ECSE faculty are world leaders in the fields of electrical communications, signal processing, robotics, computer vision, smart grids and energy transmission, 3-D integrated computer chips, and many other leading-edge research areas. Since 2010, three ECSE alumni have been awarded the National Medal of Technology by President Barack Obama.
Message from the Department Head

Celebrating Success: Announcements

The view from Rensselaer on:
- The future of Smart lighting
- Systems and Synthetic Biology
- Computer Vision and Visual Effects

faculty & Staff

Research areas

acknowledgments

NSF Smart Lighting Engineering Research Center
NSF CURENT Engineering Research Center
NSF CenSSIS Engineering Research Center
Center for Future Energy Systems
Center for Automation Technologies and Systems
Two ARPA-E Centers

Degrees Granted (AY 2012-2013)

- 19 Doctoral
- 21 Masters
- 139 Bachelors

Graduate Recruiting, Fall 2012

- 14.63% Acceptance Rate
- 738 Applications
- 108 Offers of Admission

Minority Women
- 5.3% 11%
- 10% 14.3%
- 11% 10.1%

Major Research Centers

Extramural Research Funding

- Over 200 Current Awards
- $25+ Million

FY12 expenditures in excess of $12 million

In this issue

04 Message from the Department Head
06 Celebrating Success: Announcements
18 The View from Rensselaer on:
- The Future of Smart Lighting
- Systems and Synthetic Biology
- Computer Vision and Visual Effects
29 Faculty & Staff Research Areas
30 Acknowledgments
Engineering and Innovation in the Modern Economy

“To the engineer falls the job of clothing the bare bones of science with life, comfort, and hope... That is the engineer’s high privilege.”
—Herbert Hoover

Although the style is dated, the preceding quote eloquently captures the role of the engineer in society. In fact, engineering is perhaps best described as science in service to society. It is only through engineering that science grows into technology to serve society and, by doing so, becomes part of the economic fabric. Science and technology are widely recognized as drivers of economic growth in advanced industrialized nations. Numerous studies have indicated a connection between the ascension of developed nations and their ability to create nurturing environments for invention and innovation. These environments...
Innovation: The search for, development of, adaptation of, initiation of, and adoption of technologies new to a specific context.

Innovation was once regarded as a linear progression from basic research, through applied research, development, design, manufacturing, and eventually to marketing, a model attributed to Vannevar Bush. In the case of engineering, research decisions and objectives are typically set in response to the demands of society or the marketplace (application-driven science) rather than pushed by basic science. However, innovation rarely happens in linear fashion, irrespective of which end provides the actuation (demand-pull vs. science-push). The process often appears chaotic, at least to the casual observer, and the accidental juxtaposition of people and ideas can play a significant and unpredictable role in the discovery process. The most important thing is to have the components in place to create the right conditions to allow innovation to flourish. Observing those developing countries that succeed, and those that don’t, provides compelling evidence for the importance of a well developed and functioning national innovation system, and the need for societal technological learning, the increase in technical sophistication on the part of society as a whole. Recent political and economic developments in Washington, and the often vacuous arguments offered on a range of scientific and engineering issues, threatens the underpinnings of the US innovation system and, with it, our technical leadership and economic vitality. Those who must buy technology are of necessity behind, and dependent on, those who create it. Wealth ultimately flows to the creators and producers of new technologies and the goods and services that derive from them; these are the big winners in the global economy. Think about that last statement, in light of all the technical challenges that face us today.

Think about it in light of the National Academy of Engineering’s Grand Challenges for the 21st Century (right). This list of challenges represents much more than a set of very hard problems; it represents a set of opportunities to create significant wealth for those nations with capable, functioning innovation systems and the perspicacity to invest rather than squander—and the risk of self-entrapment in a structural technology dependency for those who don’t.

It is imperative that we reaffirm the role of the American research university in a national investment strategy. To undertake long time-horizon, high-risk research of the type private enterprise cannot afford, but which society as a whole cannot afford to neglect. Managing this investment has been the traditional role of the NSF, NIH, and other agencies. To disregard universities as key elements of the national innovation system is to neglect a critically important tool for economic development. The United States has arguably the largest existing scientific knowledge base in the world, and—not coincidentally—the world’s strongest research universities. It is a hard-won advantage not to be squandered. President Obama’s initiative to map the human brain represents a good start, although we may already be playing catch up.

As always, if you have any thoughts or suggestions, we’d love to hear from you.

Best wishes,

Kim L. Boyer, Professor and Department Head
With the extraordinary success of electrical and computer engineering in miniaturization and the very large scale integration of systems into tiny microchips, it became increasingly difficult for young minds to tinker with electronics or with circuits at high frequencies. The department has always viewed “Tinkering” as a way to promote exploratory thinking, innovation, integrative learning and intuition.

The 755 sq. ft laboratory is located in JEC 6204 and provides state-of-the-art electronic test equipment, and consumable supplies to any student who is interested in exploring new ideas. The laboratory also provides faculty and staff guidance and referral, external linkages, exposure to national and international circuit design competitions, and a diverse array of other activities necessary to compete and win such competitions. The lab is unique in the way it is built and the way it revolves around students’ ideas and projects. It is a recognition that extensive use of computing and circuit simulations don’t tell us everything.

On October 4th, 2012, more than 100 students waited in line to get a glimpse of the new Douglas Mercer ’77 Laboratory for Student Exploration and Innovation. The laboratory was established by a generous $500,000 endowment from Douglas Mercer, class of ’77 and a technical fellow at Analog Devices Inc., to restore the “lost art of tinkering” amongst RPI’s electrical engineering students.

