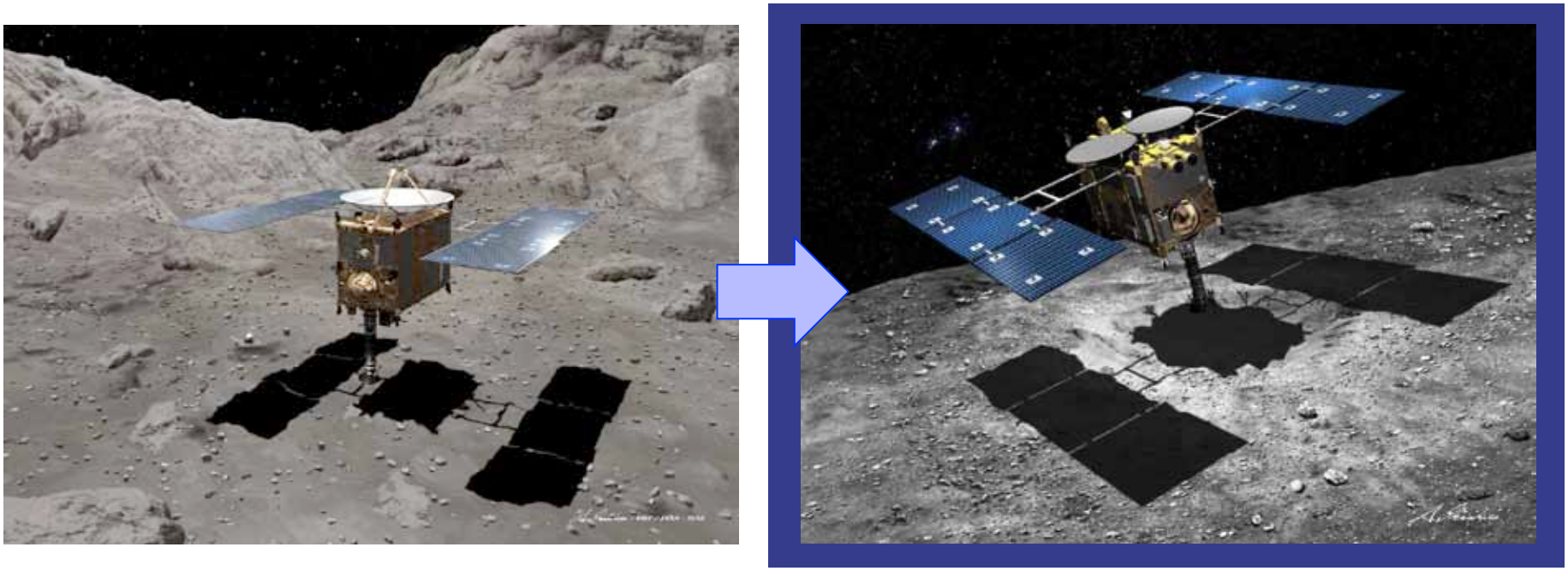
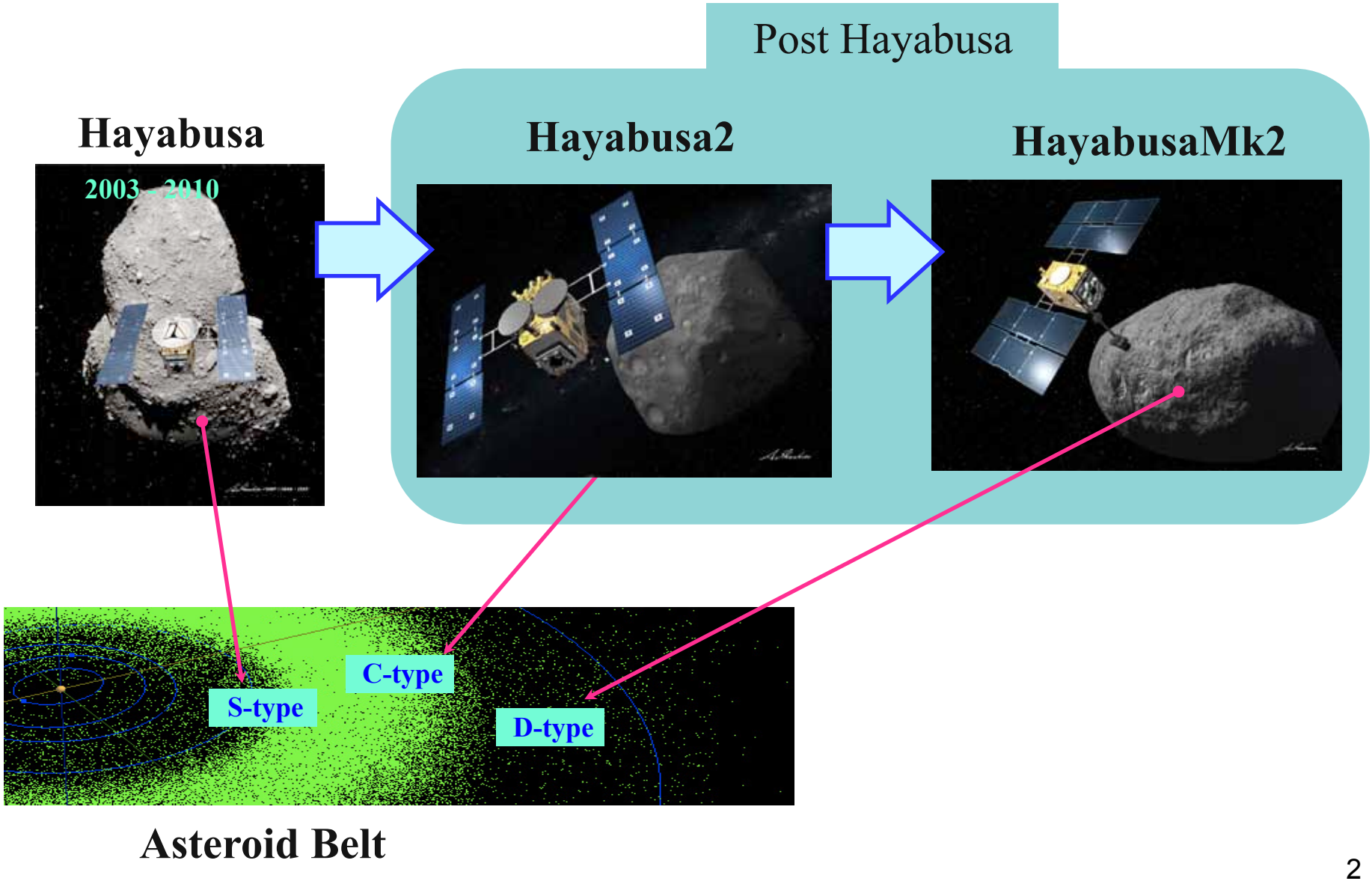
Outline of the Next Asteroid Sample Return Mission -
Hayabusa2

