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research 06

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Message from the Vice Provost for Research: Dr. Truell Hyde

Over the past several issues of *Research*, we've focused on the long-standing relationship between faculty scholarship and excellence in the classroom at Baylor.

This issue breaks new ground, exploring the connection between faculty research and local and regional economic development, a subject increasingly on the minds of university faculty and administrators across the world.

At Baylor, the integration of teaching and research has been strengthened most recently through faculty collaboration across academic units encouraged by funding from the state or federal government. Such partnerships, which routinely produce excellence in the classroom, also drive regional entrepreneurship and job creation, which are the cornerstones of economic development. The connection between Stanford, perennially a top-10 university, and Silicon Valley is probably the most-often-cited example of the impact these relationships can have.

As recognition of this fact continues to grow within the halls of government, it has led to states providing new financial support to encourage university-driven entrepreneurship. In our interview with Mark Ellison, director of the Texas Emerging Technology Fund, you'll learn how the state of Texas is positioning itself to become more competitive in this arena through a program developed by Ray Perryman, former Economist-in-Residence at Baylor University. In 2003 the Texas Legislature passed Senate Bill 275, calling for the development of strategies to strengthen the competitiveness of key industry clusters.

The Texas Industry Cluster Initiative, originating directly from the governor's office, focuses on six areas of economic strength in Texas:

- Advanced Technologies and Manufacturing
- Aerospace and Defense
- Biotechnology and Life Sciences
- Information and Computer Technology
- Petroleum Refining and Chemical Products
- Energy

This integrated, interdisciplinary approach to economic development opens an unprecedented window of opportunity for Baylor faculty to further compete across cutting-edge research areas.

In this issue of *Research* you'll learn more about Baylor's contributions to economic development through advanced research and industrial partnership. I trust you'll find the link from Baylor's classrooms, offices, and labs into the broader world outside inspiring.

As always, *Research* can relate only a few of our faculty success stories. Please contact me to learn more or visit our website at www.baylor.edu/research. I look forward to sharing with you in the coming years all that is happening on the research and scholarship front at Baylor University.

"We have already seen the great potential that such an internship program can have through the Nanotechnology Workforce Development Initiative, a program launched in January 2004 in partnership with the Texas Workforce Commission, TSTC Waco, Baylor University, Del Mar College of Corpus Christi, and Zyvex Corporation."

Mark Ellison Q&A

MARK ELLISON

director of the Texas Emerging Technology Fund,
a part of the Texas Industry Cluster Initiative

RESEARCH: Provide a brief overview of the Texas Industry Cluster Initiative in your words.

MARK ELLISON: The goal of this initiative is simple: to develop clusters of related technology-based companies in the same geographic region. The significance of the Cluster Initiative and these task force recommendations for the state is that for the first time in Texas history, we have a coordinated, market-driven economic development strategy that focuses on the areas of the economy with the greatest growth potential. Texas cannot rely on the same old methods to attract economic growth if we hope to stay competitive in the high-stakes, high-tech global marketplace of tomorrow. We also are taking those steps necessary to ensure the greatest prosperity for all Texans.

R: How will the Cluster Initiative impact economic development in the state?

ME: We already have made a tremendous amount of progress on the Cluster Initiative. Over the past year, we have put together a great team of business leaders who helped Texas assess where we are, at both the state and regional level, and developed some specific strategies on how to get where we need to go.

In September, this working group submitted a comprehensive report to the governor's office that includes the recommendations of more than 700 industry leaders from across the state. Because of their work, we now have a clear road map for reforms in education, workforce training, transportation, and regulatory policies that will help Texas build a more collaborative business climate and ultimately foster the development of industry clusters.

One of the most important areas they looked at was how we can better facilitate collaboration among industry sectors, academia, and government so we can get inventions out of the lab and into the marketplace faster.

R: What incentives are being offered to attract industries to relocate or expand their operations within the state?

ME: We are particularly proud of the fact that we replenished the Texas Enterprise Fund and set aside $200 million for the new Emerging Technology Fund.

Now the state has two powerful incentive funds to further economic development, including technology investments that are not going to immediately create direct jobs but that will lead to the development of new inventions with strong potential for commercialization. Each of these measures is important because they are helping us build an environment that rewards the entrepreneurial spirit and those who create jobs.

And on top of all these recent accomplishments, we still offer some of the lowest taxes, the least-burdensome regulations, and a workforce that has the skills to meet the needs of today's employers.

R: What is being done at the state level to promote university-industry partnerships as part of the Cluster Initiative?

ME: With the Emerging Technology Fund, Texas will help universities form new partnerships with the private sector, bolster research capabilities of Texas institutions of higher learning, and help start-up companies get the capital they need to transform ideas into life-changing inventions.

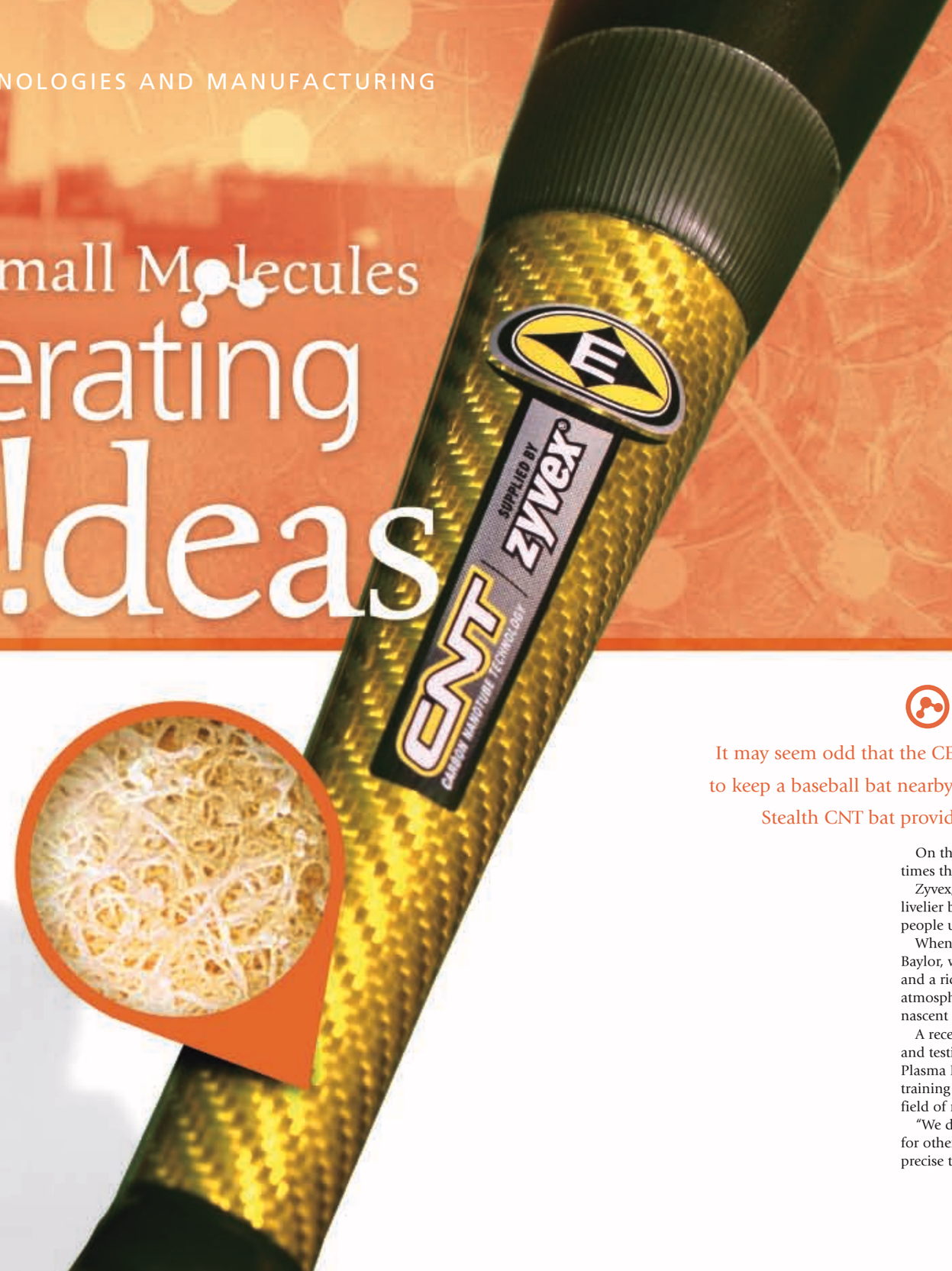
We have set up Regional Centers for Innovation and Commercialization that are made up of industry leaders. These groups will solicit and review proposals from their regions for new products and services to build and implement across the state. These leaders will provide direction and advice as the new companies develop in their regional markets.

