Mechanical Engineering

2010 NEWS

University of Delaware

UD's new hydrogen fuel cell bus — the second of its kind!

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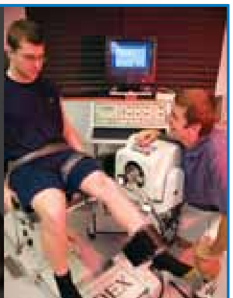
CENTER FOR BIOMEDICAL ENGINEERING RESEARCH

By Jill Higginson



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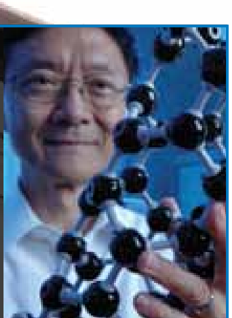
MECHANICS OF CARBON NANOTUBES

By Tsu-Wei Chou



Cover Photo by Evan Krape

MESSAGE FROM THE CHAIR

ANETTE KARLSSON

Welcome to the 2010 UD ME News. In addition to the new design, we have added some new features, including a report that highlights the work of two research centers and three individual researchers.

I'm really pleased to report that despite the economic downturn that our state and our nation have experienced over the past year, our department has set some exciting records.

We currently have more than 500 students enrolled in our undergraduate program, and we have achieved this record number without sacrificing the quality of our matriculated students.

We also had a record-high level of research funding during the past fiscal year, up more than 30 percent from the previous year. The latest budget report shows that we are on track for a similar increase this year. Some of our research is featured in this newsletter, but to find out more please visit us here on campus in Newark or at www.me.udel.edu, and follow us on Facebook.

It is also very gratifying for us to see a significant increase in contributions from alumni, faculty, staff and friends over the past year. With these generous gifts, we have increased the number of first-year graduate fellowships and significantly increased support for undergraduate research. In addition, we have initiated a graduate student achievement award based on the gift funds, and we hope that next year we can extend this to an undergraduate award as well. These fellowships and awards make a profound difference for our promising scientist and engineering students, so thank you! We hope that you will continue to support the department in the future.

Best,

Anette Karlsson

P.S. We hope to see you at the ME event on Forum and Reunion Weekend (6/4). Read more on p.4!

In this issue...

Content Direction: Nate Cloud, Anette Karlsson

Writing and Editing: Diane Kukich

Graphic Design: Sarah Rosenthal, Carrie Qualls

Photography: Ambre Alexander, Kathy Atkinson, Doug Baker, Jon Cox, Dawn Fiore, Keith Heckert, Tyler Jacobson, Evan Krape, Kevin Quinlan

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ME to Hold 6th Annual Alumni Career Celebration and Reunion

BY DIANE KUKICH

ME will hold its 6th Annual Alumni Career Celebration and Reunion on Friday, June 4, from 2:00 – 6:00 p.m., at the Roselle Center for the Arts. The event will be held in conjunction with UD's Forum & Reunion Weekend.

The forum and reunion format will provide an opportunity for attendees to reconnect with classmates and faculty as well as to hear presentations on engineering careers and how they are relevant in the "new" economy.

The event, which will include ample relaxation and networking time, will be kicked off with a welcome by department chair Anette Karlsson, followed by a review of current research and activities in the department.

The alumni career celebration has been notable for providing cutting-edge presentations on topics such as renewable and alternative energy, global engineering business opportunities, and case studies such as a behind-the-scenes look at how our alumni have played a lead role in forensic engineering analysis of the Columbia Space Shuttle disaster and American Airlines Flight 587.

The event will wrap up with presentations of Distinguished Career Award (DCA) honors to eight alumni whose careers are notable by virtue of their accomplishments and innovations.

"The DCA class of 2010 brings the number of award recipients to 35," says Bill Wagamon, who chairs the selection committee, which applies a rigorous process in choosing the awardees. "Past recipients range from the class of 1949 to the class of 1995, from CEOs and physicians to entrepreneurs and government researchers."

"We're really looking forward to this event and to honoring the new DCAs," says Wagamon. "The celebration and the award are gaining momentum, and we invite all of our alums to attend if they can and to keep us up to date on their career changes and accomplishments."

Editor's Note: Last year's five DCA recipients were not honored at a ceremony because of the swine flu scare at UD. This issue of **ME News** *highlights the 2010 winners and also includes brief bios and photos of the class of 2009 (see p.22).*

For more info, please visit www.me.udel.edu/alumni

Buchanan Named George W. Laird Professor

BY DIANE KUKICH

Thomas S. Buchanan, deputy dean of the UD College of Engineering and former chair of ME, has been appointed George W. Laird Professor of Mechanical Engineering. The appointment was effective July 1, 2009, and Buchanan delivered his inaugural lecture as named professor on March 4, 2010.

TOM BUCHANAN delivers his inaugural talk as named professor: *Neuromusculoskeletalicious*!

"Tom Buchanan is an internationally renowned scholar and one of the most highly respected members of the University of Delaware faculty," said then-Provost Dan Rich in announcing the appointment.

Buchanan's research interests include muscle coordination modeling, medical imaging, knee stability and osteoarthritis, and kinetic and electromyography patterns after ACL injury.

He is president of the American Society of Biomechanics and a fellow of the American Society of Mechanical Engineers, the American Institute for Medical and Biological Engineering, and the American College of Sports Medicine.

The 2008 recipient of the E.A. Trabant Award for Women's Equity, Buchanan is credited with playing a key role in the increase in women faculty in engineering at UD and with engaging his female colleagues in collaborative research.

Buchanan earned his Ph.D. in theoretical and applied mechanics from Northwestern University. He joined the UD faculty in 1996, served as chair of the Department of Mechanical Engineering from 2004 to 2008, and was appointed deputy dean in the College of Engineering in 2008. He has also served as academic director of UD's interdisciplinary Biomechanics and Movement Science (BIOMS) Program and director of its Center for Biomedical Engineering Research (CBER).

The Laird professorship honors the memory of George W. Laird, who earned a master's degree in mechanical and aerospace engineering at UD in 1971 and was killed in a tragic accident in 1977. A graduate fellowship in engineering is also offered in Laird's name.

NEWS!

Plans are well underway for a new interdisciplinary science and engineering building, known as the "ISE Lab," that will be constructed at UD with donor support. With a goal of engaging students and stimulating excitement about science and engineering, the 194,000-square-foot building is designed to be dynamic, dramatic and distinctive, while providing badly needed classroom and lab space for a growing number of engineering students.

Burris Wins Air Force Young Investigator Award

BY DIANE KUKICH

Assistant professor David Burris is among 37 scientists and engineers nationwide selected to receive grants totaling more than $650,000 over three years through the Air Force's Young Investigator Research Program (YIP).

The program is open to scientists and engineers at research institutions across the United States who have received Ph.D. or equivalent degrees in the last five years and show exceptional ability and promise for conducting basic research.

Burris plans to conduct research focusing on linking tribofilm nanomechanics to the origins of low friction and wear. Tribology, Burris's area of expertise, is the science and technology of such phenomena as friction, wear, and lubrication

"This is a very prestigious award," says ME chairperson Anette Karlsson, "and the department is lucky to have such an outstanding young faculty member as David. I am also very pleased to note that this is the second year in a row the department has a faculty member receiving this award." Assistant professor Erik Thostenson received the award last year.

Burris earned his Ph.D. at the University of Florida, an institution widely recognized as a leader in the area of tribology and interfacial sciences. Shortly after joining the UD faculty in September 2008, he was selected to receive the Marshall B. Peterson Award from the American Society of Mechanical Engineers (ASME). The award is given biennially in recognition of early-career achievements and promise for pursuit of research in tribology.

The objective of the YIP program is to foster creative basic research in science and engineering, enhance early career development of outstanding young investigators, and increase opportunities for the young investigators to recognize the Air Force mission and the related challenges in science and engineering.

The agency invested more than $14 million in the 2010 program.

UD ME students Adam Stager (center) and Dan McCarthy (not pictured) mentored a team of Aberdeen Middle School students who won the technical design trophy for the best robot design and presentation in the FIRST Lego League competition at Salisbury Middle School on Jan. 9. The team qualified to compete in the state competition at the University of Maryland.

Thostenson Joins ME Faculty

BY DIANE KUKICH

Assistant professor Erik Thostenson earned a bachelor's degree in composite materials engineering from Winona State University and master's and doctoral degrees from UD. His research addresses processing and characterization of composite materials, with a focus on carbon nanotube and advanced fiber reinforcements. The goal of his work is to develop novel multifunctional composites and micro/nano mechanics modeling techniques. Thostenson's research has been cited more than 1900 times in the scientific literature. In 2008, he was one of just 39 scientists and engineers throughout the country to receive three-year research grants from the U.S. Air Force Office of Scientific Research Young Investigator Research Program. His other honors include the Elsevier Young Composites Researcher Award from the American Society for Composites and the inaugural Hayashi International Memorial Award from the Japan Society for Composite Materials. Thostenson also received the Allan P. Colburn Prize for outstanding dissertation in the engineering and mathematical sciences at UD, the Center for Composite Materials Roy L. McCullough Scholars Award for exceptional contributions to the literature on composite materials, and the Society for the Advancement of Material and Process Engineering (SAMPE) Outstanding Graduate Student Award.

Chou Receives Medal of Excellence, Honored at Symposium

BY DIANE KUKICH

Tsu-Wei Chou, Pierre S. du Pont Chair of Engineering, received the 2009 Medal of Excellence in Composite Materials during the 35th anniversary of UD's Center for Composite Materials (CCM). The anniversary was celebrated during the 1st Joint Canadian & American Technical Conference on Composite Materials.

Co-sponsored by the American Society for Composites (ASC) and the Canadian Association for Composite Structures and Materials (CACSMA), the conference included a three-day symposium honoring Chou for his 40 years of service to the University and his pioneering contributions to composites science and technology during that period.

"Dr. Chou, one of the founding fathers of CCM, has had a distinguished career dedicated to research excellence and scholarship and has contributed significantly to the outstanding international reputation that CCM enjoys today," said John W. Gillespie Jr., CCM director and Donald C. Phillips Professor. "It is most fitting that after 40 years of exemplary service, he has won the prestigious Medal of Excellence in Composites during the 35th anniversary of the founding of CCM."

"This is a memorable event for everyone at CCM and especially for Prof. Chou," said Michael Chajes, dean of UD's College of Engineering, in welcoming attendees to the conference. "Few academic research centers can claim a 35-year history, and Tsu-Wei has played a major role in CCM's establishment and growth during that period. He is also credited with pioneering and sustaining many of the international collaborations that have made CCM recognized not only here in the U.S. but throughout the world."

Chou's research interests are in materials science, applied mechanics, fiber composite materials, piezoelectric materials, and nanocomposites. During the symposium, he received a unique "nano present" from one of his former students, Dr. Nyan-Hwa Tai (PhD '89), who served as Chair of the Materials Science and Engineering Department at the National Tsing Hua University in Taiwan and is now the Vice Provost there.

Containing the message "To Sir With Love - To Prof. Chou," the gift is an enlarged micrograph of words written using carbon nanotube arrays. "This is very special to me because it showed that Dr. Tai recognized my technical interest when he created it," Chou said.

A faculty member in ME since 1969, Chou holds a bachelor's degree in civil engineering from the National Taiwan University, a master's degree in materials science from Northwestern University, and a doctorate in materials science from Stanford University. He has served as a visiting professor at universities and research institutes in Argentina, China, Germany, Japan, the United Kingdom, and the U.S. In addition, he is an honorary research professor of the Beijing University of Aeronautics and Astronautics and the Northwestern Polytechnical University of China.

A fellow of six professional societies in materials and engineering, Chou has received the Charles Russ Richards Memorial Award and the Worcester Reed Warner Medal from the American Society of Mechanical Engineers, the Distinguished Research Award from ASC, and UD's Francis Alison Award. He has also been recognized by the Institute for Scientific Information as a highly cited researcher.

