

# Method for Producing Launch/Landing Pads and Structures Project

Center Innovation Fund: KSC CIF Program | Space Technology Mission Directorate (STMD)



## ABSTRACT

Current plans for deep space exploration include building landing/launch pads capable of withstanding the rocket blast of much larger spacecraft than that of the Apollo days. The proposed concept will develop lightweight launch and landing pad materials from in-situ materials, utilizing regolith to produce controllable porous cast metallic foam bricks/tiles/shapes. These shapes can be utilized to lay a landing/launch platform, as a construction material or as more complex parts of mechanical assemblies.

## ANTICIPATED BENEFITS

### To NASA funded missions:

By using in-situ materials in space, the large masses of aggregates for a concrete type of material do not need to be launched – creating a large cost savings. Launch costs to Low Earth Orbit (LEO) are typically \$4K - \$10K / kg and with a typical aero-assist gear ratio of 11:1 for transportation to the Mars surface from Low Earth Orbit (LEO), that would result in \$44K- \$110K cost savings per kg of mass launched.

### To NASA unfunded & planned missions:

Currently there are no methods of constructing landing/launch pads in space on an extra-terrestrial surface for Vertical Takeoff / Vertical Landing (VTVL). This means that there is a risk to the lander vehicle and crew due to rocket engine plume high pressure impingement on the regolith surface, which could cause erosion resulting in high velocity ejecta and a crater. The ability to robotically construct these pads out of in-situ materials will provide a method of mitigating the risk, decreasing the lifecycle cost and increasing the reliability of vertical take-off and vertical landing vehicles. Robotic precursor missions could use these methods to prepare a landing site by grading it and



Rocket plume shows impingement effects on the ground

## Table of Contents

Abstract . . . . .	1
Anticipated Benefits . . . . .	1
Management Team . . . . .	1
Detailed Description . . . . .	2
U.S. Locations Working on this Project . . . . .	4
Image Gallery . . . . .	5

## Management Team

### Program Executive:

- John Falker

### Program Manager:

- Nancy Zeitlin

### Principal Investigator:

- Robert Mueller

### Co-Investigator:

- Steven Trigwell

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stabilizing the regolith surface with autonomously emplaced pavers made from in-situ regolith, which have structural integrity and thermal resistance sufficient to withstand the forces and very high temperatures from a chemical rocket engine plume. Ultimately this will increase the safety of the crew during space exploration arrivals and departures.

## **To other government agencies:**

The US Army and DoD could use this technology for helicopter landing pads and runways made in-situ.

## **To the commercial space industry:**

Commercial space will be routinely landing on planetary surfaces. This technology will reduce the life cycle costs of landing pads and will reduce maintenance costs. Safety will be increased.

Space X is planning to land the first stage of terrestrial launch rockets on a landing pad. This high temperature resistant material could provide a viable solution to such activities.

## **To the nation:**

NASA Kennedy Space Center (KSC) Swamp Works is working in collaboration with the Pacific International Space Center for Exploration Systems (PISCES) in Hilo, Hawaii to infuse basalt based construction materials into launch and landing infrastructure on earth and other planetary surfaces (eg. Mars), as well as into the local terrestrial economy.

As a first step, basalt pavers were tested in an outdoor environment in a sidewalk in Hilo, Hawaii. The sidewalk will be exposed foot traffic and weather will be used to test the performance.

Properties of the pavers will be measured before and after one year of testing. A proof of concept VTVL pad measuring 20 m in diameter is also being constructed near Hilo, with a tele-operated robot using pavers and gravel that are produced with indigenous Hawaiian basalt from a local quarry. Robotic pre-cursor missions are the intended infusion for future space VTVL operations.

## **DETAILED DESCRIPTION**

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Currently there are no methods of constructing landing/launch pads in space on an extra-terrestrial surface for Vertical Takeoff / Vertical Landing (VTVL). This means that there is a risk to the lander vehicle and crew due to rocket engine plume high pressure impingement on the regolith surface, which could cause erosion resulting in high velocity ejecta and a crater. The ability to robotically construct these pads out of in-situ materials will provide a method of mitigating the risk, decreasing

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the lifecycle cost and increasing the reliability of vertical take-off and vertical landing vehicles. Robotic precursor missions could use these methods to prepare a landing site by grading it and stabilizing the regolith surface with autonomously emplaced pavers made from in-situ regolith, which have structural integrity and thermal resistance sufficient to withstand the forces and very high temperatures from a chemical rocket engine plume. Ultimately this will increase the safety of the crew during space exploration arrivals and departures.

