McCormick

Northwestern Engineering

Mechanical Engineering

Robert R. McCormick School of
Engineering and Applied Science
Northwestern University

SPRING 2008

Jan Achenbach receives National Medal of Science

Jan D. Achenbach, Walter P. Murphy Professor and Distinguished McCormick School Professor of the Departments of Mechanical Engineering, Civil and Environmental Engineering and Engineering Sciences, and Applied Mathematics, received the National Medal of Science from President George W. Bush at a White House ceremony on Friday, July 27, 2007.

Achenbach was honored for his seminal contributions to engineering research and education in the area of wave propagation in solids and for pioneering the field of quantitative non-destructive evaluation.

The National Medal of Science honors individuals for pioneering scientific research in a range of fields — including physical, biological, mathematical, social, behavioral, and engineering sciences — that enhance our understanding of the world and lead to innovations and technologies that give the United States its global economic edge. The National Science Foundation administers the award, which was established by Congress in 1959.

Achenbach, who joined Northwestern in 1963, is a preeminent researcher in solid mechanics and quantitative non-destructive evaluation. He has made major contributions in the field of propagation of mechanical disturbances in solids. He has achieved important results in quantitative non-destructive evaluation of materials, damage mechanisms in composites, and vibrations of complex structures.

He has developed methods for flaw detection and characterization by ultrasonic scattering methods. Achenbach's work has been both analytical and experimental. He also has achieved valuable results on earthquake mechanisms, on the mechanical behavior of composite materials under dynamic loading conditions, and on the vibrations of solid propellant rockets.

Achenbach is founder of Northwestern's Center for Quality Engineering and Failure Prevention, a state-of-the-art laboratory for quality control in structural mechanics, with profound impact on the aircraft industry, particularly the monitoring of aging aircraft.

Achenbach was awarded the 2003 National Medal of Technology, the nation's highest honor for technological innovation. He was elected a member of the National Academy of Engineering in 1982, a member of the National Academy of Sciences in 1992, and a fellow of the American Academy of Arts and Sciences in 1994. In 1999 he was elected a Corresponding Member of the Royal Dutch Academy of Sciences. He is also an honorary member of the American Society of Mechanical Engineers and a fellow of ASME, ASA, SES, AMA, and AAAS. His other awards include the Timoshenko Medal and the William Prager Medal.

Faculty honors and awards

L. Cate Brinson co-authored a new book, titled *Polymer Engineering Science and Viscoelasticity.*

Sridhar Krishnaswamy and the Center for Quality Engineering and Failure Prevention received a Partnerships for Internal Research and Education (PIRE) grant from the National Science Foundation. This five-year, $2.5 million program will establish a global partnership of universities, laboratories, and companies.

Wei Chen was elected to the advisory board of the Design Society.

Ed Colgate (left) was named the first editor-in-chief of the IEEE *Transactions on Haptics*.

James Conley was awarded “Faculty of the Year” by the Master of Product Development Program.

Isaac Daniel was elected fellow of the American Society for Composites.

Kori Ehmann received the 2008 SME (Society of Manufacturing Engineers) Gold Medal Award.

Horacio Espinosa was selected to receive the 2008 Lazan Award from the Society for Experimental Mechanics and the 2007 Young Investigator Medal from the Society of Engineering Science.

Dean Ho received a V Foundation for Cancer Research Scholar Award and was invited to serve as an associate editor of *Journal of Biomedical Nanotechnology.*

Leon Keer (left) was appointed to the editorial board of *Mechanics Research Communications*.

Wing Kam Liu will receive the John von Neumann Medal from USACM and the Robert Henry Thurston Lecture Award from ASME. He was also appointed chair of the newly developed ASME Nanotechnology Council.

Kevin Lynch received the SAE Ralph Teetor Educational Award, was named the Charles Deering McCormick Professor of Teaching Excellence at Northwestern, and was selected to the Defense Science Study Group.

John Rudnicki received the Maurice A. Biot award of the ASCE and was elected chair of the DOE Geosciences Council.

Q. Jane Wang and her team were awarded $1 million for the congressional earmark project Extreme-Condition Military Vehicle Tribology.

ASME Applied Mechanics Division honors Ted Belytschko

Ted Belytschko, Walter P. Murphy Professor of Mechanical Engineering, is now the namesake of an American Society of Mechanical Engineers award. The society’s Applied Mechanics Division Award was renamed the Ted Belytschko Applied Mechanics Award at the society’s Honors and Awards Banquet on Nov. 13.

