Asteroid explorer, Hayabusa2, reporter briefing

December 19, 2019

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2,

- Summary of near asteroid operations
- The return cruise operation plan

Contents

0. Hayabusa2 and mission flow outline
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Overview of Hayabusa2

Objective

We will explore and sample the C-type asteroid Ryugu, which is a more primitive type than the S-type asteroid Itokawa that Hayabusa explored, and elucidate interactions between minerals, water, and organic matter in the primitive solar system. By doing so, we will learn about the origin and evolution of Earth, the oceans, and life, and maintain and develop the technologies for deep-space return exploration (as demonstrated with Hayabusa), a field in which Japan leads the world.

Expected results and effects

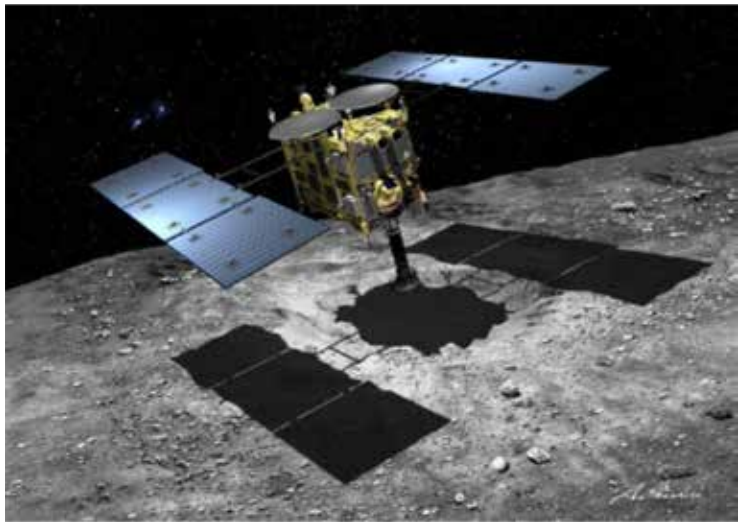
- By exploring a C-type asteroid, which is rich in water and organic materials, we will clarify interactions between the building blocks of Earth and the evolution of its oceans and life, thereby developing solar system science.
- Japan will further its worldwide lead in this field by taking on the new challenge of obtaining samples from a crater produced by an impacting device.
- We will establish stable technologies for return exploration of solar-system bodies.

Features:

- World's first sample return mission to a C-type asteroid.
- World's first attempt at a rendezvous with an asteroid and performance of observation before and after projectile impact from an impactor.
- Comparison with results from Hayabusa will allow deeper understanding of the distribution, origins, and evolution of materials in the solar system.

International positioning:

- Japan is a leader in the field of primitive body exploration, and visiting a type-C asteroid marks a new accomplishment.
- This mission builds on the originality and successes of the Hayabusa mission. In addition to developing planetary science and solar system exploration technologies in Japan, this mission develops new frontiers in exploration of primitive heavenly bodies.
- NASA too is conducting an asteroid sample return mission, OSIRIS-REx (launch: 2016; asteroid arrival: 2018; Earth return: 2023). We will exchange samples and otherwise promote scientific exchange, and expect further scientific findings through comparison and investigation of the results from both missions.



(Illustration: Akihiro Ikeshita)

Hayabusa 2 primary specifications

Mass	Approx. 609 kg
Launch	3 Dec 2014
Mission	Asteroid return
Arrival	27 June 2018
Earth return	2020
Stay at asteroid	Approx. 18 months
Target body	Near-Earth asteroid Ryugu

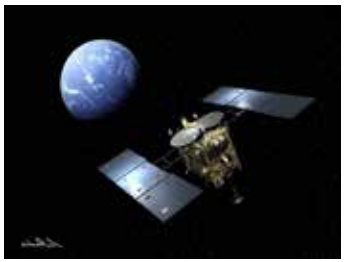
Primary instruments

Sampling mechanism, re-entry capsule, optical cameras, laser range-finder, scientific observation equipment (near-infrared, thermal infrared), impactor, miniature rovers.