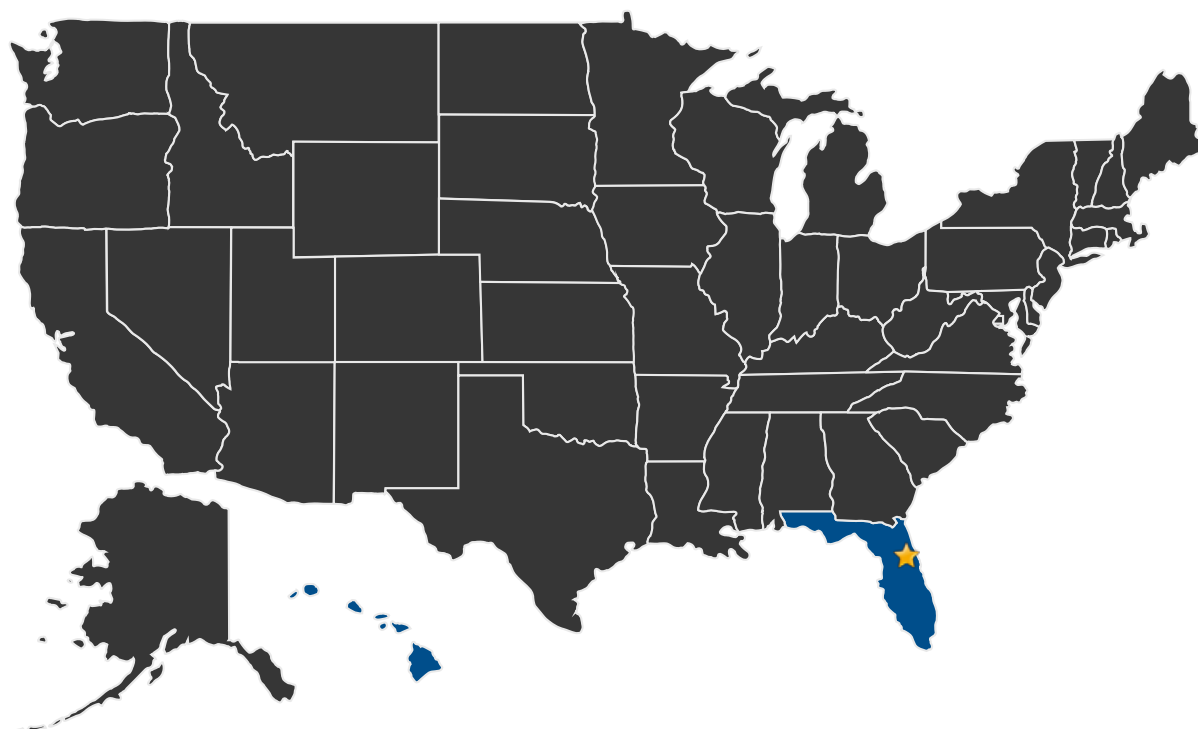
The current plans for Mars human exploration indicate that it will be necessary to build landing/launch pads capable of withstanding the rocket blast of much larger spacecraft than that of the Apollo days (20-40 metric tons landed mass). In addition, creating building materials from in-situ materials has been receiving increasing focus. To avoid having to land and launch a great distance from the focus area of exploration, methods to furnish a suitable landing area have focused on such techniques as sintering the regolith with a solar concentrator or microwave energy. The problem with these techniques is that they are very time consuming and dense materials are the result.

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## U.S. LOCATIONS WORKING ON THIS PROJECT



■ U.S. States With Work      ★ **Lead Center:**  
Kennedy Space Center

### Other Organizations Performing Work:

- SCF LLC, Gainesville, Florida

### Contributing Partners:

- Pacific International Space Center for Exploration Systems (PISCES)

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## PROJECT LIBRARY

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### NASA Technology Use

- Method for Producing In-Situ Vertical Takeoff / Vertical Landing (VTVL) Pads & Structures
  - (<https://techport.nasa.gov:443/file/16597>)

### News Stories

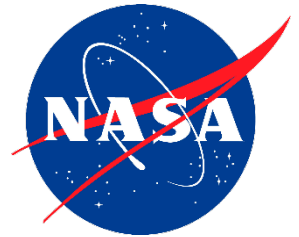
- Paving the way to space
  - (<http://hawaiitribune-herald.com/news/local-news/paving-way-space>)

## IMAGE GALLERY

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*A high temperature resistant material was created using foamed basalt*      *This paver was made of sintered basalt*



## Method for Producing In-Situ Vertical Takeoff / Vertical Landing (VTVL) Pads & Structures

### Technology Need

A method of constructing landing/launch pads on an extra-terrestrial surface for Vertical Takeoff / Vertical Landing (VTVL).

### Description

Currently there are no methods of constructing landing/launch pads on an extra-terrestrial surface for Vertical Takeoff / Vertical Landing (VTVL). This means that there is a risk to the lander vehicle and crew due to rocket engine plume high pressure impingement on the regolith surface, which could cause erosion resulting in high velocity ejecta and a crater. The current plans for Mars human exploration indicate that it will be necessary to build landing/launch pads capable of withstanding the rocket blast of much larger spacecraft than that of the Apollo days (20-40 metric tons landed mass). In addition, creating building materials from in-situ materials has been receiving increasing focus. To avoid having to land and launch a great distance from the focus area of exploration, methods to furnish a suitable landing area have focused on such techniques as sintering the regolith with a solar concentrator or microwave energy. The problem with these techniques is that they are very time consuming and dense materials are the result.



