HAYABUSA2 TOUCH-AND-GO SAMPLING AT RYUGU. S. Tachibana[1,2], H. Sawada[2], C. Okamoto[3*], H. Yano[2], R. Okazaki[4], Y. Takano[5], Y. N. Miura[6], and K. Sakamoto[2], [1]UTOPS, Univ. Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan (tachi@eps.s.u-tokyo.ac.jp), [2]ISAS/JAXA, 3-1-1 Yoshinodai, Sagamihara, Kanagawa 252-5210, Japan. [3]Dept. Planetology, Kobe Univ., 1-1, Rokkodai, Kobe 657-8501, Japan. [4]Dept. Earth Planet. Sci., Kyushu Univ., 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan. [5]Dept. Biogeochem., JAMSTEC, Yokosuka, Kanagawa 237-0061, Japan. [6]Earthquake Res. Inst., Univ. Tokyo, 1-1-1 Yayoi, Tokyo 113-0032, Japan. [*]Deceased

Introduction: Hayabusa2 is the JAXA's sample return mission from C-type near-Earth asteroid (162173) Ryugu, which may have recorded a long evolutional history of the Solar System [1]. The Hayabusa2 spacecraft arrived at Ryugu on June 24, 2018, and has been investigating the asteroid [2-4] with remote-sensing instruments (telescopic optical camera with 7 band filters (ONC-T) [5], near-infrared spectrometer (NIRS3) [6], thermal infrared imager (TIR) [7], and laser altimeter (LIDAR) [8]), two rovers (MINERVA-II1; HIBOU and OWL), and a MASCOT lander [9]. Main findings so far are: (i) Ryugu (mean radius of 448 ± 2 m) has a retrograde rotation with a period of 7.6326 hours and an obliquity of 172° [2]. (ii) Ryugu has a top shape with an equatorial ridge [2]. (iii) The bulk density is 1.19 ± 0.03 g/cm^3 [2]. (iv) Many large (>20 m) boulders are present at the surface with a number density twice as large as that of Itokawa, and there is no smooth terrain as seen in Itokawa [3]. (v) Many boulders are too large to be impact ejecta from crates [3]. (vi) The low bulk density and the abundant large boulders suggests that Ryugu is a rubble-pile body [2]. (vii) The surface has uniformity in visible spectra with very low geometric albedo (~0.043), darker than most of meteorite samples [3]. (viii) A weak 2.72-μm absorption feature, observed globally, indicates the ubiquitous presence of OH-bearing hydrated minerals [4].

JAXA announced that Hayabusa2 will perform its first touch-and-go sampling on Ryugu in the week of February 18, 2019 with a backup week of March 4, 2019. Here we review the Hayabusa2 sample acquisition and storage system (Hayabusa2 Sampler) and the sampling operation. We also expect to report preliminary results of touchdown sampling operation.

Hayabusa2 Sampler: The basic concept and design of the Hayabusa2 sampler are the same as the original Hayabusa [10, 11] (Fig. 1). In order to collect sufficient amount of samples (100 mg) compliant with both monolithic bedrock and regolith targets, a 5-g Ta projectile will be shot at an impact velocity 300 m s^{-1} at the timing of touchdown. The ejecta will be put into a sample catcher through an extendable sampler horn and a conical horn under a microgravity condition (1.5 x 10^{-4} m s^{-2} [3]). One-gravity laboratory experiments using the 1:1 scale of the sampling system with 1 mm glass spherules at one gravity shows that 150-250 mg of samples can be collected with a projectile shooting, which will be increased under microgravity because eject with low velocities can be collected. Three projectiles are equipped for sampling at three different surface locations.

The sample catcher of the Hayabusa2, located at the top-end of conical horn, has three chambers to store samples obtained at three locations separately [10] (Fig. 2). An inlet to the sample catcher is rotatable to select a chamber to store samples at each location. The size of sample catcher is almost the same as that of the original Hayabusa with two chambers, and the total volume is ~45 cm^3. The sample catcher has a design that is easier to be taken apart during curation at ISAS/JAXA [12] than that of the original Hayabusa.

After three sampling operations, the sample catcher is transported into the sample container inside the Earth re-entry capsule and sealed. The container sealing method is changed from double fluorocarbon O-rings for Hayabusa to an aluminum metal seal [11] to avoid the terrestrial air contamination (Fig. 2). The new aluminum metal seal is designed to allow only a leak of 1 Pa air for a week at atmospheric pressure. To avoid further potential contamination, volatile components released from the samples will be extracted prior to the opening of the container. The container will be attached to a vacuum line, and the bottom of the container, a part of which is thinned, will be pierced with a needle to extract volatiles (Fig. 2).

A back-up sampling method is also prepared [10]; The tip of the sampler horn is turned up like the teeth of a comb (Fig. 1), and surface pebbles will be lifted up by the turn-up part during touch down. The lifted pebbles will be put into the sample catcher by deceleration of the spacecraft.

Sampling operation: Touchdown operation for sampling will be made at the surface location without 50-cm sized or larger boulders and with the local surface angle of <30° for safety reasons. The Hayabusa2 team selected three candidate landing regions (~100 m x 100 m) in August 2018 based on landing safety, science, and samplability scores evaluated from observation data at the altitudes of 20 and 5-6 km [13]. Two regions are on the equatorial ridge (L07 and L08), and one is on the mid latitude region of the southern hemisphere (M04). Through further evaluation of the candidate regions, the L08 area (~200°E) was down-selected as the first touchdown site. A target marker that is used for autonomous navigation of the spacecraft was successfully dropped nearby the L08-B region (20 m in diameter) in October 2018, which was further selected as the target landing area in L08.

