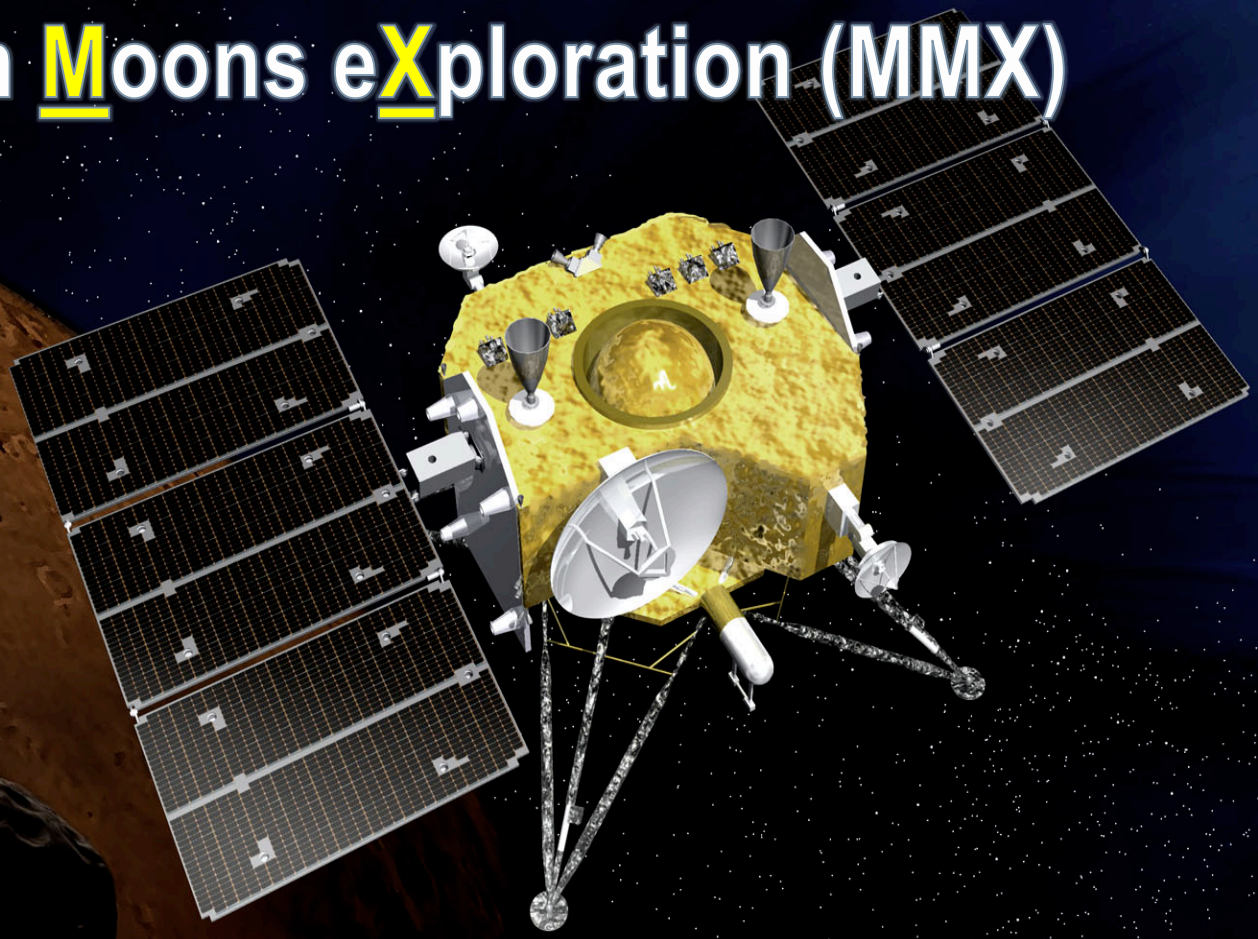
Martian Moons eXploration (MMX)



