This lab’s research is a little extreme

ASU's Extreme Environments Lab tests semiconductor technologies under some of the harshest conditions

By Mikala Kass, ASU News
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Imagine a microchip on a satellite in low Earth orbit. Temperatures swing from minus 85 degrees Fahrenheit to over 250 F. In one year, it is bombarded with over 100 times the radiation dose the average person experiences naturally on Earth. And if it needs new parts, well, it will have to wait a decade or so.

At Arizona State University, researchers and students in the Extreme Environments Lab test semiconductor technologies under some of the harshest conditions. The lab serves the Southwest Advanced Prototyping, or SWAP, Hub, supporting government and industry partners in designing technologies that are reliable in demanding settings.

This capability is critical across a wide range of applications — from space stations and missile defense systems to geothermal energy and oil exploration equipment deep underground. It also supports radiation therapy, nuclear energy systems and advanced scientific tools such as quantum computers.

ASU's SWAP Hub is part of the Department of Defense’s Microelectronics Commons. It is the only regional hub with comprehensive infrastructure for testing electronics in extreme temperature and radiation environments. By involving students at every stage, the lab helps them gain in-demand skills and hands-on experience that translate directly to career opportunities.

What happens during extreme environment testing?

“Imagine equipment in space. You can't replace parts easily. Things need to last for 10 to 20 years up there under extreme conditions,” says Hugh Barnaby, who leads extreme environment reliability efforts in the SWAP Hub.

That reality underscores why developers want to ensure their technologies perform as intended.

“There are different classifications for specifying whether these applications can work in certain environments. For us in SWAP Hub, we are working with the extreme environment specifications, which is way outside of the bounds of even military specifications in terms of temperature operation,” says Barnaby, who is also a professor in the School of Electrical, Computer and Energy Engineering.

Barnaby leads the Extreme Environment Lab team, which tests semiconductor components with special equipment from the ASU Eyring Materials Center, part of ASU's Core Facilities, and SWAP Hub partner facilities. The team evaluates pressure, humidity, mechanical shock and high temperature, but places a heavy focus on radiation exposure and extreme cold, both together and separately. The researchers can also test technology during or after exposure.

Being able to test different forms of radiation allows the lab to serve many clients. Galactic cosmic rays in space, for example, are very different from proton radiation used in cancer therapy. The lab ensures that important technology will work in the specific environment where people will use it.

The lab also performs modeling and analysis to predict performance, find problems early and guide design improvements.

Student-led solutions

PhD student Jereme Neuendank has embraced creative problem solving in the lab. One challenge involved testing devices under extreme cold and radiation at the same time.

Normally there is one machine to test extreme cold and another to test radiation. Neuendank helped develop a cryogenic device small enough to fit inside the lab’s radiation chamber — the Rigel DSTAT.

“The main reason we wanted to do that is because in a space environment, a microchip will usually be at a very cold temperature when it's getting exposed to radiation. So to get a more accurate scope of how these devices are going to perform, we wanted to simulate those environments as closely as we could. Being able to irradiate at cryotemperatures was a big breakthrough that we came up with,” says Neuendank, who is in the School of Electrical, Computing and Energy Engineering.

He also helped develop a remote testing system so that experiments — some lasting up to 10 hours — could run without needing a researcher physically present in the lab.

During a summer internship with Sandia National Laboratories, Neuendank used a similar solution to streamline a setup that had forced researchers to switch between two computers. The lab still uses his system to this day, he says.

“I like a good challenge. The Rigel DSTAT certainly didn't exist before, so it all had to be created,” says Neuendank, who hopes to work in industry after graduation. “It's a good learning experience to get familiar with building those types of testing systems and trying to build them in such a way where they're loosely applicable to a wide variety of different testing environments.”

Tyler Kirby, also a PhD student in the School of Electrical, Computing and Energy Engineering, focuses on modeling and analysis. Using advanced computer simulation tools, he builds virtual devices and studies how radiation affects them. Much of his work is part of a year-round remote internship with Sandia.

“It was always hard for me to pick one area of interest,” says Kirby, who hopes to do research-based work in a national lab after graduating. “I really like how this combines so many different areas, like materials science, electrical engineering, physics, radiation, chemistry.”

Helping the US government and industry alike

As part of the SWAP Hub, Barnaby's lab helps technology developers quickly meet U.S. defense and industry needs for technologies that perform in extreme environments.

The SWAP Hub connects over 200 members — chip manufacturers, defense firms, national labs, startups and other organizations — providing access to shared facilities, equipment and expertise to strengthen U.S. technological leadership.

