Hayabusa2 Status

SMPAG
Space Mission Planning Advisory Group 10th Meeting
STSC, UN-COPUOS, Vienna
January 31, 2018
Makoto Yoshikikawa (JAXA)
Japan's Asteroid Explorations
Past, Present, and Future

Starting Point
1985

Hayabusa
2003-2010

Hayabusa2
2014-2020

Future missions
(under discussion)

Jupiter Trojans

OKEANOS

DESTINY+

Phaethon
The impactor collides to the surface of the asteroid.

The sample will be obtained from the newly created crater.

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

Launch
03 Dec. 2014

Arrival at Ryugu
June-July 2018

Earth swing-by

03 Dec. 2015

Sample analysis

Earth Return
Nov.-Dec. 2019 : Departure

Nov.-Dec. 2020

New Experiment

Mission Scenario of Hayabusa2
Hayabusa2 Spacecraft

Science Instruments

ONC-T
LIDAR
NIRS3
TIR

Small Lander and Rovers

MASCOT
by DLR and CNES

MINERVA-II
II-1A
II-1B
II-2
II-1 : by JAXA MINERVA-II Team
II-2 : by Tohoku Univ. & MINERVA-II consortium

Ion Engine
RCS thrusters × 12
ONC-T, ONC-W1

MASCOT Lander
MINERVA-II Rovers

Target Markers × 5

Size: 1m × 1.6m × 1.25m (body)
Mass: 609kg (Wet)
Hayabusa2 and its Family

Separable payloads
Science for Wide Scale Range

On-site remote sensing

Observations on the surface

Return sample analyses

ONC (T, W1, W2)
LIDAR
NIRS3
TIR

SCI
DCAM3
Sampler

MASCOT
MINERVA-II (1A, 1B, 2)

Ground based facilities

log_{10} L [m]
Present Status of Hayabusa2 (as of Jan. 31, 2018)

• Traveled 2.82 billion km (w.r.t heliocentric inertial frame)
• Solar distance 1.22au.
• Earth distance 2.08au (RTLT=35min.)
• Distance to Ryugu 2.36 million km (0.024au)
Recent / Near Future Cruise Operation

<Recent Ops.>
2017
Apr.15 2nd IES Burn completed
Apr.25-26 IES trim burn
May16-28 Jupiter/star calibration
May.30-Jun.1 RCS test burn
Sep.5 Spacecraft clock reset
Jul.18-Nov.14 Science instruments program update
Nov.18,28 DSN-SSOC realtime Doppler transfer test
Dec.2 DSN-UDSC uplink transfer test
Dec.26-27 IES test burn

2018
Jan.10 3rd term IES Burn Start

<Near Future Ops.>
~May Ryugu first light
Jun.5 IES burn completes. OpNav begins.
Recent / Near Future Cruise Operation

<Recent Ops.>

2017

OpNav Rendezvous Phase start (Jun.5, 2018)

Ryugu Arrival (Jun.21-Jul.5, 2018)

Jun.5 IES burn completes. OpNav begins.
### Proximity Operation Plan

**Typical plan, Actual schedule fixed after arrival**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Approach Guidance Start (250km)</td>
</tr>
<tr>
<td>6</td>
<td>Asteroid Arrival (20km)</td>
</tr>
<tr>
<td>7</td>
<td>Ion Engine Stop</td>
</tr>
<tr>
<td>8</td>
<td>Gravity Measurement Descent (1km)</td>
</tr>
<tr>
<td>9</td>
<td>Mid Altitude Observation Descent 1 (5km)</td>
</tr>
<tr>
<td>10</td>
<td>TD1 Rehearsal 2 (50m)</td>
</tr>
<tr>
<td>11</td>
<td>MINERVA-II Deployment (50m)</td>
</tr>
<tr>
<td>12</td>
<td>TD1 Rehearsal 1 (100m)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Conjunction Period</td>
</tr>
<tr>
<td>2</td>
<td>Mid Altitude Observation Descent 2 (5km)</td>
</tr>
<tr>
<td>3</td>
<td>TD2 Rehearsal 2 (50m)</td>
</tr>
<tr>
<td>4</td>
<td>TD2 Rehearsal 1 (100m)</td>
</tr>
<tr>
<td>5</td>
<td>Pre-Point TD Campaign (max 4 descent)</td>
</tr>
<tr>
<td>6</td>
<td>Crater Search Descent (1km)</td>
</tr>
<tr>
<td>7</td>
<td>Kinetic Impact (500m)</td>
</tr>
<tr>
<td>8</td>
<td>Pre-Impact Descent (1km)</td>
</tr>
<tr>
<td>9</td>
<td>MINERVA-II Deployment (50m)</td>
</tr>
<tr>
<td>10</td>
<td>Asteroid Departure</td>
</tr>
<tr>
<td>11</td>
<td>Hot Asteroid Period</td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

Spacecraft ‘hovers’ at 20km altitude. All descent ops listed here are **critical** operations.
Proximity Operation Training

Landing Site Selection (LSS) Training

- **Purpose:** Verification of LSS process
  - Decision making framework/criteria, Tools and interface, ...
- **Trainee**
  - 100+ participants, JAXA engineering, Science (International), MASCOT team
- **Training data**
  - Asteroid images (CG) based on actual observation operation plan
  - Science data (Thermal, near infra-red, LIDAR data, gravity, ...)
  - Navigation data (position & velocity of S/C), Attitude data.

Real-Time Integrated Operation (RIO) Training

- **Purpose:** Real-time operation training, Verification of ground support tools
  - Touchdown operation, Impact operation, rover landing...
- **Trainee:** all the operation staffs
- **Training data**
  - Asteroid images (CG, real-time)
  - Telemetry data (with communication delay)
Fictitious Ryugu = Ryugoid

• Virtual asteroid ‘Ryugoid’ in place of mysterious Ryugu.
• Assume from the formation history of Ryugoid. The shape and all the other properties were derived from the history.
• Each property was Intendedly deviated from known Ryugu property.
• The rotation state is randomly selected from public via Twitter.
• Shape model: 25cm resolution, 370 million polygon.
• Observation data generated based on actual operation plan & actual instruments performance.
  – Generates attitude/trajectory simulation data based on operation plan
  – Observation data and their ancillary data generated based on the simulation data.
  – Goes through all the ground pipe line process as it really is.
Descent start (-1 m/s)
↓
Slow Down (-0.1 m/s)
↓
60m arrival/release
↓
Ascent to 3km
↓
Hovering
Target Asteroid: 1999 JU3 = Ryugu

Asteroid (162173) 1999 JU3

- Discovered in May 1999 by LINEAR Team
- Shape: almost spherical
- Size: 900 m
- Rotation period: 7.6 h
- Pole orientation (320°, -40°): current estimate
- Albedo: 0.05
- Type: Cg

(Data by Viras 2008, Sugita+ 2012, Abe+ 2008)

(Spectrum)

(Brightness vs. Rotational phase)

(Data by Kim, Choi, Moon et al. A&A 550, L11, 2013)
“Imagining Ryugu” Space Art Contest

http://www.hayabusa2.jaxa.jp/topics/20171227_e/

Can you predict Ryugu appearance better than scientists?
Summary

• Hayabusa2 is operated as scheduled, and it will arrive at its target asteroid Ryugu in June or July of 2018.
• We have been carrying out many training for the proximity operations.