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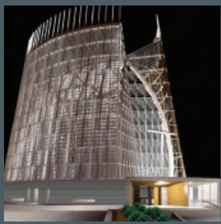
A FOCUS ON LEHIGH ENGINEERING • VOLUME 2, 2007



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Making buildings interact robustly with any natural environment

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LEHIGH UNIVERSITY®

P.C. ROSSIN COLLEGE OF ENGINEERING AND APPLIED SCIENCE

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Distant galaxies holding keys to the origin of the universe are one target of a research partnership between Lehigh and NASA.

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A FOCUS ON LEHIGH ENGINEERING

VOLUME 2, 2007

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LEHIGH UNIVERSITY®

CHALLENGING GREAT MINDS...INSPIRING GREAT IMAGINATIONS

Resolve to be published biannually

Welcome to the second issue of* Resolve*, a magazine dedicated to research and educational innovation in the P.C. Rossin College of Engineering and Applied Science at Lehigh University.

Since the publication of the magazine's inaugural issue in the fall of 2006, we have received overwhelming feedback from our readers: professional colleagues, faculty, students, alumni and friends. After reviewing these encouraging messages and the lengthy backlog of exciting stories we have yet to tell, we have decided to expand *Resolve* into a biannual publication. The magazine will be released in early fall and in spring; the print version will be accompanied by an expanded online magazine at **www.lehigh.edu/resolve**, where you can find additional photos, follow-up stories and videos.

The content of *Resolve* is organized loosely around three clusters of engineering research activities at Lehigh:

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

These clusters reflect core research competence across diverse disciplines while representing technology and methodology areas from which a variety of relevant applications stem. In each cluster, faculty-led advisory councils have organized exploratory workshops to stimulate research collaboration. A recent workshop in bioimaging and engineered biosystems was a great success, and additional workshops are being planned in energy and environmental systems and in sensor networking. The advisory councils are also examining future needs for research facilities and major instrumentation, and making recommendations for new research infrastructure.

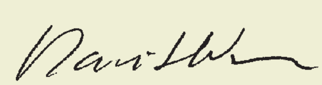
In this issue of *Resolve*, we feature several activities in the Nanotechnology area. As NASA prepares to celebrate the 50th anniversary of its founding, we explore the agency's new strategic partnership with Lehigh. The story offers a glimpse at a cross-disciplinary team of Lehigh engineers who are helping NASA make advances in materials and devices at the nanoscale. The partnership is contributing to the James Webb Space Telescope project, which will succeed the Hubble as humanity's "eye" into the cosmos and the universe's past.

We also look at the work of Professor Samir Ghadiali – a great example of bioengineering research, with engineering models, visualization and technology brought to bear on a critical health issue. A profile of Lehigh alumnus Mark Sarkisian, structural engineering partner at Skidmore, Owings & Merrill LLP, delves into the marriage of architectural vision and engineering design that supports the current global boom in superstructure development.

"The Lehigh-NASA partnership is contributing to the new James Webb Space Telescope, which will become our 'eye' into the cosmos."—S. David Wu

Every issue of *Resolve* includes an example of true innovation in undergraduate engineering education. You will find this in the story of EcoTech Marine, a company formed by Lehigh students through Lehigh's Integrated Product Development (IPD) program.

I hope you enjoy this issue of *Resolve* magazine, and I extend our sincerest appreciation for the positive response it has enjoyed since its inception. Please drop me a note to share your thoughts and comments.



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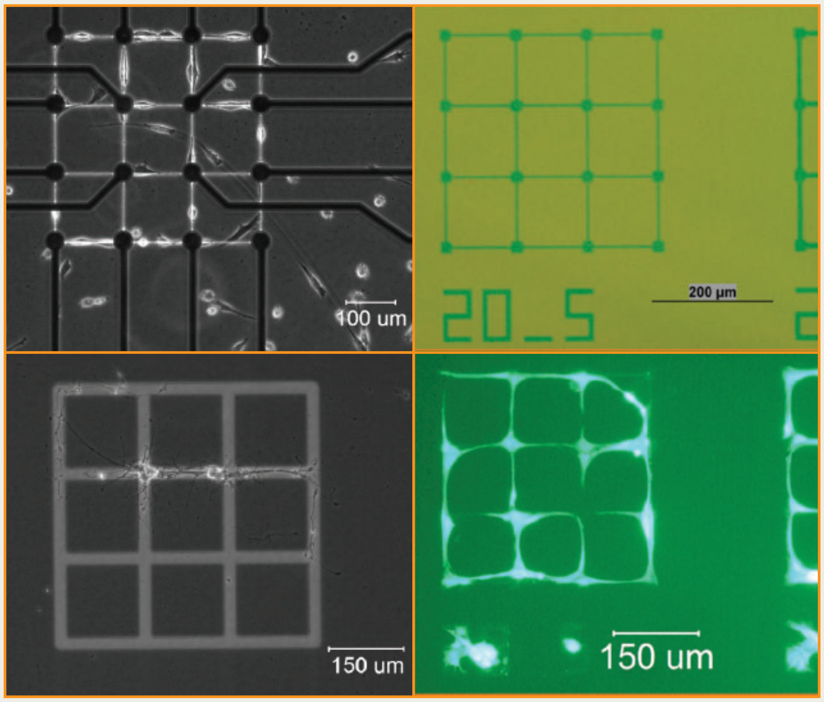


Svetlana Tatic-Lucic applies MEMS to cell biology and neurobiology. A neuronal network (top left) is formed on an MEA substrate, while the results of patterning hippocampal neuronal networks are shown at bottom left. MVD deposition of a hydrophobic self-assembled monolayer (top right) was used to create a second pattern, whose matching neuronal network is seen at bottom right.

A noble application for MEMS

The growing area of microelectromechanical systems (MEMS), which integrates mechanical elements, sensors, actuators, and electronics on silicon chips through microfabrication technology, offers many applications. Svetlana Tatic-Lucic, the P.C. Rossin Assistant Professor of electrical and computer engineering, focuses on applying MEMS to cell biology and neurobiology.

In separate NSF projects, Tatic-Lucic studies cell-based sensors and micro- and nanopatterning of cultured cells. With funding from a CAREER Award, she is designing, building and implementing a Micro Electrode Array (MEA) for extracellular recording from patterned neuronal networks with sensory applications. The arrays, designed to sense changes in cells' electrical activity, could lead to bioterrorism defense applications, such as detecting the presence of neuroactive agents. The project is a collaboration with Gregory Ferguson, associate professor of chemistry.

The second NSF project, supported by a Nanoscale Exploratory Research (NER) grant, focuses on nanopatterned neuronal networks and integrated fluorescence sensing for biomedical applications. Tatic-Lucic and her students, working with Fil Bartoli, department chair of electrical and computer engineering, use voltage-sensitive dyes to stain cells and watch for the dyes to change colors, indicating electrical activity in the cells. Using optical detectors, they will be able to detect changes in the degree of fluorescence.

In a project funded by NASA and Lehigh, Tatic-Lucic is constructing a MEMS device to determine how the mechanical properties of bone cells change when exposed to different mechanical stimulations or as a function of age. She hopes the project, done in collaboration with Arkady Voloshin and Sudhakar Neti, professors of mechanical engineering and mechanics, leads to a more effective treatment for osteoporosis.

"Biological engineering is a very logical and noble application of MEMS," says Tatic-Lucic.

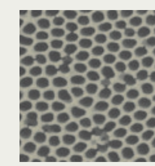
Ceramic hope for kidney patients

A nanoporous ceramic filter developed by materials scientists at Lehigh could offer relief to kidney dialysis patients.

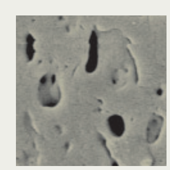
William Van Geertruyden, adjunct professor of materials science and engineering at Lehigh, says the new filter has the potential to make dialysis sessions shorter and more efficient.

An estimated 370,000 Americans undergo kidney dialysis treatment every year and the numbers are rising. The exhausting process takes up to four hours and must be done three or four times a week.

Van Geertruyden, also general manager of EMV Technologies, LLC, in Bethlehem, Pa., says the size and orderly arrangement of pores give his filter a key advantage over traditional polymeric filters.



Measuring nanometers in diameter, the pores in the ceramic filter (above) correspond more closely to the nano-sized toxins in the blood than do the larger pores of standard polymer dialysis filters. These polymeric pores vary in size and, when viewed with a microscope (below), appear in random arrangements of ovals, circles, slits and other shapes.



For these reasons, Van Geertruyden is confident the new filter will increase the amount and rate at which toxins are removed from the blood during dialysis, while decreasing the amount of nutrients removed.

Van Geertruyden, who earned his Ph.D. in materials science and engineering from Lehigh in 2004, developed the new filter with help from Zhongping Huang, assistant professor of mechanical engineering at Widener University, and Wojciech Misiolek, professor of materials science and engineering at Lehigh.

EMV Technologies has received a Small Business Technology Transfer grant from the National Institutes of Health and separate grants from the Pennsylvania Keystone Innovation Zone program and the Ben Franklin Technology Partners.

Van Geertruyden has filed a patent application on the filter.

Solving a continental crisis one village at a time

The world's worst environmental catastrophe is yielding one village at a time to a homegrown solution developed by Arup SenGupta, professor of civil and environmental engineering.

SenGupta's filtration system, which removes arsenic from water at the wellhead, has been installed in more than 150 villages in Eastern India since 1997.

The World Health Organization estimates that as many as 100 million people in India and Bangladesh drink well water containing toxic levels of arsenic. Victims suffer skin lesions, cancer and even death. WHO calls the phenomenon the "largest mass poisoning of a population in history."

In villages where SenGupta's system has been installed, arsenic levels in well water have fallen from 100 to 500 parts per billion to well below the 50-ppb maximum allowed by the Indian government. Victims have found relief from symptoms, and new cases of arsenicosis have plummeted.

The filtration systems are built in India and installed by students and faculty from India's Bengal Engineering and Science University. Cost of installation ranges from $1,200 to $1,500 and is usually paid by villagers. The systems are operated with a hand pump and require no electric power or chemicals. They are maintained by village committees with help from the university.

SenGupta was asked to tackle the arsenic crisis in 1995 by Water For People, a nonprofit group. Working with Luis Cumbal, who earned a Ph.D. from Lehigh in 2004, he learned to "impregnate" columns of tiny, polymeric ion-exchange beads with ferric hydroxide nanoparticles. The iron transmits its affinity for arsenic to the beads. The beads provide a sturdy mechanism for the fine iron powder, which would otherwise clump and clog the column, making arsenic removal inefficient or impossible. The result is a hybrid sorbent that removes arsenic from water.

SenGupta, a native of Calcutta, believes environmental problems in developing countries often respond best to indigenous solutions.

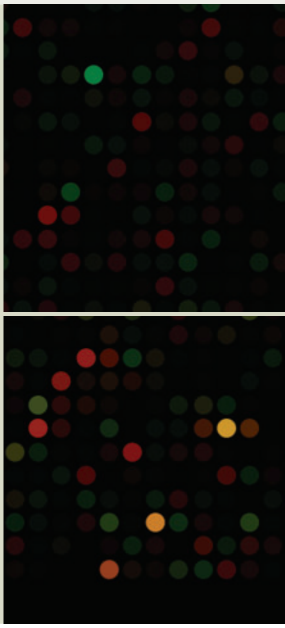
In 2002, writing in the *Journal of the Institution of Chemical Engineers*, SenGupta said, "Our attempts to solve the environmental woes of the 'developing' countries with solutions from the 'developed' ones have often been unsatisfactory, if not disastrous."

In February 2007, SenGupta and his research team, which includes Lehigh students and Bengal University faculty, received the Silver Award in the National Academy of Engineering's Grainger Challenge for Sustainability. The award carried a cash prize of $200,000.

In April 2007, SenGupta and his Lehigh students won a $75,000 award from the U.S. Environmental Protection Agency's P3 (People, Prosperity and the Planet) competition for a project that will involve the safe disposal of sludge containing high levels of arsenic. The group plans to build a reactor and disposal site in the Indian state of West Bengal.

Victims of arsenic poisoning (inset) have found relief from their symptoms thanks to the filtration system (above) designed by SenGupta and his students.

Using simulation to refine DNA microarrays



DNA microarray technology has transformed genomics — the study of genes and their function — by enabling scientists to monitor the expression of thousands of genes simultaneously. Microarrays are slides patterned with thousands of microscopic spots containing DNA molecules, or probes. Each probe is designed to hybridize uniquely to one DNA sequence, or target. As targets hybridize to probes, the various regions on a chip become fluorescent.

The potential applications of microarray technology to medicine, says Ian Laurenzi, are huge. Unfortunately, no probe sequence binds exclusively to its target; instead, because of overlaps in sequence, any or all DNA target species may bind to the microarray probe. This phenomenon, known as cross-hybridization, undermines the accuracy of the probe.

Laurenzi, assistant professor of chemical engineering, and his students are the first researchers to simulate the performance of microarrays. They have developed algorithms that can characterize the cross-hybridization occurring in any microarray design.

