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Technology is a large part of what defines us as humans. Our abilities to adapt beyond our environment, communicate beyond our voices, and grasp beyond our reach are products of the technologies we have innovated. Technology is not only the concern of a researcher in the laboratory or an engineering student in a classroom. It is the enabler of all we do. Throughout our lives, every person—man and woman, child and adult—is invested in and defined by technology.

Technology has a universal impact, and so this inaugural and each ensuing issue of Innovate is produced with a universal readership in mind. While as a university we may first speak to our alumni, faculty, staff, industrial partners, and other friends, as a land-grant institution we speak more broadly to those we are here to serve: the people of Iowa, the nation, and the world.

Our mission as a land-grant college of engineering, to develop the technologies that improve people’s lives, is in large part unchanged from prior years. However, the way we fulfill that mission must change. It must adapt and respond to a world of rapidly accelerating social, economic, political, environmental, and technological change if we are to thrive in the 21st century. Iowans in general—and those of us at Iowa State in particular—must, like the subjects of our cover story, embrace new ways of solving the most critical of society’s problems.

Consider Innovate, then, a chronicle of how Iowa State is evolving and adapting in order to help Iowa and the nation meet these demands, a mirror focused on how the College of Engineering prepares its students, the state, and more broadly the nation to address the many urgent issues of our day and to compete in a dynamic global economy. Whether we are successful in fulfilling that mission is for you ultimately to decide. As you make that assessment, consider the following:

- Innovation is not an option; it is a necessity. To remain competitive, to lead the competition, we must innovate technologies that are globally implemented. Aspiring to and becoming a leader requires that we accept risk, measured risk but nevertheless risk. We must broaden our intellectual diversity to extend beyond our traditional zone of comfort. We are where we are today because of the processes and culture we have followed. If we truly aspire to be technological leaders, we must accept the risk of challenging those processes and that culture.

- We must accelerate our transition into the post-petroleum era. It is difficult to conceive of a world where our own standard of living continues to improve, let alone that of billions in the third world, while still relying on fossil fuels for our daily necessities. Every field of engineering must bring its best and brightest to the table to solve this most critical of society’s challenges, from innovating sustainable processes to developing renewable sources of power.

- The world is becoming more interconnected—not less; more complex—not simpler. We must acknowledge this transformation by changing the way we educate our students to produce systems engineers in every field who think and work across the entire spectrum of engineering disciplines. Whether the “system” is a suite of complementary technologies that form an elegant solution or a larger social or economic process of which that technological solution is only a part, our students must have the vision to see beyond their narrow disciplines.

- We as engineers must be more vocal in the public debate on the wise use of technology…

...in order that the most critical of society’s problems are solved efficiently, humanely, and in a timely manner. Engineers must aspire to and successfully serve in elected office far beyond their present numbers if we are to successfully address these problems.

The challenge we offer you is to watch us, both in these pages and on the Web, and to hold us accountable, to demand more of us—and of yourselves as partners in this enterprise. Together, we can have the greatest positive impact on our own and our children’s futures.
Iowa State team builds crystals in open air

Researchers from the Department of Materials Science and Engineering and the U.S. Department of Energy’s Ames Laboratory have manufactured the type of 3-D photonic band gap crystals used in advanced optical communications—only four millimeters square and 12 layers high—in the open air instead of “clean” rooms with equipment costing millions of dollars. “When people hear we’re doing this in open air, it really amazes them,” says MSE Associate Professor Kristen Constant, “especially when you realize a speck of dust can disrupt the whole structure.”


CCEE researcher fights waterborne pests

Zebra mussels in the Mississippi River, sea lampreys and spiny water fleas in the Great Lakes, 230 exotic species in San Francisco Bay—these unwelcome guests got there hitching rides on commercial ships, which pick up the parasites as they fill ballast tanks with water and dump them thousands of miles away. With more than $3 million from government and commercial sponsors, Hans van Leeuwen of the Department of Civil, Construction, and Environmental Engineering is helping to develop an ozone-injection system to clear the creatures out.


IOWA STATE SUPERCOMPUTER TO SEQUENCE MAIZE GENOME

A team led by Srinivas Aluru of the Department of Electrical and Computer Engineering has acquired a $1.25-million IBM Blue Gene/L supercomputer to advance their work toward sequencing the genetic structure of maize. One of the top ten university supercomputers in the U.S. and among the world’s 100 most powerful, Blue Gene/L has 2,048 processors, 11 trillion bytes of storage, and a peak performance capacity of 5.7 teraflops—or 5.7 trillion calculations per second. Iowa State has partnered with three other institutions on the three-year, $29.5-million project to sequence the corn genome, the most complex sequencing project to date.


Look for expanded coverage of Blue Gene/L, Srinivas Aluru, and other Iowa State researchers in “Iowa State’s brave new world of bioinformatics,” appearing in the Fall 2006 issue of Innovate.

IOWA STATE CENTER LANDS $10 MILLION FOR PAVEMENT RESEARCH

A $10-million federal appropriation to the Iowa State-based Center for Portland Cement Concrete Pavement Technology will help engineers from coast to coast develop pavements that last longer and need less maintenance. Part of last summer’s federal transportation bill, the funds will help Iowa State researchers find better ways to design concrete mixes, improve the restoration and preservation of pavement, and develop techniques to monitor concrete quality during construction.


ME PROF DESIGNS DEEP SPACE CONTROLS

How do you control a craft that’s 200 feet long, will take seven years to get to Jupiter, and needs pinpoint control to move from moon to Jovian moon? Ask mechanical engineering’s Atul Kelkar, who’s been working with a NASA team on the proposed “Jupiter Icy Moons Orbiter,” a vehicle powered by a nuclear reactor and electric ion engines. The probe is designed to look for signs of life-supporting water, thermal energy, and organic chemicals.


PHOTO COURTESY OF THE U.S. GEOLOGICAL SURVEY

PHOTO COURTESY OF NASA

PHOTO COURTESY OF NASA
Clover’s day will be busy: before meeting with corporate vice presidents and lunching with leaders from Iowa State’s College of Engineering, he’ll hold a conference call with his company’s D.C. office. He’ll also make arrangements for a trip to Europe next week. Always driven, Clover wasn’t always quite this directed.

Wrapping up his PhD in mechanical engineering in 1996, Clover knew it was time to think seriously about a career. He’d been at Iowa State for some time, earning a BS and an MS in aerospace engineering, as well as an MBA from the College of Business. Clover wanted to work in virtual reality and, with a background in both engineering and business, was leaning toward starting his own company.

A new discipline, a new business

Virtual reality was a relatively new discipline, with only a handful of companies working in the field. Still, like many contemplating a new business, Clover was hesitant. After all, he wondered, if opening and running your own business was so easy, why doesn’t everybody do it?

“That’s a good question,” says Jim Bernard, distinguished professor in Iowa State’s Virtual Reality Applications Center (VRAC). “It’s not like just anybody can do it. You have to have a certain fire and a certain fearlessness,” he adds. “It’s a scary thing to start a company because sometimes you lose. And if you lose, it’s not just a few years of work—it can also be your house.”

But the more he thought about it, the more Clover figured it was the perfect time to start a company; he didn’t have much money anyway, and it would certainly be easier to start poor and build wealth rather than have a job and take a big pay cut trying to establish a new business.

Two friends from VRAC, Jim Gruening and Kurt Hoffmeister, also wanted to go into business for themselves. Their mutual training, Clover says, gave them the experience and confidence they needed to start a business in the up-and-coming field. So shortly after graduation, the three men founded Mechdyne Corporation in Marshalltown, Iowa.

Their first client was the U.S. Naval Research Laboratory in Washington, D.C. The entrepreneurs made a small profit on that initial project, which they plowed back into the business. Impressed with Mechdyne’s work, the Navy hired them again, inspiring the company to market itself to more clients—big clients with familiar names such as Boeing, Conoco Phillips, Ford Motor Company, John Deere, NASA, and the U.S. Army.

