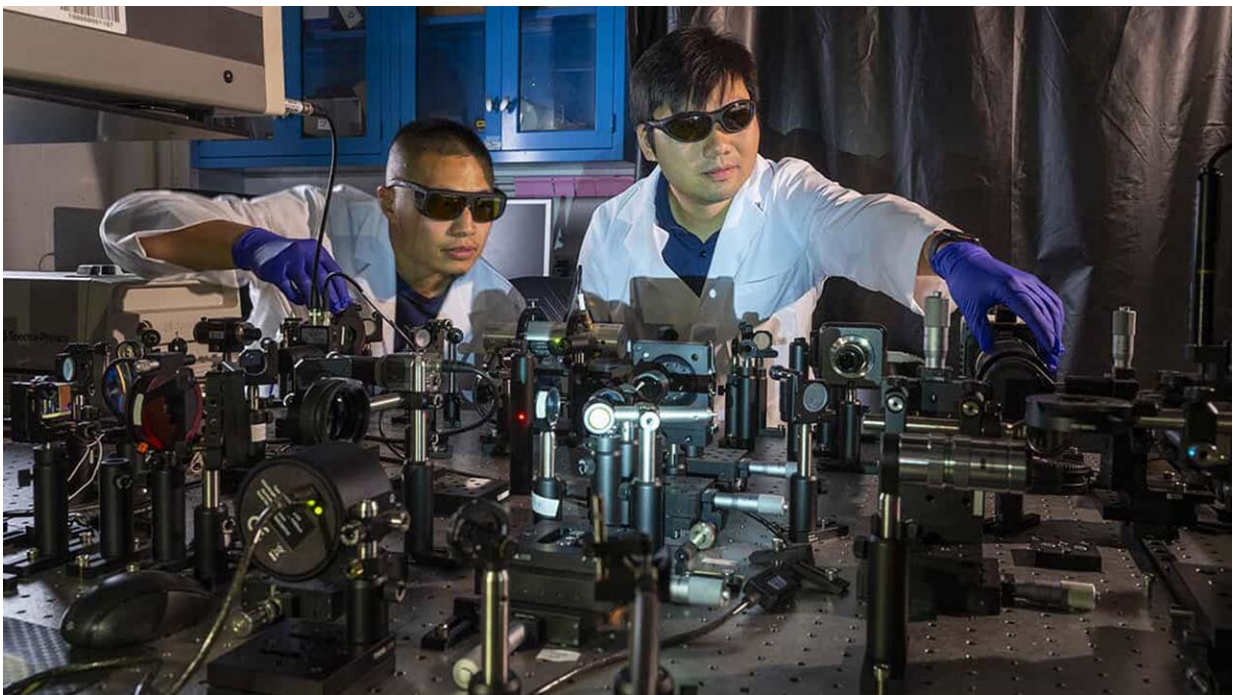


Space-based experiments could help to advance early cancer detection through blood tests

September 5 2024, by Stephenie Livingston



ISS National Lab Commercial Service Provider Space Tango worked with Luo's team to develop specialized CubeLab hardware to automate the study of bubble formation and behavior in microgravity. Credit: University of Notre Dame

Imagine a sensor so sensitive it can detect early cancer in a single drop of blood, enabling diagnosis and treatment before the first

symptoms—possibly before a tumor even forms.

Next, picture a device capable of identifying trace amounts of even the smallest plastic pollutants in ocean water, empowering scientists to mitigate the environmental impact of dangerous microscopic toxic waste like nanoplastics, a subgroup of microplastics between 1 and 1,000 nanometers in size.

The catch? Blood samples and vials of contaminated water undergo screening in space, where the absence of gravity leads to an unexpected occurrence: the formation of unusually large bubbles that more efficiently concentrate substances like cancer biomarkers for detection.

This is the futuristic vision of Tengfei Luo, a researcher at the University of Notre Dame who studies mass and energy transport at the molecular level. His concept is simple but has profound applications. By harnessing the unique properties of heat, fluid, and light and their interaction with bubbles, Luo seeks to create sensing technology that's useful on Earth but performs significantly better in the microgravity environment of space. These sensors measure biological or chemical content by generating signals proportional to the concentration of a substance.