The award will be given annually to an outstanding individual for significant contributions in the practice of engineering mechanics, whether it’s through innovation, research, design, leadership or education. It includes a $1,500 check, a plaque, and travel expenses to the ASME International Mechanical Engineering Congress and Exposition meeting. The award is funded by a $100,000 endowment which was contributed by his former students, friends and software firms.

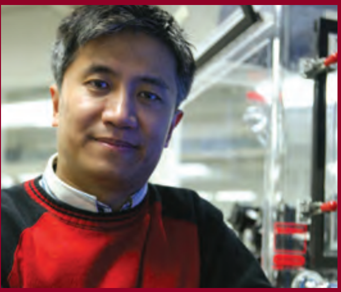
Belytschko pioneered explicit finite element methods, which have dramatically altered industrial practice in design, particularly crashworthiness design, by replacing prototype testing by computer simulation. Recently he has developed new meshfree methods and the extended finite element method for simulating arbitrary crack growth. These are already being implemented in industrial software. He is one of the most highly cited researchers in his field, with over 11,000 citations.

Belytschko is editor-in-chief of the *International Journal for Numerical Methods in Engineering*.

ASME is a professional organization that promotes mechanical and multidisciplinary engineering and allied sciences throughout the world. The society’s Division of Applied Mechanics fosters the intelligent use of mechanics by engineers and works to develop the area to serve the engineering community needs.

Professor Chang Liu joins mechanical engineering department

Professor Chang Liu joined the Department of Mechanical Engineering in the fall of 2007. Liu's research centers on sensors and sensing technology, and micro- and nano-fabrication. He has 16 years of research experience in the MEMS area. Liu earned his PhD in electrical engineering from the California Institute of Technology in 1997. He served on the faculty of the University of Illinois (Urbana-Champaign) from 1997 to 2007. He won the Xerox faculty research award as well as the Williet Faculty Scholar recognition at the University of Illinois. While there, he received a University-wide teaching award at the University and authored a textbook in the MEMS area, published by Prentice-Hall.



Chang Liu is jointly appointed at the Department of Electrical Engineering and Computer Science. His research crosses the traditional discipline boundaries. His recent interests focus on biologically inspired sensors and sensing technology — developing advanced micro- and nanofabrication technology based on innovative materials. This enables advanced sensors and systems with functions and/or structure inspired by nature. Nature and animals offer exquisite examples of sensory intelligence that is unmatched by engineered systems. By studying these biological inspirations and understanding them, one can gain insight into science and nature, and achieve quantum leaps in engineering capabilities. For example, Liu's group studies the lateral line-sensing organ of fish and amphibian animals and develops artificial lateral line systems for autonomous underwater vehicles (AUVs). Potential benefits of this study include new underwater flow sensors, innovative signal processing, and novel underwater vehicles that can operate autonomously in complex underwater environments. In terms of fabrication technologies, his group is interested in flexible sensitive skin and nanopore sensing devices.

Liu's research covers MEMS, nanofabrication, mechanical design, fluid mechanics, integrated circuits, sensor signal processing, and new materials. He collaborates broadly with biologists, chemists, material scientists, and experts in signal processing and circuit design. His group develops enabling micro- and nanofabrication technologies based on both semiconductor and polymer materials. He looks forward to fruitful collaborations with many faculty groups that will lead to advancements in science and engineering, to a better understanding of nature, and to commercialization of research results. As a teacher, he looks forward to interactions with both undergraduate and graduate students. Liu plans to be actively involved in service in the departments, in professional societies, and in the community at large.

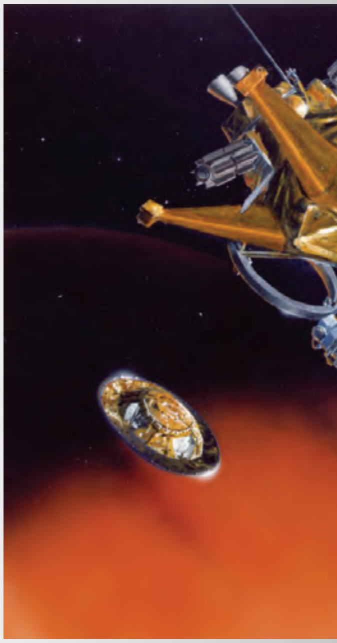
Exploring the depths of space

Research helps solve key problems for missions to Saturn and beyond

"To boldly go where no man has gone before."

