Phase I Project Summary

Firm: Creare Incorporated
Contract Number: NNX10CD37P
Project Title: A Two-Phase Cooling Loop for Fission Surface Power Waste Heat Transport

Identification and Significance of Innovation:

Current space-based Fission Surface Power (FSP) Systems that will support sustained surface outposts consist of a nuclear reactor with power converters, whose waste heat is transported to radiator panels to be rejected to the environment. The current approach is to transport waste heat using a heavy, pressurized, water cooling loop. For each 35 kW of heat rejection, the current water cooling loop components weigh approximately 117.6 kg due to the large flow rate of water, the large pressure drop, and the pump and other components. Notably, this estimate does not include additional radiator panels associated with the large temperature drop of single-phase liquid water as it is transported through the system. Additionally, all of these heavy components, including the water, must be transported from Earth to the lunar surface, consuming valuable launch space and weight. Our innovation is a novel Waste Heat Transport System (WHTS) that combines Creare's lightweight radiator technology with a Lightweight Cooling Loop (LCL) that is comprised of a two-phase water loop and a capillary pumped liquid return. Using our approach, we estimate that our LCL will reduce the cooling loop system mass by 46% compared to the current approach. That is, our LCL will weigh only 63 kg for each 35 kW of heat rejection. Our approach will have a reduced system pressure, resulting in decreased plumbing size and weight, and will eliminate the need for a mechanical pump, increasing system reliability.

Technical Objectives and Work Plan:

The ultimate objective of this effort is to develop and transition a technology that substantially reduces the mass and the footprint of the Waste Heat Rejection System (WHTS) to support long duration interplanetary- and planetary-based missions with Fission Surface Power (FSP). In Phase I, the technical activities were to fabricate a subscale sample of the LCL, test and evaluate the performance, and develop a preliminary plan for scale up during Phase II. Our technical objectives for the Phase I project were to design and fabricate a proof-of-concept LCL, evaluate its thermal performance, and develop a preliminary plan for scale up.

Technical Accomplishments:

During the Phase I project, we established the feasibility of our innovative LCL and exceeded our technical objectives by fabricating a fully operational, subscale prototype and testing it under prototypical conditions. First, we designed a subscale LCL for integration with multiple simulated heat pipes. Second, we fabricated and tested the subscale LCL and demonstrated the required heat rejection and pump-less liquid transport capability. Importantly, we demonstrated the high heat transfer performance of our film condensation approach that enables the efficient latent heat transfer from the two-phase water coolant to the heat pipe evaporator. Third, we developed a preliminary design of a scaled-up version of our LCL suitable for testing during Phase II. Thus, we clearly established the feasibility of our innovation and have a clear pathway to further improve our novel ULHRS during the Phase II project.

NASA Application(s):

The main application of our innovative LCL is for lunar-based FSP. Specifically, these systems will support In-Situ Resource Utilization (ISRU) for Mars robotic and manned missions. Our innovation has significant technical and risk advantages over competing technologies. Thus, it represents the shortest path to an optimal Waste Heat Transport System (WHTS).