Mission flow

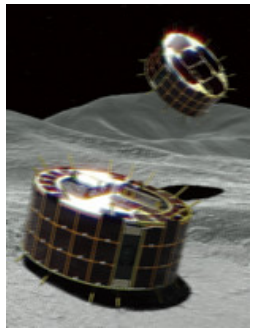
Launch
Dec 3, 2014

Earth swing-by
Dec 3, 2015

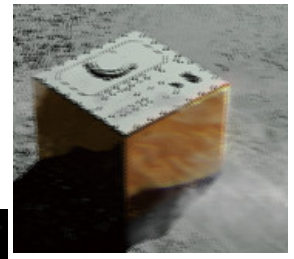


Ryugu arrival
June 27, 2018

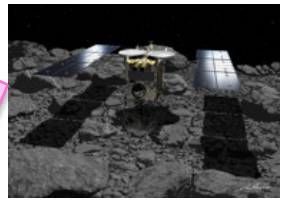
MINERVA-II-1 separation
Sep 21, 2018



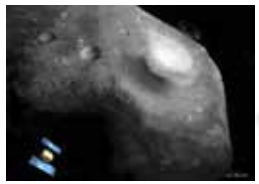
MASCOT separation
Oct 3, 2018



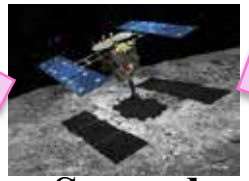
First touchdown
Feb 22, 2019



Impactor (SCI)
5 April, 2019



Second touchdown
July 11, 2019



MINERVA-II2 separation
Oct. 3, 2019

Ryugu departure
Nov 13, 2019

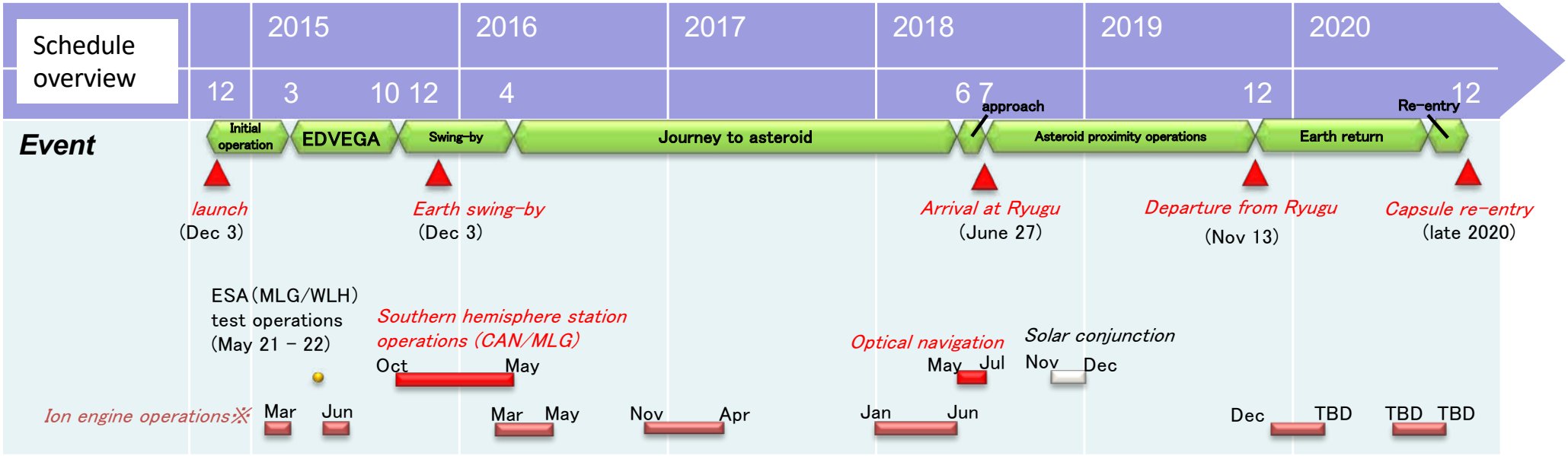
Earth return
End of 2020

(image credit: illustrations including spacecraft by Akihiro Ikeshita, others by JAXA)

