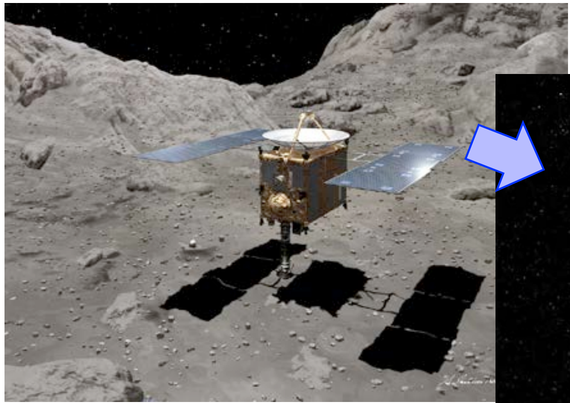
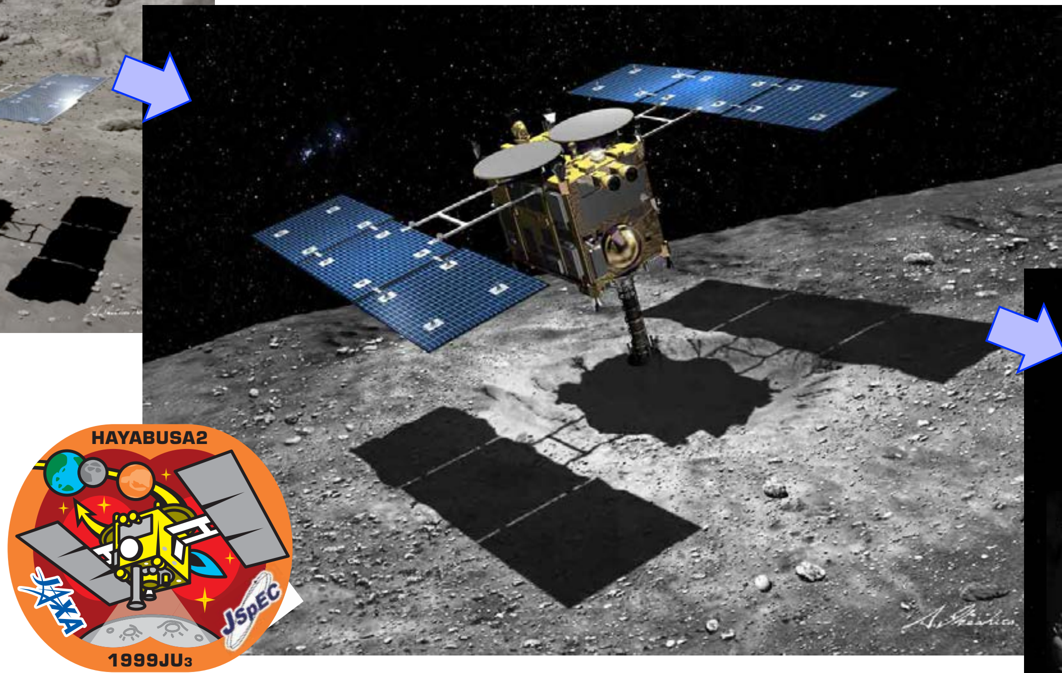
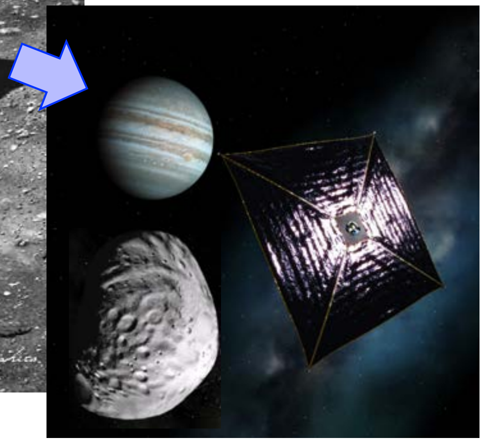
JAXA's Small Body Explorations

2nd Meeting of SMPAG







UN, Vienna, Austria

12 June 2014

Makoto Yoshikawa (JAXA)

