GLOBAL PROPERTIES OF 25143 ITOKAWA OBSERVED BY HAYABUSA.
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Mission Outline: The Hayabusa (MUSES-C) engineering demonstration spacecraft was launched on 9 May 2003 (JST throughout this text) and designed to sample an asteroid's surface and to return it to the earth [1]. After cruising with successful operation of the ion engines and the Earth swing-by on 19 May 2004, the spacecraft arrived at the “Gate Position” at an altitude of about 20 km near the sub-earth point of the near-Earth asteroid 25143 Itokawa (1998 SF36) on 12 September 2005. The spacecraft transferred to the “Home Position” (the nominal hovering position) at an altitude about 7km from the asteroid’s surface near the sub-earth point on 30 September 2005. During 8 - 28 October, the spacecraft moved from the Home Position to several various altitudes and solar phase angles to acquire images of the polar regions, finer surface topography and with different light conditions. Based on the topographic and spectroscopic data, the sampling site was selected and the spacecraft made touch downs onto the asteroid’s smooth area named “Muses Sea” on November 20 and 26.

Observational instruments onboard the Hayabusa spacecraft included a telescopic multi-band imager with filters (AMICA), a near-infrared spectrometer (NIRS), a laser ranging instrument (LIDAR), and a X-ray fluorescence spectrometer (XRS). A micro-rover named “MINERVA”, carrying a pair of stereoscopic imaging cameras and one other camera as well as thermometers; landing of the MINERVA was not successful.

Sampling during each touch down should have been made by shooting small projectiles onto the asteroid surface and catching their ejecta through a funnel-like horn attached to the base of the spacecraft. However, it was found that the projectile firings during the first touch down was aborted while those during the second touch down have still not been confirmed at the time of this writing. During the first touch down, the spacecraft hopped at least twice and stayed on the asteroid’s surface for about half an hour. Thus it is plausible that some surface samples reached in the sample canister during this unexpectedly long stay on the asteroid’s surface under the microgravity condition. After the successful ascent from the second touch down, the spacecraft started to lose its attitude control capability due to troubles with its reaction control system. Hence the return of the spacecraft with the sample capsule to the earth has been postponed from the original plan in June 2007 to June 2010.

Global properties of Itokawa
Itokawa is an Apollo type asteroid. The orbital elements are a=1.324 AU, e=0.280, i=1.622 deg., q=0.953 AU, Q=1.695 AU, and the rotational period is 12.132 hours. The spectroscopic type is S(IV) [2].

The longest dimension of Itokawa found by Hayabusa is 548m, which is consistent with that found by radar observation with 10% accuracy [3]. Pre-arrival, predicted values[4] were confirmed by Hayabusa for the rotation period, its retrograde rotation and the spin pole orientation being approximately normal to the ecliptic. Mass, volume and hence density are still under discussion: the preliminary value of its bulk density is estimated as ~2.1 g/cm³ within 10% error range.

Itokawa’s global shape appears to be composed of two parts called a “head” (smaller one) and “body”(larger one)(Fig.1). The larger section could have more than one sub-component. The appearance of the surface is completely different from any other
asteroids previously observed by spacecraft, which are much larger than Itokawa and globally covered with thick regolith layers and many craters.

The surface of Itokawa is divided into two distinct types of terrain: “the rough terrain”, which exhibits rough topography mostly due to the existence of numerous, large boulders, and “the smooth terrain”, which is mainly comprised of flat regolith region.

The smooth, regolith region is distributed in two distinct parts: the “Muses Sea” located between the head and the body and connected to the south polar region and the “Sagamihara” area surrounding the north polar region. The boundaries between the rough and smooth regions are relatively sharp.

Large impact craters with typical bowl shapes are far less than any other asteroids observed in the similar spatial resolutions. Some facets observed on Itokawa are probably of impact origin after the formation of Itokawa, and some could be surface features of the embedded large fragments. A typical impact-originated one is Little Woomera of diameter about 150 m extending around the terminator of the body.

The near infrared spectra show there are only slight differences in absorption band center position depending on respective locations. This result shows that there is not much difference in the constituent material as a function of location. This inference is also supported by the X-ray spectrometer data that shows no apparent difference in elemental abundance between the eastern or western sides.

Due to the low escape velocity of Itokawa (i.e., 10-20 cm/s), most of the fine ejecta in cratering having higher velocities would have easily escaped from the surface. Only larger fragments with lower velocities than this escape velocity could have remained on the surface. This may explain why Itokawa’s surface has relatively small areas covered with regolith but is dominated by numerous exposed boulders.

Several very large boulders were found particularly on the western side (the region of longitude 180-360 deg.) while no such large boulders exist on the eastern side (longitude 0-180 deg.). The maximum boulder size is about 50 m near the terminator. Large pinnacles were also found in the “neck” region on the western side. An empirical relationship is known between the size of an impact crater and the maximum size of ejected fragment [5]. The large boulders on Itokawa could not be produced from any of Itokawa’s existing craters and hence these boulders are likely related to a large collision event associated with formation of the present Itokawa.

The 3-dimensional numerical shape models were developed using a few different methods and the slope and gravity potential models have taken into account both the mass distribution and rotational effects. These models show that the gravity potential is high near the ends of the asteroid while the potential minima exist around the “neck” region between the head and the body. These potential minima regions and the regolith regions are strongly correlated suggesting regolith particles moved to these regions through seismic shaking due to impacts [6], or potential shift by flyby encounters with the earth [7], or electrostatic levitation.


Fig.1. Itokawa taken from 7km altitude. Eastern side, North pole downward.