A SEARCH FOR EARTH TROJAN ASTEROIDS WITH THE OSIRIS-REx SPACECRAFT. C. W. Hergenrother[1*], R. Malhotra[1], B. Rizk[1], J. N. Kidd[1], C. Drouet d'Aubigny[1], S. R. Chesley[2] and D. S. Lauretta[1], [1]Lunar and Planetary Laboratory, University of Arizona, [2]Jet Propulsion Laboratory, [*]chergen@orex.lpl.arizona.edu

Introduction: The OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, and Security – Regolith Explorer) spacecraft will be well placed to conduct a survey of the Sun-Earth L4 Lagrangian region for Earth Trojan asteroids in February 2017. Observations will be obtained over 10 dates in order to detect Earth Trojans (ET) as small as 100 m in diameter.

It has been known for more than two centuries that minor planets can share the orbit of a planet in a dynamically stable state if they remain near the triangular Lagrange points, L4 and L5, leading or trailing a planet by ~60 degrees in longitude. Significant populations of such "Trojan asteroids" are known for Jupiter, Mars, and Neptune. However, the existence and size of a primordial population of ETs is not well constrained, and represents a major gap in our inventory of small bodies in near-Earth space.

Previous Earth Trojan Searches: Recent and ongoing surveys for near-Earth objects do not usually directly observe Earth's L4 and L5 regions, due to the challenging illumination conditions during twilight/dawn hours. Previous observational surveys of L4 and L5 were carried out in the 1990s [1]. They discovered no ETs in ~0.35 square degrees of sky, and estimated an upper limit on the number density of ETs of 3 per square degree brighter than R ~ 22.8 (approximately corresponding to ~350 m diameter C-type asteroids or ~175 m diameter S-type asteroids). This observational upper limit allows a population of several hundred ETs larger than a few hundred meters in size [2].

A few NEOs (3753 Cruithne, 54509 YORP, 2001 GO2, 2002 AA29 and 2003 YN107) are known to orbit in Earth's vicinity in horseshoe or quasi-satellite orbits [3]. These may be examples of temporary captures of main belt asteroid-sourced NEOs in the Earth's co-orbital region. The only object designated an ET, 2010 TK7, is also a candidate for a captured NEO, given its large libration amplitude and its high orbital inclination. Temporary capture of NEOs into ET-like orbits is rather rare in computer simulations; the steady-state population of captured ETs is estimated to be only about 16±3 objects of diameter larger than 160 m [4].

Theoretical Motivation: Theoretical studies of test particle dynamical stability indicate that an ET population can orbit stably on timescales comparable to the age of the Earth [5,6]. While eccentric and inclined test particle orbits are strongly chaotic in Earth's vicinity, it is found that most L4 and L5 objects in low-eccentricity low-inclination orbits ($e < 0.1$; $i < 12°$) are little perturbed over giga-year timescales; only a small fraction leak out due to the effects of chaotic diffusion.

Based on plausible assumptions about the dynamical evolution of the primordial small body population in the inner solar system, the expected ET population is about a few hundred ETs of $D > 300$ m [7]. This theoretical prediction for the primordial ET population is similar to the current observational upper limit.

The survival to the present day of such a primordial ET population is reasonably assured provided Earth's orbit itself was little perturbed since its formation. The complete absence of a surviving primordial ET population would motivate a reassessment of models of Earth's formation and dynamical history and of the dynamical clearing of residual inner solar system planetesimals. Assessing the ET population would provide strong constraints on the dynamical and cosmochemical theories for the formation and dynamical history of the Earth and of the inner solar system.

Another motivation to search for ETs is provided by the observed longitudinal asymmetry of young impact craters on the Moon [8,9]. The observed leading/trailing crater density ratio is ~1.7, however, numerical simulations of NEO impacts on the Moon find that the leading/trailing crater density ratio should be only ~1.32±0.01 [10,11]. An unseen population of impactors sourced from the Earth's Trojan regions may account for this discrepancy between the observed and expected longitudinal asymmetry of lunar craters [12].

