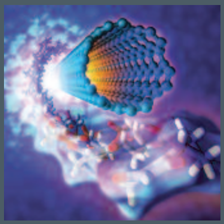


A NANO-BIO TWIST

Researchers use DNA to improve the sorting of carbon nanotubes

See page 20

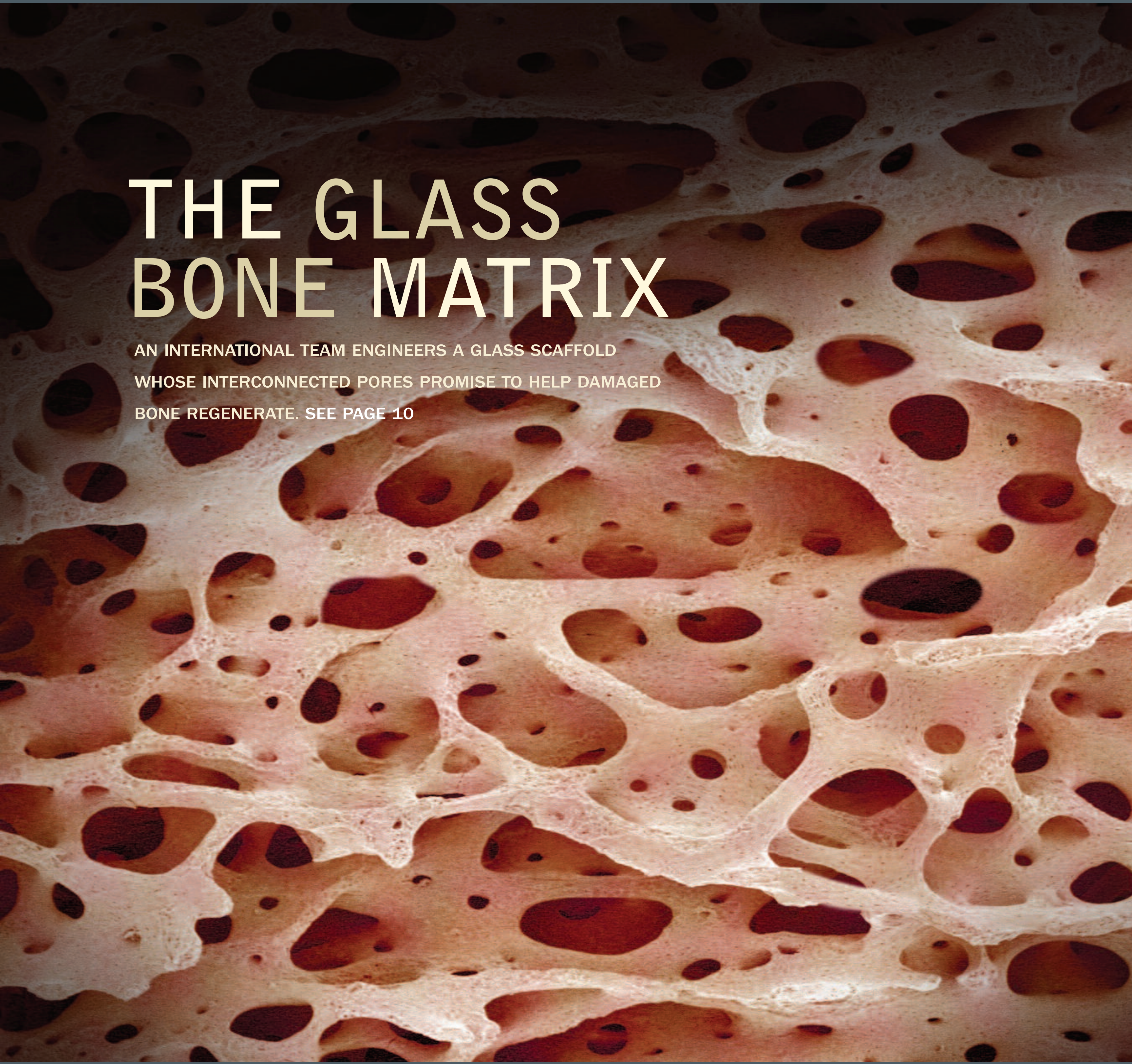
WI-FIRED UP!

Business-engineering program launches wi-fi entrepreneurs

See page 22

resolve

A FOCUS ON LEHIGH ENGINEERING • VOLUME 1, 2006



THE GLASS BONE MATRIX

AN INTERNATIONAL TEAM ENGINEERS A GLASS SCAFFOLD WHOSE INTERCONNECTED PORES PROMISE TO HELP DAMAGED BONE REGENERATE. SEE PAGE 10

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P.C. ROSSIN COLLEGE OF ENGINEERING AND APPLIED SCIENCE

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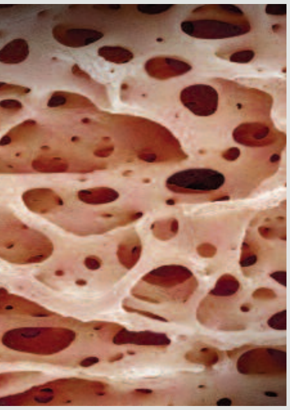

ON THE COVER

A glass-bone scaffold being developed by an international team of researchers could help this osteoporotic bone (above) and other damaged or diseased bone to regenerate

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A FOCUS ON LEHIGH ENGINEERING

VOLUME 1, 2006

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MARKETING CONSULTANT
Dina M. Silver

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P.C. ROSSIN COLLEGE OF ENGINEERING
AND APPLIED SCIENCE
Lehigh University
19 Memorial Drive West
Bethlehem, PA 18015
610-758-4025
www.lehigh.edu/engineering

OFFICE OF UNIVERSITY RELATIONS
Lehigh University
125 Goodman Drive
Bethlehem, PA 18015-3754
610-758-4487

READER FEEDBACK: Please send comments to engineering@lehigh.edu

LEHIGH UNIVERSITY®
CHALLENGING GREAT MINDS...INSPIRING GREAT IMAGINATIONS

Elevating research via clustering

Dear Readers:

Welcome to** Resolve**, a magazine devoted to research and educational innovation in the P.C. Rossin College of Engineering and Applied Science at Lehigh University. The name of the magazine epitomizes the character of Lehigh engineers: tenacious, rigorously trained thinkers and problem-solvers who excel in all domains of leadership.

This inaugural issue of *Resolve* highlights exciting research projects and novel educational programs across science and engineering at Lehigh. Much of this activity has been spurred by Lehigh 2020, a $75-million academic venture launched in 2000. More than a third of Lehigh's 120 engineering faculty have been appointed since then. This creates unprecedented energy and momentum in all major areas of engineering research, as you will see in this magazine.

Resolve is organized on the concept of "research clustering," in which three overarching research areas harness a critical mass of intellectual strengths. Each cluster represents strong cross-disciplinary synergies while elevating the scope of research above typical academic disciplines or research centers. To facilitate the formation of research clusters, faculty-led advisory councils have been formed in these three areas:

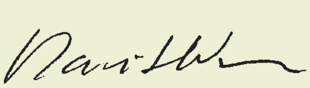
Bio: Bio, Environmental and Molecular Engineering
Nano: Nanotechnology and Applications
Systems: Complex Engineering and Information Systems

Throughout this magazine, you will notice features and news briefs devoted to each of the three clusters – fundamental research platforms with evolving themes, not fixed administrative structures. You'll note that some projects straddle more than one platform; clustering represents an effort to foster the organic growth of research collaborations and to expand the scope and impact of research, while creating a forum for dialogue among faculty concerning future research directions and infrastructure investment.

The clustering concept stands on a strong tradition of multidisciplinary research at Lehigh. Faculty in science and engineering have for years crossed boundaries to cooperate with each other. It is not at all unusual, for example, to see a materials scientist working closely with an electrical engineer, a biologist, a physicist, or a chemist, or even with a sociologist or an economist. This cross-disciplinary collaboration is reflected not only in the breadth of research at Lehigh, but also in the creation of new academic programs that integrate engineering with other disciplines.

In the following pages, you will learn about some of these collaborations, including an international effort to develop a sophisticated form of glass that can help regenerate damaged bone tissue, a unique carbon nanotube research project and Lehigh's innovative undergraduate honors program in Integrated Business and Engineering.

I hope you enjoy this first issue of *Resolve*. I welcome your thoughts and comments on this magazine, and on the exciting research and educational programs conducted here at Lehigh.

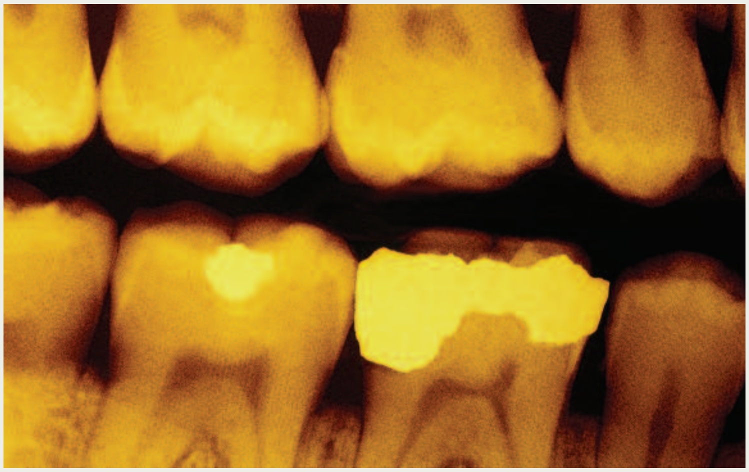


S. David Wu, *Dean and Iacocca Professor*
P.C. Rossin College of Engineering and Applied Science
david.wu@lehigh.edu

"Research clustering stands on a strong tradition of multidisciplinary research at Lehigh…It represents an effort to foster the organic growth of collaborations and to expand the scope and impact of research…While elevating it above typical academic disciplines or research centers." —S. David Wu

For dental imaging, OCT on a chip

Seated in the dentist's chair, you clamp your teeth and listen for the whir as a machine takes an x-ray of your mouth. The image is acquired in less than a second, but to Boon S. Ooi, associate professor of electrical and computer engineering, the scenario represents outdated 20th-century technology.



An OCT system-on-a-chip uses IR light to scan teeth without damaging tissue

Ooi is teaming with researchers at the University of Maryland Dental School and at Northwestern University to develop a technology that will replace x-rays as a method of imaging teeth and gums.

X-rays, as an ionizing radiation source, can harm living tissue, causing DNA damage and mutations. Although dentists use a low radiation-density x-ray, they are wary of overexposing patients by taking pictures too often.

Ooi's technology, based on the integration of Optical Coherence Tomography system-on-a-chip, or OCT-SOC, uses near-infrared light, which transmits at too small an energy level to harm living tissue or cells.

Optical coherence tomography, which was developed about 15 years ago, has become a popular, noninvasive technique for obtaining high-resolution images of cross-sectional subsurface tissue. But OCT technologies have limitations. They are large, their components are discrete, and they contain just one detecting element. As a result, OCT devices are typically slow, bulky and expensive.

OCT-SOC, says Ooi, will integrate a broadband light source, an interferometry system and micro-spectrometers on a chip measuring 2 mm by 3 mm. Ooi's OCT-SOC can be batch-fabricated in linear or 2-D arrays, making it possible to obtain an image of teeth structure and gum tissue in real time. This high-speed dental imaging tool is safe, lightweight and low-cost, and can provide a 3-D image with a resolution two orders of magnitude greater than the conventional x-ray technology.

"This is a beautiful and powerful new technology," says Ooi, who works in Lehigh's Center for Optical Technologies. "It gives us parallel imaging capabilities instead of imaging one pixel at a time."

Ooi's research partner at Maryland is Prof. Linda Otis, the person who first applied OCT to dental imaging.

Ooi collaborates on a separate project with Carl Zeiss Meditec Inc., a German-based international maker of ophthalmology systems, with whom he is developing novel light sources for an ultra-high resolution OCT technique for diagnosing eye diseases.

Plotting the pathways of pathogens

Grad student Alon Abramson tracks bacteria in columns

Scientists tracking the spread of pathogens in groundwater, and homebuilders seeking a safe distance from septic system to water well, ask the same question: How far do bacteria travel through porous media like soil?

Applying the collision efficiency – the probability that bacteria will adhere to a surface with which it comes into contact – can answer part, but not all, of that question, says Derick Brown, the Frank Hook Assistant Professor of civil and environmental engineering.

Varying cell surface properties affect bacterial transport, says Brown, making the collision efficiency a distributed, not a fixed, parameter. Brown, who has an NSF CAREER Award, studies aspects of bacterial transport through sand packed in columns at multiple-length scales.

"We have worked with columns of up to 1 meter in length," says Brown, "and we plan to set up a 10-meter flow system. By measuring bacteria concentrations and transport conditions along the 10 meters, we hope to enhance our understanding of the collision efficiency distribution and its effects on bacterial transport under near field-scale conditions."

Brown also studies the correlation between acid-base cell properties and enhanced production of adenosine triphosphate (ATP), which is a key energy carrier for living organisms. He is modeling the link between the neutralization of a cell's acidic surface, as it approaches another surface, and the formation of ATP. This research seeks to improve understanding of a well-known phenomenon – the increase in metabolic activity of a bacteria cell when the cell adheres to a solid surface.

A mechanical fix for the vulnerable middle ear

Samir Ghadiali and the University of Pittsburgh Medical Center have been awarded two NIH grants to develop computational models of the Eustachian tube.

