

## NOTES

## Stemming Spam

*Internet routing and spam data reveal trends to help researchers build better e-mail filters.*

A database of more than 10 million spam e-mail messages collected at just one Internet “spam sink-hole” suggests that Internet service providers could better fight unwanted junk e-mail by addressing it at the network level, rather than using currently available message content filters.

Also, the research — conducted at the Georgia Institute of Technology's College of Computing — identified two additional techniques for combating spam: improving the security of the Internet's routing infrastructure and developing algorithms to identify computers' membership in “botnets,” which are groups of computers that are compromised and controlled remotely to send large volumes of spam. The findings are now directing the researchers' design of new systems to stem spam.

“Content filters are fighting a losing battle because it's easier for spammers to simply change their content than for us to build spam filters,” says Nick Feamster, a Georgia Tech assistant professor of comput-



ing. “We need another set of properties, not based on content. So what about network-level properties? It's harder for spammers to change network-level properties.”

Feamster and his Ph.D. student Anirudh Ramachandran presented their findings in September 2006 at the Association for Computing Machinery's annual conference of its Special Interest Group on Data Communication (SIG-COMM).

From 18 months of Internet routing and spam data the researchers collected in one domain, they have learned which network-level properties are most promising for consideration in spam filter design. Specifically, they learned that:

- Internet routes are being hijacked by spammers;

- they can identify many narrow ranges within Internet protocol (IP) address space that are generating only spam;
- and they can identify the Internet service providers (ISP) from which spam is coming.

Route hijacking works like this: By exploiting weaknesses in Internet routing protocols, spammers can steal Internet address space by briefly advertising a route for that space to the rest of the Internet's routers. The spammers can then assign any IP address within that address space to their machines. They send their spam from those machines and then withdraw the route by which they sent the spam. By the time a recipient files a complaint related to this IP address,

the route is gone and the IP address space is no longer reachable.

“Internet routing protocols are insecure, so it's relatively easy for spammers to steal them and hard for us to identify the perpetrators,” Feamster explains. He and other researchers are working to improve the security of Internet routing protocols.

Better spam filtering also will result from a system, which Feamster hopes to design, based on collaborative, network-level filtering among ISP operators.

— Jane M. Sanders

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**ABOVE:** Internet service providers could better fight unwanted junk e-mail by addressing it at the network level, rather than using currently available message content filters, says Georgia Tech College of Computing Assistant Professor Nick Feamster.

## Liquid Crystal Polymer

Researchers at the Georgia Institute of Technology recently received funding from the NASA/Earth Science Technology Office to evaluate a material called liquid crystal polymer (LCP) for electronics applications in space.

The ultra-thin, paper-like plastic can incorporate a variety of electronic circuits, yet it molds to any shape and appears to perform well in the extreme temperatures and intense radiation encountered by NASA spacecraft.

Research indicates that LCP outperforms conventional materials for antennas and circuit boards in high-frequency radio applications aboard space vehicles, says George E. Ponchak, a co-investigator and senior research engineer at NASA's Glenn Research Center in Cleveland, Ohio.

"I think the chances are very high that LCP will be practical for a variety of NASA applications," he says.

Light weight is the material's biggest potential benefit to NASA, Ponchak says. Flexible LCP antennas would be lighter than today's structured antennas, and LCP-based circuits molded to available spacecraft areas could eliminate heavy metal boxes that currently house rigid circuit boards.

"Less weight lets us move to a smaller launch system, which in turn saves a lot of money," Ponchak notes.

John Papapolymerou, an associate professor in the Georgia Tech School of Electrical and Computer

PHOTO BY GARY MEEK



Engineering, explains that LCP's unique structure — aromatic crystal polyester comprised of benzene rings, acetyloxy polymers and carboxyl groups — allows it to be heat-resistant, flexible and strong, while also possessing excellent electrical performance.

Moreover, the material can serve as a highly efficient substrate — material on which semiconductor chips are attached — as well as the backplane that connects those chips together, says Papapolymerou, who with Georgia Tech Associate Professor Manos Tentzeris leads a team researching LCP. Even microelectromechanical system (MEMS) devices could be embedded on LCP, along with integrated circuits.

