# In Brian Walsh's group, interdisciplinary collaboration helps bring satellites into space and sensors to the moon

By Tess Joosse

Every day, hundreds of billions of dollars' worth of space infrastructure orbit Earth– everything from the global positioning system (GPS) satellites that power our smartphones' map capabilities to the International Space Station (ISS) that hosts crucial space research projects.

"We lean on it for a lot of things," Brian Walsh says of this fleet of satellites and instruments. "Like many of things, if it always works, you don't necessarily appreciate it. But things like GPS – that's become pretty integrated in everyone's daily life."

Walsh and his research team build tools to study the forces and conditions that interact with these essential satellites in the space environment – conditions known as "space weather."

"Space weather is very similar to terrestrial weather, but it's a little more applied," he says. "When we say 'space weather,' it typically means how the space environment interacts with our technology," explains Walsh, a Photonics Center faculty and Center for Space Physics faculty member who was recently awarded tenure and promotion to the rank of associate professor of mechanical engineering in the College of Engineering.

While space weather and Earth weather might be conceptually similar, Walsh says the former is much more intense. "The radiation environment is wild, unlike anything we see on Earth," he says of conditions in space. On a typical day in Boston, the temperature might go from 32 to 41 degrees Fahrenheit, or about 0 to 5 degrees Celsius. "That's not a very big change," Walsh says. But "in space, from a spacecraft orbiting the Earth, on the day side it can be over 100 Celsius -- hotter than boiling water. And on the night side, it can be lower than 0 Celsius. In just 40 or 45 minutes, it can go from boiling to below freezing."

As the temperature in space swings, the materials in a spacecraft expand and contract. "It impacts our electronics in really intense and spectacular ways," Walsh says. "Understanding how our technology, our electronics, and our materials interact and how those temperatures change -- that's really important."

Temperature change is just one feature of space weather than can affect what we do on Earth but there are many others, Walsh notes. During events known as geomagnetic storms, radiation from space slams into the Earth's atmosphere (the same phenomenon that gives rise to dazzling auroras in the sky). Pilots and flight attendants who work on airplanes are regularly exposed to higher doses of this radiation than those of us who work on the ground (as are astronauts, at even greater doses), and flights sometimes have to be diverted during these large space storms to ensure the humans onboard aren't exposed to the bursts of cancer-causing radiation, Walsh says.

The ISS and the many satellites orbiting Earth carry sensors to monitor this space radiation. But the instruments currently available are limited in energy and can only cover segments of the total range a scientist might need to measure. Walsh and his team are building an integrated circuit that would allow electronic sensors to cover this large range. They've dubbed it the Boston Extended Amplitude Range Chip, or BEAR. "We want to develop one piece of electronics that can do the whole range from very low to very high … many orders of magnitude more than anyone's ever done," Walsh says of the project.

The lab also builds X-ray sensors with which to image space weather. For Earth weather, satellites from the National Oceanic and Atmospheric Administration (NOAA) take pictures of clouds swirling across the planet and measure fronts for weather forecasting. In space, chemical reactions between the upper Earth atmosphere and material from the Sun emit X-rays that can be imaged and analyzed in a similar way, Walsh says.

"You can't see it with your eyes, but if you build a special X-ray imager, you could," he explains. "We have developed both the theoretical underpinnings and the observational techniques to image clouds, motion of boundaries in space, and motion of radiation in space through X-ray images," he says of his group's work.

Walsh and his colleagues are currently working on special optics that widen the field of view of the telescopes that can image these X-rays. "People have used lenses for decades that could give you a tiny, pencil-beam field of view much smaller than a degree," Walsh says. "We have worked with our collaborators to develop optics that can give you tens of degrees field of view, orders of magnitude bigger than people have done in the past. That allows you to take big pictures, instead of just a pencil beam."

These optics will go into an instrument called the Lunar Environment heliophysics X-ray Imager, or LEXI for short. It is slated to travel to the moon in 2024 as part of NASA's Artemis program and is being built in collaboration with NASA Goddard Space Flight Center, Johns Hopkins University, University of Miami, University of Kansas, and the University of Leicester.

"The moon is a fantastic place to look back at Earth and the Earth space environment," Walsh says. From this vantage point, the LEXI instrument will train its wide view on our planet and take images of the interactions between the Earth's magnetic fields and the solar wind, sending the data back down to the team nearly in real-time.

Once LEXI is on the lunar surface, the researchers will have only about two weeks to collect data until it reaches the night side of the moon, where temperatures are so cold (sometimes reaching below -200 Celsius) that the instrument's electronics will die. That experimental pressure might seem intense, but Walsh says it's also motivating and thrilling to the group.

"A feature of our research is that there are often fairly strong deadlines," he laughs. "You've got to make a launch, or you've got to deliver this thing to the rocket, and sometimes that's stressful," he says. "But the spirit of the team and the teamwork makes these hard deadlines exciting."

Bringing a sensor to life, sending it to the moon, and analyzing the data it collects requires many hands and a wide array of skills and expertise. Walsh's lab works closely with outside institutions including those on the LEXI project, as well as fellow researchers at BU. "The Photonics Center is the perfect place to have this type of interdisciplinary group," he says.

The researchers within Walsh's lab come from many scientific backgrounds, counting astronomy, mechanical engineering, and electrical and computer engineering students among their ranks. This diversity of expertise isn't just essential in building complex space technology – it also creates an environment that helps students become better scientists, Walsh says.

"When we get to group meetings, the student who has only thought about developing integrated circuits is now forced to describe her work in a way in which an astronomy student who doesn't have any electrical engineering background can understand it," Walsh says. "I always love seeing the progress students make over their graduate career in being able to communicate in that way."

The ability to explain their research to scientists from different backgrounds and non-scientists alike is vital, Walsh says, and he relishes watching students grow as communicators. "I really get excited seeing that, because we can make all the progress we want in our narrow fields, but it's important to be able to talk about these things with the broader public, with our family, with our colleagues, with people you see on the street."

In many of the projects in his lab, success can be measured by completing a launch or getting a machine to function properly. But Walsh says the best way to get envelope-pushing tools and technology to work is to make sure the people building them are interested in what they're doing.

"My approach is often to focus on encouraging collaboration, encouraging interpersonal interactions, encouraging people to feel connected to the project, rather than [just be] a person that builds a widget and then gets detached from the project," Walsh says. "If people are successful, engaged, and feel connected to the projects, the products that come out of them or the team will be successful, too," he says.