Armor for Astronauts

Developing High-Tech Wearable Radiation Shields

By Stephenie Livingston,
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A view of the AstroRad vest in the Cupola module onboard the space station.
NASA

Drifting weightlessly onboard the International Space Station (ISS), NASA astronaut Kayla Barron carefully pulls on an unfamiliar garment. It feels snug, a bit bulky—like an over-engineered life vest. Only this isn't for water. It's the AstroRad vest, a cutting-edge wearable technology designed to protect astronauts from one of space's invisible and more relentless dangers: solar radiation.

Developed by StemRad in collaboration with Lockheed Martin, the vest might soon protect astronauts on missions that push far beyond the safety of Earth's protective bubble. Barron, who tested an early version during routine tasks and sleep on the space station, said, at times, it felt "like a gravity blanket in space."

"It wasn't ideally sized for my anthropometric dimensions… but, you know, it's prototype hardware," she said. She also pointed out the vest's main challenge: "They're trying to cover all of these critical parts of your body, so they want to maximize the coverage without really interfering with your mobility."

But at the time, the vest wasn't quite there. Comfort and flexibility are essential when floating in microgravity. Barron and other astronauts' feedback sparked a slew of new tests and improvements to refine the vest's design and make it more customizable.

Behind the scenes, Kat Coderre, an aerospace engineer at Lockheed Martin whose resume includes designing the Orion spacecraft for the Artemis I Moon mission, played a pivotal role in developing the vest. She refers to the long, intricate design and testing process involving various partners and experts as the "vest saga." "What's cool about this whole thing," Coderre says, pulling up data from the vest's recent tests on her computer, "is how multiple linked projects have come together. Lockheed Martin and StemRad are at the core, but we've also brought in other partners to push the innovation further. It's really a story about how all these partnerships came together to keep our astronauts safe."

The team partnered with the ISS National Laboratory® to test run the vest in microgravity, evaluating how it fit, moved, and functioned in real space conditions. Sure, Earth's magnetic field provides some shielding in low Earth orbit (LEO), but astronauts on the ISS can still experience more than 100 times more radiation than people on Earth.

Radiation becomes a more ruthless adversary during missions beyond Earth's protective magnetic shield to the Moon or Mars. Galactic cosmic rays, solar particle events, and radiation trapped in the Van Allen Belts can result in exposure levels up to the equivalent of 6,000 chest X-rays—and cause illnesses like cancer and radiation sickness. The vest, with layers of high-density polymers, aims to take the brunt of that punch.

Barron, who also served as a submarine warfare officer in the U.S. Navy, knows firsthand the challenges of working in radiation-heavy environments. "Radiation shielding is a really hard thing to do," she said, recalling her military experiences working in nuclear environments during her "previous life." On Earth, traditional solutions like lead walls work well, but mass and volume constraints on spacecraft make such methods impractical in space. This is where innovations like AstroRad become essential.

The idea of wearable, customized protection for astronauts offers a more feasible solution. “The idea that you could have wearable technology customized for each crew member, it’s kind of like an aha moment,” Barron remarked. “It’s an elegant solution to a really challenging engineering problem.”

From Fukushima to the Final Frontier

Speaking from his home in Tampa, Florida, Oren Milstein, founder and CEO of StemRad, is animated as he talks about AstroRad’s origins—how it all began with a disaster on Earth. “It started after the Fukushima nuclear disaster in Japan,” he recalls, leaning forward in his chair. “We developed the first gamma radiation personal protective equipment (PPE) for nuclear disaster first responders, so there’s a lot of heritage in protecting first responders.” The company developed a solution called selective shielding, which focuses on the body’s most vulnerable parts, such as bone marrow, the tissue most sensitive to radiation.

The idea to develop PPE for astronauts came in 2015 after NASA launched Orion with Mars ambitions in mind, followed by the Artemis program in 2017 to return astronauts to the Moon for the first time in more than 50 years. “We saw NASA’s ambitions and thought, ‘We can help,’” Milstein said.

He discussed the severity of cosmic radiation with an earnestness that underscored the urgency of his technology. “Space radiation can kill,” he said bluntly. “To travel to Mars without adequate protection is to gamble with your life, and that’s unacceptable. Radiation protection is critical because radiation is unavoidable, and that’s what AstroRad is about.”

Solar particle events, for instance, are like being swarmed by a hive of bees—if the bees were charged particles, Milstein says.

And it’s not just about short-term protection from intense solar events, he explained. “We’re talking about long-term protection to reduce the risk of cancer and other radiation-induced health issues for astronauts on long-duration missions.”

During a meeting in Tel Aviv, Milstein presented AstroRad’s concept to a room of aerospace executives. John Karas, a vice president at Lockheed Martin at the time, was in the audience. As Milstein recounts this moment, he leans back and grins. “John stood up, extended his hand, and said, ‘You’ve got a partner for this.’ It was that simple. Suddenly, we had Lockheed Martin on board.”

