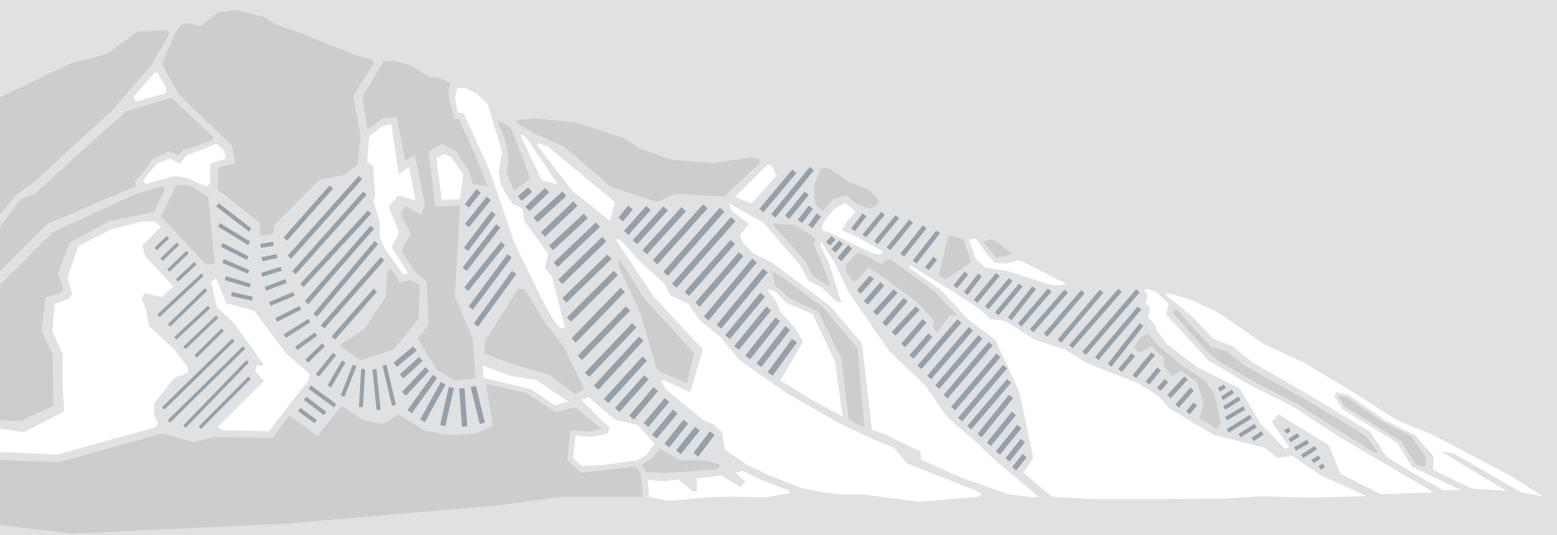


RESEARCH REPORT

COLLEGE OF ENGINEERING

2010





Contents

BUILDING ENGINEERING AT THE U.....	2
THE SCIENCE OF SIMULATION.....	4
SCIENTIFIC VISUALIZATION.....	6
BUILDING A FUTURE FOR NUCLEAR ENGINEERING	8
BIOMEDICAL POLYMERS	10
RADIO WAVES 'SEE' THROUGH WALLS.....	12
NANOMATERIALS AND DEVICES.....	14
FACTS AND FINANCIALS	16



From the Dean

JUNE 17, 2010, was a red-letter day for the University of Utah as President Michael K. Young signed the acceptance letter joining the Pacific-10 conference, surrounded by cheering friends and fans. Such recognition distinguishes the entire University, and the College of Engineering joins the University and the community in celebrating this milestone.

Engineering has plenty of reason to cheer. Mechanical engineering 2009 graduate Zane Beadles, an outstanding student who was a first-team All-American, was recruited last April as an offensive lineman for the Denver Broncos. Engineering student athletes, both men and women, distinguish themselves in collegiate sports ranging from skiing, swimming and soccer, to tennis and track. All will benefit from the Pac-10 inclusion.

Utah's academic profile is a great fit for the Pac-10 conference, which includes such schools as Stanford, UCLA and USC. The research-metric-driven *Academic Ranking of World Universities* lists both the University of Utah and its College of Engineering among the top 100 in the world. Utah has particular distinction in medicine, genetics and engineering. Acclaimed faculty member Mario R. Capecchi, a 2007 Nobel Prize winner, will fit well into the roster of 25 Nobel Laureates from other Pac-10 institutions.

A feeling of momentum and excitement pervades the University of Utah campus, particularly in the College of Engineering. For nearly a decade, Engineering has been focused on a strategy of growth with quality. The University

of Utah is graduating 76% more engineers and computer scientists than it did 10 years ago. This is three times the national growth in engineering degrees over the same time period.

For the first time, the College of Engineering has been ranked by ASEE among the top 50 schools in the nation (out of 341 institutions) in the number of bachelor's degrees granted, and 37th in the number of Ph.D.s graduated. Equally compelling is the fact that the U of U is 41st in the nation in engineering research expenditures and 38th in the number of tenure-track engineering faculty.

Our strategy for growth is built on a commitment to quality and the understanding that Utah and the nation need more highly qualified engineering and computer science leaders. Ninety students are currently enrolled in the Engineering Honors Program, and the academic index of entering students is higher today than it was in 2000. The addition of 48 faculty in the past 10 years, including 18 USTAR hires, to an excellent, established faculty has raised performance in our teaching and research programs to an unprecedented level.

Despite a challenging economy, we remain optimistic—our state and University support are strong. As the U looks forward to competing as a Pac-10 team, the College of Engineering will be scoring touchdowns as one of the fastest growing engineering programs in the nation.

Richard B. Brown
DEAN, COLLEGE OF ENGINEERING

Building Engineering at the U

Two University of Utah building and expansion projects will enhance the College of Engineering campus, ensuring a continued robust program of innovation and technology development. The newly renovated Floyd and Jeri Meldrum Civil Engineering Building was completed in August 2010, and the James L. Sorenson Molecular Biotechnology Building—a USTAR Innovation Center, is expected to be finished in December 2011.

The Floyd and Jeri Meldrum Civil Engineering Building is a new integrated home for the Department of Civil and Environmental Engineering. The 14,500-square-foot addition to the former Energy and Minerals Research Building brings together civil, environmental, and nuclear engineering faculty into contiguous space with a newly designed transportation operations center and environmental engineering labs. The student-designed construction showcases sustainable engineering systems, materials and structural elements. The Layton Construction Auditorium provides facilities for distance learning and communication training. Leadership and

mentoring centers provide homes for student organizations and tutoring opportunities. The Dunn Commons features an informal gathering space for students and professionals. The renovations are supported by a \$3.3 million gift from alumnus Floyd Meldrum and his wife Jeri.

The James L. Sorenson Molecular Biotechnology Building—a USTAR Innovation Center, will unite the health sciences campus and main campus in order to accelerate research at the interfaces of medicine, engineering, pharmacy and science. The 200,000-square-foot interdisciplinary facility will support 25 senior faculty researchers, junior faculty, and administrative and laboratory personnel in a number of lab and research spaces, including four specialty core research facilities for small-animal imaging, biomedical microscopy, engineering microscopy and nanofabrication. The building is funded by a \$15 million cornerstone gift from the Sorenson Legacy Foundation, \$100 million from the state of Utah, and private donations. USTAR (Utah Science Technology and Research) is a long-term economic development initiative to promote Utah-based technologies and research for commercialization.



NEW FACULTY HIRES



Otakuye Conroy
Civil & Environmental Engineering

EDUCATION:
Ph.D., environmental engineering, University of Arizona

PREVIOUS POSITION:
Research fellow, Climate and Energy, National Congress of American Indians

RESEARCH INTERESTS:
Organic micro-pollutant removal during wastewater treatment, soil-aquifer treatment, and riverbank filtration; endocrine disrupting chembioassays



Tatjana Jevremovic
Nuclear Engineering
Civil & Environmental Engineering
Chemical Engineering

EDUCATION:
Ph.D., nuclear engineering, University of Tokyo

PREVIOUS POSITION:
Associate professor of nuclear engineering, Purdue University

RESEARCH INTERESTS:
Computational methodologies for current and future generation nuclear applications



Faisal H. Khan
Electrical & Computer Engineering

EDUCATION:
Ph.D., electrical engineering, University of Tennessee

PREVIOUS POSITION:
Senior power electronics engineer, Electric Power Research Institute in Tennessee

RESEARCH INTERESTS:
DC-DC converters, multilevel converters, hybrid and fuel cell vehicle power management, and energy management of renewable sources



Hanseup Kim
Electrical & Computer Engineering

EDUCATION:
Ph.D., electrical engineering, University of Michigan

PREVIOUS POSITION:
Visiting scholar, Solid State Electronics Laboratory, University of Michigan

RESEARCH INTERESTS:
Bio nano- and microsystems in moving fluids, system integration, robots, and energy harvesting



↑ James L. Sorenson Molecular Biotechnology Building—a USTAR Innovation Center

← Floyd & Jeri Meldrum Civil Engineering Building



Gianluca Lazzi
Electrical & Computer Engineering

EDUCATION: Dr. Eng., electronic engineering, Sapienza University of Rome; Ph.D., electrical engineering, University of Utah

PREVIOUS POSITION: Professor of electrical & computer engineering, North Carolina State University

