

JAXA Space Science

Masaki Fujimoto

Director for Dept. Solar System Sci.

JAXA/ISAS

ISAS

- Institute of Space and Astronautical Science
- The science institute of the Japanese space agency JAXA
- ISAS is undergoing a **big transformation** in these five years.

Outline

- Where ISAS stands now
- ISAS style
- How ISAS used to be
- Modernizing the ISAS style

The drivers of the transformation

- Return to Earth of Hayabusa in 2010
- H-IIA launcher available for L-class space science missions
- Epsilon launcher available for M-class space science missions
- Becoming a visible member in the global space science landscape
- Then... the Hitomi mishap in 2016

- **Return to Earth of Hayabusa in 2010**
- H-IIA launcher available for L-class space science missions
- Epsilon launcher available for M-class space science missions
- Becoming a visible member in the global space science landscape
- Then... the Hitomi mishap in 2016

Hayabusa



Hayabusa

- An asteroid sample return mission
- Being a big challenge, it was proposed as an engineering demonstration mission
- Interplanetary cruise by an ion engine, optical navigation, touch-and-go sampling on the surface of an asteroid, return cruise, Earth reentry-landing-recovery
- Big boom created (spontaneously) among the public.



Hayabusa

- It did bring back samples from the Asteroid Itokawa.



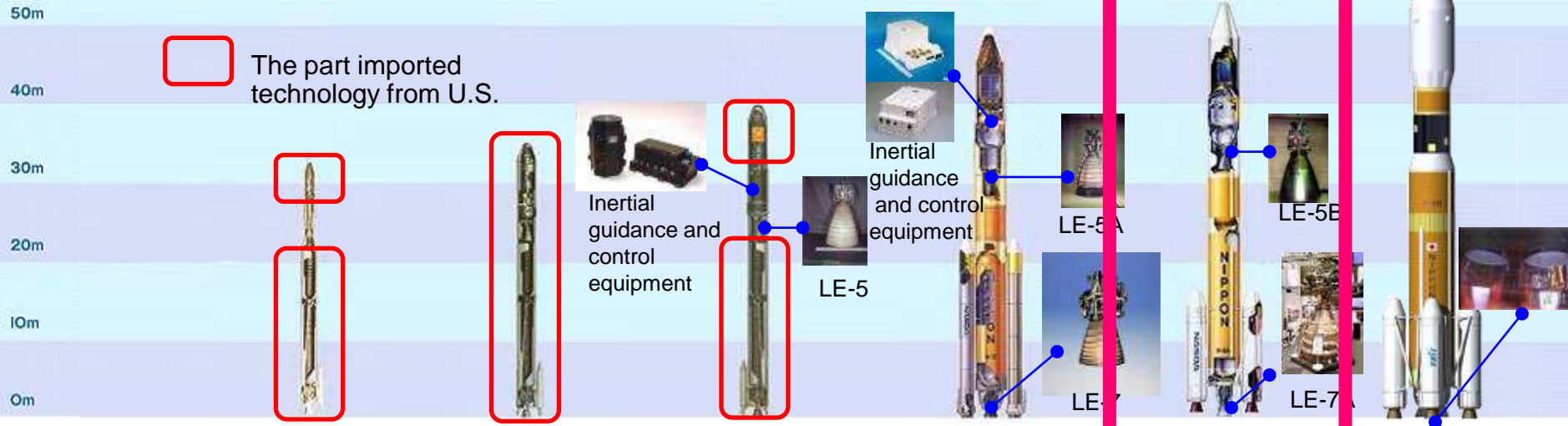
Hayabusa

- (Even though the public does not pay too much attention to this aspect), the powerfulness of sample return in planetary science was clearly demonstrated .
- **Sets the strategy for ISAS-planetary** that sample return from small bodies (with small gravity) is the mainstream.

- Return to Earth of Hayabusa in 2010
- **H-IIA launcher available for L-class space science missions**
- Epsilon launcher available for M-class space science missions
- Becoming a visible member in the global space science landscape
- Then... the Hitomi mishap in 2016



JAXA Liquid Propellant Rockets



 The part imported technology from U.S.

	N-I	N-II	H-I	H-II	H-IIA	H-IIB
Rocket's Profile	Based on Thor-Delta Rocket, and only propulsion system in the second stage was developed in-house	The first stage was manufactured under the license. Other parts were purchased from U.S. (no major in-house developed items).	The first stage was manufactured under the license. Inertial guidance and control equipment (parts were partially procured overseas) and propulsion systems in the second/third stage were developed in-house.	Technologies in all stages were developed in-house. Original purely Japanese-made Rocket	Technologies in all stages were developed in-house. Parts etc. were partially imported.	Technologies in all stages were developed in-house. Parts etc. were partially imported.
Payloads (GSO)	130kg	350kg	550kg	2ton	2ton~3ton	4ton
Operational period	1975~1982	1981~1987	1986~1992	1994~1999	2001~	2009~
Launch records (failed)	6/7	8/8	9/9	5/7	20/21	3/3

Hayabusa2 launch by H-IIA



Hayabusa2 launch by H-IIA

- Hayabusa2: The 2nd asteroid SR mission by ISAS, having NASA OSIRIS-REx as his brother.
- Targeting at a primordial asteroid, we expect the returned samples will tell how life-origin related materials formed in the solar system upon its formation.
- A more picky target asteroid, more challenging science themes.



Hayabusa2 launch by H-IIA

- Hayabusa2: The 2nd asteroid SR mission by ISAS, having NASA OSIRIS-REx as his brother.
- Targeting at a primordial asteroid, we expect the returned samples will tell how life-origin related materials formed in the solar system upon its formation.
- A more picky target asteroid, more challenging science themes.

Hayabusa2 launch by H-IIA

- Making ISAS missions bigger.
- Are we happier?



- Return to Earth of Hayabusa in 2010
- H-IIA launcher available for L-class space science missions
- **Epsilon launcher available for M-class space science missions**
- Becoming a visible member in the global space science landscape
- Then... the Hitomi mishap in 2016

Promotion of Small Satellite Program

- ***Epsilon Launch Vehicle*** is a solid propellant rocket capable of launching a satellite weighing 1.2 tons into LEO.
- The first was launched on Sep.14 2013.
- With Epsilon Launch Vehicle, we intend to ***perform low-cost, focused missions in a timely manner.***



Hisaki launch by Epsilon



Hisaki launch by Epsilon

- Hisaki: Earth-orbiting EUV spectrometer that is dedicated to stare at Jupiter (and others).
- Not as capable as Hubble Space Telescope, yet enabling long-term and continuous observations (that is not possible with large facilities such as HST) of Jupiter.
- A nice dataset in itself, and good partnership with large missions such as HST, CXO and JUNO (NASA's mission that arrived at Jupiter this July).

Hisaki launch by Epsilon

- Making smaller yet more frequent missions available
- Are we happier?

