NC STATE UNIVERSITY

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results.

Research and Graduate Studies
at North Carolina State University

SAFETY AND SECURITY RESEARCH

Protection, Prevention, and Response

results.

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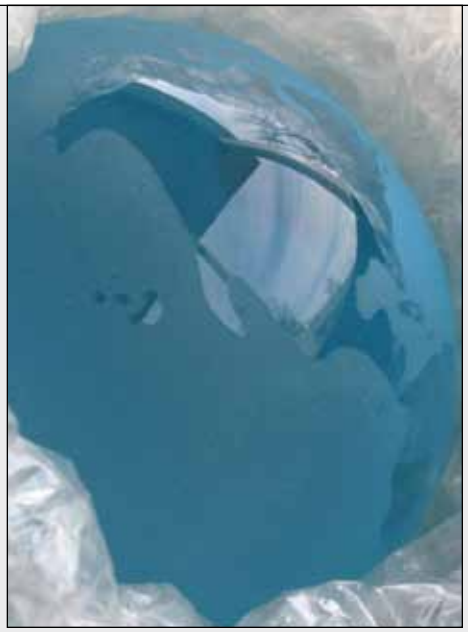
NC State Research: Protecting the Public



Let's face it. The world can be a dangerous place. Whether it's from a suspected terrorist trying to detonate explosives on a jet, tainted peanut butter killing dozens of people and sickening hundreds more, or hackers unleashing the latest virus on millions of computers and disrupting business transactions, today's needs for protective measures require the efforts of the best and brightest in developing high-tech solutions. NC State researchers are working in a broad range of fields to create more protection against menacing elements, improving safety and security for government, business, and the public.

Such research has become more of a focus at NC State in recent years as University faculty and students conduct innovative safety and security efforts, integrating fields as diverse as chemical engineering, anthropology, soil science, textiles, computer science, nuclear physics, remote sensing, plant pathology, microbiology, and supply chain management. "We work hard to connect our researchers in interdisciplinary ways," says Vice Chancellor for Research and Graduate Studies Terri Lomax. "Safety and security issues, whether faced by individuals, the state, or the nation, are complex problems that call for expertise and creativity across multiple disciplines."

NC State has already formed several research initiatives to handle safety- and security-related projects, Lomax says. She points to NC State's Secure Open Systems Initiative to address threats to software and computer operating systems, the Textile Protection and Comfort Center to produce gear that insulates first responders from harm, and the Forensic Sciences Institute to support law enforcement in solving crimes. NC State also is teaming with the University of North Carolina at Chapel Hill on a $5 million Department of Homeland Security project to connect disparate databases for better monitoring of disease outbreaks and other biohazards. "These are high-priority issues for the nation and the world," Lomax says. "Because of its unique combination of strengths, NC State has developed many innovative approaches that show great, near-term promise in addressing some of the most intractable safety and security problems."

Safety and security issues are complex problems that call for expertise and creativity across multiple disciplines.

This issue of RESULTS features research that promotes safety and security on various fronts. It also highlights achievements across the full range of NC State's research in the 2008–09 Research and Graduate Studies Annual Report summarized in the last four pages.

Filter Protects Blood Transfusions

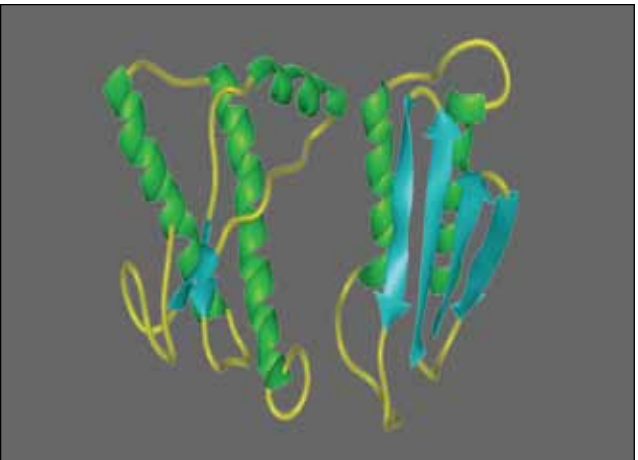
Dr. Ruben Carbonell tapped libraries of small molecules to pinpoint some that would bind to the infective proteins in variant CJD so they could be filtered from donated blood before a transfusion.

Mad Cow Disease jolted the United Kingdom in the 1980s, crippling the beef industry and panicking the public as scores of people—not just cattle—succumbed to the insidious infection known in humans as variant Creutzfeldt-Jakob Disease (CJD). Eating tainted beef was the most obvious means of transmission for the disease, but blood transfusions were also seen as a potentially deadly source of infectivity. Research by Dr. Ruben Carbonell, Frank Hawkins Kenan Distinguished Professor of Chemical and Biomolecular Engineering, could soon significantly reduce the threat of contracting CJD from donated blood.

The human effects of Mad Cow Disease are similar to those of Alzheimer's disease.

CJD is caused by an accumulation of misshapen proteins, called prions, in the brain. Prions are abnormally folded, and their presence induces other proteins to adopt abnormal structures. Prions form plaques similar to those in Alzheimer's disease, creating holes in the brain tissue. The infection is incurable and fatal.

Portions of a prion protein, right, unfold and adopt an abnormal structure and then induce normal protein molecules, like the one at left, to become misshapen as well.



Fearing prions could be in blood donated by infected people, Red Cross officials destroyed countless units stored in blood banks and banned donations from anyone in the U.K. who received a transfusion after 1980. They also turned to Carbonell, who had been studying small molecules that bind to specific proteins, to help find a way to filter prion infectivity and ensure that donated blood could safely be given to patients in need.

In designing the filters, Carbonell tapped libraries of small molecules, using assays to pinpoint some that bind to prions. He then sequenced these molecules to determine their structure, so they could be replicated easily on a large scale. Porous plastic particles were then impregnated with the molecules, and the particles were sandwiched between membranes of nonwoven fabric using a process developed by the Nonwovens Cooperative Research Center in the College of Textiles. Several of these sandwiches were layered atop each other to create a prototype filter. A University of Maryland researcher working with Carbonell tested the device by giving infected blood to hamsters. The animals that received unfiltered transfusions all developed CJD-like conditions, while the hamsters that received filtered blood showed no signs of infection. "The results were quite stunning," Carbonell says.

After extensive studies, a British safety panel recently recommended a final version of the filter for removing prions from donated blood, a key step to final adoption of the product in the U.K. Other countries, from Japan to France to Canada, also have expressed interest in the filters. "With the removal of prions from blood, the risk of CJD transmission during blood transfusions is significantly reduced," Carbonell says. "This device will bring great peace of mind to patients requiring this vital treatment."

Over 8 million units of blood are needed each year for transfusions in the U.S. and U.K. alone.

Dr. Gary Payne has sequenced the genome of the fungus that produces aflatoxin to find ways to block it and to help crops develop resistance to toxin accumulation.

Food Safety from

Dozens of cruise ship passengers felled by gastrointestinal illness. Hundreds across the U.S. sickened by *E. coli* in spinach and *Salmonella* in tomatoes and peppers. Scores killed in Kenya by a toxin in moldy corn. The headlines in recent years have repeatedly ratcheted up concerns about food safety among consumers, regulators, and farmers. NC State researchers are trying to calm those fears by attacking the problem on several fronts, such as building resistance in crops, detecting germs in advance, and tracking disease outbreaks.

An estimated 4.5 billion people worldwide are exposed each year to aflatoxin, a fungal compound known to suppress the human immune system and cause liver cancer. Exposure is most prevalent in developing countries in Africa and Asia, says Dr. Gary Payne, William Neal Reynolds Professor of Plant Pathology. A subtropical fungus, *Aspergillus flavus*, produces the toxin in the seeds of crops like corn and peanuts, which aren't well adapted to the hot, dry growing conditions. "Many of these places are so poor," he says, "the people don't have any choice but to eat the crops, even if they know the aflatoxin is present."

Payne has studied aflatoxin for about 30 years, starting in the realm of *aspergillosis* management. He has since moved to the world of genetics and bioinformatics to find ways to develop resistance to toxin accumulation and predict the presence of other potentially lethal compounds in the fungus. He helped sequence the *Aspergillus* genome and determine which genes are responsible for aflatoxin production. He's now using assays to measure the expression of the genes under various conditions. "We need to figure out which genes are important to making the fungus a pathogen so we can find a way to block them," he says. On the opposite side of the equation, Payne and other researchers are analyzing the genetics of corn to determine which of its genes might be vital to creating resistance to aflatoxin accumulation and how their expression can be increased in high-yield lines of the crop.

