Asteroid explorer, Hayabusa2, reporter briefing

February 20, 2020

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2,

- Current operation status
- Ion engine operation results

Contents

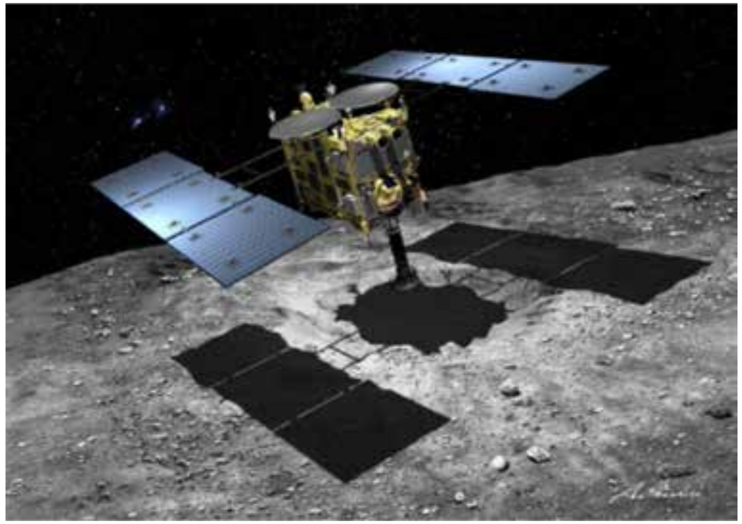
Overview of Hayabusa2

<u>Objective</u>
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.

<u>Expected results and effects</u>
- 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.

<u>Features:</u>
- 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.

<u>International positioning:</u>
- 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.



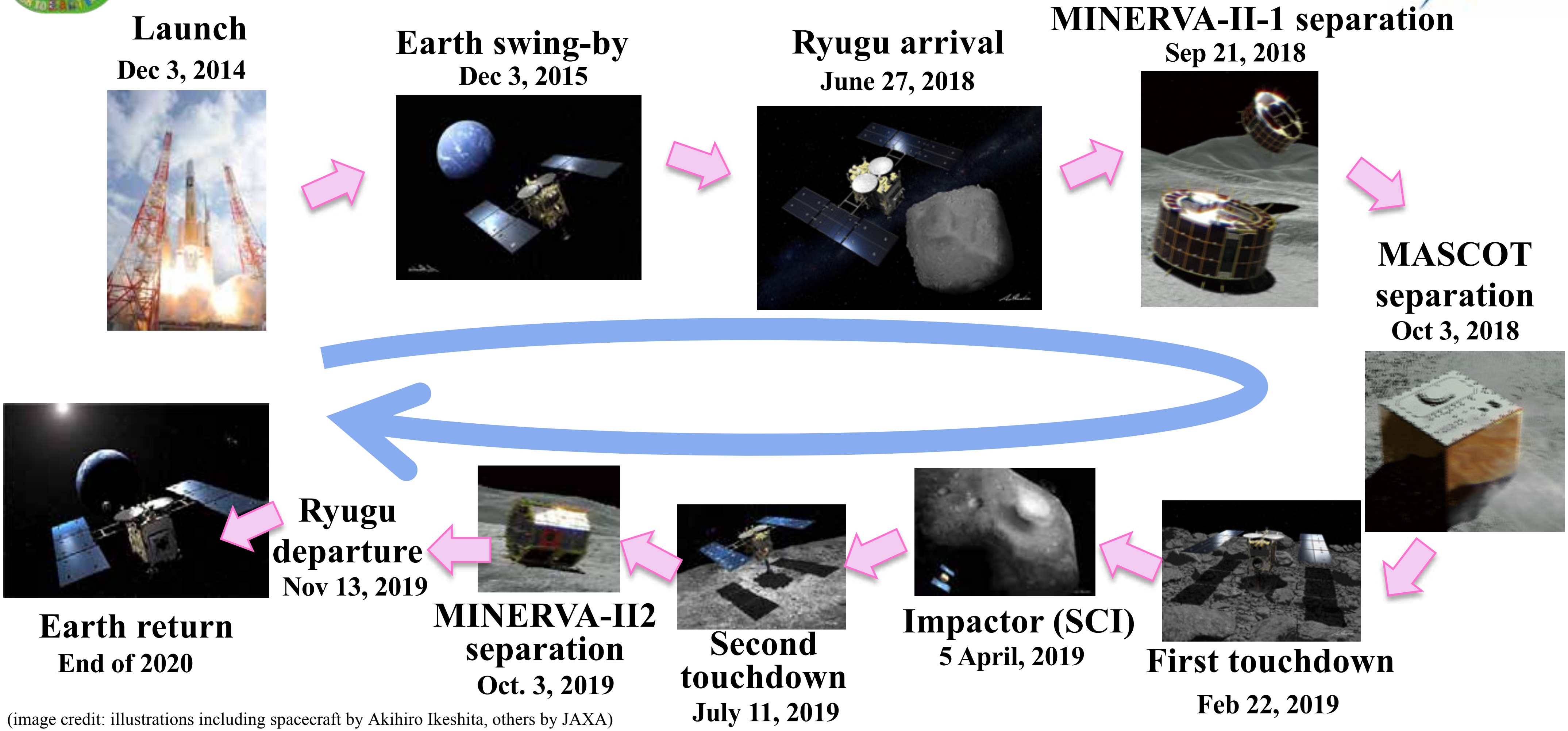
(Illustration: Akihiro Ikeshita)