"Using our stochastic computational methodologies," says Laurenzi, "we are able to quantify the quality of microarray designs for a wide variety of screening applications.

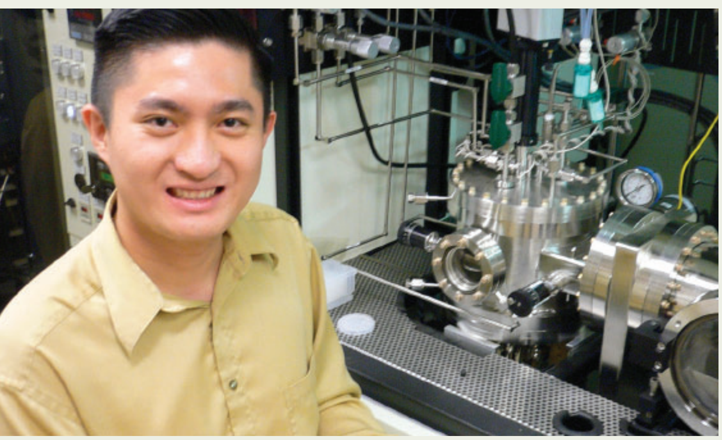
"A microarray is really a complicated network of chemical reactions between all probes and all targets. To evaluate microarrays in the lab can be expensive and time-consuming. But with simulation, we can evaluate all of the chemical reactions simultaneously."

Laurenzi's group works in the lab to evaluate the cross-hybridization of yeast DNA to probes designed for yeast genes.

"We are currently developing methods of probe design that will reliably relate changes in genetic expression to changes in fluorescence intensity."

More efficient LEDs for a brighter future

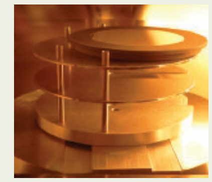
Illumination accounts for much of world energy use, but the efficient production of light is notoriously challenging. Photons must be generated from semiconductor nanostructure layers and take a specific path away from their source to be extracted as light; otherwise, they are reflected back and dissipated as heat. Thus, the U.S. Department of Energy has launched a major initiative addressing solid state lighting technology.



Nelson Tansu, assistant professor of electrical and computer engineering, studies semiconductor nanostructures to increase the efficiency of solid state lighting and solar photovoltaic cells.

"Energy," says Tansu, "is a driving force in modern society. To generate and use energy efficiently for lighting, we must rely on semiconductor nanotechnology as the enabling technology."

Using metalorganic chemical vapor deposition (MOCVD), Tansu fabricates semiconductor nanostructures as active media with a precision of one or two planes of atoms for the efficient generation and absorption of light. He and his group have achieved highly efficient light generation from semiconductor nanostructure active regions used in light-emitting diodes (LEDs) for solid state lighting and medical applications. Their work has also led to greater wavelength extension and increased optical gain for efficient laser application. By enhancing the generation of photons, Tansu hopes, his group can develop efficient lasers and LEDs that are inexpensive to manufacture.



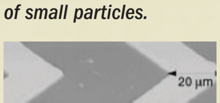
Tansu fabricates semiconductor nanostructures as laser gain media.

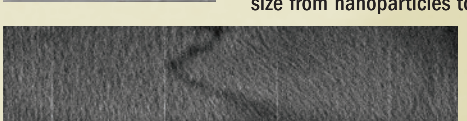
Tansu's group is testing several novel approaches for enhancing the "wall plug" efficiency of nitride-based LEDs. In one project, Tansu is collaborating with James Gilchrist, assistant professor of chemical engineering, to investigate the potential for microlens arrays on LED surfaces to enhance the extraction of photons by increasing their ability to be refracted out.

NSF, the Department of Defense and the Pennsylvania Infrastructure Technology Alliance are funding Tansu's work, which has been published in *Applied Physics Letters, IEEE Photonics Technology Letters* and elsewhere.

Particle flows: "Not all stirring is equal"

Gilchrist fabricates microchannels in which he measures the mixing and segregation of small particles.





Particles in flows are found everywhere, from sediment in rivers to blood cells in veins and even to windblown leaves in the backyard. Determining how these systems behave, and what causes some particles to mix well while others segregate from the fluids through which they're flowing, can have profound implications.

"If you're pumping thousands of pounds per hour of material from one process to another, and you assume it's well mixed but it's not, that can ruin everything," says James Gilchrist, the P.C. Rossin Assistant Professor of chemical engineering. "For example, pharmaceutical companies make hundreds of millions of pills every year. If segregation takes over a system, one pill might have none of the active ingredient while another has 100 times what it should have — enough to kill someone."

Gilchrist studies the flow behavior of small particles that range in size from nanoparticles to grains of sand. He has fabricated channels as fine as a human hair and added ridges that enhance mixing by stirring the fluid as it passes through the channel. The use of such small systems allows him to measure the mixing and segregation of small particles more accurately and will have direct impact on the design of microscale "lab-on-a-chip" systems used as chemical and biological sensors.

Other researchers have demonstrated that simple Newtonian fluids such as water mix exponentially faster in chaotic flows generated by channels similar to the ones Gilchrist has fabricated. Gilchrist, though, has come up with different findings. Typically, adding energy to a system of fluids causes a faster, more uniform mixing. In a system containing both particles and fluids, however, the energy can produce a more efficient separation.

"Not all stirring is equal," says Gilchrist. "Even within an ideal fluid without particles, stirring that leads to chaotic mixing can still produce large regions in the flow that internally mix poorly, and do not mix externally with the rest of the fluid except via diffusion."

Gilchrist's research is funded by NSF, the American Institute of Chemical Engineers' North American Mixing Forum and the American Chemical Society's Petroleum Research Fund, which seeks the efficient removal of impurities from crude oil.

A clarity in adhesion, “beautifully conceived”

Interfacial fluid mechanics had its genesis when Chaudhury discovered that droplets can be made to migrate on surfaces

Manoj Chaudhury has won recognition for wide-ranging and influential contributions to the fields of adhesion and interfaces.

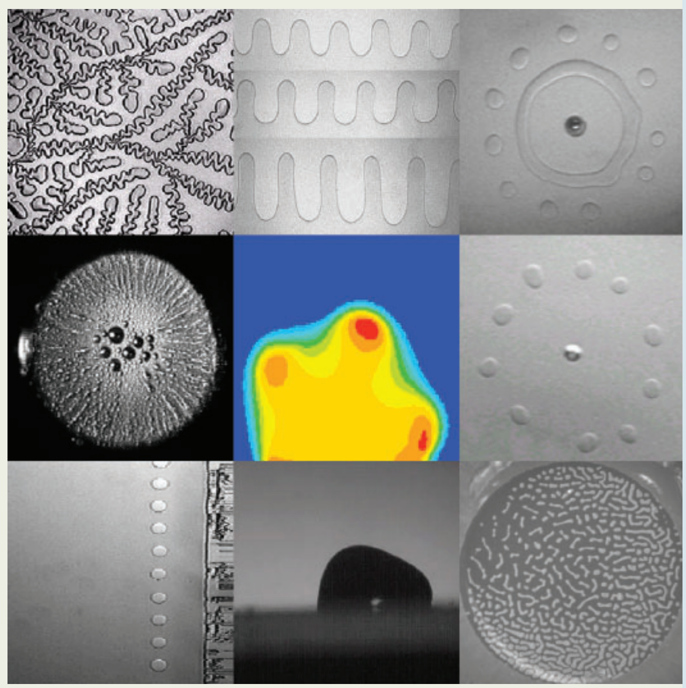
Chaudhury, the Franklin J. Howes Jr. Distinguished Professor of chemical engineering, has published more than 100 papers, in journals ranging from *Science* to *Nature* to *Physical Review Letters*. Peers have praised him for “research that is beautifully conceived, clarifies basic ideas, and immediately suggests ways in which it can be used practically.”

In 2005, when he received the Award for Excellence in Adhesion Science from the Adhesion Society, Chaudhury was commended “for exceptional creativity and ingenuity in research.”

In 2006, the American Physical Society elected Chaudhury a Fellow, lauding his “fundamental studies on the roles of energetic and kinetic processes on adhesion, fracture and tribological properties of polymeric interfaces.”

Chaudhury is credited with helping launch a new field of interfacial fluid mechanics when, writing in *Science* in 1992, he and George Whitesides of Harvard described a method of making water droplets migrate on surfaces by controlling surface chemical forces. The discovery, he says, has potential for the conducting of chemical reactions useful to biotechnology.

In 2001, writing again in *Science*, Chaudhury – along with his former Ph.D. student Susan Daniel, now an assistant professor of chemical and biomolecular engineering at Cornell University, and John Chen, professor of chemical engineering at Lehigh – reported another breakthrough: By condensing saturated steam over a surface with a tension gradient, they caused the droplets to move at a much faster speed, approaching 1 meter per second. The high speed, Chaudhury believes, stems from the asymmetric properties of the gradient surfaces, which “rectify” the random motion and coalescence of the droplets.



“The practical side of this discovery,” he says, “is that the increased speed of the droplets can be used to design more efficient heat transfer devices.”

Chaudhury and Daniel have also collaborated with L. Mahadevan of Harvard to induce a flexible hydrogel rod to mimic the movements of snails, worms and snakes. The researchers described this work in *Proceedings of the National Academy of Sciences*. MIT’s *Technology Review* said the new method “could lead to new motion techniques for tiny machines, including robots that inspect difficult-to-get-to nooks, and for manufacturing processes that involve moving substances across surfaces.”

Increasing the speed of the droplets could lead to better heat transfer devices, says Chaudhury. Gradient surface properties are key.

A sub-nanoscale leap in reactivity

Engineers have long known that most catalytic reactions occur at the nanoscale, where materials have a larger relative surface area and greater reactivity.

Now, new evidence shows that some metal-oxide catalysts achieve an additional and dramatic increase in reactivity at the extreme low end of the nanoscale, in dimensions measuring 1-2 nanometers or less.

Israel Wachs, professor of chemical engineering, made this discovery while anchoring nanoparticle catalysts of titania on a silica substrate. He developed a “multilevel substrate,” with the titania serving as a nanoscaffold able to anchor metal-oxide catalytically active sites and control their reactivity.

One of those catalysts, tungsten oxide, is a solid acid whose applications include increasing octane content in gasoline. Wachs was able to attach catalytically active sites of tungsten oxide to nanoparticles of titania ranging in size from 5 nm to less than 1 nm.

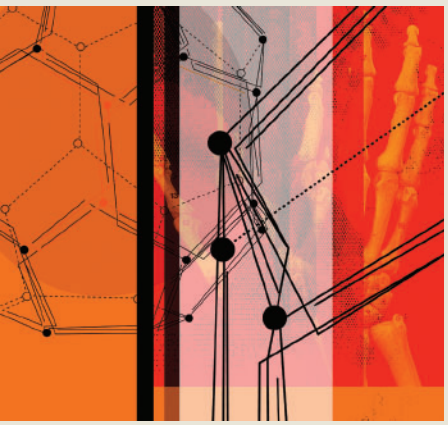
“Tungsten oxide’s behavior is a function of what it is attached to,” says Wachs. “If you’re seeking greater acidity in tungsten oxide, it is better for the tungsten oxide to be attached to titania than to silica, and it is better for it to be attached to smaller rather than to larger particles of titania.

“We achieved 100 times as much acidic reactivity with tungsten oxide attached to nanoparticles of titania measuring 1 nm or less, as we did with tungsten oxide attached to titania measuring roughly 5 nm.

“This is sub-nanoscale work.”

Energy-efficient sensor networks

Sensor networks were originally developed for battlefield surveillance and other military uses, but they have found application in many other areas, including traffic control, civil engineering, monitoring of the environment, health care, home automation and homeland security.



Blum's algorithms enable sensors to cease transmitting, thus saving power, when likelihood is determined.

Because they are widely dispersed and increasingly wireless, sensor networks are usually powered by batteries. Finding a way to stretch battery life could conserve resources in a big way, says Rick Blum, the Robert W. Wieseman Chair in Electrical Engineering.

Blum applies signal processing and communications to develop energy-efficient sensor networks that are as effective as their power-hungry counterparts. His work is based on the fact that wireless sensors in the same network can "hear" each other. When the sensors detect something – a sound or a vibration, a change in temperature or pressure, the presence of an unknown material – they process the data to determine its importance. The sensors with the most informative data transmit back to the central decision point before the others. Once there is enough information to determine the status of likelihood – is radioactive material present or not, for example – the sensors cease transmitting data, thus saving power.

"We're able to show a lot of things mathematically," Blum says. "For example, you can save half the sensors in a network from transmitting data without losing any performance. If the network is large, that's phenomenal savings."

Networks range from a few sensors to thousands, and Blum and his team are writing algorithms to achieve greater energy efficiency within them. "Our simple algorithms can reduce energy usage by one-half, which is very good," he says. "We have more complicated algorithms that can save even more."

The project is supported by the U.S. Air Force and Army. In a related project also funded by the military, Blum is studying multi-input/multi-output radar technology, a sensor network of radar devices that is far more accurate at determining the location of an object than a single device is.