NC State researchers are attacking the food safety problem on several fronts, building resistance in crops, detecting germs in advance, and tracking disease outbreaks.

Dr. Lee-Ann Jaykus discusses ways to detect norovirus in food with Dr. Hari Dwivedi, a 2009 graduate in comparative biomedical sciences.

Across campus, building resistance to norovirus, a leading cause of food-borne illnesses, is an equally challenging proposition. Even recovering from a norovirus infection brings only temporary immunity, says Dr. Lee-Ann Jaykus, a professor in the Department of Food, Bioprocessing & Nutrition Sciences. Norovirus disease has gained notoriety in recent years for shutting down schools and

Farm to Fork

Tracing the origin of fresh produce at the State Farmers Market in Raleigh is easier for Dr. Benjamin Chapman than the task consumers face at the supermarket.

curtailing Caribbean cruises by spreading rapidly among groups in close quarters. It is often spread by a lack of hand washing by food handlers or by fecal contamination of shellfish harvesting areas or water used to irrigate crops. Jaykus' research has shown that the virus can last for weeks in foods and for months on surfaces, and only a concentrated dose of chlorine bleach can overpower the germ.

"With produce eaten fresh, anything the food comes in contact with can contaminate it."

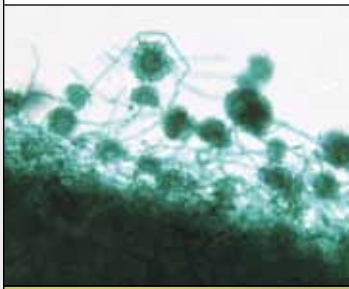
Jaykus is working on a sensor to detect noroviruses, both to test suspect food samples to determine the origin of an outbreak and for environmental monitoring of oyster beds and other potential contamination sites. She's using a technique known as reverse transcription polymerase chain reaction that converts norovirus RNA into DNA, which is then copied repeatedly. Amplifying the virus' genetic material makes it sufficiently concentrated to make detection possible in a food or water sample. For the sensor to work properly, it must also break down other components of the food without damaging the virus. "It only takes a few particles of norovirus, maybe 10, to make you sick," she says. "We have to be able to detect minute amounts of the virus in a food sample of 25 grams or so."

Meanwhile, for Dr. Benjamin Chapman and the rest of the NC Fresh Produce Safety Task Force, tracing the source of a food-borne pathogen is as important as knowing what—a norovirus, *E. coli*, or some other germ—caused the outbreak. Formed three years ago, the task force includes members from NC State and NC A&T State University, state and federal agriculture officials, industry representatives, and growers. It is dedicated to promoting practices "from farm to fork" that will limit the potential for contamination. "With produce eaten fresh, anything the food comes in contact with can contaminate it," Chapman says, "and because you're not cooking it, there is no kill step for bacteria."

A food safety specialist and assistant professor in the Department of 4-H Youth Development and Family & Consumer Sciences, Chapman has studied how various types of produce move from the field to consumers to help improve "traceability," which he says could benefit North Carolina farmers in the future. For example, when *Salmonella*-tainted tomatoes began sickening people in 2008, farmers in the state couldn't prove that their tomatoes weren't the source of the outbreak. Much of their crop then ended up in lower-margin processed foods. "A lot of product moves around, and tracking it isn't always simple," Chapman says. He found smaller produce like berries easier to track than melons and other large produce because berries are usually packed on the farm in labeled cartons instead of being put in bins that include produce from numerous fields.

Diane Ducharme, a Cooperative Extension Service horticulture and food safety specialist at the NC Research Campus in Kannapolis, is using Chapman's findings to help large and small farmers improve their ability to track their produce as it moves to consumers. The procedures need to be scalable, she says, because small farmers often have limited finances. "Food safety is pretty much an all-or-nothing proposition," Ducharme says. "You need to accommodate everyone, or it doesn't work."

Microscopic views of *Aspergillus* and *E. coli*.



Dr. Marian McCord became interested in fighting mosquitoes and the spread of malaria after studying ways to make protective bed nets last longer.

Professor Nets Idea to Fight Malaria

At least a million deaths occur every year due to malaria—90 percent of them in sub-Saharan Africa—because the very efficient *Anopheles gambiae* mosquito ensures high transmission. "It's really, really hard to do anything to a mosquito to keep it from biting you," says Dr. Marian McCord, an associate professor of textile engineering at NC State. "We need a way to injure mosquitoes without using toxic chemicals."

"If we can shorten a mosquito's lifespan by even a day or two, we might be able to keep it from transmitting malaria."

How does someone in the College of Textiles get involved with mosquitoes? It started out as a proposal to the Centers for Disease Control and Prevention to find ways to increase the lifespan of the mesh nets hung over beds in many tropical countries to keep the bugs at bay overnight. The thin mesh is prone to tearing, often rendering it useless. McCord's proposal didn't win funding, but it was enough to pique her interest in finding ways to stop mosquitoes. She notes that the bloodthirsty insects are becoming resistant to the insecticides often applied to nets to boost their effectiveness.

Malaria is a mosquito-borne infectious disease widespread in tropical regions.

After obtaining seed funding from the University and consulting with Drs. Michael Roe and Charles Apperson in the Department of Entomology for the best way to attack mosquitoes, McCord and some biomedical engineering students went after the bugs with a vengeance. The students anesthetized the insects and then disabled their legs or antennae, but they found that even hobbled mosquitoes were able to bite. They then tested ultra-smooth and particulate-laced surfaces for the netting to try to make it difficult for mosquitoes to land.

"We need a way to injure mosquitoes without using toxic chemicals."

One of the particulates, diatomaceous earth, was found to be particularly effective. Instead of hindering landing mosquitoes, the chalky, ground-up remains of fossilized algae proved to be insecticidal, McCord says. The abrasive particles, which are safe for humans, disrupt the waxy layer that makes up a mosquito's exoskeleton, causing the insect to dehydrate and die. Damaging the exoskeletons could also make mosquitoes more susceptible to other infections, she says. "If we can shorten a mosquito's usual two-week lifespan by even a day or two," she says, "we might be able to keep it from transmitting malaria to someone."

McCord also is looking at stopping mosquitoes by more traditional means—for textiles researchers, at least. She's working with German researchers on bite-proof fabrics, such as an extremely tight weave that a mosquito's proboscis can't fit through or nonwoven fabrics that don't provide a straight shot at the skin. "Hundreds of millions of people are infected by disease-carrying mosquitoes every year," McCord says. "We've got to use every safe tool possible to fight these insects and the spread of disease."

Counter-Terrorism Device Finds IEDs

Glenwood Garner, a Ph.D. student in electrical engineering, aligns a rock inside a test chamber so it can be blasted with sound waves to determine the unique vibration pattern of its molecules.

Whenever Capt. Kirk and Mr. Spock found themselves on strange planets in the old *Star Trek* television series, Spock would always check the readings on his trusty tricorder to see if potential threats were nearby. "What a tricorder did was give them total awareness of their surroundings, and that's what we're after," says Dr. Michael Steer, Lampe Professor of Electrical and Computer Engineering, whose research at NC State is moving such a device closer to the realm of reality.

"We want to be able to detect things at a distance so a convoy moving at 60 miles per hour has time to stop."

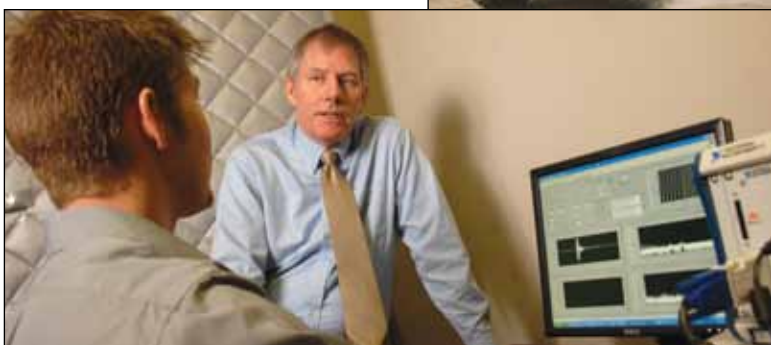
Steer has worked for years on defense grants to improve radio communication in the field by limiting signal disruptions. After 9/11, he was asked to take his work to a new level and assist with counter-terrorism efforts. Now, his expertise with electromagnetic fields is helping create a portable detector so troops can locate roadside bombs and pick suicide bombers out of a crowd. "We're finding the acoustic and radar signatures of different objects," he says, "so we can tell the difference between a rock and an IED (improvised explosive device)."

