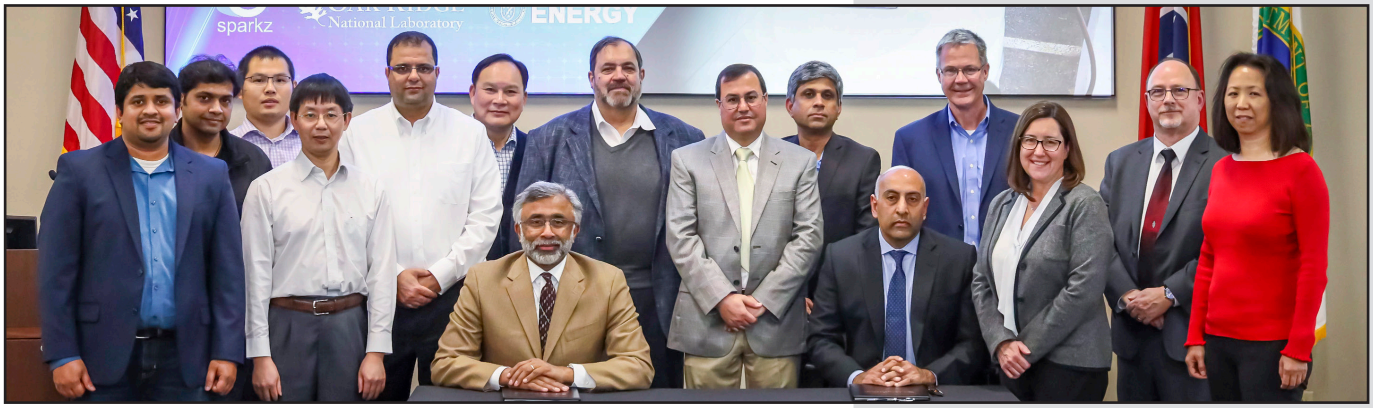
2022 Technology Innovation Program

Oak Ridge National Laboratory

U.S. Department of Energy

The Technology Innovation Program



Delivering new technologies and solutions to industry to help increase the nation's economic competitiveness is an important part of Oak Ridge National Laboratory's (ORNL's) mission. The Technology Innovation Program (TIP) was created to accelerate the commercial adoption of promising ORNL-developed technologies by making targeted investments to increase the technologies' commercial readiness and raise their visibility to prospective partners. TIP is funded by royalties from previously licensed ORNL technologies.

Each year, ORNL scientists and engineers compete to participate in TIP. A panel of laboratory managers and commercial experts selects four to five of the most compelling technologies for a year of research and development (R&D) investment and increased outreach to prospective partners. Toward the end of the year, prospective industry partners are invited to submit applications to commercialize the TIP technologies, and the companies with the most compelling commercialization plans are offered licenses. A portion of TIP teams whose technologies are successfully licensed are competitively awarded additional funding for further R&D to be performed at ORNL in partnership with the licensing companies.

The 2021 cohort of TIP technologies includes:

- ChemSitu Microfluidic Imaging
- Eco-Friendly, High-Lubricity Ionic Liquids as Lubricant Additives for Hydraulics/Hydropower
- Sintered Composite Electrolyte for Lithium Batteries (SINC-lyte)
- Operation Duration Extender for UAV
- CAN-D: Controller Area Network Decoder

Since 2013, ORNL has invested more than $10 million in 44 TIP projects, resulting in 32 commercial licenses and options with partners ranging from Fortune 100 companies to early-stage startups. This brochure provides brief descriptions of the 2021 TIP technologies, introductions to the inventors behind the innovations, and contact information for the technology transfer managers responsible for licensing.

About Oak Ridge National Laboratory

ORNL is the largest US Department of Energy (DOE) science and energy laboratory, conducting basic and applied research to deliver transformative solutions to compelling problems in energy and security.