R: What role do you see public and private universities playing in the Cluster Initiative?

ME: The fact of the matter is high-tech companies are not going to come to Texas if we cannot offer them a highly skilled workforce. Our entire education system is a vital component of our economic development strategy. That means that we must improve applied math, science, and technology programs in our public schools and expand curriculum to focus on future workforce needs. We should also help industry develop apprenticeship and internship programs for secondary students so they are ready to succeed in the workplace.

We have already seen the great potential that such an internship program can have through the Nanotechnology Workforce Development Initiative, a program launched in January 2004 in partnership with the Texas Workforce Commission, TSTC Waco, Baylor University, Del Mar College of Corpus Christi, and Zyvex Corporation. This initiative gives students the opportunity to work together with leading scientists and engineers and produced the curriculum and training to create the "gold standard" for nanotechnicians. This partnership has been a true win-win for students, colleges, and participating companies, and now serves as an innovative and effective model to produce a highly qualified and talented workforce.

Small Molecules Generating Big!deas



JAMES VON EHR
CEO of Zyvex Corporation

NANOMANUFACTURING

It may seem odd that the CEO of a cutting-edge technology company likes to keep a baseball bat nearby, but James Von Ehr says the new Easton Sport Stealth CNT bat provides a glimpse into the future of manufacturing.

On the market for a few months, the bat incorporates carbon nanotubes thousands of times thinner than a single human hair but 15 times stronger than steel.

Zyvex, Von Ehr's Richardson, Texas, company, developed the material to create a stronger, livelier bat with more flexibility. The baseball bat is a single tangible object that can help people understand the potential of manufacturing on an atomic scale.

When Von Ehr needed a partner for a Texas Workforce Commission research grant, Baylor, with its Center for Astrophysics, Space Physics and Engineering Research (CASPER) and a rich tradition of collaboration, was a perfect fit. In CASPER, he said, he found an atmosphere of excitement about technology and science, as well as the brainpower the nascent nanomanufacturing field needs to begin tapping into its potential.

A recent $500,000 grant partially funded a Zyvex S100 nanomanipulator, a manipulation and testing tool used for nanoscale research in CASPER's Hypervelocity Impacts and Dusty Plasma Lab. The S100 provides a valuable tool for CASPER researchers and interns who are training for the burgeoning industry and will, in turn, help drive new discoveries in the field of nanotechnology.

"We developed the S100 to do our own assembly and then began to sell it as a manipulator for other nanotechnology industries," Von Ehr said. "We are starting to develop atomically precise tools and materials that allow us to make sure that every atom is exactly where it

needs to be. We are about 10 years away from really doing some of the things we hope to do."

Von Ehr said that the partnership with Baylor will help move the industry along by providing technical training and quality interns, who give Zyvex and the industry much-needed brainpower. The collaboration is already feeding state and local economic development initiatives by keeping opportunities for Texas residents at home.

"If we had not been able to establish this collaboration with Baylor, Zyvex would have probably outsourced this project to Asia," Von Ehr said. "Instead, because we were able to use interns, the project has stayed in Texas and several interns have moved on to full-time permanent jobs in the industry."

Dr. Truell Hyde, Baylor's vice provost for research and director of CASPER, said that the project illustrates the cluster approach, which brings together industry, researchers, and educators from different locations. "This is a completely different way of looking at things. It calls for a team of interdisciplinary researchers who work well together in a cutting-edge area. That's something Baylor is already doing and has been doing for some time," said Hyde. "We can go to industry and say, 'We understand where you're headed, we know the science, and we can help get you there.'"

"If we had not been able to establish this collaboration with Baylor, Zyvex would have probably outsourced this project to Asia. … Instead, because we were able to use interns, the project has stayed in Texas."

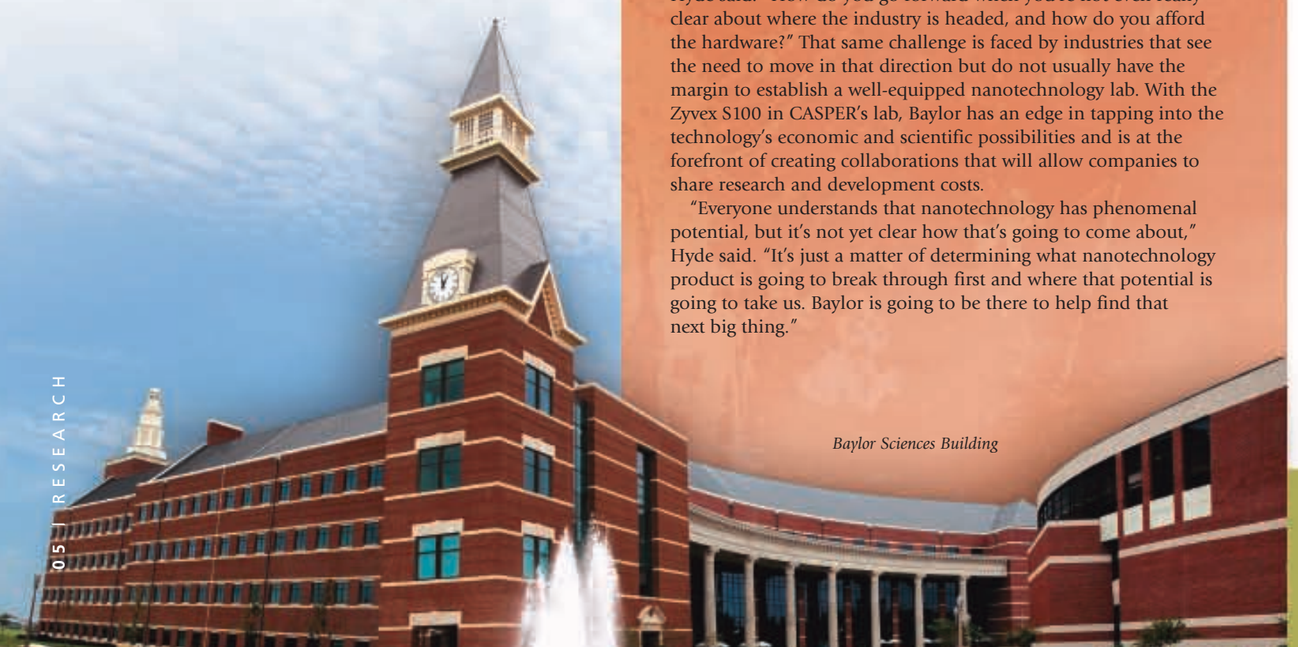
JAMES VON EHR,
CEO of Zyvex Corporation,
on workforce development collaboration with Baylor University

Clusters present an opportunity for Baylor to be competitive, utilizing an approach that generally wasn't pursued in the past when large teams of scientists tended to work in one location. "You have to hire people who are willing to work with each other and have overlapping interests – physicists who are also chemists, for example," Hyde said. "And that's something Baylor has been doing for some time, so we're well positioned to be a player.

