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NEWSLETTER OF *Oak Ridge National Laboratory's Energy and Environmental Sciences Directorate*

Driving the Future of Transportation

Computational framework for optimizing traffic flow could be the beginning of a road revolution

Visualization of an ORNL connected vehicles simulation using decentralized control algorithms developed by researchers with the lab's Urban Dynamics Institute. Image provided by Andreas Malikopoulos.

Drivers trying to get to work or home in a hurry know traffic congestion wastes a lot of time, but it also wastes a lot of fuel. In 2011, congestion caused people in US urban areas to travel an extra 5.5 billion hours and purchase an extra 2.9 billion gallons of fuel costing $121 billion. But despite the tangle of vehicles at busy intersections and interstate ramps, most of the country's highways are open road with vehicles occupying only about 5% of road surface.

Scientists with ORNL's Urban Dynamics Institute (UDI) are working to reduce travel time and fuel consumption by developing a computational framework for connected vehicle technologies that facilitate vehicle-to-vehicle communication, as well as communication between vehicles and traffic controls like traffic lights. Researchers envision vehicles exchanging information—such as location, speed, and destination—to generate individualized instructions for drivers.

"By telling drivers the optimal speed, the best lane to drive in, or the best route to take, we can eliminate stop-and-go driving and improve safety," said Andreas Malikopoulos, UDI deputy director and principal investigator of the Laboratory Directed Research and Development project. "As a driver, you may get additional instructions suggesting you change

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OAK RIDGE National Laboratory

in focus letter

Martin Keller, Associate Laboratory Director for Energy and Environmental Sciences.

Martin Keller on a strategic vision for sustainable communities

An increasingly important principle of energy research and development is integration, and solutions for improving energy efficiency and providing energy security are in high demand. At Oak Ridge National Laboratory (ORNL), new opportunities in materials characterization and development, manufacturing, and computer modeling and simulation are equipping researchers with the innovative tools needed to solve national energy challenges.

ORNL's Energy and Environmental Sciences Directorate (EESD) represents the research communities that will help develop the buildings, transportation, electrical power, and manufacturing sectors of tomorrow's sustainable communities. Our directorate also houses the environmental and climate science knowledge to reduce the environmental impact of next-generation materials, infrastructures, and energy practices.

A sustainable community is one that is energy efficient, environmentally healthy, secure, and productive enough to maintain its sustainability. With the vision of integrating our research applications based on the needs of such a community, EESD leadership is writing a long-term strategic plan for the directorate. To ensure the plan is ambitious as well as actionable, we are seeking input from all EESD staff to guide the document's development.

At the group level, we are encouraging brainstorming sessions for staff to consider what an ideal sustainable community would look like and what their individual and group roles would be in its development.

Communication, creativity, and training action teams have been set up to advise the development, writing, and internal and external placement of the strategic plan so that our staff, collaborators, and the public will clearly understand our directorate goals for the next year, 3 years, and 10 years.

Our research divisions and institutes will serve as the organizational structure to help us achieve specific goals. Our capability to meet these goals likewise will be determined by our collaborations inside and outside the lab, as with our world-leading materials characterization and leadership computing facilities located at ORNL and our industrial partners from around the country.

Our leadership team is finalizing the strategic vision document, which I plan to present to the directorate in May 2015. Thank you in advance for your contributions and insight.—*Martin Keller*

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lanes or follow a different path that may not be the route your GPS would give you to avoid congestion."

The first step for the project team is developing decentralized control algorithms that govern how vehicles will communicate locally among vehicles interacting directly on the road but also act globally to optimize traffic flow across a city. The computational framework uses "decentralized control" algorithms because, realistically, all the vehicles in a city cannot communicate information to a central control center due to the staggering amount of data that would be involved.

"The first phase is an exploratory project. We'll validate our framework through simulation," Malikopoulos said.

The second phase of the project will connect the team's communication framework with a transportation analysis simulation system that uses data analytics to simulate traffic conditions in real urban areas to predict congestion. Simulations will predict and plan traffic flow based on large-scale data, such as the layout and population distribution of the area that reflects driver activities (for example, school zones are likely to be busier early in the morning and mid-afternoon, whereas entertainment districts are likely to be more congested during evenings and weekends), as well as the destinations and schedules of the connected vehicles in the simulation.

Phase two simulations also will allow the team to begin exploring questions related to cybersecurity and possible incentives for drivers to follow connected vehicle instructions, such as digital ticketing.—*Katie Elyce Jones*

in the spotlight

Laboratory Director Thom Mason, right, presents Lonnie Love, group leader for the Manufacturing Systems Research Group, with the 2014 Director's Award for Outstanding Team Accomplishment at ORNL Awards Night in November. Love also received the Distinguished Research Award and the Technology Transfer Award.

Love sweeps awards for large-scale additive manufacturing

Lonnie Love, group leader for the Manufacturing Systems Research Group, has turned a career in robotics into a mission to advance American manufacturing through additive manufacturing, also known as 3D printing. Love and his colleagues aren't just thinking about the 3D printer that fits on a desk; they want to help transform the automotive, aerospace, power, and national security sectors through large-scale additive manufacturing that can print vehicle parts and expensive factory tools at reduced cost and time using innovative materials.

Love started at ORNL in 1999 in the Manufacturing Systems Research Group, after completing a postdoctoral assignment, also at ORNL. "I started out doing a lot of work with design and control of robots for nuclear waste clean-up," he said.

In the months and years after 9/11, Love shifted to developing designs and controls for military robotic platforms. Over the last decade, increasing demand for efficient, low-cost manufacturing for energy applications led Love's group to work closely with ORNL materials scientists to create manufacturing and processing techniques for the strong plastics and reinforced carbon fiber used in 3D printing.

"About four or five years ago, ORNL started getting its first 3D printers in, and I said, 'either that machine is going to be in my lab or I'm moving my office next it,'" Love said.

When ORNL's Manufacturing Demonstration Facility opened in 2012, Love's group gained a designated facility for collaborating with academic and industry partners to accelerate and scale new manufacturing processes. Among their 3D printed technologies is a robotic arm that was displayed during an event with President Barack Obama to demonstrate the future of advanced manufacturing.

"3D printers are really robots," Love said. "And my group understands how to use this technology to develop new platforms."

New platforms like the BAAM—the Big Area Additive Manufacturing Machine that can print components 10 times larger than most additive manufacturing machines—which ORNL developed with partner Cincinnati Incorporated. Love was project lead for the BAAM development, and the success of the BAAM and two significant projects that have stemmed from it—the 3D printed Strati and Shelby Cobra cars—has made it a banner year for Love.

In June, Love delivered the keynote speech at the RAPID 2014 conference, where ORNL and Cincinnati Incorporated received the 2014 Innovation Award "that recognizes the most innovative new products or services exhibit to have the greatest potential impact on the industry" for their collaboration in large-scale additive manufacturing with the BAAM.

In September 2014, Love worked closely with Local Motors to print the body and chassis of the Strati, the first 3D printed car, which was additively manufactured, assembled, and driven at the International Manufacturing Technology Show in Chicago, including only 44 hours of printing time.

Just over a month later, back home at ORNL, Love was awarded Distinguished Researcher during ORNL's Awards Night on November 7 as a leader and innovator in additive manufacturing who has "inspired and mentored others while personally making broad, significant impacts upon the development of AM [additive manufacturing] processes; innovative design; and application of the technology in robotics, medical devices, defense, and energy-efficient vehicles."