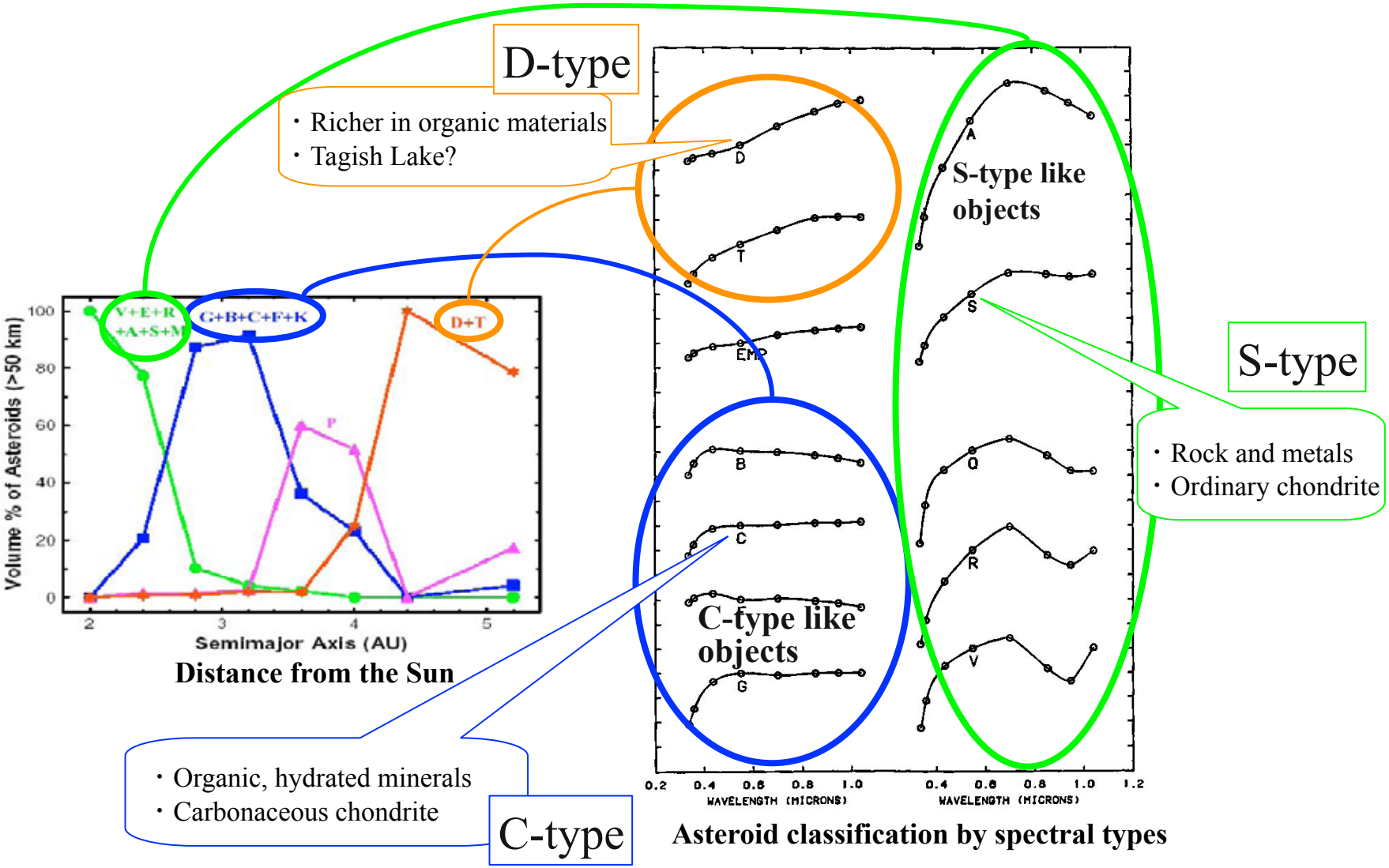


JAXA

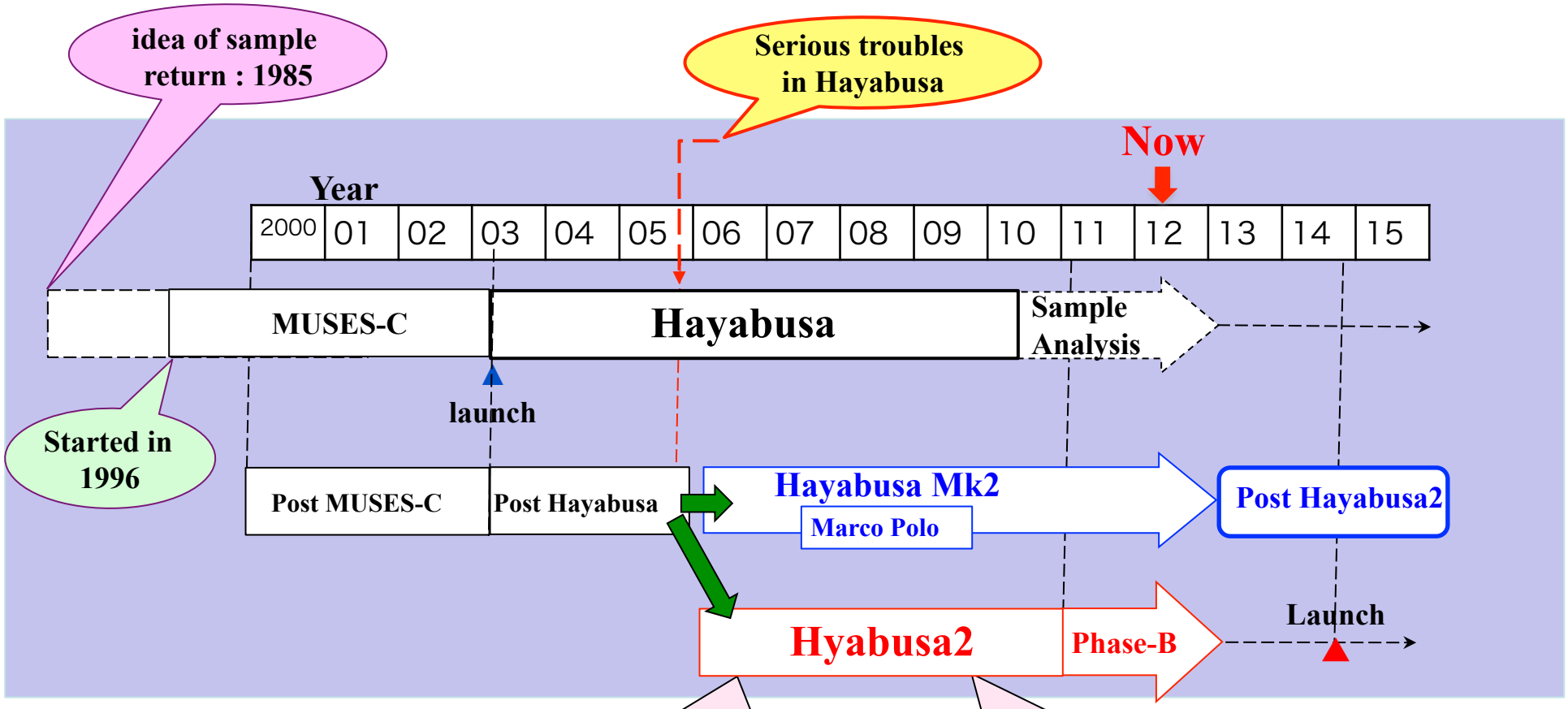
Primitive Body Exploration Program considered in Japan



Spectral Types of Asteroids



History



Initial proposal in 2006
Copy of Hayabusa
but modified
Target : C-type asteroid
1999 JU3
Launch: 2010

New proposal in 2009
Modified Hayabusa adding
new challenges
Target : C-type asteroid
1999 JU3
Launch: 2014

Current Status of Hayabusa2

- **May 2011** : Phase-B has started.
- **March 2012** : CDR of Hayabusa2 was finished.
- **April 2012** : We have started manufacturing of subsystem and system.
- **May 31- June 1, 2012 :** COSPAR : Planetary Protection (colloquium)
- **July 14-22, 2012 :** COSPAR : Planetary Protection
- **Jan. – Apr. 2013** : First interface test will be done.
- **Oct. 2013 – Sep. 2014** : FM test
- **Dec. 2014** : Launch (!)

Objectives : Hayabusa vs Hayabusa-2

Hayabusa

Technological demonstrator
- Round-trip to asteroid
- Sample return

Engineering
- Ion engine
- Autonomous navigation
- Sample collection
- Reentry capsule
- Earth Gravity Assist with Ion Propulsion

Science :
Origin and evolution of the solar system
- Remote sensing observation
- Sample analysis

Hayabusa2

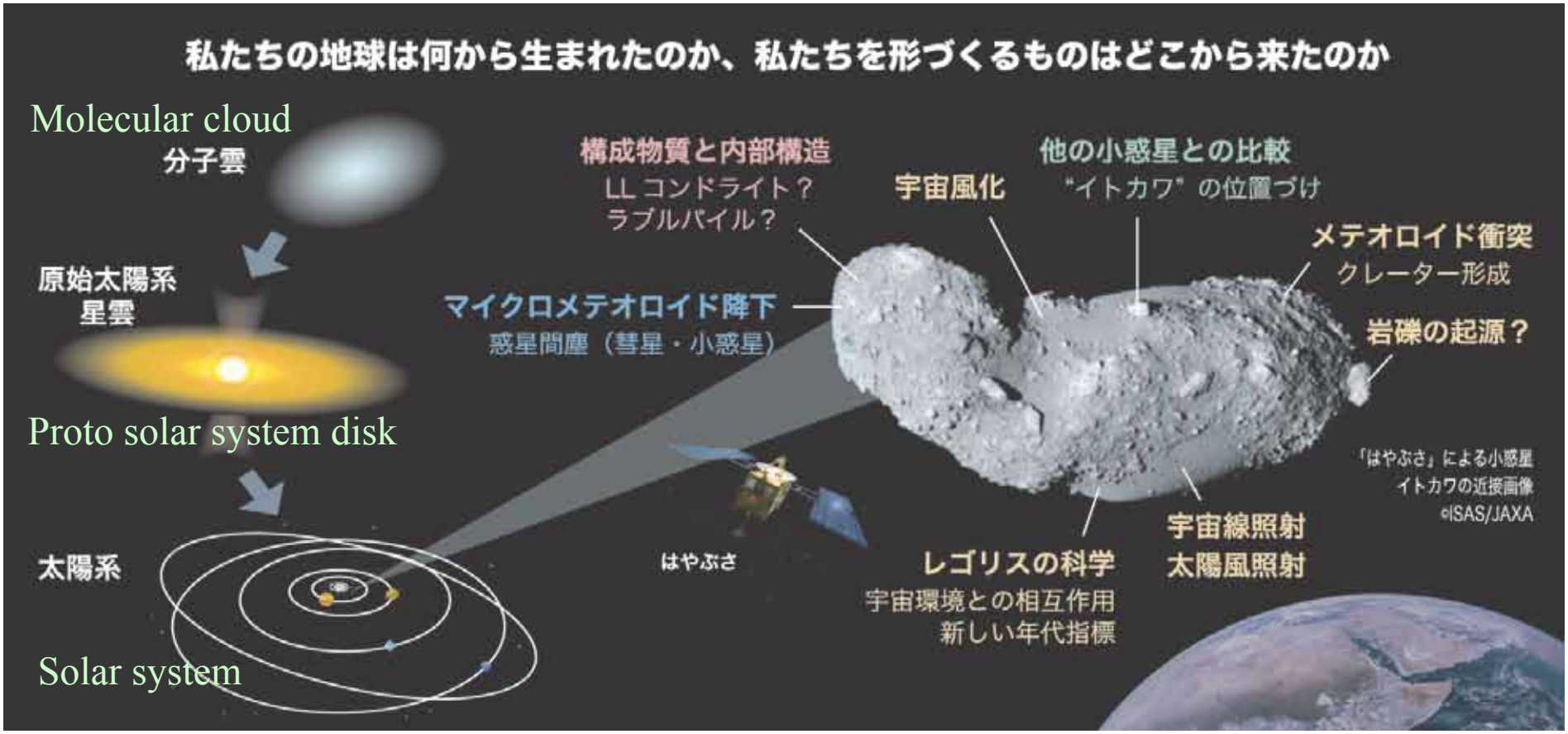
1. Science
- Origin and evolution of the solar system
- Matter, Organic matter, H_2O