Luo's technology uses bubbles to concentrate and extract the tiniest substances submerged in liquid samples, promising to achieve sensitivity and accuracy in detection several orders of magnitude better than what's currently possible. The key to this technology is freeing the bubbles from the constraints of gravity-induced forces, allowing them to act as the concentrator of targeted microscopic substances for a larger spatial extent and longer duration, making the substances easier to detect and analyze.

Luo says this biosensing method could ultimately improve the efficiency

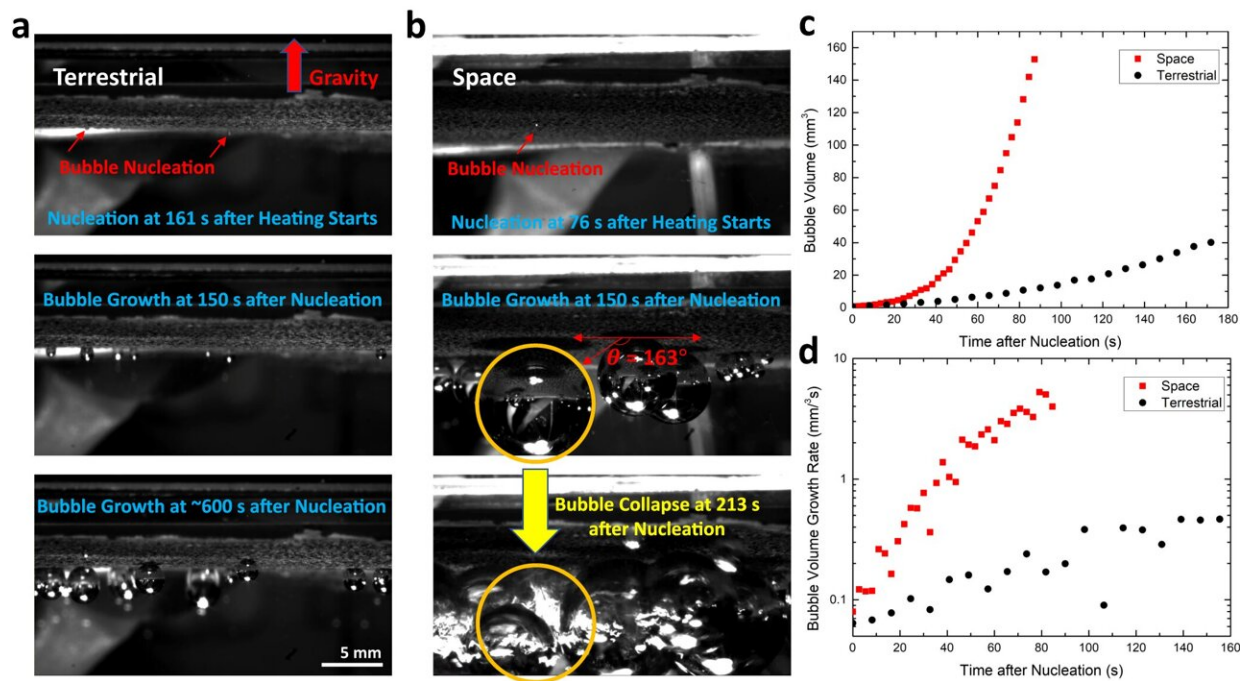
of cancer diagnostic tools reliant on highly concentrated sample extraction from liquids.

"The technology currently available to screen for early, asymptomatic cancer before a tumor is visible during imaging is very limited to just a few cancers," Luo said. "If cancer screening using our bubble technology in space is democratized and made inexpensive, many more cancers can be screened, and everyone can benefit. It's something we may be able to integrate into annual exams. It sounds far-fetched, but it's achievable."

The first in a series of International Space Station (ISS) Laboratory experiments aimed to study how bubbles form and grow on surfaces of different roughness when water boils in space compared with the process on Earth. The initial experiment examined bubble behavior on one surface, and a second iteration that flew on Northrop Grumman's 17th CRS mission studied four different surfaces.