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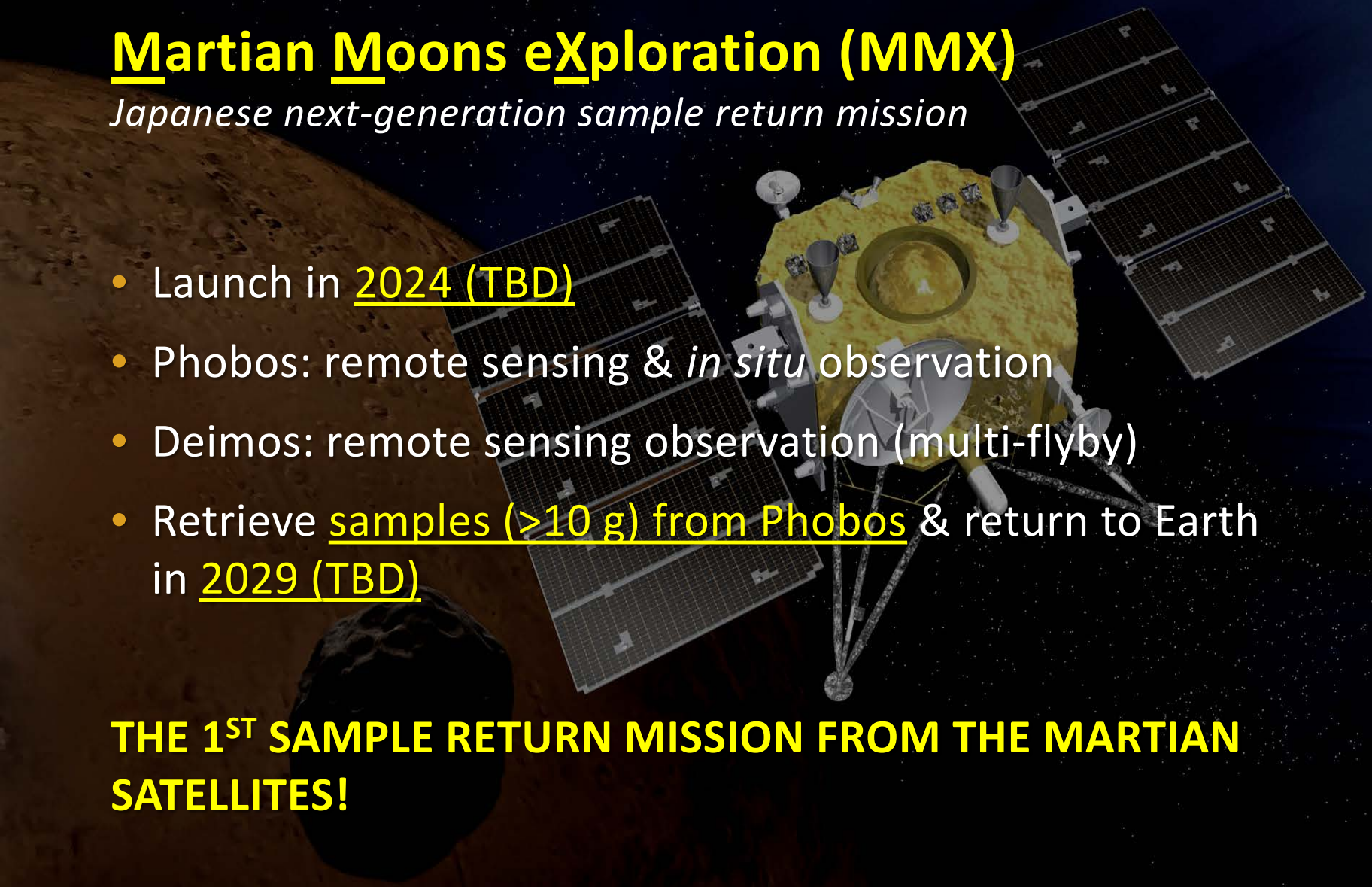
MMX Science Board, JAXA MMX Pre-Project Team

Martian Moons eXploration (MMX)

