

GREENER, COOLER, AND REVOLUTIONIZING THE DATA CENTER INDUSTRY

by Carly Keeny

The touch of a button. The click of a mouse. The swipe of a touch screen. In today's digitally-driven society, keeping the data flow that controls everything from financial markets and private health records, to commerce and homeland security, running smoothly and unimpeded goes beyond the merits of convenience—it is crucial.

the work of a data center. Often tens of thousands of square feet in size, data centers house millions of dollars in computer server equipment and constitute the nerve center of the Internet. As our reliance on instantaneous access to information grows, so does the need for data centers.

In order to meet and manage the demand for data, these centers require a significant amount of electricity—estimated at about 3 percent of the nation's total use per year. As the electronic machines these centers house process information, they

Engineering faculty has joined forces with colleagues from around the country to explore the possibilities on behalf of some of the world's best known multinational corporations—and in the process, revolutionize the way data centers are designed and managed.

Introducing I/UCRC E3S

Last fall, the National Science Foundation (NSF) elevated the importance of data center energy issues to national prominence by awarding its first Industry/University



Dr. Aaron Wemboff, Assistant Professor; Dr. Kamran Fouladi, P.E., Adjunct Professor; Dr. Amy Fleischer, Associate Professor; Dr. Alfonso Ortega, the James R. Birle Professor of Energy Technology and Associate Dean for Graduate Studies and Research; and Dr. Gerard F. "Jerry" Jones, Professor and Associate Dean for Academic Affairs, in the Laboratory for Advanced Thermal and Fluid Systems.

“Data centers are the lifeline of any business,” says Gary Aron, Vice President of Business Development for software provider Asset Vue. “Without access to critical data, businesses can't operate.”

Then there's the Internet. Every email sent, video downloaded, or breaking news story read online triggers a chain reaction of information processing, which requires

dissipate huge amounts of heat and require sophisticated cooling systems, all of which drives up the costs of operation. Currently, about half of the electricity delivered to a modern data center operates the cooling systems.

How can these data centers be made more energy efficient, sustainable, and more cost-effective to run? A team of Mechanical

Cooperative Research Center (I/UCRC) on “greener” data centers. With five-year funding of \$3.4 million, the Villanova team and partners from Binghamton University and the University of Texas at Arlington, with collaboration from the Georgia Institute of Technology, established the I/UCRC on Energy-Efficient Electronic Systems (I/UCRC E3S).

BETTER FOR BUSINESS:

“Our goal is to develop innovations that will make data centers more efficient and sustainable,” says Dr. Alfonso Ortega, the James R. Birle Professor of Energy Technology and Associate Dean for Graduate Studies and Research. “By working together, we can take a holistic approach to designing the physical structure of a data center and its subsystems, allocating computing resources, and deploying solutions for environmental control. Together, we may also create non-traditional ways of reusing waste energy.”

Each institution brings its own area of expertise to the Center, but members from each university work collaboratively on a number of research projects. Contributing a focus on thermal fluid sciences, the Villanova team draws from the Mechanical Engineering Department, including:

- **Dr. Alfonso Ortega**, the James R. Birle Professor of Energy Technology and Associate Dean for Graduate Studies and Research, E3S Villanova Site Leader
- **Dr. Gerard Jones**, Professor and Associate Dean for Academic Affairs
- **Dr. Amy Fleischer**, Associate Professor
- **Dr. Aaron Wemhoff**, Assistant Professor
- **Dr. Kamran Fouladi, P.E.**, Adjunct Professor and aerospace industry consultant

Binghamton brings computing science and data center thermal management expertise, while the University of Texas at Arlington focuses on thermal management systems and dynamic systems controls, and Georgia Tech offers leadership in simulating fluid dynamics and flow internal to data centers.

The NSF’s award also requires each institution to recruit industry partners as contributing members of E3S. To date, the Center has attracted nearly 20 members, representing the entire supply chain, from hardware manufacturers and software developers, to end-users. The Villanova team has recruited Verizon Wireless; Comcast; DVL, Inc.; and Steel ORCA. Other members include Microsoft,



Facebook, IBM, General Electric, and Bloomberg (for a full list, see the sidebar on page 8).

In exchange for their membership investment, each partner company receives access to:

- A shared pool of research, publications, short courses, and electronic systems databases
- PhD-level consultative services

“Data center owner/operators are working with the manufacturers of technology, academia, and many think tanks to use less power, or at the very least, use it as efficiently as possible. Not to be forgotten is the social responsibility of America’s companies to be leaders in energy conservation.”