- Return to Earth of Hayabusa in 2010
- H-IIA launcher available for L-class space science missions
- Epsilon launcher available for M-class space science missions
- **Becoming a visible member in the global space science landscape**
- Then... the Hitomi mishap in 2016

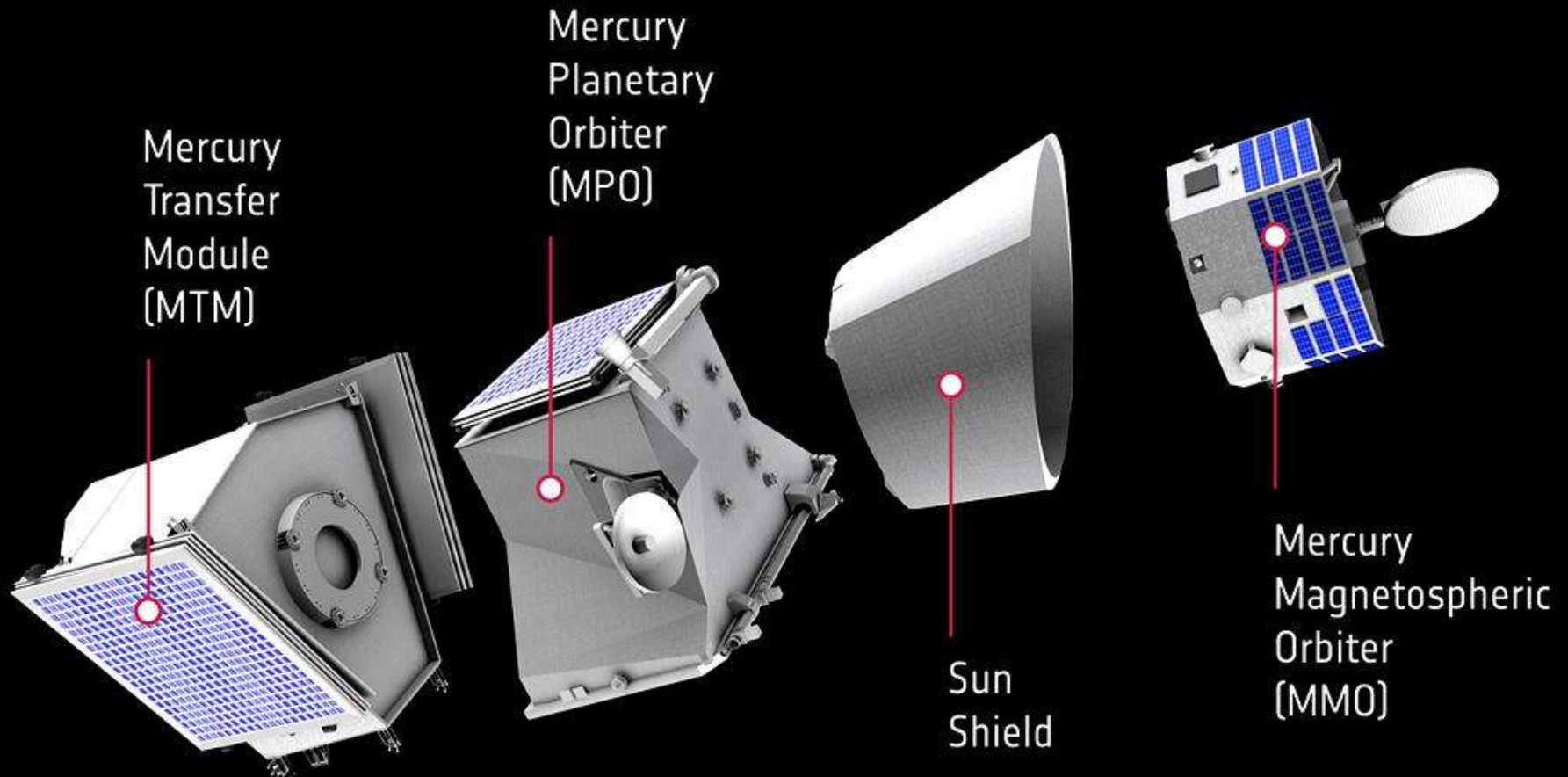
Intl collaboration

- BepiColombo: ESA-JAXA two-spacecraft mission to explore the planet Mercury, to be launched in 2018.
- Has been subject to delay, which made <old> people at ISAS to complain “No more intl collaboration, please.”
- Given how mandatory intl collaboration is these days, we could have gone into a super-wrong direction.
- Now ISAS has formally set the path for intl collaboration to be pursued smoothly.

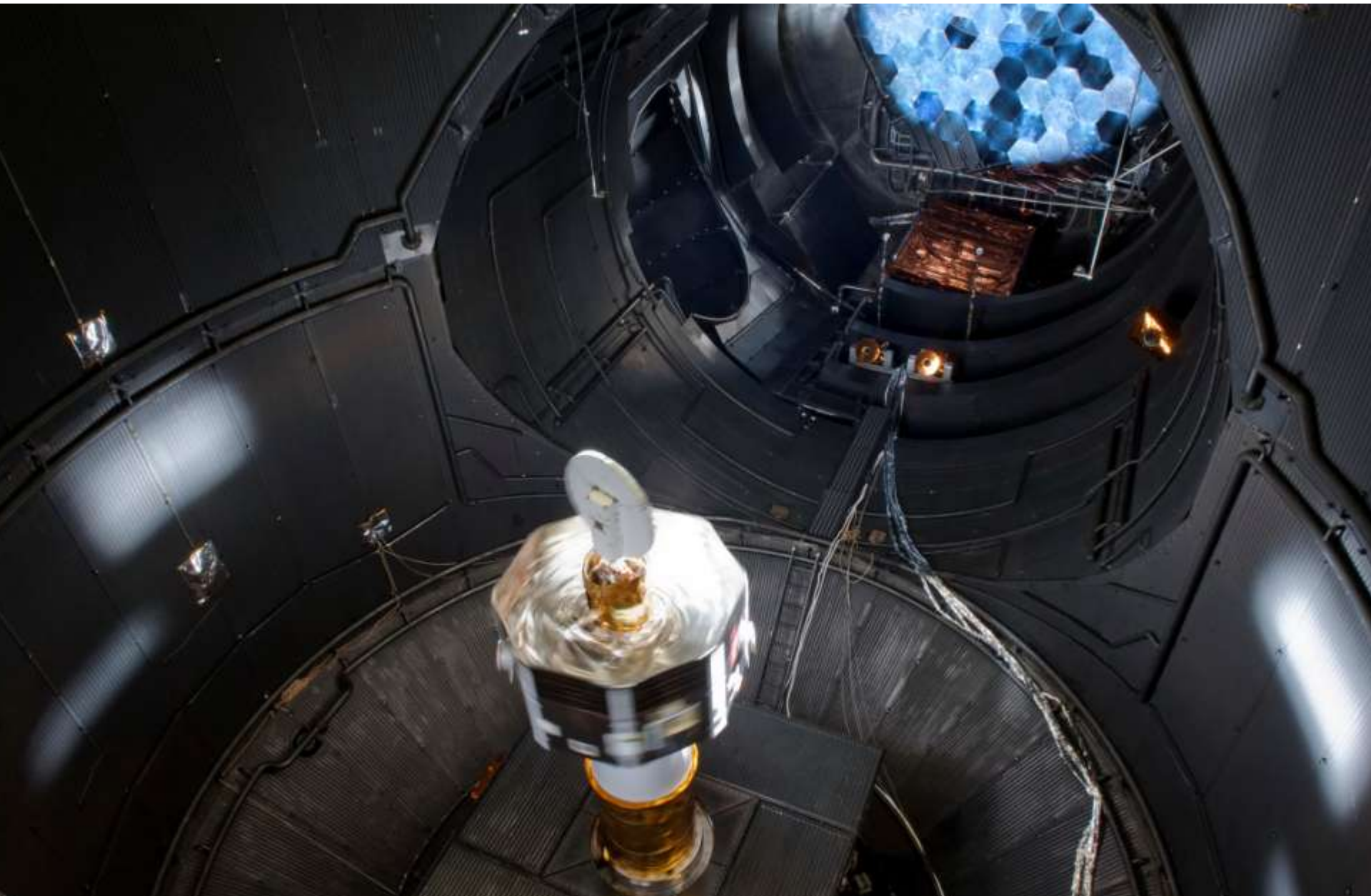
- ISAS alone can never fly a mission like this.