Figure 1. Morpheus VTVL Vehicle at KSC

The ability to robotically construct these pads out of in-situ materials will provide a method of mitigating the risk, decreasing the lifecycle cost and increasing the reliability of vertical take-off and vertical landing vehicles. Robotic precursor missions could use these methods to prepare a landing site by grading it and stabilizing the regolith surface with autonomously emplaced pavers made from in-situ regolith, which have structural integrity and thermal resistance sufficient to withstand the forces and very high temperatures from a chemical rocket engine plume. Ultimately this will increase the safety of the crew during space exploration arrivals and departures.

### Infusion

NASA Kennedy Space Center (KSC) Swamp Works is working in collaboration with the Pacific International Space Center for Exploration Systems (PISCES) in Hilo, Hawaii to infuse basalt based construction materials into launch and landing infrastructure on earth and other planetary surfaces (eg. Mars), as well as into the local terrestrial economy.

As a first step, basalt pavers were tested in an outdoor environment in a sidewalk in Hilo, Hawaii. The sidewalk will be exposed foot traffic and weather will be used to test the performance. Properties of the pavers will be measured before and after one year of testing. A proof of concept VTVL pad measuring 20 m in diameter is also being constructed near Hilo, with a tele-operated robot using pavers and gravel that are produced with indigenous Hawaiian basalt from a local quarry. Robotic precursor missions are the intended infusion for future space VTVL operations.

**NASA Technology Infusion**

## Solution

This project uses basalt regolith fines as a molten feedstock and extrudes it while injecting it with a fluid such as supercritical CO<sub>2</sub> to produce controllable porous cast foam bricks/tiles/shapes. Alternatively, the pavers can be sintered in a mold. These shapes can be utilized to lay a landing/launch platform, as a lightweight construction material or as more complex parts of mechanical assemblies. The primary technical challenges with this method of launch/landing pad and structure production is even heating of the regolith and supply of CO<sub>2</sub>. For exploration activities, CO<sub>2</sub> would have to be supplied with the exception of Mars, where CO<sub>2</sub> could be harvested from the atmosphere. In addition, sintered in-situ regolith pavers are being fabricated in a portable paver maker oven. These pavers are resistant to high temperatures (2,000° C -2,500° C), and are stronger than typical Portland cement based concrete, so they would be suitable for landing/launch pad construction.



Figure 2. Foamed Basalt Test Samples for Analysis and Testing

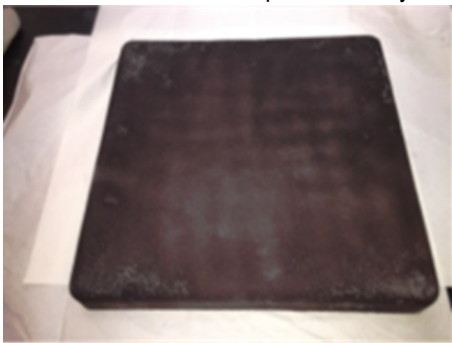


Figure 3. 40 cm x 40 cm Sintered Basalt Paver

## Benefit

By using in-situ materials in space, the large masses of aggregates for a concrete type of material do not need to be launched – creating a large cost savings. Launch costs to Low Earth Orbit (LEO) are typically \$4K - \$10K / kg and with a typical aero-assist gear ratio of 11:1 for transportation to the Mars [www.nasa.gov](http://www.nasa.gov)

surface

**Lead NASA Center:** Kennedy Space Center  
**Funding Organization:** Space Technology Mission Directorate  
**Location:** Florida, Kennedy Space Center  
Swamp Works  
Florida, SCF Processing, LLC, Gainesville  
**Year of Infusion:** Fiscal Year (FY) 2015  
**Timeframe:** FY 2014 through FY 2015

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from LEO, that would result in \$44K-\$110K cost savings per kg of mass launched.

### **Development Team Leads**

**Robert P. Mueller** was the Principal Investigator for the In-Situ VTVL Pads & Structures project. He graduated with a B.S. in Mechanical Engineering from the University of Miami, an MS in Space Systems Engineering from the Technical University of Delft in the Netherlands, and an MBA from the Florida Institute of Technology.

**Ivan I. Townsend** was the technical lead for the In-Situ VTVL Pads & Structures project. He graduated with a B.S. in Aerospace Engineering from the University of Central Florida is now performing research, design and testing related to solar system robotics, exploration, and habitation.

**Steven Trigwell** was the technical lead for the foamed basalt regolith materials processing task. He graduated with a B.Sc. in Physics from the University of Leicester in the UK, an M.S. in Materials Engineering from San Jose State University, and a Ph.D. in Applied Science (Materials Engineering) from the University of Arkansas at Little Rock.

**Thomas Lippitt** was the technical lead for the sintered basalt regolith materials processing. He graduated with a B.S. in Mechanical Engineering from Georgia Institute of Technology.

**Siobhan Matthews** was the small business innovator for the foamed basalt regolith materials processing. She graduated with a BSc in Polymer Technology from Athlone Institute of Technology in Ireland, an MSc in Polymer Science from Loughborough University in the UK and a PhD in Materials Engineering from Brunel University in the UK.