Blum is also taking part in a NASA-funded project in Lehigh's Center for Advanced Materials and Nanotechnology to develop nanotechnology arrays to serve as sensors capable of detecting chemical leaks aboard spacecrafts. Blum is working on the system's signal processing.

Teaching computers to learn like we do

In 1997, IBM's "Deep Blue" defeated Garry Kasparov and became the first machine to win a chess tournament against a world champion.

Deep Blue's game strategy is a testament to the computer's ability to sift quickly through huge amounts of information and calculate a successful course of play, using algorithms created by humans.

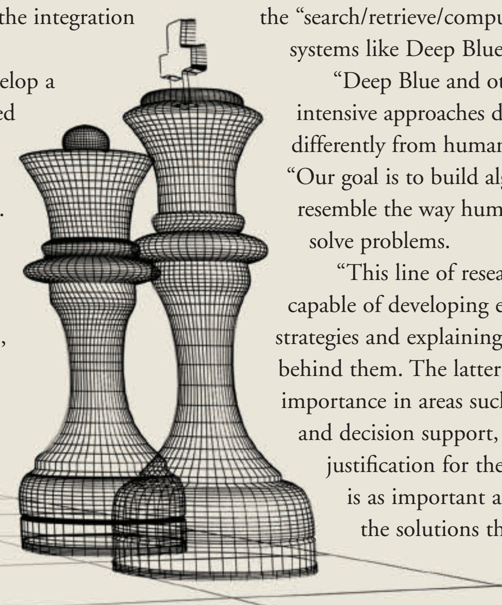
Héctor Muñoz-Avila, assistant professor of computer science and engineering, wants to take computers a step further.

With a five-year CAREER Award from NSF, Muñoz-Avila hopes to enable computers to "learn" as humans do – by taking a set of inputs, evaluating past outcomes of similar scenarios and making decisions based on experience.

"Many cognitive scientists believe humans begin acquiring knowledge by mastering simple skills and combining them to learn more complex ones," says Muñoz-Avila. "With chess, we start by learning how to move individual pieces. Then we learn simple strategies, such as opening moves and basic positioning. We build incrementally on our expertise until we master complex game-playing strategies based on the integration of basic skills."

Muñoz-Avila is seeking to develop a "unified architecture for automated learning of skill hierarchies" from a collection of examples, such as outcomes of previous chess games.

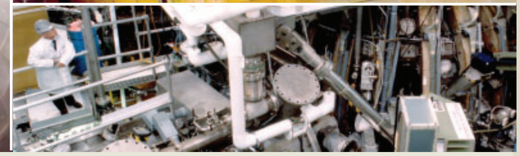
"The architecture incrementally learns simple skills by mimicking a few examples," he says. "As more examples are given, it learns complex skills that build on the simpler skills it learned previously. The goal, after many examples, is for the computer to be able to generalize these inputs into abstract, complex concepts and apply them to new situations."



This approach is a departure from the application of computational power and algorithms to a game or problem, says Muñoz-Avila. And it is potentially more powerful than the "search/retrieve/compute" power of systems like Deep Blue.

"Deep Blue and other search-intensive approaches develop strategies differently from humans," he explains. "Our goal is to build algorithms that resemble the way humans learn and solve problems.

"This line of research will be capable of developing effective strategies and explaining the reasoning behind them. The latter is of crucial importance in areas such as teaching and decision support, where providing justification for the solutions is as important as providing the solutions themselves."



The best of times for fusion research

Few control systems are as complex as the system required to optimize a nuclear fusion reactor.

And few human endeavors have been as ambitious as the international collaboration to build ITER, a giant fusion reactor, in France.

Eugenio Schuster, assistant professor of mechanical engineering and mechanics, is embracing the first challenge directly and the second indirectly.

Schuster recently received an NSF CAREER Award to study the nonlinear control of plasma, or ionized hydrogen gas, in nuclear fusion. He has helped edit two special editions of *IEEE Control Systems Magazine* on fusion, and has organized an NSF workshop on the modeling and control of fusion.

Nuclear fusion offers the promise of unlimited supplies of clean energy, but only if scientists and engineers can control the volatile conditions inside the fusion reactor, or tokamak, where temperatures reach 100 million degrees Celsius as isotopes of hydrogen fuse to create atoms of helium.

The long-term goal of ITER, which is a collaboration of the U.S., the European Union and five other nations, is to generate more energy than is required to heat the hydrogen plasma.

The key to achieving a high ratio of fusion energy to input energy, says Schuster, is active control systems that maintain a self-sustaining fusion reaction for long periods of time. These systems, he says, need to regulate the density, current and temperature of the plasma, to keep the plasma stable, and to confine it inside the magnetic fusion reactor. The shape of the fusion reactor and the material of which it is made are other variables with which control engineers must contend.

Schuster is working on several critical challenges in the control of fusion reactors, including stabilization of neoclassical tearing modes, current profile control, and stabilization of resistive wall modes.

He and his Lehigh students and colleagues have close ties with all three major U.S. fusion research centers – General Atomics in San Diego, the Princeton Plasma Physics Laboratory and MIT's Plasma Science and Fusion Center. Schuster also maintains contact with ITER scientists.

ITER is projected to cost $10 billion, take 10 years to build and require several decades of tests. Experts say it could be at least 30 years before humans enjoy the fruits of fusion.

Schuster is optimistic.

"For a fusion researcher, these are really exciting times. ITER is the biggest scientific endeavor in human history, a product of 50 years of work with 30 years more to come.

"I'm very confident we will succeed. This will be something I can tell my grandchildren about."

Schuster, who has close ties to the three major U.S. fusion research centers, studies several challenges related to fusion reactor control.

Software for optimization

The routing of automobile traffic and the management of a stock portfolio both involve optimization — using a mathematical model to increase the efficiency of a complex system with many components, variables and input parameters.

Ted Ralphs, associate professor of industrial and systems engineering, writes optimization software that can be customized to a variety of applications. He attempts to accelerate optimization by applying more efficient computing power and using multiple processors and parallel computers in tandem.

"I deal with difficult problems that have a very large space of possibilities," Ralphs says. "Searching through that space is the key. You cannot search efficiently by merely rating all the possibilities and determining which is best. There are too many possibilities. The efficient use of computing power is paramount."

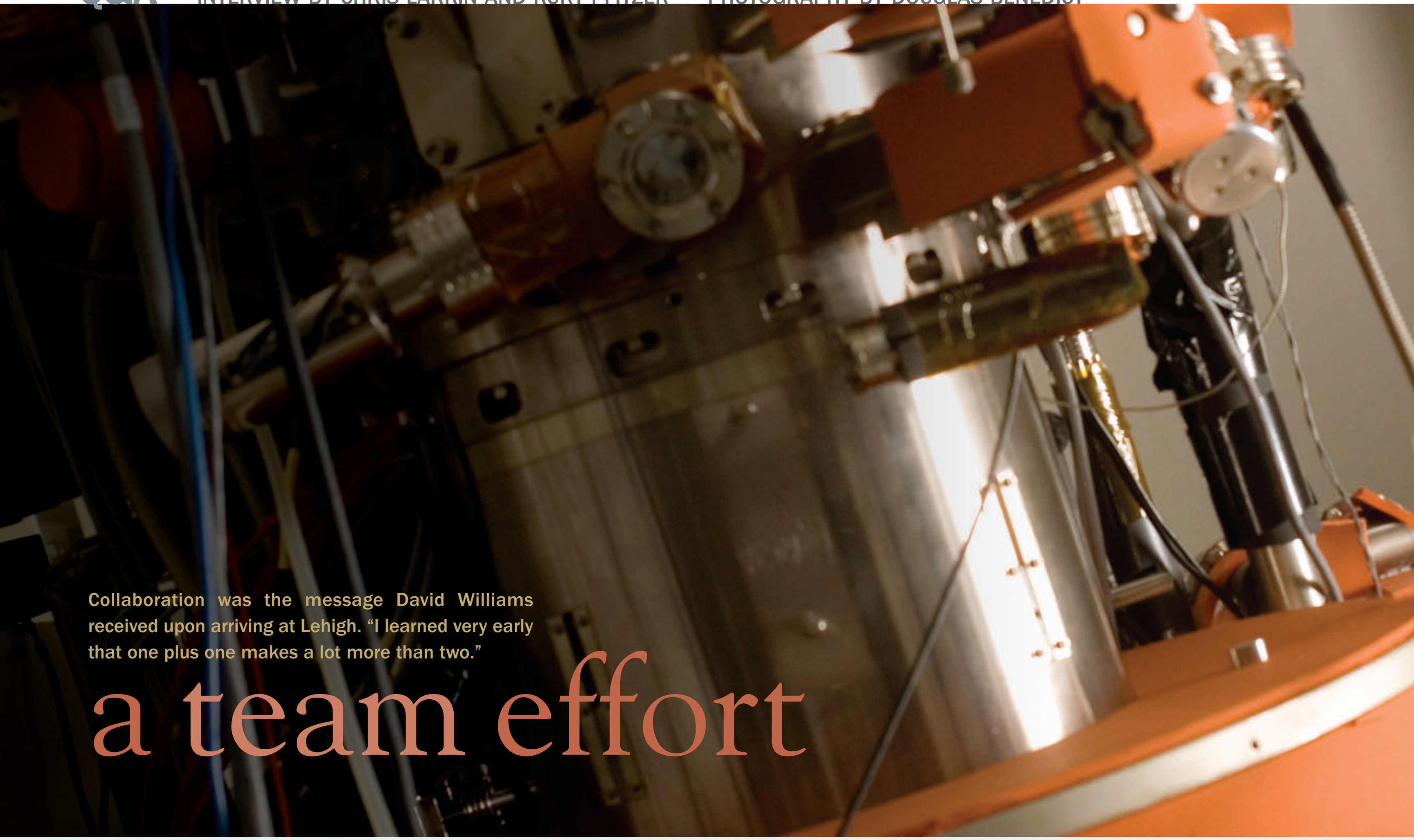
The task for Ralphs might seem simple — segment the search space into smaller pieces and assign a single processor to each. But many of these tiny segments "contain nothing of interest," leaving too many processors with nothing important to do.

The solution, he says, lies in sharing information between processors.

"If one processor is doing something that seems interesting, it has to be able to note that and hand it off to another processor. Doing that efficiently is the challenge."

Ralphs, who has developed software packages to solve large-scale optimization problems, chairs the Technical Leadership Council of an open source software foundation called COIN-OR. He has attracted funding from NSF, IBM, the Commonwealth of Pennsylvania and the U.S. Army.

INTERVIEW BY CHRIS LARKIN AND KURT PFITZER • PHOTOGRAPHY BY DOUGLAS BENEDICT



Collaboration was the message David Williams received upon arriving at Lehigh. "I learned very early that one plus one makes a lot more than two."

a team effort

FINDING, AND SUPPORTING, "THE RIGHT FACULTY"

David Williams left Lehigh on July 1 to become president of the University of Alabama in Huntsville (UAH), the premier research institution in Alabama. In 31 years at Lehigh, Williams served as department chair and Harold Chambers Senior Professor of materials science and engineering and as the university's vice provost for research. Williams is a past president of the International Federation of Microbeam Analysis Societies and a Fellow of TMS, ASM International and the Royal Microscopical Society. He is also author of *Transmission Electron Microscopy* and coeditor of *Images of Materials*.

Q: ***What inspired you to devote your career to materials science and engineering?***

A: I had gone to Cambridge to read physics, and I barely scraped through my end-of-year exam. My tutor said to me, "Williams, if you want to graduate from this institution, pick another subject." I ended up getting a first-class degree in materials science. Nobody offered me a job, so I stayed on to do research. I knocked on the door of one professor, but he said, "I don't need any more Ph.D. students." The next office belonged to a microscopist who welcomed me in. That's how I became an electron microscopist. Life is a series of failures. That's been a very important lesson for me.

Q: ***What is your most memorable achievement as a professor?***

A: The 20-odd master's and 20-odd Ph.D. students who taught me just about everything I know. One of my Ph.D. students, for example, earned straight A's, published six papers, and worked at Los Alamos National Lab and the Max Planck Institute. She is now at the University of Newcastle in Australia. The chance to work with people like that is the most remarkable part of my career.

Q: ***What do you consider your most impressive discoveries?***

A: Joe Goldstein [former vice president for research at Lehigh] and I were able to examine the microstructure of meteorites and gain insight into the cooling rate of the solar system. This was fascinating, but absolutely

Universities, says David Williams, must compete in the marketplace to recruit and retain tomorrow's top researchers.

irrelevant to anything commercial. And recently, my group has been able to understand how slight changes in electron distributions between adjacent atoms can control catastrophic events such as brittle failure of metals.

Q: ***How can universities encourage research?***

A: When I arrived at Lehigh as a young assistant professor in 1976, Joe Goldstein wrote me into his ongoing grant with NASA, even though I had no knowledge whatsoever of meteorites. Joe also asked me to advise one of his graduate students on transmission electron microscopy. So collaboration was the message that I received very clearly. One plus one makes a lot more than two.

