HUMAN EXPLORATION OF THE MOON AND MARS SYMPOSIUM (A5)
Going Beyond the Earth-Moon system: Human Missions to Mars, Libration points, and NEO's (4)

Author: Mr. Arthur Guest
Massachusetts Institute of Technology (MIT), United States, aguest@mit.edu

Mr. Wilfried Hofstetter
Massachusetts Institute of Technology (MIT), United States, wk_hof@mit.edu
Mr. Paul Wooster
DevelopSpace.net, United States, paul@developspace.net

ESTABLISHING A NEAR-TERM HUMAN TOEHOLD ON MARS AS A PRELUDE TO COLONIZATION: A FEASIBILITY STUDY

Abstract

This paper investigates the technical and financial feasibility of establishing a "toehold" outpost with a crew of four on the surface of Mars. Of all the possible destinations for human missions in the inner solar system, Mars is by far the most viable for permanent human presence and colonization because it offers all the resources required for sustained human existence in its atmosphere or on its surface. The strategy for toehold establishment and operation is based on the assumption that the crew transfers to Mars once and does not return to Earth.

The paper first establishes the feasibility of emplacing and operating the toehold based on an extension of currently existing Mars Entry, Descent and Landing (EDL) technology which could land 2000 kg on the surface of Mars. High-level estimates of Net Present Cost (NPC) indicate that the dominant cost contributor is the expenditure associated with the initial development of the transportation and surface infrastructure required for the toehold (in the vicinity of 10 billion dollars measured in FY 2004), with long-term re-supply cost over 18 opportunities being less than a quarter of NPC. The following technologies emerge as key enablers for the technical and financial feasibility of the Mars toehold: in-situ production of oxygen and water on the surface, Mars landing accuracy within 100 m of a target, low-maintenance extravehicular suits and equipment, long-term food preservation and storage, automated in-space docking, and establishment of pressurized connections on the surface of Mars.

The paper then proceeds to investigate the impact of developing more capable Mars EDL (in terms of landed mass), Earth launch (in terms of payload mass in Low Earth Orbit), and in-situ food production manufacturing technologies on toehold NPC and operational risk. Results indicate that the development of higher net payload (8000-40000 kg in one "chunk" on the surface of Mars) transportation systems have a significant positive effect on toehold operational risk and sustainability. The analysis also indicates that the mass-based break-even for in-situ food production and manufacturing takes a long time, although there is also a significant reduction of operational risk associated with having these capabilities.

The paper concludes with a discussion of the programmatic aspects of establishing a near-term human Mars toehold with particular focus on financing as well as on possible contributions of open-source engineering communities and efforts to lowering the initial cost for developing the transportation and surface infrastructure required for the toehold.