Expanding nationally and globally

By 2002, Clover was ready to expand. He met with leaders from Mechdyne’s main competitor, Fakespace Systems Inc., headquartered near Toronto. The merger was completed in the spring of 2003, with Clover serving as president and CEO of the new subsidiary in addition to leading the parent company. Since the merger, Fakespace has become a global leader in developing, deploying, and enabling advanced visualization systems for engineering design, exploration, research, the life sciences, and entertainment.

“We had one primary competitor, and it became obvious that if you can’t beat them, join them,” Clover explains about the merger. “We knew we could be a better company by combining resources, so we struck a deal.”
In November 2005, Mechdyne grew again, acquiring VRCO, Inc., a company that develops interactive 3-D visualization software. Mechdyne was searching for the best way to expand its software capabilities, Clover says, and since VRCO had that expertise, combining the companies was a logical move. VRCO, Clover notes, will maintain its offices in Virginia as Mechdyne’s software products and services division, while Fakespace continues as the company’s systems integration division.

The Virginia Beach office increases to five the number of domestic Mechdyne locations. In addition to company headquarters in Marshalltown, U.S. offices are located in Houston, Los Angeles, and Washington, D.C., with foreign bureaus in Canada, China, France, Malaysia, and the United Kingdom. With the recent acquisition of VRCO, the corporation’s workforce now totals more than 100 employees, about half based in Marshalltown, with academic credentials ranging from associate’s degrees to PhDs.

“We have various skill sets that require engineering, project management, sales, marketing, and a lot more,” Clover says. “We’ve hired mechanical engineers and computer engineers from Iowa State. We have people from the University of Iowa and UNI, and we’ve hired several people from Indian Hills Community College to help install and design our systems.”

A model for the university and the state...

Mechdyne’s diverse, Iowa-centered workforce is just one benefit of the economic development model Iowa State is trying to promote based on the transfer of technologies developed at the university. Mark Reinig, economic development program manager for the College of Engineering and Center for Industrial Research and Service, says Mechdyne is the perfect model for university leaders, the state legislature, and the Board of Regents to encourage.

“Mechdyne shows how we can take technology developed at our state universities into Iowa’s communities to grow high-tech companies,” Reinig says. “This technology originated in the College of Engineering, moved to the commercialization phase, and then was developed by a company that has remained in Iowa despite its tremendous growth.”

Ted Okiishi, the College of Engineering’s associate dean for research and outreach, agrees with Reinig. “It’s a very successful international business that was started by an Iowa State graduate who decided to keep the company in the state,” he notes. “We hope all companies started by our graduates, faculty, or staff can be this successful.”

The College of Engineering, Reinig adds, works closely with faculty members and students who conceive ideas for potentially marketable products, helping them calculate the feasibility of commercializing a particular product. “We ask questions,” he says, “such as, ‘Is it best for this person to license his or her product or idea to a larger company? Or is it something he or she can make into a business, either alone or with the help of the university?’”

If the decision is made to start a new company, the budding entrepreneur can get help from the university’s research park, from writing a business plan to arranging for legal services. And since funding is usually the main obstacle, Iowa State can also provide assistance with finding those resources. Still, Clover acknowledges, raising venture capital can be difficult.

“Iowans are pretty conservative, for the most part,” he says. “If you’re looking for seed capital of, say, a half-million or even a million dollars, there are a few venture capitalists around. But if you’re looking at expanding your business and need 10 or 20 million dollars, that isn’t going to happen in Iowa. We need to raise the level of capital available for investment in the state, because that’s what’s happening in other places.”

...and a vision for the future

Fortunately for Clover, Mechdyne has the cash flow to keep expanding. And the CEO is confident his company can continue growing through internal expansion as well as additional acquisitions. “I would like to have a thousand employees in Iowa in the next 15 years,” Clover says. “If we keep working hard and provide great service to our customers, I think we can get there.”

There’s much to be done if that’s going to happen, Clover admits, but he plans to do whatever it takes, including searching for more acquisitions and mergers. He’ll gladly accept the challenges of traveling to Europe and Asia, search for the best and brightest graduates from Iowa State and elsewhere, and, of course, always keep track of the latest trends in virtual reality. In fact, don’t be surprised if Mechdyne sets most of those trends.

“We always have to stay a step or two ahead of the competition,” he says, as he calls to schedule another flight.
INNOVATE
SPRING 2006

Iowa State takes the lead in combinatorial discovery of materials

BY DENNIS SMITH
“Look.” The chemical engineering professor sweeps his hand over his desktop. “I can go to Krishna Rajan and say, ‘Here’s the data from 200 experiments I did in parallel. I’m looking for trends. So mine this; tell me what we’re looking for.’”

Narasimhan’s desktop database might have millions of data points. However, he might not have the luxury of time to sift through the data looking for trends. Take avian flu, for instance.

“I might be looking for a certain kind of polymer to activate immune cells to produce antibodies we need for a vaccine to work effectively,” Narasimhan says. “Krishna can analyze these experiments in six hours. If I did them one at a time, it would take 60 days.

“He could take that data and tell me, ‘OK, it looks like you have some action here.’” Narasimhan continues, punching the desktop with his forefinger. “And here and here.’ And since he’s just across the road, I can send him that data and say, ‘Do this for us.’”

Narasimhan relaxes in his chair. “And it’s not just me,” he adds. “There are 20 other people here who can do that now.”

Managing the numbers

While Iowa State’s Institute for Combinatorial Discovery (ICD) was not founded specifically to address doomsday scenarios like this, the rapid response capability of its core technologies is just one reason researchers such as Narasimhan are high on combinatorial science.

Historically, the discovery of new materials has been a painstaking process, often involving thousands of experiments conducted serially over months and years to achieve only incremental improvements at best. By contrast, using parallel computation, “CombiSci” researchers can conduct those experiments simultaneously, mining massive databases of properties to identify and isolate trends that can render a relative handful of the most promising approaches to a given materials problem.

A chemist by training, ICD founder and director Marc Porter notes that combinatorial techniques have been used by the pharmaceutical industry for years, with proven success in discovering new drugs. However, materials scientists have been slower to adopt the practice.

“Compared to materials science,” Porter says, “chemistry is fairly mature in terms of the ability to predict performance. We know how to manipulate a molecule to some degree, but we don’t necessarily know how to design new materials to be used, say, in some of Balaji’s vaccines, because these are now cooperative interactions of large polymers.

“These interactions have multiple length scales,” Porter continues, “the atomic scale, the molecular scale. So you need to know how groups of molecules interact, then you need to know how this group interacts with this other group.”

A call for innovation

Porter was the director of Iowa State’s Microanalytical Instrumentation Center when in 2002 Iowa State President Gregory Geoffroy called for proposals in “big picture” interdisciplinary research areas to attract resources to the university and create economic development opportunities for the state of Iowa.

“We built small stuff,” Porter says, “miniaturized devices that could go on spacecraft for exploration,
implanted devices, techniques to look at multiple biomarkers at one time to improve diagnosis."

However, Porter realized, the problem of negotiating multiple length scales in designing new materials was slowing down the process of taking miniaturization into new areas. As with any engineering application, their technologies would run into the inevitable limitations of the materials they were made from.

“We’d been growing a lot of these skill sets from the instrumentation and analysis side of things,” Porter recalls. “So what was the next step in the evolution of what we were doing? The call came from the president’s office, and the combinatorial discovery of materials just seemed like a natural fit.”

"People would ask ‘where’s the physics in all this?’"

The ICD was one of six initiatives selected by the president’s office for funding (see page 10). Within two years Porter had joined nearly two dozen colleagues from departments and colleges across the campus, including chemistry, chemical and biological engineering, physics, mechanical engineering, veterinary microbiology, and materials science and engineering. Yet despite this gathering of high-powered scientific and engineering talent, one critical component was missing.

“We were all experimentalists,” Narasimhan says. “We needed somebody who did informatics, who could take all that experimental data and mine it and process it and crunch it. So we found Krishna—quite easily, too, because he’s probably the top guy in the world in this field.”

From a ‘lack of focus’…

A native of Canada, Rajan had earned his bachelor’s degree in materials science at the University of Toronto and his doctorate from MIT, followed by a postdoc at Cambridge University in England.