ORNL's diverse capabilities span a broad range of scientific and engineering disciplines, enabling the laboratory to explore fundamental science challenges and to carry out the research needed to accelerate the delivery of solutions to the marketplace. With an annual budget of $2 billion, ORNL is home to more than 5,800 research and operations staff. ORNL's diverse capabilities span a broad range of scientific and engineering disciplines, enabling the laboratory to explore fundamental science challenges and to carry out the research needed to accelerate the delivery of solutions to the marketplace. ORNL supports DOE's national missions of scientific discovery, clean energy, and national security through leadership in four major areas of science and technology: neutrons, computing, materials, and nuclear technologies.

Over the past decade, ORNL researchers have produced a portfolio of more than 900 US patents, and the laboratory currently has more than 150 active technology licenses.

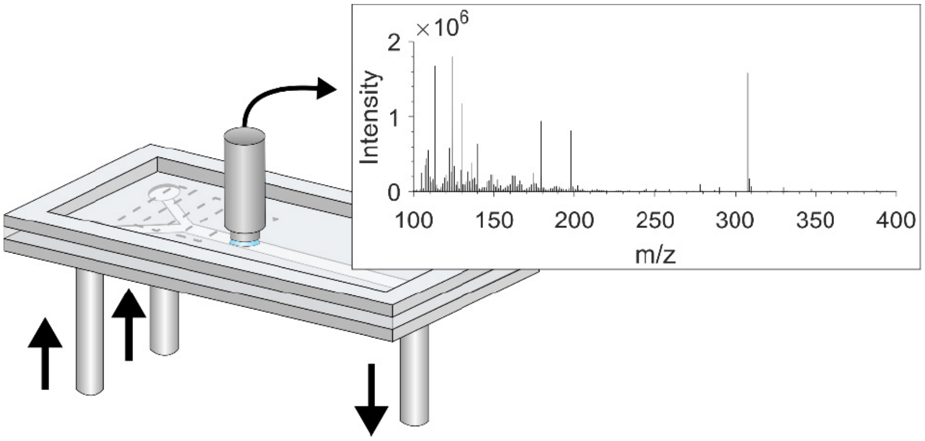
For more information, please visit our webpage at www.ornl.gov.

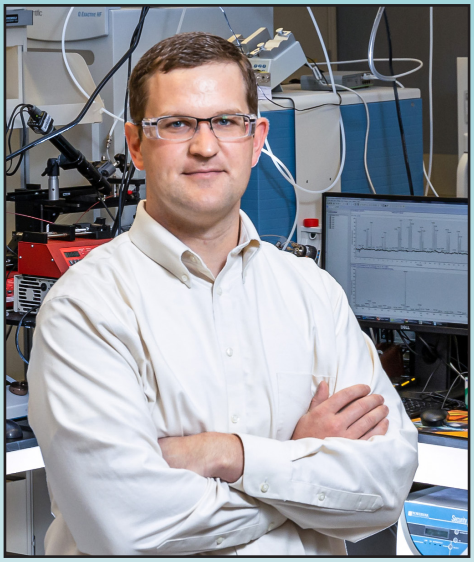
ChemSitu Microfluidic Imaging

Problem: Biology-on-a-chip devices are increasingly being used to mimic real-world biological systems with reduced cost and increased experimental control. However, current technologies provide limited chemical information, especially for small molecules, and often destroy the device in the process. Given the chemically complex and dynamic nature of biological lab-on-a-chip devices, new technologies are needed to enable in situ mass spectrometric characterization of components within microfluidic devices.

Solution: The ChemSitu microfluidic technology provides a new analytical capability to solve the problem of elucidating the complex chemistry occurring within microfluidic devices. This technology uses the combination of a porous membrane-microfluidic chip and a liquid microjunction-surface sampling probe with mass spectrometry to enable broad chemical characterization and chemical imaging of contents of microfluidic chips in situ, at any point within the device and without destroying the device in the process. Uniquely, the porous membrane layer on the device allows normal microfluidic operation, but when in contact with the sampling probe, it allows extraction of nanoliter volumes of liquid through the porous membrane at that location. The extracted liquid is then chemically characterized by mass spectrometry.

