FALL 2024

40 YEARS OF

TECHNOLOGY TODAY®

SOUTHWEST RESEARCH INSTITUTE®

This 1949 Institute brochure discussed SwRI's Fire Technology program, including aims to advance the scientific understanding of the chemical and physical aspects of fire, combustion and explosions. See story about SwRI's Fire Technology program on p. 2.

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FIRE TECHNOLOGY

A Division of SOUTHWEST RESEARCH INSTITUTE

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TECHNOLOGY TODAY

CONTENTS

ON THE COVER

103383

Southwest Research Institute developed a portable technique for destroying chemical warfare agents (CWAs) found in the field. The "fire whirl" technique draws in air along with the chemical agents, allowing safe, complete combustion of the CWAs.

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IN THIS ISSUE

Southwest Research Institute was founded in 1947 with some pretty lofty goals, which ultimately led to our mission statement: Benefitting government, industry and the public through innovative science and technology. This issue of Technology Today features programs demonstrating how we continue to fulfill that multifaceted mission.

The cover story celebrates 75 years of fire technology at SwRI. Just a couple of years after the Institute began, then-President Harold Vagtborg learned of the death and devastation caused by fire and established the first such fire research and development program at any similar organization. Over the years, SwRI staff have played, and continue to play, a key role in developing the standards and tests that certify the fire resistance and material flammability of transportation technology, construction materials and consumer products as well as fire extinguishing agents and systems. Seventy-five years of fire testing has improved safety for all.

Today, extreme weather associated with climate change is causing devastation across the country, bringing into sharp focus international goals of net-zero carbon emissions by 2050. While SwRI addresses this from many angles, this issue features a unique heavy-duty tractor-trailer demonstration vehicle using carbon-free hydrogen in an internal combustion engine. Developed through a collaborative consortium, this vehicle provides an alternative to battery-electric vehicles and fuel cells, offering a complementary and scalable solution, particularly for heavy-duty applications.

The final feature shows how Institute engineers are combining ENABLE™ markerless motion capture technology with artificial intelligence to enhance human performance. SwRI has used this user-friendly and biomechanically accurate technology to capture and quantify human motion in applications to enhance military medical training, predict injury risks in specialized miliary training exercises, enhance rehabilitation efforts, improve performance and decrease risks for athletes and more.

These three diverse programs all have one thing in common — on some level they all use innovative science and technology to benefit government, industry and the public.

Sincerely,

Walter D. Downing, P.E.
Executive Vice President/COO


75
YEARS

OF FIRE TECHNOLOGY

By Karen Carpenter

Over the last decade, fire deaths have increased by 32 percent following three decades of relative decline. One contributing factor may be the rise in wildfires, which are escalating in both frequency and ferocity. Four of the 10 deadliest wildfires in U.S. history, including the devasting 2023 Lahaina Town fire that killed 98 people on the Hawaiian island of Maui, happened in the last decade while all other fires listed occurred prior to 1933.

Another contributing factor could be the increased use of synthetic materials, which burn hotter and produce more toxic gases than fires from natural materials such as wood, leather, cotton and wool. Today's open-concept floor plans allow fire to spread more readily and are more dangerous from a fire-safety standpoint when compared with the compartmentalized homes built prior to the 1950s.

Even with a flurry of technological advancements, including computer fire modeling, improved building materials and standardized testing methods, fire remains a threat to human life and property. With a shift toward new technologies and energy sources such as hydrogen, compressed natural gas and lithium-ion batteries, Southwest Research Institute's advanced fire technology research is as relevant today as it was 75 years ago.

To combat fires involving aircraft and railroad cars made of magnesium alloys, SwRI's fire technology engineers experimented with various combinations to find the best formula to use as an extinguishing agent.

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THE SPARK

In 1949, SwRI established a fire technology program, currently a department within the Chemistry and Chemical Engineering Division, in the interest of public welfare after a report showed a serious need for such services. At that time, more than 10,000 people died annually in fires, with property losses exceeding $700 million. No other industrial research institute had a focused fire research program, in a time before standards and regulations provided basic fire protections for the public.

SwRI's first president, Harold Vagtborg, wrote, "In establishing the division, the trustees and staff of the Institute hope to contribute materially toward reducing the appalling loss of human life and suffering, and the property destruction caused by fire — a toll which continues to mount steadily year after year."

Fire department chiefs, industry leaders and government officials from across the country signed on to help the efforts by serving on a board of counsellors for the new division.

SwRI developed and built this fire extinguisher, designed to function in zero gravity, for the Apollo Moon missions. Engineers later modified the device for Skylab.

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The newly formed program had several mandates. First, SwRI's new fire technology program needed to advance the fundamental understanding of the chemical and physical aspects of fire, combustion and explosions.

Based on this new knowledge, the team was charged with helping industry develop better firefighting equipment and chemical extinguishing agents as well as fire protection technology, to fireproof and create flame-resistant materials.

SwRI provided fire technology services to industries with fire or explosion hazards as well as equipment manufacturers interested in developing more effective firefighting or fire-prevention equipment. Fire technologists sought to help manufacturers develop fireproof and fire-resistant materials for the consumer goods, transportation and construction industries.

The post-World War II era gave rise to new technologies and materials like alloys, plastics and other synthetic fabrics. One early

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The National Fire Protection Association (NFPA) is a U.S.-based, international nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. As of 2023, the NFPA cites 50,000 members and 9,000 volunteers working with the organization through its 250 technical committees.

DETAIL

project experimented with a variety of formulations to quickly combat fires involving magnesium alloys, used in the construction of railroad cars and aircraft. New materials all possessed unique fire characteristics that required evaluation.

SETTING STANDARDS

Fast forward 20 years to the 1970s, and fire deaths often still exceeded 6,000 per year. In 1973, the U.S. government released "America Burning," a comprehensive report outlining the threat posed by fire in the U.S. with recommendations to improve public safety. The following year Congress established the U.S. Fire Administration to work with national fire service organizations like SwRI to develop comprehensive and actionable solutions to fire-related challenges.

The list of building codes, transportation material guidelines and product fire standards grew in the years that followed the report. New and standardized testing methods, along with the development

Using the only indoor jet fire test facility in the world, SwRI evaluates different passive fire protection systems, pipeline components and various building materials for their ability to maintain integrity in extreme fire conditions.

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SwRI conducts fire detection and suppression studies in its large-scale warehouse/sprinkler facility.

of computer fire modeling, gave rise to more accurate measurements and improved understanding of fire behavior.

SwRI fire technology staff played a key role in standards development and continue to contribute, serving on technical committees to develop and revise a range of standards including ASTM and National Fire Protection Association codes. For instance, SwRI conducted the preliminary research behind the test setup and parameters for jet fire resistance testing. These ISO and Offshore Technology Institute standards qualify passive fire protection systems for tanks, pipes and other equipment associated with flammable liquid storage and transport. Fire technology specialists also contributed to intermediate-scale multistory building fire performance and generator standards and have published several SwRI test procedures.

Cone calorimetry, jet fire, furnace and most recently pool or bonfire testing became the standard for evaluating materials, passive fire-protection products and hydrogen storage tanks, respectively. SwRI's fire technology engineers use these techniques to evaluate and develop safer building materials, wire cable coatings, interior finish materials, furnishings and more. SwRI evaluates materials on a microgram scale all the way up to an entire room or warehouse scenario. High-bay facilities and a 1,600-acre remote site support fire research and testing for the road, rail, marine and air transportation industries.

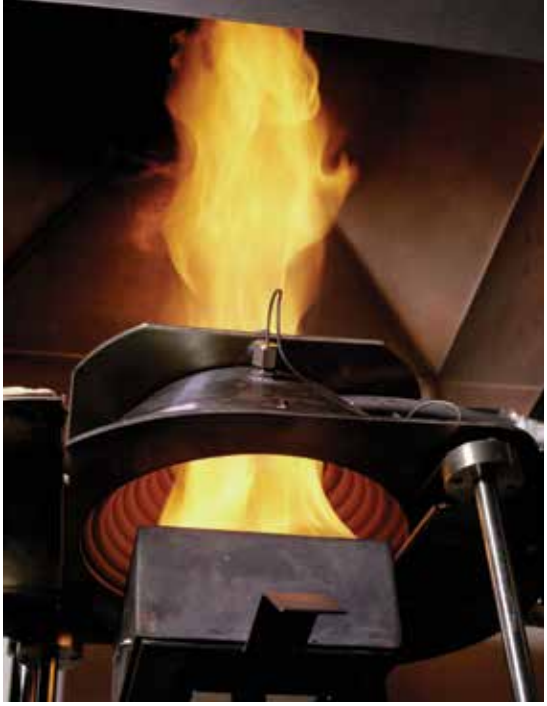
SwRI Institute Engineer Dr. Marc Janssens was named a "DiNenno Prize Laureate" for his role in the widespread adoption of the cone calorimeter.

DETAIL

For instance, SwRI is a leader in fire resistance and material flammability testing for compliance with the International Maritime Organization (IMO) Resolutions. SwRI is also recognized as an

SwRI's Fire Technology Department is ISO 9001:2015 registered by NSF International Strategic Registration Ltd. and accredited to ISO/IEC 17025 and 17020 by the International Accreditation Service Inc. Also, SwRI is a Nationally Recognized Testing Laboratory (NRTL) by the Occupational Safety and Health Administration (OSHA).

DETAIL



Cone calorimetry efficiently characterizes the heat release and material flammability of materials, burning sample coupons at laboratory scales. The device received the 2024 Philip J. DiNenno Prize for its lasting impact on fire safety.

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SwRI fire technology specialists worked with the Department of Transportation to improve the fire safety of motor coach class vehicles, developing tests to evaluate automated fire extinguishers for wheel wells and engine compartments.

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independent testing laboratory and quality assurance agency by the U.S. Coast Guard, Det Norske Veritas, Lloyd's Register of Shipping, the American Bureau of Shipping, and other classification societies.

Today SwRI conducts more than 225 standard tests recognized by more than a dozen accreditation entities ranging from international, national, state and municipal agencies and organizations, such as ASTM International, the National Fire Protection Association, U.S. Department of Defense, CAL FIRE and the City of New York.

FIRE TECHNOLOGY TODAY

Today, the Institute operates one of the world's largest and oldest fire research facilities, with more than 50,000 square feet of offices, laboratories and high bays, offering standard, nonstandard and custom fire testing research and development to support government and industry clients. Engineers study fire dynamics, developing unique engineering and scientific resources for the resolution of fire and explosion safety issues, serving both government and commercial clients in the construction, transportation, chemical and petrochemical, nuclear, and telecommunications industries. High-quality and timely services evaluate and mitigate clients' fire- and explosion-related hazards.

With this expertise, SwRI offers Listing, Labeling and Follow-Up Inspection Services to ensure that products, materials and assemblies meet specified requirements and performance. Inspectors select material samples from manufacturers, which are tracked and documented throughout the accredited testing process.

Then SwRI develops a follow-up procedure (FUP) document describing the product, production process and aspects that could change the quality and performance of the product. Visits to the manufacturing facilities verify the accuracy of the finalized FUP document, which authorizes the use of SwRI's label and addition to SwRI's Directory of Listed Products. Follow-up field plant inspections comply with the frequency recommended by the approving standard body.

To verify resistance to fire and explosion, fire specialists expose fully charged electric vehicle batteries to gasoline pool fires to assure they meet safety standards.

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Directories include products for the marine and construction industries, aboveground storage tanks for flammable liquids, fire extinguishing agents and systems, and other listed products.

TOMORROW'S TECHNOLOGIES

Today, SwRI builds on its legacy as a pioneer in fire technology, applying its expertise in standardized testing to emerging technologies ranging from deep sea to deep space applications. The Institute's multidisciplinary approach to research and development and fire tech staff's decades of experience serve as a resource for government and industry clients. Not confined to one industry or market segment, fire technology research is critical for everything from spaceflight to offshore drilling.

As innovation advances, safety standards and testing techniques often lag. In those cases, SwRI develops customized approaches to evaluate the fire safety of new products. Our expert engineers help reduce the gap between innovation and safety by conducting unique, nonstandard fire tests that lay the groundwork for tomorrow's standards.