RESEARCH INTERESTS: Bioelectronics engineering; implantable devices; biological effects and applications of electromagnetic fields; wireless electromagnetics and antennas; and computational electromagnetics



John McLennan
Chemical Engineering

EDUCATION: Ph.D., civil engineering (rock mechanics), University of Toronto

PREVIOUS POSITION: Research professor, Energy and Geoscience Institute, University of Utah

RESEARCH INTERESTS: Gas storage mechanisms in resource plays, stimulating low permeability reservoirs, carbon dioxide enhanced oil recovery, enhanced geothermal systems



Rajesh Menon
Electrical & Computer Engineering

EDUCATION: Ph.D., electrical engineering & computer science, MIT

PREVIOUS POSITION: Research Laboratory of Electronics, MIT

RESEARCH INTERESTS: Nanopatterning, nanofabrication, optical nanoscopy, micro- and nano-optics, solar concentrators, and plasmonics



Richard J. Porter
Civil & Environmental Engineering

EDUCATION: Ph.D., civil engineering, Pennsylvania State University

PREVIOUS POSITION: Assistant research scientist, Texas Transportation Institute, Texas A&M University

RESEARCH INTERESTS: Study and modeling of driver behavior and decision-making for highway safety and traffic operations



Darrin J. Young
Electrical & Computer Engineering

EDUCATION: Ph.D., electrical engineering and computer sciences, UC-Berkeley

PREVIOUS POSITION: Associate professor of electrical engineering & computer science, Case Western Reserve University

RESEARCH INTERESTS: MEMS design, fabrication, and integrated circuits design for wireless sensing, biomedical implant, RF and optical communication, and industrial applications

The Science of Simulation:

REPLICATING COMBUSTION AND REACTING FLOW PROCESSES

Combustion has been fundamental to the growth of society since the discovery of fire, and remains vitally important today. More than 85 percent of energy used in the United States comes from coal, oil and other fossil fuels. Energy from burning these sources provides electricity and fuel for everyday uses: from heating and cooling our homes to running our automobiles.

“Combustion is the heart of energy conversion processes everywhere,” says Philip Smith, professor of chemical engineering. “The world has been studying fire since before the written word, but even now we still don’t fully understand the combustion process. Yet it’s essential to the world.”

Smith is director of the Institute for Clean and Secure Energy (see sidebar on opposite page) and the fire leader for the Center for the Simulation of Accidental Fires and Explosions (C-SAFE), both at the University of Utah. C-SAFE is a large interdisciplinary team from computer science, chemical engineering, mechanical engineering, physics, chemistry, and other departments, that produces cutting-edge research in simulating and visualizing complex physical phenomena including reacting flows, material properties, multi-material interactions, and atomic-level chemistry.

Smith and his research group study the complexities of combustion through “simulation science,” where researchers use large-scale computers to calculate and reproduce what will occur in the physical world often without having to conduct real-life experiments. Simulating fires helps the group analyze real fires and conditions that affect them. Smith and his team perform computer simulations with the aim of designing combustion processes to be more efficient and create less pollution.

“Simulation science is helping to advance our understanding of combustion—a process which is too big and complicated for analytical solutions,” says Smith. “We can use computer simulations to replicate an industrial furnace, as an example, and predict its functionality and capability. This allows us to explore the most efficient, environmentally friendly options before we go to the expense and time of building the furnace.”

Besides industrial and utility furnaces, the research team has developed 3-D computer simulations of process heaters for ethylene production, flash copper smelters, chemical process kilns and reactors. They have also created simulations that model the “flow” or behavior of fluid in accidental fires and explosions.

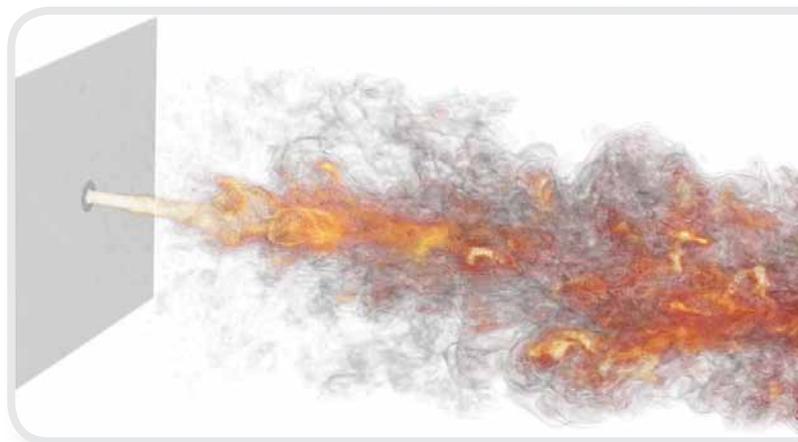
A further step in analyzing combustion involves scientific visualization, or transforming simulations into images. Smith’s work is connected to visualization methods developed by his colleague Charles Hansen, professor in the School of Computing, who is also featured in this report. Read more about Hansen’s research on page 6.

CAPTURING CO₂ AND OTHER EMISSIONS

Smith and his associates have been working on a simulation project to capture carbon dioxide (CO₂), a gas emitted during the combustion process and important to researchers concerned about climate change. Although there are a number of ways to capture CO₂, Smith is simulating capture through a “fluid” process. The method involves “bubbling” or passing carbon dioxide gas through a chemical-water mixture. The gas reacts with the chemicals and is absorbed into the water. The CO₂ undergoes additional reactions to precipitate a cement solid that can then be separated from the water. The cement may be used in building materials, such as Portland cement for driveways.

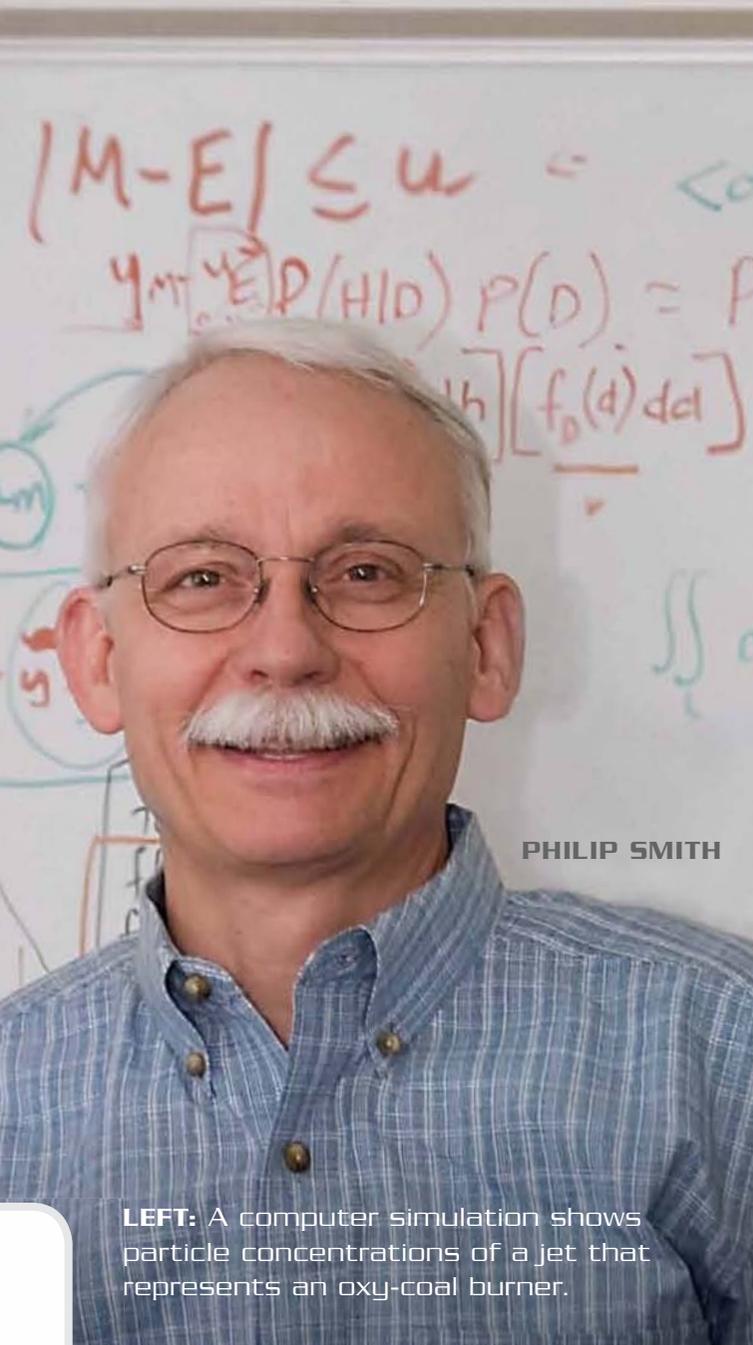
“We simulate the process so we can make sure the CO₂ solid has the right properties for cement,” says Smith. “We’re currently working with some companies who are demonstrating this technology now.”

The researchers are employing similar simulation techniques to effectively capture other emissions created by combustion, such as sulfur and nitrogen oxide, which contribute to acid rain and smog.



CONVERTING COAL TO NATURAL GAS

Smith and his team are simulating methods of coal “gasification,” where coal is converted into syngas, a gas mixture of carbon monoxide and hydrogen, by reacting with a controlled amount of oxygen or steam at high temperatures. Coal gasification is used in countries that have



PHILIP SMITH

LEFT: A computer simulation shows particle concentrations of a jet that represents an oxy-coal burner.

abundant sources of inexpensive coal but little petroleum reserves, as well as in countries seeking to decrease their dependence on foreign oil.