Impact: Knowledge of the chemical constituents (e.g., lipids, metabolites, proteins) inside microfluidic devices is valuable for understanding cell function and the mechanisms of molecular transport in living systems. Society and industry rely extensively on our chemical understanding of living systems to diagnose disease and to develop new and more effective therapeutics. Industries such as cancer diagnosis and pharmacokinetics need to evaluate therapeutic effectiveness in living systems, and biology-on-a-chip devices with a broad chemical analysis capability represent an ethical, cost-effective means to assess therapeutics. The collective features of the ChemSitu microfluidic technology make it more versatile than any other chemical analysis capability in the microfluidic device market, opening the door to numerous applications that require mass spectrometric chemical analysis of such devices.





John "Jack" F. Cahill, PhD
Chemical Sciences Directorate

Dr. Cahill is an associate research scientist in the Biosciences Division. His research focuses on the development and application of novel surface sampling and high-throughput mass spectrometry techniques to chemically characterize tissues, plant systems, bacterial colonies, and materials at small spatial scales. Dr. Cahill's work on elucidating metabolic chemistry in plant–microbial communities led to the development of the ChemSitu technology.

Intellectual Property

"Porous Membrane Enabled Mass Spectrometry Characterization of Microfluidic Devices," Invention Ref. No. 201904446

"Laser Sampling Liquid Microjunction Droplet Probe," Invention Reference Number 201904465; US Patent Application 16/797,712, February 21, 2020; US Patent Application 17/514,304, October 29, 2021

Publications

- J. F. Cahill, M. Khalid, S. T. Retterer, C. L. Walton, and V. Kertesz, "In Situ Chemical Monitoring and Imaging of Contents within Microfluidic Devices Having a Porous Membrane Wall Using Liquid Microjunction Surface Sampling Probe Mass Spectrometry," *J. Am. Soc. Mass Spectrom.*, **2020,** 31 (4), 832–839. DOI: 10.1021/jasms.9b00093.

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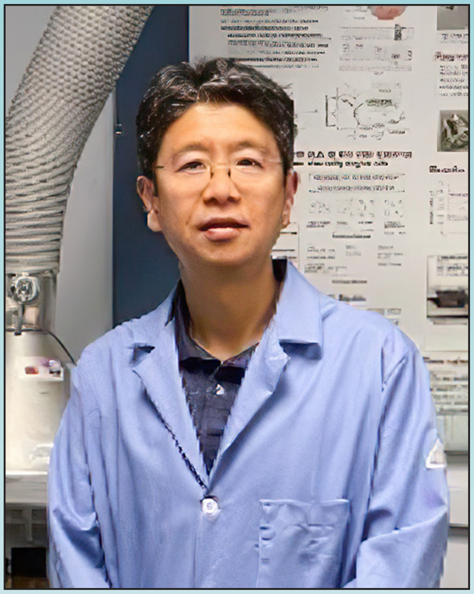

Jun Qu, PhD
Physical Sciences Directorate

Dr. Qu currently is a distinguished R&D staff scientist and group leader in the Materials Science and Technology Division. His research interests include advanced lubrication, surface engineering, materials tribology, nanostructured materials, and manufacturing. He holds 8 US patents and has published 3 book chapters and 110+ peer-reviewed journal papers with 5,500+ citations. Dr. Qu has received multiple national awards including the 2020 UT-Battelle Distinguished Researcher Award, a 2014 R&D 100 Award, and a 2014 DOE Vehicle Technologies Office R&D Award. He is a Fellow of the Society of Tribologists and Lubrication Engineers and serves on the Board of Directors for Wear of Materials.