In these scenarios, SwRI's experienced fire research specialists consider what could happen and the potential ramifications if it does. Examining these conditions through the scientific process, our staff designs tests to identify and mitigate potential problems,

SwRI offers environmentally friendly fire testing and research, with all Fire Technology facilities connected to pollution abatement systems. SwRI now burns materials without releasing visible smoke or toxic gases into the environment.

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Vehicle fire deaths reached 700 in 2022.

DETAIL

SwRI upgraded its Steiner fire testing tunnel with new pollution abatement technology as part of an extensive environmental upgrade.

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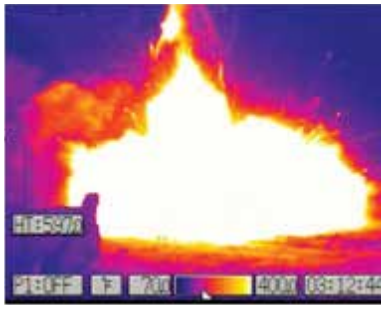
helping government and commercial clients release safer materials, products and technologies.

For instance, as battery electric vehicles become increasingly popular, the likelihood of overheating and catching fire increases if they are damaged or improperly used, charged or stored. The European ECE R100 test for rechargeable electric car batteries became mandatory in 2016. The standard requires exposing a fully charged electric vehicle battery to a gasoline pool fire. Using sensors, engineers measure temperatures up to 800°C during the two-minute pass or fail test. The battery must show enough fire resistance to allow a driver and passengers to escape in the event of fire.

Recently, SwRI engineers helped evaluate the performance of an enclosure system designed to contain a battery electric vehicle fire and prevent spreading. Engineers initiated thermal runaway, a chemical reaction that leads to an out-of-control fire, by exposing the battery to a heat source. The team monitored the ensuing fire from a safe location, capturing video footage while collecting corresponding temperature and air quality data. The interior wall peaked at nearly 2,000°F while the exterior wall remained relatively cooler at just over 350°F. The customized experiment provided the client with key data about their product's effectiveness, where no standard exists.



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From a 1,600-acre remote location, SwRI evaluates compressed hydrogen cylinders installed in vehicles to understand the explosion hazards. Engineers collect data in the infrared to characterize catastrophic failures.

With 40 million electric and hybrid vehicles on the road today, the potential for a fire involving vehicles with different fuel sources increases. As the push for alternative fuel sources to gasoline and diesel — including compressed natural gas and hydrogen — will add another layer of complexity to the question of fire safety on America's roads.

COOL FACTOR

Conducting a full-scale fire test is an awe-inducing feat of engineering, requiring planning from purchasing materials to burn to experiment setup, cleanup and reporting. SwRI manages hundreds of fire tech projects each year and pollution abatement and wastewater collection systems added over the last 15 years minimize environmental effects.

Fire is fascinating. However, fire research is more than just cool — it's essential for advancing public safety. Great strides have been made to reduce fire deaths and to improve fire safety over the last 75 years. However, in 2022 a staggering 3,790 deaths were still attributed to fire, and more than 13,250 people suffered fire-related injuries. As materials and technologies evolve, SwRI must advance fire testing methods. By helping to validate the safety of cutting-edge technology, the Fire Technology Department truly embodies SwRI's mission of using science and technology for the betterment of humankind.

Questions about this article? Contact Karen Carpenter at (210) 522-3718 or karen.carpenter@swri.org

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Karen Carpenter, P.E., started her Institute career in Fire Tech in 2003. She is now the department director, overseeing standard, nonstandard, and large- and small-scale fire performance evaluations.

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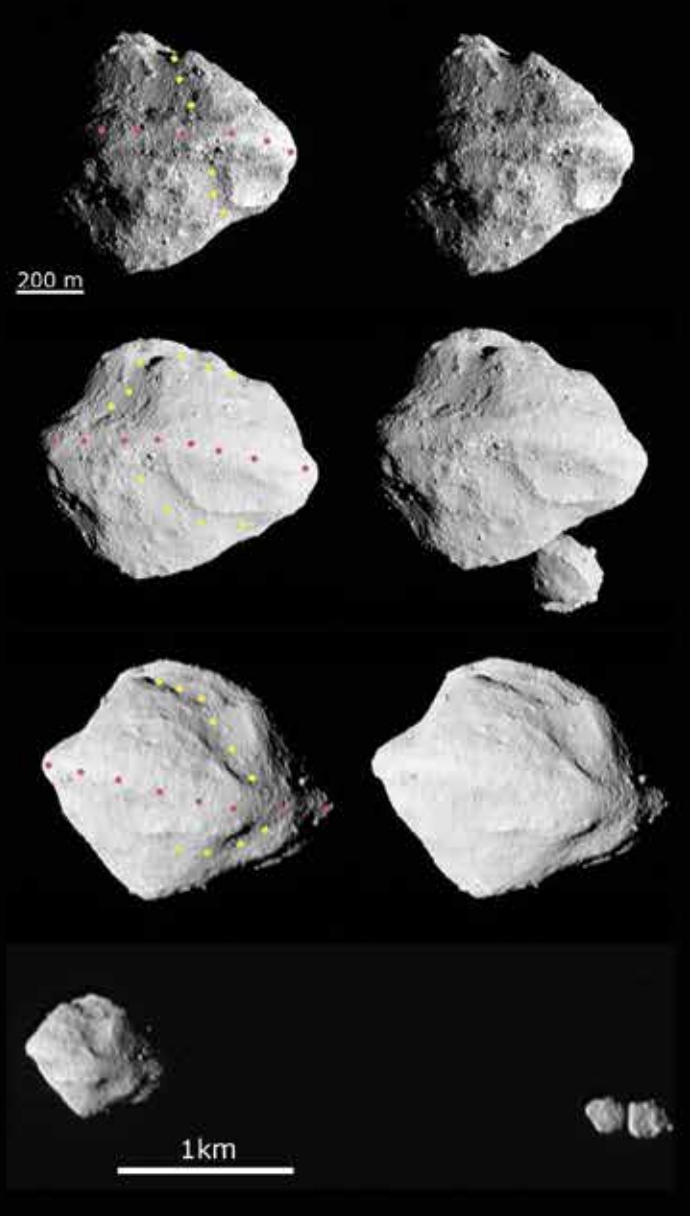
Lucy Makes First Flyby



As NASA's Lucy spacecraft flew past the asteroid Dinkinesh, its L'LORRI instrument produced stereographic images of the Nov. 1, 2023, encounter. The SwRI-led science team analyzed processed images, identifying a trough (yellow dots) and ridge (rose dots) on its surface. The final panel shows a side view of Dinkinesh and its satellite Selam taken a few minutes after closest approach.

IMAGE COURTESY NASA/SwRI/JOHNS HOPKINS APL/NOIRLAB 103400

When NASA's Lucy spacecraft flew past the tiny main belt asteroid Dinkinesh last November, the SwRI-led mission discovered a trough and ridge structure on the main asteroid as well as the first-ever-encountered contact binary satellite. The flyby data revealed a dramatic history of sudden breakups and transformation for the half-mile-wide object.

Scientists think a big chunk of Dinkinesh suddenly shifted, excavating the trough and flinging debris into its vicinity. Some materials likely fell back to the asteroid body, forming the ridge, while others coalesced to form a contact binary satellite known as Selam. The complex shapes indicate that Dinkinesh and Selam have significant internal strength and a complex, dynamic history.

"To understand the history of planets like Earth, we need to understand how objects behave when they hit each other, which is affected by the strength of the planetary materials," said SwRI's Hal Levison, principal investigator for the Lucy mission and lead author of a paper in Nature discussing this research. "We think the planets formed as zillions of objects orbiting the Sun, like asteroids, ran into each other. Whether objects break apart when they hit or stick together has a lot to do with their strength and internal structure."

Researchers think that Dinkinesh is revealing its internal structure in how it has responded to stress. Over millions of years, its surface was unevenly heated by the Sun. This slight imbalance caused Dinkinesh to gradually rotate faster. Stress built over time and was suddenly released as a large piece of the asteroid shifted into a more elongated shape.

"The Lucy science team started gathering data about Dinkinesh using telescopes in January 2023, when it was added to our list of targets," said SwRI's Simone Marchi, Lucy deputy principal investigator and the paper's second author. "Thanks to the telescopic data, we thought we had quite a good picture of what Dinkinesh would look like, and we were thrilled to make so many unexpected discoveries."

If the structure of Dinkinesh were weaker, more like the rubble-pile asteroid Bennu, the fragmented materials would have gradually moved toward the equator and flown off into orbit as it spun faster. However, images suggest Dinkinesh has more cohesive strength, because it could hold together longer, more like a rock that suddenly gives way under stress, fragmenting into large pieces.

"This flyby showed us Dinkinesh has some strength and allowed us to do a little 'archeology' to see how this tiny asteroid evolved," Levison said. "When it broke apart, a disk of material formed, some of which rained back onto the surface, creating the ridge."

The rest of the disk materials likely formed the double-lobed moon Selam, a contact binary. How this unusual moon ultimately formed remains a mystery, one that the scientists are already digging into.

"We see ridges around asteroids' equators regularly among near-Earth asteroids, but seeing one up close, around an asteroid with a satellite, helps to unravel some of the possible histories of these binary asteroids," said SwRI's Kevin Walsh, an astrophysicist specializing in planetary formation.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HARNESSING HYDROGEN

Combatting a Warming Climate with ICE

By Ryan Williams

In 2024, extreme weather including deadly heat, flooding, and hurricanes continues to raise alarms about the broader implications associated with rising global temperatures. With 196 nations now party to the Paris Agreement, which seeks to limit global temperature rise to less than 2 degrees, the resolve to combat climate change has never been stronger. Although the exact pathway to accomplishing this objective is far from clear, the commitment to net-zero carbon emissions by 2050 remains the centerpiece of the agreement. This daunting goal means finding carbon-free alternatives for the more than 37 gigatons of CO_2 emitted across the globe annually.

THE CHALLENGE OF DECARBONIZING TRANSPORTATION

The transportation sector remains one of the largest contributors to global CO_2 emissions, accounting for nearly a quarter of total emissions, or 8 gigatons. Within the transportation sector, road sources contribute about 75% of these emissions. These include everything from the cars, SUVs, motorcycles and buses that move us around to the pickups, vans and medium- and heavy-duty trucks that transport the goods that we use every day. While we could

In 2022, SwRI launched the H_2-ICE consortium to create a heavy-duty tractor-trailer demonstration vehicle using a hydrogen internal combustion powertrain.

undoubtedly reduce carbon emissions by doing some of this moving around more efficiently, we will never fully eliminate carbon emissions through efficiency improvements alone. Because it is hard to imagine a world without the ease, convenience and freedom of movement that we enjoy today, the only real solution is to replace all carbon-emitting modes of transportation with zero-CO_2 options.

The real challenge here is that pound-for-pound and gallon-for-gallon, it is difficult to match the energy density of hydrocarbon fuels and modern internal combustion engines (ICEs). For transportation to be effective, each vehicle must be able to carry enough energy on-board without the need for constant refueling. To be a viable replacement, any new carbon-free energy source must be as energy-dense, in terms of both weight and volume, as the status quo. For smaller vehicles, the trade-off is less significant, though range anxiety is still a legitimate concern for battery electric vehicles. As vehicle power and distance requirements increase, energy density becomes critical to maintaining vehicle range and cargo capacity. This is especially true in the heavy-duty trucking industry where profit margins are extremely narrow.

Southwest Research Institute has been at the forefront of combustion research and engine development for decades. Over the years, the Powertrain Engineering Division has led consortia, government and commercial projects investigating conventional and unconventional ways of lowering all emissions. The most recent efforts have targeted carbon emissions. While Institute engineers support a range of decarbonization solutions using battery electric, hybrid electric and fuel cell powertrains, recent experience has highlighted the need for a more suitable option to decarbonize heavy-duty vehicles.

