NASA Planetary Protection Subcommittee 2012

Planetary Protection of Hayabusa-2 Mission, a Sample Return from 1999 JU3, C-type NEO

May 1-2, 2012
NASA Headquarters, Room 3H46, Washington, D.C., USA
(via Teleconf/WebEx)

Presented by Hajime YANO (JAXA/ISAS & JSPEC) and the Hayabusa-2 Project Team (PM: Makoto YOSHIKAWA)

Motivation of This Presentation:
To Receive Kind Understanding from International Partners and COSPAR PPP Resolution in 2012 for Hayabusa-2

USA

NASA

(e.g., DSN support, Airborne observation of the re-entry, Collaboration with OSIRIS-Rex, etc.)

Australia

SLASO/DIISR

DoD/AOSG

AQIS/AC

(e.g., ERC recovery operation at Woomera, etc.)

Europe

DLR

(e.g., Provision of the lander, Microgravity test facilities, etc.)

Agenda

(1) Hayabusa-2 Mission Description
(2) Observed Nature of 1999 JU3
(3) COSPAR Six Questions for the 1999 JU3 Sample Return Mission

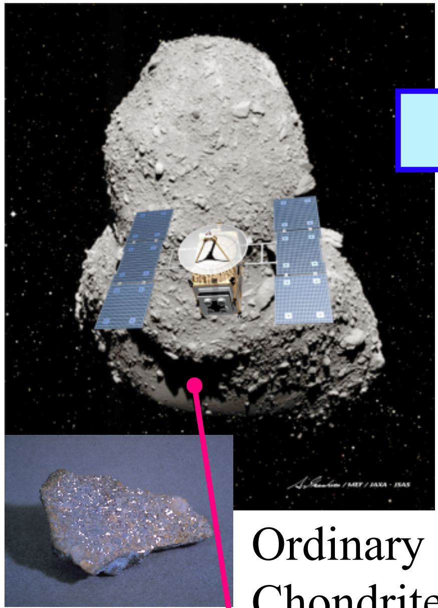
Hayabusa-2 Mission Description

Japan's Primitive Body Exploration Program: Sample Return Strategy for "Further, Smaller, More Primitive" Objects

Post Hayabusa Series

Hayabusa

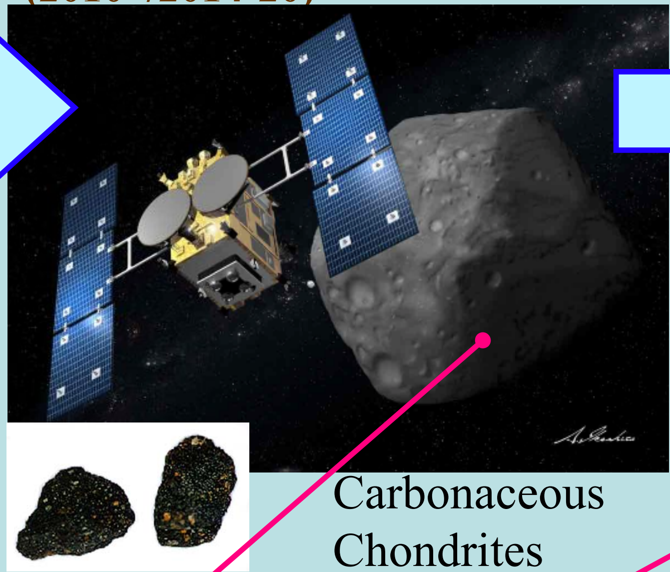
Itokawa = S type
(1996~/2003-10)



Ordinary Chondrites

Hayabusa-2

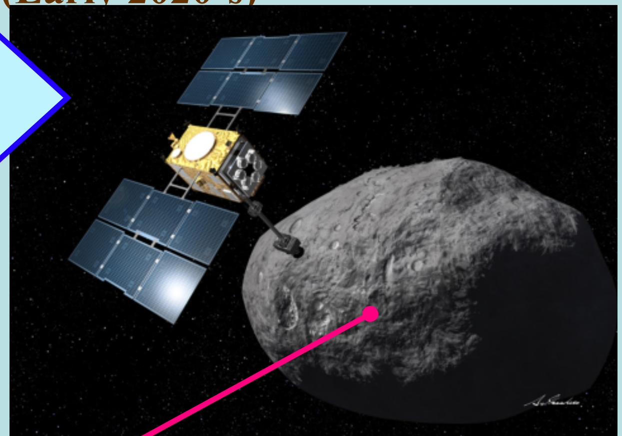
1999 JU3 = C type
Lessons Learned from Hayabusa
(2010~/2014-20)

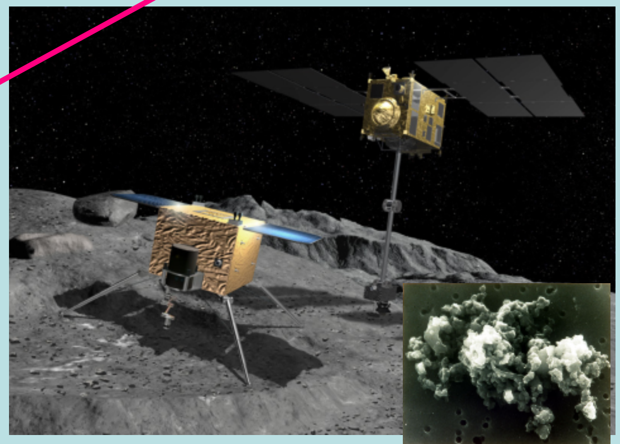


Carbonaceous Chondrites

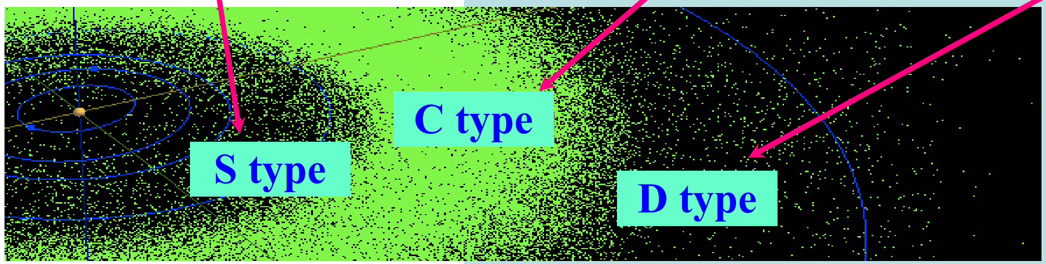
Hayabusa Mk-II (plan)

D type, Dormant comet
Advanced, Full Model-change
(Early 2020's)



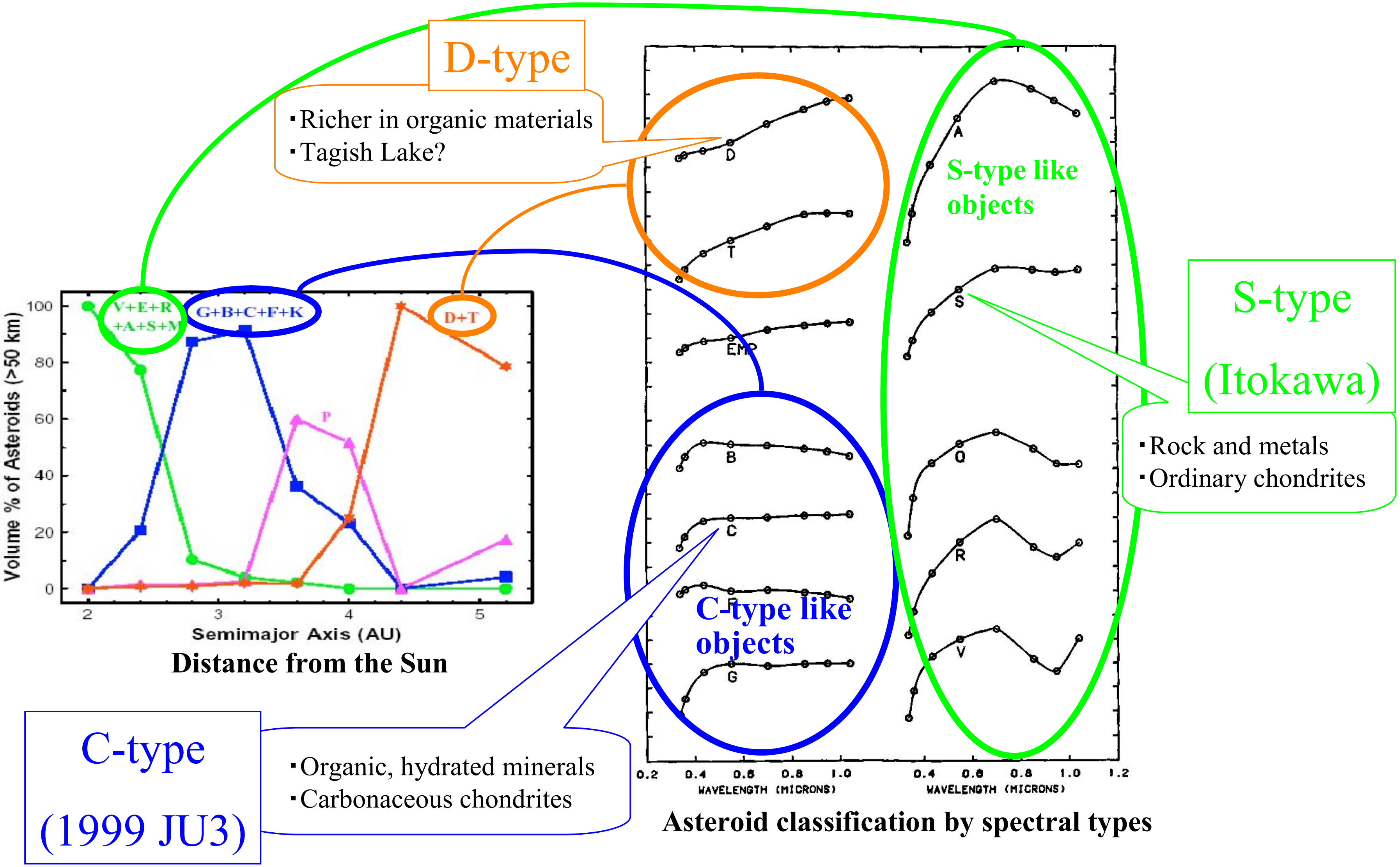


IDP, Micrometeorites, Tagish Lake?



Main Asteroid Belt

Major Spectral Types of Asteroids Related to Heliocentric Distances



Hayabusa-2 Mission Outline: Follows the Hayabusa-1's Path with Some New Additions

Launch

Dec. 2014
(back-up 2015)

June, 2018 : Arrival at 1999 JU3

The spacecraft observes the asteroid, deploys multiple small landers/rovers, and conducts multiple samplings.

Sample Analysis

Earth Return

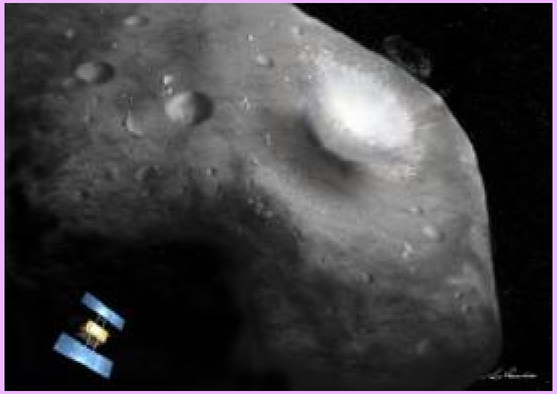
Dec. 2020

Dec. 2019 : Departure

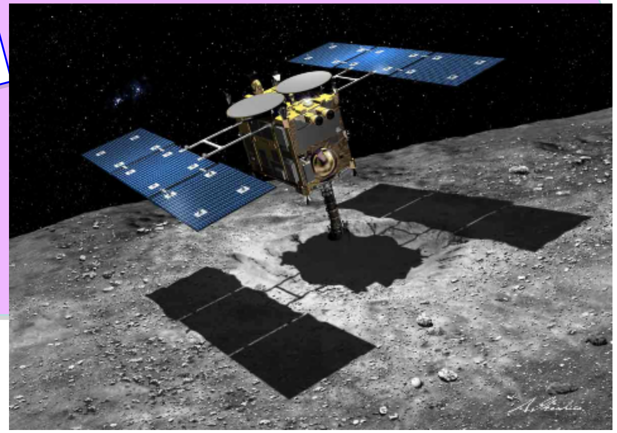
The spacecraft carries an impactor.

