Southwest Research Institute®

SPRING 2022

TECHNOLOGY TODAY®

SwRI microbiologists use these gel cultures to investigate how additives, biocides and storage conditions affect existing microbiological activity in fuel stockpiles. Environmental chambers control temperature and humidity, including using programmed exposure cycles. Scientists monitor fuel composition using a range of techniques, including pH tracking, membrane filtration, visual indicators and fuel properties. Microbiological activity is evaluated with adenosine triphosphate (ATP)-based measurements, viable growth on specialty media, thixotropic gel cultures and dark-field, brightfield and membrane-staining microscopy.

D024983_7794

SPRING 2022 • VOLUME 43, NO. 1

TECHNOLOGY TODAY

CONTENTS

ON THE COVER

D025301 P_V_150

To address potential risks associated with transitioning to a hydrogen-based economy, SwRI engineers used detonation experiments and computer simulations (shown here) to evaluate shockwaves generated by hydrogen explosions.

D024089_2653

IN THIS ISSUE

Welcome to the first issue of Technology Today in our 75th anniversary year. It's gratifying to know that, after three-quarters of a century, SwRI remains ahead of its time.

Consider the times when Tom Slick Jr. decided to expand his dream of a Scientific Research ranch (named "Essar" for the phonetic sounds of S and R) into an organization including technology and engineering — the so-called "hard sciences." In 1947, the world, and Tom Slick himself, had just emerged from a costly and brutal war into an uneasy and challenging peace. The war had been won largely through new technologies that were necessarily ahead of their time. His new creation, Southwest Research Institute, caught that tidal wave of technical advancement and has never allowed it to calm or flatten.

Through the lens of this Spring 2022 issue of Technology Today, let us compare events in the late 1940s with the Institute's activities now:

• 1947: High-octane leaded gasoline was gaining popularity as a preferred automotive fuel. 2022: SwRI is evaluating a transition to cleaner hydrogen and hydrogen-fuel blends to offer a more natural progression away from carbon-based fuels.

• 1947: U.S. policymakers laid out maps of what would become the preliminary federal highway system. 2022: SwRI is leading the development of a vehicle-to-everything platform in Florida that will pave the way for tomorrow's road systems that are fully and intelligently connected to prioritize mobility and safety.

• 1947: The X-1 became the first supersonic airplane. 2022: SwRI uses computational modeling and a two-stage light-gas gun to investigate the effects of sustained hypersonic (Mach 5-plus) flight.

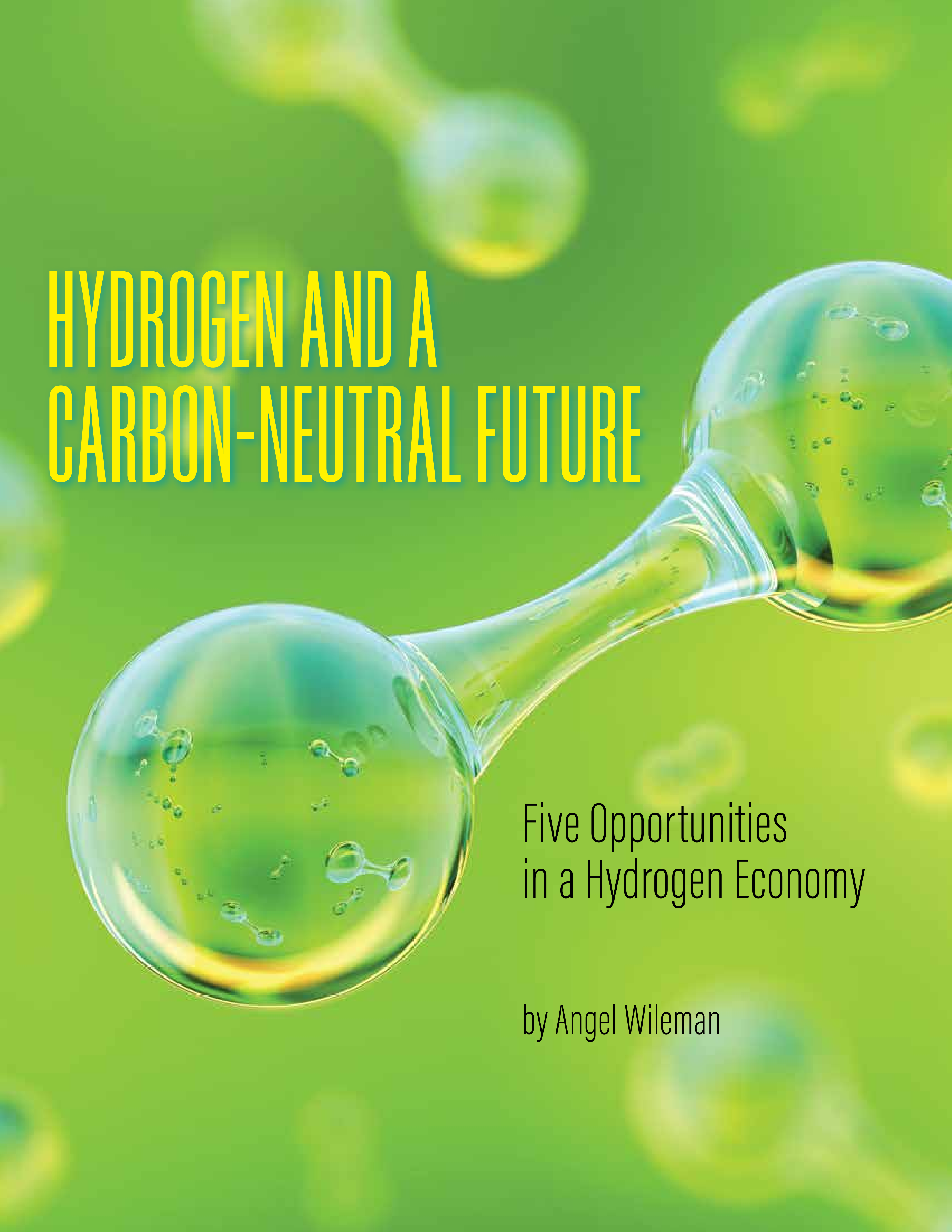
• 1947: The latest high-altitude rocket experiments had yet to escape Earth's atmosphere. 2022: The SwRI-led New Horizons spacecraft, having explored Pluto up close seven years ago, is now viewing the far-ultraviolet glow of deep space from a location so distant, it's no longer overwhelmed by sunlight.