Nation hopping would give way to career hopping. After nearly ten years with Canada’s National Research Council, with service on the side teaching biomechanics at the University of Ottawa’s medical school (his doctoral thesis was in implant materials), Rajan decided it was time for a change.

“I realized my research revolved around everything I’d done—a broad range of applications,” Rajan says. “I wanted the freedom to mix and match, to maintain flexibility in my interests. I always liked the idea of teaching, so I made the move.”

Rajan would spend the next 18 years at the Rensselaer Polytechnic Institute in upstate New York, where he moved effortlessly among his interests in materials, condensed matter physics, his core training in electron microscopy—and anything else that struck his fancy.

“We were dealing with a microscopy technique,” Rajan recalls, “and I got interested in the quantification of the technique—a data science problem. After solving the problem, I realized what the data-mining people were doing, and that you could apply that to any kind of data. But then the question became, what was the data? And where did you get it?

“There was not an ‘aha!’ moment per se,” he adds. “And it wasn’t new. I was aware of the question and had consciously thought of it in regard to materials over the last 10 to 15 years. I had the vague notion that you might be able to use informatics methods to relate information at one length scale to another.”

A process of self-education brought that notion into sharper focus, and Rajan’s rambling curiosity and restless intellect led him to confront some key issues in combinatorial science and materials informatics.

“I was always reading things outside my field—papers on biology and physics, social sciences, mathematics,” Rajan relates. “I’d get books from the library on climate change and geophysics, and I’d see how they were doing all of these model predictions using massive amounts of data to understand what’s going on.

“It was just a hobby almost, second nature to what I was doing,” he adds. “And for once, I think that lack of focus paid off!”

...comes a ‘CosMIC’ vision

No mere bookworm, Rajan didn’t limit his ruminations to other scholars’ pastures but also began talking to people from a variety of backgrounds. He would grab computer scientists in the Rensselaer hallways and ask them exactly what they did. He learned about the predictive power of data mining and began to immerse himself in a vast body of literature that had gone largely ignored in the materials science community.

“We in materials science do a lot of classification with data,” Rajan notes, “but we don’t do much prediction. So the data just sits there in textbooks. It gives you some guidance, but nothing more.”

Rajan’s thinking continued to evolve as he performed his regular teaching and research duties at Rensselaer. He attended meetings and gave talks as his vision of the marriage of materials informatics to combinatorial experimentation took shape.

But the interest of colleagues in Rajan’s ideas didn’t necessarily translate to support. He submitted proposal after proposal to funding agencies for research in the area that were routinely rejected.

“People would ask ‘where’s the physics in all this?’” Rajan remembers. “One reviewer wrote and said that the only way to discover new materials is the old-fashioned way, by trial and error.”

In 2002—about the time Porter and his colleagues at Iowa State were developing their proposal for the
Institute for Combinatorial Discovery—Rajan learned of a National Science Foundation initiative to establish a handful of “International Materials Institutes” (IMIs) dedicated to materials development. The experimental program seemed tailor-made for Rajan, requiring neither cost sharing, pre-screening, nor university approval.

It was, according to Rajan, a “shot in the dark”; he had no inside track. “So I wrote down what I believed. We entered a program that didn’t have many rules or regulations and threw our hat into the ring with about 80 to 100 other proposals. To my pleasant surprise, we were selected.”

And from its creator’s “lack of focus,” the Combinatorial Science and Materials Informatics Collaboratory—CoSMIC for short—was born.

Convergence: Porter, Rajan close the gap

Half a continent away, Porter and colleagues had shepherded their own proposal through review and selection as one of six Presidential Initiatives Iowa State would use to raise its profile in science and technology. But, Porter acknowledges, there were pieces missing to the puzzle.

“What we tried to identify gaps,” Porter recalls. “We had some really good people. But we had a couple areas where we needed to bring in some expertise.”

The ICD’s first major hire was chemical engineer Andy Hillier, a specialist in electrocatalysts, a field where combinatorial techniques have demonstrated early success. But Hillier was yet another star experimentalist on a roster full of stars both established and rising; what the ICD needed was an expert in materials informatics to serve as the program’s computational linchpin.

Rajan had the opposite problem: his network of experimentalists hailed from the four corners of the globe. But while they could collaborate via the Internet, the critical intellectual mass possible only through face-to-face interaction was not available.

While working on a major NSF proposal in 2003, Porter invited Rajan to Ames to share his experience in developing CoSMIC. Rajan accepted, and Porter wasn’t shy about making the next move.

“I asked other folks what they thought about trying to move Krishna here,” Porter recalls. “We approached Krishna. We asked him if he was interested; he was, so we started the chase.”
For his part, Rajan was a man just waiting to be caught: from the ICD’s core of nearly two dozen accomplished experimentalists to Iowa State’s international reputation in analytical chemistry and instrumentation to the presence on campus of the U.S. Department of Energy’s Ames Laboratory, Iowa State offered in one place the kinds of resources otherwise scattered across Rajan’s global IMI network.

“Krishna was looking for those kinds of things,” Porter observes. “It was a perfect match.”

**The revolution starts here: Innovation**

Like the partnership between Rajan and the ICD, the match between combinatorial experimentation and materials informatics is still in its infancy, and both Porter and Rajan are careful not to oversell the technology’s promise. Still, neither are they reluctant to tout CombiSci’s potential, not just for the discovery of new materials, but for Iowa State and the people of Iowa themselves.

“Our goal a few years down the road is to be recognized as one of the top centers on the planet for doing this stuff,” Porter offers. “Hiring Krishna goes a long way toward doing that.”

More than just “doing stuff,” Porter and his colleagues focus squarely on just what this “stuff” can do. Like Narasimhan, Rajan discusses the speed of the process in the context of current events. “The word I use is ‘acceleration,’” he says. “Right now, the pace of innovation from the lab to the marketplace with regard to materials technologies is inherently slow. You may have an issue with a time-limited horizon—fuel, energy, health care, security.”

Rajan invokes the specter of a bird flu pandemic,
adding, “My 50-second elevator speech to a senator who says, ‘why do you need this?’ is, very simply, that we just can’t wait for a disaster to happen before we come up with the technological part of the solution.”

Beyond realizing a more timely response to disasters natural or man-made, however, lies the promise of the unexpected, the accelerated discovery of knowledge leading to breakthroughs that redefine entire fields of science and technology.

“Combinatorial science goes from the known to realms you may not have anticipated,” Narasimhan stresses. “Sometimes, when you do an experiment, you know the trend you’ll get. But CombiSci throws things at you that you may not even have thought of. Doing experiments this way, you have the opportunity to make those breakthroughs.”
Iowa State Student Engineers Do Star Turns at NASA

Three selected for prestigious international conference in Japan

BY MARY JO GLANVILLE

The three 2005 Iowa State alums each contributed to NASA research projects while still undergraduates. In recognition of their outstanding work, they received all-expense-paid trips to Fukuoka, Japan, to present their research at the 56th International Astronautical Congress last October.

That’s a pretty amazing accomplishment—but these students are amazing too. Yet while they shared a common ambition as children and young adults, they followed unique paths to achieve their goals.

Kara Kranzusch: “Precision landing” on a promising future

A native of Appleton, Wisconsin, Kranzusch knew since 7th grade that she wanted to be a NASA flight controller. She attended space academy at Marshall Space Flight Center in Huntsville, Alabama, and was intrigued by how engineers monitor data and solve real-time problems to ensure the success of the missions.
Kranzusch came to Iowa State as an aerospace engineering (AerE) and public relations major. To complement her academic work, she applied for and received a co-op position at NASA’s Johnson Space Center (JSC). With her avid interest in astrodynamics and orbital mechanics, in 2003 Kranzusch chose descent analysis, a branch of flight dynamics and design, for the first of three tours with NASA.

During her initial tour, Kranzusch studied the feasibility of using a neural network—an “artificial intelligence” program—to determine if the 2009 Mars Science Laboratory (MSL) should abort its precision landing objective. Previous Mars rovers had used air bag systems to “bounce” to landings as far as 100 km off target, so the research was an important aspect of developing a new precision reentry guidance protocol for the MSL.

