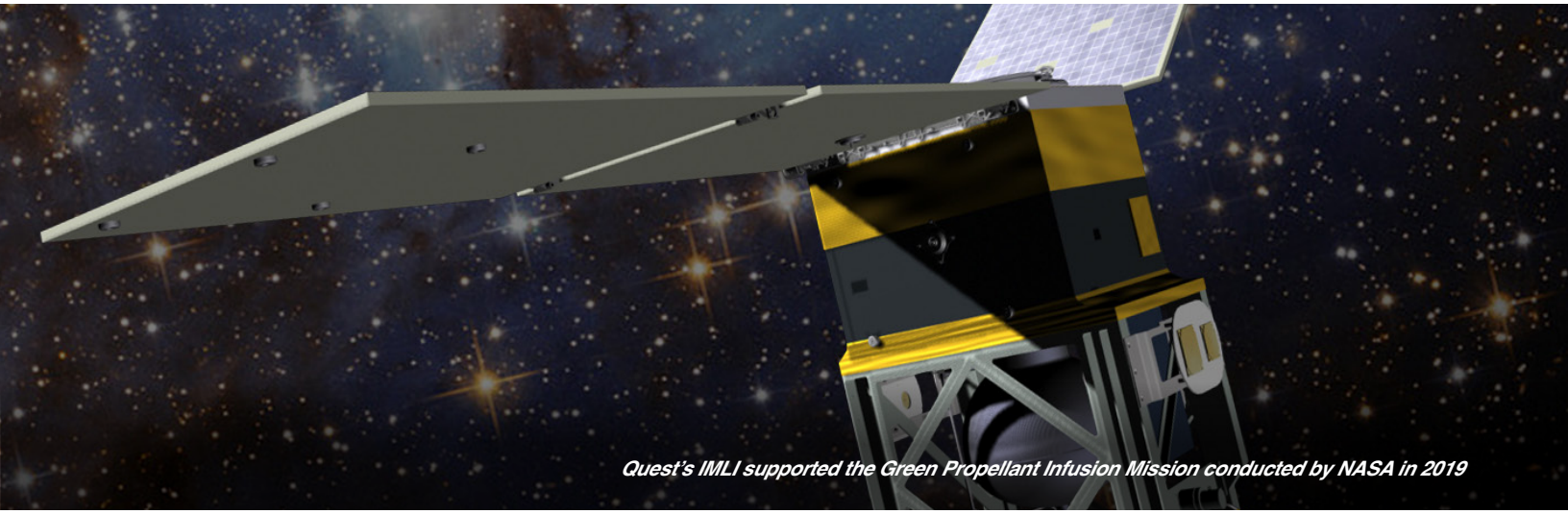
National Aeronautics and Space Administration



Quest's IMLI supported the Green Propellant Infusion Mission conducted by NASA in 2019

Novel Lightweight Insulation Protects Fuel Tanks from Extreme Temperatures

Challenge

During the span of its mission, a spacecraft is exposed to extreme temperatures: highs caused by radiation from the Earth and the sun reflecting off the Earth, and lows within the freezing vacuum of deep space or the lunar surface. Multi-layer insulation (MLI), consisting of several layers of lightweight reflective film, safeguards the interior of the spacecraft from external temperatures. MLI is especially important for protecting the propellant tank, which contains cryopropellants such as liquid hydrogen or liquid oxygen, and must minimize heat loads at cryogenic temperatures to keep the fuel in a liquid state. Effective MLI reduces "heat leak"—heat that seeps through the insulation—to prevent fuel from wastefully boiling off.

While MLI has been used on spacecraft and cryogenic systems for many years, NASA seeks novel developments to make the technology more lightweight, durable, and predictable, while also reducing propellant boil-off for future space exploration.

Solution

Quest Thermal Group, a small business based in Arvada, Colorado, spent several years developing its Integrated MLI (IMLI), a high-performance insulation system that features robust structure, low heat leak, fewer layers, and lower mass. In particular, IMLI is unique in its placement and design of

Project

Integrated Multi-layer Insulation (IMLI), a novel lightweight technology to insulate spacecraft exposed to extreme temperatures

Mission Directorate

Space Technology

Post-Phase II and Follow-on Success

More than $2.1 million in NASA funding and commercialization revenue attributed to IMLI

Snapshot

Quest Thermal Group developed its integrated multi-layer insulation (IMLI) with funding from the NASA SBIR/STTR program. IMLI is high-performance insulation that protects spacecraft and cryogenic systems from extreme temperatures at a lighter weight than traditional MLI. IMLI performed successful flight demonstrations on NASA's Robotic Refueling Mission 3 in 2018 and NASA's Green Propellant Infusion Mission in partnership with large business Ball Aerospace in 2019, opening the door for additional opportunities with NASA and commercial customers.