New Challenges

2019



The impactor reaches to the surface of the asteroid.



Sampling will be attempted to a newly created crater if proven to be safe.

Purposes of Hayabusa-2 Project

1. Science

Investigate “where we came from"

- The origin and evolution of the Solar System
- Life Precursor
- The origin of the ocean water

2. Engineering

Develop technology needed for the Solar System exploration

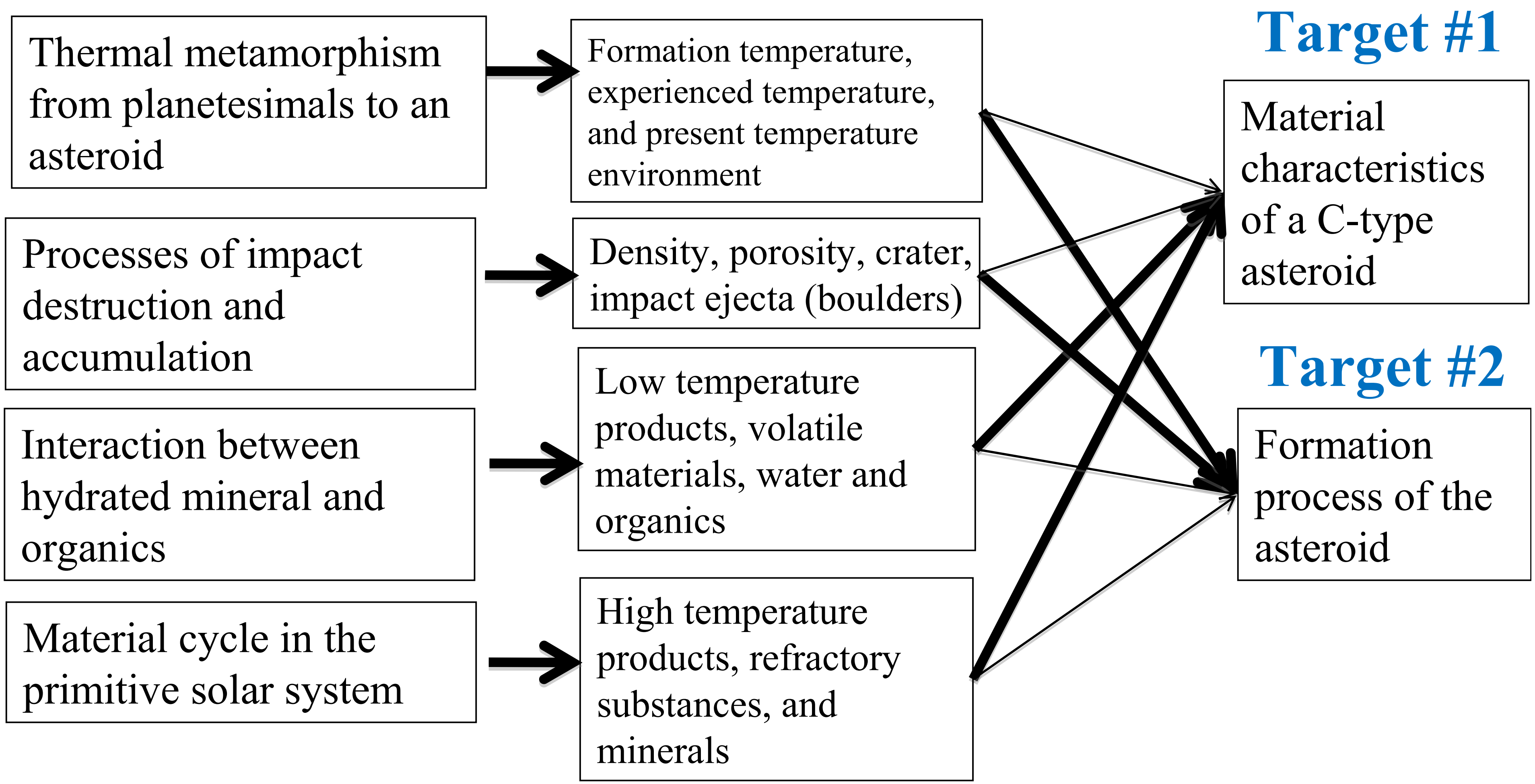
- Improve technology heritage from Hayabusa for being more reliable and robust
- New challenges, e.g., the impactor and the lander/rover(s)

3. Exploration

Extend the area where humanbeings can reach

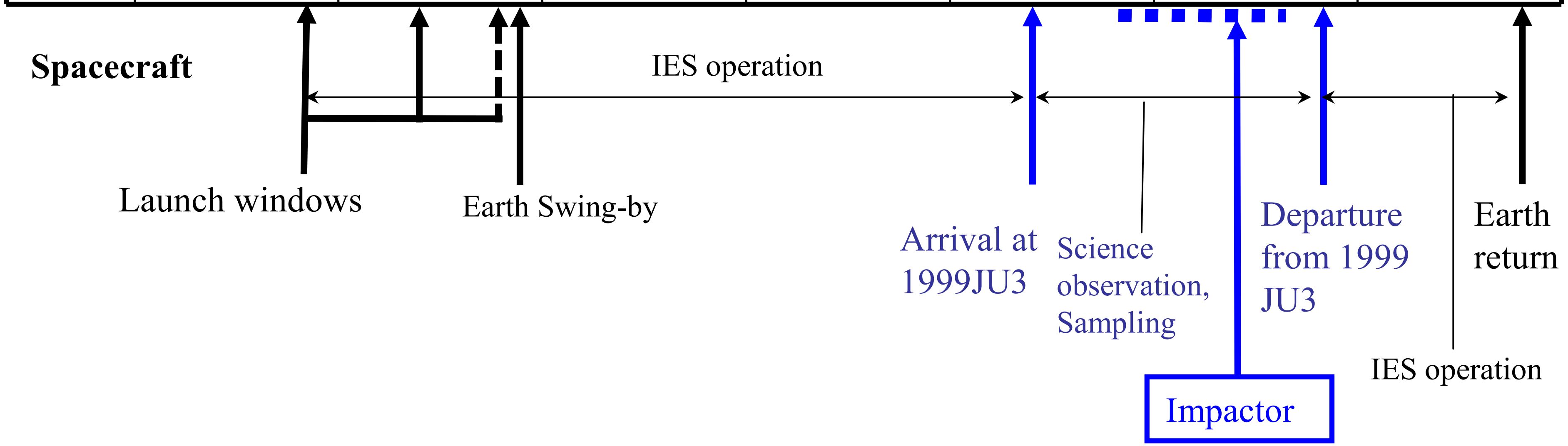
- Deep space round trip
- Spaceguard, resources, precursor for human mission, etc.

Approach to Scientific Objectives



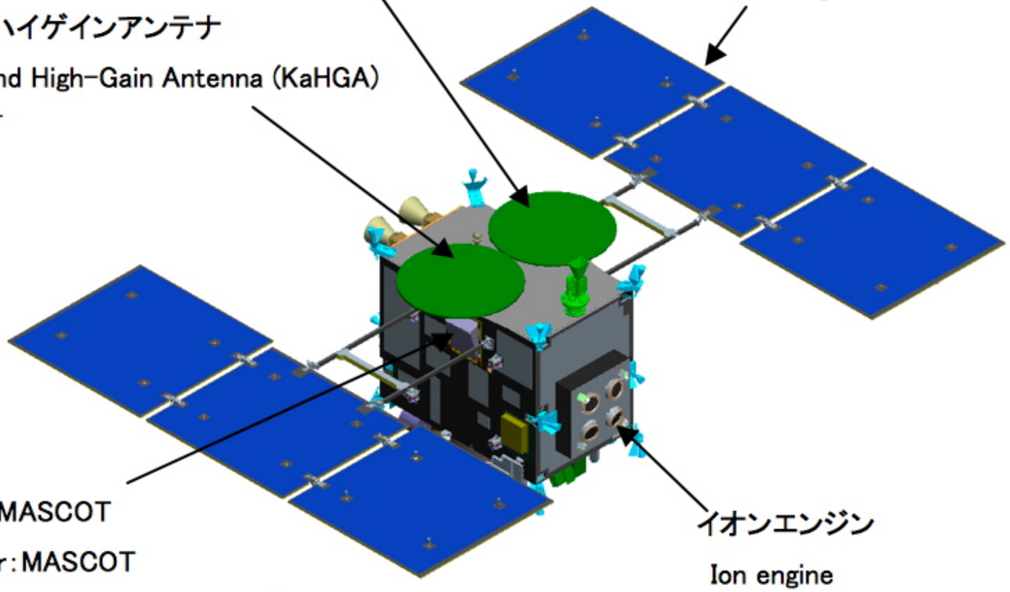
Hayabusa-2 Mission Schedule

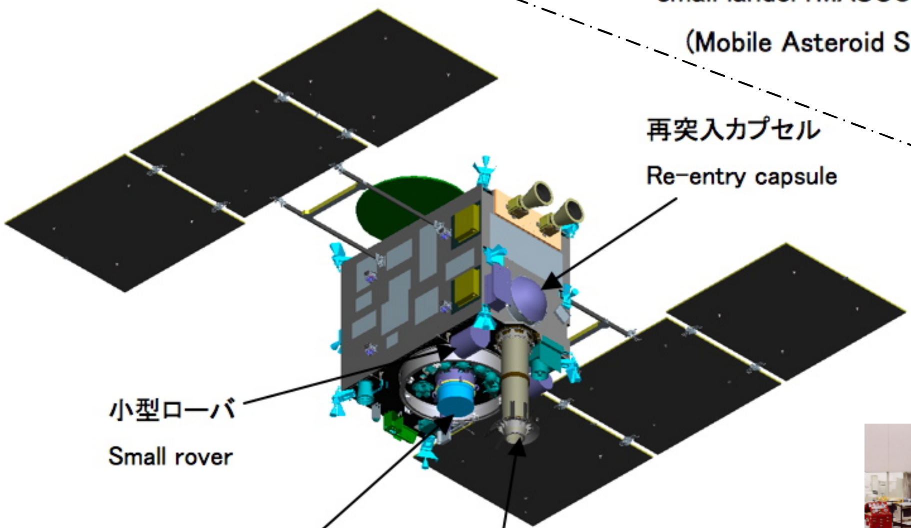
year	2014	2015	2016	2017	2018	2019	2020
month	12	06 12			06	08 12	12

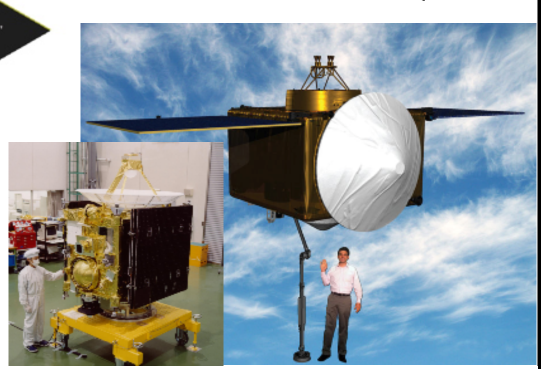


Hayabusa-2 Spacecraft Design

Wet Mass：~600 kg

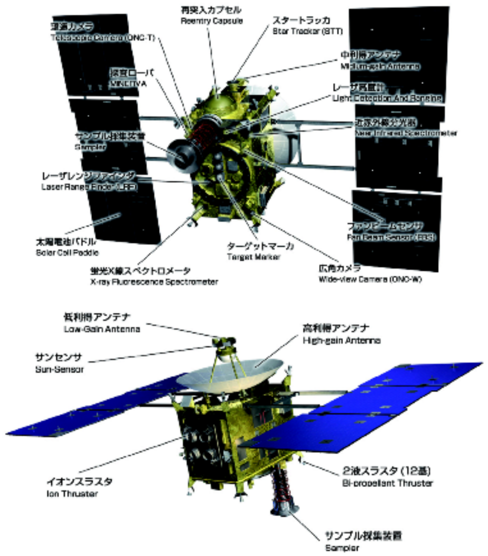






Size Comparison with OSIRIS-REx

cf. Hayabusa (510 kg)