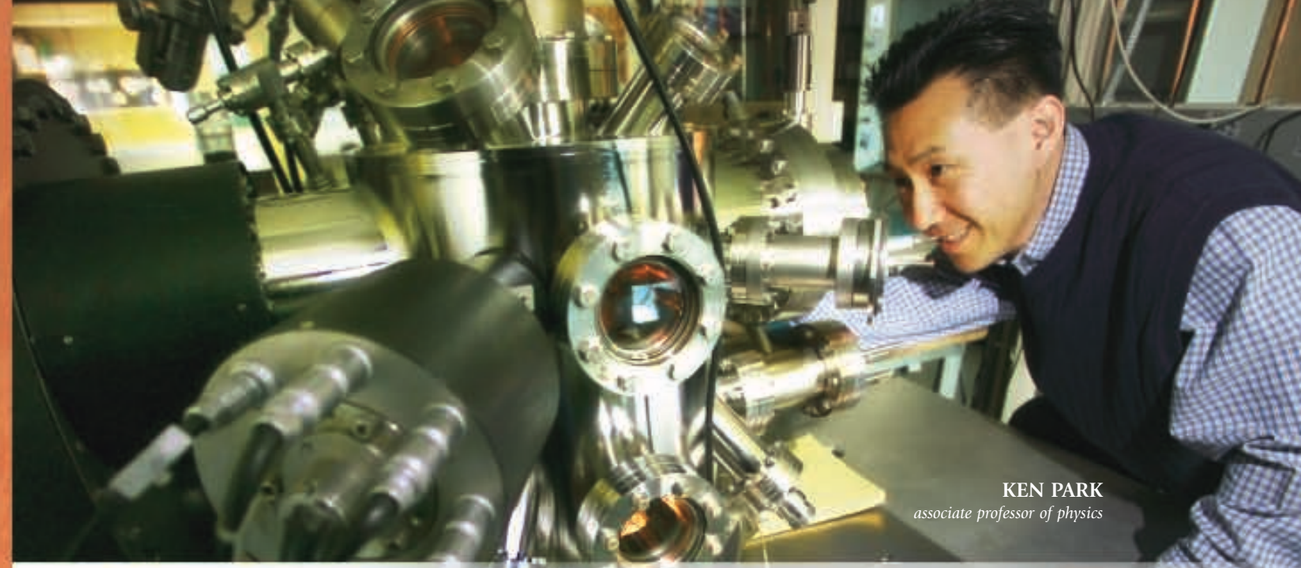
"Everything is moving very rapidly to an interdisciplinary environment," Hyde said. That trend toward interdisciplinary research influenced the development and design of the Baylor Sciences Building, which houses scientists from multiple disciplines and provides an opportunity for faculty researchers and students to collaborate on projects side by side.

"One of the problems companies have right now is that nanotechnology is still so tenuous, no one has defined it clearly," Hyde said. "How do you go forward when you're not even really clear about where the industry is headed, and how do you afford the hardware?" That same challenge is faced by industries that see the need to move in that direction but do not usually have the margin to establish a well-equipped nanotechnology lab. With the Zyvex S100 in CASPER's lab, Baylor has an edge in tapping into the technology's economic and scientific possibilities and is at the forefront of creating collaborations that will allow companies to share research and development costs.

"Everyone understands that nanotechnology has phenomenal potential, but it's not yet clear how that's going to come about," Hyde said. "It's just a matter of determining what nanotechnology product is going to break through first and where that potential is going to take us. Baylor is going to be there to help find that next big thing."



Baylor Sciences Building



KEN PARK
associate professor of physics

Semiconductors and Nanosurface Technologies

> Nanotechnology came about partly as an outgrowth of the semiconductor industry's constant search for a way to create smaller and smaller integrated circuits. As such, semiconductor researchers are continuously seeking ways to improve this technology, which has multiple electrical and chemical properties.

Dr. Ken Park, associate professor of physics, said that scientists have been trying over the past 30 to 40 years to identify materials that might be used differently or combined into alloys. "They found that they often got different properties and reactions when they combined new materials with well-known, traditional materials," Park said. Now he and other surface physicists are exploring the dramatic differences at the nanoscale or atomic scale and coming up with huge discoveries.

To give the nanoscale some perspective, a nanometer is one-billionth of a meter. A typical sheet of paper is 100,000 nanometers thick. Using advanced technologies, scientists can now manipulate and create objects only a few nanometers in size, a scale one-millionth the size of the period at the end of this sentence.

"When we get down to that size, many exotic things start happening," Park said. "We may find that a material we are familiar with in the macroscopic world may have a completely different application in the nano world. Suddenly it has different properties, and we may have the opportunity to apply them in completely different ways."

One example is gold, which has long been recognized as one of the purest and most stable metals. When gold is examined on the nanoscale, not in inches, centimeters, or millimeters, but down to a billionth of that dimension, a cluster of maybe 100 or fewer gold atoms, "then these gold nanoparticles suddenly show remarkable catalytic properties of oxidizing carbon monoxide into carbon dioxide," Park said. "While the idea of producing more carbon dioxide may not be appealing, it is an important reaction step in catalytic processes. The discovery opens the possibility of identifying other as-yet-unknown properties from gold and other materials in the nanoscale."

Park is studying surface physics, the reactions of the atoms at the very edge of a material. "Part of a material's property comes from the reactions of its atoms with neighboring atoms in three-dimensional space," he said. "Because those atoms at the surface are missing some of their neighbors, however, they have different properties from those on the inside.

"That's why we study surface physics, also called reduced dimensions," Park said. "Instead of three dimensions, up and down, left and right, the atoms are only able to react down and along the (vertical) planes." In the last 10 to 20 years, studying these dimensions has shrunk to just the nanometer scale, revealing dramatically different properties. This field is called nanoscience. Scientists now look not only at the two-dimensional surface, but also at two-dimensional finite nanoparticles, where materials can behave as solids or liquids.

"It's exciting," Park said. "We don't know much of the 'why.' That is part of what scientists are trying to discover," he added. "As we understand more and more, we can find more applications for the betterment of humankind and technology."

Protecting Earth and Sky

"Without Baylor, FreeFlight Systems wouldn't have moved to Waco."

STEVE WILLIAMS,
president of FreeFlight Systems,
on the benefits of the industry-university collaboration

At the surface, Baylor's connection to the Aerospace and Defense Cluster might seem clear, due in part to its long history of aviation and engineering research.

But defense and homeland security can come in surprising forms. While some Baylor researchers explore projects that shout "defense," such as ways to keep Air Force fighters up-to-date and strategies for protecting commercial airliners, others explore less obvious, but no less vital issues, such as ways to make drinking water safer at home and on the battlefield.

Such cluster initiatives can't flourish without collaborative relationships between businesses and educational institutions, said Steve Williams, president of FreeFlight Systems, which designs and manufactures satellite guidance and navigation avionics systems. Williams has become a tireless advocate for Waco as an aviation and avionics business hub.

To encourage hi-tech aviation companies to relocate or start up in Waco, he aggressively recruits firms and organizes seminars in cooperation with the city's Chamber of Commerce. Waco's advantages include educational opportunities and a steady supply of trained employees through Baylor, more than 1,000 aviation companies within 500 miles, three regional airports, affordable housing, and close proximity to Dallas/Fort Worth, Houston, and Austin.

Key to Williams' efforts to attract other companies to the region is the close ties between businesses and universities like Baylor. Williams predicts the next major advance in avionics will depend on integrating the Internet with real-time information systems like weather mapping and traffic flow reports. "We've got to create the systems and technology to do that," he said, "and it's the universities that are working in this arena. It's industry that is tied to universities that's going to bring this style hardware and this kind of capability and functionality to the cockpit."

STEVE WILLIAMS
president of FreeFlight Systems

Advanced Avionics

> One such cutting-edge approach can be found in Baylor Associate Professor of Electrical and Computer Engineering Russ Duren's research on reconfigurable computing. Although Duren's current work could have applications in many industries, his focus is on allowing systems in space such as satellites to be reprogrammed remotely to match changing mission needs in the field. He also works to extend the life of electronics systems on military aircraft.

The electronic devices that serve as the brains for such systems as navigation and weapons targeting in military craft often become obsolete faster than the aircraft themselves, Duren explained. Developing and replacing these systems, which are at least 20 years old, can cost millions per plane. The tab to create just one new computer chip can easily top $1 million, he said.

A more cost-effective option, Duren said, is to substitute the expensive custom-designed computer components with universal field programmable gate arrays (FPGAs). Like any computer chip, the FPGAs are etched with semiconductor devices such as diodes, transistors, resistors, and capacitors. In a conventional chip, etched wires, called traces, establish permanent connections. In FPGAs, software that can be loaded directly or broadcast to the device directs a battery of semi-conductor switches to reconfigure it into any number of circuits. "We have applied it to sonar processing," Duren said. "It could be used for any kind of signal processing, such as radar processing or image processing, which could be used for aviation or biomedical (purposes), for instance."

Duren has 13 years of experience working for Lockheed Martin Aeronautics Company in Fort Worth and has strong ties to one of the key elements in Waco's aerospace and defense clusters, L-3 Communications Integrated Systems. Waco houses one of five development sites for the aircraft company. This relationship, along with Duren's first-hand experience and collaborative endeavors in the aviation industry, affords Baylor students the opportunity to hold internships at the L-3 Waco facility, providing them valuable industry experience.

RUSS DUREN
associate professor of electrical and computer engineering

Aerospace and Defense

> Like Duren, Richard Campbell, a lecturer in engineering, also works with L-3 and has a solid background in aviation. His focus is on civilian aircraft. "I'm interested in developing technologies that allow you to retrofit protection systems into commercial airliners that can be cost effective and minimize the vulnerability of the aircraft," he said.

