SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Space Transportation Solutions for Deep Space Missions (8-A5.4)

Author: Dr. Jeffery Greenblatt
Emerging Futures, LLC, United States, jeff@emerging-futures.com

ENERGY AND RESOURCE ANALYSIS OF A LARGE-SCALE EARTH-MARS HUMAN TRANSPORT SYSTEM

Abstract

Spurred by recent interest both within and outside of NASA focusing on human spaceflight beyond low Earth orbit, we perform the first comprehensive assessment of energy and resource requirements of a large-scale human transport system between Earth and Mars. We model SpaceX's Mars Colonial Transporter (MCT) plans as closely as possible, based on publicly available information, including their announced goal of building and maintaining a one million-person settlement on Mars. We develop credible estimates of a reusable, multi-stage spacecraft for moving humans and cargo between Earth and Mars each 26-month synodic period, as well as additional spacecraft for moving CH4/O2 propellant from either Earth's surface or the Moon to a LEO depot. Additional propellant is produced on Mars for spacecraft returning to Earth. Consumables, passenger cargo and crew are included, but other infrastructure requirements (including the more significant and technologically challenging Mars surface infrastructure needs) are not examined. We assume 10 cargo trips per passenger trip, resulting in 16 t/passenger of cargo to provide physical infrastructure for the Mars settlement. We develop a scenario starting in 2042 to achieve a Mars settlement population of one million after 90 years, taking into account finite ship lifetimes, transport capacity growth, population growth and attrition from those returning to Earth. Cumulative fleet mass is estimated at 21 million tonnes (Mt), while cumulative propellant mass is 270 times as large (5,600 Mt). Cumulative shipped cargo is 22 Mt. We find that very significant mass and energy savings are available in shifting propellant production for the LEO refuelling depot from Earth to the Moon, resulting in 77 percent less cumulative propellant or 1,260 Mt. However, a source of lunar carbon is required, which may need to be supplied from the Earth or asteroids, and raises concerns about depletion of limited lunar water resources. We also considered shifting from CH4/O2 to H2/O2 propellant, but it results in approximately the same lunar water demand. Therefore, entirely asteroid-derived propellant may be necessary in the long term. SpaceX's proposed plan provides 5 m3/person habitable volume, which is very cramped compared with the International Space Station (65 m3/person); we estimate that increasing this habitable volume to a more reasonable 20 m3/person would increase mass and energy requirements by 2.4 times, however. We consider reductions in shipped cargo mass, human hibernation to reduce spacecraft and consumables mass, and space elevators as possible long-term strategies to reduce cumulative mass and energy requirements.