Today's Talk

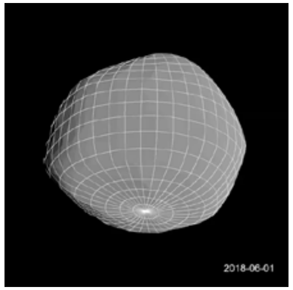
■ Hayabusa

Sample return from a small S-type NEO

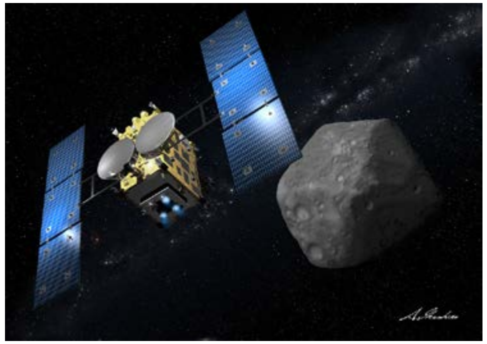
(25143) Itokawa

■ Hayabusa2

Sample return from a small C-type NEO



(162173) 1999 JU3

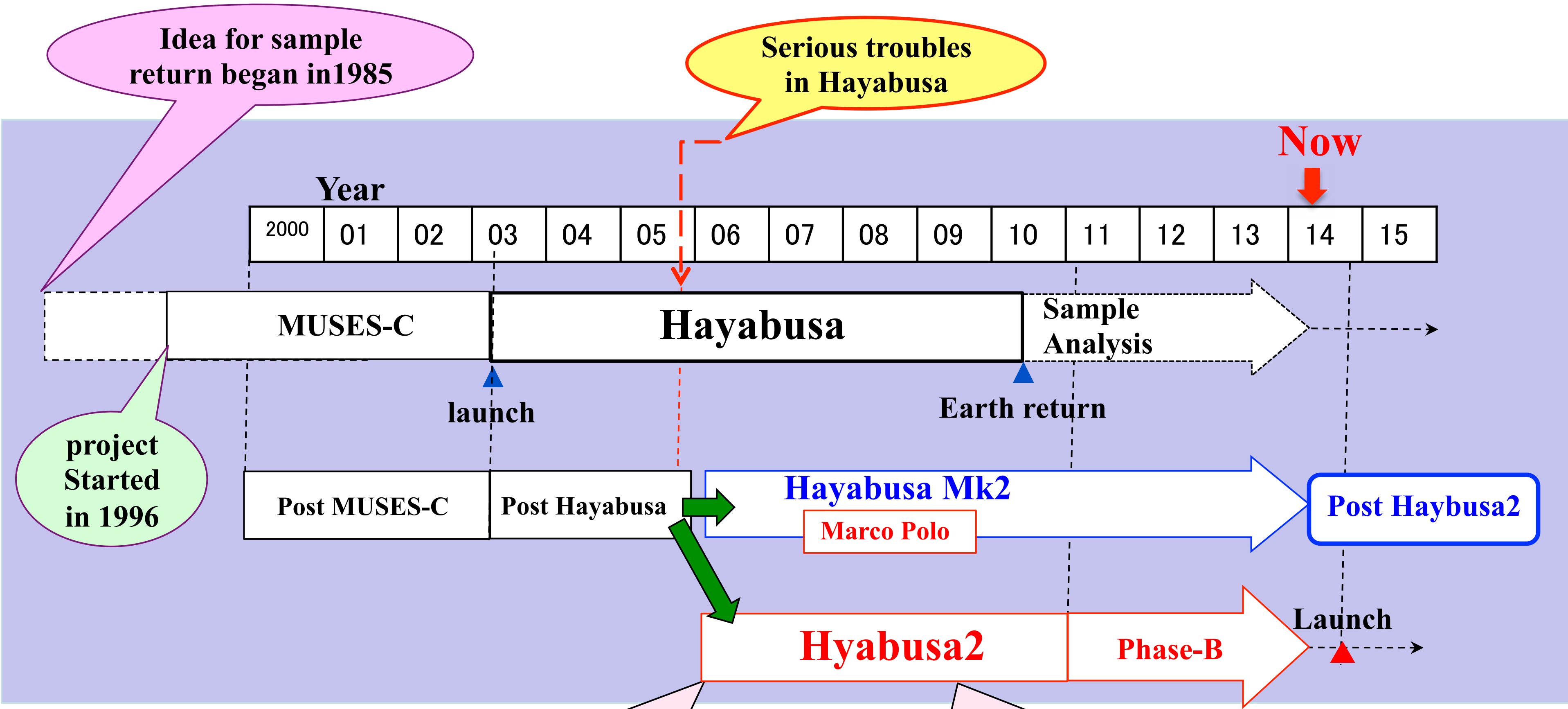


●Deflection

Basic studies for asteroid deflection

From the point of SMPAG activity

History of Hayabusa and Hayabusa2



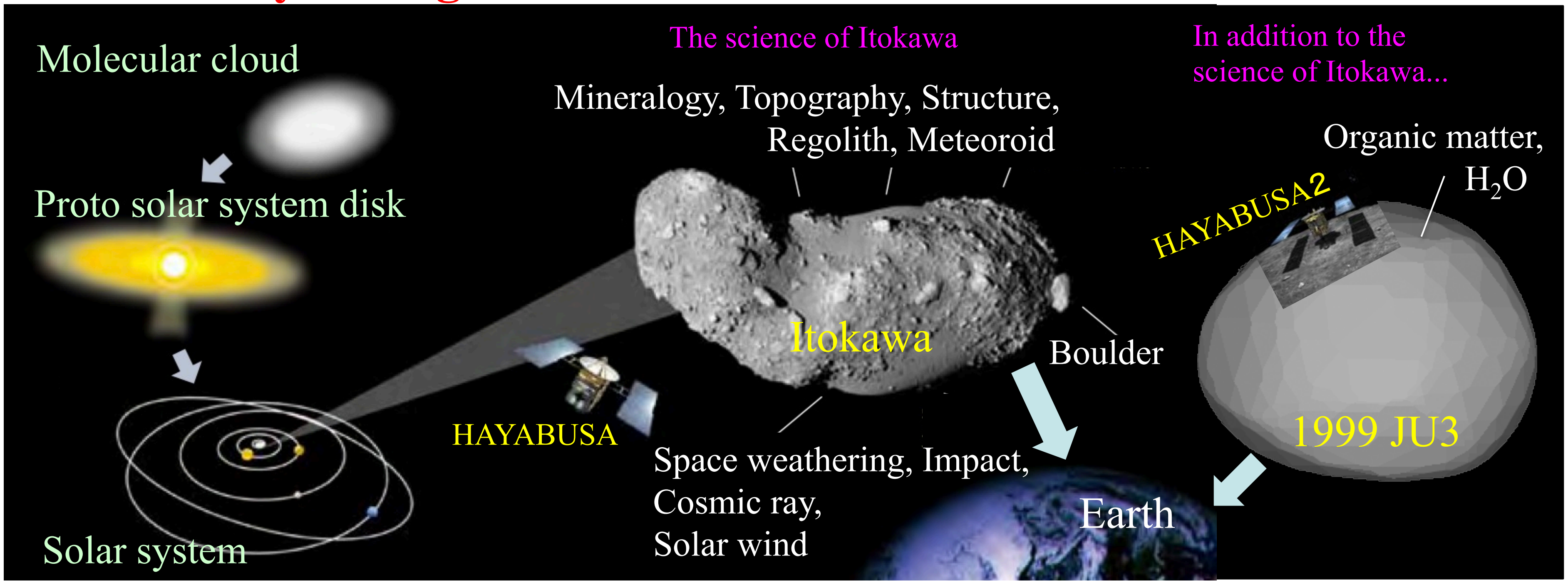
Initial proposal in 2006
Copy of Hayabusa but modified
Target : C-type asteroid 1999 JU3
Launch: 2010

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

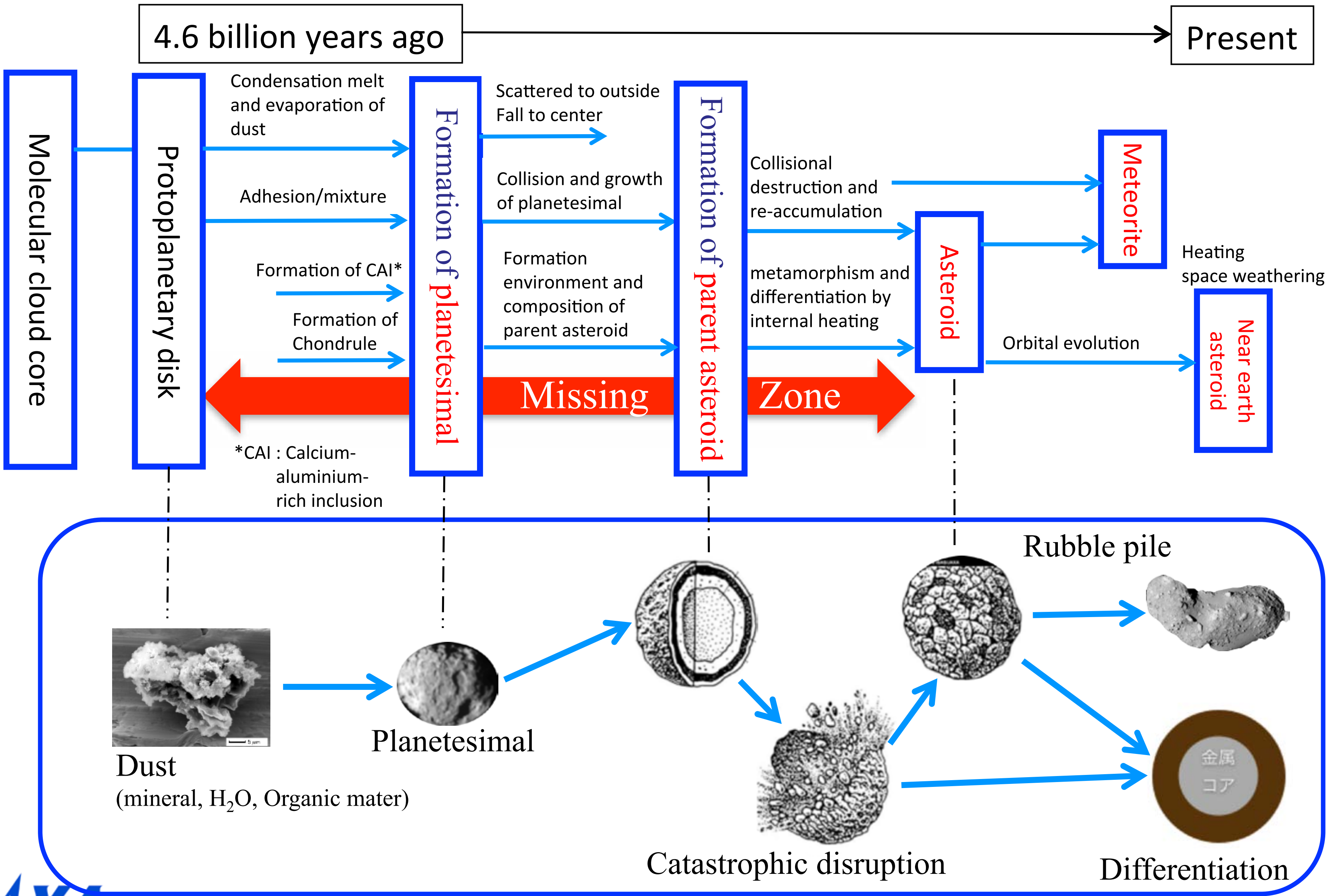
Science of Hayabusa and Hayabusa2

Study of the origin and evolution of the solar system

4.6 billion years ago...



Solve the "Missing Zone"



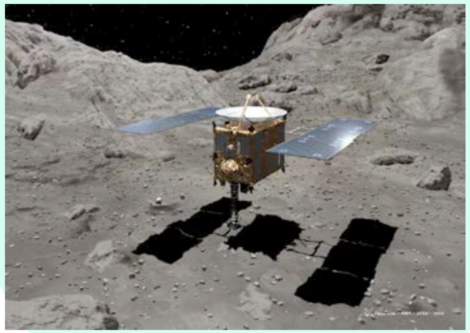
Hayabusa Mission Outline

Launch
9 May 2003

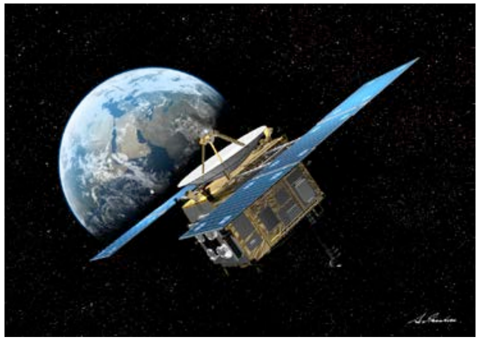
Earth Swingby
19 May 2004

Asteroid Arrival
12 Sept. 2005

Observations, sampling



Serious
troubles



Earth Return
13 June 2010

Hayabusa Mission CG

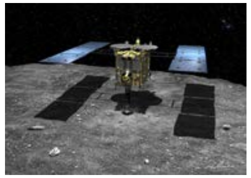
Hayabusa2 Mission Outline

Launch

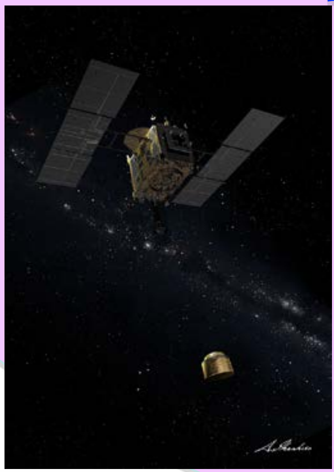
2014

June 2018 : Arrival at 1999 JU3

The spacecraft observes the asteroid, releases 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

