Electrical and Computer Engineering

Spotlight

PUSHING THE BOUNDARIES

NC STATE UNIVERSITY

FROM THE **DEPARTMENT HEAD**

It has been great to have students back on campus during the fall 2021 semester! Although masks are a constant reminder that the pandemic is not yet over, almost all of our classes are back in person and the campus is buzzing again. In particular, our laboratory courses are back in full swing offering world-class hands-on experiences.

As students returned to the teaching labs, they found a number of positive changes. While there were few people on campus, our IT and Operations team took advantage of the opportunity to make a number of improvements and upgrades to our labs. Improvements included replacing the seating in most of the ECE teaching labs, updating the instruments in four teaching labs, repainting the teaching labs, and updating the signage in the Troxler Design lab and the department. In addition, availability of 3D printers has been expanded and a new WAZER water cutter was installed in the ECE MakerSpace.

Just as our faculty and students found a way to continue their coursework through the pandemic, research has continued as well. In this issue of the Spotlight we highlight an eclectic sampling of recent research: advanced wireless research, hardware security vulnerabilities, and hurricane forecasts.

A significant milestone has been achieved this fall by our National Science Foundation (NSF)-sponsored platform for advanced wireless research: AERPAW (Aerial Experimentation and Research Platform for Advanced Wireless). This is one of only four such platforms in the US sponsored by the NSF. The goal is to provide testbeds for advanced wireless research by university and corporate researchers. After extensive planning, design, and installation, the first phase of general availability to the research community was announced in November. The platform focuses on research into both advanced wireless connectivity and airspace operations using drones.

Professor Aydin Aysu's research group has developed a software toolkit that enables researchers to search for security vulnerabilities in iPhones, and used this toolkit to identify a new vulnerability.

Professor Michael Kudenov and his collaborators are taking inspiration from the eyes of a shrimp to develop an tiny optical sensor capable of hyperspectral and polarimetric imaging.

Finally, I am truly grateful for the generosity of our alumni who go out of their way to give back so that the next generation of students will have the best possible opportunity to launch a satisfying career in electrical and computer engineering. In this issue, we highlight the generosity of one of our relatively recent graduates, Dr. Ioannis Papapanagiotou.

