SOLAR SYSTEM HUMAN EXPLORATION AIDED BY LIBRATION-POINT ORBITS, LUNAR GRAVITY ASSISTS, AND "PHASING ORBIT RENDEZVOUS"

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ABSTRACT

Reusable spacecraft will likely play a key role in any sustained program of human exploration beyond the Moon. Such vehicles can 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 and Earth-Moon libration points. This architecture enables missions that use significantly less propellant than would be needed if all vehicles departed and returned to low-Earth orbit (LEO). The work builds on ideas developed by the International Academy of Astronautics' exploration study group presented at the 2008 International Astronautical Congress in Glasgow[1], which in turn was an extension of a 2004 IAA study[2]. The first missions will probably go to the Moon and its vicinity (A halo orbit about the Earth-Moon L2 libration point would be useful for far-side exploration[3] and a distant retrograde orbit about the Moon has been proposed as a destination for NASA's proposed Asteroid Redirect Mission), but this paper will discuss the next possible missions beyond those, for a stepping stone approach to eventually reach Mars. Some of these missions might be for servicing large space telescopes in Sun-Earth libration-point orbits. Next, flyby and rendezvous missions to Near-Earth Objects (NEO's) will be presented. Finally, trajectories to reach Mars, first to Phobos and/or Deimos, will be calculated.

This study uses highly-elliptical Earth orbits (HEOs) whose line of apsides can be rotated using lunar swingbys. The HEO also provides a convenient and relatively fast location for rendezvous with crew, or to add propulsion or cargo modules, a technique that we call "Phasing Orbit Rendezvous" or PhOR. Launch windows and optimal strategies for PhOR using taxi vehicles launched from the Earth or from LEO will be presented. From a HEO, 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. A small propulsive maneuver is used at the perigee of the return trajectory, to capture the spacecraft in a high orbit loosely bound to the Earth. But at the return, the astronauts onboard could separate in an Apollo-style capsule for a direct return. Sun-Earth (and possibly Earth-Moon) libration point orbits 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 halo or small-amplitude Lissajous orbit about a libration 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 unmanned and controlled remotely from the Earth. Sequential missions to fly by and then rendezvous with NEO's will be presented, followed by a mission to the Martian moons.

An early mission might depart Earth on a low-energy half-year or one-year return trajectory to fly by a near-Earth asteroid. There would be little scientific value in such a mission, but it would be valuable for gaining experience for human missions beyond the Earth-Moon system. There are frequent opportunities for such missions with the current catalog of near-Earth asteroid orbits. We show a sample list of such possibilities, and present details of one trajectory that leaves a halo orbit about the Earth-Moon L2 libration point, then uses three lunar swingbys and relatively small propulsive maneuvers to fly by the approximately 100m asteroid 1994 XL1, and return to the Earth-Moon L2 halo orbit for a total deterministic ΔV of only 432 m/s.

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