“One of MSL’s mission objectives is to land within 5 km of the target,” says Kranzusch. “Precision landing is an important capability, because when humans are sent to Mars we’ll send supplies first, and we need the humans to land in the same place.”

In a typical descent scenario, an on-board guidance system determines the descent approach based on multiple parameters, including flight path angle, velocity, altitude, and bank angle. However, because so little is known about the Martian atmosphere, traditional analytical abort determination techniques often do not work.

The challenge, then, was to determine if a neural network could be developed to address this deficiency. The neural network, according to Kranzusch, is a calibrated black box in which trajectory parameters are entered; based on the MSL’s deviation from these parameters, the network can predict any need to abort the landing.

Kranzusch was tasked with writing the network training code, determining the input and network parameters, and running thousands of iterations to find the optimal parameters to help the neural network learn the pattern of Mars descent. She addressed the specific scenario of a heavy storm in which high dust levels cause atmospheric expansion and reduced density at lower altitudes. Using traditional techniques, the MSL would deploy the supersonic parachute outside of constraints, causing a failed landing.

“My research showed that for a dust storm scenario, there’s an 18% chance of losing the vehicle,” Kranzusch says. “Implementing the neural network reduced that significantly to 3.5%.”

Since Kranzusch completed her research, NASA has been applying the algorithm she developed to a variety of abort scenarios in preparation for the 2009 mission. Her research paper won an American Institute of Aeronautics and Astronautics (AIAA) regional competition, and AIAA asked her to present the paper at the 2005 international competition in Japan.

Kranzusch received assistance at JSC from NASA mentors Gavin Mendeck and Richard Mrozinski and at Iowa State, where she continued working on the research as an honors project, from Frederick Haan, AerE assistant professor. After December graduation, Kranzusch returned to JSC to work on her certification as a space shuttle flight controller.

Andrew Riha: Communicating success in “real time”

It was a dream come true when Riha learned he had been accepted into NASA’s Undergraduate Student Research Program (USRP) for summer 2005.

A computer engineering major from Cresco, Iowa, Riha had chosen astronomy as a minor, but wasn’t sure how he could combine his two interests. Then one day it clicked: he could program computer systems for spacecraft and satellites through NASA’s USRP.

Now all he needed was to get in at NASA. Knowing USRP was highly competitive, Riha worked diligently on his application. He laid out his qualifications for his eventual assignment to the communications networks group at the Jet Propulsion Laboratory in Pasadena. A senior, he was able to cite comprehensive academic work as well as the design project in which he helped to develop a communications protocol for an autonomous helicopter.

Riha’s dream came true when he received his acceptance in May for a summer 2005 internship. NASA mentor Clayton Okino sent resource materials related to the research he would perform, including recommendations from the Consultative Committee for Space Data Systems (CCSDS) regarding
the Advanced Orbiting Systems (AOS) space-based communications protocol. Riha’s task would be to modify the AOS protocol to enhance space-based intelligent communications networks.

Deep space communications pose multiple challenges. It can take anywhere from 3 to 19 minutes for signals to travel from Earth to Mars, depending on the planets’ relative positions, and spacecraft have limited power for transmitting signals. Also, the Doppler shift caused by the movement of a planet relative to Earth “stretches” the signal. Finally, when a relay orbiter is behind the moon or a planet, it loses direct communication with Earth, requiring data received or generated by the relay to be stored until communication is reestablished.

Riha’s research involved classifying data as either “real-time” or “non-real-time,” then selectively discarding real-time data. Real-time traffic can be thought of as person-to-person communications, as in a phone conversation during which information goes back and forth seamlessly. By contrast, non-real-time communications are essentially robotic, and information processed robotically (e.g., e-mail or machine-generated images) seldom requires immediate transmission.

“Our goal was to modify a portion of the AOS protocol that specified whether data was being replayed or sent in real time,” Riha says. “We redefined two bits so four different types of traffic could be transferred: high-priority or low-priority real time, and high-priority or low-priority non-real time.”

The researchers developed simulations to determine what happens when the relay automatically discards real-time data stored when a connection to Earth is unavailable. This also allowed them to analyze how much space would be needed to store all non-real-time data during outages.

According to Okino, the CCSDS people are interested in the team’s approach, so research on the project is continuing. For his part, Riha continued to work on the problem fall semester at Iowa State with Ahmed Kamal, a professor in electrical and computer engineering, with a break in the action to present his research to some of the world’s leading aerospace researchers in Japan.

“The really cool thing,” Riha says, “is that something I worked on could end up a part of every single space communication in the future.”

Chris Hansen: A mind for materials, a mission to the stars

Growing up in Hills, Iowa, Chris Hansen wanted to be an astronaut. When he arrived at Iowa State in 2001, his interests had evolved, and he chose to study materials science and engineering because for him MSE represented the fusion of science and engineering. Not forgetting his love of space, however, he minored in astronomy.

He had no idea his twin passions would soon converge.

As a sophomore, Hansen worked in the lab of Rohit Trivedi, an MSE distinguished professor and Ames Laboratory scientist. Trivedi had been working on a NASA project when he received notice about NASA’s USRP. He wrote a recommendation for Hansen, who was accepted and began the first of three USRP internships at Marshall Space Flight Center in January 2003.

Hansen’s research focused on fabricating and testing a material that would protect astronauts from galactic cosmic radiation (GCR). The present generation of spacecraft and other space structures offers little protection against GCR, Hansen observes, and any metal such as lead would need to be several meters thick to stop the radiation—an option too heavy to be practical.
"I want to be a university professor," he says, "and integrate teaching and research so I can pass on knowledge to other students."

Hansen notes that the composite material comes on cylinders. "Fabricating panels out of it is very labor intensive," he says. "It's only about six thousandths of an inch thick so we had to lay a lot of pieces to get any sizeable thickness."

The research team's task was to determine the mechanical properties of the composite. One-foot-by-two-foot panels were fabricated and cured at high temperature and high pressure, then cut into pieces for testing. To assess strength, the team tested for tension, compression, and shear, as well as hypervelocity.

"We have an apparatus that sends spheres made out of aluminum and other materials at so many kilometers per second," says Hansen. "We had to see if it could stand up to micrometeoroid impacts."

Three years through the five-year project, the research has shown both that the material meets NASA's stated criteria for radiation flux reduction and that its mechanical properties provide adequate strength for structural integration into future spacecraft.

After his last internship, NASA's Office of Education selected Hansen to present a poster of his research at the International Congress. He was one of only nine USRP interns, including Riha, selected to travel to Japan.

A May 2005 graduate, Hansen is now a doctoral student at the University of Illinois. And while he can still see himself working at NASA someday, he has another goal. "I want to be a university professor," he says, "and integrate teaching and research so I can pass on knowledge to other students."
EN SCHOOL CHILDREN, AGES 8 TO 15, ARE IN A KITCHEN WHEN THE STOVE CATCHES ON FIRE. WHILE FLAMES LEAP INTO THE AIR, SMOKE BILLOWS THROUGH THE OVEN DOOR, CLIMBING THE WALLS AND SPREADING THROUGH THE KITCHEN, TAKING JUST A FEW SECONDS TO ENVELOP THE ROOM. ALL 10 CHILDREN DROP TO THE FLOOR AS THEY’VE BEEN INSTRUCTED AND CRAWL TOWARD SAFETY.

A potential tragedy? Fortunately, no. It was actually a fire simulation exercise in Iowa State’s Virtual Reality Applications Center (VRAC)—a simulation set up to prevent a tragedy, such as 10 children dying in a house fire, from happening.

A secure homeland means secure homes

Shana Smith, an associate professor of agricultural and biosystems engineering with an appointment in VRAC, developed the fire safety simulation with help from a one-year, $54,000 grant from the U.S. Department of Homeland Security, $6,000 from Iowa State, and hands-on assistance from the Ames Fire Department. Even Smith was a little surprised that Homeland Security took an interest in this type of research, but she soon realized that the agency does more than just prepare for terrorist attacks in the U.S.