"Syngas would be used in place of petroleum to make a chemical feedstock for common products, such as plastics and other chemicals currently made from petroleum," Smith says.

Smith is working on simulations to improve the efficiency of coal gasification and reduce emissions. Eventually, he hopes the process will be improved to where it will be used more widely around the world.

DESIGNING INDUSTRIAL FLARES

Oil refineries and chemical plants use gas flares to combust waste gas and liquids that often contain harmful pollutants. Flare stacks—elevated vertical vent pipes that burn released gases—act as safety devices to protect equipment from being overpressured. But Smith says there are no government regulations on flares and there is growing concern that waste gas may escape unburned under high-wind or high-steam conditions.

"It's difficult to measure what is coming out of flares," says Smith. "People are worried about the emissions from flares and whether all the hydrocarbons are burned off or being emitted as pollution."

The researchers are simulating the chemical composition and temperature of flares to provide information that may help them design or operate flares in a way that reduces or eliminates harmful pollutants and increases combustion efficiency.

"Our simulations are unique in the world," says Smith. "Simulation tools are helping to provide insight into solutions of longstanding combustion problems. The program we've set up, the large-scale computers, and our multidisciplinary research combine to create a program on clean and secure energy that is unprecedented in the world."

THE INSTITUTE FOR CLEAN AND SECURE ENERGY

Combustion and related energy-generation activities affect our quality of life through the cost and availability of power and through their impact on health and the environment. The Institute for Clean and Secure Energy (ICSE) comes from a long tradition of combustion research at the University of Utah beginning in the 1950s and continuing today. It employs an

integrated, multidisciplinary approach to the study of energy, combustion and high-temperature fuel-utilization processes by combining hands-on experimental work with analytical tools and simulation.

Directed by professor Philip Smith, ICSE is focused on pragmatic solutions to future energy demands,

technological challenges and carbon-related problems with the goal of identifying the most effective ways to use coal, oil shale and oil sands resources. Large-scale environmental mitigation strategies, including oxy-fuel combustion, carbon sequestration, and the use of opportunity fuels are also explored. ICSE currently funds more than 110 researchers.

Scientific Visualization:

ANALYZING AND UNDERSTANDING COMPLEX DATA

Since the dawn of computing, the world has undergone an information explosion. As the amount of available information increases exponentially, the problem of understanding and effectively using the data becomes more challenging.

Scientific visualization, also referred to as visual data analysis, is the transformation of scientific data into graphical images. It is especially useful when studying massive amounts of complex data in order to gain visual understanding and insight into the information.

Charles Hansen, professor in the School of Computing, focuses his research on developing novel algorithms and building tools and systems that assist in the comprehension of large quantities of scientific data. Hansen is also associate director of the Scientific Computing and Imaging (SCI) Institute at the University of Utah. SCI is an internationally recognized leader in visualization, scientific computing and image analysis.

“Interactive techniques provide better cues when trying to understand spatial and temporal relationships between data,” says Hansen. “Therefore, the main focus of my research is on developing better methods for visualization and rendering at interactive rates.”

For the past 20 years, Hansen’s research has involved employing parallel rendering techniques for visualization, utilizing innovative data structures for faster access to information, and developing visualization algorithms.

“With the advent of the programmable GPU [graphics processing unit], my background in parallel algorithms is providing unique opportunities to develop new methods using the GPU hardware,” says Hansen. “We’re also able to generate imagery very fast.”

VISUALIZING SIMULATED FLUID FLOW

Hansen is using interactive methods to analyze behavior of fluids (liquid, vapor or gas) and applying them to computational fluid dynamics. Hansen and his team have developed software tools for the University of Utah’s Center for the Simulation of Accidental Fires and Explosions, or C-SAFE, a large interdisciplinary team from computer science, chemical engineering, mechanical engineering, physics, chemistry, and other departments, that produces cutting-edge research in simulating and visualizing complex physical phenomena including reacting flows, material properties, multi-material interactions, and atomic-level chemistry.

C-SAFE was established through the U.S. Department of Energy’s Advanced Simulation and Computing Program.

Through unique 3-D computer simulations, C-SAFE researchers can model the “flow” or behavior of fluid when, for example, fuels or explosives ignite accidentally or intentionally. With Hansen’s visualization tools, researchers can analyze real fires and conditions that affect them. “Understanding fluid flow is a difficult problem and of increasing importance because computational fluid dynamics produces a huge amount of simulation data,” says Hansen.

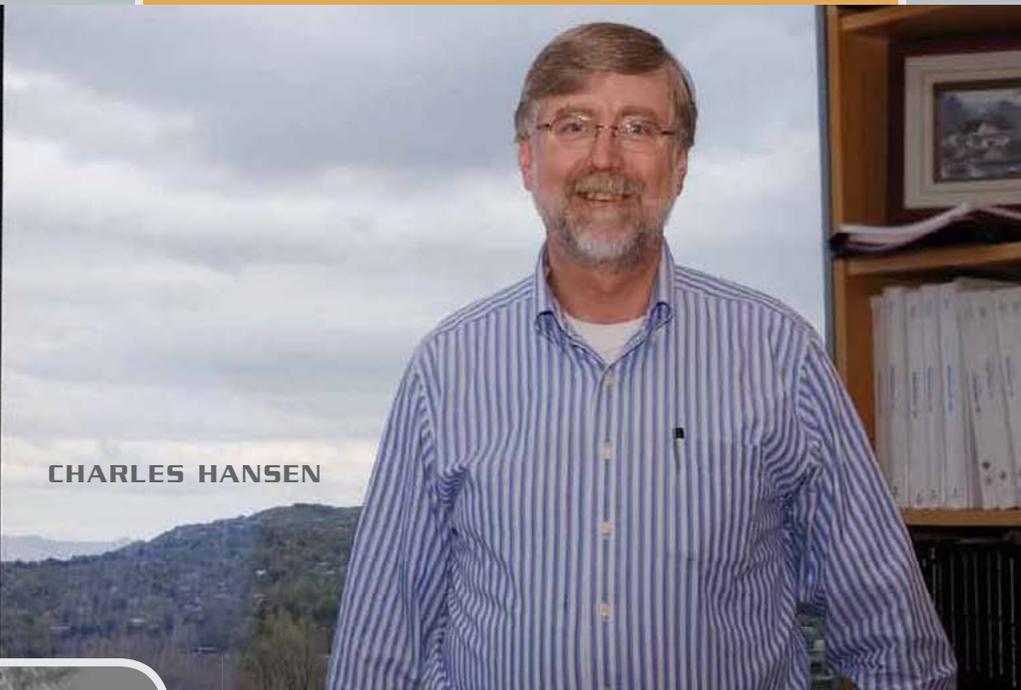
Hansen’s work at C-SAFE is connected to simulation research done by his colleague Philip Smith, professor of chemical engineering, who is also featured in this report. Smith conducts the fire simulations and experiments that Hansen visualizes through graphical images. Read more about Smith’s research on page 4.

Hansen and his team have recently developed a novel computational method to analyze fluid flow based on an experimental technique. Their method simulates the refraction of light to generate synthetic flow visualization images derived from computational fluid dynamics data. They use both shadowgraphs (where flow is shown through its shadow) and schlieren images (where flow is shown through light refraction). The group’s method uses a combination of GPU programming, acceleration methods, and schlieren techniques to achieve interactive, physically accurate images.

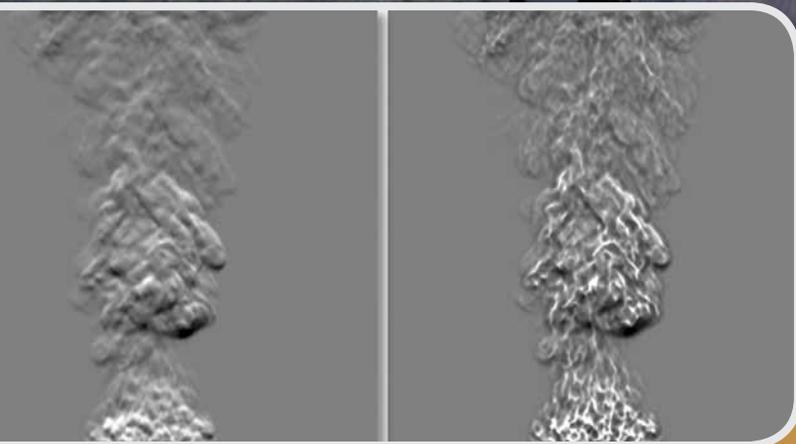
“If we can simulate schlieren imagery to analyze computational fires, we can apply the same analysis methods to computational data that people do to experimental data,” says Hansen. “We can link experimental and computational data to try out new and different ideas.”

Although shadowgraph and schlieren techniques have been around for a long time, Hansen says, “We’ve





CHARLES HANSEN



ABOVE: A helium plume is depicted using **(LEFT)** a traditional volume rendering technique, **(CENTER)** a shadowgraph image, **(RIGHT)** a computational schlieren method developed by Charles Hansen's group that achieves an interactive, physically accurate image.

improved upon previous work by tracing curved light paths rather than relying on line-of-sight approximations."

Hansen's team won the Best Paper Award for their research at the 2010 Institute of Electrical and Electronics Engineers (IEEE) Pacific Visualization Symposium.

