Stopping slime on Earth and in space

ASU team works to prevent $4 trillion in biofilm damage globally with tech tested in cooling towers, International Space Station

By Lisa Irish, ASU News
October 6, 2025

How do you prevent biofilms — large communities of bacteria like the slime on your teeth before you brush — from growing in water systems in space and on Earth?

A multi-university research team led by Arizona State University Regents Professor Paul Westerhoff is investigating ultraviolet light as a cost-effective, safer alternative to disinfecting chemicals to prevent biofilm growth on surfaces, thus reducing health risks and equipment damage.

The team's National Science Foundation-funded Germicidal Ultraviolet Light Biofilm Inhibition, or GULBI, experiment was one of the 15 projects launched on NASA's Northrop Grumman Commercial Resupply Services 23 mission to the International Space Station on Sept. 14.

In the humid space station, preventing biofilm is essential because "anywhere there is any moisture, biofilms will grow on surfaces," says Westerhoff, who develops novel technologies to address emerging water issues at the School of Sustainable Engineering and the Built Environment, part of the Ira A. Fulton Schools of Engineering at ASU.

"On Earth, biofilms cause an estimated $4 trillion in damage every year because they corrode metals, promote mold on surfaces, harbor harmful pathogens in medical devices such as catheters and increase energy consumption in heat exchangers," Westerhoff says. "Biofilms in crustaceans attached to boats are responsible for over 10% of their energy or diesel costs."

Why this research matters

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Why use ultraviolet light?

Westerhoff's team observed how germicidal ultraviolet light, or UV-C, broke bonds in bacterial DNA, prevented repairs and inhibited biofilm growth.

Partnering with NASA, his startup company H2Optic Insights developed UV-C side-emitting optic fiber that proved effective at controlling growth of the bacteria that causes Legionnaires' disease in cooling tower structures that use water and a fan to chill air in buildings.

They wondered if this technology could work effectively in space's microgravity and reduce the need for disinfecting chemicals?

That question became especially relevant given the high cost of sending even basic supplies to the ISS — with one estimate putting a 500 milliliter bottle of disinfectant at $20,000 or more, says Robert McLean, a Texas State University Regents Professor who focuses on biofilms and is part of GULBI's multi-university team.

On the ISS, wastewater is collected, purified by distillation, treated, disinfected and reused as drinking water, says McLean, noting wastewater biofilms are resistant to usual disinfectants.

"In the past, some tubing on the ISS located before the treatment steps became clogged with biofilms and needed to be replaced," McLean says. "While such emergency measures can be done on the ISS, travel to the moon or even Mars does not allow for replacement items to be sent from Earth or crew evacuation in an extreme situation."

Experiment details

The GULBI experiment compares how biofilm from the bacteria Pseudomonas aeruginosa grows in space's microgravity versus on Earth when treated with UV-C light delivered through thin, flexible, side-emitting optical fibers.

The setup includes 16 small units called BioCells, each containing five sample wells. Built by implementation partner BioServe Space Technologies, these BioCells hold liquid nutrient media, bacteria and metal surfaces inside a plate habitat, or PHAB, connected to a control box that powers the LED light sources and cooling system.

BioServe also designed the flight hardware and handled all the mission integration steps required to get the GULBI experiment onboard the ISS, says Stefanie Countryman, director of the center within the University of Colorado Boulder's Ann and H.J. Smead Department of Aerospace Engineering Sciences.

The organization has designed, built and flown hundreds of microgravity life science research experiments and spaceflight-certified hardware on more than 110 missions.

On the third, ninth, 15th and 21st day of the experiment, astronauts remove one PHAB from storage and place it in the Life Science Glovebox, Westerhoff says.

"(These plate habitats) are individual packages the astronauts take out," Westerhoff explained during the Northrop Grumman CRS-23 Pre-Launch Science Webinar hosted by the International Space Station National Laboratory. "They'll (inoculate the) BioCells, close them back up and essentially (allow the bacteria) to incubate over time."

(Video: {https://youtu.be/Vh9J7w-WelI?feature=shared})

The samples are then exposed to continuous, intermittent or no UV-C light. Later, crew members collect bacterial samples, inject fixatives and place BioCells in temperature-controlled storage until they return to Earth.

“This is the first time (that) hardware was designed and spaceflight-certified (using) the science team’s UV-C side-emitting fibers to limit or eliminate biofilm formation in a microgravity environment,” Countryman says.

McLean’s team helped plan the science and analysis for the GULBI experiment with Westerhoff and ASU School of Life Sciences Professor Cheryl Nickerson.

“We developed a rapid, molecular-based test to measure individual population levels of a multi-species biofilm to see if any antimicrobial effect showed a preference for a small number of species or was universal in nature,” McLean says.

Nickerson’s team has flown 12 life sciences and health experiments to the International Space Station.

“We have more than 20 years of experience in space biomedical research to protect astronaut health and sustainability of their spacecraft, which includes onboard life support systems like drinking water,” says Nickerson, who focuses on dynamic interactions between microorganisms, their environment and infected hosts in space and Earth.