"It's like having a PC board type of technology that has many other advantages," Papapolymerou says. "We are already developing LCP-based technology for NASA applications, and I think eventually you will see LCP in next-generation consumer systems."

— Rick Robinson

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## Needle in a Haystack

Because of their efficiency and reduced pollution, fuel cells offer a promising alternative to traditional power sources in transportation and other applications. Yet more durable, less expensive materials are needed before these electrochemical devices replace internal combustion engines in vehicles.

Finding those materials will require analyzing potentially billions of possible material combinations. In response, J. Carson Meredith, an associate professor at Georgia Tech's School of Chemical and Biomolecular Engineering, is developing a new screening system that will enable researchers to evaluate hundreds or thousands of potential materials in a single experiment. Meredith presented details of this combinatorial toolkit at the American Chemical Society's 2006 national meeting in September.

When it comes to proton exchange membrane (PEM) fuel cells — the type of fuel cell that the automotive industry is focusing on — one of the biggest stumbling blocks is the membrane itself.

Resembling a piece of kitchen plastic wrap, the membrane is sandwiched between two electrodes — an anode and cathode — just as in a battery. As hydrogen gas flows into the fuel cell at the anode side, a platinum catalyst separates the hydrogen into electrons and protons. The membrane's job is to conduct the positively charged protons through to the cathode side

and prevent the negatively charged electrons from passing through. Instead, electrons are conducted through an external circuit to the cathode, creating an electrical charge that can power a vehicle's electrical motor. Then at the cathode side, the electrons reunite with the protons and oxygen to form water as a byproduct.

"Current membranes on the market are costly because they're made out of fluorinated materials as opposed to conventional hydrocarbon-based plastics," Meredith says. "Durability is another issue. Due to the harsh environment of the fuel cell, the typical lifespan for a PEM is a couple thousand hours. After that, the membranes begin to degrade chemically — and literally fall apart. They develop leaks, and the fuel begins to 'cross over' to the oxygen side, causing the electrical current to drop drastically."

Part of a multi-partner project funded by the U.S. Department of Energy, Meredith is developing a methodology to produce low-cost, thermally stable membranes. In addition to Georgia Tech, project partners include the University of Hawaii and three private companies — Arkema Inc., United Technologies Corp. and Johnson-Matthey.

— T.J. Becker

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*LEFT: Associate Professor John Papapolymerou, left, and Associate Professor Manos Tentzeris demonstrate antenna arrays embedded on liquid crystal polymer in a laboratory at Georgia Tech.*

PHOTO BY GARY MEEK



*ABOVE: Georgia Tech Associate Professor Carson Meredith holds a combinatorial fuel cell membrane he developed using a novel chemical screening technique he devised. With it, he can evaluate hundreds or thousands of potential materials — such as the precursor material in this vial — in a single experiment.*

## NOTES

## Explosives at the Nanoscale

Using nanometer-scale analysis techniques and quantities too small to explode, researchers have mapped the temperature and length-scale factors that make explosives behave the way they do.

Using the “world’s smallest controlled-heat source” — a tiny atomic-force microscope (AFM) cantilever — scientists from the Georgia Institute of Technology and Texas Tech University have developed a new way to study explosives that have nanometer-scale features.

The technique provides new information about such phenomena as melting, evaporation and decomposition of explosives — also called

specific responses, with a given temperature producing a given burn rate, for example,” explains William King, an assistant professor in the Georgia Institute of Technology School of Mechanical Engineering. “Before our measurements, no one was able to interrogate these properties at the nanometer scale. With the data we have generated, it is possible to build physics-based models of how these materials behave rather than relying on empirical relationships seen at the macro scale.”

Using an AFM tip capable of heating spots as small as a few nanometers in diameter, the researchers performed nanometer-scale thermal analysis on thin films of a polycrystalline energetic material known as Pentaerythritol Tetranitrate (PETN). They melted, evaporated and decomposed the PETN at length scales ranging from 100 nanometers to a few micrometers.