2. Engineering
- Technology : more reliable and robust
- New challenge : ex) impactor

3. Exploration
- Extend the area that human can reach
- Spaceguard, Resources, Research for manned mission, etc.

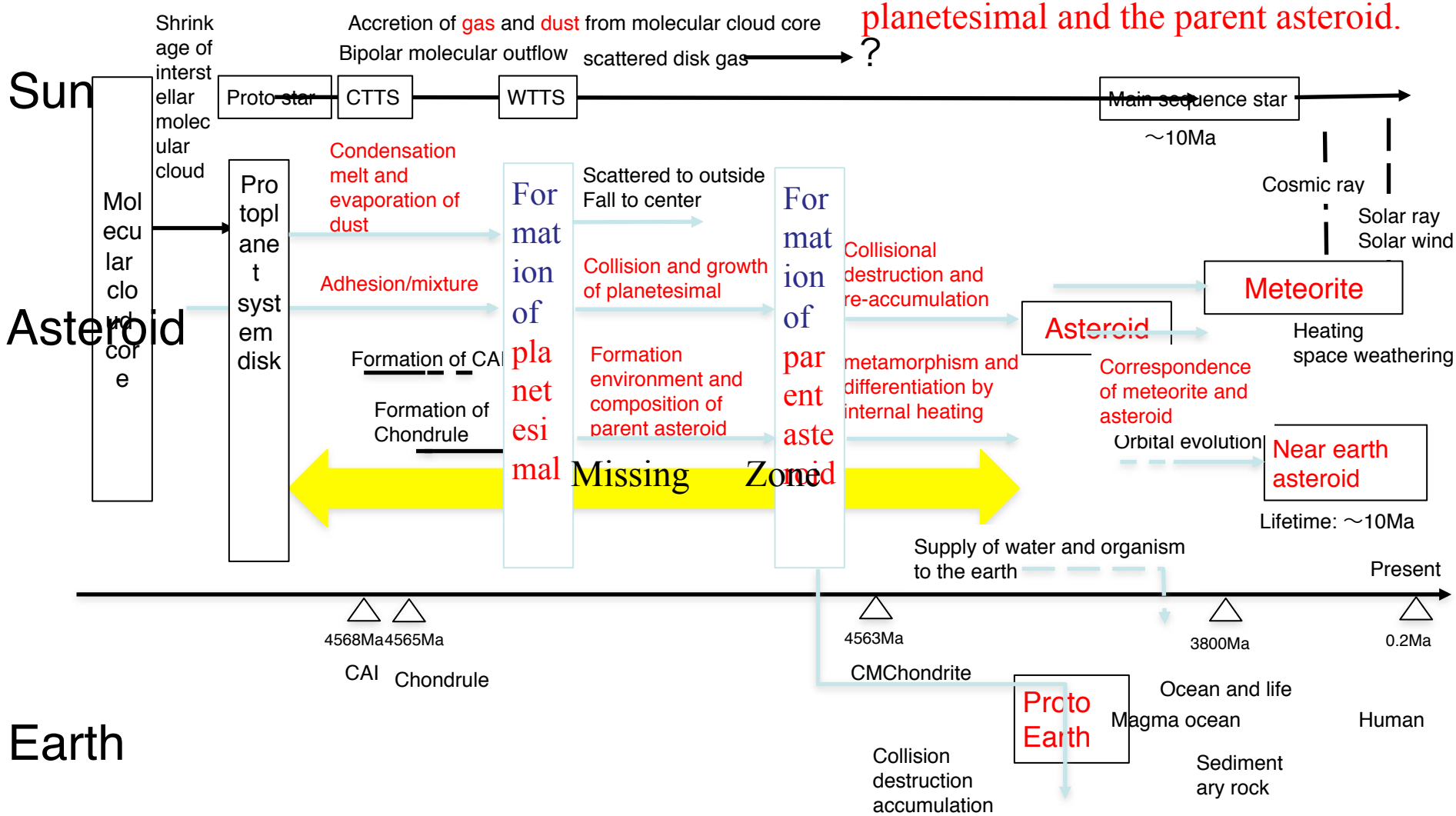
Study of the origin of the solar system

4.6 billion years ago...



History of Sun/Asteroid/Earth

Resolve the event in an early solar system caved for the asteroid. Clarify the appearance of the planetesimal and the parent asteroid.



Hayabusa2 Mission Outline

Launch

Dec 2014

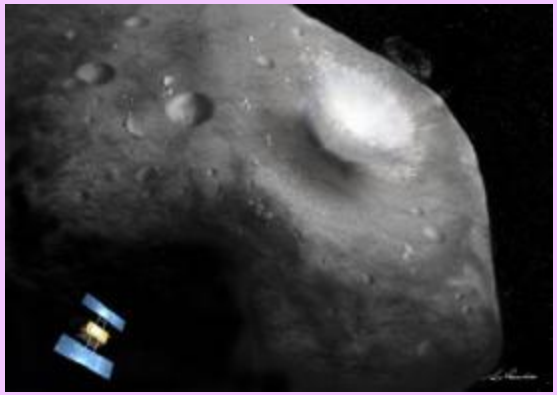
June 2018 : Arrival at 1999 JU3

The spacecraft observes the asteroid, deploys the small rovers and the lander, and executes multiple samplings.

The spacecraft carries an impactor.

2019

New Experiment



The impactor collides to the surface of the asteroid.

The sample will be obtained from the newly created crater.

Dec. 2019 : Departure

Earth Return

Dec. 2020

Sample analysis

Hayabusa2 Mission CG

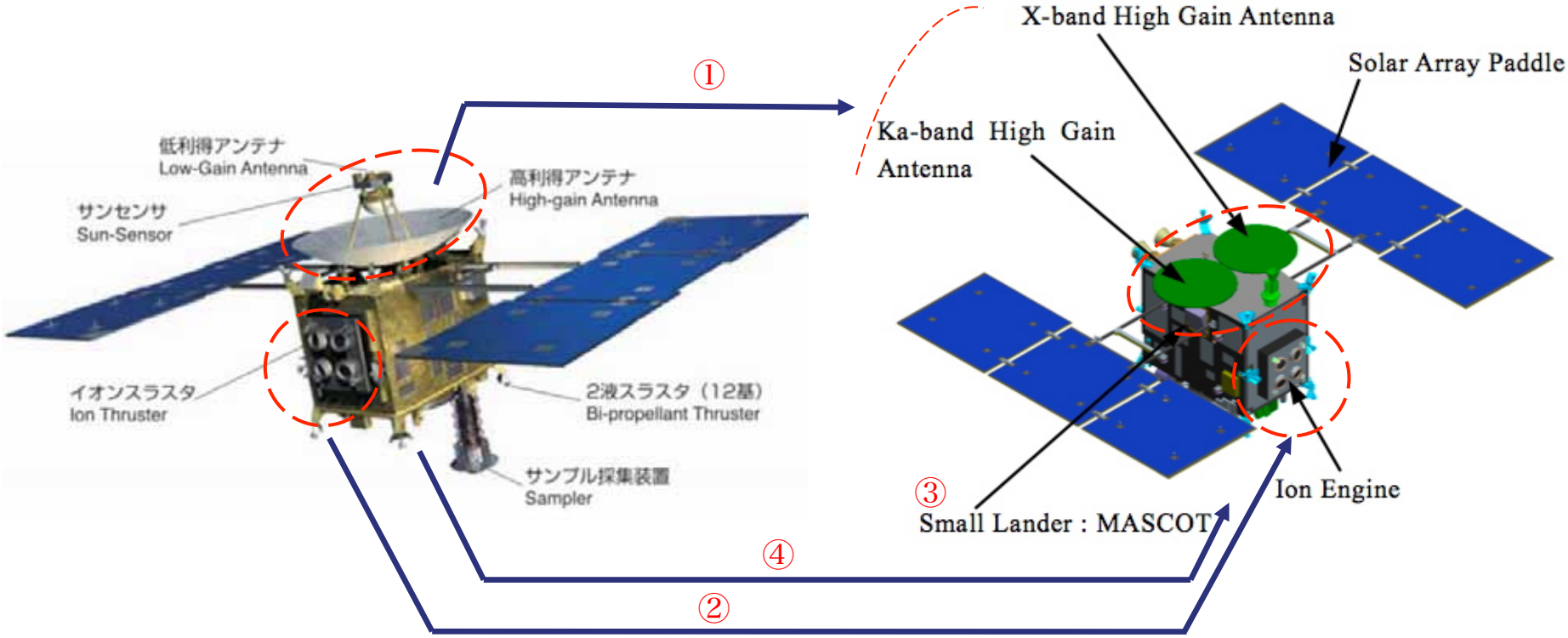
Hayabusa vs Hayabusa2 (1)

Hayabusa

Size ： 1m×1.6m×1.1m（body）
Mass： 510kg（Wet）

Hayabusa2

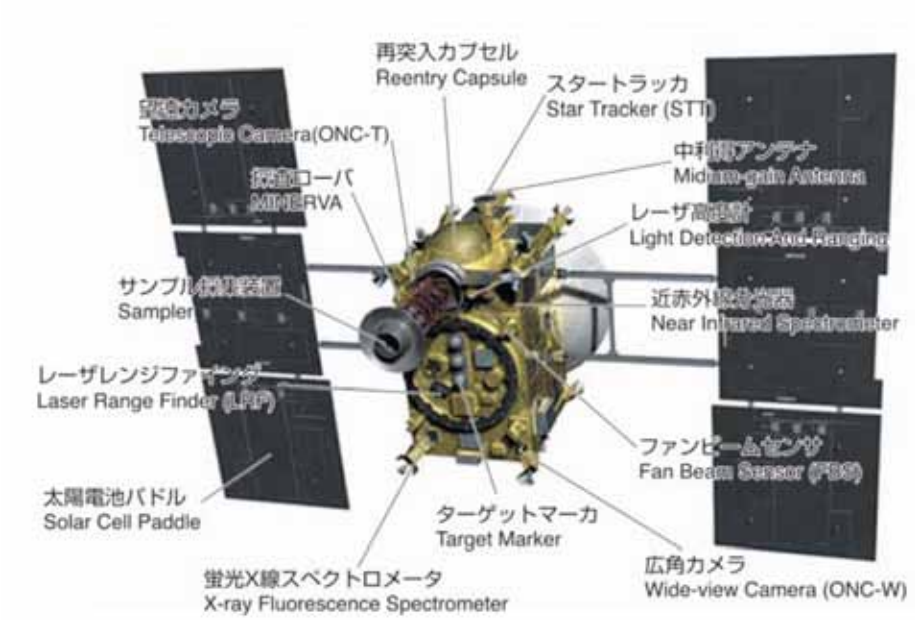
Size ： 1m×1.6m×1.25m（body）
Mass： 600kg（Wet）



