MISSION STATUS OF HAYABUSA2. M. Yoshikawa[1], Y. Tsuda[1], S. Watanabe[2], S. Tanaka[1], S. Nakazawa[1], F. Terui[1], and T. Saiki[1], Hayabusa2 Project Team, [1]JAXA/ISAS (3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan, yoshikawa.makoto@jaxa.jp), [2]Nagoya University.

Introduction: Hayabusa2 (Fig.1) is the second sample return mission from an asteroid after Hayabusa mission (2003-2010). The target asteroid is (162173) Ryugu (the provisional designation is 1999 JU_3), which is a C-type asteroid. The main science objective is to investigate organic matters and water at the beginning of the solar system. The technological purpose is to maturate the new technology developed by Hayabusa and to develop other new technology for space missions ([1],[2],[3]).

Hayabusa2 has four science instruments: Optical Navigation Camera (ONC, Multiband Imager), Near Infrared Spectrometer (NIRS3), Thermal Infrared Imager (TIR), and Laser Altimeter (LIDAR). It has one lander, MASCOT (Mobile Asteroid Surface Scout) and three small rovers, MINERVA-II. By using these instruments, we will execute remote sensing observations and observations on the surface of Ryugu.

Hayabua2 also has an impactor (SCI, Small Carry-on Impactor) to make a small crater on Ryugu. A mass of two kg copper will be accelerated at the speed of 2km/s, and it will hit the surface of Ryugu. It is expected that a crater of a few meter diameter will be created. If possible, the spacecraft will touch down to this crater to get the sub-surface materials. The explosion of the impactor and the subsequent impact on the surface of Ryugu will be observed by a separation camera (DCAM3). This experiment using impactor is quite challenging. It will be done in the later stage of the proximity phase. (Before the impact experiment, the spacecraft will touch down to the surface of Ryugu once or twice to get the surface material.)

See [4] for detailed explanations of each instrument.

Mission Schedule: Hayabusa2 was launched December 3, 2014 by an H-IIA launch vehicle from Tanegashima Space Center in Japan. Just one year later, on December 3, 2015, Hayabusa2 came back to the Earth to execute the Earth gravity assist, which was successfully done and its orbit was changed toward Ryugu. We observed the Earth and the moon by using the remote sensing instruments on board at the Earth gravity assist. In addition to this, Hayabusa2 spacecraft was observed by many grand-based telescopes as an outreach event.

The main engine of Hayabusa2 is the ion engine, which was modified from the engine developed for Hayabusa. The ion engine was used before the Earth gravity assist, but long-term operations of the ion engine were done after the Earth gravity assist. We need three long-term ion engine operations before arriving at Ryugu and we have already done twice. The final long-term operation will be done from January to June of 2018. When the ion engine was not in operation, we carried out test observations of planets and stars. We also tried to discover Earth Trojan asteroids when the spacecraft was near L_5 point (L_5 : one of the Lagrangian points) in April 2017, but we could not find any asteroids there.

In June or July of 2018, about three and half years after the launch, Hayabusa2 will arrive at Ryugu. At first, we will observe Ryugu carefully and decide the landing place. Then we will release the lander and rovers, execute touchdown once or twice, and try the experiment of the impactor. Hayabusa2 will leave Ryugu at the end of 2019 and bring back the capsule to the Earth at the end of 2020.