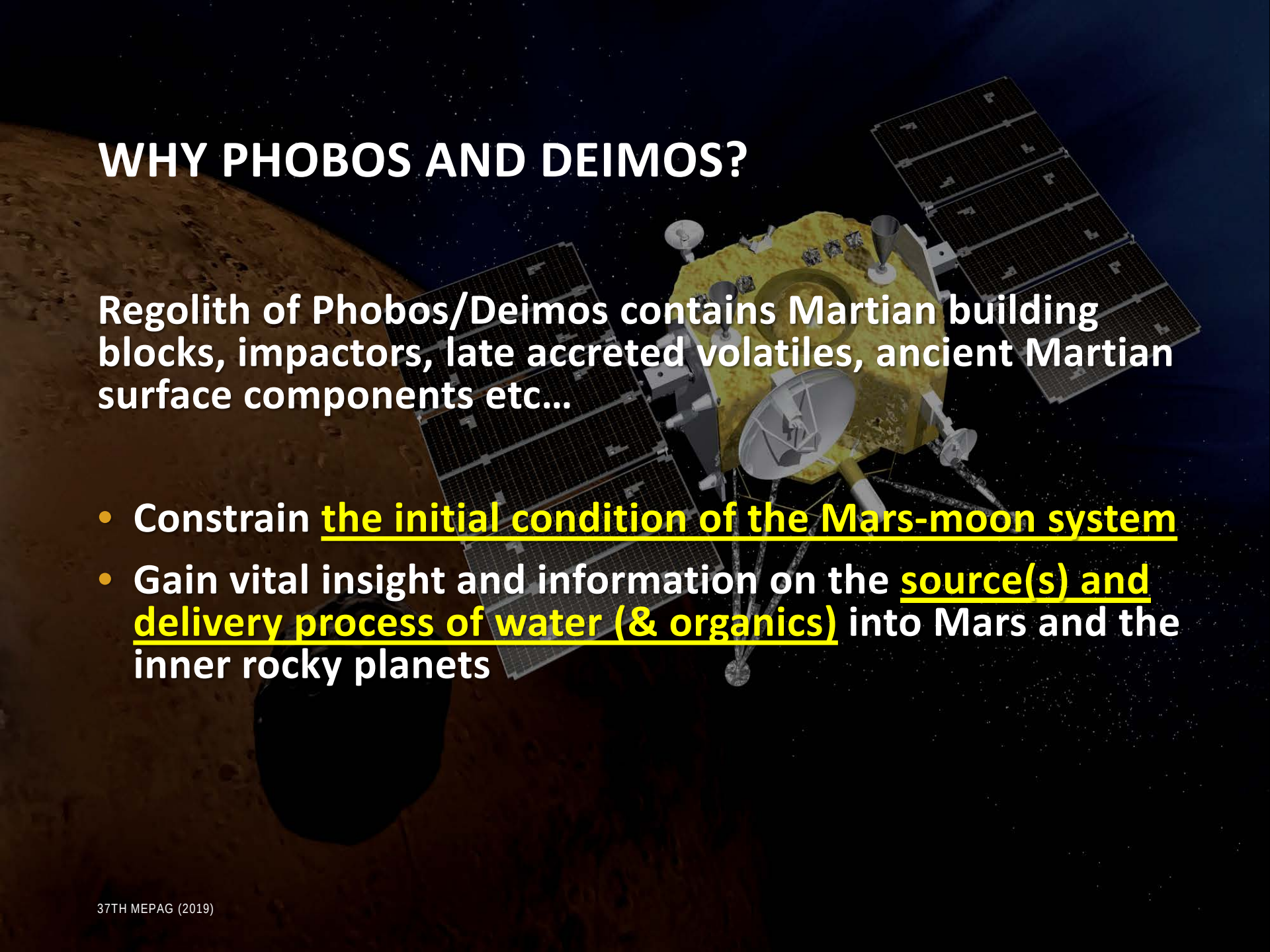
Japanese next-generation sample return mission



- Launch in 2024 (TBD)
- Phobos: remote sensing & *in situ* observation
- Deimos: remote sensing observation (multi-flyby)
- Retrieve samples (>10 g) from Phobos & return to Earth in 2029 (TBD)

THE 1ST SAMPLE RETURN MISSION FROM THE MARTIAN SATELLITES!

WHY PHOBOS AND DEIMOS?



Regolith of Phobos/Deimos contains Martian building blocks, impactors, late accreted volatiles, ancient Martian surface components etc…

- **Constrain the initial condition of the Mars-moon system**
- **Gain vital insight and information on the source(s) and delivery process of water (& organics) into Mars and the inner rocky planets**