(L to R) Qingxuan Kong and Sagar Ray worked on a 3GHz communication receiver. They designed and fabricated high frequency printed circuits boards and tested their functionality in the Mercer Lab.
we need to know, and that creating a virtual model of an electrical design could be deceptive compared to doing it in real life. And experimentation outside of class is an essential part of any electrical engineering education.

Although it has been around for only a few months, the lab is already reaching students. One month after grand opening, we had the first “Silicon Chef” event in which 16 tinkerers competed to design, build and test a project in one day. In December 2012, it hosted another competition, sponsored by Harris Corporation, to design a radio frequency receiver at 3GHz. Such circuit and system design competitions are an exceptional vehicle for understanding the limits of theory versus practice.

Electrical engineering needs to be more than lectures on theory, reading textbooks, and taking exams. Aristotle said, “For the things we have to learn before we can do them, we learn by doing them.” Advances in technology can now provide students with their own personal portable electronics laboratory, which removes the constraints of fixed space, equipment, and schedules to conduct their experiments. However, this entry-level hardware can take the student only so far. A more advanced set of capabilities is impossible to replicate on an individual, personal basis. Electrical engineering departments seldom have room in their meager budgets to build and outfit advanced laboratories for extracurricular learning. So when presented with the proposal for a student centered open laboratory, I saw a good opportunity to positively impact the students.”

— Douglas Mercer ’77

Six hours to design, build, and test a solution to a secret design challenge in a unique hackerspace.

 Winners of the “Silicon Chef” competition who in six hours implemented a 2x6 character display providing a textual user-interface. They were awarded Embedded Hardware Club T-shirts, Raspberry Pi microcomputers, and an edible pie (l to r): Thomas Hartmann, Bryant Pong, Raymond Tse and Joe Nied.
CELEBRATING SUCCESS: ALUMNI

Brian Glinsman elected Vice President of Texas Instruments.

DALLAS (May 17, 2012) – Texas Instruments Incorporated (TI) (NASDAQ:TXN) announced that Brian Glinsman has been elected a vice president of the company. In his role, Glinsman is responsible for TI’s high-performance multicore processor product lines for the fixed and mobile infrastructure market, including base stations, media gateways and core networking applications as well as new markets such as mission critical, industrial automation, embedded vision, high performance computing, medical imaging and audio and video infrastructure.

“Brian’s appointment as vice president of the multicore processors division is well deserved,” said Brian Crutcher, senior vice president and general manager, analog business, Texas Instruments. “He brings a solid balance between driving strategic product direction and tactical execution to customer commitments and he is a true asset to the multi-core processors division.”

Previously, Brian was the general manager of TI’s communications infrastructure and voice over Internet protocol (VoIP) business. Prior to that, he was responsible for product management and marketing of the company’s infrastructure VoIP business, and also served as the director of field application engineering for Telogy Networks, which was acquired by TI in 1999.

Glinsman earned a B.S. in electrical engineering at Rensselaer Polytechnic Institute.

ALUMNI HALL OF FAME PROFILE

J. Erik Jonsson ’22
Class of 1922 Philanthropist, Leader, Public Servant 1901-1994

Jonsson began working at an early age to help support his Swedish immigrant family. In 1930 he joined Geophysical Service Inc., a firm destined to become Texas Instruments. Under Jonsson’s guidance, outstanding research and development led to the company’s invention of silicon transistors. A pioneer in modern electronics, the company produced the first transistor radio and the first handheld calculator. Other innovations included the integrated circuit, the single-chip microcomputer and three-dimensional seismic surveying. Even while building a successful company, Jonsson never lost sight of his civic responsibility. As mayor, he helped Dallas rebuild its confidence following the assassination of President Kennedy. He spearheaded the effort to build the Dallas-Fort Worth Airport, at its opening in 1973 the largest in the world.

Jonsson touched every aspect of Rensselaer as a trustee and one of the Institute’s most generous benefactors. He was the first recipient of the Rensselaer Alumni Association’s Distinguished Service Award in 1967.
ECSE alumnus earns distinction for work in wireless technologies

Dr. Nambirajan Seshadri elected to the National Academy of Engineering

Dr. Nambirajan (Nambi) Seshadri, ECSE alumnus (MS ’84, PhD ’86), is senior vice president and general manager of the Mobile Wireless Group at Broadcom Corporation, as well as the chief technology officer for mobile platforms and wireless connectivity. Recently, he was elected as a new member of the National Academy of Engineering (NAE), an honor considered among the highest of professional engineering distinctions.

Seshadri was selected for his contributions to wireless communications theory and the development of mass market wireless technology. His research has been focused on developing techniques for reliable transmission of data, speech, and audio for mobile communications. During his first few years at Bell Labs, his research collaborations resulted in novel techniques for understanding the impact of channel errors on low bit rate speech coders resulting in combined speech and channel coding and decoding solutions.

In the 1990s, he co-invented space-time trellis codes with Vahid Tarokh and Robert Calderbank and their paper on this topic won the 1999 IEEE Information Theory Society Best Paper Award. Another paper on the implementation of a modern based on space-time coding (co-authored with Tarokh, Calderbank and Ayman Naguib) was selected by IEEE Communications Society in 2002 as one of the 50 most influential works published by IEEE Communications Society in its first 50 years – The Best of Best: 50 Years of Communications and Networking Research.

Dr. Seshadri’s contributions in wireless communications have fundamentally changed the way we work, play, and interact across time and space. With his election to the National Academy of Engineering, the Nation will benefit in yet another way from the enormous wealth of his experience and intellect. We at Rensselaer are enormously proud to count him among our distinguished alumni. “Changing the World.”

