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Argonne NATIONAL LABORATORY

DRIVING MOBILITY

ARGONNE'S CENTER FOR TRANSPORTATION RESEARCH

THESE ARE EXCITING TIMES IN THE WORLD OF TRANSPORTATION

As transportation choices transition toward an ever more energy-efficient, environmentally friendly future, the Center for Transportation Research (CTR) at Argonne National Laboratory leads the way.

From individual component technologies to powertrain, vehicle and transportation system-level research, to analysis of how people interact with their surroundings, the CTR's combination of unparalleled engineering expertise and outstanding scientific tools produces brilliant solutions to our nation's energy and greenhouse gas challenges.

CONTENTS

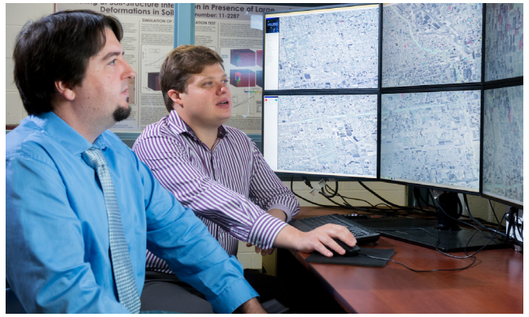
HOW CAN PERSONAL TRANSPORTATION EVOLVE?

Maximizing mobility, safety and energy efficiency

Advanced technology vehicles that drive themselves and communicate with one another, batteries that both give and receive energy from the grid and cities with a range of transportation options—from car- and bike-sharing to on-demand buses and light rail—are all aimed at decreasing travel time, maximizing energy efficiency, increasing safety and creating an infrastructure conducive to advanced technology vehicles and alternative fuels. While many of these things, and many more, are indeed possible, their development requires advanced multidisciplinary research in many areas, including:

- Transportation as a system
- Computationally enhanced mobility
- Behavioral and decision science
- Connectivity and automation
- Multi-modal transportation
- Urban science
- Vehicles and infrastructure

Few places are better equipped to address these opportunities than Argonne, which has been at the forefront of transportation systems research for over two decades.



Researchers discuss a visualization that explores the potential energy and mobility ramifications of dedicating road lanes to certain types of traffic along Chicago's lakefront.

WHAT ARE THE ENERGY IMPACTS?

Evaluating mobility, safety and energy ramifications

Argonne has developed series of integrated tools and processes to quickly and efficiently evaluate the impact of advanced vehicle and transportation technologies from both a mobility and energy perspective. Our research includes:

- Evaluating the energy and cost impacts of advanced vehicle technologies (such as component technologies and powertrain configurations) using the Autonomie© modeling and simulation framework
- Developing vehicle-level control algorithms to minimize energy consumption
- Quantifying the impacts of component technologies at the system level using virtual vehicles
- Assessing the impacts of connected and automated vehicles
- Quantifying the mobility and energy impacts of new transportation technologies and policies at the regional level
- Understanding consumers' travel choices

Argonne researchers use a variety of tools to assess the effects of component technologies using virtual vehicles.

HOW CAN WE FUTURE–PROOF EV CHARGING INFRASTRUCTURE?

Meeting consumers' needs now and in the future

Ensuring that electric vehicle (EV) charging is convenient, reliable, safe—and meets the future needs of consumers—requires cooperation between vehicle and charge equipment manufacturers, utility companies/energy service providers and government regulators. Consumers expect EVs to be universally interoperable with charge equipment. Electricity providers expect revision of regulations to allow reselling electricity through charging networks. Utility companies expect 'smart' charging to best use their generation and distribution capacity.

The common thread is cooperation to develop universal standards for grid connectivity and communication. The U.S. Department of Energy and the European Commission collaborate through official EV-Smart Grid Interoperability Centers at Argonne and the Joint Research Centre's Institute for Energy and Transport in Ispra, Italy (JRC-IET). The two centers promote harmonization through the development of standards, technology, verification procedures and test equipment that support universal connectivity and communication between plug-in vehicles and the electric power grid. Argonne applies its embedded controls technologies to integrate plug-in vehicles, buildings and renewables, through:

- Developing and verifying technology and standards for grid integration
- Developing open-source embedded controls to minimize technical barriers to integrating grid-connected devices
- Testing communication and control systems in a network of grid-connected devices
- Supporting international harmonization through coordination with JRC-IET and Global InterOP

HOW DO WE QUANTIFY ADVANCEMENTS IN VEHICLE TECHNOLOGY?