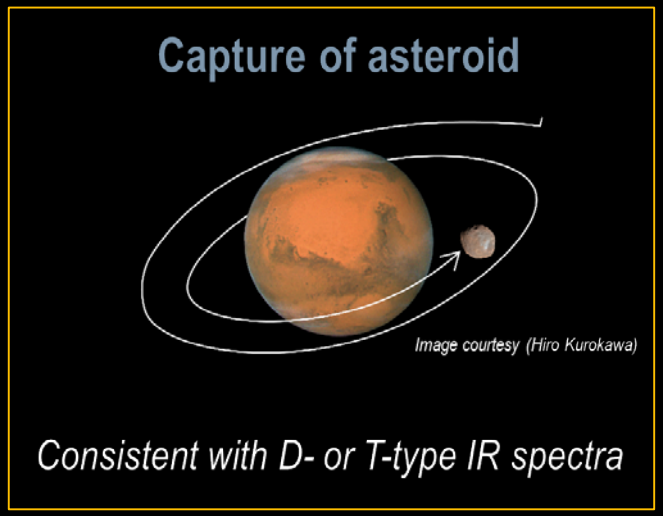
MMX Science Goals

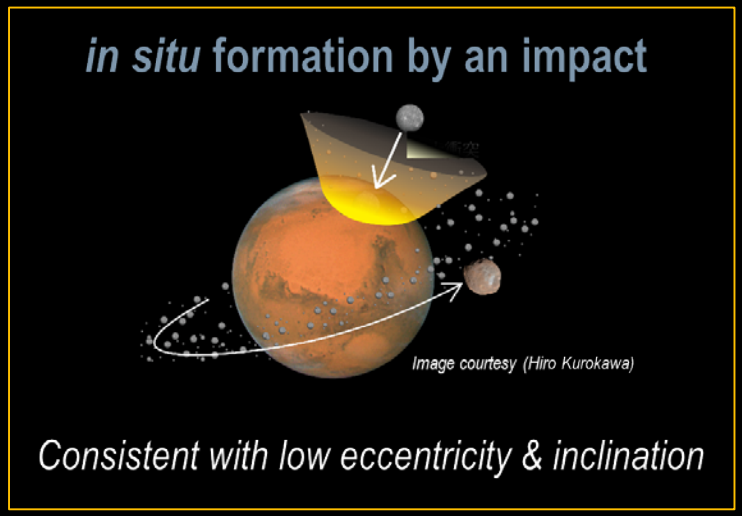
<Goal 1>

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

<Goal 2>

To observe processes that have impacts on the evolution of the Mars system from the new vantage point and to advance our understanding of Mars surface environment transition