Inside a chamber lined with echo-dampening foam spikes in Steer's Centennial Campus lab, his research team blasts objects with sound waves at up to 156 decibels. (By comparison, the sound produced by a jet engine is about 120 decibels.) Every object has a unique "ringing" or vibration pattern, Steer says, and bouncing sound waves off an item in the chamber helps isolate its pattern. Steer's research team has compared rocks similar to those found in Iraq and Afghanistan with the hard foam insurgents use to disguise IEDs.

The team also uses microwaves to detect metal in the various objects to further refine the radar signature of each. By varying the frequency of the radar wave or adjusting the amplitude, Steer can tweak the signal into a non-linear wave, which he says exaggerates the signature and makes it easier to identify by U.S. troops. "We want to be able to detect things at a distance so a convoy moving at 60 miles per hour has time to stop," he says, "and we can get better response by using sound and radar at the same time."

For his device, which has been deployed in two war zones, Steer was recently awarded the U.S. Army Commander's Award for Public Service by the commanding general of the U.S. Army Research, Development and Engineering Command. At the public ceremony in March, Major General Nick Justice said, "This is a game-changer in modern warfare. It changed the way the enemy behaves." He added, "We had lost the capability to operate in that environment, and this put us back on the battlefield and gave us the ability to go out there knowing we can protect the young soldiers' lives and engage the enemy and not have to hide behind the castle walls."

Dr. Michael Steer and Jonathan Wilkerson, a Ph.D. student in electrical engineering, discuss the results of tests Steer's research team is conducting to develop a portable detector the military can use to locate roadside bombs.

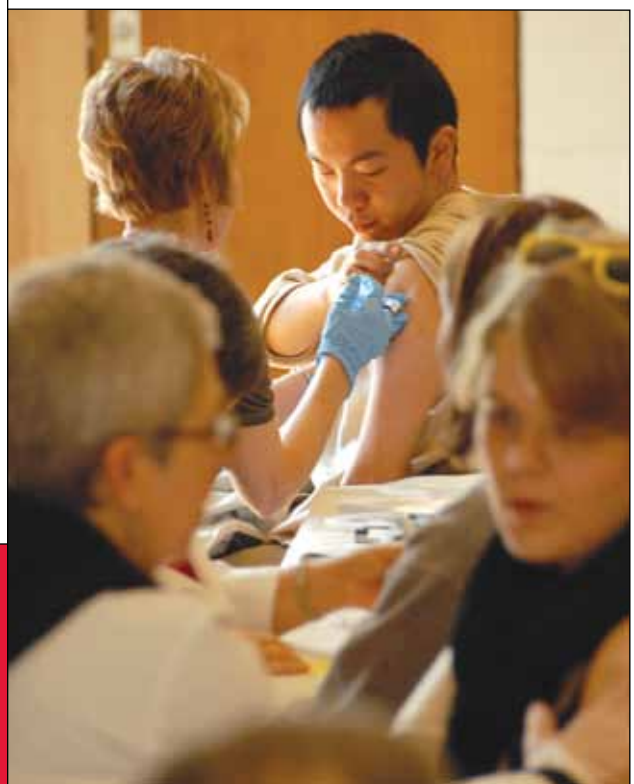


Dr. Robert Handfield interviewed company executives and trade group representatives in key industries to formulate some basic rules businesses should follow to limit the impact of a pandemic.

Preparedness is Key to Outlasting Pandemics

The chaotic scenes were played out repeatedly nationwide in recent months. Panicky parents lined up with their children for hours at vaccination clinics to get immunized against the H1N1 virus, only to have the clinics run out of their limited supplies of the flu vaccine. Dr. Robert Handfield, NC State's Bank of America University Distinguished Professor of Supply Chain Management, says the situation will likely occur on a much larger scale and jolt much of the U.S. economy in the future unless businesses better prepare for an influenza pandemic.

After a drug company asked Handfield how it could best build capacity to handle a viral outbreak that's nearly impossible to predict, he began looking at the overall issue of pandemic preparedness. Because most economic resources are in the private sector, he interviewed company executives and trade group representatives in key industries, such as health care, financial services, food distribution, and utilities. "The biggest concern, beyond the tragic fatalities, is worker absenteeism," says Handfield, who had to miss a few days of class himself last fall when his wife and daughter contracted H1N1. "Think of the impact on our gross domestic product if 20 to 30 percent of the work force is out sick for a few weeks."



The vaccine shortages and other problems seen during the H1N1 flu outbreak are indicative of the issues the public and businesses will have to face in future pandemics.

Handfield's experience led him to formulate five basic rules that businesses large and small should address to limit the impact of a pandemic. First, get management on board for any planning effort. Second, identify risks in supply chains, especially with sole suppliers of products or services. Third, start stockpiling vaccines, masks, and gloves to limit the spread of the illness, as well as key components to keep operating if a supply chain is disrupted. Fourth, create back-up systems like beefed-up computer networks to handle large numbers of people working from home. Finally, train people ahead of time and eliminate confusion by outlining each employee's responsibilities in a crisis. "Not everyone has to be at the über-planning level," he says. "Just put a group together to do some basic preparations."

"Think of the impact on our gross domestic product if 20 to 30 percent of the work force is out sick for a few weeks."

Handfield is currently partnering with the Center for Infectious Disease Research and Policy at the University of Minnesota on a more in-depth analysis of the risks to businesses and the economy from a widespread flu outbreak. "We've made it through H1N1 pretty well, but this was fairly mild," he says. "A true pandemic may hit next year or not for 50 years, but we need to be ready for it."

Easy Access Makes Best Crime Scenes

Drs. William Smith and Perver Baran layered information on land use and street connectivity in Cary, N.C., on top of local property crime data to determine which features attract or deter crime.

As with real estate, the three most important considerations for some crimes appear to be location, location, and location. Drs. William Smith and Perver Baran have found strong correlations among locations like accessible streets and retail settings and crimes like burglary, robbery, larceny, and auto theft. "Crime follows commerce, and commerce follows traffic patterns," says Smith, a criminologist and associate professor in the Department of Sociology and Anthropology.

Findings by NC State researchers run counter to a popular theory that having more eyes on the street in high-traffic areas deters crime.

Smith and Baran, an urban design specialist who splits her time between the College of Design and the Center for Earth Observation in the College of Natural Resources, used geographic information systems (GIS) analysis to examine several years of crime reports from suburban Cary, North Carolina. Incidents were plotted on a map overlaid with breakdowns of commercial areas and residential neighborhoods, home ownership, ethnic and overall population density, and the accessibility and connectivity of local streets.

The GIS data showed that the four types of crime the researchers tracked were much more prevalent on easily accessible streets. Land use was another good predictor of crime, with retail establishments like restaurants, malls, and gas stations acting like magnets for thieves and thugs. "Offenders tend to go to areas that are familiar to them," Smith says, noting they are quickly pegged as outsiders in neighborhoods with lots of cul-de-sacs and few cross streets—if they can even navigate their way in and out of these areas to begin with. "Accessibility is an important factor in crime."

The NC State research could influence the way cities look at their street design, land use, and park systems. For example, despite its frequent ranking among the safest cities in the U.S., the town of Cary is looking at ways to lay out new streets to reduce crime, Baran says.

"Crime follows commerce, and commerce follows traffic patterns."

Baran and Smith are also looking at how crime affects the use of neighborhood parks in Durham by overlaying GIS data on crimes, land use, and infrastructure like streets and sidewalks on maps of local parks. And they're checking the NC State campus to determine which underlying factors might prevent certain areas from attracting crime. "Even after a space has been designed," Baran says, "you can make modifications that could limit crime."

Criminals are drawn to areas that are easily accessible—and easy for a getaway—according to NC State research.

Forensic Science: Integrating Evidence CSI-style

A student retrieves fiber evidence from a mock crime scene.

Crime scene investigators on television make it all look quick and easy, and NC State faculty are doing their best to turn that bit of TV fiction into reality. Researchers in at least six of the University's colleges are using their talents to crack unsolved crimes and make it easier for police, prosecutors, and evidence experts to analyze crime scenes. "Most of us aren't forensic scientists," says Dr. David Hinks, a professor of polymer and color chemistry in the College of Textiles (COT). "We're scientists putting our expertise to work in a forensic setting."

