Phase I Project Summary

Nonproprietary

Firm: Creare Incorporated
Contract Number: NNX11CF95P
Project Title: An Efficient Heat Exchanger for In Situ Resource Utilization

---

Identification and Significance of Innovation:

In-situ resource utilization (ISRU) is essential for several of NASA's future flagship missions, including a planned Mars sample return mission. Currently envisioned ISRU plants include production of oxygen from hydrogen reduction of Martian or Lunar regolith and extraction of water from Martian regolith or asteroid material. These ISRU processes require heating of the regolith to high reaction temperatures. Once the reaction is complete, most thermal energy exits the system in the spent regolith batch and is therefore wasted.

A system to recover most of this thermal energy would mean faster resource production rates and smaller power plant requirements. Both of these factors will potentially reduce mission payload size. The current baseline ISRU design is either powered with solar concentrators, solar panels or a radioisotope thermal generator. Whatever the power source, improvement in the overall energy efficiency of the ISRU plant is imperative. For the current baseline ISRU design the fresh and processed regolith are transferred using pneumatic conveyance, which offers the potential for a purely passive heat exchanger for regolith heat recovery.

Technical Objectives and Work Plan:

During Phase I of this project, our objective was to demonstrate the feasibility of using a counter-flow heat exchanger for transferring heat between pneumatically conveyed regolith streams. The objective was achieved by designing and instrumenting a benchtop heat exchanger where heat could be applied to a dusty stream and calorimetric measurement conducted. The work plan also included extensive modeling effort and heat exchanger design.

Technical Accomplishments:

During Phase I of this project, Creare developed a heat exchanger for recovering more than 50% of the thermal energy from the spent regolith and transferring it to a fresh batch of regolith before it enters the process reactor. Our novel heat recovery design is purely passive, robust, and compact to accommodate tight mass and volume constraints. Our testing proved the feasibility of our heat exchanger design and enabled us to determine the heat transfer properties of gas suspended regolith. We were able to determine key heat transfer correlations that enable detailed model prediction. These model predictions informed our heat exchanger design which was completed during Phase I.

NASA Application(s):

The main application area for NASA for the proposed heat exchanger for ISRU plants will be for future missions now being planned to Mars and the Moon, as well as other bodies such as Near Earth Objects (NEOs). Long duration missions to the Moon will need substantial amounts of

resources for life support and energy. Martian sample return missions and manned missions to Mars may be prohibitively expensive, technically exigent, and unacceptably risky unless resources can be produced on Mars. For example, NASA will need an ISRU propellant production plant on Mars for the sample return mission that it is envisioning in the 2020s.

Non-NASA Commercial Application(s):

Many commercial processes involve the heating of particulate matter to high temperatures to affect a certain reaction, e.g., Portland cement kilns, drying processes in the agricultural and paper sectors, etc. As energy costs increase and with the focus on limiting greenhouse gas emissions, more emphasis will be placed on improving the overall energy efficiency of such processes. Heat recovery methods using advanced heat exchangers, such as the one we propose, could have a tremendous impact to improve the efficiency of these inefficient processes.

Name and Address of Principal Investigator:

Paul H. Sorensen
Creare Incorporated
P.O. Box 71
Hanover, NH 03755

Name and Address of Offeror:

NASA/Shared Services Center
Building 5100
Stennis Space Center, MS 39529-6000