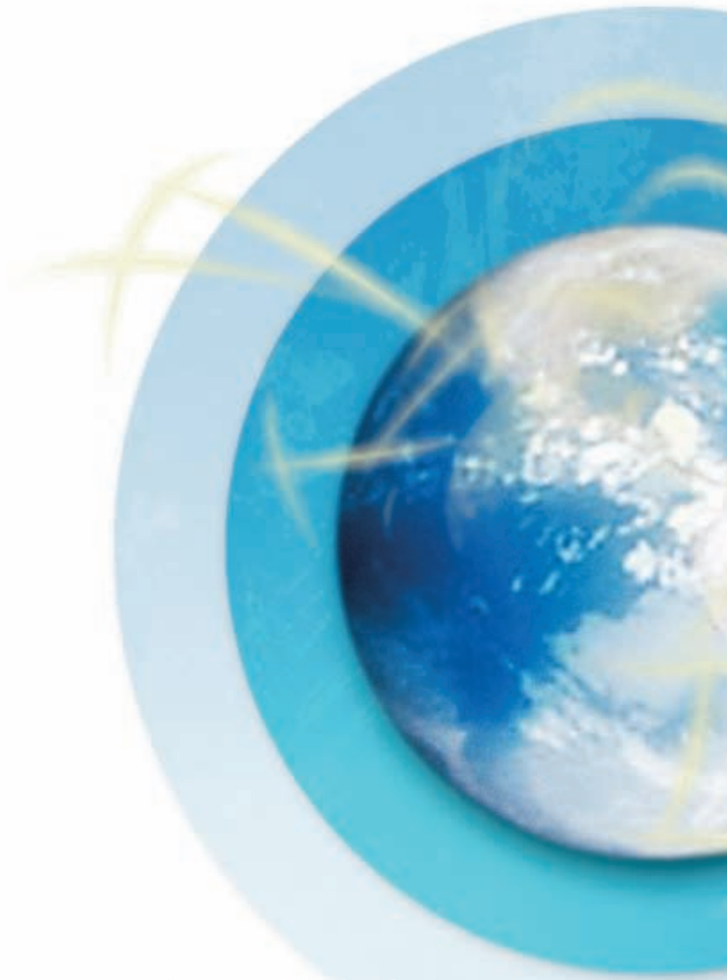
Specifically, he is investigating ways to protect commercial aircraft from shoulder-fired missiles. So far the surface-to-air weapons haven't been linked to an attack on American soil, Campbell said, but they have been implicated in foreign terrorism, including a hit on a plane in Baghdad in November 2003.

Strategies to protect airliners fall into two classes, Campbell said. One is avoiding the missile and the other is preparing the airplane in case the missile finds its target. Because shoulder-fired missiles have a very limited range, airliners are vulnerable only on takeoff and landing. "If it's going to be difficult to (evade an attack), then maybe you want to take some steps to improve the hardiness of the aircraft if it does get hit," Campbell said.

That's why he's focusing on ways to reinforce aircraft and protect vital flight systems. Successful protection schemes have to balance costs and benefits, he said. For example, adding armor would help protect airplanes. Although this sort of flying tank might resist projectiles, armor adds weight and extra weight costs fuel. So, the first step in assessing costs and benefits is to analyze each type of aircraft that could be retrofitted. Such an analysis might, for example, identify an aircraft's hydraulic system as a prime candidate for reinforcement.

A commercial airplane's hydraulic system is as much an essential tributary as an artery in a person's circulatory system. Failure of a hydraulic line can freeze vital components like flaps, rudders, brakes, and landing gear. One way to reduce the risk of losing hydraulic power, Campbell said, would be to install dual hydraulic systems. But it's not as simple as running one line next to the other, where a single projectile could cut both. Instead the second hydraulic system must be run independently.

Other possible enhancements include installing shielding around the engines' compressor blades and turbine blades, extending exhaust pipes on the engine, which can help reduce damage if a missile strikes the exhaust, and developing frangible actuators and hinges. In a scenario, a missile could hone in on the infrared generated by the engine. "If the control surface gets jammed up, it has a breakaway feature so that you can continue to use the control system and use the other control surfaces to operate the aircraft," Campbell said.



"I'm interested in developing technologies that allow you to retrofit protection systems into commercial airliners that can be cost effective and minimize the vulnerability of the aircraft."

RICHARD CAMPBELL
lecturer in engineering

Homeland Defense and Countermeasures to Terrorist Threats

> In the Department of Biology and the Department of Environmental Studies, rather than looking to the skies, scientists are looking at water. Bryan Brooks, assistant professor of environmental studies and director of the Ecotoxicology Research Laboratory, and Rene Massengale, assistant professor of biology, have separate research agendas, but often collaborate on interdisciplinary projects. One such project is finding new ways to identify waterborne contaminants and environmental toxins, some of which could serve as microscopic weapons for terrorists. "I don't think that the ability to (culture and intentionally release such toxins) has been dismissed as a possibility. If we look at relatively available toxins, is it possible that they could be used in some sort of a targeted fashion? It's certainly a possibility," Brooks said.

"The emphasis that has developed is to be able to effectively identify potential biological terrorism events," Massengale added. Her group is improving methods for high-speed identification of potentially deadly organisms in water, such as *Escherichia coli*, the bacteria often found in spoiled or contaminated foods; enterococci, which are common causes of disease outbreaks at beaches and recreational areas; and giardia, which is found in mountain streams and urban water supplies alike.

"The emphasis that has developed is to be able to effectively identify potential biological terrorism events," Massengale added. Her group is improving methods for high-speed identification of potentially deadly organisms in water, such as *Escherichia coli*, the bacteria often found in spoiled or contaminated foods; enterococci, which are common causes of disease outbreaks at beaches and recreational areas; and giardia, which is found in mountain streams and urban water supplies alike.

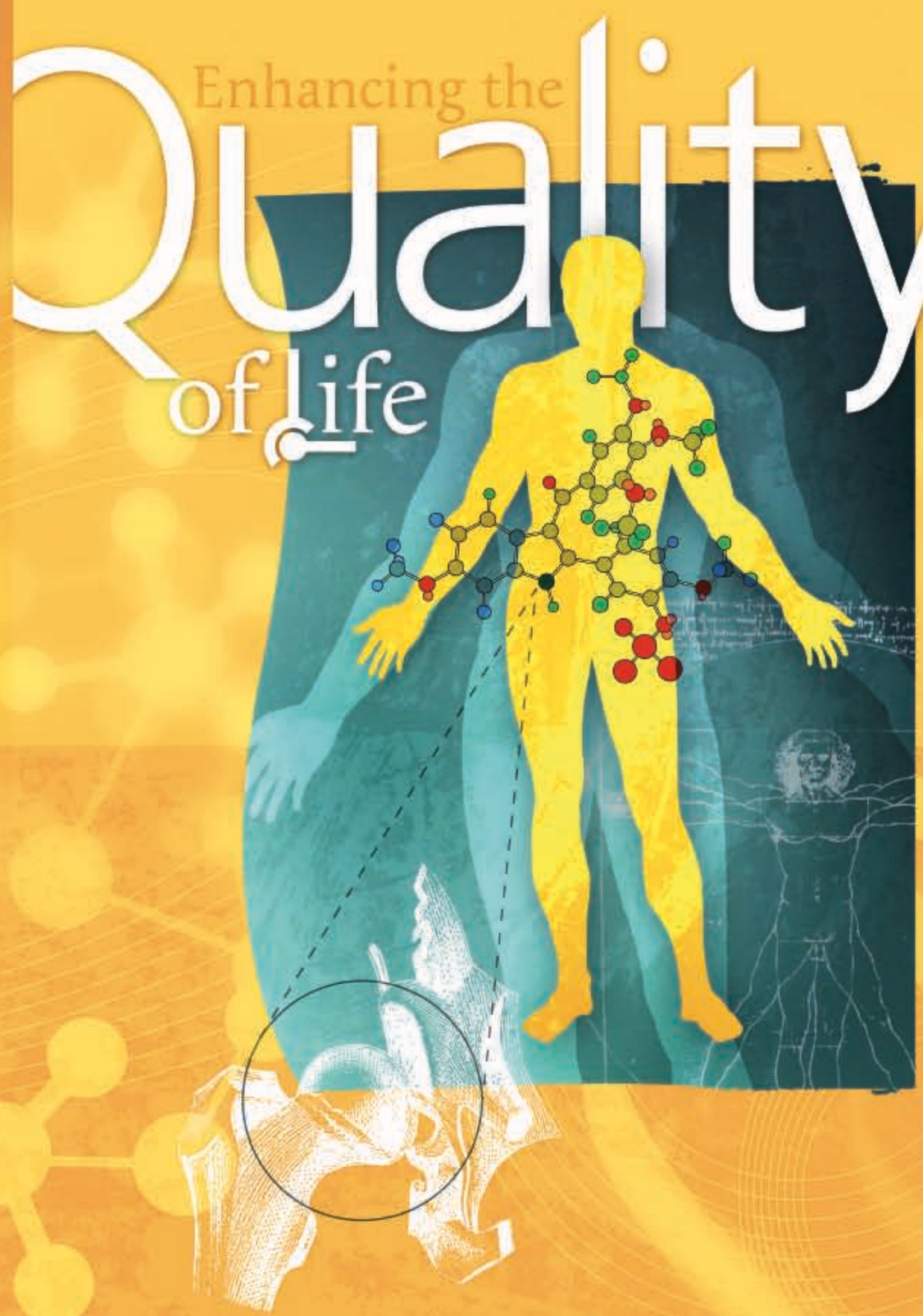
Massengale's group is improving established, hi-tech methods for rapidly identifying organic water contaminants, such as real-time PCR, DNA analysis, and carbon-usage analysis for use in water facilities and in the battlefield. In particular, finding a fast and mobile way to recognize potentially pathogenic organisms within nature's vast lineup of waterborne organisms could benefit public health, homeland security, and national defense, which explains why her group has received funding from local and federal sponsors.

