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Architecture Study for a Fuel Depot Supplied From Lunar Resources

Heretofore, discussions of space fuel depots assumed the depots would be supplied from Earth. However, the confirmation of deposits of water ice at the lunar poles in 2009 suggests the possibility of supplying a space depot with liquid hydrogen/liquid oxygen produced from lunar ice.

This architecture study sought to determine the optimum architecture for a fuel depot supplied from lunar resources. Four factors – the location of propellant processing (on the Moon or on the depot), the location of the depot (on the Moon or in cislunar space), and if in cislunar space, where (LEO, GEO, or Earth-Moon L1), and the method of propellant transfer (bulk fuel or canister exchange) were combined to identify 18 potential architectures. Two design reference missions (DRMs) – a satellite servicing mission and a cargo mission to Mars – were used to create demand for propellants, while a third DRM – a propellant delivery mission – was used to examine supply issues. The architectures were depicted graphically in a network diagram with individual segments representing the movement of propellant from the Moon to the depot, and from the depot to the customer.

Delta-v and time-of-flight information were developed for each network segment using restricted two-body techniques. Propellant expended was calculated using the rocket equation, while anticipated boiloff was calculated using the modified Lockheed equation. Chilldown losses

were also calculated with respect to bulk fuel transfer. The depot was assumed to have active cooling of cryogens, while the DRM vehicles were assumed to employ passive insulation only. Overall, propellant consumption and losses were calculated in moving propellant to the depot, or in direct delivery to the customer. Similar consumption and losses were calculated for the customer DRMs in performing their missions and maneuvering to the depot or transfer location to refuel. The network diagram was then analyzed to determine which architecture satisfied the DRMs for the smallest mass of propellant.

The study concluded that propellant processing (electrolysis and liquefaction) are best performed on the Moon, due to the power required and the rate at which propellants would be needed. L1 is the most efficient fuel transfer location because of delta-v considerations. Direct delivery of propellants from a lunar depot to customer vehicles at L1 is the most efficient means of operation, because the supply vehicle transports only the fuel needed, and carries only the propellant necessary to deliver it. Propellant boiloff in microgravity was less of a factor than anticipated, and was far overshadowed by delta-v requirements and resulting fuel consumption. Bulk fuel transfer is recommended as being the most flexible for both the supplier and the customer. However, since canister exchange bypasses the transfer of bulk cryogens in microgravity and the necessary chilldown losses, canister exchange shows promise and merits further investigation.