He has performed composites technology assessments in Europe and Asia for the Office of Naval Research and the Army Research Office, respectively, and he has authored over 300 archival journal papers and book chapters in these areas. Chou is the author of *Microstructural Design of Fiber Composites* (Cambridge University Press), co-author of *Composite Materials and Their Use in Structures* (Elsevier), and the editor of several other books. He is also editor-in-chief of the international journal *Composites Science and Technology*.

Chou joins 28 other internationally renowned composites scientists and engineers who have received the Medal of Excellence since it was first awarded in 1984 during CCM's decennial celebration.

Designed by Charles Parks, a local sculptor with an international reputation, the medal was created to honor those who have achieved outstanding leadership in the field of composites. Recipients are chosen by a committee of past medal winners chaired by professor R. Byron Pipes of Purdue University, who is credited with developing CCM's industrial consortium in the 1970s and 80s.

TSU-WEI CHOU

Tsu-Wei Chou is the Pierre S. du Pont Chair of Engineering. Read more about Chou's research on page 16.

ME Faculty Win UDRF Grant for Fuel Cell Research

ADAPTED FROM AN ARTICLE BY TRACEY BRYANT (UDAILY, JAN. 28, 2010)

Two ME faculty members—assistant professor Joshua Hertz and professor Ajay Prasad—have received funding from the University of Delaware Research Foundation (UDRF) to support their work in the development of a novel fuel cell. The grant was awarded through UDRF's 2009 strategic initiatives grants competition.

Fuel cells convert hydrogen and oxygen into water, producing electricity in the process. However, fuel cells are hampered by the fact that their waste product—water—can collect at the electrodes, reducing power output, an effect called "flooding."

Hertz and Prasad are devising a novel fuel cell that uses two electrolytes: one that conducts hydrogen ions and another that conducts hydroxide ions. The water byproduct collects in a porous membrane at the interface of the two electrolytes rather than at the electrodes, thus eliminating flooding. Through collaboration with the Intellectual Property Center within UD's Office of Economic Innovation and Partnerships (OEIP), a non-provisional patent application has been filed.

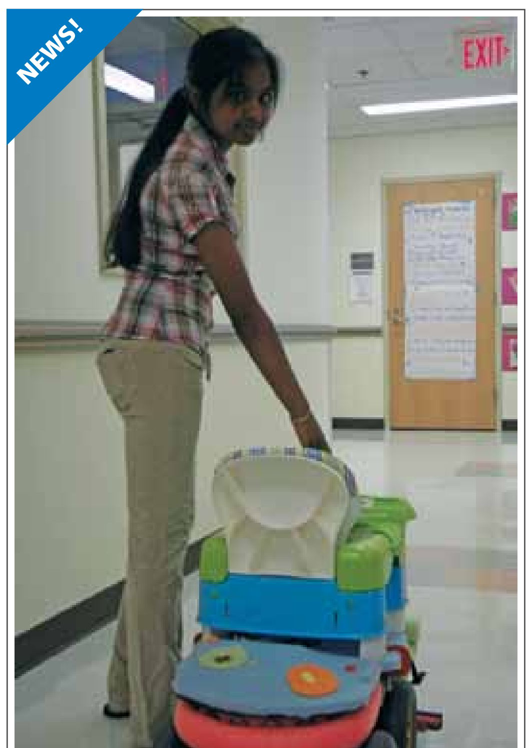
Chartered in 1955, UDRF is a non-profit, tax-exempt corporation that supports fundamental research in all fields of science at the University. It is governed by a research committee of scientists, physicians, and engineers. The grants, which are merit-based and administered by the UD Research Office, focus on assisting untenured early-career, tenure-track UD faculty.

The UDRF strategic initiatives grants specifically support collaborative projects focusing on one of the three research areas emphasized in the University's Path to Prominence strategic plan: life and health sciences, energy, and the environment.

The two-year, $35,000 awards include $25,000 in UDRF funding, which is matched by $5,000 from the provost and $5,000 from the faculty member's respective dean.

"Each project focuses on a strategic priority for the University and involves both a junior and senior investigator, a collaboration that is designed to provide faculty who are early in their careers with valuable mentoring from a veteran researcher," said Mark Barteau, senior vice provost for research and strategic initiatives.

NEWS!



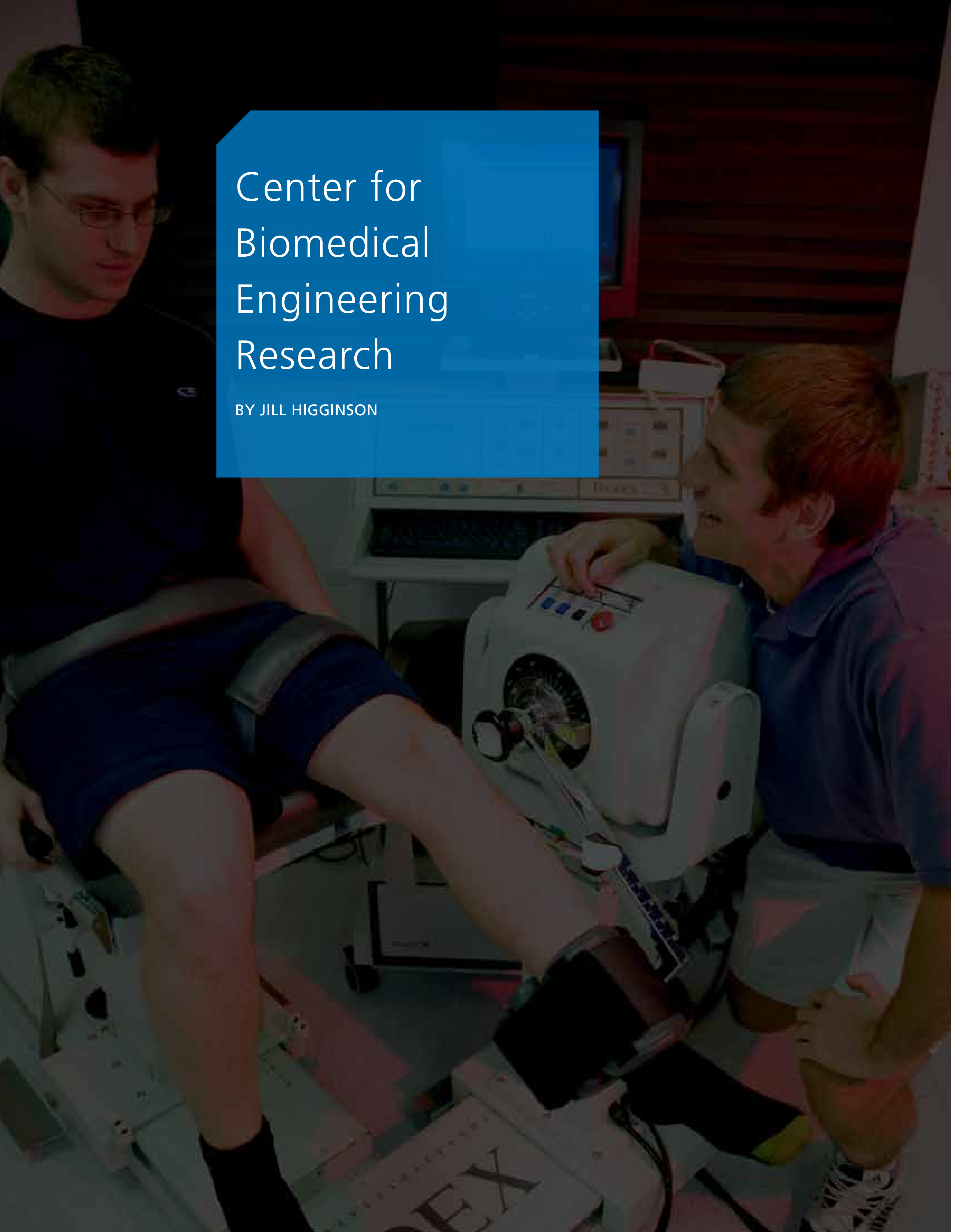
Four high school students from the Charter School of Wilmington (CSW) spent the summer working on UD's infant mobility project, led by Sunil Agrawal (ME) and Cole Galloway (physical therapy). Pictured are, from left, CSW student Allaa Megeid, UD undergrads Jie Ge and Manasa Sridhar, doctoral student Christina Ragonesi, and CSW students Emily Yang, Ponni Vel and Carina Blair.

University of Delaware

MECHANICAL ENGINEERING

RESEARCH REPORT

This research report highlights the work of two research centers—the Center for Biomedical Engineering Research and the Center for Fuel Center Research—as well as three individual researchers—Professors Tsu-Wei Chou, Lian-Ping Wang, and Bert Tanner.



Center for Biomedical Engineering Research

BY JILL HIGGINSON

The Center for Biomedical Engineering Research (CBER) is an interdisciplinary research center housed in ME. The CBER mission is to provide engineering science and clinical technology to reduce the impact of disease on the everyday life of individuals. At the moment, CBER has 14 current studies with funding from federal agencies and industry sponsors. Involvement in the center has increased to nearly 40 faculty, extending beyond ME and representing biology, physical therapy, health, nursing, exercise science, and fashion and apparel studies! Students have become more engaged with CBER through leadership of center activities such as the bi-weekly journal club and the annual research symposium.

The success of CBER is also coupled with the development of the Delaware Health Sciences Alliance and Delaware Rehabilitation Institute, recently announced by UD President Patrick Harker, and will flourish under new opportunities offered by stimulus funding under the American Recovery and Reinvestment Act to support collaborative efforts in novel research directions. Ongoing projects involve a multi-scale, multidisciplinary investigation of osteoarthritis as well as several studies of stroke rehabilitation modalities including functional electrical stimulation, fast treadmill training, and robotic exoskeletons. Computational modeling is employed to quantify forces acting on musculoskeletal structures and fluid transport in the bone lacuna-canalicular system. The collective skill set of the collaborating investigators makes a formidable team ideal for large-scale research proposals.

Multidisciplinary research in the field of osteoarthritis (OA), from the lab bench to the clinic, with a unique focus on mentoring Women In Science and Engineering (WISE) is currently supported with an $11 million grant from the National Institutes of Health (NIH). The scientific goal of this proposal, directed by Prof. Thomas Buchanan, is to create the infrastructure and expertise base to address the mechanisms of OA, as well as its prevention and treatment. The investigators take a unique approach to examine OA from the integrated perspectives of tissue mechanics, biomechanics, physical therapy and clinical intervention. Since 2002, at least 54 graduate students and post-doctoral researchers have been supported by this mechanism.

Sunil Agrawal is developing robotic exoskeletons embedded with a variety of position and force sensors to facilitate gait training of individuals recovering from stroke. Current solutions include a simple un-motorized device, known as a gravity-balancing orthosis, which increases range of motion in impaired individuals by removing gravity from the joints. Another active leg exoskeleton is equipped with servo motors and a controller to apply forces on the leg to not only improve its motion but also maximize learning, or retraining of the brain. Implementation of these devices is done in conjunction with Profs. John Scholz, Stuart Binder-Macleod and Jill Higginson.

Solute transport in the bone lacuna-canalicular system is essential to bone and cartilage health, according to Liyun Wang. Her NIH-funded project will delineate the transport mechanisms that are essential for osteocyte viability and bone mechanotransduction, and provide new insights into mass transport in other biological and engineered systems such as tissue engineering scaffolds. Using a novel microscopic imaging method based on fluorescence recovery after photobleaching (FRAP), Wang seeks to visualize and quantify how rapidly nutrient molecules (which also serve as signaling agents) are transferred between cells in living bone. Results will shed light on the cause and initiation of OA and may enable the development of more effective drug therapies to treat these debilitating bone and joint diseases.

With collaborators from physical therapy, Jill Higginson is leading a study to determine whether weakness several months or years following stroke is due to muscle atrophy or impaired activation. Coupled experiments and musculoskeletal simulations are used to identify factors that limit gait speed post-stroke. The development of subject-specific computer simulations is hoped to assist rehabilitation professionals in designing treatment interventions that address the specific impairments of individual stroke survivors.

