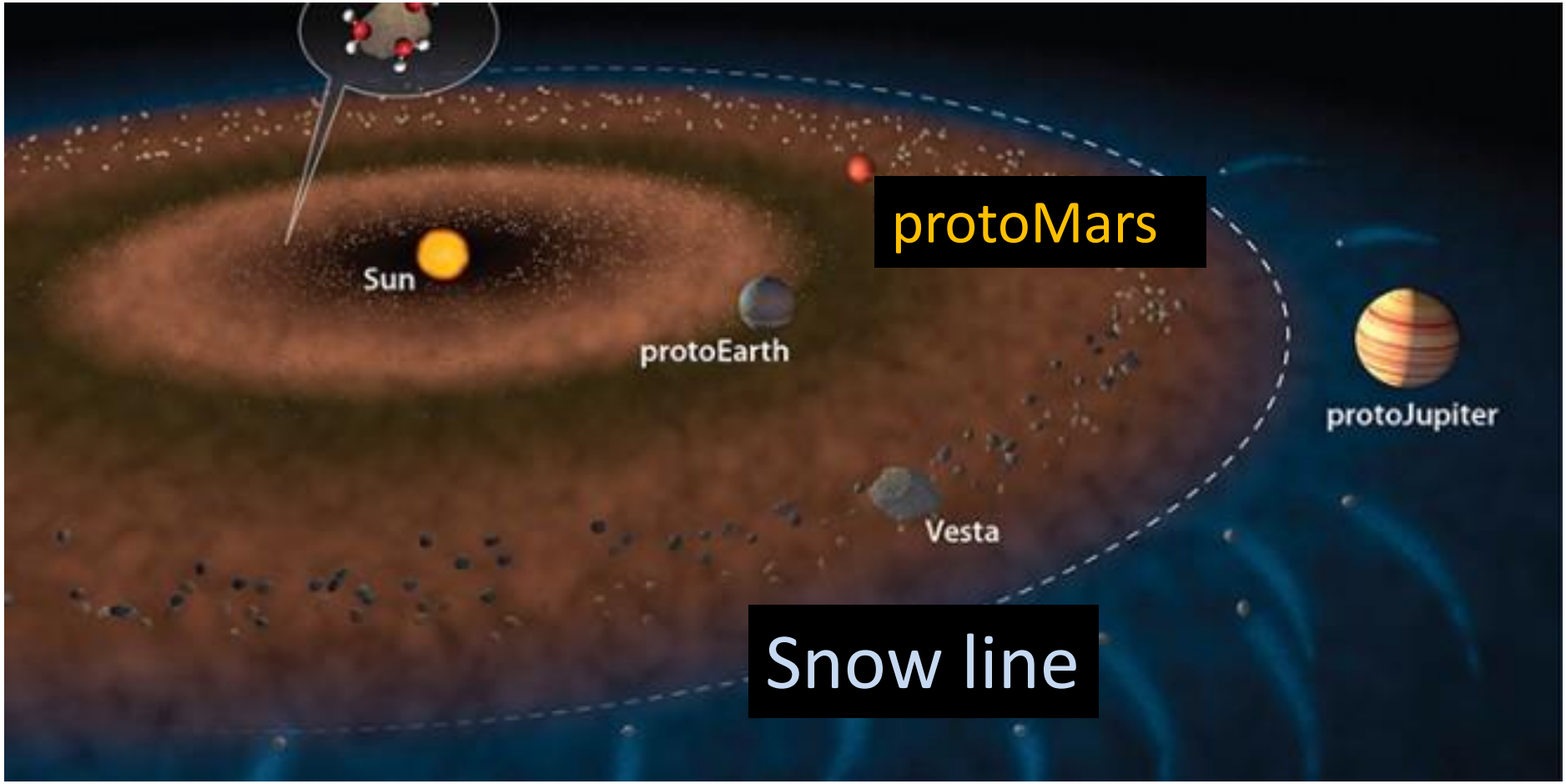
Martian Moons eXplorer (MMX)

So many missions to Mars
Why?

Driven by the interest in its possible past habitability

- The habitability question





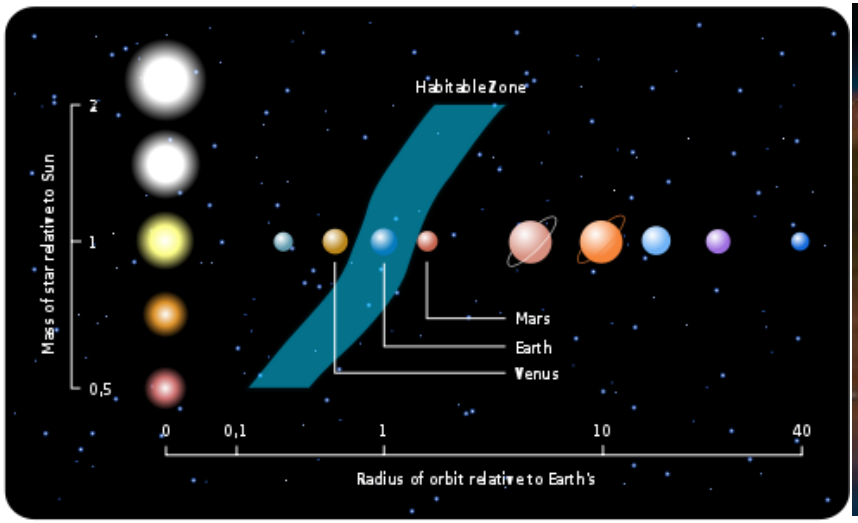
- Rocky planets that are in the habitable zone was born inside the snow line: They must have been born dry.