Planned Payloads for Scientific Outcomes

Payloads	Specifications
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) **(Heritage of Hayabusa)**
Near IR Spectrometer (NIRS3)	Wavelength: 1.8 – 3.2 μm, FOV: 0.1 deg x 0.1 deg **(Heritage of Hayabusa except 3μm range, which 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)**
Sampler	Minor modifications from Hayabusa-1 **(Heritage of Hayabusa)**
Small Carry-on Impactor (SCI)	Small, deployable system to form an artificial crater on the surface **(New)**
Separation Cameras (DCAM)	Small, deployable camera to observe the SCI operation **(Heritage of IKAROS)**
Small Rovers (MINERVA II-1, II-2)	Almost the same as MINERVA of Hayabusa-1 (Possible payloads: Cameras and thermometers) **(Heritage of Hayabusa)**
Small Rover (MASCOT)	Contirbution from DLR **(New):** MicrOmega, MAG, CAM, MARA **(Heritage from PhobosGrunt, etc.)**

Heritage from Hayabusa: Impact Sampling System

- Collect sufficient amount of samples (>several 100 mg) compliant with both monolithic bed rock and regolith targets
- Projectors designed to fire a 5-g metal projectile at 300 m/s
- Powder cartridge and sabot to conceal residual gas during sampling
- “Ta” projectile not to spoil sample analysis with enough material strength

Spacecraft

Return Capsule
(Sample Catcher & Container inside)

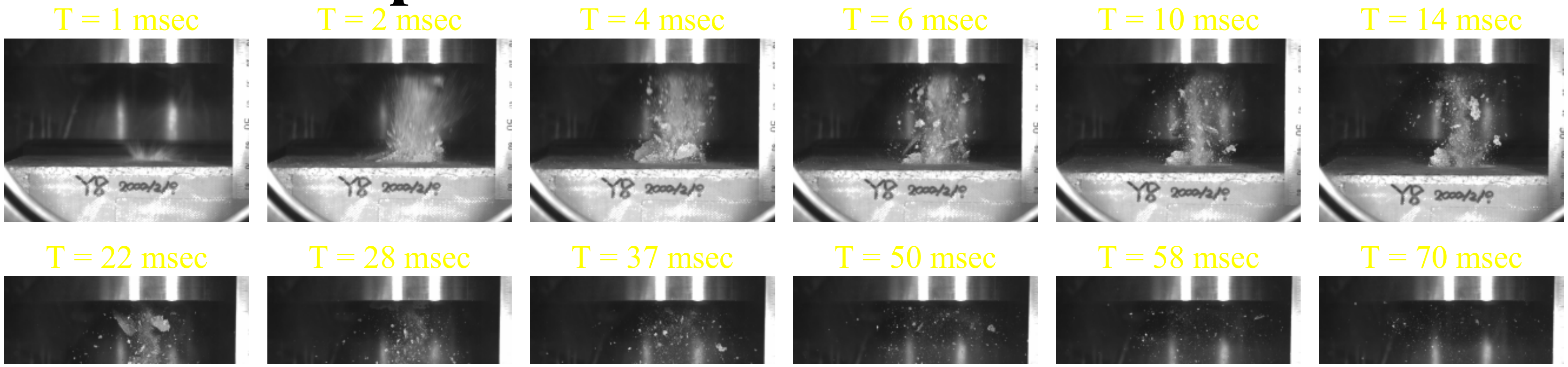
Projectors
(Up to three)

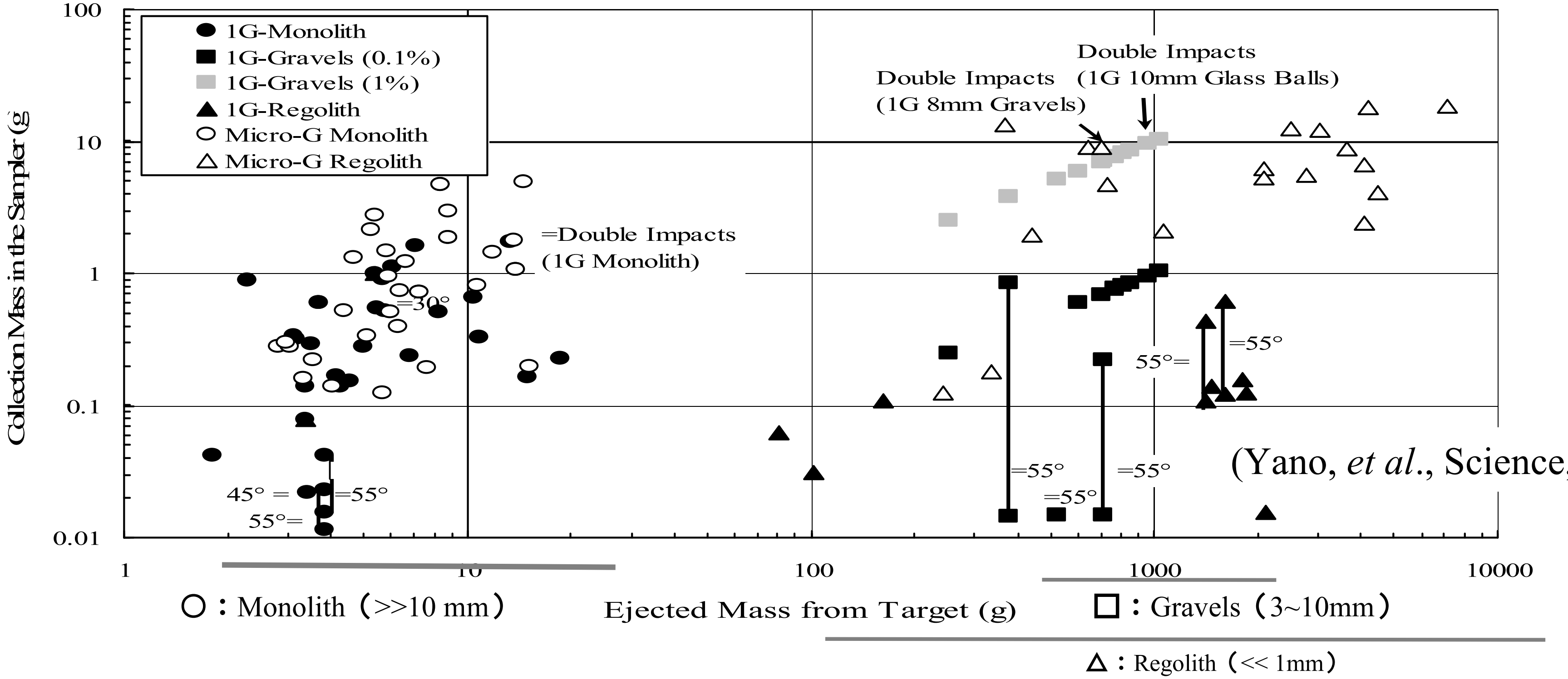
Conical Horn
(Concentrator)

Extendable Fabric Horn

Metal (Al) Horn with Dust Protection Skirt and LRF Trigger Target

Heritage from Hayabusa: Sample Collection Performance

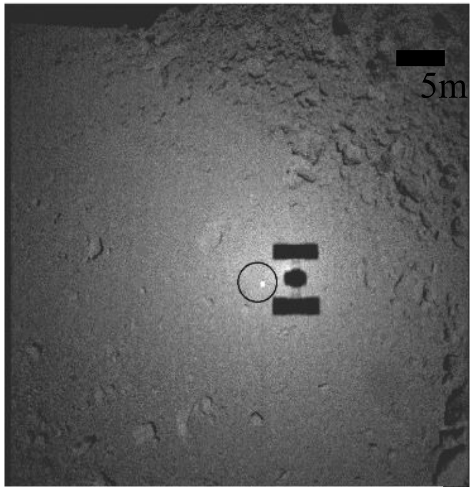


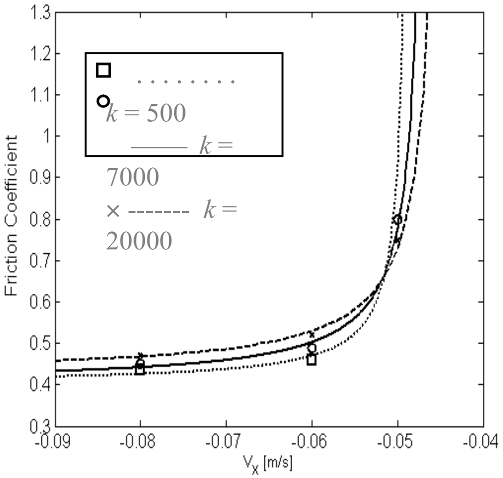


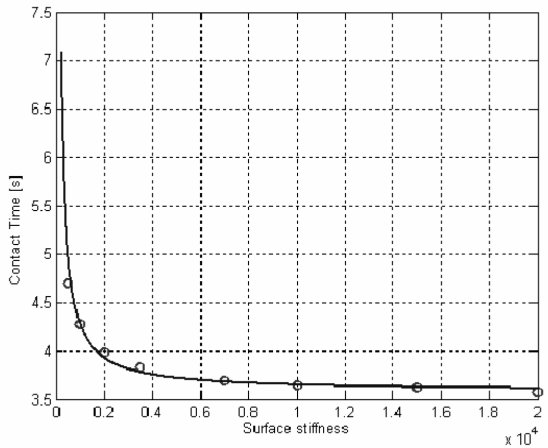
(Yano, *et al.*, Science, 2006)

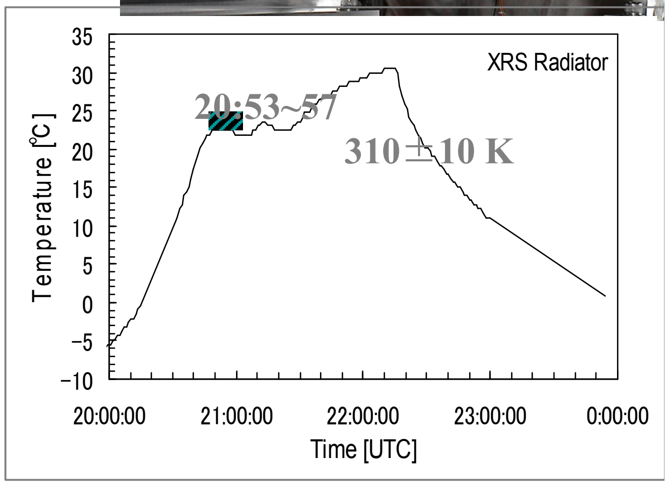
Heritage from Hayabusa:
Direct Sampling Site Investigation by the Spacecraft

* From experiences of the Hayabusa operation, physical properties, thermal inertia, close-up images of the sampling site can be measured by the Hayabysa-2 spacecraft









Yano, et al., *Science* (2006)

Heritage from Hayabusa: Landing of the ERC at Woomera in Australia in December, 2020

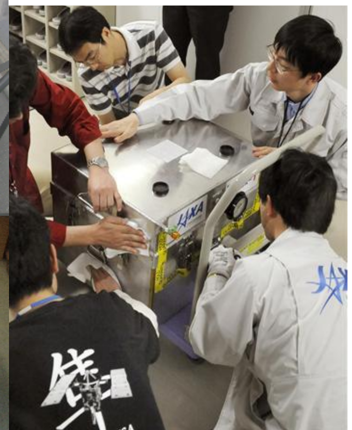
(From examples of the Hayabusa-1 ERC recovery)

