Technique for Configuring an Actively Cooled Thermal Shield in a Flight System

New shields could potentially provide considerable mass savings.

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Broad area cooling shields are a mass-efficient alternative to conductively cooled thermal radiation shielding. The shield would actively intercept a large portion of incident thermal radiation and transport the heat away using cryogenic helium gas. The design concept consists of a conductive and conformable surface that maximizes heat transfer and formability.

Broad Area Cooled (BAC) shields could potentially provide considerable mass savings for spaceflight applications by eliminating the need for a rigid thermal radiation shield for cryogen tanks. The BAC consists of a network of capillary tubes that are thermally connected to a conductive shield material. Chilled helium gas is circulated through the network and transports unwanted heat away from the cryogen tanks. The cryogenic helium gas is pumped and chilled simultaneously using a specialized pulse-tube cryocooler, which further improves the mass efficiency of the system. By reducing the thermal environment temperature from 300 to 100 K, the radiative heat load on a cryogen tank could be reduced by an order of magnitude. For a cryogenic liquid propellant scenario of oxygen and hydrogen, the boiloff of hydrogen would be significantly reduced and completely eliminated for oxygen.

A major challenge in implementing this technology on large tanks is that the BAC system must be easily scalable from lab demonstrations to full-scale missions. Also, the BAC shield must be conformable to complex shapes like spheres without losing the ability to maintain constant temperature throughout. The initial design maximizes thermal conductivity between the capillary tube and the conductive radiation shielding by using thin, corrugated aluminum foil with the tube running transverse to the folds. This configuration has the added benefit of enabling the foil to stretch and contract longitudinally. This allows the BAC to conform to the complex curvature of a cryogen tank, which is key to its success.

To demonstrate a BAC shield system with minimal impact to current cryogen tank designs, the shielding must be applied after the final assembly of the tank and supporting structure. One method is to pre-fabricate the shield in long strips. A spool of corrugated aluminum foil with a thermally sunk aluminum capillary running through the center could then be simply wound around the cryogen tanks and encapsulated within the multi-layer insulation (MLI) blanket. Then, on orbit, the BAC would intercept thermal radiation coming in through the MLI and transport it away from the cryogen tanks. An optimization of the design could be done to take into account mass savings from thinner MLI blankets, eliminating solid thermal shields, and ultimately, a reduction in the required cryogen tank size.

This work was done by Peter Barfknecht and Shuvo Mustafi of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15958-1