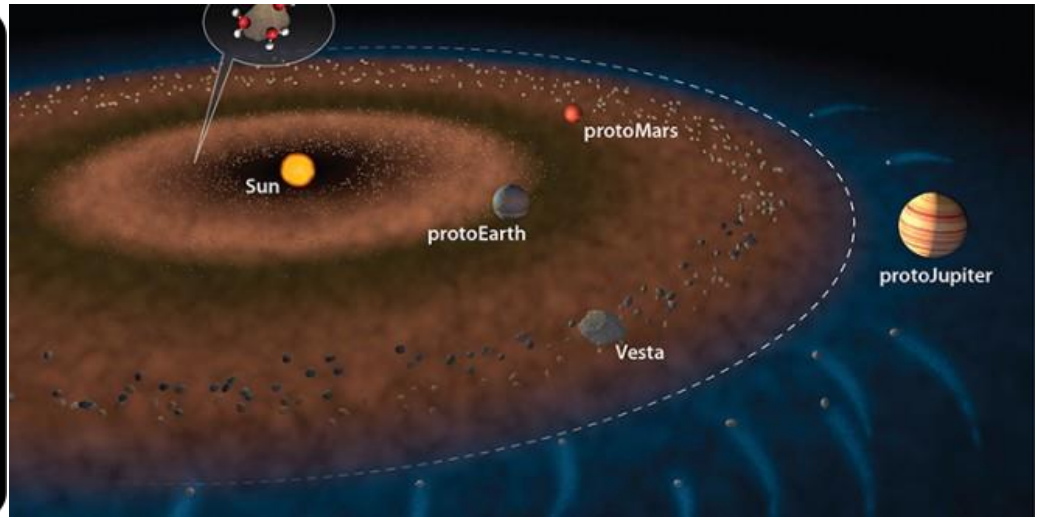
Realizing that rocky planets must have been born dry leads to the key question of *different type*

- How was water delivered to Mars?

as a part of the big question:

How was the habitability of the solar system enabled?





The habitable zone and the snow line

- Small bodies would have played the role of delivery capsule of water from outside the snowline.
- Mars at the outer-edge of the habitable zone must have witnessed the transport process.
- Phobos could be related to a delivery capsule that was on its inward journey.

The MMX Goal

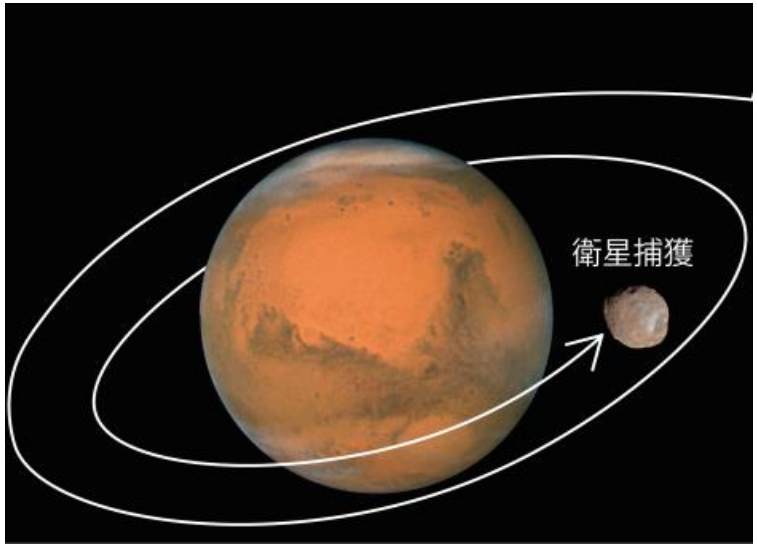
- To reveal the origin of the Mars moons, **and then** to make a progress in our understanding of the water transport across the border between the inner- and the outer-part of the early solar system.

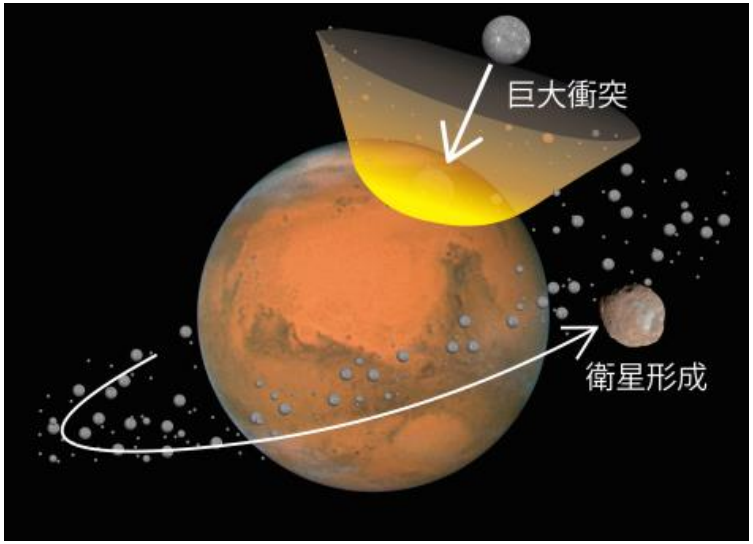
- The goal is to understand how the habitability of the solar system is enabled at all.

