# Tele-robotic Basalt Construction and Testing of a Vertical Takeoff, Vertical Landing Pad Prototype for Lunar/Mars Operations

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Human settlements on the Moon or Mars will require some infrastructure to be constructed in advance of human arrival. This work will have 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.

Lunar or Mars lander rocket plume ejected regolith can attain high velocities (up to 2,000 m/s) and cause significant damage to nearby hardware or infrastructure. In order to mitigate this risk, the construction of Vertical Takeoff, Vertical Landing (VTVL) Pads would provide a stable and leveled platform on which materials and equipment could be delivered safely to the landing site.

Between the summer of 2015 and the spring of 2016, 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 construction of the VTVL was a technology proof of concept to demonstrate that it is possible to do a “start to finish” construction project of a VTVL Pad through tele-robotic operations.

A 20 meter diameter lunar analog topography site was constructed using Hawaiian regolith 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 (grading, leveling and compaction) and to deliver and place custom, inter-locking sintered basalt pavers used for the 3m x 3m central “bullseye” area of the landing pad.

The pavers used for the bullseye section of the landing pad where fabricated using Hawaiian basalt fines only, 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 which eliminated the need to use any extra binders (cement, adhesive or grout).

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 of the VTVL pad were successfully achieved from Hilo and KSC, Florida 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. Results from the hot fire test will be covered in the presentation.

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