The broad range of research topics addressed by CBER faculty and graduate students is visible at the annual biomechanics research symposium. This year's symposium is scheduled for May 7, 2010, and will feature a keynote lecture by a distinguished leader in the field. Details regarding this upcoming event and other CBER efforts are updated regularly at www.cber.udel.edu.

JILL HIGGINSON

Jill Higginson is an assistant professor in ME and director of the Center for Biomedical Engineering Research.

Center for Fuel Cell Research

BY AJAY K. PRASAD

Fuel cells combine hydrogen and oxygen in an electrochemical reaction to directly produce electricity. Because electrochemical conversion, unlike combustion, is not limited by the Carnot cycle efficiency, fuel cells are two to three times more efficient than internal combustion engines. Of course, the only product of the reaction is water, and so fuel cells are zero emission devices. For these reasons, fuel cells offer the potential to alleviate major concerns facing our nation today including our dependence on foreign petroleum, the emission of greenhouse gases, and urban air quality.

Fuel cells have three major application areas: automotive, stationary power, and portable electronics. Although fuel cells have been routinely used in space applications, research activity has greatly accelerated in the past decade, and several prototypes for fuel cell powered cars, buses, laptops, soldier power, and stationary applications have been demonstrated. Despite this success, fuel cells face major barriers to commercialization including high cost, limited durability, and the lack of a hydrogen infrastructure.

The Center for Fuel Cell Research was established to address these challenges. The Center conducts fundamental research on fuel cell and hydrogen infrastructure science and technology to improve performance and durability with novel materials, architectures, and operating strategies, while enabling commercialization with technology transfer to industry. UD is ideally positioned for such a center. About 20 faculty in the College of Engineering are actively engaged in fuel cell research with federal, state and industry funding. Delaware is also home to major fuel cell/hydrogen infrastructure corporations including DuPont, W.L. Gore, Air Liquide, and Ion Power. Placement of the center at UD facilitates collaboration with these companies and gives students the opportunity to participate in multidisciplinary fuel cell research and demonstration projects. The center also conducts public outreach to educate the community about the benefits of fuel cells. For Delaware, the Center creates an opportunity for national and international recognition and a platform for economic growth.

The polymer electrolyte membrane that is at the heart of fuel cells currently requires careful control of hydration, suffers from fuel crossover, undergoes cyclical hygrothermal loading which can lead to fatigue failure, and demonstrates poor cold-climate performance. Furthermore, the membrane cannot operate at high temperatures implying that a high loading of precious metal catalyst must be employed to overcome activation overpotentials. Platinum, which is the catalyst of choice, is susceptible to CO poisoning, so the hydrogen fuel must be of very high purity. All of these factors are responsible for the high cost and limited durability of the membrane electrode assembly. Research at the center is focused on developing novel polymer membranes for improved strength, better freeze-tolerant behavior, and greater resistance to fuel crossover. Researchers are also developing novel tungsten-carbide catalysts, which have shown high tolerance to CO poisoning, while providing comparable catalytic activity at a fraction of the cost of platinum. Other related topics include the development of nano-engineered electrodes, alternate catalyst supports based on carbon nanotubes, and degradation studies of the catalyst layer using XPS and XRD.

Faculty are also engaged in developing mechanics-based models for improving the mechanical durability of fuel cell membranes during fuel cell operation. They have used experiments to extract the mechanical properties of the membrane electrode assembly materials and are conducting numerical and analytical modeling to elucidate the mechanical response of the membrane as well as nanostructure/mechanical response relationships. These studies will provide insights on how to alleviate hygrothermal stress in fuel cells and control the damage mechanics of freeze-thaw.

Fuel cells use a layer of porous carbon paper on either side of the membrane electrode assembly to diffuse reactant gases into the electrodes. Carbon paper suffers from several shortcomings such as poor electrical and thermal conductivity, liquid water retention, and mechanical fragility. Faculty have developed a novel porous, metallic-foil gas diffusion layer (patent pending) that greatly improves performance, particularly in terms of limiting flooding by liquid water, while reducing the fuel cell stack size by about 25%. Automotive companies have shown great interest in this new material. Faculty have also developed optimization methods using genetic algorithms to rapidly identify and evaluate optimal flow channel geometries within the bipolar plates to supply reactants to the electrodes and evacuate product water.

At the system level, faculty have developed a unique technique that allows simultaneous optical and thermal neutron imaging of operating fuel cells. This technique provides quantitative information about liquid water and flooding within fuel cells, which has led to the identification of optimal materials and operating protocols to improve performance and prolong fuel cell life. Fuel cell stack performance and durability can also be greatly enhanced by monitoring the voltage from each cell in the stack and taking remedial action as necessary. A novel cell voltage monitoring system for real-time fuel cell stack diagnostics has been developed (patent pending).

The center's most visible project, the UD Fuel Cell Bus Program, is aimed at building and demonstrating a fleet of four buses and a network of three hydrogen-refueling stations in the state of Delaware. To date, we have designed and built two buses and are operating them daily on our campus. We have also created one hydrogen refueling station with the help of our consortium partner, Air Liquide. The first bus is 22 ft long and can hold 22 passengers. It is powered by a 19.4 kW stack and is driven by a single three-phase AC induction motor rated for 130 kW of peak power. The bus incorporates a series-hybrid powertrain that employs liquid-cooled Ni-Cd batteries with an energy capacity of 60 kWh, which enables a smooth power request to the fuel cell stack while giving the bus excellent regenerative braking capacity. Twin composite 5000 psi tanks mounted on the roof store 12.8 kg of hydrogen for a range of about 140 miles. The second bus is identical to the first, except that it incorporates a dual stack for higher sustained speeds. Future buses will be larger (30 to 40 ft) and will employ advanced stacks and lightweight Li-Titanate batteries for efficient hybrid operation.

Our buses are equipped with onboard sensors that measure voltage, current, reactant flow rate, temperature, pressure and humidity, as well as latitude, longitude, and velocity on every trip. These data are uploaded in real time with a cellular link so that data can be processed continuously. A major achievement of the bus program has been the development of a virtual vehicle simulator based on a MATLAB/SIMULINK model. The program models every subsystem on the vehicle such as the fuel cell, batteries, traction motor, and balance-of-plant. It then uses a drive cycle-based, forward-facing model where each subsystem is linked using electrical, mechanical, and control signal links to produce critical performance outputs such as hydrogen consumption and battery state-of-charge. These outputs have been successfully validated against actual measurements from onboard sensors confirming that the vehicle simulator is a robust and reliable design tool. We now have the confidence to test new hybrid drivetrain designs such as varying the degree of hybridization (for example, doubling the fuel cell stack and halving the size of the battery pack) without incurring expensive hardware modifications.

A commonly asked question about fuel cells is "Where will the hydrogen come from?" Although steam reformation of natural gas is the cheapest way to make hydrogen today, it does not wean us away from fossil fuels. Faculty at the center are researching a host of renewable, solar-based methods to generate hydrogen. These include two-step thermochemical cycles based on zinc oxide, photoelectrochemical methods, and photobiological water splitting. Although these methods are still in the early research stages, a major scientific breakthrough can revolutionize the field. Finally, hydrogen, being the lightest element, is notoriously difficult to store. Even at pressures of 10,000 psi, the gravimetric and volumetric storage efficiency is poor. In addition, liquefied hydrogen requires highly specialized tanks and cryogenic temperatures. Such conventional methods are unable to meet DOE's 2010 targets. Hence, faculty are exploring new storage methods where hydrogen is absorbed into hydride materials at potentially unprecedented storage densities. The hydrogen charging process is a rich and complex problem involving flow through porous media, heat transfer and reaction kinetics.

In summary, the Center for Fuel Cell Research supports a wide variety of interdisciplinary efforts aimed at addressing some of society's critical energy and environmental needs. Students enjoy the opportunity to work at the leading edge of clean-energy technologies that can define their future careers. The involvement of industry in the fuel cell research ensures that the work is practical and relevant. In turn, the center will translate research results back to industry to enable a future where fuel cells are affordable and widespread.

AJAY PRASAD

Ajay Prasad is a professor in the Department of ME and director of the Center for Fuel Cell Research.

Environmental Fluid Mechanics

BY LIAN-PING WANG

Broadly speaking, environmental fluid mechanics deals with naturally occurring fluid flows of air and water on the Earth, especially those that affect the comfort and quality of our everyday environment. By definition, this is an interdisciplinary research area that overlaps with meteorology, climatology, hydrology, environmental soil science, hydraulics, limnology, oceanography, and others. A unique feature is that one can find a rich range of physical phenomena encompassing a wide range of length and time scales.

Researchers in a group led by Professor Lian-Ping Wang are applying an advanced computational approach known as Direct Numerical Simulation (DNS) to probe, understand, and quantify physical processes in turbulent multiphase flows relevant to the environment. Unlike the traditional computer modeling that is aimed at reproducing known physics, DNS generates original data for unknown physics utilizing first-principle-based mathematical formulations and advanced computing algorithms. For this reason, DNS is also known as "computer experiments," and the work has been used by theoreticians and modelers as a benchmark to guide the development of their theories and models.

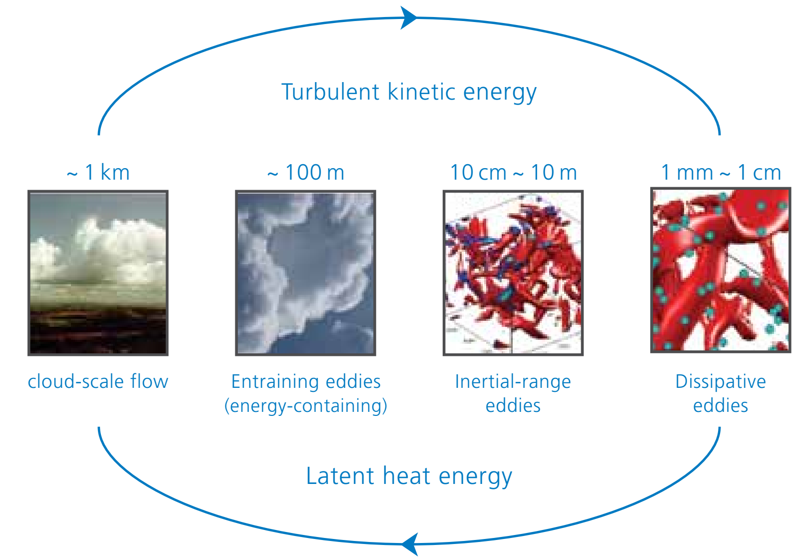
Unlike traditional turbulence modeling, where turbulent fluctuations are treated as a random phenomenon, DNS takes a fully deterministic view by resolving the small-scale flow features. For example, small-scale vortical structures in the atmosphere are composed of a collection of worm-like tubes. An amazing consequence is that rain droplets and dust particles can be thrown out of these tiny vortex tubes and accumulate near the edges of these tubes, a phenomenon that is known as preferential concentration and was first shown in DNS. The researchers then demonstrated that this phenomenon could significantly enhance the collision rate among inertial particles suspended in a turbulent flow.

About 10 years ago, the group teamed up with Wojciech Grabowski, a cloud physicist at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. They were awarded funding from NSF to study this enhanced collision rate in the context of cloud physics and to study its impact on precipitation formation in ice-free warm clouds. This is an important application, since cloud dynamics and precipitation formation is an important component in weather and climate modeling from short-term storm-scale forecasts to longer term climate change.

Under the support of two NSF grants, the UD-NCAR team developed a hybrid direct simulation tool to quantify the enhanced collision rate by air turbulence. They showed that air turbulence could enhance the collision rate by an average factor of about two over the collision rate computed from the simplified gravitational collision growth. They also conducted model studies to show that cloud turbulence can significantly reduce the time for warm rain initiation.

Their joint work has attracted attention from the international cloud physics community and has led to more than 15 papers in journals covering atmospheric sciences as well as fluid mechanics. The collaboration has also led to a third NSF research grant involving Professor Alberto Aliseda of the University of Washington, where they are comparing simulated statistics from the hybrid DNS to those obtained in parallel experimental measurements at UW.