“We have shown that we can control the morphology of energetic materials on the nano scale, and also measure nanoscale properties of these materials,” says Brandon Weeks, an assistant professor in the Department of Chemical Engineering at Texas Tech University. “The hope is that since very small amounts of the material are needed for study, we can measure the properties in a very safe manner and extrapolate the information to bulk properties.”

— John Toon

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energetic materials — at the smallest-length scales. Because the performance of these materials depends heavily on nanometer-scale factors, such as crystal size and voids between crystals, the research ultimately could lead to safer explosives and better control over how they work.

Dubbed “nanodectonics,” the research was described in the September, 2006 issue of the American Chemical Society journal *Nano Letters*.

“Scientists would like to design energetic materials with

PHOTO ILLUSTRATION BY KISS BOTOND

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ABOVE: LCD panels are part of modern computers and other devices, but their manufacture is complex. A Georgia Tech research team has developed a simpler approach that may be used to create future generations of flexible display systems.

## LCD Shortcut

A new technique for creating vertical alignment among liquid crystal molecules could allow development of less-costly flexible displays and lead to a better understanding of the factors that govern operation of the popular liquid crystal display systems.

Liquid crystals are a key component of the displays used in most laptop computers and the increasingly popular flat-panel televisions. Controlled by a network of transistors, the liquid crystals change their optical characteristics in response to electrical signals to create the text and images we see.

Manufacture of the panels is complex, requiring multiple steps that can introduce defects. Among the steps is the application of a polymer film — the so-called alignment layer — to the two pieces of glass between which the liquid crystals operate. The film, which must be rubbed after being coated on the glass, anchors the crystals with a fixed alignment. The process of rubbing to create the necessary

alignment can damage some of the transistors and introduce dust, producing defects that can reduce the manufacturing yield of the panels.

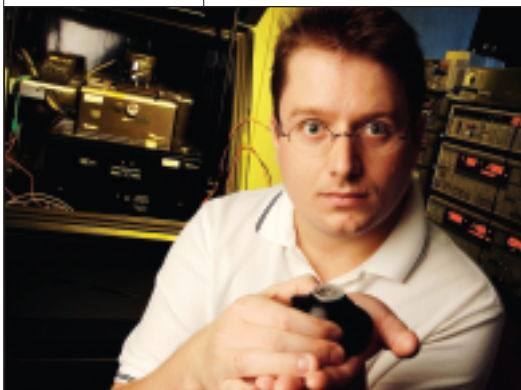
By adding side chains to the polymer molecules, researchers at the Georgia Institute of Technology have found a way to eliminate the polymer rubbing step. Instead, they use in situ photopolymerization of alkyl acrylate monomers in the presence of nematic liquid crystals. This process provides a cellular matrix of liquid crystalline droplets in which the chemical structure of the encapsulating polymer controls the liquid crystal alignment.

“Small changes in the chemical nature of the polymer will change the alignment of the molecules at surfaces,” says Mohan Srinivasarao, a professor in Georgia Tech’s School of Polymer, Textile and Fiber Engineering. “It turns out that this can be done over a fairly large area, and it is reproducible. This would be an alternative way to create the alignment that is needed in these devices.”

Srinivasarao described the self-aligning of liquid crystals at the 232nd national meeting of the American Chemical Society in September 2006. The research is supported by the National Science Foundation’s Division of Materials Research.

— John Toon

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ABOVE: Georgia Tech Assistant Professor William King displays an experimental apparatus used for thermal analysis of explosives on the nanoscale.

PHOTO BY GARY MEEK

# Pavement Marking

*An automated system developed by GTRI installs pavement markers, improving safety for road crews and drivers.*

**O**n rainy nights in Georgia and across the nation, drivers greatly benefit from small, reflective markers that make roadway lanes more visible.

There are more than three million of these safety devices, called raised pavement markers (RPMs), in service on Georgia highways. They are installed and then need to be replaced about every two years by road crews who consider the task one of the riskiest they face. Workers typically ride on a seat cantilevered off the side of a trailer just inches from highway traffic.