<Retrieval, Transport, Cleaning, Storing, Purging>

<Soil Sampling>

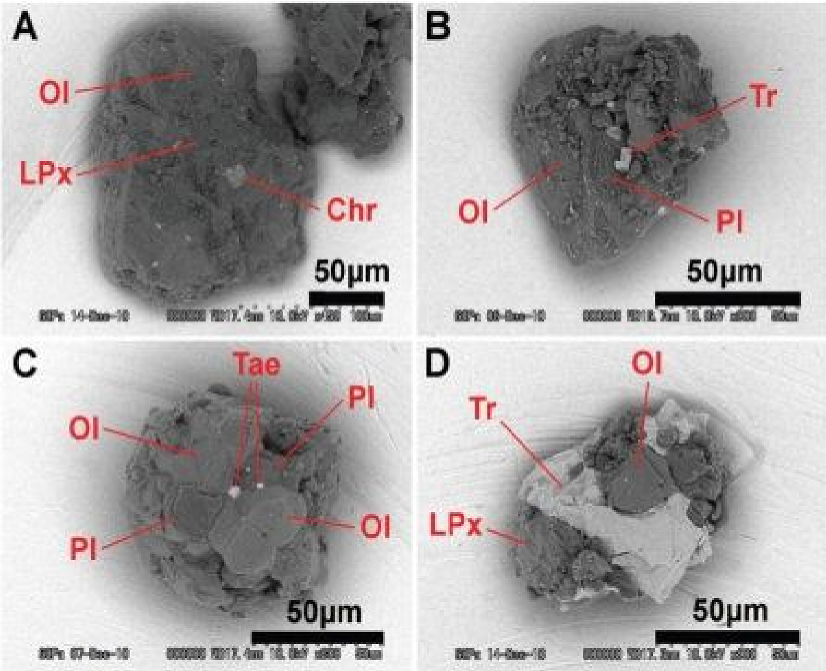
<International Witness>

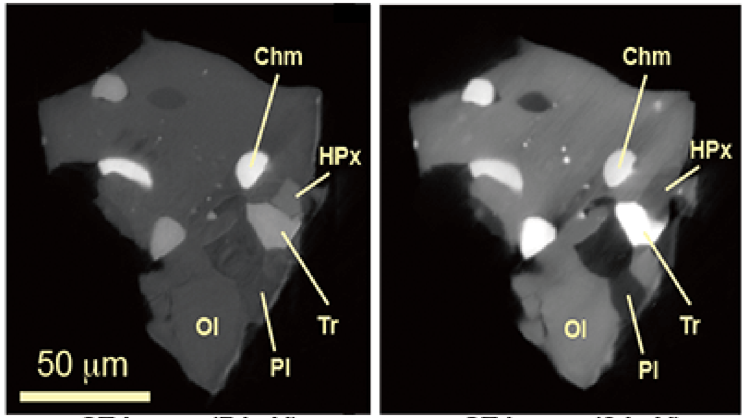
<Arrival to Curation Facility>



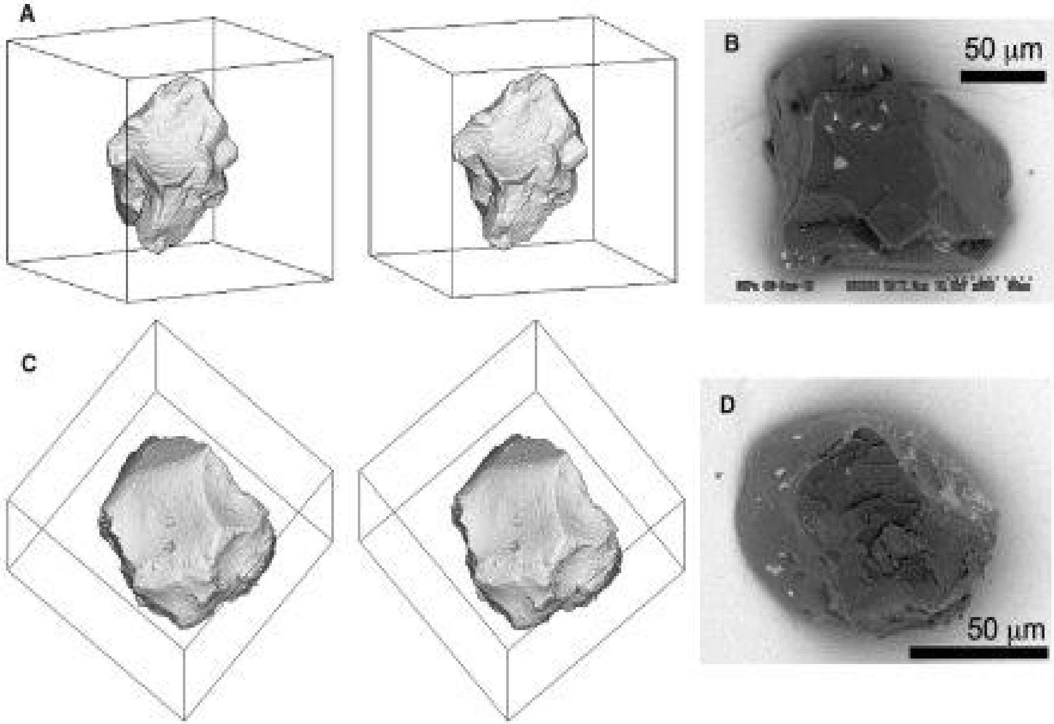
<XCT Scanning>

Heritage from Hayabusa: Curation Facility for Initial Sample Handling, Description and Storage like Itokawa Samples

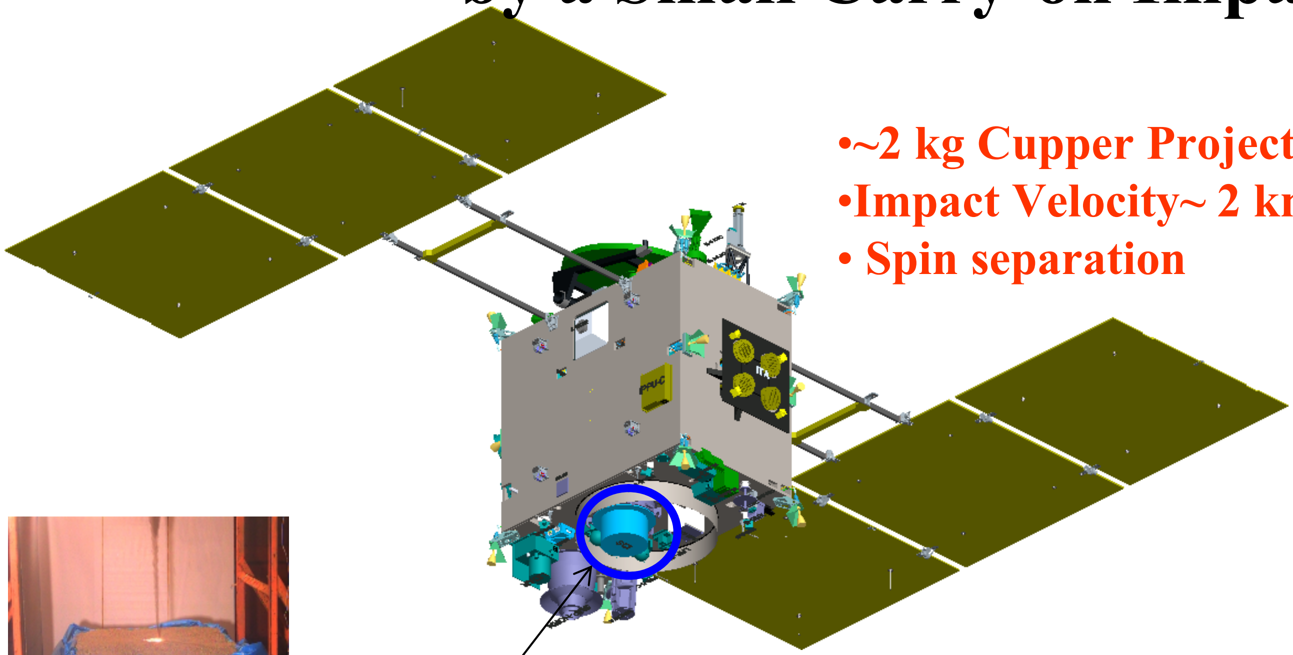




CT image (7 keV) CT image (8 keV)



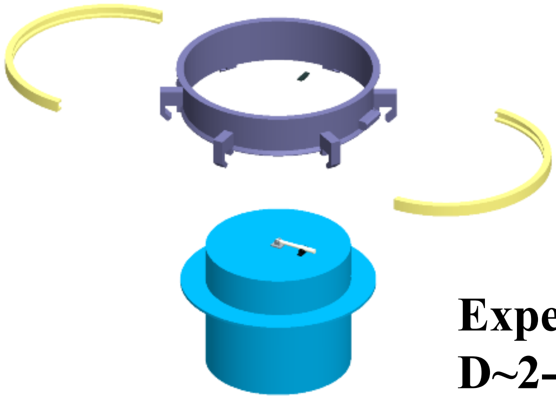
A New Challenge:
Observe and Sample Excavated, Sub-Surface Materials by a Small Carry-on Impactor



- ~2 kg Cupper Projectile
- Impact Velocity~ 2 km/s
- Spin separation

Impactor

EFP (Explosively Formed Projectile) Demonstration



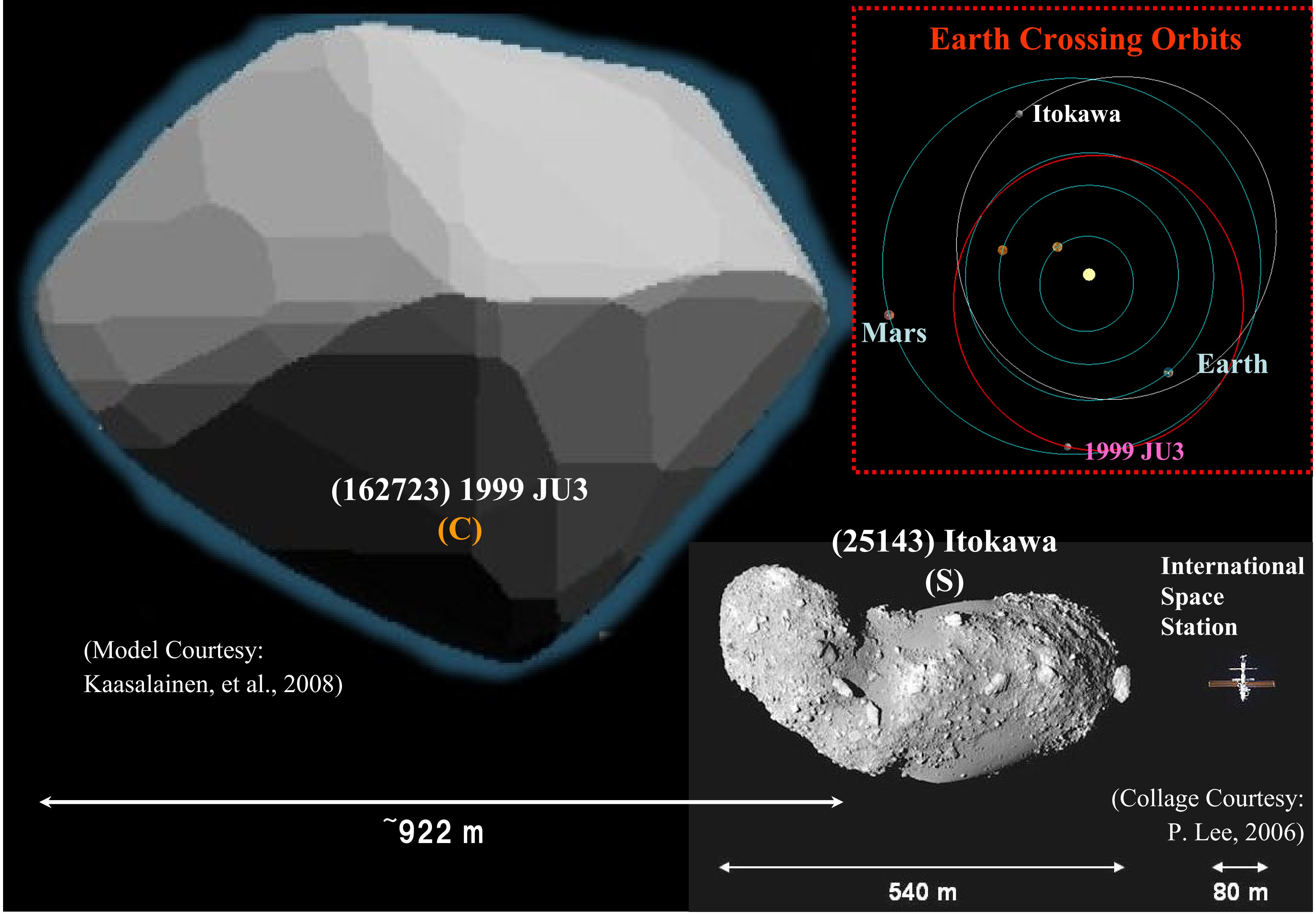
Expected Crater Size:
D~2-3m: Autodyn Simulation
D~4 m: Takagi et al.
D~7.4 m: Housen & Holsapple

Hayabusa vs. Hayabusa-2 at a Glance: From Technological Challenges to Programmatic Sample Return Missions