Although scientific visualization is his main research focus, Hansen is also working on improving computer graphics and rendering models. He plans to develop faster algorithms for visualization techniques, better methods for volume rendering, and improved methods for using GPUs in visualization.

A LEADER IN DIGITAL MEDIA

The University of Utah has long been at the forefront of computer graphics and animation. In the late 1960s, David Evans and Ivan Sutherland took the lead in creating the field of computer graphics and establishing the U's world-renowned computer science program. In addition to their own fundamental contributions, their legacy includes a remarkable group of graduates who pioneered personal computing and computer graphics, including Alan Ashton, Ed Catmull, Jim Clark, Alan Kay and John Warnock.

Computer science professor Charles Hansen is part of a search committee seeking to build a team of experts in digital media at the University of Utah. The Digital Media Institute is being organized as part of the USTAR (Utah Science, Technology and Research) initiative—a long-term, state-funded effort to strengthen technological research and stimulate economic development in Utah. With an emphasis in computer game technology, the institute will be a research center for the university's colleges of engineering, fine arts and architecture. The institute will also collaborate with Utah computer gaming studios to promote entrepreneurship by licensing university technology to spin-off companies.

The search team has already recruited Craig Caldwell, a professor in film studies, and is looking for other experts in computer science and fine arts.

"I think this effort is good for the School of Computing, the College of Engineering, and the state of Utah," Hansen says. "I believe it's where a lot of the future education and research in computer science is moving. It will be a great platform for teaching students in an engaging environment."

Building a Future for Nuclear Engineering



TATJANA JEVREMOVIC

RIGHT: Two different views of a nuclear reactor's core are displayed on iPhones using ImageVis3D Mobile software developed by the University of Utah's Scientific Computing and Imaging Institute.

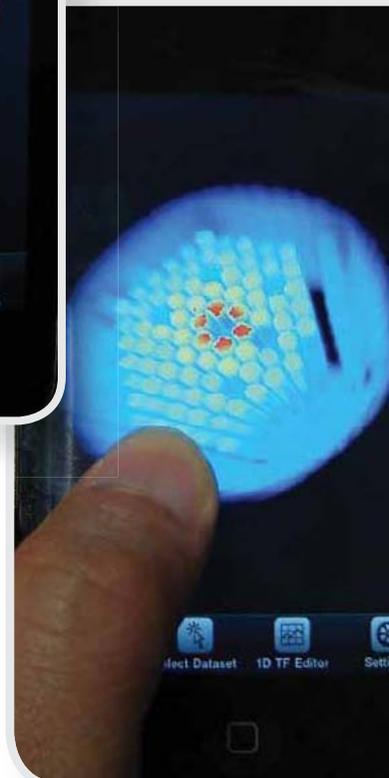
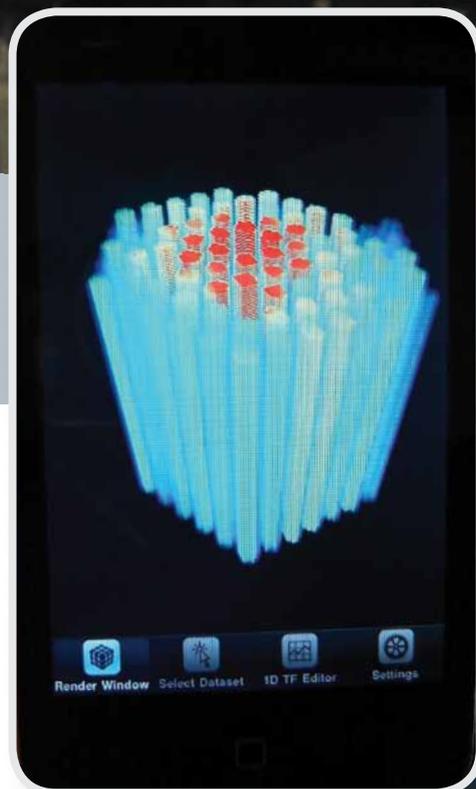
PHOTO CREDIT:
Shanjie Xiao,
University of Utah

With concern over dependence on foreign oil and climate change due to carbon dioxide emissions from burning coal, oil and other fossil fuels, "there is now an overall renaissance in nuclear engineering, not just in the United States but in the world," according to Tatjana Jevremovic, director of the University of Utah Nuclear Engineering Program (UNEP).

"We certainly have to consider the environment for our children," she says. "The future is nuclear energy for many reasons. It's safe and proven technology. The world has more than 40 years experience in operating nuclear power plants."

Jevremovic is the EnergySolutions Presidential Endowed Chair Professor in Nuclear Engineering. The chair is supported by a generous gift from the EnergySolutions Foundation. Jevremovic is also a professor of chemical engineering and of civil and environmental engineering.

An expert in computational modeling and theoretical analysis applied to nuclear engineering, Jevremovic is helping



to build the nuclear engineering program at the University of Utah. Her research focuses on developing advanced computational simulation tools for such areas as nuclear reactor design, education, medicine, homeland security, and space exploration.

SIMULATING A NUCLEAR REACTOR

Jevremovic and her research team are developing computational tools to reproduce real-time simulations of a nuclear reactor. A nuclear reactor core contains long, cylindrical fuel rods packed together vertically in a fuel assembly. The University of Utah's Training, Research, Isotopes and General Atomics (TRIGA) Reactor was built 35 years ago to promote nuclear engineering research, education, radiation science and health physics. The reactor is among only 13 of its type still operating at universities in the United States. It runs on a mixture of uranium-235 and uranium-238 fuel.

Simulations involve computational calculations that reproduce what will occur in a real reactor and provide details about a reactor's performance. They follow the movement of neutrons, which collide with uranium to cause a fission reaction. A simulation can show the density of neutrons in the reactor over space and time, and can also display fission reaction rates and the level of power being produced.

Jevremovic's team can also calculate the distribution of reaction rates across the core, which gives them information about fuel use at any instant in time. Simulations help the group better understand neutron transport and interactions in a reactor core, which helps them improve the design, cost and speed of building nuclear reactors.

"We simulate everything now on a computer," she says. "Computer technology has developed rapidly, and we can do calculations and simulations we could just dream of five years ago."

The U of U's Nuclear Engineering Program is actively seeking to improve nuclear reactor design and engineering. UNEP is working with a group of nine other universities, as well as nuclear industry experts and small companies on developing innovative 3-D, multi-scale simulation tools using novel computational platforms to improve existing nuclear reactors as well as aid in the design of new reactors.

IPHONE GOES NUCLEAR

An iPhone application designed by the U's Scientific Computing and Imaging (SCI) Institute to look at medical CT or MRI scans is now being used by the nuclear engineering program to display simulations of a nuclear reactor's core on an iPhone. The visualization software—an iPhone app named ImageVis3D Mobile—is an important teaching tool for nuclear engineering students.

"A lot of students already have iPhones or iPods, so I thought we could use the software SCI had already developed to teach students," says Jevremovic. "Humans react much better to what they see than just looking at some numbers."

Jevremovic plans to develop a secure way for nuclear engineers in academic settings to share simulation data with those at commercial power plants—something that will speed up communication and the transfer of information in a modern and advanced way.

SECURITY AND MEDICINE

In the area of national security, Jevremovic is developing computational software to detect nuclear materials in cargo ships. She is specifically focused on creating tools to screen the nine million cargo containers that come into the United States every year. The project is supported by the Department of Homeland Security. "It is impossible to open each shipment," she says. "We need an easier, faster way to detect nuclear materials potentially smuggled into the U.S."

Another project involves radiation therapy for metastasized breast cancer. Jevremovic is simulating using a neutron beam from a nuclear reactor to irradiate cancer cells treated with tumor-fighting drugs. She hopes that computational simulations will help determine the optimal approach.

"Nuclear energy produces clean energy and it creates tools for medicine, biology, agriculture and more," says Jevremovic. "The field of nuclear engineering is broad and reaching, which is why I work in it."

NUCLEAR ENGINEERING AT THE U

As director of the University of Utah Nuclear Engineering Program (UNEP), professor Tatjana Jevremovic is helping to establish new courses and a new minor in nuclear engineering, which begins fall 2010. The University has offered only graduate degrees in nuclear engineering since the program was established in the late 1960s.

"There is a huge need for training nuclear engineers because 40 percent of the current nuclear engineering force will retire in the next four years," says Jevremovic.

Nuclear engineering students are trained with the U's unique facilities and technology, including the university's nuclear reactor, radiochemistry

laboratories, an optical microscopy laboratory, a measurement laboratory, a clean room and advanced computational tools. The program's new minor was established to meet standards of the nuclear industry and government agencies in preparing a new generation of nuclear engineers for diversified jobs in Utah, the nation and the world.

Biomedical Polymers:

INNOVATIVE DRUG DELIVERY TECHNOLOGY TO FIGHT CANCER



JINDŘICH KOPEČEK

MEMBERS OF JINDŘICH KOPEČEK'S LAB (from left to right):

Kui Luo, PhD
postdoctoral fellow

Stefan Krimmer
exchange student

Monika Sima
technician

Jihua Liu, MD, PhD
research assistant professor

Stewart Low
graduate student

Huaizhong Pan, PhD
research assistant professor

Pavla Kopečková, PhD
research professor

Biomedical polymers—chemical compounds made from synthetic and biological materials—have come a long way in the last half-century. In the early 1950s, chemists Drahošlav Lím and Otto Wichterle at Czechoslovakia's Institute of Macromolecular Chemistry in Prague initiated a research program to design polymers for medical use. They invented the first biomedical polymer suspended in water, called a hydrogel, for use in humans. It was used to make the first soft contact lenses, which were later licensed to eye-care products maker Bausch and Lomb.