— *Richard Werner, Executive Director of Data Center Services, Comcast*

- Access to research equipment, infrastructure, and expertise at partner campuses
- Graduate students, mentoring and recruitment opportunities, and workforce training programs and internships

Members may also:

- Commission research exclusively for their own organizations
- Develop business-to-business relationships
- Initiate research partnerships across E3S

Partners that join at the full membership level also enjoy a stake in the strategic planning of the Center’s research initiatives. When the full complement of university and corporate partners meet at biannual Industry Advisory Board (IAB) meetings, these members help choose the research projects in which E3S will invest its resources. Representatives from these companies also serve as industry mentors for projects, with responsibilities for maintaining close oversight of progress and offering real-world insight and support when needed.

Keeping Their Cool

In data centers, heat is the enemy of smooth, reliable performance, which makes cooling a priority, and also the number one source of power consumption for these buildings. “Many data centers still in use today were built in the 1980s and 1990s. In those days, we would add cooling as needed,” says Aron, who has more than 30 years of experience designing and managing data centers for Fortune 500 companies. “Today, we’re starting to incorporate tools that modulate

“Our participation in E3S is extremely exciting. Our goal is to provide a dual platform for researchers to use our digital utility center labs to innovate, test, and prove theory. We are also pleased to provide a production theatre for commercial applications consequent to the work done in the lab.”

– Dave Crocker, CEO, Steel ORCA

cooling and have controls to drive energy conservation, which not only saves money but also decreases waste heat.”

In December, the IAB approved nine projects put forth by the university teams deemed to offer the best value to E3S. The highest rating went to a project spearheaded by Dr. Ortega, which emphasizes achieving energy efficiency by leveraging targeted cooling only to the areas of the data center that truly need it, when they need it.

Dr. Ortega is working with Dr. Wemhoff and Dr. Fouladi to build a thermodynamic model capable of assessing data energy consumption as a function of server activity loads, computing temperatures, and cooling needs. The team can then use this information to define the optimum layout of a data center’s design and integrate that layout with recommendations for its management and operation. Representatives from Panduit, Microsoft, and Steel ORCA serve as mentors.

“The simulation tool we are building can also help us model viable methods to conserve energy and help us keep track of the exergy, or quality, of waste energy, based on how well we can harness it for reuse,” says Dr. Ortega.

PhD candidate Marcelo DelValle and Kayvan Abbasi MSME ’13 will participate. They will be joined by a student in the College’s Master of Science degree program in Sustainable Engineering, who will focus

on lifecycle assessment and be co-advised by William Lorenz, Adjunct Professor of Chemical Engineering.

Recovering Waste Energy

E3S members also approved a project led by Dr. Fleischer, in collaboration with Dr. Jones, aimed at capturing waste energy before its exergy deteriorates. By comparison, the electricity used to power data centers maintains a high exergy level, while the warm air dissipated by computer equipment ranks lowest in terms of its potential for reuse. But what if you could capture the waste energy before it becomes warm air?

Dr. Fleischer and Dr. Jones have begun a comprehensive literature review, spanning a number of industries, to survey the best ideas for improving waste energy potential in data centers. Concepts may include an exploration of the merits of replacing fans in electronic equipment with liquid heat sinks or exchangers, which can pick up the heat highly locally and capture it in liquid. Perhaps that hot fluid could then be converted into electricity that could be put back into the grid or used to heat and cool the building.

“Through our partnership in E3S, we see an opportunity to test the limits of technology in a lab environment while developing and leveraging the talents of future leaders in this very important and highly competitive field.”

– Richard Craig, Director of Engineering and Operations Support, Verizon Wireless

Once the literature review is complete, the team will make recommendations on the most viable options for improving waste energy reuse in data center environments, which will commence an experimental phase of the project. Endicott Interconnect Technologies and Facebook serve as mentors. The team will also support a graduate student.

E3S Corporate Partners

Advanced Electronics Company, LTD
Bloomberg
Comcast
Commscope
Corning, Inc.
DVL, Inc.
Emerson Network Power
Endicott Interconnect Technologies
Facebook
General Electric
IBM
Microsoft
NYSERDA
Panduit
Sealco/Bick Group
Steel ORCA
Verizon Wireless

Just Getting Started

The NSF’s funding will support E3S for five years, with the potential for five-year funding renewal. New projects will be considered once a year, and both industry and university partners will provide formal updates (separate from regular mentor meetings) on projects twice annually.