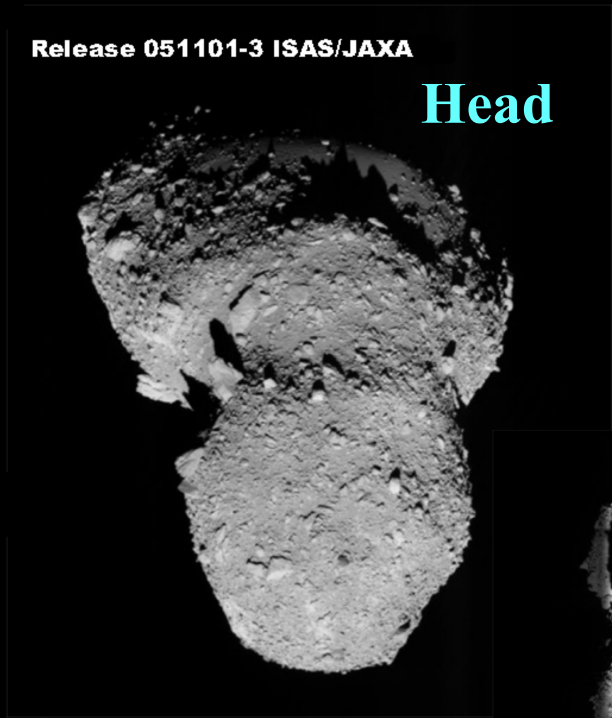
Sample analysis

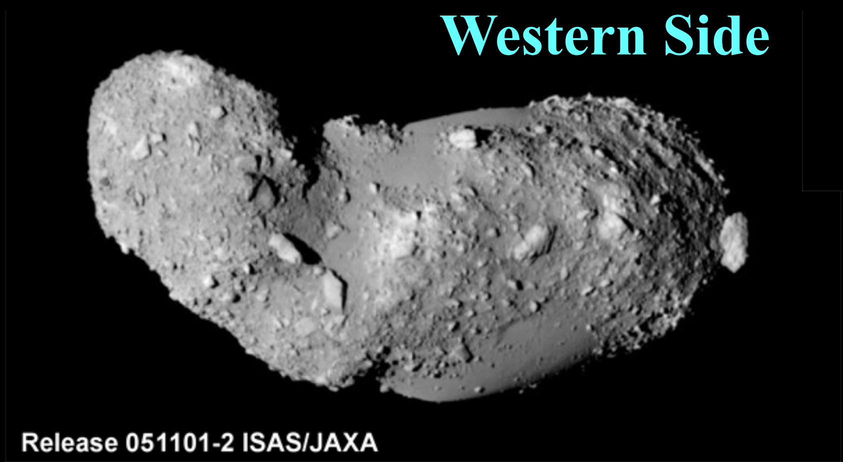
Hayabusa2 Mission CG

Important data for asteroid deflection

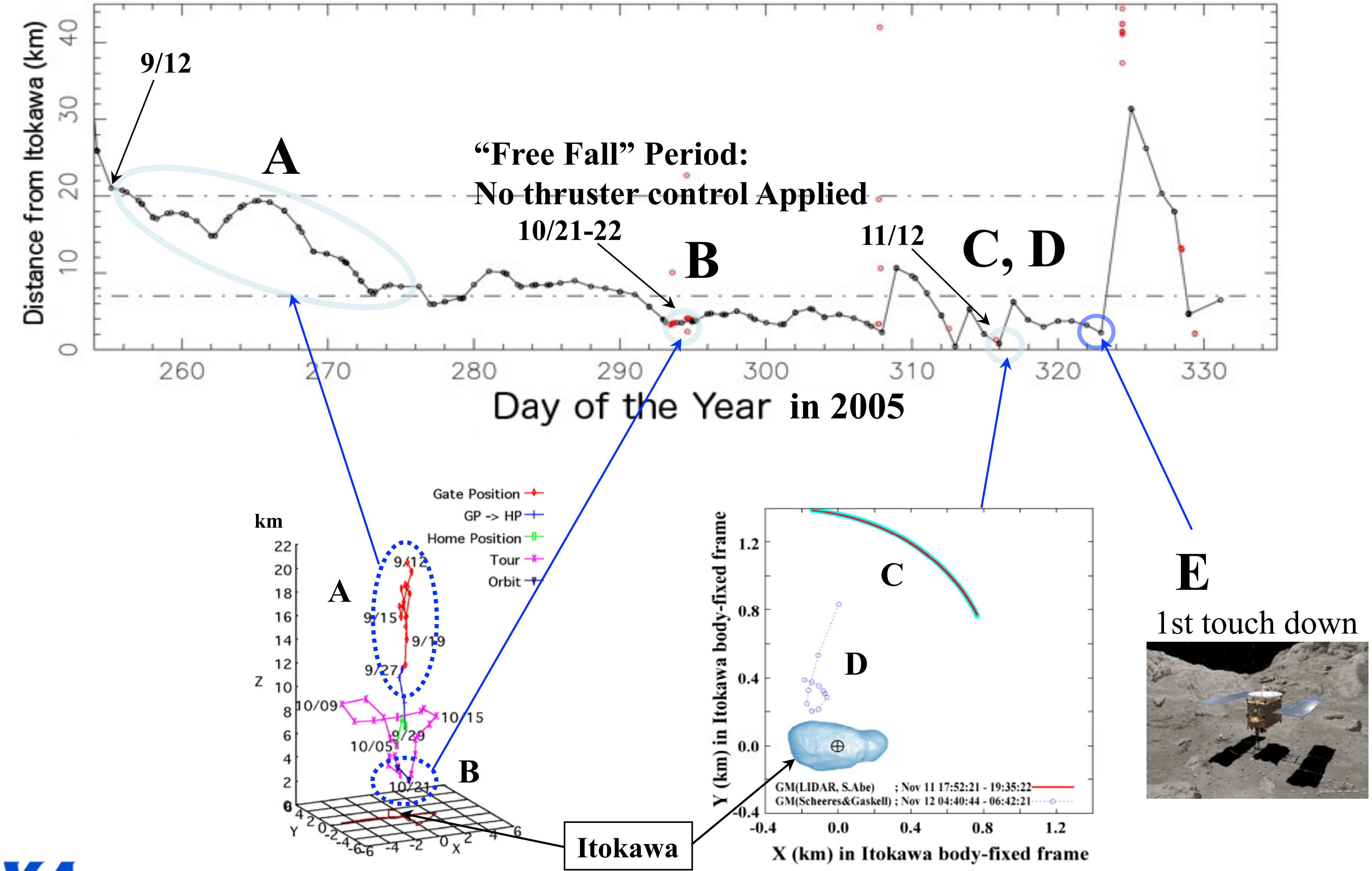
- Mass
- Shape, size, spin
- Density
- Albedo
- Material
- Structure
- etc.

Images of Itokawa



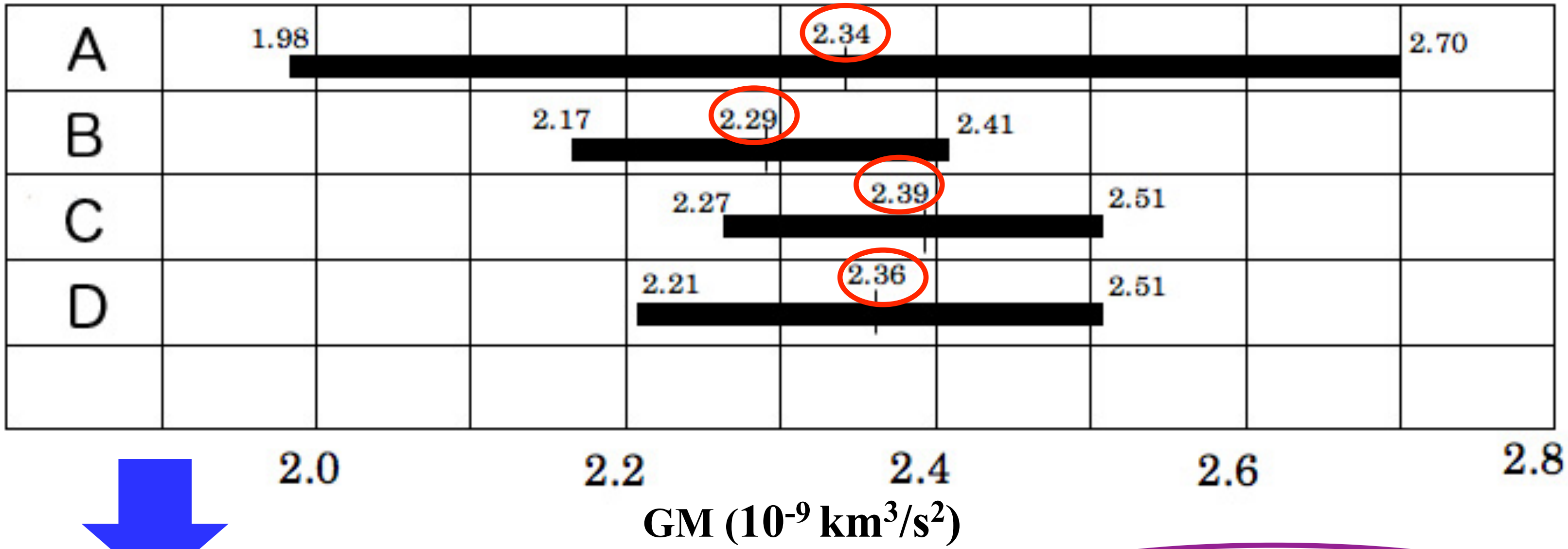


Mass Estimation



Mass and Bulk Density of Itokawa

Estimated GM in each period (GM=Gravity Constant x Mass)



GM : (2.34± 0.07) x 10^{-9} km^3/s^2

Mass : (3.51 ± 0.105) x 10^{10} kg

Volume = (1.84 ± 0.092) x 10^7 m^3

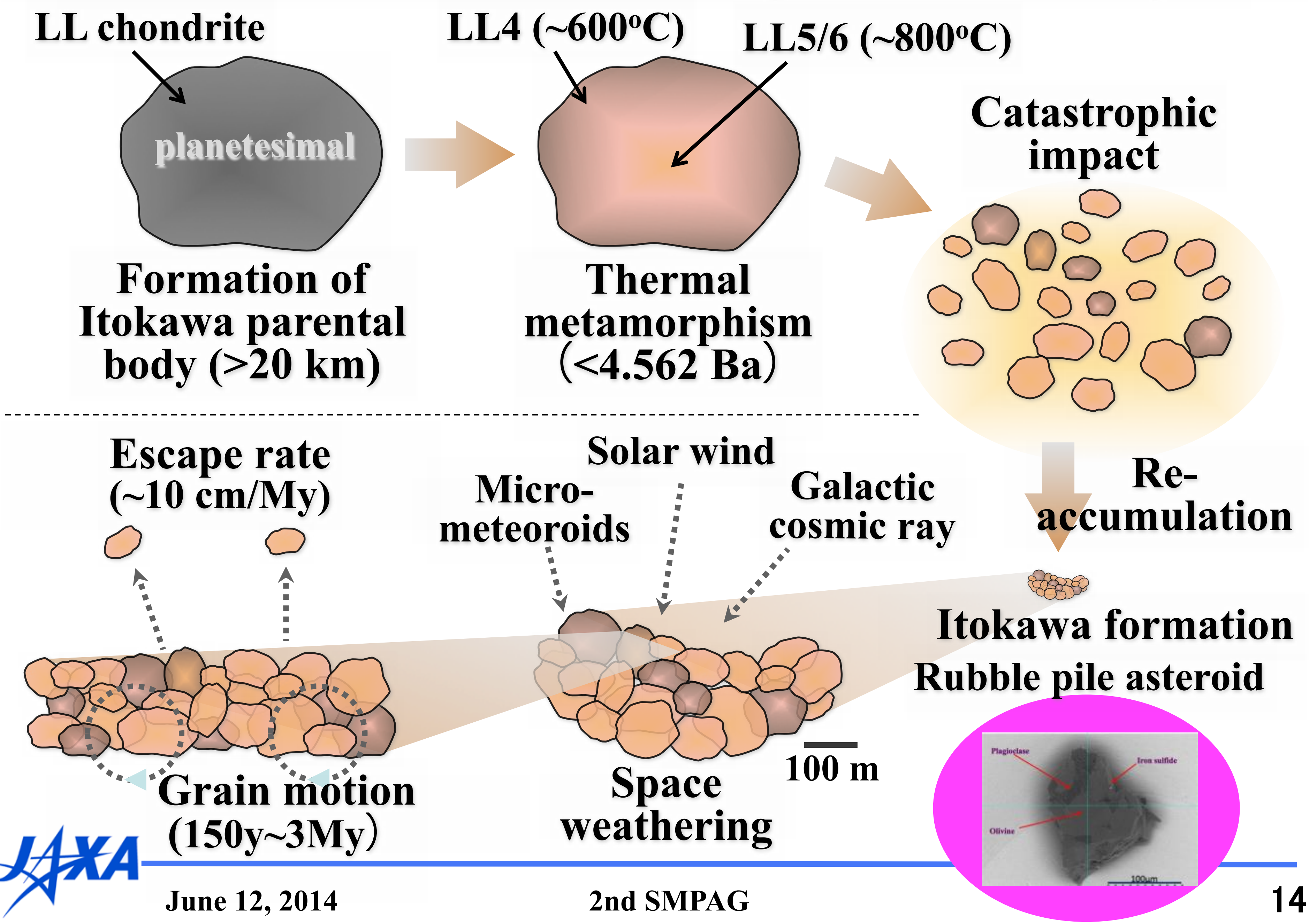
Bulk Density : 1.9 ± 0.13 g/cm^3

Macro-porosity = 40%

Ordinary chondrite

Density ~ 3.2 g/cm^3

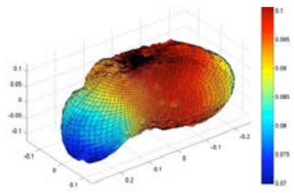
Scientific Results from Sample Initial Analysis