- ISAS alone can never fly a mission like this.



- ISAS alone can never fly a mission like this.



Intl collaboration

- BepiColombo: ESA-JAXA two-spacecraft mission to explore the planet Mercury, to be launched in 2018.
- Has been subject to delay, which made <old> people at ISAS to complain “No more intl collaboration, please.”
- Given how mandatory intl collaboration is these days, we could have gone into a super-wrong direction.
- Now ISAS has formally set the path for intl collaboration to be pursued smoothly.

- Return to Earth of Hayabusa in 2010
- H-IIA launcher available for L-class space science missions
- Epsilon launcher available for M-class space science missions
- Becoming a visible member in the global space science landscape
- **Then... the Hitomi mishap in 2016**

Hitomi



Hitomi

- Supposed to be the X-ray mission of the decade, the only one for the global X-ray astrophysics community, and the pathfinder for a larger mission to be led by ESA in a decade later (ATHENA).
- A large instrument that is the key to the next generation X-ray astrophysics was provided by NASA
- Launched successfully in Feb 2016.
- Initial obs shows the NASA instr to be in perfect shape (See a paper published in Nature)
- Lost contact at the end of March.

Hitomi

- What went wrong: attitude control went wrong to spin up the spacecraft until a solar array paddle was detached.
- The background: Operation scheme too optimized for science (to minimize the dead time for obs), not enough attention paid to the safety aspect.
- Lessons: More solid management while keeping the essential minimum of the *<ISAS style>*.
- Intl aspect: There was a role for us to play in the intl landscape. How to live up to the expectation? How to maintain the partnership?

Space science at ISAS

- Covers space-astronomy, heliophysics (space around planets, interplanetary space and the solar physics), planetary science and ISS-related space experiments
- Most successful are: X-ray astronomy, solar physics, magnetospheric physics and asteroid exploration (sample return)

Space science at ISAS

- Members at ISAS: Scientists, space-engineering researchers and engineers
- Space engineering researchers have cutting-edge ideas that they wish to fly.
- It is the **style of ISAS** to try to blend their wish into a mission.
- This makes planetary exploration missions to be the symbol of ISAS, which trend is getting stronger since the Hayabusa's return to Earth.

ISAS: a unique combination of space science and space technology

Space Technology Divisions

Space Flight Systems
Spacecraft Engineering

Technology driven

Leading and creating space science programs

Science driven

Stimulate and encourage new technology research

Space Science Divisions

Space Astronomy Astrophysics
Solar System Science
Interdisciplinary Space Science

Space science at ISAS

- Members at ISAS: Scientists, space-engineering researchers and engineers
- Space engineering researchers have cutting-edge ideas that they wish to fly.
- It is the style of ISAS to try to blend their wish into a mission.
- This makes planetary exploration missions to be the symbol of ISAS, which trend is getting stronger since the Hayabusa's return to Earth.

How it used to be at ISAS

- The MV launcher was the only vehicle for space science.
- It was a single straight path story to plan a mission: Construct a good mission plan that flies on MV.





MV missions

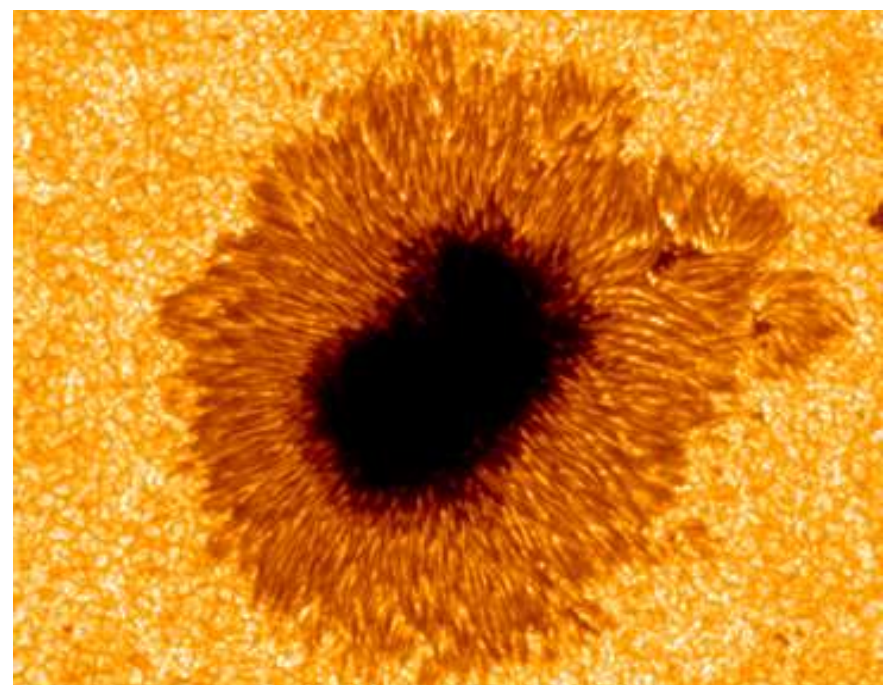
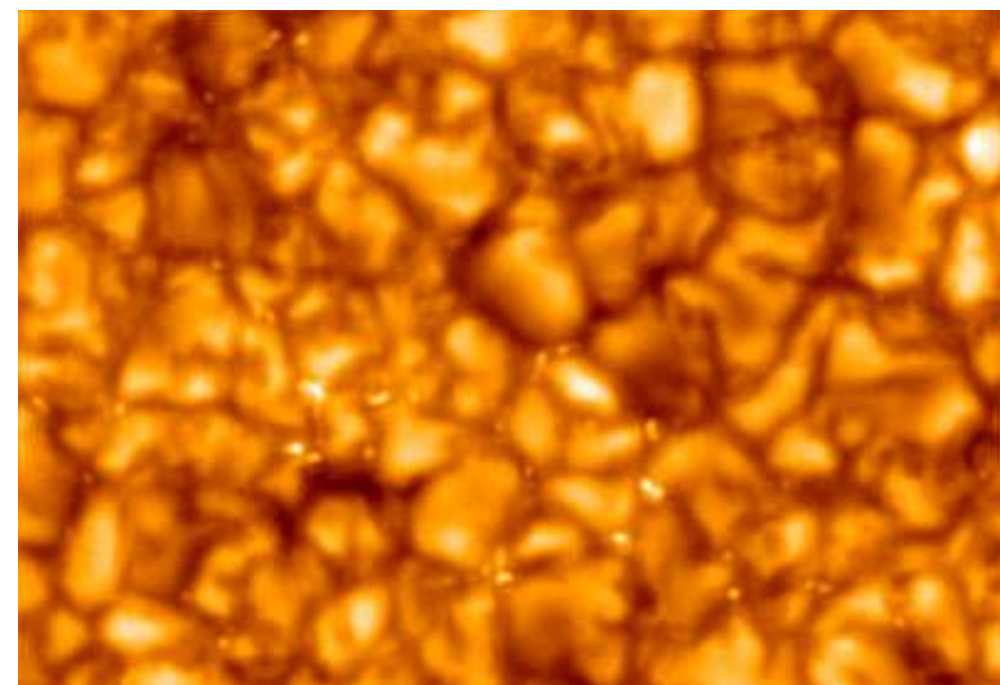
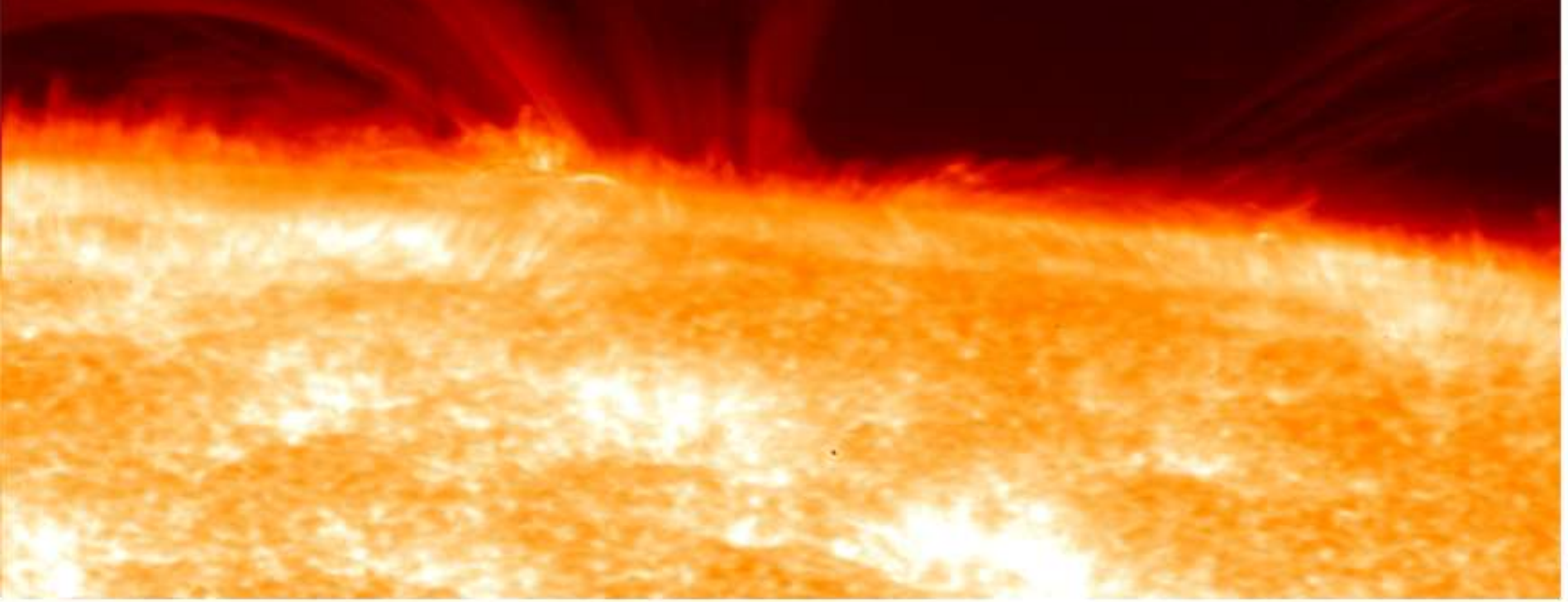
- Hayabusa: Sample return mission from an asteroid → Funaki-san's talk



