Adventure of Asteroid Explorer "HAYABUSA"

July 2014

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What to know・・・

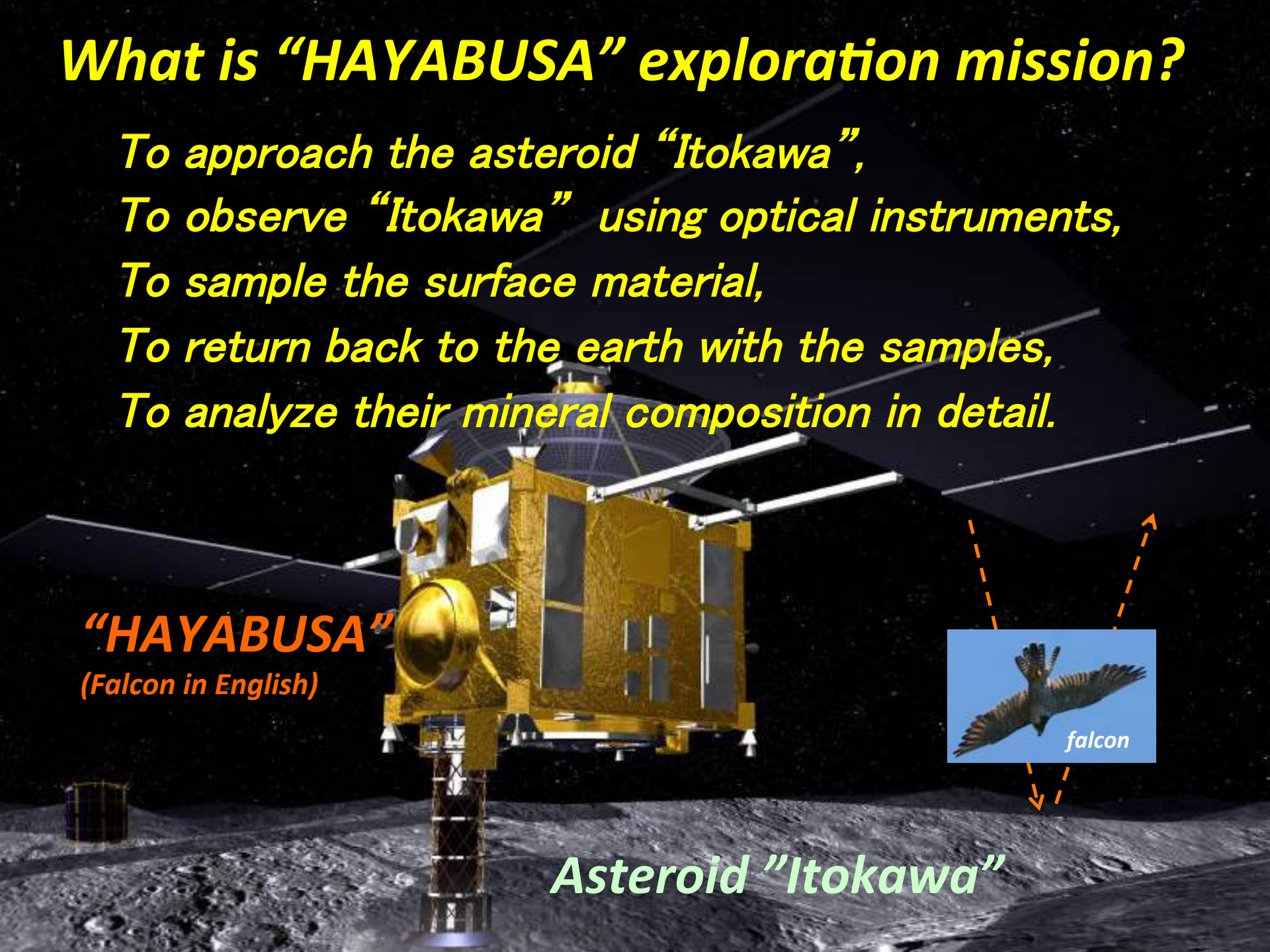
- *Origin of the solar system（Sun, Earth,…）*
- *Unique ideas for planetary exploration*

What to feel・・・

- *Significance of courage to overcome difficulties*
- *Interests of planetary exploration*

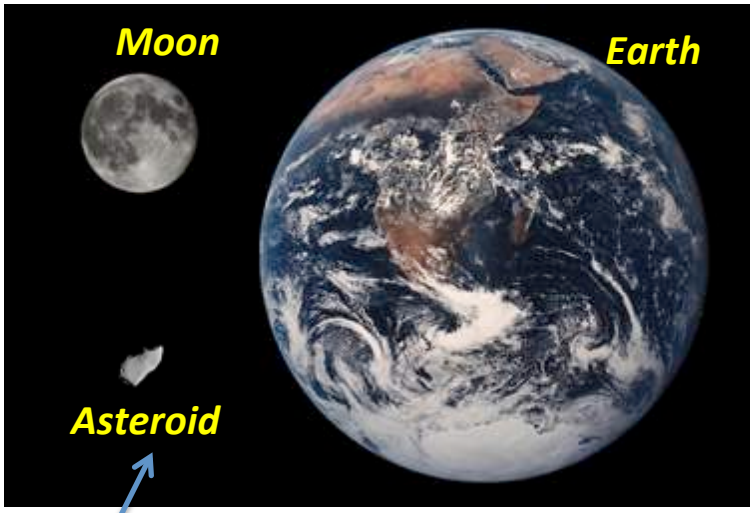
What is “HAYABUSA” exploration mission?

To approach the asteroid “Itokawa”,
To observe “Itokawa” using optical instruments,
To sample the surface material,
To return back to the earth with the samples,
To analyze their mineral composition in detail.