The UD-NCAR research group was recently awarded a $1M NSF grant to further develop the hybrid DNS tool, couple the tool with a large-eddy simulation tool developed in parallel at NCAR, and solve a number of computer implementation issues to allow the simulations to be done on future petascale computers. The collaboration with NCAR also helped UD join the University Corporation for Atmospheric Research (UCAR) in 2007, thus enhancing Delaware's visibility in research related to atmospheric sciences.

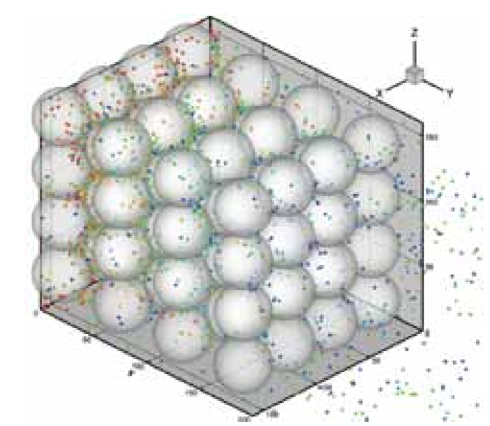


MULTISCALE INTERACTIONS

Multiscale interactions in atmospheric clouds. The turbulent kinetic energy flows from cloud-scale motion to dissipative eddies. Latent heat energy flows from individual droplets to cloud-scale motion.

A second major application of the current research on environmental fluid mechanics concerns transport of colloids in soil porous media. The importance of colloid and microbial transport in subsurface porous media has been increasingly recognized in recent years. The large surface area of mobile colloids can be an effective means to transport strongly sorbing contaminants, for example, organics, metals, and radionuclides. Some colloids such as pathogenic microorganisms—for example, viruses, bacteria, and protozoa—are contaminants; hence their transport in soil and groundwater is a serious public health concern. The rapid development of nanotechnology in recent years brings with it concerns about the environmental impact of nanoparticles released into natural water systems.

Under two USDA grants, the ME researchers have collaborated with Professor Yan Jin in UD's Plant and Soil Sciences Department to advance quantitative understanding of colloidal retention in both saturated and unsaturated soil. Here the computational challenges are to simulate flow in a complex porous matrix and to include short-range physico-chemical forces such as the electrostatic double-layer force and van der Waals force in the trajectory modeling of colloidal particles. The pair recently obtained NSF funding to study nanoparticle transport in soil porous media. They plan to develop an experimentally validated, mechanistic simulation approach that can connect micro- to nanoscale phenomena to a centimeter scale retention profile. The resulting simulation tool will eventually be used to guide the design of better experiments for studying nanoparticle retention in natural soil. The researchers will focus on addressing questions related to the effects of size and aggregation on nanoparticle transport.

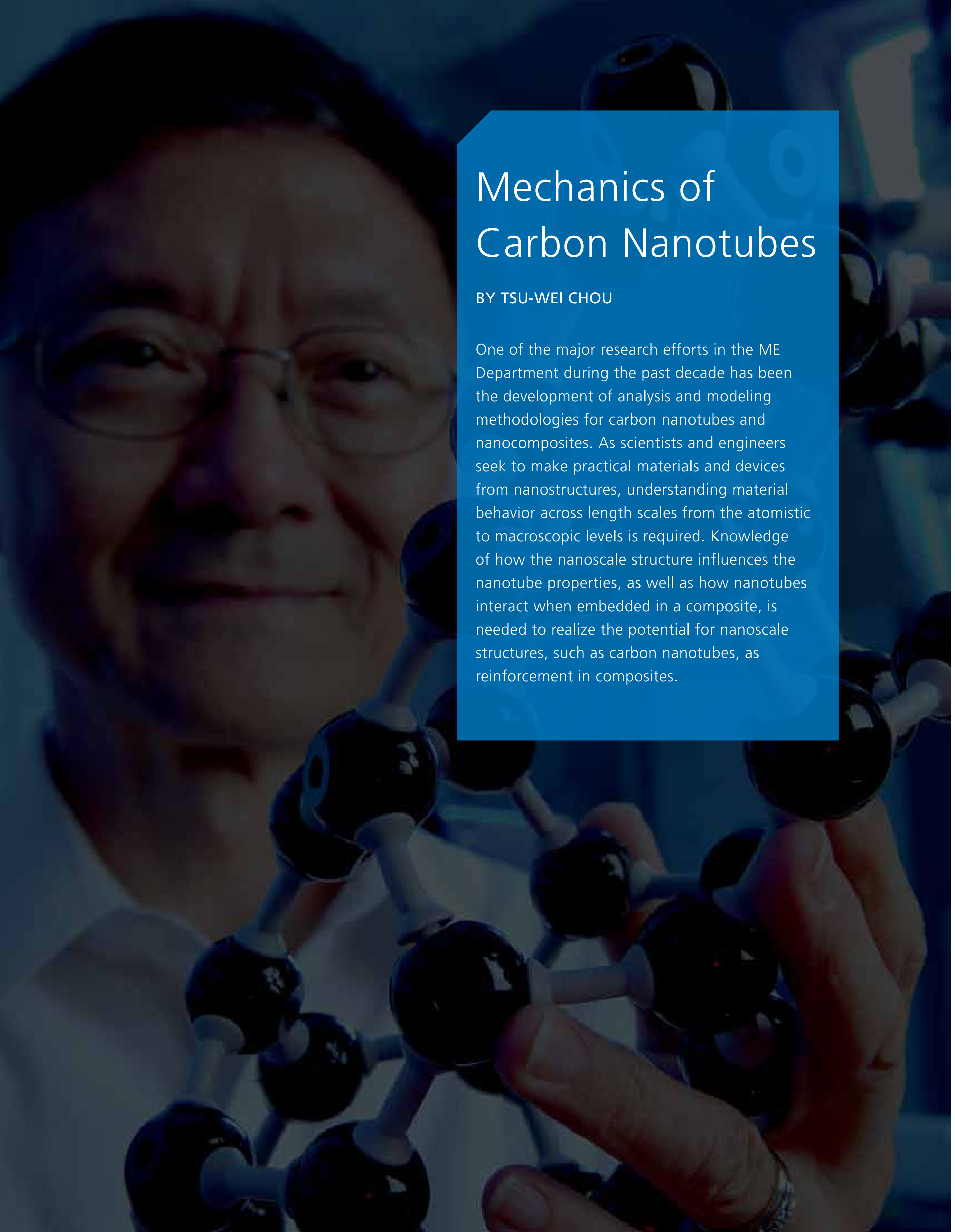


STIMULATED COLLOID TRANSPORT

Simulated colloid transport and retention through a three-dimensional saturated porous medium.

LIAN-PING WANG

Lian-Ping Wang is a professor in the Department of ME.



Mechanics of Carbon Nanotubes

BY TSU-WEI CHOU

One of the major research efforts in the ME Department during the past decade has been the development of analysis and modeling methodologies for carbon nanotubes and nanocomposites. As scientists and engineers seek to make practical materials and devices from nanostructures, understanding material behavior across length scales from the atomistic to macroscopic levels is required. Knowledge of how the nanoscale structure influences the nanotube properties, as well as how nanotubes interact when embedded in a composite, is needed to realize the potential for nanoscale structures, such as carbon nanotubes, as reinforcement in composites.

Tsu-Wei Chou, Pierre S. duPont Chair of Engineering, has done extensive work in the mechanics of nanotubes. Due to significant computational demands, practical applications of atomistic modeling techniques developed within the past decade have been limited to systems containing a small number of molecules or atoms and to studies of relatively short-lived phenomena, from picoseconds to nanoseconds. At the same time, classical continuum mechanics models neglect the detailed characteristics of nanotube chirality and are unable to account for forces acting on the individual atoms.

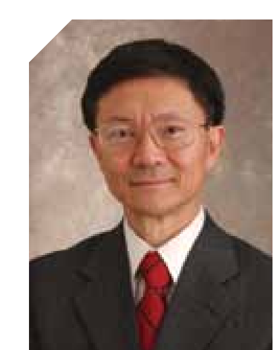
Chou's research has focused on developing a modeling technique that analyzes the mechanical response of nanotubes at the atomistic scale but is not perplexed in time scales. In a paper published in 2003 (IJSS, 40, 2487-2499), Li and Chou presented a molecular structural mechanics (MSM) approach to modeling the deformation of carbon nanotubes. Fundamental to the proposed concept is the notion that a carbon nanotube is a geometrical frame-like structure, and the primary bonds between two nearest-neighboring atoms act like load-bearing beam members, whereas an individual atom acts as the joint of the related load-bearing beam members. Establishing a linkage between structural mechanics and molecular mechanics enables the sectional property parameters of these beam members to be obtained. The accuracy and stability of the method have been verified by its application to graphite, and the predictions of nanotube elastic properties are in good agreement with existing theoretical and experimental results. The authors of a paper published in January 2010 in *Computational Materials Science* praised the molecular structural mechanics method for "having attracted great attention from academic circle because of its simplicity and effectiveness and it has been regarded as a very efficient and cost-effective method for simulating the mechanical properties of nanomaterials in contrast to other theoretical approaches."

But the extent of impact of the MSM method turned out to be more far-reaching than it first appeared. This method has now been applied to an array of mechanical and physical properties of carbon nanotubes. These include the studies of elastic buckling of carbon nanotubes, elastic moduli of multi-walled carbon nanotubes and the effect of van der Waals forces, and elastic wave velocities in single-walled carbon nanotubes. The theoretical basis has also been demonstrated for the application of single-walled and multi-walled carbon nanotubes as ultrahigh frequency nanomechanical resonators, mass detectors, and strain and pressure sensors. Also, Li and Chou were successful in adopting a quantized molecular structural mechanics modeling for studying the specific heat of single-walled carbon nanotubes, axial and radial thermal expansions of single-walled carbon nanotubes, and modeling of heat capacities of multi-walled carbon nanotubes.

In recent years, analytical research in the lab has assumed a new focus, the electro-mechanical coupling behavior of carbon nanotube-based composites. The work was primarily motivated by the superb electrical current carrying capability of carbon nanotubes (about 1,000 times that of copper). The initial work of Chou and Li in this area focused on electrical charge-induced strain and failure of single-walled carbon nanotubes. Then as more physical insights were gained, the focus of the modeling work turned to the simulation of electrical percolation in nanocomposites with particular attention on the effect of conductive fillers of various shapes, the role of tunneling resistance, the effect of nanotube waviness, and the precise determination of backbone structure and conductivity of 3D percolation networks by the direct electrifying algorithm. Then the electrical part of the modeling work, from percolation threshold to conductive spanning cluster to conductivity prediction, was finally combined with the mechanical aspect of nanocomposites which involved detailed analysis of the deformation and fracture behavior due to the presence of nano-fillers and micro-meter size continuous fibers.

In summary, the theoretical studies over the past decade, starting from a simple "molecular structural mechanics" analysis and evolving into the electro-mechanical coupling analysis, have enabled the better understanding of multifunctional nanomaterials in general and enriched the scientific base of damage sensing of fiber composites in particular.

Editor's Note: The 2003 paper co-authored with Li is now ranked as the most cited among Dr. Chou's research papers.



TSU-WEI CHOU

Tsu-Wei Chou is the Pierre S. du Pont Chair of Engineering.