Intellectual Property

"Eco-Friendly Ionic Liquids as Lubricant Additives," Invention Reference 201904491; PCT Application PCT/US2021/043260, July 27, 2021

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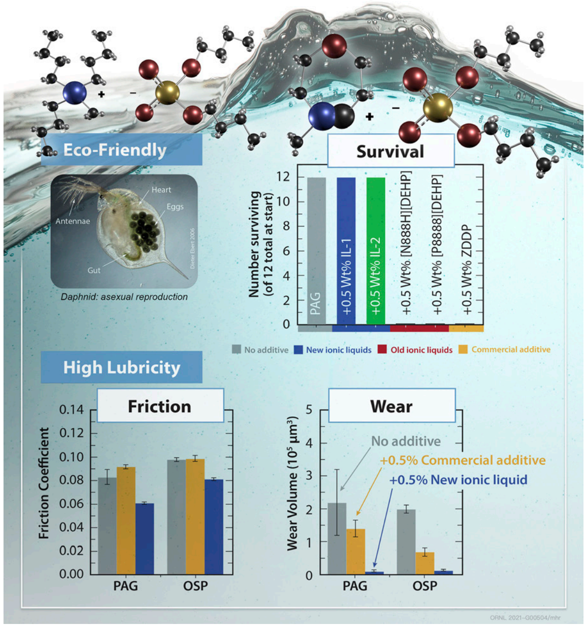
Eco-Friendly, High-Lubricity Ionic Liquids as Lubricant Additives for Hydraulics/Hydropower

Problem: Nearly half of all lubricating fluids used in industry—37–61 million liters per year—end up in the environment due to leaks or discharges, with the major sources including hydraulic fluids and hydropower turbomachinery oils. Responses to lubricant leaks and spills cost more than $300 million annually. The need for moving toward eco-friendly lubricants is increasingly recognized. While multiple groups of eco-friendly base fluids have been approved by the US Environmental Protection Agency (EPA), the market lacks anti-wear additives that are both nontoxic and highly lubricative.

Solution: ORNL is a global leader in R&D of ionic liquids (ILs) for lubrication applications, having received a 2014 R&D 100 Award for previous development of ILs for automotive engine oils. The award-winning ORNL team recently developed new groups of eco-friendly high-lubricity ILs as lubricant additives for hydraulic and hydropower lubrication. They are thermally stable, nonflammable, noncorrosive, miscible, and chemically compatible with the EPA-approved eco-friendly base oils. In EPA standard chronic aquatic toxicity tests, the model organism, *Daphnia*, had survival rates of 90%–100% when exposed to selected candidate ILs, but they were all killed by the baseline commercial anti-wear additive. In lubricity evaluation, the new ILs outperformed the commercial baseline by reducing friction by an additional 20%–30% and reducing wear by an additional 80%–90%.

Impact: This new class of eco-friendly IL lubricant additives is expected to significantly improve equipment efficiency, durability, and reliability while reducing the environmental impact of lubricant spills or discharges. This eco-friendly IL additives technology is low-cost and production-scalable and can be applied to many industrial sectors including automotive, hydraulics, hydropower, and metalworking. The size of the global eco-friendly lubricants market was $2.7 billion in 2018 and is expected to have a compound annual growth rate of 5.9%—twice that of the overall global lubricants market.

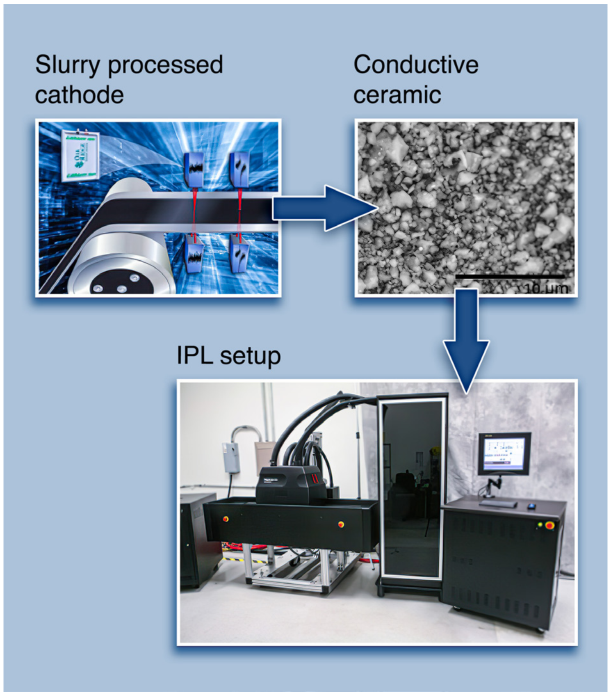


Sintered Composite Electrolyte for Lithium Batteries (SINC-lyte)