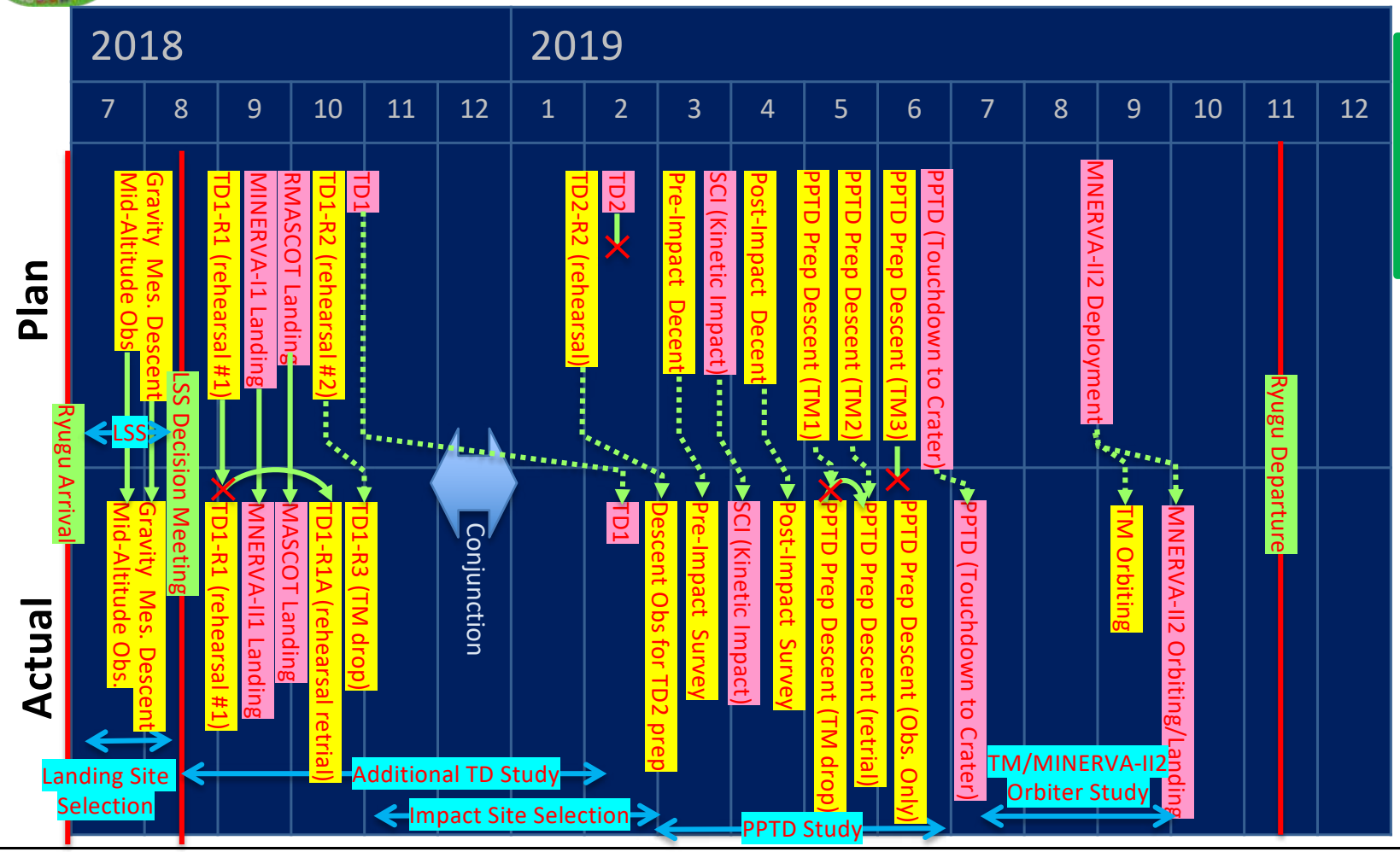
1. Current project status & schedule overview

Current status:

- On December 3 at 11:00 JST (on-board time), we entered the Earth Return Cruise with the operation of three ion engines. Since December 14, operation has continued two ion engines.
- Hayabusa2 was selected for a Union session of the AGU (American Geophysical Union) Autumn Meeting (9 – 13 December in San Francisco).



2. Asteroid proximity operations summary (JAXA)



	Plan	Actual
Critical Descent	: 17	18
Touchdown	: 3	2
Landed Rovers	: 4	4
Artificial Crater	: 1	1
Used Target Marker	: 5	4
Orbiting Objects	: 0	3

While dealing with the unexpected environment of Ryugu, the asteroid proximity operation was completed within the pre-planned schedule for resources such as fuel and personnel.