Few parents would be surprised to learn that the most common illness among small children in the U.S. today is the middle ear infection. Americans spend $5 billion a year on ear infections, while doctors perform 500,000-plus surgeries, usually inserting a tube in the eardrum to ease pressure. Meanwhile, researchers scramble to find new antibiotics as bacteria become resistant to existing drugs. Samir Ghadiali believes the solution to middle ear illness lies in understanding and, in some cases, altering the mechanical and physical properties that govern the Eustachian tube, which connects the middle ear to the nose and throat and helps regulate air pressure inside the ear.

Ghadiali, assistant professor of mechanical engineering and mechanics, has designed a device to measure the mechanical properties of the Eustachian tube and has developed mathematical models to interpret those properties.

Recently, Ghadiali and the University of Pittsburgh Medical Center received two five-year grants from the National Institutes of Health to further develop and fine-tune his computational models of the Eustachian tube.

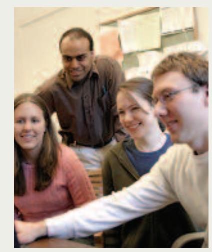
The researchers are studying "patient populations," including young children, who are significantly more prone to disease of the middle ear.

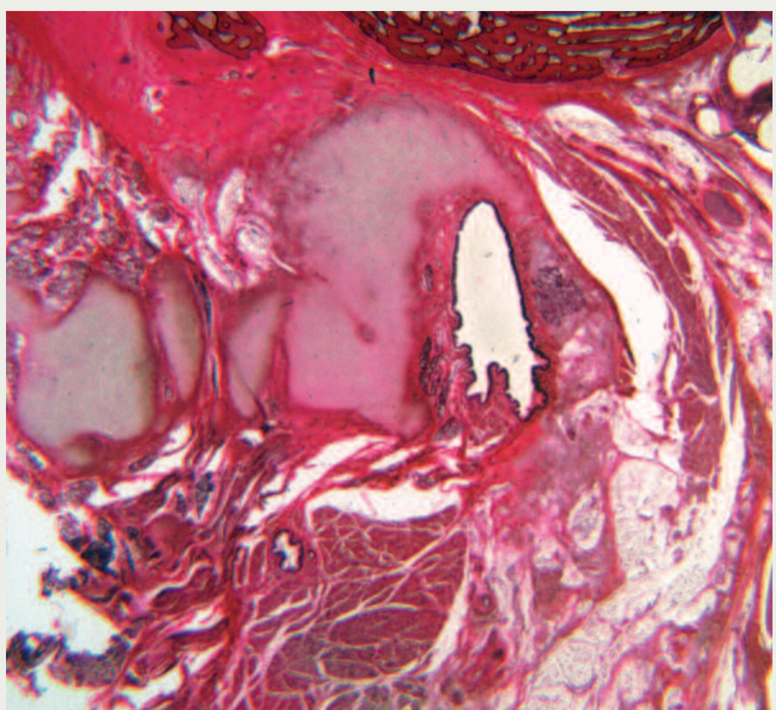
"If we can identify the key genetic, anatomical and physiological properties that cause disease in a specific patient or groups of patients, one day doctors will be better equipped to apply the right type of treatment," says Ghadiali, who is a member of Lehigh's bioengineering and life sciences program.

Ghadiali, who uses Finite Element Analysis to model fluid flow, tissue deformation and cellular phenomena in the ear and Eustachian tube, has collaborated for six years with Children's Hospital of Pittsburgh on studies of the middle ear.

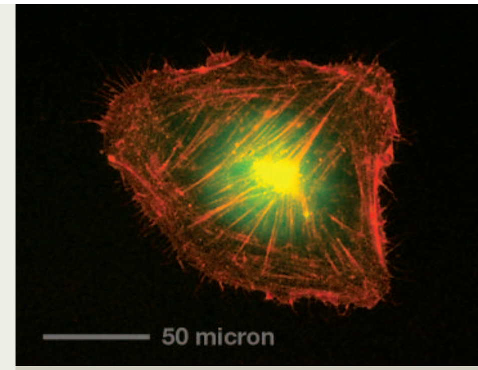
In 2005, Ghadiali received a Parker B. Francis Fellowship in Pulmonary Research to study the mechanics of respiratory disorders and lung function.

He and his students are conducting lab experiments and developing mathematical simulations to determine the effects of injury and disease on lung mechanics. Ghadiali's group is particularly interested in the fluid-mechanical forces, which can injure the lungs of patients who are being mechanically ventilated.





Samir Ghadiali (second from left in inset photo above) recently received two NIH grants to study the mechanics of the middle ear



Synthetic corneas, a layer at a time

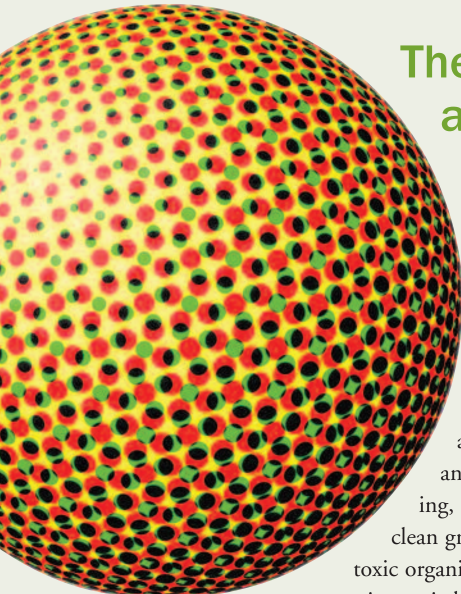
Padma Rajagopalan, a member of Lehigh's bioengineering and life sciences program, assembles 3-D layered cellular architectures that resemble the stratified, lattice-like structure of tissues *in vivo*.

Rajagopalan fabricated 3-D liver-like tissues at Harvard Medical School's Center for Engineering and Medicine before she was appointed P.C. Rossin Assistant Professor of chemical engineering at Lehigh in 2005.

She approaches her current project on three fronts. First, she designs polymeric substrata that mimic the porosity and topography of basement membranes. Second, she assembles 3-D cellular architectures on the polymeric surfaces. Third, she incorporates thermally responsive biopolymers between layers of cells to enable the detachment and subsequent study of the contribution of each cell layer in a 3-D cellular structure.

Rajagopalan's goal is to assemble multilayered corneal epithelial constructs that can be integrated into the design of future tissue-engineered corneas. Her studies are motivated by the fact that corneal malfunction is a leading cause of blindness in the world. Corneal function can be restored by donor transplants, but the high demand and the cost of transplanting human corneas provide strong incentives for a tissue-engineered substitute.

Cytoskeletal organization and focal adhesions in a corneal epithelial cell adhered to a nanoporous basal membrane mimic



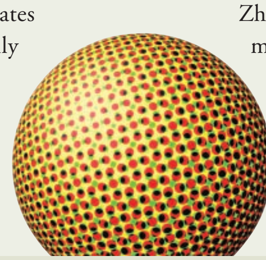
The invisible nanoparticle flexes a mighty cleanup muscle

The solution to one of America's biggest environmental problems could come from iron-based particles that are 1,000 times thinner than a human hair.

Wei-xian Zhang, associate professor of civil and environmental engineering, uses these nanoparticles to clean groundwater that contains toxic organic solvents, pesticides and carcinogenic heavy metals.

With a larger proportional surface area, nanoparticles are more reactive than larger cleanup agents

In site tests in New Jersey and Florida, nanoparticles made at Lehigh have reduced contaminants by as much as 96 percent in four weeks, says Zhang. This compares to success rates of 25 to 35 percent typically achieved in one year by traditional, more costly cleanup methods.



With as many as half a million sites requiring cleanup, estimates of the cost of remediating America's groundwater, much of it tainted by industrial pollution, run well over $1 trillion.

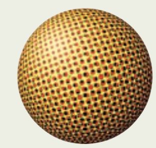
Zhang believes his method could cut these costs by as much as 75 percent.

The U.S. EPA's National Center for Environmental Research has praised Zhang's work, saying his nanoparticles are "highly reactive, can be scaled to fit the pollution problem and could be used for a wide variety of common contaminants, including chlorinated hydrocarbons, pesticides and explosives."

Zhang's work has been featured in *Technology Review, Environmental Science and Technology* and *Chemical and Engineering News*.

Zhang's nanoparticles contain more than 99.9 percent iron and less than 0.1 percent palladium, a catalyst used in catalytic converters and other applications.

The nanoparticles' size gives them their advantage, says Zhang. Measuring 20 to 50 nanometers in diameter, the particles have a greater proportional surface area than larger quantities of the same catalyst, giving them more reactivity with the toxins. And being small, the particles "flow with the groundwater through the ground, chase the waste and treat it in the ground," he says.



Zhang has a patent pending on his cleanup technology, and Lehigh has licensed his technology to two environmental remediation companies. He has received funding from NSF and EPA.

"The key to commercializing this process will be to make the material in a large enough quantity to achieve economies of scale," says Zhang, who is enlisting chemical companies and industrial partners to help overcome that problem.

In 2005, Zhang served as guest editor for an issue of *Environmental Science and Technology* that was dedicated to nanotechnology research.

$10-million lab leads gains in optics

Lehigh's optical research portfolio has enjoyed a banner year.

- In October 2005, **LEHIGH'S CENTER FOR OPTICAL TECHNOLOGIES (COT)** opened a $10-million laboratory where researchers will make advanced devices with biomedical, military, pharmaceutical, sensor and other applications. The new Smith Family Lab enables researchers to make and analyze new classes of optical materials and devices. Its 3,000-square-foot clean room and epitaxial growth facilities make it possible to develop new compound semiconductors that emit light ranging from infrared wavelengths to the ultraviolet.

The COT has received more than $63 million in funding since 2001.

- Also in October 2005, **FILBERT BARTOLI** was appointed chair of electrical and computer engineering after completing five years as program director for electronics, photonics and device technologies with NSF's Electrical and Communications Systems Division.

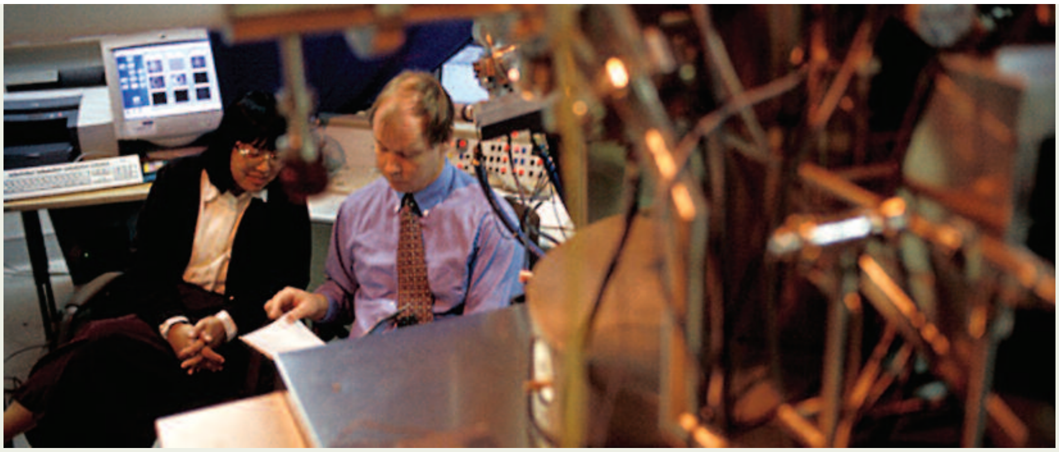
Bartoli has conducted groundbreaking research in photonics, optoelectronics, quantum well devices and nanotechnology in his 35-year professional career. At NSF, he oversaw research programs in optoelectronics and photonics, MEMS, sensors, integrated microsystems and biomedical applications.

- In February 2006, COT director **THOMAS KOCH** was elected to the National Academy of Engineering, which cited his "contributions to optoelectronic technologies and their implementation in optical communications systems."

Koch, former vice president for technology platforms at Agere Systems, explores the fundamental performance limits of lasers used for telecommunications and for the design and demonstration of semiconductor photonic integrated circuits.

He is part of an international research team that in 2006 began investigating nanophotonics and developing a silicon-based laser, in an MIT-based project funded by the U.S. Department of Defense. The initiative also involves researchers from Boston University, Caltech, Cornell, Stanford, Delaware, Rochester and MIT, as well as from Canada, Italy and the Netherlands.

Prof. Nelson Tansu demonstrates the MOCVD (Metal Organic Chemical Vapor Deposition) reactor in Lehigh's Smith Family Laboratory



Lehigh, NASA collaborate on successor to Hubble

Martin Harmer, director of Lehigh's Center for Advanced Materials and Nanotechnology, received a Humboldt Fellowship in 2006

NASA's Goddard Space Flight Center is developing a successor to the Hubble telescope and the Mars Rovers with help from Lehigh's aberration-corrected transmission electron microscopes and its Nano- and Micro-Mechanical Behavior Laboratory (NMBL).

Lehigh is the only university in the world with two aberration-corrected TEMs, which can determine the chemical identity of individual atoms in crystalline materials. The university has hosted an annual two-week microscopy school, the largest of its kind, since 1970.

Under a cooperative agreement signed in 2006, NASA will support three research projects at Lehigh, including Production and Properties of Advanced Nanomaterials, as well as Design and Reliability of NEMS and MEMS.

