**HAYABUSA2, THE NEW CHALLENGE BASED ON THE LESSONS LEARNED OF HAYABUSA.**
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**Introduction:** Hayabusa, which was launched in 2003, was the first asteroid sample return mission in the world. It explored Asteroid (25143) Itokawa in 2005, and came back to the earth with the sample of Itokawa in 2010. Now Hayabusa2, the follow-on mission of Hayabusa, is being prepared[1]. Hayabusa2, which will be launched at the end of 2014, is also an asteroid sample return mission, but its target (162173) 1999 JU3 is C-type, which is different from S-type Itokawa. Moreover Hayabusa2 has been changed in many parts, because we leaned a lot from Hayabusa. In this paper, Hayabusa2 mission is introduced in comparison with the Hayabusa mission (Fig.1).

**Difference of Mission:** The purpose of both missions is the sample return from asteroids. Although the taxonomic type of the target asteroids are different as mentioned above, they are near earth asteroids, the orbits of which exist from just inside of the orbit of the earth to the outside of the orbit of Mars. Therefore, from the point of the mission operation, the both missions are rather similar. After the launch, the spacecraft once come back to the earth to perform the earth swingby, and then they approach to their target asteroids by using the ion engines. After the proximity operation around the asteroid, they leave from it and come back to the earth also by using the ion engines. When they arrive at the earth, the reentry capsule is released and it lands on the earth.

In this way, the sequence is quite similar in both missions, but one difference is the period of the asteroid proximity operation. The proximity operation period of Hayabusa was just about three months. This is too short to do many operations, such as the remote sensing observations, the rover release, and the sampling from the surface of the asteroid. So in the Hayabusa2 mission, the spacecraft stays around 1999 JU3 for about one and half years.

**New Payloads of Hayabusa2:** The spacecraft of Hayabusa2 looks like almost similar to that of Hayabusa. The size is almost same, and the mass of Hayabusa2 is about 100 kg heavier than that of Hayabusa, whose wet mass is 510 kg.

The major difference that we recognize from the appearance is High Gain Antenna (HGA). Hayabusa had one parabolic HGA, but Hayabusa2 has two planar HGAs. The type of HGA has been changed because the mass of the planar HGA is much more lighter than that of the parabolic one, while the performance is the same. The reason why Haybusa2 has two HGAs is that Hayaubsa2 has the Ka-band communication as well as the X-band communication. In the daily operation, we use the X-band, but when we download the observation data of the asteroid, we use the Ka-band, because the Ka-band communication is about four times faster than the X-band. The bit rate is up to 32 Kbps.

Another new payload of Hayabusa2 is Small Carry-on Impactor (SCI). SCI is a small box, about 30 cm in size. SCI is released about a few hundred meters above the surface of the asteroid, and it shoots the 2-kg copper liner to the asteroid by exploding itself. The liner is accelerated up to 2 km/s and it will create a small crater on the surface of the asteroid. The size of crater may be about 2 or 3 meters in diameter. The purpose of this impact experiment is not only to know the physical characteristics of the asteroid surface but also to reveal the subsurface material, which Hayabusa2 will try to get.

Before the SCI explodes, Hayabusa2 must hide behind the asteroid to avoid the high-speed debris of SCI. This means that the spacecraft cannot observe the ex-

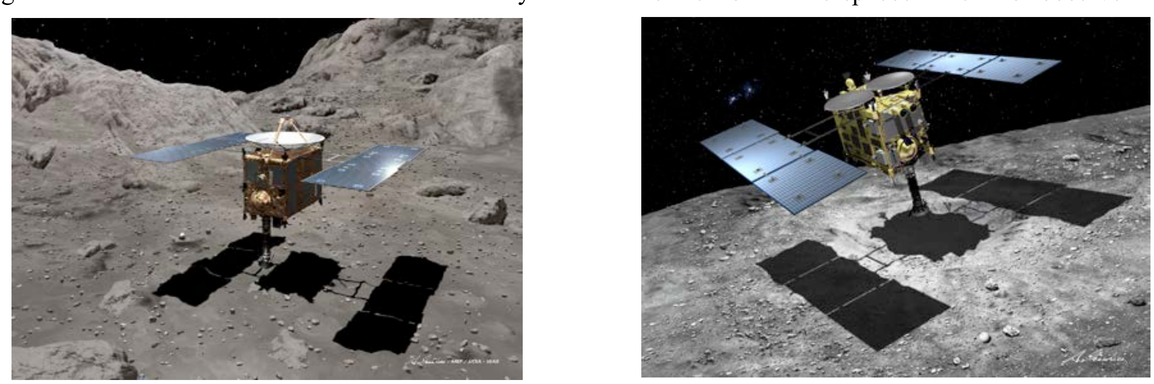

*Fig.1 Hayabusa (left) and Hayabusa2 (right)*

plosion of SCI and the impact of the liner to the surface. In order to observe these impact events, Hayabusa2 has a deployable camera (DCAM3), and it is released before Hayabusa2 hide behind the asteroid. DCAM3 is the heritage of IKAROS, the solar power sail mission of Japan launched in 2010.