Dr. Ann Ross' expertise, for example, involves revealing information from the bones of slain people. A forensic anthropologist in the College of Humanities and Social Sciences, she examines skeletal remains to determine who they might belong to and how the victims might have died. In one recent case, for example, she identified the remains of a murder victim found near Rocky Mount, North Carolina, by comparing the skull with an X-ray performed on the woman years ago.

With funding from the National Institute of Justice, Ross developed a software program that forensic scientists can use to determine the gender and ancestry of remains by plotting up to 33 locations on a skull and comparing the findings to characteristics of known populations. "You can also use the software in a situation where you have mass fatalities and have only bone fragments for comparison," she says. Ross often is called in such situations, having identified bodies in mass graves left by "ethnic cleansing" in the former Yugoslavia and by the repressive regime of the late Chilean dictator Augusto Pinochet. She has devised mathematical equations for different groups that allow her to determine someone's height by analyzing a leg or arm bone. "It's hard dealing with death," she says, "but what makes it easier for me is knowing that I'm helping provide closure for families."

Students learn the proper techniques in the recovery of buried remains during NC State's annual Discovery and Recovery course.

In the College of Agriculture and Life Sciences, entomology researcher Dr. Geoff Balme deals with bugs instead of bones. He studies the maggots and flies found at crime scenes. "We're just getting started understanding some of the things insects do at these scenes," says Balme, who gleefully admits never outgrowing his boyhood fascination with all things creepy and crawly.

> "Without the science behind it, you're just guessing. That's no good when you're trying to nail someone for murder."

After maggots feed on decaying flesh, Balme says, some species bury themselves in dirt while they pupate, and the resulting flies dig themselves out after emerging from the pupae. So he devised an experiment to determine how deep a grave could be without disrupting the process. He tosses beef liver scraps and maggots from two species of blowfly into the bottom of long plastic tubes and buries them with soil. After a few days, he removes cross-sections of the soil to see where pupae casings are located. Some flies have been able to dig out from as deep as 4 feet, he says. By noting the location of the casings and the soil temperature at a crime scene, Balme says, he can get a better fix on how long a body has been buried.

Drs. David Hinks, Ann Ross, Michael Young, Mitzi Montoya, and Geoff Balme, left to right, are among the NC State faculty applying their skills to forensic science so police, prosecutors, and evidence experts can more easily analyze crime scenes and arrest and convict the perpetrators.

"Without the science behind it, you're just guessing," he says. "That's no good when you're trying to nail someone for murder."

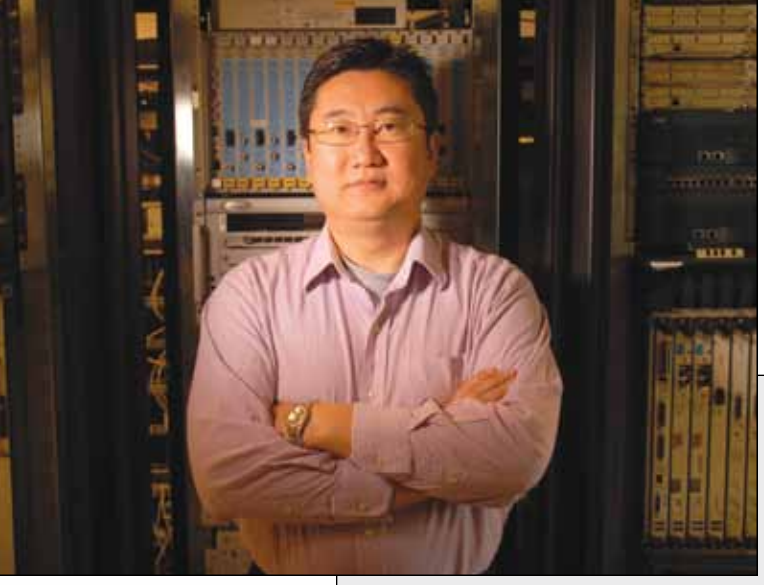
Meanwhile, Hinks and COT colleague Dr. Keith Beck are after better science to analyze fiber evidence found at crime scenes. They are creating a database of dyes used in various fabrics so law enforcement can link with more certainty a fiber found on a victim to a fiber found in a suspect's car, home, or clothing. "Trace fiber evidence is found at more crime scenes than DNA is," Hinks says. "There's a need for a more scientific basis in analyzing it."

The textile researchers are developing a technique to snip off a tiny amount of fiber evidence to determine the concentrations of various dyes and other chemicals, then matching that evidence against their database. They are starting with automotive fabrics, using the extensive COT library of books detailing all fabrics in vehicles since the 1950s. The number of dyes used in vehicles is much smaller than those used in home furnishings or clothing. "What's done today in forensic fiber analysis is relatively rudimentary," Hinks says. "We want to make the testing more quantitative than qualitative and apply statistics to fiber evidence analysis."

In the College of Management, Dr. Mitzi Montoya, Zelnak Professor of Marketing and Innovation Management, wants to make crime scene reconstruction and analysis more accessible to law enforcement. She leads an NC State team that recently won a $1.4 million National Science Foundation grant to develop a system to allow virtual recreation of a crime scene. "The best evidence experts don't all work in the same city," she says. "So we need to take advantage of electronic tools to bring them together where needed."

Team members Dr. Michael Young, an associate computer science professor in the College of Engineering, and Tim Buie, an assistant professor in the College of Design, are using videogame technology to translate a 360-degree rendering of a crime scene captured with laser scanning and high-resolution digital photos into a scenario worthy of an Xbox 360 game. The location of evidence and angles of witnesses and suspects can be plotted precisely, and investigators—even jurors—can "walk through" the scene later to see if eyewitness testimony jibes with the physical evidence. "Crime scene investigation hasn't evolved much in decades, despite advances in forensic science," Montoya says. "NC State is speeding that evolution by introducing interactive, collaborative elements to take advantage of complementary expertise in high-tech fields."

Emily Gomez, a 2009 master's graduate in anthropology, plots points on a skull to determine its gender and ancestry.



Locking Down Cloud Computing

Dr. Peng Ning is technical director of the Secure Open Systems Initiative at NC State, which hopes to build on his work with wireless sensors, pictured at bottom, and secure open-source software and computer systems from malicious attack.

Wireless sensor networks increase flexibility in military and industrial settings, but they also raise the potential for nefarious elements to wreak havoc. Even Dr. Peng Ning, a good-natured associate professor of computer science at NC State not given to paranoia, sees threats everywhere. "Someone could pick up a sensor and reprogram it to send false signals. Terrorists could use a powerful computer to overwhelm a network of sensors," he says. "Network security is critical."

Wireless sensors are deployed by the military for battlefield surveillance and by a growing number of industries to monitor machinery vibration, fluid flow, and other systems. The minicomputers are smaller than a tin of Altoids, run on batteries, and use radio transceivers. When they're deployed throughout a factory or military front, they relay messages to and from their closest neighbors, with one end of the chain communicating with a central computer. "The sensors notify people when something in the manufacturing environment has changed, so they can repair it quickly," Ning says. "The sensors could save lives by keeping troops aware of enemy activities."

"We hope our work will make all open systems safe for users."

But here's the rub: The sensors' small size and limited memory make them easy targets for terrorists and hackers, Ning says, so his research team has developed a suite of security algorithms and open-source software packages. Although these packages use advanced cryptography to secure a network and provide services securely across it, they include a minimal amount of code to avoid taxing the sensors' capacity. For example, Ning developed a message-specific puzzle, where certain pieces of data create a pattern, to ensure that only the network operator can program the sensors.

To expand beyond sensor networks, NC State launched the Secure Open Systems Initiative (SOSI) in 2008 to find ways to secure open-source software and computer systems against malicious attacks. Gathering various computer-security efforts under one umbrella is boosting collaboration and attracting more federal funding for projects, says Ning, who is SOSI's technical director. Industry collaborators like Red Hat, IBM, and Cisco Systems are attracted by the opportunity to test the security tools SOSI develops.

NC State launched the Secure Open Systems Initiative in 2008 to find ways to secure open-source software and computer systems against malicious attacks.

The initial focus is on virtual cloud computing systems, where data residing on remote servers could be vulnerable to attacks from other users or the system itself. Ning and Drs. Xuxian Jiang and Mladen Vouk recently won a $3 million National Science Foundation grant to develop security solutions for next-generation computing clouds. "Wireless sensor networks are just a small piece," Ning says. "We hope our work will make all open systems safe for users."

