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

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Researcher Jun Qu with a new lubricant additive to improve the energy efficiency of light-duty cars and truck.

New ionic lubricant additive technology could save US billions of gallons of oil annually

A team of Oak Ridge National Laboratory (ORNL) and General Motors (GM) researchers has developed a new group of ionic liquids as lubricant additives that could help improve the energy efficiency of light-duty cars and trucks. The ionic liquid, when added to prototype low-viscosity engine oil, boosted fuel economy by more than 2% compared with a commercially available synthetic 5W-30W oil, as demonstrated by an industrial standard fuel efficiency engine test.

The ionic lubricant reduced the engine parasitic friction losses by about 20%, resulting in an overall fuel economy boost of 2%. Lubricants are one of few technologies that can be retrofitted into the legacy vehicle fleet.

Results from these tests, performed by an independent firm, Intertek Automotive Research, with oversight by GM, show a promising path for ORNL to

(continued on page 1)

OAK RIDGE National Laboratory

in focus letter

Sustainable Transportation Program Director Ron Graves discusses advancements in vehicle technologies, fuels, and intelligent transportation systems.

The first transportation R&D at ORNL coincided approximately with the creation of the US Department of Energy (DOE). Some things have changed dramatically since then. The number of vehicles on the road has nearly doubled, and cars are remarkably cleaner, safer, and more efficient. Thirteen billion gallons of renewable fuels are used per year, versus virtually none in 1977. However, many challenges remain the same. Transportation is still 95% petroleum-powered; electric vehicles continue to struggle for market acceptance; Americans still embrace the freedom of the personal automobile while suffering the related congestion; and trucks deliver practically all consumer goods.

There are also new challenges. Society faces the long-term threat of climate change and greenhouse gas (GHG) pollution. To address these challenges, we restructured and renamed our research as the Sustainable Transportation Program (STP). The STP serves a strategic mission of easing dependence on foreign oil and decreasing GHG emissions through the development of more efficient engines, hybrid powertrain technology, lightweight vehicle materials technology, alternative fuels, low-cost batteries for electric vehicles (EVs), and intelligent transportation systems. The STP office is located at the National Transportation Research Center on the Hardin Valley campus, where power electronics, engine, battery, vehicle systems, and fuel cell labs are housed.

ORNL has already left an indelible mark in transportation technology. Millions of cars and trucks use our materials technology. We have twice contributed to the implementation of national clean fuel regulations and helped make "clean diesel" a reality. We also publish data that the public and government use to make decisions every day through Fueleconomy.gov, DOE's most-used website.

We fully support the president's "all of the above" energy initiative to achieve GHG reduction and energy security goals. DOE has made major new investments in line with this initiative. The Battery Manufacturing Facility is enabling increased contributions to electrification, which also complements our long-standing leadership in power electronics where we recently demonstrated new performance levels in wireless EV charging. The Carbon Fiber Technology Facility is the new flagship of our R&D on lightweight materials, and our teams are developing new metal alloys and methods to join dissimilar light materials. Energy analysts predict that even beyond 2040, nearly 95% of vehicles will use an internal combustion engine (ICE). We work with many industry partners on pushing the ICE to its full potential while achieving lower emissions. Our recently commissioned Vehicle Systems Integration (VSI) Lab is unique in its ability to accommodate R&D on hybrid powertrains large enough for Class 8 trucks.

President Obama recently unveiled his administration's priority to implement tougher fuel economy regulations for trucks. Research in the VSI Lab will help inform the Environmental Protection Agency's and National Highway Traffic Safety Administration's rule-making process over the next year.

The "SuperTruck" used as the backdrop of the president's announcement was built by ORNL partners Cummins and Peterbilt under the umbrella of the 21st Century Truck Partnership. ORNL is highly engaged with this partnership, as well as with U.S. DRIVE for passenger vehicles, placing us in constant interaction with industry's challenges and needs in vehicle and fuel technology.

The STP integrates ORNL's science capabilities into applied research and implementation. Data and imaging from the Spallation Neutron Source and High Flux Isotope Reactor are providing new understanding of material structure and processes in batteries, engines, fuel cells, and emission control devices, as are the insights from ORNL's world-class collection of electron microscopes. Industry partners frequently seek our analytical chemistry capabilities for detailed analysis of exhaust emissions and catalyst processes, and leadership computing has been tapped for simulation of batteries and combustion in collaboration with companies like Ford Motor Company and General Motors. The Manufacturing Demonstration Facility is bringing intriguing possibilities for the use of additive manufacturing in components for power electronics, electric drives, and large lightweight vehicle body parts.

There is no shortage of emerging, innovative approaches and technologies to meet industry challenges. We are developing a program dubbed "Virtual Car" that would create

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in the spotlight

David E. Smith

David E. Smith named Center for Transportation Analysis director

Since its inception in the 1970s, ORNL's Center for Transportation Analysis (CTA) researchers have fostered decades-long collaborations with numerous government agencies and industry partners in developing necessary data for vehicle and transportation system architectures. The predictive information that CTA creates empowers the country in decision making that addresses growing energy demands, energy security, and global climate change.

In 2013, CTA welcomed David E. Smith as the center's new director. Smith joined ORNL in 2009, and last year he led a team that brought online ORNL's Vehicle System Integration (VSI) Laboratory. The VSI Lab was created to accelerate the pace of powertrain development by performing prototype research and characterization of advanced systems and hardware components.

The VSI Lab contributes to the larger CTA mission of supplying the foundational data needed to define future vehicle architectures. The VSI Lab is the only lab of its kind capable of testing both engines and transmissions together and is the only facility in the automotive industry with the capacity to accommodate advanced light-duty vehicles to hybridized Class 8 (large semi-truck) powertrains.

"Coupling this data-rich asset with CTA's complementary capabilities in analysis, modeling, simulation, and visualization represents a powerful resource for users," said Smith, who doubles as program manager for ORNL's Advanced Vehicle Systems research. "Our goal is to improve overall transportation efficiency and reduce emissions."

Currently, ORNL researchers are working with the US Environmental Protection Agency (EPA) by running real-time experiments in the VSI Lab to simulate Class 8 truck activity. The results will help the EPA determine ways to reduce emissions and assist in rulemaking for greenhouse gas emission standards testing and also support the rewrite of the Society of Automotive Engineer's (SAE's) J2711 standard.

Smith received his doctorate in mechanical engineering from the University of Tennessee (UT). He is a member of SAE International and holds three patents in hybrid electric vehicle supervisory control systems. Before ORNL, he worked for Ford Motor Company, Toyoda–Koki Automotive North America, and Sentech.

He teaches 400- and 500-level engineering courses at UT and serves as a co-faculty adviser for the DOE- and General Motors–sponsored Advanced Vehicle Technology Competition called EcoCAR, which seeks to develop the next generation of automotive engineers with unparalleled experience designing, promoting, and building leading-edge automotive technologies.

the foundation for petascale simulation of entire vehicles. We are conducting research to support an internet of connected vehicles and exploring a new level of vehicle controls for "cars that think."

We are working to scale up new battery chemistries like lithium-sulfur and making advances in fuel cell chemistry and hydrogen storage, as well as novel engine concepts and grid/building-connected vehicles. Advanced biofuels will remain a focus for low-GHG transportation, and we are at the forefront of fuels research to simultaneously achieve Corporate Average Fuel Economy standards, the Renewable Fuel Standard, and new emissions regulations.

Ultimately, we aim to redefine the standard of vehicle efficiency, accelerate introduction of renewable fuels, and change the way vehicles interact on the road in pursuit of a cleaner energy profile and a more sustainable mobility future.

(continued from cover)

achieve DOE's goal of a 2% efficiency gain through lubricants.

"There are more than 250 million cars and trucks on the road, consuming approximately 200 billion gallons of oil per year and accounting for 70% of the US annual oil consumption. A 2% improved engine fuel economy would potentially save billions of gallons of oil annually," said ORNL researcher Jun Qu. The prototype oil also successfully passed a 100-hour high-temperature, high-load engine dynamometer test.

This research is sponsored by the DOE Vehicle Technologies Office.

An unmanned, autonomous underwater vehicle surveys a fjord in western Greenland. ORNL researchers are working with the Navy to automate analysis of sonar data. Photo: Woods Hole Oceanographic Institution (A. Kukulya).

ORNL robotics sensors detect underwater explosive ordnance

Modern weapons technologies often keep members of the military out of harm's way by allowing them to perform missions from a distance. Researchers at ORNL are helping the military conduct defense from a distance as well.

