Asteroid Sample Return Mission Hayabusa2 - Next New Challenge

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Abstract

After the successful return of Hayabusa, we have started Hayabusa follow-on mission, Hayabusa2. It is an asteroid sample return mission again. The target asteroid is C-type, so we can study the organic matters and water that existed at the formation of the solar system. The spacecraft is similar to Hayabusa, but many parts are modified so that we will not have the troubles that we experienced in Hayabusa. The spacecraft has aimpactor, which will make an artificial crater on the surface of the asteroid. The planned launch year is 2014, arriving at the target asteroid 1999 JU3 in 2018, and coming back to the earth 2020.

1. Introduction

Hayabusa is the first asteroid sample return mission in the world. Hayabusa, which was launched on May 9, 2003, arrived at the target asteroid (25143) Itokawa on September 12, 2005 (Fig.1). We were surprised to see the strange and unexpected nature of Itokawa. After overcoming several serious problems, Hayabusa came back to the earth on June 13, 2010, and the capsule landed successfully on the desert of Australia. When Hayabusa returned to the earth, it became a large and bright fireball. It was quite dramatic and moving. Although Hayabusa had a lot of troubles and difficulties, it was successful to bring back the surface materials of Itokawa. The initial sample analysis has already been done, and we revealed a little about the birth of Itokawa.

After Hayabusa, we have started next asteroid sample return mission, Hayabusa2. Hayabusa2 is similar to Hayabusa, but the target asteroid is C-type, which is different from Itokawa, S-type. Many parts in the spacecraft will be modified so thatHayabusa2 will not have the same trouble occurred in Hayabusa. From the next section, we show the outline of Hayabusa2 mission. In the following part of this section, we summarize the importance of explorations of small solar system bodies.

There are several purposes for exploration of small solar system bodies. The small solar system bodies, such as asteroids and comets, are not outstanding except that comet shows long tail near the sun. However, the number of these small bodies is quite large, and at present about 600,000 asteroids have been found. These objects are supposed to have information at the time of the birth of the solar system. Therefore, the study about the formation and evolution of the solar system is the one of the major purposes of the exploration to the small solar system bodies.

Another important thing is spaceguard. Asteroids or comets may collide to the earth. If such collisions occur, we will have large disaster. So we must prevent such collision. In order to do this, at first we must discover the objects that will come close to the earth or that have possibilities to collide to the earth. If we find such objects, then we must try to do something to avoid the collision. We must know the characteristics of colliding objects to avoid their collision. These are the activities of the spaceguard, and asteroid exploration is quite important to know the nature of such colliding objects.

Small bodies will have such materials like metal or water. These materials are necessary when mankind goes into the interplanetary space. Of course, these materials cannot be used right now, because it costs a lot to get them form asteroids or comets to the earth. However, in the future, it may be possible that such materials are utilized. In addition to these, the asteroids that approach to the earth have another important aspect. Such asteroids can be the targets of manned mission. Human beings have already been to the moon, and it is said that the next target is Mars. However, Mars is too far form the earth to send manned spacecraft in near future. Asteroids approaching to the earth will be the good targets before manned mission to Mars. In Fig.2, the purposes of exploration to the small solar system bodies are summarized.

Fig.1: Hayabusa and Asteroid Itokawa

2. Hayabusa2 Mission

In Japan, we have several categories of space mission to the solar system bodies, such as lunar mission like "Kaguya (SELENE)", planetary missions like "Nozomi (PLANET-B)" and "Akatsuki (PLANET-C)", and missions to small solar system bodies like "Sakigake (MS-T5)", "Suisei (PLANET-A)", and "Hayabusa (MUSES-C)". Hayabusa2 is the next mission to the small solar system bodies.

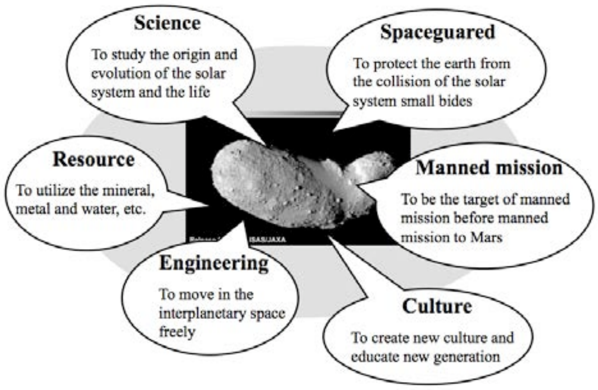

Fig.2: The purposes of exploration of the small solar system bodies

2.1 History

The Hayabusa2 mission was proposed in 2006 at first. In the year before this, 2005, Hayabusa tried to get the surface material from Asteroid Itokawa, but it could not do this as planned. Moreover Hayabusa had very serious problems, and we were not sure whether it could come back to the earth or not. Therefore, we proposed another mission to try again. Asteroid 1999 JU3 was selected as the target object for Hayabusa2, because it is C-type asteroid. Since Asteroid Itokawa is S-type, we thought that we would have much more new scientific results if we explore a different kind of asteroid.