The exercise begins with a small group of students watching a traditional fire safety video, followed by a short lecture by Ames firefighters. After that, the kids put on
3-D goggles and step into the virtual reality chamber, which “transports” them to a three-story mansion in Colorado with a view of the Rocky Mountains through the windows.

To ensure they’re not lost during the simulation, the kids are led through the house and shown their escape route. During this tour, firefighters ask the children to point out potential hazards along the way, such as an oven mitt left on a burning stove, a candle near a billowing curtain, or a book left near a lit fireplace.

The Ames Fire Department provided direction for setting up the hazards, Smith says. “We asked them to look at our environment and make suggestions on improving what we had,” she adds. “They showed us what we needed to fix to make it real.” Fire officials also helped Smith with flame placement and showed her how smoke would spread through a room in an actual fire.

**Lessons for a lifetime**

According to Smith, nearly every child who goes into the simulation comes back out fascinated. And when the entire group escapes safely from the burning mansion, they talk about their experience, bombarding firefighters with questions. The lessons are valuable and, Smith hopes, will stay with the kids for a lifetime.

“They learn by doing and practicing, instead of just watching a video,” Smith notes, “so they pay more attention and remember more. Virtual reality can fully immerse you inside that environment, and you get a better feeling of how to react in that situation. You really see how everything looks.”

Ames Deputy Fire Chief Paul Sandovol agrees. “School-aged children have heard this message over and over again,” he says, “but this is a different medium to get the message across. It helps retention because they see the fire in virtual reality—they remember to get low when the smoke comes down.”

“A lot of times kids get bored with a video or listening to someone talk about fire safety, and then they start daydreaming,” the 22-year veteran adds. “This is a new way to reach out to the students in a safe environment.”

Despite the absence of any real peril, there have been a few kids too frightened to set foot in the virtual reality mansion—at first, anyway. But after hearing their peers marvel at the experience, the ones who stay behind usually change their minds, put the goggles on, and head inside. It doesn’t take long for the fear to go away, Smith says, and those who stay behind at first always end up having a good time.

**Training more than kids**

Now that Smith has made the fire simulation such a valuable learning tool, she hopes to get more funding in the future. Her initial grant runs out in May. If renewed by Homeland Security or picked up by a different agency, Smith envisions a virtual model of a school, since kids spend more time there than anywhere other than home. She plans to simulate a fire inside a classroom, as well as in the hallway.

Sandovol thinks that’s a great idea. “The more ways we can do this,” he offers, “the better it is for the people we serve. It’s also good training for firefighters. It helps us make better decisions and improve on what we’re doing.”

Because the project received initial funding for only one year, Smith has focused her attention on school children in central Iowa. If the project receives additional money, she plans to expand the focus group and, eventually, broaden the program’s availability.

“It’s a great tool to train workers in different types of hazardous situations,” Smith notes. “We can put firefighters and other public personnel inside hazardous environments—without a real hazard—and train them to handle those situations.”
Q: Did you want to be a scientist growing up in Detroit?
A: Oh, yeah. When I got into my high school chemistry class, I said, “That’s what I want to do.”

Q: Any family influence?
A: My dad encouraged me to go to college. So I went to the University of Detroit, a private school—150 bucks a semester!

Q: You got your BS in chemistry. At that point, most people get jobs, but you ended up at Iowa State. What was your thesis on?
A: Rare earth carbides. I actually found a whole new sequence of compounds that weren’t known before. And then I investigated the lanthanum-carbon phase diagram, which had melting points ranging from 800 to around 2,300 degrees centigrade. I pretty much worked out the whole diagram.

Q: And then you went to Los Alamos. What did you do there?
A: Plutonium metallurgy. We did a lot of work on alloys, intermetallic compounds, and phase diagrams—basic knowledge.

Q: So what brought you back to Ames?
A: My co-major prof was leaving for Kansas State, so they had a slot open. Los Alamos was interesting, but basically I was just in charge of a section—three PhDs with a technician-and-a-half among us. I thought I’d come back to Iowa State and have graduate students and postdocs and work on all the things I was interested in.

Q: You were doing fundamental science early in your Ames Lab career, right?
A: When I first came we studied rare earth alloys, intermetallic compounds, determining structures, and phase relationships. And then I got into measuring low-temperature physical properties, primarily specific heat or heat capacity at low temperatures. Over the years, 95 percent of my money has been from basic energy sciences.

Q: What about the other 5 percent?
A: Well, in the late seventies I got a call from a DOE project manager who asked, “Karl, what have you done that has an impact on the American economy?” We had to say we did this and that and vaguely tied it to...
our research—it wasn’t direct. In the early nineties we started on magnetic refrigeration. A few years later at a program review, I made a brief explanation of magnetic refrigeration and tried to explain why we were interested in magnetic cooling.

Q: Well, that should have satisfied them.
A: No! One of the DOE guys jumped on me and said, “What are you talking about? You guys aren’t supposed to be doing this! You’re supposed to be doing the fundamentals, not applied research!”

Q: So you’ve caught it from both sides?
A: That’s right! They say our mission is in basic energy sciences, the fundamentals. Of course, when the bosses talk, they say, “Oh, yeah, we’re supporting magnetic refrigeration.” But if I say, “This work is going to support refrigeration”? That’s wrong. It’s a funny game!

Q: Well, maybe the DOE won’t read this. So when did you first get involved with magnetic refrigeration?
A: John Barclay at Los Alamos came to me about 20 years ago and said they were working on the magnetocaloric effect for magnetic refrigeration. I had done lots of work on magnetic materials, and initially I felt it wasn’t going to work.

Q: You told Barclay you didn’t think it would work?
A: I didn’t tell him that! I kept my doubts to myself. But in time I became a believer. A few years later he said, “Karl, we’ve got this material, gadolinium-palladium, but it’s too expensive. Can you come up with something just as good and much cheaper?” So I said, “Sure, I can come up with something.” My first choice was a rare earth aluminum alloy. I’m replacing palladium with aluminum, which means replacing kilo-bucks with pennies. Not only was my compound much, much cheaper, it was 30 percent better.

Q: This was in the eighties?
A: The early nineties. So they were happy. A year or so later I called Barclay and said, “You know, John, I think we might be able to get some funding for magnetic refrigeration that would work at room temperature. How about us putting a proposal together?” He said OK, so we were the lead lab.

Q: It seems you came some distance from your initial skepticism. Your Ames Lab colleague Vitalij Pecharsky says it’s not a stretch to call you “the father of modern magnetic refrigeration.”
A: I don’t think that’s quite fair. Other people deserve a lot of credit. Barclay was a prophet crying out in the desert and Carl Zimm was the guy who put the actual magnetic refrigerator together.

Q: So what brought you around?
A: I found the more I learned, the more I became like St. Paul: persecuting others, then finally getting religion, saying, “Well, this guy’s not wrong!”

Q: And now you’re one of the leading “apostles.” Did you have any particular applications in mind in those early years?
A: Yes: supermarkets—billions of kilowatts per year running meat cases, dairy cases, frozen vegetables, etc. We did some rough
calculations and thought, yeah, it might work. So we put the proposal together, got about $300,000 a year for three years, plus $100,000 for a superconducting magnet, and subcontracted half to Astronautics to build a “proof of principle” machine. We supplied them with materials for the apparatus—the gadolinium refrigerant—and showed that the magnetic cooling machine worked.

Q: OK, but how well did it work?
A: We approached thermal (Carnot) efficiencies greater than 60 percent—that’s almost unheard of. We had a coefficient of performance (COP) maximum of 16, which means you get 16 watts of cooling for one watt of input—really impressive.

Q: What’s the baseline for an average household refrigerator?
A: A COP of about two; better units maybe pushed to four.

Q: Those numbers suggest it would cost one-third or less to run a magnetic fridge than the unit I’ve got at home now.
A: Yeah, but you’re comparing apples with oranges. Our numbers were obtained under the most optimal conditions; they weren’t really practical.

Q: Maybe not, but that was eight years ago. Where have you taken it since?
A: Well, if you look at the thing realistically, eight years ago the coefficient performance was maybe one or two. We’re about even with gas compression technology now—probably four.

