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Title

Low-Cost Uncrewed Lunar Landers: Mission Design and Preliminary Feasibility Assessment

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Abstract

Lunar exploration is poised for a renaissance. The Artemis program intends to create a "permanent human presence on the moon." There has been much research and development interest in launchers, crew vehicles and habitats for lunar outposts. These lunar outposts will necessitate regular two-way cargo deliveries between the Earth and the Moon. Since the cost of space transport is so high compared to terrestrial shipping costs it is interesting to investigate cost effective and suitable ways of delivering cargo to a human lunar outpost.

This paper uses a systems engineering approach to identify, evaluate and size a set of 5 possible mission architectures for unmanned cargo delivery from Earth to the lunar surface. The first three mission architectures are fully reusable, single stage, two-stage and three stage architectures. The fourth uses a reusable electric space tug, and the fifth is a non-reusable Apollo-style architecture.

The five mission architectures are sized using statistically derived sizing rules from a database of 42 lunar landers and transfer vehicles compiled from an extensive literature review. Two sizing exercises were carried out for each architecture: a maximalist case to see what is the upper bound to payload delivery mass , and a 2-ton payload delivery case comparable to the mass of ISS cargo deliveries. A trade-off is then performed based on 7 figures of merit: Landed Payload [kg/trip] Returned Payload [kg/trip], Cost of Landed Payload [$/kg], Cost of Returned Payload [$/kg], Delivery Time [days], System Complexity and Extensibility.

The most cost effective and suitable mission architecture is chosen and a lander design which can carry 2-tons of cargo down to the lunar surface and back up again is sized from statistical and parametric sizing rules. This small lander is then costed using TruePlanning software.

It was found that the main cost drivers for lunar cargo delivery are fuel carriage and launcher costs. These costs could be reduced by Orbital fuel depots in LEO and at the Lunar Gateway and ridesharing on very large launchers.