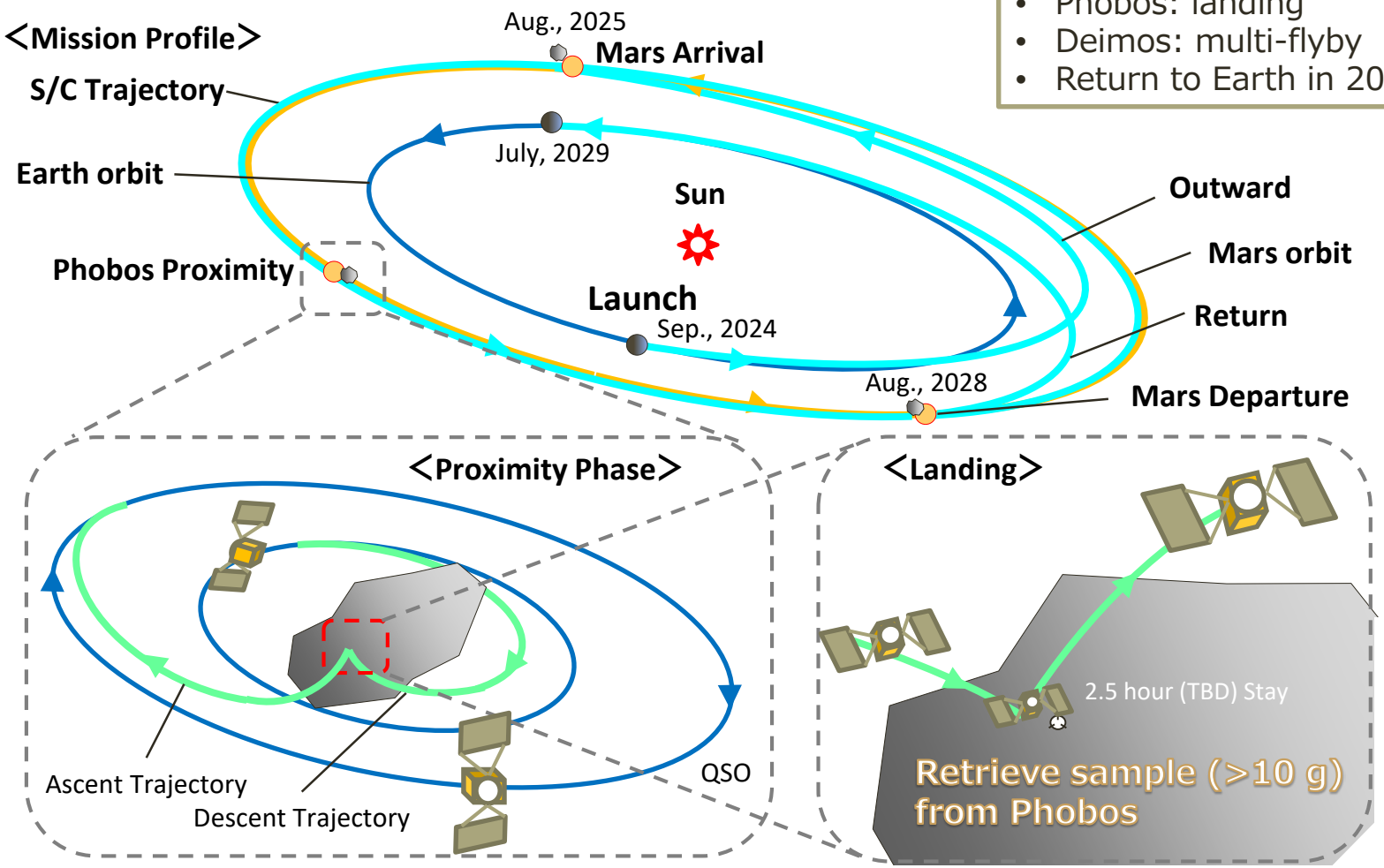




Mission Profile

- The total of 5 years trip by use of chemical propulsion system
- Interplanetary flight: 1 year for outward/homeward
- Stay at curcum-Mars orbits 3 years

- Launch in 2024
- Phobos: landing
- Deimos: multi-flyby
- Return to Earth in 2029

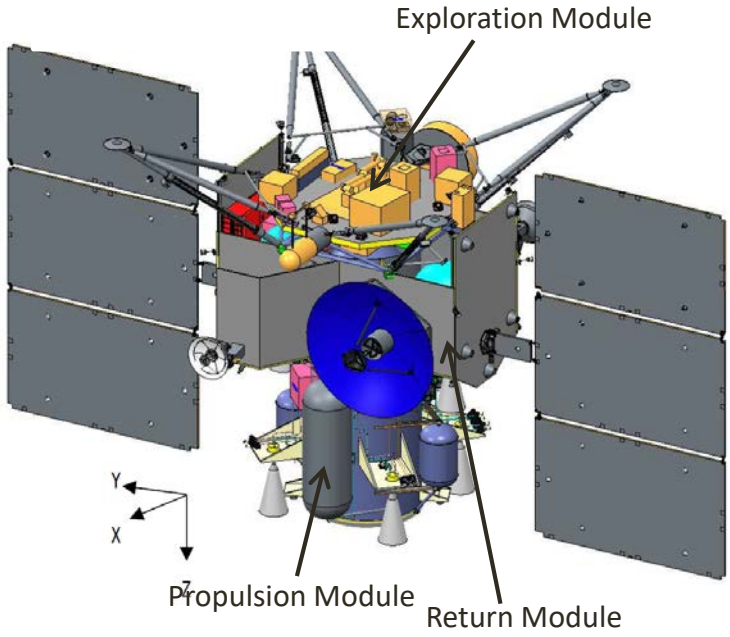


(written above is an example, and could change in the future)

