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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.