Center Gives Firefighters a Hand With Protection

The PyroHands Fire Test System is the latest addition to Dr. Roger Barker's center on Centennial Campus that designs and tests protective gear for firefighters and first responders.

If not for their charred appearance, the model hands in Dr. Roger Barker's lab could easily be advertising skin cream or jewelry. Instead, Barker uses the state-of-the-art PyroHands Fire Test System to ensure that firefighters' gloves provide adequate protection. The device is the latest addition to the array of equipment in the Textile Protection and Comfort Center (T-PACC) to test how well turnout gear and accessories insulate firefighters and first responders from harm. "If you're responding to a fire or chemical emergency, you can't afford to have any skin area left exposed," Barker says. "You need to be protected from the tips of your toes to the top of your head."

> "As we're developing new textiles, we're advancing testing on fabrics."

A professor of textile engineering, Barker has been studying the thermal protection characteristics of fibers and textiles for years. He launched T-PACC many years ago with PyroMan—a sensor-laden mannequin blasted from different angles by gas torches—to test firefighter uniforms. His research team has since expanded the center's capabilities to include PyroHands, a PyroHead to test helmets and headgear, and a simulated chemical exposure chamber.

Jessica Watkins, left, a graduate textile engineering student, slips a firefighter's glove over the PyroHands system to determine how well it insulates the hand from the heat of a fire.

With PyroHands, Barker's researchers no longer need to cut a swatch from a glove and lay it flat for testing. They can now see how the entire glove performs while engulfed by flames. His team studied the physiology of the human hand and learned how variations in skin thickness affect the burn-injury model. Data obtained in PyroHands tests are used to engineer new protective materials—thinner, more heat-resistant fibers in a nonwoven fabric that provides greater dexterity without sacrificing protection. Barker previously used the same bulk-reducing technology in the liner of a firefighter's turnout coat. "If you maintain a certain level of protection while increasing functionality," he says, "you're actually improving overall safety."

> "If you're responding to a fire or chemical emergency, you can't afford to have any area left exposed."

T-PACC's testing equipment also allows Barker's team to obtain data that can be used to establish new safety benchmarks. For example, firefighters complained that they would sometimes get burned when the fabric of their uniforms pressed against their bodies as they moved. NC State researchers determined that thermal energy that had built up in the uniforms was being released suddenly, and they developed a test to measure a fabric's heat discharge. Because of the findings, the National Fire Protection Association is considering a new performance requirement for firefighter suits that addresses stored thermal energy. "As we're developing new textiles, we're advancing testing on fabrics," Barker says. "T-PACC's unique facilities allow us to truly meet the needs of these people who put their lives at risk to protect us."

Students Aid Nonproliferation Effort

NC State is building an undergraduate research relationship with the U.S. Department of Energy's Los Alamos National Laboratory in New Mexico.

What were you doing when you were a college junior? Last summer, while most NC State undergraduates were working to earn some extra money or taking a class or two, juniors Chris Pope and Luke Westfield were helping to keep the world safe from people determined to have their own nuclear bombs. The two physics majors worked in the Nuclear Nonproliferation Division at Los Alamos National Laboratory as part of a new effort to build an undergraduate research relationship between the University and the government lab in New Mexico.

"These are very challenging times for the U.S. in nuclear security."

A Navy nuclear officer candidate, Westfield says he jumped at the chance to work at Los Alamos to get some technical experience that he could meld with his interest in nuclear policy issues. During his time at the lab, he ran computer simulations for a neutron detector that was deployed to Kazakhstan so the International Atomic Energy Agency (IAEA) could monitor the movement of spent fuel rods from nuclear reactors. The simulations were designed to find legitimate explanations for why readings on the detector might not match up with IAEA inspectors' calculations of how much nuclear material should be at a particular site. For example, Westfield says, the arrangement of fuel-rod canisters inside a large cask could throw off the readings.

Meanwhile, Pope was conducting stress tests on radiation detection equipment by subjecting a test monitor to different temperatures and humidity levels. By comparing the readings on the monitor with those on a second test monitor at room temperature, he worked to develop a mathematical formula that inspectors could use in the field to compensate for local climate and ensure their readings were accurate. "The whole goal of the safeguards group we were working with is to ensure that nuclear material is not being diverted to non-civilian uses," Pope says. "We need to be sure the equipment is precise."

It's heady stuff for undergraduates, a growing number of whom are getting hands-on research experience through NC State's partnerships with the U.S. Department of Energy's world-class national laboratories. While Pope says the experience pointed him toward policy work in nuclear nonproliferation, Westfield says he's jumped into more research on campus, running simulations for the Department of Nuclear Engineering. Dr. Chris Gould, the physics professor who recommended the pair for the Los Alamos internships, says he hopes that the growing relationship with the lab will help other undergraduates find their niches. "These are very challenging times for the U.S. in nuclear security," Gould says. "We need our best and brightest young people working on these problems, whether it's in the lab or the field."

2008–09 Annual Report for Research and Graduate Studies

The 2008-09 annual report for the Division of Research and Graduate Studies is condensed in this issue of Results. As the year came to a close, NC State faculty were heavily engaged in preparing proposals in response to the newly approved American Recovery and Reinvestment Act (ARRA). While resulting ARRA awards will be more evident in the 2009-10 annual report, early indications point to very positive growth in sponsored research funding as a resul t of the extraordinary efforts of our faculty in responding to research funding opportunities in the economic stimulus package.

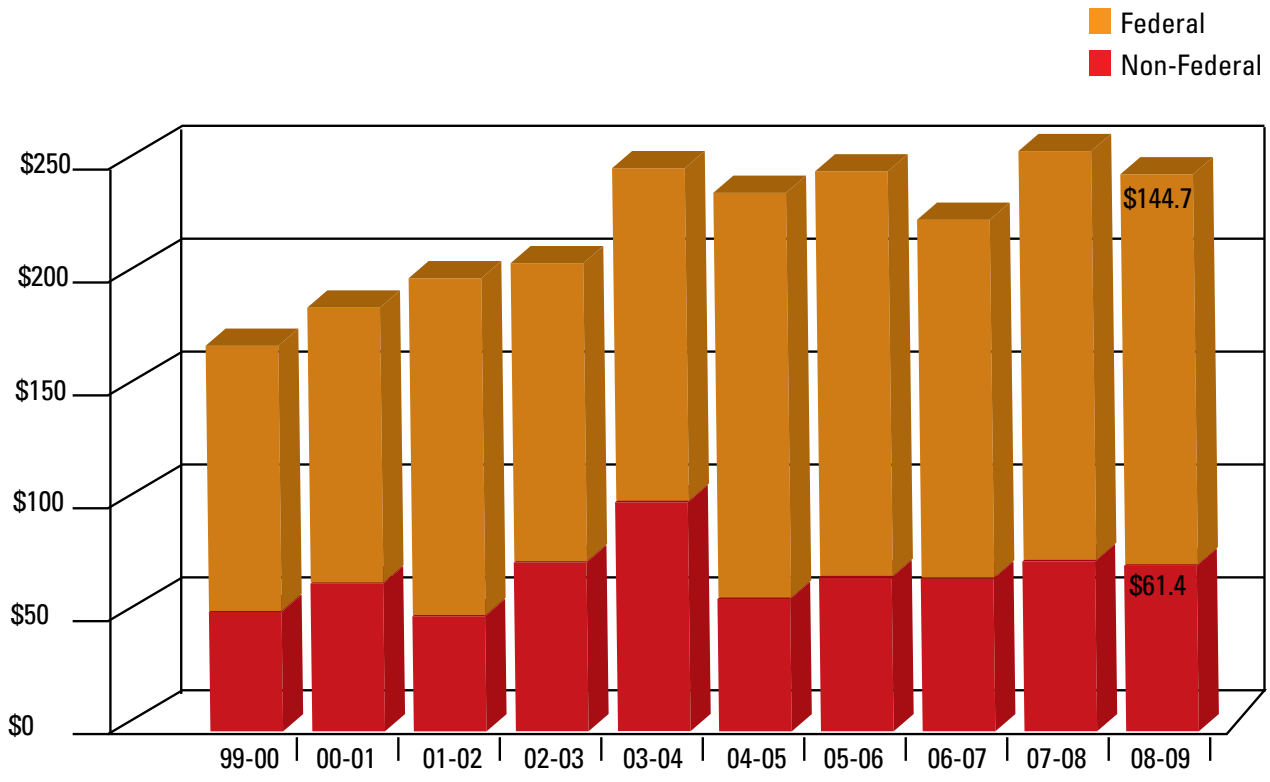
For more detailed sponsored research information, please visit http://ncsu.edu/research/results. For more detail about technology transfer, please visit http://www.ncsu.edu/ott/documents/2008OTTAnnualReport.pdf. For more detailed information about graduate programs, please visit http://www.ncsu.edu/grad/faculty-and-staff/facts.html.