MV missions

- Hinode: Solar physics





From planning to proposal: how it used to be

- A person who wishes to fly a mission forms a Working Group.
- The WG applies for ISAS funding to perform a PrePhaseA study.
- As the study by WG matures, they become ready to draft a proposal.
- The proposal is submitted upon AO issued by ISAS.
- Up to the proposal, it is a committee formed by peers, not ISAS, that navigates the process.
- When selected, the leader himself reforms the WG to a mission team and the implementation phase starts.

Good old MV days

- Nice missions
- A launch every year by the ISAS-owned rocket
- <My> mission: doing everything by yourself, from the WG to the scientific publications
- Would be nice if a mission of this size that can be run by minimum management continues to be truly competitive scientifically...

The reality: Now H-IIA, not MV

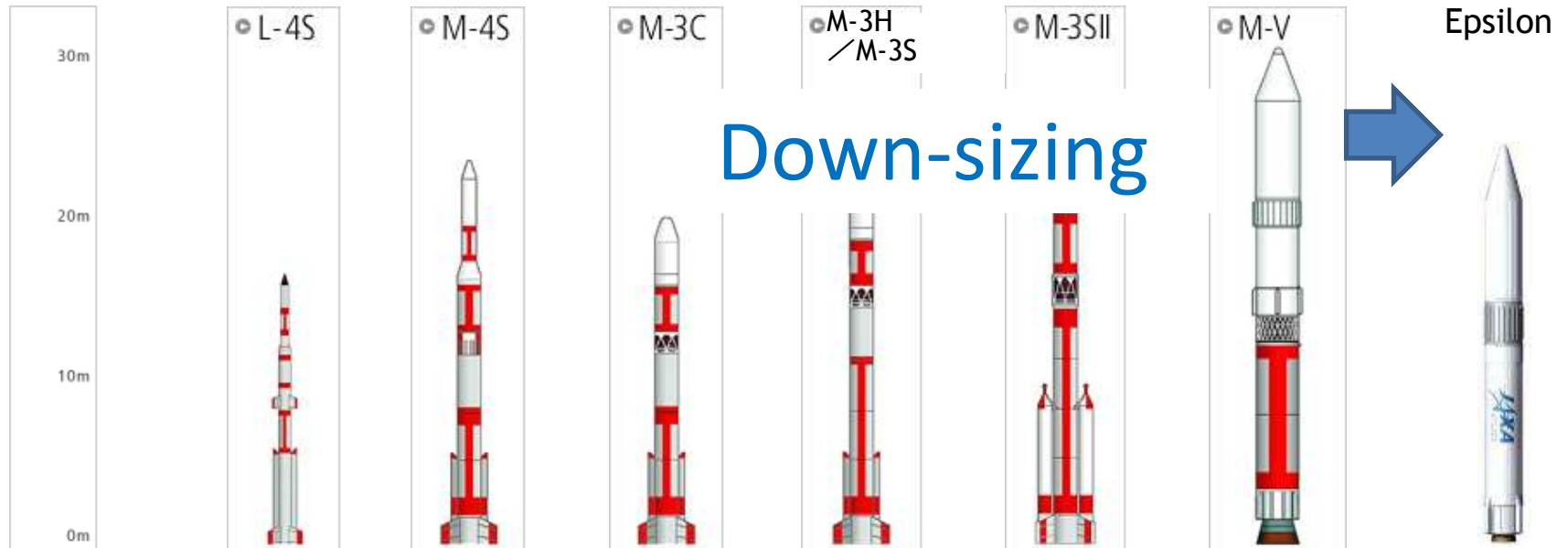
Pure bottom up, from the beginning to the end.

- No room for ISAS to arrange intl collaboration via agency-agency dialogue.
- No room to inject guidance from ISAS at earlier phase of the study.
- No room for ISAS to inject management upon formation of a mission team.

Needs modification to fabricate a good mission plan that matches up with the boundaries that ISAS is embedded in.

The reality: Now Epsilon, not MV

JAXA Solid Propellant Rockets



	L-4S	M-4S	M-3C	M-3H M-3S	M-3S II	M-V	Epsilon
Rocket's Profile	Launched Japan's first artificial satellite OHSUMI	Launched the first scientific satellite SHINSEI	Improved orbit-injection accuracy by Thrust Vector Control	Improved payload to LEO	Launched the first and second Japanese interplanetary probes SAKIHAKI and SUISEI	The best solid-propellant rockets in the world launched Asteroid Explorer HAYABUSA	Solid propellant rocket under development aims at mobility and efficiency
Payload to LEO	26kg	180kg	195kg	300kg	770kg	1800kg	1200kg
Operational Period	1966~1970	1970~1972	1974~1979	3H: 1977~1978 3S: 1980~1984	1985~1995	1997~2006	2013 ~
Launch Records (Succeed/Launched)	1/5	3/4	3/4	3H: 3/3 3S: 4/4	7/8	6/7	-

The reality: Now Epsilon not MV

- Tougher boundary requiring yet harder thinking to come up with a nice mission idea that is doable.
- Should ISAS leave it to a pure bottom-up process and just wait for a good proposal to be submitted?