In the initial descent phase down to the altitude of 100 m, the horizontal position and velocity is controlled from the ground using surface images taken by ONC-T and ONC-W1 (wide-angle optical navigation camera) and the vertical velocity is controlled in the range of 0.1–1 m/s on board by LIDAR (Fig. 3). Further descent will be in fully autonomous mode. The spacecraft tracks the target marker that reflects light from an on-board flash lamp using ONC-W1. The laser range finder with four laser beams (LRF1) determines the surface orientation relative to the spacecraft below an altitude of 30 m and the spacecraft aligns its position to the local touchdown area. The spacecraft will land on the surface with the velocity close to free-fall, and the detection of the shrinkage/bending of the sampler horn determined by another laser range finder (LRF2) triggers the projectile shooting for sampling followed by the escape operation for ascent. Images of the sampling site before and after touchdown will be taken by ONC-W1 and CAM-H (a small monitor camera for monitoring sampling operation).

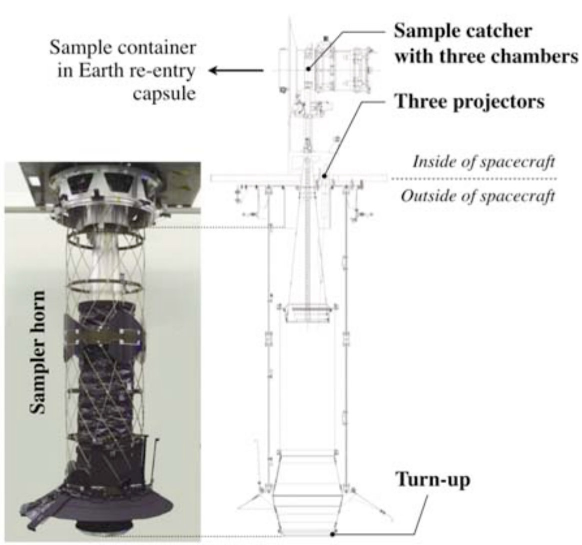

Fig. 1. Photograph of the Hayabusa2 sampler horn and schematic illustration of the Hayabusa2 sampler [1].

References: [1] Tachibana S. et al. *Geochem. J. 48,* 571-587. [2] Watanabe S. et al., in revision. [3] Sugita S. et al., in revision. [4] Kitazato K. et al. in revision. [5] Mizuno T. et al. (2017) *Space Sci. Rev. 208,* 33-47. [6] Kameda S. et al. (2017) *Space Sci. Rev. 208,* 17-31. [7] Iwata T. et al. (2017) *Space Sci. Rev. 208,* 317-337. [8] Okada T. et al. (2017) *Space Sci. Rev. 208,* 125-142. [9] Ho T.-M. et al. (2017) *Space Sci. Rev. 208,* 339-374. [10] Sawada H. et al. (2017) *Space Sci. Rev. 208,* 81-106. [11] Okazaki R. et al. (2017) *Space Sci. Rev. 208,* 107-124. [12] Yada T. et al. (2019) *LPS XXXXX,* this meeting. [13] Yabuta H. et al. (2019) *LPS XXXXX,* this meeting.

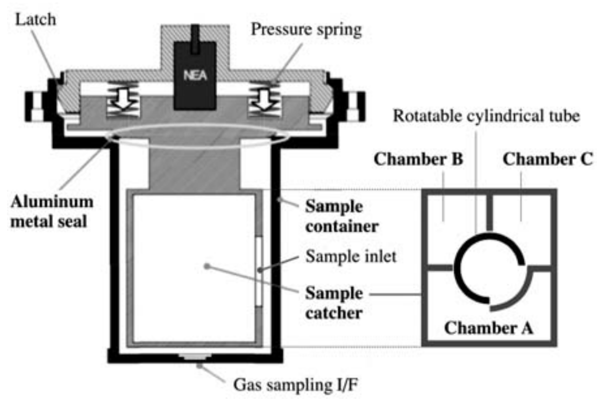

Fig. 2. Schematic illustration of the Hayabusa2 sample catcher and container [1].

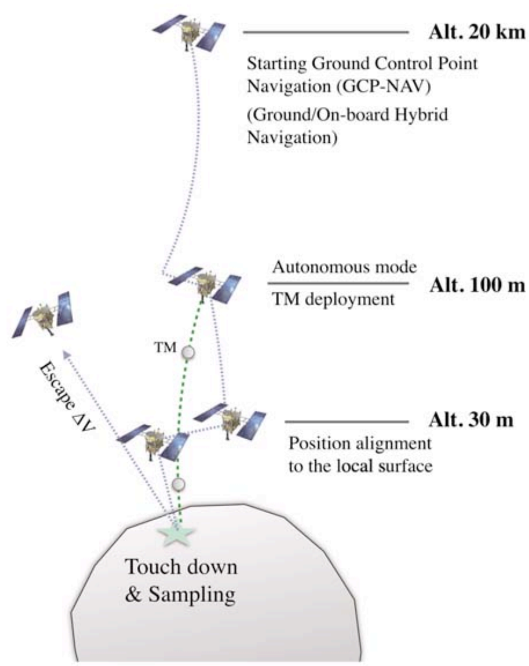

Fig. 3. Operation sequence for touchdown and sampling [1].