<u>Hayabusa 2 primary specifications</u>

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

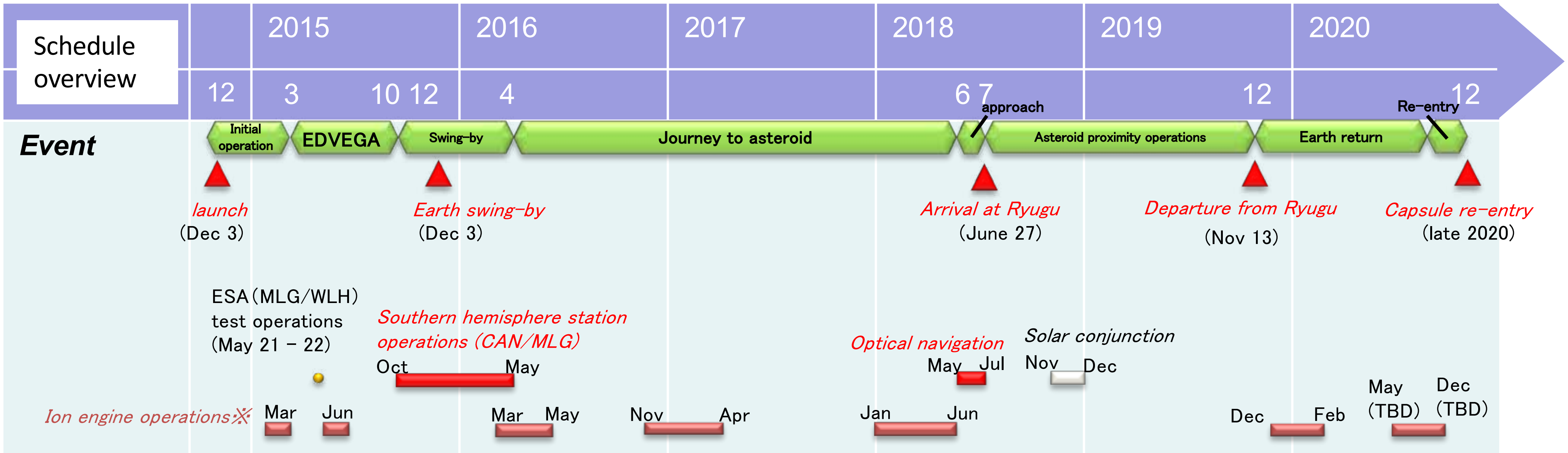


(image credit: illustrations including spacecraft by Akihiro Ikeshita, others by JAXA)

1. Current project status & schedule overview

Current status :

- The ion engines began operation on December 3, 2019 and were temporarily stopped on February 5 to allow for the determination of a precise orbit. Based on the results, a minor modification to the ion engine injection was made from Feb. 18 to today (February 20) and the first phase of the ion engine operation in the return phase was completed.
- Journal papers have been written and submitted by the science team.



2. Ion engine operation results

・After departing from Ryugu on November 13 last year and a trial run of the ion engines, the first phase of the ion engine operation for the Earth return was implemented.