Love was also part of the 11-member team that won the Outstanding Team Accomplishment and the Technology Transfer Award—both for the development of the BAAM, which was commercialized by Cincinnati Incorporated in 2014. Other team members included Craig Blue, Chad Duty, Charles Carnal, Vlastimil Kunc, Alan Liby, Randall Lind, Peter Lloyd, Jennifer Palmer, Brian Post, and John Rowe.

In January, Love discussed the manufacture of ORNL's own 3D printed car, named after the classic Shelby Cobra, with President Obama and Vice President Joe Biden during their tour of the Techmer PM plant in Clinton, Tennessee, where the Cobra was displayed. Love's team printed the Cobra, and materials for the surface finish were formulated by the Techmer PM subsidiary Techmer ES.

"Additive manufacturing, 3D printing, is a new manufacturing paradigm that requires designers to think completely differently," Love said. "We're really moving in a new direction."

—*Katie Elyce Jones*

ORNL researcher Kaushik Biswas analyzes the thermal performance of a 2 × 2 ft composite panel covered with smaller modified atmosphere insulation panels, developed by ORNL and industry partners NanoPore and Firestone. The performance of these new panels is expected to nearly double that of traditional insulation panels.

Envelope researchers, industry partners develop next-generation insulation material

Inadequate insulation is one of the largest causes of wasted energy, quickly allowing heating or cooling to slip away to outdoor air. That's why researchers at ORNL are collaborating with industry to develop a material that nearly doubles the performance of traditional insulations without a high cost premium.

"Buildings are responsible for 40% or more of the energy consumption in the United States," said Kaushik Biswas of ORNL's Building Envelope Systems Research Group. "There's a huge opportunity to save energy."

More specifically, about 6% of the entire US energy consumption—which includes the building, industrial, and transportation sectors—can be attributed to energy used by heating and cooling, Biswas said.

In residential and commercial buildings, roofs and walls are insulated to reduce heating and cooling losses. But the lower the insulation performance, the more often a heating or air-conditioning unit will have to run.

Commercial buildings commonly use polyisocyanurate, or polyiso, foam boards, whereas many residential structures are insulated with spray foam. Compared with the product ORNL is developing with partners NanoPore and Firestone Building Products, these materials have low "R-values"—the measure of resistance to heat transfer through an insulation material.

The material being developed by ORNL and its partners is a composite polyiso foam board containing modified atmosphere insulation (MAI) cores. While polyiso and spray foam hover around an R-value of 6 per inch of thickness, the goal for MAI-polyiso composites is to double that figure.

"What we want to do is get a new insulation product that's cost effective and achieves R-12 per inch," Biswas said.

To reach the increased R-value, MAI technology borrows from the design of vacuum insulation panels (VIPs), which display some of the highest R-values but are expensive to manufacture. To make MAIs more viable, NanoPore changed how they are made and reduced the cost by about half.

MAI panels are made of a porous core material with nanoscale pore diameters, which are evacuated and sealed within multiple barrier layers. The nanoporous structure and vacuum within the MAI cores help to reduce two of the three modes of heat transfer in insulation materials: solid conduction and gas/vapor conduction. The third mode of heat transfer, radiation, also can be reduced by adding opacifiers to the core. The lower the heat transfer, the higher the R-value.

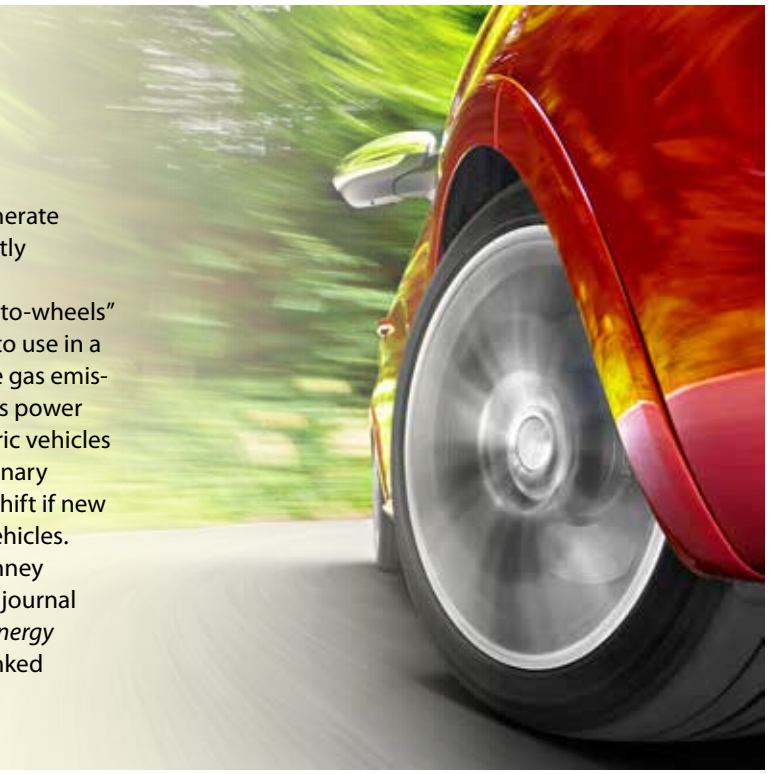
Truly distinguishing MAIs from VIPs, however, is the manufacturing process. Almost 75% of the cost for VIPs is bundled up in the processing and overhead stages. MAI manufacturing cuts out about half the price by reducing the processing steps and eliminating the need for much of the specialized equipment used in making VIPs.

Firestone Building Products is developing a composite that uses polyiso foam to encapsulate the MAI cores and protect against puncture of the barrier layers. An added advantage is that the new MAI-polyiso composite can be a drop-in replacement for existing polyiso board insulation without special installation considerations.

"Development of next generation insulation materials achieving R-10 to R-12 per inch can lead to substantial energy savings in the buildings sector," Biswas said. "Modified atmosphere insulation is a lower cost alternative to vacuum insulation panels and is a good candidate for next-generation insulation materials."

The DOE Building Technologies Office provided funding for the project, and research is being conducted at ORNL's Building Technologies Research and Integration Center user facility and in the facilities of NanoPore and Firestone.—*Chris Samoray*

ORNL "well-to-wheels" study finds most effective transportation use for natural gas



Is it more efficient to use our abundant natural gas resources to generate electric power for an electric vehicle or to put the natural gas directly into the vehicle?

To answer that question, researchers at ORNL engaged in a "well-to-wheels" analysis, an evaluation of a raw material from extraction from a well to use in a vehicle, that included evaluation of total energy use and greenhouse gas emissions. The results show that the high efficiency of modern natural gas power plants makes using natural gas–generated electricity to power electric vehicles the better option with current technologies. Natural gas in the stationary power application won by a small margin, so that advantage might shift if new technologies increase the fuel conversion efficiency of natural gas vehicles.

The study, conducted by EESD's Scott Curran, Robert Wagner, Johney Green, Ron Graves, and Martin Keller, originally was published in the journal *Energy* and was followed by a *Forbes* article in November 2014. The *Energy* research paper outlining their well-to-wheels analysis is currently ranked among the journal's most downloaded articles.—*Kim Askey*

Researchers hope lunch conversations will lead to serious, lab-wide research

A national laboratory, often organized in distinct research hierarchies from group to directorate levels, may not be the first place you expect to find grassroots discussions where scientists toss out creative ideas, but it's happening among ORNL researchers who share a common interest in the emerging topic of complex systems.