Manual RPM placement is not only risky for personnel, but it is also expensive and time-consuming. A typical RPM placement operation includes four vehicles and a six-person crew. All the vehicles must stop at each marker location, so there is tremendous wear on the equipment and increased fuel use.

The Georgia Department of Transportation (GDOT) believed there was a better way to do it and funded the Georgia Tech Research Institute (GTRI) to develop a first-of-its-kind system capable of automatically placing RPMs along the lane stripes while in motion. After almost three



**ABOVE:** GTRI researcher Colin Usher uses a touch-screen monitor mounted in the cab of the truck. It provides the primary operator interface to the automated raised pavement marker (RPM) placement system developed by GTRI.

years of research and development, GTRI expects to deliver a prototype system by early 2007.

"The advantages of our automated system are: it's less labor-intensive, it's faster and safer, uses less fuel, and it causes less wear and tear on GDOT equipment," explains project manager Wiley Holcombe, a GTRI senior research engineer.

Engineers conducted the work in two phases. First, they designed an RPM-placement mechanism using pressure-sensitive adhesive and a lane-stripe tracking system. Then, they developed a full-scale, truck-mounted RPM placement system. It is based on a single GDOT-owned truck and includes the lane-stripe tracking system and electrical power support systems, compressed air, hydraulic power, and adhesive melting and dispensing systems. Some components of the system were off-the-shelf parts, but the GTRI Machine Services shop fabricated most of the custom components for the system, Holcombe notes.

After some field-testing, the project resulted in a

prototype system capable of dispensing an RPM onto the pavement along with the necessary hot-melt adhesive applied at 380 degrees Fahrenheit while traveling at 5 miles an hour. A pattern-change mechanism can position two placement mechanisms to accommodate any of GDOT's five specified RPM placement patterns, Holcombe explains. Operation of the system only requires two people.

"The GDOT's primary use for the automated RPM placement machine will be placing markers on the skip lines for interstate and multi-lane highways," says GDOT spokes-

woman Karlene Barron. "These types of routes pose the highest safety risks to our employees and equipment."

"The GDOT also plans to use the system on high-traffic-volume secondary or two-lane roads, when possible," Barron adds. "Using the automated system, we will not have to stop at every placement, which will increase safety and productivity plus reduce wear and tear on GDOT equipment."

GTRI's automated raised pavement marking system could be used outside Georgia, though Holcombe explains that its design is most appropriate for Southern states with warmer climates. In regions that get a lot of snow, RPMs must be applied somewhat differently to reduce the risk of damage to RPMs by snow-clearing equipment.

— Jane M. Sanders

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**ABOVE:** During a June 2006 demonstration, GTRI researchers Wiley Holcombe, standing, and Steve Robertson examine the placement mechanism on truck-mounted, automated raised pavement marker (RPM) placement machine that GTRI developed for the Georgia Department of Transportation.

**BELOW:** On an automated system that places reflective raised pavement markers (RPM), a lane-stripe pattern-change mechanism is mounted on a lift mechanism and carriage.



PHOTO BY GARY MEEK

## NOTES

## Seeing the Unseen

*Infrared computer vision system could help make meat products safer, tastier and less costly to produce.*

Consumers can expect that meat products will be safer, tastier and less costly to produce within a year or so as the food processing industry begins to use infrared computer vision scanning systems under development at the Georgia Tech Research Institute.

Infrared (IR) camera technology promises to help prevent potentially harmful undercooking and minimize overcooking — which diminishes taste — of ready-to-serve meat products. It is also expected to reduce energy costs and lower yield loss in the food processing industry.

“IR camera technology is evolving,” says Craig Wyvill, chief of the Georgia Tech Research Institute (GTRI) Food Processing Technology Division.

Some new IR cameras no longer require specialized cooling systems, and the cost of ownership has dropped significantly during the past five years. Such advances encouraged GTRI researchers to explore the use of IR camera technology in screening and controlling thermal operations in food processing plants.

“We started with a study designed to use this technology to help measure product core temperature as it comes out of the oven,” Wyvill explains. “Now, the research has fanned out to include oven control and



help for technicians on the production line.