2. Near-asteroid operations summary (JAXA)
Engineering achievements

7 world firsts:

1. Mobile activity of exploration robots on small body.
2. Multiple robots deployment on small body.
3. 60cm-accuracy landing and sampling.
4. Artificial crater forming and observation of impact process.
5. Multiple landing on extra-terrestrial planet.
6. Access to subsurface material.
7. Smallest-object constellation around extra-terrestrial planet.

2. Near-asteroid operations summary (JAXA)

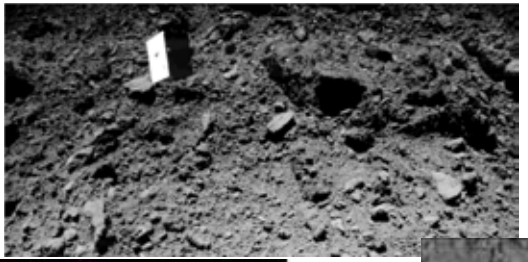
7 “world firsts” achieved by Hayabusa2

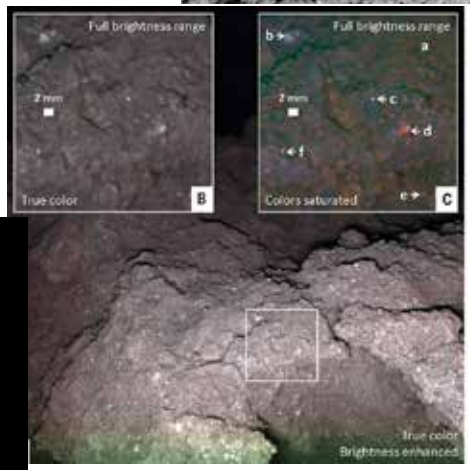
1. Mobile activity of exploration robots on small body.
2. Multiple robots deployment on small body.

Surface of Ryugu captured by MINERVA-II1A.

Hayabusa2 photographed by MINERVA-II1A

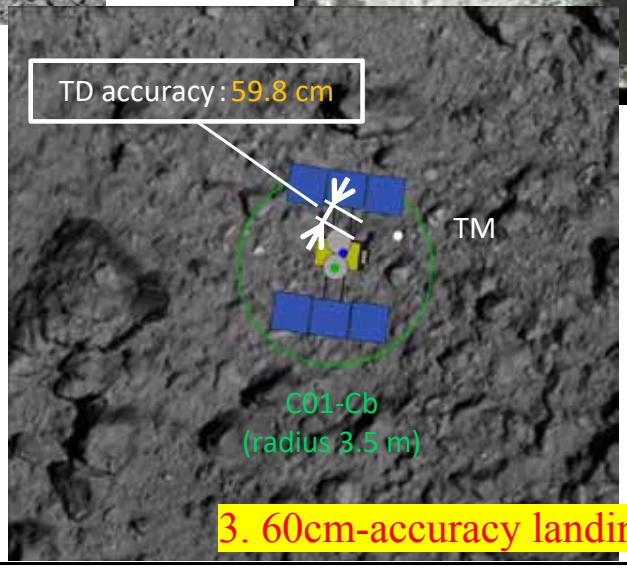
MASCOT immediately after separation, imaged by the ONC-W2





MASCOT observation image

Moment of first touchdown captured with CAM-H



2nd touchdown point & accuracy

3. 60cm-accuracy landing and sampling.

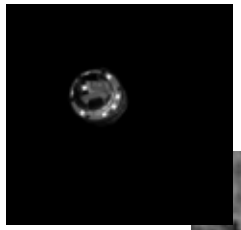
2. Near-asteroid operations summary (JAXA)

7 “world firsts” achieved by Hayabusa2

4. Artificial crater forming and observation of impact process.

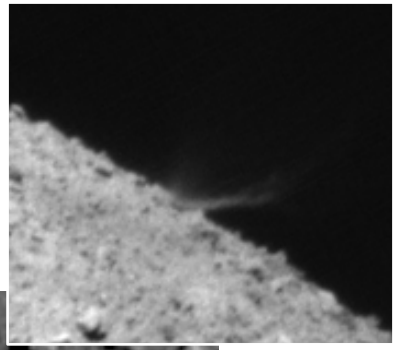
5.Multiple landing on extra-terrestrial planet.