Q: But the prototype was fully functional otherwise?
A: We showed that it worked. By the time we finished, we’d logged 18 months at eight hours a day, five days a week, with basically no maintenance, just minor tweaking. The Japanese built a machine much like ours and reproduced our results.

Q: Speaking of the Japanese, how far does MR research extend beyond your group? Is scientific collegiality yielding to commercial competition?
A: Oh, sure. Most people working on the engineering aspects don’t want others to know what they’re coming out with. So unless they’ve got a patent, people don’t talk—they’re keeping their cards pretty close to the vest on this.

Q: Is anyone ahead of you and your partners at Astronautics?
A: My guess is no. But we don’t know! There have been about 16 magnetic refrigerators built since we announced our proof-of-principle machine in 1997. They’ve tried a lot of different things. And it’s good to know that if this guy tried something and it didn’t work, we don’t have to worry about it!

Q: Pecharsky thinks the Europeans and maybe even the Chinese might commercialize this technology before the U.S., at least on a large scale. Do you agree?
A: No. There’s a guy in France, and a lot of PR has come out. But I don’t think he’s as far along as he thinks. I think he’s got some problems—most people do.

Q: So what are some of the challenges that remain?
A: The scientific challenge is to come up with magnetic refrigeration materials that are better and cheaper. I’m looking at just the applied aspects. But for our basic research, the goal is simply to better understand the magnetocaloric effect. The better we understand that, the better we’ll be able to answer questions on the commercial side.

Q: And your partners at Astronautics?
A: Well, the other big challenge is engineering: what’s the best way to design this thing to get heat in and out? Astronautics keeps coming up
with designs that get better all the time. But this is a learning process. There may be better materials available than what we’re using now for a magnetocaloric effect, but they’re not cheap enough.

Q: Your original aluminum alloy didn’t do the trick?

A: That was for hydrogen liquefaction, not room temperature. There’s nobody in the world we can’t beat the heck out of with our materials at low temperatures. But that’s not where the money is. So there are lots of challenges to get the magnetocaloric properties at the temperatures you need. The best choice right now for near-room-temperature cooling is a lanthanum-iron-silicon alloy. It’s the cheapest and seems like it might do the job.

Q: OK. I’m going to put your collaborator on the spot again: Pecharsky suggested this technology might see commercial applications in the next six to twelve months.

A: Hmmmn—possibly. I don’t want to say more than that. But I said back in ’97 it’s going to be five to ten years. So I’ve still got one year plus to go!

Q: Am I going to be able to walk into Sears in a couple years and say “show me a magnetic refrigerator”?

A: I doubt it. But it’s possible we may see the first units then. Right now we’re working on the laboratory prototype. And they’re about to come out with a commercial prototype at Astronautics; that’s what our current contracts are about.

Q: But Astronautics isn’t going to manufacture refrigerators, are they?

A: Not likely. But they’re getting close to licensing the technology. I think there are companies with the guts to say, “Hey, we need to get a foothold in this so somebody doesn’t put the screws to us.” You have to take a risk and make some investments. Some are going to win and some are going to lose.

Q: But who’s going to buy the technology if the price isn’t competitive with conventional refrigeration?

A: Say a company decides they’re going sell magnetic refrigerators. And they’re going to cost twice as much as conventional refrigerator-freezers. But there are guys out there looking for new technology. “Yeah. Looks good. Let’s go get it. It doesn’t matter if it’s a flop in two years. I’ll throw two thousand bucks in—I use that kind of money to light my cigarettes.” There are those kinds of people out there.

Q: Would that be the same guy who paid $4,000 for the first DVD player?

A: You got it! There are people who want to be the first with a new technology.

Q: OK. But cars and consumer electronics are “sexy”—at least the marketing pros want us to think so. Some would argue there’s not much less sexy than a refrigerator.

A: No! What’s sexy is magnetic refrigeration!

Q: Oh, “magnetic.”

A: It’s the word: “magnetic.” That lights up everything because people know about magnets and stuff like that. They say, “Magnetic refrigeration? WOW!” You know, it’s got pizzazz just in the name!

Q: Well, it’s magnetic. And it’s “cool.”

A: Hey! It’s both!
Iowa State’s Vance joins ’95 alum to revolutionize mechanism design

BY MARY JO GLANVILLE
When Vance began her work, human-computer interaction was strictly a matter of using a keyboard and a mouse to manipulate information on a computer monitor. Animations of engineering analyses were rendered and written frame by frame to videotape or disc in a time-intensive procedure. With the advent of virtual reality (VR), however, Iowa State would find itself at the forefront in moving computer-generated graphics from two-dimensional monitors to three-dimensional VR environments.

**Refining the mechanics of virtual vision**

Seizing the opportunity afforded by this revolution in imaging, Vance began to develop tools for using VR to visualize and understand the design of rigid-link mechanisms, devices that can transmit power or control motion, yet will not themselves bend, stretch, or deform. Such mechanisms use linkages, joints, and fixed pivots to effect specific actions—for example, the crank on a casement window that generates a force to open the window when the user turns a handle.

Most rigid-link mechanisms are planar; that is, the motion of the mechanism’s working links is constrained within a relatively flat (if not two-dimensional) surface. With the development of VR, however, Vance began to explore spatial rigid-link mechanisms, devices whose combinations of links and joints are assembled to allow them to move more freely in three dimensions. As a demonstration, Vance’s team built a mechanism that could pick up soda cans from a conveyor and place them in a recycling bin.

While it is possible to make spatial mechanisms suitable for many of the general-motion tasks found in manufacturing, however, the multitude of potential mechanism configurations that might work for a given problem makes the design process extremely complicated.

“For example,” explains Vance, “say I need a mechanism that moves a part from position one to position two, then to positions three and four. After you’ve modeled the design problem mathematically and solved the equations, you might end up with 4 million possible solutions. We can use other equations to reduce the solution set somewhat,” she adds, “but we still might have 3,000 possibilities to consider.”

To help designers visualize and understand exactly how their mechanisms might look and move in actuality, Vance’s team developed VRSpatial, a virtual reality tool that converts these myriad mathematical solutions into three-dimensional drawings. The tool also offered designers an advantage over traditional computer-aided design (CAD) programs by focusing on possible solutions that fit intuitively into a given task’s design parameters, thereby radically limiting the solution set.

“With our VR tool,” Vance says, “the designer can pick up CAD models of the parts that will be moved by the mechanism, position them according to the design problem, generate and pick from a solution set, and then walk around the synthesized mechanism while it is operating. We call this ‘design in context’ because the designer can visually verify that the mechanism fits where it needs to and will perform the desired three-dimensional motion.”

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Ramping Up the Pace
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“Did North Carolina have a monopoly on semiconductors?” asks Krishna Rajan.

“Did Texas have a monopoly on microelectronics? It’s fine to focus on a technology because it’s relevant to some pre-existing foundation. But we also need to invest beyond what is already there.”

ICD team members have themselves entered the marketplace, launching the kinds of enterprises Porter says will form the backbone of an Iowa CombiSci industry. Porter alone has started two firms in the ISU Research Park—Advanced Analytical Technologies and CombiSep—both of which are going strong.

Nonetheless, the work of the ICD could also have a tremendous impact on Iowa’s traditional industries. Narasimhan, for one, foresees applications in food security and safety, particularly in the detection of foodborne pathogens and the development of therapies to counter them. “CombiSci,” he says, “can provide reliable ways to determine to what extent contamination has occurred.”

“It’s high-risk, high-reward,” Narasimhan adds. “But if you’re willing to take that gamble, this is the ticket. Business as usual is not something you will get with this method—as I said, it will give you answers you hadn’t even thought of.”

Countering the fading luxury of time

Given emerging crises, not to mention the critical economic and environmental challenges modern societies routinely face, science and technology no longer have the luxury of the 30-year time frames common to the 20th century for developing new materials. Nor, for that matter, do states like Iowa—places that have seen traditional economies turned on their heads—have 30 years to develop new industries to keep their towns and cities from emptying out.

Still, no matter how quickly methods such as CombiSci ramp up the pace of discovery, Rajan acknowledges, technology is no panacea for these problems.

