Hayabusa2

SBAG, Washington DC, USA
29 July 2014

Presented by Paul Abell
H. Kuninaka, N. Inaba, Y. Tsuda, M. Yoshikawa (JAXA)
Current Status

- We are now doing final integration test, which will be continued to September.
- Then the spacecraft is shipped to Tanegashima Space Center.
- The launch is scheduled in the winter of 2014.
Objectives: Hayabusa vs Hayabusa2

Hayabusa

Technological Demonstrator
- Round-trip to asteroid
- Sample return

Engineering
- Ion engine
- Autonomous navigation
- Sample collection
- Reentry capsule

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

Hayabusa2

1. Science
- Origin and evolution of the solar system
- 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.

C-type Asteroid

S-type Asteroid
Hayabusa2 Mission Outline

Launch 2014

July 2018: Arrival at 1999 JU3

Sample analysis

Earth Return

Dec. 2019: Departure

Dec. 2020

Summer 2018 – Winter 2019

- In-situ remote science
- Rovers deployment
- Surface Sampling
- Impact

2014
Hayabusa2 Mission CG
External View of Spacecraft (1/2)

- Deployable Camera (DCAM3)
- Xband HGA
- Xband LGA
- Xband MGA
- Kaband HGA
- Solar Array Panel
- Star Trackers
- Near Infrared Spectrometer (NIRS3)
- Reentry Capsule
- Sampler Horn
- LIDAR
- ONC-W2

Size: 1m × 1.6m × 1.25m (body)
Mass: 600kg (Wet)
External View of Spacecraft (2/2)

Ion Engine
RCS thrusters ×12
ONC-T, ONC-W1
 Thermal Infrared Imager (TIR)
Small Carry-on Impactor (SCI)
Target Markers ×5

DLR MASCOT Lander
MINERVA-II Rovers

+Z
+X
+Y
# Spacecraft System Specifications

| Structure            | -1.6m × 1.0m × 1.4m (Height) box structure with two fixed SAPs  
|                      | - Mass 600kg (wet), 500kg (dry) |
| Data Handling System | - COSMO16 based DHU-PIM bus system  
|                      | - Onboard autonomous command generation feature  
|                      | - 1Gbyte Data Recorder |
| Attitude and Orbit Control System | - HR5000S based processor, Double redundant.  
|                      | - 4 Reaction Wheels, 2 IRUs, 2 Star Trackers (STT), 4 Coarse Sun Aspect Sensors (CSAS), 4 accelerometers (ACS).  
|                      | - Sensors for Proximity Operation LIDAR, LRF, 5 Target Makers (TM), Flash lamp (FLASH)  
|                      | - Optical Navigation Cameras (ONC) Wide: ONC-W1, ONC-W2 (FOV 54deg × 54deg, 1Mpix)  
|                      | - Telescopic: ONC-T (FOV 5.4deg × 5.4deg, 1Mpix, 5 band filter) |
| Propulsion System    | RCS  
|                      | - Bi-propellant hydrazine system  
|                      | - 20N thruster × 12.  
|                      | IES  
|                      | - Xe microwave discharge ion engine system  
|                      | - Maximum thrust 28mN, Isp=2800sec.  
|                      | - 4 thruster heads on gimbaled stage  
|                      | - 3 operative at once (4/3 redundant) |
| Communication System | - X-band TT&C (Coherent X-up/X-down), 8bps-32Kbps, Double redundant.  
|                      | - Kaband Telemetry (Coherent X-up/Ka-down), 8bps-32Kbps  
|                      | - Normal/Regenerative Ranging System  
|                      | - DDOR support  
|                      | - 1 X-HGA, 1 Ka-HGA, 1 two-axis gimbaled X-MGA, 3 X-LGA |
| Power System         | SAP  
|                      | - 1.4kW@1.4AU, 2.6kW@1AU.  
|                      | BAT  
|                      | - Li-ion Battery 13.2AH.  
|                      | Power Bus  
|                      | - Series Switching Regulator (SSR) System, 50V Bus. |
| Mission Payload      | - Sampler Horn (SMP)  
|                      | - Small Carry-on Impactor (SCI)  
|                      | - Near Infrared Spectrometer (NIRS3)  
|                      | - Thermal Infrared Imager (TIR)  
|                      | - 3 Rovers (MINERVA-II-1A/1B/2)  
|                      | - Lander (MASCOT)  
|                      | - Deployable Camera (DCAM3)  
|                      | - Reentry Capsule (CPSL) |
Science Instruments

• **Sampler Horn**
  – Increased sample container rooms (2→3 rooms)
  – Metal seal adopted for gas-sealing performance
  – Several improvements in mechanical design to increase yield performance

• **NIRS3 (Near Infrared Spectrometer)**
  – Newly developed for HYB2
  – Observation wavelength 1.7-3.4µm. (Water)
  – Passive cooling

• **TIR (Thermal Infrared Imager)**
  – Planet-C (AKATSUKI)-derived component
  – Observation wavelength 7-14µm. (Thermal distribution, Hydrated minerals distribution)

• **Lander (MASCOT)**
  – Developed and provided by DLR
  – 10kg surface exploration lander
  – Detail observation of local surface (MARA, MicrOmega, MAG, CAM)

• **Rover (MINERVA-II 1A / 1B / 2)**
  – Developed by JAXA and a Japanese university consortium
  – Three 1.5kg class surface exploration rovers

• **Optical Navigation Cameras (W1/W2/T), LIDAR**
  – Multipurpose components both for bus and scientific operation
  – ONC: Global mapping/asteroid relative navigation, LIDAR: altimeter/gravity determination