A [high-speed camera](#) inside the flight hardware captured the bubble growth process, and then Luo's team analyzed the videos together with computer simulations. The experiment focused on two fundamental factors affecting bubble formation: the surface's texture and the surrounding liquid's movement. According to Luo, the results are promising, showing that the bubbles grew larger and faster in space than on Earth.

Understanding the mechanisms behind bubble growth in space will help Luo advance his technology to extract extremely low concentrations of substances from liquids, which he says is the next step in detecting cancer in [blood samples](#) or minute traces of pollutants in water. Beyond Earth applications, the technology could bolster the low Earth orbit economy and potentially accompany astronauts during deep space exploration to assess onboard water sources for contamination or monitor crew member health.



Surface bubble nucleation and growth dynamics. The snapshots showing the moments of surface bubble nucleation (upper), growth (middle) and the final phase (lower) at the end of the video in terrestrial **a** or space microgravity **b** condition. The measured surface bubble contact angle is provided in the middle panel of **b**. **c** The volumes of space (red) and terrestrial (black) bubbles as a function of time after nucleation. **d** The volume growth rates of space (red) and terrestrial (black) bubbles as a function of time after nucleation in log scale. Credit: *npj Microgravity* (2024). DOI: 10.1038/s41526-024-00352-0

Unraveling the physics of bubbles in space

Originally from China, Luo joined Notre Dame after completing a postdoc at the Massachusetts Institute of Technology and started the MONSTER (Molecular/Nano-Scale Transport and Energy Research) Lab in 2012 to study molecular-level energy and mass transport.

For a 2020 study [published](#) in *Advanced Materials Interfaces*, Luo and his research team used a laser to heat a solution containing nanoparticles coated with DNA biomarkers. They successfully lured the nanoparticles to the bubbles generated by the laser and deposited them on the substrate, creating what Luo calls a "high-density concentrated island."

Thanks to a phenomenon called the Marangoni flow, nanoparticles are transported to the surface of bubbles. The bigger the bubble and the longer it is maintained in a liquid without detaching from the surface, the more concentrated the substances attracted to it become. The biomarkers migrate along the bubble to the solid surface, where they bunch together and collect, ready to study. At that point, Luo uses microscopy to examine the bubbles and determine what's deposited on the surface.

To grow "larger bubbles that last longer on the surface" and make his biosensors more sensitive, Luo turned to the space station's unique microgravity environment and enlisted the help of Space Tango.

"Microgravity provides an ideal environment to explore physics fundamentals by removing one of our universe's fundamental forces," explained Twyman Clements, president and co-founder of Space Tango. "On Earth, bubbles are influenced by competing forces such as surface tension and buoyancy, but in low Earth orbit, these forces are removed."

Space Tango partnered with Luo's team to develop customized hardware to ensure the success of the spaceflight project.

"For this study, the team designed an automated experiment, from fluid containment systems to high-speed imaging tools, that function under microgravity conditions and heat the liquids under study safely on the space station," Clements said. "As we continue to improve our technologies, this effort underscores our commitment to pushing the

boundaries of fluid dynamics research for applications that benefit humanity on Earth and beyond."

The experiment was housed in a novel CubeLab, an automated platform the size of a shoebox, developed by Space Tango. The hardware includes four specialized fluid chambers and high-resolution imaging systems specifically designed to observe and analyze bubble formation in microgravity. The experiment involved the controlled introduction of various fluids into the chambers, allowing researchers to study bubble formation, growth, and coalescence under microgravity conditions.



Top: Bubble formation in the Space Tango CubeLab on the space station.
Bottom: Bubble formation during experimentation on Earth. Credit: Image courtesy of Luo Tengfei

"We found that bubbles form much quicker in space than on Earth. For instance, in one experiment, bubbles formed after 4 minutes and 35 seconds in space, but it took twice as long on Earth due to the movement of liquid cooling the area known as thermal convection," Luo said.

In space, without the presence of buoyancy and convective flow, the dynamics of bubble growth change drastically. On Earth, buoyancy—the tendency of objects to rise or fall in a fluid due to gravity—plays a significant role in bubble formation and growth. Additionally, convective flow, caused by the movement of hot liquid around the heating area, helps regulate temperature and slows bubble growth.