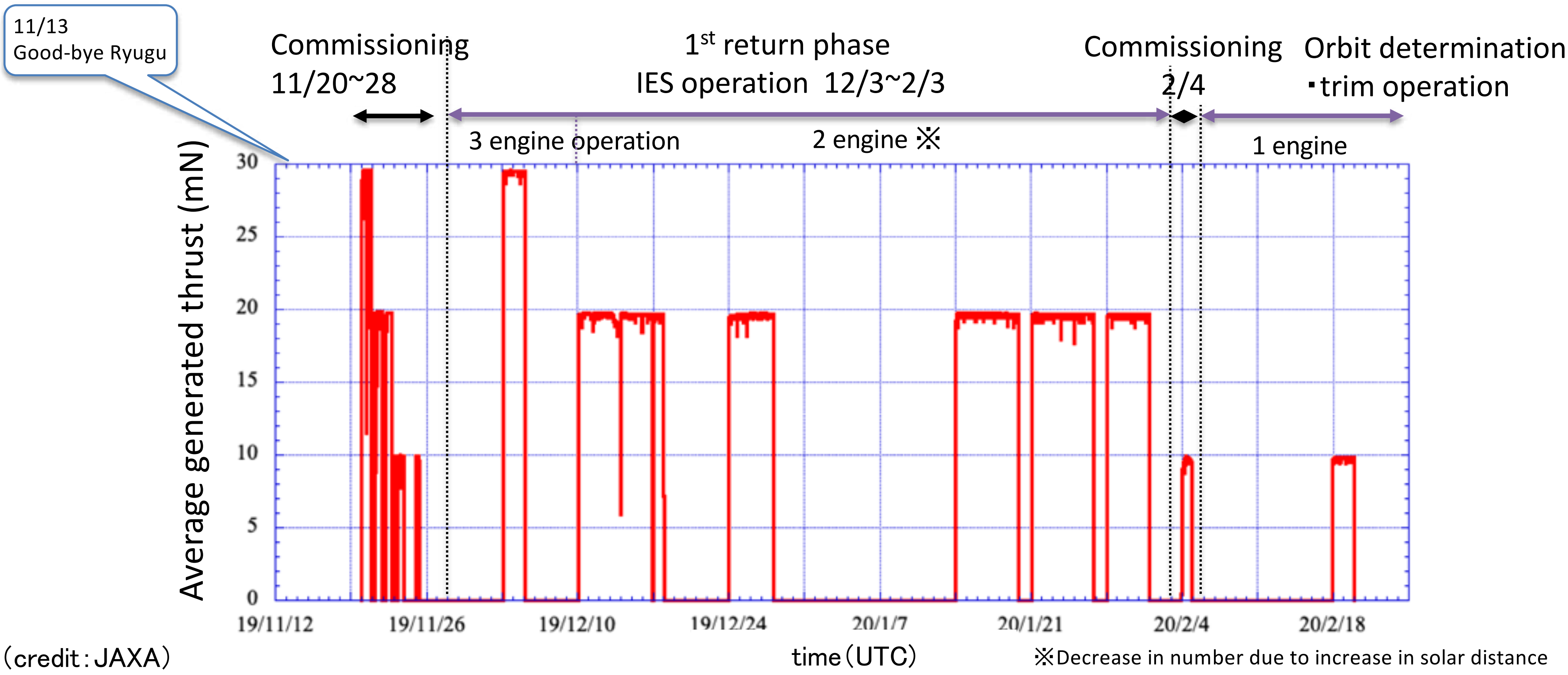
・After February 5, the ion engines were shut-off to implement a precise trajectory estimation. After this, a trim operation was performed between February 18 – 20 and the ion engines were stopped today at 8:01 JST. This completed the first-stage ion engine operation.

・ Navigation time powered by ion engines is 7396 hours (return: 881 hours). The speed increase on the return trip is about 100 m/s. Remaining Xenon is a little less than 60%.

・Details of the trail run will be described separately.

2. Ion engine operation results

Ion engine operation history after leaving Ryugu (2019.11.20 – 2020.2.20)



（credit：JAXA）

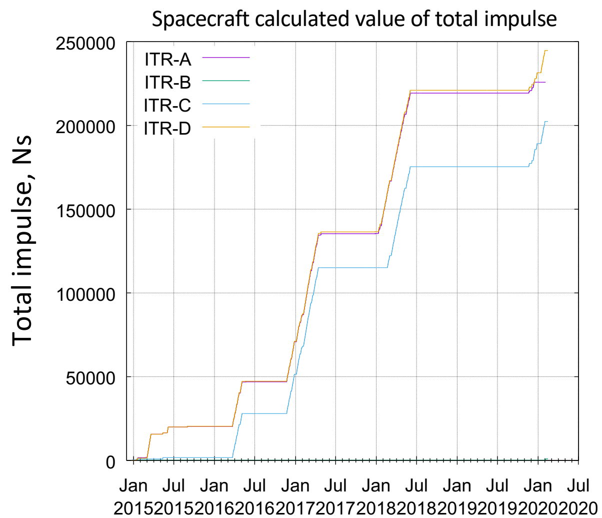
※Decrease in number due to increase in solar distance