Cooperative Robotics

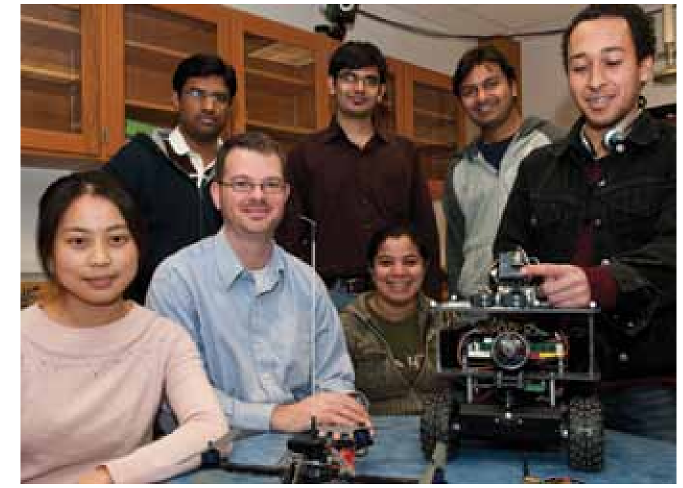
BY HERBERT TANNER

Among the main motivations for designing, deploying, and controlling robots is to relieve humans from having to operate in unfriendly environments. From the deepest oceans to outer space, robotic devices have been used to conduct measurements and collect samples. In most cases, these devices are tele-operated:

Underwater robots are typically connected to a mother ship using a tether cable; bomb-defusing robots and unmanned aerial vehicles have a team of human operators that monitor their activity and direct their motion; planetary rovers receive planning and control commands from the mission control station back on Earth. There is a reason for that: the real world outside a factory floor is simply too unstructured, unpredictable, and sometimes hostile, for these machines to reason and act on their own.

This is one of the challenges that the group in the Cooperative Robotics Lab is attempting to meet. Recently established in Spencer 122, the lab is equipped with five wheeled mobile robots, one aerial vehicle, a motion capture system that tracks their motion in real time, and a number of computer workstations. In the lab, a research group led by Dr. Bert Tanner is developing mathematical frameworks and designing the algorithms that will make robots autonomous, capable of safely and predictably interacting with an uncertain environment as well as with each other. A team of undergraduate and graduate students models robots as highly nonlinear dynamical systems and is using several aspects of Lyapunov stability theory to establish desirable properties for the control laws we design for them. Clearly in robots, but also evident in most modern engineering systems, the machine itself interacts physically with its environment, and this interaction is governed both by physics (expressed by differential equations) as well as software (expressed by discrete logic). The two driving forces of the interaction between machines and the physical world are also interdependent, since computation shapes the dynamics through control action, and dynamics affect computation through sensory feedback. Robots are hybrid, "cyber-physical" systems, and part of our research effort is directed toward developing the formal mathematical framework that will enable one to capture their hybrid nature, model them appropriately, reason about them, and design their behavior. This quest leads the group to explore and combine concepts from dynamics, control theory, stochastic processes, computer and cognitive science, and artificial intelligence.

The group envisions different types of robots working together as a team: each doing its part within a well orchestrated plan that is certain to meet a final objective, without the sequence of maneuvers to be necessarily choreographed in advance. To these



robots, the world is a puzzle, and they will need to solve it. Not every challenge may be met with a pre-computed solution. So part of what the group is doing is to enable them to calculate and execute a solution on their own.

With support of about $400K from the National Science Foundation, the group continues to develop models of interaction between multiple robots and their environment and use these models to design autonomous behaviors for robots. After pioneering the design of robot controllers that reproduce stable flocking and swarming behavior in robot groups by synchronizing the motion of each individual with that of its nearest neighbors, the researchers are now looking at more complex interactions, in which the action of one individual prepares or enables another action by one of its teammates. In an earlier study, a hybrid model was constructed to enable a small mobile robot to solve a desktop sliding tile puzzle. In that case study, the tile environment itself was modeled as a combination of inert autonomous agents. In more recent work, the group is creating new hybrid models and computational frameworks that will enable our small mobile robots to learn from each other, physically interact, and coordinate toward the completion of a variety of more complex tasks. Among the challenges presented to them in the lab environment would be cooperatively negotiating obstacles—possibly by repositioning them—transporting or recharging each other, fetching objects to operators that request them, and transitioning autonomously among various locations in Spencer Lab. This technology for modeling, planning and control could also be useful for efficiently coordinating emergency response or disaster relief efforts.

The group is also involved in designing control and navigation algorithms for miniature robots to move autonomously in partially known unfriendly environments, and provide real-time reconnaissance information and situational awareness. This is part of a multi-university research initiative funded by the Army Research Lab at the level of $12M to develop a new generation of highly agile, autonomous, bio-inspired microscopic robotic vehicles that can be deployed from within a backpack. The challenge is to design motion control algorithms that with minimum adjustments can be applied over a wide range of mobility and computational platforms, both ground and aerial, without requiring excessive power or computational resources that these miniature systems cannot provide.

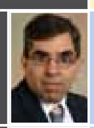
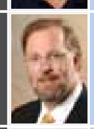
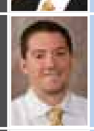
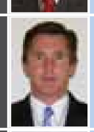
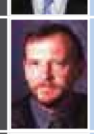
In a new $450K NSF-supported project, the group is attempting to harvest and locally process sensory information from environments that may be difficult to access (for example, the bottom of the sea, the surface of Mars, or a contaminated site), using a coordinated swarm of robots. The robots will prioritize measurement collection by updating their beliefs as to which regions are more interesting in terms of information content and process the collected information locally, on their own processors, through a new type of spatially distributed neural network. The envisioned system is novel due not only to its autonomy in discovering patterns in the information collected without the need for direct human intervention, but also to its inherent robustness to measurement noise and subsystem failures: it should be able to perform even when part of the swarm is lost. This is going to be the first system in which spatially distributed associative memories are constructed and implemented over a swarm of robots.

The cooperative robotics group develops the algorithmic foundations for a collection of robots to exhibit autonomous cooperative action and achieve a level of coordination comparable to that of diversified biological groups. The approach followed is not to mimic nature but rather to become inspired by it on how control action can be used to shape the dynamics of programmable machines and steer them into performing complex tasks in a safe, predictable, efficient, and repeatable way. The group envisions diversification and cooperation between autonomous agents to play just as important a role in engineering systems as it does in human teams, enabling ensembles of machines to cooperatively perform tasks that none of them can complete in isolation.

HERBERT TANNER

Herbert Tanner is an assistant professor in ME.

ME Faculty Research

Faculty		Biomedical Engineering	Clean Energy and Environment	Composites and Advanced Materials	Nano Materials and Nanotechnology	Robotics and Controls
SURESH ADVANI			●	●	●	
SUNIL AGRAWAL		●				●
THOMAS BUCHANAN		●				
DAVID BURRIS		●	●	●	●	
TSU-WEI CHOU				●	●	
JAMES GLANCEY		●		●		
IAN HALL				●		
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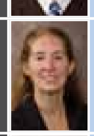
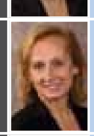
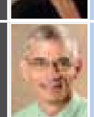
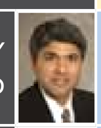
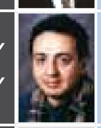
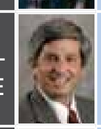
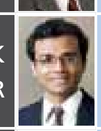
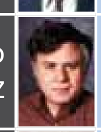
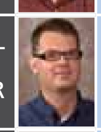
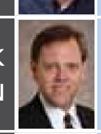
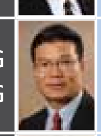
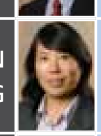
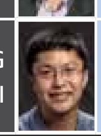
JILL HIGGINSON		●				
ANETTE KARLSSON			●	●		
MICHAEL KEEFE				●		
AJAY PRASAD		●	●		●	
VALERY ROY			●			●
MICHAEL SANTARE		●	●	●		
KAUSIK SARKAR		●				
LEONARD SCHWARTZ			●			
HERBERT TANNER						●
ERIK THOSTENSON				●	●	
LIAN-PING WANG		●	●			
LIYUN WANG		●				
BINGGING WEI			●	●	●	

UD ME Alumnus Wins National Dissertation Award

BY DIANE KUKICH

Xiaoyi Li, who completed his Ph.D. at UD in ME in 2007, has received the 2009 Andreas Acrivos Dissertation Award in Fluid Dynamics from the American Physical Society (APS).

Li is now a senior research scientist in the Thermal and Fluid Sciences Department at United Technologies Research Center (UTRC). His thesis describes a detailed computational investigation of the dynamics of drops, the rheology of emulsions, and the mechanics of biological cells subjected to fluid flow.

Li presented the Andreas Acrivos Dissertation Talk at the 62nd annual meeting of the APS Division of Fluid Dynamics.

Established in 2000 to honor the outstanding contributions in fluid mechanics of Prof. Andreas Acrivos, the award recognizes exceptional young scientists who have performed original doctoral thesis work in the area of fluid dynamics.

"This is a very important award," says Kausik Sarkar, associate professor and Li's dissertation adviser. "The Division of Fluid Dynamics is the most prestigious organization of fluid dynamicists working on fundamental and applied problems related to fluid flows all over the world. Members come from physics, mathematics, mechanical engineering, chemical engineering, civil engineering, aeronautical engineering, environmental engineering, and ocean and atmospheric sciences. Therefore, every major university in the world has fluid mechanists in not just one but all of these departments."

In making its selection, committee members noted that they were particularly impressed by the wide range of fundamental questions addressed in Li's thesis and its potential long-term impact on the field of multiphase flows.

"Li's computational modeling expertise was a key factor in recruiting him," says Catalin Fotache, his supervisor at UTRC. "His expertise boosts our capabilities, especially in the challenging area of multiphase flows."

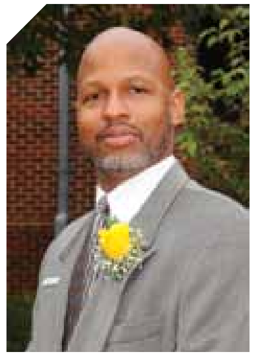
For Sarkar, seeing his former student's success is tremendously rewarding. "Students are our most important product as faculty members," he says. "I really enjoy the part of my job that involves mentoring students and watching their evolution."

Li earned his bachelor of science degree from the University of Science and Technology of China. His dissertation was published in 2008 as a book co-authored with Sarkar, and he is the author of seven articles published in leading journals in the field.

In addition to the Acrivos Award, Li received UD's Allan P. Colburn Dissertation Prize in Engineering and Mathematical Sciences in 2007.

Bullock Honored with UD Presidential Citation

BY MARTIN A MBUGUA



David Bullock, CEO of White Bullock Group, a business development firm with a focus on social media, was honored during the Presidential Citation for Outstanding Achievement recognition ceremony at UD on Friday, Oct. 30.

The Presidential Citation program honors UD graduates who have exhibited great promise in their professional and public service activities.

Bullock, who received a bachelor's degree in ME in 1990, is president and CEO of White Bullock Group, Inc., a business development firm in Murfreesboro, Tenn., that helps businesses increase sales through the use of various tools, including social media.

He also serves as chief marketing officer at Social Media Connection. Bullock also is co-author, with UD alumnus Brent Leavy, of Barack 2.0, which has been referred to as "a field manual to social media."

"The UD experience launched me on a wonderful journey from manufacturing to an 'engineer's playground' at a robotics firm, and on to my own business," Bullock said.

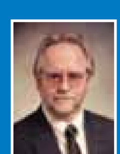
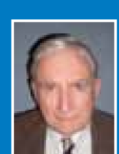
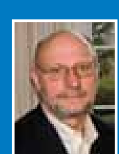
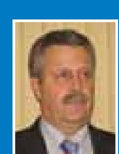
"I thank my loving parents and all those who have made this honor possible. Special thanks to Dr. Ralph Cope for demonstrating that engineering is everywhere, and to Dr. Burnaby Munson for teaching me that there are no new problems, only interesting ways to solve them," he said.

Three Selected for 2010 Distinguished Career Awards

BY DIANE KUKICH

Three distinguished alumni will be honored at the Mechanical Engineering Business & Career Conference, to be held in conjunction with Forum & Reunion Weekend on June 4, 2010: Ralph Cope, Frank Hyer, and Doug McKenna. Alumni are selected for recognition based on several criteria, including achievement, impact, uniqueness, and interest.

The following highlights the careers of this year's distinguished alumni.

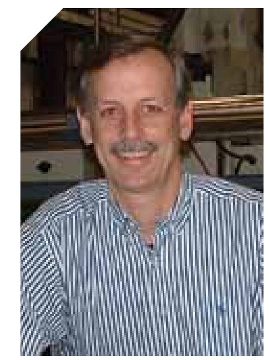






2009 Distinguished Career Awards

Five individuals were selected to receive 2009 Distinguished Career Awards, but the ceremony to honor them was cancelled due to the swine flu scare at UD last spring. They are reprised here and will be recognized at the 2010 Alumni Career Celebration and Reunion.

