What do spore-launching mushrooms have in common with highly water-repellant surfaces? According to Duke University engineers, the answer is “jumping” water droplets. As it turns out, the same phenomenon that occurs when it’s time for certain mushrooms to eject spores also occurs when dew droplets skitter across a surface that is highly water repellant, or superhydrophobic. **continued on page 3**
LETTER FROM THE CHAIR

A very wise mentor of mine once told me that one should never succeed someone who has been outstanding in their position. I have not always followed that advice, but in succeeding Tod Laursen, even if only for a year, I am acutely aware of the risk involved.

The closest previous incident of mine that comes to mind at Duke is having once had the opportunity to follow Mike Kryzyzewski as a speaker to a group of prospective Duke students and their parents. I do recall a mother of a prospective student who said something nice about my comments, but mothers tend to be sympathetic to those clearly in need.

We are going to miss Tod a great deal as we also take some substantial pride and bask in his reflected glory as he follows his dream and career to Abu Dhabi. We not only wish him all success there, but know that he will continue to bring distinction to the global academic community. I believe that his strong roots at Duke will serve him, MEMS and the Pratt School exceedingly well.

Global initiatives and internationalization are very much in the academic air and on the agenda of universities in the US and around the world. Tod’s departure brings this home in a particularly special and poignant way. What will the next several decades bring? I once attended a luncheon talk by Michael Hooker, then Chancellor at UNC-Chapel Hill, who predicted that merger mania would reach higher education and that at some point there would be fewer than ten mega-universities worldwide interconnected by the Internet and other technologies yet to be developed. Whatever the future will bring to higher education, it is clear that engineers will be some of the leaders and many of the enablers of that revolution. For folks who tend to be seen as conservative in the main, engineers have had and continue to have a radical impact on our world. And some would say, that is a very good thing and I hope you agree. But we also need to recognize that this technology revolution that can also be charac-
terized by rows and rows of tiny bumps, covered with even tinier hairs projecting upward. When a water droplet lands on this type of surface, it only touches the ends of the tiny hairs. This creates pockets of air underneath the droplet that keep it from touching the surface. This cushion of air keeping the droplet aloft is much like a puck in an air-hockey game. The same principle allows water striders, which skim along the surface of ponds without falling into the water, to continue to move. Duke, the Pratt School and MEMS are indeed all experiencing, not just interesting, but exciting times. Please join the MEMS team in pursuing another successful year.

Earl Dowell
Chair and William Holland Hall Professor

Research Cover

Using a specially designed high-speed camera and microscope set-up, the engineers for the first time captured the actions of tiny water droplets on a man-made superhydrophobic surface, and to their surprise found that the droplets literally jumped straight up and off the surface.

Simply put, when two tiny water droplets — whether on a mushroom’s spore or on a water-repellent surface — merge to form a larger drop, enough energy is released in the formation of the new droplet to cause it to “jump” off the surface.

“This spontaneous jumping is powered by the surface energy released when droplets coalesce,” said Jonathan Boreyko, a third-year graduate student at Duke’s Pratt School of Engineering, who works in the laboratory of Assistant Professor Chen. “Because this process involves very tiny droplets at high speeds, no one had captured this phenomenon before.”

The results of the team’s experiments were published early online in the journal Physic Review Letters.

“A similar phenomenon occurs with the ejection of spores, known as ballisto-
spores, from certain kinds of mush-
rooms,” Boreyko said. “When a drop of water condensate at the base of the spore comes into contact with the wetted spore, it triggers the propulsion of the spore into the air.”

Chen and Boreyko’s research is the first known experimental reproduction of the ballistospore ejection process. The work also has immediate applications in energy harvesting and thermal management, Chen said. For example, the spontaneous jumping motion offers an internal mechanism, independent of gravity, to remove condensate from the condensers in power plants.

The superhydrophobic surface used by the researchers is characterized by rows and rows of tiny bumps, covered with even tinier hairs projecting upward. When a water droplet lands on this type of surface, it only touches the ends of the tiny hairs. This creates pockets of air underneath the droplet that keep it from touching the surface. This cushion of air keeping the droplet aloft is much like a puck in an air-hockey game. The same principle allows water striders, which skim along the surface of ponds without falling into the water, to continue to move. Duke, the Pratt School and MEMS are indeed all experiencing, not just interesting, but exciting times. Please join the MEMS team in pursuing another successful year.