— Kim L. Boyer, Ph.D., Professor and Head

Nambi received a B.E. degree in Electronics and Communications from Regional Engineering College (now called NITT), Tiruchirapalli, India, and a M.S. and Ph.D. from Rensselaer. He is a Fellow of IEEE, Distinguished alumnus of National Institute of Technology, Tiruchirapalli, India.
Ming Ma receives $30,000 for breakthrough research on LED technology
Ming Ma has developed a new method to manufacture light-emitting diodes (LEDs) that are brighter, more energy efficient, and have superior technical properties than those on the market today. His patent-pending invention holds the promise of hastening the global adoption of LEDs and reducing the overall cost and environmental impact of illuminating our homes and businesses.

For this innovation, Ma, a doctoral student advised by Dr. E. Fred Schubert, Wellfleet Senior Constellation Professor, Future Chips Constellation, Department for Electrical, Computer, and Systems Engineering, has been named the winner of the prestigious 2013 $30,000 Lemelson-Rensselaer Student Prize. First given in 2007, the prize is awarded annually to a Rensselaer senior or graduate student who has created or improved a product or process, applied a technology in a new way, redesigned a system, or demonstrated remarkable inventiveness in other ways.

"Invention is critical to the U.S. economy. It is imperative we instill a passion for invention in today’s youth, while rewarding those who are inspiring role models," said Joshua Schuler, executive director of the Lemelson-MIT Program. "This year’s Lemelson-MIT Collegiate Student Prize winners and finalists from the Massachusetts Institute of Technology, Rensselaer Polytechnic Institute, and the University of Illinois at Urbana-Champaign prove that inventions and inventive ideas have the power to impact countless individuals and entire industries for the better."

Ma’s LED research focuses on improving efficiency and uniformity of LED lighting. Current generation LEDs only output about 25 percent of the light they produce. The rest of the light is trapped and eventually converted to heat because the refractive properties of the LEDs surface. Ma’s innovation, which almost triples the amount of light output, was inspired from a naturally occurring phenomenon in the earth’s atmosphere: graded refractivity. Rather than have a fixed refractive index, the atmosphere— and Ma’s LEDs— have a graded refractive index. This discrete gradient, five nanolayers of material each with decreasing refractive indexes, results in much less light being trapped in the LED. Additionally, Ma’s production process allows for much finer control over LED emission patterns. By molding the nanolayers like tiny star-shaped pillars, the LEDs can achieve a much wider radiation pattern, resulting in more even lighting in real world use. Ma’s GRIN LEDs "hold the promise of hastening the widespread adoption of LEDs, reducing the overall cost, energy consumption, and environmental impact of illuminating our homes and businesses." Ma isn’t stopping now, however; he says he wants to continue “developing products that have a great impact on the whole of society.”
**CELEBRATING SUCCESS: STUDENT AWARDS**

**The IEEE Power and Energy Society Scholarship Plus Initiative Program**

Joshua Klmaszewski has been awarded, competitively, a scholarship from the IEEE Power and Energy Society Scholarship Plus Initiative program.

Josh is a junior in ECSE, with a power concentration. In his sophomore year, he started as an Engineering Ambassador for the School of Engineering, an outreach activity to high schools. He has also participated in undergraduate research. He is a coauthor of an article on wind farm design, which will appear in an upcoming issue of IEEE Power and Energy Magazine. Josh will be eligible for a second award during his senior year, and will have an opportunity for a summer internship at one of the companies that sponsor the scholarship program.

**Grainger Scholar Awards**

The Grainger Foundation was established in 1949 by Mr. & Mrs. William Wallace Grainger and provides support to a broad range of organizations including educational institutions. We are extremely grateful for the Grainger Foundation’s long-standing support over the years of many deserving students interested in the study of energy sources and systems, particularly with respect to electric power systems. The Grainger Foundation is a true “Partner in Excellence.”

**Grainger Scholar Awardees**

**Christopher Hunter Hladik**

**Christian W. Johnson**

**William Schmitt**

**2012 Graduation Prizes**

**Allen B. Dumont Prize**
Guoqiang Dong
Zheng Xu

**Harold N. Trevett Award**
Branden C. Buchner
Jeffrey Streu

**Henry J. Nolte Memorial Prize**
Christian Johnson
Brandon Kieft

**Richett Prize**
Tammy C. Chow
Bryan A. Clifford

**Wynant James Williams Prize in Electrical Engineering**
Kathryn Celentano
Andrew Stevens

**Lt. Charles D. Dyce Award**
Benjamin Lane
Matthew Nevins

**Best Testbed Research Project**

One of the main purposes of an NSF Engineering Research Center (ERC) is the development of advanced testbeds, showing how transformational engineering research can be used in actual applications. In 2012, the NSF asked each ERC to submit an example of their best testbed research projects for a competition of testbed programs that embraced basic research, and also involved close collaboration between graduate and undergraduate students in a research environment. The Smart Lighting Engineering Research Center’s submission entitled “Lighting and Health: The Circadian Rhythm Testbed” was selected as one of three winners from over 25 submissions from all of the NSF’s active Engineering Research Centers.
CELEBRATING SUCCESS: STUDENT AWARDS

The Sky’s the Limit

Designing Wind Farms: A Hands-On STEM Activity for High School Students

Every year hundreds of eleventh grade high school girls come to campus to experience engineering first-hand at Design Your Future Day (DYFD). This year, The Center for Ultrawide-Area Resilient Electric Energy Transmission Networks (CURENT), an engineering research center jointly supported by the National Science Foundation (NSF) and the U.S. Department of Energy (DoE), created “Harness the Wind & Generate Electricity!” program.