Partners turn to the lab for help solving complex problems, identifying design flaws and validating performance under extreme conditions. The team typically works with semiconductor components such as circuits, transistors and capacitors through both physical testing and modeling.

For example, the lab is collaborating with Kyocera to study how its capacitors respond to radiation and with Microchip Technology to evaluate radiation effects on power transistors.

The results help partners refine products and processes, ensuring critical technologies perform when it matters most.

"Our group walks along with them and supports all of the testing that they need to be confident that their product is good for extreme environments," Barnaby says.

Why this research matters

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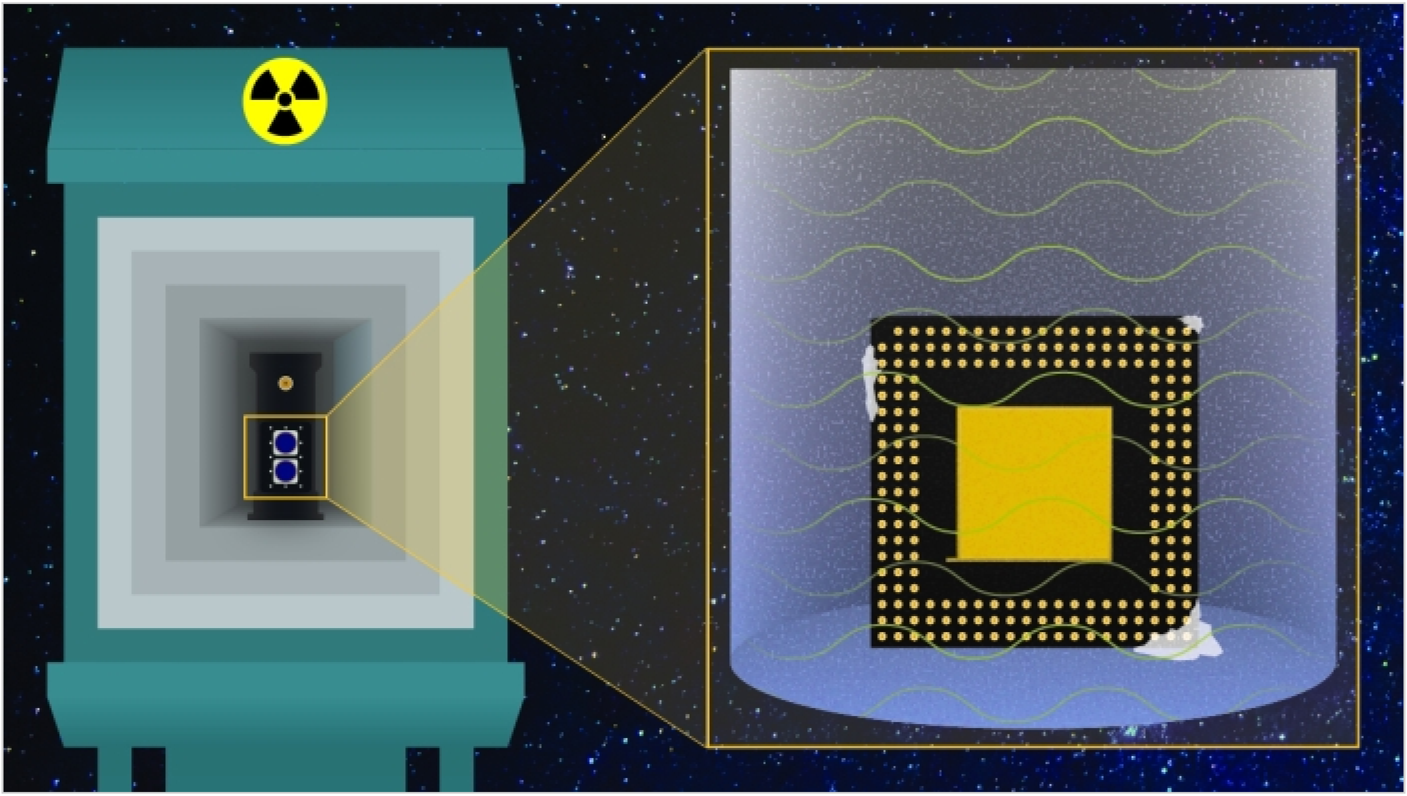
Main image



The Extreme Environments Lab uses special equipment to test how semiconductor parts respond to different extreme environments. This illustrated setup shows the how the lab would test radiation and extreme cold together to mimic space. Illustration by Sophia Franz