From the Director

Welcome to the inaugural edition of *Connect*!

At the Coordinated Science Laboratory, we see it as our mission to connect. And that philosophy permeates everything we do. CSL researchers, strongly rooted in fundamentals, come together from many different disciplines to tackle problems from a broad interdisciplinary systems perspective. This unique approach allows our researchers not only to contribute to basic science and engineering but also realize breakthroughs that have immediate national- and societal-scale impact.

It's a mission we are firmly committed to preserving, even in light of the state's current financial climate. While challenges remain within the University, CSL is successfully pursuing opportunities both regionally and nationally that continue to keep our organization strong.

We'd like to share just a few of those opportunities in this issue of *Connect*.
CSL is proud to play a key role in a new $25 million, NSF-funded Emerging Frontiers of Science of Information Science and Technology Center, led by Purdue University, which will develop novel interdisciplinary approaches for science and technology advancement. Three CSL researchers represent Illinois and will focus on work that could shed light on brain architecture, novel methods for medical treatments and design principles of next-generation wireless networks. Not only is our team part of a major federal initiative, but they also are pursuing breakthroughs that could transform life for the disabled, among others.

In addition, CSL is helping drive Illinois' new Neuroengineering Integrative Graduate Education and Research Traineeship (IGERT) program, recently awarded by the National Science Foundation. The $3 million grant will facilitate an educational program, housed at Beckman Institute, to train neuroscience and engineering students in an emerging field filled with endless opportunities. Two of CSL's faculty members played an instrumental role in Illinois receiving the IGERT, which will help establish Illinois as a leader in this exciting area.

Along with other research you'll read about in *Connect*, CSL is also poised to capitalize on tomorrow's innovations, such as 4D teleimmersive systems, smart building models and parallel architectures that require less energy and reduce programming costs without sacrificing performance.

We hope you'll take the time to connect with more information about our work in this newsletter and online at www.csl.illinois.edu. And thank you for giving us the opportunity to connect with you – our valued friend.

William H. Sanders

Managing Editor: Kim Gudeman
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Comments and suggestions are welcome. Please send them to kgudeman@illinois.edu.

igert

NEUROENGINEERING IGERT

The National Science Foundation has awarded Illinois an IGERT grant to study neuroengineering, an emerging field that falls outside the boundaries of traditional disciplines like neuroscience and engineering.

This fall, a select group of Illinois students will have engineering on the brain, thanks to a nearly $3 million grant through the National Science Foundation.

The 5-year grant is provided through NSF's Integrative Graduate Education and Research Traineeship program, which aims to spark interdisciplinary education in emerging frontiers. In Illinois' case, IGERT will provide graduate students with the opportunity to study neuroengineering, which falls outside the boundaries of traditional disciplines like neuroscience and engineering.

"So often, neuroscientists see the need for a new technology, but don't think it's possible," said Doug Jones, professor of electrical and computer engineering. "Engineers, conversely, often have the ability to make advances happen, but don't know what is needed. We're going to retrain students in both disciplines to tackle problems in a richer way."

The program will provide training for a group of 30 to 40 engineering and neuroscience students over five years. Students in both disciplines will immerse themselves in the other discipline through coursework and joint research.

The research will focus on three thrusts; the first two showcase key core strengths that are unique to Illinois, while the third has potential for transformational impact in the future. The thrusts are:

1. Audition – By learning how the brain processes sound, researchers will be able to build better cochlear implants and other types of hearing aids, among other benefits.

2. Neuroimaging – This work will focus on unlocking the mysteries brain functioning and identify what parts of the brain are active under various circumstances. The research will not only help engineers build more effective imaging technology, but also help doctors make better decisions at the bedside.

3. Brain-machine interfaces – This forward-looking thrust will look at how brain signals recognized intent. Applications include: A) rehabilitation – For example, a paraplegic could direct the movement of his wheelchair through thought; B) visual implants that stimulate the optic nerve and restore sight.