Ralph Cope '78, '79

Ralph Cope is President and Senior Partner of Accudyne Systems, Inc., a world leader in developing equipment for composite part fabrication and supercritical fluid separation. With current annual revenues of over $6 million, the company employs 35 people, many of them graduates of UD's engineering programs.



After completing his bachelor's and master's degrees at UD, Cope went on to earn a Ph.D. in ME from the Ohio State University. At Delaware, he was one of the first graduate students in the newly formed Center for Composite Materials and the first student to serve on the University's Board of Trustees.

Cope taught at UD for several years before starting his own company in 1994, and he is credited with re-emphasizing the "consulting company" organization of the ME capstone course. He also introduced the use of design problems being drawn from challenges faced by researchers across campus.

Cope also started, in 1991, UD's interdisciplinary Orthopedic and Biomechanical Engineering Center, which brought together researchers from the College of Engineering, the former College of Physical Education, Athletics and Recreation, the former College of Life and Health Sciences, and the A.I. DuPont Institute to address a variety of issues in biomechanics.

In 1995, Cope's ME consulting firm merged with an electrical design consulting company to form Accudyne. Customers of the company include DuPont, Airbus, NASA, Haliburton, Gore, and GE.

"To date," he says, "we have built over 150 unique machines ranging in value from $10,000 to $1.7 million that are working in plants all around the globe."

"But just as important as our equipment is our staff," he adds. "I am proud that we have never laid anyone off, and despite the recent economic times, we continue to hire and grow at an annual rate near 20 percent."

Among the company's more interesting projects are a fully instrumented mechanical baby to allow obstetricians to realistically practice child delivery and two machines that extract key chemical compounds from natural materials for the production of herbal and nutraceuticals.

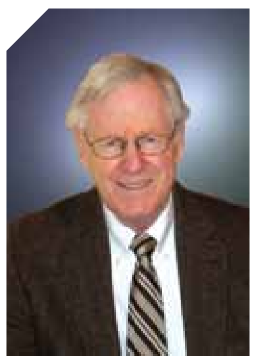
Cope's formula for success has been to focus on the team and its success, not on individuals and their wins and losses. "I have led my company the same way I approached my career," he says. "I believe that if you do good work, success will come."

DR. E. FENTON CAREY, JR. ('67, '70M), who currently runs his own consulting business, has been a national policy maker in the areas of defense, energy, transportation, and the environment. A former Navy Captain and naval aviator who did combat duty, Carey holds a Ph.D. in aeronautical engineering from the Naval Postgraduate School in Monterey, California, in addition to bachelor's and master's degrees from Delaware. He has won awards for superior achievement and service from the U.S. Departments of Defense, Energy, and Transportation as well as the U.S. Navy.

JOHN W. GILLESPIE, JR. ('76, '78M, '85Ph.D.) is Donald C. Phillips Professor at UD and Director of UD's Center for Composite Materials. An internationally recognized authority in composites, he has led four Centers of Excellence in Composites on processing, mechanics, and performance of multifunctional composite materials, as well as an industrial consortium with more than 60 companies conducting research at the forefront of composites science and engineering. He was the recipient of the 2009 Outstanding Research Award from the American Society for Composites.

Frank Hyer '58

Frank Hyer is President and Chairman of Thayer Scale - Hyer Industries, Inc., which offers automated weighing equipment and systems to customers around the world, enabling them to improve their productivity and the quality of their offerings. Hyer is credited with maintaining a stable and profitable manufacturing business for almost 40 years through various economic conditions by constant re-adjustment of product offerings.



Hyer holds 20 patents for inventions including packaging machinery, wrapping and bundling machinery, article transfer mechanisms, article pacing and spacing apparatus, bin level control, bulk material weighing and feeding equipment, hopper and bin flow aids, and calibration control systems.

He began his career with Cutler-Hammer as a design engineer for control components. Quickly displaying an aptitude for—and, perhaps more important, an interest in—process automation, he eventually purchased an underperforming division of the company involved in process weighing equipment.

While working at Cutler-Hammer, Hyer completed a master's degree in ME at the University of Wisconsin. His thesis focused on a scientific approach to conveyor weighing, which initiated an extended series of developments involving conveyor weighing and instrumentation. Hyer has since written numerous technical papers and training manuals on this subject.

"I think my career demonstrates that it's possible to stay deeply involved in the technical details of engineering while enjoying the benefits of running your own company," Hyer says. "It's not only possible, but given the unique benefits of an engineering education, it's not all that difficult to do."

"Not only do engineers learn important theories and facts, but they are conditioned to think rationally and to work through very difficult and time-consuming challenges. Very early in their careers, many will have opportunities to display their individual competencies to the 'higher-ups' in the organizations they choose to work for, which in turn can lead to rapidly increasing opportunities."

"For a few of us, having control over our destinies is perhaps the most rewarding achievement of all. Having to sink or swim on the decisions of other bosses—bankers, lawyers, and venture capitalists—is not for everyone."

Hyer is a lifetime member of the American Society of Mechanical Engineers and the International Society of Automation.

Doug McKenna '82

As an undergrad at UD, Doug McKenna conducted research that not only won him an award but also led to a career. In 1982, he was selected to receive the Samuel Amen Award for Outstanding Research, for work focusing on simultaneous heat and mass transfer through Gore-Tex® membranes and laminates.

This research led to a career at W. L. Gore and Associates, Inc, where McKenna worked in the Fabrics and Industrial Products Divisions. While focusing on industrial filtration products at Gore, McKenna invented and patented a water-tolerant CO_2 adsorbent designed to solve problems for Navy SEAL diving operations. While Gore specializes in products utilizing PTFE polymers, the technology developed by McKenna was found to be optimal utilizing other polymers, and as such was outside the business direction of Gore.

Just as Bill Gore had asked the DuPont Company if he could leave to pursue market opportunities for one of its products, McKenna requested the chance to follow the development of the adsorbent he had invented. Bob Gore gave his blessing, and from the garage of his rented townhome, McKenna developed the business that has become Micropore, Inc.

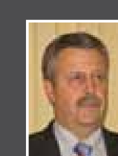
Watching Doug create the company from the ground up has been an incredible experience," says his twin sister, Carol Mongan, who is also a UD alum. "With limited resources, he designed and built almost every piece of equipment that was needed to produce his products and was able to sell and market to the top brass of the Navy of many countries. He handled the hiring decisions, the packaging decisions, the branding decisions, the IT decisions, the technology decisions—every aspect of starting and running a multi-million dollar business was on his plate and he was able to juggle it all."

Today, Micropore, Inc. has 34 employees and recently opened a 95,000-sq.-ft. manufacturing facility in Elkton, Maryland. The original CO_2 adsorbent has evolved into products for submarines, medical anesthesia, sport and technical diving, first responder breathing equipment, mining applications, and other emergency escape devices. McKenna serves not only as CEO of the company, but also as Vice President of Technology. With eight patents to his credit, McKenna says he is also focused on training others in his company to patent innovative solutions to customer problems, and plans to keep the company on the cutting edge of reactive plastic innovation.

"The strong education Doug received at UD, combined with his innate talents for product design, innovation and development, have led to a unique company that is clearly an American success story," says Mongan. "Thanks to UD for giving him a strong knowledge base and the confidence to follow his ideas to successful completion."

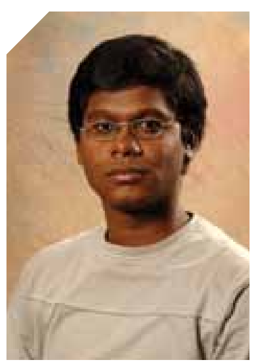
E. DOUGLAS HUGGARD ('55, '61M) spent his entire career with Atlantic Electric, a utility servicing the southern one-third of New Jersey, and then with Atlantic Energy, a holding company formed in 1987 consisting of four non-regulated energy-related subsidiaries Huggard was instrumental in directing the company into the holding company format, which enabled participation in activities other than regulated areas, such as cogeneration projects, real estate development, conservation projects, and energy-related investment opportunities.

JIM LASER ('69) is currently self-employed as a consultant, primarily to the pharmaceutical and biotech industries. Before establishing Whitney Consulting in 2002, Laser spent 28 years with Merck & Co. Inc., where he held increasingly responsible positions in operations, materials management, engineering and technical services in the manufacture of pharmaceutical and biological products. His last position at Merck was Vice President of Vaccine and Sterile Operations.



ERIC SVENDSEN ('71) is CEO of Foster Wheeler Energia in Madrid, Spain and CEO for Foster Wheeler Global Industrial Boilers, providing leadership of the Spanish office of Foster Wheeler as well as worldwide industrial boiler products for Foster Wheeler Global. Svendsen and his wife Ana, a Spanish citizen and naturalized US citizen, were married in Spain in August 1976.

Graduate Student Spotlight



Srikanth Arisetty

Srikanth Arisetty, a Ph.D. student in ME, was drawn to UD by the extensive opportunities available in fuel cell research. He holds a chemical engineering degree from the Indian Institute of Technology, which he says provided him with an understanding of the basic processes underlying fuel cell technology, and he has now turned to the mechanical engineering discipline to gain a systems-level perspective.

Co-advised by Profs. Ajay Prasad and Suresh Advani, Arisetty is focusing on regulation of transport processes in direct methanol fuel cell systems, which are used for portable power applications such as laptops and cell phones.

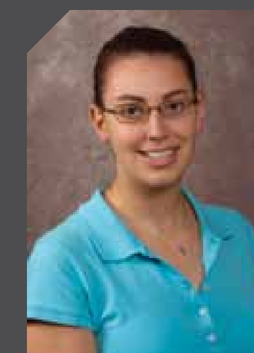
"Srikanth is an extremely gifted Ph.D. student," says Prasad. "He already has four papers and will write three or four more based on his doctoral research. He also initiated a collaboration with Dr. Ulrike Krewer at the Max Planck Institute in Magdeburg, Germany, and spent three months there earlier this year."

For Arisetty, the stint at the Max Planck Institute was quite beneficial. "It's a very well-known fuel-cell research lab," he says, "and working there helped me understand from an international perspective how various people look at the research issues involved in developing fuel cell technology. I had the chance to interact with some great experts in the field and have since implemented some of their ideas in the lab here."

Arisetty recently placed third in the national 2009 Bernard S. Baker Award competition, given annually to three Ph.D. students for performing competitive research in fuel cells.

He also finds time to give back to the community. Last year, he coordinated an effort that raised $28,000 for a school in India through ASHA, an action group that helps to provide basic education for underprivileged children in India. He is currently serving as president of ASHA at UD.

After completing his PhD, Arisetty plans to seek a career in research in the area of sustainable energy at either an academic or industrial organization.



Elisa Schrank

Elisa Schrank, a doctoral student in ME, became interested in biomechanics and human movement at the age of 13, when she volunteered in a swim program for children with special needs. That experience, coupled with her strengths in math and science, spurred Schrank's decision to major in biomedical engineering as an undergraduate.

At the University of Virginia, where she earned her bachelor's degree in 2008, she supplemented her major courses with offerings in mechanical engineering and sports medicine. She also spent three summers as an intern in the Physical Disabilities Branch of the National Institutes of Health (NIH).

Schrank is co-advised by Jill Higginson, assistant professor in ME, and Steven Stanhope, professor in the Department of Kinesiology and Applied Physiology.

Her experience at NIH introduced her to Stanhope as well as to the topic that would become the focus of her doctoral research. At the time, Stanhope was director of NIH's Physical Disabilities Branch, and Schrank worked with him on the design of a novel passive-dynamic ankle-foot orthosis (PD-AFO), which is intended to enhance functional gains by replicating a patient's muscle function via a spring-like action.

"The problem," says Schrank, "is that the design of these assistive devices is complicated by a lack of understanding as to how they interact with the complex dynamics of the human musculoskeletal system. My research focuses on modeling and simulating that interaction in order to explore the adaptive movement control strategies required in the presence of the customized PD-AFO. The long-term aim of this work is to optimize PD-AFO features so that patients can achieve maximum gait function."