Chen’s research is supported by the National Science Foundation. Jonathan Boreyko is supported by the Pratt-Gardner Fellowship.
Scientists drew fittingly from Roman mythology when they named a unique class of minuscule particles after the god Janus, who is usually depicted as having two faces looking in opposite directions.

For years, scientists have been fascinated by the tantalizing possibilities of these particles for their potential applications in electronic display devices, sensors and many other devices. However, realizing these applications requires precise control over the positions and orientation of the particles, something which has until now eluded scientists.

Duke University engineers say they can for the first time control all the degrees of the particle’s motion, opening up broad possibilities for nanotechnology and device applications. Their unique technology should make it more likely that Janus particles can be used as the building blocks for a myriad of applications, including such new technologies as electronic paper and self-propelling micromachines.

Typical Janus particles consist of minuscule spherical beads that have one hemisphere coated with a magnetic or metallic material. External magnetic or electric fields can then be used to control the orientation of the particles. However, this coating interferes with optical beams, or traps, another tool scientists use to control positioning.

The breakthrough of Duke engineers was to devise a fabrication strategy to coat the particle with a much smaller fraction of material. This discovery allows these particles to be compatible with optical traps and external magnetic fields, allowing for total control over the particles’ positions and orientations.

“We have created a novel Janus particle that can be manipulated or constrained with six degrees of freedom.” - NATHAN JENNESS

Using optical traps on dot-Janus particles, researchers controlled three degrees of movement – up and down, left and right, forward and backward, while constraining one degree of rotation – side-to-side tilting. Using magnetic fields, they controlled the remaining two degrees of rotation – forward and backward tilting, and left and right turning.

“The solution was to create a particle with a small cap of cobalt that covers about a quarter of the particle,” Erb said. He and Jenness conducted their research in the laboratory of Benjamin Yellen, Duke assistant professor of Mechanical Engineering and Materials Science. “This gave the particle just enough of a magnetic handle to allow it to be manipulated by magnetism without interfering with the optical tweezers.”

The researchers said that the fabrication of these unique dot-Janus particles combined with the ability to control their orientation will have important ramifications in the burgeoning field of nanotechnology.

“Bring able to more completely control these particles affords us a greater ability to measure the mechanical properties of biomolecules, including DNA,” Yellen said. “It may also be possible to control the behavior of cells by manipulating dot-Janus particles attached to cell surfaces. These biological applications, as well as the ability to control the assembly of nanostructures, establish the broad scientific value of these findings.”

The research was supported by the National Science Foundation and the Nanoscale Interdisciplinary Research Team.
Tod Laursen, professor and chair, was selected through an inter- national search to become the president of Khalifa University of Science, Technology and Research (KUSTAR) in Abu Dhabi, United Arab Emirates. He begins his term in August 2010.

“This opportunity is both an honor and the opportunity of a lifetime,” said Laursen. “Khalifa University is entering a new chapter in its history. We will be building a new campus and aggres- sively expanding the scope of our programmatic offerings. I see my responsibil- ity as helping to shape the future of genera- tions of technically-skilled graduates in the United Arab Emirates who can then con- tribute to the social and economic development of their nation.”

During his time at Duke, Laursen has contributed significantly to the growth and success of the Pratt School of Engineering. He served as senior associate dean for education from 2003-2008, and then as the chair of the Department of Mechanical Engineering and Materials Science. His teaching career at Duke University has spanned 18 years; serving first for 16 years as a faculty member in Civil and Environmental Engineering before becoming the Chair of MEMS in 2008. Together with Professor John Doolow, he is the co-director of the Duke Computational Mechanics Laboratory and is a recognized expert in the development of computational algorithms for treatment of interfaces in mechanical systems.

As senior associate dean for educa- tion, Laursen led the school through major curriculum enhancements such as redesigning the core physics courses required for all engineering majors. By embedding practical engineering applications into the physics classes and labs, these courses have become stronger and more productive founda- tion pieces in both the engineering and physics curricula.