Dr. Daniel D. Stancil
ECE Department Head

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NUMBERS **AT A GLANCE**

63 Tenured/Tenure-Track

$41M+ Research Expenditures

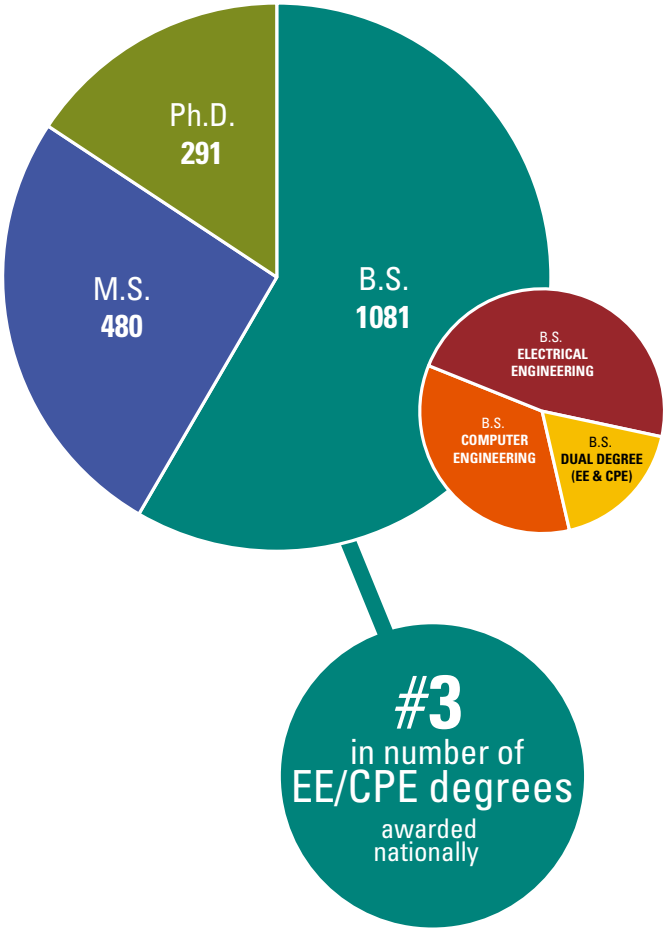
22 NSF CAREER Awards

24 IEEE Fellows

2 National Academy of Engineering Members

135 Undergraduate ECE Scholarship Awardees

66,758 Research Lab Square Footage



According to ASEE 2020

BEST
U.S.News & WORLD REPORT

#6

Best value among public universities nationally

according to U.S. News & World Report

#8

University in the U.S. to study Electrical Engineering

according to ShanghaiRanking's Global Ranking 2021

AERPAW

TESTBED FOR ADVANCED RESEARCH ON WIRELESS CONNECTIVITY AND UNMANNED AERIAL VEHICLES

The NSF Platforms for Advanced Wireless Research (PAWR) Project Office announced in November 2021 the general availability of the AERPAW wireless testbed for network communications and unmanned aerial systems (UAS) research. Located at NC State, the AERPAW – or **Aerial Experimentation and Research Platform for Advanced Wireless** – testbed is designed to accelerate the integration of UAS into the national airspace and enable research into advanced wireless technologies supporting dynamic, mobile, and airborne networks.

In phase one of operations, the AERPAW testbed includes two fixed network nodes on Centennial Campus, and one tower with a fixed node deployed at Lake Wheeler Field Laboratory, an agricultural site owned by the university. These fixed nodes combine with two aerial-mounted nodes on custom multicopter drones, and one portable node attached to a ground-based rover. All nodes feature software defined radios that can be configured to create different types of network environments using a variety of open source software stacks.

Initially, AERPAW is supporting UAS experiments that allow researchers to collect signal measurement data with a single drone flying a path pre-programmed by the researcher. Factoring in the variables of speed, direction, and location in space, this data collection will provide valuable insights into radio performance and opportunities for network optimization. Future experiments supported will include dynamic on-the-fly vehicle control, new network nodes being built out across the testbed footprint, and the integration of commercial radio hardware and software alongside open source network components.

"The AERPAW platform uniquely combines programmable wireless networking with custom drones to enable research into both airspace operations and wireless connectivity through 4G, 5G, and beyond," said **Ismail Guvenc**, AERPAW Principal Investigator, and professor of electrical and computer engineering at NC State. "Given significant public and private sector interest, we're excited to see where the first experiments lead, and what early insights may emerge from the research community."

"The PAWR program set in motion the development of four wireless testbeds to be used as shared national infrastructure assets," said Gurdip Singh, Division Director for Computer and Network Systems at the National Science Foundation. "AERPAW marks the third platform to reach general availability, and the first with a direct focus on application-level research through its use of unmanned aerial vehicles. We couldn't be more pleased to recognize the progress made by the AERPAW team and to welcome researchers to the North Carolina platform."

RAISING UP THE NEXT GENERATION

Even while completing his degree as an undergraduate student in Greece, Ioannis Papapanagiotou already had his eyes set on research with the WolfPack. With a dream to be an academic, he would go on to complete a Master's (2009) and Ph.D. (2012) in Computer Engineering at NC State and chart a path continuously bridging the gap between academia and industry.

Now, as a Senior Engineering Manager at leading cloud services company Snowflake, as well as a research assistant professor at the University of New Mexico, he's ensuring that future computer engineering and computer science graduate students—and especially those who share Greek culture and heritage—have every opportunity to succeed and engage in cutting edge research with his newly endowed **Papapanagiotou Graduate Student Award**.

"I started observing that, based on statistics I was reading online, that many colleges were having a hard time attracting international students [during the pandemic]," explained Papapanagiotou. "I thought how I'd be able to facilitate these students coming to the United States?"

"Having a diverse group of students at NC State benefits the university, but also benefits the students that get an amazing education at NC State."