Important data for asteroid deflection

Results for Itokawa

- **Mass**
- **Shape, size, spin**
- **Density**
- **Albedo**
- **Material**
- **Structure**
- **etc.**



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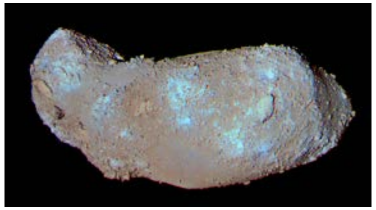
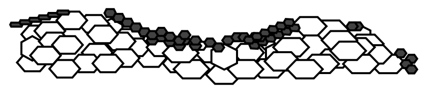
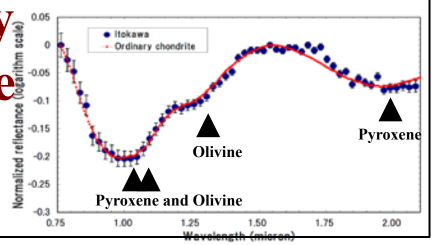
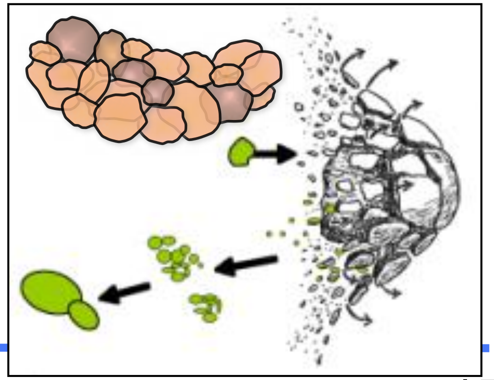




Ordinary chondrite



Rubble pile

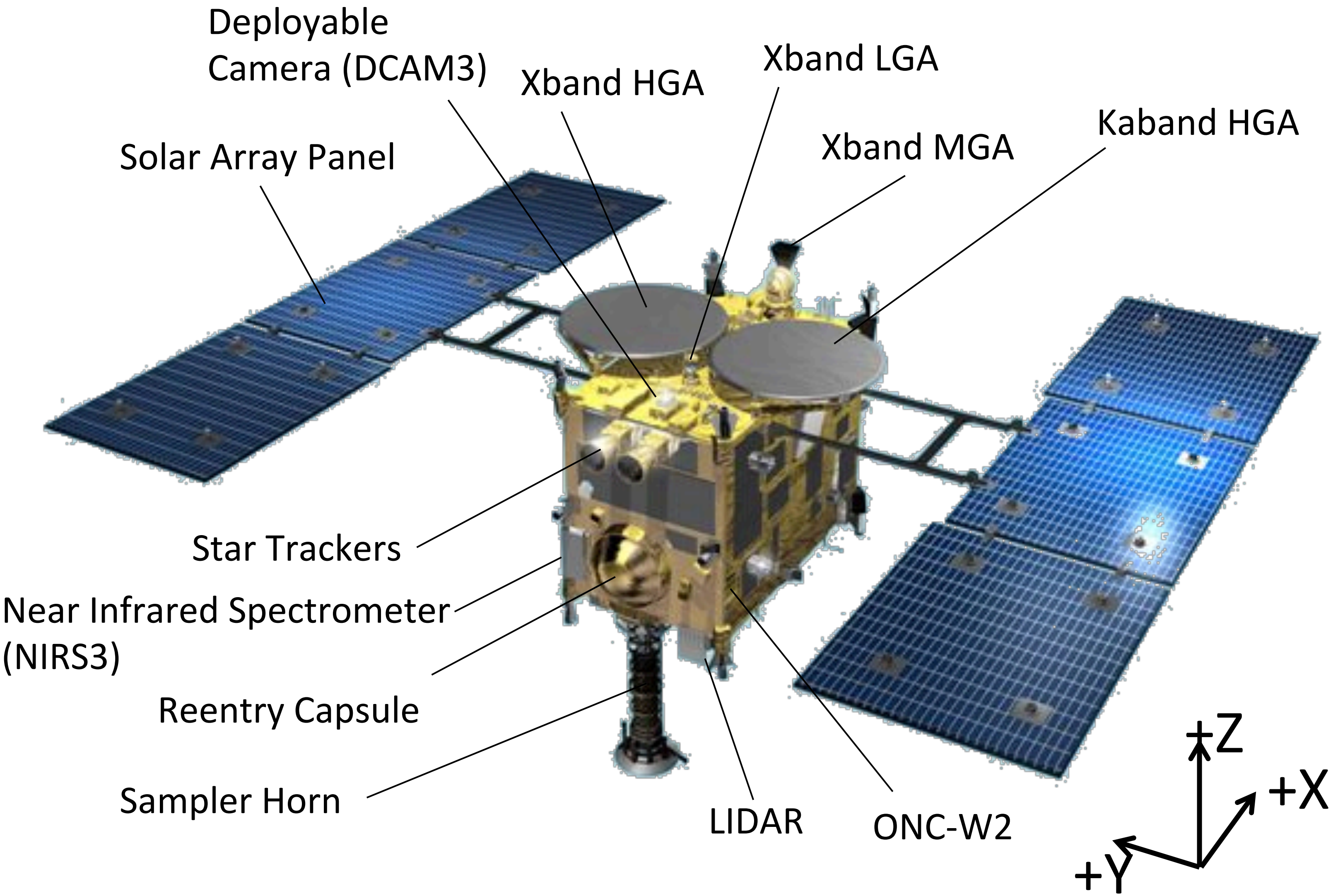


Science Publications

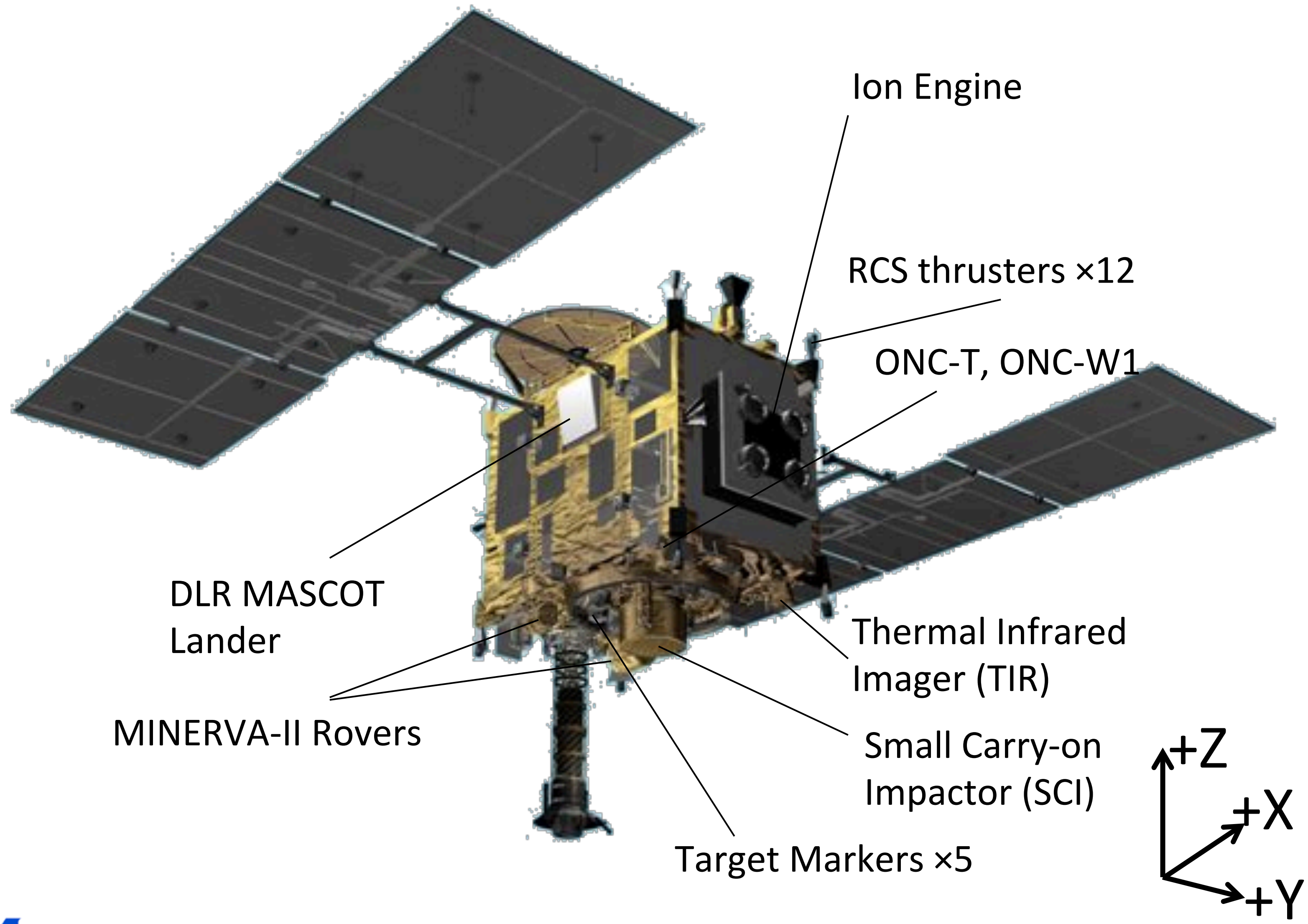
2 June 2006

26 August 2011

Hayabusa2 Outlook (1/2)