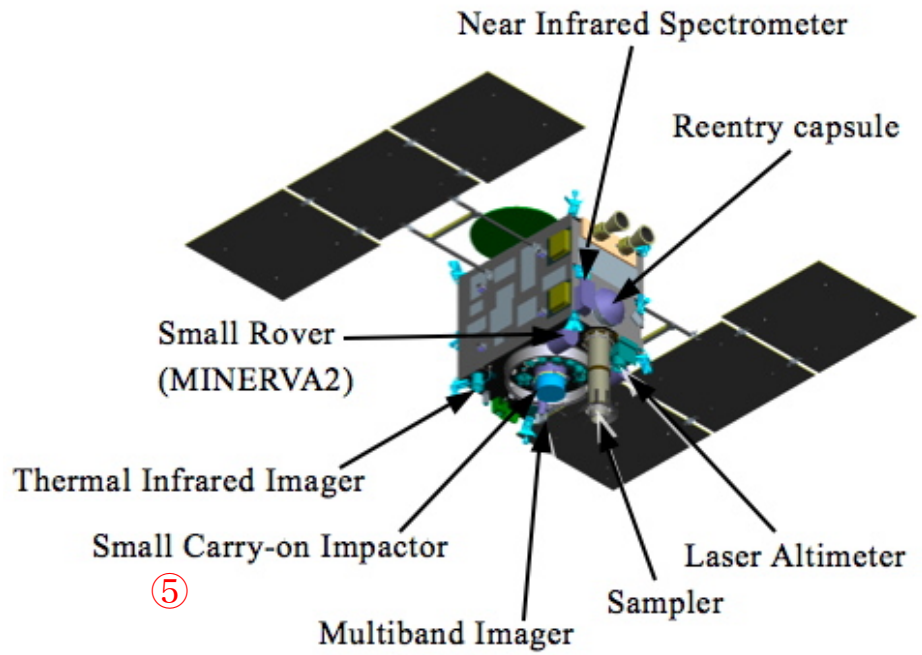
① Communication : X-band + Ka-band
② Ion engine : modified
③ Small lander : MASCOT(Mobile Asteroid Surface Scout） from DLR
④ AOCS : 4 reaction wheels

Hayabusa vs Hayabusa2 (2)

Hayabusa



Hayabusa2

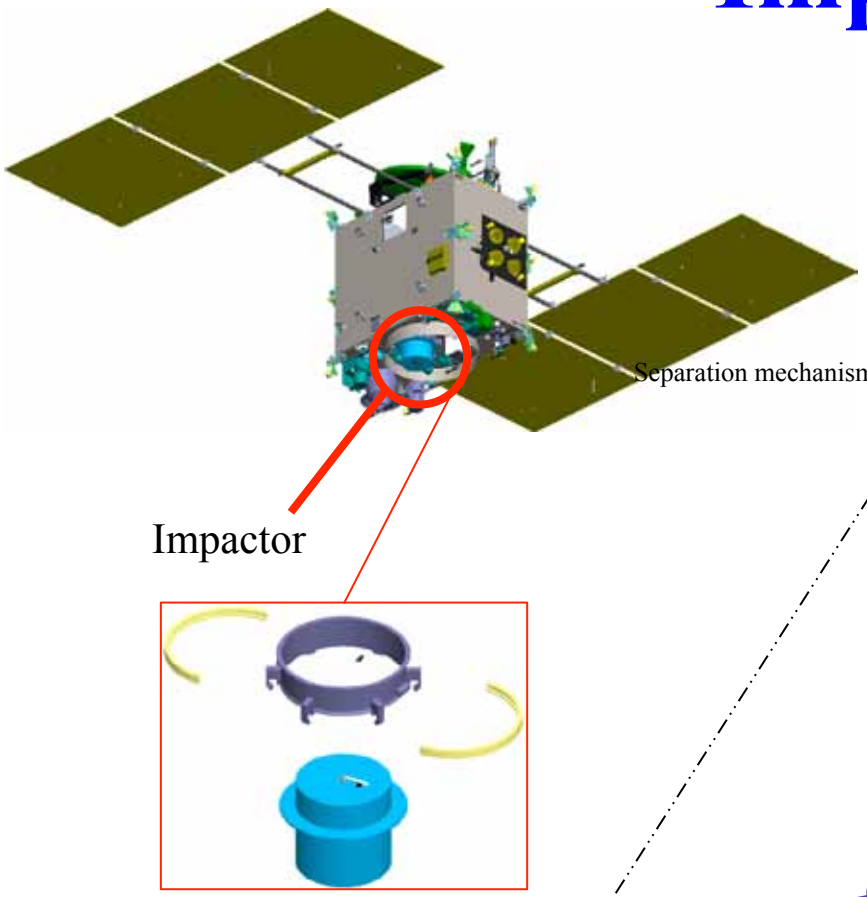


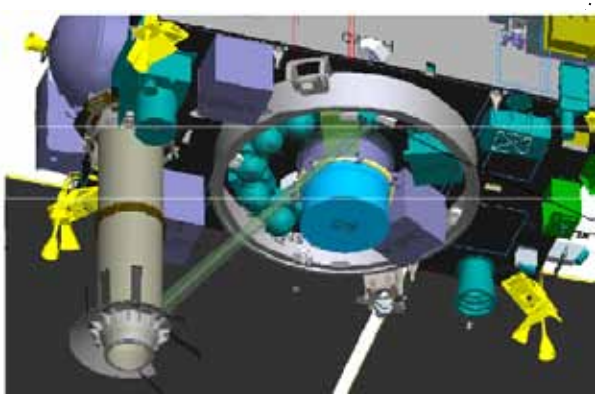
⑤ Small Carry-on Impactor

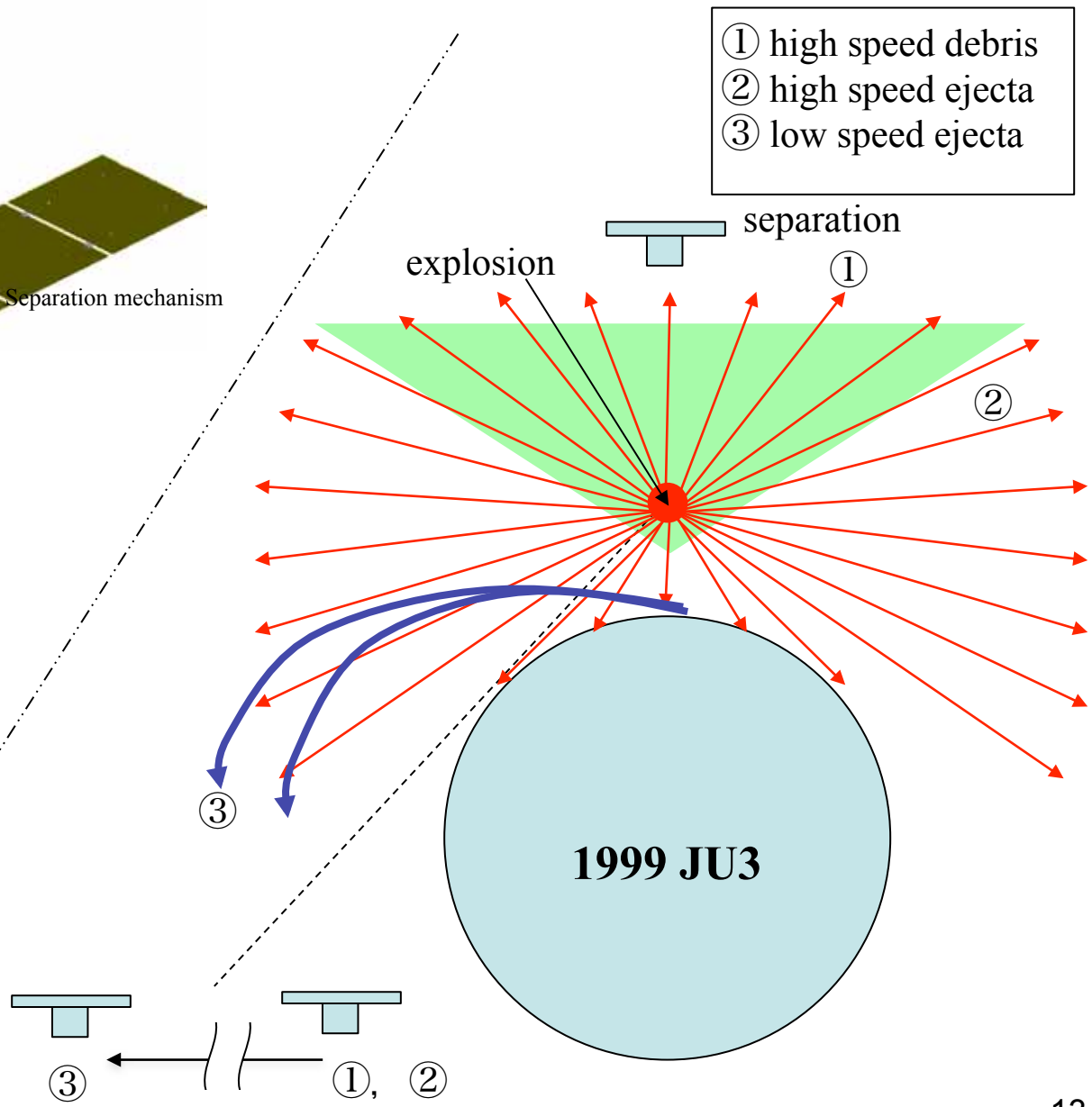
Technology Enhancement

Technology Element	Achieved in Hayabusa-1	achieved in Hayabusa-2
Ion Engine	△（3 out of 4 reached End Of Life)	・ プラズマ対策／小惑星粒子付着防止対策（MLI接地） ・ 推力UP（８mN→１０mN）
姿勢制御用化学スラスタ（RCS)	△（着陸後燃料漏れ）	・ 燃料/酸化剤の押しガス系統を１→２系統化 ・ ヒータ主従系を完全独立冗長化
姿勢制御用リアクションホイール（RW）	△（３台中２台が故障）	・ ３台→４台
レーザー高度計（LIDAR)	△（測定精度の問題で実運用では使用せず。）	・ 受光系１→２式（長距離受光系＋短距離受光系） ・ 測距モードに加え、ダストカウントモード、光通信モードの追加
姿勢制御用コンピュータ	○(達成）	・ 処理速度の高速化（20MHz→　50MHz） ・ 処理系統１→２（待機冗長）
通信	○(達成）	・ Xバンドに加え、Kaバンド送信機を追加（８Mbps→　３２Mbps） ・ アンテナの軽量化
回収カプセル（シールコンテナ）	○（達成）	Oリング→メタルシールにより、地球帰還時の地球物資によるコンタミ（汚染）対策を実施