Pictured, DYFD attendees working on the parameter selection phase of the activity.
Design Your Future Day (DYFD) is an annual activity that brings more than 200 female high school juniors to the RPI campus for a day of exploring science and technology as a career path. The program includes exploratory and design activities in all engineering disciplines. The Center for Ultrawide-Area Resilient Electric Energy Transmission Networks (CURENT) is an engineering research center jointly supported by the National Science Foundation (NSF) and the U.S. Department of Energy (DOE) and led by the University of Tennessee, Knoxville. At CURENT, we plan to develop innovative power grid and electronics activities to engage K–12 students as a way to introduce them to science and technology, and we volunteered to create and conduct a module for DYFD. In order to meet the goals it was determined that the project should, among other things, be of high current interest to students, be of real-world significance, and require the participants to be actively engaged. Based on these criteria, we chose wind energy as the topic and developed a module for building a wind farm in New York State including and investigation of the financial aspects (investment, revenue, and profit and loss) of the wind farm design. Wind is a renewable resource that has attracted the attention of young people and educators.

This project, “Harness the Wind & Generate Electricity!” was presented in two sessions to groups of nine and 12 high school students, respectively. The session began with a brief presentation on wind energy. In less than 15 minutes, it stepped through the history of wind farms, attempted to put the scale of these machines into perspective, explained the design activity, and introduced the factors that the students would need to consider to complete the activity. The goal of the presentation was to help the students move from thinking of wind turbines as “those big shapes on the horizon” to a real and complete project whose major parameters they could analyze. It was important to keep the data as realistic as possible, and to create a realistic model for the students to study. Important data to model included land and turbine costs, maintenance costs, energy prices, wind speeds and capacity factors. Data for the project were obtained from a number of publicly available sources including the National Renewable Energy Laboratory (NREL) and the New York Independent System Operator (NYISO).

We prepared a pencil-and-paper worksheet for the students to use in selecting the design parameters. This worksheet focuses the students to work through the process one step at a time without overloading them with information. In addition, it allows greater involvement across the team, as each student was provided with a worksheet, while only one computer was available per group. An Excel spreadsheet was developed to help expedite the analysis of the input values calculated with the worksheet. The students were then broken into teams of three or four, with each team led by an undergraduate student. The small group size let the students easily work together as a team as they discussed options and completed the worksheet.

There was enough information in the presentation and available in the worksheet that the students should have been able to complete the activity without help. However, the presence of a discussion leader allowed the students to discuss the pros and cons of different geographical regions and terrain types as well as the importance of wind speeds and capacity factors. While supporting a valuable discussion of these factors, the group leaders also fostered an iterative approach so the students could compare and contrast multiple results as time allowed. Once all costs were calculated on the activity worksheet, the students entered these values into the Excel spreadsheet, which provided an analysis of the project over a 20-year period. The spreadsheet was organized into four categories: basic information, capital costs, ongoing costs, and production data. Basic information included the choice of locations, wind speed, and capacity factor at that location.

With all values entered in the spreadsheet, net yearly income or loss and cumulative income or loss were calculated and represented in both tabular and graphical form. Other factors, such as the financing and maintenance costs of the turbines, were included in the model but treated as fixed variables not requiring input from the students. These graphical representations of the project’s cash flow proved very valuable for the students in visualizing how costs were changing over the life of the project and sparked many good questions about why a trend appeared or how the graph would change if a particular input were changed. The spreadsheet was designed for just this sort of “What if...?” exploration; a value under question could be changed and the results instantly seen in the plots.

At this point, the group leader initiated an interactive conversation about what the results meant, what factors affected them, and how. The students were encouraged to go back and experiment with their design decisions to see how changes in the input parameters altered the results and, ultimately, the feasibility of the project. The results from one group are provided here as an example. Figures 1 and 2 summarize the yearly...
From the workshop survey, it seems that the materials were presented at the right level and students were engaged. The wind farm design module will be put to use in multiple outreach programs at Rensselaer, including a one-week summer program on the smart grid and the Engineering Ambassador Program, in which undergraduate students visit local high schools for science and technology outreach. The module will also be used in the CURENT program for the University of Tennessee, Northeastern University, and Tuskegee University.

We would like to thank Elizabeth Herkenham and Barbara Ruel for their input to the project and for organizing the workshop and Summer Liu for her assistance on assessment analysis. This article was paraphrased from: Designing Wind Farms: The Sky’s the Limit! A Hands-On STEM Activity for High School Students, IEEE Power & Engineering Magazine January/February 2013.

Participants were asked if they would recommend this workshop to their friends. All the participants answered in the affirmative. Here are a few responses:

- I would recommend that my friends participate in this activity because it offered a good opportunity to learn about wind farms and how it helps the environment but also how much it costs to run one.
- I believe that this activity would be useful to anyone interested in engineering or electricity. You learn how slight changes in your decisions can make a big difference.

Cash Flow Diagram

Cumulative Income

We see a graph titled "Cash Flow Diagram" showing years from 0 to 20 with corresponding yearly profit/loss in million USD. The graph shows a significant decline in profit/loss over the years.

We also see a graph titled "Cumulative Income" showing total return in million USD over years from 0 to 20. The cumulative income increases steadily over the years.
CELEBRATING SUCCESS: FACULTY ACCOMPLISHMENTS

PROMOTIONS & HONORS

**Honors from the Archives**

ECSE faculty and alumni have a rich history of achievements. Here are a select few:

**National Medal Winners by Class Year**

1951: Hermann A. Haus, National Medal of Science
1965: John L. Swigert, Presidential Medal of Freedom
1972: Steven J. Sasson, National Medal of Technology and Innovation
1974: B. Jayant Baliga, National Medal of Technology and Innovation

**Promotions**

James Lu was promoted to full Professor.
Richard Radke was promoted to full Professor.
Tong Zhang was promoted to full Professor.
Shayla Sawyer was promoted to Associate Professor.
Kim Boyer was elected President, International Association for Pattern Recognition.