He established first-year design alternatives for incoming students, oversaw the redesign and standardization of the first-year engineering comput- ing requirement, and the establishment of mid-semester interdisciplinary certificate programs with significant components in engineering, including the new Energy and the Environment (En2) Certificate (joint with the Nicholas School for the Environment and Earth Sciences). On the graduate level, he worked with the graduate school to develop broader institutional fellow- ship opportunities for incoming PhD students, and pioneered the process by which graduate students are recruited, including school-sponsored graduate visitation days.

Laursen led the acquisition of new teaching laboratories in the Fitzpatrick Center for Electric, Nuclear, Engineering, Medicine and Applied Sciences and the renovation of the Ten Engineering Building into a modern teaching hub with student design labs, an informa- tion commons, a hub for entre- preneurship ideas, and a consolidated office suite for the academic deans and staff who directly support our stu- dents. He presided over a 20 percent increase in the number of undergradu- ate engineering students over a four- year period of time.

Laursen was elected a Fellow of the ASME (American Society of Mechanical Engineers) in 2008, and will be awarded Fellow distinction in the IACM (International Association on Computational Mechanics) in the summer of 2010. He is also a member of the American Society of Civil Engineers, the United States Association for Computational Mechanics, Tau Beta Pi — the National Engineering Honor Society, and Pi Tau Sigma — the National Honorary Mechanical Engineering Fraternity.

We wish him well.

Tom Katsouleas, professor and dean.
Faculty Focus

Franklin Hadley Cocks, professor, specializes in applications of materials science, the treatment of kidney stone disease, and energy and the environment research. Cocks is a primary researcher in the Duke-Siemens Medical lithotripsy basic research collaboration. In the past year, he co-authored research titled “Comparison of Tissue Injury Produced by Electrohydraulic and Electromagnetic Shock Wave Lithotripters” in the Journal of Urology, Journal of Endourology, vol. 22. He also published the text “Energy Demand and Climate Change,” through Wiley-VCH.

Stefano Curtarolo, associate professor, specializes in computational materials science, with programs on the nanoscale science of energy, nanotube growth, characterization, alloy theory, superconductivity on quasi-crystals, and superconductivity in metal borides. In recognition of his discovery and characterization of novel combinations of elements, he is a 2009 winner of the Presidential Early Career for Scientists and Engineers (PECASE), and $1 million in funding from the Department of Defense. His research titled “Surface Geometry of C60 on Ag(111)” was featured on the cover of Physical Review Letters 103, 056101 (2009).

Earl H. Dowell, the William Holland Hall Professor, specializes in the study of aeroelasticity for applications such as aircraft wings to wind loadings on tall buildings and long bridges to blood flow through arteries. He is also developing computational models of nanoscale biological materials and devices. He was awarded $100,000 from the Air Force Office of Scientific Research to conduct research on aeroelastic computations in support of flight flutter testing. A recent publication includes “Improved Flutter Boundary Prediction for an Isolated Two-Degree-of-Freedom Airfoil,” published in the Journal of Aircraft, Nov-Dec, 2009.

Laurens Howle, associate professor, conducts research across a broad range of fields, from hydroelastic modeling of deformable structures, to computational and experimental fluid dynamics, to pharmacokinetics and pharmacodynamics to wind power. He recently published research on the value of marginal decompression sickness events for probabilistic decompression model optimization in the Journal of Applied Physiology 107(5), 2009, and other work on altering the volume, rate and use of a saline chaser to better match the imaging windows during contrast agent administration for angiography in the American Journal of Roentgenology 193(6). Howle’s research on the aerodynamics of humpback whale flippers was featured in Natural History Magazine, Discover, Popular Mechanics, R&D Daily, Science Daily, and The New York Times.

Robert Kieb, associate department chair and senior research scientist, specializes in structural dynamics and aerelasticity. He gave an invited lecture to the IFToMM-International Symposium on Dynamics and Vibration and Gas Turbines in Gdańsk, Poland in December 2009. Kieb serves as the faculty advisor to the Duke Robotics Club, and has been instrumental in developing a student exchange program with the Royal Institute of Technology in Stockholm, Sweden, where he serves as a distinguished lecturer. He is also a principal in the collaboration of Duke, the Swedish Royal Institute of Technology, the University of Lege, and the Aristotle University of Thessaloniki, development of the aerospace THRUST master’s student graduate exchange program funded by the European Union.

