TASTER: Trojan ASteroid Tour, Exploration, and Rendezvous, a JPL planetary science summer school mission design exercise.

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Introduction: We present a mission concept to explore Trojan Asteroids recommended by the Planetary Science Decadal Survey [1] as target candidates for a future New Frontiers class mission. Observing Trojan asteroids and getting detailed measurements of their physical characteristics may yield answers to fundamental questions regarding the formation of the early Solar System. In particular, Trojan asteroids may harbor primordial material originating from the time and location of their formation. Our mission design, Trojan Asteroid Tour, Exploration, and Rendezvous (TASTER), is the result of mission design exercise carried out during the 2011 JPL Planetary Science Summer School.

Identification of Trojan composition and structure would reveal information about their source location (i.e, scattered KBOs vs. capture during Jupiter's formation), thereby testing the Nice Model. These observations would also provide information about their impact history and subsequent evolution. Earth-based observations of size and surface characteristics are sparse and spectral measurements are insufficient to resolve composition; therefore close-range observations are needed.

Science goals: Our primary science questions are (1) Where and how did the Trojan asteroids form? and (2) How have the Trojan asteroids evolved since their formation? To address these science questions, our proposed mission would flyby 1999 XS143 before orbiting 911 Agamemnon for 12 months. The mission's planned prioritized scientific objectives are: (1) Determine surface and subsurface composition, (2) Determine bulk physical properties (e.g., size, mass, rotational state)., (3) Determine internal structure.,(4) Establish the surface's geological history, (5) Map surface properties (e.g., albedo, color, light scattering), and (6) Search for outgassing. Our payload would provide an unprecedented high-resolution global dataset for the target bodies.

Mission requirements: The mission is designed as a New Frontiers class mission with an AO specified cost cap of $902M (FY11$ and not including the launch vehicle). We also take advantage of the propulsion credit ($16M) for incorporating NASA's Evolutionary Xenon Thruster (NEXT). To maximize the deliverable spacecraft mass, we considered only the largest launch system allowed by the AO: an Atlas V 551.

Instruments: *WASABI–NACHO* **(**Wide Angle multi-Spectral Asteroidal Body Imager – Narrow Angle Camera Hi-resolution Optics) is a dual camera system, which would produce multispectral images of the Trojan asteroids. Based on the Mercury Dual Imaging System (MDIS) on the MESSENGER spacecraft [2], the unit consists of a multispectral wide-angle camera and a monochrome narrow-angle camera. The wide-angle camera has a 10.5° x 10.5° field of view with 18 m/pixel resolution at 100 km altitude. It has a 10-color filter wheel, with one clear filter and two polarizers to provide color imaging over a wide spectral range. The narrow-angle camera has a 1.5° x 1.5° field of view with 2.5 m/pixel resolution at 100 km altitude.

CAVIAR (Compositional Analysis from Visible and InfrAred Radiation) is a visible and near infrared spectrometer. This instrument is based on the Moon Mineralogy Mapper (M^3) flown on the Chandrayaan-1 mission [3] and would be used to characterize the surface compositions of the two target Trojan asteroids. These data would provide clues to help understand the Trojans' formation and history. The CAVIAR spectrometer has a field of view of 250 μrad, resulting in a resolution of 25 m/pixel at 100 km. It has a spectral range of 0.5 –5 μm, with 512 bands at full spectral resolution and 228 bands at reduced spectral resolution.

ICING (Instrument for Collection of Incident Neutrons and Gamma rays) is a neutron/gamma ray spectrometer that would map the abundances of volatile compounds and ices in the upper meter of the subsurface to unambiguously identify and map the major rock-forming elements. The design of the ICING instrument is directly adopted from the GRaND instrument on the Dawn spacecraft [4, 5] and draws on experience from the successful Mars Odyssey and Lunar Prospector missions. During orbit, the instrument would record the spectra of gamma rays and neutrons emitted from the surface to build a full-surface map with resolution of 80° or less.

Spacecraft description: The main spacecraft bus is a 2 x 2 x 2 m cube with the science instruments mounted on the nadir-facing (target-facing) side (Fig. 2). A fixed high-gain antenna, the propulsion system consisting of a dual propellant chemical system and twin NEXT ion engines, and solar wing mounts occupy four of the remaining five sides of the spacecraft bus; the zenith-facing side is empty. The spacecraft is stabilized using reaction wheels and thrusters. Using JPL design principles, 30% margin is applied to mass, power, and propellant.

