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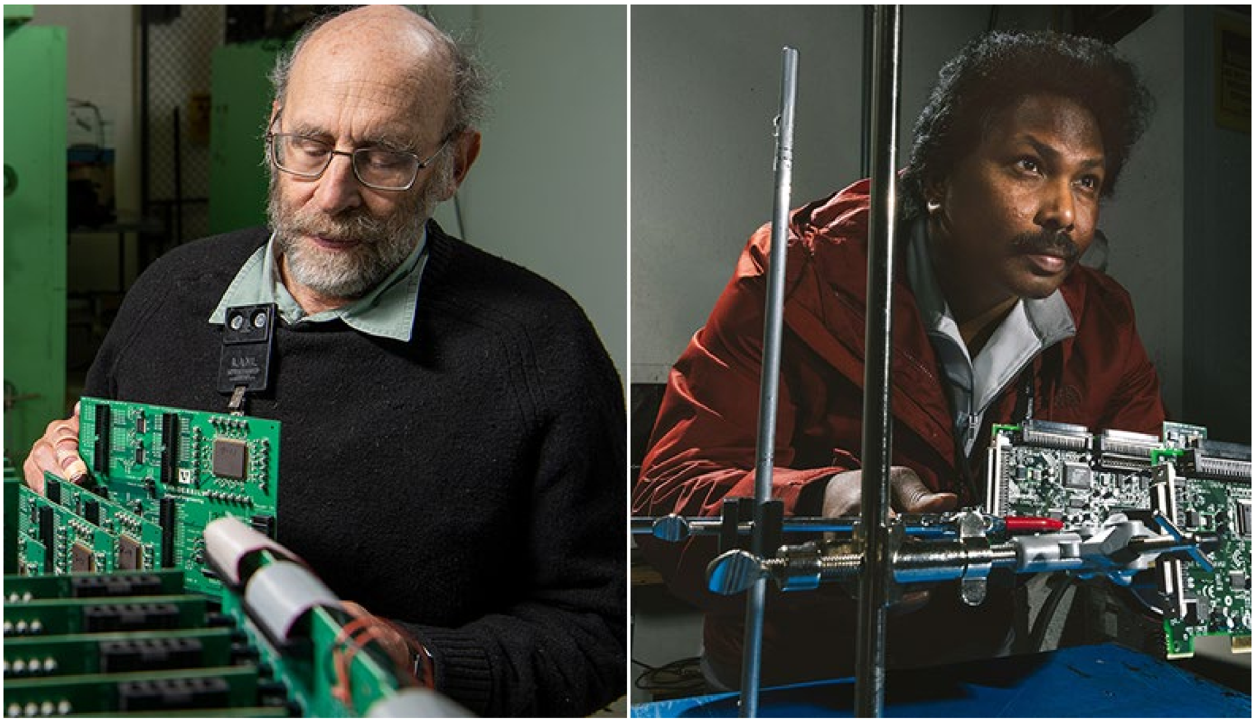
Hed: Ask an Expert: How does solar radiation impact everyday electronics

Dek: How the Lab tests the impact of cosmic rays on industry technology

By Ian Laird



Left to right: Stephen Wender and Kranti Gunthoti

On Saturday, Nov. 29, 2025, in the midst of Thanksgiving travel across the United States, thousands of planes had to be grounded for a software update. The cause? A realization that solar radiation could interfere with flight control computers on some fly-by-wire planes (aircraft that are controlled entirely electronically rather than with mechanical linkages between the cockpit and other parts of the plane). The previous month, a plane had suddenly lost altitude because of one of these incidents, which are often referred to as single event effects (SEEs). To better understand the relevance and likelihood of these events, **Stephen Wender**, a scientist in the Applied and Fundamental Physics group, and **Kranti Gunthoti**, also a scientist in the Applied and Fundamental Physics group, sat for an interview in this new edition of Ask an Expert. Together, they explained the science behind SEEs and how work at the Lab is impacting the safety, security and reliability of our technology-centric world.

What causes these SEEs, and why are these events so disruptive?

Kranti Gunthoti: We are constantly bombarded with cosmic rays from outer space — the nearest source being our sun but also from far away galaxies. These cosmic rays mostly consist of protons and some heavy ions. When those particles interact with atoms of our atmosphere, they'll produce showers of other particles: neutrons, electrons, protons. Neutrons, because they are uncharged, can travel through the atmosphere easily while other charge particles are absorbed and, because of our earth's magnetic field, will be deflected. These neutrons can interact with semiconductor devices, which mostly consist of transistors. When neutrons pass through semiconductors, they can cause nuclear reactions with the silicon atoms to produce charged particles. These charged particles lose energy and deposit charge in the semiconductor. When this charge is deposited in a sensitive region of a transistor, it can disrupt or damage the whole transistor. This process can create bit flips where a bit goes from a 1 to a 0 or a 0 to a 1, which corrupts the data. There are also more drastic failure modes that may actually destroy the device. These invisible particles can have very visible consequences.