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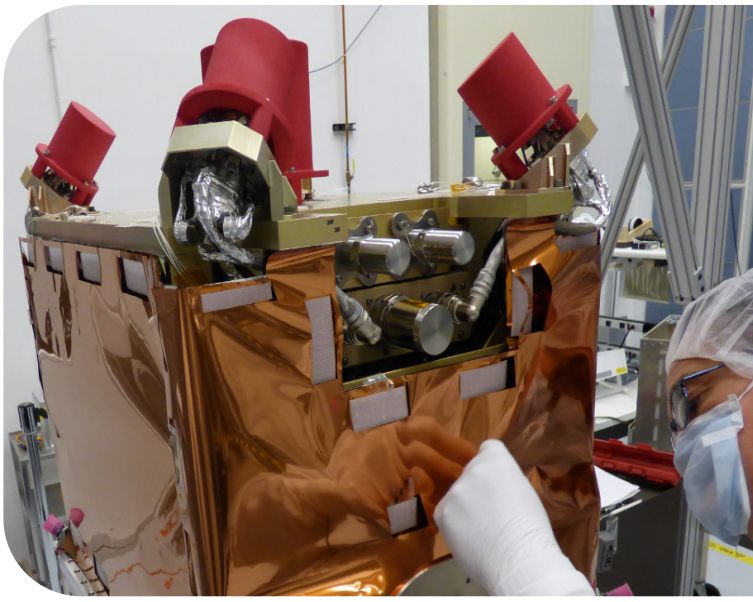
spacers: while traditional MLI uses netting to separate layers of insulation, Quest's IMLI uses discrete micro molded polymer spacers with low thermal conductivity. Quest developed IMLI with support from the NASA Small Business Innovation Research / Small Business Technology Transfer (SBIR/STTR) program. The company received its first NASA SBIR award in 2006 with subcontractor Ball Aerospace—a space and defense business based in Boulder, Colorado—and developed advanced thermal insulation using micro molding technology. As of May 2021, Quest has received 30 SBIR Phase I and II awards to advance MLI technology, collaborating with six NASA centers. After multiple SBIR awards, IMLI was matured through NASA-supported testing from a concept into a usable product, with large-scale testing enabled by NASA's Game Changing Development **program** in 2013.

Quest's IMLI uses discrete micro molded polymer spacers to separate layers of insulation

NASA, Quest, and Ball collaborated to develop IMLI's ability to support structural loads, with minimal degradation in its insulative capability. Traditional netting MLI could not support weighted loads, so a separate structure was required to support the MLI's structure. IMLI reduces mass by self-supporting structural loads. As Alan Kopelove, CEO of Quest, notes, "heavy is bad in the space business," so reducing the mass of structural components is valuable for any spacecraft. The structural developments of IMLI led to five SBIR Phase III contracts between 2012 and 2020, including one to improve the thermal performance of NASA's zero boil-off systems. The tests demonstrated that IMLI could survive extreme acoustic, vibration, and thermal environments encountered by propellant tanks.

Though the company's connection with NASA's Goddard Space Flight Center, Quest had its first successful flight opportunity with IMLI in December 2018 on NASA's Robotic Refueling Mission 3 (RRM3), a flight experiment on the ISS intended to test cryogenic storage and transfer. Following RRM3, IMLI flew on the Green Propellant Infusion Mission (GPIM) conducted by NASA's Space Technology Mission Directorate, an opportunity that came from Quest's partnership with Ball. While GPIM was slated to launch in 2015 aboard a SpaceX Falcon Heavy rocket, the flight was delayed for four years while the Falcon Heavy was in development. IMLI's flight performance on GPIM—which launched on a 13-month mission on June 25, 2019—matched the modeled thermal performance and kept the spacecraft within required temperature limits.



IMLI flew on GPIM through an opportunity that came from Quest's partnership with Ball

Business Impact

Quest's journey with IMLI exemplifies that persistence can be rewarded when it comes to space technology. Kopelove notes, "It wasn't an easy transition, but NASA recognized the potential value in IMLI, so they really helped us push that technology forward." From its beginnings with the NASA SBIR/STTR program, Quest has since

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>
> – Alan Kopelove
> CEO of Quest Thermal

patented IMLI and other thermal insulation systems, and has sold IMLI to industry customers, valuing the investments from NASA and commercialization revenue for IMLI at more than $2.1 million.

Quest also attributes its business development to IMLI's flight demonstrations on RRM3 and GPIM. By proving IMLI's technology readiness, Quest joined the team supporting the Lunar Environment Monitoring Station (LEMS), funded by NASA's Development and Advancement of Lunar Instrumentation program. IMLI was selected to protect the LEMS spacecraft and its electronic components from the extreme thermal environment on the lunar surface. IMLI will also insulate the spacecraft radiator on the Lucy spacecraft, scheduled to launch to Jupiter's Trojan Asteroids in 2021.

As of May 2021, Quest is partnered with NASA and Primes to develop solutions for the Human Lander System program, which aims to take astronauts to the Moon as part of the **Artemis** program. Wesley Johnson, a cryogenic researcher at NASA's Glenn Research Center who worked with Quest to develop IMLI, remarks, "It takes a lot of effort and a lot of time to turn a concept into a good, marketable idea. The SBIR program funds businesses to do high-risk, high-reward developments, which helps NASA diversify our research experience."