A CENTURY OF DIESEL DOMINANCE

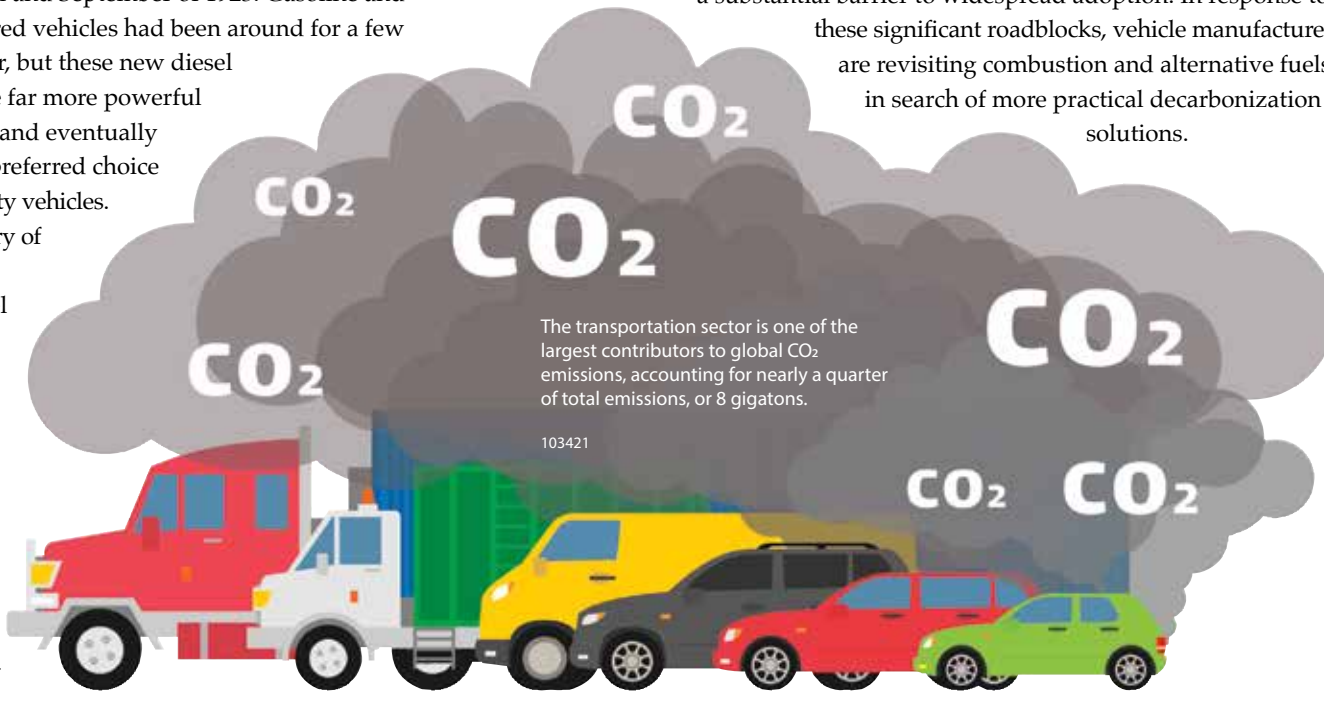
Benz and Daimler debuted the first diesel-powered trucks nearly 100 years ago when they introduced competing vehicles just months apart in April and September of 1923. Gasoline and steam-powered vehicles had been around for a few decades prior, but these new diesel engines were far more powerful and efficient and eventually became the preferred choice for heavy-duty vehicles. After a century of refinement, today's diesel engines are hardly recognizable from the original designs. With technologies like ultra-high-pressure fuel injection, variable-geometry turbocharging, and advanced model-based control algorithms, modern diesel engines boast more technology than the Apollo rockets that carried the first astronauts to the Moon. Exhaust aftertreatment systems have also evolved alongside the engines to meet increasingly stringent emissions regulations.

In recent years, however, the diesel engine has become a victim of its own success. The relative convenience and low cost associated with moving goods by road has led to an explosion in truck traffic and a subsequent increase in carbon emissions from transportation. Once celebrated as technological marvels of the industrial age, ICEs are now vilified as a symbol of the excesses and environmental exploitation of the modern era. As a result, many countries have announced future bans on ICE sales as the silver bullet solution to decarbonizing transportation.

DETAIL

Aftertreatment systems reduce harmful exhaust emissions from internal combustion engines. Various technologies include diesel oxidation catalyst, diesel exhaust fluid, diesel particulate filter, selective catalytic reduction and ammonia slip catalyst systems.

The specter of ICE bans has led to a surge in research and investment in battery-electric and fuel cell-electric vehicles; however, the transition to these technologies for heavy-duty long-haul trucks presents significant challenges. The primary concern is scalability. A battery for a heavy-duty truck can weigh up to 20,000 pounds, significantly reducing the vehicle's cargo capacity. Additionally, the current cost of these powertrain options is a substantial barrier to widespread adoption. In response to these significant roadblocks, vehicle manufacturers are revisiting combustion and alternative fuels in search of more practical decarbonization solutions.



The transportation sector is one of the largest contributors to global CO_2 emissions, accounting for nearly a quarter of total emissions, or 8 gigatons.

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SwRI has taken a systems approach to lower emissions from diesel engines, applying a variety of techniques and technologies such as ultra-high-pressure fuel injection, variable-geometry turbocharging and advanced model-based control algorithms to improve engine performance while decreasing tailpipe emissions.

REVISITING COMBUSTION: THE CARBON PROBLEM

The primary issue with ICEs isn't the combustion process itself but rather the carbon emissions produced as an unavoidable byproduct of the hydrocarbon fuels they typically burn. The long chains of carbon molecules that form the backbone of these fuels are the root of the problem. The carbon-to-carbon bonds along these hydrocarbon chains store immense amounts of energy and, without getting too deep into combustion chemistry, the only way to release all that stored energy is to break those bonds apart and form new bonds through the oxidation process that eventually forms CO_2. As the carbon molecules break apart, the potential to form other undesirable products like solid carbon soot and carbon monoxide that contributes to air pollution and smog gives the ICE a "dirty" reputation. While these harmful emissions can be readily cleaned up with more efficient combustion and appropriate aftertreatment, it is impossible to escape the CO_2 production.

But what if we could retain the power and convenience of combustion while eliminating carbon emissions? What if we simply decarbonize the hydrocarbons themselves?

ENTER THE HYDROGEN INTERNAL COMBUSTION ENGINE

Once the carbon chains are removed from a hydrocarbon fuel, what remains are single hydrogen atoms that readily bond to form H_2 molecules. As it turns out, these hydrogen-to-hydrogen bonds are even stronger than the carbon bonds, giving hydrogen fuel an energy density approximately three times that of diesel fuel, by mass. Crucially, pure hydrogen combustion produces no carbon emissions, which means no CO_2 aside from trace amounts originating from engine lubricants. A hydrogen internal combustion engine (H_2-ICE) presents a unique opportunity to harness the benefits of combustion without the environmental drawbacks of hydrocarbon fuels.

OTHER BENEFITS OF H_2-ICE

Apart from the inherent lack of carbon, hydrogen internal combustion engines offer several other intrinsic advantages to decarbonization, including durability and longevity, total cost of ownership (TCO), component compatibility, and retrofit potential.

In terms of TCO, H_2-ICE vehicles benefit from decades of cost reductions and optimization of traditional ICEs, making them significantly less expensive than their battery-electric or fuel-cell counterparts. Even with slightly lower operating efficiency, it is projected that an H_2-ICE vehicle will have the lowest TCO of all zero-carbon vehicle options. Lower costs will incentivize higher rates of adoption.

About 90% of the components from existing diesel and natural gas engines can be directly applied to H_2-ICEs without any modification, and the remaining 10% can be adapted from existing technologies

DETAIL

Hydrocarbons are organic chemical compounds made up of hydrogen and carbon atoms. Hydrocarbon fuels, derived from fossil sources, include natural gas, propane, butane, gasoline, diesel, kerosene and jet fuel.

SwRI has conducted multiyear low-NOx engine research, developing regulatory support for new aftertreatment systems and software and hardware support. NOx is a generic term for the nitrogen oxide emissions associated with air pollution.

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The transition to hydrogen fuel required a new fuel storage and distribution system. SwRI's demonstration vehicle also established how long-lasting diesel engines could be retrofitted to run on hydrogen.

The H2-ICE engine in the demonstration vehicle used 90% of components from existing engines, leveraging existing supply chains and service networks to potentially bring these vehicles to market at scales able to affect decarbonization targets.

with minor changes to work with hydrogen. This compatibility leverages existing suppliers, logistics, and service networks, facilitating rapid production scale-up and allowing industry to bring these vehicles to market in the numbers needed to reach decarbonization targets.

Because traditional diesel powertrains often last more than 10 years and at least 1 million miles, these vehicles will continue to emit CO_2 long after zero-carbon options are available on the market. The potential to retrofit existing diesel engines to run on hydrogen can accelerate the transition to zero carbon vehicles.

And in terms of durability and longevity, H_2-ICEs are expected to offer the same benefits as traditional diesel engines, making them a robust, reliable option for heavy-duty applications.

CHALLENGES FOR H_2-ICE

H_2-ICE vehicles are not without their own challenges. First and foremost, while hydrogen combustion produces no carbon, H_2-ICE vehicles cannot currently be classified as zero emissions vehicles. In a perfect world, the only product of hydrogen combustion would be pure H_2O; however, just as conventional engines produce some undesirable emissions, H_2-ICEs do as well. One of the byproducts of hydrogen combustion is the formation of nitrogen oxides (NOx). In some forms, these compounds have an even stronger greenhouse gas effect than CO_2. In other forms and at high enough concentrations, they can lead to air quality degradation and other health risks. NOx has been central to emissions regulations for decades, and current standards allow for only 0.2 grams per horsepower-hour, but some argue that even this is too high for densely populated areas where air quality is already challenged. For H_2-ICEs to be recognized as 'zero-emissions,' NOx emissions will have to be addressed.

H_2-ICE DEMONSTRATION

SwRI has explored hydrogen combustion in some detail over the years, initially focused on providing greater energy independence from fossil fuels. More recently, seeing a need for alternative decarbonization strategies, H_2-ICE research and development has come back into focus.

In 2021, SwRI launched two internal research and development (IR&D) programs aimed at improving H_2-ICE power density and thermal efficiency and understanding aftertreatment operation and performance in a hydrogen exhaust environment. Under the first program, we patented a new multimode combustion concept using

diesel-like combustion of hydrogen with the assistance of a spark-ignited pilot flame to eliminate abnormal combustion events. Under the second program, engineers discovered some very interesting catalytic behavior from traditional aftertreatment systems in the presence of hydrogen. These programs provided a perfect platform to discuss H_2-ICE development with other experts across the industry and establish our capabilities in the H_2-ICE research community, laying the groundwork for additional research.

In November 2022, SwRI established the H_2-ICE consortium, a collaborative initiative aimed at demonstrating the potential of hydrogen-fueled internal combustion engines to reduce CO_2 and other harmful emissions while retaining the benefits of traditional ICEs. Supported by a membership consisting of 20 engine and vehicle manufacturers, component suppliers and energy providers, the SwRI team worked to convert an existing 15L natural gas engine to run on hydrogen. The work leveraged the previous IR&D to develop combustion and aftertreatment systems capable of meeting the consortium targets of high efficiency and ultra-low emissions. Consortium members provided both financial support for the engineering effort as well as in-kind contributions of essential components for the program.

The consortium's efforts culminated in the completion of a Class 8 heavy-duty H_2-ICE demonstration vehicle. The 370-horsepower hydrogen-fueled internal combustion engine showed a 99.7% reduction in CO_2 emissions compared to a similar diesel engine. Additionally, tailpipe NOx emissions from the reconfigured aftertreatment system were lower than both EPA / CARB 2027 NOx targets as well as the voluntary ultra-low emissions standard over all regulatory test cycles.

SwRI has showcased the demonstration vehicle at major industry trade shows, including the 2024 ACT Expo, the California Hydrogen Leadership Summit and SAE's COMVEC™ conference. These events provide an opportunity to present the technology to legislators, policy-makers and fleet operators, highlighting the viability and benefits of H_2-ICE as a sustainable solution for heavy-duty transportation.