Origin of Phobos/Deimos

- Not known.

- Two leading hypotheses: captured primordial asteroid or giant impact.





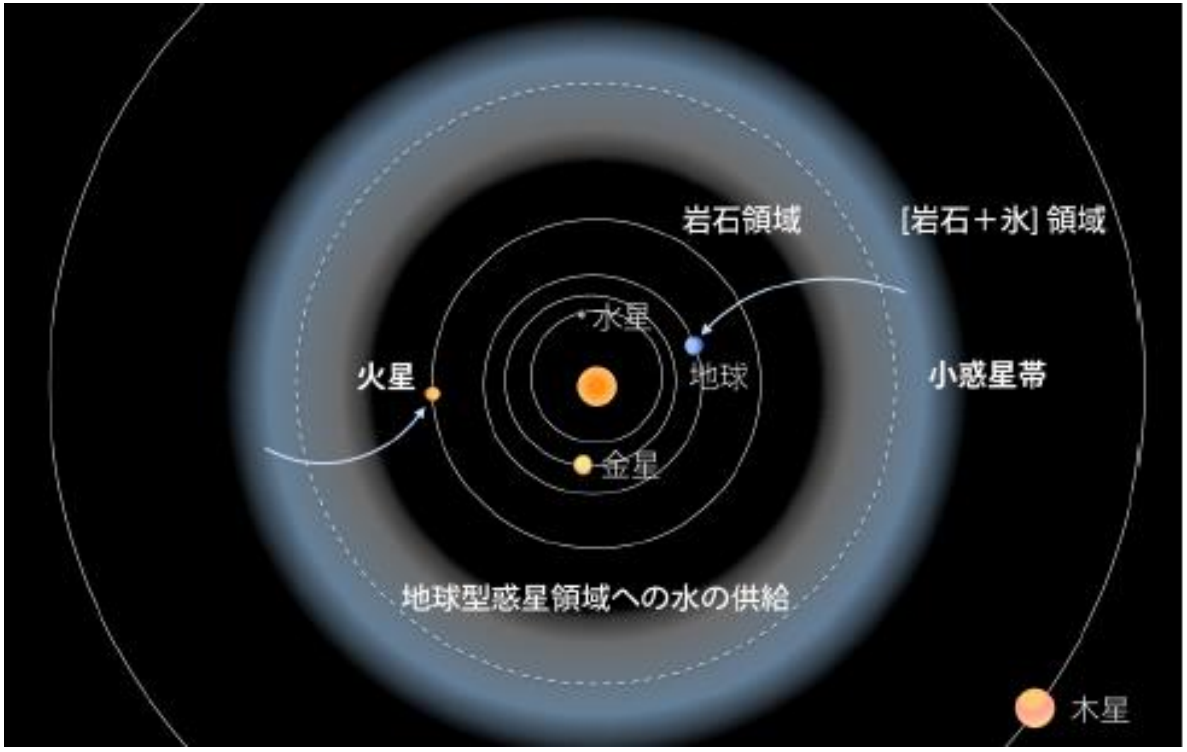
Origin of Phobos/Deimos

- Knowing the origin is guaranteed once the sample is subject the analysis by the ground facility.

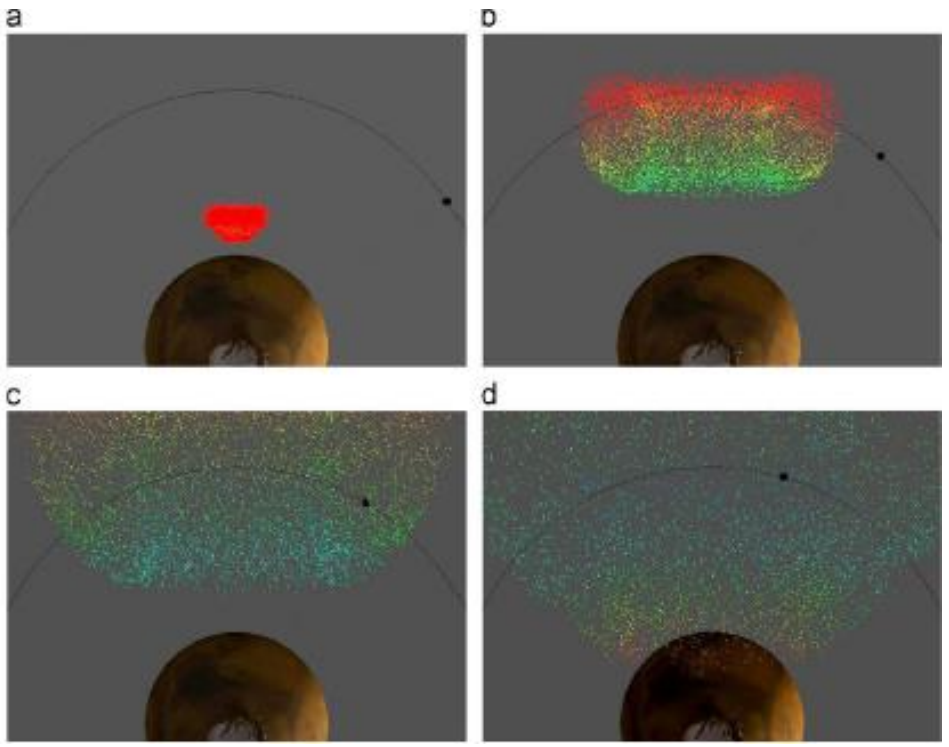
- Whichever idea found to be the case, further information related to the behavior of the Phobos-creating small body that originated outside the snow line will be revealed.