Impactor


Separation mechanism
Impactor

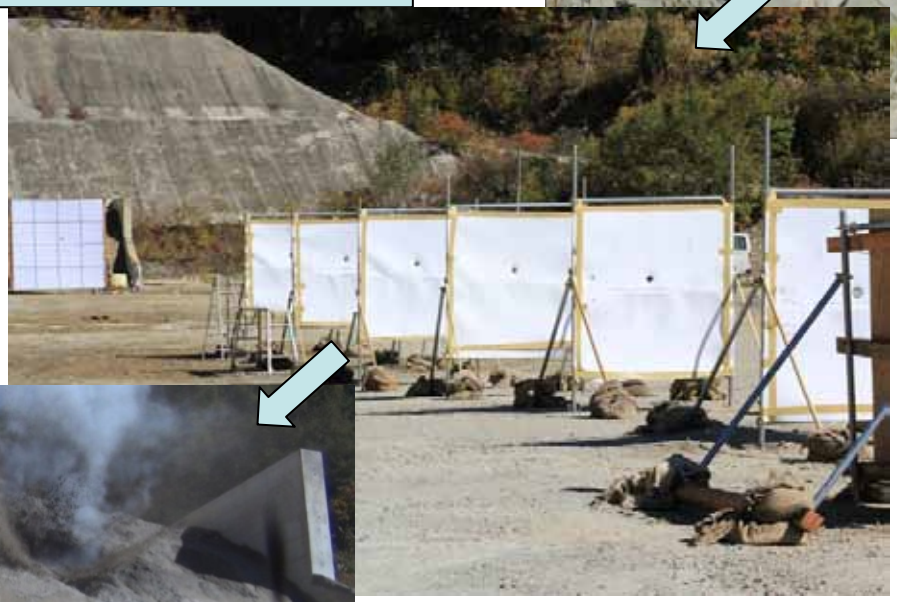



① high speed debris
② high speed ejecta
③ low speed ejecta
separation
explosion
①
②
③
1999 JU3
③
①, ②

Impactor experiment

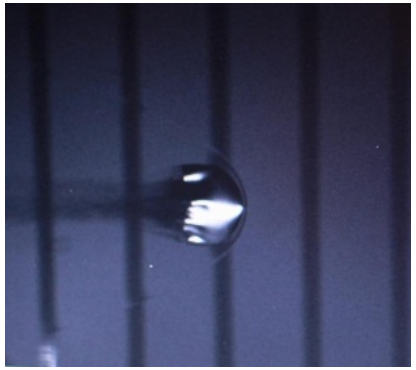
half size case

explosion



trajectory

impact!

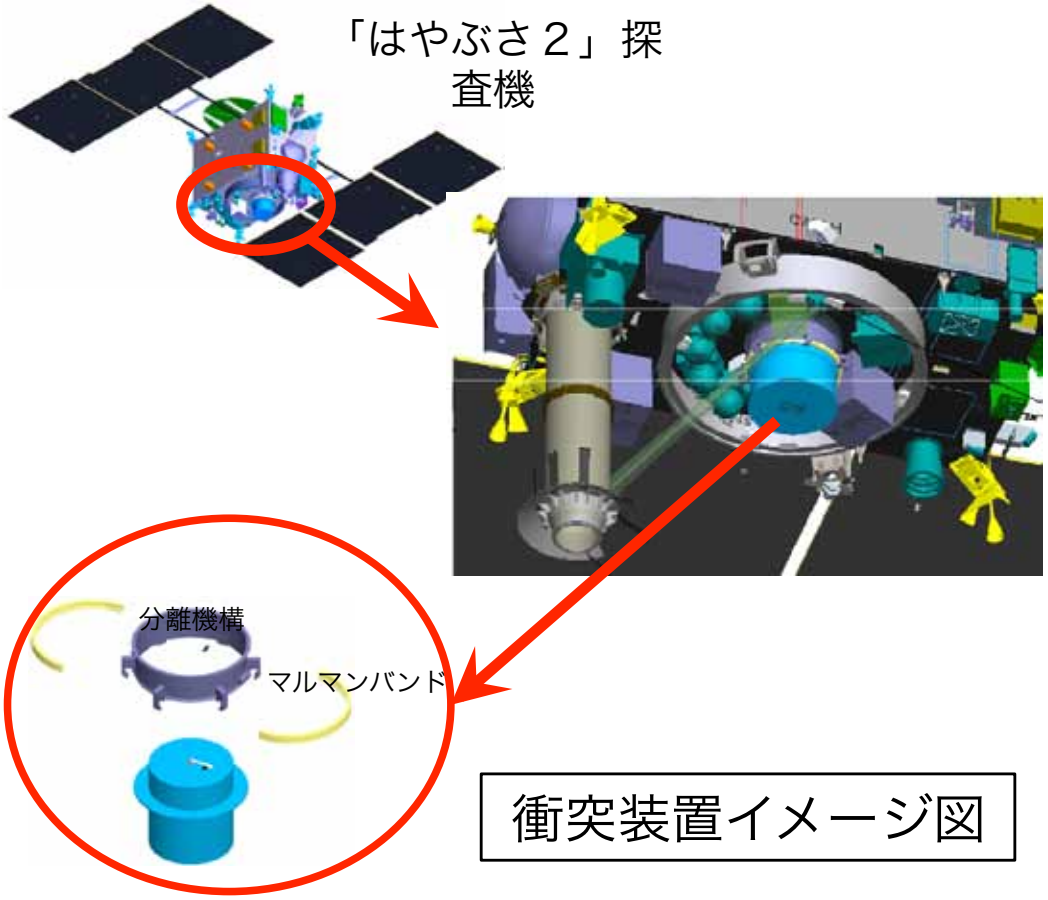


「はやぶさ２」の技術的意義

（２）新しい小惑星探査技術への挑戦

◆　小惑星衝突掘削(インパクター）技術(世界初)

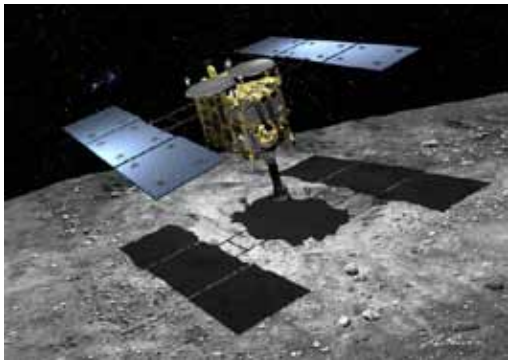
衝突体を小天体に衝突させ、人工的なクレーターを作る。表層下を露出させることで、小惑星内部についての知見を得たり、変成度の少ないと考えられる地下物質を採取する。このようなやり方の探査は世界初である



衝突装置イメージ図

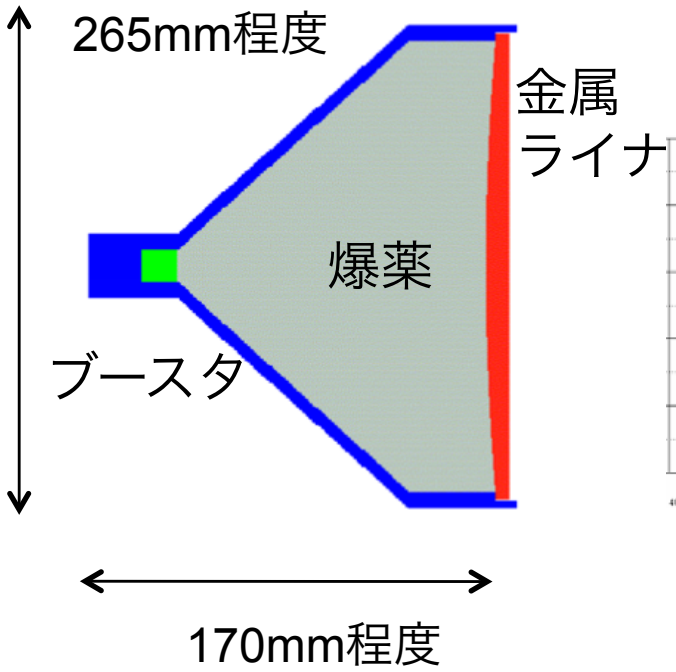
衝突装置を分離し、探査機が退避後に発射、衝突する。

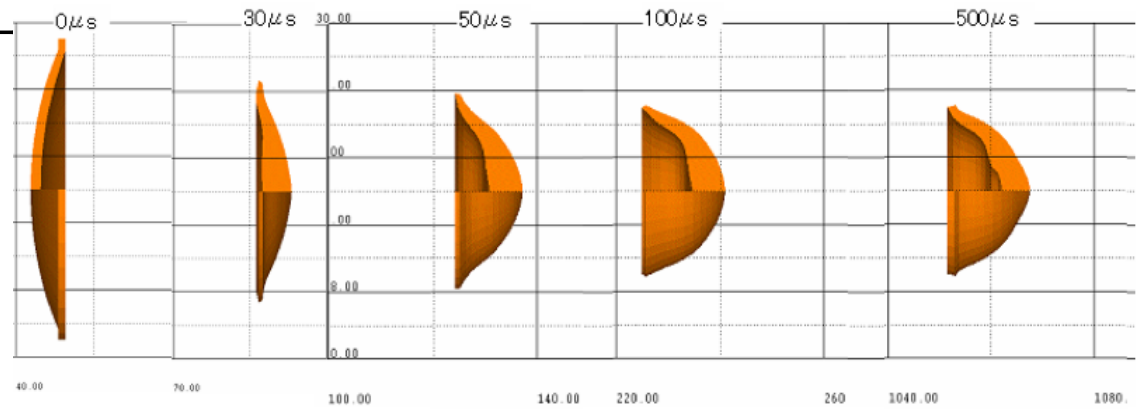
内部構造、地下物質の観測を行い、露出した地下物質を採取する。



小惑星衝突掘削(インパクター）技術
（参考１）　金属体の超高速射出

- 金属体（銅）の超高速衝突によってクレーターを作る。
- 金属体を瞬時に加速するために、高性能爆薬を使用する方法を採用。
  - 爆薬、金属ライナ、ケースから構成される爆薬部を搭載。
  - ライナは爆薬の爆轟により弾丸形状へと変形し飛翔。
  - ライナが変形し加速するまで1ms。ライナの速度は2km/s。
  - 爆薬質量は5kg程度。

