

24th IAA SYMPOSIUM ON HUMAN EXPLORATION OF THE SOLAR SYSTEM (A5)
Space Transportation Solutions for Deep Space Missions (4-D2.8)

Author: Dr. Christie Maddock
University of Strathclyde, United Kingdom

Mr. Lorenzo Angelo Ricciardi
University of Strathclyde, United Kingdom

Mr. Ben Parsonage
University of Strathclyde, United Kingdom

Prof. Massimiliano Vasile
University of Strathclyde, United Kingdom

Prof. Michal Kocvara
University of Birmingham, United Kingdom

Prof. Jörg Fliege
University of Southampton, United Kingdom

Ms. Orr Cohen
ESA, The Netherlands

DESIGN OPTIMISATION AND ANALYSIS OF VERY HIGH POWER TRANSPORTATION SYSTEM
TO MARS

Abstract

This paper will present results of a study undertaken in 2020 through ESA to develop a preliminary flight vehicle engineering model of a Very High Power Transportation System to Mars for a crewed return mission.

The preliminary design examined the mission performance, and a vehicle configuration study with numerical models for structural mass, radiation, propulsion, habitat and consumables, and a structural analysis of the separation truss between the spacecraft, including crew habitat module, and the nuclear engine.

The system analysis focuses on a nominal crewed mission to Mars, as it is the more limiting of the options of crewed versus cargo-only. The requirements and assumptions for the system are: Earth and Mars one-way journey travel time of less than 90 days, spacecraft carrying a minimum of 50 tons of cargo with a minimum of 3 crew, and in-orbit manufacturing and re-fuelling facilities are assumed as operational around both Earth and Mars. The launch and landing segments of the mission are not considered.

Scalable models for two system configurations were developed: one based on a higher-TRL nuclear thermal propulsion system, and the other using the ESA developed NTER (Nuclear Thermal Electric Rocket) engine.

A multi-objective optimisation solver was used to examine trade-offs in the mission and trajectory designs, and the driving vehicle design parameters including engine sizing, and gross and dry vehicle masses. For a cycler-based mission architecture, single and return legs were analysed independently and together, using continuous and on-off thrust models. The stay time on Mars was a variable parameter, set to values up to 100 days, to understand the impact on optimal set of timings of a such Earth-Mars-Earth trip.

Preliminary results for the mission and system design trade-off show, as expected, a single leg journey is possible within the 90 day limit (e.g., 86.0 days for Earth to Mars for a 650.86 t vehicle and 84.5 day return

for a vehicle mass of 698.84 t vehicle). For a crewed return mission, the multi-objective multidisciplinary design optimisation examined the trade-off between total transfer duration against vehicle mass for a 30 day stay on Mars, with results showing total flight times ranging from 295 days for vehicle masses of 376.8 t out and 668.28 t return compared to 541.7 days for a 111.7 t outbound vehicle and 272.21 t return vehicle.