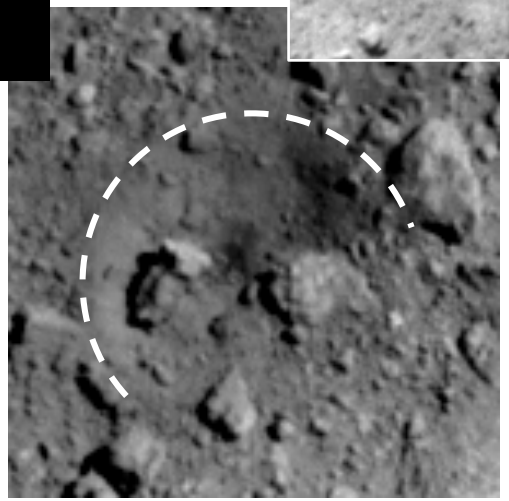
6. Access to subsurface material.



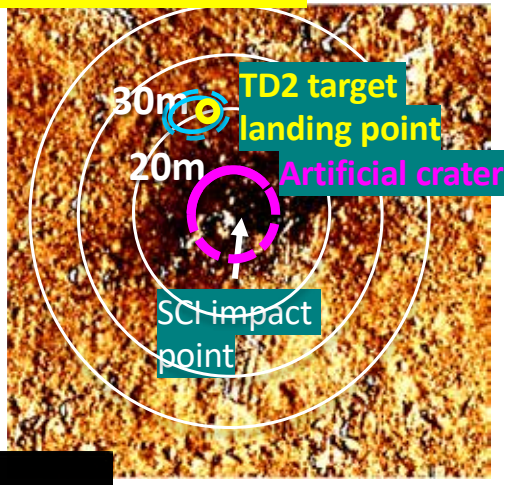
SCI immediately after separation captured with the ONC-W1.

Moment of impact captured with DCAM3.





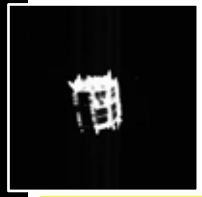
Artificial crater made with the SCI



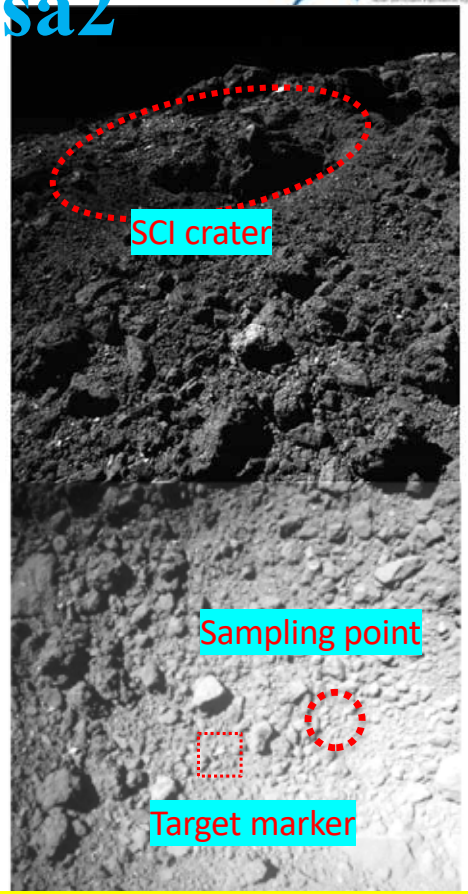
Terrain around the 2nd touchdown point

Ejecta accumulation around the artificial crater

Orbits of two target markers around Ryugu.



MINERVA-II2 immediately after separation, captured by ONC-W2



7. Smallest-object constellation around extra-terrestrial planet.

2. Near-asteroid operations summary (JAXA)

The NEC major contribution to the JAXA-NEC collaboration

- JAXA-NEC have established a close review system for operation review, which is now underway.

  Exchange between the JAXA near-asteroid phase operation team and the NEC system team: approximately 8,000 emails.

