Completed Project (2013 - 2014)

Dust as a Working Fluid for Heat Transfer Project

Center Independent Research & Developments: KSC IRAD Program | Science Mission Directorate (SMD)

ABSTRACT

The project known as "Dust as a Working Fluid" demonstrates the feasibility of a dust-based system for transferring heat radiatively into space for those space applications requiring higher efficiency, lower mass, and the need to operate in extreme vacuum and thermal environments – including operating in low or zero gravity conditions in which the dust can be conveyed much more easily than on Earth.

ANTICIPATED BENEFITS

To NASA unfunded & planned missions:

This technology benefits the In-Situ Resource Utilization (ISRU) program within NASA and the US Department of Energy and Department of Defense. The utilization of mineral dust particles for heat transfer and energy storage for space applications will allow lower temperatures for low mass radiators on the cold end, while permitting extremely high efficiency power systems at extremely low mass. Hot dust that forms the "waste" material from an ISRU chemical reactor, can be stored in a tank or piled up as a solid with no containment pressure, and can be conveyed later as a granular fluid for on-demand heat recovery. Because of its extremely low thermal conductivity, a pile of dust self-insulates to preserve its thermal energy, thus also making it an efficient energy storage medium. The thermal properties of dust will enable in-space heat transfer system applications that require vastly reduced mass, while also enabling higher efficiency ground-based and surface-based systems.

To the nation:

The technology associated with this project benefits the nation by enabling energy efficient systems involving the transfer of heat (for cooling) and the storage of energy. This technology could also provide potential benefits to the commercial space

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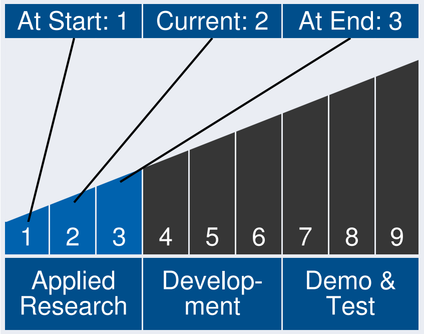
Technology Maturity



Management Team

Program Director:

- Burton Summerfield

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industry focused on developing space mining.

DETAILED DESCRIPTION

Researchers (outside of NASA) have investigated the use of granular materials (e.g., mineral dust particles) as a working fluid for solar concentrators and other heat transfer systems. A given volume of dust particles have a higher heat capacity than the same volume of any gas, and mineral granular materials do not easily undergo a phase change like liquids except at extremely high temperatures. Granular materials also provide a medium for integrated energy storage.

The radiative transfer of heat directly into space using mineral dust particles is a new, revolutionary concept for NASA and for spaceflight in general. Space applications require high efficiency, low mass, and the ability to operate in extreme environments – including low or zero gravity where dust can be conveyed much more easily than on Earth. This project demonstrates the feasibility of dust-based heat transfer systems for space applications, but also has terrestrial applications. The project demonstrates and quantifies the radiative heat transfer efficiency by using a closed-loop, pneumatic regolith conveyance system in a laboratory experiment to test the critical function, thus achieving TRL 3.

Management Team *(cont.)*

Program Executive:
- Karen Thompson

Program Manager:
- Nancy Zeitlin

Project Managers:
- Philip Metzger
- Robert Mueller

Principal Investigator:
- James Mantovani

Technology Areas

Primary Technology Area:
Heat Rejection (TA 2.4.4)

Secondary Technology Area:
Energy Storage (TA 3.2)