ISAS now

Keywords

- Mission categories clearly defined.
- More intl elements.
- More channels by which ISAS strategy can be blended into the bottom-up efforts.

ISAS mission categories

- L-class to be launched by H-IIA/III
- M-class to be launched by Epsilon
- Opportunities for grand missions to be led by foreign agencies
- S-class incl those onboard suborbital and ISS programs.

L-class

- Akatsuki: Venus Climate Orbiter
→ Ueno-san's talk
- MMX: Martian Moons eXploration

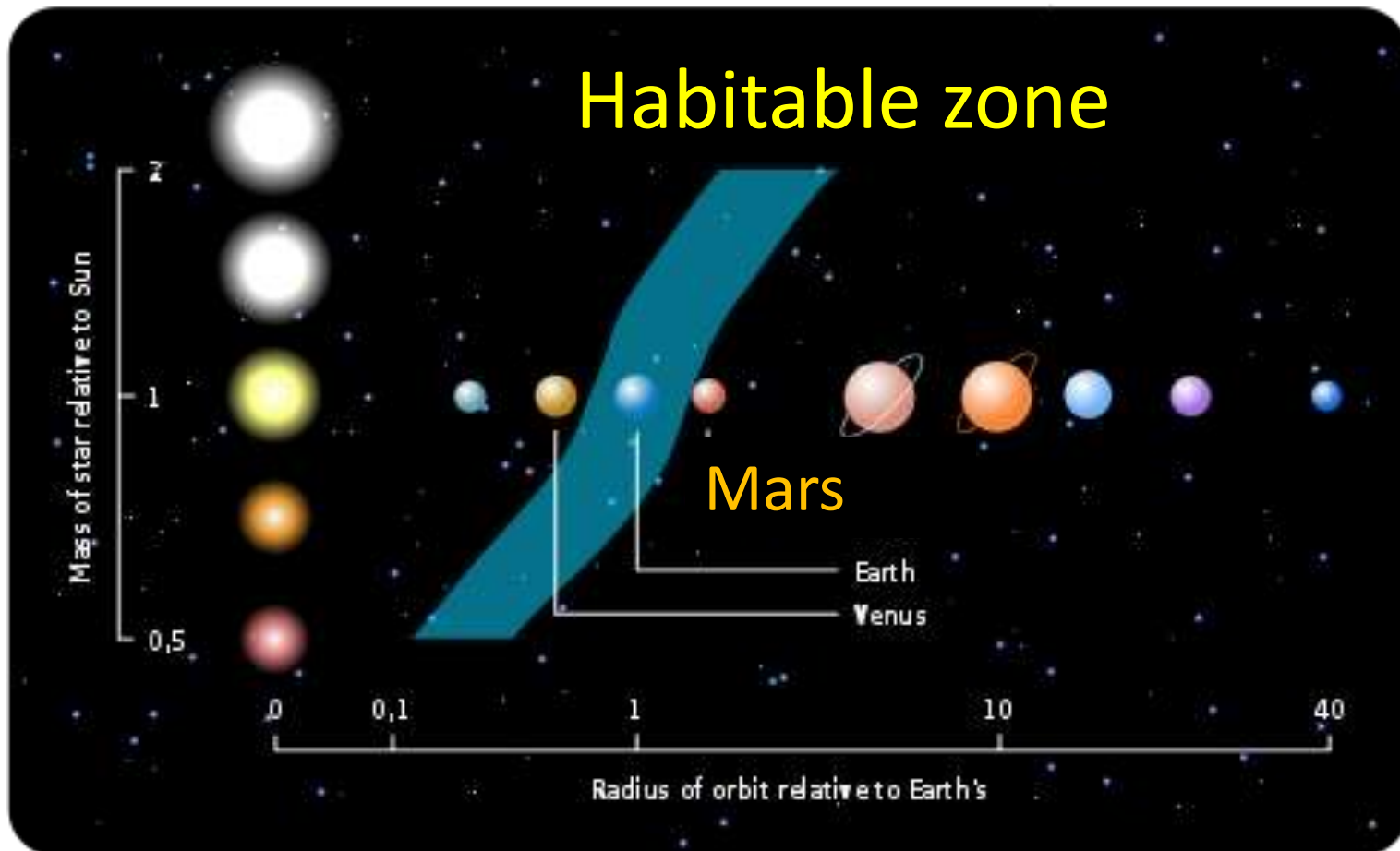
Martian Moons eXplorer (MMX)

