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Author: Mr. Rodrigo Romo
Pacific International Space Center for Exploration Systems (PISCES), United States, rfvromo@gmail.com

TELE-ROBOTIC BASALT CONSTRUCTION AND TESTING OF A VERTICAL TAKEOFF, VERTICAL LANDING PAD PROTOTYPE FOR LUNAR/MARS OPERATIONS

Abstract

Lunar or Mars settlements will require some infrastructure to be constructed prior to human arrival. This work is expected to be done tele-robotically through a combination of autonomous, semi-autonomous and operator-controlled systems. The use of local resources as the construction materials will be critical, to avoid the associated expensive space transportation and logistics. Regolith ejected by the lander's rocket plume can attain high velocities (up to 2,000 m/s) and cause significant damage to nearby hardware or infrastructure. To mitigate this risk, the construction of Vertical Takeoff, Vertical Landing (VTVL) Pads provides a stable and leveled platform on which materials and equipment could be delivered safely to the landing site. NASA's Swamp Works at Kennedy Space Center (KSC) and the Pacific International Space Center for Exploration Systems (PISCES) worked together under a project called Additive Construction with Mobile Emplacement (ACME) to design, construct and test a VTVL Pad in Hilo, Hawaii using local crushed basalt regolith as the construction material. The project was a technology proof of concept to demonstrate the feasibility of a "start to finish" construction of a VTVL Pad through tele-robotic operations. A lunar analog topography site was constructed with similar physical and chemical characteristics to lunar regolith. The PISCES planetary rover "Helelani" was used as the primary robotic mobile platform to perform the site preparation and to deliver and place sintered basalt pavers used for the central area of the landing pad. The pavers used for the bullseye section of the landing pad where fabricated using Hawaiian basalt fines, fired in a kiln under a high temperature profile to achieve sintering of the fines to produce a stable and hot rocket engine plume resistant paver with an interlocking design, eliminating the need to use any extra binders. The bullseye was tested using a "Class M" solid fuel rocket motor with 960 lbf of thrust to evaluate the damage and material volume loss on the pavers due to the engine plume impingement as well as to verify the stability of the pavers in the pad and their interlocking design. Tele-robotic operations were performed from Hilo and KSC via an internet data connection. The basalt pavers are expected to have the structural strength to withstand heavy objects and rocket plume impingement on them without cracking or shifting, indicating a stable platform that meets the requirements set by NASA for small robotic spacecraft landing on the Moon or Mars.