Flight Status of Hayabusa2:
Asteroid Sample Return Mission to C-type Asteroid Ryugu

Small Bodies Assessment Group
16th Meeting

Jan. 12, 2017

Yuichi Tsuda, Makoto Yoshikawa
(ISAS/JAXA)
December 3, 2016
Happy 2nd Birthday of Hayabusa2!
Hayabusa2 is the 2nd Japanese sample return mission to small body. JAXA launched Hayabusa2 in 2014, which will explore the C-type asteroid *Ryugu (1999 JU3)*, and will return back to the Earth in 2020.

- **Round-trip mission**
  - High specific impulse ion engine for continuous-thrust trajectory control.
- **In-situ science at “Ryugu”**
  - 1.5year proximity operation at “Ryugu”
  - Four landers, four remote science instruments.
- **Touch down & sample collection**
  - Two normal touch down, one pin-point touch down (to the artificial crater) are planned.
- **Artificial crater generation**
  - Kinetic impact on the asteroid surface to create a 2m-class crater.
  - Sub-surface structure of the asteroid can be acquired.
The spacecraft carries an impactor. The impactor collides to the surface of the asteroid. The sample will be obtained from the newly created crater.

**New Experiment**

Launch

Dec. 3, 2014

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

June-July 2018 : Arrival at Ryugu

Dec. 3, 2015

Earth swingby

Earth Return

Nov.-Dec. 2020

Nov.-Dec. 2019 : Departure

Sample analysis

Mission Scenario of Hayabusa2

Dec. 3, 2014

Earth swingby

2019

The impactor collides to the surface of the asteroid.

The sample will be obtained from the newly created crater.
Present Status of Hayabusa2 (as of Jan. 12, 2017)

- Traveled 1.91 billion km (w.r.t heliocentric inertial frame)
- Solar distance 1.02AU, Earth distance 1.10AU (RTLT=1099sec).
- 2nd Ion Engine powered cruise phase was started on Nov.22, 2016. (until next May)
Operation Summary (2016)

- Mar. 23 - May 20: 1st ion engine powered cruise
  - $\Delta V=127\text{m/s}$, IES 3 heads, 798hr drive
- June 1 - 9: Mars observation (ONC, NIRS, TIR)
  - NIRS: 139hr observation, ONC: 15 observations
- June - July: Communication test
  - DSN-DSN (GDS-CAN) uplink transfer (June 22-23)
  - DSN Ka test (June 29, July 1-3)
  - Ka-band DDOR Operation (July 1-2)
  - ESA Ka Compatibility test (July 5, 7, 8, 21)
- July 1 - Aug. 15: Ryugu observation campaign
- Aug. 8 - Oct. 8: OWC (One wheel control / solar sail mode)
- Oct. 9 - 16: Mars observation by STT (for OPNAV)
- Oct. 16 - 22: ONC-T calibration (Star observation)
- Oct. 28: OME-E software update
- Nov. 2,4: DSN-JAXA (GDS-UDSC) uplink transfer
- Nov. 8 - 13: MASCOT operation
- Nov. 22 - (May, 2017): 2nd ion engine powered cruise
  - $\Delta V=440\text{m/s}$, IES 3 heads, 2800hr drive (plan)
• **HYB2-DSN Ka-band test (June 29 - July 3)**
  – Longer distance Ka link (50 million km) with DSN demonstrated successfully.

• **HYB2-ESTRACK Ka-band compatibility test (July 5-8)**
  – Successfully established Ka link with MLG for the first time.
  – Ka TLM, X/Ka RNG, Ka DOR are all good.
  – *Now all the stations are ready for proximity operations!*

• **Inter-agency (NASA-ESA-JAXA) Ka-band DDOR (July 1-2)**
  – Ka-band DDOR operation using MLG-GDS baseline was conducted.
  – *Japanese spacecraft, European and American stations.* All three assets from different agencies. (First time in the world!)
  – Received high appraisal by CCSDS and JPL as a successful case of the DDOR cross support operation standardization.
Uplink Transfer Technique demonstration (June, Nov. 2016)

- **1st Uplink Transfer Technique test (June 22-23)**
  - Seamless uplink (without sweep) were successfully demonstrated between DSN-DSN.

- **2nd Uplink Transfer Technique test (Nov. 2-4)**
  - Seamless uplink were successfully demonstrated between UDSC (Usuda, Japan) and GDS (Goldstone, USA).

Uplink OFF/ON handover timing between two stations is synchronized perfectly.

Succeeded in receiving the uplink signal seamlessly from the two stations.