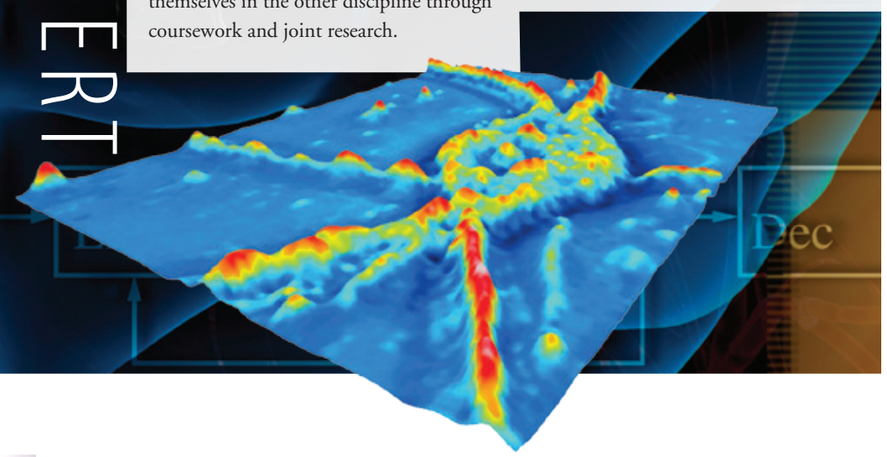
The research draws on the collective strength of Illinois' expertise in psychology, integrative physiology, biochemistry, audition and speech recognition, and engineering, particularly in the areas of materials science and electrical & computer engineering.

"We have world-renowned experts in these areas," said Todd Coleman, a professor of electrical and computer engineering and co-principal investigator. "Illinois could be a huge leader in the neuroengineering field. Both Jones and Coleman are researchers in the Coordinated Science Laboratory and Beckman Institute

Other co-principal investigators include Monica Fabiani and Bob Wickesberg, both professors of psychology.

The researchers believe that students may hold the key to breakthroughs in neuroengineering.

"Traditional neuroscience and engineering disciplines are deeply ingrained in traditional ways to view problems, which have benefits as well as limitations," Coleman said. "Sometimes ignorance is bliss: having an unbiased perspective can allow people to re-think problems in unique ways. This is the opportune time to cross-fertilize these two areas and attack problems with a combination of scientific and engineering viewpoints."



About IGERT

IGERT is the National Science Foundation's flagship interdisciplinary training program, educating U.S. Ph.D. scientists and engineers by building on the foundations of their disciplinary knowledge with interdisciplinary training.

Collaborative research that transcends traditional disciplinary boundaries and requires teamwork provides students with the tools to become leaders in the science and engineering of the future. Diversity among the students contributes to their preparation to solve large and complex research problems of significant scientific and societal importance at the national and international level. IGERT students obtain the personal and professional skills to succeed in the careers of the 21st century. Since 1998 the IGERT program has made 215 awards to over 100 lead universities in 41 states, the District of Columbia, and Puerto Rico. IGERT has provided funding for nearly 5,000 graduate students.

CSL researchers to study emerging information frontiers in $25 million NSF center

The National Science Foundation has awarded a group of nine universities, including Illinois, a $25 million, five-year "Science and Technology Centers" grant to develop novel inter-disciplinary approaches for science and technology advancement. CSL researchers Olgica Milenkovic, P.R. Kumar, and Todd Coleman, all electrical and computer engineering faculty, will represent Illinois in this endeavor.

The center will explore emerging frontiers of information science to develop a set of principles extending information theory to integrate the elements of space, time, structure, semantics and context. The team hopes to create formal methodologies, algorithms and computation tools to assist in analysis and modeling for the life sciences, communications, financial transactions and patterns of consumer behavior.

"We envision a future consisting of wireless and wireline networks that may well be revolutionary by today's standards," Kumar said. "Instead of transporting just data, they may transport information. This center will help confront the many long-term challenges in fundamental theory, architecture and design we must overcome to realize this vision."

The project, "Emerging Frontiers of Science of Information," will begin June 1 and is led by Purdue computer science professor Wojciech Szpankowski. The Massachusetts Institute of Technology, Stanford, the University of California – Berkeley, Princeton, Howard, Bryn Mawr and the University of California – San Diego are also participating.