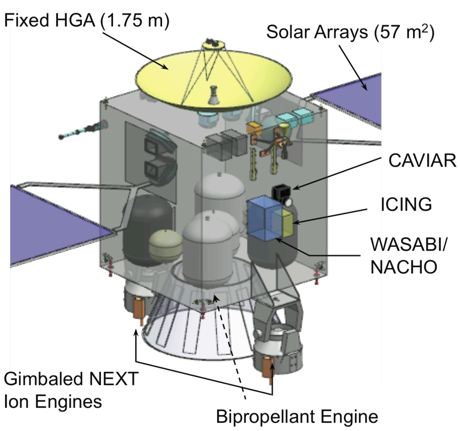

Fig. 1. Close-up of spacecraft body showing locations and relative sizes of important components and instruments.

With 30% margin, the spacecraft dry mass is 1187 kg and wet mass is 1998 kg. The primary mass drivers are the solar power system and fuel. The solar power system is 33% of the dry mass due to the large arrays (57 m^2) required to provide sufficient power at ~5 AU. More than 800 kg of fuel (70% chemical fuel) is required for the nearly 4 km/s of onboard ΔV necessary to reach the target asteroids.

The design of the TASTER spacecraft was driven by a requirement for high reliability over an 11-year mission duration. Systems are fully redundant. No science instruments are deployable, which reduces complexity and risk. No new technology is required for the spacecraft design and NASA is responsible for development of the NEXT engines prior to launch per the New Frontiers AO [6].

Mission design: The mission trajectory is optimized for an 11-year operational life with one primary orbital target and one flyby target of opportunity selected from the group of Trojan asteroids in Jupiter's L4 point (Fig. 2). The large and relatively well-studied 911 Agamemnon was chosen as the primary target and the flyby target (1999 XS143) was selected for its proximity to the spacecraft's trajectory to 911 Agamemnon.

The NACHO instrument would collect data during the 100 hours preceding and following the closest approach (500 km) of 1999 XS143. Similarly, for the last 5 hours of approach and the first 5 hours of departure, WASABI and CAVIAR are continuously operational. Seven months after the flyby, the spacecraft enters an orbit of 911 Agamemnon. This maneuver requires considerable delta-V (1135 m/s) that is supplied by the chemical engine.

After orbit insertion, at 1000 km from the surface, WASABI-NACHO and CAVIAR will execute a global imaging campaign. This phase would last 20 days. The second phase is at 300 km from the surface, lasts 3 months, and adds the operation of ICING. In the third phase, the spacecraft would be placed in an orbit 100 km above surface, from where the imaging instruments would carry out targeted observations of features found earlier from the higher orbits while ICING would further refine the subsurface distribution of volatiles.

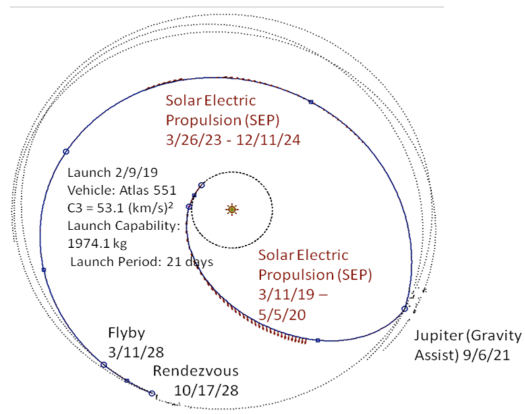

Fig. 2. Proposed trajectory showing the orbits of Earth, Jupiter, and the two Trojan asteroids to be visited during the mission. Total delta-v required is 3.914 km/s.

Cost: Our cost estimate for this mission was \$907M, which was below our cost cap of \$918M (\$902M AO cap + \$16M propulsion credit). The amount was estimated using JPL Team-X methodology which uses a mix of quasi-parametric and grassroots algorithms.

References:

[1] National Research Council. (2011), Visions and Voyages for Planetary Science in the Decade 2013-2022, *National Academies Press*. [2] Hawkins S. E., et al. (2007) *Space Science Reviews*, doi:10.1007/s11214-007-9266-3. [3] Green, R. O. et al. (2011) *JGR*, doi:10.1029/2011JE003797. [4] Thomas et al., 2003 [5] Russell et al., 2007 [6] NASA. (2009) Announcement of Opportunity: New frontiers 2009.

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