Her team — including research assistant professors Jennifer Barrila, a co-principal investigator on this study, and Jiseon Yang, with the ASU Biodesign Center for Fundamental and Applied Microbiomics — prepared the biological science in time for the mission’s launch date and trained other team members to enable high-quality research in space, including doctoral student Ken Niimi on Westerhoff’s team.

Barrila, Yang and Niimi did extensive lab work and device fabrication over two years to get ready for this rare opportunity to perform experiments in microgravity, Westerhoff says.

“Our extensive experience in pre-flight optimization of the biology, preparation and handover of the experiment for launch, as well as the design of ground-based controls, were valuable for this effort since doing biological research in space is nothing like doing it in Earth-based laboratories,” Nickerson says.

What’s next

The team expects to learn from GULBI the impact UV-C has on the amount and structure of biofilm growth in space, since “our collaborators’ previous work shows the structures of biofilms in microgravity are very different than on Earth,” Westerhoff says.

Non-chemical methods like GULBI to reduce biofilms where moisture is found are essential.

“If we’re going to live or manufacture in space, we’re going to need water,” Westerhoff says.

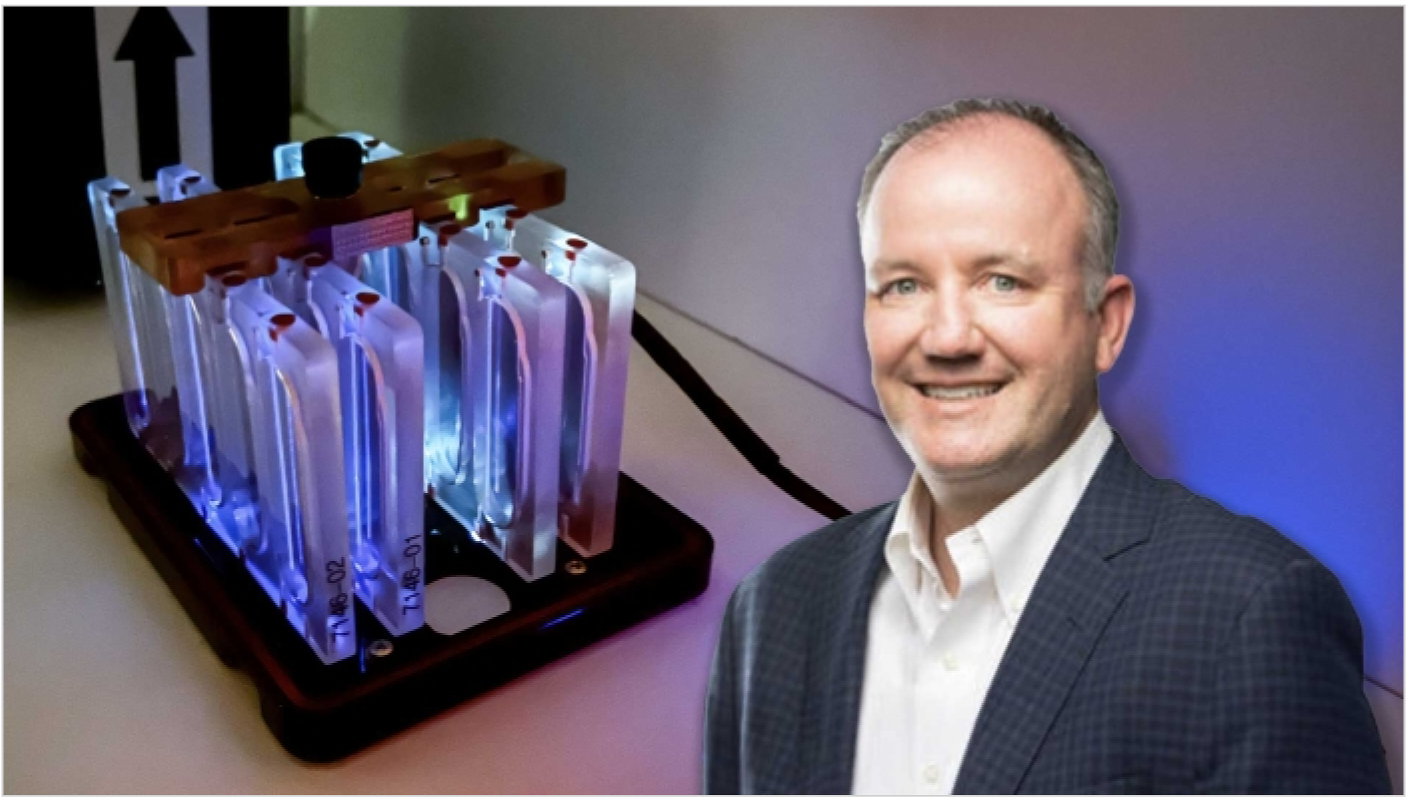
UV light reduces the need to haul more silver or iodine disinfecting chemicals to the orbiting lab and modify surfaces with different coatings, he says, noting it’s already in a portable water dispenser system on ISS to eliminate viruses before astronauts drink.