Lehigh's NMBL will help researchers design and test the microshutters that will serve as an aperture on the new James Webb Space Telescope. NMBL's instruments can characterize the mechanical behavior of nanometer-thick metal films in the extreme temperatures of space.

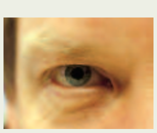
The NMBL and the aberration-corrected TEMs are housed in Lehigh's Center for Advanced Materials and Nanotechnology (CAMN).

CAMN is directed by Martin Harmer, professor of materials science and engineering, who received a Research Award for Senior Scientists from Germany's Alexander von Humboldt Foundation in 2006.

CAMN is also collaborating with Harvard, Rice, Georgia Tech, UCLA and the Illinois Institute of Technology to study the economic and environmental impacts of nanotechnology. The project is funded by a grant from NSF's Nanoscale Science and Engineering Center.

CAMN also receives nanotechnology research funding from two Materials Research Science and Engineering Centers – the Pennsylvania MRSEC and the National Science Foundation MRSEC at Carnegie Mellon University. Martin and Andrea Harmer also lead the Materials Pennsylvania Coalition, through which Lehigh and five other Pennsylvania schools use web-based technologies to share courses.

In 2005, *Small Times*, the nation's top business journal devoted to micro- and nanotechnology, ranked Lehigh third among the nation's universities for "micro industry outreach."



"The real power of nano is evident when it supports discovery and innovation in other areas – areas such as medicine, computing, materials, environmental engineering and more." —Martin Harmer

Tops in nanotech

Chris Kiely, professor of materials science and engineering, was one of 14 researchers worldwide in 2005 to receive Nano 50 Awards from *Nanotech Briefs*.

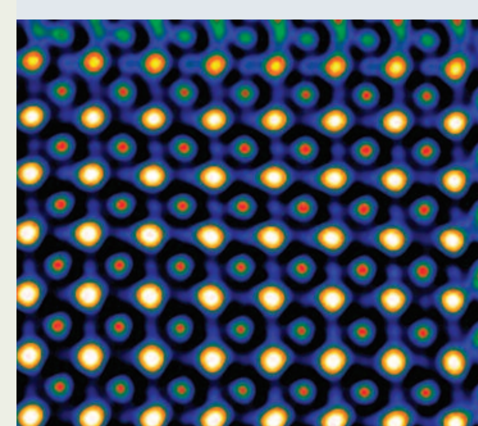
The online journal recognized the "top 50 technologies, products and innovators that have significantly impacted...the state of the art in nanotechnology." Kiely was one of 14 innovators named.

Kiely, who directs Lehigh's Nano–characterization Laboratory, develops TEM techniques to study catalysts, nanoparticle self-assembly, nanowires, fullerenes, carbon nanotubes, metal-semiconductor contacts, metal-oxide interfaces and semiconductor heteroepitaxy.

In 2005-06, Kiely and colleagues from Cardiff University in the U.K. published articles in *Nature* and *Science*.

The group reported in *Nature* that the selective oxidation processes used to make compounds contained in chemical products could be accomplished more cleanly and efficiently with gold nanoparticle catalysts.

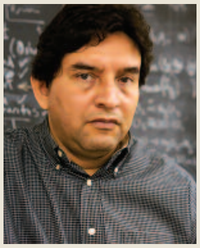
In *Science*, the group reported that they had used Lehigh's VG HB 603 aberration-corrected scanning transmission electron microscope to map the chemical structure of a nanoparticle that is the active component of a new, environmentally friendly catalyst.



The atomic structure of a strontium titanate ($SrTiO_3$) crystal as resolved by Lehigh's JEOL 2200FS aberration-corrected microscope

Modifications cut mercury emissions

Researchers at Lehigh's Energy Research Center (ERC) have developed a cost-effective technique for reducing mercury emissions from coal-fired power plants.



Carlos Romero oversaw full-scale tests at four power plants

In full-scale tests at four power plants, says lead investigator Carlos Romero, the Lehigh system cut flue-gas emissions of mercury by up to 70 percent or more with minimal or modest impact on plant performance and fuel cost.

Romero estimates that the new ERC technology could save a 250-megawatt power unit as much as $2 million a year in mercury-control costs.

The reductions were achieved, says Romero, by modifying the physical conditions of power-plant boilers, including flue gas temperature, the size of the coal particles that are burned, the size and unburned carbon level of the fly ash, and the fly ash residence time.

Making changes to the physical conditions of power-plant boilers, says Romero, can cut mercury emissions by 70 percent and save a 250-megawatt unit up to $2 million a year in pollution-control costs.

The ERC researchers reported their findings in 2005 in *Fuel*. Their work was featured in May 2006 in *Environmental Health Perspectives*, the peer-reviewed journal of the U.S. National Institute of Environmental Health Sciences.

The changes in boiler operating conditions, says Romero, prevent mercury from being emitted at the stack and promote its oxidation in the flue gas and adsorption into the fly ash instead. Oxidized mercury is easily captured by scrubbers, filters and other boiler pollution-control equipment.

The ERC team used computer software to model boiler operating conditions and alterations and collaborated with Western Kentucky University on field tests at units burning both bituminous and sub-bituminous coals.

Only about one-third of mercury is captured by coal-burning power plant boilers that are not equipped with special mercury-control devices, Romero says.

Romero says cost savings could be achieved by applying the ERC method solely or in combination with a technology called activated carbon injection.

The ERC group was funded by a group of utility companies, the Pennsylvania Infrastructure Technology Alliance and the U.S. Department of Energy. ⓡ

Engineering for the life cycle

The Sears Tower and the John Hancock Center in Chicago are two of the impressive structures designed by Fazlur Rahman Khan (1929-1982).

Lehigh has endowed a Khan Chair in structural engineering and architecture and appointed Dan M. Frangopol, an expert in structural reliability and optimization, as its first holder.

Frangopol, formerly of the University of Colorado at Boulder, will set up new programs in life-cycle engineering and in the maintenance and management of structures.

Life-cycle engineering, he says, optimizes the investment made in structures by considering conflicting objectives over a specified time. It employs probability and statistics to account for the changes structures undergo, and it helps engineers select the solution that best balances performance enhancement and cost reduction.

"A structure should be planned and built for a life cycle of 50 to 100 years, or more," says Frangopol. "From the beginning, you should estimate how much money you need to spend to optimize the cost of maintaining structures over their lifetime.

"As our civil infrastructure systems continue to grow more complex, we need to use an integrated approach to understand the effects of technological, environmental, economical, social and political interactions on the life-cycle performance of systems."

Frangopol is founding president of the International Association for Bridge Maintenance and Safety, chair of the executive board of the International Association for Structural Safety and Reliability, and vice president of the International Society for Structural Health Monitoring of Intelligent Infrastructure. ⓡ

Enhanced control through algorithms

The control of systems, Mayuresh Kothare likes to say, is not only an enabling technology, but an invisible discipline as well.

"If a system works as it should," says Kothare, "no one ever thinks about control. If a system fails, the first person to be blamed is the control engineer."

Kothare, the R.L. McCann Associate Professor of chemical engineering, is co-director of Lehigh's Center for Chemical Process Modeling and Control. He serves on the editorial boards of *IEEE Transactions on Automatic Control* and *Automatica*.

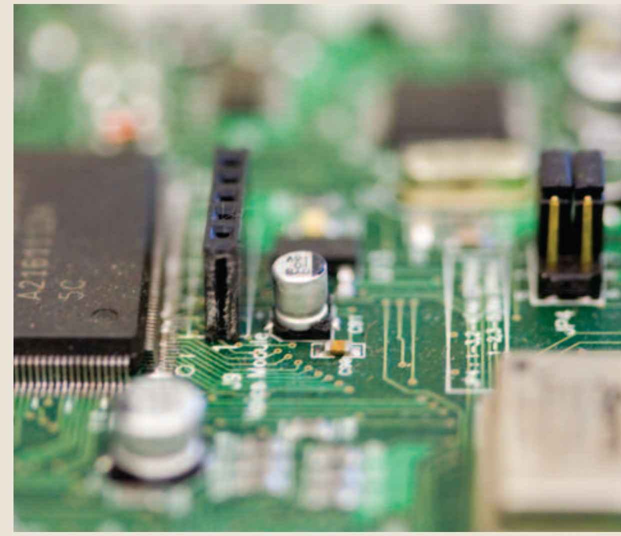
An expert in model-based controls, Kothare uses applied mathematics, modeling and simulation to obtain algorithms that control systems automatically. He has filed a patent for a microreactor that produces hydrogen through methanol reforming.

The success of Kothare's Ph.D. students testifies to the ubiquitous need for control systems. One student recently joined Harvard's Bauer Center for Genomics Research, where he develops feedback loops in cellular systems to help cells regulate their functions. Another was hired by Xerox for his background in MEMs, control theory and microreactors. A third works on control of polymerization reactors for petrochemical applications at ExxonMobil. A fourth develops control systems for GE, and a fifth teaches process control at the University of Kuwait.

Kothare is collaborating with ADCUS Inc., a semiconductor design company, to develop and embed Model Predictive Control technologies in a system-on-a-chip framework. Lehigh and ADCUS hope to download an entire computer control software program onto a chip. Applications include iPods, CD drive controllers, conventional control systems and an implantable biomedical device for insulin delivery, which could use an optical sensor to determine the optimal dose.

Kothare is co-principal investigator on the project with Mark Arnold, director of Lehigh's Computer Architecture and Arithmetic Research Laboratory.

Kothare has a separate contract with General Dynamics to design and fabricate a control system for the gun and gun turret on a military tank.



Among the applications for embedding a control algorithm on a chip, says Kothare, is the regulation of human glucose using a glucose-insulin model

Judging a site by the company it keeps

Searching the Internet, Brian Davison likes to joke, begins with a popularity contest. You enter a topic, and the search engine produces a list of websites. The pages listed first have received the most votes, or "recommendations," with each link to a listed page from a credible site representing one vote.

This simple concept underpins how search engines function. But each web page's links are made in different contexts, says Davison; thus, recognizing those contexts can lead to improved quality of web search results.

Davison, assistant professor of computer science and engineering, recently received a five-year NSF CAREER Award to study this approach.

"Our goal is to improve web searches – from eliminating search engine spam to improving search engine ranking functions," he says. "One way to begin to identify a good page is to determine how many credible sites are linked to it."

A search engine might count each link to a site as a recommendation, Davison says, but recommendations can't be weighted equally. "While doing a search for 'home improvement' you may discover a page on plumbers," he says. "While they may be credible plumbers, your objective is to redecorate your house. We're working to filter out the 'recommendations' that cause such a page to be viewed as authoritative on one topic, but are not relevant to your desired topic."

Davison and his students are considering the topical context of a link and determining how to assign rank by authoritativeness within the query topic, thus improving the authority calculation. They are also seeking new ways to determine context beyond this topical approach and to estimate why a link was created. This will help decipher links that are created, say, for advertising purposes and do not match the search intent.

After finishing its analysis, Davison's team will be able to identify a site's topical content and the communities in which it is well-respected.

The NSF award will also help Davison purchase storage equipment.

"We'll begin with 12 terabytes and expand to approximately 50 terabytes," he says, estimating his team's eventual capacity at 500 million to 1 billion web pages. "This is a small fraction of Google's capacity, but it is substantially more than the typical research trial."

INTERVIEW BY KURT PFITZER AND CHRIS LARKIN • PHOTOGRAPHY BY THEO ANDERSON

ENLISTING NEW RESEARCHERS FOR GLOBAL CHALLENGES

A GRAND MISSION

Alice Gast became Lehigh's 13th president on Aug. 1, 2006. An expert in surface and interfacial phenomena, Gast served previously as vice president for research at MIT and as professor of chemical engineering at Stanford and its Synchrotron Radiation Laboratory. Gast is particularly interested in the behavior of complex fluids, colloidal aggregation and ordering, protein-lipid interactions and enzyme reactions at surfaces. She has been elected to the National Academy of Engineering and the American Academy of Arts and Sciences and has received Guggenheim and Humboldt fellowships.

Q: ***You often quote Lehigh founder Asa Packer and his mission for Lehigh – "to instill in students the values of a liberal education while preparing them for life in an increasingly technical world." What does the combination of classical and scientific education mean for the modern university?***

A: I believe strongly in this dual mission. Many universities are trying to define what higher education will be in the 21st century. Some of them are finding they need to come back to their core values. My sense is that Lehigh has never left its core values and has maintained its balance between classical and scientific education while evolving into new areas and pursuing new disciplines.

In the future, I think we will find that overspecialization will not be valued. People who can cross disciplinary boundaries, work well with others and solve problems in a variety of ways will be those who are most successful. People with a well-balanced education will have those tools. They will have learned how to define and to solve problems from a variety of perspectives because of the breadth of their education.

Q: ***Many researchers today are exploring the interaction of biological and engineering systems. Where do you think this new field is headed?***

A: Biomedical engineering and bioengineering are exciting new forefronts that transcend disciplinary boundaries. Pathways in disease and cell-signal processing, for example, are two areas where analogies can be drawn to engineering systems.

Engineers should also be thinking about how their work can contribute to human health in a broader sense. I think we as a nation have turned our attention from infectious disease and really crippling diseases to

Engineers, says Alice Gast, should embrace the world's grand challenges

chronic illnesses and the aging population. Yet the specter of pandemic flu recently turned our attention back to infectious disease. Clearly globally infectious disease is still a huge issue facing the world, and as the world shrinks and diseases travel more rapidly from one continent to another, I think there are a lot of opportunities for engineers, scientists and social scientists to work together.