- 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 scenario

The three steps towards the science goals are realized by the mission scenario as follows:

(1) Mars orbit insertion

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

(3) Landing and sampling from Phobos

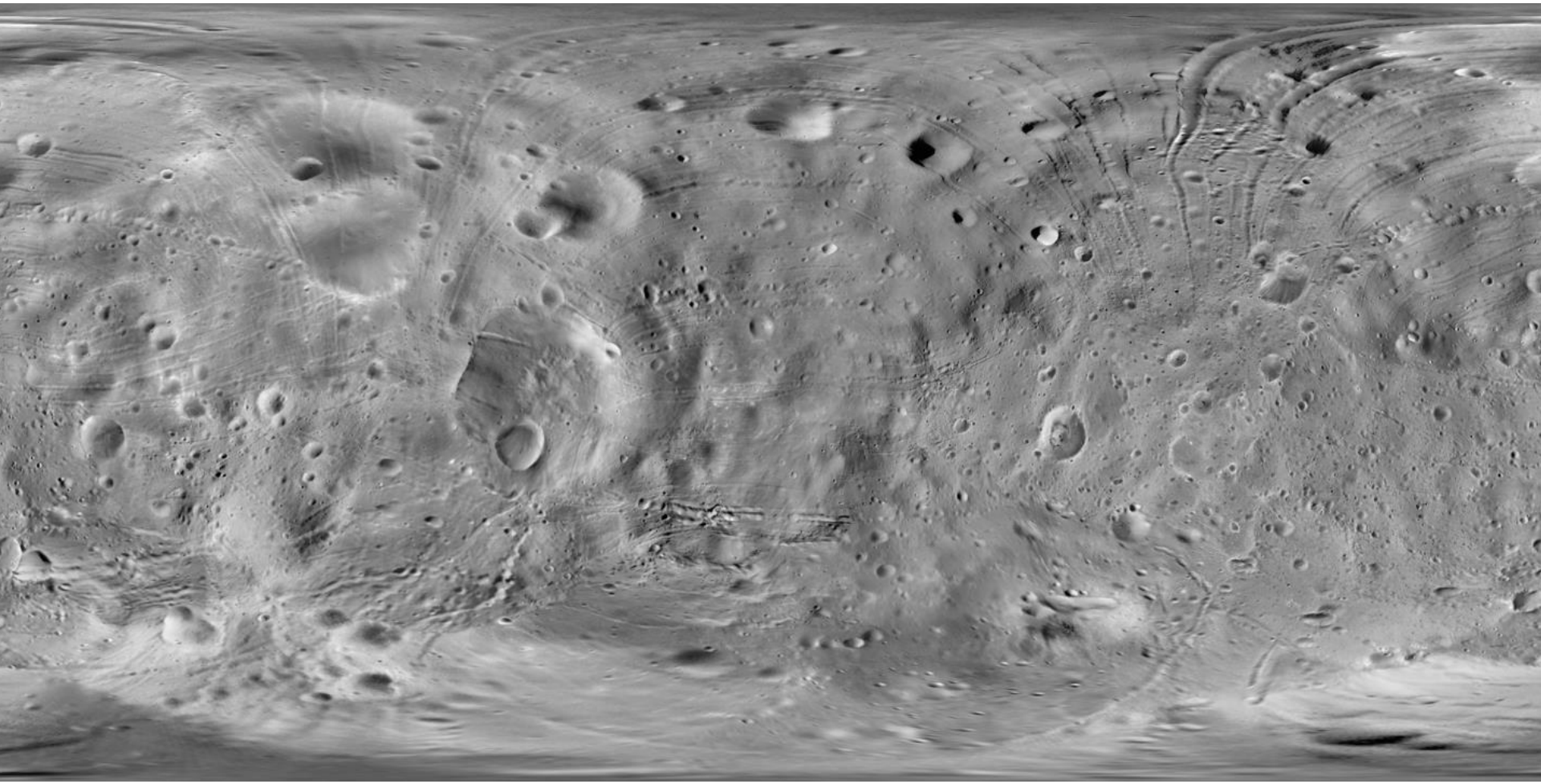
(4) Transfer to Deimos for multi-flyby observations (or from a quasi-satellite orbit).

