Science Experiments with the Trojan Asteroid Lander in the Solar Powered Sail Mission

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Scientific exploration on the Jupiter Trojan asteroid is under study for the solar-powered sail (SPS) mission. This mission includes a scientific lander jointly studied by Japanese and European engineers and scientists [1]. We present the objectives and the strawman payloads for this mission. The SPS is a candidate as the next medium class space science mission in Japan. This engineering mission is based on the technologies such as the solar sail and the ion engine system inherited from Ikaros and Hayabusa missions, respectively. With this hybrid propulsion system, the spacecraft will cruise to the Jupiter and beyond, even if a radioisotope thermoelectric generator (RTG) is not used. A Trojan asteroid will be investigated by remote sensing after rendezvous, and then a small lander will be deployed from the mothership to conduct *in situ* experiments on the asteroid. As an option, sample will be returned to the Earth. Mission duration is typically 15 years to arrive at the Trojan asteroid, and 30 years in total for Earth return. The shortest one way trip to the asteroid is less than 12 years. The lander should be designed within 100 kg wet mass. Total mission payloads should be within 20 kg, including all the science payloads, sampling and sample return systems [2].

Jupiter Trojan asteroids are located around the Sun-Jupiter Lagrange points. Most of them are volatile-rich D- or P-type asteroids, and their origin and evolution, composition and physical conditions still remain unknown. In a classical model of solar system evolution, they formed around the Jupiter orbit and survive until now. But in a recent model such as Nice model [3], they formed at the far end of the solar system and transferred inward due to dynamical migration of giant planets. Physical, mineralogical, and isotopic studies of surface materials could solve their origin and evolution processes, as well as the solar system formation [4]. To achieve these goals, *in situ* observations using the lander is planned, as well as the asteroid global characterization with a near-infrared hyperspectral imager.

Geological, mineralogical, and geophysical observations will be conducted to characterize the landing site, by using a panoramic camera, an infrared hyperspectral imager, a magnetometer, and a thermal radiometer. The surface conditions and composition will be investigated with a close-up imager and a Raman spectrometry. The imager is also used to check the conditions whether the sampling could be done or not. If the configuration is unsuitable for sampling, the lander must relocate and change the configuration. The surface and subsurface materials will be collected into a carousel by bullet-type and pneumatic drill type samplers, respectively. Samples in the each case of carousel will be viewed by infrared microscope to identify them. Those samples will be transferred for evaporation of volatiles for high resolution mass spectrometry (HRMS). Some samples will be heated for pyrolysis for isotopic analysis. Mass resolution $m/\Delta m > 30,000$ is required to investigate isotopic ratios of D/H, $^{15}N/^{14}N$, and $^{18}O/^{16}O$, as well as molecules from organic matters (M = 30 to 1000).The MULTUM type in Japan and the Cosmorbitrap type in France are being

investigated for the HRMS. A set of strawman payloads are now considered to meet the science, mission, and system requirements and constraints (total mass < 20kg, and total energy consumption < 600 WHr). They will be finally determined by the international announce of opportunity.

References: [1] Mori O. et al. (2015) *11th Low-Cost Planetary Missions Conf.,* S3-10. [2] Saiki T. et al. (2015) *ISSFD2015*, S19-3, #84. [3] Morbidelli A. et al. (2005) *Nature 435*, 462-466. [4] Yano H. et al., (2014) *COSPAR 2014*, B0.4-2-14. [5] Mori O. et al. (2016) *Lunar Planet. Sci. Conf.* , submitted.

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