2008–09 Sponsored Research

Proposals Submitted	3,109
Awards Received	1,938
Grant and Contract Dollars Requested	$988.3M
Grant and Contract Dollars Awarded	$206.1M
Grant and Contract Research Expenditures	$380.6M
Recovered Indirect Cost Expenditures	$30.1M

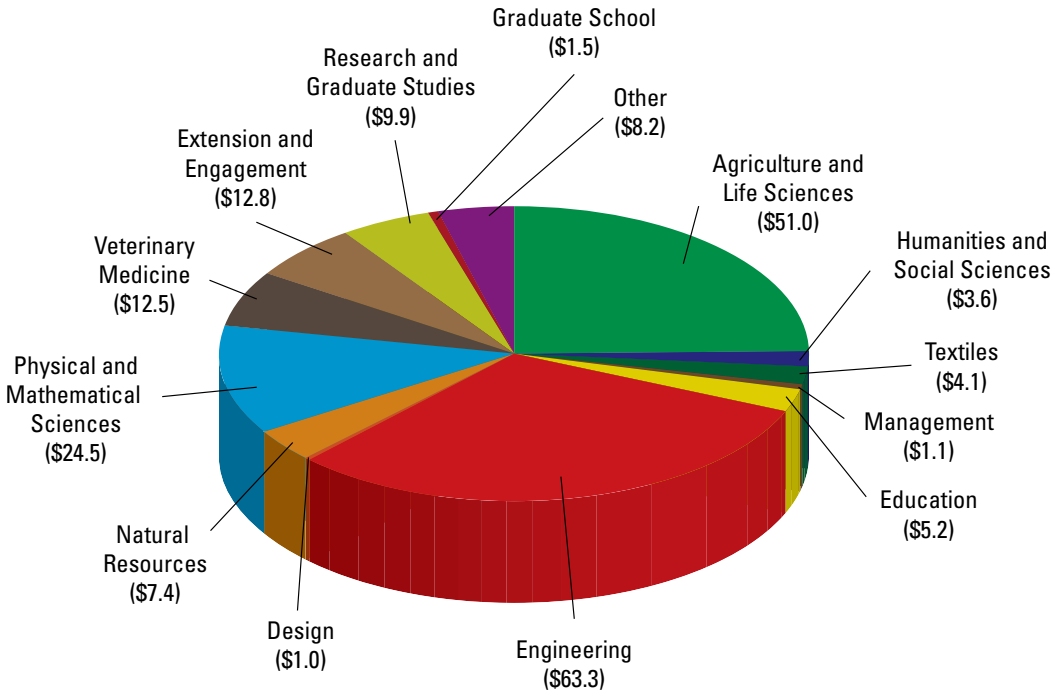
2008–09 Federal/Non-Federal Research Awards

(in millions)



2008–09 Research Awards by Unit

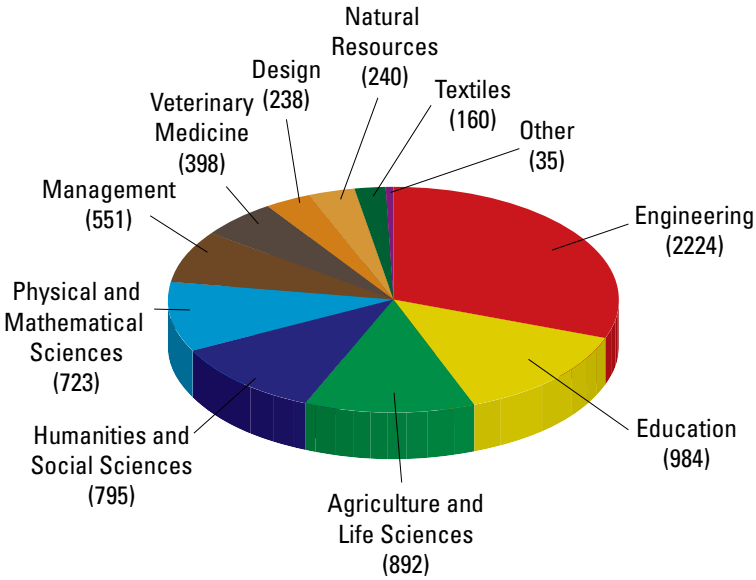
(in millions)



Where NC State Ranks

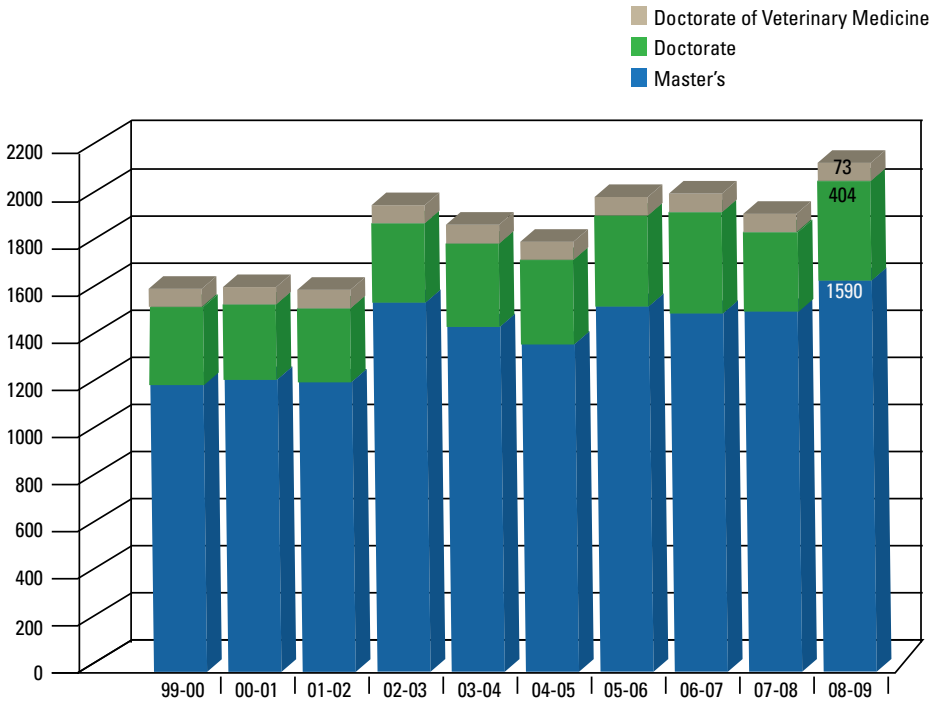
- 3rd nationally in Industry Licensing Partnerships per $100M in research expenditures (*Association of University Technology Managers*, 2008)
- 3rd nationally in Commercialization of Micro/ Nanotechnology Inventions (*Small Times Survey*, 2008)
- 4th nationally in Industry Research Funding among universities without medical schools (*NSF*, 2008)
- 5th nationally in Graduate Veterinary Medicine (*U.S. News & World Report*, 2009)
- 7th nationally in Graduate Graphic Design (*U.S. News & World Report*, 2009)
- 7th nationally in Graduate Nuclear Engineering (*U.S. News & World Report*, 2009)
- 9th nationally in R&D Expenditures among universities without medical schools (*NSF*, 2008)
- 10th nationally among all American Public Research Universities without medical schools (*Center for Measuring University Performance*, 2008)
- 13 graduate programs among top 30 Public Universities (*U.S. News & World Report*, 2009)