For example, Massengale's group is in the process of tracing the source of fecal contaminants in local watersheds. By collecting fecal samples throughout the watershed, they have constructed a library of bacteria that indexes the organisms by their DNA sequences and other characteristics. They can then compare bacteria found in the streams to this library and find where they originated in the watershed. Similar techniques could help authorities detect organic contaminants introduced into a water supply, either through inadvertent contamination or through an intentional act of terrorism. And as for the battlefield, portable, fast water tests could allow soldiers to drink from local water sources, rather than depend on water that must be trucked in or mechanically purified through other labor-intensive processes.

A vital method for replicating the natural aquatic environments, which aids in the development of these detection technologies, Brooks said, is the Baylor Experimental Aquatic Research (BEAR) Facility, part of the Center for Reservoir and Aquatic Systems Research, or CRASR. Scientists and technicians at the center have developed model streams that include riffle and run sections that approach 60 feet in length. They conduct research in areas such as toxicology in waterways and the land near them, erosion, and sedimentation. "If we were interested in what might happen to a contaminant once it's placed in an aquatic system, we could manipulate these experimental systems using different concentrations of the contaminant," Brooks said.

BRYAN BROOKS
assistant professor of environmental studies and director of the Ecotoxicology Research Laboratory

Enhancing the Quality of Life



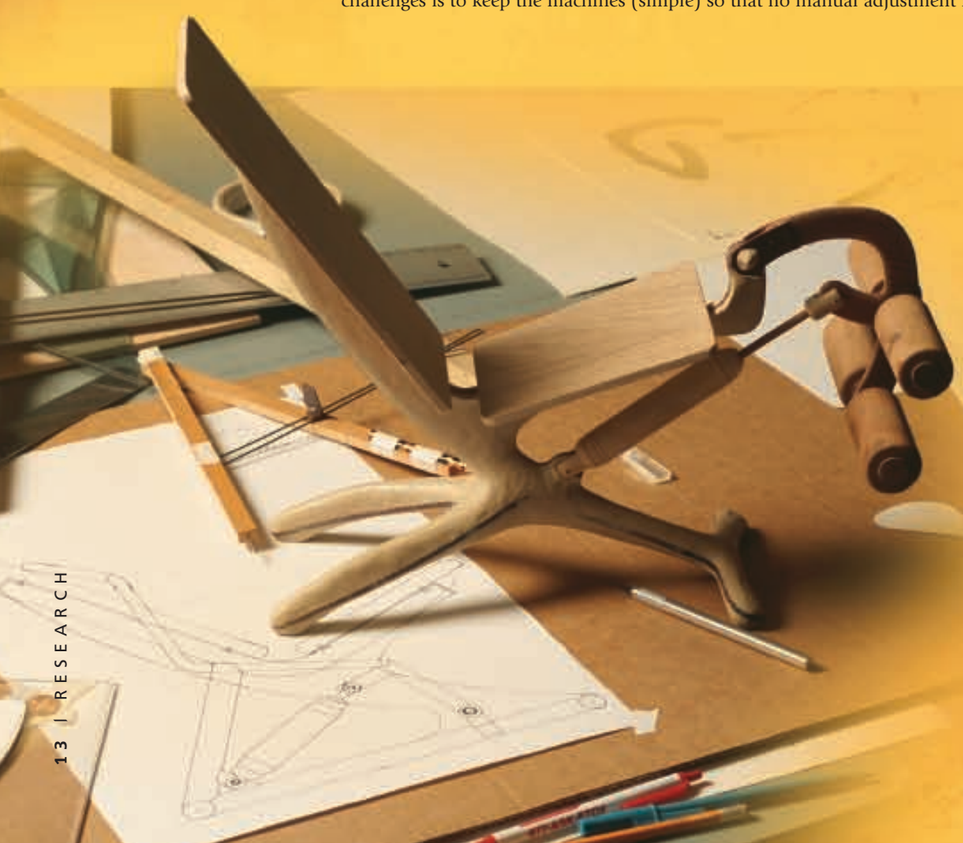
Engineering and Biomechanics

Brian Garner, an assistant professor of mechanical engineering, is using his knowledge of mechanical engineering and biomechanics in a team effort to create the next generation of exercise machines for Curves International.

Curves, headquartered in Waco, encourages fitness, strength training, and weight-loss guidance for women through an exercise program that provides an overall workout in 30 minutes. Curves exercisers typically go through eight to 13 exercise stations during that time. For founder and CEO Gary Heavin, the company was born from a desire to prevent deteriorating health and potential illness.

Garner and his colleagues began evaluating how well the existing machines were providing resistance, with the goal of maximizing the effectiveness of the exercise equipment using new, state-of-the-art designs.

"We want to make sure these new versions improve upon that so that we provide the best exercise in the time allotted," said Garner. The Curves program is popular because of the speed of the workout, and one of the factors allowing speed is that the machines don't have to be adjusted for each user. "We need to accommodate women of all sizes, shapes, and strength levels. One of the challenges is to keep the machines (simple) so that no manual adjustment is needed," said Garner.



BRIAN GARNER *(on left)*
assistant professor of mechanical engineering

PHOTO COURTESY OF SHARON PEREGRINE JOHNSON

The industry partnership began when CEO Heavin approached Baylor because of its proximity to his company and his support of Baylor's Christian mission. An interdisciplinary team of students and professors from Baylor's engineering and art departments joined together to create the new machine designs. The engineering team developed computer models to simulate the biomechanics and ergonomics. The art team sculpted scale clay models to represent style and form. Through an iterative process and close communication, new designs emerged from which prototype machines were built.

The goal of designing each machine to fit every body type remained paramount. For example, one machine requires the user to stand and rock from side to side while holding handles that exercise abdominal muscles. The solution was to create handles with a gradual angle so that the user simply grabs the handle at a position that naturally fits.

The researchers used computer models to design linkages for the machines so that exercise resistance would match the measured strength curves of women. Then they built the prototypes from special materials that allow for easy adjustments. "It's a fancy engineer's version of an erector set," said Garner of the prototypes. "(They) allow real-life tweaking and adjusting."

To make sure the machines are doing what the computer models predicted, a group of Curves' exercisers tested them. The engineering group was "pleased and amazed at how well the computer models predicted the results," said Garner. As an example of a successful industry-university partnership, Baylor will continue to be involved in the development and manufacturing process, helping to integrate technologies into the designs and find a manufacturer for tens of thousands of machines.

The project is great exposure for Baylor, Garner said. "Once these products get to the field and people start using them, they'll be quite impressed, and Baylor will receive a lot of positive recognition for that. We've done professional work, and that will reflect well on Baylor."

Medical Devices and Biomedical Engineering

> Students who work in engineering professor Carolyn Skurla's lab posted this celebrated Albert Einstein quote: "If we knew what it was we were doing, it would not be called research, would it?"

The display illustrates the students' common realization that even the greatest researchers may not have all the answers and that research is a means to discovering new information. Furthermore, students begin to understand that success happens even when results are unexpected, said Skurla.