Do we have an idea of what is happening at a particle level with SEEs?

Stephen Wender: The simple picture is that a neutron, which is produced by a cosmic ray, striking an atom in the atmosphere, will probably hit silicon because that's the most popular atom in semiconductors. This will kick out the silicon atom from its normal site. The silicon atom will go barreling through the semiconductor, losing energy and creating charge. This extra charge, that the electrical engineers didn't anticipate, can flip the bits and corrupt the data or do other damaging effects.

When one of these SEEs happens, is there a quick fix?

SW: A chip could just have the data corrupted or it could fail catastrophically where you might need to power it down and restart it or even replace the device. These are things that are very difficult to predict when the chip is designed. In fact, there's no way to reliably predict the failure rate. We just don't know enough about the design and the physics of what goes on to do that. To know its reliability, testing is crucial. The aircraft industry in general is particularly invested because it's a critical situation. If something fails, you don't get a blue screen of death, you may get a control problems at altitude. Also, since you're flying, at say 40,000 feet, the neutron intensity is about 300 times greater than at sea level, so something that will fail once a year in Silicon Valley will fail once a day in an airplane.

What was happening around Thanksgiving, and what updates were performed to get the planes ready to fly again?

SW: My understanding of the problem is that, in some planes, they installed new software, and the new software didn't adequately compensate for inherent failures in the semiconductor. I'll stress, though, that airplanes are very safe. They have a lot of redundancy. Occasionally they have a problem, but generally airplanes have redundant flight control devices and redundant computers, which work in lockstep. If they don't agree, they roll back to where they agreed and then go forward, losing just a few milliseconds worth of data.

You mentioned component testing, what is the history of testing, and what does the Lab do to support these efforts?

SW: The idea that neutrons can cause failures in semiconductors was, I think, first recognized by the Boeing Company in the mid-90s. They also recognized that the Los Alamos Neutron Science Center (LANSCE), and specifically the Weapons Neutron Research Facility (WNR), was an excellent place to test parts to find out how they behaved under neutron radiation. Since then, the testing program has grown to where just about every semiconductor company tests their parts at our LANSCE facility. The neutron spectrum produced by cosmic rays hitting the atmosphere is very, very similar to the spectrum of neutrons that we produce at the WNR. We designed it so they were similar, and this is huge value that we add to these companies in understanding how devices are going to perform in real life situations. To test their semiconductor devices, companies can put their boards in the beam, run it for an hour or day, and get an enormous amount of real-world experience. An hour of beam time is equivalent to about 100 years of exposure, so they can test their parts very extensively and quickly. We're the only place in the United States that can do this, and globally, we're generally considered the best place to do this because of our spectrum and intensity.

Looking to the future now, as technology becomes more integrated into our lives, will occurrences of SEEs increase, or is technology developing at a rate where advancements will mitigate these types of incidents?

SW: Chips are in everything nowadays: computers, cell phones, self-driving cars, data centers, household appliances. Your home appliances probably have more transistors than my whole university had when I went to graduate school. Chips are everywhere, and you might laugh if your refrigerator stops in the middle of the night, but it could be worse. Everybody wants smaller feature sizes to cram more functionality into cell phones while using less power. When we started at WNR, feature sizes were at the scale of hundreds of nanometers. Now they're down to sub-10 nanometers, so they're orders of magnitude denser. The failure rate per bit has gotten better, until very recently. With sub-5-nanometer feature size the failure rate seems to be increasing. As we rely more and more on transistor and semiconductor technology, SEE is a continuing and perhaps increasing problem, and it is not going away. A lot of people in universities and industry are looking at ways to try to make chips more robust. The military uses radiation hardened technology, which is pretty good. The problem is those rad hardened parts are expensive, their functionality is generally several generations behind, they use more power, more space and you can't take advantage of the latest technologies with rad hardened parts.

And is WNR equipped to continue providing that service, even if demand were to increase with further implementation of technology into society?

KG: We have two flight paths known as ICE I and ICE II, which have the best match to the natural cosmic ray-induced neutron spectrum. Matching the natural cosmic-ray neutron spectrum is essential for industry certification and qualification. If you go to other flight paths, you will change the neutron spectrum. But not everyone will care about that spectrum, so we have developed another flight path where people who don't care about the exact spectrum can test their devices. This third beam line, because it doesn't have quite the same spectrum, will not be used by industry to certify their parts, but there's a lot of research that can be done in terms of mitigation techniques, software development, hardware development, where scientists just want to see failures. By adding that third flight path, we've increased capacity 50%. This means more measurement, more users and faster turnaround times. As a result, we can now support both industry certification and research and development efforts and meet the growing demand from both communities for the foreseeable future.