**Faculty Books in Print**

- “Surface Acoustic Waves and Acousto-Optical Effects in Nitrides” Gang Bu, Daumantas Ciplys and Michael Shur, VDM Verlag Dr. Muller, 2008

**From the Archives**

Meng Wang joined ECSE as an Assistant Professor.
Wencen Wu joined ECSE as an Assistant Professor.
awards

Kim Boyer was the Honorary Chair of the Mexican Conference on Pattern Recognition in Huatulco, Mexico. He was also named to the Editorial Committee of the “ECEDHA Source”, the journal of the Electrical and Computer Engineering Department Heads Association. He was also named to the IEEE Computer Society Fellows Committee for 2013.

Michael Shur received the 2012 Tibbetts Award from US Small Business Administration. Appointed Member, Scientific Committee of the 7th International Conference on Interactive Mobile and Computer Aided Learning. Michael Shur was also appointed as Peer reviewer of the Georgian National Science Foundation. He was also appointed Chair, Fellow Committee, IEEE Sensors Council for 2012.

Jian Sun was elected an Administrative Committee Member of the IEEE Power Electronics Society for a 3 year term starting January 1, 2012.

Tong Zhang accepted the invitation to extend his role as Associate Editor for “IEEE Transactions On Signal Processing” for one more year, from February 2012 to January 2013.

Lester Gerhardt received the prestigious Benjamin Garver Lamme Award and Medal from the American Society for Engineering Education (ASEE). The Highest Award Bestowed by American Society for Engineering Education. He was also elected Chair of the Faculty in association with the re-created Faculty Senate at Rensselaer.

Ishwara Bhat
Kim Boyer
Richard J. Radke

Shayla Sawyer

Lester Gerhardt

Partha Dutta

Robert Karlicek

Joe Chow

Michael Shur
Jian Sun

ECSE faculty are often guest lecturers, conference speaker and special guests at a variety of events. This year, ECSE faculty gave over 50 invited talks around the world.
In 2008, Rensselaer was awarded a prestigious NSF Engineering Research Center (ERC) to develop advanced solid state lighting systems. Now in its 5th year of operation, the Smart Lighting Engineering Research Center continues to develop advanced LED lighting system concepts that save energy while providing higher quality illumination and new features and services that promote human health and productivity.

The future of Smart Lighting

Robert Karlicek Professor and Center Director

Working with academic partners (Boston University and the University of New Mexico) and over two dozen ERC Industrial member companies, the ERC defines Smart Lighting as a fusion of efficient solid state lighting sources (or fixtures), distributed light sensor networks, and new adaptive control and communication systems that efficiently provide illumination, wireless data services, and dynamic lighting capabilities that will revolutionize modern lighting, just as Edison’s incandescent light bulb did over 100 years ago. This work is particularly timely since exciting new research on how light impacts human health and performance is opening new opportunities for dynamic, advanced lighting systems in hospitals (faster, better recovery).

Figure 1: A conventional incandescent bulb produces 17 Lm/W while the recently announced laboratory prototype LED bulb (CREE) produces about 170 Lm/W, a tenfold improvement over the bulb. This new bulb technology offers lifetimes in excess of 20 years in normal use.
schools (improved learning), office buildings (higher productivity) and homes (better health and comfort). To realize these benefits, radically new approaches to lighting system design and operation will need to be developed, and this is the mission of the Smart Lighting ERC.

Today, we are seeing the rapid development of solid state LED light bulbs that can be up to 10 times more efficient than incandescent bulbs [Figure 1]. With the phase out of incandescent bulb technology now occurring on a global scale, more and more simple replacement LED bulb technology is becoming available, even as the underlying technology continues to evolve very quickly. More importantly, properly designed LED lighting technology can have exceedingly long lifetimes relative to current lighting technologies. Current LED bulbs are designed to fit in sockets intended for bulbs and tubes because that is where today’s lighting market is. The ERC calls this the first wave of LED lighting and offers simple illumination with reduced energy consumption. The ERC is working on radically different future lighting systems (or the “Second Wave” of LED lighting) which will generally not be socket based, will offer high quality lighting with automatic color and brightness tuning, simultaneous wireless data communications capability, position and motion sensing and improved man/machine operating interfaces. Smart Lighting systems will think on their own, having the embedded intelligence needed to reduce lighting energy costs while maximizing lighting quality, offering new apps-based features and capabilities that will automatically know how to provide the right light only where and when it is needed.

Some of the possible features of future Smart Lighting systems include:

- Efficient, color tunable lighting systems that can help maintain circadian entrainment, promote alertness, and improve mood, all while improving lighting system energy efficiency
- Adaptive lighting systems that can switch between spot (variable angle) and diffuse lighting functions, allowing the lighting system to dynamically readjust illuminance as required by occupants or changes in interior design
- Lighting panels combining video and illumination capabilities (Figure 2) in single unit, creating immersive, realistic access to outdoor scenes even in spaces without windows or skylights
- Wireless data access from lighting, offering higher bandwidth mobile connections in locations where RF based mobile connections are either unavailable or are overloaded and slow due to limited RF spectrum availability

Lighting represents between 40% and 60% of the electrical energy used in commercial office spaces and it has been estimated that adaptive lighting control can cut lighting energy consumption in half. Lighting control systems, though available for the past half century, are rarely specified by lighting designers because they are not adaptive, difficult to calibrate or re-program, and are made obsolete by minor changes in interior design or lighting system modifications. Smart Lighting systems can provide simpler, lower cost and more robust solutions by making illumination systems that not only transmit wireless lighting control data at high bitrates, but use their own modulated light
The Future of Smart Lighting

While the lighting community wrestles with the current high cost of first wave LED light bulb technology, the research being performed by the ERC will drive improved performance and functionality at a lower cost.