“The technology is fueling opportunity in cooking operations and may make microwave precooking more practical in plants,” he adds. “It could eliminate the risk of undercooking while minimizing the level of overcooking required.”

An initial GTRI study funded by Georgia's Food Processing Advisory Council (FoodPAC) focused on using IR technology to measure the mean surface temperature and then estimate the core temperature of meat products as they come out of industrial ovens. GTRI senior research engineer John Stewart led that project, which included a field study of GTRI's IR computer vision system at a Gold Kist plant in Boaz, Ala.

Stewart discovered the system could reasonably estimate core temperature on uncoated, whole-muscle meat and products with a porous coating, such as a light layer of breadcrumbs. But in formed and heavily breaded items, such as chicken fingers, the mean surface temperature is not well correlated with core temperature, Stewart says.

While imaging some of the heavily coated products,

researchers discovered that some product had lower surface temperatures than the bulk of product being imaged. Upon closer inspection, they discovered that most of these cold areas were caused by ruptures in the outer casing.

“This finding and the additional observation that the variability of the temperatures measured on the ruptures was lower than the variability of product core temperatures measured by hand reinforced our belief that the near-term potential of IR camera technology is in identifying what is happening as products come out of the oven,” Wyvill explains.

These findings led to a new FoodPAC-funded project that GTRI began in 2006. Now, Stewart and his colleagues are studying how information from IR cameras, in conjunction with visible light cameras, can be used to control product temperature within emerging microwave precooking technology, which will be used in conjunction with conventional ovens to shorten overall cooking time.

One of the challenges researchers have addressed is synchronizing the images from two different camera systems together to simultane-

ously deliver information on product temperature, color and size. Bigger challenges researchers are addressing are dealing with high product-flow rates and complex product presentations.

An algorithm analyzes the data, allowing the system to adjust microwave oven cooking on the fly — something that is more difficult to do with conventional ovens.

Such a system will allow processors to cook food quickly, thus reducing energy costs, an attractive incentive for the food processing industry.

In addition, GTRI researchers believe IR computer vision technology can help oven technicians in food processing plants as they randomly pull product from conveyor belts to measure core temperature with thermal probes.

The food processing industry is likely to begin using IR computer vision technology by late 2007, Wyvill says.

— Jane M. Sanders

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Read more at: [gtresearchnews.gatech.edu/reshor/rh-f06/infrared.html](http://gtresearchnews.gatech.edu/reshor/rh-f06/infrared.html)

**ABOVE RIGHT:** Researchers are using an infrared computer vision system to measure core temperature in various meat products. In the foreground, the computer screen displays an infrared image on the left as it scans chicken nuggets on a conveyor belt.

## Assessing Indoor Air

As scientists learn more about the potentially harmful effects of indoor air pollution, nations around the world are imposing increasingly strict regulations on chemical emissions from furnishings, paints and building materials.

Using a new, room-sized environmental test chamber, more than a dozen smaller

chambers and a mass spectrometric center able to measure ultra-trace concentrations of airborne chemicals being emitted from products, scientists at the Georgia Tech Research Institute (GTRI) are helping manufacturers meet those international standards to minimize emissions.

“We can help manufacturers address regulatory issues,” says Charlene Bayer, a GTRI principal research scientist. “Because U.S. manufacturers

sell their products worldwide, they must meet emission regulations imposed by nations in Europe and Asia. We make the measurements companies need to improve their products.”

For example, the testing helps manufacturers of indoor furnishings select components that have lower emissions. It also helps textile and apparel companies choose fabric finishes that both survive cleaning and minimize emissions. And it helps makers of paints and other wall coverings select biocides and other chemical constituents with the least impact on the indoor environment.

Large enough to accommodate humans or animals, the new 27.5-cubic-meter environmental chamber allows researchers to study broader concerns — including the impact of low-level indoor air pollutants on productivity and human health.

“There is an emphasis now on developing high-performance schools, and part of that will be to measure how

**LEFT:** Laboratory technician Danielle Bayer prepares a mannequin for testing in the Georgia Tech Research Institute's room-sized environmental test chamber.