The ISS National Lab’s sponsorship and Lockheed’s involvement accelerated the project’s momentum. Speaking from her office in Denver, Coderre recounted the moment she was brought onto the project. “At first, we were like, ‘A

NASA astronaut Kayla Barron in the Blue Flight Control Room at NASA’s Johnson Space Center in Houston.

NASA/Bill Ingalls

radiation vest? This is different from what we’re used to.’ But the idea was intriguing. We knew we’d need to test how well it performs in the actual environment, and the best place to do that was the ISS.”

“There’s a lot of complexity when designing something that must protect against space radiation. It must be comfortable enough to wear for long periods and not add too much mass,” she explained, gesturing toward mockups of the vest on her laptop. “Space is always mass-constrained, so every decision comes down to balancing those factors.”

As Coderre speaks, it becomes clear that the project is not just about protecting astronauts in space—it’s also about making sure anyone can explore it, regardless of biology. The risk of radiation-related illnesses, for example, is particularly concerning for female astronauts. Research has shown that females are more susceptible, primarily because certain tissues, such as breast tissue and reproductive organs, are more prone to radiation-induced cell mutations. In fact, women have up to twice the risk of developing cancer from radiation exposure compared to their male counterparts.

“Women’s access to space was the whole impetus behind this,” said Coderre.

International Atomic Energy Agency (IAEA) team leader Mike Weightman examines Reactor Unit 3 at the Fukushima Daiichi Nuclear Power Plant in 2011 to assess tsunami damage.

Greg Webb/IAEA

Historically, NASA imposed stricter radiation exposure limits for female astronauts, though recent adjustments have aimed at equalizing these limits. In addition to those changes, protective measures like AstroRad remain crucial for mitigating the risks in customizable ways, ensuring that deep space exploration is safe and accessible for everyone.

This is even more relevant as the commercial space industry opens doors to space travel for more people from various walks of life. Projects like AstroRad are increasingly personal, says Coderre. It's no longer just a select few heroic figures going to space who seem distant from our everyday lives. "Now, they're our colleagues, scientists, neighbors, and friends," she noted. In other words: space is for everyone.

Trial by Space

In late 2019, a version of AstroRad designed for female astronauts, with extra protection for breast tissue and ovaries, flew to the ISS for its first real test in the environment where it must perform. The goal was to assess whether astronauts could wear the vest comfortably during their normal routines: sleeping, eating, exercising, and performing experiments in microgravity.

Jordan Houri, StemRad's lead scientist, discussed the experiment over Zoom from the Tampa office. "The ISS tests were a game-changer for us," he said as he played a video of NASA astronaut Jessica Watkins discussing the vest onboard the ISS. "We needed real feedback from astronauts in space—how the vest fit, whether it restricted movement, and if they could wear it for extended periods without discomfort. Without that data, we couldn't move forward."

Teams at NASA's Kennedy Space Center in Florida prepare two manikin "phantoms," Helga and Zohar, for the Artemis I mission to the Moon.

NASA

The vest is made from high-density polymer rich in hydrogen, which is particularly effective at shielding against cosmic radiation. "It's perfect for space because it's lightweight and highly effective at blocking the kind of charged particle radiation astronauts encounter," Houri explained. The vest's design incorporates a series of hexagonal blocks carefully arranged in layers to maximize protection while maintaining flexibility. These blocks are sandwiched between durable yet flexible fabric layers, allowing the vest to bend and move with the astronaut's body.

There's selective shielding, too: thicker protection for the bone marrow concentration in the hips, chest, stomach, and ovaries and thinner layers for areas where protection is not as critical and mobility is key. The result? A vest that blocks cosmic rays without transforming the astronaut into the Michelin Man. Afterall, an astronaut needs a full range of motion to perform even during a solar storm. However, according to Milstein, some limitations are fine compared to the alternative of being stuck in a cramped storm shelter during an event.

After a 25-day lunar mission, Artemis I Orion manikins Helga and Zohar undergo post-flight inspections at Kennedy Space Center on Jan. 11, 2023. Equipped with radiation detectors, Zohar tested the AstroRad vest to assess its effectiveness for future astronaut protection.

NASA

Four female astronauts tested the vest on the ISS. However, the team also tested its cross-gender applicability when a curious male astronaut tried it out. Surveys and real-time video assessed the vest's comfort and ergonomics. Feedback from astronauts is being used to refine the final design before future missions.

To test how the vest performed in different scenarios, Barron wore it for two distinct situations: during weekly housekeeping tasks and for a sleep period. The arm openings weren't in the perfect spot for her, so she had trouble controlling her body in microgravity, especially while holding things. Due to the

mobility restrictions and the size, "it was kind of hard to get into my sleeping quarters. And then once I was in my sleeping bag, I couldn't zip it up all the way," she said.