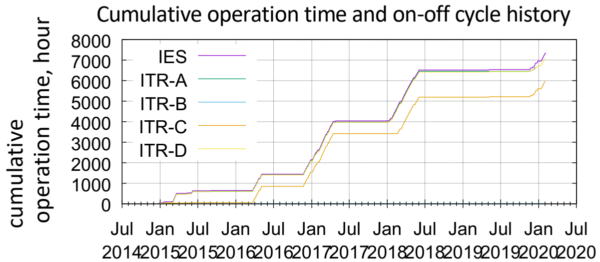
2. Ion engine operation results

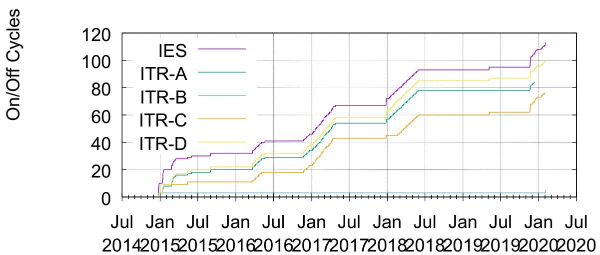
- As of Feb. 20, 2020, 27kg of Xenon propellent have been consumed. 39 kg remain.
- Cumulative operation times:
  A: 6638 h, B: 33 h, C: 6024 h, D: 7106 h,
  IES (powered navigation) : 7396 h
- Plasma ignition - extinguishing cycle
  A: 84 times, B: 5 times, C: 77 times, D: 99 times, IES: 114 times

	Thruster	Hayabusa2	Hayabusa
Cumulative operation time (h) ※	A	6638	7
	B	33	12809
	C	6024	11989
	D	7106	14830
	IES	7348	25590
	のべ	19753	39635
Total impulse (MN・s)	A	0.2258	0.0001
	B	0.0009	0.3221
	C	0.2040	0.2639
	D	0.2447	0.3613
	IES	0.6738	0.9474
Maximum thrust (mN)	A	10.03	7.42
	B	9.90	8.36
	C	10.16	8.30
	D	10.16	7.95
	IES	29.67	24.12

※ Including operation tests. “IES” refers to one or more engines.
※ Hayabusa data for the entire mission.

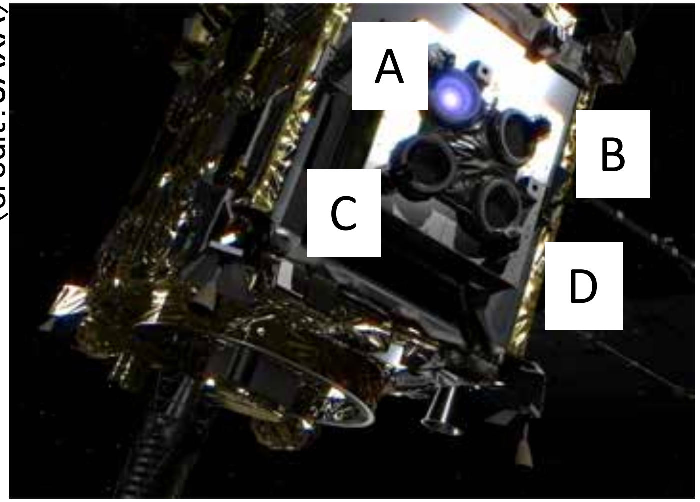






（credit：JAXA）

2. Ion engine operation results



(credit: JAXA)

Details of trial run

1. Operation check of all combinations of ion engines A,C,D（3 ACDs、2 each for AC/AD/CD 、1 for A/C/D）
    - After a long pause, operation check of all thrusters and combinations.

2. Performance check on back-up ion engine B
    - Confirm that ion engine B functions as a back-up during the most critical second stage ion engine operation.

3. Confirmation of automatic control of ion engine gimbal (controls the thrust axis with respect to the center of gravity).
    - The handling and confirmation of the position of the center of gravity has changed during the near-asteroid operations.

2. Ion engine operation results

1. Operation check for all combinations of ion engines A, C, D (2019.11.20～28)

【Concern】

- Given the potential exposure to regolith during touchdown, can a high voltage be applied properly to accelerate the ion beans after no use for a year and a half?
- Are operations successful with all engines in use?

2. Performance check of back-up ion engine B (2020.2.3～4)

【Concern】

- Not used since check in 2014. The total operation time has been about 11 hours. Does the plasma still ignite? Is ion beam acceleration possible?