In this first proposal, the spacecraft was almost same as that of Hayabusa, because we wanted to start it as soon as possible. Of course, we will modify the parts where trouble occurred in Hayabusa, but there were no major changes. The launch windows to go to 1999 JU3 were in 2010 and 2011. However, since we could not start Hayabusa2 mission immediately, we missed these launch opportunities. The next launch windows are in 2014. Therefore, we have changed our original plan and we are now planning to launch Hayabusa2 in 2014.

Since the launch was delayed, we changed our plan a little. The new plan of Hayabusa2 is basically same as that of the first proposal, so the spacecraft is similar to Hayabusa. However, we are planning to have new equipment. One of them is what we call "impactor." The impactor is a small box that contains explosive. After released from the spacecraft about a few hundred meters above the surface of the asteroid, the impactor will explode and a lump of copper will be accelerated at the speed of 2 km/s or so. The mass of the copper is about 2 kg, so wethink that a crater about a few meters in diameter will be created on the surface. Then we will try to get the materials inside the crater or those ejected from it. Then we may get the material which would be less changed in quality.

The status of Hayabusa2 project shifted to Phase-B in May 2011, and we have stated to develop the spacecraft of Hayabusa2 for the launch in 2014. The critical design review (CDR) was finished in March 2012, and the first interface test will be done at the beginning of the year of 2013.

2.2 Mission Scenario

The launch window that we are aiming at now is December 2014. We use H-IIA rocket to launch Hayabusa2. The launching site is in Tanegashimaisland in Japan. There are other launch windows in 2015, which are backup windows. After the launch, the spacecraft comes back to the earth in December 2015 to execute the earth swingby, and departs from the orbit near the orbit of the earth.

In the cruising phase, Hayabusa2 uses the ion engine, which is the modified one that was used for Hayabusa. Hayabusa2 will arrive at 1999 JU3 in June 2018. It will stay near the asteroid for about one and half years. This period is much longer than the case of Hayabusa. Hayabusa had only three month to explore Itokawa and this was too short to do the many missions. Therefore we have the period long enough for Hayabusa2.

At the asteroid, Hayabusa2 observes the asteroid in detail at first. Next it releases small rovers and a lander. Then Hayabusa2 performs touchdown to collect the surface material. The method of sample correction is almost same as that of Hayabusa. Finally, we use the impactor to make a small crater and touchdown again to the crater to collect the material revealed from the subsurface.

Hayabusa2 will leave the asteroid at the end of 2019, and come back to the earth at the end of 2020. The capsule will be released and it will land on the desert in Australia. The spacecraft will flyby near the earth and go somewhere. The capsule will be brought back to Japan and it will be opened in the curation facility in JAXA. We hope that we will find the sample of 1999 JU3 in it. If we find some samples then the initial analysis will be done by the science team of Hayabusa2 first. And later, the samples will be distributed to researchers in the world.

The whole scenario is summarized in Fig.3.