That's how exploration leads to discovery in the realm of biotechnology and life sciences, an arena in which Baylor occupies veteran status while adding new dimensions to its reputation as a center of research. From tissue and joint repair to the creation of a new generation of exercise equipment to drugs that starve the blood supply of tumors, Baylor has developed sophisticated centers that encourage academic excellence, drive industry, create employment opportunities, and enhance the overall quality of life.

One such area is the Center for Drug Discovery, envisioned by Dr. Bob Kane as a place where professors could find collaborative research opportunities and build bridges between departments.

"My vision was just to use it as a catalyst for increasing interaction between faculty, and that certainly has happened," said Kane, the Center's director. "It really is faculty driven. We just provide a couple of social opportunities a year for the community to interact formally or informally. We expose what everyone is doing in the hopes of creating new collaborations."

Such interaction has happened between Kane, an associate professor of chemistry who is interested in tissue engineering, and Skurla, an assistant professor of mechanical engineering interested in the mechanical integrity of tissues and bones. They've combined their expertise and specialty areas to collaborate on tissue repair.

Skurla's research has taken her on journeys from discovering how implantable devices fare inside the body and how the body influences the integrity of these devices, to studying osteoporosis and what it does to bone, to collaborating with Baylor organic chemists in developing strong adhesives for repairing torn or damaged tissues.

"We are developing test methodologies that we are going to study with orthopedic surgeons at Scott & White Hospital in Temple," said Skurla. For the upcoming pilot study, researchers will perform mechanical testing to compare the initial stability of different models of implants in the bone.

Skurla wants to stay focused on total joint replacements, which includes examining what materials manage the best inside the body and how long they last. Scott & White Hospital has an exceptional reputation in the area of orthopaedics, and the collaboration has the potential for developing into a long-term research program, due in part to the hospital's proximity to the Baylor campus.

With the need for joint replacements growing as the population ages, and these devices lasting about 15 years, Skurla's research has the power to positively influence the quality of life for people in terms of their ability to remain active and move about without pain. "We work at the interface of engineering and medicine. We are trying to solve problems in a person by using our knowledge of engineering and biomaterials," said Skurla.

PHOTO COURTESY OF SHARON PEREGRINE JOHNSON

CAROLYN SKURLA
assistant professor of mechanical engineering

"Baylor is interested in this idea of research incubators: academics and industry working and collaborating together under the same roof. We've done that in many ways with OXiGENE."

DR. KEVIN PINNEY, professor of chemistry, on Baylor's collaboration with OXiGENE

Drug Discovery and Cancer Pharmaceutics

> An industry-university partnership between Baylor and OXiGENE, a pharmaceutical development company in Massachusetts, has the potential to drive new discoveries in both cancer treatment and ocular disease, as well as create a model for such partnerships worldwide.

Two years ago, chemistry professor Kevin G. Pinney and OXiGENE announced the development of a new cancer drug developed at Baylor that works by starving tumors of their blood supply. Pinney and his team of researchers began studying the vascular targeting agents in 1996. By 1999, OXiGENE had licensed Pinney's patents, paid a licensing fee to Baylor, and assumed future patent costs. In addition, the company also began providing research support for Pinney's group.

The compound, OXi-6197, is still in pre-clinical development, said Pinney, as is OXi-8007, another Baylor-developed compound. They've been in a variety of animal models, though not humans, and OXiGENE is still considering both. "It's a field that's growing by leaps and bounds daily, and one of the biggest things that's happened is the enthusiasm that people have for not only continuing to look at this as a treatment for cancer, but as a treatment for ocular diseases," said Pinney.

The partnership allows for the employment of more people in Baylor's chemistry department, said Dr. David "Dai" Chaplin, OXiGENE's chief scientific officer and head of research and development. "As we further develop the compounds, that's more money back into Baylor."

Getting the compounds into the advanced pre-clinical stage is costly, Pinney noted. "It requires someone who is willing to take the risk and has the financial backing to do it. People look at how it compares to therapies already out there, how it compares to other compounds that are in pre-clinical development that haven't received FDA approval."

Baylor's knowledge and skill prompted OXiGENE to look at Baylor as a partner, Chaplin said. "Baylor had the expertise, and we were interested in the chemicals." The relationship has been productive and one that OXiGENE values highly, Chaplin added. It is particularly helpful to OXiGENE because the company does not have its own laboratories. With only two dozen employees, OXiGENE outsources everything, using Baylor facilities and expertise as a research arm in the generation of new chemical entities.

The possibility of OXiGENE or a similar company building a lab in Texas is not lost on Pinney. "If you have one company doing that, another might do it, too, and you start to create an area of emphasis that employs people and brings industry to the area."

Through Texas' Industry Cluster Initiative, the state is looking to do just that. It's money that could outfit a lab that Baylor and OXiGENE would share "that ultimately encourages them to build something permanent here," Pinney said. "Baylor is interested in this idea of research incubators: academics and industry working and collaborating together under the same roof. We've done that in many ways with OXiGENE."

KEVIN PINNEY
professor of chemistry

integrated Intelligence

Through Advanced Information Systems

Radio Frequency Identification

Managing the supply chain of goods and services has become increasingly important to companies within a competitive, global marketplace.

PEDRO REYES
assistant professor of management

One way to achieve the orderly, automated flow of information is through the use of radio frequency identification technology (RFID) systems, which enable companies to manage their supply chain as a series of systematic processes. RFID systems provide remote and automatic identification of products and materials, storing and remotely retrieving data using imbedded tags or transponders.

Dr. Pedro Reyes is studying RFID applications in tightly controlled and sophisticated commercial settings. Reyes, an assistant professor in the Department of Management and Entrepreneurship, is developing ways to use RFID to integrate inventory management and improve decision making, especially in the grocery supply chain industry.

"That area has great potential in the logistics side," he said. "Instead of someone manually going through the shipment and checking it against the bill of lading, the RFID can scan the shipment and send an itemized listing to a printer or computer, even verify it against the order. At the same time, a priority list can be created, comparing readouts of low stock against the shipment, saving time and money."

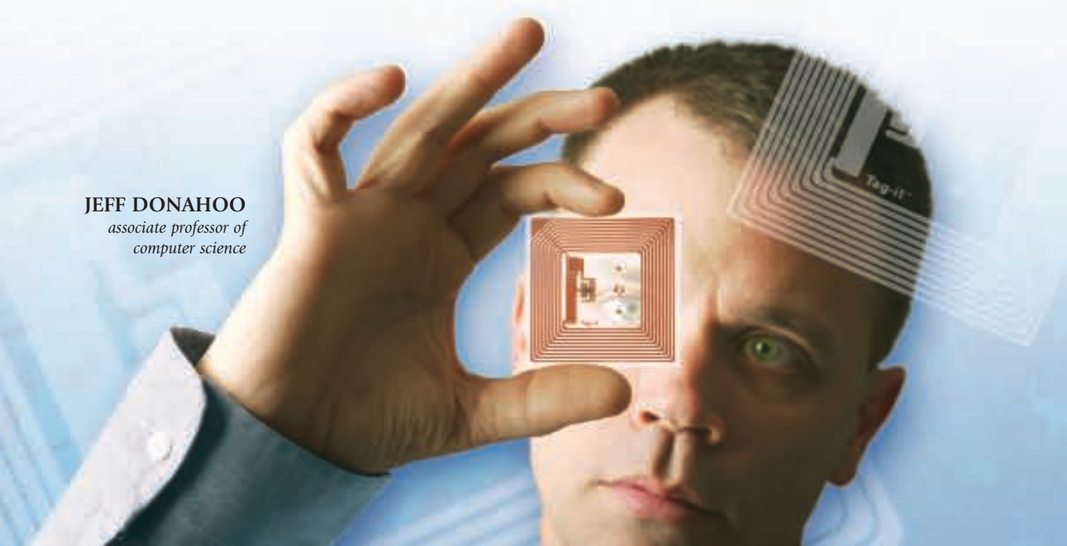
Ken Allen, senior vice president of supply chain and logistics for H-E-B, has met with Reyes to discuss RFID applications in the Texas-based grocery chain. Because the technology is so new, H-E-B has not yet incorporated RFID into its operations but is beginning to explore options.

"Reyes has identified RFID as a technology that will help us in the future," Allen said. "We, and a lot of other industry people, look to academic researchers to help us forecast systems and identify coming trends. They, the academics, help us come up with concepts and work with us in joint efforts."