	Hayabusa	Hyabusa-2
Objectives	 Verify key technology needed for deep space round trip exploration	 C-type asteroid sample return and improvement of the deep space round trip exploration technology
Mission Target	Itokawa: S-type, sub-km NEO	1999 JU: C-type, 1-km NEO
Major Payload Instruments	•Sampling System •Earth Return Capsule •Multi-band Optical Camera •LIDAR •Near Infrared Spectrometer •X-ray Fluorescence Spectrometer •Micro-Rover	•Sampling System •Earth Return Capsule •Small Carry-on Impactor with DCAM •Multi-band Optical Camera •LIDAR •3 μm Near Infrared Spectrometer •Thermal Imaging Camera •Micro-Rover •Micro-Lander
Mission Epoch	2003-2010	2014-2020

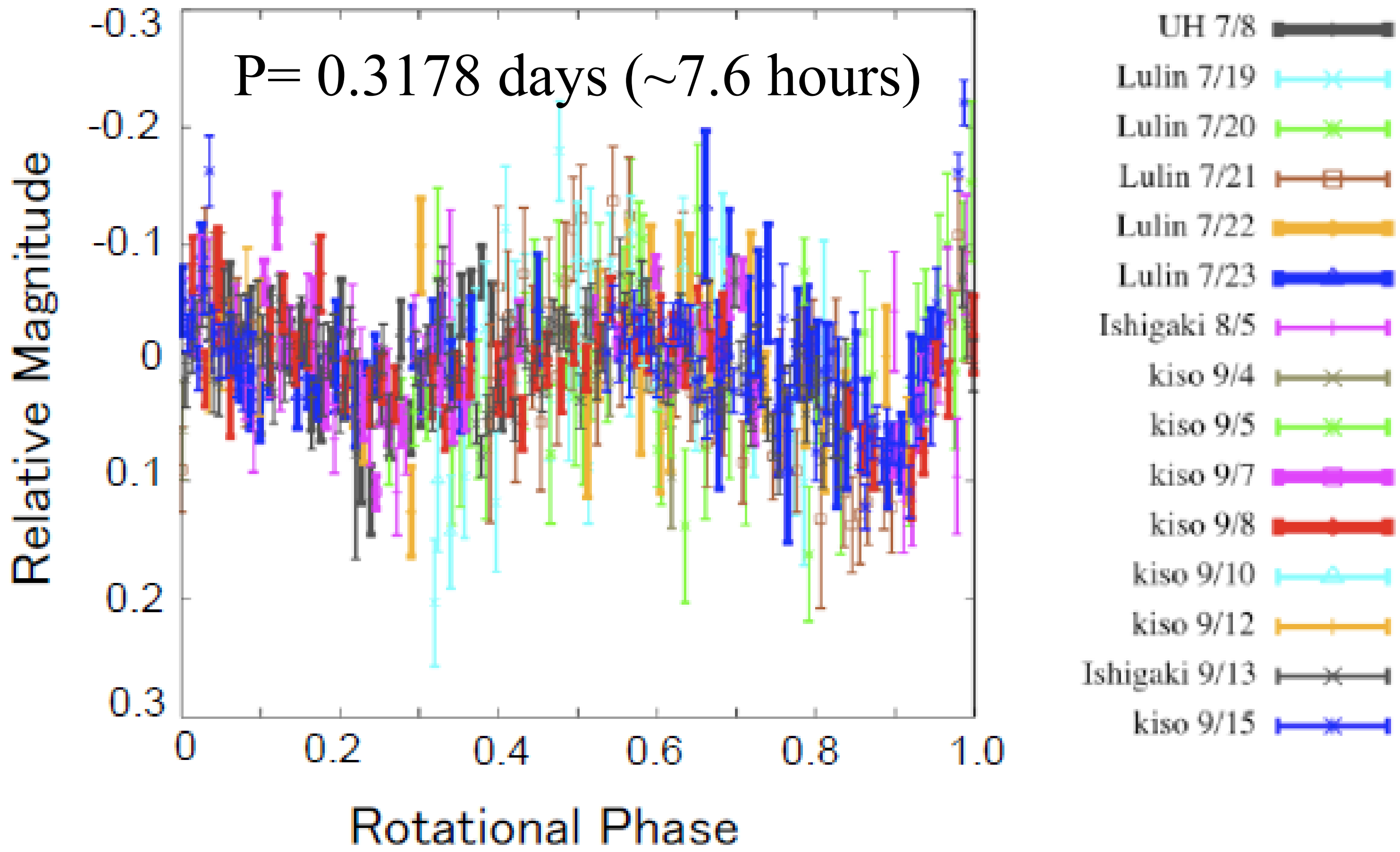
Observed Nature of 1999 JU3

Near Earth Objects: Itokawa vs. 1999 JU3 at a Glance



Remote Sensing Studies:
1999 JU3, Hayabusa-2's Target (1)

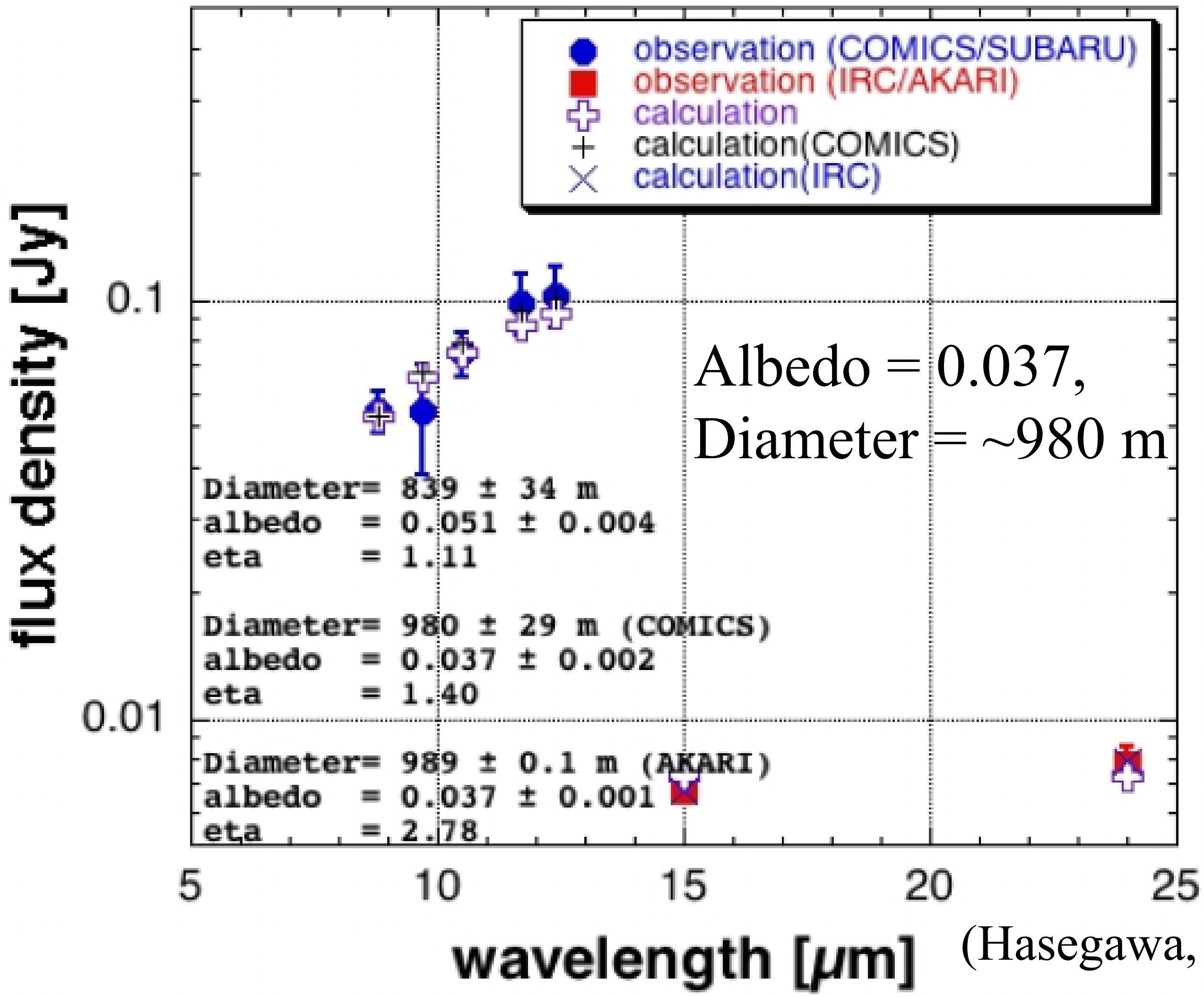
Rotational Period Defined from Ground Observations



(Kawakami, et al., 2008)

Remote Sensing Studies: 1999 JU3, Hayabusa-2's Target (2)

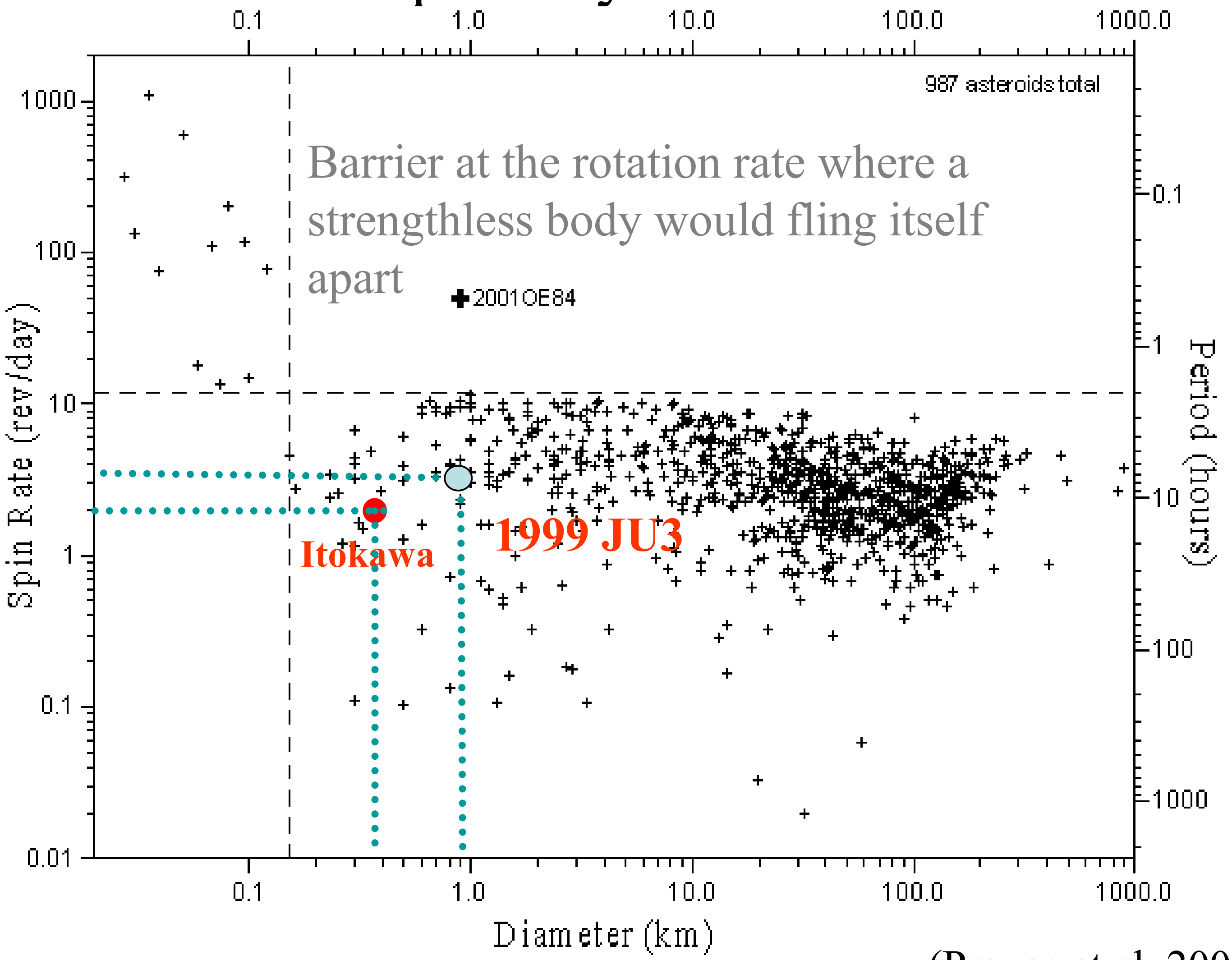
Geometric Albedo and Size Estimated from Space and Ground Observations



