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Aerospace Technology newsletter talks about Quest and new thermal insulation systems

Integrated insulation set for space mission in 2015

NASA will be testing a next generation version of thermal insulation on its Green Propellant Infusion Mission, or GPIM, scheduled for 2015. The GPIM mission is to provide an alternative to hydrazine in spacecraft propulsion systems. This green propellant will be used on a small satellite manufactured by Ball Aerospace & Technologies Corp. of Boulder, Colorado, the prime contractor on the GPIM project. Ball Aerospace and Quest Thermal Group LLC have jointly developed the new insulation, called Integrated Multi-Layer Insulation, or IMLI. Once IMLI is proven successful in the GPIM project, it could be used on other spacecraft.

Spacecraft and cryogenic space systems make use of high performance insulation to store and preserve cryogenic propellants used for spacecraft, launch vehicles and space instruments, enabling them to operate more efficiently and for longer periods. These characteristics will help enable longer space voyages.

The Quest Thermal team focuses on technology and product development. Gary Mills, an Aerospace Engineer and Staff Consultant at Ball Aerospace, had a novel idea about trying to use micromolded parts to control the layer density of conventional Multilayer Insulation (MLI), which is difficult to control and strongly affects thermal performance. "Gary and I met and discussed working together, Quest was able to put together a solid team and proposal to the NASA Small Business Innovation Research (SBIR) program. We won an SBIR contract, and we were off and running," recalled Alan Kopelove, Chief Executive Officer of Quest Thermal Group LLC.

IMLI and Quest Thermal's other advanced thermal insulation systems use a novel, patented Discrete Spacer Technology, in which individual spacers support the radiation barrier layers and reduce heat leak. These spacers are micromolded polymer parts – challenging to make - designed to have extremely low thermal conduction. The discrete spacers separate metalized films, which form the radiation barriers and reduce heat transferred via radiation. The third way heat is transferred – convection – is eliminated by having an internal vacuum, with the vacuum either from space or held inside a lightweight vacuum shell when used in-air. Multiple layers are then further built up into a single, ruggedized structure, which can be fabricated in panels that are easily attached to cryogenic tanks, satellites, cold transfer piping, even home appliances. A twenty layer IMLI structure has a heat flux of 0.41W/m^2 (77K to 295K), which is about 50% lower heat leak per layer than typical MLI installations.

Kopelove described IMLI as the first major advance in insulation in several decades, and since earning their first NASA contract in 2006, the company has designed, developed, built and tested nine new versions of thermal insulation engineered to serve on the cryogenic propellant tanks on launch vehicles, insulating cold/hot transfer lines, providing micro-meteoroid/orbital debris (MMOD) protection, or self supporting ultra high performance thermal shields for reduced or zero boil-off of cryopropellants for long duration NASA missions.

There were technical challenges to developing IMLI; what could be done with modern materials and fabrication processes to reduce heat leak through the system to near theoretical minimum? "We focused on new methods to control interlayer spacing (between the multiple radiation barrier layers that reduce heat transfer via radiation), to eliminate interlayer touching and thermal shorting, and to reduce heat conducted through the interlayer spacers," explained Kopelove. A careful iterative process was used designing micromolded polymer parts, analyzing their structural strength and heat conduction via FEA and proprietary thermal models, prototyping hardware, testing the thermal performance and then comparing actual results to modeled results in order to make continuous improvements.

One of the unique properties of IMLI that Quest Thermal cited is that it is a structural MLI – able to form robust bonded up structures with great strength and the ability to support external components (like vacuum shells, thermal shields or MM/OD shields). "Our engineering design work balanced the structural strength versus solid heat conductance – and we came up with some very novel approaches – including a dynamic spacer that compresses with external load (such as a thin, lightweight vacuum shell in air) and rebounds with no load (as when in a vacuum on-orbit). This led to our `Load Responsive MLI' that offers high thermal performance both in-air and on-orbit."

Another challenge was finding the optimal path to commercialize new insulation systems. "We use a phased approach, early phases build and test quick prototypes to demonstrate feasibility of a new concept," said Kopelove. Following phases further develop the concept and mature the technology. Each phase increases the TRL (Technology Readiness Level, a NASA metric for judging technology maturity and spaceflight worthiness). And Quest Thermal is now approaching the next phases which transition to volume product fabrication processes.