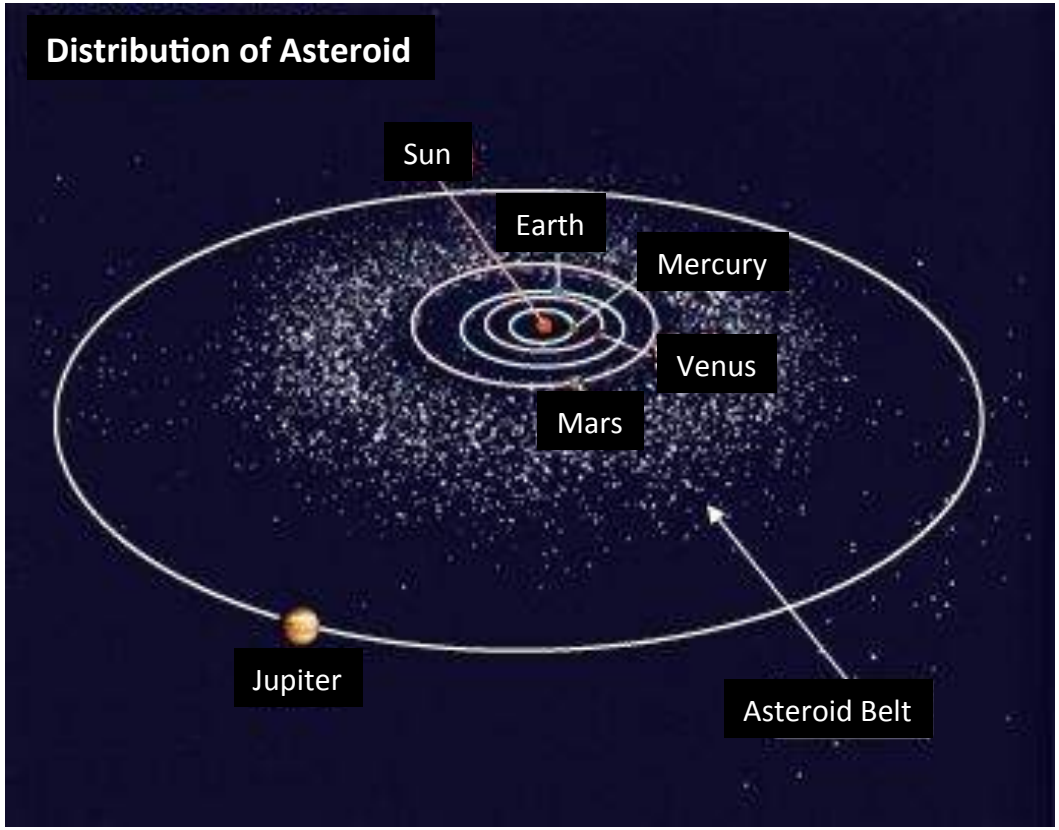


What are Asteroids?

- *Small bodies orbiting around the Sun, just like the Earth.*
- *Typical size less than 100 km, even the largest one less than 1/3 of the Moon.*
- *Mainly distributed between the orbits of Mars and Jupiter.*
- *"Itokawa" is one of the near-earth asteroids.*



Various shapes and sizes. More than 300,000 asteroids with determined orbits have been identified.



Why "HAYABUSA" explored the asteroid ? (1/2)

To understand it, let's look at the birth of the solar system 4.6 billion years ago.

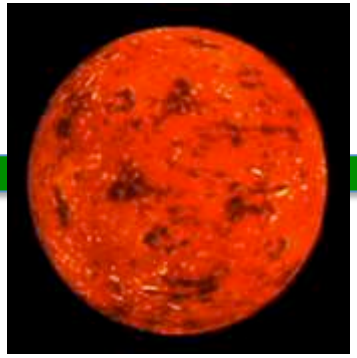
Molecular cloud (a stellar nursery) → ***Accretion to protosun and small planets*** → ***Accretion to larger planets***

Why "HAYABUSA" explored the asteroid ? (2/2)

Magma ocean formed by collisional heating

A lot of collisions

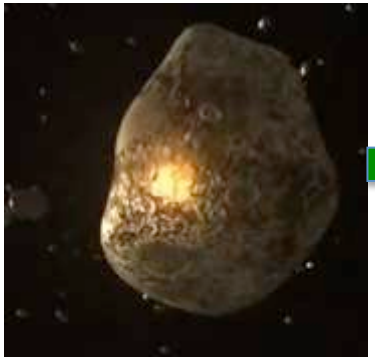
Large planet like Earth



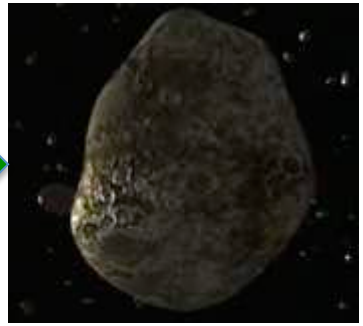
Memories of the early age were lost.

