TROJAN TOUR ENABLED BY SOLAR ELECTRIC BASED MISSION ARCHITECTURE. D. B. Smith[1], K. Klaus[1], J.Behrens[1], G. Bingaman[1], M. Elsperman[1], J.Horsewood[2], [1]The Boeing Company (5301 Bolsa Avenue, Huntington Beach, CA 92647, david.b.smith8@boeing.com, kurt.k.klaus@boeing.com, john.w.behrens@boeing.com, gary.l.bingaman@boeing.com, michael.s.elsperman@boeing.com), [2]Space Flight Solutions (28 Barnsdale Lane, Hendersonville, NC 27891-7901, horsewood@spaceflightsolutions.com).

Introduction: A Trojan Tour and Rendezvous mission was one of the missions recommended by the most recent Planetary Science Decadal Survey [1]. As part of the work related to developing the final report, a number of mission concepts were studied to develop cost/risk evaluations. One of these studies was a Trojan Tour mission concept, led by Mike Brown [2]. To the greatest extent possible, we will utilize this concept as a basis for re-examining the feasibility of a Solar Electric Propulsion (SEP) mission using a Boeing bus and Advanced Modular Power System (AMPS) solar power generation. We strongly feel this is a viable option in addition to the ASRG/Chemical mission selected for the study.

Background: Jupiter shares its orbit with a number of small bodies. An estimated 600,000+ objects larger than 1 km in diameter librate about the L4 and L5 points in the Jupiter – Sun system [3,4]. No mission has gone through the regions of space where Trojan asteroids are found (also known as the Trojan Clouds). Compositional data from Trojan asteroids are scarce. Density information currently from only 2 Trojans give disparate results. Composition inferred from studies are roughly similar to comets. Key questions are whether Trojans are leftover objects related to the formation of Jupiter or are captured trans-Neptunian Objects (TNOs). Studying Trojans can offer a critical test of planetary formation and migration models and the solar system as a whole.

The concept study for the Decadal survey concluded that s SEP mission is not viable because of low solar intensity levels. Also concern was expressed that the large size of the arrays required to generate enough power for the mission would compromise science data gathering due to flexible body effects of the arrays. Our study will determine whether or not our AMPS system will be able to address these concerns.

Mission Overview: With the advent of the new AMPS Technology that involves a Solar Concentrator array, SEP missions to the outer planets become viable. The mission design features a direct injection by an Atlas 401 with a C3 energy of 17.2 Km^2/Sec^2. The mission objective is 1143 Odysseus, a Trojan within the Trojan cloud, consistent with the Decadal Survey REP (Radioisotope Electric Propulsion) mission objective. The launch date is November 11, 2016; the probe reaches Odysseus May 13th, 2022. There are 3 NEXT thrusters, 2 are operated during the first 420 days, throttling down a single thruster the remainder of the approximately 6 year cruise. In comparison, the REP mission concept flight time was 8 years. The thrusters are duty cycled at 95 percent to allow at least one contact per week with the spacecraft during the cruise.

The initial wet mass is 2607 kg, and contains 30% margin. With a 98 Kg adaptor, the initial mass is 2705 kg (Atas 411). The Xenon propellant used was 757 Kg. By delaying the launch so the probe reaches Odysseus nearer to perihelion, the SEP Delta V is reduced, providing unallocated margin. On station, the AMPS concentrator can still operate a throttled down NEXT thruster for station keeping and science maneuvering, so the extra margin can be additional propellant within the 6 tanks, which are off loaded.

Space Craft Description: The Trojan asteroid exploration spacecraft is based around our flight proven 702HP bus. The bus has been slightly modified for this mission. The NTO/MMH propellant tanks have been reduced in size and more Xe tanks have been added. The 4 XIPS thrusters and XPCs have been replaced by 3 NEXT engines and PPUs. Two 30 kW FAST solar wings replace the 9 kW 6 panel solar wings. Additional radiation shielding has been added to accommodate the various environments encountered during the mission.

The 702HP ADCS system (IRU, star trackers, RWAs, SWD/SWP, etc.) enables the spacecraft to maintain a pointing accuracy of 1 mrad and a pointing stability of 0.3 microrad/sec. with 2 standard 6 panel solar wings. These wings have a first mode frequency of 0.016 Hz. Adding the AMPS arrays, which are much stiffer and have a first mode frequency of 0.05 Hz, enhances the pointing accuracy of the system such that it will easily meet the requirements of the mission.

The AMPS array has a 12.5:1 concentration ratio. Thus, 12.5 suns are on each solar cell at Earth (1 AU). At Jupiter (5.2 AU), the AMPS array solar cells still see .46 suns, which is high enough that LILT effects are negligable. The AMPS array is also inherently rad hard. The top of the cell is covered with at least 8 mil coverglass, which is a minimal mass hit given the small size and number of cells. The back and sides of the cells are protected by the composite Multifunction

Concentrator Arrays (MCA), for an effective thickness of 20 mils.

For the purposes of this study, the science payload instruments, data rates, mass and power requirements are identical to the Trojan Decadal study**.**

Technology Maturity: The AMPS Technology benefits from over $30M in development investment by DARPA and the AFRL. The investments focused on innovative lightweight structures, advanced solar array deployment systems, linear concentrator arrays, high voltage power systems, and high efficiency solar cells. Solar concentrator concepts are not new, but AMPS uses a linear concentrator with a 12.5:1 ratio, incorporates advanced materials (carbon composites) into the structure, operates at 200V, and uses high efficiency (33%) solar cells to produce a system that has a specific power density (133W/Kg) that is 4-5 times better than state of the art. The DARPA FAST and AFRL IBIS programs matured these technologies to a system TRL of ~3-4. Numerous component and system level tests, including power production in Thermal Vacuum at Glenn Research Center in 2009, validated the concept and performance predictions. Ongoing investment by Boeing has furthered the maturity of this system such that selected components are at TRL 5. Additional investment in a flight demonstration mission is needed to reach TRL 7.

Conclusions: The SEP concept examined in this poster, updates the conclusions drawn by the Decadal Survey. Utilizing the AMPS technology with the concentrator array, SEP becomes a viable alternative. It is shown that a SEP mission reduces the flight time to the Trojans by 2.5 years. It is also shown that a proven bus like the 702HP can provide the necessary pointing accuracy and stability required for the Decadal mission concept and its science instrument suite. Flexible body dynamics ceases to be a concern with the stiffer concentrator construction. SEP with the AMPS concentrator also provides efficient on - station maneuvering for science at the target Trojan. We seek support from the science community for an SEP Technology Demonstration Mission through the NASA Office of Chief Technologist.

References: [1] Committee on the Planetary Science Decadal Survey; National Research Council (2011) Visions and Voyages for Planetary Science in the Decade 2013-2022. [2] Brown, M. et al. (2011) *Trojan Tour Decadal Study,* SDO-12348. [3] Jewitt, D.C. et. al. (2000) *Astron. J., 100, 1140-1147*. [4] Yoshida, F. and Nakamura, T. (2005) *Astron. J., 130, 2900-2911*.