Q: ***What other emerging areas of science and technology should engineering schools pursue?***

A: There are grand challenges facing the world where researchers in engineering, the sciences and social sciences, working together, can have a huge impact. Issues like climate change, environment and energy clearly have a place in an engineering college. Lehigh can excel in these areas. In a small university with a collaborative environment, it's relatively easy for researchers to cross boundaries and pursue new themes of research.

Q: ***Recent advances in nanotechnology, information technology and bioengineering have underscored ethical dilemmas regarding embryonic stem-cell research, security, privacy, end-of-life issues and more. How can engineering schools prepare students to deal with these issues?***

A: I certainly think that engineering schools have an obligation to pursue their research with a view to its impact on society. I think faculty should bring real-life examples from their areas of scholarship into the classes they teach and into classes on ethical issues in science and engineering. Students are very concerned about the societal impacts of technology. I think the time is right to bring together scholars from a variety of disciplines to develop realistic courses that will make students want to gain a deeper understanding of ethical issues.

Q: ***You have stated that the U.S. system of higher education is the envy of the world. Can you elaborate?***

A: I'm a firm believer in our national system of higher education. One of the main reasons that the finest students in the world have flocked to American universities is the strong marriage between research and education in the U.S. In many other countries, research is assigned to institutes and is somewhat separate from the educational function. In the American system, professors do cutting-edge research and bring this experience into the classroom. That makes education much more meaningful for students.

Today, American higher education faces much more competition from abroad. Universities in other countries have done a good job emulating U.S. universities and copying what's best about them.

Q: ***In the 1960s, science enjoyed great public support in the U.S. and Americans were almost universally excited about the goal of sending a man to the moon. What endeavor today could galvanize the nation and renew popular interest in science and technology?***

A: Today's challenges are global in scale and require international collaboration. There have been some notable successes. The virus responsible for SARS (Severe Acute Respiratory Syndrome) was identified, and a diagnostic test developed in a few months, by a collaborative effort involving 11 laboratories in nine countries. The ITER fusion reactor, which will be built in France, involves the European Union, the U.S. and five other nations. I don't know if these examples will galvanize people, but I hope they motivate them. We need public support to work together on a global scale.

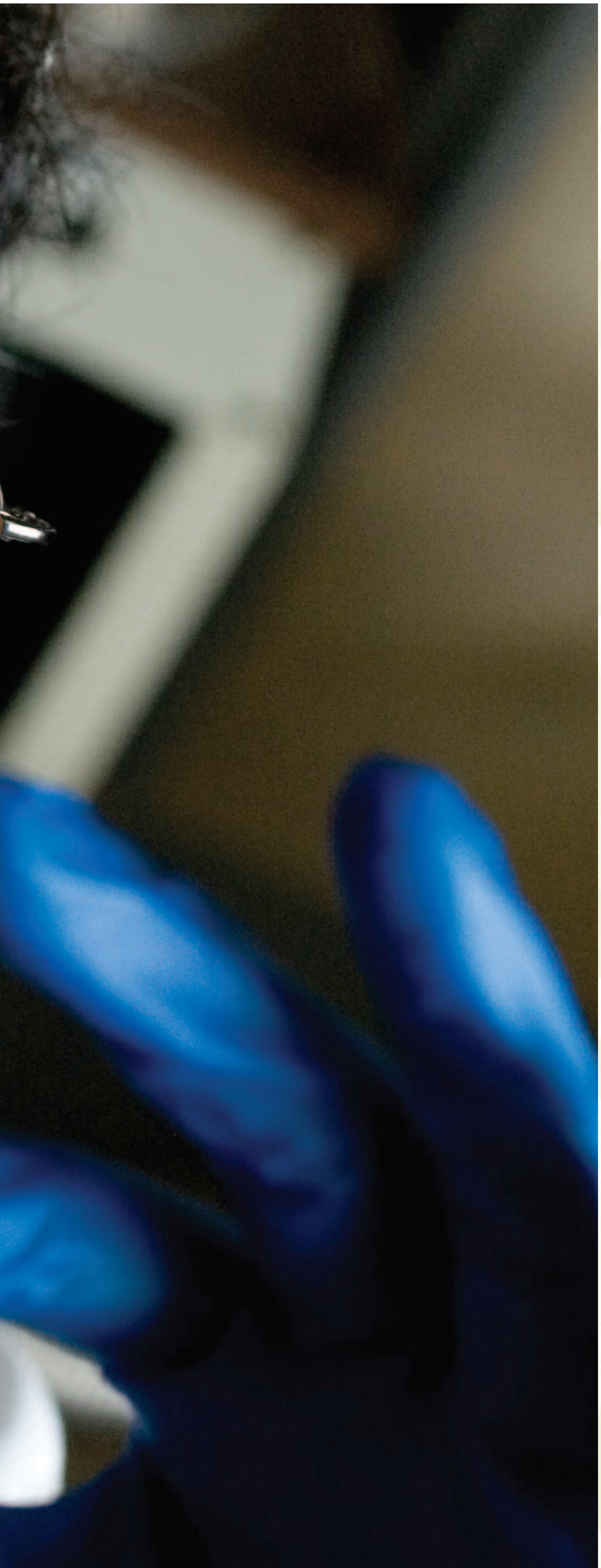
Q: ***What are your goals for research at Lehigh?***

A: My goals for Lehigh stem from my experiences at MIT and Stanford. I've learned that research excellence comes from hiring the very best faculty and recruiting the very best students and giving them the environment it takes to excel. In the right environment, faculty and students will see new directions, find exciting opportunities, cross boundaries and catalyze groups. That's how research excellence thrives. Fund-raising is at the heart of this goal. Lehigh has reflected its commitment to excellence in its current capital campaign by raising funds for endowed chairs and scholarships.

Q: ***You have earned an international reputation for your work in surface and interfacial phenomena and the behavior of complex fluids. What was your most memorable moment as a researcher?***

A: Some of my best moments in research have been in finding analogies. I'm a chemical engineer. I work on complex fluids. Some people in chemistry, physics and mechanical engineering work on similar things. It's exciting when I learn something from another field and can make an analogy to a problem I'm working on and use it in my research.

But I'm most proud of my students. I was one of those faculty members who believes that my products are really my students. Developing their potential and their ability to solve problems and pursue research has been, I think, the greatest joy of being a professor.



THE GLASS BONE MATRIX

GLASS, IT SEEMS AT FIRST GLANCE, IS ALMOST ENDLESSLY VERSATILE. We use glass to repair our eyesight, to adorn skyscrapers and to create artistic treasures. We employ it to reflect, refract and transmit light, and to exchange unthinkable quantities of information in slices of seconds. But all this is just the surface, says Himanshu Jain. Someday, if we can learn to tailor its chemical and mechanical properties, glass may be used to mimic and even restore the miracles of nature.

An international group led by Himanshu Jain is preparing glass for a major new medical role

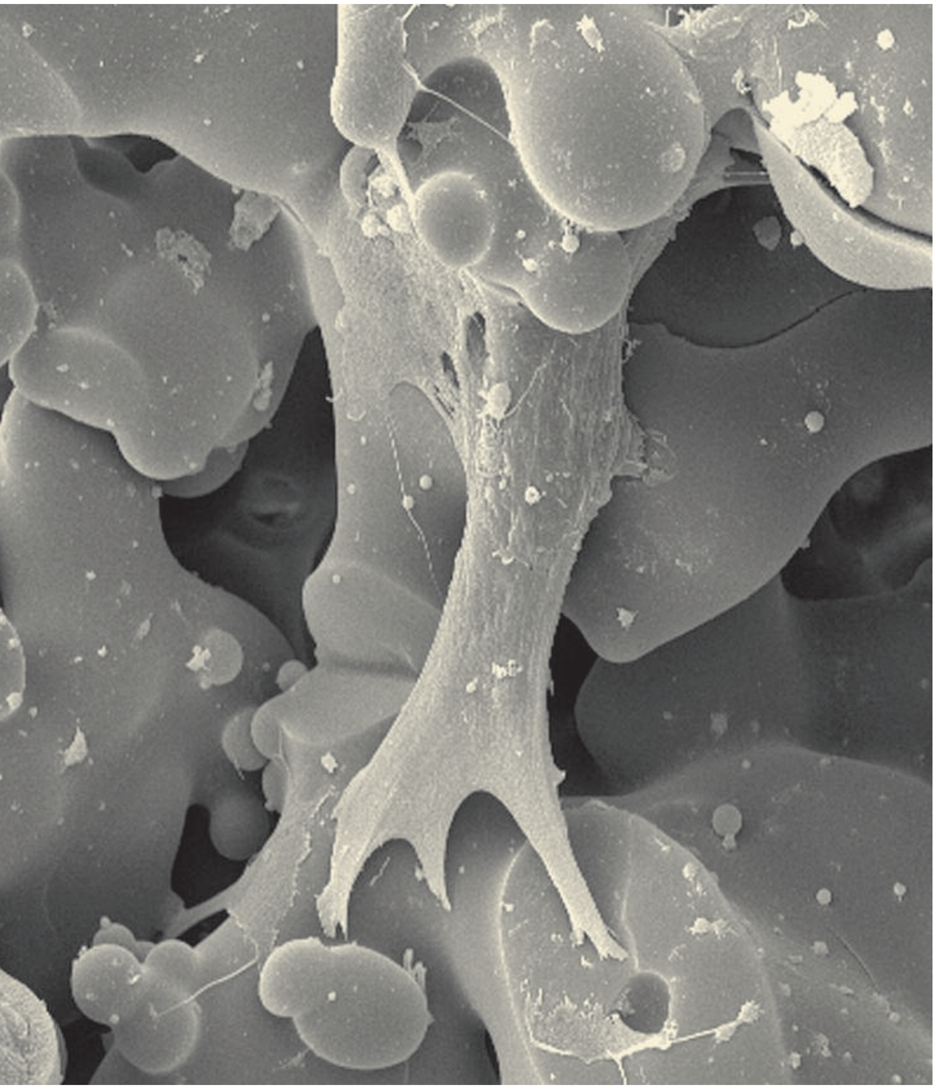
Jain, director of NSF's International Materials Institute (IMI) for New Functionality in Glasses at Lehigh University, has spent three decades exploring the myriad uses of glass.

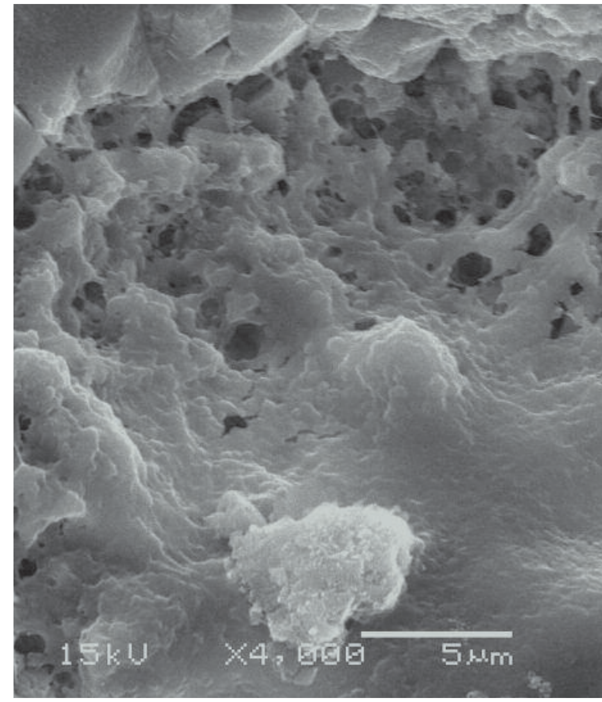
He accepted a new challenge during the 2004 U.S.-Africa Materials Workshop in Cairo, when he took a break to visit the University of Alexandria on Egypt's Mediterranean coast.

Mona Marei, head of the tissue-engineering lab at the university's Faculty of Dentistry, had asked Jain for help with a growing medical problem – the deterioration of people's teeth and jawbones. Osteoporosis, she told Jain, was causing the bone around people's teeth to weaken, making it difficult for doctors to replace loosening or diseased teeth with prosthetics or implants and, in severe cases, causing fractures that required removal of bone and teeth.

Marei was experimenting with biocompatible glass bone transplants to replace damaged teeth and bone, but was not satisfied with her results.

PHOTOGRAPHY BY THEO ANDERSON





A glass scaffold with interconnected nano- and macropores shows promise in stimulating damaged and diseased bone to regenerate

Biocompatible materials can be placed inside the body without triggering a systemic reaction or an infection. But Jain suspected something more than biocompatibility was required of the glasses that Marei was testing.

The ideal treatment for diseased or damaged bone is to coax the body's natural bone tissue to regrow. Doctors have succeeded in taking a bone graft from one part of a person's body and using it as a "scaffold" to stimulate bone tissue elsewhere to regrow. But although biocompatible glasses have been used as bone transplants, no one has yet succeeded in using glass as a bone scaffold.

Until now.

Today, working with researchers in four countries on three continents, Jain and his collaborators have modified a biocompatible glass belonging to the calcium-phosphate-silicate family into a scaffold that promises to stimulate bone regeneration. They have successfully tested the glass in *in vitro* experiments at Lehigh's IMI. Marei and her group are preparing to run *in vivo* tests at the University of Alexandria.