Few collisions

Asteroid



Not heated to melting temperature

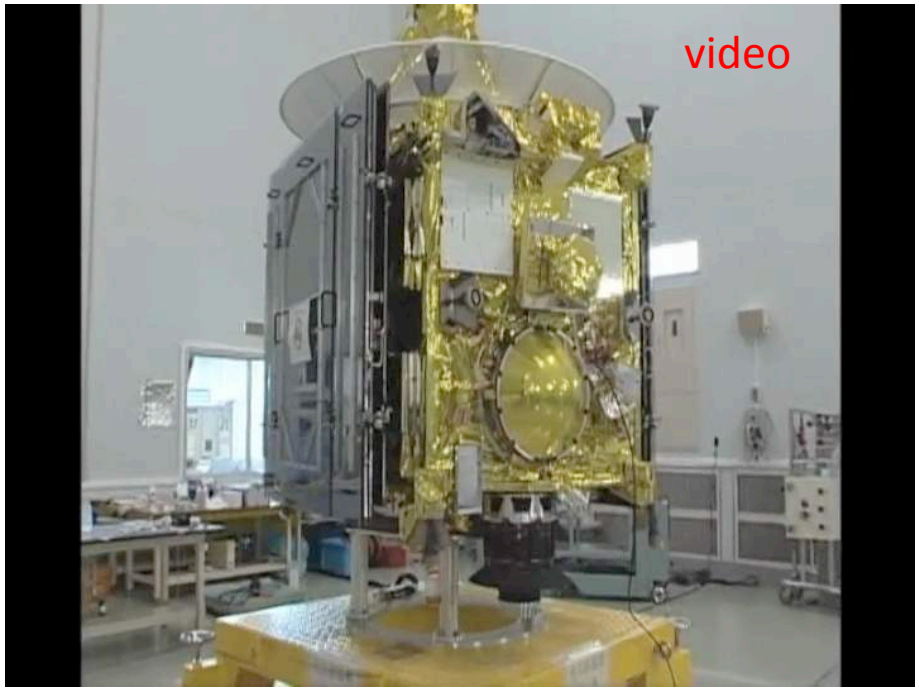


Memories of the early age are kept.

By bringing the samples of the asteroid back to the earth and by analyzing them, the original materials of the asteroid and the environment of the early solar system are figured out.

Development of "HAYABUSA" and its Launch

Early studies by scientists started around 1985.
"HAYABUSA" project started in 1996.
"HAYABUSA" departed from the Earth for "Itokawa" in 2003.



Integration of sample return capsule to "HAYABUSA" main spacecraft.

Launch by the M-5 solid rocket from Uchinoura Space Center in 2003.