UD proved to be a perfect fit for Schrank, as Stanhope joined the faculty here in 2007, and his expertise is complemented by that of Higginson, who specializes in the development of musculoskeletal models and simulations. Schrank plans a career in academia, where she can teach and conduct research.

Schrank's work is supported by a prestigious National Science Foundation Graduate Fellowship.

"Elisa is a very gifted student and an aspiring scholar," Stanhope says. "Even in her first year as a graduate student, she demonstrated a remarkably mature desire and a wonderful aptitude for engaging colleagues in the intellectual process of 'drilling down' into the details of her learning and research efforts."

Higginson agrees. "Elisa has a unique background with extensive experience in biomechanics. She is a self-motivated and capable student, as can be seen by her numerous presentations and publications at this early stage of her academic career. Already, Elisa has demonstrated a passion for and commitment to her dissertation research. I feel fortunate to have the opportunity to collaborate with her and her other advisor, Steven Stanhope."

For Schrank, having two advisors is both a challenge and a benefit. "Their backgrounds are very different," she says, "so they look at things very differently. But it's good for me to get perspectives from both sides of the story. I also think that I'm helping to bring each of them into the other's world and broadening the way they look at the problem."

Seniors Deliver Final Design Presentations

CONTINUED ON NEXT PAGE

BY DIANE KUKICH

Sixteen teams of ME senior design students delivered final presentations on their semester-long projects at the Perkins Student Center on Dec. 14 to an audience of sponsors, review panelists, faculty, staff, students and parents.

Team AMSAA: Contactless Angular Position System

Pierre Yao Koffi, Andrew Polnyj, Terrell Corder, Adam Eby, Steven McKeefrey

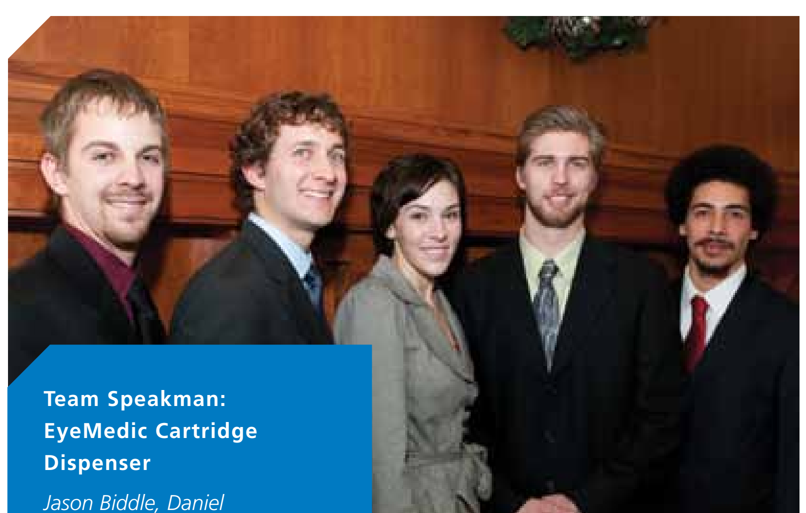
All of the projects address real industrial problems posed by sponsors, with this year's work ranging from a diamond slab polisher to an unmanned underwater vehicle payload module. The reviewers consider three criteria in their assessment: design synthesis, resource/project management, and communication.

The student teams are advised by 1964 ME alumnus Nate Cloud and professors James Glancey, Robert Hartman, and Michael Keefe. Cloud is also responsible for identifying and securing the businesses who sponsor the projects.

This year's outstanding projects were designed and executed by Team Speakman (Jason Biddle, Daniel De Leonardis, Erin Phillips, Spencer Popejoy, and Jesse Whitley) and Team AMSAA (Pierre Yao Koffi, Andrew Polnyj, Terrell Corder, Adam Eby, and Steven McKeefrey).

"It was a pleasure working with the group, and we're looking forward to next year," said Michael W. Boyer, design engineer with Speakman.

Tim Biscoe, senior design program coordinator for AMSAA, had similar comments about his team: "It was a pleasure working with the students.



Team Speakman: EyeMedic Cartridge Dispenser

Jason Biddle, Daniel De Leonardis, Erin Phillips, Spencer Popejoy, Jesse Whitley

We thank you all for the opportunity, and we appreciate the team's hard work. We wish Pierre, Adam, Steve, Andrew, and Terrell a healthy and successful future."

"We were really pleased to have such an experienced and respected team of people to review and assess the projects this year," said Nate Cloud. "Collectively, they have some 300 years of academic, engineering, and business experience. Three are UDME alums, five are current or former faculty members, and five are current members of ASME."

REVIEW PANELISTS

DAVID BURRIS
Assistant professor of ME at UD

YOGENDRA CHADDA
Retired professor and chairman of the Department of ME at the University of Detroit

PETER CLOUD (BME 65)
Former president and general manager of several of Astra Zeneca's Specialty Chemical Businesses

SCOTT DAVIDSON
President of MechPro Engineering

BILL FAGERSTROM
Independent consultant and instructor of the manufacturing course in ME at UD

ED GARGIULO
Senior staff engineer with Siemens Healthcare Diagnostics

PETER POPPER
Former researcher with DuPont and now vice president of Peacock Sales

DINA RILEY (BME 98)
Manufacturing engineering manager at Agilent Technologies

SHAWN RILEY (BME 98)
Engineering associate with Gore Filtration Products

SPONSORS & PROTOTYPES

Prototypes were produced and tested by the student teams to validate their concepts.

CONGRATS, SENIORS!

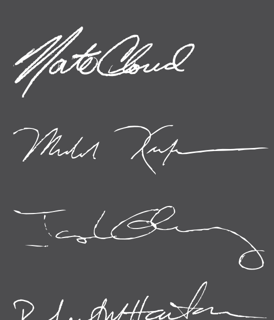
Dear Seniors,

We offer our congratulations for your successful completion of Senior Design! The professionalism, enthusiasm, diligence, and teamwork that you demonstrated in completing your project were exemplary. We trust that this experience will be a good beginning of a long and prosperous career. We are proud of your accomplishments, as are your project sponsors. You have represented yourselves, your teammates, and the University of Delaware well!

Sincerely,

Anette Karlsson,
Department Chairperson

Senior Design Team Staff:



Team Air Liquide:
Gas Cylinder Filling Station
Alexander McDonald, Cameron Showell, Melissa Fox, Francois Chaubard, William Baetz

Team CNH America:
Round Baler Weighing System
John Elliott, Philip Zandona, Robert Hackendorn, Daniel Traub, Christopher Meehan

Team Container Research Corporation:
Container Cushion Production Redesign
Richard Walsh, Jennifer Gradischer, Stephen Cummings, Cory Nataro

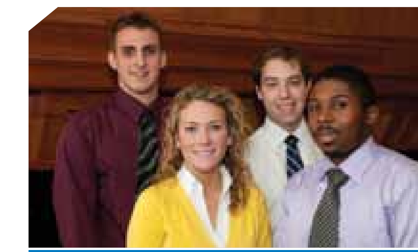
Team Delaware Diamond Knives:
Diamond Slab Polisher
Winston Arnold, Nick Damiani, Dan Ruhlman, Greg Specht, Pete Trainor

Team ILC:
Flexible Containment Crimp Tool
Todd Sack, Brendan McCracken, William Hunt, Patrick McQuaid, Joe Collins

Team Schiller Lawn Care:
Reversing Transmission System
William Power, Thomas Malone, Hugh Kettler, Edward Kowalski, Zach Schoepflin

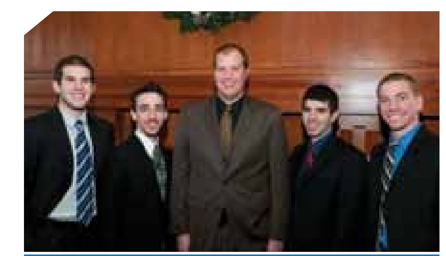
Team Siemens:
Cryogenic Blend Preparation System
Jacob Sherry, Andrew Phillips, Sarah Shovestul, Eric Evers, Jason Landesberg

Team Southco:
Release Pin Latch Mechanism
John Sumner, Tyler Richardson, Shane Smith, Robert Schank



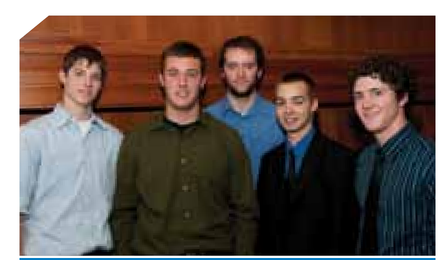
Team SRT:
Radiation Ablation Capsule
Aaron Brauner, Lindsay Wallace, Thomas Cender, Mason Gibbs

Team Survice: Underwater Unmanned Vehicle Payload Module
Thomas Ebanja, Brittany Wilder, Daniel Collins, Christina Thoresen, Maurice El-Deiry

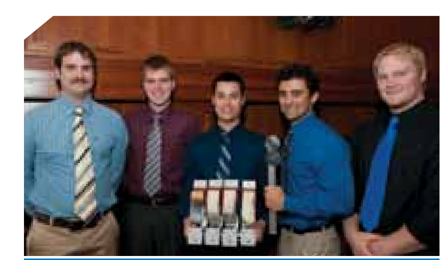


Team Synthes:
Locking Cap Assembly Station
Peter Bocchini, Marc Henderson, Pat Erbe, Kevin Schultz, Nick Morrisey

Team Terumo:
Pump Impeller Bonding Improvement
Adam Deveaney, Andrea Schuck, Jennifer Iskra, Hyeyeon Jeon, John Zerhusen



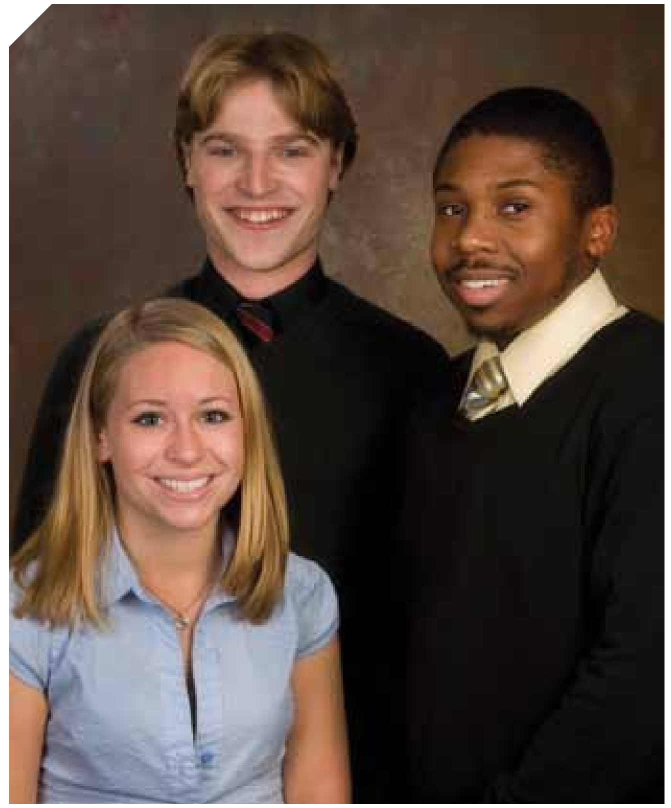
Team Varitronics:
Wireless Interoffice Communications System
Kyle Autz, Harrison Woytko, Chad Phillips, Richard Parsons, Paul Yeager



Team W. L. Gore:
Fabric Decontamination Process
Brian Bourdon, Alexander Hamilton, Stephen Schumann, James Sargianis, Edward Udinski

Team AMSAA and Team Speakman are featured on the previous spread (p.28–29).

THREE OUTSTANDING SENIORS



BY DIANE KUKICH

The UD College of Engineering not only trains engineers but also develops leaders, and three students in the 2010 ME senior class exemplify this effort.