Dan Archer and Thomas Karnowski, along with their team of scientists, are working with the Navy and the Woods Hole Oceanographic Institution to continue the development of unmanned, autonomous underwater vehicles with sensors that can scan areas, detect anomalies, and differentiate between objects—like a wrench and a hammer versus an explosive mine.

"It's a difficult problem because if you have a wrench and a hammer—fine—you can distinguish those," Archer said. "But throw a bunch of other stuff on the table and then try to find the tools amongst the clutter and distinguish them from one another."

Underwater machine vision can use both visual and sonar data. However, in depths greater than 15 feet, water filters the visible light spectrum, making a red object appear gray. Combine that with sand, salt, seaweed, current, and bubbles, and accurate perception becomes difficult.

As a result, scientists are emphasizing the collection and processing of sonar data. During a mission, vehicles can collect many hours of data that will be analyzed by humans looking at each frame searching for an anomaly. The idea behind the unmanned vehicles is to automate this process using machine vision embedded in efficient computational resources.

Supported by laboratory funding in collaboration with an Office of Naval Research–funded project, Karnowski analyzes the visual and sonar data and is developing an algorithm to make data analysis a more efficient process. With an efficient algorithm, the unmanned underwater vehicle can use the algorithm to understand what is being seen, eliminating the need for human workers doing their best to sift through hours of data.

The next step is a merging of the sensor analysis with the controls of the vehicle.

Using the data from the multiple sensors (like depth, speed, and heading), the onboard processors can make sense of all the information at one time to lead more efficient missions and relay the information back to whoever is looking at the data.

The defense needs of the future are not human oriented, but robotics oriented. For robots to perform their mission of safety and security they have to have sensors embedded, and the work at ORNL will provide those sensors.—*Dylan Platz*

Getting the grid under control: ORNL device could efficiently distribute power at low cost

ORNL researchers are developing a power flow control device to maximize the energy efficiency and reliability of the electric grid. The project is part of DOE's Advanced Research Projects Agency–Energy (ARPA-E) program that advances high-potential, high-impact energy technologies that are too early in development for private investment.

The US power grid underutilizes available electricity because of an aging infrastructure that is ill prepared for the penetration of renewable energy—such as the electricity generated by solar and wind farms or community-scale efforts to store energy from solar and fuel cells for reuse on the grid.

Advancements to the power grid must not only include stronger, more reliable transmission lines and other hardware, they must also rely on power electronics to answer the needs of distributed energy sources (in particular, renewables) rapidly, reliably, and efficiently.

"Even though the grid is congested, at any point in time, the grid is using less than 50% of the total available capacity, so it's evident that this is a power flow control problem," said Aleksandar Dimitrovski of the Electrical and Electronics Systems Research Division and principal investigator on the project. "Losses are running in the tens of billions of dollars for the nation per year due to lack of grid control."

As more utility providers consider using power electronics–based devices on the grid, researchers are realizing and responding to the challenges of effectively using these sensitive devices in high-power grid applications.

"Current, state-of-the-art flexible ac transmission system [FACTS] devices are expensive, unreliable, and ineffective because high-power current flows through the electronics as well as the main power circuit," Dimitrovski said.

The current cost of a FACTS device is $100 per kilovolt-ampere (kVA) or more, depending on the technology, but Dimitrovski projects the ORNL device will cost as little as $10 kVA, making it an attractive investment and more likely to be widely distributed on the grid.

ORNL's magnetic amplifier for power flow control cuts cost and improves reliability by using a magnetic field to isolate power electronics components from the high voltage and current power flow on the main circuit. It also eliminates the need to use superconducting equipment and expensive, high-maintenance cryogenic installation.

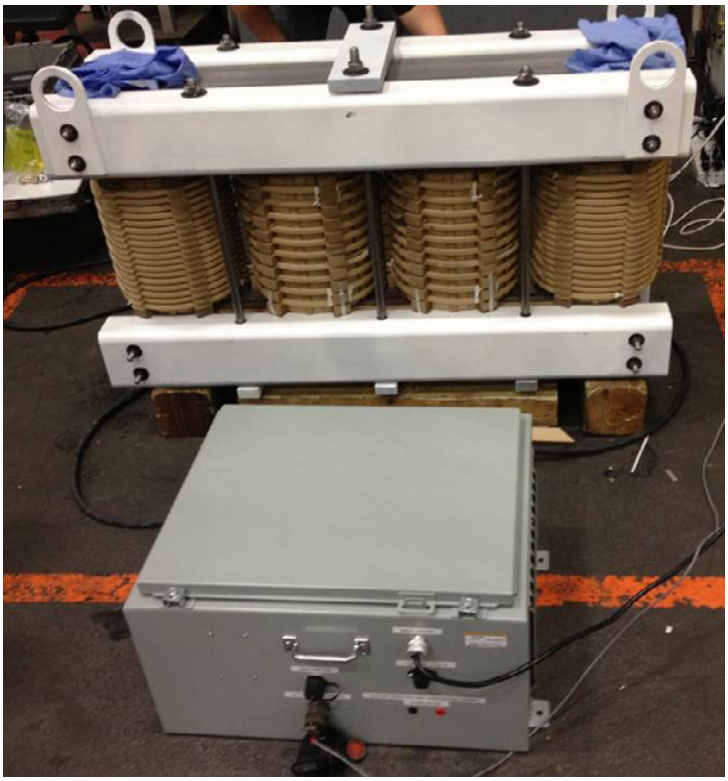
For the first phase of the project, currently near completion, researchers installed a laboratory prototype on the ORNL Distributed Energy Communications and Controls Laboratory's microgrid, a controlled test environment for evaluating the device in high-power applications. Partners SPX Transformer Solutions and the University of Tennessee–Knoxville assisted in designing and building the prototype device and in performing testing.

"The laboratory model met all our expectations, and the next step is to install the device on a 115 kV substation on the electric grid," Dimitrovski said.

ARPA-E will grant an award of $3.5 million for phase two of the project, which will introduce an additional partner—a major utility company to be announced later this year—to perform the field demonstration.

The ORNL project is just one project in the portfolio of ARPA-E's Green Electricity Network Integration program, which focuses on modernizing the electric grid. Although other research teams are developing solutions for reliable power flow control, Dimitrovski said, "We believe this is the least expensive and the most reliable one. We think that this device does for controlling energy flow what the transistor did for controlling information flow."

ORNL prototype of magnetic amplifier for power flow control developed for DOE's Advanced Research Projects Agency–Energy program.



ORNL industrial partnerships aim to boost momentum in American manufacturing

On February 17, ORNL signed a cooperative research and development agreement (CRADA) with Cincinnati Incorporated, a manufacturer of high-quality machine tools, to develop a large-scale polymer additive manufacturing (3D printing) system.

The commercialization of a large-scale 3D printing system would enable aerospace companies to rapidly produce tooling for use in composites layup and sheet metal forming. Most 3D printers on the market today can fabricate only small prototype parts, but the system developed under the ORNL–Cincinnati Incorporated partnership could fabricate components 10 times larger and 200 to 500 times faster than many available machines.

David Danielson, DOE's assistant secretary for Energy Efficiency and Renewable Energy, and US Representative Chuck Fleischmann attended the signing at ORNL's Manufacturing Demonstration Facility (MDF) in February.

"When private-sector businesses connect with the tremendous expertise and capabilities of Oak Ridge National Laboratory, everybody wins," Fleischmann said at the signing. "That's not just the company and scientists. Most importantly it's the American taxpayer, whose investments in the national laboratory system are so important for driving American competitiveness."

ORNL manufacturing partnerships provide American manufacturers with the advanced physical and virtual tools available at the MDF to rapidly design and evaluate new technologies and optimize manufacturing processes for cost-effectiveness and energy efficiency.

In FY 2013, ORNL executed eight CRADAs lab-wide. In FY 2014, ORNL has already executed nine manufacturing-related CRADAs alone—a significant commitment between the lab and its industrial partners to revitalize the American manufacturing sector.

Among those nine, Local Motors will work with ORNL to develop technology to produce the world's first production 3D–printed vehicle. This cooperation will explore making vehicle construction more efficient in every way, including lower production time, costs, and part count, coupled with higher standards of control, safety, aesthetics, and mechanical flexibility.

ECM Technologies, LLC, will investigate the potential of precision electrochemical machining (PECM) technology to improve the surface finish of additively manufactured parts. Current 3D printers can leave the surfaces of hard, metal alloys such as titanium with small-scale imperfections manufacturers would like to refine.