AN OVERSEAS ASSIST WITH DUAL POROSITY

In seeking an effective scaffold for bone regeneration, Jain and Marei sought to develop a glass that would promote transport of nutrients and blood while allowing new cells to "in-grow" and adhere to the scaffold.

Like the spongy interior of bone, the new material would need interconnected pores to facilitate the production of red blood cells and the flow of blood to other areas of the bone.

A glass scaffold might emulate the mechanical properties of bone, Jain believed, if it could be made porous at both the nano and macro scales.

Nanopores measuring several nanometers in diameter (1 nm equals one one-billionth of a meter) would allow cell adhesion and crystallization of bone's structural components.

Macropores measuring in the tens of microns or larger, roughly 10,000 times the size of nanopores, would allow bone cells to grow inside the scaffold and to vascularize, or form new blood vessels and tissue.

"This is the next generation of biomedical applications. It will be helpful for all bones, ranging from teeth to arms and legs. It can be used for breaks, tumors and other defects." —Ana Marques

To achieve "dual porosity" in a biocompatible glass, Jain turned to two researchers he knew from the Instituto Superior Técnico in Lisbon, Portugal – Rui Almeida, professor of materials science and engineering, and Ana Marques, a research scientist who has studied pore formation while preparing wave guides for optical amplifiers.

During a recent stay at Lehigh's IMI, Marques used common lab equipment, including a ventilated hood and a hot plate, to develop glass with dual porosity. She employed standard experimental techniques – nitrogen adsorption and porosimetry to measure material surface areas and pore-size distributions and high-resolution scanning electron microscopy (SEM) to detect pores.

Marques also employed the sol-gel process, a wet-chemistry technique that uses relatively low temperatures to prepare glass. After mixing a solution, she allowed it to gelate and then heat-treated the gel until it formed a glass.

The sol-gel process inherently promotes nanoporosity, says Marques. To achieve interconnected macroporosity, Marques added a polymer to the sol-gel solution, causing a phase separation to occur parallel to the sol-to-gel transition.

The phase separation enabled Marques to overcome a simple law of thermodynamics, says Jain.

"Thermodynamically, the coexistence of nanopores and macropores is unstable in that the larger pores should absorb the smaller pores," he says. "But with Ana's help, we have developed a material that defeats that expectation."

After three months at Lehigh's IMI, Marques was able to produce glass with nanopores measuring 5 to 20 nm in diameter and macropores measuring more than 100 microns across.

"The aim of our project was to create nano- and macro-porosity in a bioactive material while achieving mechanical properties that match those of bone," says Marques. "We believe our material will stimulate bone regeneration because cells will proliferate inside the scaffolding material and form tissues, thus facilitating the delivery of nutrients to regenerating bone tissue."

"When you attach the glass to the damaged bone," says Mohamed Ammar, a dentist and research scientist at the University of Alexandria's tissue-engineering lab, "a layer forms on the surface of the glass that has the same chemical composition as the natural bone. The bone cells come to this layer and attach to it, in effect, forming a bone matrix around the glass."

As the treated bone regenerates, says Marques, the scaffold, being biodegradable, is absorbed by the body.

"This is the next generation of biomedical applications," says Marques. "It will be helpful for all bones, ranging from teeth to arms and legs. It can be used for breaks, tumors and other defects."

"This kind of material," says Jain, "might have other applications, such as controlled drug delivery, which could be achieved when a drug is released at differing rates because of the varying porosity."

The scaffolding material, says Ammar, who is now helping Marei supervise *in vivo* tests in Egypt, offers new hope to his patients, many of whom are women suffering from osteoporosis.

"We've been giving our patients medicines and prescribing exercises to strengthen their bone tissue and slow down the disease," says Ammar, who recently concluded four months of research at Lehigh's IMI. "This gives us something new. It is personally very exciting."

For undergraduate researcher, "initiative goes a long way"

Lehigh undergraduate Greg Brentrup has helped the University of Alexandria's Hassan Moawad (top) refine the melt-quench technique to produce a dually porous glass

Greg Brentrup '08 wanted a university that offered big opportunities with smaller classes. So the New Hampshire native bypassed colleges in New England in favor of Lehigh and its department of materials science and engineering.

"There are only 4,600 undergraduates at Lehigh," says Brentrup, "but the resources are large-scale. You just need to show initiative, and the opportunities follow."

And follow they have. Brentrup has already toured South Africa with the Lehigh Philharmonic Orchestra (he plays violin) and competed nationally on Lehigh's downhill ski team.

Last summer, he completed a 10-week research internship with NSF's International Materials Institute (IMI) for New Functionality in Glasses at Lehigh.

"At most universities, sophomores are overlooked for internships," says Brentrup. "But early last fall, I expressed an interest and my professors connected me with the IMI team managing a glass-bone scaffold project."

The IMI is leading an international effort to modify a biocompatible glass into a scaffold that promises to stimulate bone regeneration.

"I worked directly under Dr. Hassan Moawad, who is heading a group charged with adapting the melt-quench glass-making technique to achieve dually porous glass," says Brentrup.

Brentrup's previous classroom lab experiences enabled him to help Moawad mix and weigh rock chemical materials for the glass-melting process. He also polished the glass and used optical microscopes to study its microstructure.

"My work with the IMI really exposed me to the field of biomaterials," he says. "That's a huge field right now. It's great that students can work on projects like that.

"Lehigh has so many opportunities. Being at the right place at the right time helps, but initiative goes a long way – especially since professors are willing to work with you. It's really been a great place for me."


HAWK'S NEST

TWO TECHNIQUES IN A FRIENDLY DUEL

While the Lehigh IMI team is applying for a patent on its sol-gel technique, it is also testing a second technique for producing glass with dual porosity.

The melt-quench technique, also called the melt-and-pour technique, is the traditional process for making glass, says Hassan Moawad, who leads a Lehigh group that is modifying the technique to achieve dually porous glass (see story, p. 13). Moawad is also a member of the materials science faculty at the University of Alexandria.

"This is a friendly competition between two groups," says Jain, "that will enable us to compare and contrast the efficiency of the two techniques."

The researchers in Moawad's group use standard glass-making techniques, weighing and mixing the oxide powders, melting them at 1500 degrees Celsius, then grinding and polishing the glass and cutting it into small discs. The heat treatment stimulates crystallization, which strengthens the glass. Researchers also use a chemical treatment to etch the glass and introduce desired porosity, x-ray diffraction to measure the degree of crystallization and hardness, and optical microscopy and SEM to characterize the glass.

The melt-quench technique produces a stronger, more solid glass than does the sol-gel process, says Moawad. Glass made with the melt-quench technique can also be more readily molded.

But glass made with the sol-gel technique appears to be more biocompatible than melt-quench glass, says Moawad.

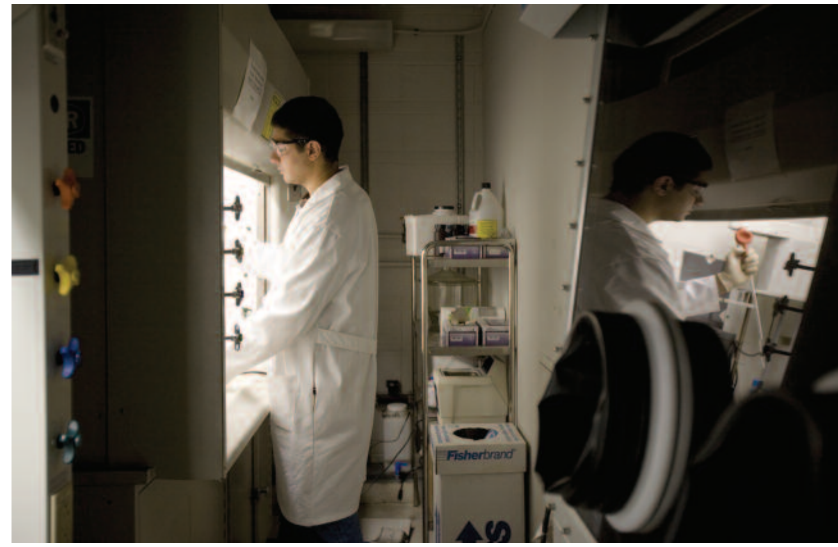
Moawad's team has succeeded in producing glass that is porous at the nano- and macro-scales. They have used SEM to verify pore diameter and surface area, along with BET (Brunauer-Emmett-Teller), a technique that measures nanopore dimensions, and mercury porosimetry, which measures slightly larger pores.

A key to the team's success, says Moawad, was discovering the correct proportion of oxides in the glass powder mixture. Moawad worked one year to develop the most effective mixture of silicon, calcium, phosphorous and boron oxides.

The next step for the researchers, says Jain, is to investigate the mechanical properties and bioactivity of the new materials, as well as the responses of cells that interact with the material.

The Lehigh-Lisbon-Alexandria research team is working on these challenges with researchers from Princeton University through the U.S.-Africa Materials Institute, which is headquartered at Princeton and directed by Wole Soboyejo, a materials engineer at Princeton.

A graduate student from Senegal will come to Lehigh later in 2006 to work on the project, says Jain.



Ammar (above) is conducting in vivo *tests on both types of glass. Moawad (left) spent a year optimizing the melt-quench mixture*

A jewel of a new glass technology

Himanshu Jain keeps one eye ever alert to new uses for glass.

Jain is currently studying the jewel beetle, or *Melanophila Acuminate*, which scientists believe can detect forest fires from a distance of up to 50 miles – something man can do only from an aircraft. The beetle lays its eggs in the bark of burnt trees to gain a competitive advantage for its young.

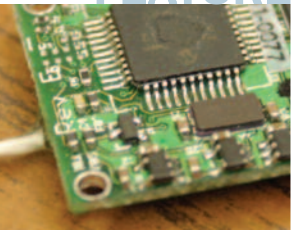
Scientists credit the beetle's sensing abilities to tiny cuticles under its wings that absorb infrared radiation at 3 microns – the wavelength emitted by wildfires.

The U.S. Army Research Lab recently granted Jain a contract to try to replicate what nature has accomplished with the jewel beetle.

"We need devices that can detect very weak infrared radiation, which has a range of wavelengths that transfer through the atmosphere without being absorbed. That happens to be the range of wavelength that the beetle can detect."

Lessons learned from the beetle, says Jain, could form the basis of new heat-sensing devices, which would utilize carbon nanotubes and chalcogenide glasses developed at Lehigh.

"This is another potential example of bio-inspired technology."






ROBUST SYSTEMS
LARGE AND SMALL

Robust engineering systems manage uncertainty in an infrastructure and respond effectively to emergencies and interruptions. The systems developed by Lehigh engineers run the gamut of scale, from micro-devices to large-scale structures to complex computing architectures. This section of Resolve *looks at four of these systems.*

Bridge safety, no strings attached

AN EARTHQUAKE STRIKES A LARGE CITY, wrecking roads and bridges, stranding rush-hour commuters, trapping office workers inside high-rise buildings.

As director of the city's transportation authority, you have minutes to make a momentous decision. What is the safest, fastest route that rescue teams can take to travel to hard-hit areas of the city? Which bridges, even if damaged, can still support traffic loads?

The answers, says Yunfeng Zhang, can be provided by sensors – networks of tiny sensors embedded in computer chips that are attached to a bridge to monitor its structural integrity and performance.

Sensors deployed strategically on a bridge, says Zhang, assistant professor of civil and environmental engineering, can provide a high-resolution, multidimensional picture of a critical part of the structure, giving engineers vital information about the bridge's performance and, in the aftermath of a catastrophe, its reliability.

To be useful in the event of an earthquake or other emergency, says Zhang, sensors must be able to transmit data in real time, virtually without delay, to the processing centers where data is interpreted.

Ancient wisdom: Yunfeng Zhang's students build a pagoda to gain insight into why the wooden temples have for centuries withstood seismic events better than most other structures in earthquake-prone Japan.

Wired sensors can transmit data in real time, but they have limitations, says Zhang. Installing and maintaining the wires is costly and labor-intensive. Wires degrade over time and are prone to interference from electromagnetic signals. And wires occasionally give off faulty signals.

Zhang this year received a five-year NSF CAREER Award to develop wireless sensor networks for bridges and other structures and thus improve the transmission, storage and retrieval of sensor data. The project is titled "Integrated Research and Education in Smart Sensing and Intelligent Structures Technology."

Wireless sensor networks, which are relatively new, avoid many of the problems that plague wired sensors. But they face obstacles. The relatively narrow communication bandwidth available for civil-engineering wireless sensors can reduce download rates to 1 kilobyte per second, not nearly fast enough to crunch the enormous amounts of data generated by a bridge in operation.

To overcome this limitation and improve data transmission and management, Zhang is developing high-performance data-compression algorithms for structural monitoring. His algorithms incorporate structural system information to remove redundancies and maximize the data's usefulness. Zhang also uses data-mining techniques to more efficiently extract key information from data.

"Using the data-compression algorithm I'm developing," he says, "we can minimize data-downloading time and download data in real time and evaluate it in a near real-time basis."

Zhang's research draws on computer science, information technology and electrical engineering, as well as structural engineering.

As part of his NSF project, Zhang plans to implement a wireless sensor network on a cable-stayed suspension bridge in eastern China to monitor its structural health and operating condition. The bridge, built in 2000, was accidentally damaged during construction, and its actual operating condition is thus different from its design condition. The bridge was repaired and is operating, says Zhang, but aggressive monitoring is needed to ensure that it can continue to be safely used by traffic.

Using wireless sensor networks that he will help develop, Zhang and Chinese engineers are planning to conduct a full-scale validation test on the Chinese bridge in 2009.

