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A PARAMETRIC ANALYSIS OF LOW-COST, NEAR-TERM, SUSTAINABLE HUMAN LUNAR EXPLORATION

Abstract

Since the days of Apollo, many different concepts and architectures for a return to human lunar exploration have been proposed, examined, and abandoned, usually due to excessive costs. The general tendency has been to focus on a point design - *this* rocket, *that* spacecraft - rather than ask the related questions of what can we afford, and how can we work within this budget?

This paper takes a parametric approach to human lunar exploration, with the focus on developing an architecture based on a firm annual cost cap, with three top-level requirements: (1) proceed to the first human lunar return mission as quickly as feasible, (2) support at least one human lunar surface mission per year indefinitely, and (3) maintain enough funding capability to be continually developing new capabilities for progressively more ambitious missions. These three Level 1 goals are intended to shift the focus away from the traditional emphasis on the development of new vehicles and towards maximizing the fraction of funding spent on mission operations - in a single phrase, *spend the money flying.*

The paper begins with historical studies and parametric analyses on critical classes of components, including launch vehicles, launch and entry spacecraft, in-space and/or lunar landing spacecraft, lunar habitats, lunar rovers, and in-space propulsion stages. In each category, past experience, current concepts, and future extrapolations are used to define a "feasible region" for that class of vehicles, as a function of crew size, duration, and other critical mission design parameters. Emphasis where possible will be on the use of already existing systems (or systems well along in development), rather than new systems just beginning the development process. Costing will be performed based on NASA standard cost models, with modifications based on data from the Commercial Cargo and Commercial Crew programs.

The final result of the analysis is the development of an approach to defining a cost-driven architecture which emphasizes flight operations and increasingly ambitious missions. This includes defining the minimum budget at which any human lunar return program is feasible, and how various aspects of the mission (e.g., number of crew, surface duration, growth to more extensive surface architectures) are constrained by the overall cost caps. The conclusion of the paper is that many more successful architectures for human lunar exploration are feasible if viewed primarily as a budget-constrained problem, rather than making the program architecture fit a desired set of vehicles.