Accuracy would need to be improved, Allen said, and the cost of the tags would have to drop for the technology to gain wide use in the grocery industry. "One of the most feasible applications for such tags at this time is on items that are either costly, or more importantly, for those items that can affect consumer safety," he said. In the pharmacy department, for instance, prescriptions could be tagged at the manufacturer and traced all the way through customer pickup. "We are very conscientious about the integrity of our supply chain, and this would be an extra safeguard for the consumer."

Reyes said it reduces the number of times a human has to touch the product and helps with the automation of the process. "The system can help manage the inventory better so managers can focus on the customer."

Another way to measure the return is that the ability to move stock with fewer employees or to be notified when items near their expiration date makes rotating stock more efficient



JEFF DONAHOO
associate professor of computer science

and cost effective. The technology shows great potential, but developing it is too much for one person or organization, Reyes said. "That is why it is important that inquisitive minds work together to look at the challenge from different angles."

While Reyes' focus is on applications for orderly, integrated supply chain management, other research at Baylor is focusing on using radio signals in dynamic, often chaotic situations, establishing communications within high-pressure and austere environments.

It is a scenario that has become all too familiar in the aftermath of recent natural disasters: entire regions flooded, homes washed away, power lines downed, and much of the communication infrastructure disabled. Though this may be a daunting task under extreme circumstances, maintaining network communications can be essential for survival and to get people and supplies moving again.

These are exactly the types of situations where radio information networks can come into play, said Dr. Jeff Donahoo. An associate professor in Baylor's School of Engineering and Computer Science, he is working to incorporate RFID into wireless networks that can relay information to rescue workers and others in the field.

"We are very conscientious about the integrity of our supply chain, and this would be an extra safeguard for the consumer."

KEN ALLEN,
H-E-B's senior vice president of supply chain and logistics,
on radio frequency identification technology

RFID tags can be attached to supplies, materials, and backpacks. Tags are then detected by readers to provide a running assessment of what has been used and what is needed at each location. "In this context, RFID provides a great source of information that can be collected and disseminated through delay-tolerant networks," Donahoo said. "These networks could then use short-range radio technology to relay the information from one to the other, eventually reaching command centers, where staff could arrange delivery logistics."

The research is preliminary, but Donahoo believes it holds great potential. The project involves integrating Bluetooth, a short-range personal radio technology used in mobile devices including laptops, PDAs, and cell phones, into delay-tolerant networking (DTN) technology. Because they all use short-range personal wireless technologies, they can be synchronized. "The idea is to use mobile RFID readers in the field to collect information about supply placement and consumption," Donahoo said. "We can then relay data and directives to the people who need it using DTN over Bluetooth in environments where mobile communication services are compromised."

Biostatistics

> In a different realm of the Information and Computer Technology Cluster, Dr. Dennis Johnston, a professor in Baylor's statistical science department, said he and his colleagues help make sense of information that could easily overwhelm medical researchers. "We have technically identified 30,000 genes, but some people think there may be as many as 60,000 and 500,000 different protein states," he said. "The problem is that we don't know what they are in terms of their sequence, and we have not identified them in terms of purpose.

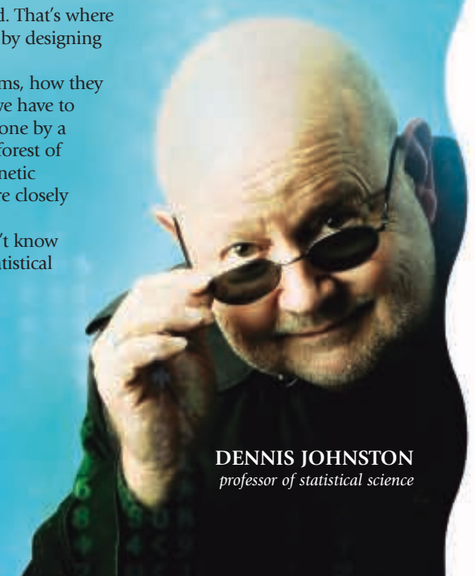
"That's enormous. You're going to get lost in it if you aren't careful," Johnston said. That's where biostatistics comes in, helping researchers make sense of all the genetic information by designing studies, retrieving and managing data, and interpreting findings.

"You have to be able to organize a plan in terms of different experiments, organisms, how they respond. It's a complicated thing, at the very least," Johnston said. "At some point, we have to stand back. That's why this can no longer be done just in a laboratory. It has to be done by a group of people who can organize the information and begin working through the forest of material." Biostatistics helps organize that material by isolating common traits in genetic markers and grouping them into statistical clusters, thus allowing researchers to more closely identify possible causes for cancers and other diseases.

"It's both science and art," Johnston said. "We try to pick up a pattern. … We don't know what the pattern is going to be, but at least we can begin watching." This process, statistical cluster analysis, is possible because of today's faster and more powerful computers.

"In really big science, the individual combinations are not even connected, but instead are Web-based," Johnston said. Researchers draw information from each other's projects through data mining, pulling data from a range of research projects to augment their own research projects.

"People are working on different pieces of problems," Johnston said. "The answer could be in any one thing or in a number of them or in interactions. You have to determine which interactions are involved specifically in the process you're trying to control. … This is an exciting time to be a scientist," Johnston said, "but we are getting buried in the information. Collaboration helps us make sense of it."



DENNIS JOHNSTON
professor of statistical science

Bioinformatics

> Like Johnston, Dr. Erich Baker also is developing computer applications for managing the biological and genetic data that far exceeds the capacity to manage it. Baker, a Baylor assistant professor of bioinformatics, focuses on using computational resources to address biologically meaningful questions through data retrieval, management, and analysis.

His current research includes collaboration with the U.S. Department of Energy to develop a system that will connect researchers studying *Shewanella*, an organism used for bioremediation because it breaks down heavy metals and toxic substances.

Different researchers are studying different parts of the organism's genome, and Baker is working on a database to collect all that information to be put into one place. He is developing the algorithms to identify different parts of the genome. "This grant is a fairly sizable grant that will allow us to coordinate all these different views," Baker said. After that system is successfully developed, researchers can apply the same concept to other projects.

"This is a very exciting field because everything we're doing is new," Baker said. "Almost every question we ask is a new question, every approach we take is a new approach, and every answer is a new answer. It's mind-boggling, almost like detective work.

"We want to figure out how the puzzle goes together," Baker said. One of those scientific puzzles he is trying to solve is how phenotype evolves from genotype. "Everybody's complement of genes is very similar, but we look very different," he said. "So my research analysis is based on what makes the difference."

To answer that question, researchers isolate sets of genes and observe how they interact with each other over different time scales. In evolutionary time, for instance, genes are altered from one species to another. Over the aging process – developmental time – genes that interact in one way at the embryonic stage interact in an entirely different way as the organism ages. In the here-and-now present of physiological time, genes interact in other ways.

"Understanding how those interactions change will probably give us the biggest clues to why we look so different when we share almost the same genomes," Baker said.

ERICH BAKER
assistant professor of bioinformatics

Powering the Energy Sector

With interdisciplinary energy research, innovative educational training programs, and a focus on industrial applications, Baylor is poised to enhance the bottom line of one of Texas' largest and most familiar industries.

In the United States, petrochemical begins with "T," as in Texas. Texas produces more oil than any other state and alone handles almost a third of the oil refined nationally. It is also the leader in natural gas production, churning out nearly as much as the next five top-producing states combined.

But in recent years, the stereotypical Texas oilman has lost some of his swagger. Demand for energy is increasing as political situations and geographic realities cause supplies to dwindle worldwide. Industry recruitment has dropped just as engineers and scientists attracted to the industry during the boom of the late 1970s start retiring. It is no wonder Texas Governor Rick Perry has identified the petrochemical refining and energy sectors in Texas as clusters worth nurturing.

"It's really difficult right now," said Hank Jamieson, chuckling at his own understatement. A Baylor alumnus, member of the Baylor Geology Advisory Board, and geological associate at ExxonMobil, Jamieson received his MS in geology from Baylor during the oil and gas heyday, a time when oil and gas were a little easier to find here in Texas. He explains that while it was exciting to be a geologist during those times, the current challenging environment provides greater opportunities for students. Hydrocarbon seekers have found and tapped most of the "easy" oil and gas. Now, some of the large remaining reserves around the world are in "heavy oil," which is viscous, difficult to extract from the ground, and even more difficult to refine.

"We have to be more and more creative with what we do," Jamieson said. "We've gotten everything that we could get with the tools we have. It's time to move from the end of the proverbial road to another path, to new ways of doing things that will help us start finding and producing additional hydrocarbon resources."