"Complex systems consist of many diverse but interconnected parts, and the behavior of these parts changes in response to each other," said Stan Wullschleger, UT-Battelle Corporate Fellow in the Environmental Sciences Division.

Complex systems are all around us in the dynamics of nature and our built environments. Small units—cells, atoms, electrical signals—all behave within larger systems, such as the human body, the global climate system, or energy and transportation infrastructures.

"The area now referred to as complex systems science has emerged historically from the study of nonlinear dynamics," said Stuart Daw, UT-Battelle Corporate Fellow and Fuels, Engines, and Emissions Research Center staff researcher. "In the past, researchers avoided the complexities of nonlinear mathematics by treating real world systems as if their parts were actually linear. But linear models don't often fit the real world. We are finding that groups of nonlinear entities behave in surprising and unpredictable ways. It's not possible to describe their collective behavior by simply summing the behavior of their individual parts."

For instance, rush hour traffic is a type of complex system. Each car may be capable of going 60 mph, but traffic light schedules, weather conditions, and interactions between drivers with different driving styles can lead to sudden, global changes in traffic density. If a few cars at critical locations slow down, other nearby cars are forced to slow down as well, creating an avalanche effect that evolves into a traffic jam. Researchers are particularly interested in understanding the threshold conditions (called tipping points) at which such large-scale shifts happen in complex systems.

By holding a series of brown-bag discussions last year, Wullschleger, Daw, Andreas Malikopoulos, David Weston, and a small group of researchers who were striking up informal conversations on the topic decided to draw out other scientists and engineers who might be working with complex systems.

"Dave Weston, who studies cellular dynamics, and I have been interested in complexity-related issues in biology for a number of years," Wullschleger said. "We never really got past 'this is a fascinating area of research,' but we knew there was value in asking tough questions related to biological complexity in the context of larger living systems. We wanted to see if other people across the lab were encountering complexity problems similar to those we see in biology and if there might be common approaches to addressing those challenges."

Over the past year, the brown-bag participants have continued conversations about the complexity questions that arise in their disciplines. Wullschleger and Daw said these new connections have shown that disparate research groups are trying to solve similar problems, and there is ample opportunity to share experiences and solutions, stressing the need for cross-discipline collaboration.

"We would benefit from an organizing approach that is consistent across disciplines so there isn't a duplication of effort," Daw said.

Wullschleger said disciplines have unique questions about complex systems, but significant commonalities could be modeled at-large, then applied on a case-by-case basis.

"It's a multi-disciplinary challenge to understand how to deal with aspects of how to measure and model these systems, but here

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ORNL team takes unprecedented neutron images of refrigerant flow through heat exchangers

To observe the effects of heat on refrigerants, ORNL researcher Patrick Geoghegan used the High Flux Isotope Reactor to capture undistorted neutron images.

ORNL researchers have captured undistorted snapshots of refrigerants flowing through small heat exchangers to better understand heat transfer.

Using additive manufacturing and neutron imaging capabilities, researchers examined microchannel heat exchangers that hold refrigerants used to move thermal energy and provide cooling or heating in many applications. The noninvasive techniques allowed the researchers to visualize how refrigerants reacted to different temperature levels without disrupting the refrigerant flow.

"That's what we're trying to understand—what does the refrigerant look like on the inside of these channels?" said Patrick Geoghegan, a researcher with the Buildings Technologies Research and Integration Center (BTRIC). "Then you can understand how the heat transfer is actually taking place."

The goal with microchannel heat exchangers is to improve overall heat transfer, which could potentially reduce the temperature difference between the air and a refrigerant in a heating, cooling and ventilation system, resulting in energy savings. Additionally, the heat exchangers minimize airside pressure drop, which results in more energy savings gained from the fan energy consumption.

The ORNL team is the first to make use of neutron imaging in microchannel studies.

Previously, researchers have cut off the top of a larger heat exchanger tube, covered it with Plexiglas and then peered inside as it was heated, a method Geoghegan said could lead to inaccurate results.

ORNL partnered with 3D printing company Fabrisonic to specifically design microchannels for neutron imaging. Additive manufacturing kept the microchannels small and compact, eliminating the need for extra material and refrigerant, and provided a cost-effective and environmentally friendly approach to the research.

Researchers ran refrigerant through the microchannels and subjected them to increasing amounts of heat over 5 days. At a number of cool-, medium-, and high-heat stages, the team used neutrons from ORNL's High Flux Isotope Reactor—a DOE Office of Science User Facility—to take images of the refrigerant while it was in the microchannel. Funding for the study was provided by ORNL's Laboratory Directed Research and Development Program. Researchers also made use of the Manufacturing Demonstration Facility and BTRIC at ORNL.—*Chris Samoray*

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at the lab, we have experts in all these areas," Wullschleger said.

Computational scientists have the capability to create logical models that can capture some of the problems introduced in complex systems, but model development will require input from researchers who conduct experiments and make observations within these systems, according to Wullschleger.

"We need to design experiments in each discipline that examine collective behavior, then identify through modeling common behaviors that may reveal fundamental principles," Wullschleger said. "Many forms of collaboration are possible if we just keep talking."

Wullschleger, Daw, and others who participated in the brown-bag sessions are also taking their discussions to laboratory leaders in hopes of identifying a plan for tackling complexity research at ORNL.—*Katie Elyce Jones*

Integrated energy systems research rethinks reliance on traditional electric grid

The electric power grid—the network of transmission and distribution lines and substations that delivers electricity to homes and businesses—is vulnerable to extreme natural events such as heat waves and storms and even to human threats. It's also under continuous pressure to provide reliable service in the most cost-effective manner.

"As we get more into the technology age, we're more dependent on electricity being there and being reliable," said Roderick Jackson, group leader of the Building Envelope Systems Research Group.

To ensure access to reliable electric power despite extreme weather or attempted cyberattacks, ORNL researchers are examining alternatives to the traditional centralized grid. One potential solution is distributed energy generation, which relies on more localized and smaller-scale power production from sources such as solar arrays.

"Distributed energy helps with resiliency," said Tom King, director of ORNL's Sustainable Electricity Program. "We are seeing more 100-year storms than ever, and this puts a tremendous burden on the energy infrastructure of distribution lines and transmission towers. During some of these storms, people have been without power for weeks. Resiliency is needed to ensure continued power to the country."

The dropping cost of photovoltaic technologies, combined with renewable energy mandates and other economic incentives, has added to growing interest in distributed energy. But despite ongoing technological improvements, solar can rarely go it alone—when the sun isn't shining, another source of power must meet a building's energy needs.

And that's exactly where ORNL researchers are hoping to fill in the gaps.

Jackson, King, and a multidisciplinary team across ORNL are developing integrated energy systems to demonstrate how new technologies can provide sustainable power to communities where and when they need it. The project's larger goal is to establish the foundation for an ORNL institute focused on integrated energy systems.

The team plans to start with a Laboratory Directed Research and Development project that looks at the intersecting aspects of energy generation, storage, and building demand.

ORNL's flexible research platforms, part of DOE's Building Technologies Research and Integration Center, will serve as home for the team's research project over the next two years. The lab's 50-kilowatt solar array and Distributed Energy Communications and Controls facility will help the research team create a holistic test bed.

"We have unique technologies and control approaches, so we can isolate and separate from our distribution systems and be our own microgrid," King said.