THE ROAD AHEAD

Hydrogen internal combustion engines hold significant promise in the path toward decarbonizing transportation. Through the ninth phase of its long-running "clean diesel" collaborative program, SwRI's Clean Highly Efficient Decarbonized Engines (CHEDE-9) consortium will continue to advance our fundamental understanding of H_2-ICE combustion. By harnessing hydrogen's potential, we can address the challenges of heavy-duty transportation and contribute to a more sustainable future.

The future of decarbonized transportation cannot be confined to a single solution. While battery-electric vehicles and fuel cells play crucial roles in reducing carbon emissions, hydrogen internal combustion engines offer a complementary and scalable solution, particularly for heavy-duty applications. As we continue to innovate and collaborate, the path to a cleaner, cooler world becomes clearer, with H_2-ICE leading the transition to a broader hydrogen economy.

Questions about this story? Contact Ryan Williams at ryan.williams@swri.org or (210) 522-5185.

SwRI has showcased the H_2-ICE demonstration vehicle at major industry trade shows, including the 2024 ACT Expo, the California Hydrogen Leadership Summit and SAE's COMVEC™ conference.

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The Environmental Protection Agency and the California Air Resources Board are national and state entities regulating emissions. EPA and CARB aligned their 2027 targets for tailpipe nitrogen oxides, or NOx, emissions, which call for 0.035 grams per horsepower-hour during normal operations, 0.05 grams at low load, and 10 grams at idle.

DETAIL

ABOUT THE AUTHOR:
Ryan Williams, a specialist in advanced diesel and spark-ignited engines, manages SwRI's Engine Systems Research & Innovation Section. As the program manager of the H_2-ICE consortium, he led the joint SwRI-industry team that developed the Class 8 heavy-duty H_2-ICE demonstration vehicle now touring the U.S.

103423

SwRI supports NASA's Europa Clipper mission with two instrument packages. The spacecraft will orbit Jupiter to study its moon Europa to determine whether the ocean beneath its icy shell could support life. Launched in October 2024 and arriving in the Jovian system in 2030, the spacecraft complements ESA's Jupiter Icy Moons Explorer, which launched in 2023 and includes another SwRI-led UVS instrument.

516 million MILES FROM EARTH

SUBSURFACE **H_2O OCEAN**

2X EARTH'S OCEAN VOLUME

EUROPA

90% THE SIZE OF **EARTH'S MOON**

25% THE SIZE OF **EARTH**

PAYLOAD
SwRI-LED MASPEX

SwRI's Mass Spectrometer for Planetary Exploration (MASPEX) will "sniff" Europa's gases to study the chemistry of the moon's suspected subsurface ocean. Principal Investigator: Dr. Jim Burch

The novel MASPEX instrument provides **50** times finer resolution than other space spectrometers. At **3** feet long, it provides a **4,800**-foot flight path as ions bounce **800** times back and forth to reveal chemistry.

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EUROPA CLIPPER MISSION

NASA'S LARGEST PLANETARY SPACECRAFT

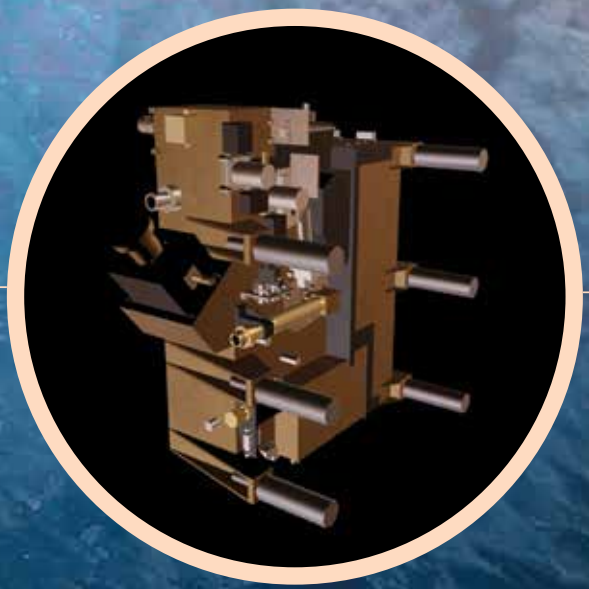
16 FEET tall
100 FEET wide w/solar arrays deployed
7,145 POUNDS without fuel/propellant
600 WATTS of solar energy power

4th largest MOON OF **JUPITER**

JANUARY 8, 1610
Europa discovered by
GALILEO GALILEI

~50 CLOSE PASSES **OVER EUROPA** as close as **16** MILES **FROM SURFACE**

This **6**th-generation, **8.5**-Watt UVS instrument is **14x14x6** inches and weighs just **43** pounds.



PAYLOAD
SwRI-LED EUROPA-UVS

SwRI's Europa Ultraviolet Spectograph (UVS) images and characterizes Europa's atmospheric gases and surface materials.
Principal Investigator: Dr. Kurt Retherford

103432

Markerless Biomechanics Technology

ENABLE

Enhancing human performance & health with markerless motion capture

By Dan Nicolella, Ph.D., and Kase Saylor

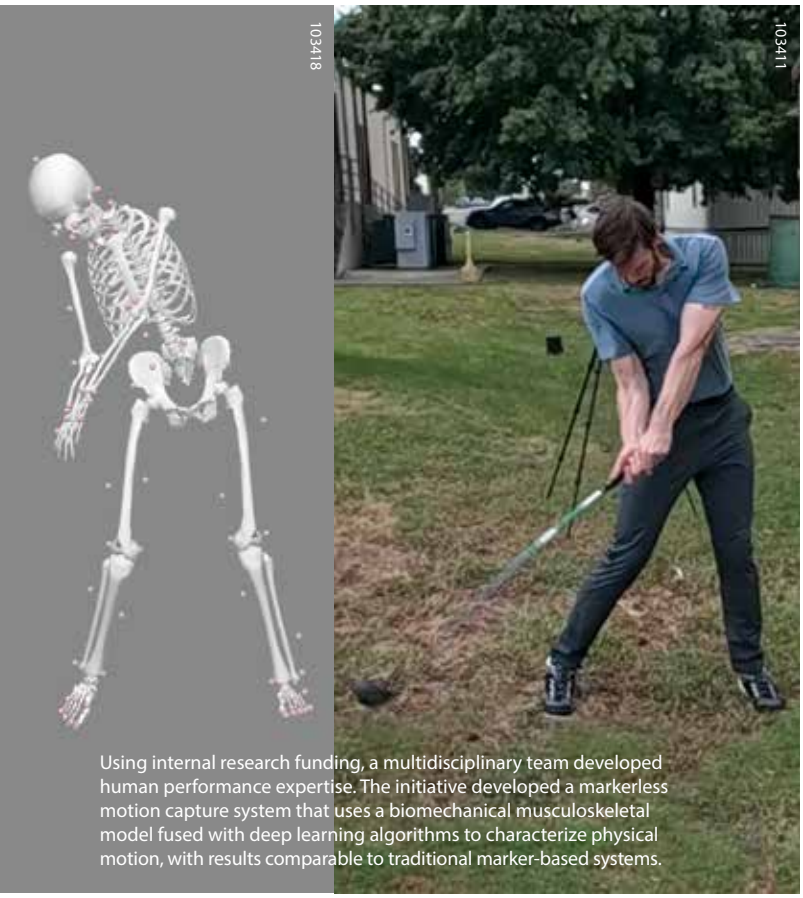
Biomechanics studies the structure and function of biological systems using mechanical principles, a discipline that dates back to the Renaissance. In the 1600s, Italian physiologist and physicist Giovanni Alfonso Borelli was the first to explain muscular movement and other body functions according to the laws of statics and dynamics.

In the 20th century, biomechanical research fueled a diverse array of advances affecting daily human life, such as the biomechanics of labor focused on increasing worker efficiency without sacrificing safety. In the world wars, biomechanics advanced prosthetics and rehabilitation medicine. Contemporary biomechanics has also advanced dentistry and orthopedics, designed safer civilian and military vehicles, and enhanced athletic prowess.

A key component of biomechanics is measuring and studying human motion. Biomechanics applies the tools of mechanics and mechanical engineering to generate valuable insights into how muscles, bones and joints work together to produce motion. Applications are widespread and numerous, ranging from understanding and treating musculoskeletal disorders and diseases such as cerebral palsy and osteoarthritis to improving athletic performance, identifying injury risks and improving workplace ergonomics.

CONVENTIONAL MOTION CAPTURE

For centuries, scientists used drawings and calculations to quantify movement. In the late 1800s, photography ushered in a new era of biomechanics analysis, but that capability was limited by manual analysis. Advancements in computer vision eventually led to 3D motion capture, starting in the 1970s. In recent decades, traditional measurement of human movement involved attaching up to 85 reflective markers to specific anatomical locations, typically at bony landmarks. These markers are tracked in 3D space as the subject performs actions such as walking. The process requires purpose-built



Using internal research funding, a multidisciplinary team developed human performance expertise. The initiative developed a markerless motion capture system that uses a biomechanical musculoskeletal model fused with deep learning algorithms to characterize physical motion, with results comparable to traditional marker-based systems.

infrared cameras, a controlled environment with consistent lighting and a complex data analysis procedure. It can take an hour to attach the markers and capture the data, followed by several days of analysis. While time-consuming and tedious, this method is considered the "gold standard" in human motion capture and analysis. Its application has significantly advanced our understanding of human movement and provided crucial insights into what happens when our musculoskeletal system fails.

However, this approach is not without limitations. The labor-intensive nature of the process along with the need for a controlled laboratory environment restricts its broader application. Additionally, placing markers on the subject can often make them self-conscious, leading to unnatural movement patterns that complicate the analysis.

MARKERLESS MOTION CAPTURE

Consider a scenario where quantifying and analyzing human movement biomechanics is as simple as observing someone in action. Southwest Research Institute developed the Engine for Automatic Biomechanical Evaluation, or ENABLE™, a markerless biomechanics software system designed to make this a reality. Unlike traditional methods, this technology enables accurate and reliable human motion quantification and automated analysis, significantly streamlining the process. The technology combines neural network algorithms, machine vision technology and biomechanical modeling to generate reliable and accurate assessments of human motion. This technology has the potential to significantly advance biomechanics, enabling widespread kinematics analysis in natural environments such as medical clinics, military training settings and athletic competitions. The applications are limited only by the imagination.

SwRI has an extremely broad and deep technical program, allowing the ability to build multidisciplinary teams to solve some of the toughest problems for our clients. This drive to collaborate led to the development of ENABLE, our markerless biomechanics technology. A chance meeting between the authors nearly eight years ago sparked brainstorming within their respective teams of

Kinematics is the branch of physics that describes movement in relation to joints and related parts.

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SwRI performed research and validation of its markerless biomechanics system to quantify whole body biomechanics during activities such as the counter-movement jump shown in this image.

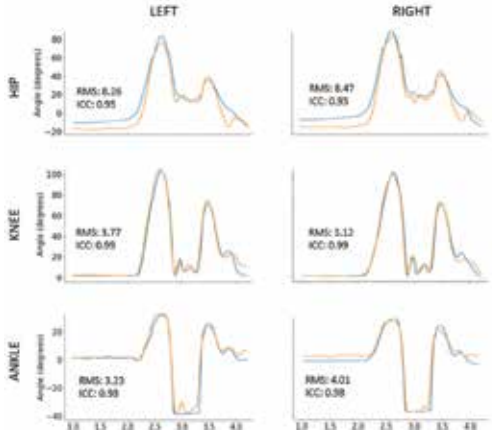

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IMAGE COURTESY SwRI/DAN NICOLELLA/U.S. DoD

SwRI's markerless biomechanics system was used to assess medical trainee performance on specific medical tasks such as suturing a wound.

ENABLE, developed through SwRI's Human Performance Initiative, estimates the underlying kinematics by analyzing video of human movement.