It's a lofty goal, and a logistical nightmare. As scientists prepare spacecraft to explore the universe, they are challenged with designing for environments where there are often more questions than answers. In one of his projects, Professor Richard Lueptow strives to provide tools to help NASA and the European Space Agency clear key hurdles in their quest to explore our universe through unmanned space missions.

Lueptow's research has found application in unmanned probes exploring the moons of Saturn. After publishing several papers with post-docs Yefim Dain and Andi Petculescu about their work with NASA on the development of acoustic sensors for detecting gases in spacecraft cabin atmospheres, Lueptow was contacted by a team working on the Cassini-Huygens space probe to see if the same analytical techniques could be used to predict acoustical properties in the atmosphere of Titan, one of Saturn's moons. The Cassini-Huygens mission is a collaboration of NASA's Jet Propulsion Laboratory and the European Space Agency and consists of the Cassini orbiter and the smaller Huygens landing probe.

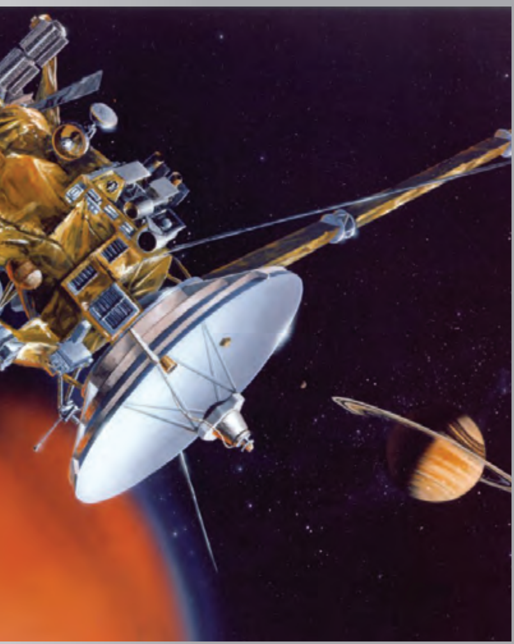


"We considered the gases that are present on Titan and thought we could absolutely predict the acoustics there," Lueptow says. "The reason that this is important is that often there are acoustic sensors on these probes. For instance, on the Huygens probe, there's a sensor that tracks changes as the probe moves through the atmosphere and lands on the surface."

While some past probes have used acoustic sensors, they haven't been standard on spacecraft, and there hasn't been a clear understanding of how sound propagates in different atmospheres. Lueptow's modeling techniques, which are based on quantum mechanics and the kinetic theory of gases, gave scientists the tools they needed to relate the acoustical properties of an atmosphere to its gas composition in order to better use the data captured by the sensors. With this ability, measurements of the acoustic properties obtained during descent can provide information on atmospheric composition and temperature. In addition, the sensors provide the ability to acoustically monitor thunder related to electrical storms, which can provide important data about the nature of the weather on a planet.

Lueptow describes this project as an unintended yet exciting result of his collaborations with NASA. And his work is providing solutions that may bring us one step closer to a deeper understanding of our universe.

An arms race
Building better prosthetic limbs



“We considered the gases that are present on Titan and thought we could absolutely predict the acoustics there.” –Richard Lueptow

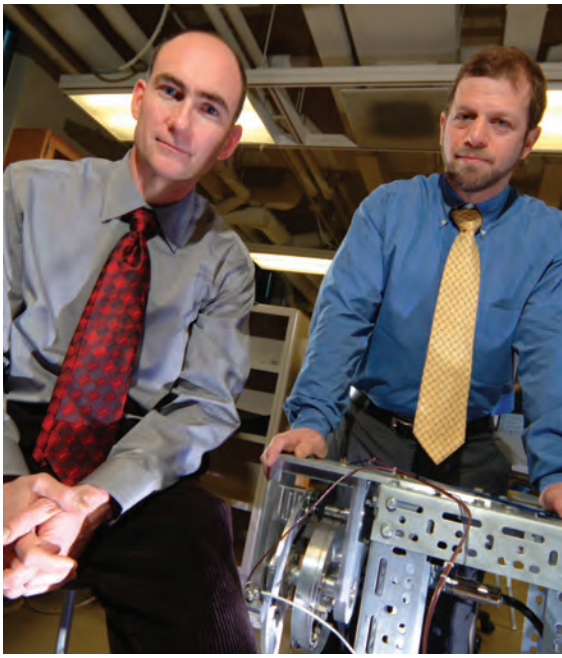
Researchers at McCormick are exploring ways to build and control better prostheses for arm amputees. Todd Kuiken (PhD ’89, Feinberg ’90), associate professor of biomedical engineering and physical medicine and rehabilitation and director of the Neural Engineering Center for Artificial Limbs at RIC; Richard Weir (MS ’89, PhD ’95), clinical professor of biomedical engineering and research associate professor of physical medicine and rehabilitation; Michael Peshkin, professor of mechanical engineering; and Ed Colgate, Pentair–D. Eugene and Bonnie L. Nugent Teaching Professor and professor of mechanical engineering, are pursuing collaborative research that aims to allow arm amputees to control their prosthetic hands and arms just as you control yours — without even thinking about it.