To tackle the issue of irregular solar power generation, the ORNL research team is looking at a diverse and complementary set of energy generation and storage approaches. One technology under development is called Ground-Level Integrated Diverse Energy Storage (GLIDES), which stores energy by compressing gas in high-pressure tanks. The team's initial analysis indicates that the GLIDES approach could outperform lead-acid batteries in terms of round-trip efficiency and storage costs.

A second tactic is a heat engine generator, commonly known as a Stirling engine, which could bridge the energy needs of transportation and buildings. Unlike internal combustion engines, heat engine generators can run on a wide variety of fuels or external heat sources but are comparatively inefficient. The researchers plan to apply ORNL expertise in vehicle technologies and advanced manufacturing processes toward understanding and improving an existing Stirling engine. Recovering waste heat from the generator for use in the GLIDES storage technology, for instance, could raise the engine's efficiency.

"Instead of using a battery, the Stirling engine runs on whatever fuel you want it to run on. It could be stationary or mobile as part of a vehicle. You could potentially hook this engine up to help balance the solar variability," King said.

Looking farther ahead, the team also is exploring basic research in ultracapacitors by drawing on ORNL strengths in materials science. The current generation of capacitor devices boasts a high power density but low energy density, which limits their use in energy storage applications. By fabricating atom-thin layers of graphene and boron nitride, the researchers will investigate ways to increase the performance of next-generation electrostatic capacitors.

Finally, to tie together the pilot project's different approaches to energy generation and storage, the ORNL team is developing building management system software to control the individual building environment and integrate distributed energy sources into the existing grid.—*Morgan McCorkle*

ORNL's flexible research platforms, part of DOE's Building Technologies Research and Integration Center, will serve as home for integrated energy systems research over the next two years.

Launch of the 3D printed car

The past year has led to new and exciting possibilities for ORNL advanced manufacturing and transportation research. In 2014, the lab teamed up with partners Cincinnati Incorporated and Local Motors to create the first 3D printed electric car, a Local Motors concept and design. Recognizing the research potential in relatively inexpensive printed cars of flexible design, ORNL printed its own electric car in January 2015, attracting international media attention. Looking forward, the lab is exploring how to use 3D printed vehicles to demonstrate new transportation concepts and technologies.

Printing Big

In 2014, an object the size of a car could not have been printed with any commercial 3D printer or additive manufacturing machine on the market. However, in February of last year, ORNL signed a Cooperative Research and Development Agreement with Cincinnati Incorporated, a 116-year-old Ohio machine tooling company, to build a large-scale additive manufacturing system at DOE's Manufacturing Demonstration Facility (MDF). ORNL modified a Cincinnati Incorporated laser cutting machine to deposit a carbon-reinforced thermoplastic at 40 pounds per hour and print components 10 times larger than most additive manufacturing machines. The Big Area Additive Manufacturing (BAAM) machine was born.

Thinking Big

Jay Rogers, the CEO of Local Motors—the consumer-driven design, micro-manufactured custom vehicle company—visited the MDF in spring 2014 and watched large-scale printing in process. "He sat and watched the machine for about half an hour and started peppering me with questions about speed, accuracy, and quality of material, and within 30 minutes, he had completely changed the direction of his company from high-end vehicles to mass, customized electric vehicles that use 3D printing," said Lonnie Love, group leader of the Manufacturing Systems Research Group. Rogers approached ORNL with his plan to 3D print the body and chassis of a custom-designed car for the International Manufacturing Technology Show (IMTS) in Chicago, which was only 5 months away. ORNL signed on.

The Strati

The Strati design (strati means "layers" in Italian) was selected in June out of 200 entries submitted to Local Motors' 3D Printed Car Design Challenge. About a week before the IMTS, ORNL designed a new BAAM extruder, which deposits the melted pellets during manufacture. By replacing the extruder, they were able to print 1,000 cubic inches per hour instead of 200, cutting down a 6-day printing time to just under 2 days. With the help of ORNL team members, Local Motors printed the body and chassis in 44 hours during the IMTS. Local Motors then assembled the Strati's powertrain components from various suppliers and made an historic first drive on September 13.

The Research Possibilities

With the ability to print a car quickly and use flexible designs, ORNL manufacturing and transportation research teams realized the potential to turn printed cars into mobile test beds for materials and transportation technologies. With its own 3D printed car, ORNL could plug in components such as battery and fuel cell technologies, power electronics, and wireless charging systems, testing these components under real-world conditions. Given the short design and development time (only a few weeks) and the affordability of printing a car, ORNL also could research connected vehicles with a small fleet of printed cars. Researchers with the MDF and ORNL's National Transportation Research Center (NTRC) decided to print a research vehicle and install the electrical powertrain in time to display at the North American International Auto Show (NAIAS) in Detroit in January 2015. They began a rapid, 6-week project to design, manufacture, and assemble a new printed vehicle—with a classic style.

The Shelby Cobra

Based on a design inspired by the classic Shelby Cobra, ORNL's manufacturing team printed the body and chassis at the MDF, and an NTRC team assembled the powertrain. To select the best electric motor, battery, inverter, and other components for the performance and size requirements of the Shelby Cobra, the NTRC team simulated the powertrain in three steps. First, they performed a full simulation for component size and selection; then they used NTRC's Vehicle Systems Integration (VSI) Laboratory to physically test the motor on a virtual drive platform that simulated the rest of the powertrain; finally, they physically tested the entire powertrain in the VSI lab by simulating real-time driving conditions. After the Strati's completion, the manufacturing team had improved the bead size used in printing, resulting in a smoother surface. They also reduced print time to only 24

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President Barack Obama viewed ORNL's Shelby Cobra 3D printed car during his visit to the Clinton, TN-based Techmer PM manufacturing site. Pictured from left to right: Techmer PM CEO John Manuck, Managing Director of Techmer Engineered Solutions Tom Drye, President Obama, ORNL Manufacturing Systems Research Group Leader Lonnie Love, and Vice President Joe Biden. Image courtesy of Randy Sartin Photography.

ORNL researchers to "crash" test vehicle cybersecurity and develop safety tools

Many drivers think of the car as their protected bubble, an isolated space during their commute. However, today, vehicles are only as isolated as the technologies that are connected to them, including phones, navigation systems, Bluetooth, and Wi-Fi. Even familiar automated sensors, such as tire pressure monitors, adaptive cruise control, self-parking, and traction control, are connected to a central communications network in the vehicle.

Moreover, as auto manufacturers introduce autonomous and semi-autonomous vehicles into the market, the US Department of Transportation (DOT) has announced plans to enable vehicle-to-vehicle (V2V) communication in lightweight vehicles and is researching vehicle-to-infrastructure (V2I) communication.

While V2V and V2I communications are expected to reduce highway accidents and fatalities, decrease traffic congestion, and curb transportation-related carbon emissions, vehicles with these capabilities also need adequate protection against cyberattacks that can spread malware or disrupt controls.

"When there's a cyberattack on your laptop, it's not a physical or life-threatening attack, but with cars, it's different," said Joseph Raetano, research scientist with ORNL's National Transportation Research Center.

Researchers like Raetano are concerned that if vehicle cybersecurity systems are not preventively strengthened and standardized, malevolent hackers could remotely disable or manipulate brakes, airbags, steering, and other controls, causing disastrous events.

"Until recently, vehicles didn't normally have external communications. Vehicles used to be an island on their own," Raetano said. "But now, the electronic attack surface has been expanded, and the safety standards that have grown over the years to make vehicles safe are critically impacted."