Along the way, university partners may offer their expertise to any of the inaugural nine projects as needed. For example, faculty from all three collaborating universities will offer valuable insight into the development of Villanova’s computer simulation tool for energy consumption, while a student at the University of Texas, who has a particular interest in water sustainability, may participate in both Villanova-led projects.

“I envision Villanova being able to offer a great deal of additional analyses from a sustainability point of view, which is unique to the College of all the E3S partners,” says Dr. Ortega. “This work dovetails perfectly with work of the Villanova Center for the Advancement of Sustainability in Engineering (VCASE), and we hope VCASE faculty eventually will be able to bring their strengths to bear on our projects.”

For more information on E3S, visit www.binghamton.edu/e3s

DISTANCE LEARNING GROWS UP

By Debbie Clayton

It was a “no-brainer” for Steve Wilrigs, an MSME student, to take one of the inaugural graduate engineering classes at the College of Engineering’s Center of Learning within Philadelphia Technology Park at the historic Philadelphia Navy Yard last fall.

“The facility is absolutely gorgeous, and it’s right down the street from where I work,” says Wilrigs, a graduate intern in the Major Programs Division at the Naval Surface Warfare Center. “I actually prefer to take my classes in the classroom when I can, and this is probably the most high-tech classroom I’ve ever been in.”

Designed as the next step in distance learning, the College’s state-of-the-art

classroom at the Navy Yard features the latest in web broadcasting and video teleconferencing capabilities. Professors use tablet PCs to project notes to students, who view them on 17-inch monitors and interact on-site via web technology. All lectures are simulcast to distance-learning students, who participate in discussions through texting or voice interaction. Lectures—including discussions—are digitally archived in perpetuity for later viewing.

“From the furniture in the room, to the glass walls, to the screens used, the classroom was built for heightened efficiency of learning,” notes Sean O’Donnell, Director of E-Learning and Graduate Marketing for the College of Engineering. “Everything has a purpose and functionality, seamlessly integrated with technology. The biggest advantage is that everything done in the classroom can be re-watched throughout one’s career.”

When O’Donnell began working on distance learning as a Villanova computer engineering student in 1997, the blueprint involved TV networks, satellites, and microwave transmission. The Internet, of course, changed everything.

“In the last few years, I’ve seen distance learning evolve into e-learning,” says O’Donnell, who graduated in 2000 and began working at Villanova in 2001. “Here on campus, we have an ambitious e-learning program, but we have a large contingency of engineering graduate students who work for the Navy and for companies like Boeing, Kimberly Clark, Sunoco, and Lockheed Martin—all located within 10 miles of the Navy Yard—and not all that close to our main campus.”

Expanding Student Reach

The Philadelphia Navy Yard has a rich history, including serving a strategic shipbuilding role in World War II.

Though the Navy officially closed the Yard in 1995, it kept several significant military facilities there.

“In the past, we would send our professors down to the Navy Yard to interface with students,” adds O’Donnell. “But the only area available was located inside the Navy facility, meaning no one except Navy employees could be in the classroom. So we were expanding our reach but limiting our market space within that reach.”

In recent years, the Navy began working with the city to foster technology development, attracting a number of industry players. It has since become the fastest-growing technology and life-sciences zone in the Mid-Atlantic region. In September 2010, the Philadelphia Technology Park opened at the Navy Yard, featuring a \$25 million, 25,700-square-foot single-use, fully redundant enterprise data center. When the opportunity arose to occupy a 1,400-square-foot facility within Philadelphia Technology Park, the College snapped it up.

“It took a year to develop the space available to us, but we built our curriculum to match the facility,” explains O’Donnell. “Our two models for revenue were graduate



Rev. Peter M. Donohue, O.S.A., Ph.D., University President; Dr. Gary Gabriele, Drosdick Endowed Dean of Engineering; and John Grady, President, Philadelphia Industrial Development Corporation, cut the ceremonial ribbon at the new Center of Learning at the Philadelphia Navy Yard.