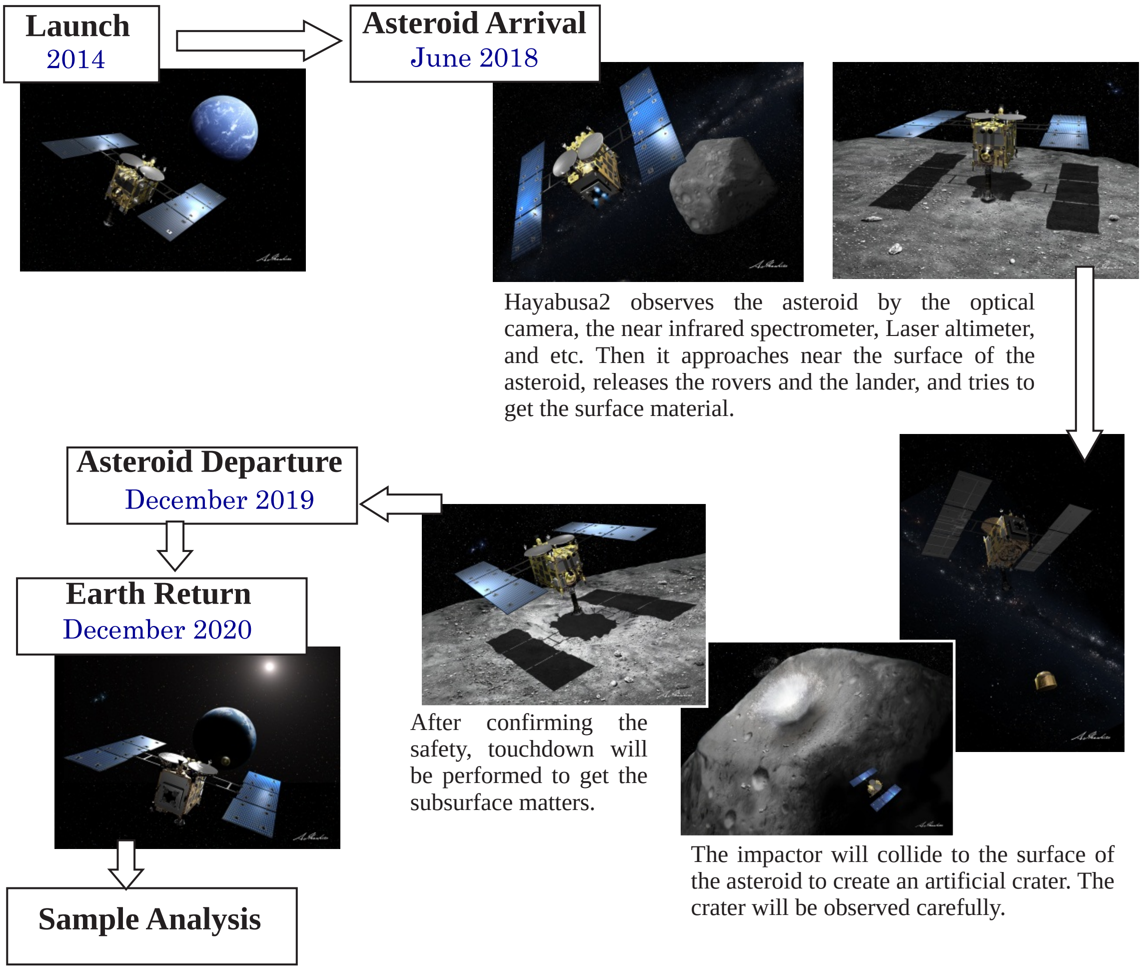

Fig. 3: The current scenario of Hayabusa2 mission

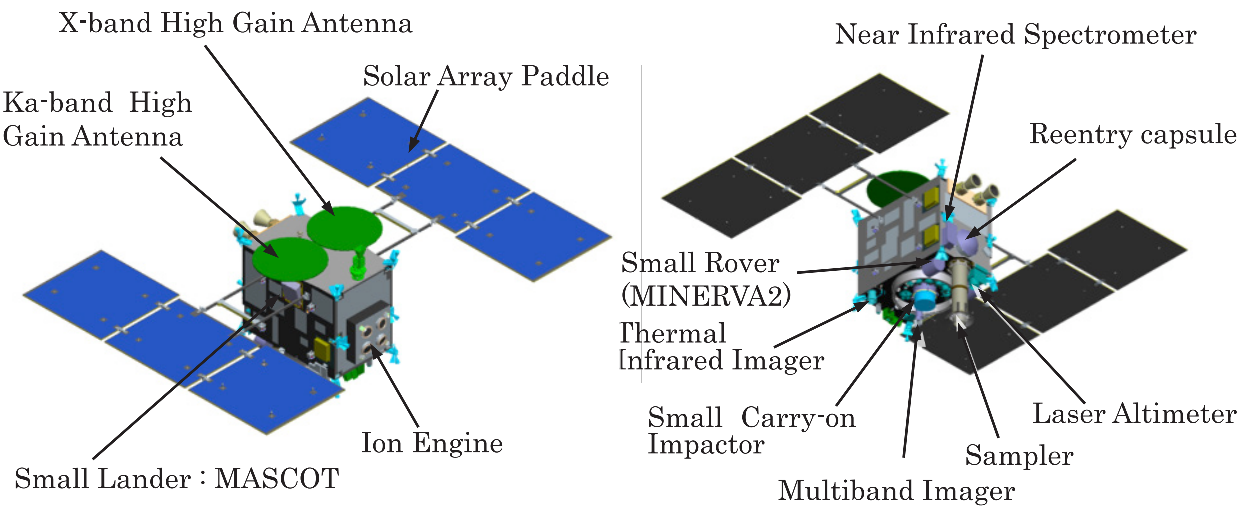

Fig. 4: Hayabusa2 spacecraft

2.3 Spacecraft and Payloads

As we already mentioned, the spacecraft of Hayabusa2 is basically similar to that of Hayabusa (Fig.4). However, we have the experience of Hayabusa, so we will modify many parts of Hayabusa2 so that the mission will be more reliable and robust. Especially we will modify the attitude control system, the ion engine, the chemical thruster system,and etc. One of the new things for Hayabusa2 is Ka-band communication. Since it is better to have high-rate downlink, we have Ka-band in addition to X-band. Ka-band communication will be used when the observed data of 1999 JU3 are sent to the earth.

As for the guidance and navigation in the proximity phase, we consider more precise method than Hayabusa using the experience of Hayabusa. For example, Hayabusa2 will have five target makers in order to navigate Hayabusa2 more accurately at the touchdown (Hayabusa has three target makers).

The mission payloads of Hayabusa2 are summarized in Table I. As for the science, we have four instruments; Multiband Imager (ONC-T), Near IR Spectrometer (NIRS3), Thermal IR Imager (TIR), and Laser Altimeter (LIDAR). ONC-T and LIDAR are almost same as those of Hayabusa, although the filter of ONC-T is changed slightly. NIRS3 is the same as NIRS of Hayabusa, but the wavelength is different. Since we want to study the absorption by water, NIRS3 must observe 3 μm wavelength. TIR is new for Hayabusa2, but we have already developed it for the Venus mission of Japan, "Akatsuki" (PLANET-C).

Other mission payloads are the sampler and the small rover (MINERVA2) , which were the payloads of Hayabusa. They will be a little changed from those of Hayabusa, but the basic functions are similar. The completely new payload is Small Carry-on Impactor (SCI), which is already mentioned in the previous subsection.Another new payload is a small lander called MASCOT, which is mentioned in the next sub-section.