Josiah Knight, associate professor, specializes in solar thermal and transportation energy storage, research, and technology. He is the associate director of the Gundell Center for Engineering, Energy and the Environment. He recently received a one-year award from the NC Space Grant through NASA for research on space solar thermal power. He also co-authored research on the viability of wood energy in America, published in Science, 325.

Linda Franzoni, professor of the practice and associate dean for undergraduate education, specializes in acoustics and structural dynamics, particularly in the development of prediction methods for high-frequency broadband sound fields. Franzoni was nominated to the inaugural class of the Duke Leadership Academy, a program for emerging leaders from across the university the opportunity to participate in a unique 12-month development initiative based on the Fuqua/Coach K Center on Leadership & Ethics (COLE) leadership model. The curriculum includes a focus on leadership and management styles and behaviors to implement strategy.

Devendra Garg, professor, specializes in robotics and automatic control. He was awarded a three-year $226,286 grant from the Army Research Office for research on optimization of robotic swarm composition in micro-unnanned systems for military applications. And he recently published research titled “Intelligent Sensor Uncertainty Modeling Techniques and Data Fusion,” in the International Journal of Control and Intelligent Systems, vol. 57 (2), 2009. He also published two book chapters on the topics of multi-sensor data fusion in the presence of uncertainty and inconsistency in data, and neural controllers. In 2009, Garg was given a Distinguished Alumni Award by the Indian Institute of Technology in Roorkee, India.

Anne Lazarides, assistant professor, specializes in plasmonic nanomaterials. The Lazarides lab is examining how materials of unlikely properties such as metals and silicon control how light from a nanostucture is distributed, i.e. scattered or captured by a substrate. The goal of the research is to direct emission from molecules and to increase both the efficiency with which light is captured by solar cells and the efficiency of light emitting diodes (LEDs). Recently Shira/Yeh Chen, a member of the Lazarides lab, with ECE and BME collaborators Jack Mock and Ryan Hill of the David Smith and Ashutosh Chilkoti labs, has demonstrated that nano antennas can control the distribution of light from molecules. The research takes advantage of a capability developed by Mock and Hill who reported single nanostructure imaging of the nanostuctures in 2008. The work is made possible by a custom microscope in the Center for Metamaterials and Integrated Plasmonics built by Mock.

Brian Mann, assistant professor, specializes in dynamical systems theory, and nonlinear dynamics and vibrations research in application areas where analytical, numerical, and experimental techniques are required. Mann received $250,000 from the National Science Foundation for a three-year exploration of stochastic delay systems, and an additional $100,000 from the Office of Naval Research for work on parametric energy harvesting. He co-authored a book chapter in Delay Differential Equations: Recent Advances and New Directions titled “Stability analysis and control of linear periodic delayed systems” with Chebyshev and Truncated Fourier Exponential Methods.” The publisher is Springer-Verlag.
Turning Proteins Into Glass

Duke engineer and chemist David Needham has devised a method to dry and preserve proteins in a glassified form that seems to retain the molecules’ properties as workhorses of biology. Now he’s exploring whether the glassification technique could bring about protein-based drugs that are cheaper to make and easier to deliver than current techniques which render proteins as freeze dried powders to preserve them.

He describes this classification process as “molecular water surgery” because it removes virtually all the water from around a dissolved protein by pulling the water into a second solvent. “It’s like a sponge sucking water off a counter,” said Needham, who has formed a company called Bogyali (“gyali” means glass in Greek).

In collaborations with Duke’s Brain Tumor Center and Comprehensive Cancer Center, the researchers are seeking additional funding to do initial procedures retained all or most of their original activity when water was removed. The researchers speculate that these processes should be seen as a new class of proteins, whose unique properties could yield valuable insights into disease.

David, with graduate student Deborah Mickard, with protein microbead on screen.