3. Confirmation of automatic control of ion engine gimble (control of thrust axis relative to the center of gravity).

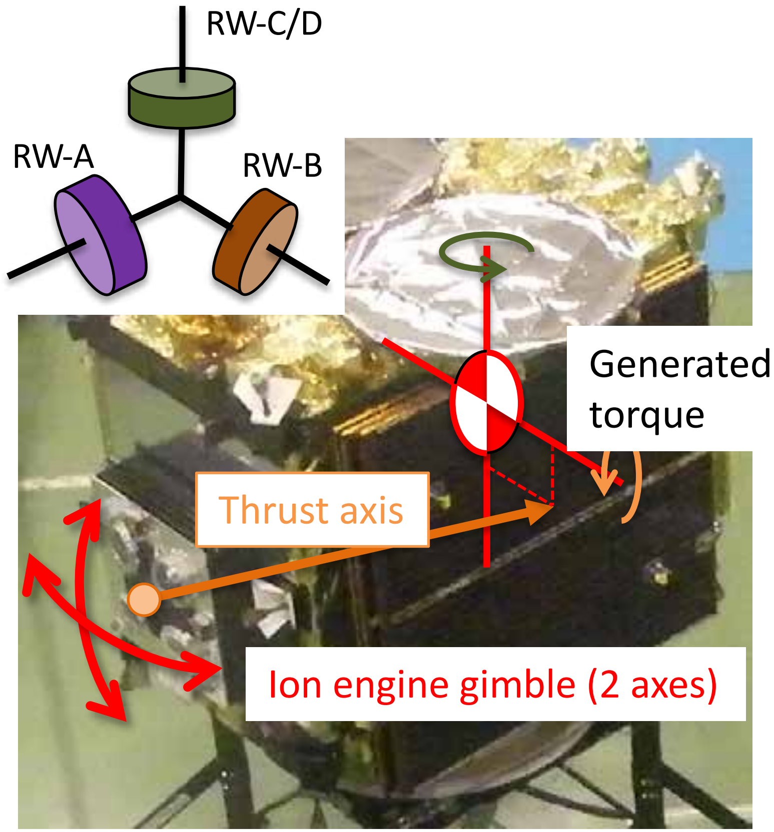
【Concern】

- The location of the spacecraft's center of gravity changed during the near-asteroid operations. Can the gimbal still respond?

Everything is OK. The Earth return operation will be performed with all four available ion engines.

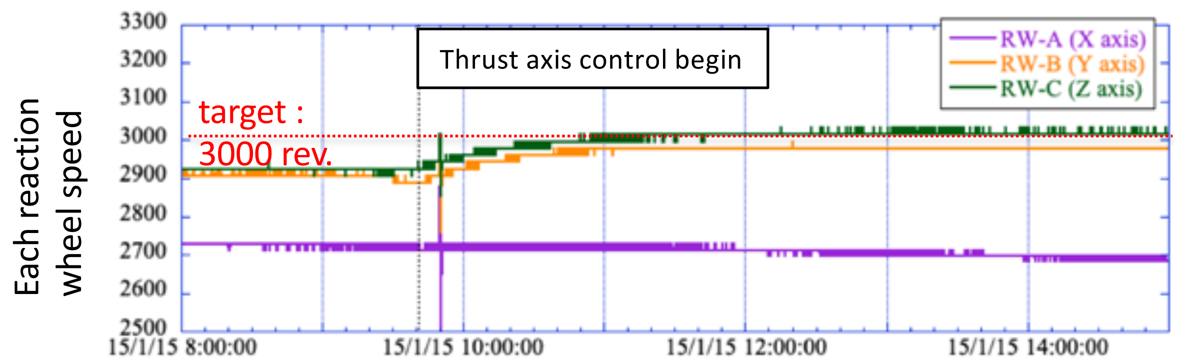
2. Ion engine operation results

Explanation for "automatic control of ion engine gimble":



(Credit：JAXA)

- The ion engine has a gimble that can be tilted on two axes, allowing control of the thrust axis so that it always passes through the center of gravity.
- Additionally, torque can be intentionally generated by shifting the thrust axis from the center of gravity and automatically keeping the number of revolutions of the reaction wheels constant (IES unloading function).
- This feature eliminates the need to unload the two reaction wheels via chemical propulsion during the ion engine operation, contributing to fuel preservation.