In the early 1960s when the study of biomedical polymers was still new, Jindřich (Henry) Kopeček became a graduate student under Lím and Wichterle. It was then he began to devote his life's work to hydrogels and biomedical polymers, becoming an early pioneer in the field of targeted drug delivery. Kopeček is a distinguished professor of bioengineering and of pharmaceuticals & pharmaceutical chemistry.

"I became interested in the biocompatibility of different kinds of hydrogels," says Kopeček. "When they were successfully used in the clinic, I focused my attention on water-soluble polymers and their potential as drug carriers. We eventually went on to design and combine genetically engineered polymers and self-assembling hybrid copolymers as smart biomaterials."

In the 1970s, Kopeček invented a copolymer (a combination of two or more monomer molecules) called HPMA—or N-(2-hydroxypropyl)-methacrylamide—which was first used as a blood plasma expander, and later, as a drug delivery carrier to treat cancer. Anti-cancer drugs and cancer-targeting compounds are bound to the HPMA "backbone," then transported

through the body and released in cancer cells. The treatment may be administered either intravenously or orally.

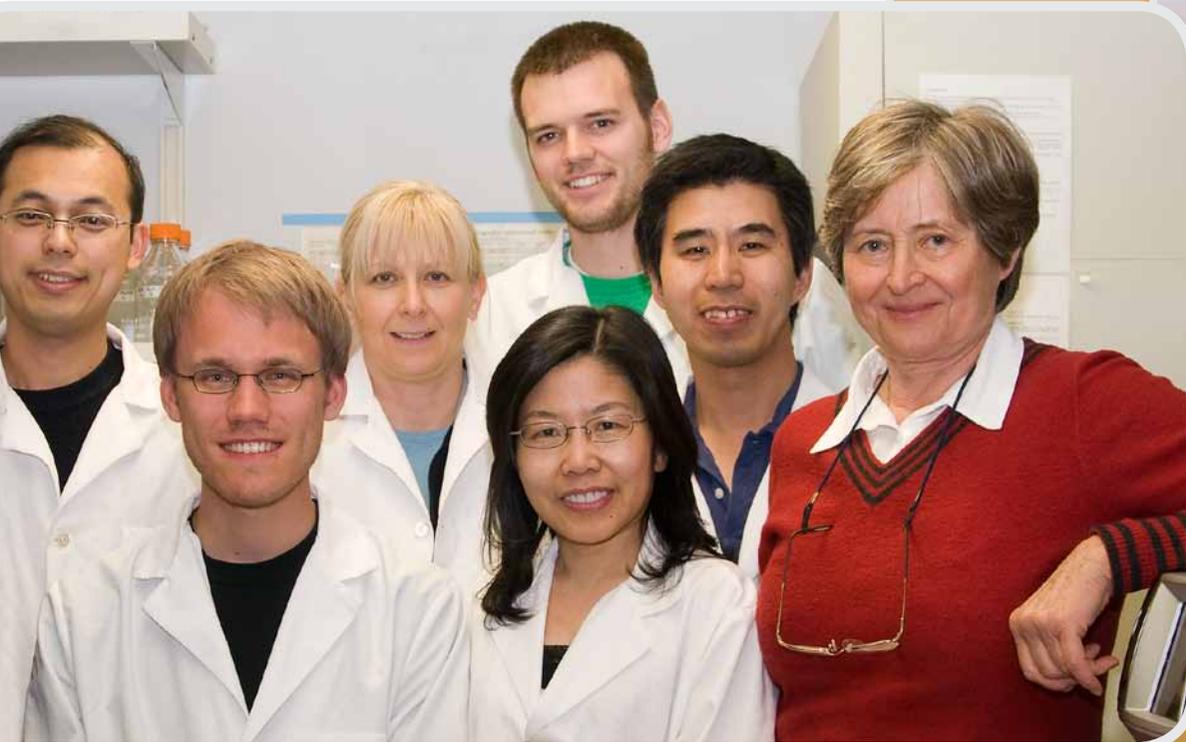
Doxorubicin is a typical anti-cancer drug used in chemotherapy. When the drug is combined with an HPMA copolymer, patients can tolerate a much higher dosage—about four times more than when the drug is used in traditional chemotherapy alone. Kopeček says the increased dosage allows for a more effective, targeted approach to killing tumors.

TARGETING CANCERS AND OSTEOPOROSIS

Today, Kopeček leads the Biomedical Polymers Laboratory at the University of Utah to further the research and development of targeted drug delivery for various cancers and osteoporosis.

Kopeček and his team are exploring a number of methods to treat ovarian cancer. In collaboration with Dr. Matthew Peterson from the U's Department of Obstetrics and Gynecology, Kopeček is studying combinations of therapies: conventional chemotherapy, photodynamic therapy (a cancer treatment consisting of a photosensitizer and light), and HPMA combined with vitamin A. Kopeček says combining anti-cancer drugs with polymers may result in a better cure rate than a single therapy.

The success of treatment also depends on reaching the proper location within the cancer cell. Kopeček is developing techniques for specific targeting inside the cell. "Using polymer carrier technology, the drug may be delivered not only to the cancer cell, but to a particular location, such as the mitochondria or nuclei, within the cancer cell. This enhances the drug efficacy," he says.



ABOVE: HPMA polymer containing an anti-cancer drug and yellow fluorescent label.

He is also developing a new multiple-therapy approach to target prostate cancer with water-soluble HPMA copolymers. The copolymers contain a component that specifically goes after prostate cancer cells and a drug that causes cells to self-destruct through a process known as “apoptosis,” or programmed cell death.

HPMA-drug combinations may also be used for the treatment of diseases other than cancer. Kopeček’s group is working with Dr. Scott Miller in radiobiology to design therapies specifically targeted to bones that treat osteoporosis and other skeletal diseases. They are using an established bone-growing agent called prostaglandin, which is delivered by the hydrogel and released over time to grow bone.

Another current project in Kopeček’s lab is the design of “smart” biomaterials for drug delivery that sense specific environmental changes in the body and adjust accordingly.

“Smart biomaterials use the principle of self-assembly, meaning that they order or arrange themselves through physicochemical interactions,” says Kopeček. “Their unique properties make them especially useful for drug delivery.”

The newest project in Kopeček’s laboratory is the design of HPMA-drug delivery copolymers that break down over time. “Incorporating degradable bonds into the structure of HPMA copolymer carriers enhances the time the nanomedicines stay circulating in the blood,” says Kopeček. “This provides a window for the polymer-drug combination to find the cancer cells and improves their efficiency.” The University of Utah’s Technology Commercialization Office has filed a patent application for this technology.

COMMERCIALIZING TECHNOLOGY

In 2008, distinguished professor Jindřich (Henry) Kopeček and professor Hamid Ghandehari, both of bioengineering and of pharmaceuticals & pharmaceutical chemistry, launched TheraTarget, Inc., a biopharmaceutical drug delivery start-up company. Their goal is to develop innovative nanomedicines and polymer-drug combinations.

The company has begun collaborating with Rexahn Pharmaceuticals, a Maryland-based company specializing in oncology and central nervous system therapeutics.

Anti-cancer drugs developed by Rexahn will be attached to polymer carriers synthesized by TheraTarget. Because of their high molecular weight, the polymer-drug combination stays in the bloodstream longer than conventional pharmaceuticals, thereby enhancing their effect.

“We are entering a new paradigm in drug design,” says Kopeček. “Polymer-drug conjugates and other nanomedicines may help us give patients an effective, targeted treatment that will provide them a better option than traditional cancer drugs.”

Radio Waves 'See' through Walls

METHOD COULD HELP POLICE, FIREFIGHTERS, ELDERLY

University of Utah engineers showed that a wireless network of radio transmitters can track people moving behind solid walls. The system could help police, firefighters and others nab intruders, and rescue hostages, fire victims and elderly people who fall in their homes. It also might help retail marketing and border control.

"By showing the locations of people within a building during hostage situations, fires or other emergencies, radio tomography can help law enforcement and emergency responders to know where they should focus their attention," says Neal Patwari, assistant professor of electrical and computer engineering.

Patwari and doctoral student Joey Wilson conducted studies on the method, which uses radio tomographic imaging to "see," locate and track moving people or objects in an area surrounded by inexpensive radio transceivers that send and receive signals. People don't need to wear radio-transmitting ID tags.

One study involved placing a wireless network of 28 inexpensive radio transceivers—called nodes—in an indoor atrium and a grassy area with trees. Radio signal strengths between all nodes were measured as a person walked in each area. Processed radio signal strength data were displayed on a computer screen, producing a bird's-eye-view, spot-like image of the person.

A second study tested an improved method that allows tracking through walls. The study details how variations in radio signal strength within a wireless network of 34 nodes allowed tracking of moving people behind a brick wall. The method was tested around a building and successfully tracked a person's location to within 3 feet.

The wireless system used in the experiments was not a Wi-Fi network like those that link home computers, printers and other devices. Patwari says the system is the kind of network often used by wireless home thermostats and other home or factory automation.

