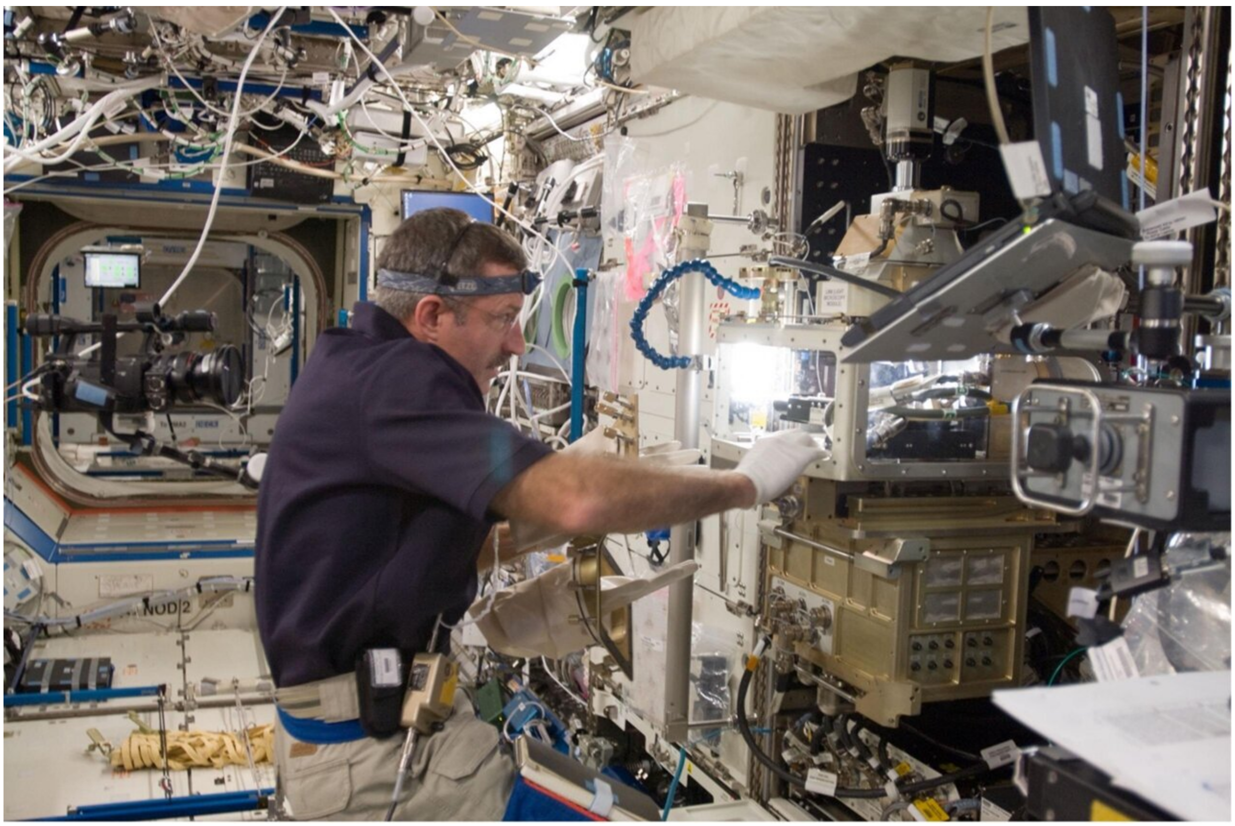
Making the invisible visible: The remarkable journey of a powerhouse space microscope

June 24 2022, by Science@NASA



In the International Space Station's Destiny laboratory, NASA astronaut Dan Burbank, Expedition 30 commander, conducts a session with the Preliminary Advanced Colloids Experiment (PACE) at the Light Microscopy Module (LMM) in the Fluids Integrated Rack / Fluids Combustion Facility (FIR/FCF). PACE is designed to investigate the capability of conducting high magnification colloid experiments with the LMM for determining the minimum size particles which can be resolved with it. Credit: Science@NASA

Colloids are mixtures of microscopic particles suspended in fluids—substances that are part solid, part liquid. Colloids are found in products including toothpaste, ketchup, paint and liquid hand soap, and are part of a field of study known as soft matter.

Another familiar experience with colloids: "settling," which is when these mixtures separate into layers over time, pulled apart by gravity. That's why researchers set out to study how these substances behave at a fundamental level in space—to prolong the "shelf life" of materials, both in space and on Earth.

To gather this data, researchers needed a special tool that would enable them to see deep into the world of these tiny particles. Enter NASA's LMM—the Light Microscopy Module.

Since 2009, scientists and researchers from six countries, including 27 universities and research organizations, have spent thousands of hours employing the remarkable power of this state-of-the-art light imaging confocal microscope facility to study a variety of physical and biological phenomena. Formerly housed in the Destiny module of the International Space Station, the LMM contributed greatly to scientific discovery.

The LMM has been used by private companies to find new ways to improve their consumer products. Procter & Gamble, for instance, received approval on three patent applications for new products as a direct result of the company's research using the LMM.

The device also helped other engineers design the next generation of highly efficient quantum-dot-sensitized solar cells, greatly improve biomedical device technology, and deliver potential innovations in construction materials for use on Earth, the moon, and Mars.

Diane Malarik is currently the deputy director of NASA's Biological and

Physical Sciences Division, but in the 1990s, she was the project manager responsible for LMM's initial design. As she recalls: "We designed payloads for the space shuttle, but they had much simpler designs and operation then. The equipment was designed to be used only once by a single investigator. When the idea of building an LMM to install in the space station came to light, we knew it would have to be used by at least four investigators and had to design it with a great deal more flexibility."

Since installation, the LMM was used in 40 experiments, capturing images instrumental in helping scientists and engineers understand the forces that control the organization and dynamics of matter at microscopic scales. In effect, the LMM has helped make the invisible world of colloids more visible.

What made the LMM unique among microscopes was that it allowed scientists to use the microgravity environment to observe the separation of physical and biological mechanisms over much longer timescales than possible on Earth. And the microscope's high-quality, three-dimensional images deepened our scientific understanding of multiple micro and macroscopic fields including heat transfer, colloid interaction, and phase separation. In doing so, it has enabled scientists to improve the efficiency of commercial products on Earth, as well as contributed to the greater scientific community's understanding of colloids.

Having completed over a decade of research, the LMM's last experiment took place in October 2021. During this time the LMM was used for research in soft matter/complex fluids (colloids and gels), fluid physics (heat pipes), biophysics (protein crystallization, drug delivery) and plant biology (gravity sensing in roots). Over 30 conference presentations have been given and approximately 50 journal publications published or are in development that use data directly from the space station LMM results.

Museum professionals hope that one day LMM can be preserved for others to interact with on Earth as well. Lauren Katz, program manager of NASA Artifacts and Exhibits, said she would be excited to oversee LMM's potential use in future NASA exhibits and loan to museums. "We feel the inclusion of the LMM could serve as a fascinating introduction to how science in space can be conducted from Earth," says Katz. "Further, because the microscope is controlled remotely, we believe this interactive feature could serve as the 'cool' factor as visitors control the microscope (or representative device) themselves."

Many factors will influence whether LMM is able to be returned to Earth, namely space constraints aboard both the space station and return vehicles. Regardless of LMM's final destination, its legacy as a workhorse for science will remain.

Provided by NASA

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