Hayabusa2 Outlook (2/2)

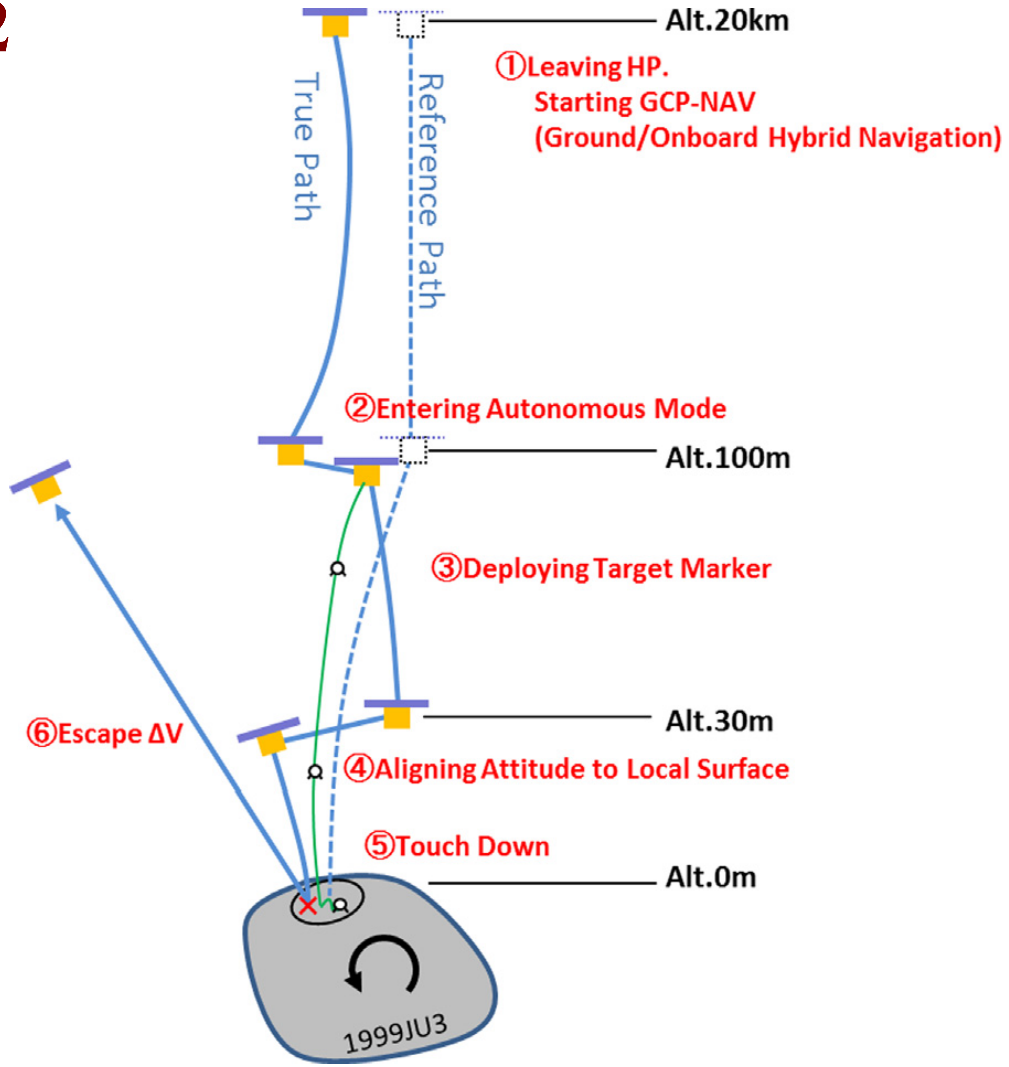


Hayabusa2 : Payloads for Science

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-A1,A2, B)	Similar to MINERVA of Hayabusa-1 (possible payload: Cameras, thermometers)	Heritage of Hayabusa (largely modified)
Small Lander (MASCOT)	Supplied from DLR & CNES MicrOmega, MAG, CAM, MARA	New

