# NEW APPROACHES FOR HUMAN DEEP-SPACE EXPLORATION

**David W. Dunham**[(1)], **Robert W. Farquhar**[(2)], **Natan Eismont**[(3)], **and Eugene Chumachenko**[(4)]

[(1)]*KinetX, Inc., 7913 Kara Ct, Greenbelt, MD 20770, USA, +1-301-526-5590, david.dunham@kinetx.com*

[(2)]*KinetX, Inc., 9007 Parliament Dr, Burke, Virginia 22015, USA, +1-703-303-9824, robert.farquhar@kinetx.com*

[(3)]*Space Research Institute of Russian Academy of Science, 84/32 Profsoyuznaya Str., 117997, Moscow, Russia, +7 916 628 6139, NEismont@iki.rssi.ru*

[(4)] *Moscow Institute of Electronics and Mathematics, per. Trekhsvyatitelskiy B., d. 3, 109028, Moscow, Russia, +7-495-917-07-50, kommek@miem.edu.ru*

***Keywords:*** *human space exploration, libration-point orbits, lunar swingby orbits, ISEE-3*

## ABSTRACT

The Russian Ministry of Education and Science has awarded us a "megagrant" to study orbital options to extend human exploration beyond the Moon's orbit. For a viable program, we believe that international collaboration, as established now for the International Space Station, and reusable spacecraft will be needed. For reusable spacecraft, we will use high-energy Earth orbits that can be drastically modified with lunar swingbys and small propulsive maneuvers in weak stability regions, especially near the collinear Sun-Earth libration points, mostly using techniques already proven in flight by the Third International Sun-Earth Explorer (ISEE-3)/International Cometary Explorer[1] and other spacecraft. The work will build on ideas developed by the International Academy of Astronautics' exploration study group presented at the 2008 International Astronautical Congress in Glasgow [2]. The first crewed mission might enter an expanding Lissajous orbit about the Earth-Moon L2 libration point to support operations by robotic rovers and sample-return landers on the Moon's far side. Calculations of fast transfer trajectories with post-injection deterministic $\Delta V$'s under 400 m/sec will be shown. The next efforts could be for servicing large space telescopes in Sun-Earth libration-point orbits. Low-cost transfers between the vicinity of the Earth-Moon L2 point and the Sun-Earth L1 and L2 points will be presented. Next, flyby and rendezvous missions to Near-Earth Objects (NEO's) will be designed, with an emphasis on options for defense against potentially hazardous objects. Finally, trajectories to reach Mars, first to Phobos and/or Deimos, will be calculated. The study will use highly-elliptical Earth orbits whose line of apsides can be rotated using lunar swingbys; then a propulsive maneuver, considerably smaller than that needed from a circular low-Earth orbit, can be applied at the right perigee to send the spacecraft on the right departure asymptote to a desired destination. The double-lunar swingby technique [3] to control and move the orbit, as pioneered by ISEE-3's extended mission [2], will be used. During the highly-elliptical "phasing" orbits, the "inner loops" of the double-lunar swingby orbits (the outer loops would often extend out to Lissajous orbits about the Sun-Earth L2 point), about a revolution before a perigee maneuver sends the large spacecraft to an asteroidal or interplanetary destination, astronauts could be sent in small spacecraft to rendezvous with the larger one, a technique that we call "phasing orbit rendezvous". Aerocapture can be used at the return, perhaps helped with a lunar swingby. But the astronauts onboard could separate in an Apollo-style capsule for a direct return. Sun-Earth libration point orbits (most likely L2) and double-lunar swingby orbits, like those flown first by the third International Sun-Earth Explorer, will be used, along with time to change the orbital orientation between missions. There might be waits of several months between

missions, when the interplanetary spacecraft could be "parked" in a small-amplitude Lissajous orbit about the Sun-Earth L2 point, similar to that flown by the WMAP mission. During that time, if there wasn't an L2 space telescope needing servicing, the spacecraft could be uncrewed and controlled remotely from the Earth. The first missions might start with an Orion capsule (or something similar) to which modules could be added, including fuel tanks, as needed, for later missions that could include rendezvous with a NEO.


1. Farquhar, R., "The Flight of ISEE-3/ICE: Origins, Mission History, and a Legacy", *Journal of the Astronautical Sciences*, Vol. 49, pp. 23-73, 2001.
2. Farquhar, R., Dunham, D., and Veverka, J., "An Affordable Program of Human Missions beyond Low Earth Orbit", *Paper IAC-08-A5.3.02* presented at the 59th International Astronautical Congress, Glasgow, United Kingdom, September 29-October 3, 2008.
3. Farquhar, R, Dunham, D., and Muhonen, D., "A New Trajectory Concept for Exploring the Earth's Geomagnetic Tail", *J. Guidance and Control*, Vol. 4, pp. 192-196, 1981.