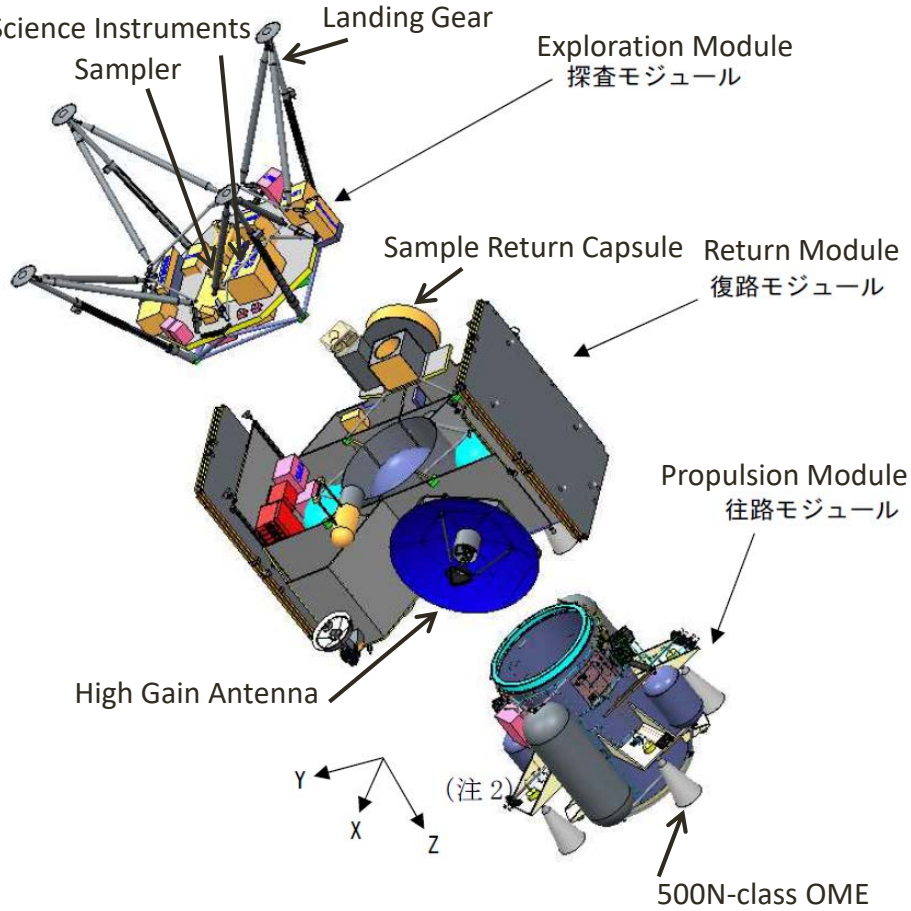
Spacecraft Configuration

As a result of Phase-A study, spacecraft system's configuration and major specification are defined preliminarily.

Launch Configuration



Launch Mass : 4000kg
Three stages system.
Return module: 1780kg
Exploration module: 330kg
Propulsion module: 1890kg
Mission Duration : 5 years
(written above is an example, and could change in the future)



On-Orbit Configuration

Nominal Science Payload

Payload	Measurements
Wide-angle multiband camera (OROCHI)	• Global mapping of hydrated minerals, organics, and the spectral heterogeneity of the Martian moons • Characterize the material distribution around the sampling sites
Telescopic camera (TENGOO)	• Determine the global topography and surface structure of the Martian moons • Characterize the topography around the sampling sites
Gamma-ray, neutron spectrometer (MEGANE) (*provided by NASA*)	• Determine the elemental abundance beneath the surface of the Martian satellites (Provided by NASA)
Near-infrared spectrometer (MacrOmega) (*provided by CNES*)	• Global mapping of minerals, molecular H_2O and organics of the Martian moons. • Characterize the material distribution around the sampling sites • Monitor the transport of H_2O vapor, H_2O/CO_2clouds, and dust in the Mars atmosphere (Provided by CNES)
Light detection and ranging (LIDAR)	• Determine the Phobos shape and topography
Circum-martian dust monitor (CMDM)	• Detect and monitor: 1) the circum-Martian dust ring; 2) interplanetary dust; 3) Interstellar dust
Mass spectrum analyser (MSA)	• Determine the mass and energy of ions from Phobos, Mars and Sun
Rover's payloads (*by CNES/DLR*) : Raman, radiometer, cameras	• Determine surface composition and physical properties

ORIGIN OF PHOBOS AND DEIMOS

Two competing hypotheses are proposed for their origins

Capture of asteroid

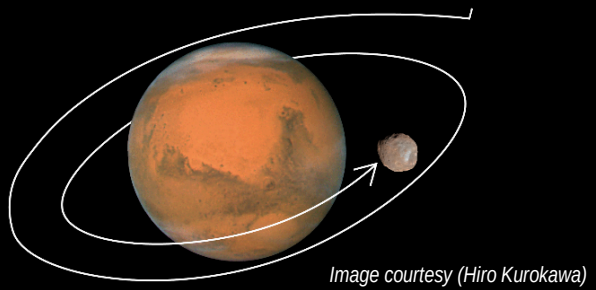


Image courtesy (Hiro Kurokawa)