Notable Neighbors

The College of Engineering rubs elbows with several recognizable residents of the Philadelphia Navy Yard, including:

- Tastykake—world headquarters and manufacturing plant
- Urban Outfitters—world headquarters
- Aker Philadelphia Shipyard
- Glaxo Smith Kline—regional headquarters
- NSWCCD—Naval Surface Warfare Center



In the foreground: The Greater Philadelphia Chamber of Commerce's Joseph W. Mahoney, Jr., Executive Vice President, and Chermaina Roundtree, Partnership Marketing Coordinator. Back row: Mechanical Engineering Professors Dr. Sridhar Santhanam and Dr. Hashem Ashrafiuon, Director of the Center for Nonlinear Dynamics and Control, are among the first faculty members to teach in the new space.

nighttime education and educational space design/online learning expertise for lease by corporations. We are now up and running with both initiatives.”

Three classes were offered at the Navy Yard Center of Learning during fall semester, and all exceeded enrollment expectations. For spring semester, the curriculum expanded to include four classes, taught by both adjunct and full professors. Classes run from 4:30 to 7:30 p.m., allowing nearby working engineering graduate students to put in a full day’s work and still avoid rush hour traffic.

If they are called out-of-town for work, as Wilrigs was during his class, they can participate online in real-time, as if they were sitting in the classroom. Wilrigs is hoping to take another class this summer during a job rotation in Washington, D.C. “Flexibility is the key,” he says. “The e-learning component is definitely a benefit for me.”

Enriching the Experience

Dr. Sridhar Santhanam, Professor of Mechanical Engineering, teaches advanced engineering math at the Navy Yard during spring semester. “The new program allows Villanova to reach beyond our geographical vicinity and serve more students with different needs and backgrounds,” he notes. “The experience they bring always makes a big difference—especially in a graduate class. It really enriches the classroom experience.”

Similarly, Dr. Hashem Ashrafiuon, Professor of Mechanical Engineering, feels

the biggest innovation the new facility offers is that each student sees class notes close-up on the monitors provided. “This makes it easy for them to follow the notes and simultaneously watch the instructor,” he adds.

O’Donnell agrees. “Students are no longer looking at the back of the professor’s head as he writes on the blackboard,” he says. “It’s more friendly and collaborative. Anecdotally, it increases the caliber of learning. Plus, we are integrating it seamlessly online to make distance students feel they are right in that classroom.”

In total, the College now offers 32 distance education classes per semester. According to O’Donnell, that’s 96 hours of live lecture every week. Over the course of a semester, it adds up to 1,200 hours of live

lecture—all archived for viewing on demand.

Beyond the classroom, as part of its second initiative, Villanova leases the state-of-the-art Navy Yard facility to corporations for in-house training. “There are huge advantages for our corporate clients, including a centralized location dedicated to training with a high-tech classroom and exciting space,” adds O’Donnell.

Also on tap for the facility are continuing studies courses, graduate recruitment events and STEM (science, technology, engineering, and mathematics) outreach programs for the region’s K-12 students and educators.

“There’s so much we want to do with the space that it’s a matter of being patient and doing them one at a time, so they are done appropriately,” O’Donnell explains. “It’s a thrilling time for the College of Engineering.”



The 1,400-square-foot facility houses a 40-seat classroom and 10-seat collaboration area—both of which employ the latest in web broadcasting and video conferencing capabilities.

LEADing THE WAY

By Jill Monahan

The summer of 2010 painted a fairly accurate picture of how Britney Davis envisioned her college years. A rigorous academic program in engineering, excellent faculty, an engaging day of learning and teamwork, and a pervasive community spirit all added up to an excellent experience.

Back then, Davis was just a bright, high-achieving high school junior who spent three weeks on campus, not an undergraduate. But the bar had been set so high by the time she began looking at other colleges that Villanova became the school by which all others were measured. Today, she is a freshman engineering student.



Freshman Britney Davis fell in love with Villanova Engineering as a junior high school student participating in the summer LEAD Engineering program.

Davis came to the College of Engineering through LEAD (Leadership Education and Development) Engineering, which debuted at Villanova in 2010. A three-week program, LEAD helps top high school students of diversity reach their potential and develop leadership skills. This July, the arrival of 30 students will mark the third year of the College's participation in LEAD's Summer Engineering Institute.

A national nonprofit organization, LEAD collaborates with universities to offer students enrichment in business, engineering, computer science, and global studies. LEAD Engineering exposes high school rising juniors and seniors to STEM (science, technology, engineering, and math) careers.

Three years ago, LEAD approached Villanova to host a summer program. Georgia Tech and the University of California Berkeley were already a part of the cohort, and the College seemed like a perfect addition.

