Paper ID: 62802
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HUMAN MISSIONS TO CERES, A GATEWAY TO THE JUPITER SYSTEM

Abstract

Sending humans to Ceres is extremely challenging due to high delta-v and crew time of flight, this translates to high IMLEOs and radiation hazards. We used Nuclear Thermal Propulsion and four techniques to reduce the challenge; direct return, gravity assists, ISRU, and crew shielding. These techniques interact in an interesting way to make a human Ceres mission more tractable. We also found that analogous trajectories exist to reach the Jupiter system, potentially making our Ceres CONOPs a rehearsal for Jupiter missions.

Three of the features reduce the effective delta-v, important given propellant mass is non-linear in delta-v.

Firstly, direct reentry of the crew eliminates an Earth capture burn. The reentry vehicle only needs to sustain the crew for a matter of hours and could be minimal.

Secondly, gravity assists reduce delta-v in exchange for longer flights. If one finds a flyby sequence that ends with an Earth to Ceres leg, then one can send the bulk of the vehicle and consumables on the low delta-v trajectory and the crew can rendezvous at the last Earth flyby, this reduces the total impulse. The chase craft carries propellant to make a direct Earth reentry if rendezvous fails and this contingency propellant is donated to the main vehicle on a successful rendezvous.

We found pairs of Earth-DSM-Earth-Ceres trajectories a few years apart that should repeat on a 22-year cycle. If the ISRU plant were sent by the first trajectory there would be 16 months on Ceres before the crew had to commit to an Earth departure.

Thirdly, ISRU eliminates return propellant from the Earth departure manifest. For NTR propellants this can more than halve the IMLEO. The ISRU utility window exists where there is sufficient scientific value in putting humans at Ceres, but the surface is sufficiently understood to perform ISRU.

Finally, radiation shielding reduces crew dosage and extends the age and gender of astronauts who would receive less than their currently allowed career maximum. We take a two-layer approach; a storm shelter/sleeping quarters shielded by consumables, and the entire crew habitat shielded by the propellant.

We found that NH3 has interesting trade-offs and could be attractive as both propellant and shielding.

We consider this work to be a proof of concept, pointing to a potentially interesting approach. A full exploration of the concept requires co-optimizing multiple vehicles, their trajectories, ISRU, and crew consumables and constraints.