The Franklin, Tennessee–based company S-RAM Dynamics will fabricate a new commercial heat pump system using

Cincinnati Incorporated CEO Andrew Jamison and ORNL Laboratory Director Thom Mason sign a cooperative research and development agreement in February at ORNL's Manufacturing Demonstration Facility.

an integrated compressor/expander that can significantly reduce energy consumption. The innovative heat pump eliminates all greenhouse gas emissions by using air as the refrigerant, rather than hydrofluorocarbon refrigerants. The heat pump will be manufactured in the United States.

AeroValve, LLC, aims to reduce compressed air consumption in pneumatic valves by 25 to 35% by evaluating the feasibility and performance of a new class of energy-efficient pneumatic control valves.

Avure Technologies, Inc., will investigate the benefit of post-processing additively manufactured components, as few foundational studies have been conducted to compare as-manufactured components with processed ones. This partnership will also evaluate a rapid-cooling, hot isostatic pressing process Avure developed to improve the strength and performance of hard metal alloys.

Grid Logic, Inc., is looking to improve performance during additive manufacturing by manipulating local magnetic fields to sinter metal powders particle by particle rather than relying on conventional 3D printing techniques that use laser or electron beams to uniformly heat layers of metal power to build parts.

In an effort to support the American tooling industry, American Trim, LLC, will evaluate additively manufactured polymer tools for their use for electromagnetic forming operations—a method that uses electromagnetic forces to shape tools.

To enable the cost-effective manufacture of megawatt-scale energy storage devices, Sun Catalytix Corporation will develop a design-for-manufacturing-and-assembly battery architecture. The resulting design, tailored to use high-throughput manufacturing processes, will significantly reduce assembly and capital costs to effectively serve the growing demand for energy storage in a variety of grid-scale applications.

Piedmont Propulsion Systems, LLC, will create a method of repairing forged aluminum components to extend their service life, particularly in turboprop aircraft engines.

At the Cincinnati Incorporated signing, ORNL Director Thom Mason addressed the value in public–private partnerships: "Today's agreement with Cincinnati Incorporated exemplifies ORNL's strong commitment to working with industry to move our innovations into real-world applications. These partnerships come with the potential for significant energy and economic impacts."

Turning up the heat: ORNL, Chrysler, Nemak investigate new engine materials through transportation CRADA

The ORNL Propulsion Materials group, led by Allen Haynes and principal investigator Amit Shyam, has signed a CRADA with DOE, Chrysler, and Nemak of Mexico to develop a new, high-strength cast aluminum alloy for use in manufacturing engine heads. Baseline analysis has been completed, and the materials development work began in February. ORNL is leveraging Integrated Computational Materials Engineering capabilities with the objective of creating a stronger, lighter weight material that functions more efficiently in the high temperatures generated by engines. This is a four-year, $5 million sustainable transportation project.

Keeping it cool: ORNL and General Electric CRADA explores magnetocaloric cooling for home refrigeration

Refrigerators featuring magnetic cooling and 20% greater efficiency are the product of a CRADA between General Electric (GE) Appliances and ORNL. While the concept of magnetocaloric cooling has been around for many years, only since 2006 has GE explored using the technology for home refrigeration. In addition to energy savings and vastly simplified recycling at end-of-life, these refrigerators use no compressors or refrigerants that could be harmful to the environment. ORNL is working with GE to assess specific component and materials requirements for stable and reliable operation of the refrigerator-freezer, evaluate magnetocaloric effect materials, and maximize performance in laboratory testing.

Number of max and min temperature records included in CDIAC's DayRec more than doubles

ORNL's Carbon Dioxide Information Analysis Center (CDIAC) has more than doubled the number of land surface stations included in its DayRec interface, which provides historical information on record-setting daily high and low temperatures across the United States for the 100-year period 1911–2010. DayRec hosts a map and search navigation tools for finding maximum and minimum daily temperatures measured at 424 stations nationwide, along with analysis capabilities via an interface that allows the user to make several types of historical plots for a station of interest.

Previously, DayRec mapped only 200 stations based on the scientific quality and continuity of data recorded in the US Historical Climatology Network's daily database of 1,218 stations. Stations in this network are primarily located in rural areas and are monitored by a volunteer, leading to discrepancies in the completeness of temperature records. However, while the stringent requirements imposed by CDIAC in the 2012 release of the DayRec interface ensured very complete records that provided a clear picture of decadal variations in record-setting temperatures, it left some areas of the United States, particularly the Southwest, underrepresented.

Following a reevaluation of the network's stations in 2013, CDIAC has added 224 stations as "Class 2" stations, improving the range of temperature records available through the interface while only increasing an average percentage of missing data for stations by 0.9%, from 1.5 to 2.4%.

Users can visit DayRec at cdiac.ornl.gov/climate/temp/us_recordtemps/dayrec.html.

FIRST LEGO League and FIRST Robotics continue to inspire students in STEM

Several local FIRST LEGO League teams mentored by Energy and Environmental Sciences Directorate (EESD) staff achieved awards during the East Tennessee Championship at Tennessee Tech in December. The Disco Robots, mentored by Bob Slattery of the Energy and Transportation Science Division, won first place in the Strategy and Innovation category and second in the Performance category. The Atomic Eagles, mentored by Harold Shanafield of the Environmental Sciences Division (ESD) and Thomas Proffen of the Neutron Sciences Directorate, won first place in the Professionalism category. LAB R.A.T.S., mentored by Claus Daniel, deputy director of the Sustainable Transportation Program (STP), and Ingrid Busch, STP transportation analysis researcher, placed second in the Programming category. The Robertsville Middle School Ninjineers, mentored by Peter Thornton of ESD, placed second in the Mechanical Design category.

Teams used LEGO-framed miniature robots to perform a series of functions on a table to solve posed natural disaster-type challenges and presented an original research and project idea to judges. Teams were judged based on their problem-solving skills, creative thinking, teamwork, competitive play, sportsmanship, and sense of community using LEGO Mindstorms robots.

DOE's Advanced Manufacturing Office (AMO), with support from the assistant secretary for the Office of Energy Efficiency and Renewable Energy, provided funding to establish a pilot program for the 2014 FIRST Robotics Competition (FRC), donating nearly 400 desktop 3D printers to high school student teams. All 398 printers were claimed by teams from across the United States and spanning 41 states.

The project will help develop the framework for integrating additive manufacturing, or 3D printing, into the FRC. The FRC engaged more than 63,000 high school students nationwide in 2013 by hosting robotics competitions in which student and mentor teams design and manufacture competition robots to inspire students in Science, Technology, Engineering, and Mathematics. Incorporating additive manufacturing into the program will expose the next generation of engineers and technologists to the next generation of manufacturing.

A team from DOE's AMO, ORNL, America Makes (formerly NAMII), equipment suppliers including 3D Systems and MakerGear, and FIRST collaborated to make this program possible. AMO's continued support has enabled ORNL's Manufacturing Demonstration Facility to work with regional high schools as a platform to educate high school students on advanced manufacturing technologies, including both additive and conventional manufacturing.

Claus Daniel, Sustainable Transportation Program deputy director, mentors students who are engineering a miniature LEGO-framed robot for the FIRST LEGO League championship.

Hardin Valley Academy students participate in the FIRST Robotics Palmetto Regional Competition in Myrtle Beach, South Carolina, in February.

ClimateMaster heat pump, SYMMETRIX Li-ion battery technologies win FLC awards

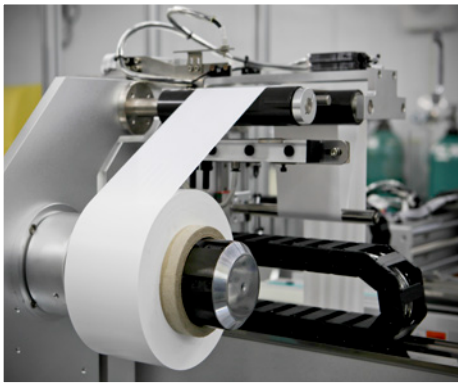
Two ORNL technologies have won Excellence in Technology Transfer awards from the Federal Laboratory Consortium (FLC) for Technology Transfer. The technologies, the ClimateMaster Trilogy 40 Q-Mode geothermal heat pump and the SYMMETRIX HPX-F Lithium-Ion Battery Nanocomposite Separator, also received 2013 R&D 100 awards.

The ClimateMaster Trilogy 40 Q-Mode Geothermal Heat Pump, was developed by ClimateMaster and ORNL through a cooperative R&D agreement. The ORNL team consisted of Ed Vineyard, Moonis Ally, Jeffrey Munk, Bo Shen, Keith Rice, Van Baxter, and Anthony Gehl, all of the Energy and Transportation Science Division (ETSD).

