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DEVELOPMENT OF A PHYSICS-BASED REUSABLE CARGO LUNAR LANDER MODELING AND SIMULATION CAPABILITY

Abstract

Purpose: The development, integration, and validation of a capability to perform design space exploration, and therefore enable architecture trades on an unmanned reusable lunar cargo lander within the Dynamic Rocket Equation Tool (DYREQT) framework will be discussed. High level requirements include the ability of the lander to operate between a station in Near-Rectilinear Orbit (NRO) and the lunar surface.

Methodology: Design space exploration of an unmanned reusable lander necessitated the creation of a lander modeling and simulation environment. In order to model a lander-type vehicle, the major subsystems had to first be defined and developed: avionics, structures, power, tanks, engines and thermal subsystems plus lander specific components, e.g., landing legs. Once the subsystem models were developed, they were integrated into the DYREQT framework in order to size, synthesize, and optimize the reusable lander and its mission in order to enable analysis of alternatives. The results of the analysis of alternatives with respect to the reusable lander has been submitted to IAC in a separate paper for consideration.

DYREQT is a modular, object-oriented framework that performs sizing, synthesis, and optimization on integrated space vehicles. By reformulating the problem into one that is more amenable to Multi-Disciplinary Analysis and Optimization algorithms, DYREQT leverages OpenMDAO's state-of-the-art optimization algorithms in order to dynamically build and solve the corresponding MDAO environment from the specified model through a vehicle architecture (e.g., vehicle type, number of stages, propulsion system type, etc.), mission profile (e.g., trajectories, coast phase durations, staging, etc.), and a vehicle element-to-mission event mapping representing the concept of operations. Because of its generality to space systems, modularity, and speed, the DYREQT framework enables rapid evaluation of space system alternatives at the pre-conceptual and conceptual phases of design, representing a state-of-the-art capability.

Results: An overview of how to develop the lunar lander modeling capability will be overviewed, followed by validation using the Descent Module (DM) of the Altair lunar lander and its mission. Discussion will include additional modifications to subsystem modules in order to include characteristics of the Altair that were not common to the reusable lander (e.g., fuel cells for power generation). The validation results were found to be within 4.7 percent of the gross mass. The results of the validation increased confidence in the modeling and simulation capability of the integrated environment, thus allowing for trade space exploration of the lunar lander.