PDC 2025
Stellenbosch, Cape Town, South Africa

Space Mission & Campaign Design

TREx: A Temporarily-Captured Orbiter Rendezvous Explorer & In-Situ Characterization Mission

Adrienne Rudolph[a,1,*], Arthur Chadwick[b,2,*], Ananyo Bhattacharya[c,6], Gianfranco Di Domenico[d,6], Inhae Lee[b,3], Ana Sofia Alonso[b,3], Claudio Toquinho Campana[d,6], Siamand Lalisani[b,2], Azadeh Fathi[b,2], Max Luo[b,3], Mathieu Boyer[b,4], Nitya Jagadam[e,7], Zane Emery[b,3], Kaylin Borders[b,2], Matteo Calabrese[b,2], Steven Yang[b,5], Victor Lançon[b,4], Grace Genszler[b,8], Joshua Umansky-Castro[b,8], Andrew van Paridon[b,9], Elaine M. Petro[b,9], Dmitry Savransky[b,10], Mason A. Peck[b,10]

[a] *The University of Maryland, 3181 Glenn L. Martin Hall, College Park, Maryland, 20742, USA, (301) 405-2376*
[b] *Cornell University, 130 Upson Hall, 124 Hoy Rd, Ithaca, New York, 14850, USA, (607) 255-3623*
[c] *University of Michigan, Ann Arbor, MI, 48109, United States*
[d] *Politecnico de Milano, Via Giuseppe La Masa 34, Milano (MI), 20156, Italy*
[e] *University of Illinois Urbana-Champaign, Urbana, IL, 61801, United States*

Keywords: SmallSat, Mission Design, Near-Earth Objects, Temporarily Captured Orbiters, Rendezvous

The 2023 National Academy of Sciences, Engineering, and Medicine Decadal Survey on Planetary Science and Astrobiology lists several key questions regarding the collisional, dynamical, and physical evolution of small body populations in the solar system. Among those objects are Temporarily Captured Orbiters (TCOs), a subset of near-Earth objects (NEOs) that enter the Earth-Moon system and become temporarily captured by Earth's gravitational field, orbiting as a natural satellite or "mini moon" of the Earth before exiting the Earth-Moon system sometime thereafter. TCOs remain largely unstudied, in part due to a lack of data from both ground- and space-based telescopes. TCOs present a unique opportunity for studying bodies external to our Earth-Moon system without the need for expensive deep-space missions to investigate them. This paper will present the mission concept of Mini-Luna, a cislunar mission designed by students from Cornell University's Smallsat Mission Design School (SMDS), tailored for NASA's Small Innovative Mission for Planetary Exploration (SIMPLEx) program. The Mini-Luna mission concept, with its 12U TCO Rendezvous Explorer (TREx) CubeSat, aims to demonstrate the viability of smallsat form factors for traveling to, rendezvousing with, and in-situ characterization of TCOs, thereby also addressing gaps in our knowledge about the TCO population. Historically, no spacecraft has visited a TCO, highlighting the Mini-Luna mission as a novel scientific and technological pursuit. The TREx technology demonstration can also be a potential minimum viable product (MVP) for future small body targets.

After the commissioning of the Vera C. Rubin Observatory in August 2025, its nightly surveys are expected to discover one TCO every two to three months, on average, yielding a total of approximately

*Corresponding authors
Email addresses: rudolpa@umd.edu (Adrienne Rudolph), ac2334@cornell.edu (Arthur Chadwick)
[1] PhD Student, Aerospace Engineering
[2] PhD Student, Mechanical & Aerospace Engineering
[3] Masters Student, Mechanical & Aerospace Engineering
[4] Undergraduate Student, Mechanical & Aerospace Engineering
[5] Post-Doctoral Associate, Mechanical & Aerospace Engineering
[6] PhD Student, Aerospace Engineering
[7] Masters Student, Aerospace Engineering
[8] PhD Candidate, Department of Mechanical & Aerospace Engineering
[9] Assistant Professor, Mechanical and Aerospace Engineering
[10] Professor, Mechanical and Aerospace Engineering

75 TCOs during the ten year lifetime of the Legacy Survey of Space and Time (LSST) [1]. At the same time, the total number of known small bodies in The Solar System is expected to increase by a factor of ten to 100 [2]. Our mission will begin with a rideshare in the 3rd quarter of 2030, where TREx will be transported via a Falcon Heavy rocket and released into a Near-Rectilinear Halo Orbit (NRHO) about the Earth-Moon L2 Lagrange point. TREx will stay in an L2 parking orbit until a suitable TCO is detected by ground-based observations and deemed reachable by the mission operations team. Once the TCO is selected, the spacecraft will leave its parking orbit and rendezvous with the TCO to collect images of it and characterize its size, shape, and surface composition. The instrument payload will include two cameras: one with a wide field of view that operates in the visible spectrum, and another based on the specifications of an ESA Hera mission instrument, which is a visible-near-infrared multispectral imager [3]. During End-of-Life operations, TREx will be injected into a disposal orbit that leaves the Earth–Moon system, complying with NASA Procedural Requirements for Limiting Orbital Debris.

SIMPLEx program constraints include a maximum allowable budget of $55 million, a mass limit of 180 kg, and a volume restriction of 12U. The final estimates for the proposed two year mission are calculated to be ~$24 million cost, 27 kg mass, and 11.8U volume. The proposed Mini-Luna mission concept will provide more information on small body populations and pave the way for future TCO technology demonstrations.

Comments:

Alternative session: NEO Characterization. Oral Presentation is preferred; Poster presentation desired as alternate.

References

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