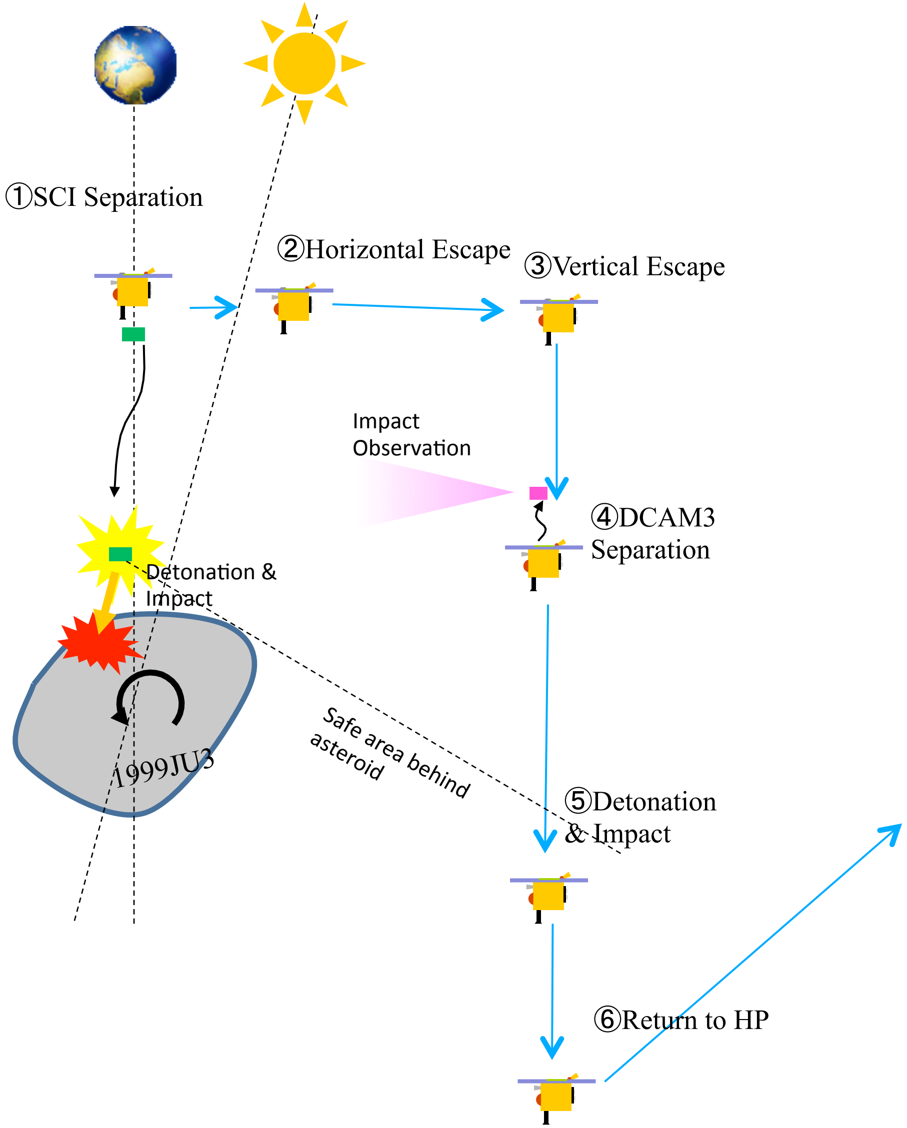
Sampling Operation Sequence

Hayabusa2

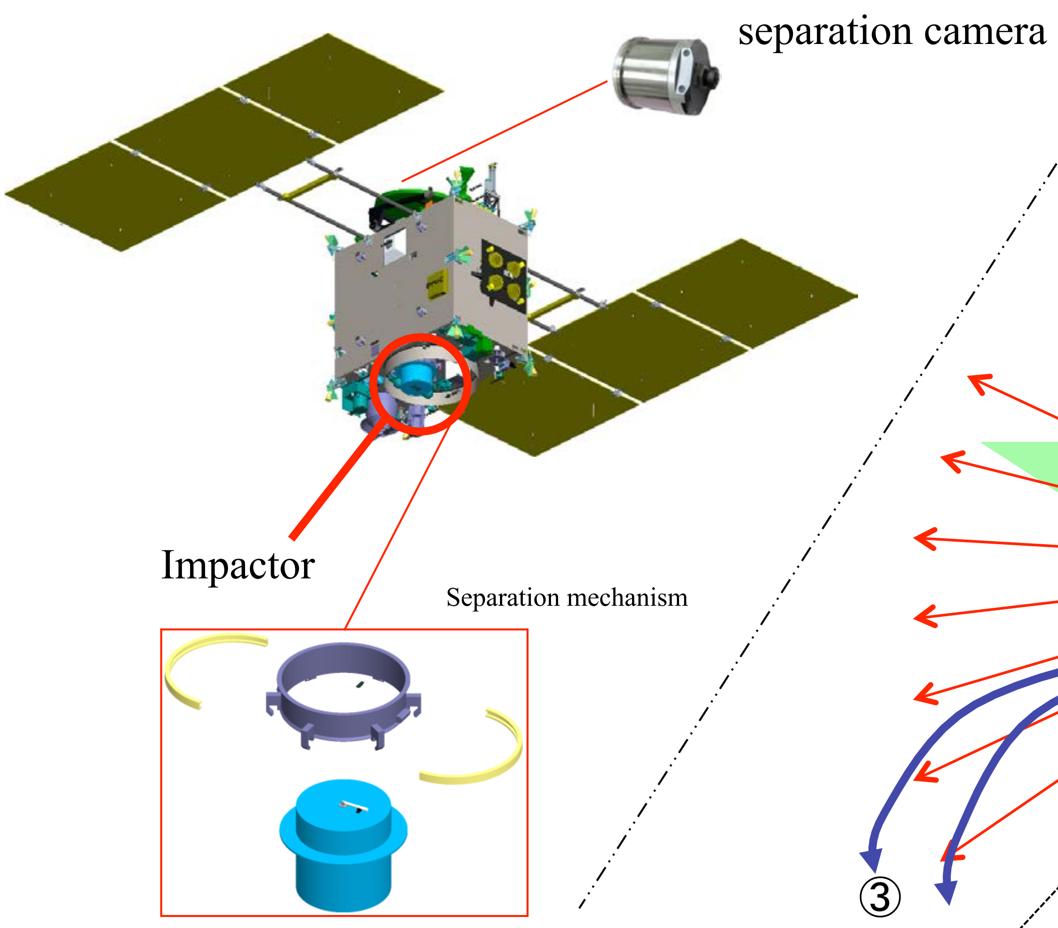


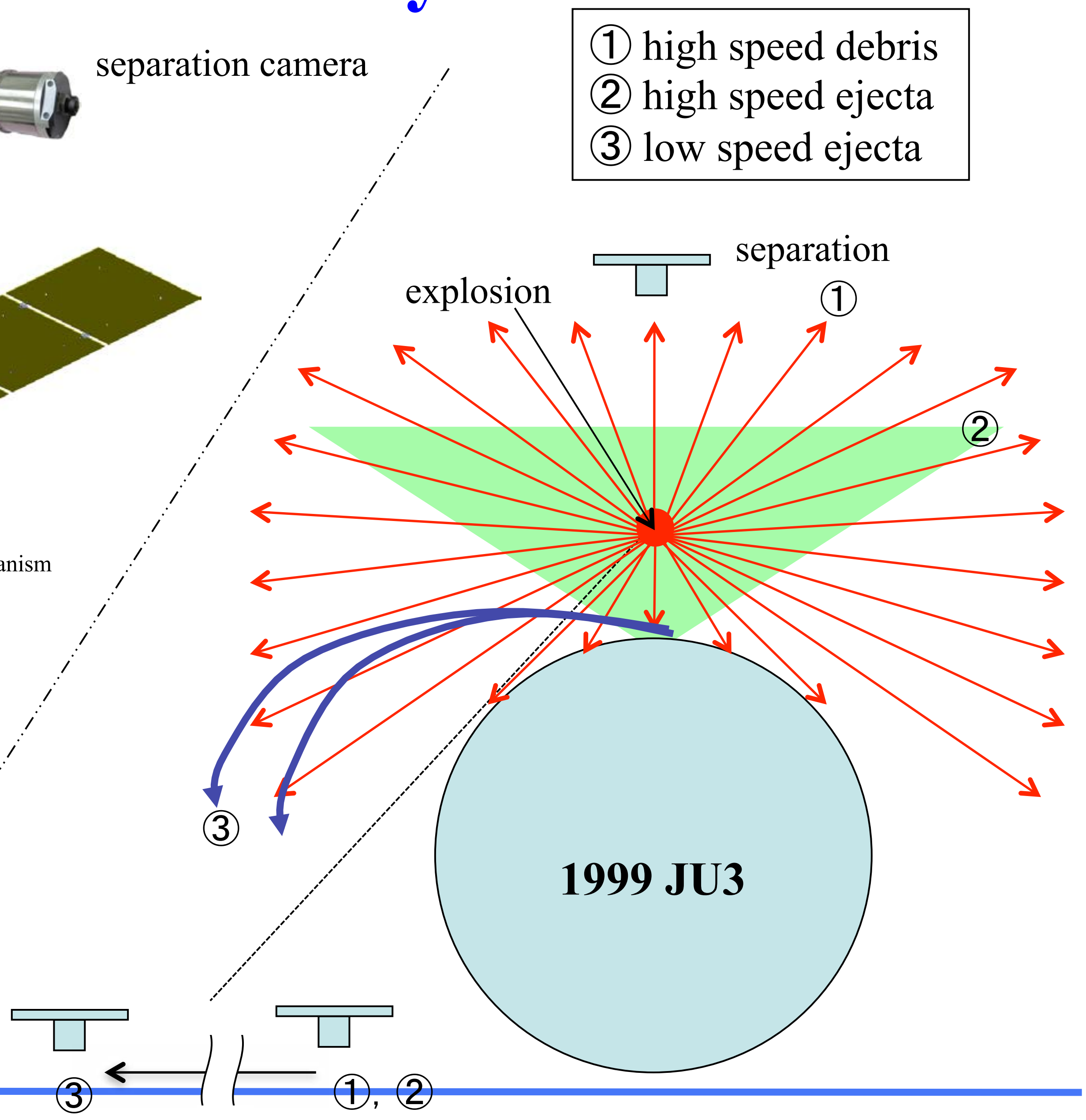
Artificial Crater Generation Operation

Hayabusa2



Impactor of Hayabusa2





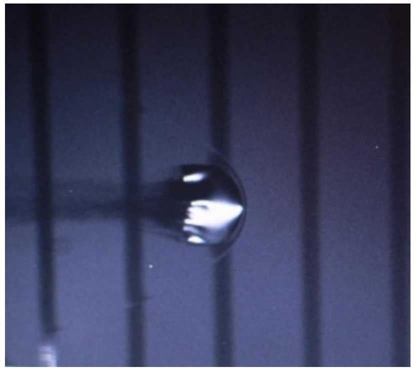
Impactor experiment

half size case

explosion

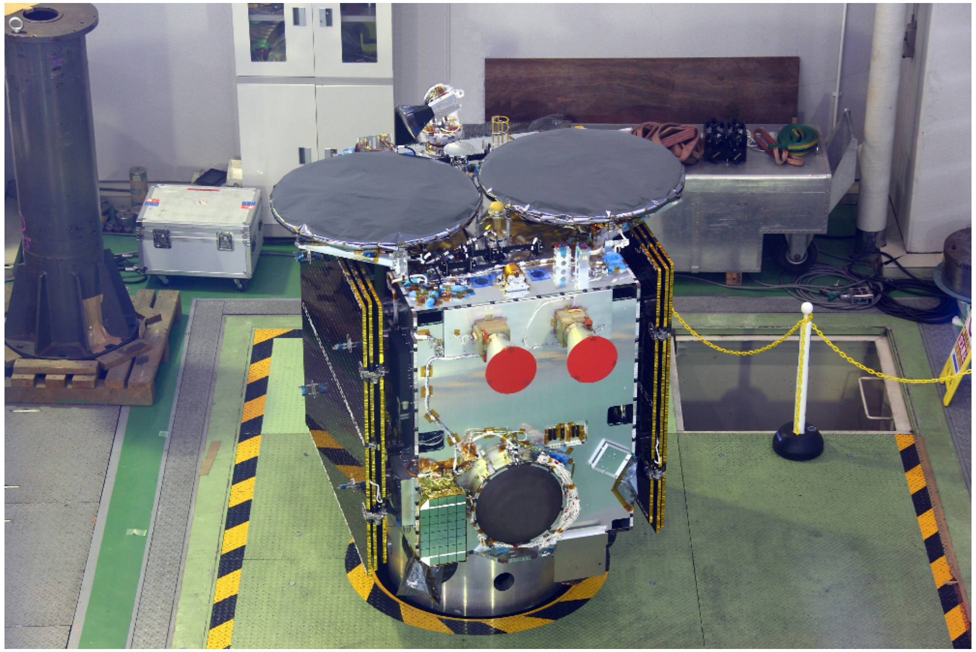
trajectory

impact!



Impactor movie

Flight model of Hayabusa2



June 2013

Target Asteroid : (162173) 1999 JU3

Current estimate:

Rotation period: 7 h 38 m

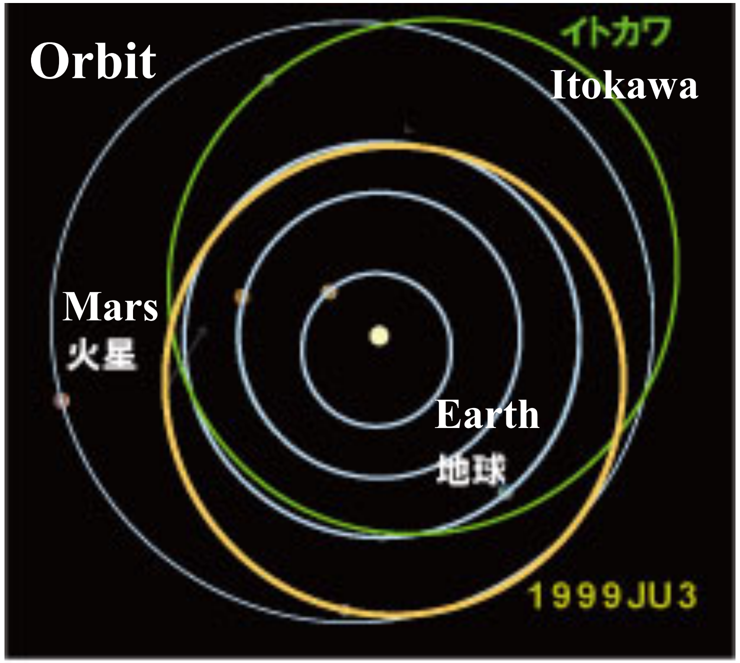
Shape : almost spherical

Size : 820 – 890 m

Albedo : 0.05 – 0.06

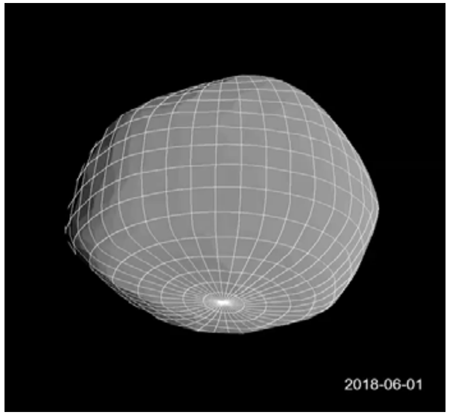
H : 19.2

Type : Cg

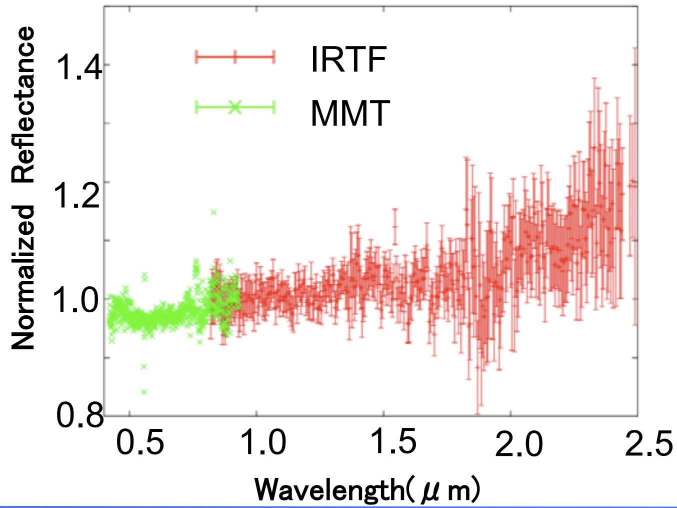


Origin:
- inner MB ?
- ν_6 secular resonance ?