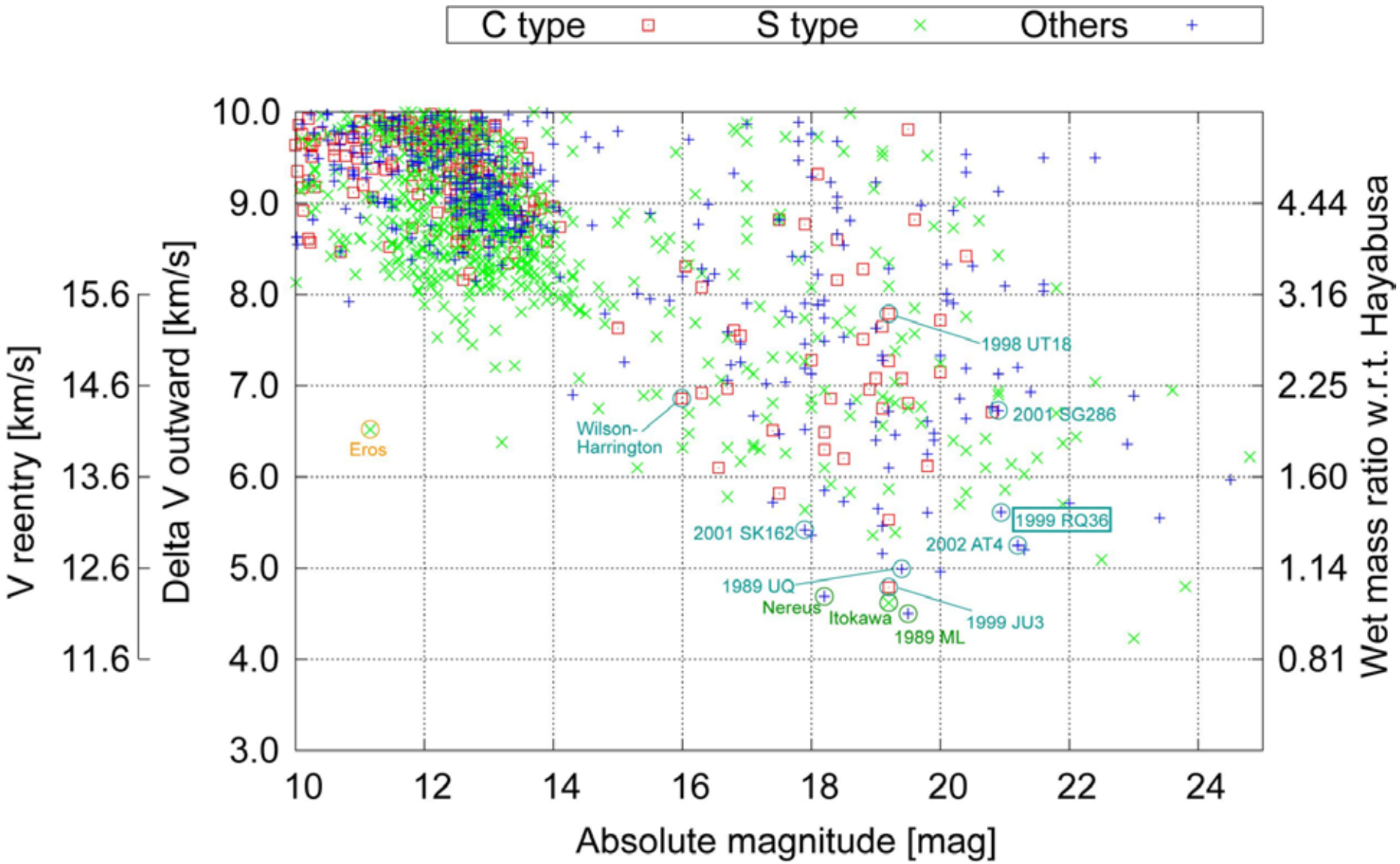


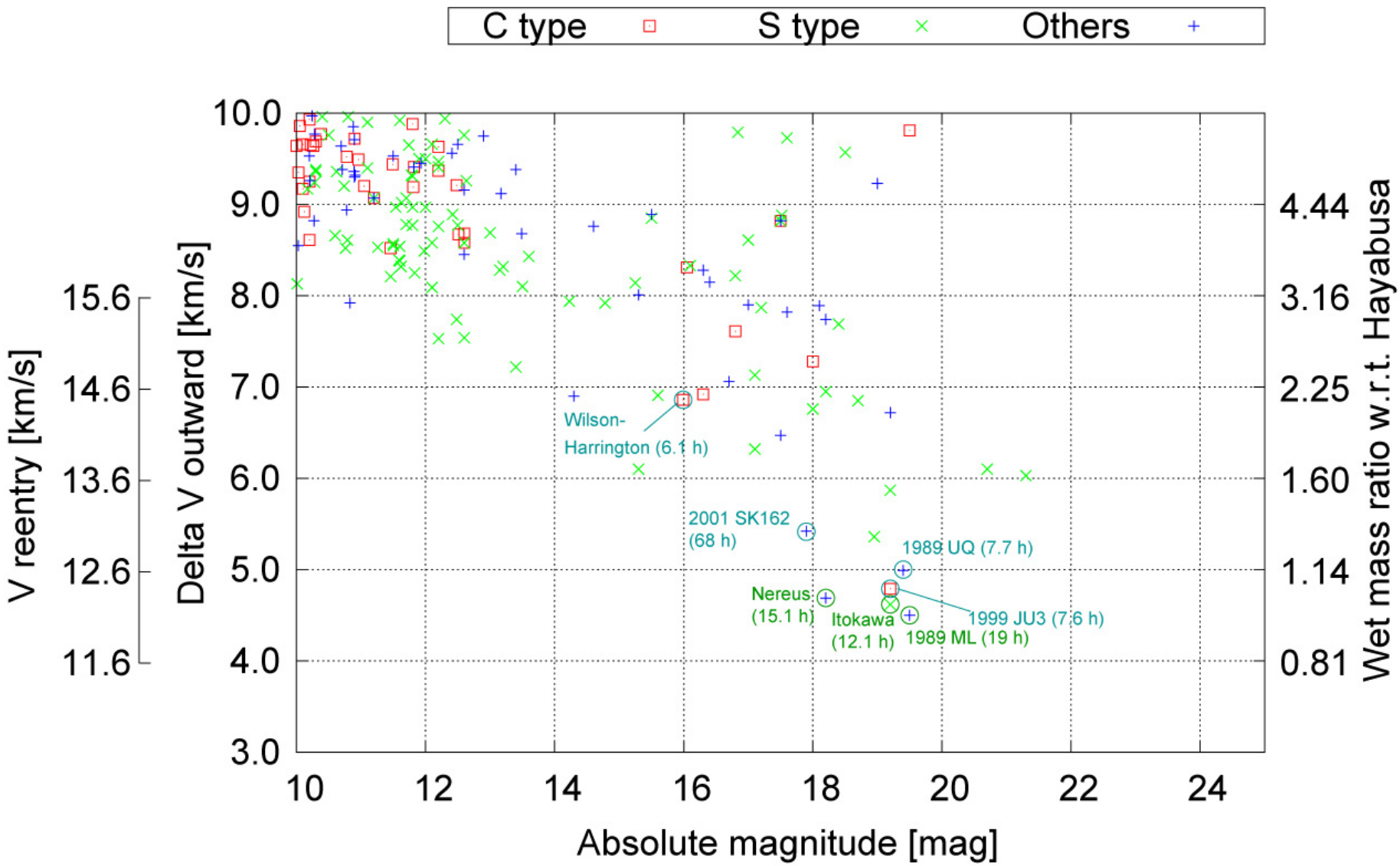


金属ライナが変形しながら飛翔する

Hayabusa2 : Nominal Payloads for Science

Payloads	Specifications	Comments
Multiband Imager (ONC-T)	Wavelength: 0.4 – 1.0 μm, FOV: 5.7 deg x 5.7 deg, Pixel Number: 1024 x 1024 px filter (ul, b, v, w, x, p, Wide)	Heritage of Hayabusa (modified)
Near IR Spectrometer (NIRS3)	Wavelength: 1.8 – 3.2 μm, FOV: 0.1 deg x 0.1 deg	Heritage of Hayabusa, but but 3μm range is new
Thermal IR Imager (TIR)	Wavelength: 8 – 12 μm, FOV: 12 deg x 16 deg, Pixel Number: 320 x 240 px	Heritage of Akatsuki
Laser Altimeter (LIDAR)	Measurement Range: 50 m – 50 km	Heritage of Hayabusa (modified)
Sampler	Minor modifications from Hayabusa-1	Heritage of Hayabusa (modified)
Small Carry-on Impactor (SCI)	Small system released form the spacecraft to form an artificial crater on the surface	New
Separation Camera (DCAM)	Small, detached camera to watch operation of Small Carry-on Impactor	Heritage of Ikaros (modified)
Small Rover (MINERVA II-1, II-2)	Similar to MINERVA of Hayabusa-1 (possible payload: Cameras, thermometers)	Heritage of Hayabusa (largely modified)
Small Rover (MASCOT)	Supplied from DLR & CNES MicrOmega, MAG, CAM, MARA	New