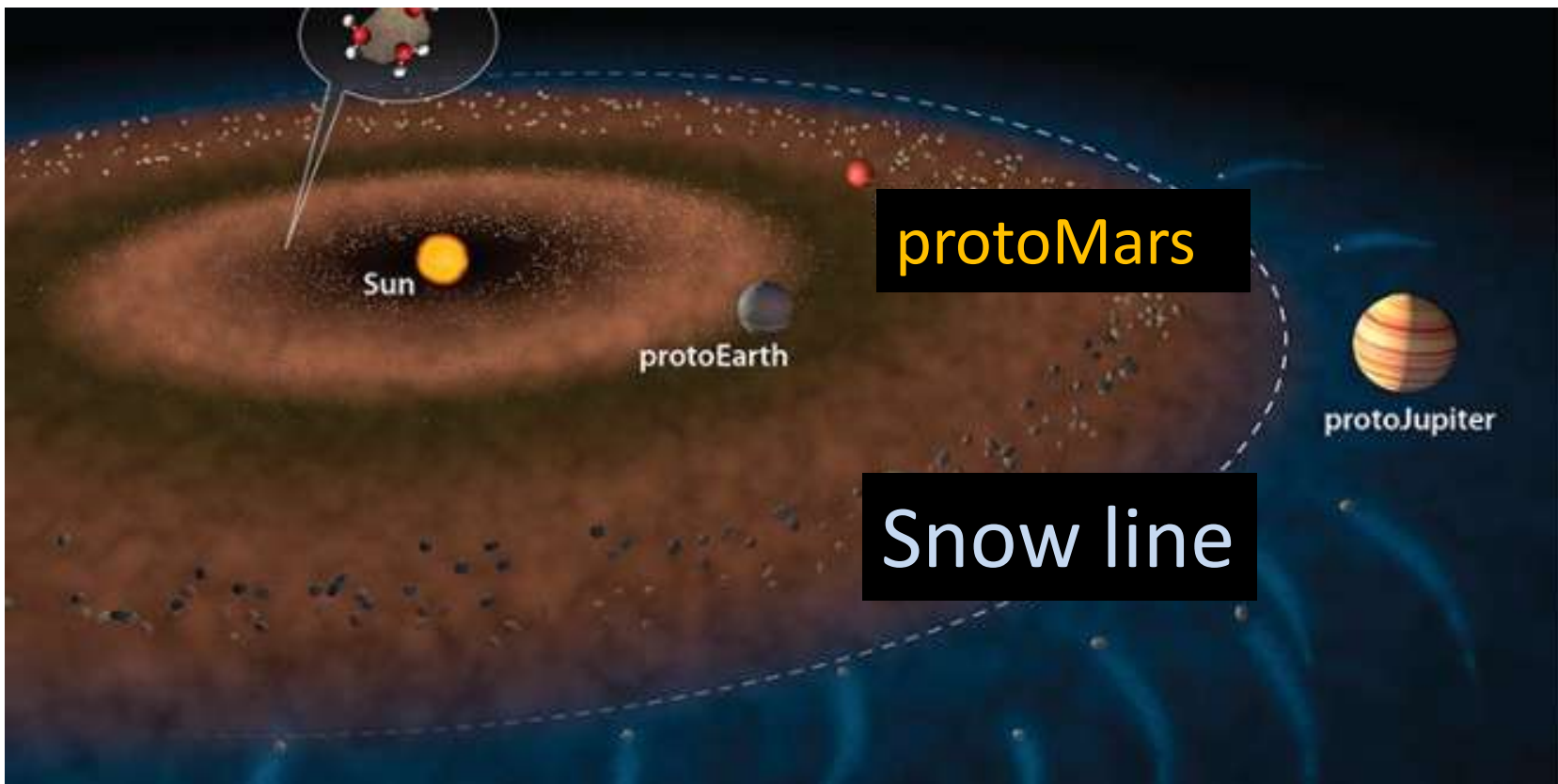


A detailed view of the Martian moon Phobos, showing its heavily cratered and irregular surface. The surface is a mix of reddish-brown and greyish tones, with numerous impact craters of various sizes. The lighting creates strong shadows, highlighting the rugged terrain. The background is a solid black, making the moon stand out prominently.

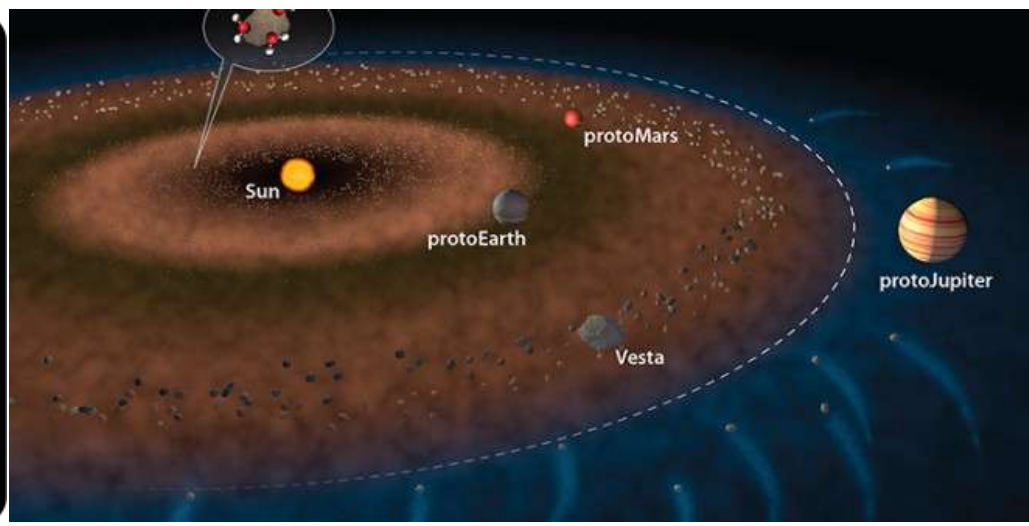
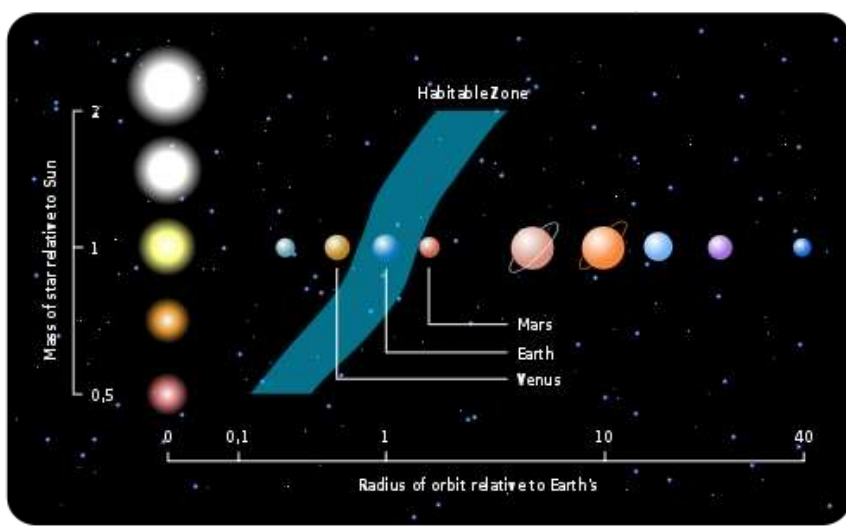
JAXA's exploration of the two
moons of Mars,
with sample return from
Phobos

- The objective: To understand the origin of Phobos
- The goal: To understand how the habitability of the solar system was enabled





- Rocky planets that are in the habitable zone were born inside the snow line: They must have been born dry. Needs transport of water from outside the snow line to enable the habitability of the solar system.