(Hasegawa, et al., 2008)

Remote Sensing Studies:
1999 JU3, Hayabusa-2's Target (3)

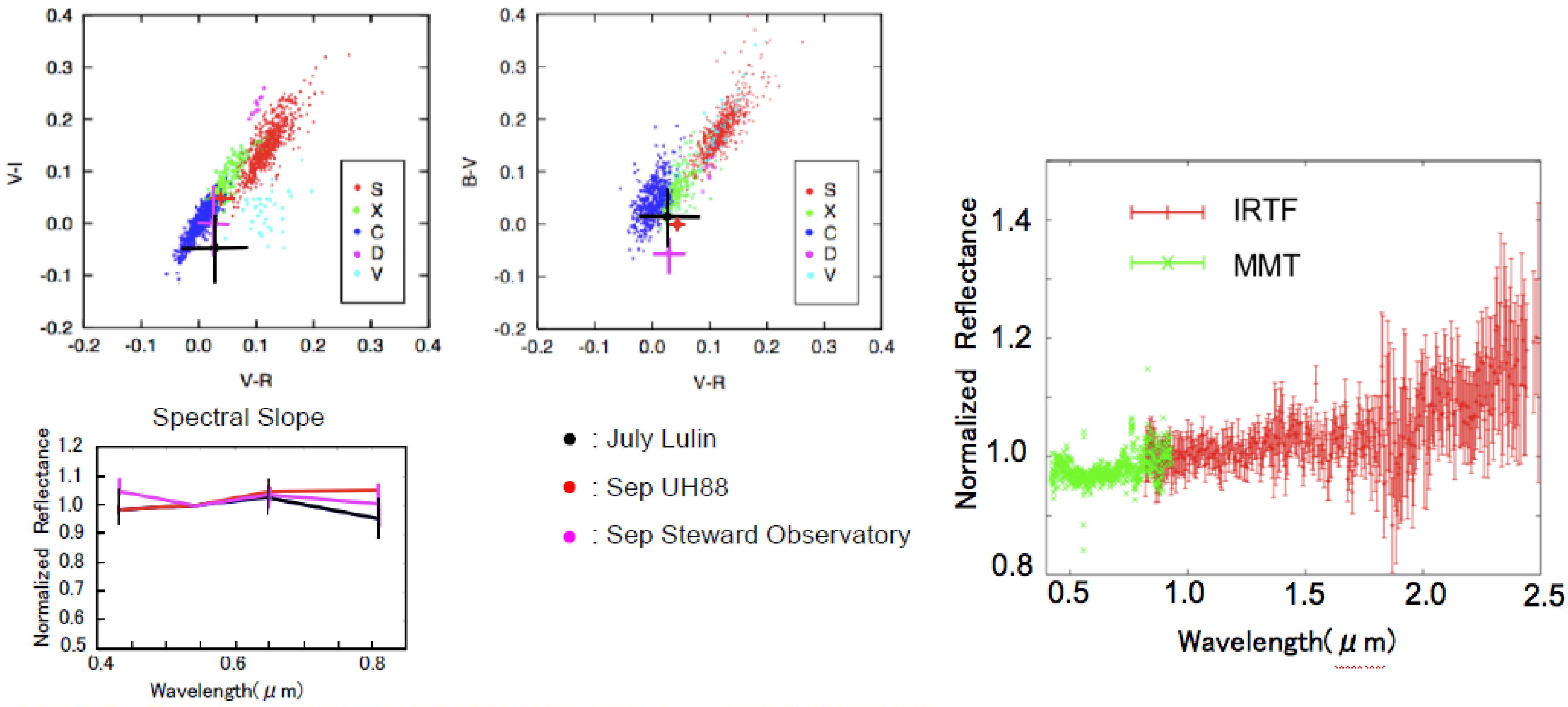
Internal Structure Implied by Rotational Periods and Sizes



(Pravec et al. 2002)

Remote Sensing Studies: 1999 JU3, Hayabusa-2's Target (4)

Spectral Type Defined from Ground Observations



(Kawakami, et al., 2008)

Cg Type = SMASS classification for the absence of the absorption feature at 0.7 μ m)

Remote Sensing Studies:
1999 JU3, Hayabusa-2's Target (5)
Surface Dichotomy Expected from Ground Observations

* Exhibits both absence and presence of absorption features similar to CM2 chondrites, implying two geological units (weathered and fresh?)

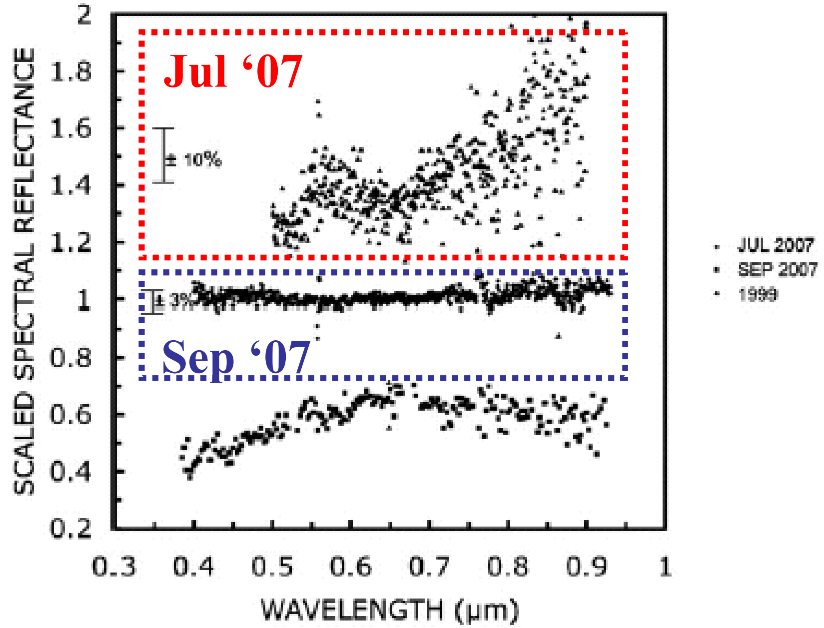


Figure 2. Relative reflectance spectra of NEA 162173 1999 JU3 obtained on (top to bottom) 2007 July 11, 2007 September 10/11 composite, and during its 1999 discovery apparition (Binzel et al. 2002). Spectra are scaled to 1.0 at 0.55 μm, and offset by a reflectance of 0.4 for clarity. Error bars represent average peak-to-peak scatter in the spectra.

(Vilas, 2008)

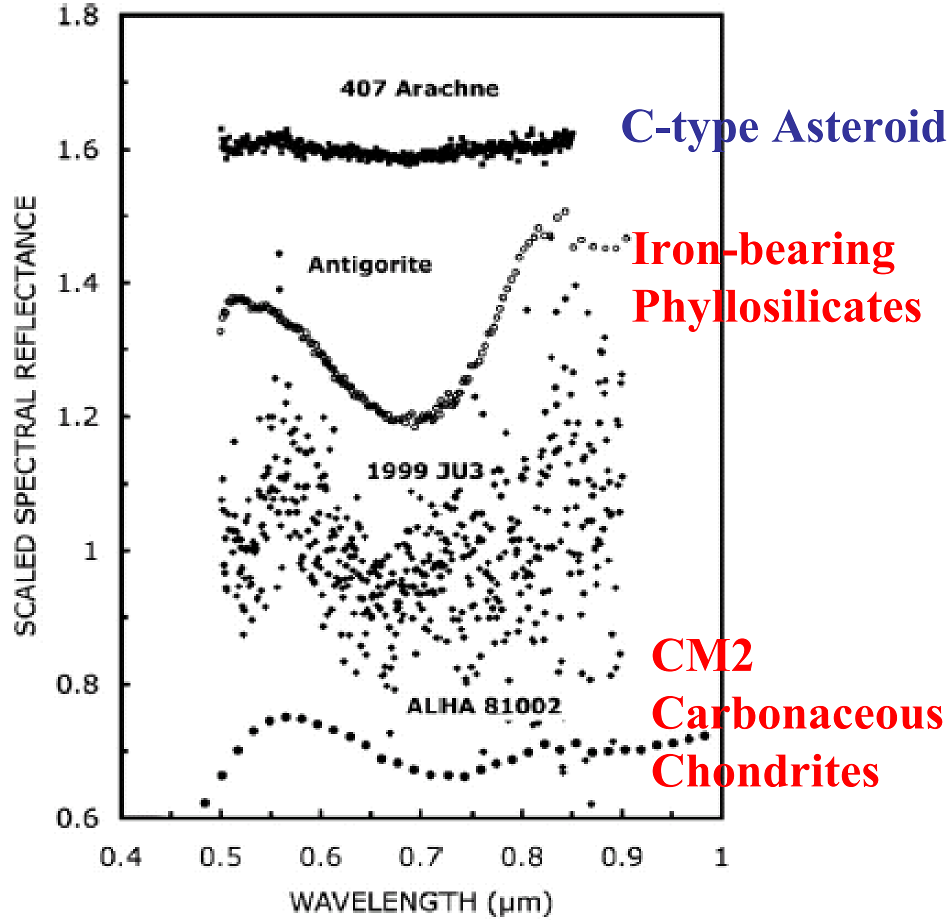
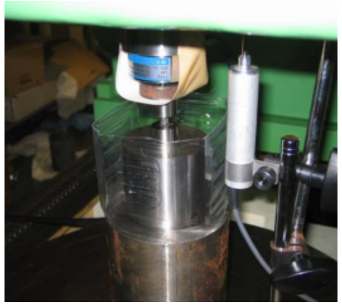


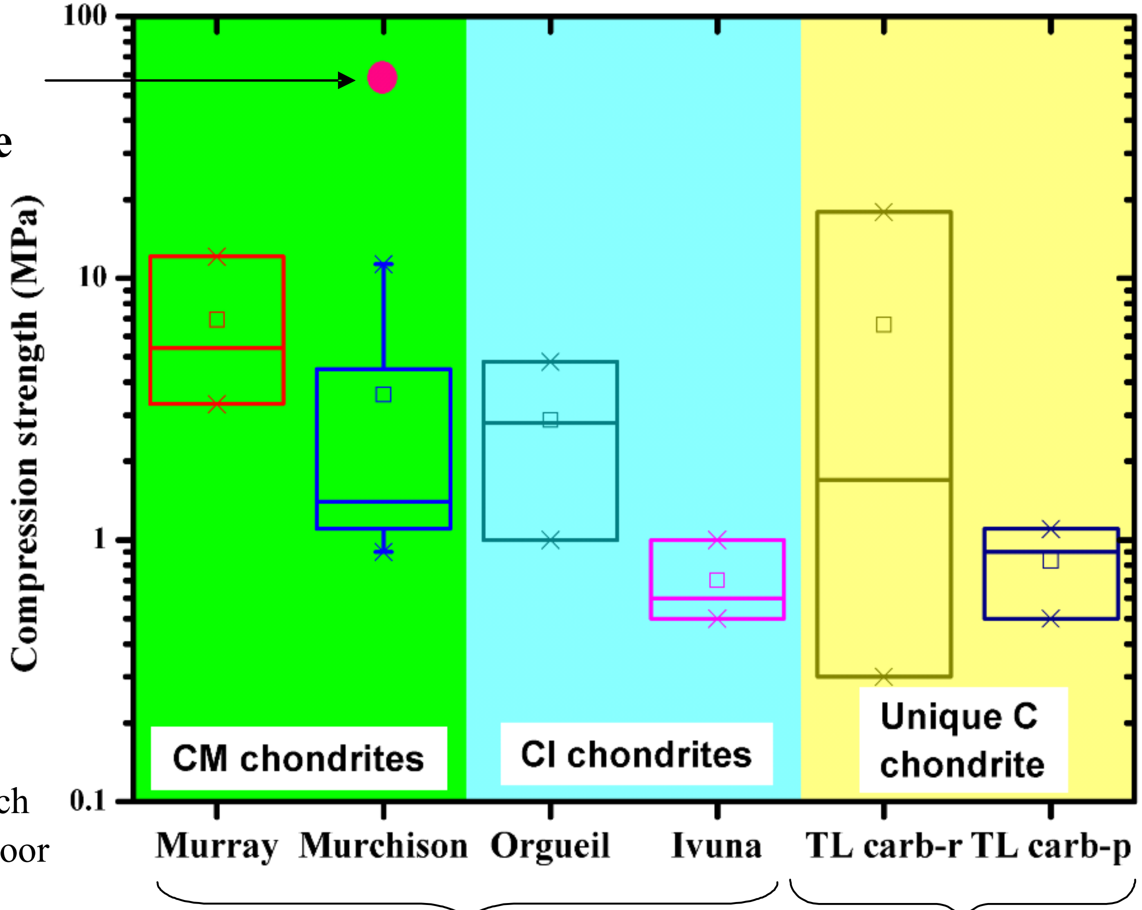
Figure 3. Relative reflectance spectra of C-class asteroid 407 Arachne (Vilas et al. 1998b), terrestrial phyllosilicate antigorite (King & Clark 1989), July spectrum of NEA 162173 1999 JU3 (this paper), and CM2 carbonaceous chondrite ALHA 81002 (Vilas et al. 1994), all showing the 0.7 μm absorption feature. Spectra are offset by 0.3 for clarity. A linear continuum defined by a least-squares fit to the 0.5–0.9 μm wavelength range has been removed from all spectra.