“HAYABUSA” Trajectory

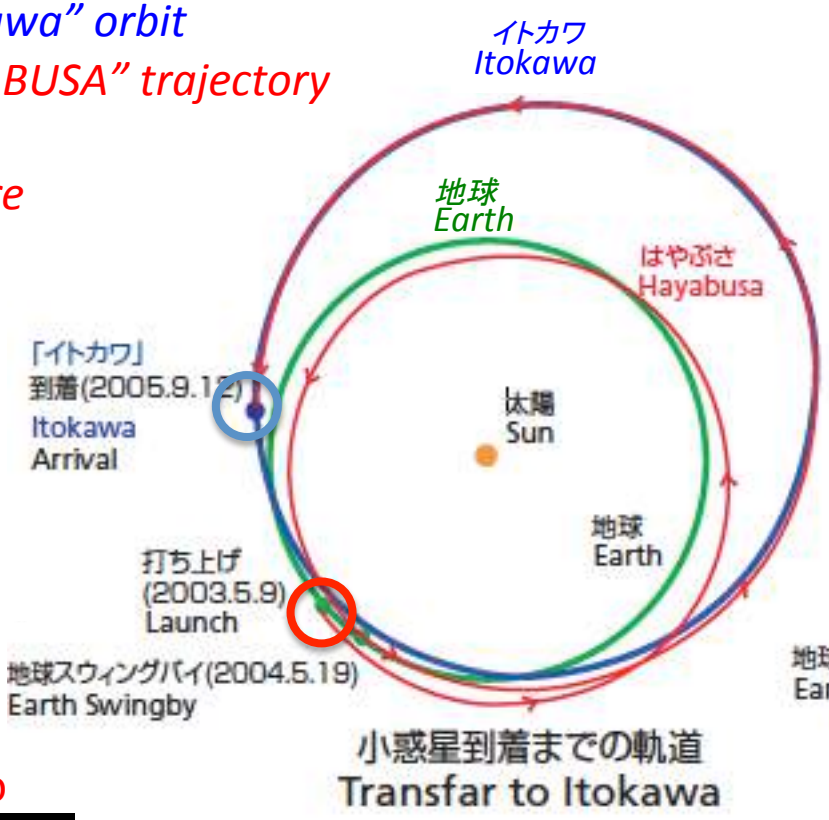
Green : Earth orbit

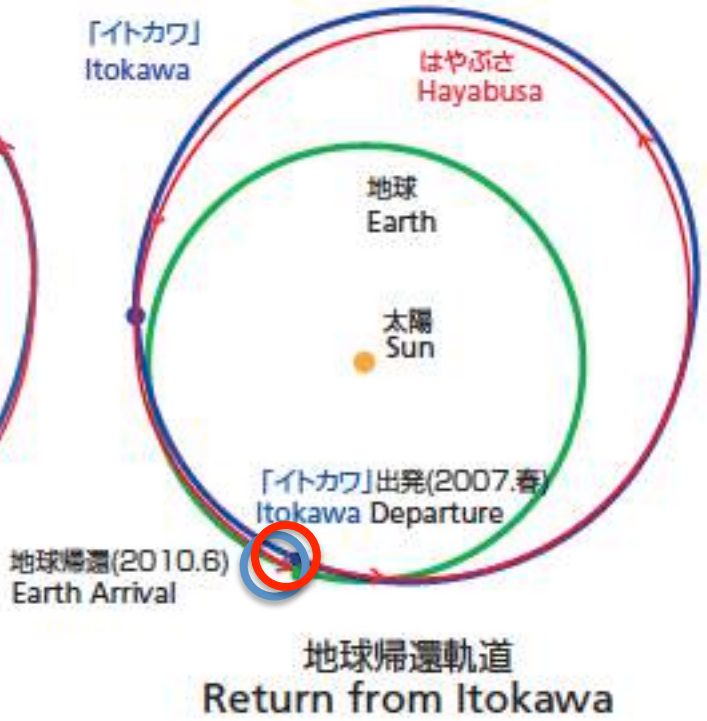
Blue : ”Itokawa” orbit

Red ; ”HAYABUSA” trajectory

○ : Departure

○ ; Arrival



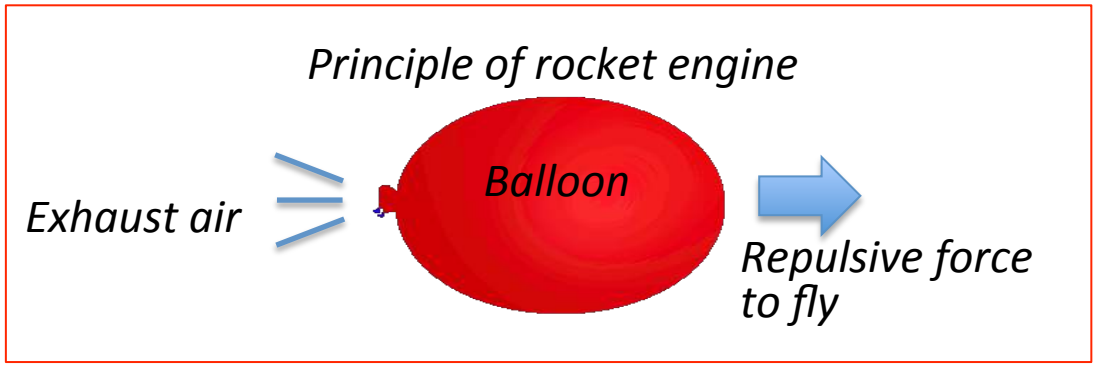


video

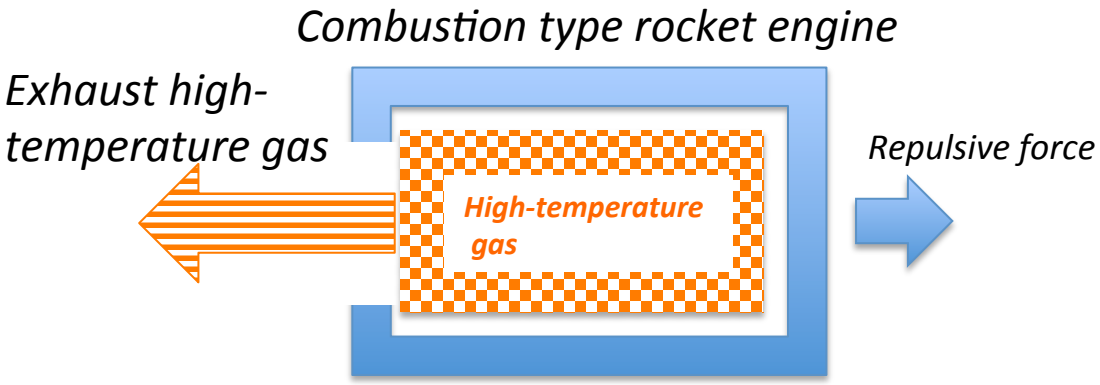
From the Earth to “Itokawa”
(2 years and 4 months)

From “Itokawa” to the Earth
(3 years and 5 months)

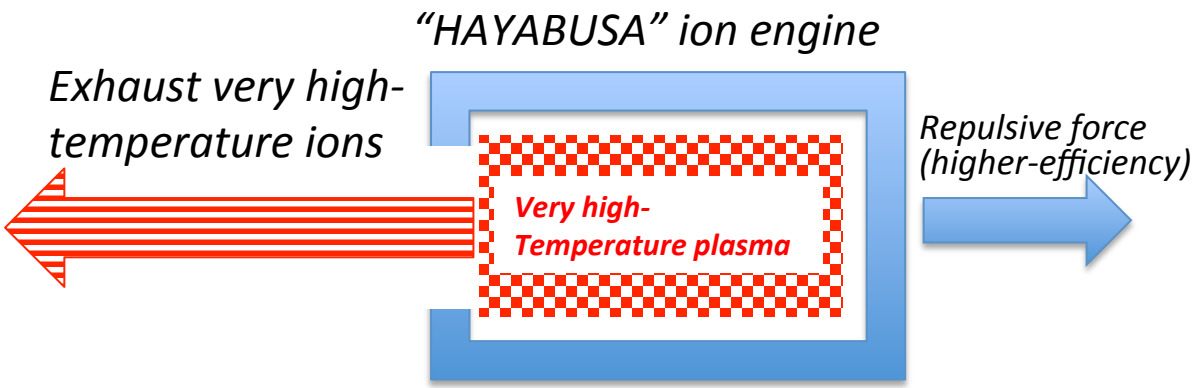
Ion Engine onboard "HAYABUSA"



"HAYABUSA"



Combustion rocket engine



"HAYABUSA" ion engine

Observation of "Itokawa" by "HAYABUSA"