Jenn Iskra

Jenn Iskra has an interest in biomedical engineering and is graduating this May, but plans to continue on the 4+1 MBA Program. She grew up in Bridgewater, N.J., and was fortunate to run into Professor Tom Buchanan when she and her family visited the UD Campus. "He gave us a tour and I was really impressed with the student research opportunities," she says. She has since taken advantage of the opportunities to work and learn.

Iskra spent one summer conducting biomechanical research under the guidance of Professor Jill Higginson to study the effects of walking speed on handrail forces for healthy subjects, with an emphasis on finding ways to help rehabilitate stroke patients. "It was a rewarding experience to work on something that is intended to help sick and elderly people," says Iskra. Although that project has ended, Iskra still works in the biomechanical lab on various other research projects.

Iskra also had the opportunity to work in a summer internship with WL Gore, in their medical products division. She spent the summer working on improving a packaging process for patches used in hernia surgery.

Her senior design project also involved a local company, Terumo Cardiovascular Systems in Maryland. Iskra and members of the Senior Design team developed an automated process for assembly of heart pump components. This replaces a manual operation and improves reliability and consistency. "It was great to work with Terumo to help them solve one of their problems," says Iskra.

Iskra will earn her degree through UD's challenging Honors Program, but she has also found time to play on the club golf team, serve as President of the UD Society of Women Engineers (SWE) chapter, and works as a TA for the ME module of EGGG101, Intro to Engineering. She has also been involved in the SAMPE student chapter and worked on the chapter's entry in the bridge design competition.

"I've had a great 4 years here," Iskra says. "I've had the opportunity to learn through classes and apply that knowledge to real world problems. I look forward to finishing my MBA and having a good blend of technical and business background."

Zach Schoepflin

Originally from Long Island, N.Y., Zach Schoepflin saw the UD campus and fell in love with it. Although he knew he liked math and science, he was unsure about the direction of an engineering major but was fortunate to be part of the first class at UD that was exposed to the Introduction to Engineering course.

"I really liked mechanical engineering," he says, "and Dr. Buchanan prompted my interest in the biomedical engineering minor."

Schoepflin plans to attend medical school and earn combined M.D. and Ph.D. degrees in biomedical engineering. In the long term, he would like to return to academia. "I see myself coming back to the education side," he says. "I really like the university atmosphere."

A bit of a Renaissance man, Schoepflin plays the viola in the University Symphony and sings in the Y Chromes, an all-male a capella group. He has also served as a Writing Fellow through UD's Honors Program, and he enjoys rock climbing and playing Frisbee in his "spare time."

Schoepflin and his senior design team helped Schiller Grounds Care redesign a hand-held tiller.

"UD has been a wonderful place for me," Schoepflin says. "I like the fact that they are very flexible here in terms of academic plans. My advisors and many other professors have gone to bat for me so I could complete all of the requirements for the premed program and my minors." In addition to biomedical engineering, Schoepflin has a minor in history.

In addition to completing the rigorous coursework for his academic program, Schoepflin is doing a senior thesis for the Honors Program. His work focuses on incorporating a walking motion into the robotic mobility devices being developed at UD for children with physical and intellectual challenges. "I'm trying to combine a physical therapy device with the robotic mobility device to encourage kids who may eventually be able to develop the ability to walk," he says.

> "***These three students are excellent examples of leadership and achievement***," says Chairperson Anette Karlsson, "***and they are shining examples of what can be achieved in Mechanical Engineering at the University of Delaware.***"

Mason Gibbs

Mason Gibbs, who hails from Chichester, Penn., was drawn to ME as a child when he became fascinated with roller coasters and airplanes. While his interest has since shifted to biomedical engineering, an ME major is taking him in the direction he wants to go.

"My mother is a unit clerk in a hospital, which got me interested in the medical aspects of engineering," he says.

Gibbs has completed an internship at Merck and will begin working there after graduation in May as part of the company's two-year Global Engineering Program. The job entails traveling to various manufacturing plants and reviewing their processes with an to improving efficiency. After the two-year assignment, Gibbs will be offered a permanent position with the company. He may consider grad school later but want to gain experience first.

Gibbs has served as Vice President of the ASME chapter at UD, Vice President of the Black Student Union, program chair for the National Association of Black Engineers (NSBE), and diversity enrichment leader for the Admissions Office. He has also volunteered on Blue and Golden Saturdays and worked for RISE.

"I always wanted to be involved," he says. "All of these affiliations have helped me develop leadership skills, learn teamwork, work efficiently, take responsibility, and become more outgoing."

One of five children, Gibbs has a younger brother who is a sophomore at UD majoring in math. He enjoys spending time with his family and plans to be engaged to be married by the end of the year.

The UD ME experience has been nothing but positive for Gibbs. "I love mechanical engineering," he says. "I love cars and airplanes, prosthetics and medical devices, and process design."

Gibbs was a member of Team SRT in senior design. Their project involved creation of a radio ablation capsule for the company, which enables targeted delivery of radiation to cancerous tissue.

MESSAGE FROM THE DEVELOPMENT DIRECTOR

ARMAND BATTISTI

Alumni often ask "What does the College of Engineering need?" This is a great question and one to which I enjoy responding. It gives me the chance to talk about the needs of our students and our faculty and to provide ways in which our alumni and friends can make a difference through contributions. Anette Karlsson's letter in this newsletter describes how gifts are being used today. The ways in which alumni dollars are currently spent are a strong indication of the department's greatest needs.

On a grander scale, I would say that the College of Engineering needs more participation and leadership, particularly from alumni. Our academic programs are well-established, strong and renowned, yet the fundraising effort here definitely has room to grow.

Presently, Engineering's alumni participation is 14%, which is 11 percentage points below the average of our peer colleges. We are working hard to earn your confidence and trust and want to encourage annual support through giving back to the department of your choice. This year, we hope that the percent of alumni giving will increase by 400 donors, to 17%! If you are not now a donor, please consider joining your fellow graduates and encourage your friends to do the same.

We also need leaders to make significant gifts to the College. The University's Delaware Diamonds Society recognizes contributors of $1,000 and greater. These benefactors are strongly engaged in the department's needs and are helping to realize its most immediate needs. Last year, the College of Engineering had 144 Delaware Diamond Society members across all departments. This year we want to have 200 members by June 30, 2010. As of January 22, we had welcomed 36 new members and are well on our way to reaching that benchmark.

WHY JOIN THE DELAWARE DIAMONDS?

- Your leadership begets others. Your gift influences others to give!
- You enjoy helping a student stay in school and become a useful contributor to society.
- You are recognized by the Dean and the University by invitation to special events and informative sessions.
- You help create a growing tradition of alumni who set a positive example to students.
- You help shape the UD College of Engineering experience.

We appreciate the legacy of alumni involvement and look forward to your involvement and financial support. If you have any questions, please contact Armand Battisti at 302.831.7273 or aab@udel.edu.

WHY PARTICIPATE?

- The ME department needs your support to remain competitive, to attract talented students and faculty, and to provide the best facilities.
- You make it possible for others to get their education, in the same way that others made it possible for you.
- The national reputation of your alma mater is strengthened by broad-based alumni support.
- Companies and foundations make grants to universities where alumni participation is high.
- You can take personal pride in ensuring the financial viability of your alma mater.
- New opportunities are seized when they present themselves because resources are available.
- Your financial involvement often opens doors to career opportunities, professional networks, and other useful contacts.

Thank You 2009 Alumni Donors!

We wish to thank the many ME friends and alumni who have made generous contributions over the past year. Your gifts are used for many worthwhile purposes, including support of our research and educational programs. To make a donation, please visit UD Connection (www.udconnection.com) and click ***Donate Today***. If you wish to give designate your gift to ME, select ***other*** from the list provided, then specify ***Mechanical Engineering***.

Names written in blue represent gifts made specifically to ME.

$15,000 – $20,000

`73 David R. & Constance LaRoe Helwig

$5,000 – $10,000

`59 James S. & Louise Lattomus Dick
`72 William G. Mavity
`83 Terri L. Kelly
`93 Archibald & Tomoeh M. Tse

$2,000 – $4,000

`51 Robert H. Irwin
`51 Frederick H. Kohloss
`51 Price K. Snyder
`52 Thomas A. & Jane Vannerson McKenna
`57 Wayne E. & Jean E. McCabe
`57 George G. & Ann Weslager Tatnall
`61 Durand R. III & Barbara Keen Kinloch
`63 Francis J. & Connie R. Suppe
`64 Nathan & Carolyn Taylor Cloud
`66 Paul N. & Flo Z. Costello
`69 James R. Laser
`79 Bernard W. Ebersole III & Jennifer J. Matlack
`96 J. Matthew & Melissa Bailey Scarborough
Andras Z. & Mary J. Szeri

$1,000 – $1,500

`48 Lewis L. Reign Jr.
`49 G. Franklin & Helen H. Moore
`50 C. Jackson & Sally Lee H. Levis
`50 David C. & Alice N. Trimble
`50 W. Murray & Mollie B. Campbell
`51 Thomas A. Wood Jr.
`53 Jules J. & Sandra B. Schwartz
`55 E. Douglas & Lois C. Huggard
`58 G. Greer MacMasters Jr.
`59 James B. & Nancy Woodward Foulk
`60 Charles B. Woodward III
`61 William T. & Nancy S. Morris
`64 David L. & Patrice Kosey Sysko
`65 Charles H. III & Jane H. Collier
`67 Aubrey S. Clemons
`67 Russ Jr. & Judy B. Bonadonna
`68 John R. & M. Carol Hitchens Starzmann
`69 John L. Jr. & Judy M. Haverstick
`71 Joseph A. Jr. & Cynthia E. Walkowski
`72 George J. & Maryann Sestak
`72 Margaretmary Torelli Weidert & Robert M. Weidert
`79 John S. Jr. & Julia Reinhart Thackrah
`80 Alex T. & Diane P. Bourdon
`81 Mark A. Sr. & Katherine H. Degli Obizzi
`82 Daniel S. & Mabeth Wilson Hudson
`84 Mary Louise Brzezicki Mogan & Kenneth J. Mogan
`93 Craig W. & Dana Testa Murray
`09 Sarah L. O'Neill

$500 – $900

`49 John M. Pursell
`50 Fred G. Harvey
`50 James P. & Nancy Corcoran McFadden
`51 Donald T. & Muriel Bear Hoffecker
`54 John D. & Jay Rowland Hukill
`56 George S. & Barbara Pearce Hudson
`56 William H. Lotter Jr.
`57 Thomas C. & Barbara Lewis VanMeter
`58 William S. Jr. & Elisabeth Snowberger Patterson
`58 V. Hayes Fenstermacher
`58 George A. III & Elizabeth H. MacFarland
`59 Robert J. & Mary McCafferty Maegerle
`62 W. Douglas & Diane Dickerson Boyce
`63 Edward A. & Patricia Bell Miller
`67 David & Susan Deppert Hutton
`67 G. Mark Jr. & Janet Fallow Stofega
`68 Dean S. & Jane G. Gilchrist
`70 David J. & Jane Mayberry Maguigan
`70 Sepehr & Nancy Waite Mostaghim
`72 James H. & Mary W. Poole
`72 C. A. Simmons Jr.
`72 Robert J. & Angela A. Singley
`73 John L. Jr. & Dana-Jeanne Fricker Morrow
`73 J. Bruce & Evelyn Ewing Spiller
`76 W. David & Katherine Ward Cockey
`79 Gregory W. Antal
`82 Jon P. & M. Megan Allen Martin
`83 Thomas J. Itchkawich
`85 Eric P. & Sarah Bryan Beyeler
`85 John T. Diamanty
`86 John K. & Suzette Asbury Ryder
`86 Nancy R. Sottos
`96 Gregory A. & Suzanne R. Norsworthy
Tsu-Wei & Mei-Sheng Chou
Megan M. Martin

To $450

`41 J. Nelson & Evelyn T. Middleton
`42 Ivan W. Herr Jr.
`43 William S. Jr. & Irvana Passmore Miller
`43 David W. Locke
`43 Robert C. Meyer
`48 Margaret Webb Osborne
`48 James V. Powers
`48 Virginia Wootten Coxe
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