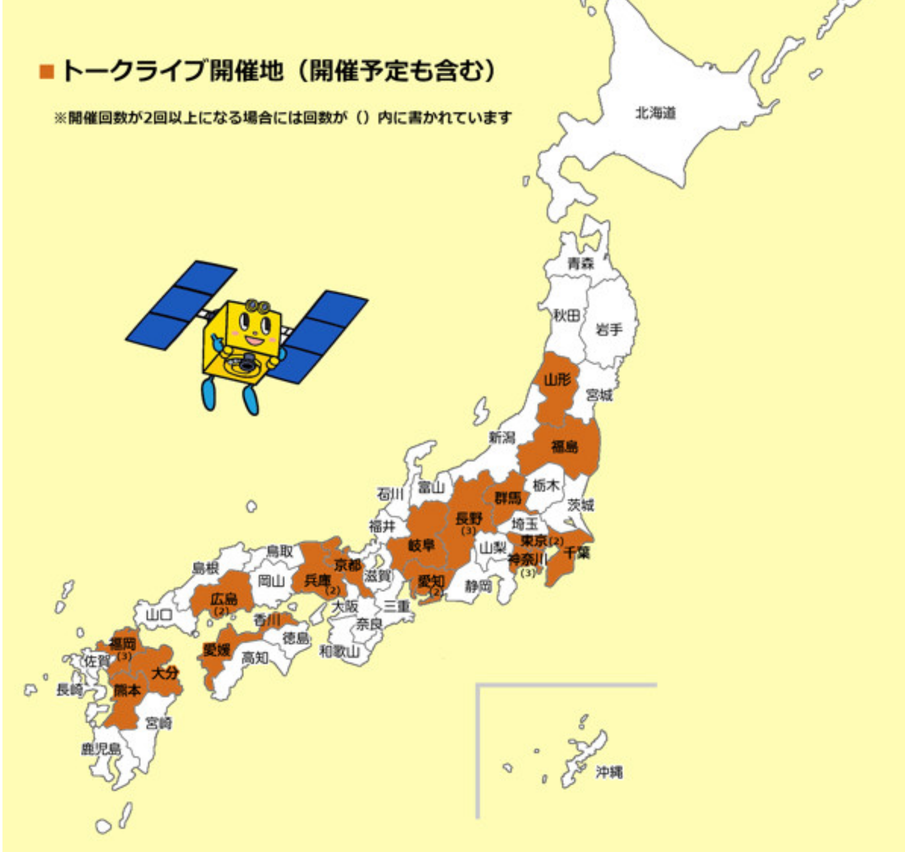
3. Outreach

Hayabusa2 Talk Live Season 2
(Project members give talks on Hayabusa2)

- Period：2020/1～9
- Currently 27 locations（17 prefectures）

(Language: Japanese)

The prefectures where Talk Live was/will be held



（credit：JAXA）

4. Future plans

■ Operation schedule

2020 / 5～ Phase 2 for the ion engine operation (planned)