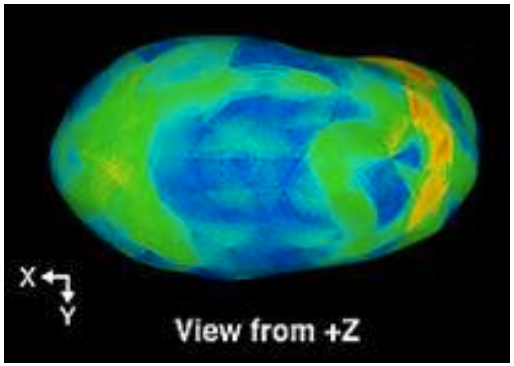
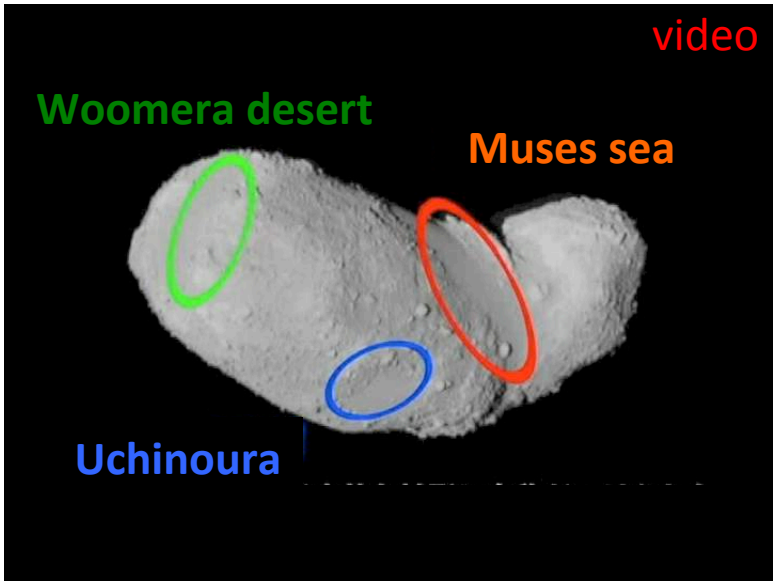


Image of "Itokawa" by ground observation

Image of "Itokawa" observed by "HAYABUSA"

It was called "Itokawa sea otter" as it lookd like in shape.



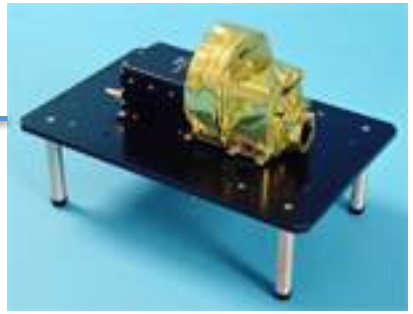
Names were given to major terrains.

Similar in shape!

Scientific Instruments used for observation of "Itokawa"

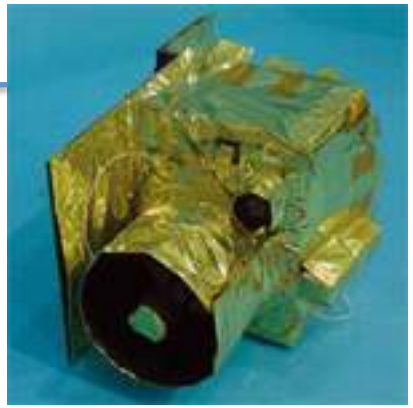
AMICA (Telescopic Camera) — Images

Measures the distribution and abundance of surface minerals using 7 filters.



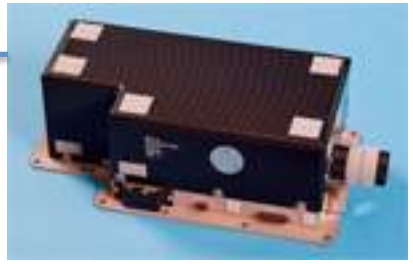
LIDAR (Light Detection And Ranging) — Surface shape

Measures the high resolution topographic profiles, by ranging from 50 km to 50 m.



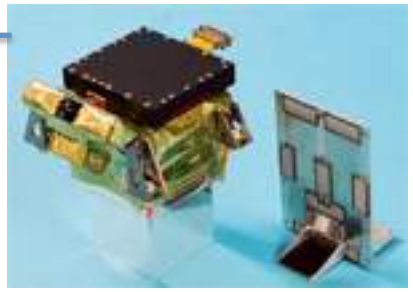
NIRS (Near Infrared Spectrometer) — Surface minerals

Measures the near-infrared spectrum to determine the distribution and abundance of surface minerals.



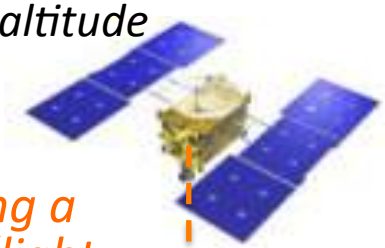
XRS (X-ray Fluorescence Spectrometer) — Surface elements

Detects x-ray fluorescence from elements excited by solar x-rays to determine the chemical composition of surface materials.



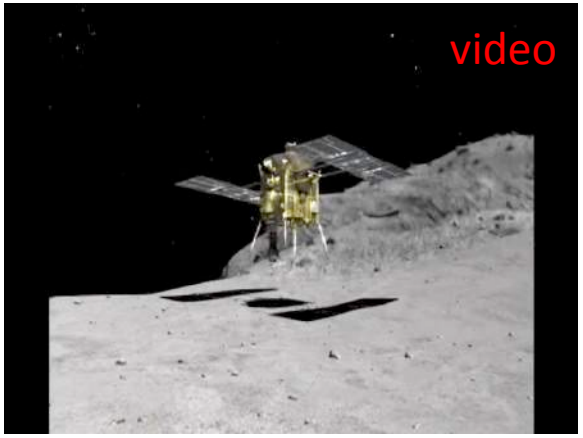
Landing and Sampling

at 30m altitude



Dropping a target (light reflector).