**Uplink power from the ground stations**

**Received signal level by the spacecraft**
Mars observation (Oct. 9-16, 2016)

- Mars was observed by Star Tracker (STT) in raw image dump mode.
- This is a practice for OPNAV (Optical Navigation), and we confirmed the procedure to measure the position of Mars using background stars.

Image of Mars obtained by STT (Oct. 11 & 16, 2016)
Two images are overlapped
Proximity Operation Training in 2017

- **Landing Site Selection (LSS) Training (2Q-3Q, 2017)**
  - Purpose: Verification of LSS process
    - Decision making framework/criteria, Tools and interface, ...
  - Trainee
    - JAXA engineering, Science (International), MASCOT team
  - Training data
    - Asteroid images (CG), HP observation, Mid. Altitude observation
    - Science data (Thermal data, NIRS data)
    - Navigation data (position & velocity of S/C), Attitude data.

  - Purpose: Real-time training, Verification of tools
    - Touchdown operation, Impact operation, ...
  - Trainee: GNC operators
  - Training data
    - Asteroid images (CG, real-time)
    - Telemetry data (with communication delay)
Hayabusa2 Operation Organization Structure

HYB2 Operation Team

Engineering Team

Subsystem Teams

Proximity Phase Planning Team (P3T)

Technical Interface Meetings

Science Team

Science Meeting + HJST

Science Instruments Teams

interdisciplinary Science Team

Science Operation Working Group (SOWG)

Operation Training Planning Team

LSS Analysis & Assessment Team

International SOWG (iSOWG)

HYB2 Sample Allocation Committee (HSAC)

- • Engineering LSS & operation training planning
  • with DSN: Navigation & stations assignment
  • with DLR/CNES: MASCOT ops. & LSS
- • IRSG (Regolith), MSASG (Multi-scale), SMG (Shape Model)
- • Science operation training planning
- • Scientific LSS process
- • MASCOT science interface
HJST meeting (Dec. 1-2, 2016)

HJST : Hayabusa2 Joint Science Team

• The 7th meeting was held on Dec. 1-2, 2016 in JAXA Sagamihara Campus.
• More than 90 people were participated from USA, Germany, France, Italy, UK, Australia, Korea, and Japan.
• The items discussed were as follows:
  • Current status of the mission, instruments, science WGs
  • Proximity operations
  • Sample analysis, curation
  • Science policy
  • Observations of Ryugu
  • Science studies
  • etc

Related meetings:
• 1st IRSG (International Regolith Science Group) Workshop (Nov. 29-30, 2016)
• 1st Multi-scale Asteroid Science group meeting (Dec. 3, 2016)
Ryugu Observation Campaign (July 1 – Aug. 15)

- On July 25, 2016, Ryugu was in opposition.
- We organized "Ryugu observation campaign" from July 1, 2016 to August 15, 2016.
- The maximum apparent brightness is about magnitude 18.5.
- Ryugu cannot be observed by small telescopes, so this is a campaign for high-end amateurs or observatories.
- About 10 observations were successful.
- Apart from the campaign, Ryugu was observed by VLT (Very Large Telescope) in Chile.

by Bisei Astronomical Observatory (July 15, 2016)

by VLT (July 12, 2016)
### Hayabusa2 Timeline (Launch – Return)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>3</td>
<td>O</td>
<td>D</td>
<td>4</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

#### Event

- **Launch** (Dec.3)
- EDVEGA
- SWBY
- **Transfer**
- **Approach**
- Asteroid Proximity
- **Return**
- MLG/WLH X-band compat. test (Apr.22-25)
- Southern hemisphere stations operation (CAN/MLG)
- **Ryugu Arrival** (Jul.?)
- **Ryugu Departure** (Dec.?)
- **Return** (Dec.?)
- Prox operation tool development
- Training planning
- Prox operation planning
- Training phase1
- SOP generation
- training phase2
- Share time
- Prox operation
- EDL operation prep.
- Global mapping
- Gravity measurement
- Mid/low altitude observation
- MINERVA/MASCOT release
- Touch down operation
- Cratering operation
- Conjunction operation
Conclusion

- Hayabusa2 is flying normally for more than two years.
- The second long term ion engine burn has started since Nov. 22, 2016, and it will continue until May of 2017.
- We executed various kinds of tests such as Ka-band communication test, Ka-band DDOR test, uplink transfer test, and optical navigation test using the star tracker. All of these tests were successful.
- We are planning two training for the proximity operation, Landing Site Selection Training and Real-Time Integrated Operation Training, for quick and reliable response / decision making.
- We are on schedule. Arrival at Ryugu will be June-July 2018.