Guiding future research to improve tomorrow's automotive systems

Argonne's Advanced Powertrain Research Facility (APRF) combines unique laboratory capabilities and expertise to perform focused technology evaluations and vehicle-level research studies. Our independent and public testing (available at www.anl.gov/d3) enables analysis critical to the development and commercialization of next-generation vehicles. Our research in this area includes:

- Evaluating technologies in a systems context over a wide range of realistic test conditions and drive cycles to assess the impact on energy efficiency and vehicle performance
- Implementing novel instrumentation techniques to capture the power flow and energy balances between powertrain components in real-world driving conditions
- Mapping vehicle and component efficiencies well beyond standard drive cycles across temperatures ranging from 0°F to a 95°F to support model development and validation
- Performing vehicle-level studies such as measuring the impact of ambient temperatures and climate control systems on energy consumption across a wide range of thermal conditions for many different powertrain types
- Providing leadership in test procedure development for advanced vehicles in standards organizations world-wide to ensure the claims associated with new technologies align with their capabilities

Argonne's Thermal Test Cell provides capabilities for testing vehicles under extreme temperature conditions.

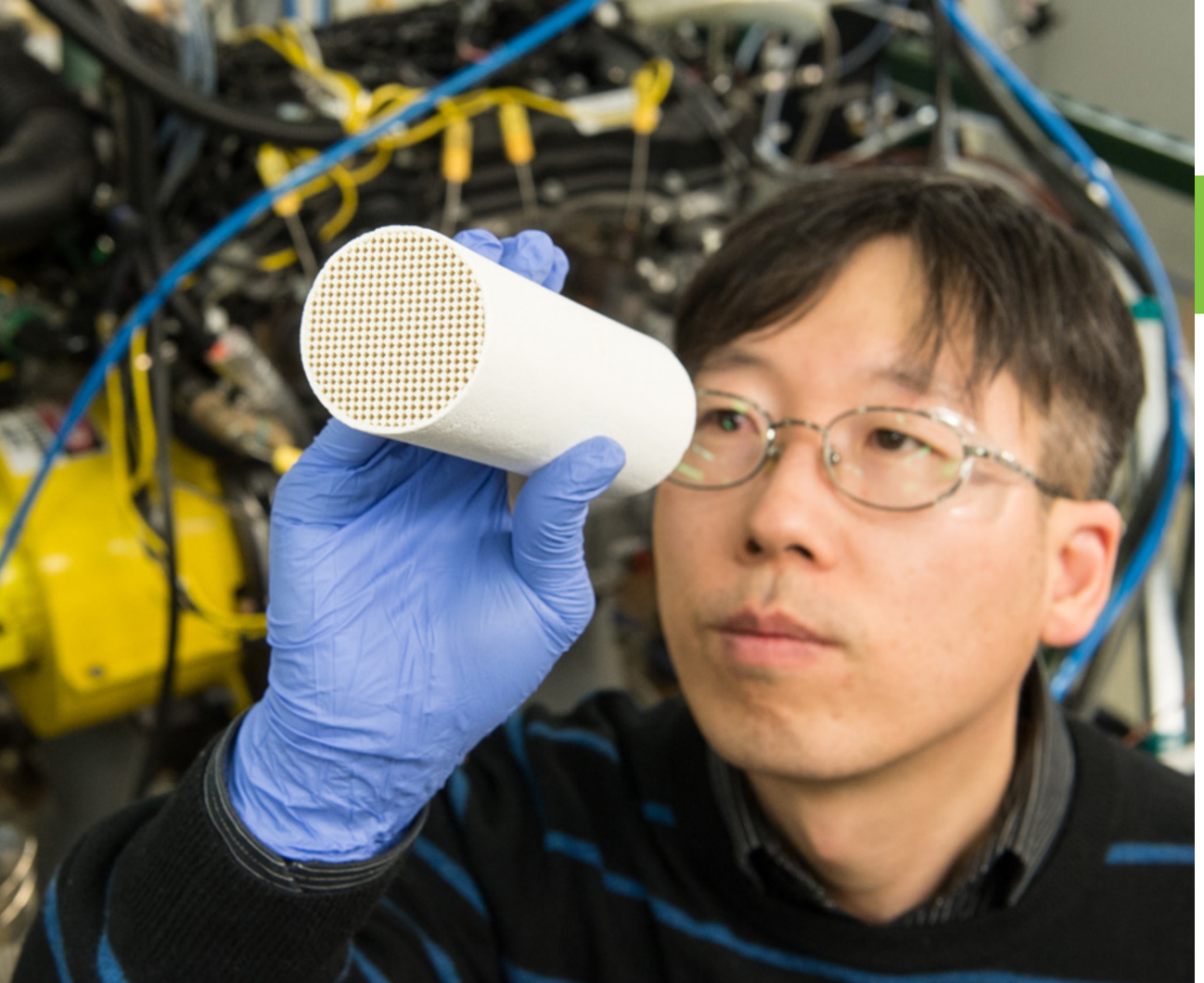
HOW CAN WE MANAGE THE HEAT IN VEHICLE SYSTEMS?