Erigone Family ?



(by Mueller et al.)



International Cooperation Structure of Hayabusa2

JAXA
宇宙航空研究開発機構
Japan Aerospace Exploration Agency

USA

NASA

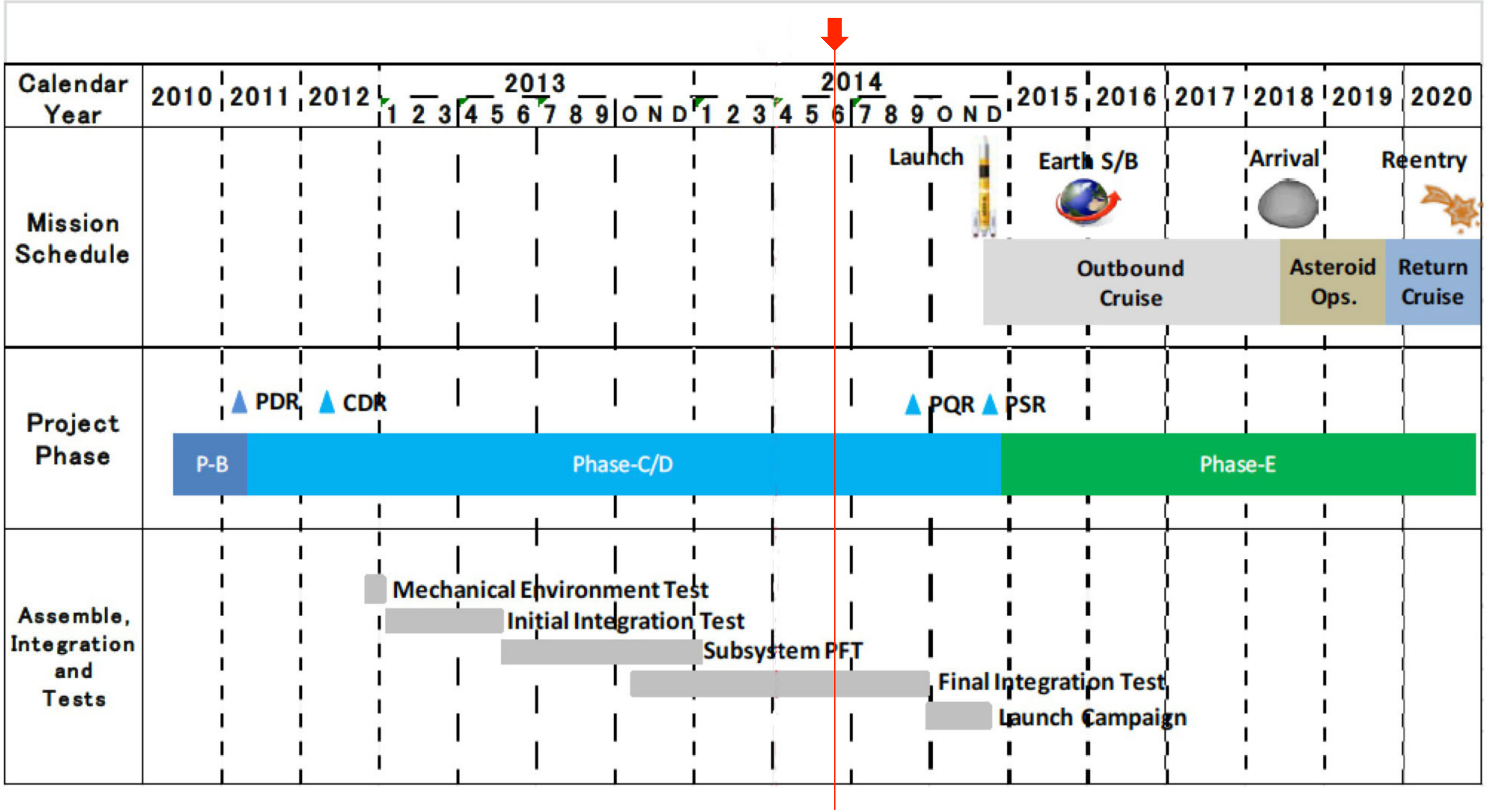
Europe

DLR
CNES

Australia

SLASO/DIISR
DoD/AOSG
AQIS/AC

Schedule of Hayabusa2



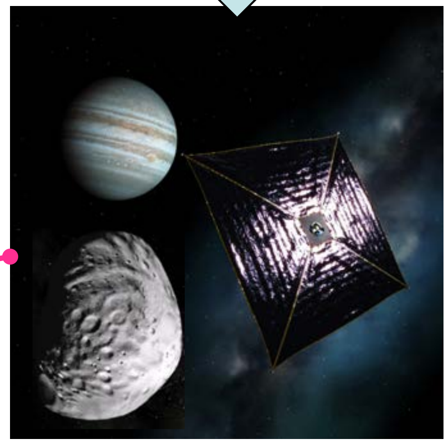
Past, Present, and Future

Starting Point
1985

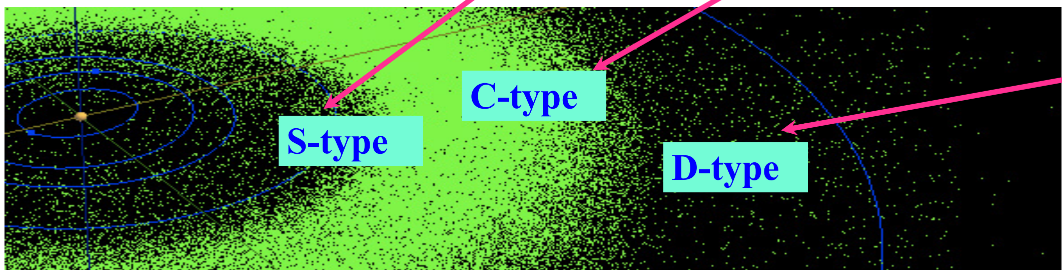

小惑星サンプルリターン
小 研 究 会
宇 宙 科 学 研 究 所
1985年 6 月29日

Hayabusa
2003-2010

Hayabusa2
2014-2020



to Trojans



Deflection Analyses

These are the works of a graduate student or a post graduate student in ISAS/JAXA.

References

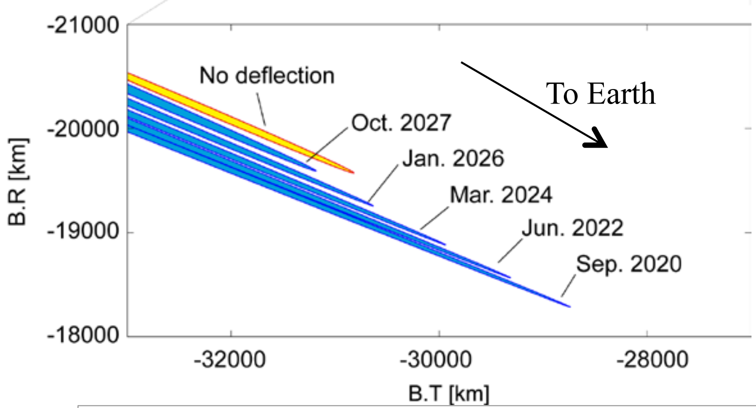
- Yamaguchi, T. and Yoshikawa, M., "Uncertainty Analysis of Apophis Impulsive Deflection Mission," 1st IAA Planetary Defense Conference: Protecting Earth from Asteroids," Granada, Spain, (April 2009)
- Yamaguchi, T, Kogiso, N., Yamakawa, H., "Optimal Interplanetary Trajectories for Impulsive Deflection of Potentially Hazardous Asteroids under Velocity Increment Uncertainties," Transactions of Japan Society for Aeronautical and Space Sciences, Vol. 51, No. 173, pp. 176-183, 2008.
- Y. Sugimoto, G. Radice, M. Ceriotti, and J. P. Sanchez, "Hazardous near Earth asteroid mitigation campaign planning based on uncertain information on fundamental asteroid characteristics," *Acta Astronautica*, DOI:10.1016/j.actaastro.2014.02.022 (2014).
- Y. Sugimoto, G. Radice, and J. P. Sanchez, "Effects of NEO composition on Deflection Methodologies," *Acta Astronautica*, 90 (2013), pp. 14-21.
- L. Palacios, Y. Sugimoto, A. Lawal, and G. Radice, "A robust Near Earth Asteroid mitigation campaign of multiple formation flying gravity tractors," the 64th International Astronautical Congress, Beijing, China, 23-27 September, 2013.