Zhang says the data he collects from testing the Chinese bridge will also be useful for bridge operators in the U.S., where cable-stayed bridges have only recently come into use and have not yet generated a large body of data.

To enable wireless sensor networks to better monitor bridge performance, Zhang is developing data-compression algorithms to improve data transmission. He also employs data-mining techniques to extract key information from data.

As part of his NSF award, Zhang is incorporating his research into his classes. Last spring, Zhang taught an upper-level undergraduate course in smart structure technology that he first taught as a graduate course in 2004.

In the course, students constructed a Japanese pagoda and attempted to shed light on an ancient mystery – why, in earthquake-plagued Japan, the wooden temples have for centuries withstood seismic forces much better than any other type of structure.

Zhang believes the smart structure technology course is the first civil engineering course in the U.S. to integrate sensors, communications, data-mining, information technology, structural engineering and structural health monitoring. Twelve senior civil engineering majors and five grad students enrolled in the course.

"I want to educate the next generation of engineers about an exciting technology that has broad future applications," says Zhang. "Smart structure technology is only in its developmental stages, but as educators, we need to plan ahead so that when this technology is available in 10 years, our graduates will know how to utilize it."

Image fusion is a lifesaver

AS A CAR PULLS UP TO A CHECKPOINT, soldiers scan driver and passengers, wondering if one of them is hiding a gun. As VIPs line up for a reception with the President, security guards look each person up and down, alert to any clue of malicious intent.

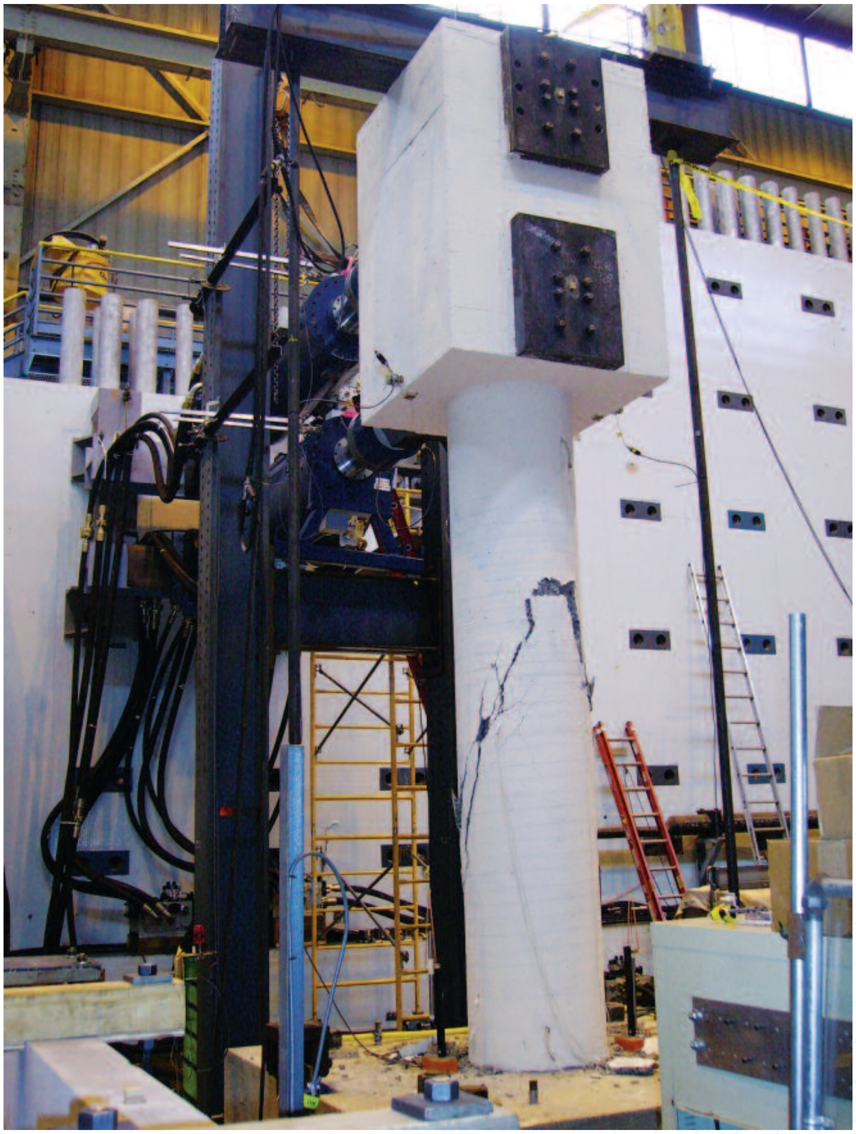
Rick Blum, the Robert W. Wieseman Chair in Electrical Engineering, hopes to equip these soldiers and security guards with a device that can save a few potentially lifesaving seconds in the search for concealed weapons.

Blum and his students have developed algorithms through which image fusion is accomplished in the wavelet transform domain. Their Portable Multi-Sensor Imaging Fusion System (PMSIFS) combines a photo taken by an optical camera with a photo of the same subject taken by a millimeter-wave camera (MMW). The composite photo exposes much more than either photo reveals by itself.

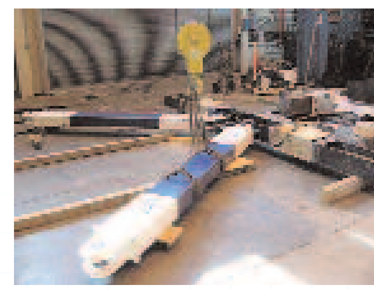
Image fusion, says Rick Blum, reveals the whole picture

Blum illustrates this application of "image fusion" with a set of three photos, arranged side by side, each showing the same shot of the same three men. The left image, taken with an optical camera, shows the men's faces and clothing. The center image, taken with an MMW camera, shows neither physical features nor clothing, but reveals that the man on the right has a gun underneath his sweater.

On the right is the fused image, which police and military personnel are seeking. It shows enough of the men's clothing and features to tell them apart, and it also reveals the unmistakable outline of a gun under the third man's sweater.



Distributed hybrid tests, conducted in the ATLSS Research Center, measure the real-time performance of a structure during an earthquake



Internet2 enables Lehigh and other NEES schools to conduct multi-site tests

The PMSIFS causes no physical harm to a person and can obtain a photo without a person's knowledge.

Blum, a fellow of IEEE, has been working on image fusion for more than 15 years. His research has been supported by NSF, the Commonwealth of Pennsylvania, AT&T, the U.S. Army Research Office, the Office of Naval Research and the Air Force Office of Scientific Research.

Last year, Blum licensed his technology to SuperVision Technologies Inc. with help from a grant from Pennsylvania's new Keystone Innovation Zone program.

Taking the bite out of earthquakes

ENGINEERS AT LEHIGH'S ATLSS (Advanced Technology for Large Structural Systems) Research Center are leading a national effort to design and test buildings that can survive an earthquake with little or no damage.

In the past 60 years, says ATLSS director Richard Sause, engineers have learned how to build structures that protect occupants and minimize loss of life from earthquakes.

Now engineers are aiming to reduce the property damage and structural "down time" caused by seismic events.

"The building design profession has progressed from the point of accepting building damage in earthquakes, as long as injuries and loss of life are minimized, to the point of seeking significantly reduced damage," says Sause.

"Our research is aiming toward a future where, if you look at a steel-frame building before and after an earthquake, you will see no significant difference."

Much of Lehigh's earthquake-engineering research is funded by NSF through a research program using the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES), a consortium of 15 universities that includes Lehigh, the University of Illinois, Berkeley and UCLA.

Lehigh's experiments are performed at the ATLSS Center's Real-Time Multi-Directional Testing Facility (RTMD), one of the largest of its kind in the world, which subjects structures to loads and loading rates similar to what they would sustain during earthquakes of the largest magnitudes.

Lehigh is using NEES research funding to develop a variety of systems to enable structures to survive earthquakes. These include braced frames and viscoelastic dampers that absorb seismic forces, columns and beams that bend without breaking while retaining their original position and strength, and steel frames that "self-center" after an earthquake.

Many of these systems direct seismic forces to structural elements that can be replaced quickly and at little cost after an earthquake.

To develop the self-centering frames, ATLSS has received a $2-million grant from NSF and is collaborating with researchers from Princeton, Purdue and the National Center for Research in Earthquake Engineering in Taiwan. The project involves numerical simulations, lab experiments and the use of advanced materials, information technology and advanced sensors. The RTMD facility is equipped with MEMS-based accelerometers, piezoelectric transducers and fiber-optic strain gages.

Lehigh and other members of NEES are linked by Internet2, which enables universities to share data from experiments in real time and allows off-site researchers to interact, again in real time, with any of the networked sites.

Earlier this year, an experiment was conducted simultaneously at Lehigh, Illinois and Rensselaer Polytechnic Institute. Researchers simulated the effect of earthquakes on a freeway bridge structure, including several columns and the soil foundation. The columns were replicas of structures that were damaged during the 1994 Los Angeles earthquake.

The novel experiment, called a distributed hybrid test, was conducted to obtain an integrated picture of what happened systemically to the bridge, soil foundation and columns during the earthquake.

Until now, says Jim Ricles, director of Lehigh's RTMD facility, earthquake engineering experiments have focused on single structural members as opposed to entire systems.

"Before, one isolated specimen was tested without integrating the data to the overall bridge structure. But if you test only one member, you don't know how the rest of the structure will react.

"After we prove the worth and accuracy of distributed hybrid testing, we can use it to demonstrate alternative types of constructions and renovations. It will be a tool to demonstrate as realistically and accurately as possible the real-time performance of a structure during an earthquake."

The RTMD facility has five 20-foot-long, torpedo-shaped actuators, which can impose 500,000 pounds of force on structures from a variety of angles at the rate of 1 meter per second. The actuators are the largest of their kind for structural testing. An advanced high-speed data acquisition, coupled with sensors and an eight-channel digital control system, enables the RTMD facility to be operated remotely.

Stochastic optimization the best bet

INVESTORS PREDICTING THE STOCK MARKET, farmers fretting over the weather, security officials anticipating a terrorist attack – the amount of uncertainty in the world can seem daunting.

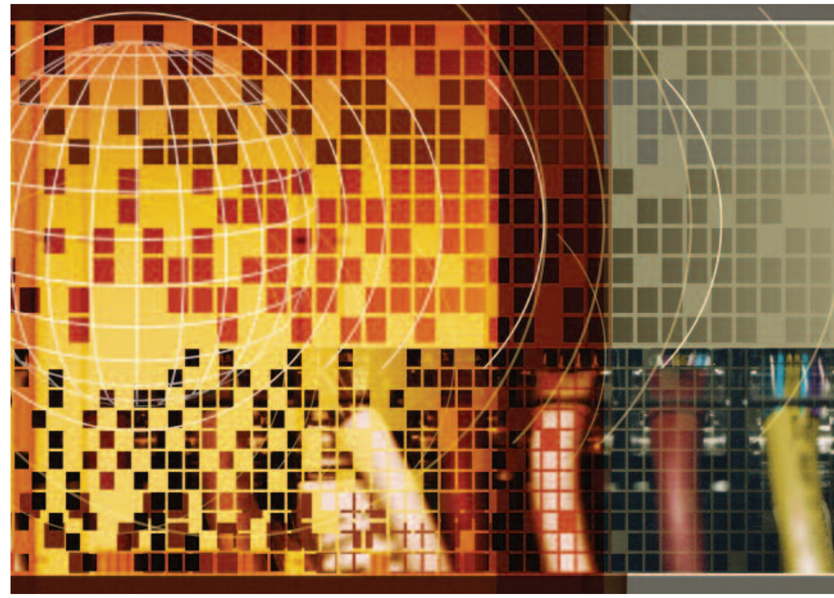
Not to Jeff Linderoth.

Linderoth, assistant professor of industrial and systems engineering, marshals the world's most powerful computers to tackle problems with millions of variables and possible outcomes.

Last year he received an Early Career Award from the U.S. Department of Energy (DOE) to solve large-scale numerical optimization problems characterized by high levels of uncertainty.

Linderoth tackles these "stochastic optimization" problems by developing software programs that use computational grids – groups and networks of computers whose collective capacities are harnessed to solve large-scale problems that would overwhelm a single computer.

Stochastic optimization problems require engineers to take into account two classes of variables, says Linderoth. Decision variables can be controlled. Random variables cannot.



Jeff Linderoth develops software programs that use computational grids to solve large-scale problems

One example of a stochastic optimization problem, says Linderoth, is the effort by the federal government to intercept illegal drugs flowing into the U.S.

"The government has a fixed budget to make it more difficult for drug smugglers to travel through the network, or border," says Linderoth. "The uncertainty comes into play when, even if we choose to beef up a part of the network by installing sensors, we don't know if the sensors will detect the drugs. The goal is to design a system that is robust with respect to these failures and will, in the long run, catch as many smugglers as possible."