DETAIL

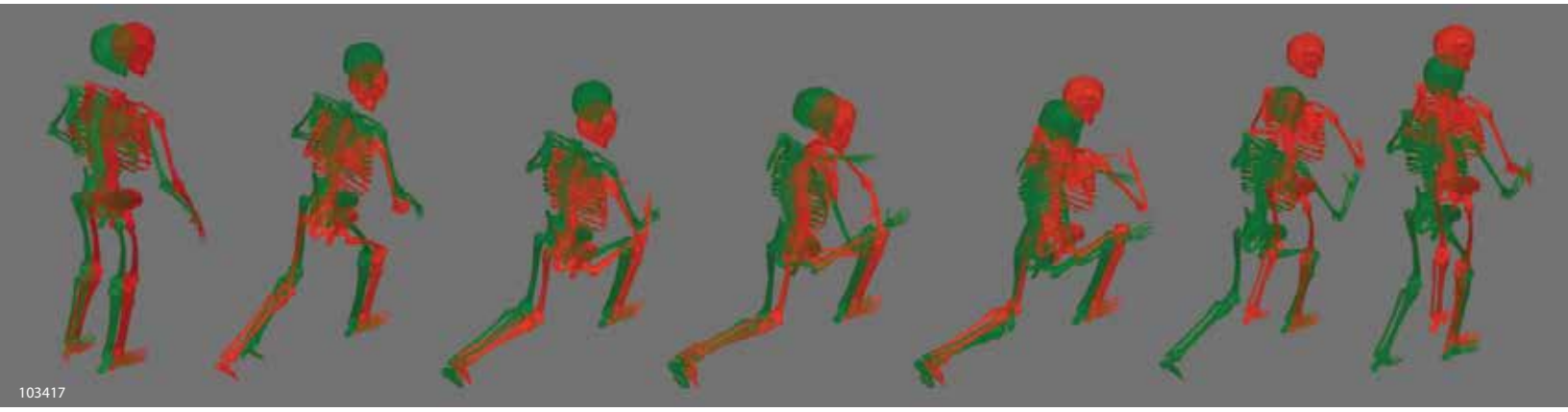
biomechanical engineers, computer scientists and machine vision experts with the goal of advancing human performance research through innovative technology. Recognizing combined interests and capabilities, the team devised a plan for markerless biomechanics.

ENABLE is a direct result of the explosive growth in artificial intelligence (AI) over the past decade, particularly in the field of machine vision and image recognition. At the heart of ENABLE is a core technology: deep neural networks. These networks, trained on thousands of labeled images, have become remarkably adept at identifying and describing what they see — for example, recognizing an Irish Setter or calico cat. ENABLE leverages this powerful technology by using AI system based on deep neural networks to identify specific anatomical points on the human body. SwRI research teaches the algorithms about the relationship between images of humans, motion and the underlying kinematics. We also developed "synthetic data," which expanded and augmented our ability to train algorithms.

SwRI's ENABLE AI is trained on a uniquely curated set of images. The team combined publicly available images commonly used for simple pose detection with video data automatically labeled through a patented method based on biomechanical modeling. The application also incorporated synthetic training data, where human avatars are precisely posed using biomechanical input data through animation. This synthetic data significantly enhances the training dataset, providing a diverse range of synthetic humans performing various activities in controlled backgrounds and environments. This capability permits rapid generation of additional training data for customized ENABLE solutions tailored to specific client applications.

ENABLE operates as a multicamera system, with each camera capturing the subject from a different angle. ENABLE's underlying AI identifies virtual markers on the subject within each camera's view in motion. Both intrinsic and extrinsic calibration data are used to reconstruct 3D trajectories of these markers as the subject moves.

The deep integration of biomechanical modeling into the ENABLE technology ensures biomechanical consistency. ENABLE automatically creates a digital twin — an accurate virtual representation — of each subject based on an OpenSim biomechanical model. This digital twin epitomizes the subject's anatomical structure, ensuring that the output from ENABLE remains biomechanically consistent and tailored to that individual.



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ENABLE identified musculoskeletal injury risks in military service members during specialized training. In this image, the motions of the red figures are at high risk of injury, while the green figures are at low risk.

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SwRI used internal funding to adapt ENABLE into a portable, user-friendly system. ENABLE is camera-agnostic, meaning it can work with video from virtually any camera system. A standalone application can wirelessly control off-the-shelf cameras, including GoPros and tablets, allowing for easy camera setup and configuration and enabling biomechanical data capture in almost any environment.

SwRI trained ENABLE using both publicly available and custom-created datasets. To supplement this limited resource, the Institute developed its own computational toolset to generate "synthetic data." The toolset compares and converts results from a statistical kinematic model with animation software, character models and other software to generate reliable synthetic data.

DETAIL

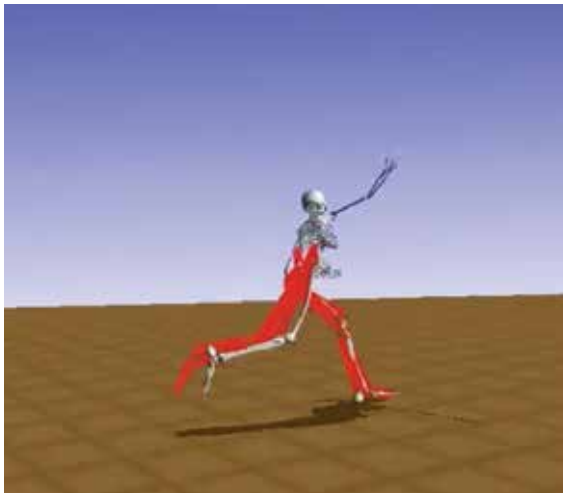
APPLICATIONS & IMPACTS

To validate the quantitative performance of ENABLE, SwRI collaborated with an academic research team to conduct a study comparing it to a traditional marker-based system during drop vertical jumps. The study included 135 participants, with both systems capturing 3D kinematics along with ground reaction forces. ENABLE, which was trained using a combination of real and synthetic data, demonstrated impressive performance. Root mean square errors (RMSE) for joint angles were as low as 2.52 degrees, with most results under 10 degrees — comparable to marker-based systems. The ability to characterize the torque joints experience, derived from kinematics and ground reaction forces, also showed strong agreement, with discrepancies within 0.23 Nm/kg of the marker-based system. These findings validate the accuracy of the ENABLE system and underscore the utility of synthetic training data in enhancing the performance of SwRI's deep neural network.

SwRI then used an early version of ENABLE to help the U.S. Department of Defense (DoD) assess medical trainees performing training exercises. Military medical training typically relies on subjective human evaluations where feedback may vary among trainers. ENABLE helped both instructors and trainees to objectively observe performance of a specific task, providing both a quantitative score, based on expert task performance, and task-specific feedback to improve performance.

Applying SwRI's technology to DoD medical training will allow complex assessments of 3D kinematic performance. The project assesses the detailed performance of trainees as they suture wounds and provide other combat and hospital care requiring precise hand movements or physical orientations to improve military healthcare training. Automated assessments based on SwRI-developed machine learning used actual data collected from ideal physical performance of specific medical tasks.

Moving into the athletic performance arena, SwRI has used ENABLE for a baseball pitching and basketball shooting characterization and optimization, particularly addressing performance and injury risk. Research focused on factors associated with excellent performance as well as lower risk of injury. SwRI collaborated with The University of Texas at San Antonio to capture the movements of more than a dozen pitchers, collecting video data for markerless analysis, optical marker-based motion capture for comparison, and ground reaction forces,



OpenSim is a freely available, user-extensible software system allowing users to develop models of musculoskeletal structures and create dynamic simulations of movement.

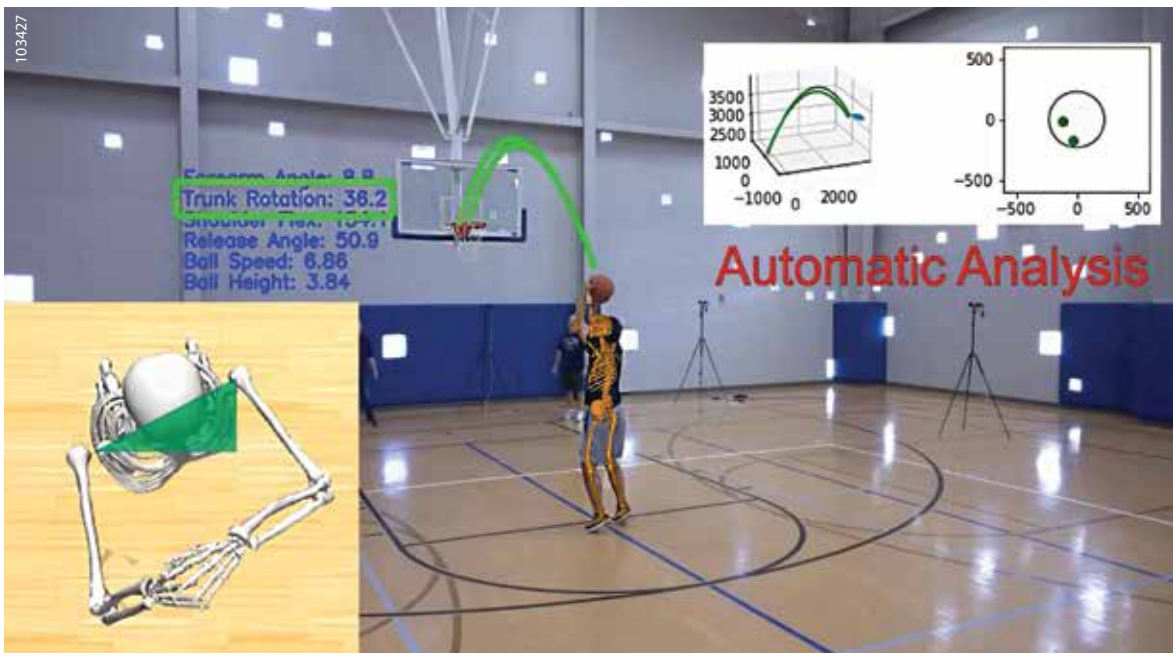
DETAIL

ENABLE allows biomechanical analysis of various sports and training exercises.

which are the forces exerted by the ground on the body when in contact with it.

In addition to tracking pitcher movements, the team sought to identify potential changes in mechanics that would improve performance or reduce risk of injury. For example, researchers found that a straightened stride leg more efficiently transfers energy into the pitch. The team ran optimization scenarios to make subtle changes to pitching motion and mechanics to minimize shoulder and elbow torque, the metrics for injury, while maximizing hand velocity, the metric for performance. Then the team started looking at the biomechanics of basketball shooting and ball tracking in terms of make, miss and rim location. The team captured data for 50 subjects performing 30 shots each — 10 free throws, 10 mid-range shots and 10 three pointers.

Recently, SwRI applied ENABLE to assess musculoskeletal injury risks in military service members during specialized training. In collaboration with the U.S. Air Force Special Warfare Human Performance Squadron, SwRI used ENABLE to analyze video of more than 150 U.S. Air Force trainees performing multiple functional movements to identify trainees at risk based on their movements, aggregating the body's entire motion. ENABLE's predictive model correctly predicted 70% of the injuries that occurred among trainees across an eight-week training course while accurately predicting 87% of the noninjuries. The approach offers a novel way to proactively address one of the largest noncombat burdens on the U.S. military. Further refinement and wider-scale implementation of these techniques could bring about substantial injury reductions.



To address performance, SwRI used ENABLE to characterize and optimize basketball shooting, based on parameters such as forearm angle, trunk rotation, shoulder flex, and ball speed and height.

A new Human Performance Laboratory features a markerless motion capture system that allows SwRI to develop advanced biomechanical analysis tools with machine vision algorithms and data analytics.

Noncombat musculoskeletal injuries during military training cost the U.S. military more than $3.7 billion annually.

DETAIL

SwRI is also using ENABLE to look at additional sports, including diving, weightlifting and track and field, including studying sprints, hurdles and the triple jump.

CONCLUSION

The ENABLE markerless biomechanics system is a user-friendly and biomechanically accurate technology for capturing and quantifying human motion. ENABLE is camera-agnostic, meaning it can work with video from virtually any camera system. A standalone application can control off-the-shelf cameras, including GoPro cameras, wirelessly, allowing for easy camera setup and configuration and enabling biomechanical data capture in almost any environment. Additionally, ENABLE can serve as a "processing engine" that integrates with existing traditional motion capture systems. This capability enables existing marker-based motion capture labs to be retrofitted with video cameras and upgraded with ENABLE to achieve markerless motion capture. The technology can also support custom solutions for specific client applications. ENABLE is also available for licensing, allowing institutions and organizations to incorporate this advanced technology into their existing motion capture frameworks.