Over the next two years, the ORNL team is developing a Trustworthy Vehicle Computing System (TVCS) that likely will be a combination of hardware and software that can detect and render safe cyberattacks in real time, such as by isolating the vehicle's computing system.

"As a national laboratory, it is our mission to defend our energy resources," Raetano said. "My team is focused on securing the communications of critical systems of the vehicle and energy delivery systems. We're designing a system that is as impervious to attacks as possible."

The initial step to developing a cybersecurity system is identifying the vulnerabilities already present across vehicle communication systems and those soon to be introduced. As private manufacturers promote new autonomous driving features, Raetano said national labs and universities can play a role in standardizing an assessment framework to determine defensive security measures so that vehicles are protected from hardware and software attacks when they go on the market.

For the first year of the Laboratory Directed Research and Development TVCS project, Raetano's team is collaborating with staff and students at the University of Tennessee–Knoxville Department of Electrical Engineering and Computer Science to analyze common hardware and software vulnerabilities across a broad range of vehicle makes and models to create such an assessment framework.

As vehicles become more autonomous and are connected to more devices, researchers are creating new tools to assess cyber threats and prevent attacks.

"Automakers focus on their own vehicles," Raetano said. "We want to compare and contrast vulnerabilities over all vehicles to determine the safest vehicles, why they are so safe, and what automakers can do to improve security."

The team will use these assessments to build a library of possible methods of cyberattack by vulnerability and scope, which will lead to the development of the TVCS that can simulate and model attacks and evaluate safety responses.

The target users for the assessment framework and the TVCS will be automaker equipment manufacturers, wireless system providers, hardware and software architects, and other federal agencies, such as DOT.

The team is engaging other national labs and universities in building a reference database of vehicle characteristics to reduce duplication and upfront costs that go into this kind of baseline research.

The project team includes more than 30 members from four organizations, including ORNL divisions Electrical and Electronics System Research, Computational Sciences and Engineering, and Global Security and Defense; the National Transportation Research Center; University of Tennessee; and Tennessee Technological University. —*Katie Elyce Jones*

Modern makeover for heat engine could help power car and home

ORNL researchers are using additive manufacturing (3D printing) to put a twenty-first century spin on a nineteenth-century technology that could convert heat energy into mechanical power to charge electric vehicles (EVs) and provide auxiliary power for homes and other buildings.

Researchers with the lab's Fuels, Engines, and Emissions Research Center (FEERC) will integrate an external combustion heat engine known as a Stirling engine into an ORNL 3D printed vehicle, creating a prototype range extended EV. This vehicle will be used for researching integrated energy applications that connect vehicles, buildings, and small power sources like generators and solar panels.

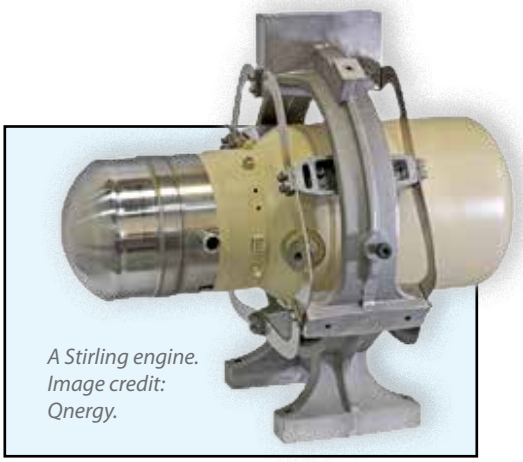
Historically, Stirling engines have not been used in automobiles because they respond to load changes more slowly than internal combustion engines, which in turn, slows vehicle response time and acceleration. However, by integrating the Stirling engine into a hybrid EV, the engine can provide power for an electric drive system that responds quickly to driver demands.

Today's much advanced Stirling engines are used often in applications where a large differential temperature is possible between the external heat source and the environment, such as in spacecraft where there is a high-temperature heat source like plutonium against the low temperature of space.

"The Stirling engine is fundamentally different than an internal combustion engine," said Robert Wagner, FEERC director. "An internal combustion engine is an open cycle where the working fluid is inducted into the engine, combustion occurs, work is done, and the exhaust gases are pushed out of the engine. A Stirling engine is a closed cycle where the working fluid is sealed within the engine and heat from an external source drives the engine."

The engine's ability to run off different heat sources makes it attractive for clean energy applications aimed at easing petroleum dependence on the road and coal power dependence for electricity. As integrated energy systems become more available to power connected homes and vehicles, ORNL researchers see the potential for these engines to be a piece of that puzzle; and FEERC's Stirling engine research is part of a Laboratory Directed Research and Development project that will demonstrate a proof-of-concept buildings integrated energy system.

Because Stirling engines are quiet during operation and durable over time (they have an operational lifetime more than an order of magnitude longer than conventional automotive engines), they could be left running to recharge an EV or provide auxiliary power to a home when other power sources such as solar or wind may not be available or consistent.



A Stirling engine. Image credit: Qnergy.

"In year 1, our plan is to characterize an existing Stirling engine in a FEERC dynamometer cell to better understand engine behavior relevant to the eventual installation of the engine in a vehicle," Wagner said.

Using natural gas as the heat source, the team will initially test the engine as-is under a range of conditions.

"We'll spend time benchmarking it, collecting data, and conducting thermodynamic analyses to understand where the opportunities are in improving the natural gas burner and cold side heat rejection from an efficiency perspective," Wagner said.

The Stirling engine will then be integrated into an EV powertrain and run through simulated drive cycles so researchers can optimize the electrical controls to manage acceleration and buffer the slow response time of the Stirling engine. Toward the end of this year, the engine will be placed in a 3D-printed car and integrated with an EV drive system to see how it performs in road tests.

One of the challenges to optimizing the Stirling engine for these applications is that it has a much lower power density and typically has a lower peak efficiency than conventional automotive engines.

That's where additive manufacturing comes in.

In year 2, the team will use additive manufacturing tools available at ORNL's Manufacturing Demonstration Facility next door to FEERC to explore opportunities to increase the engine's efficiency by improving the burner design, heat transfer from the external heat source to the working fluid, cold side heat rejection, and reducing engine weight of the auxiliary components where possible. Additive manufacturing will enable researchers to print specially-designed parts.

"At that point we should have a functional range extender EV," Wagner said. "We'll take that vehicle and work with the integrated energy systems team to develop control systems so that it can interact with a building as well as the local grid."—*Katie Elyce Jones*

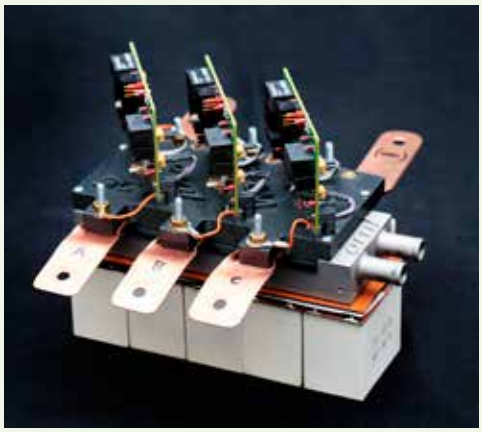
(continued from page 6)

hours. Knoxville, Tennessee-based Tru-Design then gave the car a sleek automotive finish. The final product is an all-electric vehicle that weighs about 1,900 pounds with nearly one-third of the total weight coming from printed parts containing 20% carbon fiber material.

