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

Small Bodies Assessment Group
16th Meeting

Jan. 12, 2017

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December 3, 2016
Happy 2nd Birthday of Hayabusa2!

Highlights of Hayabusa2

Hayabusa2 is the 2nd Japanese sample return mission to small body.

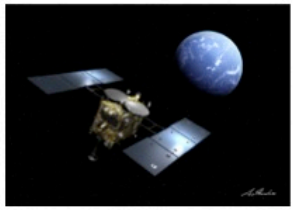
JAXA launched Hayabusa2 in 2014, which will explore the C-type asteroid *Ryugu (1999 JU3)*, and will return back to the Earth in 2020.

- 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.

Mission Scenario of Hayabusa2

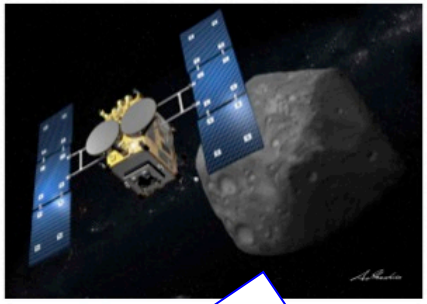
Launch

Dec. 3, 2014

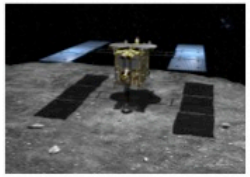


Dec. 3, 2015
Earth swingby

June-July 2018 : Arrival at Ryugu



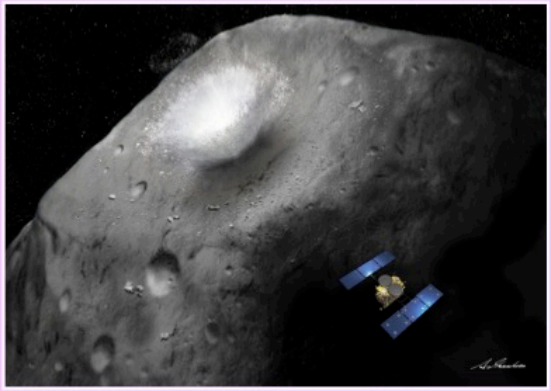
The spacecraft observes the asteroid, releases the small rovers and the lander, and executes multiple samplings.



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.