Q: ***How should universities choose areas of research focus?***

A: It's very simple. Invest in the next generation of smart young people. Hire the right faculty and get out of their way. To those who succeed, you say, "Which area do you want to go into next? How can we support you?" You build on what you already have. Research thrusts should evolve, not be imposed from the top down.

Q: ***How can we encourage more American undergraduate students to pursue graduate study in science and engineering?***

A: We have singularly failed to excite our own graduates about the long-term future of science and engineering. Read the names of new Ph.D.s – they're Chinese, they're Indian, they're international.

My son just graduated from Carnegie Mellon with a double major in civil engineering and public policy. He went to work for advertising.com in Baltimore. He certainly had the GPA to pursue a higher degree. But what would we have said to attract him? "Instead of going off to earn a solid salary and a nice bonus, why not stay here? We'll work your tail off, you can live in poverty, and if you're really good, you'll get a Ph.D. in five, six years." Which offer would you take?

If we want to persuade our best and brightest to go into engineering and science, we have to be competitive. The top graduate research fellowships now pay about $32,000 a year. That beats $20,000 to $25,000, which is more typical. But it's still only 40 to 50 percent of what a good graduating engineer or scientist can make. At the same time, we should make it easier for international graduates to remain here and teach and do research. Someone wrote recently that there should be an immigration officer waiting at commencement exercises, stamping the visa of every new international Ph.D. and saying, "Welcome! You're now on track for a green card."

Q: ***How can the U.S. motivate more of its young citizens to consider science and engineering careers?***

A: NSF has required K-12 outreach in all of its major research centers, and that's good. Lehigh does outreach through the Center for Advanced Materials and Nanotechnology, STEM, S.T.A.R. (Students That Are Ready) and many other programs. But no matter how exciting nanotechnology or DNA sequencing is, students won't be successful if they don't come to school well-fed and go home to a stable environment where their curiosity is encouraged. It all starts well before university.

Q: ***How should schools prepare students to deal with ethical issues?***

A: It's difficult to answer ethical questions without knowing what the issues are. Are ethics universal? I tend to be a gray-scale man because I'm an imaging technologist and all our images are viewed in gray. I think it's necessary to teach knowledge, in hopes that some sense of wisdom comes out at the end, before you ask the difficult questions.

Q: ***What advice would you give to students considering academic careers?***

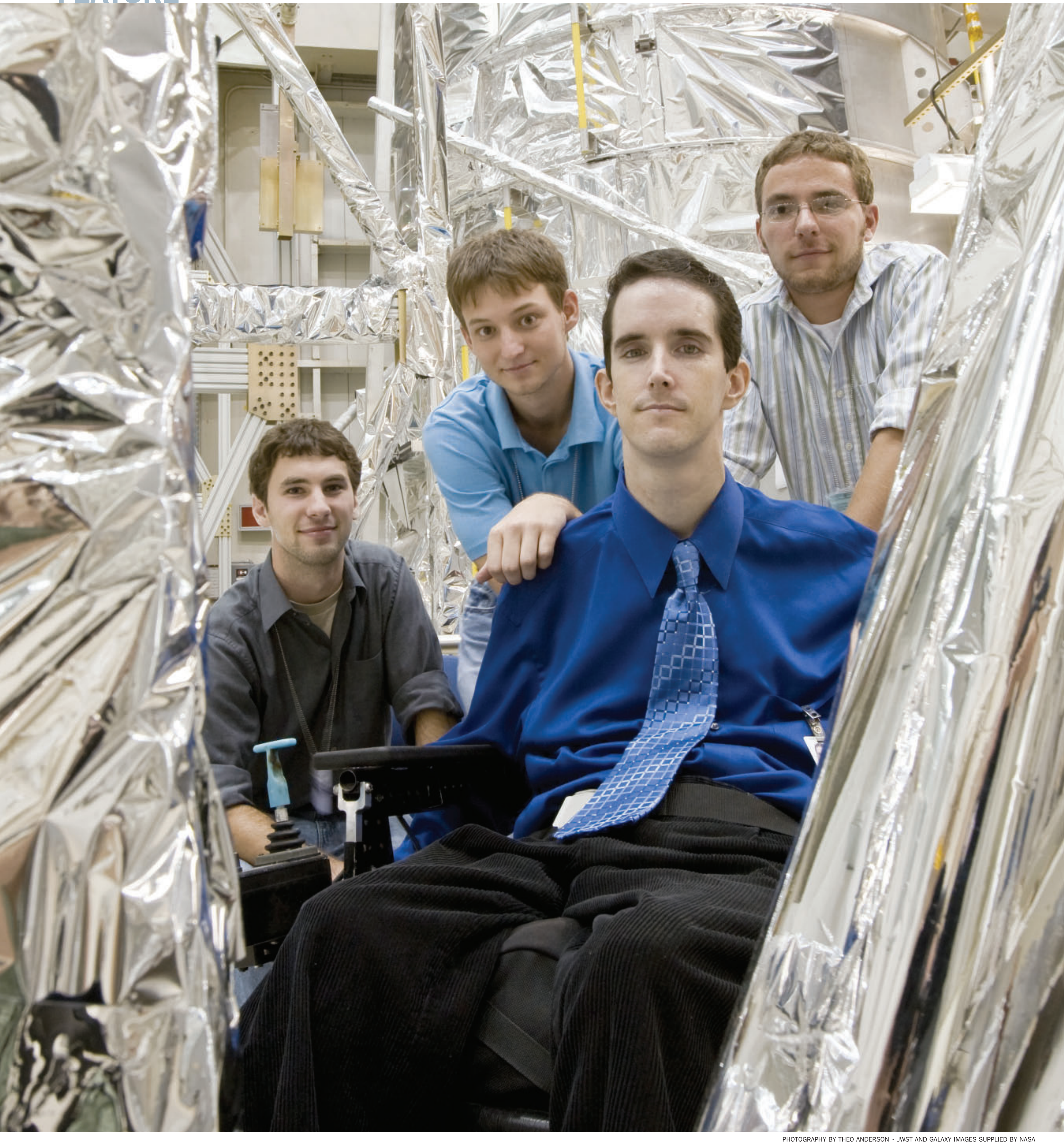
A: Do good research and teach it well in the classroom. Lehigh has consistently expected faculty to be good teachers and good researchers. It's a message I've conveyed at the UAH. The successful faculty I have seen are fine scholars who teach well in the classroom.

Q: ***Is it possible to get the American public as excited about a scientific endeavor as it was in the 1960s during the race to reach the moon?***

A: Of course. The human race has not changed; all that has changed is the circumstances under which we operate. It is possible to excite people about things that are important. We are a visual species; we need to translate science and engineering into a visual mode. We can see atoms. We can see galaxies at the dawn of time. We have got to tailor that knowledge, put it on the iPod and show it on the classroom wall.

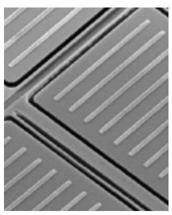
Q: ***Are you optimistic?***

A: Yes. The students we're bringing into Lehigh now are smarter than they were 20 years ago, but they are very different in their interests. Our job as professors is to build on their strengths and not expect them to be the way we were.



PHOTOGRAPHY BY THEO ANDERSON • JWST AND GALAXY IMAGES SUPPLIED BY NASA

A MATCH MADE FOR THE HEAVENS



NASA'S NEW JAMES WEBB SPACE TELESCOPE, SET TO LAUNCH IN 2013, WILL SELECTIVELY OBSERVE THE GALAXIES LOCATED AT THE REMOTEST ENDS OF THE UNIVERSE. RESEARCHERS IN LEHIGH'S CENTER FOR ADVANCED MATERIALS AND NANOTECHNOLOGY ARE HELPING THE SPACE AGENCY HONE THE TELESCOPE'S UNIQUE MICROSHUTTER SYSTEM WHILE BETTER UNDERSTANDING THE NANOSCALE BEHAVIOR OF MATERIALS IN SPACE.

Out at the edge of the known universe, billions of light-years from the earth, the elusive secrets to the beginning of time and space are speeding ever farther and faster from our grasp.

Closer to home, thousands or millions of light-years away, clues to the origins of stars and planets are concealed in giant clouds of dust where new heavenly bodies continue to take shape.

Human beings have not ceased wondering since first gazing in awe at the nighttime sky: How did the universe come into being? How do stars and galaxies form? Are there other planets in the universe capable of sustaining life?

The National Aeronautics and Space Administration will soon take a small step into space to tug at the veil shielding those mysteries.

In 2013, NASA will launch the James Webb Space Telescope (JWST) one million miles out into space, four times farther from the earth than the moon, and 2,500 times farther than the Hubble Telescope, which the JWST will replace.

The JWST will be like no telescope before it. A perfectly positioned space laboratory, it will observe the deep universe by blocking out the brighter light of closer objects to capture the faint light of vanishing galaxies.

Designing and operating the JWST is a huge engineering effort involving the European Space Agency, the Canadian Space Agency, Northrop Grumman Space Technologies and others. The telescope will be sent into space on an Ariane launch vehicle.

Lehigh is playing a critical role in a system of microshutters (see page 12) that will help the JWST capture selected infrared signals from the edge of the universe and thus observe the most distant galaxies. That project is part of a larger collaboration between Lehigh and NASA that supports research vital to space exploration while seeking to inspire the next generation of scientists and engineers.

That joint effort, the Lehigh University/Mid-Atlantic Partnership for Nanomaterials, has spawned a dozen research projects involving 14 Lehigh faculty members. In 2006, Lehigh and NASA's Goddard Space Flight Center (GSFC) in Maryland received $4 million from a congressional appropriation. Later, under a cooperative agreement signed by Lehigh and GSFC, NASA pledged to support research in Lehigh's Center for Advanced Materials and Nanotechnology (CAMN), as well as internships and research projects for Lehigh students.

The partnership also grants NASA access to Lehigh's world-class electron microscopes, which will help researchers develop new materials and devices for space exploration.

"We regard the Lehigh-NASA relationship," says GSFC program manager Dan Powell, "as a long-term strategic partnership, and not just a group of high-value development efforts."

(Photo on Left Page) Lehigh engineering students (l to r) Lehigh students Jim Blaney, Mark McLean and Scott Freese along with GSFC program manager Dan Powell (front center) worked this past summer at GSFC as part of a collaboration between Lehigh and NASA.

(Above) Lehigh physics graduate student Stacy Snyder (l) shown here with NASA's Stephanie A. Getty, Ph.D. working together at GSFC (r).

Lehigh and NASA choose research topics that couple NASA's needs with Lehigh's strengths. Lehigh has also obtained grants from the Pennsylvania Infrastructure Technology Alliance (PITA), the Pennsylvania Space Grant Consortium and other agencies to support internships and related research.

Many Lehigh-GSFC projects have interest for other funding agencies, says Gene Lucadamo, Lehigh program manager for the partnership. Carbon nanotube sensors that detect noxious gases in spacecraft, for example, are useful for bioterror prevention efforts by the Departments of Defense and Homeland Security. Transparent ceramics for tougher spaceship windows can be applied to the armored glass required by military vehicles.

These "cross-links," says Lucadamo, make it possible to leverage funding from other agencies. In addition, the CAMN's Lehigh Nanotechnology Network includes two dozen company members that can design, fabricate or utilize the new materials and devices generated by research projects.

"The structure of our partnership enables us to pursue other research opportunities as they emerge," says Powell. "If we hit barriers in existing projects, we try to be flexible enough to pursue lateral pathways.

"Lehigh has received only a small fraction of the support that some other universities receive, yet we're seeing real results in nanocharacterization and new nanomaterials."

CAMN director Martin Harmer is principal investigator for the partnership. David Williams, former vice provost for research at Lehigh (see page 8), and William Michalerya, associate vice president for government relations, played key roles in establishing the alliance.

Tiny behaviors of huge importance

Telescopes, spaceships, robots and many other devices vital to space exploration can be made to function more efficiently and reliably if engineers understand how their tiny constituent materials behave in the hostile environment of space.

Nanocomposites, nanoribbons and other nanomaterials, for example, should enable engineers to fabricate lighter-weight space vehicles with superior material properties – without sacrificing strength.

But such advantages can only be gained with an improved knowledge of the way these materials behave at the atomic scale.

For this reason, Lehigh's Nanocharacterization Laboratory is critical to the Lehigh-NASA collaboration. Lehigh, with 14 instruments, possesses one of the world's most extensive collections of electron microscopes. Using two aberration-corrected microscopes – a JEOL 2200FS transmission electron microscope (TEM) and a VG HB 603 scanning transmission electron microscope (STEM) – researchers can resolve images to 0.1 nanometer, about half the width of an atom, and can determine the chemical identity of individual atoms in crystalline materials.

Lehigh experts are constantly refining microscopes and developing new analytical techniques. These upgrades make it possible to determine a material's mechanical, chemical and electrical properties, as well as its structure and composition, at the nanoscale.

These analyses can be performed remotely. Lehigh engineers operated the JEOL 2200FS TEM from the Microscopy and Microanalysis 2006 meeting in Chicago, and have teamed with NASA engineers to set up a remote instrument terminal that could enable NASA scientists to operate the instrument anywhere.