2.4 International Collaborations

At present three international collaborations are under consideration. One is the collaboration with DLR (The German Aerospace Center). DLR provides a small lander called MSCOT (Mobile Asteroid Surface Scout). MASCOT will have four science payloads to investigate the surface properties of 1999 JU3. The second collaboration is with NASA (The National Aeronautics and Space Administration). The collaboration with NASA was done for Hayabusa, so similar collaboration is under consideration for Hayabusa2. The third collaboration is with the government of Australia for the capsule reentry.

Table I: Payloads of Hayabusa2

Payloads	**Specifications**
Multiband Imager (ONC-T)	Wavelength: 0.4 – 1.0 μm, FOV: 5.7 deg x 5.7 deg, Pixel Number: 1024 x 1024 px, filter (ul, b, v, w, x, p, Wide)
Near IR Spectrometer (NIRS3)	Wavelength: 1.8 – 3.2 μm, FOV: 0.1 deg x 0.1 deg
Thermal IR Imager (TIR)	Wavelength: 8 – 12 μm, FOV: 12 deg x 16 deg, Pixel Number: 320 x 240 px
Laser Altimeter (LIDAR)	Measurement Range: 30 m – 25 km
Sampler	Minor modifications from Hayabusa
Small Carry-on Impactor (SCI)	Small, deployed system to make an artificial crater on the surface
Separation Camera (DCAM)	Small deployable camera to observe the SCI operation
Small Rovers (MINERVA-2)	Almost same as MINERVA of Hayabusa
Small Lander (MASCOT)	Provided by DLR

3. Target of Hayabusa2

As it is already mentioned in the previous sections, the target object of Hayabusa2 is Asteroid (162173) 1999 JU3, which is C-type asteroid. The observation campaign for this asteroid was done in 2007 and 2008. We know the physical parameters of 1999 JU3 as shown in Table II ([1], [2]). The size is about 920m in diameter, so it is larger than Itokawa but still it is very small object. The shape estimated up to now is not so elongated like Itokawa (Fig. 5). The spin period is about 7.6 hours and this is rather shorter than Itokawa, the spin period of which is 12hours. However, for the purpose of the sample collecting, this spin rate is no problem. The albedo of 1999 JU3 is small, because it is C-type asteroid.