Finally, a key mission of the ERC is to educate future scientists and engineers who are not only well versed in the basics of advanced illumination technologies involved in the development of Smart Lighting, but who are also trained across the wide variety of disciplines needed to develop new lighting products and services. This educational mission involves graduate and undergraduates, as well as educational outreach programs designed to inspire children of all grades to pursue a career in a technical discipline. Lighting is so fundamental to every aspect of life that it offers a compelling platform for teaching science and engineering as well as art and design. Lighting is one of the oldest technologies developed by mankind, and with the development of Smart Lighting, future generations of scientists and engineers will most likely develop lighting systems that are just right for any human requirement and are even better than sunlight.

Figure 3: Visible Light Communications (VLC) not only enables wireless data transmission from lighting systems, but enables a wide range of sensing capabilities (LIDAR) so that lighting systems can know where, when and how to be on.

Figure 4: The Smart Lighting ERC Vision: Synthesizing Light for the Benefit of Humanity: Engineered Light for energy efficiency, health and productivity.
CASE STUDY: Smart Lighting ERC Campus Sustainability Efforts

To bridge its research efforts with currently available solid state lighting technology and expand the campus awareness of the benefits of the technology, the Smart Lighting ERC recently founded the Smart Lighting ERC Sustainability Volunteers.

The mission of this undergraduate student club is to work integrally with the Smart Lighting ERC and RPI Facilities to implement both bulb replacement and lighting redesign across campus as an essential part of Rensselaer’s long term energy conservation planning, create working demonstrations of how solid state retrofit lighting can improve lighting quality while saving energy, and open new venues for testing the ERC’s research on advanced energy efficient adaptive lighting and control systems. This past spring and summer, the group hitched off its first campus project, bulb replacement in the Great Hall and 2nd floor of the Darrin Communication Center (DCC) on the RPI campus, as part of Rensselaer’s annual $250K commitment to energy efficient smart lighting. The purpose of the project was to replace over 300 halogen bulbs in the DCC operating 24/7 with more energy efficient and significantly longer lifetime LED bulbs and explore the use of daylighting controls with a subset of the installation. Projected initial energy savings of 80% puts the return on investment for the project at a mere 18 months and an annual cost savings over $21,000.

Smart Lighting ERC Sustainability Club students inventoring bulbs removed from DCC for LED replacement.

### Case Study: RPI DCC Bulb Replacement Project Project

**Objective:** To replace all PAR 30 Halogen bulbs in DCC (2nd and 3rd floors) with LEDs to improve energy efficiency, reduce energy costs and reduce manpower costs for non-working bulb replacement.

**Current Results:**

1. **Bulb Selection & Replacement** The students evaluated the space based on use and standard lighting requirements. They explored options on brightness and color temperature through surveys and compared beam angles, thermal properties, and light field distribution through lab measurements and photometric analysis. Two bulbs, both 3000K, were selected for the installation:

   - Sylvania 15 W PAR30 Long neck LED (40° flood)
   - LEDInnovation 14.3 W PAR30 Long neck LED (55° wide flood) with 2” bulb extenders

<table>
<thead>
<tr>
<th>Halogens</th>
<th>LEDs</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Bulbs</td>
<td>330</td>
</tr>
<tr>
<td>Lifetime (hours)</td>
<td>3000</td>
</tr>
<tr>
<td>Replacement need (months)</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Although improving the overall light distribution was not a primary objective of this effort, significant improvement in the lighting experience was realized (see “before” and “after” photos on the next page) in addition to the targeted improved energy efficiency, cost reductions, and lamp lifetimes.
CASE STUDY: Smart Lighting ERC
Campus Sustainability Efforts

2. Energy Monitoring  As part of this effort, the students identified appropriate energy monitoring equipment for a single circuit in the relamped area to monitor and publicize energy savings with the bulb replacement and the future exploration of daylighting controls.

<table>
<thead>
<tr>
<th></th>
<th>Halogens</th>
<th>LEDs</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Bulbs</td>
<td>330</td>
<td>330</td>
</tr>
<tr>
<td>Bulb Energy (Watts)</td>
<td>75</td>
<td>14.3 or 15</td>
</tr>
<tr>
<td>Energy Estimation all bulbs (kWh/year)</td>
<td>216,000</td>
<td>42,000</td>
</tr>
</tbody>
</table>

Energy monitoring installation in DCC

Energy monitoring results in DCC (1 circuit, 2.5% of total replacement)

BEFORE: DCC 2nd floor hallway (Halogen bulbs)

AFTER: DCC 2nd floor hallway (LED bulbs)
Recent advances in biotechnology have transformed the field of biology in a profound way. Large quantities of data and new datasets have been obtained using high-throughput measurements of biomolecular compounds and interactions. This development has necessitated the creation of novel methods to analyze such data to extract meaningful information.

Systems and Synthetic Biology

Recent advances in biotechnology have led to more quantitative methods by which various cellular biological phenomena are analyzed using mathematical models. Further, the ability to genetically manipulate model organisms has enabled biologists to use reductionist approaches, to identify the main factors and interactions behind some of the many biological functions, from metabolism to development to circadian rhythms. Once identified, the genes and proteins involved in these processes can be manipulated to reproduce the functionalities in isolation. Systems biology is the study of an organism, viewed as an integrated and interacting network of genes, proteins, and biochemical reactions that give rise to life.

While these developments have contributed to the natural sciences tremendously, they also offer a unique opportunity for engineering breakthroughs. The ability to reproduce cellular biological functionalities, such as clocks, switches, biosynthetic pathways, and biosensors, in isolation also enables the construction of synthetic modular components that perform those functionalities. Another key enabling factor is the
Systems and Synthetic Biology

An analogy between computer engineering and synthetic biology (taken from Andrianantoandro et al., Mol Syst Biol, 2006.)

quantitative point of view, by which these components can be analyzed in a rigorous mathematical way, and the behavior of the synthetic biological systems can be mathematically predicted. This development opens the gates of opportunity to modular design of engineering systems using synthetic biological components, in the same spirit as modular design of electronic and mechanical systems. Synthetic biology studies how to build artificial biological systems using many of the same tools and experimental techniques used in system biology. However, the work is fundamentally an engineering application where the focus is on taking parts from natural biological systems and using them to build engineered systems with novel functions.