C type
S type
Others
V reentry [km/s]
Delta V outward [km/s]
Wet mass ratio w.r.t. Hayabusa
Absolute magnitude [mag]
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
15.6
14.6
13.6
12.6
11.6
4.44
3.16
2.25
1.60
1.14
0.81
10
12
14
16
18
20
22
24
Eros
Wilson-Harrington
1998 UT18
2001 SG286
1999 RQ36
2001 SK162
2002 AT4
1989 UQ
Nereus
Itokawa
1989 ML
1999 JU3


C type
S type
Others
V reentry [km/s]
Delta V outward [km/s]
Wet mass ratio w.r.t. Hayabusa
Absolute magnitude [mag]
15.6
14.6
13.6
12.6
11.6
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
4.44
3.16
2.25
1.60
1.14
0.81
10
12
14
16
18
20
22
24
Wilson-
Harrington (6.1 h)
2001 SK162
(68 h)
1989 UQ (7.7 h)
Nereus
(15.1 h)
Itokawa
(12.1 h)
1999 JU3 (7.6 h)
1989 ML (19 h)

Target Asteroid : 1999 JU3

Rotation period: 0.3178day (~7.6 h)

$(\lambda, \beta) = (331, 20), (73, -62)$

Kawakami Model Mueller Model

Axis ratio = 1.3 : 1.1 : 1.0

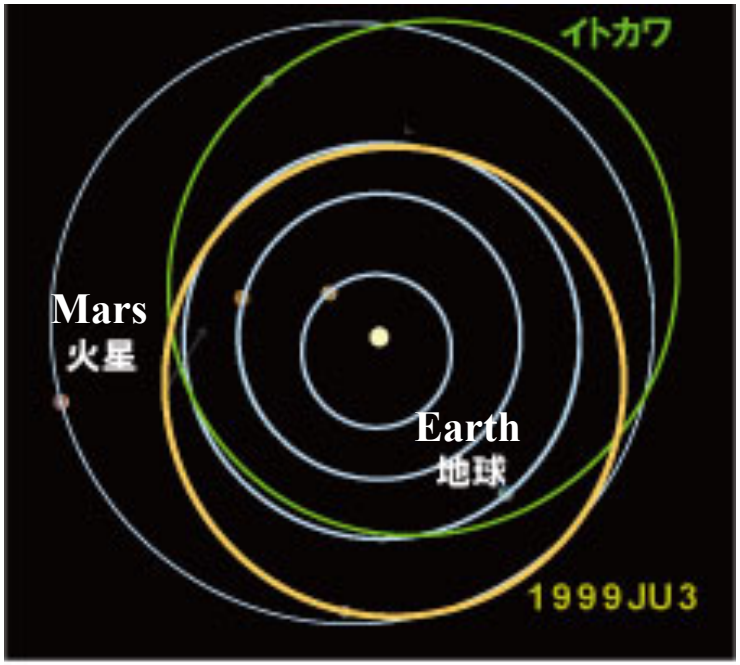
Size : 0.87 ± 0.03 km

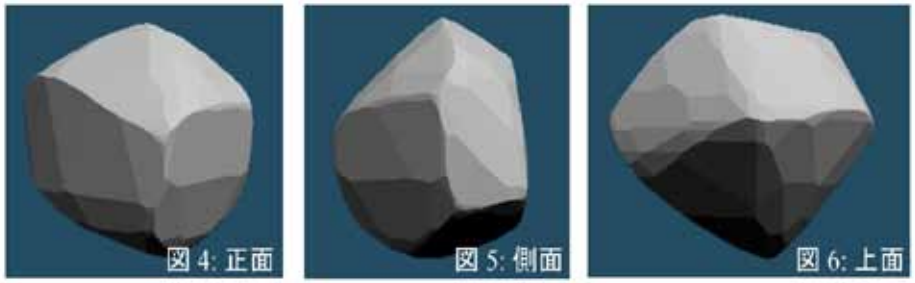
Albedo : 0.070 ± 0.006

H=18.82 ± 0.021, G=-0.110 ± 0.007

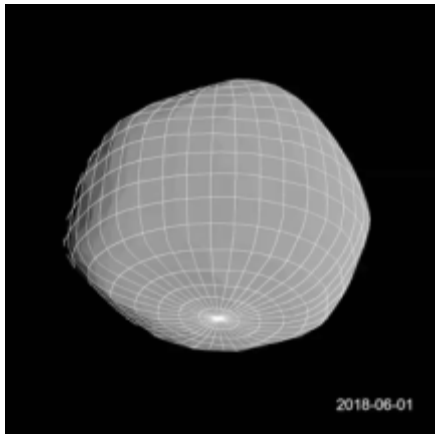
Type : Cg

Orbit





Shape model by Kawakami



(by Mueller et. al)

Target : Hayabusa vs Hayabusa2

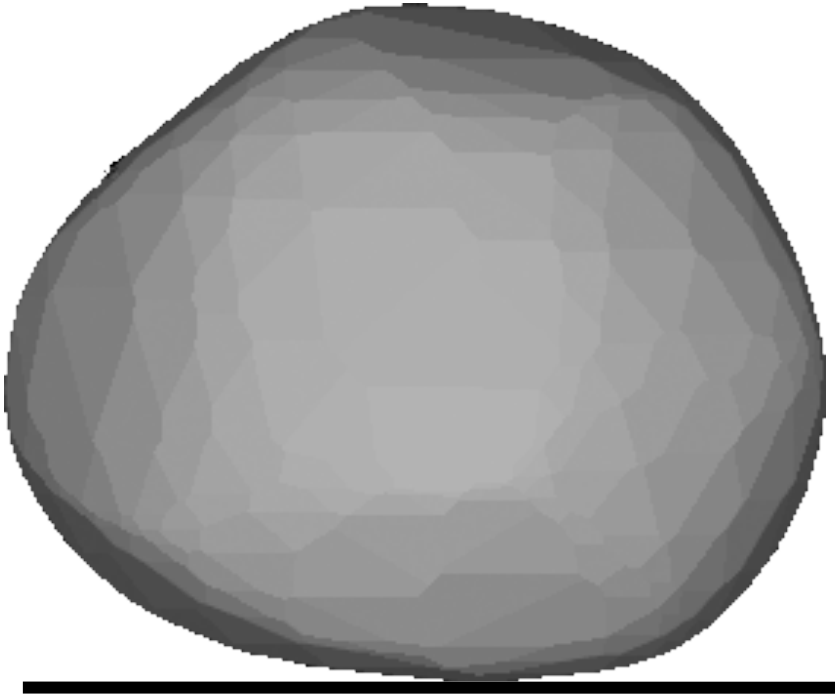
	(25143) Itokawa (1998 SF36)	**(162173) 1999 JU3**
Type	S	Cg
Spin period	0.5055 day (~12.13 h)	0.3178 day (~7.6 h)
Spin axis orientation (deg)	(128.5, -89.6)	(331, 20), Kawakami Model (73, -62) Mueller Model
Size	535 × 294 × 209 (m)	0.87 ± 0.03 km 1.3 : 1.1 : 1.0
Albedo	0.25 ± 0.03	0.063 ± 0.006
H : absolute magnitude (mag)	19.2	18.82
Mass (kg)	3.510×10^{10}	? (4.8×10^{11})
GM (km^3/s^2)	2.34×10^{-9}	? (32×10^{-9})
Density (g/cm^3)	1.90 ± 0.13	? (1.4)
q : perihelion dist. (AU)	0.9529	0.9633
Q : aphelion dist. (AU)	1.6952	1.4159
i : inclination (deg)	1.6219	5.8838
a : semimajor axis (AU)	1.3240	1.1896
T : orbital period (year)	1.52	1.30

