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LUNAR EXPLORATION ARCHITECTURE TRADE ANALYSES

Abstract

The research presents lunar exploration architectures trade analyses based on best mass, cost, and safety. The Moon was selected as a destination due to the availability of information on mass, reliability, and experience in that area. Although, the new United States space policy has an asteroid as primary destination instead of the Moon, the results of this study can be applied to other destinations. Two aggregation points were analyzed, one going directly from Low Earth Orbit (LEO) to the Moon, and a second one stopping at a Lagrange point (L2). For this study, a commercial launch vehicle is compared against a government program; they are Falcon Heavy and the Space Launch System. For the lander, LOX LH2, LOX RP, and storable propellants were compared; as well as reusable and expandable systems. For the case where the aggregation point is at LEO, Apollo data was used for its close similarity and proven technology. Delta-Vs, thrust to weight ratios, and time of flight requirements were provided for the L2 case by the National Institute of Aerospace. Mass estimation relationships were used providing a best initial mass for the lunar lander, which was then used to approximate the minimum cost of the mission. Beta curves were used to spread derived cost estimates. The transcost 8.0 model was used to calculate design, development, test, and evaluation (DDTE), production, and operation costs for the launch vehicle, stages, and crew vehicle. Ten missions were assumed, where the DDTE costs for SLS were spread over eight years and for Falcon Heavy over three years. Since there were not regression equations for reusable systems, those were assumed to be twice the expendable transcost results, with a life of five years. The system criteria followed to select the best lunar exploration architecture included economy of cargo and personnel transportation, design complexity, life cycle cost, crew safety, and mission safety. These were used in an analytic hierarchy process tool that allows assigning weightings to each criterion. This in conjunction with an overall evaluation criterion helped determined a balanced combination between mass, cost and reliability for the next space exploration architecture. In addition, a proposed lander was designed based on the results and fit into the SLS and Falcon Heavy lunar vehicles following their internal shroud diameters. Finally, a concept of operations is presented with recommended future research.