Proposed Observations: Between launch in September 2016 and an Earth Gravity Assist in September 2017 the OSIRIS-REx spacecraft is on a 0.78 au x 1.23 au x 1.6° orbit. OSIRIS-REx approaches to within 0.17 au of the Sun-Earth L4 Lagrangian point on February 16, 2017. On 10 dates between February 9 and 20, the OCAMS (OSIRIS-REx CAMera Suite) MapCam imager will survey the sky for ETs near opposition relative to the spacecraft. MapCam is a 0.038-m f/3.3 refracting telescope with a 4° x 4° FOV [13]. On each date, the MapCam will image 9 fields covering ~125° deg^2 (with 5-10% overlap between fields). Each field will be imaged 5 times over the course of ~4 hours. Fields will also be observed on consecutive dates to provide up to a 28-hour arc on any detected

Earth Trojans. Detection of moving objects will be conducted with automated detection software such as Astrometrica and with manual inspection (e.g. blinking images).

The survey will concentrate on the area near opposition to leverage the increased brightness of ETs due to minimized phase angles and ranges from the spacecraft. On the first date of the observations, the spacecraft will be located at a heliocentric range of 0.96 au. The spacecraft pointing stability limits exposure time and in turn the MapCam limiting magnitude. At this early stage in the mission the platform stability is not yet fully characterized. Based on current knowledge we expect the MapCam limiting magnitude to be between 12.5 and 14. For a phase angle of 0°, heliocentric distance of 1.0 au, geocentric distance of 0.04 au, and lower limiting magnitude of 12.5, ETs have an absolute magnitude (H) of 19.4 (corresponding to diameters of 780 m for a C-type albedo ρ=0.05 and 350 m for a S-type albedo of ρ=0.25). Smaller, fainter objects will be detectable at distances closer than 0.04 AU. On February 17, the spacecraft will be located at a heliocentric range of 0.99 au. An object detected under similar conditions to those above (but with a geocentric distance of 0.01 au) has an absolute magnitude H=22.2 (corresponding to diameters of 220 m for ρ=0.05 and 100 m for ρ=0.25). For comparison, the two deepest, wide-field ground-based asteroid surveys (PanSTARRS and Mount Lemmon Survey) can detect objects as faint as V~21 (H~19) at the L4 point [14]. Their detections correspond to diameters of 930 m for ρ=0.05 and 420 m for ρ=0.25. The ground based values are an upper limit as observing conditions for observing the L4 point from the ground may be worse than average due to observing through high airmass (increased extinction, poorer seeing, increased refraction, brighter sky background).

The survey fields will image three main belt asteroids predicted to be brighter than V=12.5 (12 Victoria, 47 Aglaja and 55 Pandora). In addition to the science return of characterizing the Earth Trojan population, this activity will test OSIRIS-REx' end-to-end science production processes. In fact, the observational cadence used for the Earth Trojan survey is similar to that planned for the search for natural satellites in orbit around the OSIRIS-REx target asteroid 101955 Bennu.

Results, both positive and negative, of the OSIRIS-REx Earth Trojan survey will be presented at LPSC 2017.

References: [1] Whiteley R. W. and Tholen D. J. (1998) *Icarus, 136,* 154-167. [2] Wiegert P. et al. (2000) *Icarus, 145,* 33-43. [3] Brasser R. et al. (2004) *Icarus, 171,* 102-109. [4] Morais M. and Morbidelli A. (2002) *Icarus, 160,* 1-9. [5] Malhotra et al. (2011) *EPSC-DPS Joint Meeting 2011,* 1215. [6] Cuk et al. (2012) *MNRAS, 426,* 3051-3056. [7] Malhotra, R. (2017), in prep. [8] Morota T. et al. (2005) *Icarus, 173,* 322-324. [9] Morota T. & Furumoto M. (2003) *E&PSL, 206,* 315-323. [10] Ito T. and Malhotra R. (2010) *A&A, 519,* id. A63. [11] Gallant J. et al. (2009) *Icarus, 202,* 371-382. [12] JeongAhn Y. & Malhotra R. (2011) *BAAS 42*, 1053. [13] Rizk B. et al. (2017) *Space Science Review,* in prep. [14] Tricarico P. (2015) *AJ, 151*, id. 80.

Acknowledgments: This material is based upon work supported by the National Aeronautics and Space Administration under Contract NNM10AA11C issued through the New Frontiers Program.