Fig.6 shows the orbit of 1999 JU3. The orbit is

Table II: Physical parameters of Asteroid 1999 JU3

Parameter	Value
Spin period	0.3178 day (~7.6h)
Spin axis	(λ,β) = (331, 20) Kawakami model = (73, 62) Müller model
Ratio of axis	1.3 : 1.1 : 1.0
Size	0.87±0.03 km
Albedo	0.070±0.0006
Magnitude	H=18.82±0.021,G=-0.110±0.007
Type	Cg

(λ,β) = (ecliptic longitude, ecliptic latitude)
These data were reported by [1] and [2].

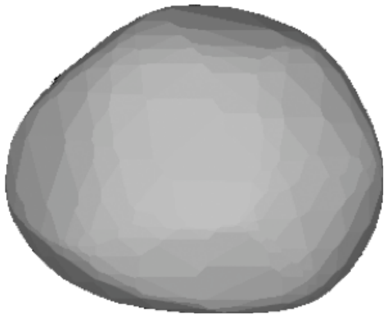

Fig.5: Estimated shape of 1999 JU3 based on Müller model.

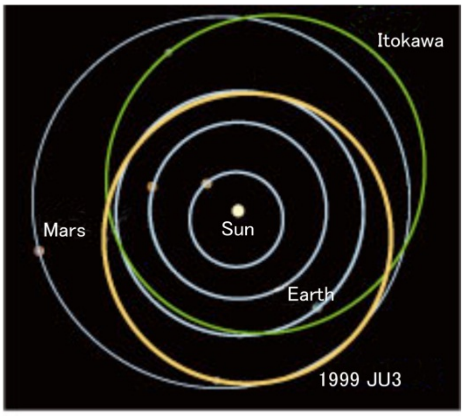

Fig.6: The orbit of 1999 JU3

similar to that of Itokawa, and it is orbiting from just inside the orbit of the earth to just outside the orbit of Mars. The inclination of the orbit is small like Itokawa. Such orbit is suitable for a small spacecraft like Hayabusa2 to reach and go back to the earth.

The observations of 1999 JU3 were done in 2011 and 2012, and we have already had some new results of observation. We think we can get more information about the physical properties of 1999 JU3. Especially the orientation of the spin axis is quite important to make the mission scenario around the asteroid, so we hope that we can get much precise values of the spin axis from the observations in 2011 and 2012.

4. Summary

In Japan, we do not have so many planetary missions, but most of our missions are very ambitious and also very advanced. Hayabusa is the most ambitious mission among them, and we have tried many new things that have not been tried yet in the world. Hayabusa gave us a lot of very precious experiences. Although there were many unexpected things and problems during the mission of Hayabusa, we could manage the mission up to the final stage. Based on such experiences, we are planning the next mission, Hayabusa2. Hayabusa2 will do the similar mission as Hayabusa, but its technology will be (and should be) much more mature than that of Hayabusa. This is the most important purpose of Hayabusa2 from the point of engineering.

Another important point is the science. Although the main purpose of Hayabusa mission is not science but technology, the results of the scientific study of Itokawa attracted considerable attention from a lot of researchers, because it was the first time that we investigate such a small object of the solar system. We can say that we saw the building block of planets. The first science results were reported in the special issue of the journal of Science in 2006 [3] and the first sample analysis results were also reported in the special issue of Science in 2011 [4]. As for Hayabusa2, science is quite important as well as technology. Therefore, we chose a C-type asteroid 1999 JU3 as the mission target of Hayabusa2. We expect that we can study organic matters and waters at the beginning of the solar system. Asteroid 1999 JU3 is also small object and it is one of the near earth objects. Therefore the study about small near earth objects will be much advanced by Hayabusa2, which will surely contribute to the spaceguard activity.

The small solar system bodies still have a lot of mysteries and potentials for the human in future. We are sure that Hayabusa2 will contribute a lot. After Hayabusa2, we want to plan the next mission, which may totally different from Hayabusa and Hayabusa2. so that we can study the origin and evolution of the solar system much further. Hayabusa was the starting point to the new exploration of the solar system, and Hayabusa2 is the next, and we hope post-Hayabusa2 will follow. We are on the way to the full understanding of our solar system.

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