The water-to-air packaged heat pump provides significantly lower energy costs, reduces peak demand for electricity, and provides environmental benefits, especially through reductions in greenhouse gases and pollutants. Using the earth as its heat source, the Trilogy 40 Q-Mode is designed to provide not only space conditioning but also all the water heating needs of a typical residence.

The SYMMETRIX HPX-F Nanocomposite Separator for Improved Lithium Ion Battery was developed jointly by Porous Power Technologies LLC and ORNL. ORNL's participants from ETSD were David Wood II, Claus Daniel, Jianlin Li, and Curt Maxey, who won the award with colleagues in the Physical Sciences Directorate.

SYMMETRIX HPX-F reduces lithium-ion battery costs and improves safety through the replacement of polymer separators. The lower-cost ceramics and mineral fillers in these internal separators can improve a battery's thermomechanical properties, making it less likely to overheat or ignite from shorting. The membrane technology could be applied to electric vehicles, grid storage applications, portable electronic applications, filters, barrier fabrics, transdermal drug delivery, and toxic chemical absorption. Following SYMMETRIX HPX-F, Porous Power released a next-generation product called SYMMETRIX NC2020, in which the ceramic particles are blended with PVDF—a higher grade polymer intended to last for many years.



(Above) The creators of the ClimateMaster Trilogy 40 Q-Mode Heat Pump are shown with their technology that won a Federal Laboratory Consortium's (FLC's) Excellence in Technology Transfer award. From the left: Van Baxter, Ed Vineyard, Jeffrey Munk, Anthony Gehl, Moonis Ally, Keith Rice, and Bo Shen.

(Left) The SYMMETRIX HPX-F Nanocomposite Separator for Improved Lithium Ion Battery also received an FLC Excellence in Technology Transfer award.

Undergraduate intern Brock Carter transplants a set of natural Populus trichocarpa genotypes in the BioEnergy Science Center's new greenhouse, which was built at an extended height to accommodate tree species.

President Obama announces the next phase of fuel economy for trucks in front of a "SuperTruck" demo vehicle built by ORNL partners Cummins and Peterbilt at a speech in Maryland in February.

ORNL partners on "SuperTruck" featured in Obama speech

On February 18, President Obama unveiled the timing for the next phase of fuel economy regulations for trucks. He delivered his speech at a Safeway store in Maryland.

Behind the president was a "SuperTruck" demo vehicle built by ORNL partners Cummins and Peterbilt.

"And thanks to a partnership between industry and my administration, the truck behind me was able to achieve a 75% improvement in fuel economy over the last year—75%. That's why we call this "SuperTruck," Obama said.

Ron Graves, director of ORNL's Sustainable Transportation Program, expressed his excitement about ORNL's work for two industry-led SuperTruck teams.

"Daimler and Cummins-Peterbilt tapped ORNL for specific and different capabilities and technologies, including advanced electric machines, combustion, and unique engine diagnostics. This is indicative of the breadth of research capabilities across ORNL," Graves said.

Researchers with the lab's Fuels, Engines, and Emissions Research Center (FEERC) invented and applied a noninvasive optical probe to measure gas mixing and distribution among the engine's six cylinders to help Cummins validate its computational fluid dynamics models in developing an engine achieving 50% efficiency, which rivals the efficiency of fuel cells. The probe provides high-fidelity spatial and temporal resolution.

Led by a team from FEERC working in collaboration with the Power Electronics and Electric Machinery group, researchers developed and evaluated a novel generator design that avoids use of rare earth permanent magnets in a system that converts exhaust waste heat into electric power for the Detroit Diesel and Daimler Truck of North America SuperTruck Team. ORNL is currently working with the Daimler SuperTruck group to explore advanced combustion strategies and their effects on fuel economy and greenhouse gas emissions.

Also relevant to the president's announcement is the research happening in ORNL's Vehicle Systems Integration Laboratory (VSI) on behalf of the US Environmental Protection Agency and others to determine the best way to characterize and certify advanced truck powertrain greenhouse gas emissions. The findings will be used by the EPA-National Highway Traffic Safety Administration (NHTSA) in their rulemaking process.

The VSI Lab is the only facility throughout the national laboratory system large enough to accommodate Class 8 truck powertrains with the needed level of control sophistication.

Graves also serves on the National Academy of Sciences panel to update the NHTSA on heavy-duty truck fuel economy technology and regulatory processes.

ORNL's participation in the SuperTruck program is sponsored by the DOE Vehicle Technologies Office.

ORNL, industry partnership establishes enhanced microscopy for vehicle emission catalyst development

One of the country's first aberration-corrected electron microscopes—which enhances resolution by adjusting for imperfections in the electron lens—was recently upgraded. Microscopy components maker Protochips tested a fourth-generation catalyst specimen holder and control system for in situ gas-reaction research at elevated temperatures and pressures on the microscope that is housed at ORNL. The new gas-cell technology makes this one of the world's most powerful and unique microscopes for characterization of catalyst materials at the single-atom level under simulated real-world conditions.

Larry Allard, ORNL's lead microscopist for catalyst materials characterization with the Sustainable Transportation Program Propulsion Materials (PM) research team, uses the microscope in cutting-edge materials research that is crucial to enabling fuel-efficient, clean, and reliable vehicle technologies.

ORNL's PM researchers resolve powertrain-related materials challenges

Driver behavior study to influence safety and energy losses

ORNL researchers are working with the US Department of Transportation's Federal Highway Administration (FHWA) Exploratory Advanced Research Program to investigate links between driver behavior and safety as part of the Transportation Research Board's (TRB's) Second Strategic Highway Research Program. The ORNL project team is assisting with a Naturalistic Driving Study (NDS) that will examine about 3,000 vehicles outfitted with video cameras that will capture valuable information, which could influence the safety of America's roadways.

Using sensor technology installed in each vehicle, data streams are collected from forward-looking radar, the accelerator, a global

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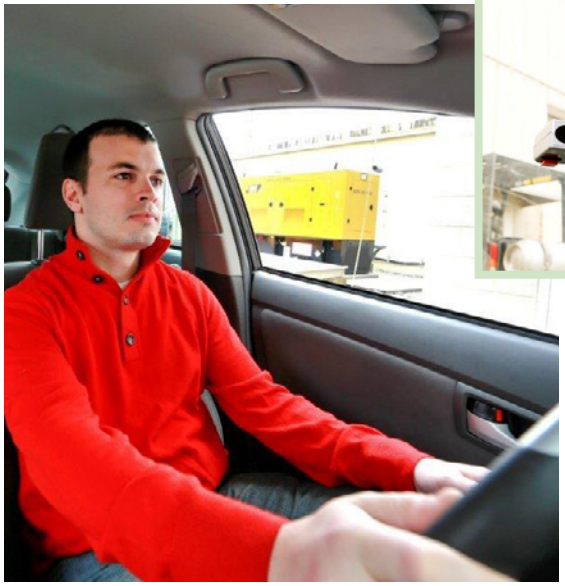


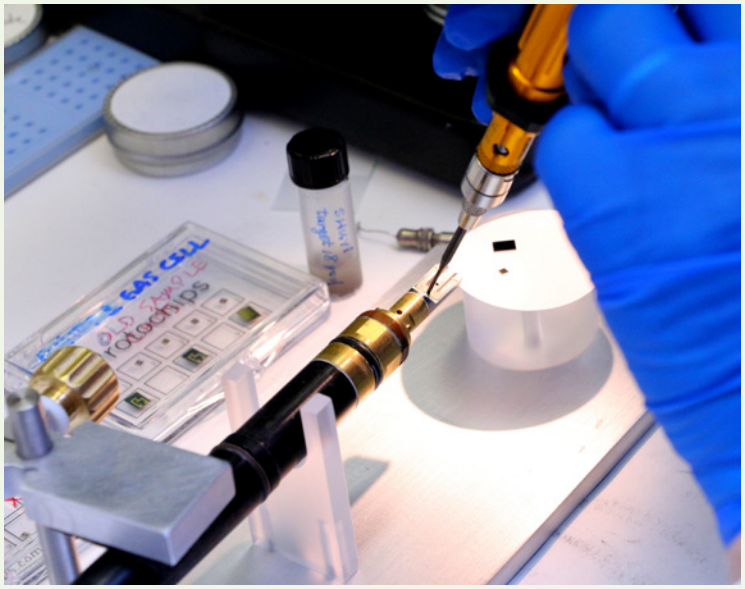
Video cameras focused on the driver's face, steering wheel and pedals, and the driver's front and rear views will record much of the Naturalistic Driving Study data.

today that impact future development of advanced engines, hybrid and electric drive systems, and vehicle exhaust systems components. Development of new materials and better catalyst system strategies, which this microscope is supporting, will enable the automotive and heavy truck original equipment manufacturers to meet the approaching design challenges of new and more stringent fuel efficiency and emissions standards. "Using Protochips' unique Aduro™ microfabricated heater devices, we can study catalyst materials for cleaner vehicle exhaust emissions, rapidly raising and lowering the temperature of the sample while watching how it reacts in certain environments," Larry said.