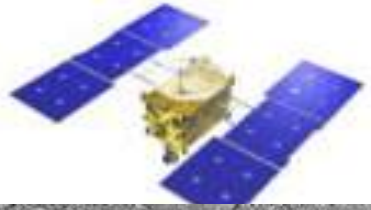
Flashing and detecting the target

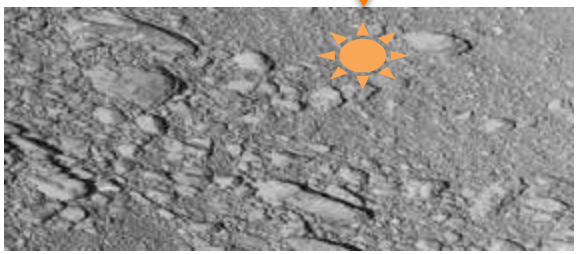


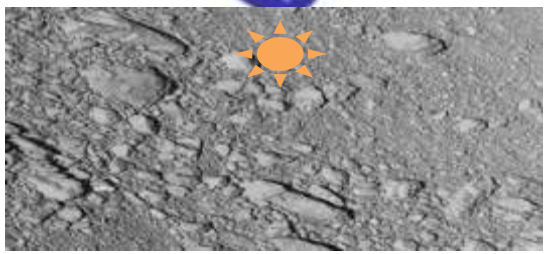
Landing

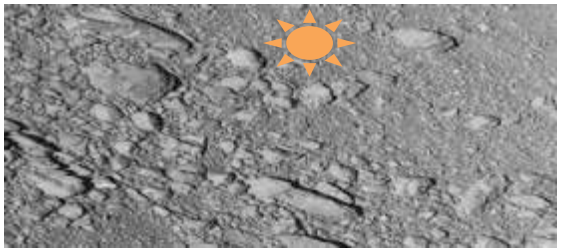
Flying away immediately after sampling.

Landing and sampling.





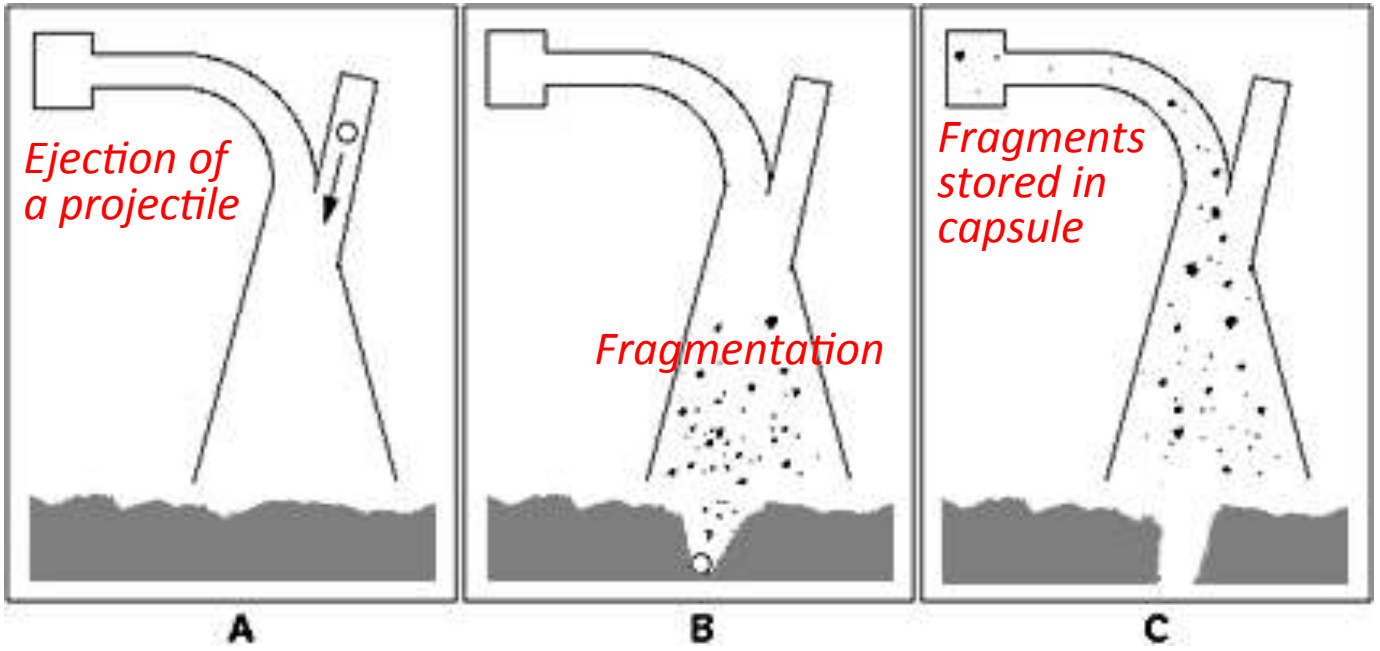




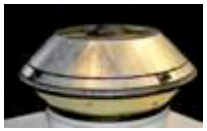
Sampling Mechanism

- *A metal projectile of several grams is ejected at 300 m/s to the asteroid surface.*
- *The surface material is scattered into small fragments by the impact.*
- *The fragments are introduced into the storage room of the capsule.*