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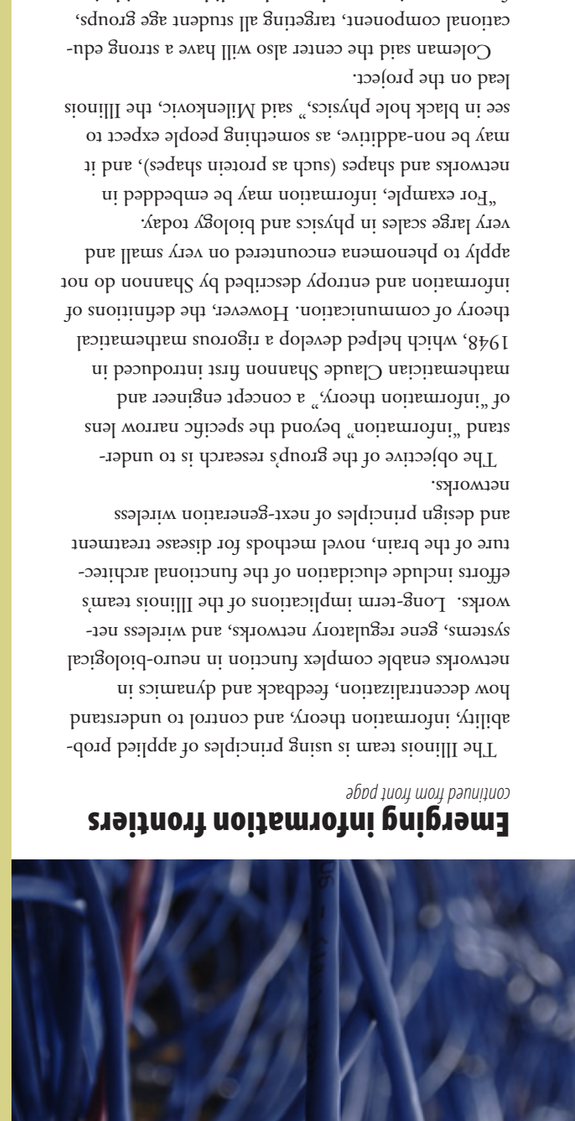

Emerging information frontiers

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The Illinois team is using principles of applied probability, information theory, and control to understand how decentralization, feedback and dynamics in networks enable complex function in neuro-biological systems, gene regulatory networks, and wireless networks. Long-term implications of the Illinois team's efforts include elucidation of the functional architecture of the brain, novel methods for disease treatment and design principles of next-generation wireless networks.

The objective of the group's research is to understand "information theory," a concept engineer and mathematician Claude Shannon first introduced in 1948, which helped develop a rigorous mathematical theory of communication. However, the definitions of information and entropy described by Shannon do not apply to phenomena encountered on very small and very large scales in physics and biology today.

"For example, information may be embedded in networks and shapes (such as protein shapes), and it may be non-additive, as something people expect to see in black hole physics," said Milenkovic, the Illinois lead on the project.

Coleman said the center also will have a strong educational component, targeting all student age groups, from mentoring post-doctoral candidates considering academia to implementing summer camps and teacher education for the K-12 community. Coleman, who was chosen to be the group's Faculty Diversity Coordinator, said that encouraging underrepresented groups and women to take part in scientific research is of particular concern to the NSF, and a special focus of this project.

"It is in the interest of our nation's economic prosperity to enable all members of these groups to harness their potential, unique thought processes, and creativity," Coleman said.

WHO WE ARE

The University of Illinois' Coordinated Science Laboratory is a premier, multidisciplinary research laboratory that focuses on information technology at the crossroads of computing, control and communications.

With a rich history of nearly 60 years of innovation, CSL has developed and deployed new technologies that have achieved international scientific recognition and transformed society.

Led by a faculty of world-renowned experts and researchers, CSL uses these innovations to explore critical issues in defense, medicine, environmental sciences, robotics, life-enhancement for the disabled and aeronautics.