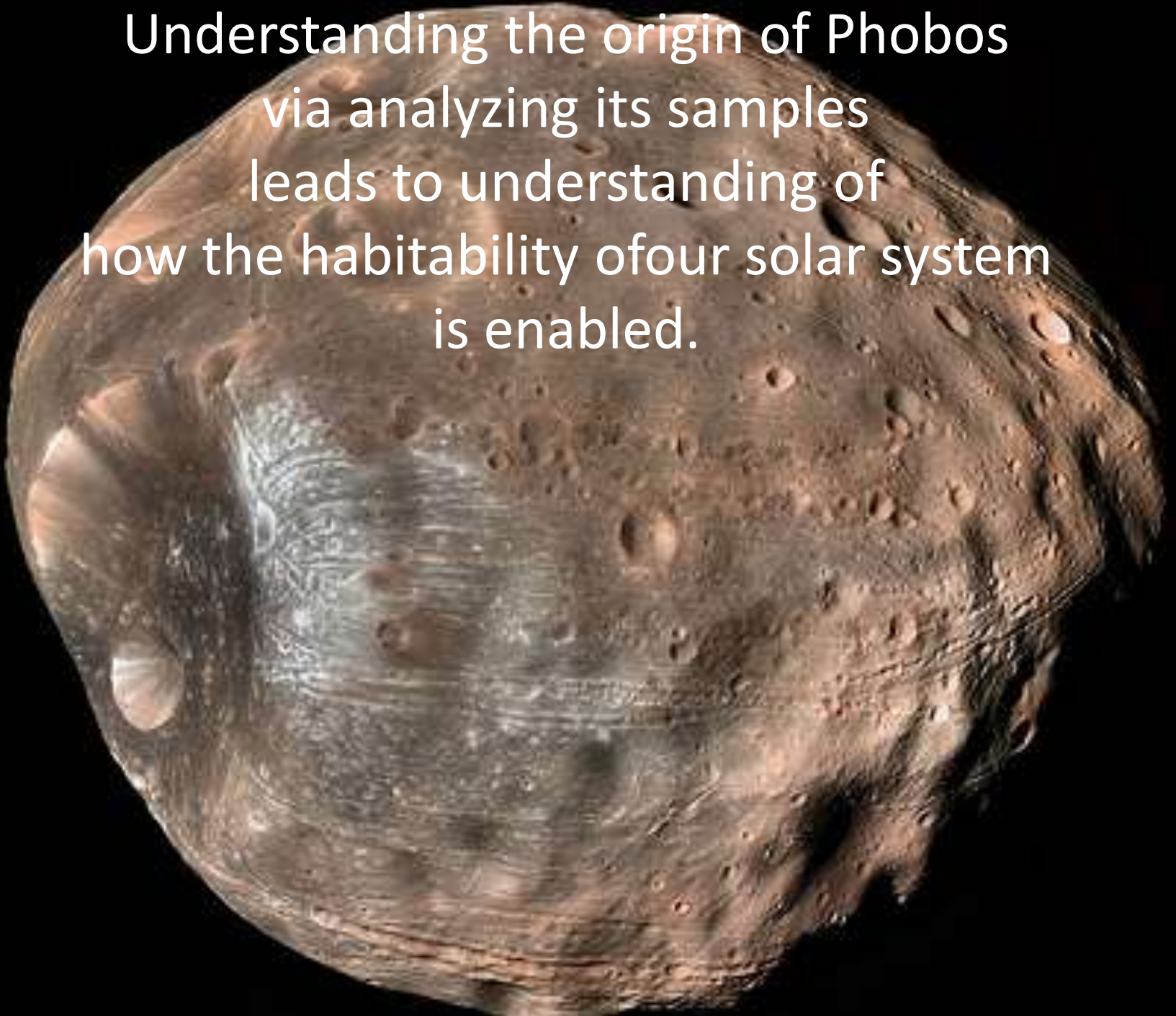


- Small bodies would have played the role of delivery capsule of water.
- Mars at the outer-edge of the rocky planet region must have witnessed the transport process.
- Phobos could have been a delivery capsule that was captured by Mars during its inward journey.

Mission scenario

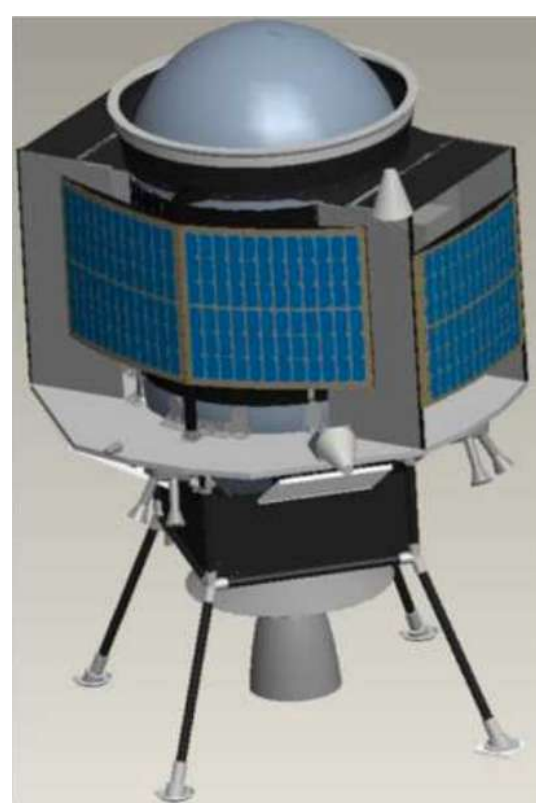
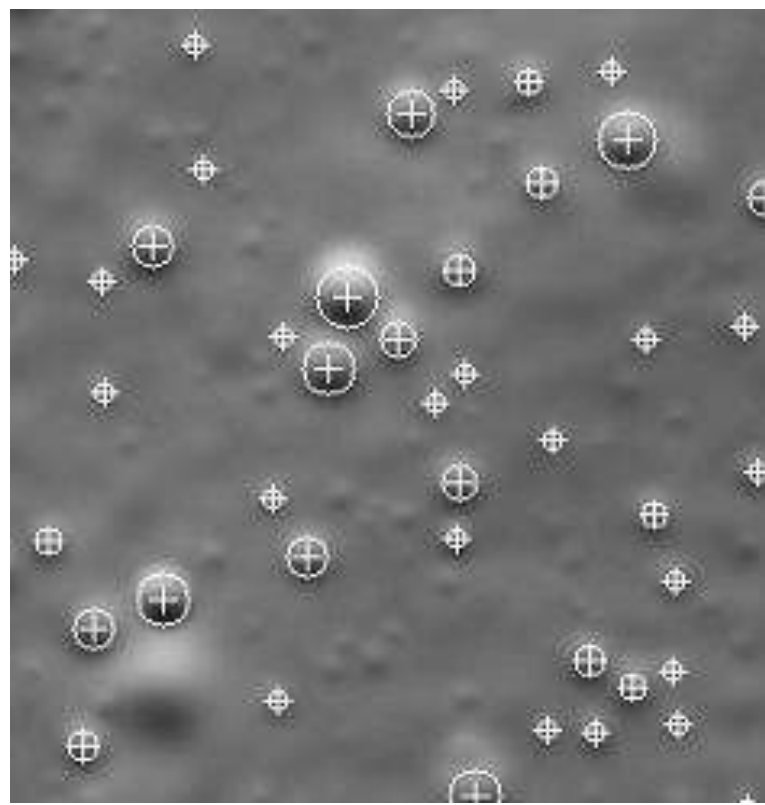
- (1) Mars orbit insertion
- (2) Transfer to a quasi-satellite orbit around Phobos for close-up observations
- (3) Landing and sampling from Phobos
- (4) Transfer to Deimos for multi-flyby observations (or from a quasi-satellite orbit).
- (5) In-situ space observations and Mars remote sensing observations 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

Understanding the origin of Phobos
via analyzing its samples
leads to understanding of
how the habitability of our solar system
is enabled.



M-class

- SLIM: Precisely targetted landing on the lunar surface
- Precision=100m
- Was a technology demonstration, now a small science payload onboard



- Was a technology demonstration, now a small science payload onboard: Land in an area where ejected interior material is known to exist on the surface, and make a spectroscopic obs of them to learn about the early thermal (cooling) history of the Moon formed by the giant impact.



How to secure a smooth path for intl collaboration in L and M classes

In the process of finding the way that works...

MMX case: Has been extremely well because ISAS stepped in an early stage for coordination with foreign agencies (NASA, ESA, CNES, DLR).

SLIM case: <Is a good planetary mission possible at all?> is still the biggest question.

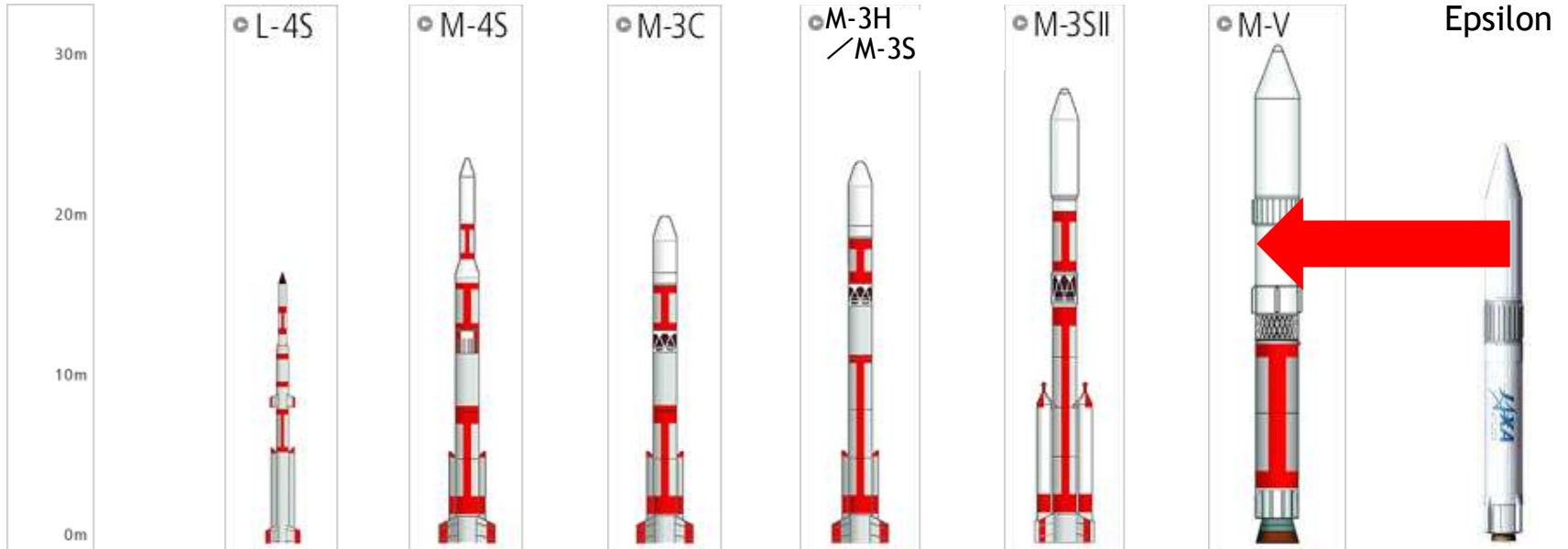
Brain-storming meeting in the US will be tried.



