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ASTEROID MINING: MULTIPLE SPACECRAFT LOGISTICS FOR MARS SUPPLY

Abstract

The expansion of humankind to extra-terrestrial bodies will require supplying colonies with materials. Necessary resources can be either used in a closed loop, produced from in-situ available resources, or resupplied from Earth on a regular basis. In cislunar space, all three options may be combined for optimal efficiency. However, when considering more distant bodies such as Mars, supplying a settlement with resources from Earth becomes increasingly challenging, considering higher requirements in delta-v and reduced launch opportunities for transfers between Earth and Mars. Near Earth asteroids and Main Belt asteroids have been considered as an alternative point of extraction for some resources. This is of particular interest in the case a settlement's size has reached a threshold above which Earth based supply together with in-situ resource production cannot support the needs anymore. This paper describes a method and digital tool designed to optimize an interplanetary economy including Earth, Mars and asteroid groups (NEA and MBA), which can supply a Martian colony with the additional resources required for enabling the development. The mission starts in 2040. The asteroids that could provide the resources are identified from a database. Metallic and carbonaceous asteroids are selected to extract metals and produce propellant. Delta-v maps showing local minima on a timescale of 20 years are then created for each considered asteroid using defined input parameters including payload, maximum delta-v and number of vehicles. From this, having an upper limit of delta-v that the spacecraft can guarantee, the reachable asteroids are selected. The optimization problem is based on a multi-objective genetic algorithm with the aim of minimizing the total delta-v of the mission and maximizing the mass of metals mined and propellant produced. The mining rate and the propellant production rate depends on the power available, so several options are analysed. Then, the Pareto front and the optimal schedules are computed. By associating a spacecraft to each element of the Pareto front, the total quantity of extractable material is computed. Finally, we evaluated how many rovers and habitats can be built applying additive manufacturing. We demonstrate that asteroid mining could provide the colony with a greater number of supply opportunities considering more frequent launch windows, smaller delta-v for material transportation and various consumable types that cannot be resourced in-situ. Recommendations include specifications for vehicle architecture based on the variations tested in payload and number of vehicles and further observation and cataloguing of NEA and MBA.