Using electrons instead of light, the microscope with the new gas-cell is doing more than just taking pictures. It is turning the instrument into a laboratory.

"The systems we provide as accessories to transmission and scanning electron microscopes let the researcher recreate in real time, or in situ, reaction conditions that allow imaging at high resolution," said David Nackashi, CEO and cofounder of Protochips.

ORNL's research with this new equipment is providing materials discoveries related to atom mobility and reactivity on catalyst oxide support surfaces, which will play a key role in enabling the development of catalysts that use smaller amounts of precious metals, as well as self-regenerating catalyst systems.



ORNL researcher Larry Allard loads the Protochips Aduro™ heater device with a catalyst material into the gas-cell holder.

The Protochips relationship through ORNL's applied materials user program began in 2006 with a DOE Small Business Innovation Research (SBIR) Phase I award to the Raleigh, North Carolina–based vendor. Through work for others contracts and a research collaboration, ORNL and Protochips are developing and deploying new high-tech characterization tools that are accelerating the scientific understanding of catalytic materials.

After the SBIR ended in 2008, ORNL and Protochips continued to collaborate on the development of new in situ capabilities for characterization of catalysts and other nanophase materials, with Protochips providing ORNL with prototype equipment.

"The High Temperature Materials Laboratory, the Propulsion Materials program, as well as DOE's SBIR program, have played a key role in enabling Protochips' growth from 3 to 30 employees and contractors over the course of our relationship," said Allen Haynes, ORNL's PM program manager.

Protochips' gas-reaction system—first established and refined through testing at ORNL—is aimed to be commercially introduced in the near future as the company continues evaluation by international electron microscope manufacturers.

ORNL Propulsion Materials R&D is sponsored by the DOE Vehicle Technologies Office.

Chattanooga looks to ORNL's intelligent systems R&D for traffic solutions

James Li, ORNL researcher in the Center for Transportation Analysis, was the featured speaker at the Transportation Science Seminar Series, which recently hosted traffic experts from the City of Chattanooga, Tennessee, to speak on their ORNL partnership to explore the city's intelligent transportation system.

ORNL researcher Jan-Mou "James" Li navigated the latest developments in Internet and communication technologies and real-time data collection from the widespread use of sensors during a talk given on January 10 as part of the Transportation Science Seminar Series sponsored by ORNL's Sustainable Transportation Program.

Li invited traffic experts from the City of Chattanooga, Tennessee, to share their experience upgrading the city's aging traffic signal system. The ORNL-industry partnership explores intelligent transportation systems that can result in better fuel economy and shape future transportation systems. Once fully implemented, Chattanooga's roadways could become the envy of all mid-sized American cities.

Chattanooga is using federal grant money to install a signal coordination system that will use broadband Internet to feed real-time traffic data into algorithms that will direct traffic lights according to the changing demands of traffic flow rather than operating on a fixed schedule.

The system design includes 400 traffic signals, 70 closed-circuit TV cameras, 70 dynamic message signs, and 1,200 vehicle detectors. The project also includes an adaptive arterial control system for 13 intersections on State Route 153 that carries more than 53,000 vehicles a day.

ORNL plans to use data gleaned from the system, which is connected via high-speed Internet, for research.

"We can use the data and information they share in real time to do some scientific studies, such as modeling driver behavior and the system reaction time. The results can shape tomorrow's traffic operations," Li said.

"We need to take advantage of the technologies that are now available and will soon be coming online in order to improve the efficiency of existing infrastructure that we have," said John Van Winkle, Chattanooga traffic engineer. "We're happy to come to ORNL to share ideas because it could open doors for future research."

The collective presentation, titled, "Big Data Informatics: Intelligent Transportation Systems with the Chattanooga Wireless Mesh Network," was given by Li, Van Winkle, and Stephen Meyer, branch manager with Alfred Benesch and Company, who consults with the city of Chattanooga on this project.

Miniature engines could get big boost with additive manufacturing

The Energy and Transportation Science Division's (ETSD's) Fuels, Engines, and Emissions Research group is using the Manufacturing Demonstration Facility's (MDF's) additive manufacturing capabilities to improve the efficiency of tiny engines. Miniature engines power unmanned aerial vehicles, such as those used for military surveillance; a range of radio control devices; and portable generators.

For military applications, in particular, researchers are looking for ways to cut operating costs.

"The military has put a priority on lowering the operating costs of unmanned aerial vehicles, which means reducing engine mass and improving efficiency," said Mike Kass, lead investigator and member of the Fuels and Engines group.

But smaller engine size has a big effect on efficiency.

"The technology for small engines is fairly primitive and, as a result, their efficiency is fairly low," Kass said. "Miniature engines have a high surface-area-to-volume ratio, resulting in more heat loss during combustion in a miniature engine than in a full-sized engine.

Not only does the diminutive size of these engines drag down efficiency, but it also affects how easily their internal combustion process can be researched.

"Previous studies have indicated that another key reason they're so inefficient is because the combustion process in these engines is incomplete," Kass said. "By teaming with the additive manufacturing robotics group, we are building an engine head out of titanium that is more insulating than the conventional aluminum engine head, so it's better able to retain heat."

However, conventional instrumentation that can measure in-cylinder pressure and exhaust is not designed for such small components. Again, by teaming with the MDF, the team was able to specially design ports on the additively manufactured engine heads to accommodate instrumentation.

"What we found through in-cylinder pressure and exhaust measurements was that was the case: combustion was incomplete. This is the first time we have hard evidence of that," Kass said.

The team is continuing to collaborate with the MDF as they evaluate a prototype miniature engine component exposed to extreme heat and pressure.

Using additive manufacturing, ORNL researchers built a miniature engine, such as those used for unmanned aerial vehicles, with a titanium engine head.

Arcimoto partnership results in low-cost, efficient inverter for hybrid electric vehicles

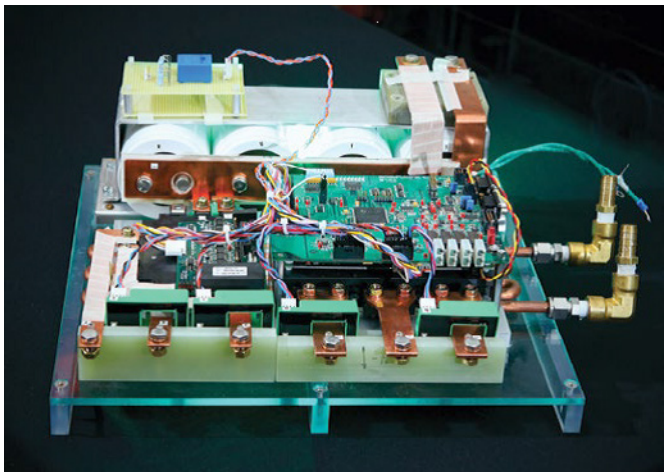
Less expensive, lighter, and more efficient inverters could put hybrid electric vehicles (HEVs) on the highway to improved viability. While batteries receive a lot of attention, ORNL inventor Gui-Jia Su noted that inverters play an equally important role in powering HEVs.

ORNL invented a new low-cost inverter, which has the critical function of efficiently converting and controlling the battery from direct current (dc) into the alternating current (ac) that motors need. ORNL licensed the inverter to US-based, all-electric prototype manufacturer Arcimoto.

The patent-pending inverter is more compact, reduces battery losses, improves operating conditions and reliability, and can be operated in high-temperature conditions. The inverter also significantly reduces undesirable motor torque ripples.

The partnership between ORNL and Arcimoto was the focus of an article titled, "A Promising New Electric Car is on the Horizon" that appeared online in *Innovation* magazine: innovation-america.org/promising-new-electric-car-horizon.

The article says of ORNL's contribution: "The technologies enable Arcimoto to build a drivetrain that eliminates the need for a standalone external charger and is capable of operating safely at higher temperatures."—*Ron Walli*



An ORNL-invented, Arcimoto-licensed inverter, primarily for hybrid electric vehicles, that is compact, efficient, and low cost.

(continued from page 9)

positioning system, and a passive alcohol sensor. The bulk of this massive data set—about 4 petabytes collected so far—comes from video data from four cameras focused on the driver's face, steering wheel and pedals, and the driver's front and rear views. Researchers expect to capture an estimated one million hours of recorded drive time over the course of the two-year study.