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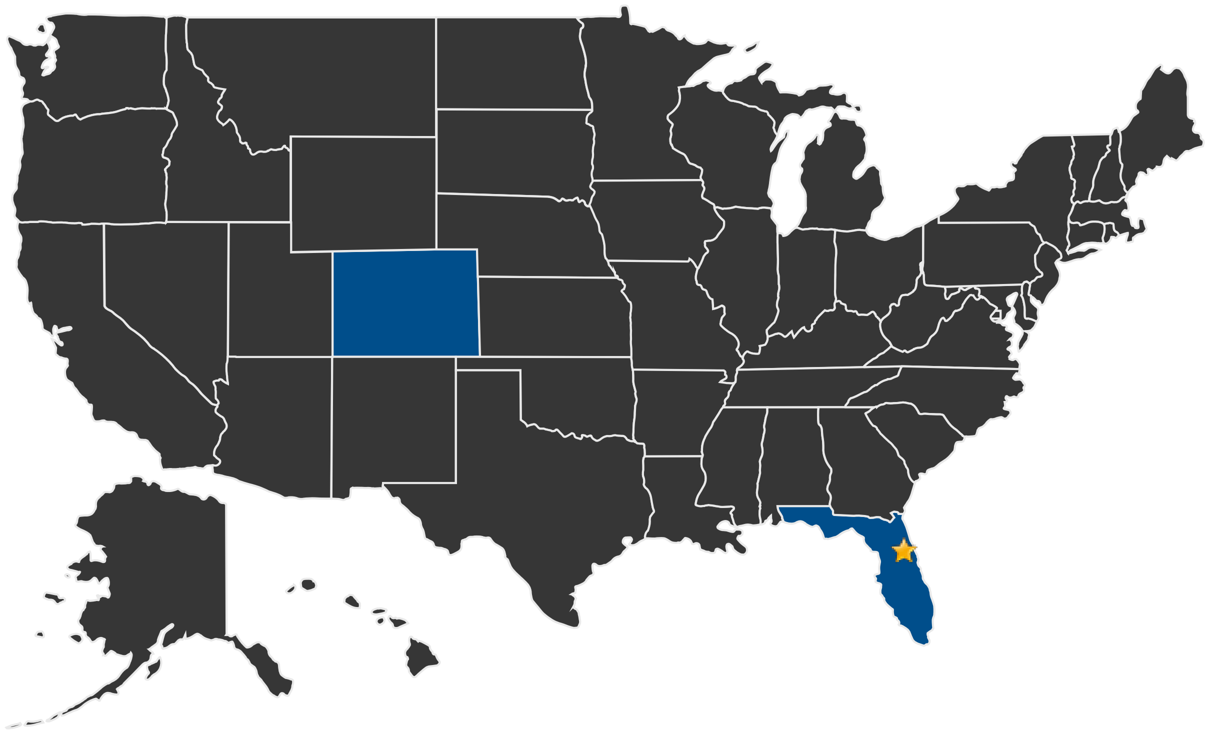
U.S. LOCATIONS WORKING ON THIS PROJECT



U.S. States With Work

Lead Center:
Kennedy Space Center

Other Organizations Performing Work:

- QinetiQ North America/ESC
- University of Colorado, Boulder

DETAILS FOR TECHNOLOGY 1

Technology Title

Dust as a Working Fluid for Heat Transfer and Energy Storage

Technology Description

This technology is categorized as a hardware system for ground scientific research or analysis

A mineral dusty gas has a higher heat capacity than a liquid does as a thermal working fluid, but avoids the phase change that a liquid undergoes at a relatively low temperature, thus allowing the use of mineral dusty gas as a working fluid at higher temperatures and energies on the hot end. Dust has extreme radiator properties due to the inherently large cumulative surface area of the constituent particles contained in a small amount of dust. (Note: for a particle of diameter D, the mass ~ D^3 and the area ~ D^2, thus the ratio of area/mass = $1/D \rightarrow \infty$ for small sized dust particles.) This makes dust the “miracle radiator” material by allowing lower temperatures for low mass radiators on the cold end, while permitting extremely high efficiency power systems at extremely low mass. Hot dust can be contained within a tank or piled up as a solid with no containment pressure, and can be conveyed later as an on-demand heated fluid. Because of its extremely low thermal conductivity, a pile of dust self-insulates to preserve its thermal energy, thus also making it an efficient energy storage medium. These “miracle” properties of dust will enable in-space thermal transfer system applications requiring vastly reduced mass, and also enabling higher efficiency terrestrial-based and surface-based systems.

Capabilities Provided

The technology involved with the project "Dust as a Working Fluid" provides the following capabilities:

- Novel method of transferring heat radiatively in a space environment.
- Enables the storage and recovery of waste heat.
- Reduces launch mass and ground processing costs.
- Increases the efficiency of nuclear energy conversion.
- Reduces vehicle mass and improves power efficiency.

Potential Applications

This project addresses the following NASA Space Technology Grand Challenges – Economical Space Access (by reducing launch mass and by reducing ground processing costs), Affordable

Abundant Power (by making nuclear energy conversion more efficient and by enabling waste heat recovery), and Efficient In-Space Transportation (by reducing vehicle mass and improving power efficiency). It addresses technology needs identified in the OCT technology Areas: TA02 – In-Space Propulsion Systems (more efficient nuclear thermal propulsion) and TA03 – Space Power and Energy Storage (low mass radiators).