HANK JAMIESON
geological associate at ExxonMobil and Baylor alumnus

"Working elbow to elbow with industry scientists, APS students are solving real problems and seeing real results, finding oil and gas reserves that companies choose to drill or not to drill because of work that a student has done."

DR. STACY ATCHLEY, associate professor of geology, on the benefits of student involvement in industrial projects

STACY ATCHLEY
associate professor of geology

Petroleum Recovery and Baylor's Applied Petroleum Studies Program

> To prepare students in forging these new paths, Baylor's geology department has itself set off in a new direction. The Applied Petroleum Studies (APS) program is one of the only programs in the country that teams students and faculty members with industrial geologists and engineers to tackle real-world problems. Stacy Atchley, associate professor of geology, initiated the program in 1996 to set Baylor students apart.

"To compete with and outperform graduates from other institutions, we need to bring something to the table that's more than other universities can provide," said Atchley. APS solicits industry for suitable research projects, with most involving the construction of geologic models to determine possible drilling locations and facilitate the assignment, assessment, and ranking of reserves for development. Atchley then identifies Baylor students to work on the project on-site with the industry partner.

In addition to providing students with solid industrial experience, APS collaborations provide substance for classroom learning and lecture topics, where hands-on experience gained in the field is brought back to the classroom. The data and research results gained from these experiences are frequently developed into graduate student theses.

"Our students are working on projects that students at competing institutions couldn't dream of doing," Atchley said. "Working elbow to elbow with industry scientists, APS students are solving real problems and seeing real results, finding oil and gas reserves that companies choose to drill or not to drill because of work that a student has done."

APS is raising Baylor's visibility and competitiveness at a time when nationwide enrollment in geology programs is down. Like Jamieson, Atchley attended Baylor during the oil and gas heyday of the 1970s and worked in the industry for seven years before joining the Baylor faculty in 1995. Since returning to Baylor, he has traced a more disturbing trend in the energy sector. In the past few years, with prices climbing to the highest they have ever been in the United States, fewer students are entering geoscience programs.

APS is changing that trend. Last year, graduate applicants to Baylor's geoscience programs doubled over those received for 2004. The quality of the applicants increased as well. According to Atchley, all APS participants seeking industrial jobs have received them, and many end up weighing multiple offers. Atchley's most recent graduate had six different offers.

Today, Baylor's geoscience programs are operating in a new league. "We competed for graduate students last year with institutions that we've rarely competed with before," Atchley said, citing the University of Texas at Austin, Texas A&M, and the University of Calgary. "These are all large research universities," Atchley notes. "Obviously, students in Texas and around the world are seeing the work we do and the opportunities available through APS and are interested in learning more about Baylor."

PETER VAN WALSUM
assistant professor of environmental studies

Biomass Research and Development

> Atchley credits Baylor's concern for students' professional and personal development as the impetus for forward-thinking, collaborative, industry-minded projects like those available through APS. It is the same attitude that drives many of Baylor's research programs, including research into a potential new energy source: biomass.

Baylor has a rich history in the research and development of alternative energy sources, as manifested in the Baylor Institute for Air Science and its research into ethanol as an alternative aviation fuel. Baylor's biomass research brings together scientists from different departments: Peter van Walsum, an associate professor of environmental studies, and Kevin Chambliss, an assistant professor of chemistry. The two are collaborating to understand the fundamental chemical reactions that occur when biomass, biological waste materials that can encompass everything from waste paper pulp to solid waste to grown "energy" crops, is degraded and converted into ethanol.

"We're asking questions in this process that others just aren't equipped to answer," said van Walsum. His research tackles the biomass pretreatment process itself, with an eye not just toward what the process produces and how these products can be exploited, but also toward how the production of these products, in turn, impacts the process. Chambliss' research specializes in the analysis of complex mixtures and is helping to elucidate the specific reactions involved in biomass degradation.

"A major goal in biomass research is to not just make energy, but to shift the entire material economy to a carbohydrate backbone, to run biorefineries that make energy as well as valuable byproducts," said van Walsum. "We know when you cook biomass, lots of stuff happens, but the process has been very much a black box, very opaque.

"Kevin (Chambliss) has the tools to clarify it, and with that knowledge, my group can find ways to monitor and optimize it," said van Walsum. As science becomes more interdisciplinary, collaborations of this type seem de rigueur on college campuses. According to Chambliss, Baylor provides a great opportunity for interdisciplinary research. "We strive to be a family, where it's more than just come to work; this is your lab; this is what you do."

The biomass project also offers Baylor students the opportunity to master techniques in chemistry and engineering. Chambliss notes that his students come away understanding all aspects of the refinery system: what's going in, what's coming out, and what's going on in between. "If you're an analytical chemist in a plant, it's not enough to find what you're looking for," said Chambliss. "The more you know about the process and the feedstock, the better prepared you'll be to find other things, materials that hinder, speed up, or add value to the refining process."

The result is students with skills and, more importantly, the knowledge to apply the skills, a combination that will be a boon to energy companies as they reshape themselves. ExxonMobil's Jamieson explains that many schools today do well teaching technology expertise but fail to teach students how to apply these techniques to industrial problems.

"There are thousands of things you can do with, say, 3-D seismic tools," Jamieson said. "But how do you narrow it down and apply the tools to the specific problem you are trying to solve? That's the magic. Students need to think first about the question they are trying to answer and then decide what technology to apply."

This, according to Atchley, is something a lecture course alone cannot teach. Professors also are learning from the integrated, interdisciplinary projects in energy research under way at Baylor.

"On these integrated teams, students see that professors don't have all the answers, that it's up to everyone to be creative and think beyond what they have seen in the classroom," said Atchley. "You don't gather cobwebs here, no way."

Graduate Degrees at Baylor

Accounting — MAcc, MAcc/BBA, MAcc/JD
Advanced Neonatal Nursing — MSN
Advanced Nursing Leadership — MSN
American Studies — MA
Biology — MA, MS, PhD
Biomedical Engineering — MSBME, MSBME/BSECE, MSBME/BSME, MSBME/BSE
Biomedical Studies — MS, PhD
Business Administration — MBA, MBA/JD
Business Administration in Informational Systems Management — MBA/ISM
Business Administration in International Management — MBI
Business Administration/Information Systems — MBA/MSIS
Chemistry — MS, PhD
Church Music — MM, MM/MDiv
Church-State Studies — MA, PhD
Clinical Psychology — PsyD
Communication Sciences and Disorders — MA, MSCd
Communication Studies — MA
Composition — MM
Computer Science — MS
Conducting — MM
Curriculum and Instruction — EdD, MA, MSEd,
Directing — MFA
Earth Sciences — MA
Economics — MSEco
Educational Administration — MSEd
Educational Psychology — EdS, MA, MSEd, MSEd/MDiv, PhD
Electrical and Computer Engineering — MSECE, MSECE/BSECE
Engineering — ME, ME/BSECE, ME/BSME, ME/BSE
English — MA, PhD
Environmental Biology — MS
Environmental Studies — MES, MS
Exercise, Nutrition, and Preventative Health — PhD
Family Nurse Practitioner — MSN
Geology — MS, PhD
Health Care Administration, Fort Sam Houston — MHA
Health, Human Performance, and Recreation — MSEd
History — MA
Information Systems — MSIS
International Economics — MA, MS
International Journalism — MIJ
International Relations — MA
Journalism — MA
Limnology — MSL
Mathematics — MS, PhD
Mechanical Engineering — MSME, MSME/BSME
Museum Studies — MA
Music Education — MM
Music History and Literature — MM
Music Theory — MM
Neuroscience — MA, PhD
Performance — MM
Philosophy — MA, PhD
Physical Therapy, Brooke Army Medical Center — DScPT
Physical Therapy, Fort Sam Houston — MPT, DPT
Physical Therapy, West Point — DScPT
Physics — MA, MS, PhD
Piano Accompanying — MM
Piano Pedagogy and Performance — MM
Political Science — MA
Public Policy and Administration — MPPA, MPPA/JD
Religion — MA, PhD
Religion, Politics, and Society — PhD
Social Work — MSW, MSW/MDiv
Sociology — MA, PhD
Spanish — MA
Statistics — MS, PhD
Taxation — MTax, BBA/MTax, MTax/JD

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Center for Ministry Effectiveness and Educational Leadership
Center for Religious Inquiry Across the Disciplines
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Institute of Archeology
Institute of Biblical & Related Languages
Institute of Biomedical Studies
Institute of Ecological, Environmental, and Earth Sciences
Institute for Faith & Learning
Institute of Gerontological Studies
Institute for Oral History
J.M. Dawson Institute of Church-State Studies

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