"We'll be able to provide an unprecedented look into what a driver was doing, or not doing, leading up to a crash or near-crash, as well as their actions during routine driving," said Tom Karnowski, principal investigator with ORNL's Imaging, Signals, and Machine Learning group.

He added that the data gleaned from the NDS study will be used to improve roadway and roadside design, the development of on-board safety systems, and law enforcement and driver's education.

The ORNL team is working to characterize the cameras used in the study, which will improve the accuracy and effectiveness of automated data extraction algorithms. In later phases of the project, the team will also be developing procedures for measuring and comparing the effectiveness of automated video data extraction algorithms. Traditionally, the extraction, or labeling, of items of interest from video data has been a brute force process, requiring tedious frame-by-frame review.

"Automating this coding through computer vision can make these data sets accessible to a wide range of researchers, improve labeling accuracy and speed, and reduce costs," Tom said.

While the primary mission in crash prevention is safety and preserving human life, crashes also represent a large energy waste, a particular concern of DOE's Energy Efficiency and Renewable Energy Office and their Clean Cities initiative. Vehicle idle time in traffic congestion is responsible for the loss of 2.8 billion gallons of fuel annually—nearly 3% of total fuel use.

ORNL's NDS project team comprises researchers from the Electric and Electronics Systems Research Division, Computational Sciences and Engineering Division, and Nuclear Security and Isotope Technology Division. The collaboration involves FHWA, TRB, and Virginia Tech Transportation Institute.

ORNL investigates reuse of electric car batteries for power grid applications

Researchers in ORNL's Power and Energy Systems group are investigating extending the usefulness of electric vehicle (EV) batteries by reusing them for electric grid applications. Currently, these systems are sent to recycling centers after being pulled from the vehicles.

"The electric vehicle has an estimated life of 10 years, but the EV battery could still have substantial useful capacity to support the electric grid for another 10 to 15 years before being recycled," said Michael Starke, R&D researcher in Power and Energy Systems.

Engineers and entrepreneurs are actively collecting used vehicle battery systems from vehicles for research into secondary-use applications. Researchers predict there will be an influx of reusable EV batteries available for secondary use around 2020 when current EV adopters begin purchasing newer vehicles.

"In the future, there is a possibility of seeing widespread energy storage throughout the grid as we see increased growth in the number of electric vehicles on our roadways and as we build an infrastructure for repackaging the batteries for secondary applications," said Starke.

ORNL has received a novel secondary-use energy storage system designed by ABB, an international leader in power and automation technologies, and General Motors (GM) composed of five, used Chevy Volt batteries. ORNL researchers in partnership with ABB and GM are testing this energy storage at the Distributed Energy Communications and Control (DECC) laboratory.

This particular system—which powers the equivalent of three to five homes with power and energy ratings of 25 kWh/50 kWh—is designed to support communities with uninterrupted power, load leveling, and renewable integration options. Larger scale aggregation and control of these units can also support electric transmission grid applications as well.

The ORNL team has developed a testing platform at the DECC laboratory to demonstrate the ability of these energy storage systems to perform a number of different grid applications. This effort includes development of test procedures and interfacing controls.

Low-cost energy storage systems are considered a game-changing technology for the electric grid. Energy storage is not only able to support grid reliability but can also provide widespread adoption of intermittent energy resources such as solar and wind power.

Since 2011, ORNL has been evaluating the secondary-use market for vehicle batteries by examining the cost benefit of reusing vehicle batteries. Long-term objectives of this multiyear project are to evaluate the impact of different grid services on the degradation of life in secondary-use systems and to estimate the value of these systems on the grid. The proposed value will be derived through real-time optimization and control demonstrations of the onsite storage system, and researchers expect that reusing EV batteries will potentially reduce the system cost to both vehicle and grid applications.

The ORNL-led project team includes ABB, GM, and ORNL staff Phil Irminger, Omer Onar, Ben Ollis, and George Andrews. The project is funded by the DOE Energy Storage Program with support from ABB and GM.

Enclosure for five Chevy Volt battery systems connected to ORNL's Distributed Energy Communications and Control laboratory grid for secondary electric vehicle battery research.

Researchers use x-rays and neutrons to study a lesser known feedstock in lignocellulosic biomass for biofuels production

Researchers from the EESD Biosciences Division (BSD) and the Biology and Soft Matter Division (BSMD) of the Neutron Sciences Directorate are working together to integrate protein engineering with x-ray crystallography and neutron scattering to study how hemicellulose can be more easily degraded for conversion into biofuels and other products.

Two papers published this year, including the cover article of the January 2014 *Acta Crystallographica Section D: Biological Crystallography*, detail their work.

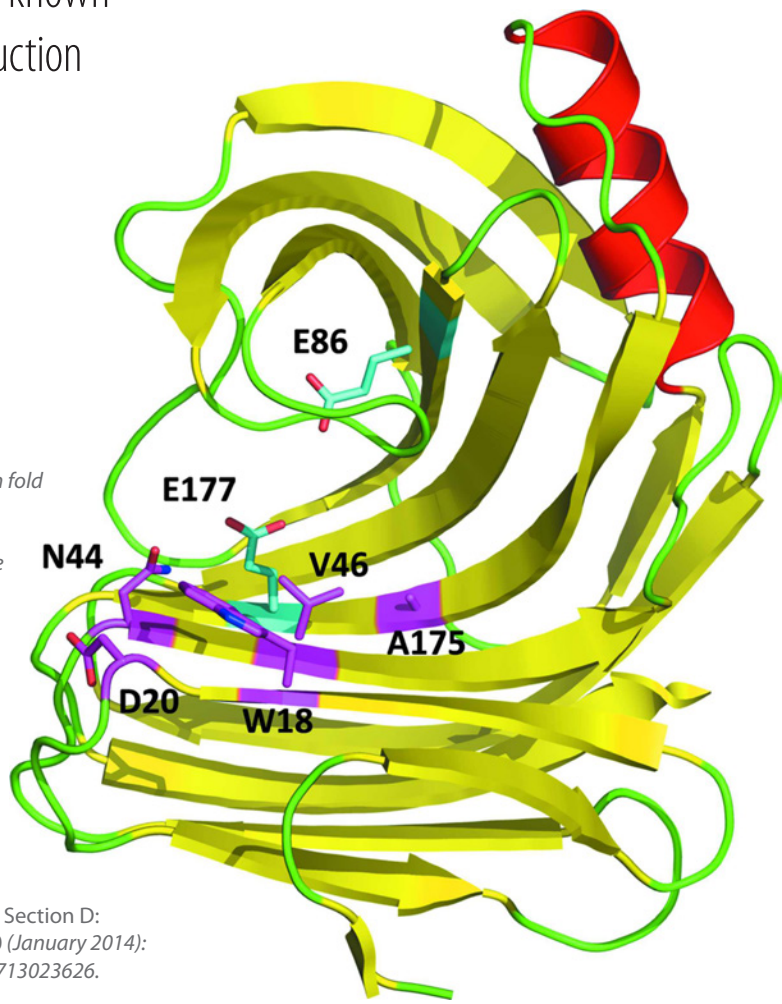
Lignocellulosic biomass, the fibrous material derived from plant cell walls, has great potential as a carbon feedstock for biofuels production. It consists of three major components: cellulose, hemicellulose, and lignin. Many lignocellulosic biomass-based biorefinery technologies use enzymes to degrade cellulose into glucose sugars that can be easily fermented by industrial yeasts.

Lignin and hemicellulose components are also potentially useful feedstocks, but they are underexploited. For these studies, researchers focused on hemicellulose, which, like cellulose, can be degraded into sugars by enzymes. However, hemicellulose enzymes operate inefficiently under typical industrial conditions. Further complicating matters, hemicellulose consists of mostly xylose sugars that conventional yeast strains cannot use.

"Rather than looking at the overall biomass degradation during processing, which has been the focus of a lot of previous biofuels research, we are taking a different strategy and looking specifically at the molecular level of hemicellulose, which is just one of the complex carbohydrates found in plant material," said David Graham, BSD Microbial Ecology and Physiology group leader and coauthor on both papers.

To analyze the molecular level of hemicellulose, the team used x-ray and neutron imaging techniques for capturing its structure and enzymatic activity.

The ORNL researchers are particularly interested in xylan, one of the most common polysaccharides in hemicellulose. In the *Acta Crystallographica D* paper, they used x-ray crystallography to observe the structure of a particular family of xylanases (enzymes that break down xylan). For the first time, their study confirmed the number and position of binding subsites in a family 11 xylanase (called XynII), which hydrolyses the xylan found in many grasses appropriate for biofuels processing.