Peshkin and Colgate are building on concepts developed in Kuiken’s work in nerve transfer. Kuiken takes the nerves that would have gone to a missing arm and transfers them into the pectoral muscle. The nerves grow into the new muscle, telling it to contract and relax based on the signals that would have controlled the arm. Using these signals, the patient is able to intuitively control a motorized prosthetic arm. Kuiken’s first patient, Jesse Sullivan, was dubbed the world’s first “bionic man” after his successful nerve transfer in 2003 and the fitting and implementation of new prosthetic arms.

Unexpected results

Kuiken discovered that the nerves transferred into Sullivan’s chest also grew into the skin on his chest, causing him to feel touch and temperature applied there as if it were in his hand. With this unexpected finding, Richard Weir and others worked to develop a proof of concept for a device that could communicate the sense of touch to a patient’s chest. The team then connected with Michael Peshkin and Ed Colgate, who have based a significant part of their research on the study of haptics, or the sense of touch, mostly in relation to robotics.

Colgate and Peshkin are now developing tactors — microrobots that can convey haptic sensations to a patient’s chest — for use in conjunction with prosthetic arms. While the research is still in its early phases, the results have been remarkable. The device can apply force in several directions and heat up and cool down based on temperature sensors. In testing, Sullivan and Claudia Mitchell, a single-arm amputee outfitted with the bionic arm, have been able to differentiate between satin ribbon and sandpaper



and feel temperature changes. This advance has both practical and social importance.

“When I asked Jesse what he wanted to do with a sense of touch, he said he wanted to be able to hold his wife’s hand,” explains Colgate. “There’s a big social dimension to this work that is sometimes underappreciated.”

Humans and robots collaborate

Colgate and Peshkin are also focusing on developing an arm based on their work in cobotics, a class of robotic devices intended for direct physical collaboration with human operators. Their prosthetic hand runs off of a central motor in the forearm to control the hand through artificial tendons. This technology is inherently flexible, allowing the arm to have a similar amount of “give” as a human arm.

“I think this project may really advance the state of the art,” says Colgate. “Coupled with Todd Kuiken’s research, it has a shot at being really helpful.”

New professor focuses on the convergence of mechanics, photonics, energy, and biology

The McCormick School welcomed Cheng Sun as an assistant professor in the Department of Mechanical Engineering in fall 2007. Sun comes from the University of California at Berkeley, where as senior research scientist he led the development of novel metamaterials that create properties that do not exist naturally, e.g. the negative refraction of light, a superlens that breaks the diffraction limit, and negative modulus of acoustic materials. Using metamaterials, he also developed device applications for nano-imaging, nano-lithography, and bio-sensing. He completed his PhD at Pennsylvania State University, where as a graduate student researcher he developed a microstereolithography process for fabrication of complex three-dimensional microstructures and devices.

During the course of his doctoral research, Sun became interested in integrating mechanical engineering and biology for basic science applications. Using the microstereolithography process, one can design and construct three-dimensional (3-D) micro-fluidic networks to guide cell growth in 3-D. This method has unique advantages in supporting the study of cell-cell and cell-extracellular matrix interactions in a highly complicated 3-D environment. Ultimately, it could pave the way for the manufacture of large implantable tissues.

After joining UC Berkeley, Sun became interested in developing novel metamaterials, a new class of man-made composites that exhibit exceptional properties not readily observed in nature. Therefore, a much broader materials parameter space can be made accessible for metamaterials for unique engineering applications. In work published in *Science* in 2005, Sun used a metamaterial superlens to record the images of an array of nanowires onto an organic polymer at a resolution of about 60 nanometers. In comparison, current optical microscopes can only make out details down to one-tenth the diameter of a red blood cell, or about 400 nanometers. In his more recent work, published in *Science* in 2007, Sun further demonstrated the metamaterial hyperlens magnifying sub-diffraction-limit image at far field. Sun's research was highlighted in *Nature*, *Science*, *Scientific American* and has been featured in the international media.