  - FY2015: SWBY operation, feasibility study of near-asteroid phase schedule.
  - FY2016: Detailed operation of various near-asteroid phase events, ground-tool renovation.
  - FY2017: Contingency study, Landing Point Selection (LSS) training, Realtime Integrated Operation (RIO) training.
  - FY2018、2019: Operations for the real Ryugu.
- A challenging and reliable operation method was constructed with JAXA-NEC, through clarification of the division of roles, mutual checks performed so that roles overlapped, complement one another and utilize attributes.

	JAXA	NEC
Document management	Overall analysis	Elaboration
Schedule management	Flexible	Strict
Plan revision / policy change proposal	Proactive	Prudent (not passive)

2. Near-asteroid operations summary (JAXA)

The NEC major contribution to the JAXA-NEC collaboration

- As the system maker, NEC know everything about the spacecraft.
  - Spacecraft status can be quickly grasped. Immediately deal with problems.
- Preparation of detailed planning documents and shift management.
  - Creation of large operation plan, management and quick revision.
- Create and review huge, complex procedures.
  - Number of procedure lines for TD1: over 80,000 lines. Over 1.2 million lines for the entire descent operation.
  - Reliable procedure review (manual confirmation of procedure, with JAXA and NEC mutually checking over 1,000 cases.)
- Strict management of operation preparation for implementation.
  - Schedule management at the time JAXA provided information.
- ONE TEAM built through discussions on the same playing field.
  - From a realistic standpoint, a relationship is built by saying NO if something cannot be done.

2. Near-asteroid operations summary (JAXA)

Examples of JAXA-NEC collaboration

Preparation for 1st touchdown

- With Ryugu having minimal flat areas, both JAXA and NEC recognised the difficulties and sought a safe and secure path, resulting in a significant change in procedure from the initial plan.
  - Procedural change to separate TM in advance of touchdown.
  - To ensure safety and accuracy, LRF distance measurement values were “fooled” based on pre-measured terrain information.

    Bold policy change to use software differently from traditional usage.

    Implemented swift change for touchdown operation at the beginning of 2019.
    - JAXA developed and proposed this method on December 27, 2018.
    - NEC instantly considered the proposal and performed simulations to demonstrate feasibility.
    - Policy decision on January 7, 2019.
    - Confirmation of simulation results by both JAXA and NEC until just before operation on February 22.

2. Near-asteroid operations summary (JAXA)

Examples of JAXA-NEC collaboration

- [Training] The plan drafted by NEC was almost perfect, with issues difficult to find. Training was used to flag any problems. Through the training, JAXA provided appropriate feedback and NEC also had the opportunity to notice potential improvements.
- [Landing feasibility study] JAXA's plan for TD1 changed repeatedly. Initially, plans were made to enhance LRF obstacle detection, followed by a method to use multiple target markers, and finally the current TD method. NEC responded flexibly to these changes. While strictly observing the constraints of the spacecraft, they were open to change and not bound to the initial plan.
- [1st touchdown] During the actual operation, JAXA-NEC understood one another's roles and were willing to make necessary decisions. During TD1, half of the decision to continue operation with a delay of five hours was made by NEC.
- [2nd touchdown] Strict measures were required to prevent lens fogging. TD2 was scheduled to be implemented at the end of June, and NEC made all necessarily preparations for this time. However, JAXA determined that fatigue of the JAXA-NEC site members had reached a peak, and that JAXA needed time to handle the remaining work up to TD2. As a result, the implementation date of TD2 was July 11. Working transparently within the teams led to the ultimate success.
- [NEC response to TD1/TD2] In addition to the NEC members of Hayabusa2, many NEC senior members from the first Hayabusa era expressed messages showing pleasure and congratulations. The fact that Hayabusa2 was able to perfectly accomplish the homework left by Hayabusa through building on the strengths of the Hayabusa management produced a large reward in terms of the development of exploration technology.

3. Near-asteroid operations summary (NEC)

(Documents from NEC)

4. Achievements (papers, awards)

※ Near-asteroid operation period (after June 2018)

■Papers:

- Science journal: 4 articles, Nature Astronomy: 1 article, other major journals: 11 articles.
- Many papers are also currently being submitted.

■Commendations

- Total of 8 awards
- Award organization names

  Aviation Week & Space Technology, The Japan Society for Aeronautical and Space Science, Toray Science Foundation, Cool Japan Council, Airbus, Japan SF Fan Group Federation, The Robotics Society of Japan, IEICE DC Research Group.