This summer, Westerhoff’s team and NASA started a Phase III application that put a mesh of H2Optic Insights’ side-emitting optical fibers into a water bellows tank designed for the ISS.

“By studying how biofilms behave in extreme environments like microgravity, we can improve both our fundamental understanding and our ability to prevent their widespread problems here on Earth,” he says.

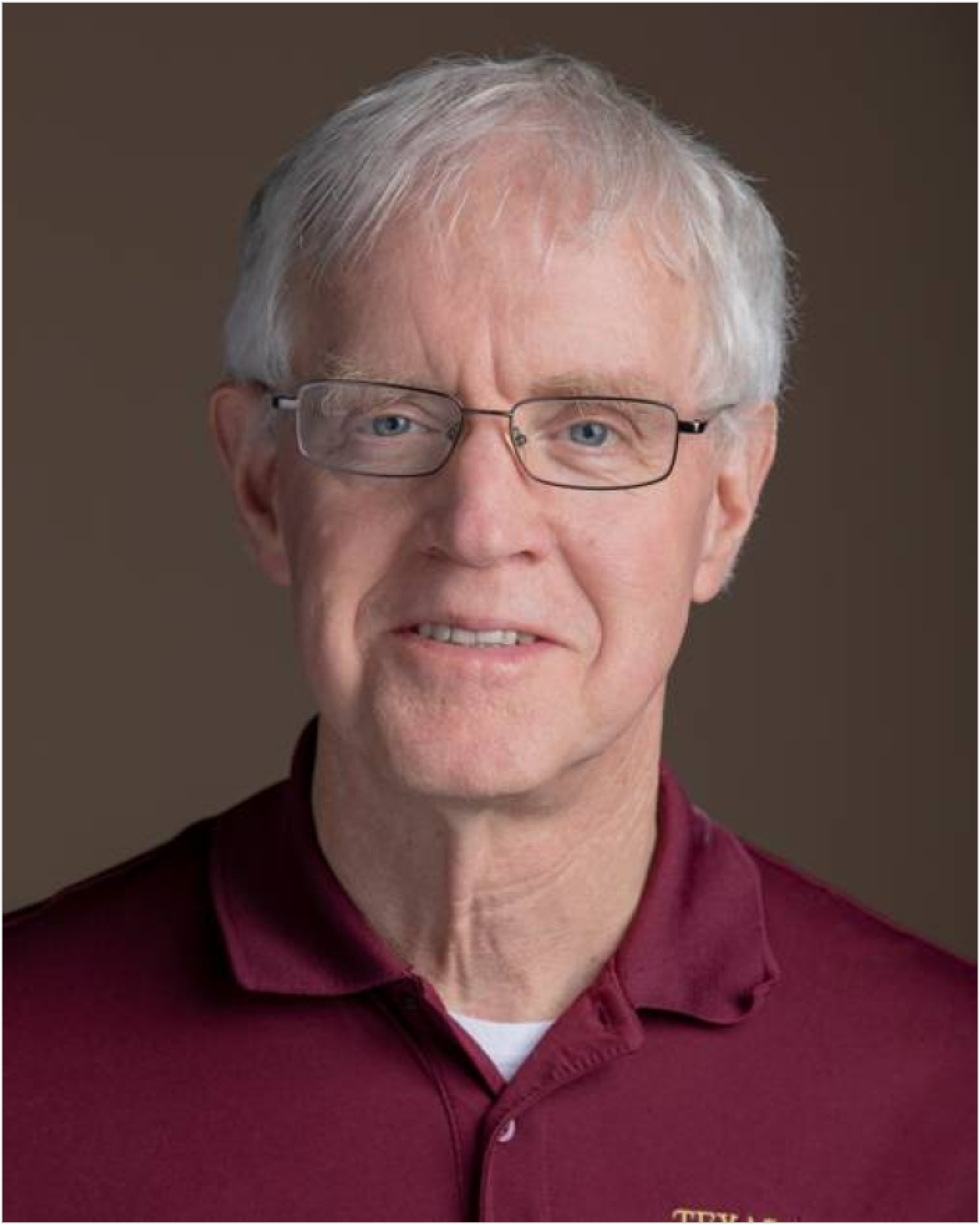
This story originally appeared on ASU News.

Main image



ASU Regents Professor Paul Westerhoff in front of the BioCells containing liquid nutrient media, bacteria and metal for the Germicidal Ultraviolet Light Biofilm Inhibition investigation that he leads. There are four parallel reactors — each with five BioCells — where biofilm growth is monitored. The glowing blue color comes from side-emitting optical fibers, supplied with light from LEDs. This research uses special optical fibers to deliver ultraviolet light to inhibit biofilm growth and examine microgravity’s effects on it. Photo by Erika/Gronek Arizona State University

Text image(s)



Robert McLean

Stefanie Countryman

Cheryl Nickerson

Assistant research professors Jennifer Barrila (left) and Jiseon Yang (center) of the ASU Biodesign Center for Fundamental and Applied Microbiomics and doctoral student Ken Niimi (right) during the GULBI experiment at the Kennedy Space Center for loading on the NG-23 mission to the International Space Station. Photo courtesy of BioServe