COUNTERING STICTION

THE CENTERPIECE OF THE JWST IS A NEAR INFRARED SPECTROMETER, one of many new instruments invented for the telescope. The spectrometer will focus on the faint glow of faraway galaxies by utilizing a waffle-like grid of microshutters. Each waffle cell is covered by a microshutter measuring 100 by 200 microns, or the width of several human hairs. There are altogether more than a quarter-million microshutters or cells.

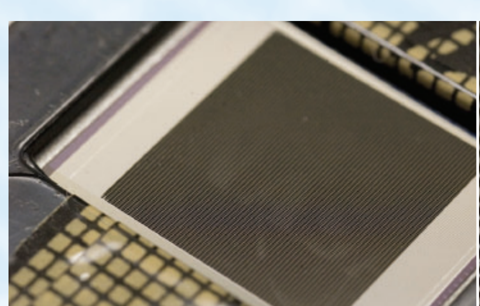
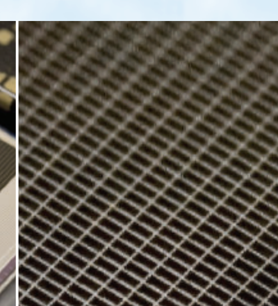
Each microshutter can be opened or closed individually, enabling the telescope to view — and block out — selected portions of the sky. The microshutter opens with the application of a magnet and closes when the magnet is removed.

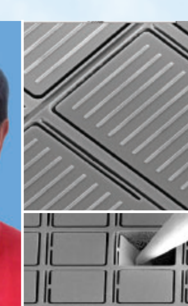
To receive weak infrared light signals from selected points at the edge of the universe, some microshutters must remain open for days at a time. In these cases, a 40-volt electrostatic charge will be applied to "latch" the microshutter to the cell wall and prevent it from closing after the magnet is removed.

This prolonged opening, however, can cause the microshutter to lock in the open position after the applied voltage is withdrawn. The problem, called "stiction," causes NASA to lose control over the microshutters.

To solve stiction, NASA turned to James Hwang, director of Lehigh's Compound Semiconductor Technology Lab. Hwang has

Hwang found that stiction, in which a microshutter remains open instead of springing shut, usually results when the voltage applied to keep the microshutter open causes a dielectric charge to be trapped in the cell's insulator.



"Internet2 and improved software developed by JEOL are making it more viable for people at NASA to do experiments in our labs," says Chris Kiely, director of Lehigh's Nanocharacterization Laboratory. "The only thing you cannot do remotely is to load a specimen. Everything else – setting the apertures, controlling the alignment and acquiring data – can be done remotely."

The Lehigh-NASA partnership includes a half-dozen microscopy-related projects. In one, CAMN research scientist Lolita Rotkina is enhancing the capabilities of the JEOL 2200FS TEM with a novel combined characterization tool – a low-current measurement circuit and scanning probe fabricated by a smaller company called Nanofactory, for Gatan Inc., a leading manufacturer of electron microscopy ancillary equipment. The tool can locate and image an object as small as a single carbon nanotube, and measure its electronic conductivity and simultaneously manipulate it using a piezo-driven probe. This tool has potential applications both to the analysis of materials like reinforced nanocomposites and also to molecular electronic devices, which are a focus of current NASA research.

In another collaboration with Gatan, researchers have attached an X-ray ultra microscopy (XuM) system to Lehigh's XL-30 SEM to study volcanic ash, fly ash, biocompatible glass, precipitates in aluminum alloys, clay-reinforced polymer nanocomposites and other materials. The XuM work is being led by CAMN research scientist Carol Kiely.

XuM obtains an image by using a CCD camera to measure the intensity of the X-rays transmitted through a specimen after it has been bombarded by X-rays emitted from a target located within the microscope. Lehigh and the Lawrence Livermore Laboratories are the only two places in the U.S. currently with such an XuM.

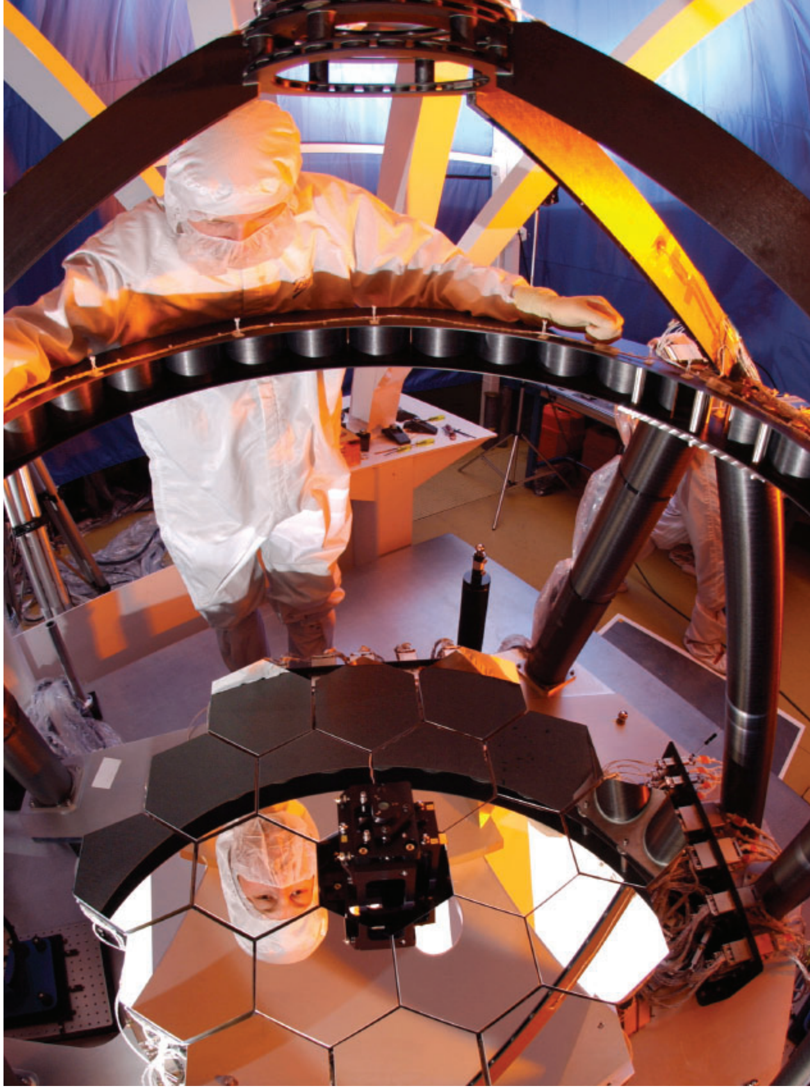


PHOTO COURTESY OF NORTHROP GRUMMAN

A one-sixth-scale optical test bed of the JWST's primary mirror, built for Northrop Grumman by Ball Aerospace & Technologies Corp. The mirror, with a collecting area seven times as large as the Hubble's, consists of 18 ultrathin beryllium mirror segments. The new telescope is optimized for near- and mid-infrared light.

modeled the movement of dielectric charges in MEMS (microelectromechanical systems) and explored methods of minimizing the accumulation of those charges.

Working with three undergraduate electrical engineering majors, Hwang discovered the reason for the stiction — the voltage applied to keep the microshutter lid open was causing dielectric charge to be trapped in the cell's silicon-nitride insulator.

"When you hold the microshutter open for several days at a time, charge starts to build up in the insulator," says Hwang. "Normally, to close the microshutter, you remove the voltage and it springs shut. But a charge that is trapped in the insulator is sufficient to keep the microshutter open.

"We established that the dielectric charging can cause stiction. We cannot say that all stiction occurs because of the dielectric charging, but we believe that a majority of it can be attributed to the charging."

Hwang and his students recommend using a bipolar voltage, opening the microshutter with alternating applications of positive and negative voltages and thus canceling the trapping of the charge in the silicon-nitride insulator.

NASA engineers have come up with two other potential solutions to the stiction problem. One involves placing ribs on the cell wall to which the microshutter latches when opened; this would minimize the contact area between shutter and wall, thus reducing charging and stiction. The other solution is to apply a hydrophobic coating to the microshutter surface. The three solutions are not mutually exclusive, says Hwang, and can be used in concert to minimize stiction.

Rob Guzzon, Andy Melchior and John Yamrick, the undergraduates who investigated the stiction problem, traveled to Maryland to use GSFC's cryogenic testing equipment. Guzzon is now a Ph.D. student at the University of California-Santa Barbara. Melchior works for Thales, the international electronics and systems group, on a MEMS project related to software-defined radio. Yamrick is completing a second B.S. at Lehigh, this one in engineering physics.

"I relied heavily on all three students," says Hwang, who also supervises six Ph.D. candidates and four postdoctoral researchers. "Even though they were undergraduate students, they were ready to take on independent research and be treated like Ph.D. students."

PHOTO COURTESY OF NORTHROP GRUMMAN

Workers test the cryogenic (extreme cold) performance of JWST's backplane (top) and align one of its mirror segments (above right).

The XuM-SEM combination, says Chris Kiely, enables engineers to obtain images from the interior of a relatively thick sample without damaging or destroying it.

"With XuM, you can see through half a millimeter of polymer, and about 100 microns of metal foil, to obtain an image of a material's internal structure," says Kiely. "Using XuM, we have created 3-D reconstructions of precipitates containing heavy atoms sitting within an aluminum matrix.

"XuM is also very effective at visualizing how a crack propagates through a material. In studying polymers reinforced with silica or clay particles, XuM has given us the clearest images yet of crack tip morphology."

Lehigh geologists have used the new XuM to study the shapes of pores within volcanic ash particles, says Kiely. NASA may want to use XuM to study lunar dust morphology to assess its abrasive effect on the mechanical parts of space vehicles.

Toward higher-performing space vehicles

XuM is proving particularly useful in two other Lehigh-NASA projects.

In a collaboration with GSFC's Powell, Wojciech Misiolek, director of Lehigh's Institute for Metal Forming, is seeking to disperse boron nanoribbons in aluminum matrix composites to improve the strength and stiffness of the composites and thus reduce the weight of the composite structures. The materials are used in aerospace applications, and NASA hopes Misiolek's work leads to lighter, stronger space vehicles with improved thermal stability and fuel efficiency.

"We believe that nanoribbons, because of their size and ability to disperse, will function as a strengthening agent for aluminum matrix systems," says Misiolek, who collaborates with experts in Europe, Australia, New Zealand and Brazil.

"At present, aluminum matrix composites dispersed with microscale powders of silicon carbide or alumina are used in the automotive and aerospace industries. We're hoping to improve the mechanical properties of these composites by 30 percent with nanoribbons of boron."

In a second project, nanoparticles of silica and rubber are demonstrating the potential to increase the interlaminar fracture toughness of carbon-fiber composites, which are also used in aerospace applications.

Ray Pearson, director of Lehigh's Center for Polymer Science and Engineering, studies toughening mechanisms in thermosetting resins used in composites. Low interlaminar fracture toughness has been the "Achilles' heel" in fiber composites, says Pearson, because resin-rich regions between plies enable flaws and cracks to travel unimpeded by fibers.

Engineers have long used microscale particles of rubber to toughen the matrix of composite materials and to improve the interlaminar fracture toughness, says Pearson. A consensus was formed in the 1990s that 200 nm was the optimal particle size and that decreasing that size would decrease the particles' effectiveness as toughening agents. Pearson, working with the international chemicals giant Arkema Inc., has recorded a five-fold increase of interlaminar fracture toughness in an epoxy resin containing a tri-block copolymer that self-assembles into 40-nm rubber nanoparticles. Additional improvements are obtained when a few percent of 20-nm particles of nanosilica are added to the nano-rubber.

"We are continuing to investigate why these nanoparticles are more effective toughening agents than their microscale counterparts," says Pearson. "We're particularly interested in finding out what kind of mechanisms the nanoparticles are triggering. What we've seen so far is a lot of ductility occurring, because of the presence of rubber nanoparticles, in a material that would otherwise be brittle."

In other projects, materials scientists led by Prof. Richard Vinci are seeking to control the mechanical properties of thin film materials exposed to the extreme cold of space. Electrical engineers are developing sensor arrays to monitor space environments, and are also studying methods of protecting sensitive equipment on spacecraft from the ultraviolet rays of the sun and the lethal radiation emitted by some planets. Engineers and physicists are studying new ways of dispersing and sorting carbon nanotubes.

Minding the future

The relationship between Lehigh and NASA dates to the early 1970s, when the space agency asked Joseph Goldstein, former vice president for research at Lehigh, to study meteorites and moon rocks.

In 1983, Mohamed El-Aasser, Lehigh provost and professor of chemical engineering, helped design a reactor that, in zero gravity aboard the Challenger STS-6, synthesized the first products ever made in space – polystyrene latex microspheres for calibrating microscopic objects.

In 2005, seniors in Lehigh's failure-analysis class became the first college students in the U.S. to be asked by NASA to evaluate debris from the Columbia space shuttle.