As a result, Quest Thermal's IMLI and family of xMLI derivative systems, provide multiple, unique benefits for launch vehicles, spacecraft, space-borne instruments, satellites, and future long duration NASA missions. For example, IMLI can provide lower heat leak than traditional MLI with fewer layers, lower mass, a robust structure, and very repeatable and predictable performance. "Launch vehicle and spacecraft designers in the past had to incorporate 'degradation factors' when dealing with traditional MLI due to the uncertainty in their real world performance – IMLI is a significant improvement in that our 'first principles' approach lets us design, build and install real systems that match predicted performance" explained Kopelove. Where traditional MLI can require degradations factors of 2 or more, IMLI real world performance is usually within 10% of that predicted.

New insulation systems that Quest Thermal and Ball Aerospace are developing include Load Responsive MLI for both in-air and on-orbit use; Launch Vehicle MLI designed to insulate and provide larger payloads and longer coast times for cryogenic upper stage launch vehicles; Wrapped MLI to insulate cryogenic feedlines; MMOD-MLI that provides thermal insulation and MMOD shielding in one system; Load Bearing MLI (LBMLI) that self-supports Broad Area Cooled; and Vapor Cooled Shields without the thermal leaks of tank supports and helps achieve critical Reduced Boiloff of cryogenic propellants, and Advanced Cooled Shield-MLI that incorporates a lightweight thermal shield directly in the IMLI structure for even higher thermal performance.

In addition to IMLI flying on the GPIM flight in 2015, the Quest/Ball LBMLI is baselined by NASA for their upcoming Cryogenic Propellant Storage and Transfer Technology Demonstration Mission. In a recent multi-center NASA test program, LBMLI provided a 56% to 74% reduction in heat leak per layer over traditional MLI with tank standoffs, a 44% reduction in mass, and was advanced to TRL5.

"Ball and Quest are continuing development of LRMLI as the insulation of choice for liquid hydrogen powered UAVs in development by Prime Contractors, and we are currently in discussion with several Primes about using IMLI or LVMLI on new launch vehicles," noted the chief executive. "We expect IMLI to reach a Technology Readiness Level of 9 (spaceflight qualified) with the GPIM flight. We hope to partner with one or more Primes to continue development and testing of LVMLI for use on current and new launch vehicles, and within the next year we plan to be implementing automated fabrication processes for xMLI production."

Quest Thermal has learned a lot about thermal insulation, the design of these new systems, and the intricacies of building and installing high performance thermal systems, according to its CEO. His company is currently working on three new insulations; the Advanced Cooled Shield-MLI system already mentioned that adds passive or active thermal shields, a new Lightweight Shell for the in-air LRMLI system as a SOFI replacement and insulation for launch vehicles, and a new system designed for full time in-air use for terrestrial applications.

A quarter inch thick panel of Quest's LRMLI insulation has the same insulation value as 16" of polyurethane foam – a household refrigerator/freezer uses typically 1" of foam insulation. Kopelove believes a substantial reduction in energy use is possible for home appliances such as R/F's and water heaters with these advanced insulations, and noted "We see a huge potential market in green energy insulation for terrestrial use."

Kopelove said that a NASA Technology Roadmap indicates improved storage and transfer of cryopropellants is the #2 technical challenge in spacecraft. "Better performance, more reliability, lower cost, and less touch labor sensitive installation of thermal blankets on vehicles and spacecraft are important needs. NASA's vision for future missions requires longer duration LOX/LH_2 storage and Reduced or Zero Boil-off, which our xMLI products can help achieve. The opportunity to replace problematic SOFI (Spray On Foam Insulation) is of interest to space launch firms. Better insulation on cryogenic upper stage launch vehicles offers many known advantages, including larger payloads to GSO or for Earth departure, and more flexibility in coast times for orbital burns," explained the executive. Good insulation of liquid hydrogen (LH2) tanks for aircraft and unmanned aerial vehicles could lead to advances in insulating tanks on future liquid hydrogen powered vehicles such as cars and trucks.

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