Having fielded several offers from top U.S. engineering programs, Sun is excited about starting his career at the McCormick School. At Northwestern, Sun will focus on the development and characterization of novel metamaterials for energy conversion and bio-sensing, as well as a 3-D fabrication methods for potential tissue engineering applications. Successful implementations of this research have the potential to dramatically improve the capability of biomedical diagnostics as well as energy conversion.

Fig. 1

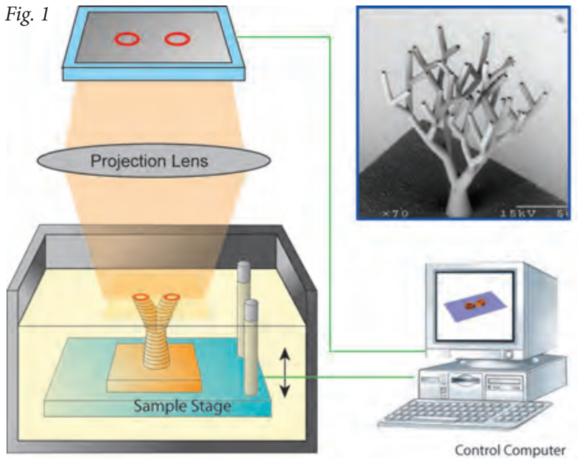


Fig 1. Micro-stereolithography method enables fully computerized fabrication of 3D micro-fluidic network at high-throughput; Fig 2. Nano-scale imaging using a silver superlens recorded the images of the word "NANO" at 60 nanometer resolution, much beyond the optical diffraction limit; Fig 3. Optical hyperlens that can magnify and project sub-diffraction-limited objects onto optical far-field.

Fig. 2

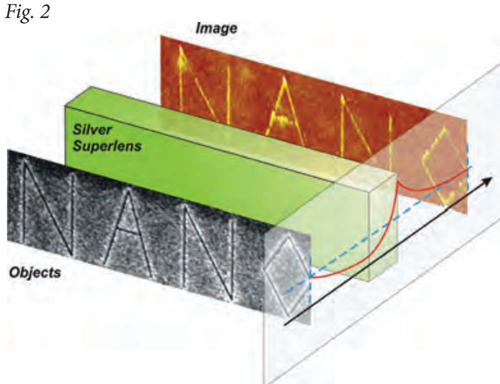
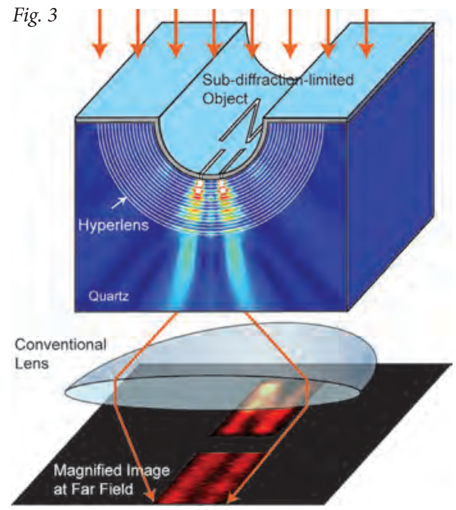


Fig. 3



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Cate Brinson takes the helm!

Cate Brinson, Jerome B. Cohen Professor of Engineering, started her term as chair of the mechanical engineering department in early September. After a PhD from Caltech in theoretical mechanics and research on smart materials at the German Air and Space Agency, Brinson joined the faculty at Northwestern in 1992. She rapidly developed a group specializing in advanced materials, where projects range from microporous active materials for bone implants to nanoreinforced composites for aerospace applications. Her work reaches from theoretical material descriptions to synthesis and characterization. She has delivered many invited talks on her research, most recently in Beijing, China, as part of a U.S.-China Bio-Nano-Mechanics Workshop. Brinson also serves on the National Materials Advisory Board of the National Academies and has participated in the recent study on benchmarking U.S. competitiveness in mechanical engineering. This background provides an excellent platform for her term as chair of the ME department. “We have such a fabulous array of talent in the ME department here at NU at all levels. ME of the future is not just about big machines; it is about nanomaterials, advanced sensing, adaptive and responsive systems, rapid prototyping, molecular rotors, and biomechanical interfaces. In short it is the design of systems that integrate traditional mechanical engineering knowledge with other disciplines to invent the engineering masterpieces of the 21st century. We are well-positioned with our current faculty and students to make stunning contributions and educate the next generation of mechanical engineering students.”

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