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CONNECT

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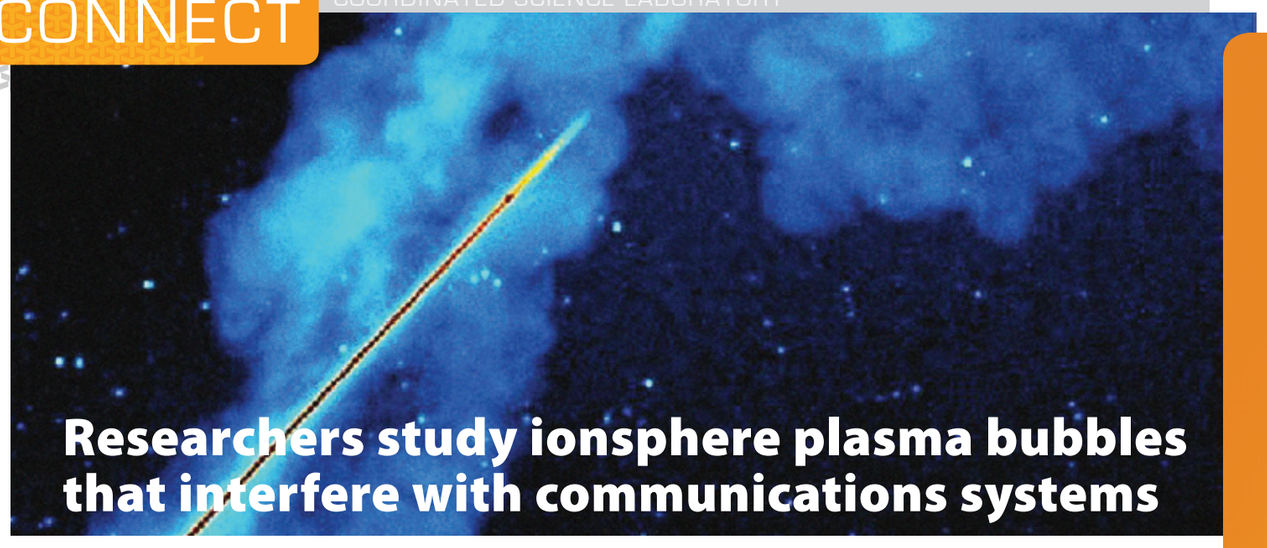


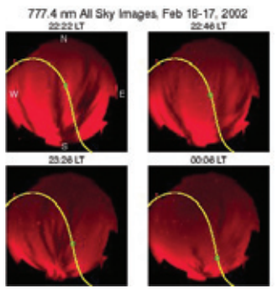
Researchers study ionsphere plasma bubbles that interfere with communications systems

High up in the ionosphere, plasma bubbles invisible to the naked eye wreak havoc on communication and navigation systems back on Earth.

Instabilities in the bubbles often cause over-the-horizon radars to either lose signals or to register readings from different regions than where they should be looking. GPS receivers can fail as these structures pass overhead.

Scientists, who have been studying the phenomenon for decades, are stymied about why the bubbles develop one night but fail to materialize under similar conditions the next night. CSL researcher Jonathan Makela hopes to change that through the Remote Equatorial Nighttime Observatory of Ionospheric Regions (RENOIR) project.

"These instabilities can really affect the reliability of critical satellite navigation and communication systems," said Makela, a professor of electrical and computer engineering at the University of Illinois. "Our hope is that RENOIR goes a long way in answering some of these questions."



Earlier this year, Makela and his team took two trailers of equipment to Brazil, where researchers will spend the next few years collecting data from the ionosphere. In Brazil, the magnetic equator and geographical equator are at a significant angle, 10 degrees, making this a unique region of the world to study. After the sun goes down at the magnetic equator, plasma bubbles can develop and create instability in the ionosphere. As the bubbles grow, they generate turbulence, which tamper with radio waves used by communications systems.

