Landing Site Selection for Hayabusa2: Scientific Evaluation of the Candidate Sites on Asteroid (162173) Ryugu

*Hikaru Yabuta[1], Sei-ichiro WATANABE[2], Tomoki Nakamura[3], Naru Hirata[4], Seiji Sugita[5], Tatsuaki Okada[6], Kohei Kitazato[4], Yoshiaki Ishihara[7], Tomokatsu Morota[2], Naoya Sakatani[6], Koji Matsumoto[8], Koji Wada[9], Shogo Tachibana[5], Mutsumi Komatsu[10], ERI TATSUMI[5], Moe Matsuoka[6], Chikatoshi Honda[4], Takahiro Hiroi[11], Hiroki Senshu[9], Rie Honda[12], Yasuhiro Yokota[6], Rina Noguchi[6], Yuri Shimaki[6], Deborah Lorin Domingue[13], Lucille Le Corre[13], Antonella Barucci[14], Ernest Palomba[15], Shota Kikuchi[6], Akira Miura[6], Tomohiro Yamaguchi[6], Yukio Yamamoto[6], Takanao Saiki[6], Satoshi Tanaka[6], Makoto Yoshikawa[6], Yuichi Tsuda[6]

1. Hiroshima University, Department of Earth and Planetary Systems Science, 2. Nagoya University, 3. Tohoku University, 4. University of Aizu, 5. The University of Tokyo, 6. ISAS/JAXA, 7. NIES, 8. NAOJ, 9. Chiba Institute of Technology, Planetary Exploration Research Center (PERC), 10. Sokendai, 11. Brown University, 12. Kochi University, 13. Planetary Science Institute, USA, 14. Observatoire Paris-Site de Meudon, LESIA, France, 15. INAF-IAPS, Italy.

On June 27, 2018, JAXA’s Hayabusa2 spacecraft arrived at its target C-type asteroid Ryugu. Immediately after arrival, remote-sensing observations were carried out with the Optical Navigation Camera (ONC), the Near Infrared Spectrometer (NIRS3), the Thermal Infrared Imager (TIR), and the Laser Altimeter (LIDAR). Based on data from this suite of instruments, we carried out the landing site selection for the first touch-down (TD1). Since the mission aims to understand i) the origin and chemical evolution of the solar system and ii) the formation process and structure of the asteroid, we have set the most scientifically valuable TD1 site as the least altered region where water and/or carbon are potentially abundant.

Landing candidate sites were first selected by engineering evaluation for operational safety followed by scientific evaluations based on criteria such as science and samplability for the most interesting sites. The process was repeated using the observations from the altitudes of 20 km, 6 km, and 5 km.

Scientific evaluations of the landing site candidates were conducted based on the data products from ONC, NIRS3, TIR, and LIDAR. The shape modeling team produced two different shape models. ONC produced multiband images and reflectance spectra, as well as maps of spectral indices and X-means clustering analysis. Measurements of boulder size-frequency and Hapke parameters in the candidate landing areas were examined. NIRS3 produced four types of spectral feature maps. TIR provided maps of maximum temperature from the October 22, 2018 TD1 practice operations, apparent thermal inertia, and typical grain size determinations. LIDAR provided time series ranging data, topography, and corrected spacecraft trajectory.

Engineering evaluation: The possible landing site candidates were selected from the engineering safety score map evaluated based on the sub-Earth distance, local solar angle, local slope and elevation maximum difference. Thermal prediction results for TD1 were obtained by TIR. Temperatures of each site are < 350 K, confirming the safe conditions. The regions that satisfied all the conditions were, L05, L07, L08, L12, M01, M03 and M04.

Scientific evaluation:
1) Boulders. Based on the distribution of boulders with a diameter larger than 3 m for each potential landing site, regions L07, L08, and M04 show smaller percentages of boulder coverage than other areas, and are regarded as safer sites for landing.

2) Geology. Ryugu exhibits a variety of topographic features and geologic settings. From a scientific perspective, it is of interest to be able to study various materials representing the evolution of Ryugu.
3) Hydrous minerals. The NIR spectral properties are nearly homogeneous across Ryugu’s surface, especially between the candidate sites. The near-infrared reflectance spectra of Ryugu is similar to experimentally heated Murchison meteorite at 400˚C.
4) Carbon contents. It is likely that visible reflectance at 0.55 μm (R(0.55)) is influenced mostly by carbon content. R(0.55) is almost homogeneous across the surface with a low value, regardless of the candidate sites.
5) Secondary processes. Although the surface of Ryugu is almost homogeneous at the macro scale in the map of spectral slope from 0.48 to 0.86 μm, a slight heterogeneity is observed across the candidate regions. L-regions are relatively bluish and M-regions are reddish. Considering that spectral reddening is observed by laser irradiation of dehydrated carbonaceous chondrites, L regions are probably less altered and preferable for sampling.

In the total evaluation, L08, L07 and M04 were selected as the TD1 candidates on August 17, 2018. In September 2018, many boulders > 50 cm were additionally found for the sites during the rehearsal of TD1. Thus, the originally scheduled TD1 in October was postponed. Further search for a flat and safe site continued, and L08-E1 was determined as the TD1 site. The TD1 will be scheduled on Feb 22, 2019.

Keywords: Hayabusa2, Landing Site Selection