Fall 2009 Graduate Enrollment by College*

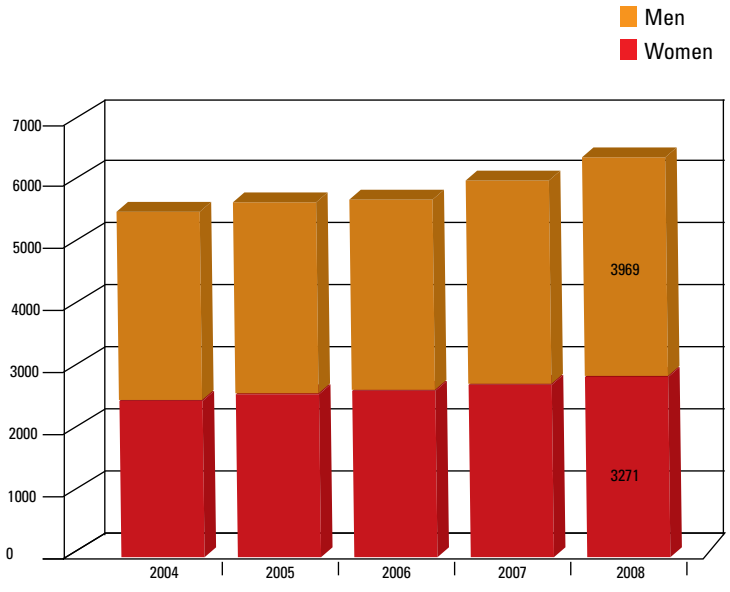


* All graduate students, including Doctors of Veterinary Medicine and distance education enrollment, as a percentage of total student enrollment

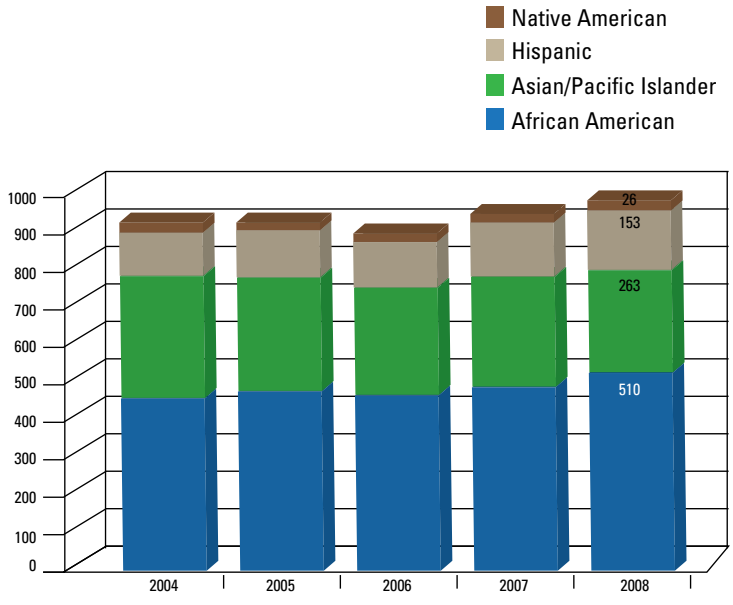
Degrees Awarded 1999–2008



Fall 2008 Graduate Enrollment*

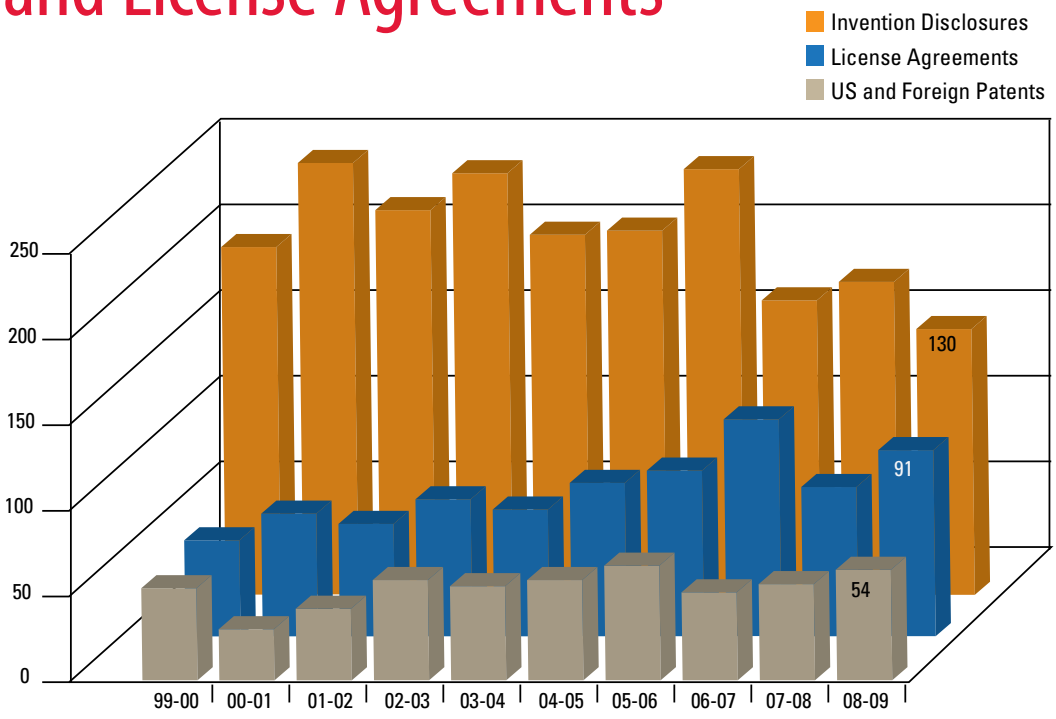


2008–09 U.S. Minority Graduate Enrollment*



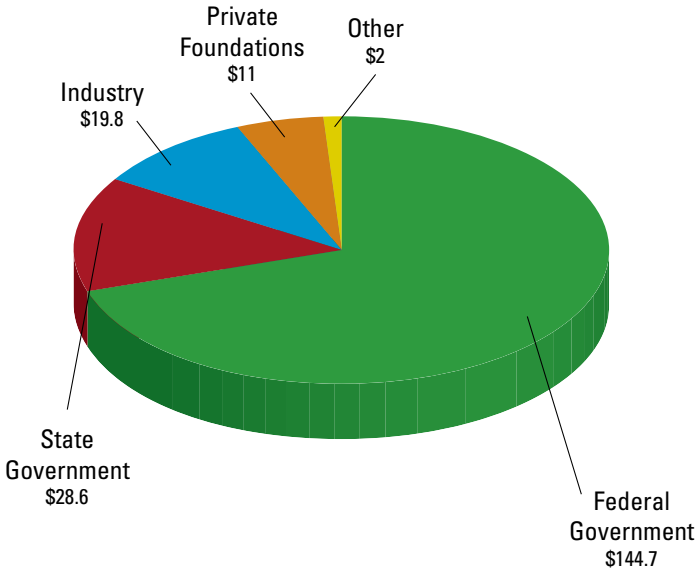
* All graduate students, including Doctors of Veterinary Medicine and distance education enrollment.

Inventions, Patents, and License Agreements



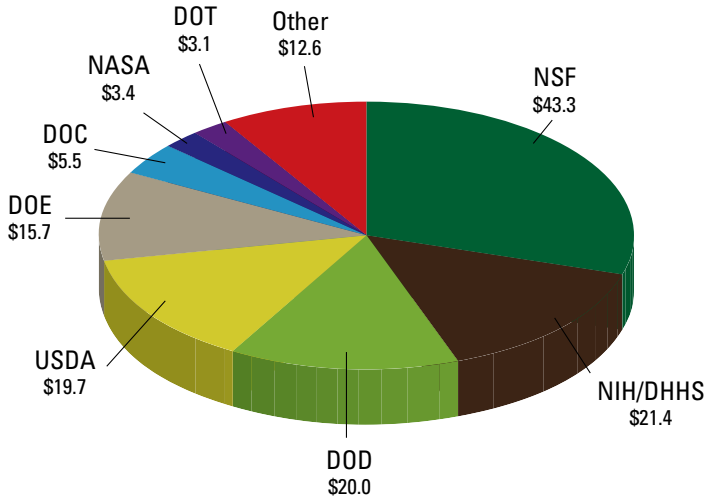
2008–09 Awards by Source of Funds

(in millions)



2008–09 Awards by Federal Agencies

(in millions)



NSF: National Science Foundation
NIH/DHHS: National Institutes of Health/ Dept. of Health and Human Services
DOD: Dept. of Defense
USDA: Dept. of Agriculture
DOE: Dept. of Energy
DOC: Dept. of Commerce
NASA: National Aeronautics and Space Administration
DOT: Dept. of Transportation

National Honors for NC State Faculty

National Academies

Peer-elected membership in these honorific societies reflects the height of professional achievement and commitment to service among distinguished leaders in business, academia, and government.