Meteoritic Studies: 1999 JU3, Hayabusa-2's Target (6)

Compressive Strength of Carbonaceous Meteorite Samples



5x10 mm Compressive Strength



TL: Tagish Lake
carb -r: carbonate -rich
carb -p: carbonate -poor

Probable parental asteroids	C-type asteroids	T- (or D-) type asteroid

(Miura, et al., 2009)

Target Asteroid : 1999 JU3
Orbital Parameters and Physical Properties

Rotation period: 0.3178 days (~7.6 hours)

(λ， β)＝(331, 20), (73, -62)

Axis ratio = 1.3 : 1.1 : 1.0 Kawakami Model Mueller Model

Size : 0.980 ± 0.029 km (Subaru COMICS)

Albedo : 0.037 ± 0.002 (Subaru COMICS)

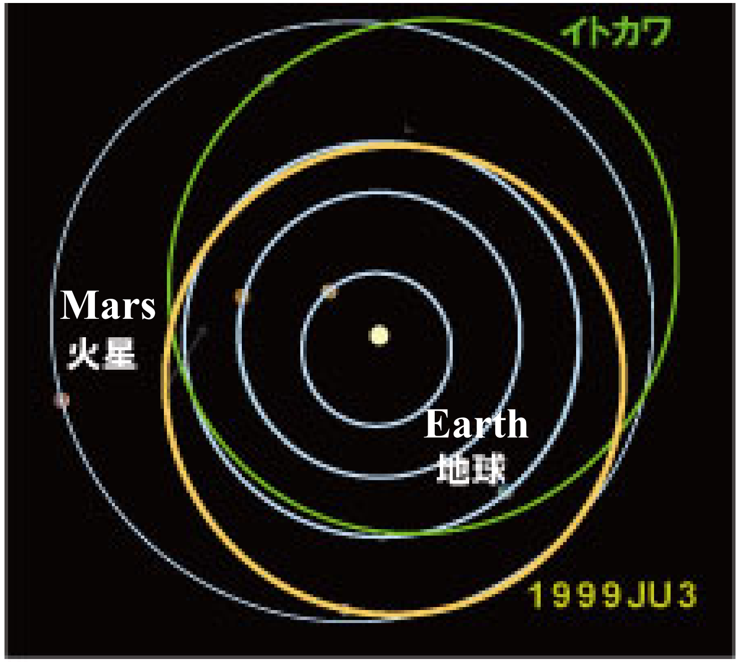
H=18.82 ± 0.021, G=0.110 ± 0.007

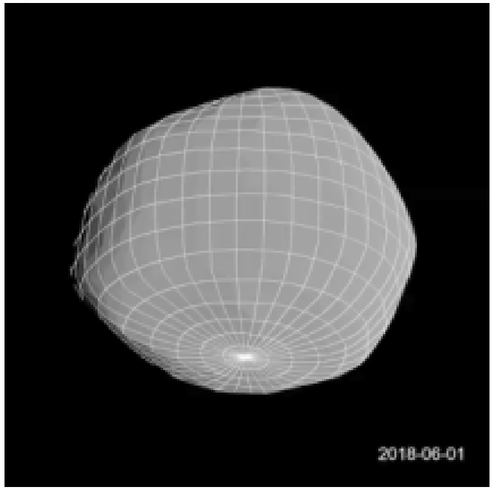
Type : Cg (SMASS: absence of the absorption at 0.7 μm)

Meteoritic Analog: Carbonaceous Chondrites

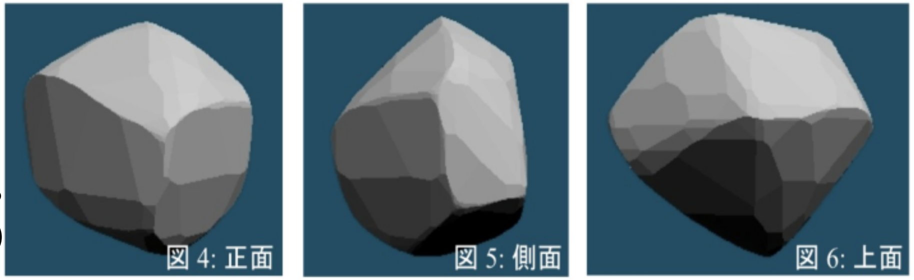
Orbit

Itokawa





(Mueller, et al.)



(Kaasalainen, et al., 2008)

COSPAR PPP Six Questions for the 1999 JU3 Sample Return Mission

Hayabusa-2's Past and Future Plan

- **Fiscal Year of 2011** : Hayabusa2 project was approved.
- **May 2011** : The status of project became officially Phase-B and the design of the subsystem and system has been continued.
- **January 2012** : Space Activities Commission (SAC) of the Government of Japan approved Hayabusa-2 mission. (SAC commenced its review in June 2011)
- **March 2012** : CDR of Hayabusa2 was finished. (March 7 : briefing, March 16 : Review)
- **Fiscal Year of 2012** : Manufacturing of subsystems started.
- ***May 2012:*** *NASA and COSPAR reviews for planetary protection*
- ***July 2012:*** *COSPAR PPP resolution to be granted, mandatory for landing operation cooperation with Australia*
- ***Jan. – Apr. 2013*** *: The first interface tests*
- ***Oct. 2013 – Sep. 2014*** *: FM integration tests*
- ***Dec. 2014*** *: H-IIA Launch at Tanegashima Space Center*

COSPAR Planetary Protection Policy Categories

Category I	**Flyby, Orbiter, Lander**	**Venus; Moon; Undifferentiated, metamorphosed asteroids, others TBD**
Category II	**Flyby, Orbiter, Lander**	**Comets, Carbonaceous Chondrite Asteroids, Jupiter, Saturn, Uranus, Neptune, Pluto/Charon, Kuiper Belt Objects, others TBD**
Category III	**Flyby, Orbiter**	**Mars, Europa, others TBD**
Category IV	**Lander**	**Mars, Europa, others TBD**
Category V	**Sample Return**	**Restricted:** **Mars, Europa, others TBD**
		Unrestricted: **Moon, Venus, others TBD**

COSPAR Planetary Protection Policy approved on 20 October 2002 and amended on 24 March 2005.

C-type Asteroids under Ib in the COSPAR Planetary Protection Policy Categories

I **No special containment and handling warranted beyond what is needed for scientific purposes**		**II** **Strict containment and Handling warranted**
Ia ***High Degree of Confidence***	***Ib*[1]** ***Lesser Degree of confidence***	
Moon **Io** **Dynamically new comets[2]** **Interplanetary Dust particles[3]**	**Phobos** **Deimos** **Callisto** **C-type asteroids (1999 JU3)** **Undifferentiated metamorphosed Asteroids (Itokawa)** **Differentiated asteroids** ***All other comets*** **Interplanetary dust particles[3]**	**Europa** **Ganymede** **P-type asteroid[4]** ***D-type asteroids*[4]** **Interplanetary dust Particles[3]**

[1] Evaluation on case by case basis.

[2] Samples from the outer 10 meter.

[3] Samples from the same parent bodies of this group.

[4] Limitation of available data led to a conservative assessment => need for containment

Amended by COSPAR March 2005 adopted from the Space Studies Board, National Research Council (US), Evaluating the biological potential in samples returned from Planetary Satellites and small Solar System Bodies, Task Group on Sample Return from small Solar System Bodies, National Academy of Science, Washington D.C., 1998.

Parameters Relevant to Assess the Potential for Presence of a Biological Entity in Returned Samples (NRC-Space Studies Board, 1998)

1. **Liquid water:** Liquid water may safely be considered a requirement for life on small solar system bodies, because the chemistry on which life is based must take place in solution, and there is no other plausible solvent.

2. **Energy sources:** A source of energy to support the origin and continuation of life in any environment is a thermodynamic necessity. For the extraterrestrial environment, the energy sources are both geochemical and photosynthetic.

3. **Organic compound:** Chemical building blocks for organic polymers must be available.

4. **Temperature:** The temperature limits for the survival of metabolically active cells (160 ° C) at 1 atm are likely to apply to extraterrestrial organisms also unless their biochemistry does not depend on the formation of amide, ester or phosphodiester bonds.

5. **Radiation intensity:** Extraterrestrial biopolymers are unlikely to differ greatly from terrestrial biopolymers with respect to radiation sensitivity.

6. **Comparison to natural influx to Earth:** Earth receives natural influx of extraterrestrial material, mainly in the form of cosmic dust. Some materials may be delivered in ways that shield it from sterilizing temperatures or radiation.

Six Questions for Assessing the Biological Potential of Small Bodies

Does the preponderance of scientific evidence indicate that there was never liquid water in or on the target body? — **Yes** →

↓ **No or Uncertain**

Does the preponderance of scientific evidence indicate that metabolically useful energy sources were never present? — **Yes** →

↓ **No or Uncertain**

Does the preponderance of scientific evidence indicate that there was never sufficient organic matter in or on the target body to support life? — **Yes** →

↓ **No or Uncertain**

Does the preponderance of scientific evidence indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperature? (i.e. >160 ° C) — **Yes** →

↓ **No or Uncertain**

Does the preponderance of scientific evidence indicate that there is or was sufficient radiation for biological sterilization of terrestrial life forms? — **Yes** →

↓ **No or Uncertain**

Does the preponderance of scientific evidence indicate that there has been a natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body? — **Yes** →

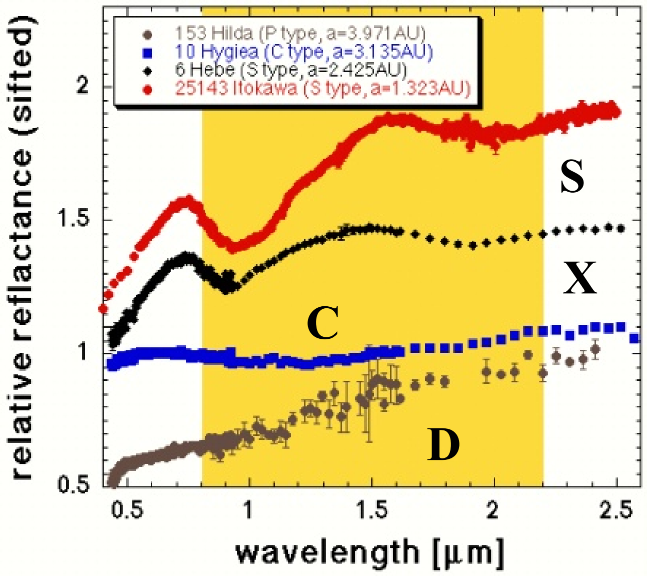
Yes → **No Special Containment Required Beyond What Is Needed for Scientific Purposes = "Unrestricted Earth Return"**

↓

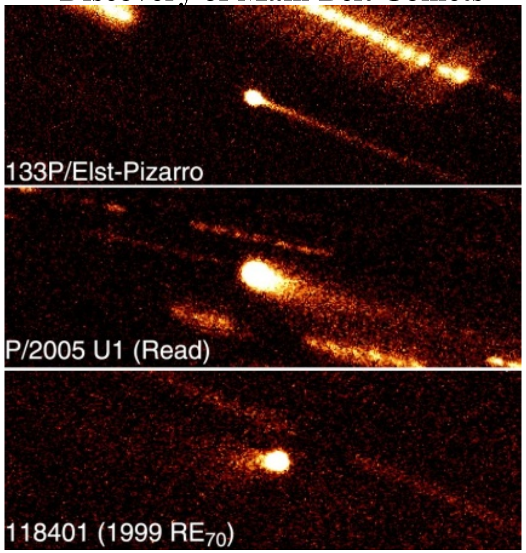
Strict Containment and Handling Required = "Restricted Earth Return"