The ENABLE markerless biomechanics system represents a significant advancement in biomechanical motion capture technology, enabling motion capture in a broad range of environments. From practical applications in healthcare, military and sports to basic and fundamental biomechanics research, ENABLE provides the capability to quickly and easily capture accurate biomechanical data in more natural environments and settings.

Questions about this story? Contact Dan Nicolella at daniel.nicolella@swri.org or (210) 522-3222 or Kase Saylor at kase.saylor@swri.org or (210) 522-3703.

ABOUT THE AUTHORS:

Dr. Dan Nicolella (right), an Institute engineer and acting manager in SwRI's Mechanical Engineering Division, has over 30 years of experience in basic and applied research in musculoskeletal biomechanics and bioengineering. **Kase Saylor** is a senior program manager in SwRI's Intelligent Systems Division, specializing in digital signal processing, embedded networks and systems engineering. Saylor and Nicolella co-lead SwRI's Human Performance Initiative, conducting research to quantify and optimize physical performance through novel techniques and technologies.

SwRI-UTD COLLABORATIVE RESEARCH

Southwest Research Institute (SwRI) and the University of Texas at Dallas (UTD) have established a new program to enhance greater scientific and engineering collaboration between the two institutions. The Seed Projects for Research, INnovation, and Technology, or SPRINT, Program funds collaborative research projects, including two projects in this inaugural round.

SEEKING NEW DOMESTIC SOURCES FOR LITHIUM

Dr. Adam Cawood, of SwRI's Earth Science Section, and Dr. Kristina Butler and Dr. Zach Sickmann, assistant professors in UTD's Department of Sustainable Earth Systems Sciences, are leading an effort to identify new domestic lithium resources. The project aims to help address a pressing national need to reduce the reliance on imported lithium from large producers in Asia and South America.

"Global demand for lithium is expected to increase 46% by 2030, according to the U.S. Geological Survey," Cawood said. "Right now, the U.S. only produces about 1-2% of the world's lithium."

To address this challenge, the project will study lithium deposit formation through fieldwork, geological mapping and subsurface interpretation in support of conceptual model development. The researchers plan to leverage their efforts to write grants seeking funding from the National Science Foundation and the U.S. Department of Energy.

"Lithium is critical to U.S. national security because we need it for battery technologies as we continue to turn toward vehicle electrification," said Butler, who specializes in studying lithium.

Lithium exploration in the U.S. is still in its early stages, Cawood said. "We will consider established techniques from other industries and apply them to this kind of search," he said. "As structural geologists, we look at faults and fractures in the subsurface where lithium-enriched fluids could flow, leading to lithium transport and accumulation below ground. Meeting domestic lithium demand is the ultimate goal."

EVALUATING SPACE SENSOR IN UNIQUE FACILITY

A second project, led by SwRI's Dr. Joo Hwang and UTD's Dr. Phillip Anderson, supports a collaboration to evaluate a next-generation sensor designed to measure neutral gas velocities in the Earth's upper atmosphere.

Geospace, the boundary region made up of the Earth's upper atmosphere and nearby outer space, contains ionized and neutral components that are separately studied and defined as the ionosphere and thermosphere, respectively. Neutral winds largely drive the dynamics of the region, serving as the primary regulators and redistributors of the mass, momentum and energy and activating geospace weather at all latitudes.

"Understanding the dynamics of neutral wind and its coupling with ionospheric plasmas is critical for protecting military and commercial space-based assets in low Earth orbit from space weather events," said Hwang, a staff scientist in SwRI's Space Science Division. "We will leverage our new Molecular Beam Facility (MBF) to validate and enhance the measurement capabilities of UTD's Neutral Wind Meter (NWM), establish development procedures, and significantly improve the signal-to-noise ratio."

The project offers a unique opportunity to verify sensor performance and demonstrate its technical readiness level, which in turn makes the instrument more likely to be selected for upcoming missions. The integration of novel sensor technologies and molecular beam testing methodologies underscores a well-reasoned and innovative strategy to address critical gaps in understanding space weather impacts.

"A version of our instrument scheduled to fly for the first time on a rocket in 2025 will be evaluated at SwRI early next year, " said Anderson, director of UTD's William B. Hanson Center for Space Sciences.

SwRI has leveraged its unique expertise to establish a molecular beam accelerator at its San Antonio headquarters to meet the critical necessity for a domestic facility to verify the functionality and effectiveness of similar space sensors.

NEXTCAR II INNOVATIONS

SwRI showcased the latest developments from its ongoing NEXTCAR Phase II project at the 2024 ARPA-E Energy Innovation Summit held in Dallas. The Institute's NEXTCAR Program aims to reduce vehicle energy consumption by more than 30% using cutting-edge connected and automated vehicle (CAV) technology.

"We are demonstrating real-world technology that highlights SwRI's continued advancements in vehicle efficiency," said SwRI's Scott R. Hotz, P.E., director of SwRI's Control Systems Department in Ann Arbor, Michigan.

In 2021, the U.S. Department of Energy awarded SwRI a three-year, $5.25 million contract through the Advanced Research Projects Agency–Energy's (ARPA–E) NEXTCAR program. This effort builds on the success of Phase I, which won an R&D 100 Award in 2021. Phase II developed a specialized algorithm suite using connectivity and Level 4 automated driving systems. These algorithms predict traffic behavior based on data from sensors, connected vehicles, and intelligent infrastructure to optimize powertrain performance.

"These technologies show significant energy savings in simulations, and our dynamometer and real-world driving tests confirm similar improvements," said Stas Gankov, an SwRI manager. "Our findings also highlight that while more data can improve predictions, full connectivity is not necessary for deploying these technologies, which addresses a common concern in the industry."

SwRI's automated driving platform, built on a production plug-in hybrid sedan, leverages widely adopted sensing technologies like lidar alongside SwRI's patented Ranger localization system. SwRI's drive-by-wire system provides seamless control over the accelerator, brake and electronic power steering. Algorithms like eco-driving were demonstrated in real-world tests and showcased at the Summit, while cooperative control, smart lane merging and smart lane changing continue to be refined. A subset of these technologies will be showcased at the upcoming NEXTCAR Field Day event, marking the culmination of the Phase II program.

"SwRI's groundbreaking research has already yielded promising results," Hotz said. "We continue to explore new research avenues and are eager to see how our NEXTCAR work progresses in the coming years."

TARGETING URBAN HEAT ISLANDS IN SAN ANTONIO

SwRI has created a comprehensive data analysis tool to help metropolitan areas curb urban heat islands (UHIs) and pursue mitigation methods, particularly for vulnerable populations. SwRI funded this project internally in collaboration with the City of San Antonio.

UHIs occur when dense concentrations of pavement and buildings absorb heat and raise surrounding temperatures. Without natural or engineered heat mitigation infrastructure, UHI temperatures can exceed other areas by as much as 20 °F, which could be dangerous to residents during summer.

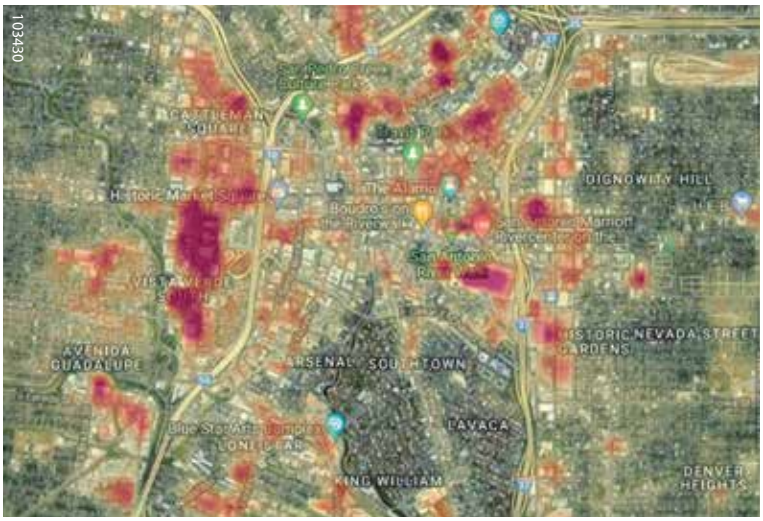
"Tackling UHIs goes beyond simply analyzing spatial temperature differences," said SwRI Senior Environmental Engineer Justin Long. "A comprehensive analysis of UHIs must also identify vulnerable populations, as well as viable mitigation methods in the areas where they reside."

SwRI has created a data fusion tool that compiled and combined more than 230 datasets collected from several different city departments and public databases. The tool allows city leaders to analyze and explore several scenarios at once.

"Before the City of San Antonio can prioritize resources to address UHIs, it needs to identify all their characteristics, particularly zones where conditions are the most severe and that have a direct impact on the public," Long said. "We discovered, for example, that many areas that experience extreme heat are also zones with historically high bus ridership. On hot summer days, pedestrians in these areas may be at higher risk of prolonged heat exposure and related illnesses."

To demonstrate how the data fusion tool could inform UHI policy making, SwRI created a hypothetical case study, merging multiple datasets from different sources for comparison. "Mitigation strategies must be tailored to the specific characteristics of locations experiencing extreme heat from UHIs," Long said.

The tool could show city leaders where bus stops and high surface temperatures overlap, locations where planting trees or erecting artificial structures to mitigate the heat could be most effective.



This map of San Antonio illustrates the distribution of urban heat islands (red) near downtown. SwRI created a comprehensive data analysis tool to help the city identify urban heat islands and pursue viable mitigation methods for particularly vulnerable populations.

CRYPTOLOGIC SYSTEMS SUPPORT FOR U.S. NAVY

SwRI will provide engineering and equipment support for advanced cryptologic technology for shipboard and airborne platforms for the U.S. Navy. The five-year, $35.7 million contract will deliver services from June 2024 through June 2029, with the option for the Navy to add $14 million and extend the contract through 2031.

SwRI develops electronic warfare (EW) technology to detect, intercept and disrupt a range of signals on the electromagnetic spectrum, supporting efforts to thwart adversaries. As part of EW systems, cryptologic technology identifies and responds to encrypted or coded radio frequency signals.

"We develop technology critical to warfighter success," said SwRI Senior Program Manager Robert C. Torres, who is leading this effort. "Our cryptologic equipment enhances battlespace awareness through intelligent signal surveillance of the electromagnetic environment."

The comprehensive contract includes support services for associated equipment from installation, calibration, integration and training to life-cycle logistics support, spare parts management, maintenance, repair and technology updates.

"The Defense and Intelligence Division at SwRI has a long history of leading communications and signals intelligence programs for Department of Defense forces," said Torres. "We continuously design and upgrade this technology, developing next-generation equipment to support U.S. armed forces and our allies."

For more than 70 years, SwRI has developed advanced signals intelligence technology, supporting maritime, airborne and land-based operations. SwRI has deployed field-proven cryptologic equipment for use in more than 300 applications worldwide, including systems for the U.S., the Five Eyes Alliance — Australia, Canada, New Zealand, the United Kingdom and the United States — and other allied intelligence communities.

SCREENING FOR TRAUMATIC BRAIN INJURIES

SwRI has developed a field-ready screening tool for traumatic brain injury (TBI). The Advanced Military Measure of Olfaction (AMMO) kit includes an array of scents, deployable anywhere from the battlefield to the football field, to help screen for TBIs in minutes.

"The AMMO test kit is not intended as a diagnostic test but as a screening tool," said SwRI Senior Research Engineer Kreg Zimmern, the project's leader.

The kit includes six sealed vials that release a range of odors, such as fruity and spicy aromas. When squeezed, a test vial turns blue to indicate a smell has been released and is ready for use. Patients identify the odor from four possible choices on an attached card; The correct answers are hidden behind a sticker. Research shows failing to identify the scents correctly correlates highly with positive results for TBI on an MRI exam.

"Someone exposed to a blast on the battlefield could be screened immediately with AMMO instead of waiting for the onset of signs or symptoms of TBI. The inability to identify the scents could be used as rationale to justify an MRI," Zimmern said.