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Genevieve Lipp

Major: mechanical engineering and materials science and German
Adviser: Brian Mann
Project: Energy harvesting from ocean waves

Sensor networks depend on remote power, which is usually supplied by batteries, but they are often undesirable due to their finite life span, need for replacement and environmental impact. Especially for small sensors, or those that necessarily have a low mass, the added weight of batteries is a problem. Sensors in remote areas (like the ocean) could especially benefit from eliminating the need for battery replacement. This project examines a method of harvesting energy from the mechanical vibration of ocean buoys using a nonlinear energy harvester. Suspending a floating magnet between two fixed magnets creates a nonlinear system because the magnets can be simply modeled with a force proportional to the inverse of the separation distance to the fourth power. However, there are various methods for modeling the magnet forces, which are vital to an accurate model for the system. This research has included determining the strengths and weaknesses of different math models for magnets by first constructing an experimental setup to accurately determine the force-distance relationship between the magnets, and then conducting trials for different magnet proportions. The most important outcome of the project is determining that the dipole model is appropriate for modeling magnet forces on the scale of interest with the manufacturer’s constants. It can now be used with confidence to determine a model for the energy harvesting system in the buoy. This model will be useful in projecting possible gains from an energy harvester and predicting the optimum frequencies it can respond to in its environment.

Future plans: Genevieve graduated with distinction in mechanical engineering. She was also a Pratt Engineering Undergraduate Fellow. She will be completing her Ph.D. in Mechanical Engineering and Materials Science at Duke under Dr. Mann...
Entrepreneurship

Mechanical engineering students competed well in the 2010 Duke Start-up Challenge business plan competition. The Micropower team won the $500 Student’s Choice elevator pitch competition for a technology called Micropower that leverages micro turbine technology, powered by biofuels, for remote power generation. The team’s micropower units will have a variety of applications ranging from hybrid battery systems to battery replacement. They can also be used alongside fuel cells to create distributed power storage. The team includes three doctoral students: William Gardener ’12, Andrew Camacho ’12, and Ivan Wang ’12, and master of science engineering student Hardy Shen ’10.

NAE Grand Challenge Summit

Students were challenged to develop a solution to a National Academy Engineering Grand Challenge for a resource poor, developing world environment. Mechanical engineering students swept the competition.

First Place: Sophomore Amanda Britt, who is double majoring in biomedical engineering and mechanical engineering, won first place and a travel stipend to attend the National Summit event in Los Angeles in October. Her poster was titled “The X-Ray Development Timer: A Device for Improving Diagnostic Efficiency and Accuracy in the Developing World.”

Second Place: The mechanical engineering team of seniors William Patrick, William Duncan, Ryan Burd and Michael Williams won second place for their research titled “Ultra-Violet Water Purification Business in a Box.”

Graduate Students

Stephen Clark has won a 2010 National Defense Science and Engineering Graduate (NDSEG) Fellowship. He was selected from an applicant pool of more than 2,500. The NDSEG Fellowship is sponsored and funded by the Department of Defense and will cover full tuition and fees for three years and provide a yearly stipend. Stephen is pursuing graduate work in the aerodynamics area.

Jonathan Boreyko, who works with Assistant Professor Chuan-Hua Chen, gave a 30-minute invited talk at the inaugural Faraday Discussion Graduate Research Seminar sponsored by the Royal Society of Chemistry, a companion to the prestigious series of Faraday Discussions in physical chemistry, chemical physics and biophysical chemistry. He won 2nd place in the poster contest out of more than 70 student posters for his work on the wetting dynamics of hydrophobic and structured surfaces. To make this success even sweeter, Jonathan had already won a fellowship that covered his attendance at the forum.

Minkyu Kim won a 2010 Student Research Achievement Award for his outstanding poster presentation at the Biophysical Society 54th Annual Meeting last month in San Francisco, California. Minkyu’s research in molecular biophysics was titled “Single-Molecule Atomic Force Spectroscopy Captures A Novel Class Of Molecular Nanosprings With Robust Stepwise Refolding Properties.” He works with Professor Pieter Marszalek.

William Gardner has won the 2010 Dean’s Award for Excellence in Mentoring from the Duke Graduate School. William was presented with a $1,000 award at a reception on Thursday, April 15, 2010. This is the second time a mechanical engineering student has been selected to receive this prestigious award, which recognizes invaluable service to the university by being a sterling example of mentoring in action.

Firas Khassawneh, a doctoral candidate in mechanical engineering under the supervision of Brian Mann, has won a fellowship from Duke’s Graduate School that will enable him to travel to the University of Bristol in England to enhance his dissertation research. He plans to visit the University of Bristol this upcoming summer. Firas is investigating the of systems that contain time delays in their mathematical models. Examples of his current and planned work consider self-excited instabilities in machining, hardware in the loop or hybrid testing, and chaos control. Congratulations, Firas. You make us proud.