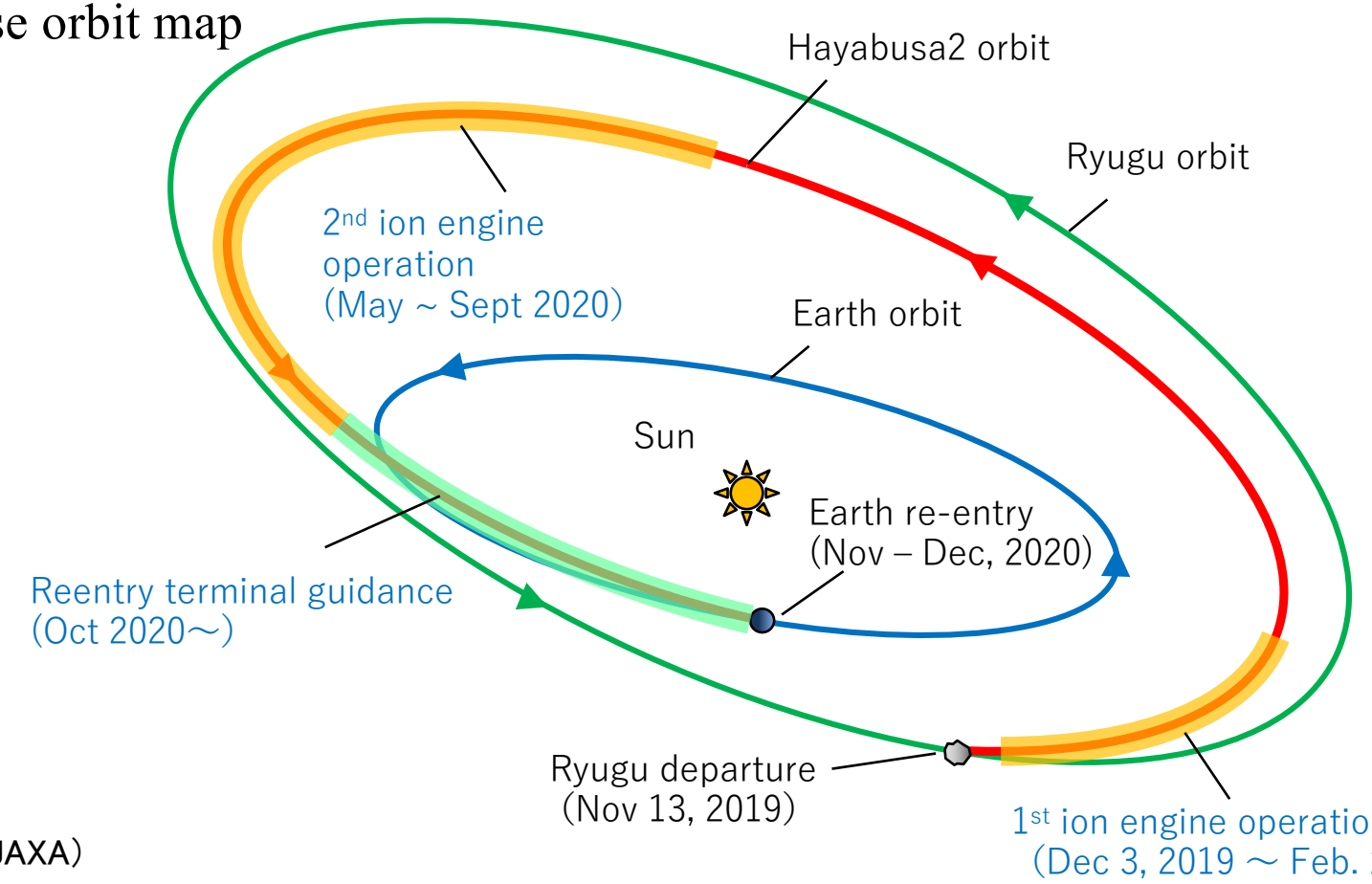
※Refer to reference material

5. Return cruise operation plan

- Current status of Hayabusa2
  - Integrity of ion engine thrusters A, C and D has been confirmed (November 20 – 29, 2019).
    ※ Thruster B is being preserved.
  - As of today（Dec 19, 2019）, Hayabusa2 is a distance of 45,000 km from Ryugu.
- Trajectory control during the return phase
  - Consists of 2 phases of ion engine operation and the re-entry precision guidance.
  - 1st ion engine operation period: Dec 3, 2019 – early February 2020.
  - 2nd ion engine operation period: May 2020 – Sept 2020.
  - Re-entry precision guidance period: from Oct 2020 to re-entry.
  - Ballistic flight during periods other than the above. Take an Earth-oriented attitude for high-speed data links as needed.
- Ion engine operation plan
  - 1st ion engine operation period: Approx. 600 hours（Thrusters used 3→2、total acceleration approx. 100m/s）
  - 2nd ion engine operation period: Approx. 1,900 hours（Thrusters used 1→2、total acceleration approx. 150m/s）

5. Return cruise operation plan

Return phase orbit map



(image credit：JAXA)

6. Future plans

■ Operation schedule

Until early Feb 2020　　ion engine operation

■Press briefings, etc.

Feb. 2020（TBD）　　Press conference @ Tokyo Office

Reference

Science, Nature list of papers

- R. Jaumann, et al., Images from the surface of asteroid Ryugu show rocks similar to carbonaceous chondrite meteorites, Science 23 Aug 2019, Vol. 365, Issue 6455, pp. 817-820
- M. Grott, et al., High porosity boulders identified on C-type asteroid (162173) Ryugu, Nature Astronomy volume 3, pages 971–976, 2019
- S. Sugita, et al., The geomorphology, color, and thermal properties of Ryugu: Implications for parent-body processes, Science 19 Apr 2019: Vol. 364, Issue 6437, eaaw0422
- S. Watanabe, et al., Hayabusa2 arrives at the carbonaceous asteroid 162173 Ryugu—A spinning top–shaped rubble pile, Science 19 Apr 2019: Vol. 364, Issue 6437, pp. 268-272