"I felt a little weird with my arms out of the vest, but I tucked them in, loosened the vest a little, and cocooned into it," she continued, "which was actually a little bit comforting, like a gravity blanket in space."

However, she added that the design limitations noted during testing weren't enough to prevent her from wearing the vest to protect herself during a high-radiation event.

Houri shared other stories about how astronauts—known to have a penchant for practicality—interacted with the vest. "One of the astronauts suggested that we add pockets, like a hoodie," he says, chuckling. "They said it would give them a place to rest their arms." Others requested more flexibility around the shoulders and legs, attachments to keep tools like iPads from floating away (during testing, astronauts stuck Velcro to the vest), and more adjustability—all feedback the team is using to modify key vest elements. They've already developed a system in which the width or height of a standard vest can be made larger using modular add-ons to the side and front and back panels.

Barron explained, "with any crew-worn hardware, how it fits you is really, really important."

Artemis I Phantom Test and Ziplock Bags

According to Milstein, the ISS project delivered proof that the vest, with several adjustments, could perform in microgravity during a solar storm lasting days. "The ISS National Lab really opened the door for us," Milstein said. "It allowed us to test the vest in a real space environment and laid the groundwork for other collaborations and tests, where we could take the concept even further."

Simultaneously, StemRad tested the vest outside Earth's protective shields during NASA's Artemis I mission in late 2022. The test subjects? Two manikins, or "phantoms," designed to mimic human anatomy. One, named Zohar, was outfitted with the AstroRad vest. The other, Helga, flew without it. Both manikins were equipped with thousands of radiation detectors to measure the levels of radiation exposure during their trip through Van Allen Belts and around the Moon.

The radiation detection results for Helga, the unshielded manikin onboard the heavily shielded Orion spacecraft, were recently published in Nature. According to study authors, including Houri and Milstein, Helga's dosimeters absorbed approximately 30.7 millisieverts of radiation during the mission—an amount vastly exceeding the radiation we experience on Earth. To put this into perspective, Helga's dose was equivalent to more than 13 years of natural radiation exposure on Earth. This exposure rate was still 60 percent less inside Orion than in previous missions where radiation was documented.

Houri pulled up data from the mission. "This is what we were waiting for," he said, displaying radiation exposure charts for Helga and Zohar. "The results exceeded our original predictions of how much protection it would provide by around 33 percent." Based on the data collected during the Artemis I experiment, if a major solar particle event had occurred during the mission, such as the historically powerful solar particle storms of August 1972, Houri says the vest would have reduced Zohar's exposure by around 60 percent.

Tests during Artemis and on the space station raised questions about reducing the vest's mass for long-duration missions, where mass is especially tight due to the challenge of exiting Earth's gravity well. Enter Redwire, with its expertise in in-space manufacturing.

At the 2024 International Space Station Research and Development Conference, Ken Savin, Redwire's chief scientist, detailed how the company is repurposing Ziploc bags into filaments for 3D printing parts of AstroRad. Yes, Ziploc bags—a prevalent plastic waste onboard the station. Using the Braskem Recycler, a device designed to convert plastic waste into usable materials on the ISS, Redwire

has transformed these bags into hexagonal pieces that snap together to form the shielding components for the vest. “We’re going to try to convert plastic waste into a recycled protective vest and solve two problems with this one solution,” Savin explained.

Humanity’s Next Giant Leap…Done Safely

The work on AstroRad isn’t over. Additional tests funded by Space Florida and redesigns to the vest are in motion, fueled by data gathered from the ISS National Lab-sponsored experiment. The team continues to refine the vest, focusing on mobility and fit and reducing its mass while maintaining the protection astronauts need for deep space missions.

“Radiation is one of the biggest barriers to deep space exploration,” Coderre said. “If we can solve this, we can send people farther for longer. That’s what makes the vest so important. It’s not just about one mission—it’s about the future of space exploration.”

When you consider the complexity of going from LEO to the Moon and from the Moon to places like Mars, “it just goes to show the power of creative ideas and collaboration with people who come up with different ways to solve problems like this,” Barron said.

The ripple effects of AstroRad’s space tests stretched to StemRad’s Earth-bound medical and first responder protection. “Even though we’ve tried to make our wearables as comfortable as possible, everyone has different limitations,” Houri explained. “AstroRad testing in space has shown us the importance of customization—of designing protection that works for various body types while remaining effective.”

StemRad’s flagship product, the 360 Gamma, developed to protect first responders during nuclear disasters, has benefited indirectly from these insights. “The idea is the same,” Milstein said, “whether it’s for space or Earth. We focus on protecting the most vulnerable areas of the body.”

“Space pushes the limits of what’s possible,” Houri added, “and simply by going there, it’s inspired us to create better solutions for those facing radiation exposure on Earth.”