Wilson demonstrated radio tomographic imaging during a mobile communication conference, and won the MobiCom 2008 Student Research Demo Competition. The researchers now have a patent pending on the method. Wilson has founded Xandem, a spinoff company, to commercialize the technology. The research is supported by a CAREER award Patwari received from the National Science Foundation. The award supports early career-development activities of young engineers and scientists.

HOW IT WORKS

Radio tomographic imaging (RTI) is different and much less expensive than radar, in which electromagnetic signals are

bounced off targets and the returning echoes or reflections provide the target's location and speed. RTI instead measures "shadows" in radio waves created when they pass through a moving person or object.

RTI measures radio signal strengths on numerous paths as the radio waves move through a person or other target. In that sense, it is quite similar to medical CT (computerized tomographic) scanning, which uses X-rays to make pictures of the human body, and seismic imaging, in which waves from



PHOTO CREDIT: Sarang Joshi and Joey Wilson, University of Utah

earthquakes or explosions are used to look for oil, minerals and rock structures underground. In each method, measurements of the radio waves, X-rays or seismic waves are made along many different paths through the target, and those measurements are used to construct a computer image.

In their experiments, Wilson and Patwari obtained radio signal strength measurements from all the transceivers—first when an area was empty and then when a person walked through it. They developed math formulas and used them in a computer program to convert weaker or "attenuated" signals—which occur when someone creates "shadows" by walking through the radio signals—into a spot on a digital map that tracks the person's movements.

"RTI has advantages. Radio frequency signals can travel through obstructions such as walls, trees and smoke, while optical and infrared imaging systems cannot," Patwari says.

Radio frequency imaging will also work in the dark, where video cameras will fail. And unlike video cameras, RTI shows location of a person but not the identity, which may be important for privacy issues.

Would bombardment by radio waves pose a hazard? Wilson says the devices "transmit radio waves at powers 500 times less than a typical cell phone."



“By showing the locations of people within a building during hostage situations, fires or other emergencies, radio tomography can help law enforcement and emergency responders to know where they should focus their attention.”

JOEY WILSON

NEAL PATWARI



LEFT: A person walks inside a square of radio transceivers mounted on plastic pipes. The person creates “shadows” in the radio waves, resulting in the image next to it, in which the person appears as a red-orange-yellow spot.

RIGHT: Dozens of inexpensive radio transceivers (which transmit and receive) like this one could be thrown down by police around a building in which someone is holding hostages. The radio signals would be processed and displayed, revealing shadows showing the location of people moving inside the building.

RADIO ‘EYES’ TO THE RESCUE

Patwari says the system still needs improvements, but when a situation might make entering a building dangerous for police or firefighters, they would place dozens of radios around the building and would be able to see a computer image showing where people are moving inside the building. The technique cannot distinguish good guys from bad guys, but at least will tell emergency personnel where people are located. Patwari says radio tomography probably can be improved to distinguish people in a burning building from moving flames.

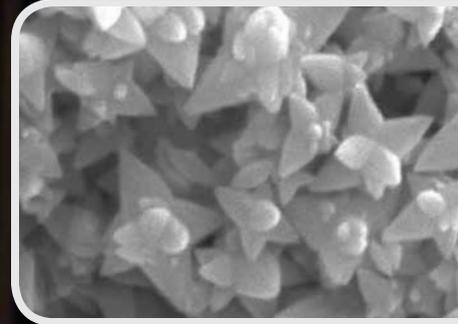
Radio tomography even might be used to study where people spend time in retail or grocery stores. “Does a certain marketing display get people to stop or does it not?” Wilson asks.

Radio image tracking might help some elderly people live at home. “The elderly want to stay in their homes but don’t want a camera in their face all day,” Wilson says. “With RTI, you could track where they are in their home, did they get up at the right time, did they go to the medicine cabinet, have they not moved today?” RTI might also detect an elderly person falling down the stairs based on the unusually fast movement.

Other possible uses include: border security; home alarm systems; and automatic control of lighting, heating and air conditioning in buildings. Radio tracking might even control sound systems and noise cancellation systems so that the best sound is aimed where people are located.



Ashutosh Tiwari holds a silicon wafer, which is used in making dye-sensitized solar cells and spintronic devices.



CAREER AWARD FOR SPINTRONICS

As electronic devices get smaller, they also get faster and more power-efficient, allowing engineers to integrate more functionality into a single silicon chip, and enabling the implementation of ultra-slim laptops, iPads and Android phones. However, as component dimensions approach the tiny nanometer scale, further miniaturization becomes increasingly difficult.

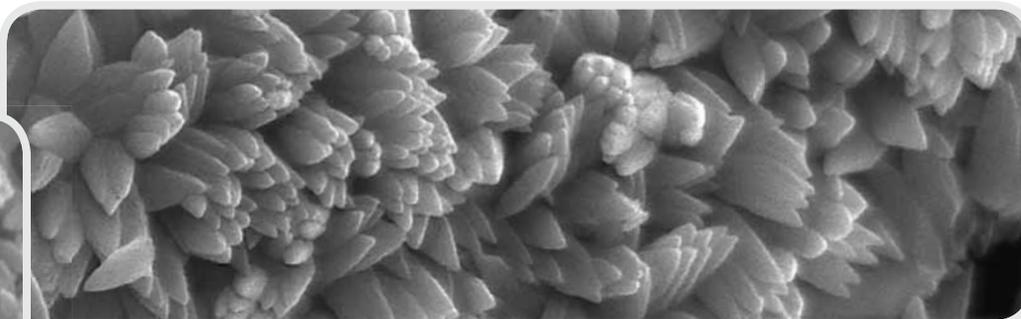
Ashutosh Tiwari, associate professor of materials science and engineering, says further improvement in devices will require a transition from conventional electronics to a branch of science known as "spintronics." While electronic devices operate using the charge of electrons, spintronic devices exploit both the charge *and* spin of electrons. Because of this additional attribute, spintronic devices

are expected to be faster, smaller and consume about 50 percent less power on average than conventional electronic devices.

In 2008, Tiwari received a five-year, \$500,000 National Science Foundation CAREER award for his work in spintronics. He is using the support to develop "dilute magnetic dielectrics," a new class of materials that may lead to innovative spintronic devices.

Nanomaterials and Devices:

TRANSFORMING RENEWABLE ENERGY AND STORAGE TECHNOLOGY



Nanoplant photographs taken with a scanning electron microscope in Ashutosh Tiwari's laboratory.

The modern world depends on an abundant supply of energy. As more countries become technologically advanced, global demand for energy continues to increase. Compounding matters are widespread concerns about fossil fuel dependence, limited resources, and related environmental effects.

Renewable sources of energy, such as solar power, may provide a significant solution to the world's energy needs. "Solar energy appears to be a practical alternative to conventional fossil-fuel based energy sources," says Ashutosh Tiwari, associate professor of materials science and engineering. "Yet solar energy is not yet able to compete fully because of a number of material challenges."

These "material challenges" include the high cost of producing solar cells and cells' inefficiency at converting solar power into electricity. Another challenge involves carbon dioxide emissions during manufacturing, a process in which raw silicon dioxide is reduced to get pure silicon (the material used in solar cells). "The cost of power produced by conventional solar cells is about three times higher than power produced by fossil-based sources," says Tiwari. "Our challenge is to reduce the cost of fabricating solar cells and improve efficiency."

DYE-SENSITIZED SOLAR CELLS

Dye-sensitized solar cells (DSSCs) may be a good alternative to conventional solar cells because they are less expensive and simpler to make, according to Tiwari. Their basic components include an electrode (an electrical semiconductor) and an electrolyte (an ionically conductive substance) deposited onto a glass plate and coated with organic dye. The dye helps make electricity through a process similar to photosynthesis — the mechanism by which green plants generate chemical energy from sunlight. When the cells are placed in sunlight, electricity is produced when the dye absorbs light and then injects electrons into the electrode and holes into the electrolyte.

The most common DSSCs have electrodes made by heating a powder-like semiconductor, which Tiwari says is problematic. "Powder won't do because the electrons get trapped in the grains, making overall energy-conversion efficiency low.

Also, solar cells must be heated at high temperatures, which restricts us to making them with nonflexible materials such as glass."

DSSCs also require a liquid electrolyte, which can evaporate or leak. "This limits the stability and also poses a problem in scaling up DSSC technology for practical applications," he says.

NANOPLANTS FOR SOLAR CELLS

Tiwari and his associates have designed an improved dye-sensitized solar cell with a specially designed "nanoplant" electrode. The exotic-looking nanoplant is not a living plant, but is made from titanium- or zinc-oxide and coated with dye. It is called a nanoplant due to its plant-like appearance, which is formed through self-assembly, a process by which molecules independently arrange themselves. "Nano" refers to the tiny, molecular scale of the material.

Like previous DSSCs, Tiwari's solar cells operate by photosynthesis, but the nanoplant structure developed by Tiwari's team is more efficient at converting solar energy into electricity. "The nanoplants are interconnected with a direct electrical pathway to ensure the rapid collection of carriers generated throughout the device," says Tiwari.

Since Tiwari's solar cells are made with little heating, the nanoplant electrode is deposited onto flexible material, making them more practical for a variety of applications. The cells also use a solid electrolyte to eliminate leakage and evaporation. Tiwari and his associates have formed a new start-up company called Sensimat, Inc. to commercialize the technology.