Makela's research will focus on how the development of these bubbles is controlled by both the ionosphere and waves generated in the terrestrial atmosphere. To accomplish this, his team has set up two sites about 150 miles apart near the cities of Cariri and Cajazeiras. After collecting data, researchers will synthesize data collected from three types of instruments:

1. PICASSO imaging system – The Portable Ionospheric Camera and Small-Scale Observatory (PICASSO) boasts custom lenses with a wide field of view that allows the system to capture images from horizon to horizon. It also is able to filter out different emissions, with bright regions indicating greater concentration of electrons and darker regions indicating plasma disturbance. Researchers can clock how fast the dark bands move through the lens, which offer a 1,000 km x 1,000 km view.

2. Fabry-Pérot interferometer – By studying the details of the spectral emissions created in the ionosphere with the interferometer, researchers can measure Doppler broadening (temperature) and shift (wind) at a 250-km range. This gives a measurement of the properties of atmospheric waves, which may be responsible for the variability in the occurrence of plasma bubbles.

3. GPS receivers – GPS can pinpoint where radio waves are being disrupted and, by comparing measurements from two closely spaced receivers, the velocity of the structures can be calculated. Comparing velocities measured at the two sites could provide insight into the disturbances and how they develop over time.

"Geospace is so large and complicated that you can't just take measurements from a single instrument at a single location," said Makela, who received funding from the Office of Naval Research to purchase equipment for RENOIR. "To understand how everything is interconnected, you need the right instruments at the right locations to make the measurements in an intelligent, coordinated way."

In addition to his Illinois team, Makela is working with researchers at Clemson University, the Instituto Nacional de Pesquisas Espaciais (INPE), and the Federal University at Campina Grande. RENOIR's deployment was funded by a NASA grant to Clemson, on which Makela was a co-principal investigator.

The research is part of a larger initiative called SpreadFX, a collaboration led by Colorado Research Associates (CoRA), in which several groups are fielding complementary instruments across Brazil to study this phenomenon in great detail.

"Ultimately, we want to get a better understanding of the conditions in which communication systems are degraded," he said. "If there is a structure that can't be mitigated, we need to understand where those structures are so we know where we have usable versus unusable skies."

For more information about Makela's work, please visit http://airglow.csl.uiuc.edu/Facilities/RENOIR/.

Researchers developing energy models with eye toward smart grid

By Kim Gudeman

During the summer of 2007, electricity prices shocked the Southern Hemisphere.

In Victoria, Australia, demand for electricity skyrocketed - and so did the price, to $10,000 per unit, many times higher than the average of $50. In neighboring Tasmania, prices crashed to -$1,000, with power companies paying the island to take electricity.

Researchers from the University of Illinois at Urbana-Champaign, including three from the Coordinated Science Laboratory, recently received a three-year, $1.03 million grant from the U.S. Department of Energy to tackle complex questions regarding energy markets. This research will allow for a deeper understanding of the competitive interplay between firms, power marketers and consumers in the face of uncertainty in both demand and resource availability.

Ultimately, the work will contribute toward the development of the smart grid—a system that is expected to lead to increased efficiency, lower power costs, and greater reliability.

During the past decade, deregulation has played a role in wildly fluctuating prices. Consider, for example, the 2000 California blackouts, during which power companies chose to "game the system" by reducing production during peak usage times to drive prices higher.

However, strategic gaming is not the sole culprit. A few years earlier during a brief period of deregulation, prices in Illinois shot to $5,000/megawatt per hour, at least one 100 times greater than the price before deregulation. The spike in this case was not the result of manipulation, but rather of plant operators being unable to meet increased demand, perhaps due to suboptimal technology.

In the markets of tomorrow, utilities will have access to a broad power portfolio including wind power and other renewable energy sources. Generation will no longer be restricted to conventional power plants but will be distributed in nature and include residential solar panels and small wind farms. In addition, consumers will play an important role in the market by responding to prices. For example, "smart" refrigerators and air-conditioners will dynamically curtail usage in response to increasing prices.

The Illinois team plans to develop the next generation of models that seamlessly accommodate new energy sources, distributed generation, and the activities of consumers. These models will be the basis for research on electricity markets of tomorrow.