Consistent with D- or T-type IR spectra

in situ formation by an impact

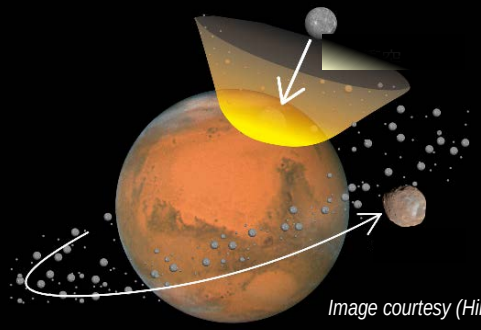
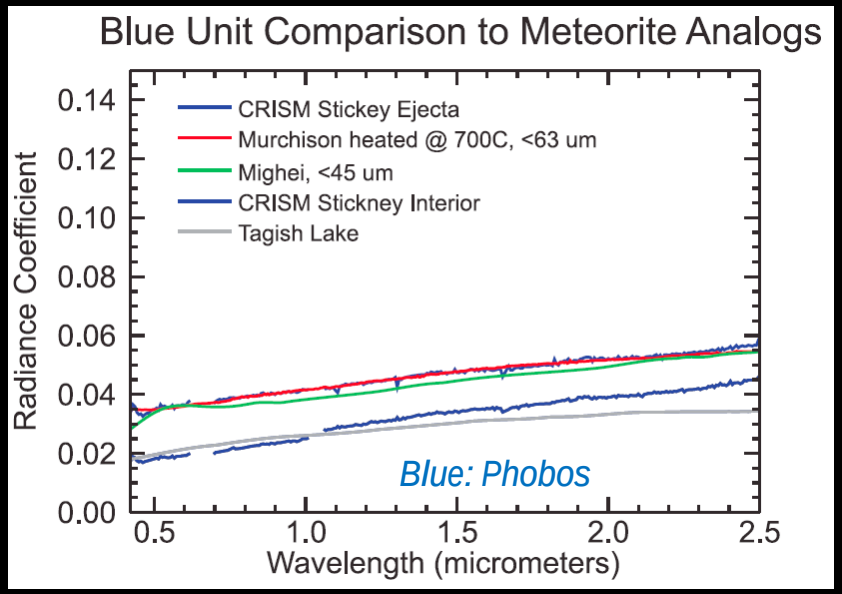


Image courtesy (Hiro Kurokawa)

Consistent with low eccentricity & inclination

ORIGIN OF PHOBOS AND DEIMOS

D- or T-type spectrum is consistent with the capture origin



Fraeman et al. (2012)

If Phobos & Deimos are "giant impact origin", the spectra reflect either

- impact-related "dark" glassy debris, or
- thin surface veneer of regolith, or
- result of space weathering

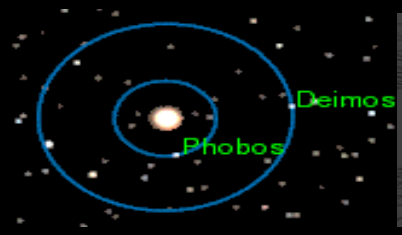
will be tested by MMX

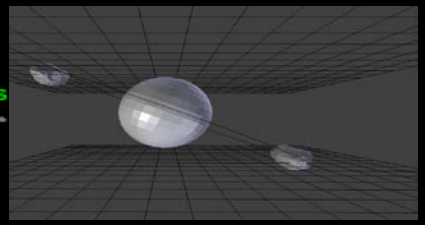
- gamma-ray & neutron, sample analysis

ORIGIN OF PHOBOS AND DEIMOS

Low eccentricity and low inclination suggest the impact origin

- Low eccentricity (Jacobson & Lainey, 2014)
  - Phobos: 0.001511, Deimos: 0.00027
- Low inclination (Jacobson & Lainey, 2014)
  - Phobos: 1.076 deg, Deimos: 1.789 deg





If Phobos & Deimos are “capture origin”...