Joint ISAS-LPL Workshop on Planetary Science Enabled by Epsilon Class Missions



With a hope to gain enough momentum to push it back...



	L-4S	M-4S	M-3C	M-3H M-3S	M-3S II	M-V	Epsilon
Rocket's Profile	Launched Japan's first artificial satellite OHSUMI	Launched the first scientific satellite SHINSEI	Improved orbit-injection accuracy by Thrust Vector Control	Improved payload to LEO	Launched the first and second Japanese interplanetary probes SAKIHAKI and SUISEI	The best solid-propellant rockets in the world launched Asteroid Explorer HAYABUSA	Solid propellant rocket under development aims at mobility and efficiency
Payload to LEO	26kg	180kg	195kg	300kg	770kg	1800kg	1200kg
Operational Period	1966~1970	1970~1972	1974~1979	3H: 1977~1978 3S: 1980~1984	1985~1995	1997~2006	2013 ~
Launch Records	1/5	3/1	3/1	3H: 3/3	7/8	6/7	

Participation in foreign grand missions

- The biggest launcher for us is H-IIA/III
- The sexiest missions such as a Mars lander are barely doable.
- Yet, Japanese community begs for a chance to be a part of them.

Participation in foreign grand missions

The solution is:

- The mission slot that provides chances to participate in these grand missions are established.
- While keeping the bottom-up backbone, dialogues and other necessary arrangements between the agencies will be taken care of by ISAS.

Precursor:

BepiColombo: ESA led, Mercury

Ongoing:

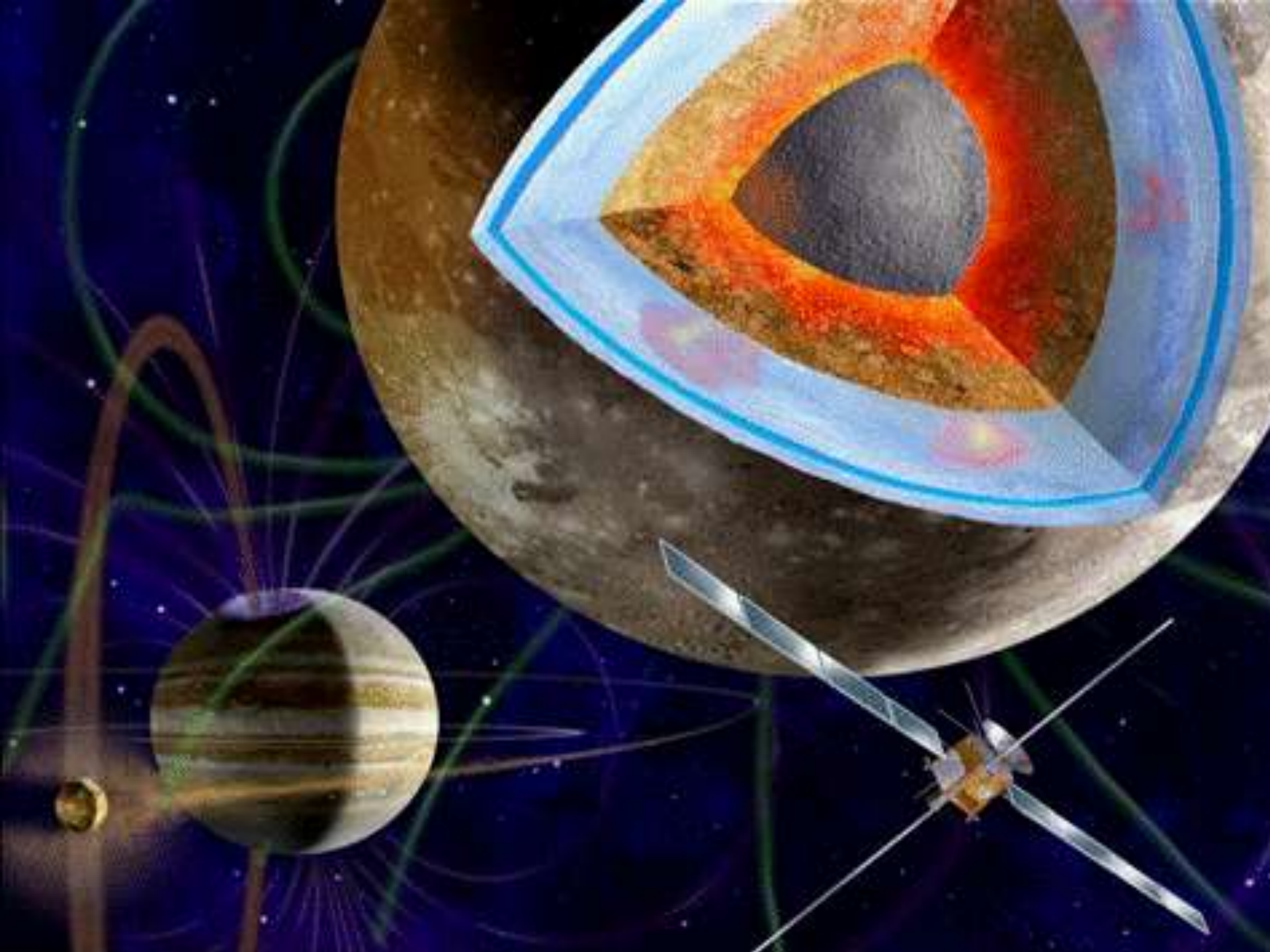
JUICE: ESA led, Icy moons of Jupiter

Under discussion:

ATHENA: ESA led, X-ray astrophys grand observatory

WFIRST: NASA led, IR astronomy grand observatory

NewFrontiers4: a billion USD planetary mission, NASA hosted competitive process, Japanese participation in a few proposals foreseen



Precursor:

BepiColombo: ESA led, Mercury

Ongoing:

JUICE: ESA led, Icy moons of Jupiter

Under discussion:

ATHENA: ESA led, X-ray astrophys grand observatory

WFIRST: NASA led, IR astronomy grand observatory

NewFrontiers4: a billion USD planetary mission, NASA hosted competitive process, Japanese participation in a few proposals foreseen

Summary

- The ISAS style: Blending the wish of the space engineering researchers into missions
- Lessons learnt (Hitomi mishap): **More management without spoiling the essential minimum of the <ISAS style>.**
- Not 100% bottom-up anymore, but **mission incubation/guidance from ISAS** to a WG in an early phase of a study
- **Strategic international partnership: Give-and-take on the whole scale**, not balancing within a single mission. Early phase conversation.

Give and take on the whole scale

- The Hitomi mishap