Although the fields of systems and synthetic biology are relatively young, they offer new opportunities to solve many important problems such as drug development and treatment strategies, pharmaceutical synthesis, and biofuel synthesis. ECSE is actively engaged in this new field, both at the research and education fronts.

Researchers from ECSE are working on applying systems theory to understand the dynamics of the biomolecular networks behind our immune system, and how it is changed by obesity. In a study that is conducted in collaboration with researchers from Boston University Dental School, two groups of mice, lean and obese, are subjected to infection. Our researchers seek to build a mathematical model based on the mice gene expression data. Medical researchers have long observed that obesity impairs the subject’s infection response. With this study, we aim to study the phenomenon quantitatively, and explore ways to mitigate the damage using genetic intervention. On a separate project, our researchers are exploring ways to manipulate human circadian rhythm using light. This study is supported by the Smart Lighting Engineering Research Center (ERC), and conducted in collaboration with the Lighting Research Center (LRC) – both at Rensselaer. In response to the natural 24-hour cycle of daylight and darkness, many organisms developed circadian rhythm. Circadian rhythm affects various biological processes including cell cycle, hormone production, and cognitive alertness. In humans, circadian misalignment, for example in rotating shift workers and long distance trav-
elers, has been associated with health issues, ranging from the lack of cognitive alertness to the increase in cancer risk. Motivated by the potential benefits of circadian rhythm adjustment, our researchers seek to develop an accurate mathematical model that is able to predict how light stimuli can alter the circadian phase. In a preliminary study using fruit flies as model organisms, we are developing new signal processing algorithms that can extract circadian phase information from the flies’ locomotor activity patterns and show how the phase is affected differently by different light spectra. Given the similarity between fruit fly and human circadian systems, we will continue this preliminary study with human study in a controlled lighting environment.

Another biology related research activity in our department is in the new field of microbiorobotics. The idea of using microorganisms as actuators for microscale structures is very appealing and a recent breakthrough in engineering particularly because they are very easy and cheap to produce. In collaboration with researchers from Drexel University, our researchers are using unicellular microorganisms as microactuators. In a recent study using Tetrahymana pyriformis, a ciliated protozoa swimmer, we demonstrated that the motion of the cells can be accurately controlled using an external magnetic field. T. pyriformis can be artificially magnetized by introducing a magnetic dipole into the cell. We can then use external magnetic field to steer the motion of the cell.

At the education front, we have introduced a new interdisciplinary course on Systems and Synthetic Biology. The course was jointly developed by ECSE faculty and Chemical and Bioengineering Department faculty, with the support of a grant from Rensselaer’s Office of Entrepreneurship. The course was offered for the first time in 2010 (and subsequently in 2012 as Synthetic Biology). It attracted students from five departments including ECSE. In this course, the students not only learned the theory of systems and synthetic biology but also diverse hands-on lab activities such as programming of mathematical simulation and genetic manipulation. At the end of the course, the students formed multidisciplinary groups and came up with project ideas based on what they learned in class. The ideas that they proposed were wide ranging, from making biodegradable plastics to programming bacteria to kill cancer. We are educating “systems thinkers” in this young interdisciplinary field, who will hopefully help solve big problems in our society.
VIEW FROM RENSSELAER ON: COMPUTER VISION AND VISUAL EFFECTS

Computer Vision and Visual Effects

Neo fends off dozens of Agent Smith clones in a city park. Kevin Flynn confronts a thirty-years-younger avatar of himself in the Grid. Captain America’s sidekick rolls under a speeding truck in the nick of time to plant a bomb. Nightcrawler “bamfs” in and out of rooms, leaving behind a puff of smoke.

James Bond skydives at high speed out of a burning airplane. Harry Potter grapples with Nagini in a ramshackle cottage. Robert Neville stalks a deer in an overgrown, abandoned Times Square. Autobots and Decepticons battle it out in the streets of Chicago. Today’s blockbuster movies so seamlessly introduce impossible characters and action into real-world settings that it’s easy for the audience to suspend its disbelief. These compelling action scenes are made possible by modern visual effects.

Visual effects, the manipulation and fusion of live and synthetic images, have been a part of movie making since the first short films were made in the 1900s. For example, beginning in the 1920s, fantastic sets and environments were created using huge, detailed paintings on panes of glass placed between the camera and the actors. Miniature buildings or monsters were combined with footage of live actors using forced perspective to create photo-realistic composites. Superheroes flew across the screen using rear-projection and blue-screen replacement technology.

These days, almost all visual effects involve the manipulation of digital and computer-generated images instead of in-camera, practical effects. Film-goers over
Modern blockbuster movies seamlessly introduce impossible characters and action into real-world settings using digital visual effects. These effects are made possible by research from the field of computer vision, the study of how to automatically understand images. Computer Vision for Visual Effects by Richard J. Radke educates students, engineers, and researchers about the fundamental computer vision principles and state-of-the-art algorithms used to create cutting-edge visual effects for movies and television.

the past forty years have experienced the transition from the mostly analog effects of movies like The Empire Strikes Back to the early days of computer-generated imagery in movies like Terminator 2: Judgment Day to the almost entirely digital effects of movies like Avatar. While they are often associated with action and science fiction movies, visual effects are now so common that they are imperceptibly incorporated into virtually all TV series and movies—even medical shows like Grey's Anatomy and period dramas like Changeling.