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

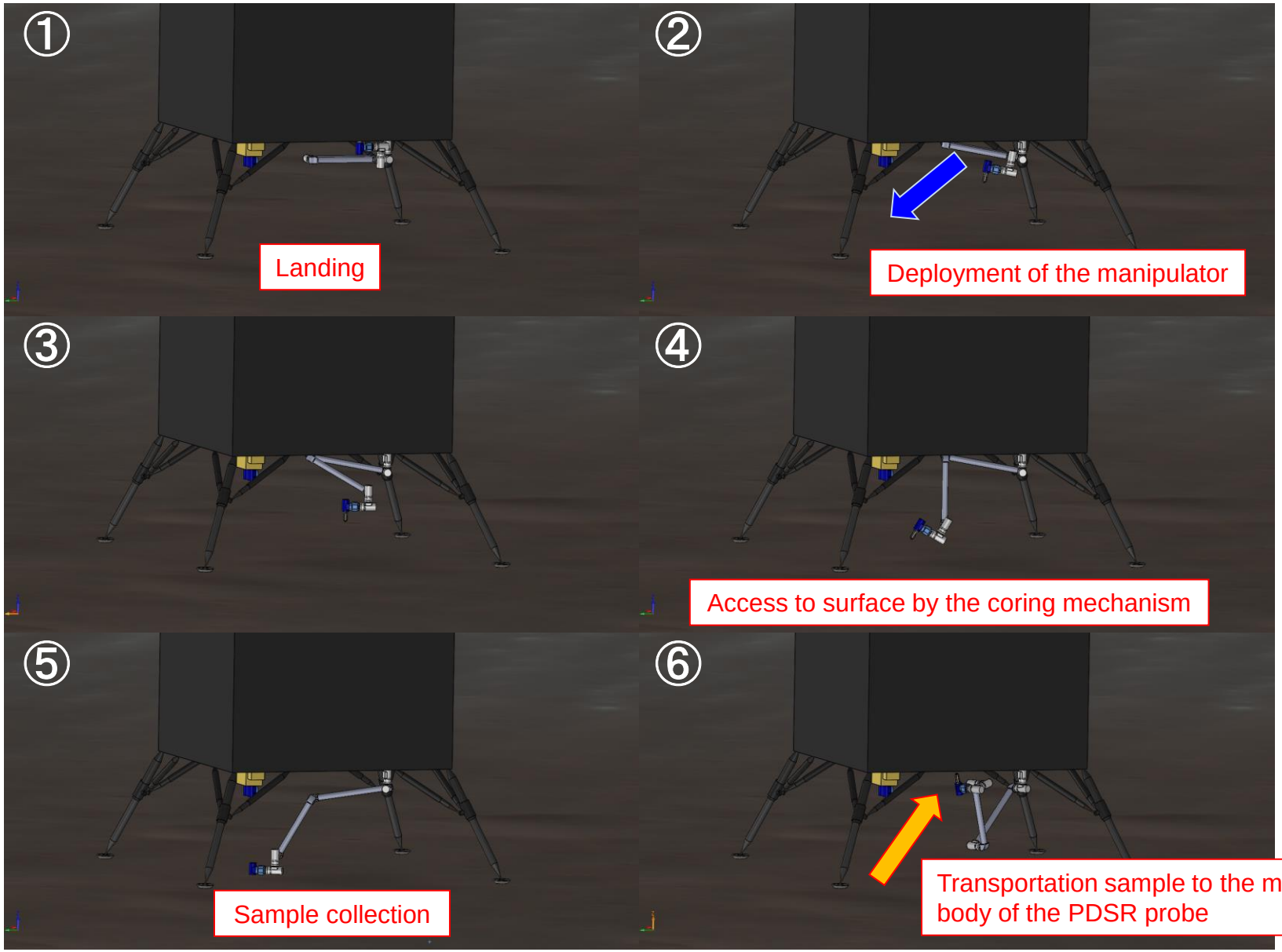
(6) Departure from Mars and return to Earth

(7) Recovery of samples and initial analysis

Phobos landing and sampling



Coring + Manipulator Concept: sample amount = 10g minimum



- Model payload:

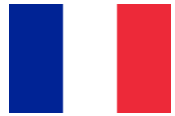
  A list of instruments that meets all the mission requirements.

[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

Timeline

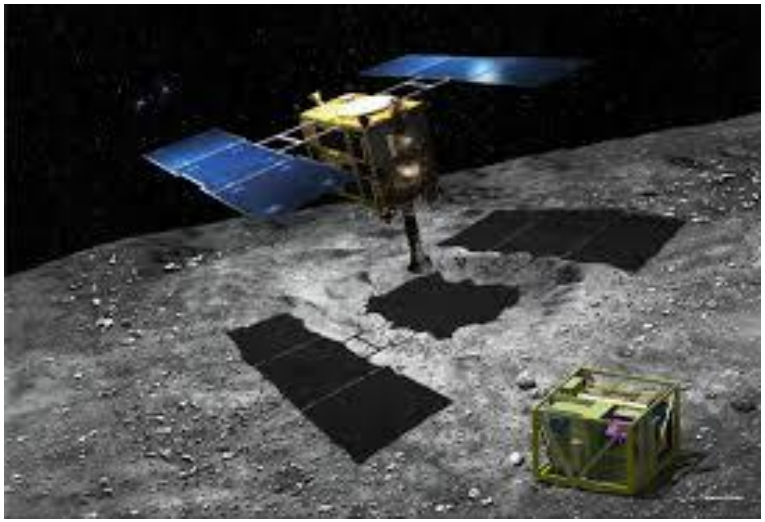
- Launch in 2024
- MOI in 2025, three years in the Mars gravitational sphere (mostly QSO around Phobos)
- Departure from the Mars system in 2028
- Sample return in 2029: 10g min, 100g target, samples from ~10cm subsurface expected

Three open issues:
(1) Small elements to be deployed
(2) Sampler
(3) Landing site selection

At the Intl Review held in Nov 2015

- Landing experiment/package that enhances the science objectives presented at the review was highly recommended.

