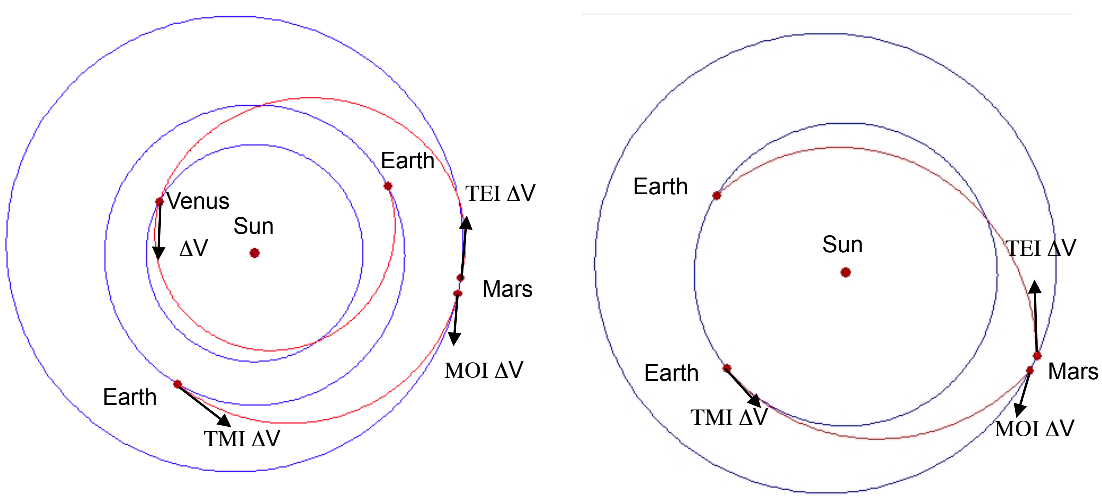
A PROPOSAL FOR A LEAN, FAST MARS ROUND-TRIP MISSION ARCHITECTURE: USING CURRENT TECHNOLOGIES FOR A HUMAN MISSION TO MARS IN THE 2030s

Lora Bailey,[*] David Folta,[†] Brent W. Barbee,[‡] Frank Vaughn,[§] Bruce Campbell,[¶]
Harley Thronson,[‖] Jacob Englander,[**] and Tzu Yu Lin[††]

We present a lean-minded, fast-transfer mission strategy and architecture concept for a first human mission to Mars that deliberately utilizes a current-technology-favored approach by means of introducing and quantitatively defining two pivotal parameters: 1) an end-to-end Mars mission duration of approximately one year, and 2) a deep space habitat of approximately 40–50 metric tons. These parameters are identified and introduced by a 2012 deep space habitat study conducted at the NASA Johnson Space Center (JSC) that focused on a subset of recognized high-engineering-risk factors that may otherwise inhibit or encumber remote space travel to destinations such as Mars or near-Earth asteroids (NEAs).[1] Additional constraints in the study favoring current technology and a lean-minded (very short) surface stay on Mars are shown to offer such Mars mission opportunities in the 2030s, enabled by a combination of on-orbit staging,[2] mission element pre-positioning, and unique round-trip trajectories identified by state-of-the-art astrodynamics algorithms.[3,4]



(a) Optimal one year duration round-trip trajectory to Mars with a Venus gravity assist on the Earth-return portion of the trajectory.

(b) Optimal one year duration round-trip trajectory to Mars without a Venus gravity assist.

Figure 1. Exemplar optimal one year duration round-trip trajectories to Mars.

This astrodynamics analysis, requested by JSC as part of the Deep Space Habitat risk-reduction study, was performed by the NASA Goddard Space Flight Center (GSFC) and utilizes a Fast Mars Transfer (FMT) approach which had previously been developed in an early study by GSFC in 2004–2005. The new 2012 analysis employed the use of parameters defined by the JSC study in order to assess the feasibility of a round

[*]Aerospace Engineer, NASA/JSC, Code EA32, 2101 NASA Parkway, Houston, TX, 77058, USA.
[†]Aerospace Engineer, NASA/GSFC, Code 595, 8800 Greenbelt Road, Greenbelt, MD 20771, USA.
[‡]Aerospace Engineer, NASA/GSFC, Code 595, 8800 Greenbelt Road, Greenbelt, MD 20771, USA.
[§]Aerospace Engineer, NASA/GSFC, Code 595, 8800 Greenbelt Road, Greenbelt, MD 20771, USA.
[¶]Integrated Design Center (IDC) Manager, NASA/GSFC, Code 500, 8800 Greenbelt Road, Greenbelt, MD 20771, USA.
[‖]Senior Scientist for Advanced Concepts, NASA/GSFC, Code 660, 8800 Greenbelt Road, Greenbelt, MD 20771, USA.
[**]Aerospace Engineer, NASA/GSFC, Code 595, 8800 Greenbelt Road, Greenbelt, MD 20771, USA.
[††]Graduate Student, Mechanical and Aerospace Engineering Department, University of Florida, Gainesville, FL, 32611, USA.

trip mission using only current chemical propulsion technology that would offer a brief (approximately two-day) human surface landing on Mars within a total round-trip mission duration of approximately one year using a deep space habitat of approximately 50 metric tons. Identification of notionally feasible and optimal (minimum Initial Mass in Low Earth Orbit (IMLEO)) trajectory solutions for these missions was enabled by a combination of GSFC algorithms for optimal on-orbit staging, pre-positioning of assets at Mars, and state-of-the-art astrodynamics algorithms for comprehensive identification of optimal round-trip trajectory solutions with and without Venus gravity assists; see Figures 1(a) and 1(b), respectively. The four-stage propulsion module for Earth return modeled in the on-orbit staging algorithms is pre-positioned in Mars orbit and subsequently docked with the crew's deep space habitat upon the habitat's arrival in Mars orbit at a later date. The results of this analysis show that one-year duration short-stay Mars mission opportunities using chemical propulsion are available in the mid-2030s and for which the predicted number of 120 metric ton to LEO heavy-lift launches is in the range of 10–12. The results also show that, when only chemical propulsion is used, this unique mission opportunity window opens briefly in the mid-2030s and does not open again for approximately 17 years.

The purpose of our effort is to provide a pilot study of a lean-minded Mars mission, with the intention of promoting affordability and making a best effort to utilize known, familiar elements—including International Space Station modules and systems when possible—as well as conventional propulsion technology (e.g. hypergolic bi-propellant and/or cryogenic propellant with appropriate storage). In doing so, it is our hopeful expectation that 1) key risks can be mitigated, and that 2) this will greatly diminish the delay in initiating such a venture.

The full architectural concept includes an evaluation of a possible gradual build-up to the previously-described short duration human landing on Mars. This build-up includes concepts for an initial non-crewed round-trip test flight to Mars featuring an autonomous sample return, followed by a preliminary short duration human mission to Mars orbit during which a sample collection experiment would be conducted tele-robotically. A Venus flyby during the Earth-return leg of the journey is also considered, weighing a slight mission mass reduction and diversity of mission destinations against close approaches to the Sun.

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