Target : Hayabusa vs Hayabusa2

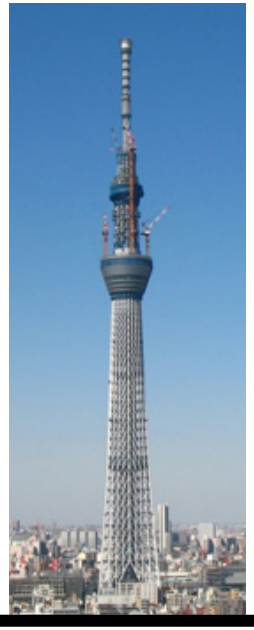
Shape and size

1999 JU3

~900m



634m

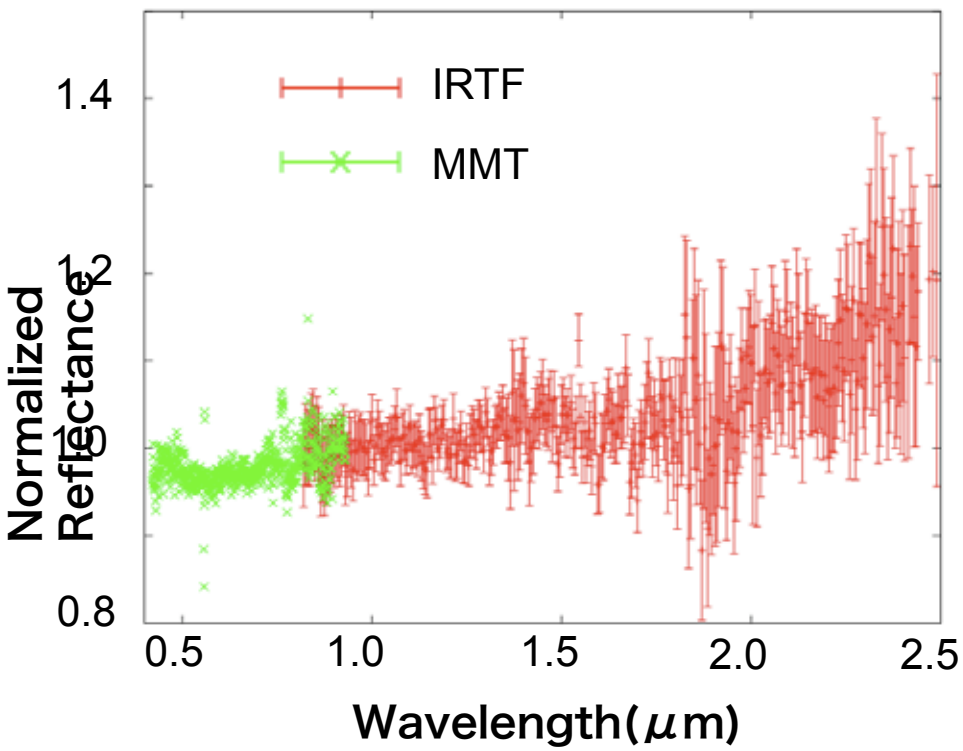


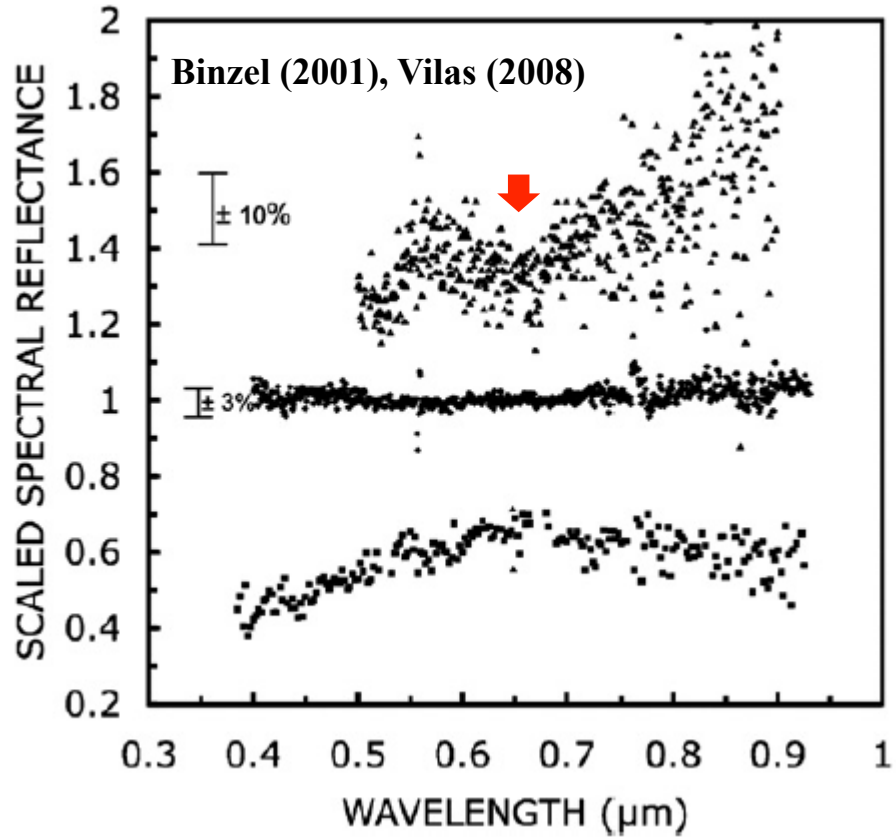
Itokawa

535m

333m

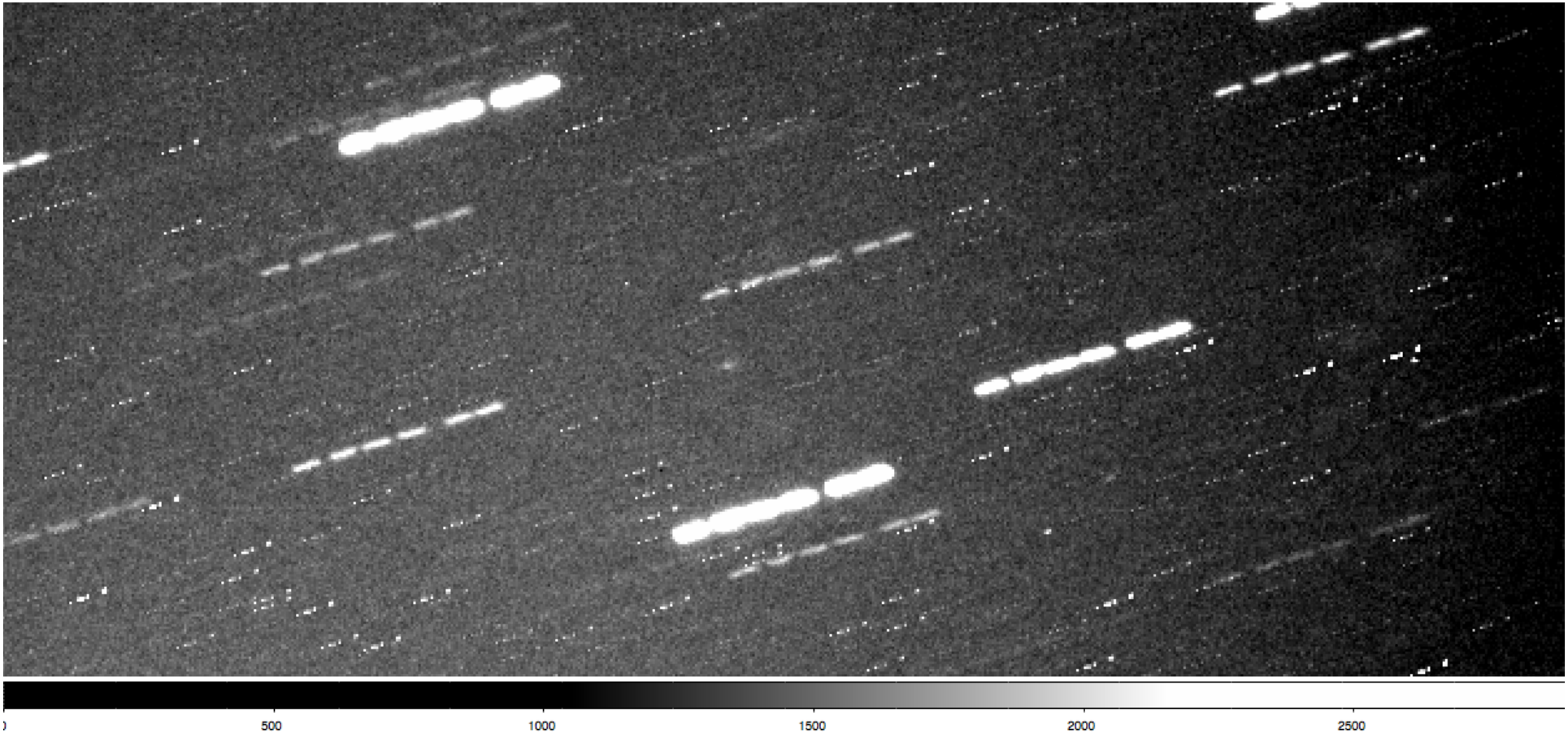
Spectrum of 1999 JU3





Ground observation has suggested existence of a 0.7-micrometer hydrated-mineral absorption band.

1999 JU3 in 2011



by **S. Abe** at Lulin Observatory in Taiwan.
Aug. 22, 2011
Mag. : 20

Observation periods:
2011: Aug/E – Oct/E
2012: Spring - Summer ➡ **new observations !**

International Cooperation on Hayabusa2

JAXA

USA

NASA

Europe

DLR
CNES

Australia

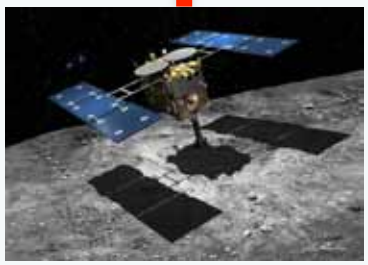
SLASO/DIISR
DoD/AOSG
AQIS/AC

Asteroid Sample Return Missions

2003 2014 2016 future

<JAXA>

Hayabusa
(Itokawa : S-type)



Hayabusa2
(1999 JU3 : C-type)

Hayabusa Mk2
= Post Hayabusa2
(D-type?)

<NASA>

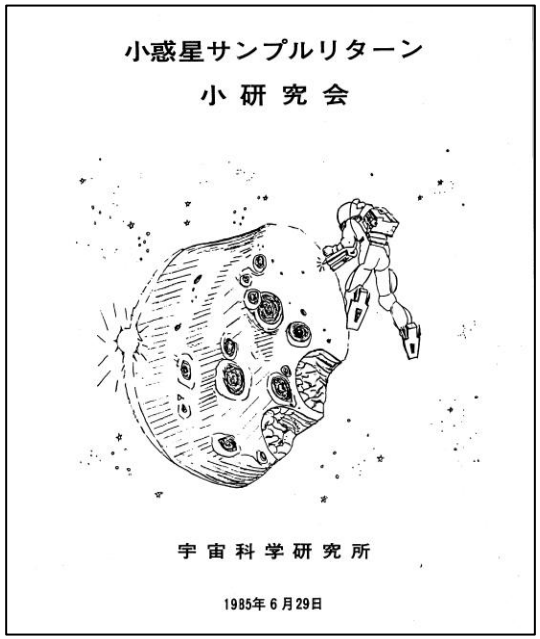
OSIRIS-REx
(1999 RQ36 : B-type)

<ESA>

MarcoPolo-R
(C-type, binary)

Summary

StartingP oint 1985



The cover of the proceedings of the meeting for asteroid sample return held in ISAS in 1985.

Hayabusa 2003-2010

Hayabusa2 2014-2020

Importance of Small Solar System Bodies

Science

To study the origin and evolution of the solar system and the life

Spaceguared

To protect the earth from the collision of the solar system small bides

Resource

To utilize the mineral, metal and water, etc.

Manned mission

To be the target of manned mission before manned mission to Mars

Engineering

To move in the interplanetary space freely

Culture

To create new culture and educate new generation