Because solar cells provide power only in daylight, Tiwari is also developing special batteries to store energy produced by his solar cells. These thin-film batteries have reasonably high energy densities but are made of lightweight, microscopically thin layers of lithium alloy. "We expect our batteries will store vast amounts of energy and can be recharged thousands of times," Tiwari says. "This technology has the potential to reduce energy costs, which is important for widespread use, in individual homes and elsewhere."

Facts and Financials



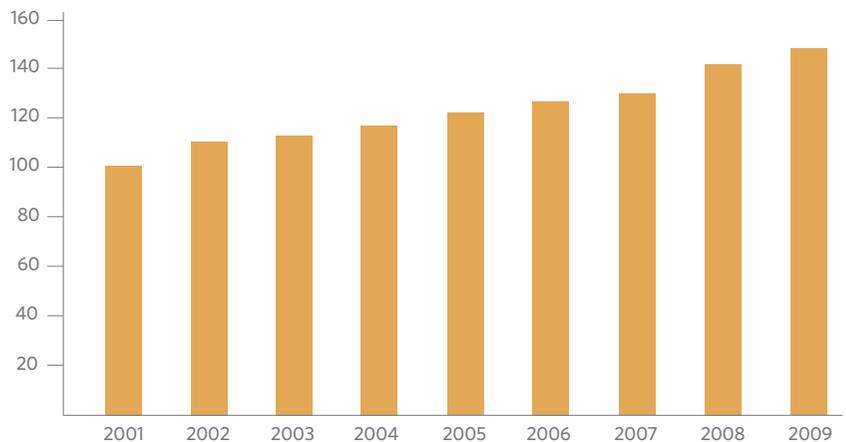
- The College of Engineering is ranked 47th in the nation out of 341 schools in the number of bachelor's degrees awarded, and 37th out of 194 in PhD degrees.
- Undergraduate enrollment in the College of Engineering increased 72% between 1999 and 2009, compared with 29% nationally.
- The number of engineering and computer science degrees awarded at the University of Utah increased 76% between 1999 and 2009, compared with 25% nationally.

SOURCE: American Society for Engineering Education (ASEE)

DEGREES AWARDED: 2001-2009



TENURE-TRACK FACULTY GROWTH: 2001-2009



The College of Engineering is ranked among the top 100 programs in the world by the *Academic Ranking of World Universities* compiled by Shanghai Jiao Tong University, one of the two most prominent world university rankings, based on international recognition, highly-cited research, publications, the Science Citation Index and Social Sciences Citation Index, and per capita academic performance.

TECHNOLOGY COMMERCIALIZATION: 2006-2009

The University of Utah is now ranked first in the nation along with MIT at starting companies from its research, according to the Association of University Technology Managers, which ranks public and private research institutions throughout the country. The U of U's accomplishment is made more significant because MIT receives almost five times more research funding.

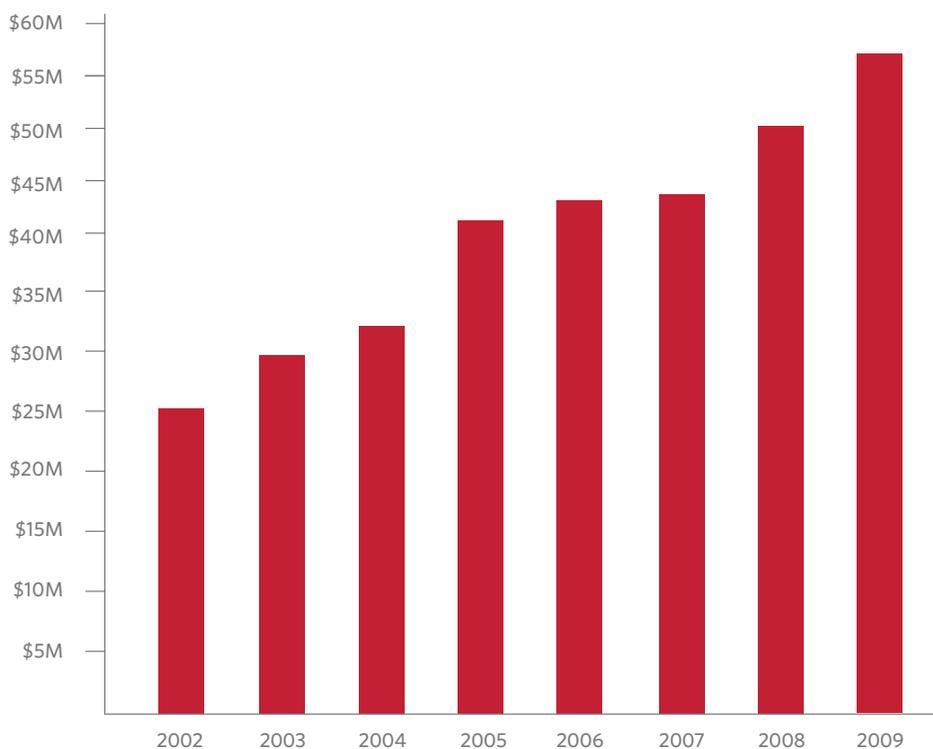
The U of U launched 20 new companies from technologies developed at the University in 2006, 17 in 2007,

23 in 2008, and 23 in 2009. The College of Engineering is responsible for 35 of these spin-off companies.

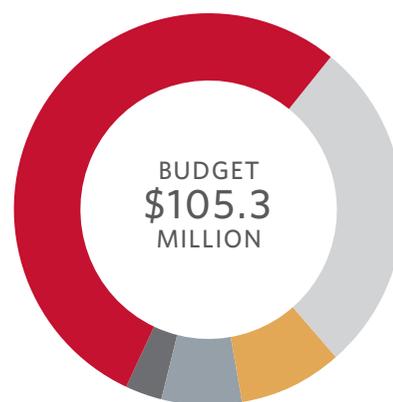
The University of Utah's intellectual property is managed by its Technology Commercialization Office (TCO). Since 2005, TCO has focused on economic development in the state of Utah. TCO has set up a satellite office in the College of Engineering to direct the College's extensive technology commercialization activities.

RESEARCH EXPENDITURES: 2002-2009

With **\$56.9 million** annually in external research funding, the College of Engineering is ranked 41st in the nation out of 203 schools in research expenditures. The College of Engineering is a vital component of the University of Utah's growing research enterprise.



BUDGET: 2008-2009



- \$56.9M Research Expenditures
- \$29.1M State Budget
- \$9.2M USTAR
- \$7.1M University Funds
- \$3M Donations

ENAC

ENGINEERING NATIONAL ADVISORY COUNCIL



Ted Jacobsen, retired board chairman of Jacobsen Construction Company, is the new chair of the Engineering National Advisory Council (ENAC), which supports and guides the strategic directions of the college. An alumnus of the College of Engineering, Jacobsen served as president of Jacobsen Construction from 1974 until 1996. He provided consulting and construction services for significant projects in the Intermountain area including the Grand America Hotel and the LDS Conference Center. He served as President (1982) and Director of the Utah Chapter of the Associated General Contractors of America (AGC). In 2002, Jacobsen's contributions were recognized with AGC's prestigious Eric W. Ryberg Award for outstanding service to the construction industry in Utah.

Ted M. Jacobsen
(Chair)
Retired-Chairman of the Board
Jacobsen Construction Company

C. Ross Anderson
President and CEO
AAA Engineering & Drafting

Harold Blomquist
Principal
HAB Global Services

Dr. Don R. Brown
President
PartNET

Craig S. Carrel
President
Team One Plastics

Dr. Edwin Catmull
President
Pixar/Disney

Paul B. Clyde
Retired-Executive VP and COO
Clyde Companies, Inc.
President
W. W. Clyde & Co.

Clair F. Coleman
Retired-President and CEO
Questar Pipeline (formerly
Mt. Fuel Resources)

Dr. David A. Duke
Retired-Vice Chairman
Corning Corporation

Dal Freeman, P.E.
Park Engineer
Lagoon Corporation

Mark Fuller
Chairman and CEO
WET Design

Bruce A. Geier
CEO
Technology Integration Group

Sidney J. Green
Retired-Chairman and CEO
TerraTek, Inc.

Brett Helm
CEO and Chairman
Coradiant, Inc.

Paul J. Hirst, P.E.
President and CEO
Caldwell Richards Sorensen

Dr. James F. Jackson
Retired-Deputy Director
Los Alamos National Laboratory

David S. Layton
President and CEO
The Layton Companies

A. Tee Migliori
President
ADC Technologies, Inc.

Harold W. Milner
Retired-President
Kahler Corporation

Jonathan Oomrigar
Global Vice President
High Technology Business Unit
Oracle

Susan D. Opp
President and General Manager
L-3 Communications Systems-West

Dr. Christopher H. Porter
Medical Genesis, Inc.

Shane V. Robison
Executive Vice President & Chief
Technology & Strategy Officer
Hewlett-Packard

Lynn S. Scott
Retired-Group Vice President and
Division General Manager
Parker Hannifin

Michael W. Soulier
Retired-Director, Human Resources
E.I. Du Pont De Nemours & Co.

Dr. Gregory P. Starley
Sr. Advisor, Business
Development
International Division
Devon Energy Corporation

Dr. Gerald B. Stringfellow
Distinguished Professor
U of U Dept. of Electrical &
Computer Engineering and Materials
Science & Engineering

Dr. Randal R. Sylvester
Chief Technologist
L-3 Communications
Systems-West

J. Howard Van Boerum, P.E.
President Emeritus
Van Boerum & Frank Associates, Inc.

Robert B. Wiggins
Retired-President
Quartzdyne, Inc.