- K. Kitazato, et al., The surface composition of asteroid 162173 Ryugu from Hayabusa2 near-infrared spectroscopy, Science 19 Apr 2019: Vol. 364, Issue 6437, pp. 272-275

Award list

Data	Recognized person, group name, affiliation	Award content	Award organization	Award title
2019/11	Hiroki Hihara, Junpei Sano, Tetsuya Masuda, Hisaki Otake, Tatsuaki Okada, Naoko Ogawa, Yuichi Tsuda	Reliability evaluation of Hayabusa2 optical navigation equipment ~ On-orbit demonstration of a highly reliable system that meets resource constraints.	IEICE DC Research Group	6th Research Meeting Best Presentation Award
2019/09	Tetsuo Yoshimitsu, Takashi Kubota	Development of the asteroid exploration rover, MINERVA-II	The Robotics Society of Japan	2019 Practical Use Technology Award
2019/07	Hayabusa2 Project	MINERVA-II Ryugu landing and asteroid exploration by moving	Japap SF Fan Group Federation	2019 50th Seiun Award in the Free Category.
2019/06	Hayabusa2 Project	MASCOT onboard camera	Airbus	Airbus Space Day Hayabusa2 Special Award
2019/05	JAXA Hayabusa Hayabusa2	Space equipment that brings together sophisticated technologies is Japan Cool!	Cool Japan Council	COOL JAPAN AWARD 2019 [General section] Outbound category.
2019/03	JAXA ISAS Director Hitoshi Kuninaka	Research & Development of microwave discharge ion engine and promotion of Solar System exploration.	Toray Science Foundation	2018 (59th) Toray Science and Technology Award
2019/03	JAXA Hayabusa2 Project Team (Represented by Project Manager Yuichi Tsuda)	Advances in deep space navigation technology for small body rendezvous with Hayabusa2 and arrival at asteroid Ryugu.	The Japan Society for Aeronautical and Space Science	Technology Award, Project Category
2019/03	Japan Aerospace Exploration Agency Hayabusa2	Japan's Hayabusa2 sample-return mission, which rendezvoused with the asteroid Ryugu in June 2018, has made a promising start, with the successful deployment and operation of three mini-rovers—one from the DLR and Onera—ahead of its first landing planned in early 2019.	Aviation Week & Space Technology	Aviation Week Network's 62nd Annual Laureate Awards, Space: Technology & Innovation