Spotlight on the Shelby Cobra's Success

Before the NAIAS, President Barack Obama viewed the Shelby Cobra as part of his January 9 visit to Knoxville and Clinton, Tennessee, to announce a new Institute for Advanced Composites Manufacturing Innovation (IACMI) composed of 122 consortium members. Within the institute, ORNL will lead Composite Materials and Process Technology, one of five technology areas. From January 12 to 15 at the NAIAS, ORNL was able not only to showcase the Shelby Cobra but also to highlight the lab's capabilities in advanced manufacturing and transportation technologies by displaying wireless charging coils, 3D printed miniature engines, carbon fiber spools, and advanced batteries, among other technologies. In just 2 weeks, the printed Shelby Cobra garnered 425 media mentions, and an ORNL video on YouTube about the car is the most-watched ORNL video ever.

ORNL creates novel 3D printed inverters with wide bandgap devices



This novel power inverter offers greater reliability and power in a compact package.

ORNL's Power Electronics and Electric Machinery (PEEM) research group is using additive manufacturing to shrink the size and weight of power inverters for vehicles. With funding from the DOE Electric Drive Technologies Program, PEEM is working with the Manufacturing Demonstration Facility to 3D print novel aluminum-based heat exchangers with integrated cooling systems.

The prototype inverters are the first to incorporate both additive manufacturing and wide bandgap (WBG) materials. WBG technology enables devices to perform more efficiently at a greater range of temperatures than standard semiconductor materials. Additive manufacturing creates many advantages for the development of new inverters, allowing use of complex 3D geometries, increasing power density, and reducing weight and waste.

PEEM's first prototype, a liquid-cooled all-silicon carbide traction drive inverter, features 50% printed parts and incorporates WBG materials. The inverter was tested successfully up to 20 kW with efficiency at 98.7%. The projected power density of this inverter is expected to surpass DOE targets.

With lab funding, researchers designed and built a second printed inverter that is half the size of a Nissan Leaf inverter.—*Kim Askey*

New ORNL EV battery simulation software released

ORNL's Computer-Aided Engineering for Batteries (CAEBAT) team has released a new computational toolset for academic, national laboratory, and industry users to accelerate the design of high-performing, safe batteries for electric vehicles.

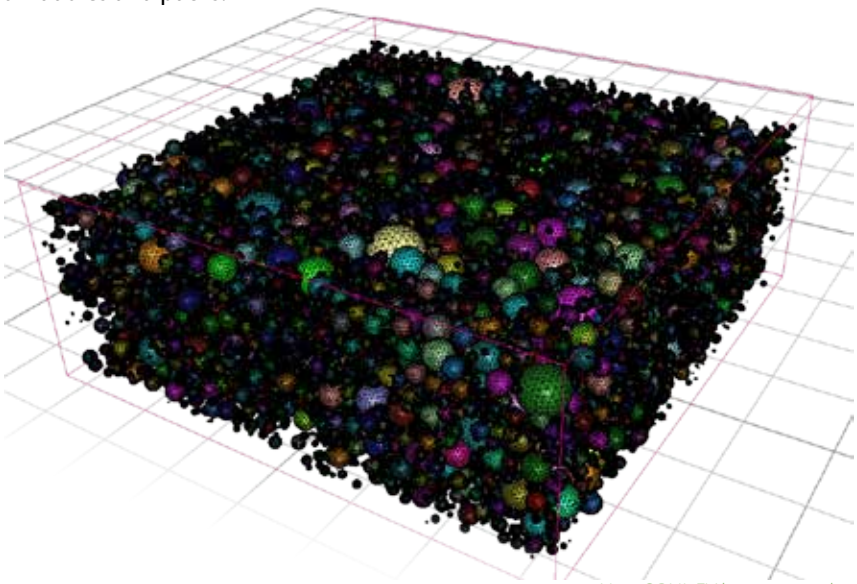
The software can accurately simulate key battery performance indicators including charge and thermal transport, electrochemical reactions, and mechanical stresses on the cell sandwich level up to cells, modules, and packs.

"We developed integrated tools so that one doesn't have to employ different performance models for different applications," said Sreekanth Pannala, distinguished research staff member at ORNL. "A materials developer might need a cell sandwich simulation; a cell manufacturer might only be looking at the cell or a module; whereas an original equipment manufacturer who is interested in the complete battery might look at modules and packs."

Users can run CAEBAT on multiple platforms as well, from workstations to computing clusters, depending on the complexity of the problem.

The software set features four tools, including Open Architecture Software for coupling and coordinating different components; BatML and BatState standards for input and information exchange among components; an Integrated Computational Environment to help users navigate, set up, and launch CAEBAT tools and process data; and the VIBE environment that performs coupled electrochemical-electrical-thermal simulations for each battery level.

CAEBAT is available for download on a new public website. Researchers at ORNL will provide support to users and improve the software based on community feedback. The CAEBAT project is funded by the DOE Vehicle Technologies Office.—*Katie Elyce Jones*



Simulation of electrode particles on virtual integrated battery environment, part of ORNL's new Computer-Aided Engineering for Batteries toolset.

Innovative, lower cost sensors and controls yield better energy efficiency

Regulating comfort in small commercial buildings could become more efficient and less expensive thanks to an innovative low-cost wireless sensor technology being developed by researchers at ORNL.

Buildings are responsible for about 40% of the energy consumed in the United States. Studies indicate that advanced sensors and controls have the potential to reduce the energy consumption of buildings by 20–30%.

"It is widely accepted that energy-consuming systems such as heating, ventilating, and air conditioning (HVAC) units in buildings are under-, or poorly, controlled, causing them to waste energy," said Patrick Hughes, director of ORNL's Building Technologies Program. "Buildings could increase their energy efficiency if control systems had access to additional information."

Collecting data such as outside air and room temperature, humidity, light level, occupancy, and pollutants is currently cost-prohibitive, whether the information is gathered by inexpensive conventional sensors that must be wired, or by using today's expensive $150–$300 per node wireless sensors.

ORNL's new wireless sensor prototype could reduce costs to $1–$10 per node by leveraging advanced manufacturing techniques such as additive roll-to-roll manufacturing. This process enables electronics components like circuits, sensors, antennae, and photovoltaic cells and batteries to be printed on flexible plastic substrates (base materials). The nodes can be installed without wires using a peel-and-stick adhesive backing.

"If commercially available at the target price point, there would be endless application possibilities where the installed cost to improve the control of energy-consuming systems would pay for itself through lower utility bills in only a few years," Hughes said.

The ultra-low power smart sensors collect and send data to a receiver, which can capture data from many different peel-and-stick nodes and provide information to the energy-consuming system. The more information received, the better the building's energy management.

Both new construction and retrofitted buildings can benefit from ORNL's smart sensors.

"This technology provides the information that enables ongoing continuous commissioning, fault detection and diagnosis, and service organization notifications when needed, ensuring optimal building system operations throughout their service life," said ORNL's Teja Kuruganti, principal investigator on the low-cost wireless sensors project.

ORNL recently established a Cooperative Research and Development Agreement with Molex, a premier international electronics manufacturer, to make the low-cost wireless sensors commercially available.

ORNL researchers are experimenting with additive roll-to-roll manufacturing techniques to develop low-cost wireless sensors. ORNL's Pooran Joshi shows how the process enables electronics components to be printed on flexible plastic substrates.