Like all forms of creative expression, visual effects have both an artistic side and a technological side. On the artistic side are visual effects artists: extremely talented (and often under-appreciated) professionals who expertly manipulate software packages to create scenes that support a director’s vision. They’re attuned to the film-making aspects of a shot such as its composition, lighting, and mood. In the middle are the creators of the software packages: artistically minded engineers at companies like The Foundry, Autodesk, and Adobe who create tools like Nuke, Maya, and After Effects that the artists use every day. On the technological side are researchers, mostly in academia, who conceive, prototype, and publish new algorithms, some of which eventually get incorporated into the software packages. Many of these algorithms are from the field of computer vision, the topic of much research in the ECSE Department and the main subject of my textbook called Computer Vision for Visual Effects (Cambridge University Press, 2012).

Computer vision broadly involves the research and development of algorithms for automatically understanding images. For example, we may want to design an algorithm to automatically outline people in a photograph, a job that’s easy for a human but that can be very difficult for a computer. In the past forty years, computer vision has made great advances. Today, consumer digital cameras can automatically identify whether all the people in an image are facing forward and smiling, and smart phone camera apps can read bar codes, translate images of street signs and menus, and identify tourist landmarks. Computer vision also plays a major role in image analysis problems in medical, surveillance, and defense applications. However, the application in which the average person most frequently comes into contact with the results of computer vision—whether he or she knows it or not—is the generation of visual effects in film and television production.

To understand the types of computer vision problems that are “under the hood” of the software packages that visual effects artists commonly use, let’s consider a scene of a human actor fighting a computer-generated creature (for example, Rich O’Connell vs. Imhotep, Jack Sparrow vs. Davy Jones, or Kate Austen vs. The Smokey Monster). First, the hero actor is filmed on a partially built set interacting with a stunt performer who plays the role of the enemy. The built set must be digitally extended to a larger environment, with props and furniture added and removed after the fact. The computer-generated enemy’s actions may be created with the help of the motion-captured performance of a second stunt performer in a separate location. Next, the onset stunt performer is removed from the scene and replaced by the digital character. This process requires several steps: the background pixels behind the stunt performer need to be recreated, the camera’s motion needs to be estimated so that the digital character appears in the right place, and parts of the real actor’s body need to appropriately pass in front of and behind the digital character as they fight. Finally, the fight sequence may be artificially slowed down or sped up for dramatic effect. All of the elements in the final shot must seamlessly blend so they appear to “live” in the same frame, without any noticeable visual artifacts. My book describes many of the algorithms critical for each of these steps and the principles behind them.

During the course of writing my book, I visited several Hollywood visual effects companies including Digital Domain, Rhythm & Hues, LOOK Effects, and Gentle Giant Studios. It was extremely interesting to compare the topics we teach in our computer vision courses to real-world practice, and find out which techniques are commonplace and which are rare in the visual effects industry."
Matchmoving or camera tracking, i.e., the estimation of the location and orientation of a moving camera from the image sequence it produces. This process is critical for realistically merging computer-generated imagery with live action plates, and involves several sub-problems, including estimating the lens distortion of a camera, calibrating a camera with respect to known 3D geometry, and calibrating a stereo rig for 3D filming. Visual effects artists on a movie set commonly insert artificial markers into the environment that can be easily tracked as input to the problem, but in many cases they must find and track natural features in the scene.

Motion capture, which is increasingly used in films and video games to help in the realistic animation of computer-generated characters. Technology exists for capturing both full-body and facial motion capture data, and requires algorithms for cleaning up and post-processing the motion capture marker trajectories and mapping them onto animation rigs. The academic community has also recently investigated purely vision-based techniques for markerless motion capture, in which no embarrassing ping-pong-ball-covered suit is required.

During the course of writing my book, I visited several Hollywood visual effects companies including Digital Domain, Rhythm & Hues, LOOK Effects, and Gentle Giant Studios. It was extremely interesting to compare the topics we teach in our computer vision courses to real-world practice, and find out which techniques are commonplace and which are rare in the visual effects industry. Some of these interviews appear in the book to tie research to reality. As a companion to the book, I also maintain a website, cvfxbook.com, with links and commentary on new visual effects algorithms from academia and industry, examples from behind the scenes of television and films, and demo reels from visual effects artists and companies. Check it out!

Three-dimensional data acquisition, also known as range scanning. Visual effects personnel routinely scan the 3D geometry of filming locations to be able to properly insert 3D computer-generated elements afterward, and also scan in actors’ bodies and movie props to create convincing digital doubles. Technologies include laser rangefinding such as LiDAR for large-scale 3D acquisition, structured-light techniques for closer-range scanning, and more recent multi-view stereo techniques.
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Paul J. Severino ’69
Sean Sullivan ’85
A. Scott Wharton ’87
*deceased

In Memory of C. Alan Borck ’47, B.E.E. electrical engineering

A pioneer in the microwave component manufacturing business he began 50 years ago, Alan Borck has been an involved and generous alumnus over the years. A member of the Livingston W. Houston ’13 Society of Patroons, Alan and his wife Virginia generously established the Alan Borck ’47 Electrical Engineering Development Endowment Fund in 1990, and in 2000 the department was grateful to dedicate the Alan Borck ’47 and Virginia Borck Control Engineering Studio in the Electrical, Computer, and Systems Engineering.

Mr. Borck served as a member of the School of Engineering Advisory Board in years past, and he served on the Advisory Board for the School of Science from 1996 to 2004. He received the Rensselaer Alumni Association (RAA) Fellows Award from the Electrical, Computer, and Systems Engineering department in 1997 and was a life member of the Institute of Electrical and Electronics Engineers, Inc. As a student, Alan served in the Navy ROTC, on the Polytechnic staff, and was a member of Phi Sigma Delta fraternity.

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