Jeff Coles and Robert Ferris, each won second place in the graduate student poster competition of the 56th International Symposium of the Remmy American Vacuum Society in San Jose. Both students will receive a cash prize of over $400. The two won with Associate Professor Stefan Zauscher.

Good Vibrations

Since he was three years old, Ben Davis E’05, Ph.D. ’09, remembers gazing skyward. After seeing the Goodyear blimp gliding effortlessly above his house one day, the flight “bug” bit him.

Fortunately for him, as well as for future astronauts, this fascination with flight remained strong. He felt destined to work for NASA, and this interest led him to Duke University, where his research at the Pratt School of Engineering as both an undergraduate and graduate student caught the eyes of researchers at the National Aeronautics and Space Administration (NASA).

Since graduating in 2009, Davis has been following his dream at NASA’s Space Flight Center in Huntsville, Alabama.

As his mentor at Duke, Lawrie Virgin, professor of mechanical engineering and materials science, said, “These vibrant vibrations didn’t so much affect the structure of the vehicle, but would make the astronauts’ eyeballs go crazy.”

Not acceptable. An answer had to be found.

Fortunately for NASA, Davis’ interest lay in developing mathematical models to better understand the vibrations inherent in the violent process of rocket blast-off. During his time at Duke, he came up with a novel way to explain these vibrations, which could lead to new ways to make any future space flight more bearable to astronauts.

“At first I was motivated by the cracking that was observed in components of the Space Shuttle’s main engine during blast-off,” Davis said. “A large contributing factor was the interaction between acoustic sound waves in fuel tank and the rocket structure itself. My dissertation addressed methods of analyzing that interaction between acoustic and structural vibrations.

“Traditionally, engineers would first try to solve the acoustical problem, then look at the structure,” Davis said. “My approach was to look at both at the same time as a whole, and as it turns out, the responses are quite different.”

While the future of the ARES project may be in doubt politically, future astronauts can be assured that when they head into space, at least they will ride in comfort. And their eyeballs will stay in their head.

Meredith Spiker, a former doctoral student of mechanical engineering Associate Chair Robert Kirby, just won a GE Clear Thinker award for her work in solving a complex aeronautics start stall problem a customer was having with a production engine. Meredith works for GE Aviation in Lynn, Mass.
Since graduating in 2005 with a degree in mechanical engineering, Noel Bakhtian has continued the life of an academic. She is currently in the middle of her PhD program in aeronautics and astronautics at Stanford.

Although her program has a heavy workload, Bakhtian admitted, “It’s wonderful to be able to pursue a specific field in more depth. I do most of my research at NASA Ames, utilizing their CFD codes and supercomputers to do research on supersonic retropropulsion for heavy-mass Mars landings.”

As one might imagine, working at NASA has come with a whole host of interesting experiences for her. “I still can’t believe I get to see C-130’s and F-16’s doing touch and go’s in front of my building at NASA,” she said, laughing. “And I landed a 757 at San Francisco International Airport! OK, I was in the NASA flight simulator.”

She also presented at the AIAA Space Conference in September about the benefits of returning humans to the moon. “Buzz Aldrin came to my talk!” she says excitedly. “I still can’t believe it.”

Much of her success she attributes to her higher education at Duke. “Pratt gave me a solid foundation in engineering which prepared me well for the intense graduate classes at Stanford. Aero/Astro is very interdisciplinary, with structures, dynamics, controls, and fluids all playing a large role,” she said. Her adviser was Professor Earl Dowell.

Bakhtian found her research experiences at Duke to be especially helpful in her higher education. “The Pratt Undergraduate Research Fellows program was incredibly helpful in introducing me to the field of research,” she remarks. “Having already performed research work before coming to graduate school definitely gave me an advantage.”

Bakhtian enjoys her life in Palo Alto, and has traveled extensively since graduating, another favorite past time. “I ran a half marathon in Budapest, sang Verdi’s Requiem in King’s Chapel in Cambridge and with Hvorostovsky in the Barbican in London. I got to meet George Lucas, saw the A380 land at SFO for the first time, climbed a volcano in Guatemala and sailed the British Virgin Islands,” she said.

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