"We were thrilled at the prospect of participating in LEAD Engineering, and I think we bring that Villanova focus on service," says Dr. Frank Hampton, Assistant Professor of Civil and Environmental Engineering and LEAD Director. "We pair learning with helping others so students see engineering in a way that showcases all the good it can do in the world."

Engineering in Action

Upon arrival, the engineering immersion experience begins. Mornings are comprised of lectures, with the first week dedicated to the basics of chemical, civil, computer, electrical, and mechanical engineering. Group projects are also assigned. Afternoons include teamwork sessions, lab experiments, guest lectures, and workshops, followed by evening "fireside chats" with faculty, students, and alumni.

Field trips also bring engineering careers to life, through visits to places such as The Boeing Company, Fairmount WaterWorks, Google's New York office, and PECO headquarters.



Nnaoma Oji of Brighton, Minn., participated with now-freshman engineering student Britney Davis during the College's first year hosting LEAD Engineering.

Toward the end of the program, the students lead a lab experience of their own for middle school students.

The program culminates with student presentations of their group research and design projects.

“Our goal is to tie the projects to a timely engineering topic, so the focus for this year’s program will be a combination of sustainability and social entrepreneurship,” said Dr. Hampton. “We throw challenges at them like developing a brick that can withstand earthquakes more easily in developing countries or building a solar-powered lantern. The goal is to give them the fundamentals, expose them to the field, and see what they come up with. They never fail to surprise and delight us.”

Engineering out Loud

LEAD Engineering at Villanova challenges students to get comfortable with presenting an idea—not just thinking up one—thanks to that same group project. While the content of the project takes up a significant amount of time in the first two weeks, the third week is all about presentation. Everything from dress to talking points to PowerPoint presentation is rehearsed and critiqued.

“I mentioned surprise and delight, and that comes in when we see a new and exciting twist on a product they’ve developed,” continues Dr. Hampton.

“But it is also associated with the maturity and polish we see in the presentation of their ideas.”

Dr. Hampton, a Juilliard-trained professional opera singer who has sung throughout the U.S. and Europe, believes that being able to stand up and communicate an idea is an invaluable lesson. “The knowledge we share with them over the three weeks, paired with the public speaking training, is something they have never gotten in their lives. It opens up a whole new world for them.”

A Lasting Impression

It takes a village to make LEAD Engineering a success, including dozens of student resident advisors (RAs), faculty members, and staff members from the College of Engineering. With RAs serving as everything from mentors, fellow engineering fans, and recreation directors, they keep the students busy outside the classroom.

While the Villanova team forms strong bonds with the students, the bonds the students form with each other are even stronger.

“We go around the room on the last night and talk about what the students did and didn’t like,” says Dr. Stephen Jones, Associate Dean for Student and Strategic Programs, who co-directs LEAD with Dr. Hampton. “And while what they didn’t like is often something small, what they did like

DID YOU KNOW?

The College’s LEAD Engineering program consistently ranks highest in student satisfaction among all LEAD Engineering host schools!

is invariably what they learned about college life and the people they met on the journey.”

Sometimes the experience inspires a new path. “We had one student who was undecided about engineering when he arrived,” says Dr. Jones. “His long-term goal was to launch his own line of sneakers, so I was really surprised to learn that the experience had been an epiphany for him. He didn’t know what mechanical engineering was when he arrived, but the program ignited a keen interest in the field.”

Facebook pages for each year of the program, ongoing friendships, and close relationships with the RAs keep the camaraderie alive long after the program has ended.

In fact, Davis made three friends through LEAD and now lives across the hall from one—a testament to the importance of the program, which brings intelligent, motivated students to Villanova.

Her experience made such a lasting impression on Davis that she couldn’t forget it.

“When visiting other schools, I always compared them to Villanova. In the end, I could actually see myself here because of my summer experience. The engineering program is excellent; I really liked the people, and the campus was beautiful,” says Davis. “Also, it really appealed to me that Villanova was small enough to have a real sense of community. I didn’t want to be lost in the crowd at college.”

Never Say Goodbye

Encouraging these smart, ambitious students to apply to Villanova means they do not always have to say goodbye. “We have eight students from the 2011 program who have applied to Villanova, and two had been accepted early action,” says Dr. Jones.

At the end of the day, it’s a win-win situation. Just ask Davis—and her professors.