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MISSION DEMONSTRATION CONCEPTS FOR THE LONG-DURATION STORAGE AND TRANSFER OF CRYOGENIC PROPELLANTS

Abstract

The ability to store, manage, and transfer cryogenic propellants on-orbit enables a paradigm shift for the space transportation architecture through on-orbit refueling. On orbit refueling enables significant increases in delivered payload mass to deep space missions; Lunar, Mars, NEO, or beyond. Prior to the significant investment required for sustainable fuel depots or operational Earth Departure Stages, it is desirable to demonstrate critical mission technologies with low-cost, subscale demonstration missions.

This paper describes an experimental platform that will demonstrate the major technologies required for the handling and storage of cryogenic propellants in a low to zero-g environment. In order to develop a cost-effective, high value added demonstration mission, a review of the complete mission CONOPS was performed. The overall cost of such a mission is driven not only by the spacecraft platform and on-orbit experiments themselves, but also by the complexities of handling cryogenic propellants during ground processing operations. Unlike loading of a standard cryogenically fueled launch vehicle, the encapsulation of significant quantities of propellants within a payload fairing requires significant innovation in standard launch processes.

On-orbit storage methodologies were looked at for both passive and active systems. Passive systems rely purely on isolation of the stored propellant from environmental thermal loads, while active cooling employs cryocooler technologies. The benefit trade between active and passive systems is mission dependent due to the mass, power and system-level penalties associated with active cooling systems.

The experimental platform described in this paper is capable of demonstrating multiple advanced zero-g cryogenic propellant management technologies. In addition to the requirements of demonstrating these technologies, the methodology of propellant transfer must be evaluated. The handling of multiphase liquids in zero-g is discussed using flight-heritage zero-g propellant management device technologies as well as accelerated tank stratification for access to vapor free or liquid free propellants. The design of this is experimental platform is also based on predictive modeling of the storage lifetime based on various thermal designs, as well as the thermodynamics associated with the transfer of cryogenic propellants from and to propellant tanks with varying initial conditions.

The mission concept presented shows the extensibility of the experimental platform to demonstrate advanced cryogenic components and technologies, propellant transfer methodologies, as well as the validation of thermal and fluidic models, from subscale tankage to an operational architecture.