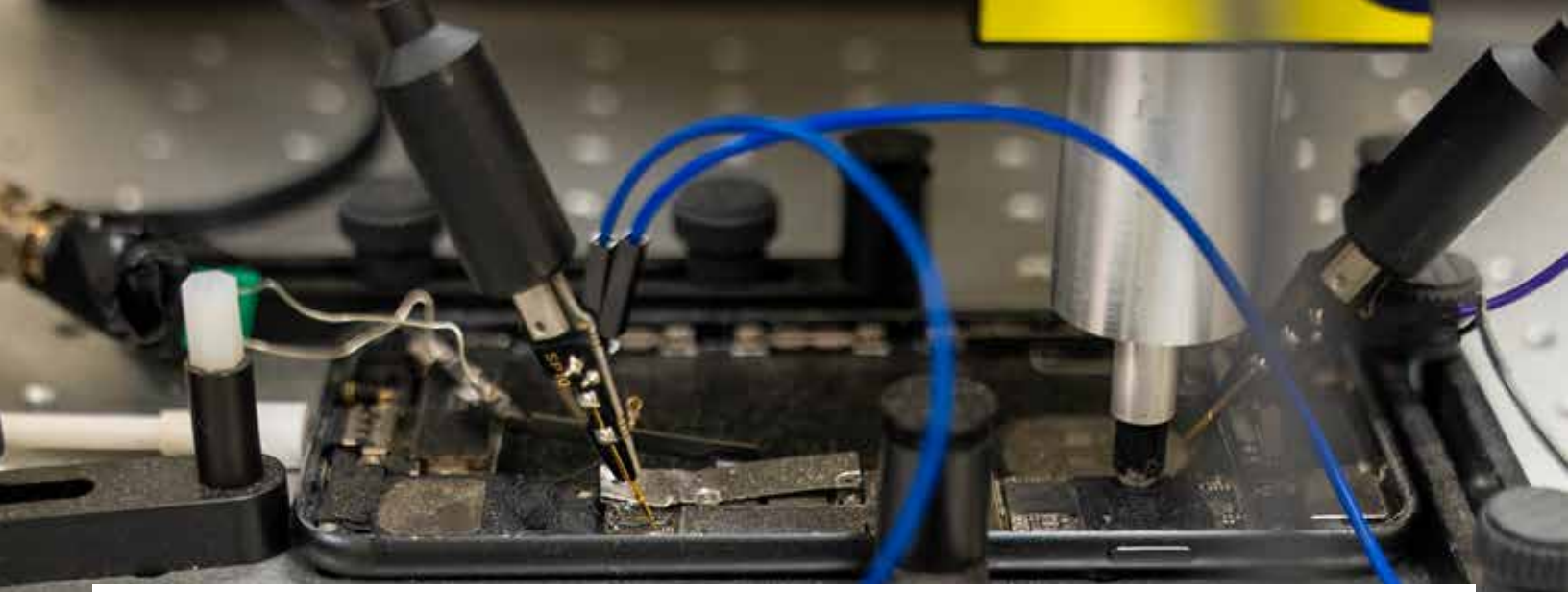
The university's standing as a leading research university with some of the highest-ranked electrical and computer engineering programs in the world brings the brightest minds from around the world to North Carolina, with a 2015 report by EMSI showing $6.5B in annual economic impact to the state alone.

"I had these experiences, it was a great experience for me, and I had the support both from the department and the college while I was a student to do my studies and focus on my research," he recalled.

However, while pursuing his doctoral studies, he had already started working to ensure that his fellow graduate students felt at home in the department and those incoming international students had the resources and knowledge to succeed. Leading a resurgent ECE Graduate Student Association (GSA) as President, he championed social and career events, industry speakers, and a website filled with resources, scholarship opportunities, and vital information to help incoming international students get settled in Raleigh and the university.

"Once you get admitted by a college in a different country, it's like a dream," he recounted. "You want to be part of that dream, and having that structure helps a lot in how you start your career."

After leaving NC State, Papapanagiotou's career has taken him to Purdue University, IBM, Netflix, and now Snowflake. His experience and work on data platforms and cloud computing in the industry provide a perspective that helps shape the academic lives of future students, through collaborative work with faculty including NC State's **Yannis Viniotis**, who received the first Snowflake faculty fellowship, and as they work to create new courses to prepare the next generation of engineers.



RESEARCHERS DEVELOP TOOLKIT TO TEST APPLE SECURITY, **FIND VULNERABILITY**

Researchers from NC State have developed a software toolkit that allows users to test the hardware security of Apple devices. During their proof-of-concept demonstration, the research team identified a previously unknown vulnerability, which they call iTimed.

"This toolkit allows us to conduct a variety of fine-grained security experiments that have simply not been possible on Apple devices to this point," says **Aydin Aysu**, co-author of a paper on the work and an assistant professor of electrical and computer engineering at NC State.

Apple is well known for creating integrated devices. The design of the devices effectively prevents people from seeing how the devices function internally.

"As a result, it has been difficult or impossible for independent researchers to verify that Apple devices perform the way that Apple says they perform when it comes to security and privacy," says Gregor Haas, first author of the paper and a recent master's graduate from NC State.

However, a hardware vulnerability was uncovered in 2019 called checkm8. It affects several models of iPhone and is essentially an unpatchable flaw.