AMMO is undergoing stability studies to determine how long the kit can be stored and still be effective. SwRI is developing AMMO in compliance with relevant FDA and ISO guidelines. It's the only olfactory test kit to undergo such rigorous controls.

"The kit is inexpensive, compact, has no special storage conditions and doesn't need electricity," Zimmern said. "This makes it a potential screening tool in emergency rooms as well as at workplaces, nursing homes and youth, collegiate and professional sports games."

While AMMO doesn't require any specialized training to administer, the results can inform the decision-making process for first responders and doctors.

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The Supercritical Transformational Electric Power (STEP) Demo pilot plant at SwRI generated electricity for the first time. The pilot plant's turbine achieved its full speed of 27,000 RPM, an operating temperature of 260 °C and generated a small amount of power.

STEP Demo Generates Electricity for the First Time

The Supercritical Transformational Electric Power (STEP) Demo pilot plant has generated electricity for the first time using supercritical carbon dioxide (sCO_2) power cycles. The $169 million, 10-megawatt sCO_2 facility at SwRI in San Antonio is demonstrating next-generation power production technology in a project led by GTI Energy in collaboration with SwRI, GE Vernova, the U.S. Department of Energy/National Energy Technology Laboratory, and several industry participants.w

"The impact of demonstrating that the sCO_2 technology works cannot be overstated," said SwRI Project Manager Dr. Jeff Moore. "I truly believe this project will change how we approach power generation in the near future."

For the first time, the pilot plant's turbine achieved its full speed of 27,000 RPM at an operating temperature of 260°C, while generating a small amount of power. Over the next few weeks, the STEP team will slowly ramp up the operating temperature to 500°C and generate 5 megawatts (Mwe) of power, enough to power 5,000 homes.

Following this test configuration, the STEP Demo project will enter its final phase. The pilot plant will be reconfigured to boost the power plant's efficiency and overall energy output. This modification requires the installation of new equipment, as well as a new commission and test phase that will continue into 2025 until the pilot plant is running at full power. At the end of its final phase, the pilot plant will produce 10 MWe hourly, enough to power 10,000 homes.

The STEP Demo pilot plant is one of the largest demonstration facilities in the world for sCO_2 technology. Unlike conventional steam power plants, which use water as the thermal medium, STEP uses high-temperature sCO_2 to increase efficiency by as much as 10% due to its favorable thermodynamic properties.

EVIDENCE OF HYDRATION ON PSYCHE

Using data from NASA's James Webb Space Telescope, an SwRI-led team has confirmed hydroxyl molecules on the surface of the metallic asteroid Psyche. The presence of hydrated minerals suggests a complex history for Psyche, important context for the NASA spacecraft en route to this interesting asteroid orbiting the Sun between Mars and Jupiter.

At about 140 miles in diameter, Psyche is one of the most massive objects in the main asteroid belt. Previous observations indicate that Psyche is a dense, largely metallic object that could be a leftover core from a planet that experienced a catastrophic collision. On Oct. 13, 2023, NASA launched the Psyche spacecraft, which is traveling 2.2 billion miles to arrive at the asteroid in August 2029.

"Using telescopes at different wavelengths of infrared light, the SwRI-led research will provide different but complementary information to what the Psyche spacecraft is designed to study," said SwRI's Dr. Tracy Becker, second author of a new American Astronomical Society's Planetary Science Journal paper discussing these findings.

The Webb data point to hydroxyl and perhaps water on Psyche's surface. The hydrated minerals could result from external sources, including impactors. If the hydration is native or endogenous, then Psyche may have a different evolutionary history than current models suggest.

"Asteroids are leftovers from the planetary formation process, so their compositions vary depending on where they formed in the solar nebula," said SwRI's Dr. Anicia Arredondo, another co-author.

Understanding the location of asteroids and their compositions tells us how materials in the solar nebula were distributed and have evolved since formation. How water is distributed in our solar system will provide insight into the distribution of water in other solar systems and, because water is necessary for all life on Earth, will drive where to look for potential life, both in our solar system and beyond.

Using NASA's Webb telescope, shown in the bottom right corner of this illustration, an SwRI-led team confirmed the presence of hydrated minerals on the surface of Psyche, a massive and heavily metallic body in the main asteroid belt.

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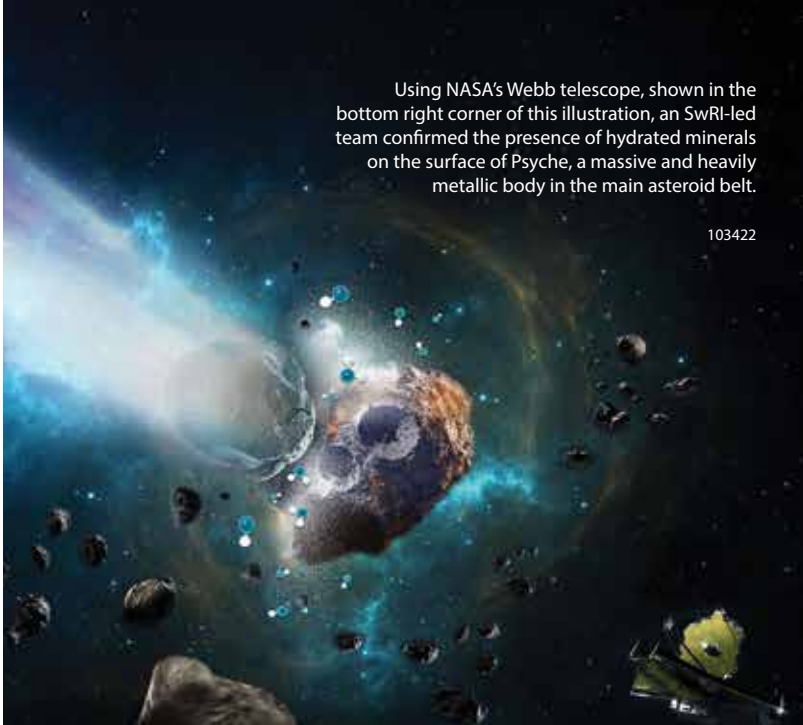

BOLSTERING EARTHQUAKE READINESS

SwRI is enhancing models to strengthen the earthquake resilience of America's transportation infrastructure and improve public safety in earthquake-prone areas. As part of a contract with the U.S. Federal Highway Administration (FHWA), an SwRI-led team is updating and improving liquefaction models. Liquefaction occurs during an earthquake when intense shaking causes soil to temporarily act more like a fluid, losing its capacity to support roads and structures.

"For highways specifically, sometimes state and local authorities don't have the luxury of choosing a different location to build to avoid areas that are potentially vulnerable to liquefaction," said SwRI Senior Research Engineer Dr. Kristin Ulmer, the principal investigator of the project.

Over the next five years, the team will expand upon past work performed for the Next Generation Liquefaction (NGL) project. The NGL project is a community-driven collaboration with an open-source database of earthquake and liquefaction case histories from around the world.

"We will build on past NGL work to develop predictive models to better understand where liquefaction is most likely to occur and determine its impacts," said Ulmer.

Liquefaction is a dangerous phenomenon that can cause catastrophic loss of life and disruptions to supply chains. To better identify at-risk areas and infrastructure, updated predictive models will identify if costly mitigation strategies are needed to prevent serious damage in an earthquake.

"That's the goal — improving public safety and providing the most useful and up-to-date tools to evaluate earthquake-related hazards to America's roads, bridges and tunnels," said Ulmer.

The SwRI team will collaborate with researchers from The University of California, Los Angeles and Oregon State University on this project. The project is sponsored by Structures and Geotechnical Programs of the FHWA Office of Bridges and Structures.

Dr. Kristin Ulmer assesses damage from a massive earthquake in Turkey in 2023. Ulmer leads a team improving models to help the Federal Highway Administration identify mitigation efforts needed to shore up America's roads, bridges and tunnels.

SwRI LAUNCHES BATTERY CONSORTIUM

SwRI launched the second phase of a consortium dedicated to understanding the performance of energy storage systems. The Electrified Vehicle and Energy Storage Evaluation-II (EVESE-II) consortium builds on more than a decade of SwRI-led, precompetitive research with companies across the mobility sector.

"We are proud to serve the EV industry by bringing together manufacturers, suppliers and battery designers and developers with materials scientists to address a variety of challenges," said Dr. Andre Swarts, an SwRI staff engineer in SwRI's Automotive Propulsion Systems Department.

EVESE-II will continue battery cell research while expanding its focus on module and pack research. "Cell research will remain at the heart of the program with a focus on test repeatability, cell aging and fast-charging behavior as well as exploring emerging cell chemistries with increased energy capacities," Swarts said.

Performance and abuse testing at various scales will provide critical data and insights to improve thermal management and safety performance using different technologies. For instance, direct cooling immerses the battery cells or packs into a dielectric fluid that dissipates heat more effectively than air cooling.

"The emphasis on immersion cooling came out of past EVESE work, which underscored its ability to enhance thermal management and mitigate thermal runaway," said SwRI collaborator Dr. Swapnil Salvi. "SwRI has developed a substantial portfolio of test capabilities over the past few years to support these research activities."

In addition, EVESE-II will explore new charging technologies, vehicle-to-everything (V2X) systems and advanced in-situ battery health diagnostics, all supported by advanced modeling and simulation.

SwRI Research Engineer Dr. Swapnil Salvi demonstrates a battery immersion cooling test rig used to support the Electrified Vehicle and Energy Storage Evaluation-II (EVESE-II) consortium.

103373

CYBERSECURITY RISKS WITH EV FAST-CHARGING EQUIPMENT

SwRI engineers have identified cybersecurity vulnerabilities with electric vehicles (EVs) using direct current fast-charging systems, the quickest way to charge electric vehicles. The high-power technology relies on power line communication (PLC) technology to transmit smart-grid data between vehicles and charging equipment.

A laboratory setup exploited vulnerabilities in the PLC, gaining access to network keys and digital addresses on both the charger and the vehicle.

"Penetration testing found that the PLC was poorly secured and lacked encryption between the vehicle and the chargers," said Katherine Kozan, who led the project for SwRI's High Reliability Systems Department. Older chips exhibited unsecure key generation when tested, which was confirmed to be a known concern.

The research is part of SwRI's ongoing efforts to help the mobility sector and government improve automotive cybersecurity spanning embedded automotive computers and smart-grid infrastructure. It builds upon a 2020 project where SwRI hacked a J1772 charger, disrupting the charging process with a lab-built spoofing device.

In the latest project, SwRI explored vehicle-to-grid (V2G) charging technologies governed by ISO 15118 specifications for communications between EVs and electric vehicle supply equipment to support electric power transfer.

"As the grid evolves to take on more EVs, we need to defend our critical grid infrastructure against cyberattacks while also securing payments to charge EVs," said Vic Murray, assistant director of SwRI's High Reliability Systems Department. "Our research found room for improvements."

"Adding encryption to the network membership key would be an important step in securing the V2G charging process," said FJ Olugbodi, who contributed to the project. "With network access granted by unsecure direct access keys, the nonvolatile memory regions on PLC-enabled devices could be easily retrieved and reprogrammed."

103409

SwRI research engineers, from left, FJ Olugbodi, Mark Johnson and Katherine Kozan demonstrate an adversary-in-the-middle device developed to test the cyber resiliency of ISO 15118-compliant vehicle-to-grid charging systems. With the device, SwRI identified cybersecurity vulnerabilities with electric vehicles using direct current fast-charging systems.

NEW HYPERSONIC ENGINE RESEARCH FACILITY UNDERWAY

SwRI recently broke ground for the Center for Accelerating Materials and Processes (CAMP), a new facility that will support research and development for tomorrow's high-speed aerospace engines.

"This project will help ensure the U.S. is a leader in high-speed propulsion research and development," said Dr. Barron Bichon, director of SwRI's Materials Engineering Department. "SwRI is committed to advancing this vital technology on behalf of Texas and the nation."

Market forces including growth in global defense, air travel, delivery and transportation needs are driving the demand for high-speed engines. Initial projects in the new CAMP facility will focus on demonstrating faster, more efficient techniques for manufacturing high-speed propulsion systems.