Problem: While solid-state lithium batteries promise transformation to significantly higher energy density and inherently safe energy storage systems, their development presents significant challenges. The major component of these batteries is the solid electrolyte, which blocks lithium dendrites, conducts lithium ions, and can be easily integrated into the battery cell structure. As of today, there is no single electrolyte that possesses all three properties.

Solution: Sintered Composite Electrolyte for Lithium Batteries (SINC-lyte) introduces a composite electrolyte that addresses lithium battery challenges by combining properties of several materials. Ion-conducting ceramic is partially sintered to provide a conductive percolative pathway and to serve as a skeleton that is subsequently back-filled with a polymer electrolyte. SINC-lyte can be tape-cast on top of the conventional battery cathode and then partially sintered using pulse light processing. In this way, SINC-lyte is integrated with the cathode, simplifying the battery manufacturing process. Because electrolyte is cast as a thin layer from colloidal suspension, the structure has sufficient flexibility for roll-to-roll processing.

Impact: Robust solid electrolyte is the key element of a solid-state battery with a metallic anode. As of today, there is no example of the integration of solid ceramic electrolyte into a battery, beyond thin-film batteries. SINC-lyte provides a robust composite electrolyte that can be co-manufactured with the cathode in a roll-to-roll manner. This will significantly impact solid-state lithium battery technology maturation, with long-term projected benefits of higher safety and structural rigidity compared to today's liquid electrolyte batteries. Batteries containing SINC-lyte, therefore, can be used as structurally integrated energy storage, making them ideal for applications such as drones and other electric aircraft.



Sergiy Kalnaus, PhD
Computing and Computational Sciences Directorate

Dr. Kalnaus is a computational scientist in the Computational Sciences and Engineering Division. He holds doctoral and master's degrees in mechanical engineering from the University of Nevada and Kharkiv Polytechnic (Ukraine), respectively. His work involves both computational modeling and experiments. His research interests include mechanics of materials for energy storage, crashworthiness of batteries in electric vehicles, and solid-state batteries. He holds four patents. He received a 2017 R&D 100 award as a part of the team that developed impact-resistant electrolyte for lithium-ion batteries.

Intellectual Property

"Thin Solid Composite Electrolyte with Zero Interparticle Resistance," Invention Reference Number 201904372; US Patent Application 17/497,023, October 8, 2021

Publications

- M. Palmer, S. Kalnaus, M. B. Dixit, A. S. Westover, K. B. Hatzell, N. J. Dudney, X. C. Chen, "A Three-dimensional Interconnected Polymer/Ceramic Composite as a Thin Film Solid Electrolyte," *Energy Storage Mat.* 26, **2020**, 242–249.

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Veda Prakash Galigekere, PhD
Energy Science and Technology Directorate

Dr. Galigekere is a group leader in the Building and Transportation Sciences Division. His research focuses on high-power, dynamic, and fast-charging wireless electric vehicle charging and wireless power transfer. Research led by Dr. Galigekere on wireless power transfer and fast-charging technologies led to Operation Duration Extender for UAVs. He holds two patents and six invention disclosures. Dr. Galigekere is a Senior Member of Institute of Electrical and Electronics Engineers and has served as session chair for numerous conferences.

