SCIENCE EXPERIMENTS ON A JUPITER TROJAN ASTEROID IN THE SOLAR POWERED SAIL MISSION. O. Mori[1], T. Okada[1,2], J.-P. Bibring[3], S. Ulamec[4], R. Nakamura[5], H. Yano[1], Y. Kebukawa[6], J. Aoki[7], Y. Kawai[7], K. Yabuta[7], M. Ito[8], Y. Saito[1], S. Yokota[1], N. Grand[9], H. Cottin[9], L. Thirkell[10], C. Briois[10], T. Iwata[1], A. Matsuoka[1], J. Matsumoto[2], T. Saiki[1], H. Kato[1], J. Kawaguchi[1], [1]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Japan, [2]University of Tokyo, Japan, [3]Institut d'Astrophysique Spatiale, Orsay, France, [4]German Aerospace Center (DLR), Köln, Germany, [5]National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan, [6]Yokohama National University, Japan, [7]Osaka University, Japan, [8]Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology, Japan, [9]LISA, Univ-Paris-XII, France, [10]CNRS, Orleans, France, Email: okada@planeta.sci.isas.jaxa.jp.

Introduction: A new mission to visit and explore a Jupiter Trojan asteroid is under study in Japan using a hybrid propulsion system of solar-powered sail (SPS) and sophisticated ion engine, and additionally using a scientific lander, which is jointly investigated between engineers and scientists from Japan and Europe [1]. We present here the key objectives and the strawman payloads of science experiments on the asteroid in this mission.

SPS Mission: The SPS mission is a candidate as the next medium class space science mission in Japan, recommended by the Committee for Space Engineering in the Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA). This engineering mission is based on the technologies such as the space yacht inherited from the IKAROS mission (the world first interplanetary space yacht), a large-area thin-film solar panel, and the improved ion engine system inherited from Hayabusa mission (the world first sample return from asteroid), enabling us to visit the outer planetary system such as Jupiter and Saturn without using a radioisotope thermoelectric generator (RTG). As the technology demonstration, 50 meter (3000 m^2) class very large area thin-film type solar cells will be used as the main sail for the space yacht as well as the power supply for the ion engine system at the same time. With this hybrid propulsion system of solar-powered sail and ion engines, the spacecraft will cruise to the Jupiter, change trajectory using the Jupiter swing-by, and rendezvous a Jupiter Trojan asteroid.

After remote sensing of the asteroid, a lander will be deployed from the mothership, land and characterize the asteroid surface, sample the surface (and also subsurface) materials, observe them by microscopy and analyze them by high-resolution mass spectrometry. As an option, part of sampled materials will be collected in the container and sent into the reentry capsule, and finally returned to the Earth.

A typical mission duration takes about 15 years from the launch to arrival at the Trojan asteroid, and 30 years in total if the sample return option is selected. But the shortest one way trip to the asteoid is less than 12 years [2]

SPS Trojan Lander: The Jupiter Trojan lander should be designed within the wet mass of 100 kg, the main body size of 650 mm diameter and 400 mm height, and with the extensionable landing legs and sampling devices. Thanks to the hybrid propulsion system, a 100 kg lander could be mounted on a 1300 kg wet mass mothership, when it will be launched by the H2A launch vehicle (or its successor). The mission payloads should be within 20 kg in total, including the sampling system and science payloads, as well as the sample container and the transfer system for the sample return option [2]. Technical discussions for the lander system have been conducted in the joint study by Japan and European team in 2014 and 2015.

Science Objectives of Trojan Asteroids: Jupiter Trojan asteroids are located around the Sun-Jupiter Lagrange points (L4 or L5), and most of them are classified as D- or P-type asteroids, which are considered as volatile rich materials such as organics and water ices, but their origin and evolution, composition and physical conditions still remain unknown.