The research team used ORNL's Nanoscale Science and Technology Laboratory (NSTL) cleanroom facility to select the best substrate material.

"We used a combination of physical vapor disposition techniques for low-temperature thin film processing in the NSTL and pulse-thermal-processing technology for low thermal-budget curing on paper and plastic substrates, which helped us overcome a key technology barrier in flexible sensor development," said ORNL researcher Pooran Joshi.

This project is sponsored by DOE's Building Technologies Office in DOE's Office of Energy Efficiency and Renewable Energy.—*Sara Shoemaker*

ORNL researchers identify genes best suited for producing biofuel from poplars in different environments

In studies involving 1,100 poplar trees, researchers at DOE's BioEnergy Science Center (BESC) at ORNL used whole-genome resequencing and intensive phenotyping to pinpoint mutations desirable for producing biofuel from poplars grown in a variety of environmental conditions. The findings, published in *BMC Genomics*, could lead to more efficient ways of breeding high-ethanol-yielding poplar and other tree species.

A major obstacle to producing ethanol for biofuels from plants is lignin, the polymer that gives strength or "woodiness" to a stalk or trunk. Lignin forms a tough protective coating around cellulose fibers and makes it difficult to deconstruct these fibers into fermentable sugars needed to make ethanol. Making cellulose fibers accessible to such deconstruction by reducing cell wall lignin content is a major objective for BESC.

In their study, the researchers—who collaborated with scientists from West Virginia University, the University of British Columbia, and DOE's Joint Genome Institute and National Renewable Energy Laboratory—wanted to know which genes caused low lignin levels in poplar trees. This task, according to the ORNL Plant Systems Biology Group's Wellington Muchero, would have traditionally taken decades before the advent of whole-genome resequencing, high-throughput phenotyping, and association mapping techniques.

Poplars are a desirable biofuel feedstock because they grow quickly and are diverse, surviving in vastly different environments. Depending on location, different DNA mutations accumulate over time so that traits such as lignin content or biomass yield may be more or less pronounced in a particular ecosystem.

To compare poplars from different ecosystems and thereby narrow down the genes that might be associated with lignin content, the researchers gathered a collection of trees from poplar groves along the west coast of the United States and southwestern Canada. To cover a diverse range of environmental conditions, the trees were planted in experimental plots in California, Oregon, and British Columbia.

Poplar trees. Image credit: DOE Joint Genome Institute.

At the same time, researchers at the Joint Genome Institute resequenced each of the 1,100 trees' genomes.

Using statistical genetics, the researchers were able to identify specific DNA mutations that were consistently correlated with low lignin content across different experimental plots, an attribute desirable for biofuel production. Researchers also assessed the performance of low-lignin plants in different environments.

"It has been surprising that some of our low lignin lines have been some of the best performing across environments," Muchero said.

Additionally, while the study focused on genes related to low lignin, the wealth of genome data also will allow the researchers to tag genes associated with other expressed traits such as biomass production, disease susceptibility, and ability to grow in harsh environments. This information will drive the potential for poplars to be modified and grown successfully on poor-quality or marginal land.

"We need to arrive at a point where we can produce biofuels economically and not compete with food production," Muchero said. "That's a major selling point for using perennial trees like poplars as biofuels feedstocks."

With poplar genomic data handy, poplar growers could assess and select genes and, therefore, specific trees optimal for production in a specific area. Muchero calls this a poplar "super tree."

"You want your super tree," he said. "It has good growth, it's resistant to diseases, it can grow in very marginal environments, and it has low lignin, which gives you tons of biofuels."

Anthony Bryan, Jin-Gui Chen, Priya Ranjan, Sara Jawdy, Lee Gunter, and Gerald Tuskan of ORNL contributed to the study. BESC, supported by the Office of Biological and Environmental Research and the Office of Science, along with the Genome British Columbia Large Scale Applied Research Program, provided funding for the project. Part of the research was conducted at the Joint Genome Institute, a DOE Office of Science User Facility.—*Chris Samoray*

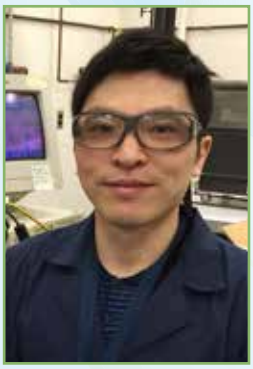
Early career researchers are developing the future of clean energy

EESD employs many scientists and engineers in the early years of their careers. Here are just a few early career researchers who are already making great strides in their research disciplines.

Omar Abdelaziz

- Group leader and senior R&D staff, Building Equipment Research Group
- PhD in mechanical engineering, 2009

Omar is involved in building equipment efficiency improvement (such as heat exchangers, cold climate heat pumps, residential absorption heat pump water heaters, and residential CO_2 heat pump water heaters) in support of DOE's goal of doubling energy productivity by 2030. He recently worked with Honeywell, one of the leading refrigerant manufacturers, to develop an alternative refrigerant with lower global warming potential for non-residential applications; the N40 refrigerant soon will be available commercially.



Jian Chen

- R&D Staff
- PhD in industrial engineering, 2010

Jian played a lead role in the successful development of an online resistance spot weld inspection system, based on infrared thermography, which is being licensed to industry. This nondestructive weld quality inspection technique can be used during or after welding and potentially could save millions of dollars per year for assembly plants in the automotive industry. Jian also is a key member of a team developing carbon fiber-to-metal bonding technology and dissimilar metal joining for the automotive industry.

Amy Elliot

- Postdoctoral researcher
- PhD in mechanical engineering, 2014

Amy recently completed a PhD that focused on inkjet deposition of additive manufacturing photopolymers. At ORNL's Manufacturing Demonstration Facility, Amy is researching inkjet-based additive manufacturing with metals and polymers; she is interested in developing and improving additive manufacturing technology for industry applications. Recently Amy was involved in the development of an additive manufacturing build platform that provides a reliable mechanical bond to the printed object, rather than a less reliable adhesive bond.

Melanie Mayes

- Staff scientist and team lead
- PhD in geological sciences, 2006

Recently elected a Fellow with the American Association for the Advancement of Science, Melanie is involved with investigations in soils and aquifer materials, ranging from how water flows as a function of physical structure and moisture content to how water flow rates influence geochemical reaction rates and transformations. Her team developed and tested a new soil carbon cycling model that explicitly includes microbes, enzymes, and soil mineral interactions to enhance the understanding of releases of greenhouse gases from soils and to expand capabilities for predicting future climate.

Wellington Muchero

- Research staff
- PhD in plant pathology, 2007

Wellington led an international effort with 23 scientists from universities and research organizations to demonstrate feasibility of gene discovery based solely on statistical genetics, without prior knowledge from model systems; the work recently was published in the *BMC Genomics Journal*. Wellington researches population-level statistical genetics for gene discovery. He uses a combination of whole-genome resequencing and phenotyping to correlate naturally occurring DNA mutations to variations in economically important plant traits such as ethanol production, disease resistance, and biomass productivity.

Michael Starke

- Research lead on projects associated with energy storage, demand response, and microgrids
- PhD in electrical engineering, 2009

Michael's research focuses on systems integration and technology development of energy storage, renewable generation, demand response, and microgrid technologies. He and his research team recently developed an energy storage testing platform for community energy storage systems, and Michael currently is constructing a microgrid controls and demonstration testing platform; both projects seek to develop technologies, gather data, and grade performance of different energy storage and microgrid controller technologies.