A representation of the protein fold of family 11 xylanases, which break down xylan during biofuels processing. The image is from a paper coauthored by ORNL researchers Qun Wan, Qiu Zhang, Scott Hamilton-Brehm, Kevin Weiss, Marat Mustyakimov, Leighton Coates, Paul Langan, David Graham, and Andrey Kovalevsky. "X-ray crystallographic studies of family 11 xylanase Michaelis and product complexes: implications for the catalytic mechanism." Acta Crystallographica Section D: Biological Crystallography 70 *(January 2014): 11-23. doi: 10.1107/S1399004713023626.*

The second paper, published in *Protein Engineering, Design & Selection*, used the unique structural information from neutron and x-ray crystallography to guide the design of another important biofuels enzyme: D-xylose isomerase. This enzyme converts the non-fermentable sugar xylose—abundant in xylan—to the fermentable analog xylulose, thereby significantly improving the yield of bioethanol. The authors used knowledge of the positions of hydrogen atoms in the enzyme at acidic pH to design an enzyme variant capable of converting xylose to xylulose more efficiently at low-pH conditions—a form of protein engineering.

Neutrons provide a previously underused method of understanding the fundamentals of hemicellulase and sugar isomerase structures and enzymatic activity.

"Neutron crystallography is excellent for characterizing structures where water molecules and proteins, both of which contain light elements like hydrogen, are crucial," Graham said. "The lighter atoms can be difficult or impossible to see using x-ray crystallography."

ORNL authors on the *Acta Crystallographica Section D* paper include BSMD authors Qun Wan, Qiu Zhang, Kevin Weiss, Marat Mustyakimov, Leighton Coates, Paul Langan, Andrey Kovalevsky, and BSD authors Scott Hamilton-Brehm and Graham.

ORNL authors on the *Protein Engineering, Design & Selection* paper include BSD authors Zamin Koo Yang and Graham, BSMD authors Langan and Kovalevsky, and Los Alamos National Laboratory lead author Mary Jo Waltman.

Governor's Chair Babu to lead UT contribution to new manufacturing institute

President Obama announces institute alongside ORNL's 3D printed robotic arm

Suresh Babu, University of Tennessee (UT)–ORNL Governor's Chair for advanced manufacturing, will lead UT's effort as part of a Detroit-based Lightweight and Modern Metals Manufacturing Innovation Institute (LM3I) announced by President Obama in February.

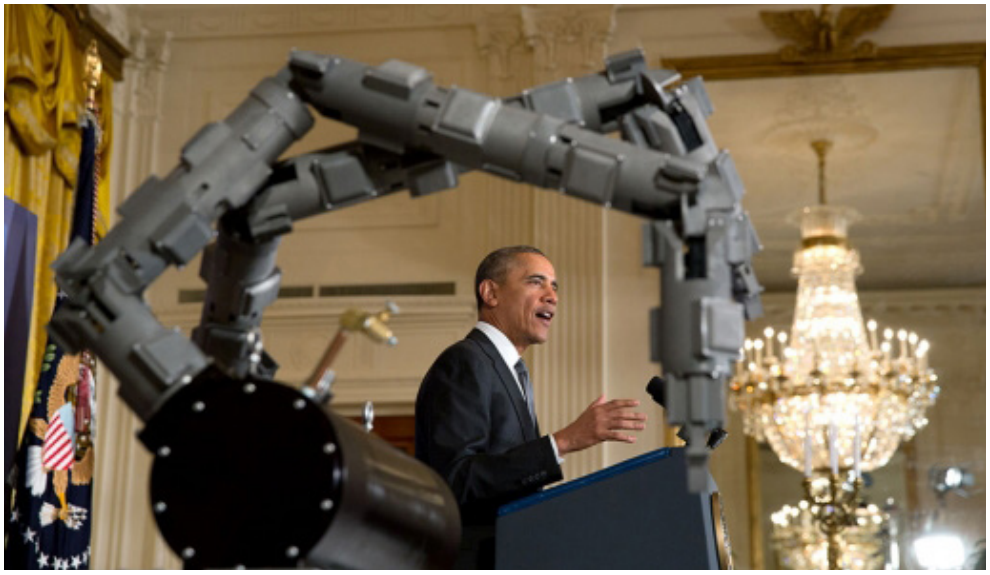
At the White House press briefing, the president spoke beside a robotic arm manufactured by 3D printing at ORNL's Manufacturing Demonstration Facility (MDF).

The institute is funded by the US Department of Defense to partner aluminum, titanium, and high-strength steel manufacturers with universities and laboratories to develop new manufacturing technologies for consumer products and defense capabilities.

The White House Office of the Press Secretary describes LM3I's long-term goal as "to expand the market for and create new consumers of products and systems that utilize new, lightweight, high-performing metals and alloys by removing technological barriers to their manufacture. The institute will achieve this through leadership in pre-competitive advanced research and partnerships across defense, aerospace, automotive, energy, and consumer products industries."

Babu works closely with the MDF to develop new materials and product designs as part of his joint appointment in ORNL's Advanced Manufacturing Program and UT's departments of Mechanical, Aerospace, and Biomedical Engineering and Materials Science and Engineering.

President Obama is pictured with a robotic arm made at ORNL's Manufacturing Demonstration Facility and funded by the Office of Naval Research.



Clean room equipped to tackle projects in solar fabrication, sensing, range of nanoscale technologies

For fabricating devices with micrometer-sized components—components the size of pollen grains and red blood cells, for example—the typical laboratory environment can be treacherous. Dust, skin cells, and other large particles can easily contaminate the delicate wafers on which electronics, sensors, and other breakthrough devices are built.

To apply complex, conductive pathways at scales so small, researchers use highly precise techniques to structure materials, such as magnetron sputtering (in which atoms knocked off a target material are directed via magnetic fields and erode away at the substrate) or electron beam evaporation (in which gas evaporates off a target material after coming in contact with an electron beam and coats a film with the substrate), among others.

ORNL's Nanoscale Science and Technology Laboratory (NSTL) is providing a modern clean room facility for ORNL researchers and industrial partners for nanofabrication and materials projects. NSTL, the lab's only clean room for device-engineering and applications-driven research, includes photolithography, thin-film coating deposition, and metrology and inspection capabilities, as well as a dual-chamber co-sputtering and evaporation system for particularly sensitive devices.

Whereas a typical office space may have a million particles per cubic foot, the NSTL clean room includes Class 100 spaces (permits no more than 100 particles 0.5 microns or larger per cubic foot) and Class 1000 spaces (no more than 1000 particles) for nanofabrication.

The clean room is open to all ORNL researchers and is managed by the Energy and Transportation Science Division. Many facility users will work closely with ORNL's new Center for Sustainable Industry and Manufacturing (CSIM). To improve industrial competitiveness and reduce industrial waste, one CSIM research focus is the

ORNL's Nanoscale Science and Technology Laboratory clean room facility.

fabrication and development of nanomaterials and nanoscale devices and sensors.

"Advanced research being done with sensors, photovoltaics (or solar cell films), and roll-to-roll processing (or the processing of flexible electronics) represents just a few of the technologies that are already being fabricated with the equipment provided," said Panos Datskos, Nanosystems, Separations, and Materials Research group leader and NSTL manager.

The facility includes a plasma-enhanced chemical vapor deposition (CVD) system for silicon-based substrates, a low-pressure CVD system for handling larger batches of wafers for silicon-based substrates, an electron-beam evaporator for depositing metal and semiconductor materials, and a magnetron sputtering system.

For substrates sensitive to light, photolithography capabilities include a mask aligner system with the ability to print sub-micron features, as well as photoresist spinners and development equipment. For metrology and inspection, a reflectometer for measuring thickness and refractive index, a stylus profilometer system for measuring step heights of a variety of materials, a brightfield and darkfield optical microscope with a 1,500-times magnification capability, and a cold field emission scanning electron microscope with 2.5 nanometer resolution are available in the clean room.

ORNL researchers may contact Datskos for more information on using the NSTL.

Terpene-producing biomass could be a surprising source of biofuels

Koalas are famous for being idle, living off the eucalyptus leaves not far out of their reach. Although eucalyptus doesn't seem to give koalas much of an energy boost, with a few modifications it might power a jet engine.

ORNL researchers are investigating eucalyptus as a plant source that can produce hydrocarbons called terpenes at high levels to convert into a biofuel, specifically jet fuel. Researchers propose to optimize terpene production in eucalyptus by improving terpene yield, increasing oil gland capacity, and reducing terpene volatility, which in total will significantly increase energy yields per plant.