Making vehicle systems more efficient

Argonne is improving vehicle system efficiencies to reduce energy consumption and emissions via innovative heat transfer concepts, simulations and energy storage solutions. A multidisciplinary team uses advanced testing capabilities and simulation tools to address complex challenges. Our research includes:

- Advancing innovative heat transfer technologies for engines, heat exchangers, power electronics modules and waste heat recovery strategies
- Utilizing single-and two-phase heat transfer and evaporative cooling
- Developing applications for thermal energy storage using phase-change materials
- Analyzing vehicle aerodynamics and underhood thermal performance to improve fuel efficiencies
- Evaluating material structure-property relationships for improved thermal and mechanical performance
- Characterizing thermoelectric materials
- Formulating high-performance heat transfer fluids

Thermal system researchers test, simulate and develop tools to better manage heat.

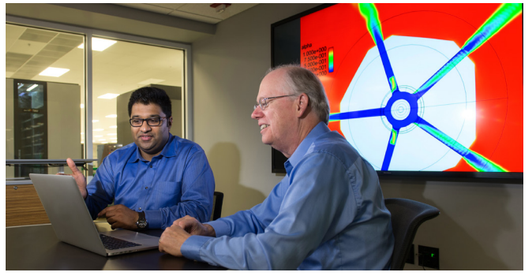


HOW CAN WE IMPROVE INTERNAL COMBUSTION ENGINES?

Maximizing energy-efficient performance

Combustion engines drive a large percentage of our nation's vehicles and generate electrical power for manufacturing facilities. Understanding the science and physics behind how those engines work, and developing approaches to improving them requires unique cross-functional expertise and sophisticated facilities that are available together at Argonne National Laboratory. This work includes:

- Enhancing engine combustion/fuel system three-dimensional computational fluid dynamics modeling
- Performing high-fidelity, three-dimensional, end-to-end, simultaneous combustion engine powertrain and fuel simulation with uncertainty analysis through the Virtual Engine Research Institute and Fuels Initiative (VERIFI)
- Exploring low-temperature combustion systems
- Developing gasoline compression ignition
- Characterizing engine particle emissions and catalysis performance
- Studying fuel properties and related combustion characteristics
- Developing engine emission controls



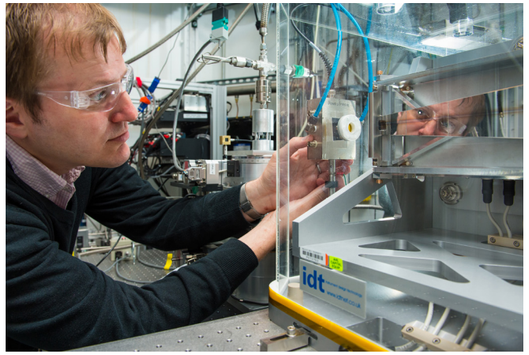
(Above) Using simulation together with experimental data, researchers can predict and refine performance characteristics and develop "virtual engines" to speed the introduction of more fuel-efficient vehicles into the marketplace. (Left) An engineer checks an experimental particulate trap mechanism prior to installing it in a test engine to evaluate its effectiveness in reducing vehicle emissions.

HOW CAN WE LEVERAGE FUELS TO ADVANCE ENGINES?

Co-optimizing engines together with low-carbon fuels for efficiency

Argonne focuses on understanding the interaction between fuels and engines in order to maximize their performance as well as enabling multi-fuel capability. State-of-the-art testing and simulation capabilities (via Argonne's Leadership Computing Facility) provide the basis for these combustion system R&D efforts; Argonne brings to bear its expertise in the areas of combustion chemistry, fuel spray characterization, combustion system design, controls and in-cylinder sensing. A team of experts spanning a range of disciplines including mechanical engineers, physicists, chemists and computer scientists collaborate in the co-development of innovative internal combustion engine concepts and alternative fuels. Our work in this area includes:

- Evaluating technologies for improved fuel efficiency
- Investigating renewable and alternative fuels
- Characterizing engine particle emissions
- Evaluating high-efficiency ignition systems
- Adopting gaseous fuels and syngas fuels
- Characterizing fuel injection and spray
- Designing and optimizing fuel systems
- Modifying fuel injectors for renewable fuels



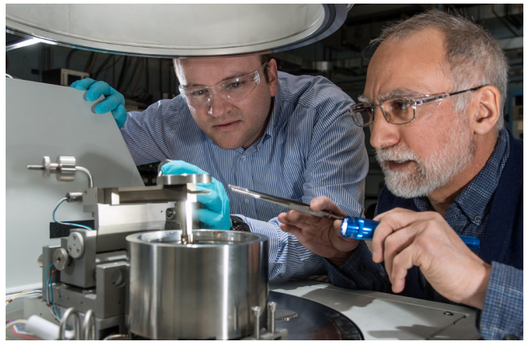
Engine test cells and unique fuel spray analysis capabilities support Argonne engineers in their efforts to advance innovative internal combustion engine concepts and optimized alternative fuels that work well together.

HOW CAN WE REDUCE FRICTION?

Improving energy efficiency and making vehicle components more durable

Argonne works with vehicle and engine manufacturers, oil and additive manufacturers, small businesses, and original equipment manufacturers/suppliers to increase efficiency and component life by understanding how lubricants and additives interact with materials in motion. This work includes:

- Developing and applying lab-engine correlation techniques for cost-effective, advanced lubricant and materials solutions
- Advancing mechanistic models of material wear and failure mode analysis of metal and composite materials components
- Evaluating lubricant systems and additives
- Formulating and applying ultra-hard surface coatings for low friction and wear
- Modeling the impacts of low-friction lubricants and surfaces on energy consumption
- Characterizing materials using high-power electron microscopy and x-rays, and mechanistic models to predict tribofilm formation and changes in surface morphology and mechanical properties



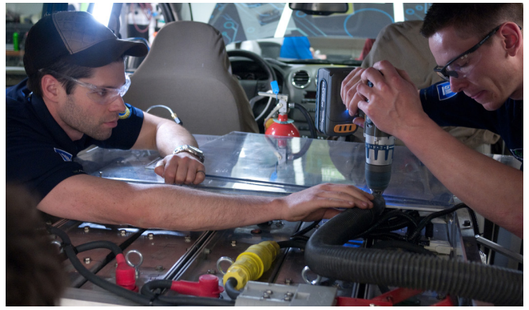
Argonne engineers use testing, synthesis and characterization to understand and improve the interactions between materials in motion.

HOW DO WE PROMOTE THE MISSION?

Supporting the Department of Energy's efforts to educate the public and the next generation of automotive engineers

Through a unique collaboration between government, industry, and academia, Argonne is paving the way for vehicle innovation while creating the skilled workforce needed to bring these technologies to market. For more than 26 years, Argonne has managed the Department of Energy's Advanced Vehicle Technology Competitions (AVTCs), providing an unparalleled educational experience for the next generation of automotive engineers while accelerating the development and demonstration of advanced technologies. Argonne's education and outreach work supports the U.S. Department of Energy's mission by:

- Providing a challenging, real-world training ground for future engineers and business and communications students, resulting in significant technical, educational and promotional benefits to the nation
- Engaging with local communities by informing and educating K-12 youth about the benefits of science, technology, engineering and mathematics education and the larger public about the energy benefits of advanced-technology vehicles
- Offering students opportunities to design and integrate energy storage systems and improve vehicle connectivity and embedded control systems in order to reduce energy consumption, criteria tailpipe emissions and well-to-wheels greenhouse gas emissions on competition vehicles



Advanced Vehicle Technology Competitions managed by Argonne for the U.S. Department of Energy provide valuable experience for student engineers and accelerate the development and demonstration of advanced vehicle technologies.

ABOUT ARGONNE NATIONAL LABORATORY

- U.S. Department of Energy research facility
- Midwest's largest federally funded R&D facility
- Located in Lemont, IL, about 25 miles (40 km) southwest of Chicago, IL (USA)
- Conducts basic and applied research in dozens of fields
- 3,300 employees
- 1,600 scientists and engineers
- Unique suite of leading-edge and rare scientific user facilities

WORKING WITH US

Argonne's Technology Development and Commercialization division works proactively with Argonne research divisions and industry partners to develop commercialization strategies, solve complex problems and introduce advancements into commercial use through licenses and start-ups. Access to Argonne technology, facilities and research assistance is available to industry, universities and other federal agencies through a number of partnership models.

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