

Design, Development, and Use of a Lunar Lander Simulation for NASA's Artemis Program

This paper describes the design, development, and initial use of a generalized and configurable lunar lander simulation to support NASA's Artemis Program. This simulation is being developed for the Crew Compartment Office (CrewCo) in the Human Landing Systems (HLS) program and is called the HLS CrewCo Lander Simulation (HCLS). The HCLS provides insight into the challenges associated with returning humans to the Moon and the particular difficulties of operating at the Lunar South Pole. The simulation models a generalized integrated lunar landing spacecraft based on a government reference design but can and has been adapted to model vendor specific designs as well. The simulation architecture and tool sets provide a flexible framework that allows for quickly prototyping and evaluating various aspects of a piloted lunar landing system. This includes the modeling of all principal human controlled flight phases: rendezvous and docking with crew transfer systems; docked orbital outpost operations; undocking and lunar transfer; lunar orbital operations; lunar deorbit, descent, and landing (DDL); lunar surface operations; lunar ascent; and return to the orbital outpost. The flexibility of the simulation allows for the integrated evaluation of potential vehicle subsystems, crew displays, guidance and control modes, and trajectory designs. The purpose of the HCLS is not to design the ideal lunar lander, but rather to understand and the strengths and weaknesses of vehicle design choices.

This paper describes the basic simulation architecture and discusses the tool sets used to develop the HCLS. This includes a number of open source tool sets and publicly available data sets. This paper also describes some of the early use cases and findings. The primary focus of early HCLS use has been on the manual piloting task to safely get the crew to the desired landing site in case of a failure in the automated guidance system. Several guidance modes and cues have been implemented which allow a pilot to manually fly the vehicle to the targeted landing site starting anywhere from powered descent initiation. It has been a valuable tool for understanding what is required to manually fly a lunar lander as well as giving a sense of the vehicle dynamics, which are much different than anything that is flown on Earth. A number of experienced test pilots have participated in manual piloting evaluations using the HCLS and provided valuable feedback on the piloting task which has been very beneficial to NASA and the HLS program.