A classical (static) model of solar system evolution suggests that they formed around the Jupiter region and survive until now as the outer end members of asteroids. On the other hand, a new (dynamical) model such as Nice model [3] indicates that they formed at the far end of the solar system and then transferred inward due to dynamical migration of giant planets. Therefore, the physical, mineralogical, and isotopic studies of surface materials and volatile compounds could solve their origin and evolution processes, as well as the solar system formation [4].

To achieve these science goals, *in situ* observations using the scientific lander is now considered. Not only the surface experiments with the lander but also the characterization of the whole surface of the targeted Trojan asteroid is required from the mothership, such as surface global mapping by optical telescopic imager as well as the surface mineralogy and the degree of hydration by a near-infrared hyperspectral imager (1 to 4 μm), with spatial resolution of higher than several tens of meters. With these context studies by remote sensing, the landing experiments should be done by multiple instruments [5].

Strawman Payloads: As shown above, the SPS mothership will carry a 100 kg class lander with 20 kg mission payloads. Just after landing on the surface of asteroid, geological, mineralogical, and geophysical observations will be conducted to characterize the landing site in detail, using a panoramic camera of 360º view, an infrared hyperspectral imager (covering 1 to 4 μm), a magnetometer, and a thermal radiometer. The surface material composition will be classified with a Raman spectrometry. A close-up imager will monitor the surface condition for the Raman spectroscopy, and also provide information on the configuration whether the sampling could be done or not. If the configuration is not suitable for sampling, the lander should relocate by hopping, and change the configuration. The surface and subsurface materials will be collected and inserted into a rotating carousel by bullet-type and pneumatic drill type samplers, respectively. The surface sampler is the type of impact sampling method, inherited from Hayabusa and Hayabusa2 missions. The subsurface sampler (down to 1000 mm) is newly developed. In the current design, the surface sampler has 4 shots and the subsurface sampler has 1 shot. There will be a no-shot slot, or a slot for floating dusts and sniff mode, so that 6 sample cases are prepared in the carousel.

Samples in the each case of the carousel will be viewed by visible and infrared microscope (covering 1 to 4 μm) with a spatial resolution of 10 to 20 μm per pixel to identify or classify the collected materials. Those samples will be transferred to the positions for evaporation of volatiles by step-wise heating for high resolution mass spectrometry (HRMS). Some samples will be heated up to 1000 ºC 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). For the HRMS, the MULTUM type in Japan and the Cosmorbitrap type in France are considered as the candidates. Development of both methods is on-going to improve their performances.

A set of strawman payloads have been discussed and determined during the concurrent engineering (CE) study for designing the Trojan lander. Table 1 shows the result of strawman payloads during the CE study, which is based on requirements from science, mission, and system, and on some constraints (total mass < 20kg, and total energy consumption < 600 WHr). Instruments will be finally determined by international announce of opportunity before the system requirement review (SRR) will be conducted. In the SPS mission, sample-return is also studied as an option, and the lander should be designed to have functions for sample-return. It carries the mechanisms for sample collection and sample transfer to the mothership.

Way Forward: The SPS mission proposal will be updated as the final selection stage, but also to the SRR in ISAS/JAXA in 2016. Payloads should be selected not only for maximizing the science outcomes but also to match the system constraints, so that progress in development of each instrument and international collaboration are crucial. The SPS science team will organize international meetings for the science and exploration of Trojan asteroids, other primitive bodies including asteroids, comets, and Martian satellites in early July 2016. Such meeting will be conducted every 2 or 3 year for discussion and promotion to maximize the science gain from this mission.

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Table 1. Strawman Payloads on the SPS Trojan Lander

Category	Details	Mass [kg]
Sampling & Distribution system	Horn-shape sampler Pneumatic drill Rotating carousel Air-guns and tanks	7.0
High Resolution Mass Spectroscopy	MS Electrode Gas Chromatograph Electronic Ionizer Electronics	5.0
Microscopy	MicrOmega type IR-microscope	2.5
Panoramic Observation	Wide angle camera IR-imager with periscope	3.4
Context Observations	Close-up imager Thermal radiometer Magnetometer Raman Spectrometer Thermogravimeter	3.0
Total		20.9