PHOTO BY GARY MEEK



**ABOVE:** Researchers Charlene Bayer and Victor DeJesus prepare samples for testing in one of the Georgia Tech Research Institute's environmental chambers.

changes in indoor air quality improve the performance of children,” Bayer explains. “By studying how emissions from normal furnishings affect children performing classroom tasks, you can estimate what might happen if you reduce the emissions.”

Tests involving humans are carefully designed to avoid exposing subjects to potentially harmful levels. The research also is done under close medical supervision, with cameras and a special windowed door to monitor subjects inside the chamber.

Beyond helping manufacturers improve their products, the new facility may lead to a better understanding of what compounds cause problems and how indoor pollutants form.

— John Toon

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PHOTO BY GARY MEEK



**ABOVE:** Researcher Charlene Bayer prepares a small environmental chamber for testing.



PHOTO BY GARY MEEK

## “Clean-Tech” Companies

Volatile weather, summer smog alerts, soaring fuel prices and rising greenhouse-gas levels have focused increased attention on cleaner, more-sustainable technologies.

That concern can be clearly seen among the start-up companies formed in the Georgia Institute of Technology's VentureLab program, which is assisting more than a half-dozen early-stage companies that are pursuing clean-technology products and services. These new technologies range from renewable fuels and high-efficiency solar cells to hurricane forecasting and tiny jet-like devices that could reduce aircraft-fuel consumption.

Georgia Tech is well positioned to pursue clean technology and renewable energy, says Stephen Fleming, Georgia Tech's chief commercialization officer. Among its many interdisciplinary research centers are: the University Center of Excellence for Photovoltaics Research and Education, the Center for Innovative Fuel Cell and Battery Technology, the Strategic Energy Initiative, the Institute for Sustainable Technology and Development, and the Center for Organic Photonics and Electronics.

“Our clean-tech companies have one aim in common — to use Georgia Tech discoveries to make a number



of things happen in a more environmentally sensitive and economically viable way,” Fleming says.

Commercialization Services, a unit of Georgia Tech's Enterprise Innovation Institute, identifies, evaluates and promotes Georgia Tech innovations with potential commercial value. Most such discoveries fall into two categories: The majority are licensed to established corporations, while a few — about one in 10 — have the right stuff to form the basis for new companies.

These new-company candidates typically come under the wing of VentureLab, a Commercialization Services unit that assists fledgling businesses through the critical feasibility and first-funding phases. Ben Hill and Jon Goldman, business advisers with VentureLab, work with clean tech and renewable energy companies and projects.

VentureLab is advising a number of “clean-tech” startups, including:

- C2 Biofuels seeks to develop fuel-ethanol production from biomass material — including Southern yellow pine — available in large quantities in the Southeast.
- Climate Forecast Applications develops tools to forecast cyclones and hurricanes 10 to 30 days ahead, a service that would be valuable to utility, energy and risk-management companies, as well as agriculture.

- WiSPI focuses on methanol-based fuel cells that can be integrated onto silicon chips, enabling self-powered, wireless sensors that could monitor everything from soil moisture content to weather patterns and secure areas.
- LumoFlex is developing organic photovoltaic materials that could result in substantial power savings in a number of products.
- Ajeetco is a solar-energy company that is using high-efficiency polycrystalline silicon films to produce large-scale photovoltaic solar panels.

— Rick Robinson

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Read more at: [www.innovate.gatech.edu/Default.aspx?tabid=32&NewsID=83](http://www.innovate.gatech.edu/Default.aspx?tabid=32&NewsID=83)

**LEFT:** Georgia Tech is well positioned to pursue clean technology and renewable energy, says Stephen Fleming, Georgia Tech's chief commercialization officer. One startup company based on Georgia Tech research is Ajeetco, which is using high-efficiency polycrystalline silicon films to produce large-scale photovoltaic solar panels.

**BELOW:** C2 Biofuels is a Georgia Tech-based startup company, led by Roger Reisert, which is developing fuel-ethanol production from biomass material — including Southern yellow pine — available in large quantities in the Southeast.