There's hardly any buoyancy in microgravity. This means bubbles aren't pulled away from the surface, allowing them to grow larger without being disturbed. Additionally, without convective flow, there's nothing to cool down the heating area. As a result, the [heat energy](#) is concentrated in a smaller area, leading to much faster and larger bubble growth than on Earth, Luo says.

The results from his space experiments successfully illustrated these concepts. The bubbles did not detach from the surface but burst at the end when they grew too big. "We still don't understand why," says Luo.

Turning dreams into tangible tech

After analyzing and quantifying the bubble volume, Luo and his team determined that space bubbles can be orders of magnitude larger than terrestrial bubbles. They [published](#) their results earlier this year in *Nature Microgravity*.

On Earth, Luo used his technique to find nanoplastics—including those from disposable coffee cups, water bottles, and fish nets—in a vial of ocean water he collected off the coast of the United States, which he

describes in another recent paper [published](#) in *Science Advances*.

"We find some kinds of particles 300 meters deep in the Gulf of Mexico in very, very low concentrations, but this gives us a look at what nanoplastic looks like in our ocean environment," says Luo.

Luo and his team will continue their research in an upcoming experiment scheduled for launch in August. This time, the team will conduct particle disposition to confirm that the larger bubbles do indeed increase the density of concentrated nanoparticles collected.



Inside the CubeLab designed by Space Tango. Credit: Tengfei Luo

The Space Tango CubeLab will also undergo some changes. Luo is working with Space Tango to implement a safe, inexpensive laser to heat the liquid; the nanoparticles absorb the laser light and convert it into heat. Heating the nanoparticle suspension with a laser allows better control of the Marangoni flow to improve biomarker concentration and collection.

"If the concentration ratio is proportional to the bubble size, we should be able to increase the sensitivity of our biosensors by another three orders of magnitude," says Luo. "So that would allow us to--theoretically--screen for early cancer."

Luo is starting to think about how to make this dream a reality. He estimates that sending around 10,000 blood samples to the space station costs a few hundred dollars. Of course, that doesn't cover the cost of flying a spacecraft. He hopes vehicles like Boeing's Starliner and future commercial space destinations may help reduce the cost of screening for diseases in space and further democratize access.

Still, scaling up this process to make space screening available to everyone is a significant hurdle to overcome. In the meantime, these experiments are improving our understanding of the physics of fluid around surface bubbles in complex environments. Validating this technology at the extremes of particle concentration, bubble size, and bubble growth rate could benefit all sorts of terrestrial screening. This translates to mapping out the scientific limits of cancer biomarkers or environmental pollutant detection.

And Luo says it's not just people on Earth who could benefit. Monitoring astronauts' health is crucial for prolonged space missions, where early detection of changes in health can ensure their well-being. Enhancing biosensor technology in space can lead to more accurate and reliable health monitoring, contributing to safer space exploration.

Dual-use applications, such as Luo's biosensing, have transformative potential, benefiting both space exploration and technology on Earth, says Jonathan Volk, business development director for Voyager Space, a commercial space company focused on advancing deep space missions, encompassing lunar and Mars exploration programs, and developing Starlab, a commercial space station.

"Increasing accessibility to space is pivotal to encouraging more projects like Tengfei's," Volk said, underscoring the ISS National Lab's role in translating visionary concepts into practical realities.

"To do science in the space environment, whether in physics or biology, innovative thinking is essential, and it's easy for an idea to sound like a pipe dream," says Volk. "But once we grasp the possibilities within the space environment, what may seem impossible can become possible."

More information: Qiushi Zhang et al, Bubble nucleation and growth on microstructured surfaces under microgravity, *npj Microgravity* (2024). [DOI: 10.1038/s41526-024-00352-0](https://doi.org/10.1038/s41526-024-00352-0)

Provided by International Space Station National Laboratory

Citation: Space-based experiments could help to advance early cancer detection through blood tests (2024, September 5) retrieved 5 September 2024 from <https://phys.org/news/2024-09-space-based-advance-early-cancer.html>

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