"We were able to use checkm8 to get a foothold at the most fundamental level of the device – when the system begins booting up, we can control the very first code to run on the machine," Haas says. "With checkm8 as a starting point, we developed a suite of software tools that allows us to observe what's happening across the device, to remove or control security measures that Apple has installed, and so on."

The researchers stress that there are practical reasons for wanting to have third parties assess Apple's security claims.

"For example, we want to know the extent to which attacks that have worked against hardware flaws in other devices might work against Apple devices," Aysu says.

It didn't take the researchers long to demonstrate how useful their new toolkit is.

While conducting a proof-of-concept demonstration of the toolkit, the researchers reverse-engineered several key components of Apple's hardware and identified a vulnerability to something they named an iTimed attack. It falls under the category of so-called "cache timing side channel attacks," and effectively allows a program to gain access to cryptographic keys used by one or more programs on an Apple device. With the relevant keys, outside users would then be able to access whatever information the other affected program or programs on the device had access to.

"We haven't seen evidence of this attack in the wild yet, but we have notified Apple of the vulnerability," Aysu says.

The NC State team is sharing much of the toolkit as an open-source resource for other security researchers.

"We also plan to use this suite of tools to explore other types of attacks so that we can assess how secure these devices are and identify things we can do to reduce or eliminate these vulnerabilities moving forward," Aysu says.

MANTIS SHRIMP INSPIRES **NEW BREED OF LIGHT SENSORS**

Inspired by the eyes of mantis shrimp, researchers have developed a new kind of optical sensor that is small enough to fit on a smartphone but is capable of hyperspectral and polarimetric imaging.

"Lots of artificial intelligence (AI) programs can make use of data-rich hyperspectral and polarimetric images, but the equipment necessary for capturing those images is currently somewhat bulky," says **Michael Kudenov**, co-corresponding author of a paper on the work and an associate professor of electrical and computer engineering at NC State. "Our work here makes smaller, more user-friendly devices possible. And that would allow us to better bring those AI capabilities to bear in fields from astronomy to biomedicine."

In the context of this research, hyperspectral imaging refers to technologies that can break down the visible wavelengths of light into more narrow bands. The human eye can't distinguish between these slight variations in color, but computers can – making hyperspectral imaging valuable for tasks such as determining the chemical composition of objects in the image.

Polarimetry refers to the measurement of polarization in light, which is data that can be used to determine the surface geometry of an object in the image. For example, is the surface rough or smooth? And what is the angle of the surface relative to the light source?

Light is famously tricky to describe, since it is both a particle and a wave. If a wave of light is moving from Point A to Point B, the path between those two points is the direction of the light. If you think of the light as a particle, it is moving in a straight line from Point A to Point B. But the light is also an electromagnetic field that fluctuates like a wave. If you picture that wave as wiggling up and down or side to side as it travels from Point A to Point B, polarization is a measurement of the orientation of that wave along the path.

While there are larger devices that are capable of capturing hyperspectral and polarimetric images, smartphone-sized imaging technologies have run into significant challenges.

For example, the design of cell phone camera technologies results in very slight errors in the alignment of the different wavelengths of light in the final image. The result is not a big deal for taking family photos, but is problematic for scientific image analysis. And the problem is exacerbated when a camera can capture more colors, as is the case with hyperspectral technologies.

The creators of the new light sensors were inspired by the eyes of mantis shrimp, which are exceptionally good at accurately capturing subtle gradations of color. So, the researchers created an organic electronic sensor that mimics the mantis shrimp's eye. It's called the Stomatopod Inspired Multispectral and POLarization sensitive (SIMPOL) sensor.

The researchers developed a prototype SIMPOL sensor that can simultaneously register four spectral channels and three polarization channels. By comparison, the charge-coupled devices used in smartphones have only three spectral imaging sensors, which detect red, green, and blue; and only two polarization channels. In addition, the SIMPOL prototype can measure the four color channels and three polarization channels at one point, whereas CCDs rely on imaging sensors spread across several points.

"SIMPOL's color channels can discern spectral features 10 times narrower than typical imaging sensors; in other words, it is 10 times more precise," Kudenov says.

NC STATE UNIVERSITY **Electrical and Computer Engineering**

NC State University
Department of Electrical and Computer Engineering
Campus Box 7911
Raleigh, NC 27695-7911

ece.ncsu.edu

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"I owe my good fortune to being able to start out at NC State. That kind of success needs to be returned."

Maurice Partin
B.S. EE 1963

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