THE SAMPLING SYSTEM OF HAYABUSA-2: IMPROVEMENTS FROM THE HAYABUSA SAMPLER.

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Introduction: Samples from C-type asteroids, which are abundantly present in the asteroid belt and of which reflectance spectra resemble those of carbonaceous chondrites, may well preserve the information covering the long history of the solar system (Table 1), compared to other bodies such as comets and Itokawa-like bodies. Their scientific values will be significantly increased for return samples obtained with detailed geological contexts. Moreover, surface samples from near-Earth C-type asteroids will provide insights into the space weathering of C-type asteroids and the surface thermal processes due to irradiation of sunlight, which cannot be obtained from meteorites and interplanetary dust particles. The Hayabusa-2 is a sample return mission from a near-Earth C-type asteroid 1999JU3 (2014-2020). Here we describe a sampling system of the Hayabusa-2 spacecraft to obtain samples from multiple surface locations of the asteroid with minimal contamination and a possible sampling strategy.

Required Spec for the Sampler: Recent developments of analytical techniques has enabled us to analyze much less amounts of samples as in the case of Itokawa samples [1-8] and the required amount will be reduced further in 2020s, but in order to obtain the typical and/or average feature of the target asteroid, at least 100 μg of surface samples including several mm-sized particles are required to attain the scientific goals listed in Table 1 by return-sample analyses.

It is also of importance to obtain samples at multiple surface locations with different geological features and to preserve them separately in a sample container to understand the geological evolution of the asteroid, which also leads to better understanding of the processes prior to the planetesimal formation and of the recent processes as a near-Earth object. Thermal effects during sampling should be minimal.

Contamination to the samples should also be minimal, and any possible contamination should be recognized in advance. It is also required that the sample container is easier to be handled during the sample curation operation than the Hayabusa sample container to reduce the curation work and ensure the time for preliminary sample analyses.

The Hayabusa-2 Sampler: A sampler with the basically same design as that used in the Hayabusa is used with some modifications to satisfy the scientific requirement. A 5-gram Tantalum bullet is shot onto the surface at the velocity of 300 m/s at the timing of touchdown, and the ejecta will be put into a sample catcher through a sampler horn under a microgravity condition.

A back up sampling method is prepared; The tip of the sampler horn is turned up like the teeth of a comb, and the turn-up of the tip of the horn will lift up pebbles during the touch down procedure. These lifted samples will be put into the sample catcher by deceleration of the spacecraft.

The obtained samples will be put in the sample catcher. The sample catcher of the Hayabusa had two rooms, but the catcher of the Hayabusa2 has three rooms to store samples obtained at three locations separately. The new catcher has a design that is much easier to be taken apart during curation at the ground.

The sample catcher is put in the sample container and sealed after three sampling operations. The container sealing method is changed from double viton O-rings to a aluminum metal seal to avoid the terrestrial air contamination after the Earth return that happened for the Hayabusa container [9]. To avoid further potential contamination, volatile components 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 will be thinned in advance, is pierced with a needle to extract volatiles.

Touch-Down Operation: The highest priority of the first TD point for sampling could be the location with the absorption features at 0.7 and/or 3 μm (observed with ONC-T (multi-band telescopic camera) and NIRS-3 (near infrared spectrometer)), which are related to the presence of hydrated minerals. The presence of hydrated minerals indicates that the materials did not experience severe thermal metamorphism that decomposed hydrated minerals, which will enable us to obtain the samples that record both the asteroidal aqueous alteration event and the events prior to the asteroidal formation. Moreover, since the close relation between hydrated minerals and organic matter has been found in carbonaceous chondrites, the presence of organic matter is also expected in the location. The second TD could be the location with little or no evidence of hydrated minerals to compare with the first TD samples. The 0.55-μm albedo, observed with ONC-T, can be the abundance indicator of insoluble organic matter, and thus be used for the selection of the second TD point. If no compositional variation is observed for the asteroid surface, sampling from a bedrock can be a candidate because it could record the irradiation history of galactic cosmic rays since the formation of the asteroid. The SCI (small carry-on impactor for an artificial impact experiment) ejecta is planned to be the target of the third (final) TD, which will be the samples with minimal (or less) surface processes.

The TD locations should be observed in details with ONC-W (wide-angle camera). The highest spatial resolution for imaging the sampling point with ONC-W is ~3 mm/pix, which is sufficiently enough to recognize the circular track of the sampler horn (~14 cm in diameter) and enough to identify the artificial crater for sampling (~1 cm). The observation of the TD area with MASCOT (a mobile small lander) is also important because the wide angle camera on MASCOT can take the surface image with the spatial resolution of ~0.1 mm, which link the spatial scales of return-sample analyses (mm-nm) and of on-site remote sensing (km-mm).

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Table 1. Science themes expected for return samples from a near-Earth C-type asteroid.

4568 Ma → ~4564 Ma → 10-1 Ma → Present

Galaxy / Molecular Clouds	Protoplanetary Disk	Planetesimal	Main-Belt Asteroid	Near Earth Asteroid
Presolar Grains Nucleosynthesis GCE **Molecular Cloud Organics** Low T. processes Enrichment of Heavy Isotopes (D, ^{15}N)	**CAIs, Chondrules Metal** High T. processes Constraint on the timing of parent body formation **Disk Organics** FTT reactions at mild T.	**Aq. Alteration** **Therm. Metamor.** **Shock Metamor.** Conditions & timing **Diversification of Organics** Mineral-Organics association L-enantiomer excess of amino acids	**Shock Metamor.** Conditions & timing **GCR** Exposure history **Bulk Density** Internal structure	**Space Weathering** Ages, Regolith dynamics, Space environments, SW, Surface activity. **Therm. Metamor.** Heating by Sunlight
Spatial Variation/Heterogeneity of Returned Samples Planetesimal formation processes, Disk evolution Parent body size, Parent body processes				