“Gold mine” for astrophysicists!
New dynamical model to reconcile

REMOTE SENSING OBSERVATIONS

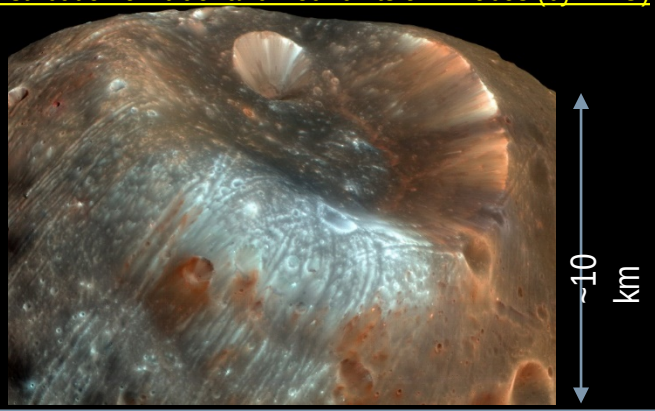
Visible & Near-infrared spectroscopy

MacrOmega from IAS, France

- Spectrum range: 0.9-3.6 μm

  cf. OH = ~2.7 μm, H_2O-ice = ~3-3.2 μm, organics = 3.3-3.5 μm
- Spatial resolution: 8.2 m/pix @ 20 km

Distribution of "blue" and "red" units on Phobos (by MRO)

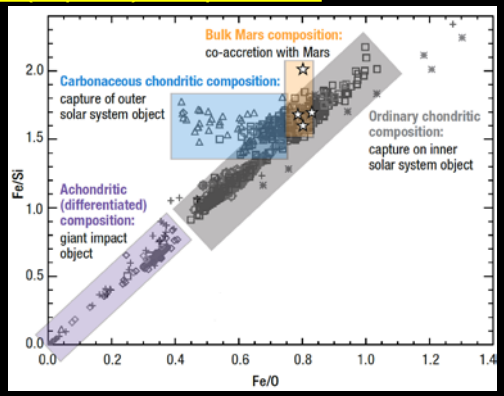


Gamma-ray & Neutron spectroscopy

MEGANE from APL, USA

- Elements: Mg, Fe, O, Si, Na, K, Ca, Th, U, H, C, and Cl
- Penetration depth: up to ~1 m

Fe/Si/O differentiates achondritic (giant impact) and chondritic (capture) compositions

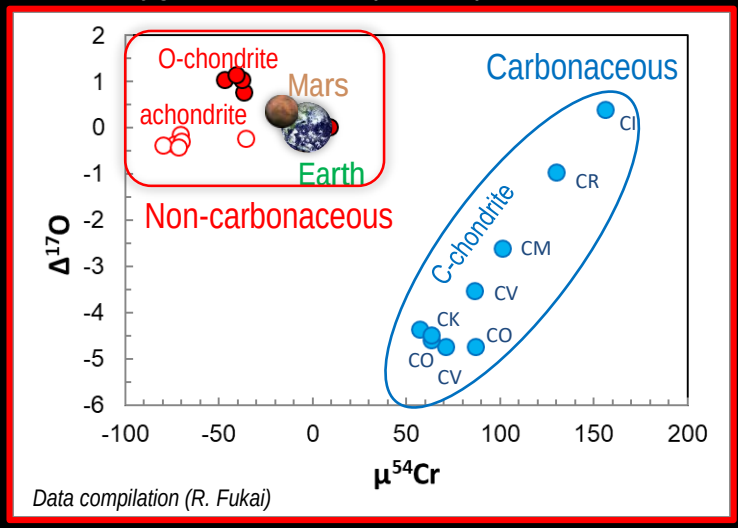


SAMPLE ANALYSIS: EXPECTED CHARACTERISTICS

Coordinated *in-situ* and bulk analyses will provide constraints on the origin(s) of the returned samples

	Captured asteroid	Giant impact
Petrology, mineralogy	Unequilibrated mixture of minerals, Hydrated phases, Organic matter	Glassy/igneous texture, High-*T* phases
Bulk chemistry	Chondritic, Volatile-rich	Volatile-poor
Isotopes	Primitive solar-system signature	Mixed feature between Mars and impactor

Oxygen and Cr isotopic compositions



Data compilation (R. Fukai)

CONCLUSIONS

- The MMX spacecraft is scheduled to be launched in 2024, and return >10 g of Phobos regolith back to Earth in 2029 (TBD)
- The origin(s) of Phobos and Deimos has been in debate: captured asteroid or in situ formation by impact
- MMX will provide clues to their origins and offer an opportunity to directly explore the building blocks, juvenile crust/mantle components, and late accreted volatiles of Mars

MMX will constrain the initial condition of the Mars-moon system,
and shed light on the source, timing and delivery process of water (& organics) into the inner rocky planets