**Major Improvements in Hayabusa2:** Hayabusa succeeded in bringing back the surface material of Itokawa, but it had a lot of troubles. We studied all the troubles and have applied many improvements for Hayabusa2, if we think it is necessary.

One of the major improvements is the attitude control system. Hayabusa had three reaction wheels, but two of them were broken before the first touchdown. Even if we cannot use reaction wheels, we can use the chemical thrusters to control the attitude. But the operation becomes much more complicated and using chemical thruster causes small acceleration. Therefore, we have one more reaction wheels in Hayabusa2 and we try not to use them much especially on the way to the asteroid. This can be done because we actually operated the attitude of Hayabusa with only one reaction wheel in the earth return phase.

Another important improvement in Hayabusa2 is the routing of the pipes of the fuel and the oxidizer. There were two routing of the pipes in Hayabusa, but these routing was not effective when some trouble occurs. In fact, the fuel of Hayabusa leaked after second touchdown, and this caused a very serious problem in the later operation. We had another experience in Akatsuki, Japanese Venus mission. It had a trouble in its main engine when it arrived at Venus. By considering these troubles, we have modified the chemical propulsion system of Hayabusa2.

The ion engine system (IES) has also been modified. Hayabusa2 has the same IES, which is Xe microwave discharge ion engine system. Hayabusa has four ion engines, and all of them had some troubles at the very end of the mission. The main reason of the troubles is the aging after using them for long time. So in Hayabusa2, IES has been modified to have less aging effect, and also the thrust level of the engines has increased about 20 % larger than the original one.

Lastly the number of the target maker (TM) has increased to five from three of Hayabusa. TM is the artificial landmark, and it is released from the spacecraft and is put on the surface of the asteroid before touchdown. Hayabusa2 can make touchdown three times, and basically one TM is used for one touchdown. However when the spacecraft touch down to the newly created crater by SCI, we must carry out pinpoint touchdown, where we may use up to three TMs.

**Changes of Mission Payloads:** Hayabusa2 has mission payloads as follows: Optical Navigation Cameras (ONC-T/W1/W2), Near Infrared Spectrometer (NIRS3), Thermal Infrared Imager (TIR), Laser Altimeter (LIDAR), Sampling System (SMP), SCI, DCAM3, three small rovers (MINERVA-II-1A/1B/2), lander (MASCOT), and reentry capsule (CPSL). The completely new items are TIR, which is a heritage of Akatsuki mission, SCI and DCAM3, which are already mentioned above, and MASCOT, which is provided by DLR and CNES.

ONC, SMP, and CPSL are basically same as those of Hayabusa, but there are many small changes. For example, the filter of ONC-T has been changed a little, SMP has a small additional mechanism to get the surface material, and CPSL has sensor units to measure and record the flight data.

Since the type of the target asteroid was changed from S-type to C-type, we changed NIRS3 and LIDAR form the original ones. As for NIRS3, the detectable wavelength is 1.8 - 3.2 μm, although the original NIRS of Hayabusa, it is 0.85 - 2.10 μm. This change has been done because we want to get the data of 3 μm to detect hydrated minerals. As for LIDAR, the system has changed a lot, because the albedo of C-type asteroid is much smaller than that of S-type. LIDAR of Hayabusa2 has two detectors, one is for long-distance and the other is for short-distance.

The small rovers MINERVA-II are the heritage of Hayabusa's MINERVA, and they move on the surface of the asteroid by hopping. Hayabusa had only one MINERVA, and we failed to land it on the surface of Itokawa. Hayabusa2 has two kinds (1 and 2) MINERVA-II and MINERVA-II-1 separates into two (A and B), so there are three small rovers in total. In addition to these small rovers, Hayabusa2 has a small lander, MASCOT. It has four science payloads on it.

**Additional Things:** Up to here, we summarized the difference between Hayabusa and Hayabusa2 mainly form the point of hardware. However the experiences from the operations of Hayabusa are also very important. For example, the failures occurred at MINERVA landing and the samplings were not due to the hardware trouble but mainly due to the operation. We have also verified about these operational things and the operation of Hayabusa2 will be modified.

**Final Remarks:** Hayabusa2 is a follow-on mission of Hayabusa, but the spacecraft has changed a lot based on the lessons learned of Hayabusa. We hope that Hayabusa2 will have much less troubles than Hayabusa and the scientific output will be much more.

**References:**

[1] Yoshikawa M., et al. (2014), *TRANSACTIONS OF THE JAPAN SOCIETY FOR AERONAUTICAL AND SPACE SCIENCES, AEROSPACE TECHNOLOGY JAPAN, 12, in press.*