Nov.-Dec. 2019 : Departure

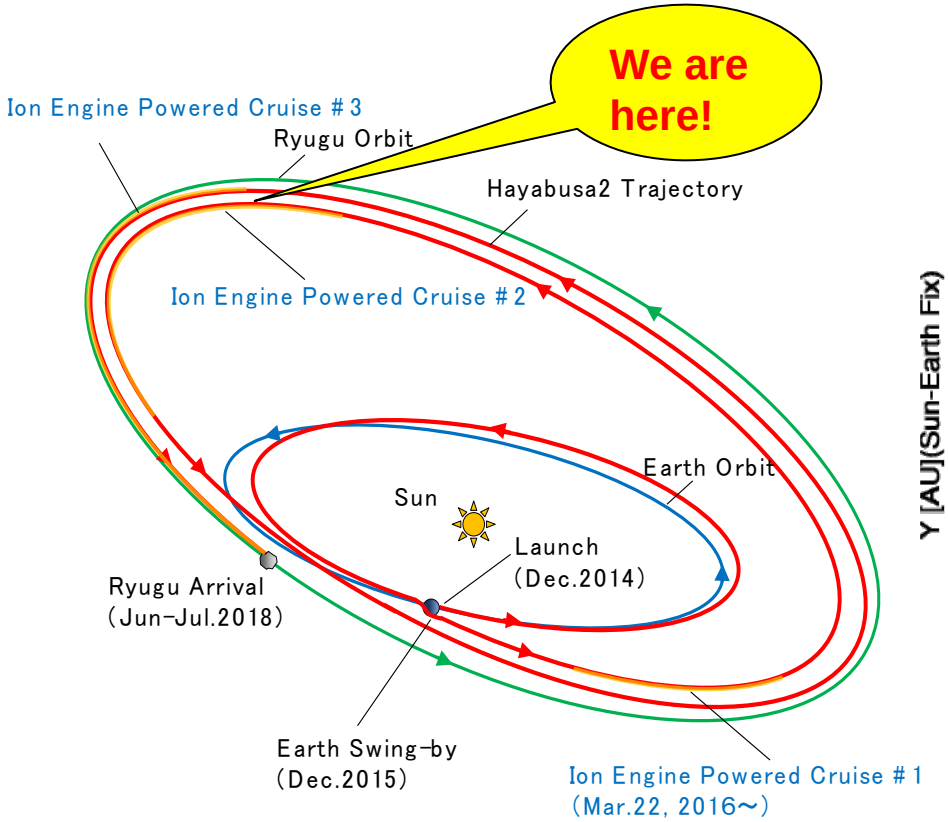
Nov.-Dec. 2020

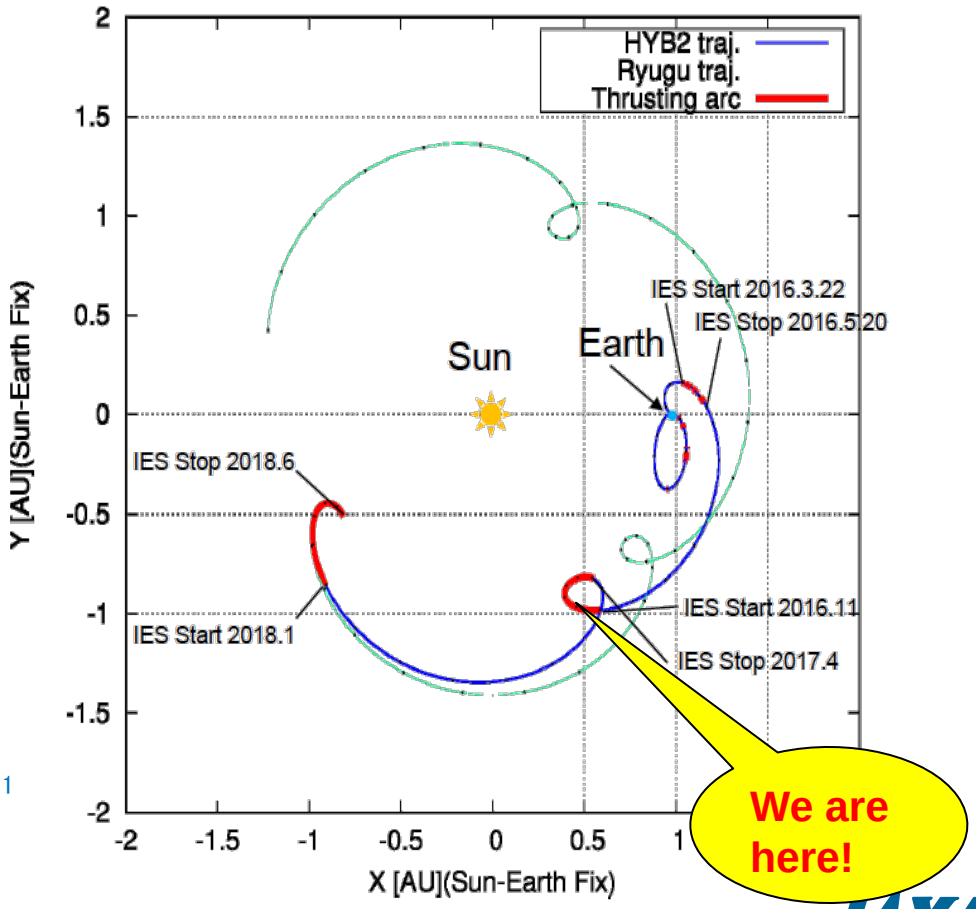
Earth Return

Sample analysis

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
  - ΔV=127m/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
  - ΔV=440m/s, IES 3 heads, 2800hr drive (plan)

Ka-COM test / Ka DDOR test (June-July 2016)

- **HYB2-DSN Ka-band test (June 29 - July 3)**
  - Longer distance Ka link (50 million km) with DSN demonstrated successfully.

Malargue Sta.