Hayabusa2 and MASCOT



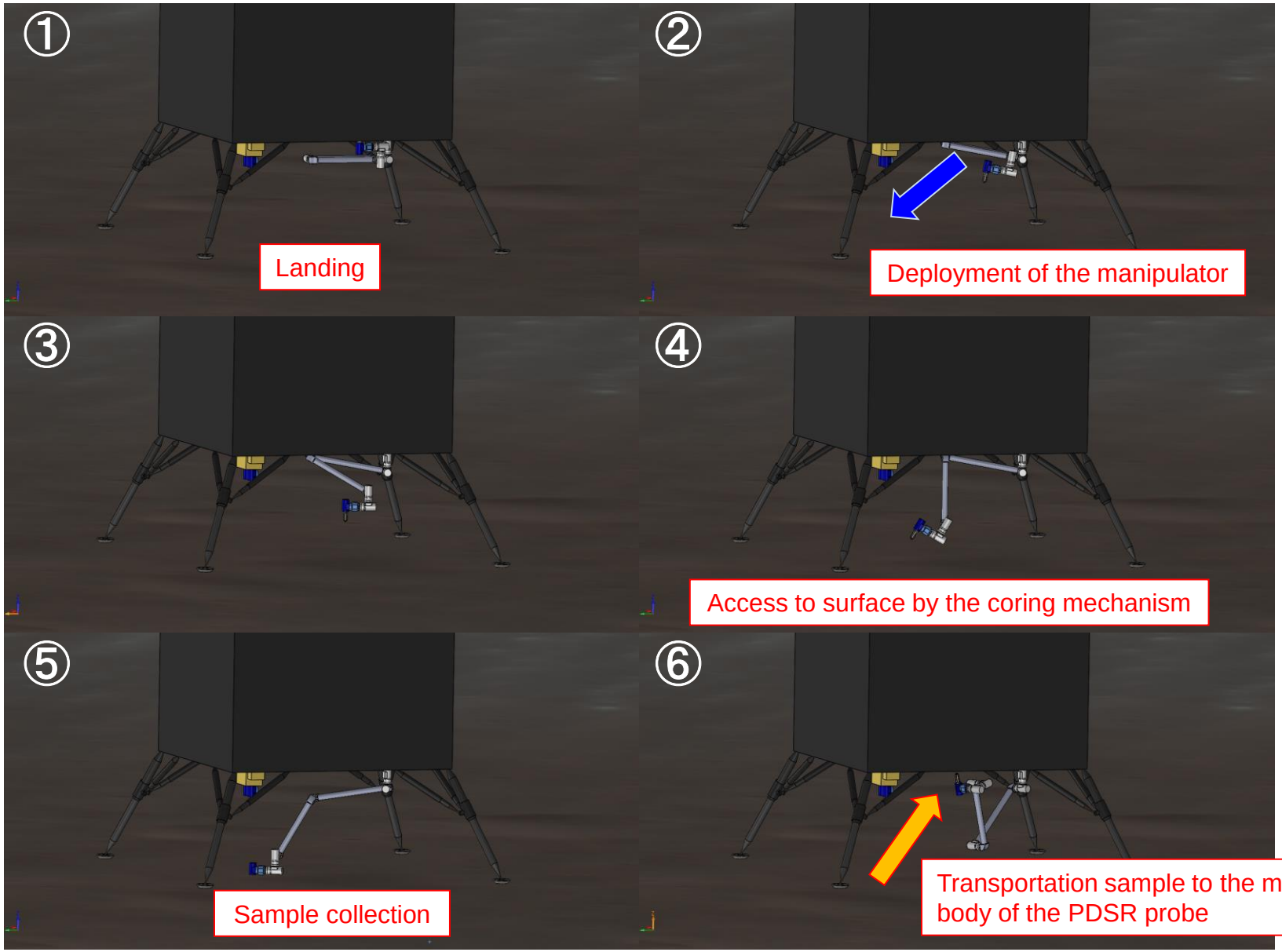
(1) Small elements to be deployed

- Strong European interest in a small lander, like MASCOT, the DLR-CNES 10kg lander onboard HAYABUSA2. Deployment during landing is the smartest option.

- Deploying a small camera to a spot on Phobos that is too risky to access by the main spacecraft to obtain images is a good idea (to be deployed from a low-altitude orbit).

- Releasing a small/cubesat from an orbit around Phobos/Deimos is also an interesting idea.