Intellectual Property

"AC/AC 50Hz/60Hz Wireless Energy Transfer, Hybrid Low and High Frequency Converter, Wireless Battery Charger, Contactless Power Transfer Concept for EV On-Board Battery Charger," Invention Reference Number 201904459; US Patent Application 17/127,197, December 18, 2020

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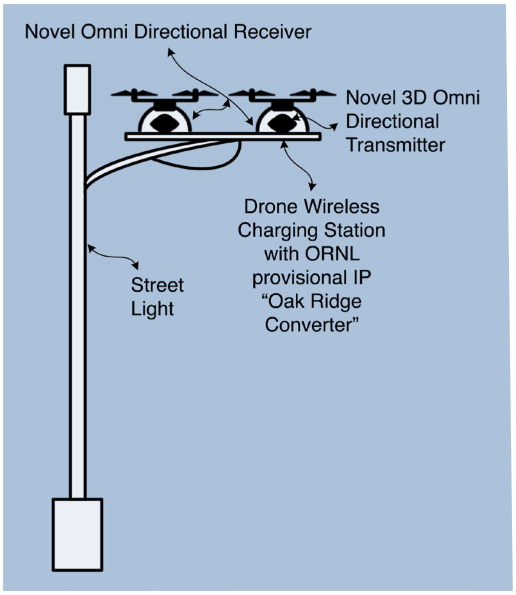
Operation Duration Extender for UAV

Problem: A critical challenge facing current state-of-the art electric unmanned aerial vehicles (UAVs) is the low energy density of batteries. As battery power is consumed, drone efficiency decreases because there is no corresponding decrease in mass, as would happen in fueled propulsion. UAV flight times are typically limited to 5–15 minutes with distance limited to just a few miles. Consequently, limited flight range is a critical challenge faced by several business sectors for which drones could deliver significant benefits.

Solution: Wireless charging technology is well suited for UAV charging applications because electrical contact is unneeded; therefore, it is neither hampered by environmental factors nor dependent on precision-based physical contact mechanisms. A practicable wireless power transfer (WPT) system tailored to extend UAV flight range will enhance the applicability of UAVs for numerous applications.

This technology uses optimized WPT systems suitable to be placed on transformers and poles with clear airways. UAVs adapted for the technology will have a compatible, efficient, and compact WPT receiver system that can fast-charge the onboard battery by merely hovering over or landing on the transmission pad. The solution leverages two ORNL technologies: state-of-the-art coupler architectures including the novel polyphase WPT system to reduce weight, volume, and cost of the overall charging system, and a novel proprietary WPT converter. The Oak Ridge Converter, invented by Erdem Asa and based on validated wireless electric vehicle charging technology, reduces weight, volume, and cost by eliminating the need for an additional stage of power electronics to interface with the electric grid. The 1 kW high-frequency power electronics and coupler design were led by Lincoln Xue and Mostak Mohammad, respectively. The system-level integration was overseen by Omer Onar.

Impact: The ability to recharge UAV drones inflight will be key to widespread adoption. This technology offers a robust and reliable system that will increase flight time for UAVs. Improved flight times and recharging capabilities will make UAV-driven package delivery a viable option, in addition to offering more efficient operation and time and energy savings to operator companies. UAV adoption for delivery services could also lead to significant reductions in greenhouse gas emissions, lower shipping costs, and growth of new services such as touchless delivery.