As part of the current Lehigh-NASA partnership, five Lehigh undergraduates are doing summer internships at GSFC. NASA is also sponsoring two teams of students in Lehigh's Integrated Product Development (IPD) program. One team is designing a boom that will stabilize a spacecraft against the earth's gravity. The second is helping to design a special vacuum chamber that will simulate the environments on the moon and on Mars as they pertain to dust migration and charging. Both teams are supervised by former NASA astronaut Terry Hart, a member of Lehigh's Class of 1968 and an adjunct professor of mechanical engineering and mechanics at the university.

Mindful of the need to inspire future engineers and scientists, Lehigh faculty and students lead projects at two nearby NASA Explorer Schools – Harrison-Morton Middle School in Allentown, Pa., and Broughal Middle School in Bethlehem, Pa. The outreach efforts at these and other schools are led by Henry Odi, executive director for academic outreach at Lehigh, and Andrea Harmer, CAMN director of Web-based education.

Lehigh is furnishing Broughal Middle School with GIS (Geographic Information Systems) technology, satellite images and remote sensing. Broughal students have toured Lehigh's microscopy labs, and will learn to use Lehigh's microscopes remotely.

Students at Harrison-Morton are not waiting for official approval to commence their own exploration of space. With help from Lehigh, which has leveraged a grant from NSF's STEM (Science, Technology, Educational and Mathematics) program, the middle school has built a lifelike Martian landscape in its basement. In their technology classroom on the second floor, eighth-graders learn the basics of computer programming from Lehigh students and professors. Then, like real engineers at mission control, the students guide the robots across the rocky "Mars Yard" terrain two floors below and direct them to fetch rocks to analyze.

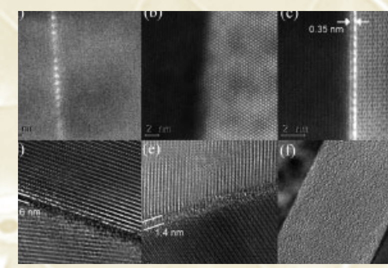
UNCOVERING NEW "COMPLEXIONS" IN A CRITICAL CERAMIC

It takes just a relative handful of rogue cells to cause cancer by dividing uncontrollably and spreading to the wrong regions of the body.

Similarly, in the interface, or grain boundary, of a material, one grain out of 10,000 can undergo a much more sudden and dramatic growth spurt, consume its smaller neighbors, and greatly alter the properties of the material.

The phenomenon has perplexed engineers for decades, says Martin Harmer, director of Lehigh's Center for Advanced Materials and Nanotechnology.

Harmer believes he has made a fundamental discovery that could help engineers better tailor the properties of ceramics. Using Lehigh's aberration-corrected transmission electron microscope, Harmer and his student, Shen Dillon, have identified six grain-boundary "complexions" in the ceramic alumina (Al_2O_3), each with a distinct rate of grain growth. The complexions can be controlled by making changes, often subtle, in chemistry and temperature, Harmer says.



"We tested types of alumina with different dopants, noticed remarkable trends in the data, and used TEM to image the atoms at the grain boundaries," says Harmer. "We matched the six growth rates with six fundamental types of interfaces, and correlated each type of interface with a specific rate of grain growth."

Scientists have long assumed that there were only two or three different types of grain boundaries in alumina, says Harmer.

Harmer will give a plenary lecture on his discovery in October 2008 at a symposium of the American Ceramics Society, which is awarding him the 2008 Sosman Award. The prize is the most prestigious given by the Society.

Harmer predicts his discovery will make it easier for engineers to control the critical rate of growth at grain boundaries. The interfaces play a key role in the creation of ceramic solids from powders and in the mechanical, chemical and other properties of the bulk material. For example, he says, slowing the rate of grain-boundary growth facilitates the formation of nanograins, which can make a material stronger and more transparent.

"Complexions are going to be very relevant for fabricating nanograined materials," says Harmer. "They will help us avoid the transition from slow-moving to fast-moving grain boundaries that happens in a relative split second and is triggered by a change in temperature of only a few degrees."

"This fundamental work has the potential to lead to materials with superior properties, lighter weight and higher strength," says Dan Powell, program manager at NASA's Goddard Space Flight Center in Maryland. "With applications, we might see a 10 to 40 percent improvement in fracture strength that could enable us to control anomalies that come up in space travel."

A MODEL THERAPY

ENGINEERS OFFER HOPE TO VICTIMS OF LUNG DISEASE

Infectious diseases that attack the lung and cause it to fill with fluid present medical science and engineering with a Catch-22 scenario, says Samir Ghadiali.

The fluid causes shortness of breath, wheezing and the sensation of drowning. Anxiety and panic set in. The patient requires immediate medical attention.

The only available remedy is a mechanical ventilator that pushes air into the lungs, breathing for the patient until he can breathe on his own. But the machine further harms air passages and causes a 40 percent mortality rate after several days of use. The phenomenon, ventilator-induced lung injury (VILI), contributes each year to the deaths of tens of thousands of Americans.

Ghadiali, the Frank Hook Assistant Professor of bioengineering in Lehigh's department of mechanical engineering and mechanics, believes the optimum

PHOTOGRAPHY BY DOUGLAS BENEDICT

treatment for VILI lies in a sound application of engineering principles. He and his students employ computational modeling and lab experiments to gain a clearer picture of the vital functions of the lung and the punishment it endures from VILI.

Ghadiali's goal is twofold. A better understanding of the biological mechanisms of lung-cell injury during VILI, he says, can lead to the development of drugs that protect lung cells and improve the survival rates of patients undergoing ventilation. Ghadiali also wants to develop a biomimetic drug-screening system that evaluates the impact of air bubbles on cells during ventilation and measures the degree to which that impact is moderated by drug candidates.

"We believe there may be cell-based therapies that can improve patient survival rates," says Ghadiali. "If you have to undergo ventilation, it may be possible to first take a drug that makes your cells less susceptible to damage during ventilation. Your cells will still be struck by the sledgehammer of passing air bubbles, but they are more resistant to it. This would minimize cell injury. Your lungs can then recover on their own and you can go off the ventilator and survive."

LIFE IN THE DEEP LUNG

Ghadiali's study of pulmonary mechanics, which is funded by a Parker B. Francis Fellowship and a grant from the American Heart Association, focuses on the "deep lung." There, at the tips of the lung's elaborately branching airways, micron-sized sacs called alveoli expand and contract when a person breathes, diffusing oxygen into the blood while drawing carbon dioxide from it.

A thin layer of epithelial and endothelial cells, called the alveolar capillary barrier, separates the alveoli from the bloodstream. A severe disease or injury can break down this barrier, allow blood and bacteria to leak into the lungs and prevent the exchange of O_2 and CO_2. A mechanical ventilator restores that exchange, but at a cost.

"The ventilator saves your life," says Ghadiali, "but exacerbates the lung injury. We're trying to understand why the ventilator damages the thin layer of epithelial cells and how that can be prevented."

Medical researchers have attempted with little success to minimize ventilator forces with surfactant, a compound that helps premature babies breathe.

GOING AGAINST THE GRAIN

Ghadiali has taken the opposite approach. Rather than modify the mechanical forces created by ventilation, his group seeks to modify the responses of cells so they better survive the trauma of ventilation.

To test its hypothesis, Ghadiali's group accounts for an array of interdependent variables – the functions of lung, blood cells and alveoli, and the mechanical responses and interior activities of cells. This complexity can best be studied, Ghadiali says, by integrating experiments in the laboratory with mathematical modeling on the computer.

"Modeling allows us to study phenomena that are too complex to investigate systematically in the lab. It also enables us to manipulate parameters that are difficult to manipulate in the lab. Models can suggest new lab experiments that might unveil important information."

Ghadiali's students use a software program to simulate the response of alveolar epithelial cells to the shear stress and pressure gradient forces imposed by passing air bubbles. They collaborate with Lehigh biologists to measure the response of cells to these forces, growing and staining a "confluent" group of fully grown cells and a "subconfluent" group of immature, less densely packed cells. They compare the lab data with the modeling results, improve the models and run new tests.

The group's results have been surprising, says Ghadiali.

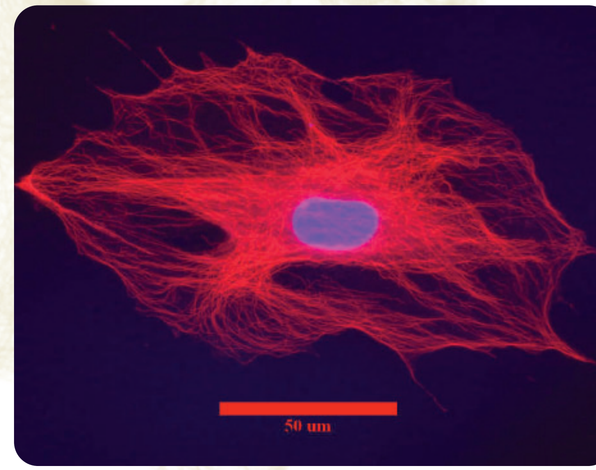
"We thought that placing more force on cells would kill larger quantities of cells, but we have found that in some cases that is not true. Like others, we also assumed that a cell modified to become more rigid would better resist certain types of forces. But the truth is more complicated."

Computational modeling – and what Ghadiali calls a "minimalist approach" to the technique – helps explain some of the counterintuitive results. Ghadiali and his students build their models one level of complexity at a time, choosing only those variables they think are critical to the phenomenon they are examining, rather than attempting to account for every variable at once.

VISCOELASTICITY IS VITAL

This "piece by piece" approach has helped reveal the lifesaving potential of viscoelasticity for epithelial cells, he says.

"We have found that a cell's ability to resist force depends not only on how rigid or soft the cell is but also on how viscous



Molecular structure of lung epithelial cells. Similar structures are being targeted with pharmaceutical agents by Ghadiali and his students.

it is, that is, how much it behaves like a liquid and how much it moves or deforms over time. In modeling the forces imposed on epithelial cells, we found that only when we added viscosity to the cells did we get results consistent with our lab experiments."

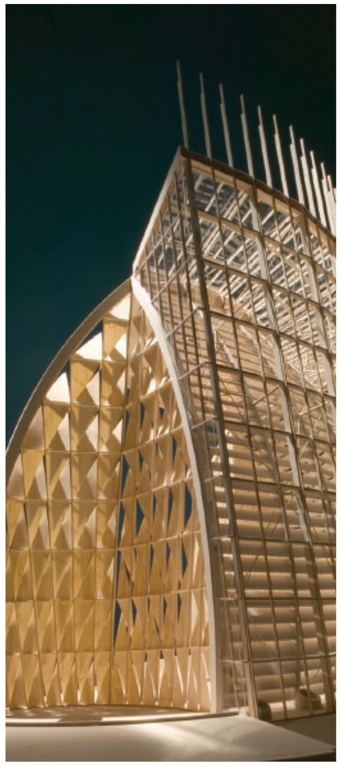
Ghadiali's group has confirmed the cells' viscosity by using "optical tweezers," a laser tool that oscillates the cell's cytoskeleton to measure its mechanical properties. The group collaborates with Daniel Ou-Yang, professor of physics at Lehigh and a pioneer in developing the tweezers.

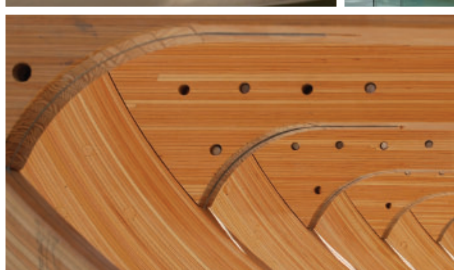
"We've found that in addition to making cells softer, some treatments can also make cells viscous," says Ghadiali. "This viscoelasticity enables a cell to 'damp out' the transient forces imposed by microbubble flows in the deep lung.

"The fact that we can manipulate this viscoelasticity suggests to us that it may be possible to develop pharmaceutical compounds that alter the viscoelasticity of the cells so they better withstand the forces of VILI."

Ghadiali's group is building a biomimetic, microfluidic system that contains flexible, branching air passages and models the entire alveolar-capillary barrier. The goal, he says, is to develop an *in vitro* system that prescreens drug candidates before they undergo *in vivo* testing.





Mark Sarkisian fitted Shanghai's Jin Mao Tower (right) with the world's tallest atrium, and used a new technology to protect Oakland's Christ the Light Cathedral (above) from earthquakes.

A PHILOSOPHY OF DESIGN, DYNAMICALLY GROUNDED

It seems an almost reckless idea – build an exquisite cathedral from the brittlest of materials, place it near a major fault line, and assure your clients it will survive, virtually unscathed, an earthquake the likes of which destroyed San Francisco in 1906.

"Thirty years ago," says Mark Sarkisian, "before new technologies and materials revolutionized structural engineering, such a proposition would have been dismissed as quixotic at best."

Sarkisian, a catalyst in that transformation, has spent a career fashioning elegant solutions to daunting assignments. After earning an M.S. in structural engineering from Lehigh in 1985, Sarkisian joined the international design firm of Skidmore, Owings & Merrill LLP (SOM), where he is now a partner. Utilizing new technologies and inventing many of his own, he has designed 50 major projects and won a dozen national and international awards.