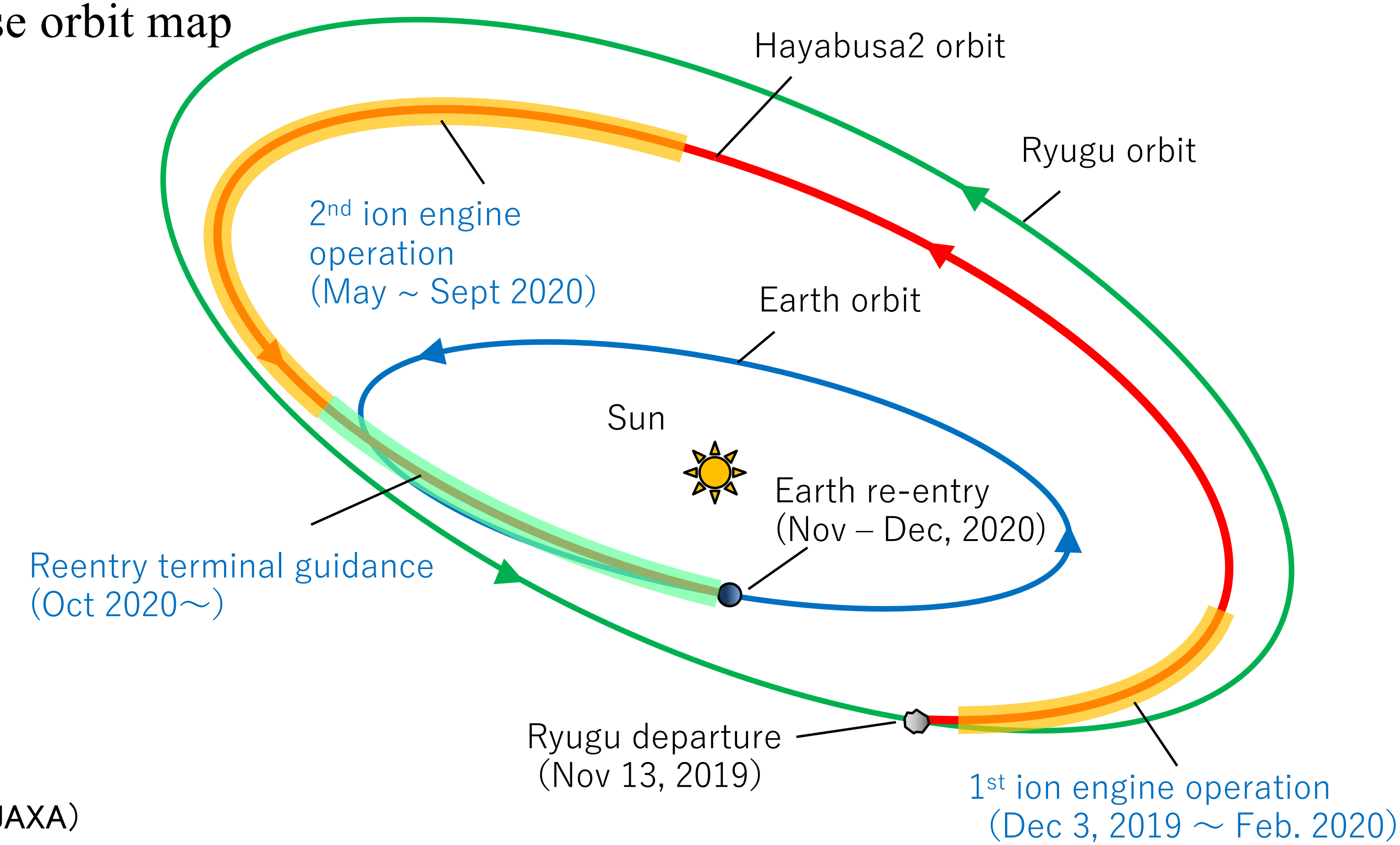
■Press briefings

2020/4（TBD)　　　Press conference @ Tokyo Office

Reference material

Return cruise operation plan

Return phase orbit map



（image credit：JAXA）

Electric propulsion (ion engine)

- Name: μ10
- Converts xenon* into plasma (ions), which is accelerated by applying voltage.
- A microwave discharge system is used to generate ions.
- Four units are mounted, and simultaneous operation of three generates thrusts of up to 28 mN.
- Approximately 60 kg of loaded xenon fuel, allowing acceleration up to 2 km/s.
- It is used to alter trajectories when cruising from Earth to the asteroid and back.

Injection test by a flight model in a vacuum chamber

Hayabusa 2 ion engine

(© JAXA)

*Why we use xenon

- Xenon is a monoatomic molecule, so its ionization voltage is smaller than that of gasses comprising two or more atoms. This increases the ratio of added energy that is used for acceleration.
- Reactivity is lower than that of other substances.
- Mass (atomic weight) is large, improving the efficiency of acceleration.