Other team members include Prashant Mehta, a professor of mechanical science and engineering, and Swanlund Chair Tamer Başar, a professor of electrical and computer engineering.

While the Illinois team will primarily focus on electricity, their work could apply to many complex economic systems, including communication networks, health care, air and ground transportation and more.

Says Meyn: "We're looking at what kinds of restrictions you can place on deregulated markets to help achieve a system that works better for everyone."

Video users can be virtually present no matter their location, thanks to novel technology being commercialized by Illinois start-up Nuvixa.

The new system will enable people to chat, communicate, and collaborate more effectively using enhanced video presence. One application, for example, would give users the ability to virtually watch the Super Bowl together. The company, lead by CSL researchers Sanjay Patel and Minh Do, debuted the technology at the 2010 Consumers Electronics Show in Las Vegas to great reviews.

"The technology enables much more useful interaction with video than possible with today's solutions," said Patel, an associate professor of electrical and computer engineering and co-founder of Nuvixa. "People want more mobile, flexible, and fluid video interaction, embedded into the content they are sharing."

Through new algorithms and imaging technology, the researchers are creating solutions to enhance image quality, computational lighting, security, cueing and eye contact between users. The technology draws upon the Coordinated Science Laboratory's strengths in image processing, 3D graphics, and parallel and GPU computing. The net result is a virtual presence experience in which participants feel more connected with each other.

"This technology makes existing video-based applications, such as video chat and conferencing, even better due to dramatic improvement in user experience. In addition, video can be embedded into new applications and usage models, " Patel said.

Two CSL researchers named IEEE distinguished lecturers

By Susan Kantor, ECE

ECE Professor Venugopal Varadachari Veeravalli has been selected as a 2010 Distinguished Lecturer from the IEEE Signal Processing Society.

Veeravalli, who was nominated for the honor, will serve from January 1, 2010, until December 31, 2011.

As a distinguished lecturer, Veeravalli will travel to chapters all over the world to present one of five topics from his recent work in sensor networks and wireless communication.

ECE Professor Jean-Pierre Leburton, the Gregory E. Stillman Professor of Electrical and Computer Engineering, was selected to serve as an IEEE Nanotechnology Council Distinguished Lecturer through the end of 2011.

As part of his responsibilities, Leburton will give at least two lectures per year at Nanotechnology Council chapter meetings, or at chapter meetings of other IEEE societies.

Deng wins best student paper for modeling work at IEEE conference

By Megan Kelly, CSL

Kun Deng, Mechanical Engineering graduate student, received the Best Student Paper Award at the 48th IEEE Conference on Decision and Control in Shanghai, China in December.

Deng co-authored the award-winning paper, "A Simulation-Based Method for Aggregating Markov Chains", with his adviser Professor Prashant Mehta and ECE Professor Sean Meyn, both members of CSL.

Deng's research makes use of Markov chains for modeling dynamic phenomena in buildings, accounting for the large dimension of state space.

Chiu studies converter efficiency with Intel grant

By Megan Kelly, CSL

CSL researcher Yun Chiu is pushing data converter energy efficiency close to its fundamental limit, thanks in part to a competitive three-year grant totaling $478,850 that Intel recently awarded Chiu.

The Intel "High Performance CMOS ADC with Unprecedented Energy Efficiency" funding will support Chiu's research in the data converter area, where he and his team of students are attempting to make analog-to-digital conversion more energy efficient.

According to the Intel grant proposal, during analog-to-digital data conversion "physical quantities such as audio, video, radio-frequency signals, sensory outputs, etc. are converted back and forth between their original analog forms and computer-compatible, ready-to-be-processed and -stored digital bits."

Winslett is named Director of Singapore-based Advanced Digital Sciences Center

By Kim Gudeman, CSL

The University of Illinois has named Marianne Winslett as Director of the Advanced Digital Sciences Center (ADSC) in Singapore. ADSC, operated by the University of Illinois and funded by the Agency for Science, Technology, and Research (A*STAR), is focused on breakthrough innovations that will make human-machine interactions as seamless and trustworthy as our interactions with each other.