Sarkisian's resume includes the U.S. Embassy in Beijing, the largest nonmilitary U.S. government building overseas, as well as Shanghai's Jin Mao Tower, which is the sixth-tallest building in the world.

His success rests on this premise: Structures should be designed, engineered and constructed to interact harmoniously with the most unpredictable of natural environments.

"A building," says Sarkisian, "should be regarded as a mechanism, not as a static entity. Buildings have to be dynamic during earthquakes, during windstorms and even during construction.

"Just as critical," he says, "is creative and honest interaction between architect and engineer from conception to completion of a project."

Sarkisian has teamed with Craig Hartman, SOM architect and design partner, on many of his most impressive endeavors, including the Beijing Embassy and the St. Regis Museum Tower in San Francisco.

"Ours has been a great and, in many ways, unusual collaboration in today's practice," says Sarkisian. "SOM provides both architecture and engineering design services because we believe an integrated dialogue is vital from the conception of a project. Each partner pushes the other to come up with new ideas. We examine these ideas closely to confirm their credibility before presenting them to our clients."

ENGINEERING FOR LIGHT, AND FOR LIGHTNESS

The San Andreas Fault, which runs the length of California, has produced some of the deadliest earthquakes in American history, including the San Francisco Earthquake of 1906 and the Loma Prieta Earthquake, which struck the San Francisco Bay in 1989. Included in the destruction of the Loma Prieta was the St. Francis de Sales Cathedral, spiritual home to half a million Roman Catholics in the Diocese of Oakland.

The diocese resolved to rebuild and to name its new home the Cathedral of Christ the Light, in keeping with the theme of the New Testament and the Second Vatican Council.

Hartman, chosen as project architect, drafted a plan that won over the diocese and the critics. When completed in 2008, wrote John King of the *San Francisco Chronicle*, Christ the Light will resemble a "woven wooden basket wrapped in opaque glass [and offering] a vision of warm, delicate layers that hint at the mysteries of things unseen."

The new cathedral expresses its devotion to light in a variety of ways. Ribs of Douglas fir form internal arches; they are wrapped in translucent glass laced with particles of ceramic to "impart a lambent glow to the interior," says Martin Holden in *San Francisco* magazine. Rays of light entering the vault into the sanctuary will be

PROPOSED M.ENG. OFFERS A GLOBAL PERSPECTIVE

PESSIKI

Lehigh is planning a master's in engineering degree for structural engineers who will design the world's future infrastructure. The proposed M.Eng. in structural engineering will be a project-based professional degree taught by practitioners currently working in the field, says Stephen Pessiki, chair of the department of civil and environmental engineering.

The 10-month residential program will be offered to students with new bachelor's degrees and to practicing professionals, says Pessiki. The target enrollment for the program is 25 students.

"The goal of our program is simple. We want to shape the future leaders of the world's top building design and architectural design firms."

M.Eng. candidates will complete a three-course sequence in structural design in which they work in teams on two projects under the supervision of the professor of practice.

In the group project, all class members will collaborate on the design of a building, bridge, stadium or other major structure. Group members will work in small teams on specific tasks, such as the foundation or superstructure.

In the small team project, groups of two, three or four students will explore design challenges of personal interest. Teams may work, for example, with Lehigh's Murray H. Goodman Center for Real Estate Studies on urban-renewal projects, or with Lehigh's chapter of Engineers Without Borders, which is rebuilding a local water system in rural Honduras.

Through coursework, students in the program will use the world-renowned testing facilities in Lehigh's Fritz Engineering Laboratory and ATLSS (Advanced Technology for Large Structural Systems) Center (below) to test structural components to failure.

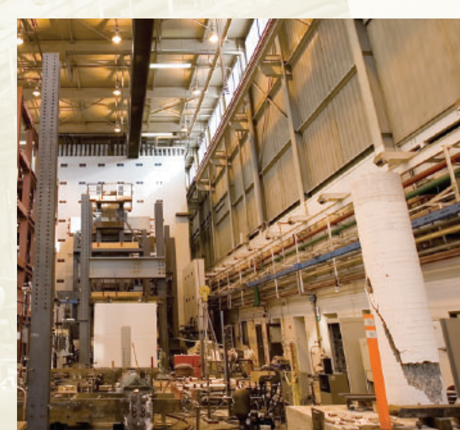
And, to gain a global perspective that is becoming increasingly critical, students will collaborate on their projects with engineers at other locations in the U.S. and overseas.

"One feature of contemporary U.S. design practice," says Pessiki, "is that a major project is worked on by a team of engineers distributed in offices across the country and sometimes across the globe. We will conduct the design courses in a manner that reflects this trend."

Overall, says Pessiki, students will learn to plan, manage and lead projects while maintaining effective communication among the owner, architect, construction manager and all other players in a project.

The program will run from July to May each academic year, beginning in 2008.

Lehigh also offers the M.S. and Ph.D. in civil engineering and in structural engineering. Both are research-oriented programs.



split by a faceted window into splinters of rainbows. The altar floor, also made of glass, will allow light to reach to a mausoleum below.

Hartman's plan received the AIA Design Award from the San Francisco chapter of the American Institute of Architects. Oakland Bishop Allen Vigneron predicts Christ the Light "will be for Oakland what Notre Dame is to Paris."

But a cathedral made of wood and glass cannot be built in an active fault zone without an innovative – to say the least – engineering design.

When Sarkisian began working with Hartman on the cathedral design, his first thoughts went to the Hayward Fault, which runs 2.9 miles from the site and is a neighbor to the San Andreas Fault. It is the Hayward, many seismologists say, that could trigger Northern California's next major earthquake.

"To an engineer," says Sarkisian, "locating a 110-foot-high cathedral made of delicate materials so close to an active fault line and expecting it to survive a 1,000-year earthquake like the 1906 Earthquake – that is the ultimate challenge."

To accommodate the desires of the diocese, Sarkisian and his team conceived of the cathedral superstructure – the reinforced concrete sanctuary floor and perimeter walls – as a table that could be isolated, or decoupled, from seismic tremors. This isolation will protect the delicate superstructure above. The deadly shaking of the ground will be absorbed by the foundation, including the concrete walls of the mausoleum, but not transmitted directly to the superstructure.

"During an earthquake," says Sarkisian, "the ground moves laterally with significant accelerations. Our approach is to let the foundation and mausoleum walls ride with the ground motions. Because they are embedded in the ground within stiff soil that doesn't significantly amplify seismic forces, the foundation will not be affected nearly as much as the superstructure above. The table and superstructure, being seismically isolated, move slowly relative to the ground and out of phase with the ground motions. This translates to lower forces imposed on the superstructure and allows it to remain elastic without permanent deformation or fracture."

> "A STRUCTURE SHOULD BE DESIGNED, ENGINEERED AND CONSTRUCTED TO INTERACT HARMONIOUSLY WITH THE MOST UNPREDICTABLE OF NATURAL ENVIRONMENTS."
> —Mark Sarkisian

The seismic decoupling, says Sarkisian, will be accomplished by "friction pendulum double-concave bearing isolators." Invented by Earthquake Protection Systems Inc. of Vallejo, Calif., the double-concave isolators, which weigh 4,200 pounds apiece, are being employed for the first time in the construction of Christ the Light. Thirty-six isolators are installed beneath the sanctuary floor. Each resembles a large ball bearing encapsulated within opposing flat bowls.

"The isolators have curved plates that allow the building to move back and forth while rising slightly," says Sarkisian. "A disk inside the bowls slides and returns to its original position after rising; it re-centers itself due to the structure's weight, after the ground motion from an earthquake stops. Because the isolators act as pendulums, with a longer dynamic period than that of the ground, the motion of the superstructure is slow and gentle."

FIRMLY FIXED IN THE SHANGHAI FLOODPLAIN

The Jin Mao Tower, which was dedicated in 1998, presented Sarkisian with a set of challenges quite distinct from those he would face in Oakland.

The tower – Jin Mao means "Golden Prosperity Building" in Chinese – dominates the skyline of Shanghai from a height of 1,381 feet. Its 88 stories include 50 floors of office space topped by a 38-story Grand Hyatt Hotel. Out of respect for the number eight, which signifies good luck in China, the tower contains an octagonal central reinforced concrete core, eight perimeter mega-columns made of concrete and steel, and eight steel built-up mega-columns, all resting on a 4-meter-thick, reinforced-concrete, pile-supported mat.

The immediate test for Sarkisian in Shanghai was to anchor the Jin Mao in soft, clay-filled local soils that had caused much shorter structures to settle 10 inches or more. He overcame this by installing a 3-foot-thick slurry wall, or diaphragm wall, 100 feet deep around the building's half-mile perimeter. Workers drove 429 evenly spaced open steel pipe pilings, each measuring 3 feet in diameter, through the spongy Huang Pu River floodplain and into the stiff sands below. The pilings extend 275 feet underground, a greater depth than any previously attempted in China.

"To overcome the weak soil, we needed, in effect, to create a table with 429 legs for the foundation to rest on," Sarkisian says.

Made of steel and concrete, the Jin Mao is a composite building, a new concept that has since gained considerable popularity. The goal was to create a system that resists winds and earthquakes with the fewest possible structural elements. To connect the concrete core to the composite mega-columns on the perimeter, Sarkisian used levers, or outrigger trusses.

"A composite building allows us to locate materials where they most efficiently resist loads, thus minimizing cost and materials. The concrete core provides excellent stiffness, while the structural steel floor framing allows us to use long, column-free spans with minimal weight.

THE JIN MAO HAS WON NINE AWARDS FOR ENGINEERING AND ARCHITECTURAL DESIGN.

This, in turn, reduces the size of the vertical members and the foundation."

The composite approach also enabled Sarkisian to hollow out that portion of the central core where structural demands were less, and to create the tower's centerpiece – a 650-foot-high atrium, tallest and highest in the world, extending up from the 56th floor.

The use of both steel and concrete in a super-tall tower, however, created a dilemma.

"The mix of materials in the vertical elements shortens when subjected to load," says Sarkisian. "Some deformations occur during construction due to self weight, while some occur over time, in some cases up to 10 years or more. Concrete and steel both deform elastically, but concrete also creeps and shrinks over time.

"For a building as tall as the Jin Mao, vertical displacement at the top could be as much as 12 inches. More significant is the relative movement between neighboring vertical elements, especially the core relative to the composite mega-columns that are interconnected with the stiff steel outrigger trusses. When subjected to large relative displacements, these trusses would attract forces so great that they could be ripped apart.

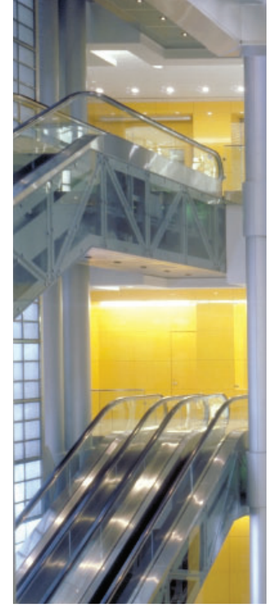
"To counteract these forces, we introduced pins into the trusses to allow rotation during construction. We did not bolt the connections until after the structure was completely built. After the bolts were installed, the structure was capable of resisting all future design loads."

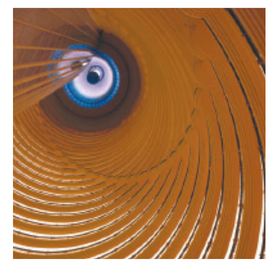
The solution to the specific challenge of the Jin Mao led Sarkisian to develop the patented Pin-Fuse Joint and the Link-Fuse Joint and Pin-Fuse Frame, for which U.S. patents are pending. All are designed to fuse and dissipate energy during earthquakes; after an event, friction in the joints is restored by high-strength bolts.

"It gets back to the idea that buildings are not static but very dynamic. The joints of buildings have to be considered as potential moving parts, especially during extreme seismic events."

The Jin Mao has won nine national and international awards for engineering and architectural design and has become one of Sarkisian's favorite havens.

"I've stayed in the Grand Hyatt many times now. The combination of living in the building and seeing what an icon it has become, in China and internationally, is really satisfying."





The atrium of Shanghai's Jin Mao Tower (photos of interior details at right) is the world's highest at 650 feet. Below (top to bottom): Sarkisian's Pin-Fuse Frame, Pin-Fuse Joint and Link-Fuse Joint.

The New Beijing Poly Plaza (right), which Sarkisian engineered, won the Award of Excellence for New Construction from the Structural Engineers Association of Northern California in 2007.

RIDING A WAVE

AN ENGINEERING SOLUTION PROPELS AQUARIUM ENTHUSIASTS

The VorTech propeller pump patented by Clasen, Lawyer and Marks has made tank life more pleasant for coral reef aquarium fish.

PHOTOGRAPHY BY DOUGLAS BENEDICT

Tim Marks '04 and Pat Clasen '04 have come full circle with Lehigh University's Integrated Product Development (IPD) program.

A few blocks from Lehigh's campus, in the house they rented as undergrads, Marks and Clasen run EcoTech Marine LLC, an aquarium equipment company that was their IPD project in 2003.