Sampling device



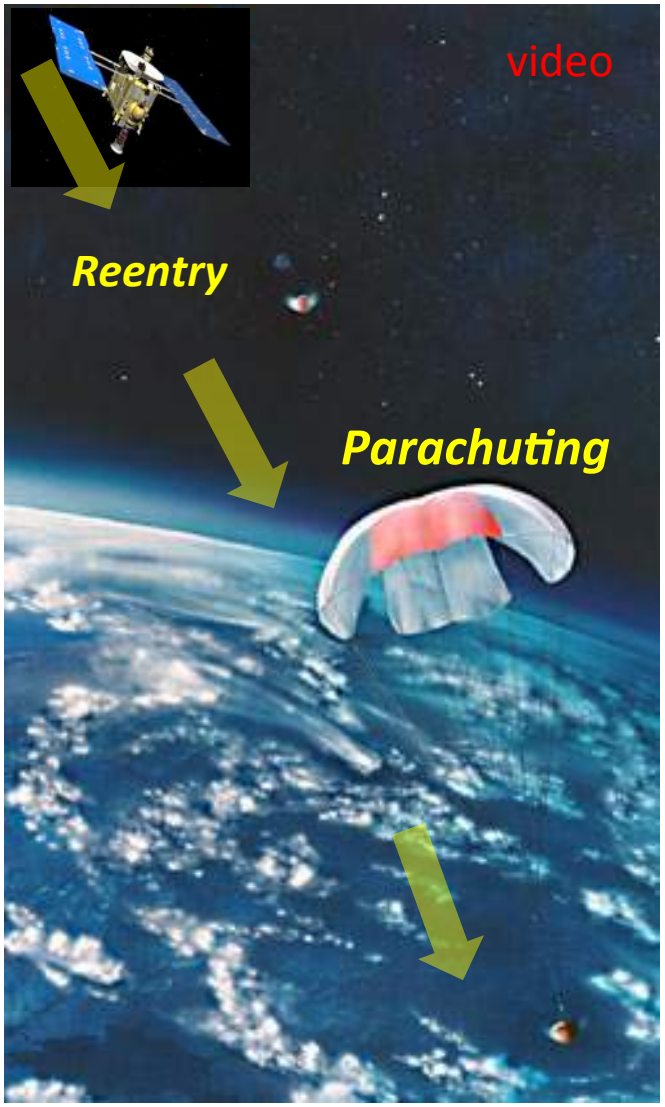
Return to the Earth/Capsule Retrieval



- *The capsule was separated from "HAYABUSA" just before reentry and entered the atmosphere at more than 12 km/s.*

- *During descending through the atmosphere, the capsule was enormously heated, but it survived. "HAYABUSA" itself was burned out in the atmosphere.*

- *The capsule ejected a parachute and landed softly on the ground. By detecting the radio waves from the capsule, it was retrieved successfully.*



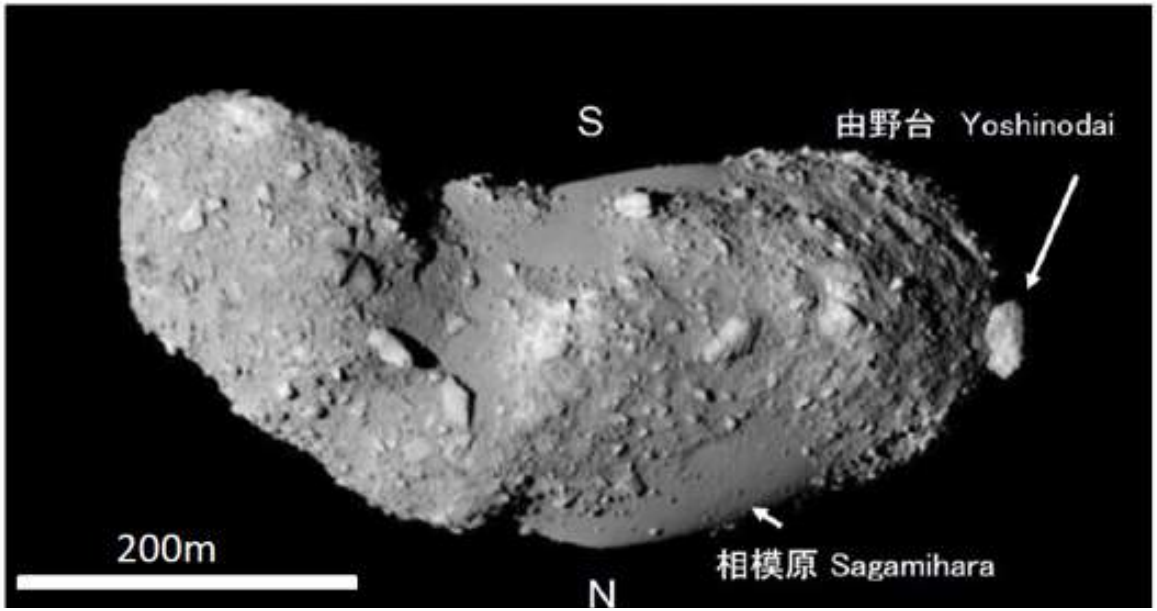
Adventure of "HAYABUSA" /Overcoming Various Difficulties

May 2003	*Launched from Kagoshima Space Center*
July 2005	*One of 3 reaction wheels to keep attitude failed.*
Sep. 2005	*Arrived at Itokawa (20 km away)*
Oct. 2005	*Second reaction wheel failed.*
Nov. 2005	*First touch-down on Itokawa (unexpected landing)*
	Second touch-down on Itokawa (fuel leak）
Dec. 2005	*Unstable attitude. Communication link to the earth was lost.*
Jan. 2006	*Communication link was recovered.*
Feb. 2007	*Ion engine was activated again.*
Apr. 2007	*Ion engine operation started for return trip to the earth.*
Feb. 2009	*Second-phase orbit change started. Ion engine operation was restarted.*
Nov. 2009	*Ion engine failed.*
	Propulsion capability is recovered by reconfiguration of two failed ion engine systems.
Mar. 2010	*Second-phase orbit change was completed.*
June 2010	*"HAYABUSA" returned to the earth and the capsule was recovered.*
July 2010	*Particulates of Itokawa were found in the sample capsule and the analysis started.*

Overcoming Various Difficulties

Nov. 2005	First touch-down on Itokawa (unexpected landing)
	Second touch-down on Itokawa (fuel leak)
Dec. 2005	Unstable attitude. Communication link to the earth was lost.
Nov. 2009	Ion engine failed.