• **Small Carry-on Impactor (SCI), Deployable Camera (DCAM)**
  – 18kg kinetic impact system (detonator+Cu liner+Electronics), 2kg impact mass at 2km/s impact speed.
  – Impact observation by IKAROS-derived DCAM (remote camera)
Trajectory Design

Earth Departure: 2014
Earth Swing-by: 2015/12
1999JU3 Arrival: 2018/7
1999JU3 Dep.: 2019/12
Earth Reentry: 2020/12

Departure C3=21km²/s²
IES Total Impulse=2km/s
Reentry Speed=11.6km/s

Total Flight Time=6yr
(Cruising 4.5yrs)
Total Powered Flight Time =1.5yr

Sun and Earth fixed rotational coordinate
Sampling Operation Sequence

1. Leaving HP, Starting GCP-NAV (Ground/Onboard Hybrid Navigation)
2. Entering Autonomous Mode
3. Deploying Target Marker
4. Aligning Attitude to Local Surface
5. Touch Down
6. Escape ΔV

Alt.20km
Alt.100m
Alt.30m
Alt.0m

1999JU3
Artificial Crater Generation Operation

(a) high speed debris
(b) high speed ejecta
(c) low speed ejecta
**Target : (162173) 1999 JU₃**

- **C-type** near-Earth asteroid
- **Diameter:** 0.9 km (nearly spherical?)
- **Hydrated minerals, organic matter?**
- **Origin:** inner MB, $\nu_6$ secular resonance
  - Erigone Family ($\sim$300Ma)?

---

**Origin of 1999 JU₃**

- 92% $\nu_6$
- 8% 3:1

---

**Data from Vilas 2008, Sugita+ 2012, Abe+ 2008**

---

**Orbit Parameters**

- $a = 1.19$ AU, $T = 1.30$ yr
- $q = 0.96$ AU, $Q = 1.42$ AU
- $e = 0.19$, $i = 5.88^\circ$

---

**Graphs**

- **Relative Reflectance**
  - **The largest member of Erigone Family**
  - **Belongs to another low-albedo family**

---

**Images**

- Earth, Mars, 1999 JU₃ orbit path

---

**Authors**

- P. Michel and M. Delbo 2010
Physical Properties of 1999 JU3

Observation results: by M. Ishiguro & D. Kuroda (As of 2014 July)

- **Photometric Properties**
  - Rotational period: $7.6312 \pm 0.0010$ hr (*1)
  - $H_0$ in V-band: $19.25 \pm 0.03$ (*2)
  - G parameter ($\alpha < 30^\circ$): $0.13 \pm 0.02$ (*2)
  - Geometric albedo: $0.047 \pm 0.003$ (*1-2)

- **Spectroscopic Properties**
  - Spectral type: C-type (*3-6)
  - Absorption around 0.7 $\mu$m (*4)
  - Rotational variability: Not obvious (*5-6)

- **Thermal Properties** (*1)
  - Effective diameter: $875 \pm 15$ m
  - Thermal inertia: $250 \pm 50$ J m$^{-2}$ s$^{-0.5}$ K$^{-1}$
  - Pole orientation: Probably retrograde (ongoing)

Science of Hayabusa and Hayabusa2

Study of the origin and evolution of the solar system

- Planetesimal formation: Destruction and accumulation
- Thermal evolution from planetesimal to near earth asteroid
- Diversification of organics through interactions with minerals and water on planetesimal
- Material circulation in the early solar system

4.6 billion years ago...

Molecular cloud
Proto solar system disk
Solar system

The science of Itokawa
Mineralogy, Topography, Structure, Regolith, Meteoroid
Space weathering, Impact, Cosmic ray, Solar wind

In addition to the science of Itokawa...
Organic matter, H₂O

1999 JU3
HAYABUSA
HAYABUSA2
Itokawa
Boulder
Earth
Hayabusa2 will solve the "Missing Zone"

History of Asteroid

4.6 billion years ago

Molecular cloud core → Protoplanetary disk → Formation of planetesimal → Formation of parent asteroid

- Condensation melt and evaporation of dust
- Adhesion/mixture
- Formation of CAI*
- Formation of Chondrule

Missing Zone

Collision and growth of planetesimal → Collisional destruction and re-accumulation

Formation environment and composition of parent asteroid → Metamorphism and differentiation by internal heating

Asteroid

Heating space weathering → Near earth asteroid

Meteorite

Orbital evolution

Dust (mineral, H₂O, Organic matter)

Planetaryesimal

Catastrophic disruption

Differentiation

Rubble pile

*CAI: Calcium-aluminium-rich inclusion
International Collaboration Structure

**To NASA**
- Membership of Hayabusa2 scientific committee
- Asteroid sample provision
- Accommodation of appointed personnel on mission ops.
  and so on

**To JAXA**
- Heat shield test
- Deep Space Network support
- Radiometric navigation support
- Airborne Observation
- Cooperation with OSIRIS-REx
  and so on

**Australia**
- Landing authorization

**Europe**
- Small Lander “MASCOT”
- ESTRACK tracking support
Hayabusa2 Joint Science Team (HJST) Meeting

1st: November 26-27, 2012

2nd: September 19-20, 2013

3rd: March 18, 2014
Collaboration with OSIRIS-REx Team

Hayabusa2

C-type

(162173) 1999 JU3

Collaborations
Science
Education
Outreach
...

OSIRIS-REx

B-type

(101955) Bennu
Summary

- Hayabusa2 is the modified spacecraft based on the lessons learned of Hayabusa, and it will aim for much more advance science to understand the origin and evolution of the solar system.

- We are now in the final stage in the integration of the spacecraft, and it will be launched in the winter of 2014.

Thank you!