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From Earth Missions to Deep Space Exploration (05)
Exploration Capabilities (1)

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DESIGN CONSIDERATIONS FOR ORBITAL PROPELLANT DEPOTS

Abstract

The current generation of human space exploration roadmap relies on large rockets that are costly to develop and cannot support high flight rates. This results in rigid architectures that need to be highly reliable, as a single failure can be catastrophic. The implementation of an orbital propellant depot can enable the use of smaller, less reliable rockets that can achieve higher flight rates and provide more flexibility to the architecture without changing the in-space components. To enable this type of architecture, the use of propellant depot must be extensively studied. The appropriate thermal management techniques, most advantageous depot location, and optimal combination of launch vehicle size and launch rates must be determined. In this paper, a thermal model of an orbital propellant depot is used to examine the effects of current state-of-the-art on-orbit thermal management techniques. For short duration missions, the mass of an active thermal management system outweighs the reduction in the cryogenic boil-off, while long duration missions require zero-boil-off technologies to minimize the mass loss due to boil-off. The thermal environment low Earth orbit, high Earth orbit, and geosynchronous orbit are compared. The mission duration for the propellant depot is highly dependent on the launch vehicle capacity and launch rates. The propellant build up rates for small, medium, heavy, and a mixed fleet of launch vehicle is examined. The results show that a medium class launch vehicle with moderate launch rates can achieve better propellant buildup rates than a heavy class launch vehicle with low launch rates even with zero-boil-off technology. A mixed fleet of small and medium class launch vehicle can provide even better propellant buildup rates. A mixed fleet option is also highly desirable, as the failure of one vehicle will not affect the other, thus giving the architecture more flexibility and thus creating a more robust architecture.