Scalable 3D Printed Circuit Structural (PCS) Microchannel Heat Exchanger

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Project Synopsis

New technologies need to be developed to support long range off-earth missions. One such crucial technology is a high efficiency heat exchanger. NASA funds the research into technologies that it deems worthy for two reasons: the first being that new technologies will be developed and the second reason is to progress the technology from being manufactured on earth to being manufactured in space. This would mean that Commercial-Off-The-Shelf (COTS) devices would be shipped off-earth in the short term whereas devices that are needed for the long term mission would be manufactured on site. This technological advancement would allow for Regolith, materials indigenous to the site, to be used in the fabrication of the device. The overarching goal for Lunar and Mars manufacturing is In Situ Resources Utilization (ISRU).

The heat exchanger that we will produce will address both of NASA's research goals. Two technologies will be developed in parallel from the same design, one on a timeline that is one step behind the other. The heat exchanger will be designed to conduct heat through vias, cylindrical passages filled with silver, which are connected to fins. These fins will be contained within a microchannel, through which a coolant will flow. Our first goal will be to create a proof of concept combining technologies that are already mature. The stability, integrity, and the maximum allowable size of the microchannels must be determined before a design is optimized. The heat exchanger structure will be built using low temperature cofired ceramic (LTCC) tape, DuPont 955 LTCC tape, as well as a fugitive material to fill the microchannels. There will also be an integrated temperature sensor inside the microchannel. We then need to test the scalability of the preliminary design.

Simultaneously, Lunar and Martian Regolith will be characterized. Once this is complete a process will be designed to turn the Regolith into an ink that can be used to make a tape and ink that can be fired according to NASA's specifications for in situ manufacturing. The fired Regolith must be a hermetic structure. This will show feasibility of a manufacturing transition path to Lunar/Mars based construction. From here on out the Regolith based heat exchanger will follow the last completed stage LTCC based heat exchange.

Once the proof of concept LTCC based heat exchanger is built, then the development of a 3D printed test structure will be started. The optimized design from the LTCC tape based heat exchanger will be optimized again since the restrictions for direct print additive manufacturing are different from tape based design.

There is further development for this project that will be completed after the conclusion of the senior design project. This project has the capacity to expand the implementation of heat exchangers by creating an industry for 3D printed or tape based LTCC heat exchangers.