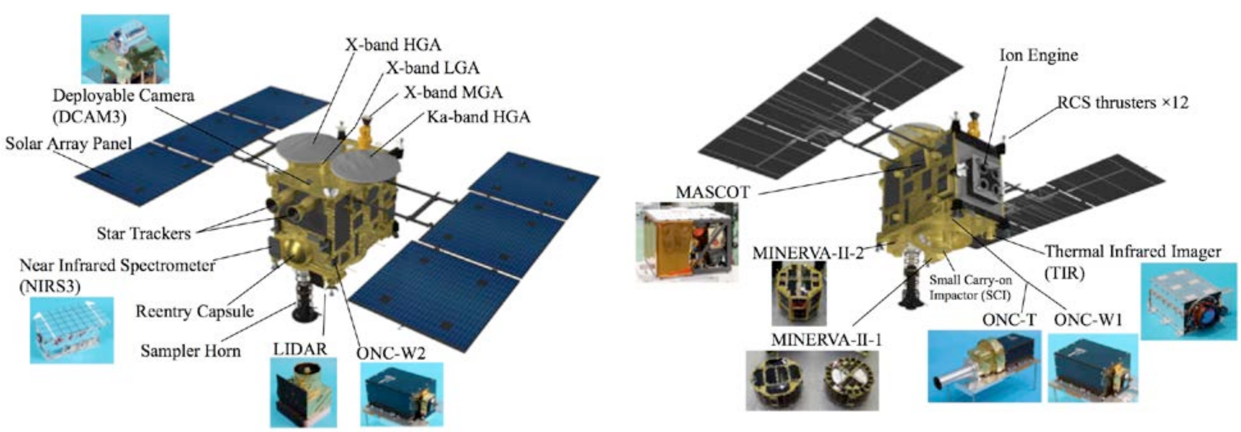

Fig.1 Hayabusa2 spacecraft and its instruments

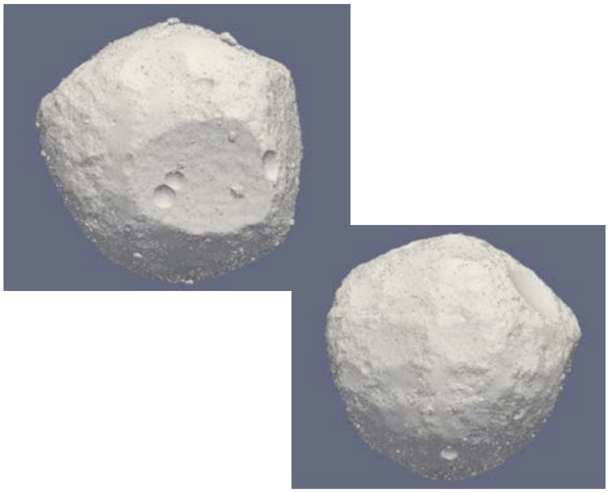

Fig.2 Fictitious Ryugu "Ryugoid" used for trainings

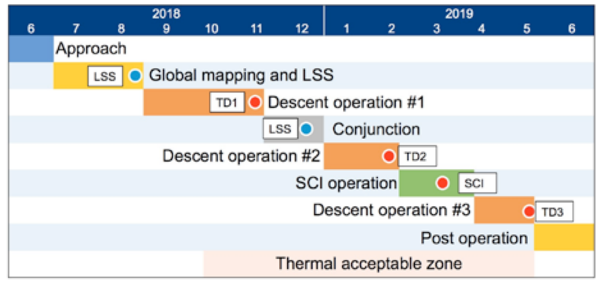

Fig.3 An example of proximity phase operation schedule

This schedule could be changed depending on the properties of Ryugu. The lander and the rovers possibly land on the surface of Ryugu before TD1 or after TD3. (LSS : Landing Site Selection, TD : Touchdown, SCI : Small Carry-on Impactor)

Training for Proximity Phase Operations: In 2017, more than one year before arriving at Ryugu, we have started our training for the proximity phase operations. There are two kinds of training, that is, Landing Site Selection (LSS) training and Real-Time Integrated Operation (RIO) training.

We started LSS training at the beginning of 2017. The purpose of this training is to verify the process of the landing site selection, especially to check the decision making framework or criteria, tools, and interface. We made a fictitious asteroid for Ryugu, which we call "Ryugoid" (Fig.2). Ryugoid is a 3D shape model of about 370 million polygons, which has various surface features such as craters, boulders, facets, and dips. We also created the fictitious observation data. The project members tried to analyze the fictitious data without knowing the assumed Ryugu. Finally we have selected the touchdown point and the training was finished.

Then we have started RIO training from the late half of 2017. The purpose of this training is to simulate various kinds of proximity phase operation in real time and to check the tools, procedures, and operation time. There are several important proximity phase operations, such as low altitude operation, lander/lover release operation, touchdown operation, and impactor operation. We will continue RIO training until final approach phase.

Proximity Phase Operation Plan: The proximity phase operation plan is very important for Hayabusa2 mission. However we cannot fix the plan before the arrival at Ryugu because we do not have enough information about Ryugu now. The important information is such as shape, size, and orientation of the spin axis of Ryugu. The current information for these are not so certain, because we could not carry out observations by radar. Ryugu did not approach the Earth close enough for the radar observation. Our current knowledge depends on the optical data obtained by telescopes. The assumption now is that the shape of Ryugu is rather spherical, the size is about 900m in diameter, and the spin axis is not vertical to the ecliptic plane but rather slanted.

The current plan of the proximity phase operations is shown in Fig.3. The basic idea is as follows. After arriving at Ryugu, we quickly determine the spin axis orientation, shape and size. We will observe the surface of Ryugu and select the touchdown point. Then the some of the lander/rovers will be released and the first touchdown will be performed. At the beginning of 2019, the spacecraft is in the position of solar conjunction, so we will cease important operation in a month or so. After the solar conjunction, we will carry out second touchdown, and finally we will try the experiment using the impactor.

Summary: Up to now Hayabusa2 spacecraft has been operated without big troubles, and the mission is going as scheduled. The status of the spacecraft is fine. We are now carrying out many trainings for the proximity phase operations, and we will finish our preparation of the proximity phase operations before arriving at Ryugu. The arrival of Ryugu will be quite exciting. How does the Ryugu look like? We are looking forward seeing Ryugu.

References:

[1] Tsuda Y. et al. (2013) *ActaAstronautica*, 90, 356-362. [2] Yoshikawa M. et al. (2014) *Transactions of JSASS Space Technology Japan*, 12, No ists29, pp. Tk_29-Tk_33. [3] Watanabe S. (2017) *Space Science Reviews*, 208, 3–16. [4] *Special issue of Space Science Reviews*, 208 (2017).