Now, as they look to double their 2006 sales of $500,000, Marks, Clasen and their business partner, Justin Lawyer, have taken six current Lehigh IPD students under their wing.

In Lehigh's IPD program, teams of engineering, business and design students work for a year to design, make and market new products for sponsoring companies like GM, B. Braun and even NASA.

A handful of IPD teams have received funding from Lehigh to form their own companies, or, in the case of Marks and Clasen, to build on existing companies.

EcoTech's partners are the first IPD alumni to sponsor IPD students of their own.

EcoTech Marine owes its genesis to the Internet. It was in a chat room for aquarium enthusiasts that Marks met Lawyer, who holds a B.S. in professional physics from the University of Oklahoma. The two founded EcoTech Marine in 2001. Clasen joined the company in 2002.

EcoTech's first product was the ETM Kalkwasser Reactor, which automatically replenishes and maintains levels of calcium and alkalinity in coral reef aquariums. The company's second product, and the source of most of its sales, is the patented VorTech propeller pump.

Magnetic attraction is the key to the VorTech. A magnet made of neodymium, a rare earth metal of exceptionally strong magnetism, enables a BLDC (brushless DC) motor outside the aquarium to adhere, through glass as thick as three-quarters of an inch, to a propeller inside the tank. The magnet transmits torque from the motor to the interior propeller, which circulates the water inside the aquarium. A knob on the tank's exterior adjusts the motor's speed.

The magnet gives the VorTech several advantages. It removes the need to drill holes through the side of the aquarium to connect the motor to the interior propeller. Electricity is kept outside the tank, and the shaft seal and housing gasket, which can cause leaking, become unnecessary. The VorTech also greatly reduces the amount of heat transferred from motor to tank water.

The BLDC, although expensive, offers additional advantages. It is 50 percent more efficient than most other motors but much lighter and smaller. Because it is brushless, it is longer-lasting.

Future plans for the VorTech include a wireless driver that will enable pumps at opposite ends of a large saltwater reef aquarium to pulse in unison and thus communicate with each other.

EcoTech is expanding beyond the aquarium business. Last year, the company received a call from a man who thought the VorTech could improve the spa industry. The man said water was leaking into his spa motor, which, as in a typical aquarium, is connected to an interior propeller through a hole in the spa tub wall. The man sent EcoTech a sample spa basin, which Marks, Clasen and Lawyer are studying in their prototype room.

EcoTech recently formed a spinoff company, EcoTech NanoSystems, and teamed with an outside researcher to seek applications for an environmentally friendly surface coating that inhibits the growth of algae and other organisms. The patented coating has potential aesthetic and energy-saving benefits.

"I found the patents on the Internet," says Clasen, "and called the researcher to see if his patents were being commercially used. I was a bit nervous, but I thought, 'What's the harm?' He answered in a scholarly voice and told me to contact his tech-transfer office. He's willing to give us a license, either full or segmented by market. We're getting outside opinions to examine the viability and profitability of the coating."

EcoTech is working on this project with Manoj Chaudhury, professor of chemical engineering at Lehigh and a world-renowned expert in adhesion and coatings (See page 5).

"We're hoping to develop a commercial coating for the sides of houses, for pools, for patio tiles, for aquariums – wherever there is a need to inhibit the growth of algae," says Clasen.

EcoTech has received grants from Pennsylvania's Keystone Innovation Zone (KIZ) program, the Ben Franklin Technology Partners, the Agile Manufacturing Program of Lehigh's Enterprise Systems Center and the Pennsylvania Infrastructure Technology Alliance (PITA). It has won three awards from the National Collegiate Inventors and Innovators Alliance (NCIIA), which promotes the teaching of innovation in higher education.

EcoTech is seeking further funding from Ben Franklin and from the Small Business Development Center, the Pennsylvania Export Finance Program and the Pennsylvania Nanomaterials Commercialization Center.

"We are a good case study for how to use government funding to start a company, out of college, that is targeted to a niche market," says Clasen.

The funding and financial advice help, as do the varied areas of expertise of EcoTech's partners – Marks has a B.S. in environmental engineering and an M.S. in mechanical engineering, while Clasen, who holds a B.S. in materials science and engineering, recently completed an M.S. in that field. The company also employs a part-time electrical engineer.

But the IPD program was critical to EcoTech's growth, the partners say.

"IPD gives students a chance at real success, either by working for a company that sponsors your product or by developing your own company into a career," says Marks. "It's not just an academic exercise; it's an entry to the real world."

Students meet sponsors and select their yearlong IPD projects at the 2007 IPD Sponsor Fair.

An integrated education for the modern workforce

Since it was founded in 1994, the IPD (Integrated Product Development) program has become one of Lehigh's most successful endeavors in integrated learning.

In the yearlong program, students in engineering, business and the arts work in teams to design and make products for industrial sponsors, and to develop marketing plans for their products.

IPD has won a curriculum innovation award from the American Society of Mechanical Engineers and has been praised by *The New York Times* for preparing students to work in the "cross-disciplinary teams" increasingly demanded by industry.

IPD students and their counterparts in Lehigh's newer IBE (Integrated Business and Engineering) program are regularly invited to display their products at national competitions. Together, they have won 11 national awards from the National Collegiate Inventors and Innovators Alliance (NCIIA).

IPD teams have made more than 300 products and they run the gamut:

- **A noncontact windshield wiper for commercial trucks**
- **An active rear spoiler for improved fuel efficiency**
- **A biomedical device for wound management**
- **A lacrosse helmet and stick made with new materials for improved performance and safety**

John Ochs, professor of mechanical engineering and mechanics and IPD cofounder, says the program's distinguishing features are its interdisciplinary approach, industry-sponsored projects, state-of-the-art facilities and committed faculty from engineering, business and the design arts. Also critical, says Ochs, is IPD's integration across the undergraduate and graduate curricula.

In 2006, Ochs won the Olympus Innovation Award, which is given annually by NCIIA to individuals who promote and demonstrate innovative thinking in education.

Taking aim at a ubiquitous and dangerous pathogen

Cryptosporidium parvum, a common and hardy parasite, can be deadly for people with weakened immune systems.

The pest is especially troublesome for two reasons, says Kristen Jellison.

Kristen Jellison's goal is to determine the sources of Cryptosporidium *in Philadelphia's water supply. She is also exploring the potential disinfectant power of UV rays in sunlight.*

Cryptosporidium is so small that it passes through water-treatment systems without being eradicated. And being resistant to chlorine, it is not easily disinfected.

There is no medical treatment for humans infected with *Crypto*. And while healthy people may suffer nothing more than gastrointestinal distress, patients with compromised immune systems, such as people with HIV, can face life-threatening symptoms. The parasite has been found all over the world and in hosts ranging from humans to wildlife to domestic animals.

Jellison, assistant professor of civil and environmental engineering, is seeking ways to reduce the waterborne transmission of the parasite.

"We're studying its fate and transport in the watershed – where it's coming from, how it's moving through the watershed, and what environmental conditions impact its survival," says Jellison. "We want to understand what's happening to it in the environment so we can design better watershed management strategies to prevent humans from being exposed."

In a project funded by the Philadelphia Water Department, Jellison is attempting to determine the sources of *Cryptosporidium* in the city's water supply. Twice a month, the department sends water samples. Jellison extracts the parasite's DNA, sequences it and compares it to the DNA of *Cryptosporidium* from various animal hosts. Because there are host-adapted genotypes of *Cryptosporidium*, Jellison can make an educated guess as to which animals may have contaminated each specific water sample with *Cryptosporidium*, though transmission of the parasite from species to species makes complete certainty impossible. Support for this work is also being provided by the Pennsylvania Infrastructure Technology Alliance.

In a related project, Jellison is studying the effect on *Cryptosporidium* of biofilms, which are sticky layers of bacteria that grow on solid surfaces immersed in water. Some evidence suggests that the parasite gets trapped in biofilms; Jellison is trying to determine whether *Crypto* remains infectious for a longer period of time while trapped or dies off. She is also studying the sloughing off of biofilms from the surfaces to which they've been attached and the impact this has on Cryptosporidium fate and transport. An NSF CAREER Award supports this research.

"We want to understand what's happening to Cryptosporidium parvum *in the environment so we can design better watershed management strategies to prevent humans from being exposed."* —Kristen Jellison

Finally, Jellison is exploring ultraviolet rays in sunlight and their potential for disinfection. Certain wavelengths of UV (such as UV-C, which is highly damaging on a per-photon basis but is outside of the solar spectrum) have been shown to adequately disinfect *Cryptosporidium* in water. Lamps producing those germicidal wavelengths are used in water treatment plants. Jellison's work is measuring the disinfection potential of natural sunlight's UV, which, while less damaging than UV-C on a per-photon basis, makes up a significant fraction of the solar spectrum.

Jellison also co-advises a group called Students for Sustainable Development, whose membership includes Lehigh's chapter of Engineers Without Borders as well as students from majors outside of engineering. The group is aiding Pueblo Nuevo, a village in Honduras, whose water supply has been inadequate and contaminated since it was damaged by Hurricane Mitch in 1998. Jellison has visited the village, met with residents and community leaders, and is helping Lehigh students design and build a spring box, water tank, sand filter and chlorination system to produce cleaner water.

Whether in Central America or Philadelphia, Jellison seeks to include a human element in her work.

"Research can be very, very tedious," she says. "The motivation to stick with it is knowing that the end product will benefit people. It's nice to know that what I'm doing is going to make a difference."

Lehigh Engineering: Our proud heritage

Many Lehigh engineering alumni have attained positions of top leadership in U.S. business. Here are a few examples:

Donald Franceschini

B.S. in industrial engineering, 1957

Franceschini oversaw the $7.5-billion personal products line of Sara Lee Corp. businesses that included Hanes, Champion, Playtex, Bali, Donna Karan and Ralph Lauren, as well as international brands marketed in 26 countries.

Eugene Grace

B.S. in electrical engineering, 1899

Grace joined Bethlehem Steel as a crane operator and by the age of 37 was appointed president of “The Steel”. He wielded incredible influence over the Lehigh Valley, and much of the country’s steel industry, for half a century.

Silhouette

Frank Lynn Magee

B.S. in electrical engineering, 1917

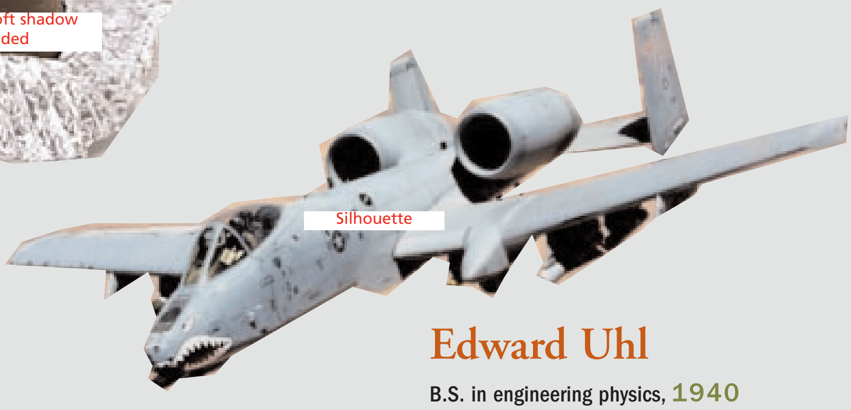
ALCOA IMAGE – USED WITH PERMISSION.

Fresh out of Lehigh, Magee bypassed the usual hiring channels and mailed his employment application directly to the president of Alcoa. Forty years and many promotions later, he became president himself. In 1960, he was named chairman of Alcoa’s board of directors.

Harold “Hal” Mohler

B.S. in industrial engineering, 1948

Mohler joined Hershey Foods as an industrial engineer after graduating from Lehigh. He rose through the ranks as assistant to the president, vice president, and, eventually, president, CEO, and Chairman of the Board.



Donald Eldridge

B.S. in electrical engineering, 1949

Eldridge used his expertise in magnetics to attain technical leadership positions with Boeing and, later, Ampex Corp. His knowledge and experience prepared him to be one of the four founding members of the Memorex Corp. in 1961.

Edward Uhl

B.S. in engineering physics, 1940

Uhl joined Fairchild Industries as president in 1961, and managed the Pershing missile, the A10 military aircraft, the ATS 6 satellite and other major development projects. Uhl became chairman of the aerospace firm in 1976.

Monroe “Jack” Rathbone

B.S. in chemical engineering, 1921

Rathbone, CEO and chairman of Standard Oil (Exxon), helped develop the first fluid catalytic cracking unit, greatly increasing the efficiency of oil refining. He was one of 19 men from two centuries of American history chosen in 1975 for permanent membership in Fortune Magazine’s Hall of Fame of Business Leadership.

ELEGANT SOLUTIONS

Mark Sarkisian ’85G, partner with the international firm of Skidmore, Owings & Merrill LLP and designer of Shanghai’s Jin Mao Tower, Oakland’s Cathedral of Christ the Light and 50 other major projects, says structures, if engineered to be dynamic, can adapt securely to the most unpredictable natural environments.

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