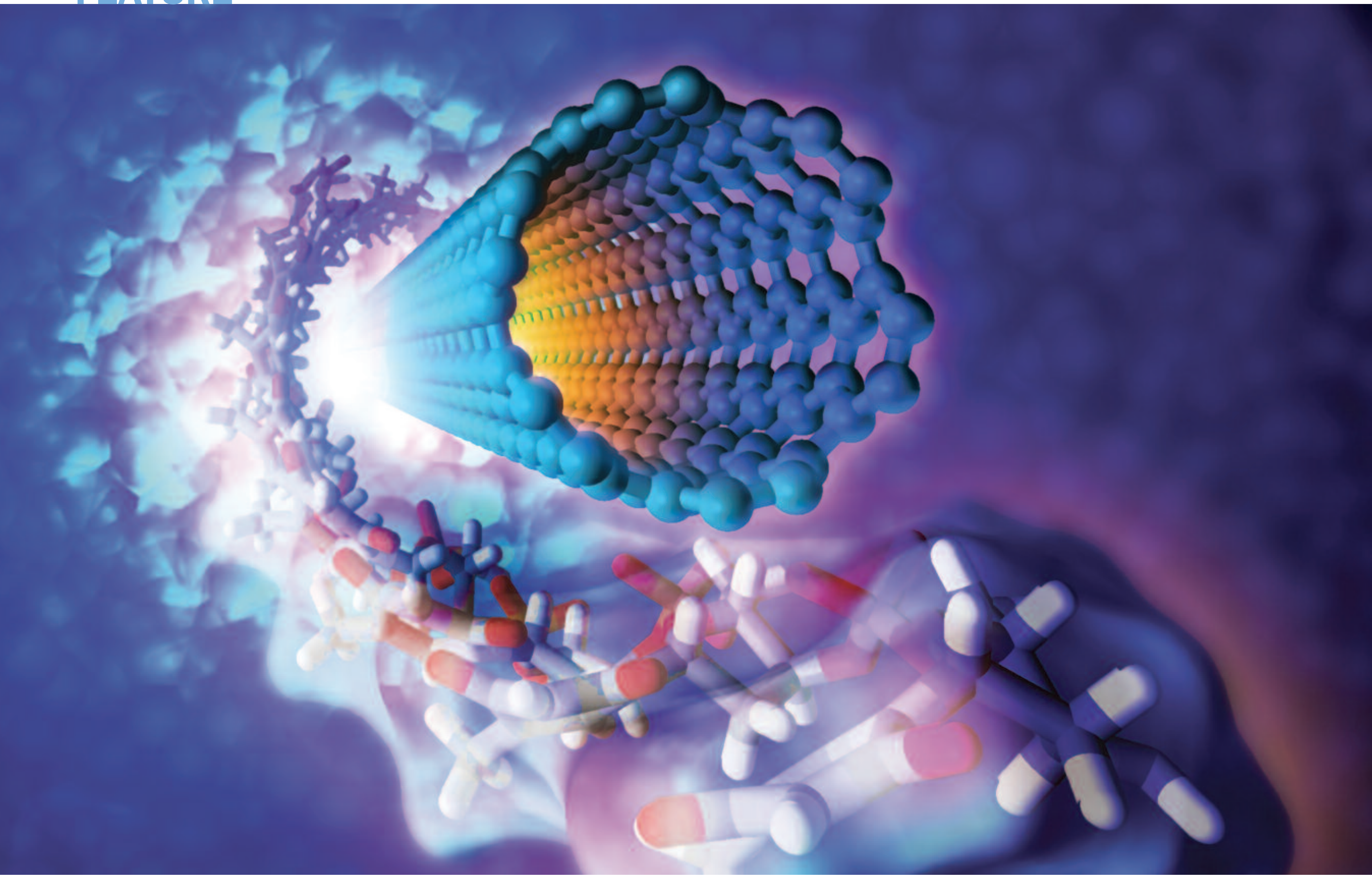
In using sensors to track drug dealers, "the goal is to design a system that is robust with respect to failures and will, in the long run, catch as many smugglers as possible." —Jeff Linderoth

Linderoth will also help DOE with mixed-integer nonlinear programming problems (nonconvex optimization), which involve discrete, yes-or-no types of decisions as well as nonlinear elements that have a continuum of random values.

The design and installation of a gas pipeline network, says Linderoth, requires engineers to make both types of decisions. The location of pipes and compressors requires discrete decisions, while calculating the optimal flow of natural gas is a nonlinear problem.

All the software Linderoth develops will be made available via the Network-Enabled Optimization System (NEOS), a server established 10 years ago to help engineers, scientists, students and businesspeople solve optimization problems remotely over the Internet.

Linderoth was a member of the Argonne and University of Iowa team that solved the nug30 Quadratic Assignment Problem, a complex facility-location problem that had been unsolved for 30 years. The computation took one week of calendar time and 11 years of CPU time, as 653 machines participated.



DNA-CNT:
A hefty hybrid for carbon nanotubes

SINCE THEIR DISCOVERY IN 1991, CARBON NANOTUBES (CNTs) HAVE CAPTURED THE PUBLIC IMAGINATION.

THESE SCROLLS OF GRAPHITE are much too tiny to be seen, but they are stronger than diamonds. CNTs can be shaped in a variety of ways and can act as metals or semiconductors. They offer great potential in nanoelectronics, medicine, sensing and lasers and as strengthening elements in composite materials.

Several obstacles must be overcome before CNTs live up to their expectations. Chief among these is the tendency of CNTs to clump together like strands of angel-hair pasta. Other challenges include achieving a better understanding of CNT structures and more effective ways of processing the tubes, sorting them, placing them on substrates and engineering their properties.

Lehigh, in collaboration with DuPont and MIT, recently received a four-year, $1.25-million grant from NSF to solve these problems by developing new ways of manipulating CNTs in solution.

Lehigh will work with MIT, Cornell and DuPont through NSF's Nanoscale

Interdisciplinary Research Team (NIRT) program. Much of the focus will be on the wrapping of single-walled CNTs with single-stranded DNA, which forms a helix around the nanotubes. The DNA-CNT hybrid has proven effective in CNT dispersion, and researchers hope it will also aid in sorting and placing the tubes.

Several years ago, a DuPont-led group found that DNA strands could be used to separate CNTs according to their electronic characteristics. The discovery was published in *Science* and cited by *Forbes* as one of the top five nanotechnology breakthroughs of 2003.

Investigators on the NIRT team include DuPont scientist Ming Zheng; Anand Jagota, formerly of DuPont and now director of Lehigh's bioengineering and life sciences program; Slava Rotkin of Lehigh's physics department; Chris Kiely of Lehigh's Center for Advanced Materials and Nanotechnology; and Yet-Ming Chiang of MIT's materials science and engineering department.

TO IMPROVE THE SORTING AND PLACING OF CNTs, SAYS ANAND JAGOTA, THE LEHIGH-DUPONT-MIT TEAM IS SEEKING TO LEARN MORE ABOUT THE STRUCTURE AND PROPERTIES OF SINGLE-WALLED CNTs THAT ARE WRAPPED WITH SINGLE-STRANDED DNA.

The two main goals of the NIRT team are to place CNTs on a substrate in specific locations and with specific densities and orientations and to sort a heterogeneous sample of CNTs into constituent types.

To accomplish this, says Jagota, the team will seek to predict the structure of the DNA-CNT hybrid, given the DNA sequence and the CNT type, and to design experiments to control the placement and separation of the CNTs.

To gain greater control over the placing of CNTs on substrates, the researchers will apply a recently discovered technique called quasi-2D liquid crystal formation at a liquid-solid interface.

"If we can do what we're hoping to do," says Jagota, "we will have achieved a major advancement in CNT research."

Kiely, who directs Lehigh's Nanocharacterization Laboratory, will supervise characterization for the NIRT project. Rotkin will oversee the theoretical work.

Rotkin is seeking to determine whether and to what degree the nanotube structure, specifically its bandgap structure, is altered when the CNT is wrapped by the DNA strand. He is using quantum-field analytical and numerical quantum-mechanical calculations to examine different types of CNTs with different types of DNA wraps.

"The answer to the question – does a CNT wrapped with DNA stay the same or undergo a change in properties? – depends on the symmetry and geometry of the wrap," says Rotkin.

Rotkin and his students have succeeded in plotting bandgap structure and mapping the areas of varying DNA-induced electric charges, which show up in repeating patterns.

"We more or less understand the rules of nature in regards to whether or not the bandgap structure [of a DNA-wrapped CNT] changes," he says. "But there are a huge number of nanotube types and a huge number of ways of wrapping a CNT." ⓡ

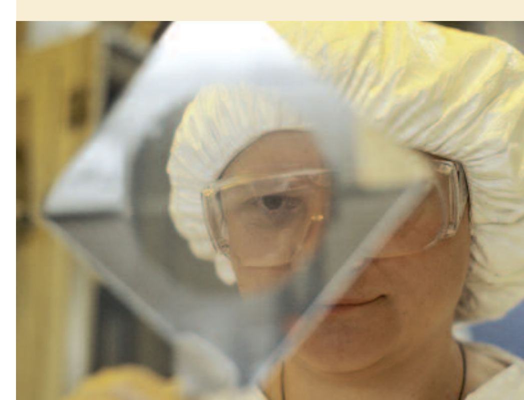
Nano for cleaner air, curing disease, more

In addition to the NIRT grant for the collaboration with MIT, Cornell and DuPont, Lehigh this year received one other NIRT grant and two one-year awards through NSF's Nanoscale Exploratory Research (NER) program.

- **ISRAEL WACHS**, professor of chemical engineering, received a four-year NIRT grant to study using nanocatalysis to convert NOx from power plants into nitrogen and water, to reduce NOx from car engines and to turn NOx and SOx from petroleum refineries into harmless substances. Wachs won the Clean Air Excellence Award from EPA in 2002 for a process that converts pollution from paper pulp mills into formaldehyde and other useful products.

- **JAMES GILCHRIST**, assistant professor of chemical engineering, and **CHRIS KIELY**, professor of materials science and engineering, received an NER grant to develop an adhesive that self-assembles into nanowires as it cures. They are seeking to send electronic pulses through a solution of metallic nanoparticles and an adhesive or polymer, causing the nanoparticles to line up in a particle-by-particle chain. One goal is to improve fabrication techniques for nano- and microfluidic devices while lowering particle content of adhesives.

- **FILBERT BARTOLI**, chair of electrical and computer engineering, and **SVETLANA TATIC-LUCIC**, assistant professor in the department, received an NER grant to create ordered arrays of nerve cells by culturing them in chains along nanochannels. The cells could be probed to analyze the effects of various agents, enabling better therapies for neurodiseases and improved biosensing capabilities and applications.



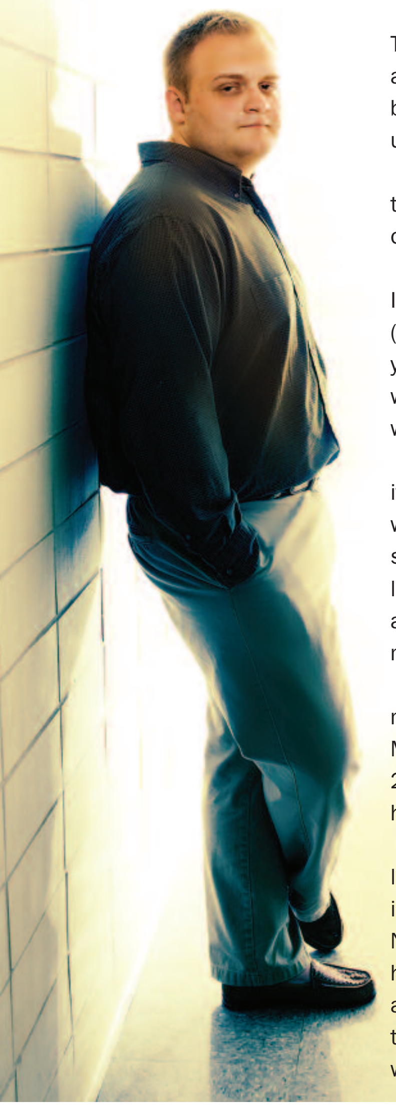
Tatic-Lucic creates ordered arrays of nerve cells

A RIGOROUS INTEGRATION

LEHIGH'S IBE PROGRAM STRESSES, AND PRODUCES, INNOVATION

The B.S. in Integrated Business and Engineering, launched in 2001, attracts Lehigh's best students and prepares them for a world in which innovation is the key to maintaining a competitive edge.

Photography by John Sterling Ruth



The move from university housing to an off-campus apartment has become a rite of passage for many undergraduate students.

Curtis MacDonald has converted the cherished ritual into a business opportunity.

MacDonald, a major in Lehigh's Integrated Business and Engineering (IBE) honors program, realized two years ago that moving off campus would require him to find another way to access the Internet.

Lehigh offers Internet access in its residence halls and at numerous wireless access points. But while still living on campus, MacDonald learned he would not be able to access Lehigh's network after he moved off.

"I didn't want to pay $40 a month to a network provider," says MacDonald, who graduated in 2005, "and I found that many of my hallmates and friends didn't either."

MacDonald embraced the challenge. He rigged an empty soup can into a wireless adapter or "cantenna." Not satisfied, he sought advice from his electrical engineering professors and then began devising an adapter that could expand the range of a wireless computing signal.

"I got to the point where I could connect from an apartment three or four blocks away from campus," he says. "But I knew I needed to perfect the device before I moved."

In 2004, MacDonald entered the annual Student Entrepreneurship Competition of Lehigh's Integrated Product Development (IPD) program. Twenty to 30 student teams submit proposals at the annual event. Two or three receive a $2,000 grant to work on a prototype and proof of concept. The winners can recruit other students to their projects and offer them IPD course credits.