Winslett, a professor of computer science and a member of the Coordinated Science Laboratory, assumed the title of Director last fall. Her research interests focus on information security and the management of scientific data.

As ADSC Director, she will provide leadership on the Human Sixth Sense Program, ADSC's signature project that seeks to seamlessly integrate human and machine interactions.

Building a bionic knee

CSL alum Robert Horst has developed a robotic knee to help rehabilitation patients with muskeoskeletal, neuromuscular deficiencies

While Robert Horst was in high school, he suffered a knee injury that required three surgeries to fix. He endured a long healing process, and the primitive rehabilitation technology used frustrated him. So he decided to do something about it.

Horst, who received his MSEE in 1978 and Ph.D. in Computer Science in 1991 from the University of Illinois, envisioned a company that developed sophisticated, robotic medical devices and therapies to help patients with musculoskeletal and neuromuscular deficiencies. After working more than 30 years in computer design, he decided it was time to make his vision a reality.

"The idea to create a robotic device was always in the back of my mind, and I eventually got the opportunity to do it," he said.

Horst cofounded Tibion Bionic Technologies with Kern Bhugra in 2002, and immediately began creating and marketing the PK 100 Bionic Leg Orthosis, a powered, assistive leg device that enhances knee rehabilitation therapy.

The PK100 is a battery-powered device with sensors to detect what the person is doing. It reacts to those sensors and acts as an amplifier for the person's muscle movement.

"That's important, especially in stroke rehab, because recent research in neuroplasticity has shown that the neural pathways can be retrained, but it requires the patient to be actively involved," Horst said. "With our device, they can walk with a much more normal gait, and when they do that, they're retraining the neural pathways to produce the right muscle forces."

Tibion received capital funding in 2006 and a medical device license for its product in 2008. This allowed the company to begin testing with actual patients at several different physical therapy facilities.

Horst said the company found the device to work very well, particularly with stroke patients who had hemiparesis, a condition that creates a weakness on one side of the body.

"Using our device helped correct several problems and taught the patients to walk better," Horst said. "Even people who experienced a stroke several years before learned to walk better after only a few sessions."

The product also shows promise for people recovering from traumatic brain injuries and incomplete spinal cord injuries; patients with Parkinson's disease and MS; and those with mobility problems due to total knee replacement surgery or arthritis.

After seeing positive results with the first patients, Horst said three clinics have begun therapy programs based on the product, with several more showing interest and serious consideration. In addition, Tibion has won two awards for the PK100. And while its focus is on the PK100 presently, Tibion has plans to expand its product line.

"I think there's a huge future for robotic therapy and assistance devices. Our PK100 is really the first commercial device in this field," he said. "We can imagine devices that assist other joints and devices that would be more affordable so that a larger population of people can use them."

CSL researcher joins RobotCub project

CSL researcher Steve Levinson, ECE, received an iCub from the RobotCub project, a cognition study funded by the European Commission that started in 2004. Levinson's team is the only one in North America to receive this robot.

The goal is to study human learning. But long term, the research could yield a robot capable of making independent decisions about household chores or care-giving.

NASA launches Hovakimyan's novel flight control system

Mechanical Engineering Professor Naira Hovakimyan pioneered the first successful flight of an all-adaptive flight control system on NASA's AirSTAR test vehicle on March 24 in Fort Pickett, Va.

Using her novel L1 adaptive control flight system, developed with Professor Chengyu Cao of the University of Connecticut (her former postdoctoral student), Hovakimyan aims to improve the performance and safety of aircraft in the presence of uncertainties, which refer to anything that cannot be modeled perfectly, such as turbulence. The aircraft applications present an ideal testbed for testing the performance of adaptive controllers due to their large variations in speed and altitudes.

Irene Gregory, a senior research engineer at NASA Langley Research Center, believes L1 adaptive control theory is a breakthrough in the field because it is the first control system to allow for fast adaptation with guaranteed robustness and performance.

The researchers will conduct further tests in June and September 2010.