National Academy of Sciences

- David E. Aspnes
- Ellis B. Cowling
- Major M. Goodman
- Todd R. Klaenhammer
- C. S. Levings
- Thomas F. Malone
- Trudy Mackay
- Ronald R., Sederoff

National Academy of Engineering

- B. Jayant Baliga
- Donald L. Blitzer
- Jerome J. Cuomo
- Joseph DeSimone
- Keith E. Gubbins
- Carol K. Hall
- Thom Joel Hodgson
- R. Wayne Skaggs
- James A. Trainham, III
- Paul Zia

Institute of Medicine

- Jim E. Riviere

American Academy of Arts and Sciences

- William R. Atchley
- Joseph Mark DeSimone
- Trudy F. C. MacKay

The Royal Society

- Trudy F. C. MacKay

AAAS Fellows

Election as a Fellow of the American Association for the Advancement of Science.

- Nina S. Allen
- Robert R. Anholt
- Pal S. Arya
- David E. Aspnes
- Donald L. Bitzer
- Wendy Boss
- Joann M. Burkholder
- Arthur Cooper
- Margaret E. Daub
- Marie Davidian
- Gene J. Eisen
- Charles F. Lytle
- Edward W. Glazener
- Leon E. Gray
- Linda Hanley-Bowdoin
- Ann C. Howe
- John J. Hren
- James H. Hunt
- Gerald J. Iafrate
- James W. Kalat
- Robert M. Kelly
- Todd R. Klaenhammer
- Steven A. Lommel
- Trudy Mackay
- Jagdish N. Narayan
- Roger Narayan
- Slater E. Newman
- Roger Powell
- Bob R. Reeber
- John S. Risley
- John E. Rowe
- Coby Schal
- Ronald R. Sederoff
- Steven Spiker
- Harriett Stubbs
- Edith Sylla
- Mike J. Vepraskas
- Charles W. Welby
- Thomas Wolcott
- Johnny C. Wynne
- James Zuiches

Presidential Awards

The White House and the National Science Foundation jointly award prestigious honors and grants for excellence in science, technology, engineering, and mathematics, recognizing technological achievement, mentors of underrepresented groups, and early career scholars most likely to become academic leaders of the 21st century.

The President's National Medal of Technology

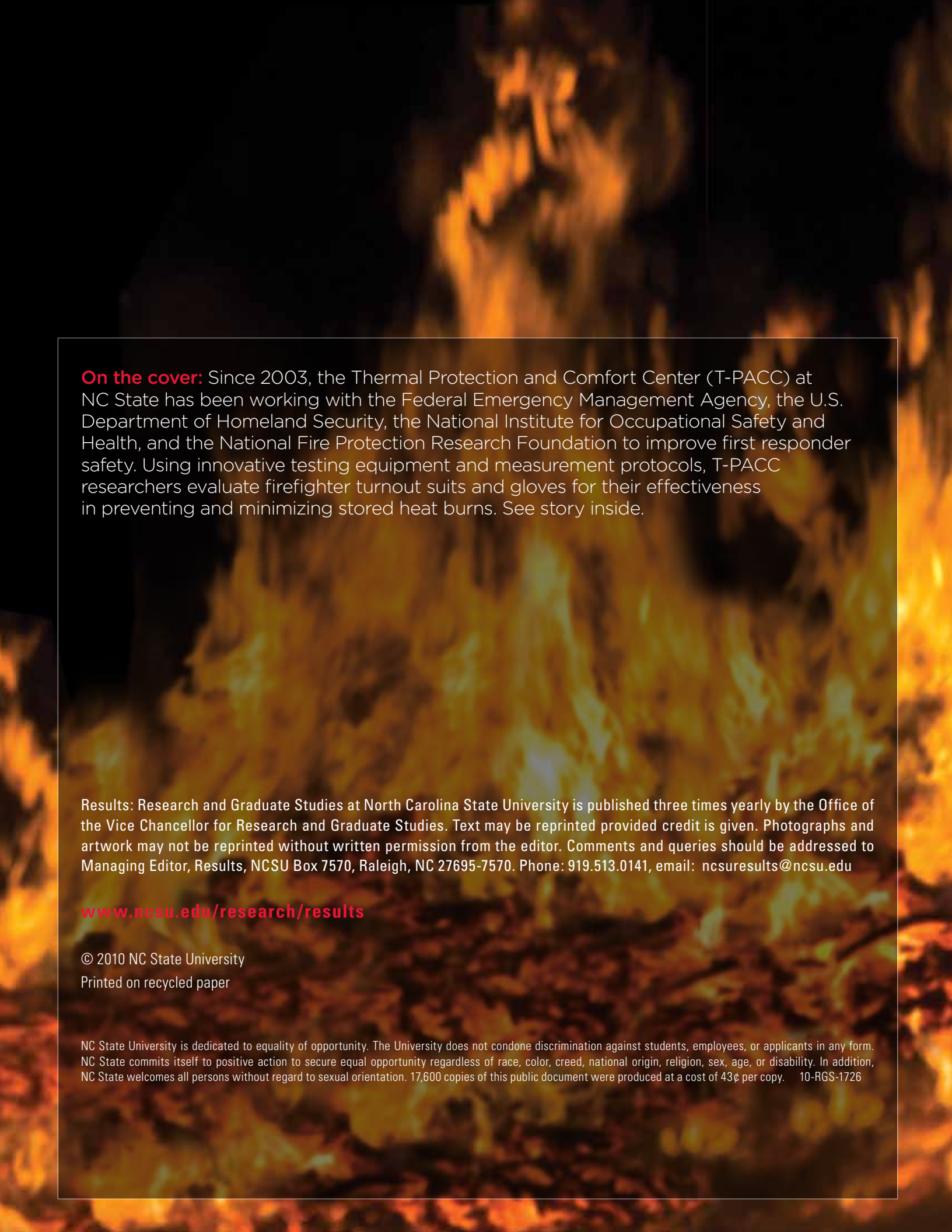
- Jerome Cuomo, 1995

Presidential Awards for Excellence in Science, Mathematics and Engineering Mentoring (PAESMEM)

- Laura Bottomley, 2008
- Christine Grant, 2003
- College of Engineering Programs for Minorities and Women, 2000
- Winser E. Alexander, 1998

Presidential Early Career Development (CAREER) Awards

- Sankarasubraman Arumugam, 2010
- Michael Escuti, 2010
- Xuxian Jiang, 2010
- Seth Sullivant, 2010
- Lingjuan Wang, 2010
- Anantha Aiyyer, 2009
- Brian Denton, 2009
- Tao Xie, 2009
- Jie Yu, 2009
- Huiyang Zhou, 2009
- Alexander Deiters, 2008
- Christina Grozinger, 2008
- Demetrio Labate, 2008
- Ting Yu, 2008
- Karen Daniels, 2007
- Rhett W. Davis, 2007
- Lin He, 2007
- Paul Maggard, 2007
- Robert Rose, 2007
- Hao Zhang, 2007
- Douglas Barlage, 2006
- Do Young Eun, 2006
- Xiaosong Ma, 2006
- Jon-Paul Maria, 2006
- Wenye Wang, 2006
- Benjamin Watson, 2006
- Rada Chirkova, 2005
- Gracious Ngaile, 2005
- Peng Ning, 2005
- Matthew Parker, 2005
- Subhashis Ghoshal, 2004
- Khaled Harfoush, 2004
- Helge K. Jenssen, 2004
- Maria Oliver-Hoyo, 2004
- Celeste Sagui, 2004
- Yan Solihin, 2004
- Agnes Szanto, 2004
- Laurie Williams, 2004
- Yang Zhang, 2004
- Thomas Gunnoe, 2003
- Gnanamanikam Mahinthakumar, 2003
- Carla Mattos, 2003
- Frank Mueller, 2003
- Afsaneh Rabiei, 2003
- Billy Williams, 2003
- Orlin Velev, 2003
- Alexander Dean, 2002
- Stephan Seelecke, 2002
- Greg Buckner, 2001
- Frances de los Reyes, 2001
- Joel Ducoste, 2001
- Jason Haugh, 2001
- Christopher Healey, 2001
- Vicki E. Jones, 2001
- Gianluca Lazzi, 2001
- Wenke Lee, 2002
- Amir Mirmiran, 2001
- Veena Misra, 2001
- Eric Rotenburg, 2001
- Peter Wurman, 2001
- Michael Young, 2001



On the cover: Since 2003, the Thermal Protection and Comfort Center (T-PACC) at NC State has been working with the Federal Emergency Management Agency, the U.S. Department of Homeland Security, the National Institute for Occupational Safety and Health, and the National Fire Protection Research Foundation to improve first responder safety. Using innovative testing equipment and measurement protocols, T-PACC researchers evaluate firefighter turnout suits and gloves for their effectiveness in preventing and minimizing stored heat burns. See story inside.

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