Once construction on the new two-story, 33,500-square-foot facility is complete, SwRI will begin evaluating new materials and processes designed to produce a high-speed engine in a considerably shorter amount of time than current production timelines.

"This new facility will see the development of innovative technology that reflects SwRI's mission of serving humankind," said Dr. Ben Thacker, vice president of SwRI's Mechanical Engineering Division. "Advancing high-speed propulsion systems propels us toward a future with stronger defense capabilities and greater global connectivity."

One of the CAMP facility's initial projects will involve procuring and installing manufacturing process test equipment. Under a contract from the Office of the Secretary of Defense's Manufacturing Science and Technology Program, SwRI engineers will demonstrate how the facility will reduce production times and costs. The Institute will invest an estimated $34 million in the construction of the CAMP facility.

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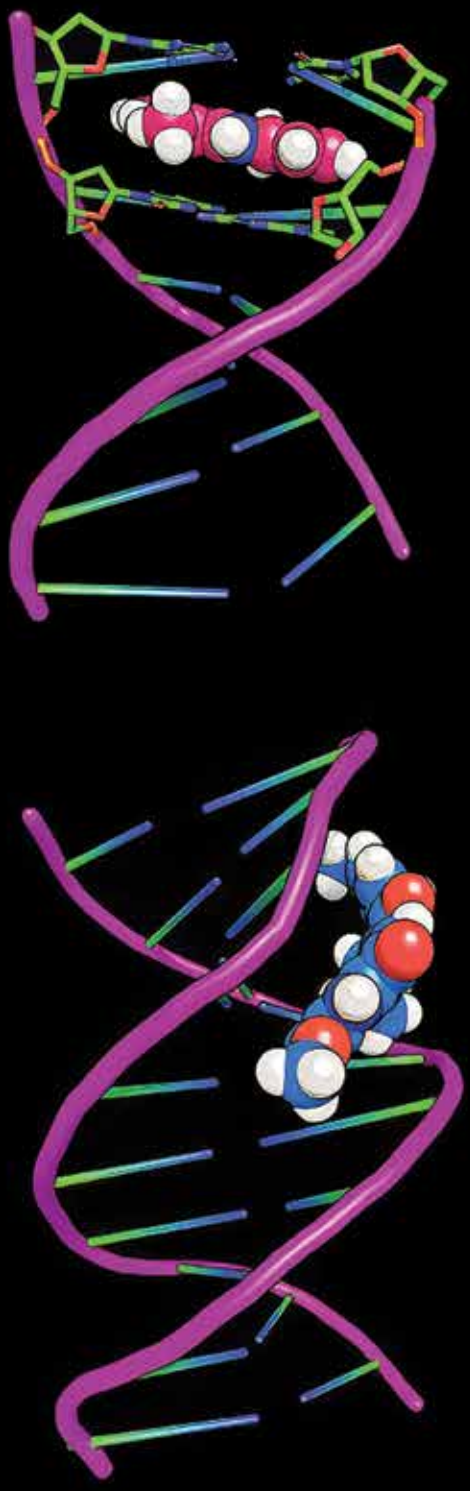


SwRI's Rhodium™ software can now screen potential DNA-targeting therapeutics for cancer and other diseases. This image was made using the PyMOL Molecular Graphics System (Version 3.0 Schrödinger LLC).

103401

SCREENING FOR NOVEL DNA-TARGETING THERAPEUTICS

SwRI has developed a unique technology to screen new DNA-targeting therapeutics designed to treat cancer and other diseases. Combining SwRI's 3D drug screening software tool Rhodium™ and machine learning techniques, SwRI scientists successfully predicted the DNA binding affinity and cancer cell toxicity for a variety of relevant drug compounds under development. This enables SwRI scientists to visualize and rapidly predict how DNA-targeting therapeutics can attack cancer cells as well as other diseases.

According to the World Health Organization, cancer is a leading cause of death worldwide, responsible for one in six deaths globally. Many chemotherapy drugs directly target DNA to shrink tumors and slow or stop the growth and spread of cancer cells. However, this approach can also damage the DNA in healthy cells, leading to severe side effects, medical complications and even secondary cancers. While many drug development platforms and machine learning methods focus on virtually screening drugs that target proteins, few methods exist for screening drugs that target DNA. SwRI has now successfully demonstrated a virtual screening application to design more effective DNA-targeting therapeutics to combat different types of cancer and infectious diseases.

"Cancer cells often have damaged DNA repair machinery and replicate much faster than healthy cells, which makes DNA a viable target for selective cancer treatment," said Dr. Tristan Adamson, a research scientist in SwRI's Pharmaceutical and Bioengineering Department. "SwRI has successfully developed and validated a powerful technique to use Rhodium for drug development campaigns that directly target DNA in oncology research for leukemia, breast cancer, liver cancer and more."

Dillon Cao, an SwRI scientist working with Adamson, added, "We want to make drug compounds more selective to target a patient's DNA for maximum efficacy while at the same time enabling scientists to prune away some of the drug toxicities."

As part of an internally funded research project, SwRI scientists developed several machine learning training sets, each serving important roles in screening potential DNA-targeting oncology drugs. These models have been validated using statistical tests and correlated with published experimental data. SwRI scientists accurately predicted the effectiveness of drug compounds against several cancer cell models using the technique. They now plan to apply this software in future drug development programs to design next-generation cancer therapeutics.

SwRI used internal funding to develop Rhodium software to provide a computer-aided tool to rapidly screen possible treatment methods to combat infectious diseases and chemical/biological warfare agents. SwRI's machine learning capabilities can evaluate more than 2 million drug compounds in just a few days to identify compounds with high probability for successful treatment with minimal adverse side effects. SwRI has used Rhodium to successfully identify highly potent therapeutics for several infectious diseases, such as COVID-19 and hemorrhagic fevers, as well as chemical nerve agent antidotes.

SwRI has more than 75 years of pharmaceutical research and development experience including virtual drug design, medicinal chemistry, formulation, microencapsulation, process development and CGMP synthesis scale-up.

UPCOMING

WEBINARS, WORKSHOPS and TRAINING COURSES HOSTED by SwRI:

Lateral & Torsional Rotordynamics Course, October 22, 2024, virtual.

Gas Turbine & Compressor Short Course, November 4, 2024, in-person, San Antonio.

Introduction to Microencapsulation, November 11, 2024, in-person, San Antonio.

Preliminary Aerodynamic Design of Centrifugal Compressors for Beginners, November 13, 2024, virtual.

Geothermal Energy Machinery and Systems (GEMS) Workshop, November 19, 2024, in-person, San Antonio.

Storage and Transportation of TRISO and Metal Spent Fuels, December 3, 2024, virtual.

Introduction to Propulsion Simulation Using NPSS, December 3, 2024, in-person, San Antonio.

Avoiding Lateral Rotordynamic Instabilities in Turbomachinery, December 11, 2024, virtual.

NASGRO Training Courses, January 14, 2025, virtual.

Industrial Processes Emissions Reduction (IPER) Technology, January 29, 2025, in-person, San Antonio.

TRADESHOWS:

ASNT Annual Meeting, Las Vegas, October 21, 2024, Booth 334.

Opportunity Crudes Conference, Houston, October 28, 2024.

SupplySide West, Las Vegas, October 30, 2024, Booth 3117.

AAAA Cribbins Readiness Conference, Huntsville, AL, November 11, 2024, Booth 1307.

CyberSat, Reston, VA, November 18, 2024, Booth 10.

Women's Global Leadership Conference (WGLC) in Energy, Houston, November 19, 2024.

Defense Manufacturing Conference (DMC), Austin, TX, December 1, 2024, Booth 228.

Aircraft Structural Integrity Program (ASIP) Conference, Austin, TX, December 2, 2024, Booth 13.

Professional Baseball Strength & Conditioning Coaches Society (PBSCCS) Winter Meeting Education & Trade Show, Dallas, December 12, 2024.

Feedwater & Secondary Systems Reliability Users Group (FSRUG), San Antonio, January 20, 2025.

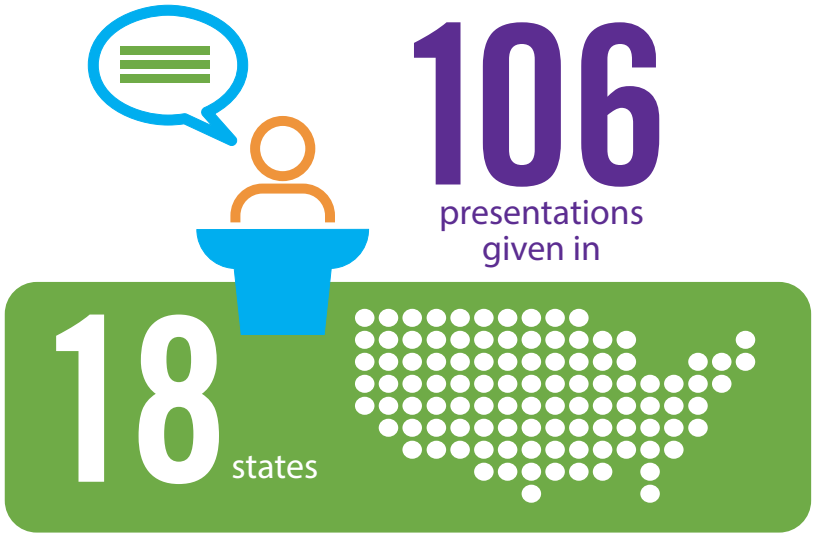
Conference on Composites, Materials, and Structures, St. Augustine, FL, January 26, 2025, Booth 8.

Operational Medicine (OPMED) Symposium & Technology Showcase, San Antonio, March 18, 2025, Booth 203.

For more information on upcoming events visit newsroom.swri.org.

BY THE NUMBERS

Summer–Fall 2024



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NASA selected Lead Scientist **Dr. Kelly Miller** to receive its 2023 Planetary Science Early Career Award. The award recognizes and supports exceptional early-career scientists who play a meaningful role in the planetary science community in areas relevant to NASA's Planetary Science Division. Miller specializes in researching the distribution and evolution of biologically relevant elements in planetary systems. She is the calibration lead for the Europa Clipper MASPEX instrument and a Europa Clipper project science team affiliate.

103419

Dr. James Oxley, an Institute scientist in the Chemistry and Chemical Engineering Division, has been named a Fellow by the Controlled Release Society. He is being recognized for excellence and innovation in delivery science. Oxley is an expert in microencapsulation, nanoencapsulation and other controlled-release technologies used in energy, food, pharmaceutical, cosmetic and consumer product applications. His research has developed novel formulations, materials and encapsulation techniques resulting in eight patents.

103424

Dr. Sergey Vinogradov, a staff engineer in the Mechanical Engineering Division, received the American Society for Nondestructive Testing Ward Rummel Engineering Excellence Award, which recognizes outstanding sustained contributions in nondestructive testing (NDT) by a single individual. NDT uses technology to evaluate and inspect materials and components for safety and reliability without damaging them. He pioneered using magnetostrictive transducer technology in NDE applications, developing the original designs as well as producing custom applications of this technology.

IEEE

Southwest Research Institute has received the Supporting Friend of the Electrical and Electronics Engineers (IEEE) Member and Geographic Activities Award in recognition of its "long and outstanding support of IEEE through paid volunteer time, membership subsidies, direct financial support and in-kind contributions." The award recognizes individuals, firms or divisions of firms that support IEEE and its members in achieving its goals. SwRI was recognized for supporting staff travel and participation in IEEE meetings, hosting IEEE meetings, promoting membership in IEEE and offering Institute resources and services for IEEE activities.

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EMPLOYMENT

Southwest Research Institute's staff of more than 3,000 employees provides client services in the areas of communication systems, modeling and simulation, software development, electronic design, vehicle and engine systems, automotive fuels and lubricants, avionics, geosciences, polymer and materials engineering, mechanical design, chemical analyses, environmental sciences, space science, training systems, industrial engineering and more.

SwRI is always looking for talented technical staff for its San Antonio facilities and for locations elsewhere in the United States. We welcome your referrals. Check our employment opportunities at **swri.jobs**.

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