MacDonald won one of the awards and assembled a team of five IBE majors and a computer science student. Today, two years and several grants later, his company, hField Technologies Inc., has begun selling Wi-Fire, an adapter that boosts a wi-fi signal range to 1,000 feet, almost three times the range of similar products.

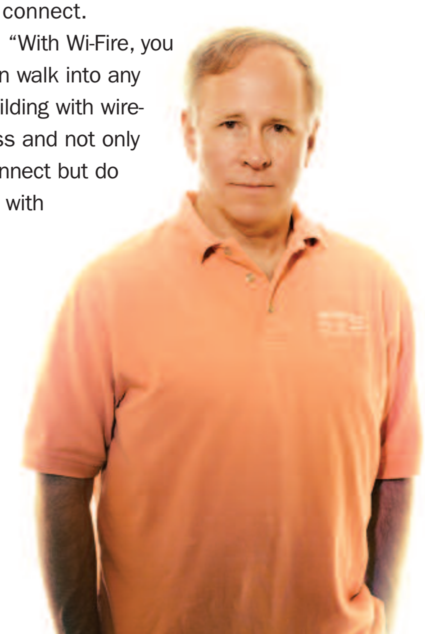
The Wi-Fire, no bigger than a computer mouse and a half-inch thick, clips to a laptop or desktop computer and has a cord that attaches to a USB port. The Wi-Fire is aimed at the nearest wi-fi access point; if a user does not know where that is, software inside the device orients the Wi-Fire in the optimal direction.

Wi-Fire's secret?

"We use radio frequencies more effectively because we offer a built-in directional antenna," says MacDonald, who concentrated in computer engineering as an IBE major. "The antenna increases the signal strength in the proper direction."

In addition, says MacDonald, Wi-Fire allows users to connect to any standard 802.11b/g wireless access point. Competing products, he says, are "non-standard compliant" and require additional equipment to connect.

"With Wi-Fire, you can walk into any building with wireless and not only connect but do so with



faster speed and greater consistency and from further away."

Similar products contain stronger antennas but require adapters to be added, says MacDonald. And some products require assembly, even soldering, while Wi-Fire, which costs $150, is ready to use.

In 2005, hField received $15,000 from the Keystone Innovation Zone program (KIZ), a state initiative to generate job growth by supporting community-university partnerships. Soon after, Blake Kleintop, who earned a B.S. in IBE with a finance concentration in 2006, joined as chief operations officer. MacDonald became chief technical officer and Tom DiClemente, who earned a B.S. in civil engineering from Lehigh in 1974, committed investment to the company from Gran Sasso Ventures LP and signed on as CEO.

The KIZ grant and fund investment enabled hField to draft a business plan and build 50 devices, which were given to local college students to test. Using feedback from the students, hField made improvements to Wi-Fire.

In the summer of 2006, hField's business plan earned it a $150,000 loan from the Lehigh-based Ben Franklin Technology Partners, which provides technical and marketing assistance to start-ups.

MacDonald attributes much of hField's success to Lehigh's IBE program, which prepares students for an economy and a job market that are becoming ever more global.

"IBE is four years of training in entrepreneurship. It gives you a strong background in business and engineering, which is good for start-ups as well as established corporations."

HField began selling Wi-Fire in August 2006, targeting bookstores and regional college campuses. The company plans to market Wi-Fire nationally in 2007 and is developing two other new wireless technologies.

Also in August, MacDonald earned an M.Eng. in mechanical engineering from Lehigh, with a concentration in IPD. He and Kleintop have found that a start-up is not a 9-to-5 job.

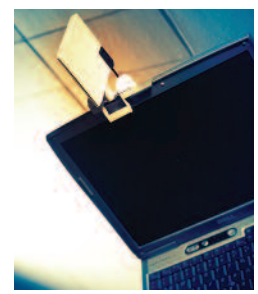
"The hours we put in are beyond counting," he says.

"I did count one week," says Kleintop, "and I got to 90."

The time is well-invested, says MacDonald.

"We didn't scrimp or compromise, and we were able truly to create a superior product. If you can hold a product in your hands and realize you made something tangible out of nothing – how extraordinary that is."

> "IBE is four years of training in entrepreneurship. It gives you a strong background in business and engineering, which is good for start-ups as well as established corporations."
>
> —Curtis MacDonald



MacDonald (above), Kleintop (left) and DiClemente (below) are selling a clip-on Wi-Fire with a built-in directional antenna and an adapter that boosts a wi-fi signal range to 1,000 feet

IBE at Lehigh: A face to the future

The future of U.S. engineering and the U.S. economy, says Robert Storer, lies in continuous innovation.

And the purpose of Lehigh's four-year IBE honors program, says Storer, is to train students to make and market new products by "infusing engineering thinking into the world of entrepreneurship and business."

Storer, professor of industrial and systems engineering, is co-director of the Integrated Business and Engineering program along with Stephen Buell, professor of finance and law in Lehigh's College of Business and Economics.

"IBE as a program seeks to address the future," says Storer. "Future engineers must understand domestic and global markets, and they must be able to translate their knowledge into new ideas and products. They will need to know how to design and develop products and bring them to market. This requires an understanding of international competition and the global economy. These are the key issues we address in IBE."

IBE attracts some of Lehigh's top students, with average SAT scores of incoming candidates exceeding 1400. It is one of Lehigh's most demanding programs. Students must acquire proficiency in a foreign language and are encouraged to do an international internship or study-abroad program. A summer industrial internship is also required.

IBE students also work in interdisciplinary teams on a yearlong project with a company, often a high-tech start-up. This capstone senior project incorporates marketing, strategic planning and competitive analysis, along with product, process and system design issues.

The IBE curriculum leads to an accredited B.S. degree in business and engineering, with majors offered in all business and engineering fields. Many IBE students opt for a fifth year of study to earn a second B.S. in their engineering major. Some have completed both degrees in four years.

Kishore seeks to provide ubiquitous low-rate coverage and targeted high-speed Internet access

A wireless way for rural residents

Shalinee Kishore studies the effectiveness of multi-tier wireless networks in providing remote, underserved geographical areas with Internet and cell phone access.

Kishore, the P.C. Rossin Assistant Professor of electrical and computer engineering, has an NSF CAREER Award to demonstrate the usefulness of the networks by developing an outreach program with rural Susquehanna County in northeastern Pennsylvania.

In 2005, she won the Presidential Early Career Award for Scientists and Engineers (PECASE), the highest honor given by the federal government to young scientists and engineers. Kishore was one of 58 PECASE recipients in the U.S. and one of 20 nominated by NSF.

Multi-tier wireless networks contain components (base stations and/or user terminals) whose coverage areas can vary in their order magnitude. The networks Kishore is designing can simultaneously provide ubiquitous low-rate coverage (such as for cell phones) and targeted high-speed Internet access through a network of base stations and user terminals.

Kishore has held workshops in Susquehanna County to explain the principles of wireless communications and to help residents adapt the technology to the county's unique communications needs. She and her students helped residents set up a wi-fi (wireless local area network) at the county's annual Blueberry Festival one year.

Susquehanna County's rugged terrain is not hospitable to the laying of cable and wires. The county lacks adequate cellular coverage and high-speed Internet access as well as reliable 9-1-1 services. Although conditions are improving, the county still lacks localized broadband access, and its existing wireless links are poor. Furthermore, the county's low population density gives providers of Internet services little incentive to install the wires necessary for digital or cable-modem access.

One of Kishore's goals is to determine how to provide the maximum amount of wireless signal coverage with the minimum number of base stations or transmitting and receiving stations.

Kishore's undergraduate students are compiling a radio contour map of Susquehanna County. The Commonwealth of Pennsylvania has funded this radio propagation study through two Pennsylvania Industry and Technology Alliance (PITA) grants. Her Ph.D. candidates are conducting theoretical research on the design and performance of multi-tier wireless networks.

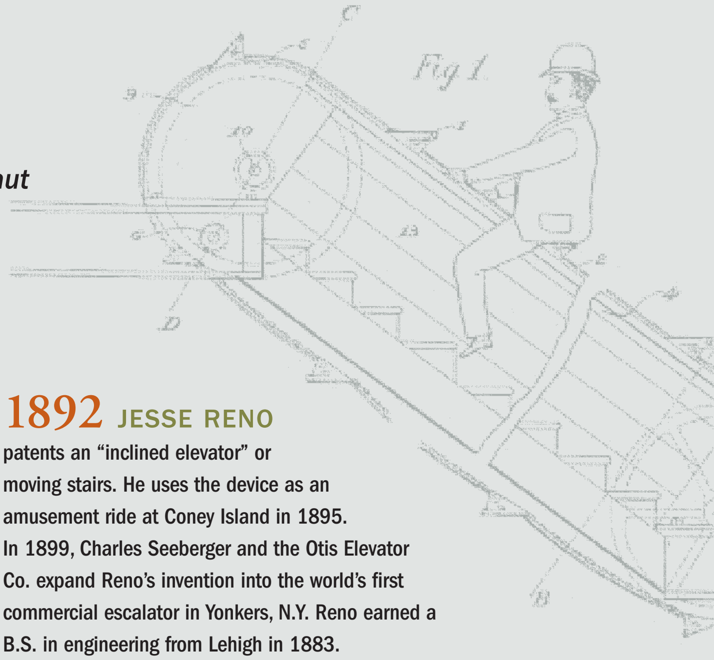
Kishore is also collaborating with Rosemary Berger, assistant professor of industrial and systems engineering, to determine how to design and lay out an optimal network of multi-tier base stations. The two professors aim to design algorithms to evaluate the capacity and coverage offered by a wireless network design. These algorithms will be helpful in implementing the multi-tier design principle not only in Susquehanna County, but in other rural communities as well.

Kishore has also recently received an NSF grant to examine methods for integrating several multi-tier wireless networks. Collaborating with Aylin Yener, associate professor of electrical engineering at Penn State, she will look at how future wireless user terminals can search, locate and adaptively connect to one of potentially several local wireless networks.

Kishore's goal in all of these research efforts is to optimize scarce bandwidth and minimize interference caused by reuse of the bandwidth spectrum across tiers. Her approach, she says, represents "a novel and expansive study of spectrally efficient multi-tier architectures."

Lehigh Engineering: Our proud heritage

The many and varied accomplishments of Lehigh engineers run the gamut from autos to artificial hearts. Here are a few examples:



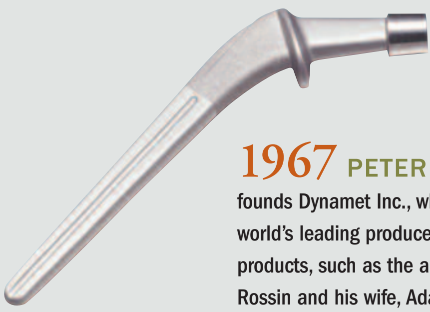
1885 TAU BETA PI, the national engineering honorary society, is founded at Lehigh by mining engineering professor Edward H. Williams. Today, there are TBP chapters at 230 universities in the U.S.

1892 JESSE RENO patents an "inclined elevator" or moving stairs. He uses the device as an amusement ride at Coney Island in 1895. In 1899, Charles Seeberger and the Otis Elevator Co. expand Reno's invention into the world's first commercial escalator in Yonkers, N.Y. Reno earned a B.S. in engineering from Lehigh in 1883.

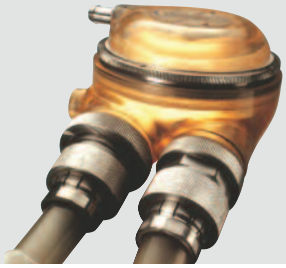
1899 JAMES WARD PACKARD, a member of Lehigh's class of 1884, and his brother, William, build the first Packard car. The one-cylinder, 12-hp machine contains a new H-pattern gear slot, which earns James Packard one of the more than 40 patents he will garner during his life.

1937 HOWARD McCLINTIC and **CHARLES MARSHALL** of Lehigh's Class of 1888 watch as San Francisco's Golden Gate Bridge opens for vehicular traffic – ahead of schedule and under budget. The bridge is today recognized as one of the "Seven Wonders of the Modern World." The McClintic-Marshall Construction Co. oversaw its construction.

1964 Under the guidance of **LEE IACOCCA**, Ford Motor Co. introduces the Ford Mustang, which has the most successful first-year sales of any car in history. Iacocca, who earned a B.S. in industrial engineering from Lehigh in 1946, later becomes president of Ford and chairman of Chrysler Corp.



1967 PETER C. ROSSIN founds Dynamet Inc., which becomes one of the world's leading producers of titanium- and nickel-based alloy products, such as the artificial joint shown above. In 1998, Rossin and his wife, Ada, give a $25-million gift to Lehigh's engineering college, which is renamed in his honor.



1980 WILLIAM S. PIERCE and **JAMES H. DONACHY** receive a U.S. patent for the Pierce-Donachy Ventricular Assist Device, one of only two air-driven, temporary artificial heart designs approved for use in humans by the U.S. Food and Drug Administration. The pump's seam-free surface limits the risk of blood-clotting. Pierce earned a B.S. in chemical engineering from Lehigh in 1958.

A MISSION FOR ENGINEERS

Lehigh University President Alice P. Gast says engineers should take on the “grand challenges” posed by health, energy, the environment and other global issues. Gast, a member of the National Academy of Engineering, served as vice president for research at MIT before her appointment on Aug. 1, 2006, as Lehigh’s 13th president.

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LEHIGH UNIVERSITY
P.C. Rossin College of
Engineering and Applied Science
19 Memorial Drive West
Bethlehem, PA 18015

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