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A COMMERCIAL CISLUNAR TRANSPORTATION ARCHITECTURE

Abstract

The United States Trump Administration's Space Policy Directive 1 (SPD-1) directs NASA to include the Moon on its path to human Mars exploration missions. SPD-1 also calls for NASA to include commercial and international partners in their space missions. This paper describes a commercial cislunar transportation architecture that not only satisfies SPD-1 but also NASA's Strategic Principles for Sustainable Exploration. Cislunar Space Development Company's (CSDC) reusable cryogenic cislunar transportation architecture was conceived to extend the reach of new small low-cost launch vehicles, move the largest launchable payload in 2010 from low Earth orbit (LEO) to the Moon's surface, carry humans round trip between LEO and the Moon and make use of lunar water when available. CSDC defined Design Reference Missions (DRM) for GTO, GEO and lunar delivery. Systems and elements are defined to satisfy mission functional requirements including: payload transfer, refueling, propellant transfer, propellant production and storage, lunar landing and human transport. Sizing analysis includes factors for mass margin, delta velocity margin, propellant reserves, specific impulse shortfall and aerobrake fraction. Propellant quantities are calculated for each DRM and as a function of payload mass. Acquisition and operations cost estimates are combined to estimate mission cost and price. Architecture systems include Earth to orbit refuelers, propulsive and aeroassisted space tugs, Moon shuttles and propellant depots. Elements include in-space propellant tankers and crew modules. DRM payload capabilities are 1,360 and 3,000 kg to GTO and GEO and 25,000 kg to EML1 and the Moon's surface. Projected cargo DRM prices are $15M to $64M for GTO, $43 to $259M for GEO and $878M to $1,624M for the Moon. Human mission price estimates are $213M to $281M for LEO to EML1, $861M to $1,262 for LEO to the Moon and $648M to $982M for EML1 to the Moon. Due to its construct, CSDC's cislunar transportation architecture is a commercial partnership, incorporates technology push and pull, supports scientific exploration, provides continuity of human space flight, is open and resilient, provides opportunity for global collaboration and leadership, can be implemented gradually, and is fiscally realistic. The architecture is viable when fully supplied from Earth and may benefit from lunar water when it becomes available. Finally, mission prices are 95% driven by the cost of propellant as acquisition costs are amortized over 240 missions and 20 years of operation.