Great advancement in understanding of planet formation/evolution by on-site observation

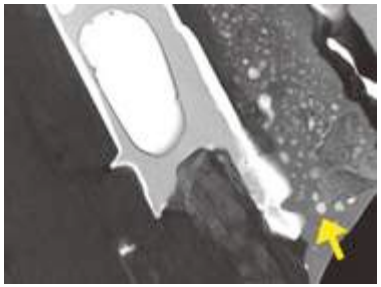


Irregular Shape ➡*Itokawa was not totally melted.*
Huge Boulders ➡*Itokawa experienced a large-scale collision.*
Low Density (based on gravity measurement) ➡*Porosity structure inside Itokawa*

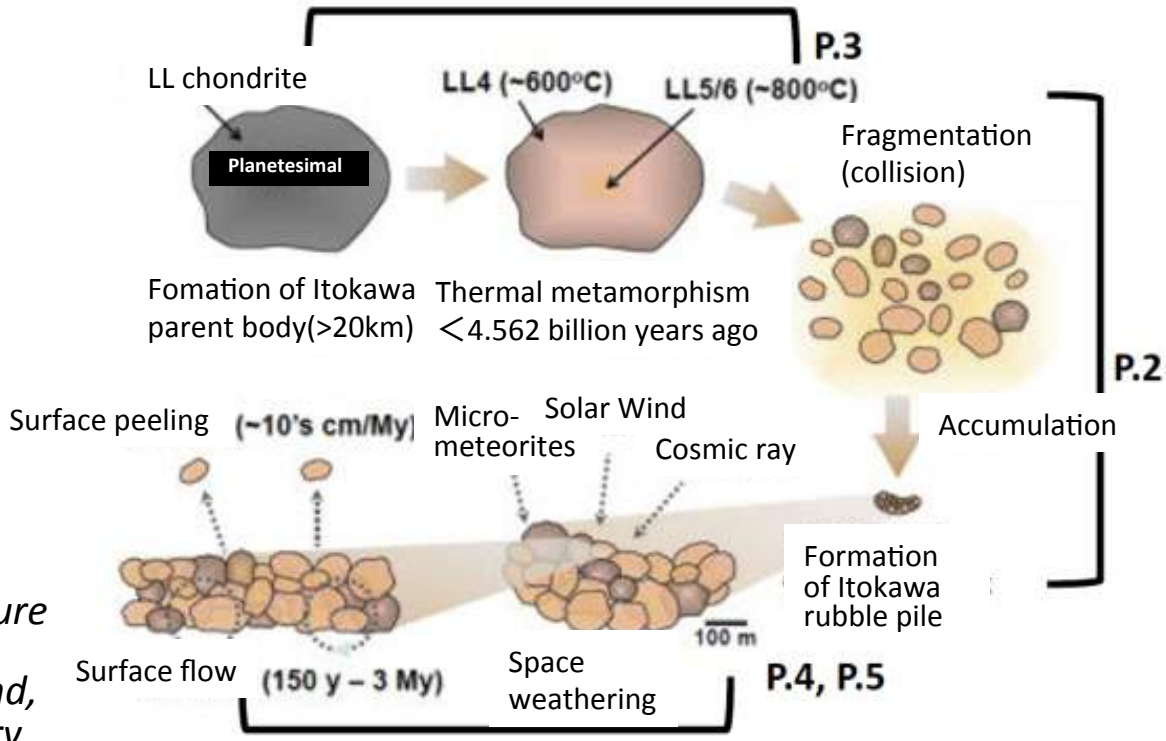
Itokawa was identified to be a rubble-pile asteroid, a primitive body solar system (Fujiwara et al., 2006 Science).

Great advancement in understanding of planet formation/evolution by sample analysis

Sample analysis



Observation of fine structure by electron microscope. Bubble structure was found, showing its thermal history. (Tohoku Univ./JAXA)



The planet evolution process, fragmentation by collision and accumulation of debris after collision, has been clarified.
It was suggested that most small asteroids are rubble piles.

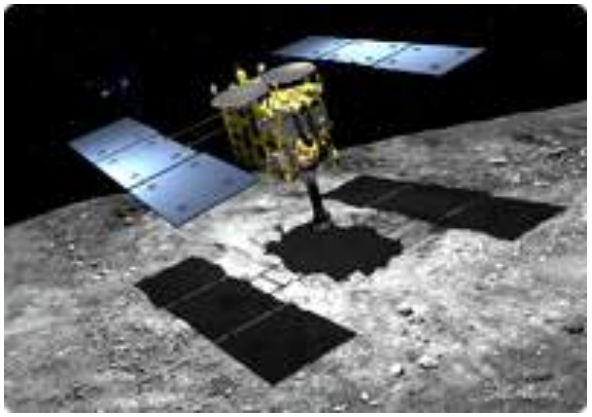
"HAYABUSA 2" ・・・Launched in Dec.2014

—Aiming at research on origin and evolution of the solar system, and on the original materials of life—

Target: Asteroid 1999 JU3 (Type-C, 900 m size)

Small robots will be landed.

Artificial crater (several meters in diameter) will be generated by colliding an impactor (2kg)."



Fresh surface material will be sampled from the inside of the artificial crater.

"HAYABUSA 2" Mission Plan

2014	*Launch*
2018	*Arrival at the Asteroid*
2020	*Back to the Earth*
2020-	*Analysis of samples*

2020

HAYABUSA 2


Challenge to make your dreams come true,
just like “HAYABUSA” !
End of Today’s Lecture