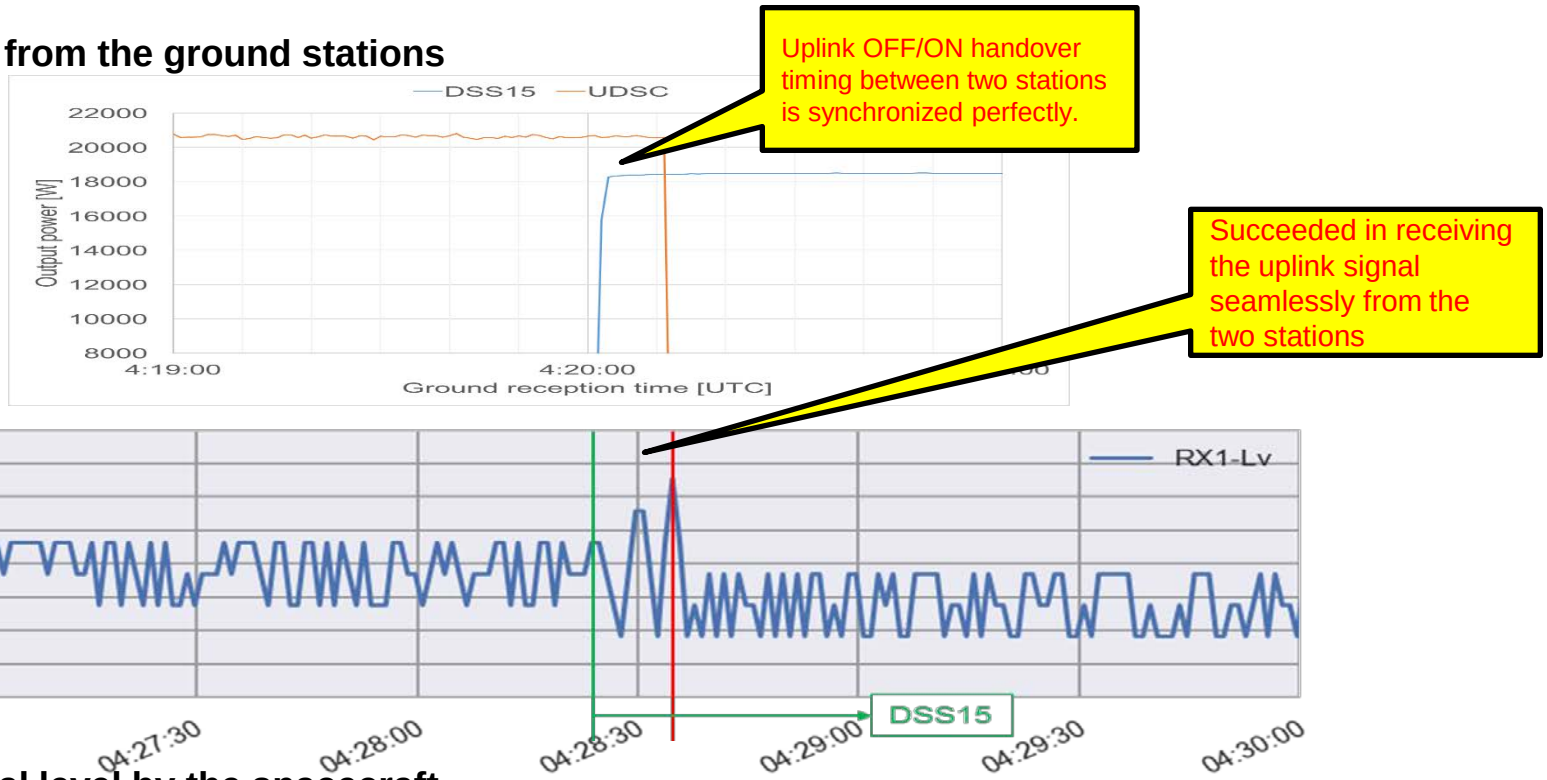
- **HYB2-ESTRACK Ka-band compatibility test (July 5-8)**
  - Successfully established Ka link with MLG for the first time.
  - Ka TLM, X/Ka RNG, Ka DOR are all good.
  - *Now all the stations are ready for proximity operations!*

- **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 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.