Coring + Manipulator Concept: sample amount = 10g minimum



(2) Sampler

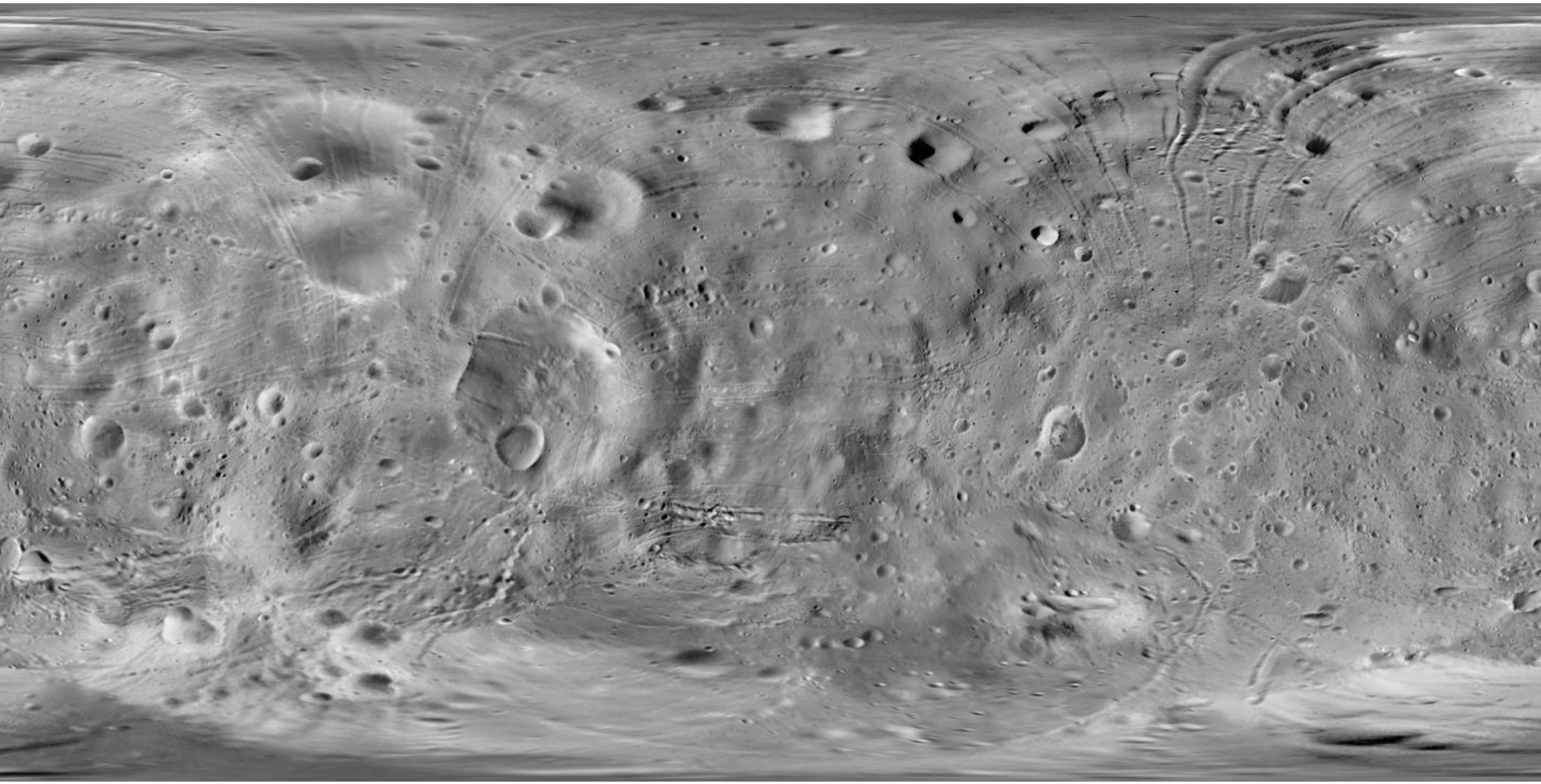
A comment at one of the Reviews

- Isn't it too sophisticated? Why not think about another one that samples in a much simpler way upon landing?

...Well, a good comment.

We need to, and we are thinking about it.

Phobos landing and sampling



(3) Landing site selection

- Why not start a study now with the existing data?

…. Cannot agree with you more, but where's the expertise and the man power?

MMX is a L class mission (a poor man's Porsche)

L-class: It has to be a very good mission.
M-class: Requires a good idea that fits within the severe constraints.

→ Both have good reasons to go international,
for nice instruments available abroad,
and/or
for broader discussion to shape-up mission ideas
and maintaining
cutting-edge-ness of the science community.

ISAS mission categories

- L-class to be launched by H-IIA/III.
  Cadence=three in ten years.
- M-class to be launched by Epsilon.
  Cadence=one every another year.
- Opportunities for grand missions to be led by foreign agencies.
  Guidance by ISAS according to its strategic plan.
- S-class incl those onboard suborbital and ISS programs.
  AO every year.

DESTINY+ is a short-listed M class mission candidate aiming at a flyby of an active asteroid

L-class: It has to be a very good mission.

M-class: Requires a good idea that fits within the severe constraints.

→ Both have good reasons to go international,
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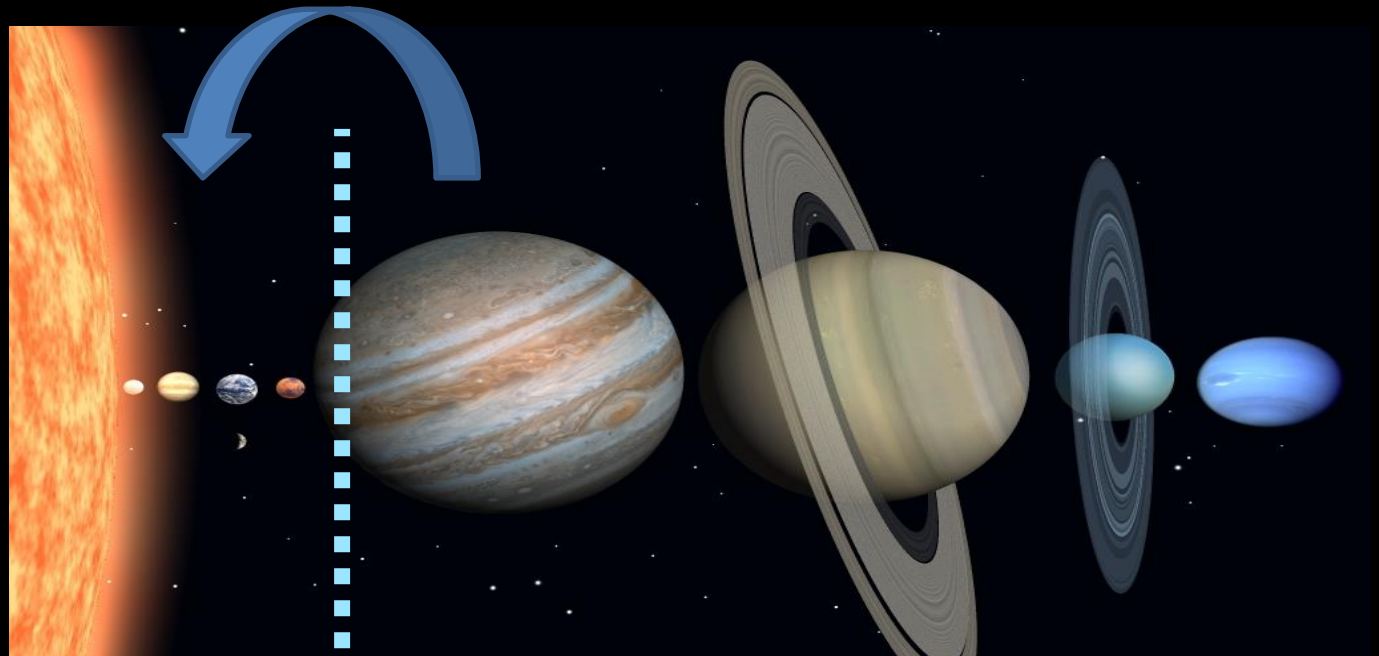
cutting-edge-ness of the science community.