Marcus Young

- Power systems researcher, Power and Energy Systems Group
- MS in electrical engineering, 2005; PhD expected, 2015; licensed professional engineer

Marcus's technical interests include substation automation, wide-area measurement, increased power flow, and power flow control. Recent accomplishments at ORNL include the development of models to represent the behavior of a continuously variable series reactor (CVSR) in the simulation of power system networks. The CVSR is currently in the testing phase at ORNL under the leadership of Aleksander Dimitrovski with support from ARPA-E; the objective is to develop a reliable and economically viable device to control the flow of power within transmission networks.

—Wendy Hames

ETSD researchers honored by Society of Automotive Engineers

Six ETSD researchers recently received awards from the Society of Automotive Engineers. From left to right: Derek Splitter, Sujit Das, Jim Szybist, Brian West, Scott Sluder, Scott Curran.

The Energy and Transportation Science Division's (ETSD's) **Jim Szybist** and **Brian West** have been selected to receive the Society of Automotive Engineers' (SAE) Horning Award for their 2013 publication, titled "The Impact of Low Octane Hydrocarbon Blending Streams on the Knock Limit of E85," published in the *SAE International Journal of Fuel and Lubricants*. The paper highlights the effectiveness of ethanol at upgrading the octane number of a range of fuels. Their research helped build the foundation for the very active ongoing debate regarding the best use of ethanol and octane level for future fuels to support higher efficiency vehicles. The award will be formally presented at the SAE World Congress in April.

ETSD's **Scott Sluder** was recently elected an SAE Fellow, the highest grade of membership. He was recognized for his significant technical contributions to mobility engineering. Sluder contributed key research in support of the 2000 Environmental Protection Agency (EPA) ultra-low sulfur diesel rulemaking, the 2010 and 2011 EPA decisions regarding E15 (gasoline containing 15% ethanol), and the 2014 EPA Tier 3 light-duty emissions regulations. Sluder has been active in SAE for many years, including his most recent role as the chair of SAE's Land & Sea Operating Group. Sluder will also receive SAE's Lloyd L. Withrow Distinguished Speaker Award at the SAE World Congress. Established in 1984, the award recognizes individuals who have demonstrated outstanding presentation skills.

ETSD's **Scott Curran**, **Sujit Das**, and **Derek Splitter** were awarded the 2015 SAE International Forest R. McFarland Award for their role in facilitating technical information dialogue by planning and organizing technical meetings, conferences, and professional development programs in adherence with the SAE Engineering Meetings Board.

Curran was recognized for enhancing the relationship between young SAE members and leading SAE professionals by coordinating a new initiative.

Das was honored for developing sustainability sessions and promoting cooperation among SAE congresses. He also served as chair of the Sustainable Development Program Committee.

Splitter was recognized for helping organize the combustion track at the 2014 SAE World Congress and for his role as session chair. The University of Wisconsin graduate also won the 2014 SAE International Myers Award for a student paper based on his thermodynamic and internal combustion engine research. The study illustrated a pathway that increased engine efficiency through minimizing emissions and heat transfer losses.

Jim Parks, left, and Robert Wagner have been named associate editors for new journal.

Parks and Wagner named associate editors for new engine and automotive journal

Jim Parks and Robert Wagner of ETSD, with Jun Qu of the Physical Sciences Directorate (PSD), have been named associate editors for a new journal, *Frontiers in Engine and Automotive Engineering*. In alliance with the Nature Publishing Group, this first-tier electronic journal publishes papers that describe advances in transportation and power generation technologies that improve energy use and reduce pollutant emissions.

Melanie Mayes

Mayes elected AAAS Fellow

Melanie Mayes has been named a fellow of the American Association for the Advancement of Science (AAAS). AAAS is the world's largest general scientific society and elects fellows based on their distinguished contributions to the advancement of science or its applications.

Mayes holds staff scientist positions in ORNL's Environmental Sciences Division and Climate Change Science Institute as well as a joint faculty position with the University of Tennessee Department of Earth and Planetary Sciences.

She was recognized "for distinguished contributions to the field of soil hydrogeology, using experimentation to improve models of biogeochemical processes relevant to contaminant transport and organic carbon cycling."

Mayes completed a bachelor's degree in geology at the University of Missouri and a master's degree and doctorate in geology at the University of Tennessee.

Melissa Lapsa

Lapsa cited for sustainability leadership

Melissa Lapsa, deputy director of the Building Technologies Research and Integration Center, is a recipient of a 2014 DOE Sustainability Award for "fervently championing sustainability across ORNL and beyond." As a winner, Lapsa will participate in a best practices workshop in which the 2014 award winners will describe successful sustainability projects.

Roderick Jackson

Jackson featured in Knoxville Business Journal's "40 under Forty"

Roderick Jackson, group leader of the Building Envelope Systems Research Group, was included in the *Greater Knoxville Business Journal's* annual spotlight of area early career professionals and was profiled in the *Knoxville News Sentinel*-affiliated publication's "40 under Forty." Jackson relates his career in energy-efficient buildings research with his family's background in building and construction.

Energy and Environmental Sciences 2014 Awards Night winners

Baohua Gu was awarded Distinguished Researcher for "sustained, significant contributions to advancing the fundamental knowledge of the biogeochemical cycling of metals, other pollutants, and carbon in the environment and for related technological achievements."

Debasish Mohanty received the Postdoctoral Researcher Award for "distinguished research contributions to understanding the structure of, and transport in, an advanced high-voltage, high-capacity Li ion-battery cathode material."

Robert Wagner received the group level Research Leadership Award for "distinguished and sustained leadership of the Fuels and Engines Research Group in transitioning science to application."

Lonnie Love was awarded Distinguished Researcher for "research as a leader and innovator in additive manufacturing who deeply appreciates and embraces the cross-disciplinary project teambuilding attitude fostered at ORNL."

Joanne Childs was awarded the Technical Support Research Award for "sustained technical expertise in the laboratory and the field for ecological research in large-scale climate experiments" and the support she provides to scientists working on those experiments.

Johney Green, Jr. received the division level Research Leadership Award for "exemplary leadership and successfully integrating S&T activities from DOE's Energy Efficiency and Renewable Energy (EERE) Office, which has enabled ORNL to become recognized as EERE's lead laboratory for energy-efficiency research."

Winners of ORNL's Technology Transfer Award and Outstanding Team Award. Seated, left to right: Vlastimil Kunc, Alan Liby, Jennifer Palmer, Chad Duty, and Brian Post. Standing, left to right: John Rowe, Charles Carnal, Lonnie Love, Craig Blue, Randall Lind, and Peter Lloyd.

EESD researchers and staff, including Lonnie Love, Craig Blue, Chad Duty, Randall Lind, Peter Lloyd, Brian Post, Charles Carnal, Jennifer Palmer, John Rowe, Alan Liby, and Vlastimil Kunc (PSD), won the Technology Transfer Award and were honored for Outstanding Team Accomplishment. Both awards recognized the team's development of a big area additive manufacturing technology.

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Operated by UT-Battelle for the US Department of Energy under contract DE-AC05-00OR22725

Lonnie Love, group leader for the Manufacturing Systems Research Group, drives ORNL's 3D printed Shelby Cobra with Craig Blue, director of the Advanced Manufacturing Office and Manufacturing Demonstration Facility at ORNL. Read more about the development of the Cobra inside on page 6.