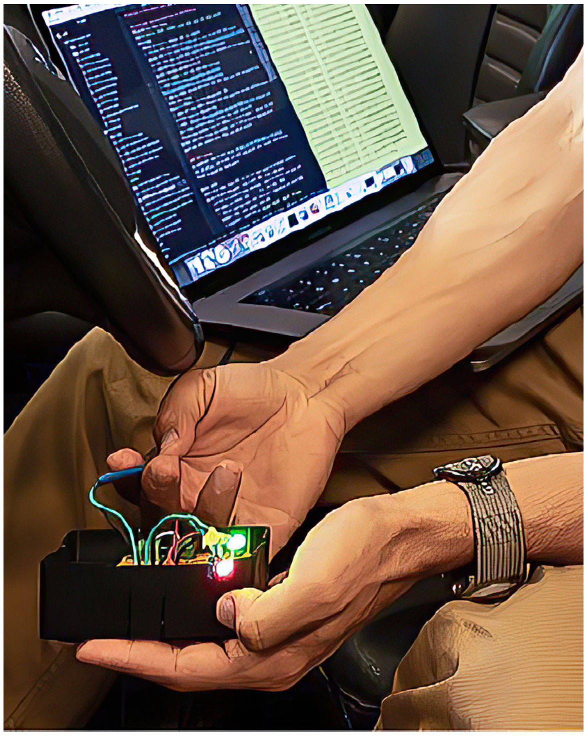
Publications

- J. Pries, V. P. Galigekere, O. C. Onar, and G. J. Su, "A 50kW Three–Phase Wireless Power Transfer System Using Bipolar Windings and Series Resonant Networks for Rotating Magnetic Fields," *IEEE Trans. Power Electr.*, 2020, 35 (5), 4500–4517. DOI: 10.1109/TPEL.2019.2942065.
- E. Asa, J. Pries, V. Galigekere, S. Mukherjee, O. C. Onar, G. J. Su, and B. Ozpineci, "A Novel AC to AC Wireless Power Transfer System for EV Charging Applications," presented at the IEEE Applied Power Electronics Conference and Exposition, New Orleans, LA, March 2020.
- E. Asa, K. Colak, O. C. Onar, D. Czarkowski, and B. Ozpineci, "Analysis of Double-Output CLL Resonant Converter for All-Electric UAV Applications," presented at the IEEE Energy Conversion Congress and Exposition, Detroit, MI, October 2020.

CAN-D: Controller Area Network Decoder

Problem: Vehicles have essentially become computer networks, with the efficiency, performance, safety, and security of the vehicle dependent on communication among its parts. The various components in a car are connected using a specialized real-time communication bus called Controller Area Network (CAN). Monitoring and improving the efficiency, performance, safety, and security of vehicles depends on understanding traffic on the CAN bus, but each manufacturer, each new model, and each additional feature added to the vehicle changes the structure of messages on the CAN bus.

Solution: ORNL's Controller Area Network Decoder (CAN-D) technology applies machine learning to quickly understand the structure of messages on the CAN bus to enable downstream technologies to understand them. This innovation creates an ecosystem of monitoring that allows for improvement of vehicle performance, efficiency, safety, and security. CAN-D is designed to be used in vehicles across manufacturers.



Impact: CAN-D enables an ecosystem of technologies that interact with each other on the CAN bus in real time, creating opportunities for enhanced performance, efficiency, safety, and security of vehicles on the road regardless of manufacturer.

Stacy Prowell, PhD
National Security Sciences Directorate

Dr. Prowell is a senior cyber security scientist in the Cyber Resilience and Intelligence Division. He also serves as the program manager for ORNL's Cybersecurity for Energy Delivery Systems Program. His research focuses on exploiting physical sensors and properties to detect and prevent intrusion and on deep semantic analysis of compiled software. Dr. Prowell's work on a system for deep analysis of compiled software led to development of the Hyperion system, which received a 2015 R&D 100 award and two awards for technology transfer.

Intellectual Property

"ACTT: Automotive Controller Area Network (CAN) Tokenization and Translation," Invention Reference Number 201804299; US Patent Application 17/117,535, December 10, 2020; non-provisional patent application in preparation

"Universally Applicable Signal-Based Controller Area Network (CAN) Intrusion Detection System," Invention Reference Number 202004640; US Patent Application Number 63/178,586, April 23, 2021; non-provisional patent application in preparation

Publications

- M. E. Verma, R. A. Bridges, J. J. Sosnowski, S. C. Hollifield, and M. D. Iannacone, "CAN-D: A Modular Four-Step Pipeline for Comprehensively Decoding Controller Area Network Data," *IEEE Trans. Veh. Technol.*, 2021. DOI: 10.1109/TVT.2021.3092354.

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