Kim Worsencroft
Retired from Software Industry



Shane Robison, executive vice president and chief strategy and technology officer of Hewlett Packard (HP), has received an honorary Doctor of Engineering degree from the University of Utah. An engineering alumnus and member of ENAC, Robison received the award at the U's commencement in May. He currently steers HP's \$3.6 billion research and development investment and fosters the development of the company's global technical community, in addition to leading the company's strategy and corporate development efforts. One of four principal architects of HP's merger with Compaq Computer Corp., Robison was named one of the world's 25 most influential chief technology officers by InfoWorld in 2004.

College of Engineering Disciplines

Our highly interdisciplinary research environment has enabled faculty to respond to emerging needs in such diverse areas as visualization and graphics, energy, robotics, software engineering, advanced electronics, neuroprosthetic development, new construction and transportation technology, photonics, and nanotechnology.



A new wall display in the Warnock Engineering Building represents the College of Engineering's seven academic units.

Bioengineering // Chemical Engineering // Civil & Environmental Engineering // Electrical & Computer Engineering // Materials Science & Engineering // Mechanical Engineering // School of Computing

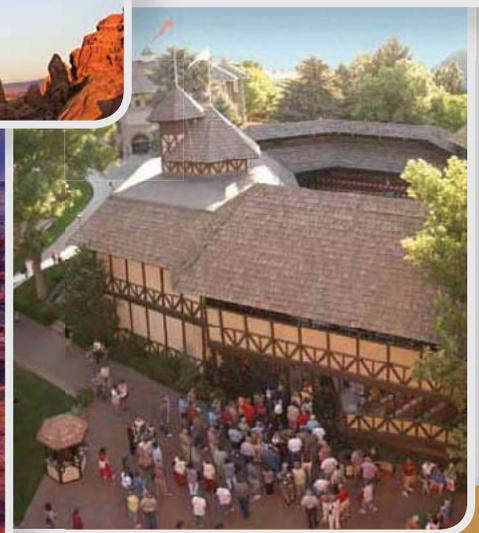
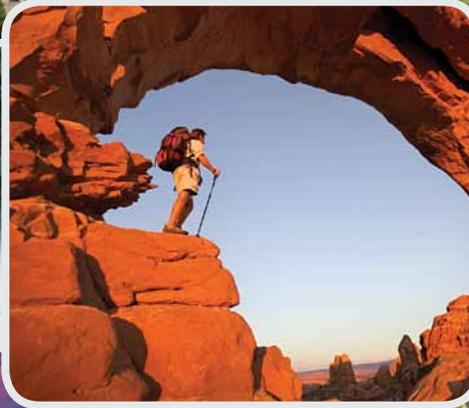
RESEARCH INSTITUTES

- The Brain Institute
- Institute for Clean and Secure Energy (ICSE)
- Scientific Computing and Imaging (SCI) Institute
- Energy and Geoscience Institute (EGI)
- Cardiovascular Research and Training Institute (CVRTI)
- Center for High Performance Computing
- Nano Institute

RESEARCH CENTERS

- Center for Excellence in Nuclear Technology, Engineering, and Research (CENTER)
- The Keck Center for Tissue Engineering (KCTE)
- Nanofabrication Laboratory
- Center for Integrative Biomedical Computing
- Center for Controlled Chemical Delivery
- Petroleum Research Center
- Rocky Mountain Center for Occupational and Environmental Health
- Quality and Integrity Design Engineering Center
- Utah Center for Advanced Imaging Research
- Moran Eye Center

Utah Living



The University of Utah campus is located in beautiful Salt Lake City, which sits in a large valley surrounded by the Wasatch Range of the Rocky Mountains to the east and the Oquirrh Mountains to the west. Forming the backdrop to the U of U campus, the Wasatch Mountains offer students a network of hiking, biking and running trails. Salt Lake's cultural scene includes symphony, ballet and opera companies, and nearby Park City is the home of the Sundance Film Festival. Sports fans enjoy Jazz Basketball, Salt Lake Real Soccer, as well as AAA Bees Baseball and IHL Grizzlies Hockey.

Salt Lake's commuter-friendly urban setting includes an extensive bus system, light rail, and a commuter rail line that links the U of U campus with valley neighborhoods and

downtown Salt Lake. The International Airport is located about four miles west of downtown.

Utah is home to some of the best skiing in the world. Utah has 13 incredible resorts, most of which are located within minutes by car from the U's campus. Salt Lake City hosted some of the world's top athletes during the 2002 Winter Olympics. Salt Lake is also the gateway to some of the world's most stunning national parks including Bryce Canyon, Arches, Canyonlands, Capitol Reef and Zion National Parks, all located within a five-hour drive to the south. Five hours to the north in neighboring Wyoming are Grand Teton National Park and the south entrance to Yellowstone National Park.

(TOP) LEFT: Skiing Utah's Wasatch Mountains. Photo credit: Utah Office of Tourism (Howie Garber). **CENTER:** Downtown Salt Lake City. **RIGHT:** Cache County—Biking—White Pine Lake. Photo credit: Cache Valley Visitors Bureau (Monique Beeley). **(BOTTOM) LEFT:** Canyonlands, Photo credit: Utah Office of Tourism (Tom Till). **CENTER:** Arches National Park, Moab. **RIGHT:** Utah Shakespearean Festival—Globe Theatre. Photo credit: Utah Shakespearean Festival.

Cultural Attractions:

- 1 Logan—Utah Festival Opera
- 2 Salt Lake City—State Capital
- 3 Park City—Sundance Film Festival
- 4 American Fork—Timpanogos Cave
- 5 Moab—Slickrock Trail
- 6 Cedar City—Utah Shakespeare Festival
- 7 St. George—Dinosaur Discovery Site

13 Major Ski Resorts in Utah:

- 1 Beaver Mountain
- 2 Wolf Creek Utah
- 3 Powder Mountain
- 4 Snowbasin
- 5 The Canyons
- 6 Park City Mountain
- 7 Alta
- 8 Brighton
- 9 Deer Valley
- 10 Snowbird
- 11 Solitude
- 12 Sundance
- 13 Brian Head

5 National Parks in Utah:

- 1 Arches National Park
- 2 Canyonlands National Park
- 3 Capitol Reef National Park
- 4 Bryce Canyon National Park
- 5 Zion National Park

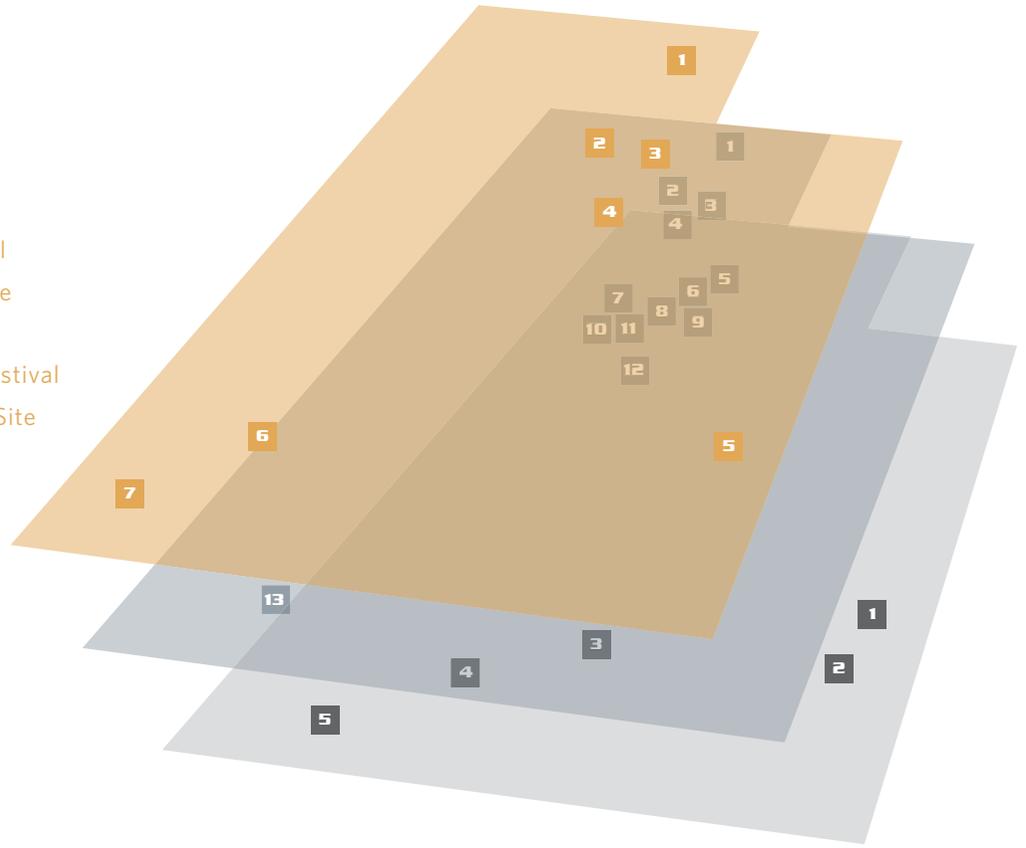


PHOTO CREDIT: Lawrence Boye, University of Utah



College of Engineering
2010 RESEARCH REPORT

Office of the Dean

72 S. Central Campus Drive
Salt Lake City, UT 84112-9200
T 801.581.6911 F 801.581.8692
www.coe.utah.edu