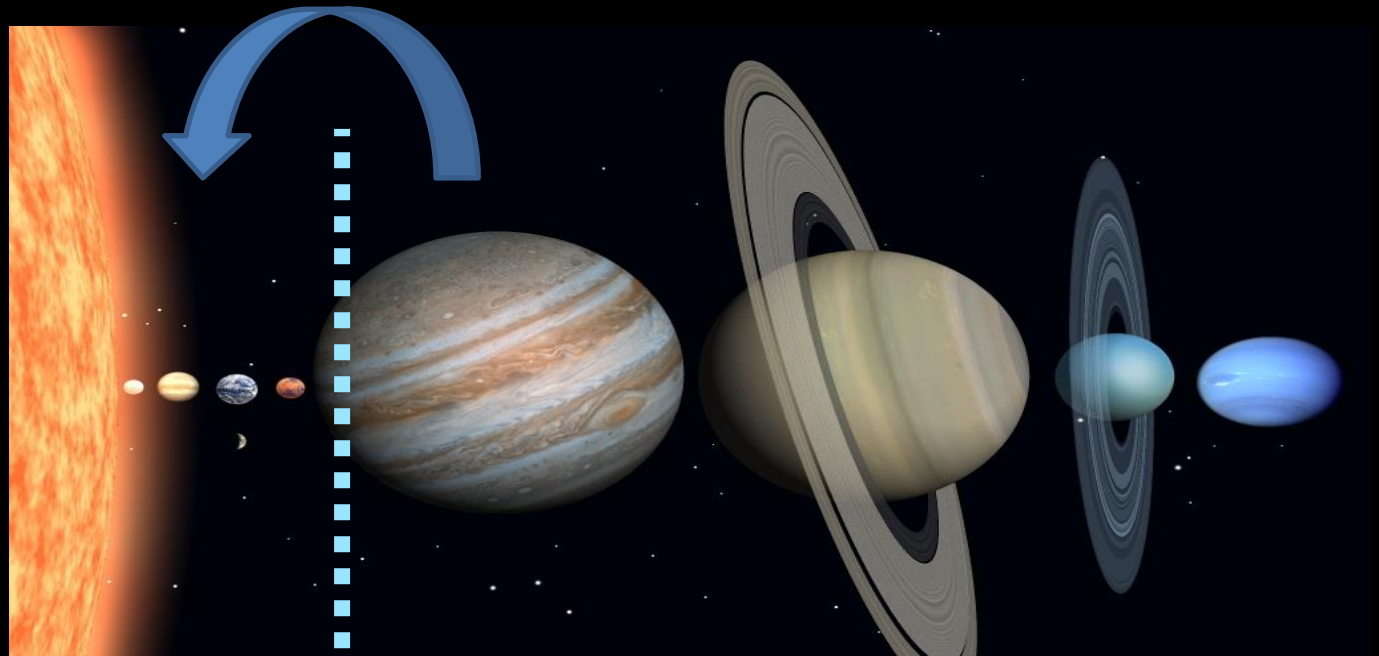
The MMX story

- Delivery of water, volatiles, organic compounds etc. from outside the snow line to entitle the rocky planet region to be habitable
- Small bodies as delivery capsules of water
- Then, dynamics of small bodies around the snow line in the early solar system is the issue that needs to be understood
- Mars was at the gateway position to witness the process



The DESTINY+ story

- Delivery of water, volatiles, organic compounds etc. from outside the snow line to entitle the rocky planet region to be habitable
- Small dust releasing bodies as delivery capsules of organic compounds
- Evolution of dust releasing small bodies during its orbital evolution across the snow line, evolution of dust properties in the interplanetary space after release from the parent body



Born outside the snow line

Recent/future small body missions related to this story that are

ISAS: Hayabusa2, MMX, DESTINY+

NASA: ROSETTA, DAWN(@Ceres), **LUCY,** O-REx

How about a (series of) joint WS on the grand question?

How do small bodies originated outside the snow line evolve and enable the habitability of the solar system?