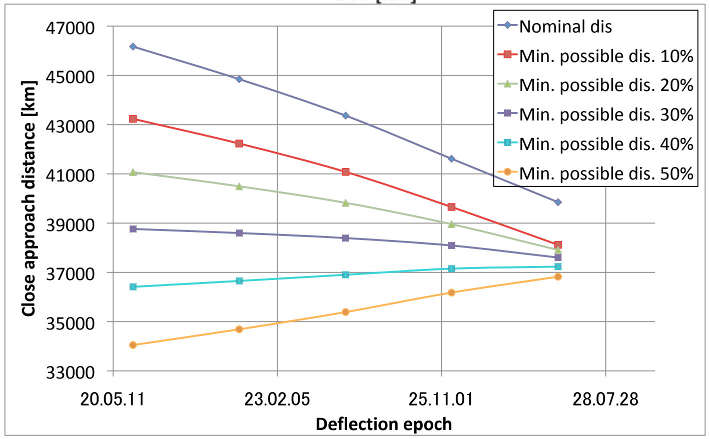
Trajectory optimization of kinetic impactor considering deflection uncertainty

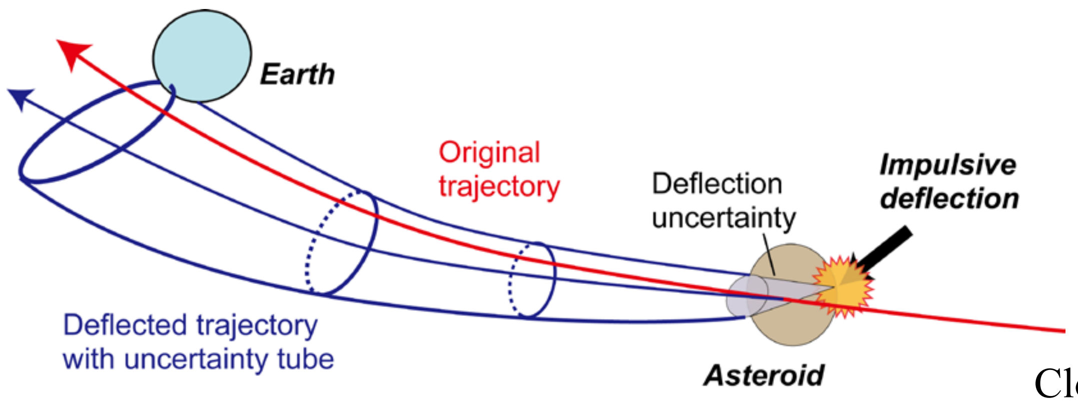
by T. Yamaguchi

Evaluation of an uncertainty on the impulsive deflection is essential because the uncertainty could decrease the minimum possible miss distance to the Earth.

- This study investigates the uncertainties of the velocity change due to an impulsive deflection assuming a mission to Apophis.
- The effect of impulsive deflection uncertainty strongly depends on the magnitude of deflection delta-V associated by a deflection strategy.







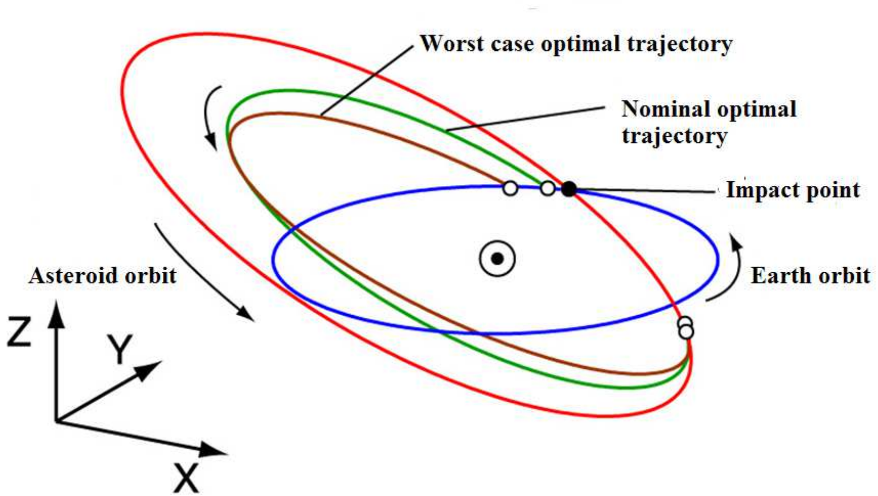
Close approach distance with different level of deflection uncertainties

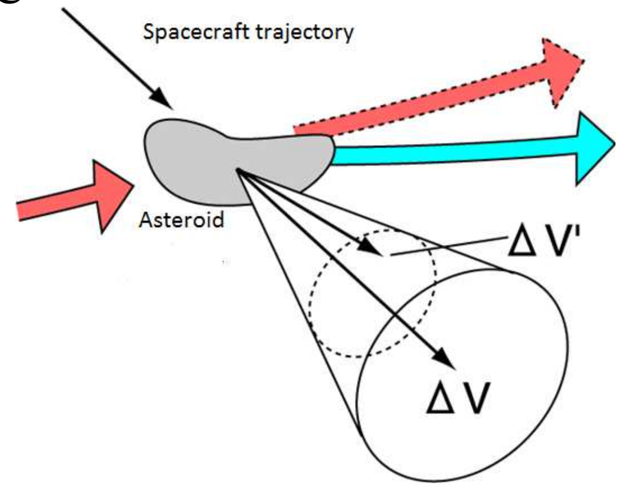
Trajectory optimization of kinetic impactor considering deflection uncertainty

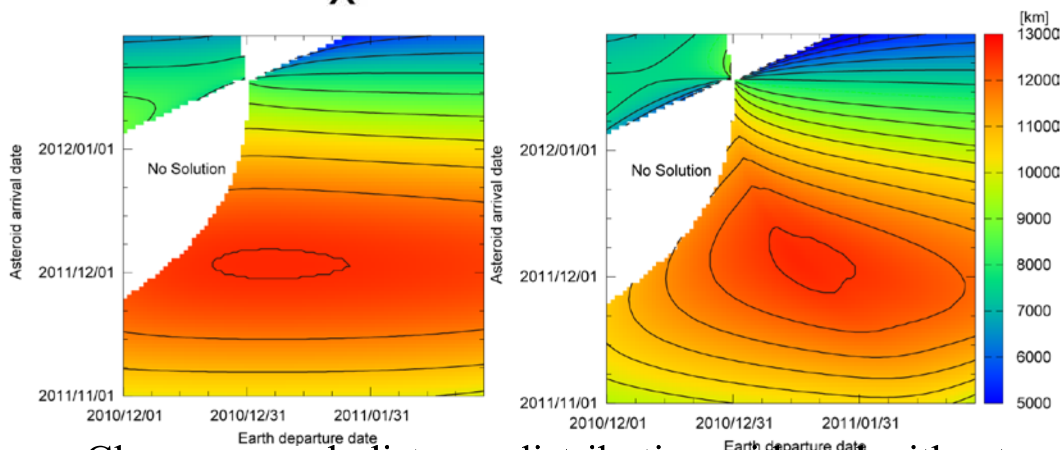
by T. Yamaguchi

Optimal trajectory for a kinetic impactor mission changes due to the deflection uncertainty.

- This study investigates the optimal trajectory for kinetic impactor considering the deflection uncertainty.
- The optimal trajectories of the spacecraft are sensitive to uncertainty of the velocity increment direction, but insensitive to uncertainty of the velocity increment magnitude



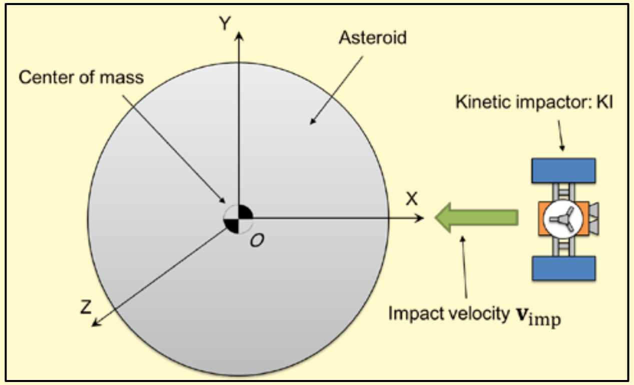




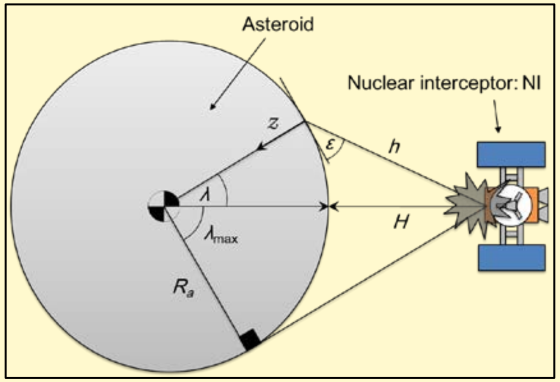
Close approach distance distribution with and without deflection uncertainty

Deflection mission under uncertain information

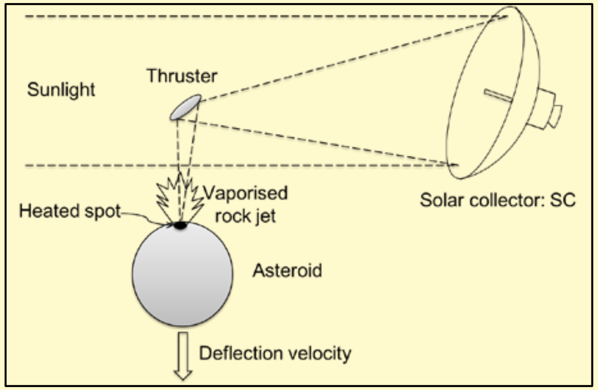
by Y. Sugimoto



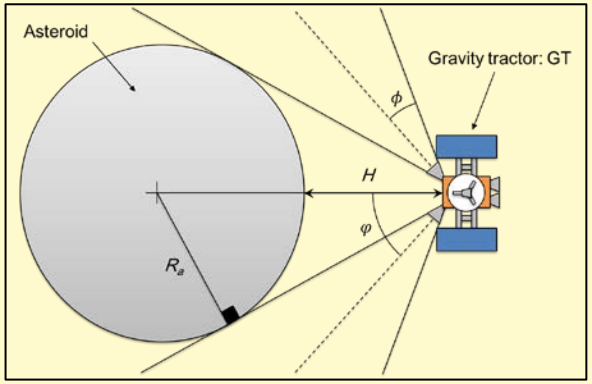
Kinetic impactor



Stand-off nuclear interceptor



Solar collector



Gravity tractor

If we know the physical properties of NEO
↓
OK

If we do not know
↓
?

This can be happened when the warning time is short.

Physical properties of asteroid:
mass, size, shape, density, albedo, material,･･･

Deflection mission under uncertain information
Summary of study

by Y. Sugimoto

Uncertainty of physical properties of asteroids

Observation from ground ------ large uncertainty

Observation from space

Observation in situ -------------- small uncertainty

mass, albedo,
density distribution

Calculate the effects of uncertainty to deflection

Robust deflection mission concepts

for example : combination of Kinetic Impactor and Gravity Tractor