MULTI-SCALE SCIENCE FROM ORBITER, LANDER, AND SAMPLE-RETURN BY HAYABUSA2

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Outline of Hayabusa2: Hayabusa2 is the second near-earth asteroid sample return mission organized by Japan Aerospace Exploration Agency, which was launched by H2A launch vehicle on 3 December 2014. After the Earth swing-by on 3rd December 2015, the spacecraft is en route to the target asteroid 162173 Ryugu. It will arrive at the asteroid and start remote observations to determine global features of the asteroid in July 2018. A set of hopping rovers MINERVA-II and a moving lander MASCOT collaborated with European countries will be released to conduct *in situ* experiments on the asteroid. Hayabusa2 will descend to the asteroid surface and collect samples at maximum three different sites and return them back to Earth in December 2020. Before its last touchdown, an impact experiment will be carried out with the Small Carry-on Impactor excavating the asteroid surface and the deployed camera DCAM3 viewing the phenomenon [1-3].

Target asteroid Ryugu: The asteroid to be explored by Hayabusa2 is 162173 Ryugu (formally 1999 JU_3). It is a near-earth asteroid whose perihelion and aphelion is 0.96 to 1.42 AU, respectively. Its visible to near-infrared spectrum shows rather flat and low reflectance within the range of C-type and has a weak absorption at 0.7 μm once detected [4], showing the existence of phyllosilicates. Its averaged thermal inertia is 250 ± 50 tiu, indicating the regolith surface mainly consisted of pebbles. Ryugu has rather rounded shape with 880 m in diameter, rotates in 7.61 hours, and its pole axis is not determined but probably declined [5-6].

Global observations from orbit: Hayabusa2 has remote sensing instruments: an 8-point filter wheel based multiband telescopic imager with (ONC-T) with 5.7° FOV, a set of nadir and side looking panchromatic wide angle imagers (ONC-W) with 60° FOV, an uncooled micro-bolometer based thermal infrared imager (TIR) with 16° x 12° FOV [7], a near-infrared point spectrometer with 1.8-3.2 μm range (NIRS3), a single footprint laser ranger (LIDAR), and the radio science. During most of period at the rendezvous phase, the spacecraft will keep its position at Home Position, 20 km altitude Earthward from the asteroid (sunlit side). With those remote instruments, the global properties of the asteroid will be measured: shape and rotation state, temperature and thermophysical properties such as thermal inertia, mineralogy and hydration state, and geologic features of the asteroid surface. The spacecraft will descend to the lower altitude (5 km) for high-resolution mapping and for close-up imaging during the touchdown operations (< 0.1 km) to investigate local features such as thermal, mineralogical, and geologic features as well as gravity. Using these information, the landing sites for surface experiments and sample collection will be selected both from the viewpoints of scientific and safety landing.

Local observations on asteroid: MASCOT has scientific instruments [8]: a wide angle imager CAM with four color LED to view the close-up surface physical and compositional state and the surrounding geologic features, a radiometer MARA based on 6 thermopiles with different wavelength filter to determine temperature profile and thermal inertia of the surface imaged by CAM, a 3-axis fluxgate magnetometer MAG to study the magnetic properties and remnant magnetic field of asteroid, and a near-infrared hyperspectral microscope MicrOmega to investigate the size, shape, mineralogy, and hydration state of each grain on the asteroid surface. CAM, MARA, and MicrOmega measures the surface with tens of micron to tens of centimeter resolution, providing the ground truth for the remote instruments which observes the asteroid global features with a centimeter to tens of meter resolution. *In situ* surface measurements give us the geologic context for the collected samples, and the bulk properties of surface materials as they are, which might be lost from the returned samples by destructing and shaking during the sampling and recovery processes. *In situ* observations help us interpret the results of detailed analysis of returned samples with millimeter to nanometer scale.

Micro and nano-scale observations of returned samples: Samples returned by Hayabusa2 will be treated in the Extraterrestrial Curation Center in JAXA for the initial description without terrestrial contamination, and delivered to researchers for extended analyses. Advanced technologies and methods will be used for a variety of measurements from millimeter to nano-meter scale. Those results of microanalysis help us interpret the results of remote sensing and in situ observations, verify the models based on the larger scale observations. In the case of Hayabusa, no information of bulk feature of rocks is obtained since we got a very small amount of samples and no grains larger than 1 mm exist [9]. In Hayabusa2, some grains larger than 1 mm are expected to show the bulk rock properties, which are directly compared with the results of remote sensing and *in situ* observations.

Summary: Multi-scale science from orbiter, lander, and sample return from kilometer to nanometer scale is panned to conduct in Hayabusa2, which will bring us the opportunity to understand the asteroid science by the synergy effects.

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