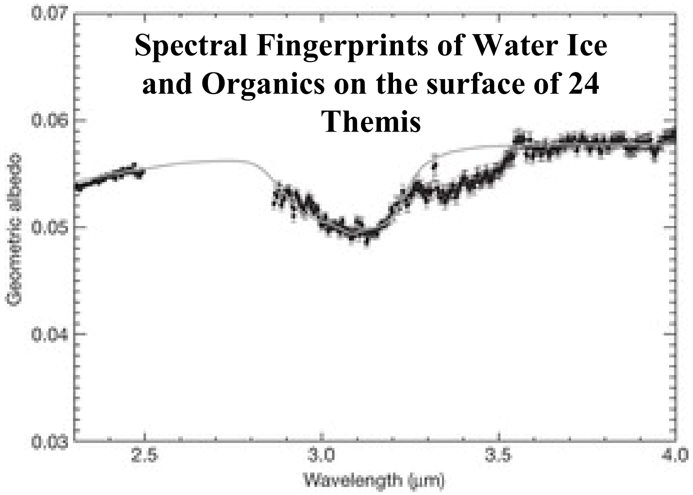
Rediscovering C-type Asteroids: Interactions among Minerals, Water and Organics

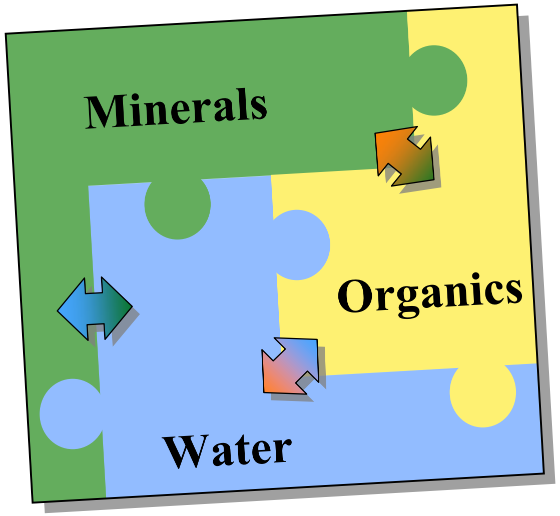
Heliocentric Distance and Taxonomic Types

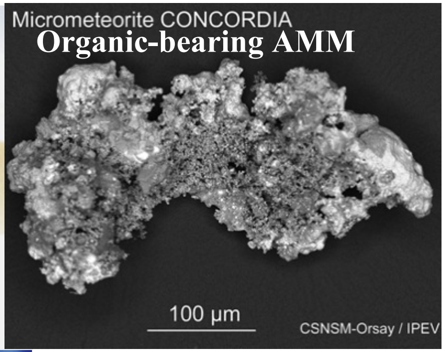


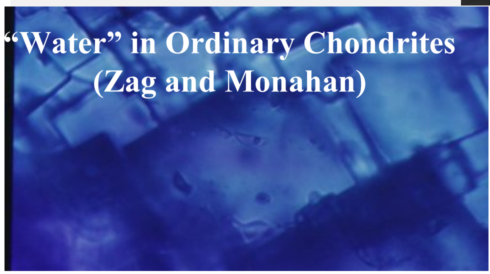
Discovery of Main Belt Comets











PPP Question # 1

Does the preponderance of scientific evidence indicate that there was never liquid water in or on the target body?

Answer #1: **"UNCERTAIN".** Recent discoveries provide mounting evidences that there was water on and in main belt C-type asteroids. However, "liquid" cases for NEOs of the same type are less certain.

- Aqueous alteration of primitive parent body material is well known from carbonaceous chondrite samples, in which liquid water penetration likely ended billions of years ago.
- Water ice and organic absorption signatures are recently reported for the surface of (24) Themis (C-type main belt asteroid).
- Discovery of "main belt comets" raises a possible water presence inside Co-location of hydrated minerals and organic compounds are suggested for carbonaceous chondrites.
- Dormancy period of hypothetic spores must be in the order of billions of years in a dry environment.

PPP Question # 2

Does the preponderance of scientific evidence indicate that metabolically useful energy sources were never present?

Answer #2: **"NO"**. Primitive meteoritic material could provide sufficient energy resources to potential life-forms

- Both photosynthetic and chemical processes are considered at the near earth space.
- Chemical reduction-oxidation (red-ox) reactions playing the key role
- Mineralic components like phyllosilicates, sulfides, phosphates, carbonates, silicates provide nutrients like S, P, Ca, Mg, K, Fe, Cl, etc.
- Mautner et al. (1997) reported that microbial life and plants have been grown on Murchison extracts

PPP Question #3

Does the preponderance of scientific evidence indicate that there was never sufficient organic matter (or CO_2 or carbonates *and* an appropriate source of reducing equivalents) in or on the target body to support live?

Answer #3: **"NO".** Carbonaceous meteorites contain organic material to support grow of organisms.

- Primitive meteoritic material usually contain a "few" percent of carbon
- Carbon phases are ubiquitous in primitive meteorites
- Tagish Lake meteorites have up to 5 % organic content (D/T-type?)
- Callahan et al. of NASA/GSFC (2011) reported some nucleobases such as DNA blocks (Adenine, Guanine) and nucleobasis analogs were extracted from Antarctic meteorites
- Organic inventory makes them scientifically interesting

PPP Question # 4

Does the preponderance of scientific evidence indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperatures (i.e. >160° C)?

Answer#4: **"NO"** for most of pristine materials as 1999 JU3 perihelion does not exceed the recommended temperature on its surface. **"YES"** for local heat maximums like impact craters.

- Usually in meteorites there is no evidence that this temperature has been exceeded significantly.
- Surface temperature usually do not exceed 130° C in NEO orbits, unless very close perihelion (e.g., 1989 UQ @ 0.67 AU >200° C).
- Impact processes create very local extreme temperatures.

PPP Question # 5

Does the preponderance of scientific evidence indicate that there is or was sufficient radiation for biological sterilisation of terrestrial life-forms?

Answer#5: **“YES”**. Given the extremely long exposure time with slow turn over rate, a sterilisation of the top surface regolith layer is assumed.

- Distinction between interior and surface regions are needed, with unknown factor of “gardening” time scale of regolith and gravel cases.
- Galactic cosmic rays and solar cosmic rays produces high radiation dose in surface layers 20 Mrad in less then 10 Myr (Clark, *et al.* 1999).
- Long-lived radio nuclides (K,U, Th) have an additional non-negligible contribution.

PPP Question #6

Does the preponderance of scientific evidence indicate that there has been a natural influx to Earth e.g. via meteorites, of material equivalent to a sample returned from the target body?

Answer#6: **"YES"**. With variations over time the asteroidal (and certainly NEO) material including carbonaceous chondrites has been collected on the Earth in large quantities.

- Spectral comparison to date considers carbonaceous chondrites as representative of C-type asteroids.
- There are indications that certain materials are under represented in the world's meteorite collection (e.g. brittle carbonaceous material).
- Today's incoming stream of meteoritic material may be not representative and may vary over time.
- For NEO, the material should have been already arrived at the Earth.

Six Answers for Assessing the Biological Potential of 1999 JU3

Does the preponderance of scientific evidence indicate that there was never liquid water in or on the target body?

UNCERTAIN — **Themis, Main belt comets and Zag/Monahan meteorites**

Does the preponderance of scientific evidence indicate that metabolically useful energy sources were never present?

NO

Does the preponderance of scientific evidence indicate that there was never sufficient organic matter in or on the target body to support life?

NO

Does the preponderance of scientific evidence indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperature? (i.e. >160 ° C)

→ **YES** **for surface craters**

NO **for pristine materials**

Does the preponderance of scientific evidence indicate that there is or was sufficient radiation for biological sterilization of terrestrial life forms?

→ **YES** **for long exposure**

NO **for freshly excavated interior**

Does the preponderance of scientific evidence indicate that there has been a natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body?

→ **YES** **Carbonaceous Chondrites and Cosmic Dust on the Earth**

CATEGORY V: Strict Containment and Handling Required

Hayabusa-2 Team's Position :
Outbound Planetary Protection Requirement
for the 1999 JU3 Sample Return

Category-2:

➔Degree of Concern:
Record of planned impact probability and contamination control measures

➔Range of Requirements:
Documentation only (all brief):
(1) PP plan
(2) Pre-launch report
(3) Post-launch report
(4) Post-encounter report
(5) End-of-mission report

Hayabusa-2 Team's Position :
Inbound Planetary Protection Requirement
for the 1999 JU3 Sample Return

Category-5:

(A) Restricted Earth Return

➔Degree of Concern :

- No impact on Earth or Moon
- Returned hardware sterile
- Containment of any sample

➔Range of Requirements :

- Category-2 documents +
- Pc analysis plan
- Microbial reduction plan
- Microbial assay plan
- Trajectory biasing
- Sterile or contained returned hardware
- Continual monitoring of project activities
- Project advanced studies/research

(B) Unrestricted Earth Return

➔Range of Requirements : None

Summary

- Hayabusa-2 is a C-type NEO sample return mission taking advantage of Hayabusa-1's heritage and new challenges.
- It will be launched in 2014, arrive at the target for observations and sample acquisition in 2018-19, and return to the Earth in 2020.
- 1999 JU3, Hayabusa-2's target is a ~1-km-sized, Cg-type NEO with 7.6 hours rotation, similar orbital parameters as Itokawa.
- COSPAR PPP resolution is needed in the summer of 2012 in order to proceed the preparation for landing co-ordination with Australian government; the COSPAR Alpbach colloquium is set for its discussion in May-June 2012.
- According to the most recent scientific knowledge combined, the Hayabusa-2 team considers the 1999 JU3 mission as Category-2 for the outbound and Category-5 "unrestricted" Earth return for the inbound.
- We welcome all your inputs at NASA-PPS and wish to continue as good collaboration with NASA as the Hayabusa-1.

Appendix

(FYI) Category V "Restricted Earth return" Requirements

Unless specifically exempted, **the outbound leg of the mission shall meet contamination control requirements to avoid "false positive" indications** in a life-detection and hazard-determination protocol, or in any search for life in the sample after it is returned. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later missions to that body.

Unless the sample to be returned is subjected to an accepted and approved sterilization process, the **sample container must be sealed after sample acquisition**, and a redundant, **fail-safe containment with a method for verification of its operation before Earth-return shall be required.** For unsterilized samples, the integrity of the flight containment system shall be maintained until the sample is transferred to containment in an appropriate receiving facility. **Three individual layers of bio-sealing of sample container are required.**

The mission and the spacecraft design must provide a method **to "break the chain of contact" with the small body.** No uncontained hardware that contacted the body, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the the body's environment shall be provided during sample container loading into the containment system, launch from the body, and any in-flight transfer operations required by the mission.

Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving the body or its environment for return to Earth; and 3) prior to commitment to Earth re-entry.

For unsterilized samples returned to Earth, **a program of life detection and biohazard testing, or a proven sterilization process,** shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

A quarantine facilities are required and corresponding procedures for sample handling to be developed.

Planetary Protection Requirements

Sample Return - ***unrestricted***

- ***Documentation requirement only***

Sample Return - ***restricted***

- ***End to end documentation and reviews***
- ***Severe impact on technological requirements and AIV process***

  e.g. redundant fail safe biological containment (3 biological barriers)
- ***Returned material considered as biohazard and infectious***

  e.g. dedicated sample receiving facility

Etc.

Cf. COSPAR Planetary Protection Panel Resolution in 2002 for Itokawa, S-type NEO

"The committee heard presentation on the MUSES-C mission, and on the nature of the MUSES-C target body, 1998SF36. We have evaluated the mission for planetary protection requirements. Based on the framework presented in Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making, The Committee affirms that the target body belongs to class Ib. After discussion of this mission and the target body *Committee recommends that no special containment for sample returned from 1998SF36 is required for the purpose of planetary protection,* provided that subsequent information obtained prior to sample return remains consistent with the Classification of that body *as an undifferentiated metamorphosed asteroid.* As such, we recommend that for NASA purposes, the mission is designated Planetary Protection Category V, *"unrestricted Earth return" ".*