Reference: how the ion engines work

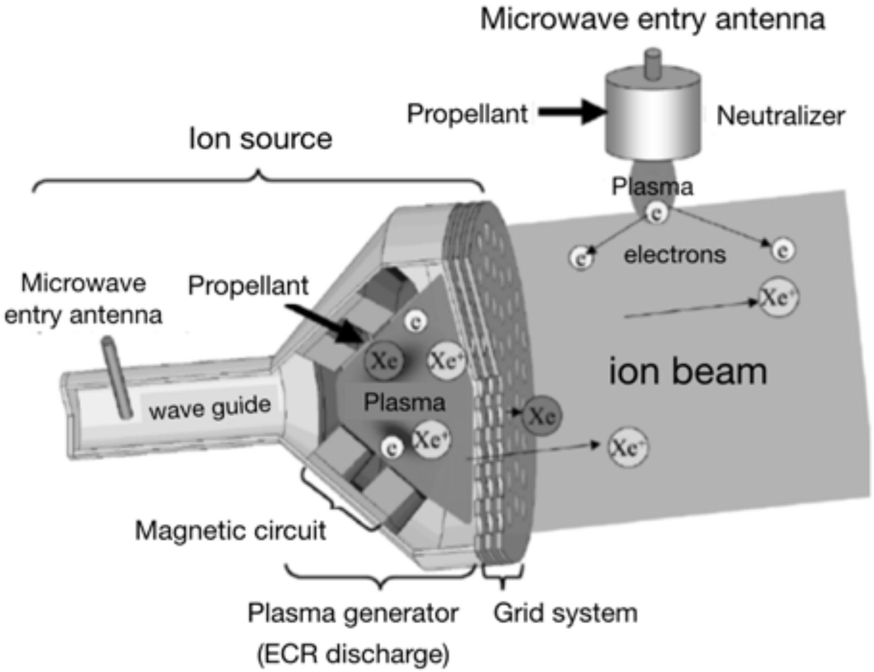


Fig: Schematic diagram of microwave discharge type ion engine

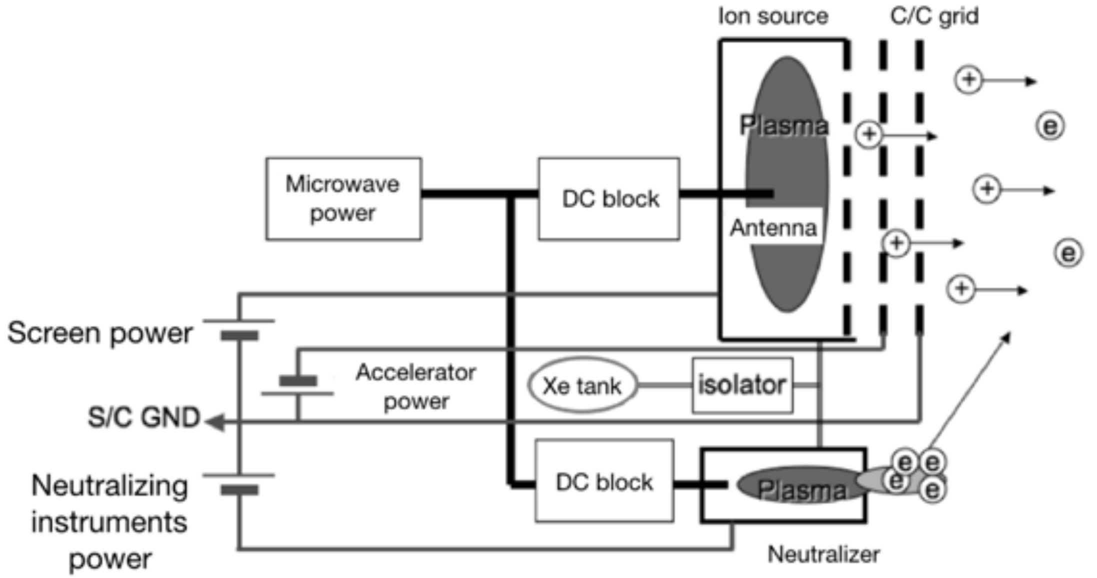


Fig: System diagram of microwave discharge type ion engine

(credit: JAXA)

Note: the ion engine developed at Institute of Space and Astronutical Science in Japan is a microwave discharge ion engine

Reference：Spin-off ion engine technology

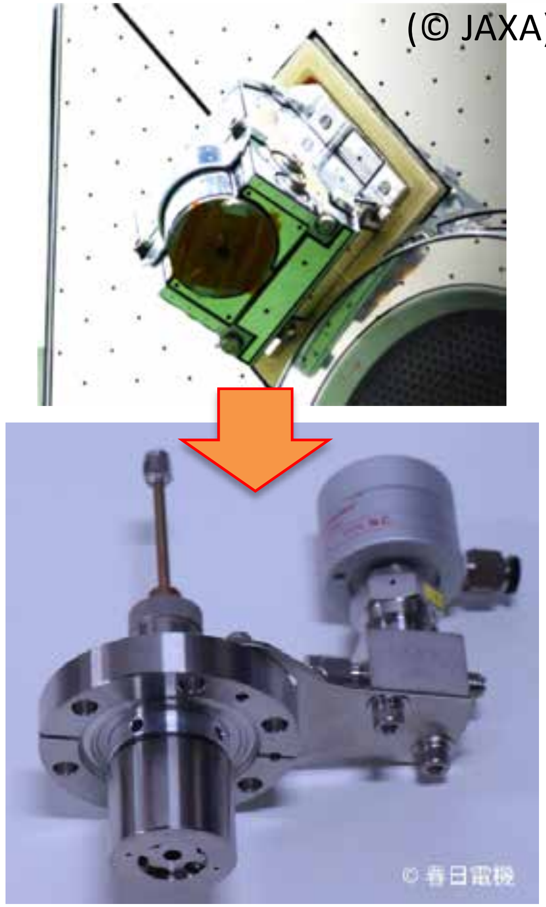
Applying the ion engine technology of Hayabusa2 asteroid explorer to the development of the “microwave plasma discharge treatment system”

・Regardless of the type of business, the generation of static electricity at a manufacturing site that requires a high vacuum environment has an adverse effect on product manufacturing. (For example, when manufacturing high-end film material such as OLEDs or a high barrier film, an electrostatic discharge can be generated on the film and lower the manufacturing yield).

・Attachment of charged dust to a spacecraft from the asteroid or lunar surface also has an adverse effect (e.g. camera lens dirt).

・By applying the neutralizer technology developed for Hayabusa2, we developed a device that can eliminate static electricity even in a high vacuum environment through plasma emission. With manufacturer Kasuga Electric, we commercialised this with domestic parts in FY2019. (The main feature is a large amount of static electricity can be removed without breaking the high vacuum environment).

(© JAXA)



※For inquires, please refer to the JAXA press release: http://www.jaxa.jp/press/2019/10/20191008a_j.html

2019/11/13 Commemorative photo of Ryugu departure