“There are other components,” he acknowledges, “social, legal, political. And even in the technological part, we can’t just design our way out of a problem any more; we need to find other ways of making materials. The difference now is that we don’t have another 30 years to implement a solution.”

Rajan pauses to reflect, then adds, “That’s where we come in.”

A Virtual “Rule of Thumb”
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The promise of compliant mechanisms...

Today Vance’s groundbreaking work in developing human-computer interaction to solve spatial mechanism design problems in a virtual environment has led to a new collaboration with Martin Culpepper, a 1995 Iowa State graduate in ME and currently Rockwell International Assistant Professor of Mechanical Engineering at the Massachusetts Institute of Technology (MIT).

The two researchers teamed up after Culpepper visited his alma mater in 2004 to present a seminar on his work. Vance used the opportunity to take him into Iowa State’s C6, the world’s first wireless, fully immersive six-sided VR theater, and let him work with the tools her team had developed for designing spatial mechanisms.

Funded by the National Science Foundation, Vance and Culpepper’s three-year project focuses on using VR as a tool for designing compliant mechanisms, which enjoy a number of advantages over rigid-body mechanisms. Unlike rigid mechanisms, compliant mechanisms typically do not use joints or pins, relying instead on parts that flex or bend to achieve motion (simple examples include binder clips, backpack strap latches, and fingernail clippers).

Because they have fewer parts and can even be molded out of a single piece of material, compliant mechanisms are not only less costly to make, they are also relatively easy to miniaturize, offering increased precision, reliability, and reduced weight. These characteristics make them ideal for a wide variety of applications including consumer products, micro-electromechanical devices, and machines requiring precision controls.

According to Denis Dorozhkin, an ME PhD student and Vance’s research assistant, compliant mechanisms are a good choice for tasks in which engineers want to adjust the shape of a product. “For example,” he offers, “the Air Force would like to be able to change the geometry of the profile of a jet’s wing to optimize its aerodynamic characteristics for different stages of flight. The shape that enhances cruising speed can make the plane less stable at the lower speeds used for takeoff and landing. So the best design would have flexibility for altering the wing shape based on desired performance.”

Another possible application for compliant mechanisms, Dorozhkin adds, might be in automobile seats. Instead of providing manual or electric controls to adjust a seat’s lumbar support, for instance, a compliant mechanism that adjusts the lumbar support based on the occupant’s weight could be embedded beneath the seat. Applying force to the seat platform would cause the flexible structure in the seat back to change shape.

...meets the challenge of a non-intuitive process

Culpepper, who has gained national recognition for his work in the use of compliant mechanisms in precision engineering applications, led the MIT research team that developed the HexFlex, a novel six-axis nano-manipulator that was cited by the editors of R&D Magazine as one of the 100 most significant new technologies of 2003.

A flat, six-pronged aluminum device approximately six inches in diameter, the HexFlex is essentially a one-piece compliant mechanism that uses six axes to perform micro- and nano-scale positioning tasks, such as bringing together the ends of two fiber-optic cables. Three of the implement’s prongs are mounted on the base and three are tabs that can be moved in different directions with electromagnetic actuators. Adjusting these tabs moves the piece in the center, called the stage, on which the device being manipulated has been positioned.

Whether at the nano- or macro-scale, however, designing such mechanisms is an extremely challenging task that requires an understanding of both solid mechanics and mechanism kinematics. In order to realize the mechanism’s motion path through the compliance and deformation of its parts, for example, Culpepper’s MIT group employs constraint-based methods that an engineer usually must learn either directly through experience or through apprenticeship to a more
experienced practitioner. As a result, only a fairly limited and highly experienced group of engineers have succeeded in designing these mechanisms.

"The design process is highly non-intuitive, and often the only effective way one can learn is by actually designing and building such devices," says Dorozhkin, who spent several weeks at MIT learning about compliant mechanism design from Culpepper last fall. "Connected in a complex network, the flexible elements can have different thicknesses, lengths, and cross sections, and each variation affects the response. Until you try it, you usually don’t know how the mechanism is going to respond when you apply a force."

**A “rule of thumb” for successful design**

Vance and Culpepper have developed their collaborative project to enable a broader group of engineers to design compliant mechanisms by adapting tools developed by Culpepper’s MIT group for use in the kinds of virtual environments pioneered by Vance at Iowa State. While at MIT, Dorozhkin shared his expertise in VR with the Culpepper group, helping them set up a small-scale VR system.

In addition to the visual enhancements of VR, the MIT team also acquired two touch-sensitive devices so that they could actually feel forces as they’re applied to the modeled mechanism’s parts.

At their end, Culpepper’s team has developed CoMeT (i.e., Compliant Mechanisms Tool), a software instrument to assist students such as Dorozhkin and other engineers who aspire to design compliant mechanisms. The program, which runs on a tablet PC, converts the designer’s sketch into equations that are analyzed and then presented as a rendering of the compliant mechanism in its deflected state. CoMeT allows students to explore many designs and gain a working sense of the fundamentals of compliant mechanisms without spending hours creating and analyzing their geometry.

The MIT group is currently working on mathematical computations that will create all possible configurations resulting in a specified motion. Yet the possible is not necessarily the desirable; in addition to determining the precise motion of a compliant mechanism, an optimal design solution must take into consideration other factors such as accuracy, stability, and ease of construction. It’s a challenge quite familiar to Vance.

"They’re finding what we found with spatial mechanisms," Vance says. "All of the possible solutions for a given mechanism can be represented by geometric shapes. Our role with VR is to make sure the designers understand the three-dimensional nature of the solution space in order to pick out good solutions."

Once integrated into the virtual environment, the researchers will solicit real-world industrial problems to test the design framework, as well as applying it to Culpepper’s micro- and nano-scale precision manipulators. Still, as sophisticated as the design of mechanical devices has become, Vance reflects, in the end the tools she and Culpepper are developing accomplish for the 21st century essentially what their predecessors had to accomplish through a simpler process.

"The World War II-era engineers might not have had all of the book knowledge and math that underlies everything we do today," explains Vance, "but they knew intuitively how joints and links respond when you make adjustments. We’re trying to model this stuff so the ‘rules of thumb’ this previous generation of engineers were so familiar with are incorporated."
Regents approve engineering tuition surcharge

In December the Iowa Board of Regents, responsible for governing Iowa’s public universities, approved a tuition surcharge for junior and senior engineering students at Iowa State and the University of Iowa, effective fall 2006. When the surcharge is fully implemented in 2010, upper-level engineering students will pay an additional $1,750 per year in tuition.

According to college administrators, the surcharge was justified both on equity issues and the need to ensure the continuing competitiveness of engineering degrees from Iowa State. The costs of educating engineers, as well as average starting salaries for graduates, they note, are considerably higher than for other majors in the university. Also, due to diminishing state appropriations, the college must identify and exploit other financial resources to remain competitive with peer institutions.

A significant portion of the surcharge has been earmarked for additional financial aid to ensure equal access for all qualified applicants to the college, college leaders say. In addition, Dean of the College of Engineering Mark J. Kushner has appointed a Tuition Surcharge Advisory Committee to determine disposition of the rest of the additional tuition monies among labs, equipment, and, significantly, new hires to lower the student-to-faculty ratio in the college.

LEADERSHIP PROGRAM RECEIVES $500k FROM 3M, APPOINTS DIRECTOR

Minnesota-based 3M Corporation contributed $500,000 last fall toward Iowa State’s Engineering Leadership Program (ELP), a multi-faceted initiative that will integrate academics with experiential learning and public service to develop the leadership potential of students in the college. Also, the College of Engineering announced the appointment of Dr. Krishna Siddhanta Athreya as ELP director. Athreya received her Ph.D. in experimental condensed matter physics from Iowa State in 1996, and is a co-founder of Engineers for a Sustainable World. She will be assisted by junior mechanical engineering major Sarah Walter, who will serve as student director of the program.