Jerry Tuskan, Biosciences Division, and his team at ORNL (including coprincipal investigators at the Spallation Neutron Source [SNS]), the University of Tennessee, University of Florida, and Georgia Institute of Technology are investigating the genetic basis and structural features of oil gland formation to understand pathways for foliar biomass production and terpene biosynthesis in the eucalyptus plant.

Researchers initially examined 15 alternative eucalyptus species and will select suitable lines within each species based on number of oil glands per square centimeter, oil gland volume, and terpene content and chemistry. Using neutron imaging, electron microscopy, anatomical profiling, metabolite profiling, and RNA-sequencing, researchers will characterize heritable variation in oil gland number and terpene chemistry.

As colead on the eucalyptus genome sequencing effort, Tuskan reports that the eucalyptus genome contains more terpene synthase genes than any other sequenced plant genome. Leveraging this information, along with advanced imaging capabilities at SNS, the team hopes to identify the genes that minimize terpene volatility and optimize terpene membrane interactions for improved energy yield.

In addition, researchers are evaluating the effects of fungal inoculations on terpene production among the selected plants. Beneficial associations with mycorrhizal fungi (root fungi) are known to promote plant growth, terpene levels, and, ultimately, agronomic sustainability. Preliminary data demonstrate that mycorrhizal colonization modifies the leaf chemistry.

To explore this theory, Tuskan's group currently has 15 different species of eucalyptus and 1,000 fungal isolates known to associate with woody plant roots growing in the ORNL greenhouse.

Coppice (energy crop) rotations of eucalyptus meet or exceed all expectations for an energy crop in the southern United States, including broad adaptability, low chemical inputs, suitability on marginal lands, and high energy yields. Improving terpene yields through genetic and anatomical characterization will increase the chances of eucalyptus being introduced as a new energy crop into existing agricultural systems.

Eucalyptus seedlings budding in an ORNL greenhouse.

Martin Keller, Sudarsanam Suresh Babu, and Terry Clyde Hazen.

Keller, Babu, Hazen elected AAAS fellows

As newly elected fellows of the American Association for the Advancement of Science (AAAS), EESD Associate Laboratory Director **Martin Keller** and Governor's Chairs **Sudarsanam Suresh Babu** and **Terry Clyde Hazen** will receive the highest honor bestowed by members of the AAAS on their peers. AAAS is the world's largest general scientific society and publisher of the journal *Science*.

Keller came to ORNL in 2006 from Diversa Corporation, where he held a series of research management positions. He was cited by his AAAS peers for "distinguished contributions to bioenergy science, and for dynamic and inspiring leadership of innovative partnerships to advance the development and deployment of clean energy technologies." Keller is the founding director of the BioEnergy Science Center at ORNL, one of DOE's Bioenergy Research Centers, and directed the laboratory's Biosciences Division before leading EESD. He received his doctorate in microbiology from the University of Regensburg in Germany.

Babu is the University of Tennessee (UT)–ORNL Governor's Chair for advanced manufacturing. He was cited for "distinguished contributions to computational materials sciences, nonequilibrium phase transformations and application of in situ neutron and synchrotron diffraction tools and other advanced characterization methods." Babu received his master of technology in industrial metallurgy-welding from the Indian Institute of Technology, Madras, Chennai, India, and earned his doctoral degree in materials science from the University of Cambridge.

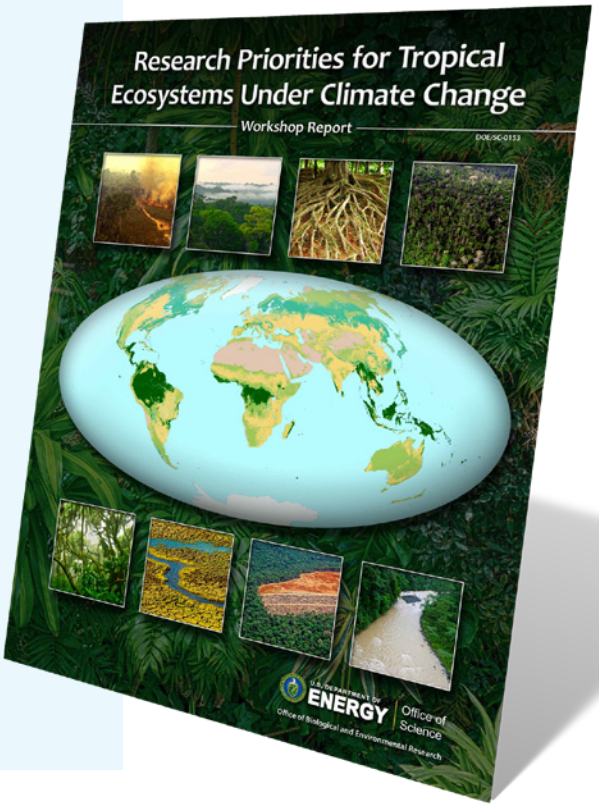
Hazen has been the UT–ORNL Governor's Chair for environmental biotechnology since 2011. He was cited for "distinguished contributions in the field of microbial ecology and bioremediation, particularly for the systems biology approach to the Deepwater Horizon oil spill disaster." Hazen received his bachelor's and master's degrees in interdepartmental biology from Michigan State University and his doctorate in microbial ecology from Wake Forest University.

The new fellows were honored at the AAAS annual meeting in February.

The Biological and Environmental Research Information System (BERIS) has won three awards in the Society for Technical Communication (STC) Washington, DC–Baltimore Chapter's 2013–2014 Summit Competition. These communication tools were prepared for DOE's Office of Biological and Environmental Research (BER).

Awarded entries are Research Priorities for Tropical Ecosystems Under Climate Change (Distinguished and Best of Show in Print, Informational Materials, and Technical Reports); BER Virtual Laboratory: Innovative Framework for Biological and Environmental Grand Challenges (Distinguished in Informational Materials, Technical Reports); and DOE Joint Genome Institute Strategic Planning for the Genomic Sciences (Excellence in Informational Materials and Technical Reports).

BERIS team awardees are **Kris Christen** (science writer/editor), **Holly Haun** (technical editor/writer), **Sheryl Martin** (QC text reviewer/webmaster), **Marissa Mills** (communications and marketing outreach strategist / webmaster), **Judy Wyrick** (editor/ document designer/print production manager/25-year STC member), **Betty Mansfield** (group leader/research interface), and ORNL Creative Media's **Brett Hopwood** (illustrator/document designer). Contributors also include **Richard Norby**, Environmental Sciences Division, and DOE BER's **David Thomassen**, **Daniel Stover**, **Daniel Drell**, and **John Houghton**.



Patrick Hughes, Building Technologies program manager and director of the Building Technologies Research and Integration Center, was recognized by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) with the Distinguished Service Award (DSA) as well as the Exceptional Service Award (ESA). The DSA recognizes those who have served the society faithfully and with distinction to accomplish its research, standards writing, publishing, and continuing education. The ESA recognizes those who have served the society with exemplary effort, far in excess of that required for the DSA.

John Shonder, Energy and Transportation Science Directorate (ETSD), began a four-year term on ASHRAE's Research Advisory Committee, which works with ASHRAE's technical committees to coordinate basic research and technical studies in heating, ventilating, air conditioning, refrigeration, and related fields. John is the head of ASHRAE's Section 10 and is liaison to seven technical committees concerned with refrigeration.

Brian Fricke, ETSD, was recognized by ASHRAE with the DSA. The DSA recognizes those who have served ASHRAE faithfully and with distinction in general society activities, or otherwise given freely of their time and talent on behalf of the society to accomplish its research, standards writing, publishing, and continuing education.

Mike Kass, ETSD, was invited to serve on the advisory committee of the University of California–Riverside Center for Environmental Research and Technology (CE-CERT) to guide the research program of their materials and fuels compatibility projects. CE-CERT collaborates with industry and government to research and impact environmental regulations and policy and energy-efficient engineering for a range of applications.

Santonu Goswami, Environmental Sciences Division, was awarded the US Permafrost Association American Geophysical Union Travel Award for Early Career Scientists.

LeJean Hardin, ORNL Creative Media, won a gold MarCom award for the design of the first issue of *Clean Energy* from the Association of Marketing and Communications. The international MarCom competition recognizes "outstanding creative achievement by marketing and communication professionals."

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

Bill Partridge of ORNL and David Koeberlein of Cummins stand with the Cummins-Peterbilt SuperTruck during a recent visit to ORNL's National Transportation Research Center. ORNL research contributed to the SuperTruck's advanced technology and efficiency gains, including a 75% increase in fuel economy and 43% reduction in greenhouse gas emissions. To read more about the SuperTruck, see page 8.