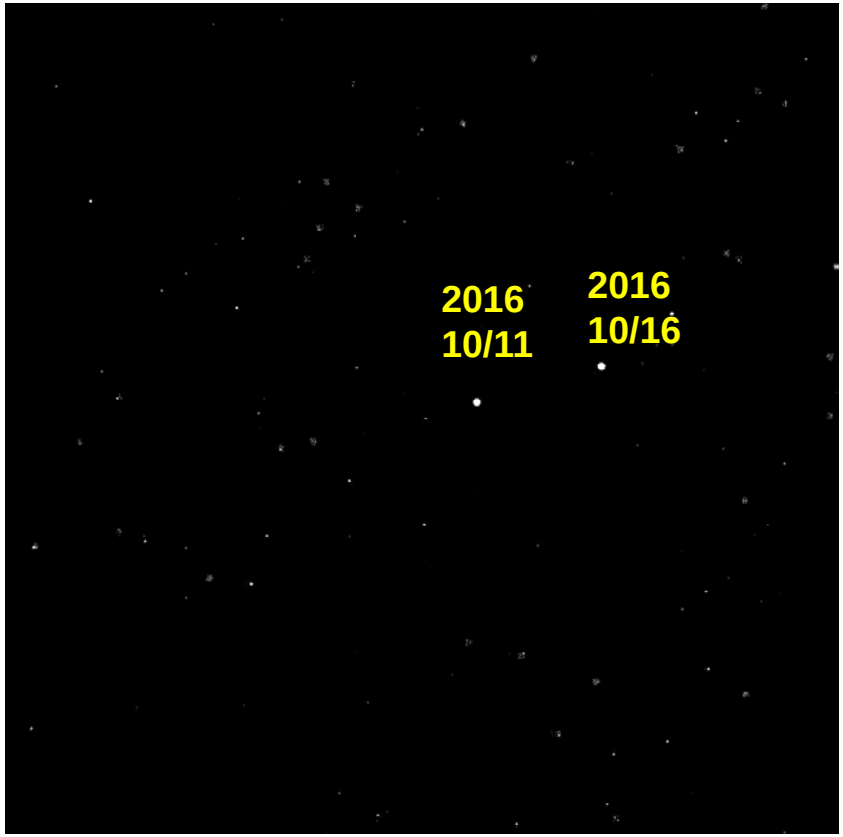


Image of Mars obtained by STT（Oct. 11 & 16, 2016）
Two images are overlapped

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.

- Real-Time Integrated Operation (RIO) Training (4Q, 2017)
  - 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） ・・・*Engineering LSS & operation training planning*
    - Technical Interface Meetings ・・・*with DSN: Navigation & stations assignment with DLR/CNES: MASCOT ops. & LSS*
  - Science Team ・・・*Science Meeting + HJST*
    - Science Instruments Teams
    - interdisciplinary Science Team ・・・*IRSG (Regolith), MSASG (Multi-scale), SMG (Shape Model)*
    - Science Operation Working Group (SOWG)
      - Operation Training Planning Team ・・・*Science operation training planning*
      - LSS Analysis & Assessment Team ・・・*Scientific LSS process*
      - International SOWG (iSOWG) ・・・*MASCOT science interface*
  - HYB2 Sample Allocation Committee (HSAC)

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

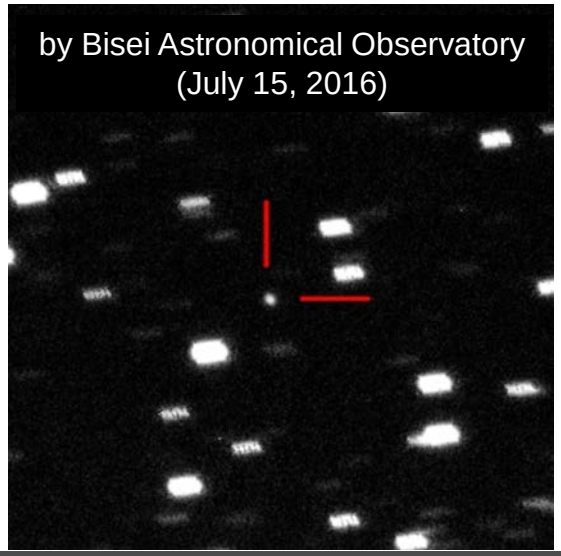
Group photo of 7th HJST meeting

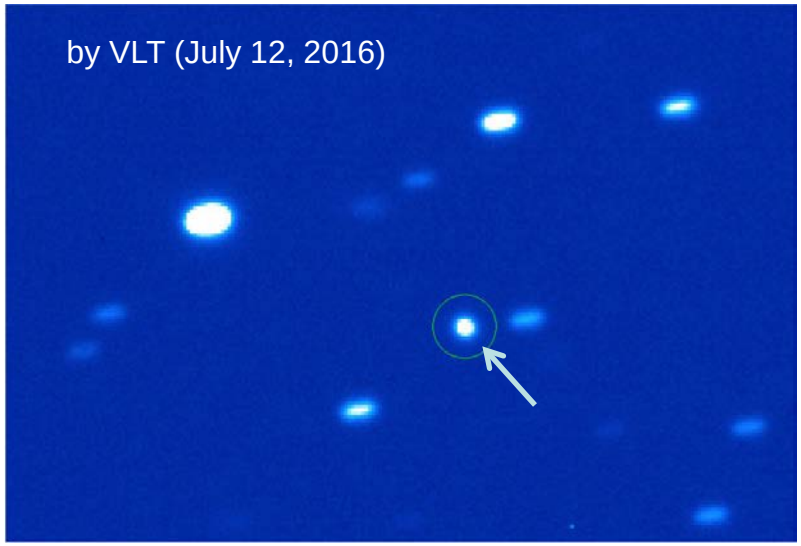
Related meetings:

- 1st IRSG (International Regolith Science Group) Workshop (Nov. 29-30, 2016)
- 1st Multi-scale Asteroid Science group meeting (Dec. 3, 2016)

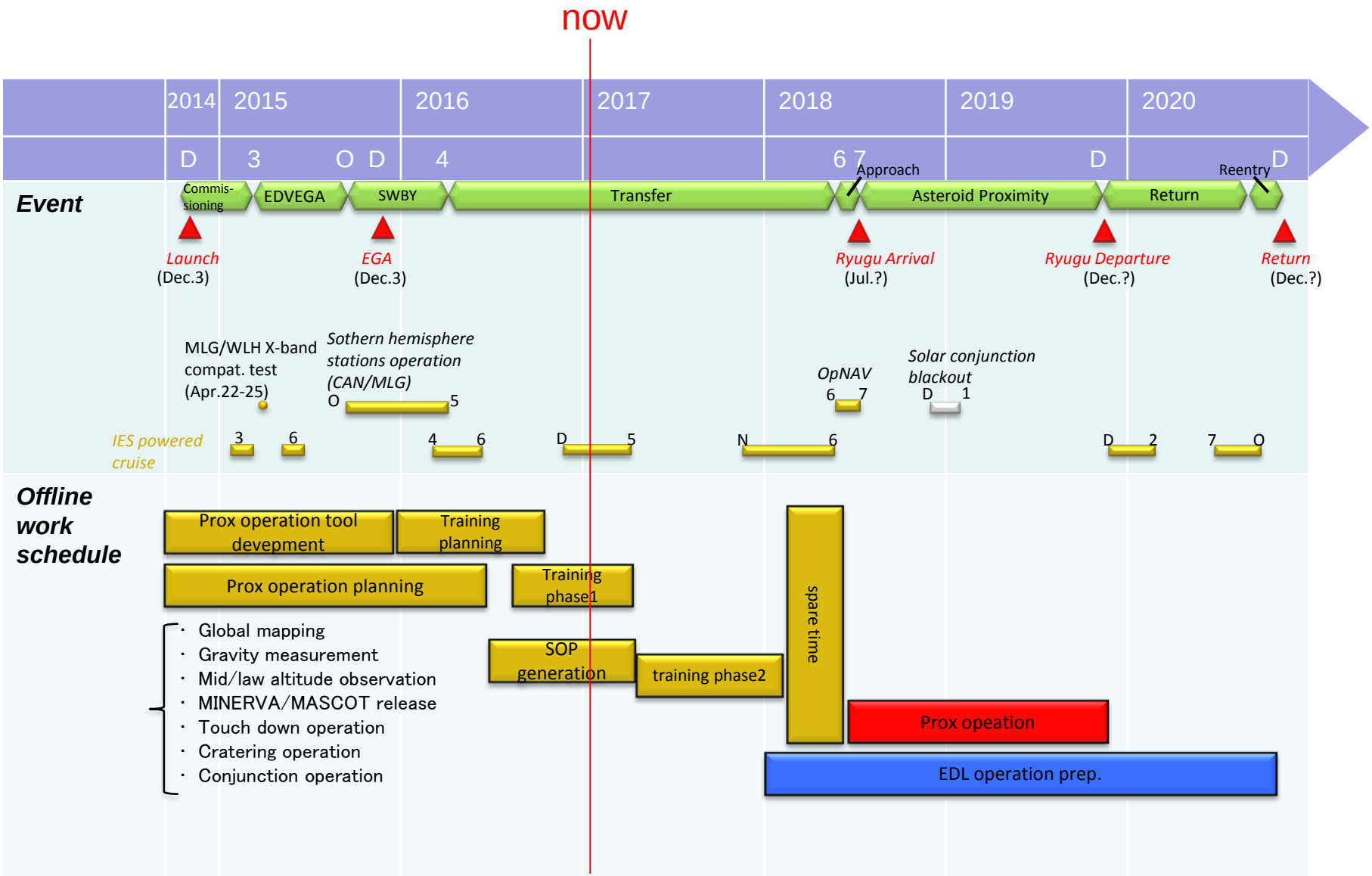
Ryugu Observation Campaign (July 1 – Aug. 15)

- 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 oserved 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.





Hayabusa2 Timeline (Launch – Return)



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.