The gift was presented at 3M corporate headquarters in St. Paul at an event attended by Iowa State administrators and a number of 3M’s approximately 450 Iowa State engineering alumni. The ELP’s first 11 3M Scholars were selected during the spring 2006 term. The number of scholarships will increase over the next four years until the goal of 60 3M Scholars is reached. The ultimate goal of the ELP is to prepare students for life-long leadership roles in industry as well as public service, with a particular emphasis on the development of public policies related to technology.

Read more about Iowa State’s Engineering Leadership Program in the fall 2006 issue of Innovate.

CERNEY TAKES FIRST IOWA STATE PHD IN HCI

Last spring Omaha native Melinda Cerney became the first person to earn a PhD in human-computer interaction (HCI) at Iowa State, one of only three such programs in the nation. Funded in part by a National Science Foundation Graduate Research Fellowship, Cerney’s dissertation—“Quantifying Motion from Non-Rigid Structures: Extended Geometric Motion Analysis Methods and Applications”—grew from her research on the identification of the relationships between motion trajectories and body shape for the purposes of human-centered design. After graduation, Cerney accepted a position in Seattle with Microsoft’s User Experience Group, which is engineering the next version of Windows (“Longhorn”).
NSF CAREER AWARDS TO FOUR YOUNG FACULTY

Four young College of Engineering faculty members have received prestigious Faculty Early Career Development Program (CAREER) grants from the National Science Foundation. According to the NSF Web site, the awards support the development of “teacher-scholars who most effectively integrate research and education within the context of the mission of their organization.” The highly competitive program provides recipients a minimum of $400,000 in support over a five-year period.

Winners include Aleksandar Dogandžić of the Department of Electrical and Computer Engineering for “Distributed Space-Time Processing for Sensor Networks,” Hui Hu of the Department of Aerospace Engineering for “Development of a Molecule-Based Diagnostic Technique to Study Joule Heating and Micro-Scale Heat Transfer Process in Electrokinetically Driven Microfluidics,” the Department of Mechanical Engineering’s Pranav Shrotriya for “High Resolution Interferometry-Based Surface Stress Sensors for Chemical and Biological Species Detection,” and Jiming Song of the Department of Electrical and Computer Engineering for “Accurate and Efficient Electromagnetic Modeling Techniques for RF Integrated Circuits.”

CBE, CCEE appoint new chairs

The Departments of Chemical and Biological Engineering (CBE) and Civil, Construction, and Environmental Engineering (CCEE) have appointed new department chairs effective the 2005–2006 academic year.

University Professor James C. Hill was named to replace outgoing CBE chair Charles Glatz, who had served as chair since 1997. Hill joined Iowa State’s chemical engineering faculty in 1971. A Fellow of the American Institute of Chemical Engineers, he served on the AIChE board from 2001 to 2003 after receiving the George Lappin Award for service to AIChE in 1999, among other honors conferred throughout his career.

Professor James Alleman joined CCEE as chair in January from Purdue University, where he had taught and conducted research since 1982. He replaces former chair Lowell Grienmann, who retired last year. Alleman, who has been a visiting professor at the University of Leeds in the U.K. and conducted research in Greece last year on a Fulbright scholarship, received his BS, MS, and PhD degrees in civil engineering from the University of Notre Dame.

IDED FUNDS COLLEGE RESEARCHERS

Iowa State has used monies from the Iowa Department of Economic Development’s Grow Iowa Values Fund to award four of nine grants to researchers from the College of Engineering. Grant winners were selected on the potential for their work to create new jobs and businesses or to enhance the sales and profitability of Iowa firms using technologies developed at Iowa State, among other criteria. The program is slated to make similar economic development/technology transfer grants over a ten-year period.

Awards from the initial round of grants included $96,000 to Suraj Kothari and Srinivas Aluru of the Department of Electrical and Computer Engineering for their work with EnSoft Corporation of Ames to improve a tool that allows users to better distinguish the differences between different types of modeling software. David Grewell of the Department of Agricultural and Biosystems Engineering received $73,500 to team with Samir Kumar Khanal and Hans van Leeuwen from the Department of Civil, Construction, and Environmental Engineering to study the pretreatment of corn for ethanol with high-power ultrasound, with the ultimate goal of increasing ethanol yields.

The Department of Mechanical Engineering’s Atul Kelkar will get $72,000 to work with Vibroacoustics Solutions Inc. of Boone in testing a commercial-scale prototype of a technology to control vibration in the seats of agricultural and construction equipment. Finally, Surya Mallapragada of the Department of Chemical and Biological Engineering was awarded $21,500 for her work with Cellular Engineering Technologies of Iowa City to determine how protein patterning might be used in technologies to measure cell health.

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Point of Departure: Reinventing Agriculture for Environmental Enhancement

BY ROBERT C. BROWN

North America’s prairies are among the world’s greatest natural resources for the production of food and fiber. Before agriculture, however, they were also gigantic sinks for carbon dioxide sucked from the atmosphere by forbs and grasses and stored underground—one of nature’s processes for sequestering greenhouse gases.

The sodbusters changed all that. Their plows ripped up the prairie, subjecting the exposed soil to erosion, washing and blowing its fertility elsewhere at the rate of five tons per acre per year. Agriculture had the further effect of exposing soil carbon to oxidation, releasing carbon dioxide into the atmosphere where it contributes to global climate change.

Iowa is thought to have lost half its soil carbon since cultivation began 150 years ago. That number is open for debate, but it is generally recognized that, as currently practiced, agriculture is slowly depleting soil fertility.

Good land stewardship minimizes the negative impacts of agriculture. But this alone is not enough to pass the test of sustainability, which requires that natural resources be employed in a manner that assures their availability for future generations.

Modern agriculture’s reliance on fossil fuels to power tractors and produce nitrogen fertilizer, as well as its role in the depletion of topsoil and soil carbon, add up to a less than stellar record of sustainability.

We can reinvent American agriculture in a way that doesn’t just minimize its impacts on soil, air, and water, but actually enhances the environment, a “new” agriculture inspired by the pre-Columbian peoples of South America.

Recent archaeological studies in the Amazon basin have revealed that the highly oxidized, infertile soils common in this region are interspersed with well-defined areas of highly productive soils. Known as Terra Preta (“dark earth”), they are substantially darker than surrounding soils and contain large amounts of charcoal and pottery shards. These anthropogenic soils were created by indigenous people through the gradual addition of manure and charcoal formed by burning plant material.

Thought to arise from the increased biological activity of bacteria and fungi colonizing the porous char, these soils have remarkable fertility compared to untreated soils in the same locations. Furthermore, this carbon appears to have been stably sequestered as soil organic matter for hundreds if not thousands of years.

Could we duplicate these results, yielding a system that not only produces food crops but also rebuilds soils, meets the energy demands of modern agriculture, and sequesters greenhouse gases from the atmosphere?

Iowa State is studying the feasibility of just such a system for corn production. In this system, about half the stover (the residue of stalks, leaves, husks, and cobs) is harvested along with the grain. The stover is then partially burned to form charcoal and an energy-rich liquid known as bio-oil, which is reacted with steam to form hydrogen in lieu of the natural gas typically used to manufacture fertilizer. The ammonia and charcoal are then injected into the soil to serve as a nitrogen fertilizer, a biologically active soil amendment, and a carbon sequestration agent.

In effect, the farmer provides all of the energy to manufacture fertilizer for his own farm. Using stover to manufacture ammonia, a 640-acre corn operation would save one million cubic feet of natural gas annually and would avoid releasing 65 tons of CO$_2$ into the atmosphere. The farmer would also receive a fuel credit equal to about 50% of the cost of anhydrous ammonia.

While switching from conventional tillage to no-till would sequester only about 310 tons of carbon dioxide per year, the charcoal produced by this farm would effectively sequester 1,800 tons—the annual tailpipe emissions from 340 automobiles. Although their value in the U.S. is only speculative at this time, carbon credits in international markets average about $3.50/ton, or $6,900 for a 640-acre farm.

Not least among these benefits is the anticipated improvement in soil quality as a result of the application of char. And though these results have not been fully demonstrated, the experience of the pre-Columbian peoples of the Amazon basin—not to mention the futures of our children and the land—encourages this attempt to reinvent agriculture.
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