Welcome to our celebration of 75 years of scientific and engineering progress. Welcome to our future.

Sincerely,

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

HYDROGEN AND A CARBON-NEUTRAL FUTURE



Five Opportunities in a Hydrogen Economy

by Angel Wileman

Some of the largest carbon contributors are the power generation, transportation, residential gas and manufacturing industries. For more than a century, petroleum products have fueled these activities, and extensive capital has been invested worldwide to build up petroleum-based processes and infrastructure. Upending the fossil fuels industry and redesigning the power grid in one fell swoop would be cost-prohibitive. An alternative such as transitioning to hydrogen gas that works with existing infrastructure could offer a more natural progression away from carbon-based fuels.

Consider power generation. Across the U.S., 61% of electricity is generated from natural gas and coal-fired power plants. In comparison, only 20% of our power is generated by renewables.[1] A 10-year industry-wide pivot to renewable electricity generation is estimated to cost more than $4.5 trillion dollars, including a $32,000 price tag for individual households.

The United States and many other countries have set goals to reach carbon neutrality by 2050 or sooner. To achieve this end, entire economies will need to be decarbonized.

Incrementally transitioning to alternative fuels using existing infrastructure offers distinct advantages.[2] For example, the power generation industry could begin blending small quantities of hydrogen gas into its natural gas pipelines within the next few years. This blended gas can be used at power plants to create electricity, or it can be supplied to residential homes for heating and cooking. The automotive industry has taken similar steps by blending hydrogen into diesel and natural gas engines to decarbonize large industrial vehicles.

Even these incremental changes in processes create technology challenges to be overcome in transitioning toward net zero carbon emissions. Hydrogen gas, the fuel discussed in this article, presents challenges with high generation costs, safety and material compatibility.

Transitioning to a hydrogen economy will require multidisciplinary approaches and broad expertise, particular strengths available at Southwest Research Institute. SwRI engineers and scientists are collaborating across multiple disciplines, looking at the opportunities and obstacles associated with this potentially clean energy source. For example, specialists from the Chemistry and Chemical Engineering Division are looking at hydrogen generation and safety. Teams from the Mechanical Engineering Division are looking at distribution as well as how hydrogen could be used for power generation. And Powertrain Engineering Division specialists are looking at different techniques for using hydrogen in transportation applications. SwRI is leveraging multidisciplinary approaches, working with U.S. government agencies and industrial partners to address technology challenges to move us closer to a carbon-neutral future.

D025231_1402

ABOUT THE LEAD AUTHOR
Angel Wileman, manager of the Thermofluids Section in SwRI's Mechanical Engineering Division, is leading SwRI's multidivisional hydrogen collaboration initiative.

[1] U.S. Energy Information Administration

[2] Wood Mackenzie, "Deep decarbonisation: the multi-trillion-dollar question" (2019)

D025235_1671

HYDROGEN GENERATION

Eloy Flores

SwRI's Chemical Engineering Department, led by Director Eloy Flores, is evaluating lab-scale techniques to produce zero-CO_2-emission hydrogen that creates useful carbon-based byproducts.

D025313

SwRI specializes in developing new processes for creating hydrogen and other fuels. We then demonstrate these processes in pilot plant facilities (shown here) that can be scaled up for actual production plants.

One of the primary challenges that must be solved is with hydrogen generation. How will the world make enough hydrogen to put a dent in carbon emissions at a price point comparable with fossil fuels? SwRI assists clients in areas of "clean" hydrogen production and utilizing hydrogen in the production of fuels and chemicals. SwRI's broad technology base offers an "all-of-the-above" option for our clients to develop, optimize and scale-up advanced production processes.

Hydrogen is already an important feedstock used to produce many of today's fuels, lubricants and chemicals. The two main methods for generating hydrogen are steam methane reforming (SMR) and electrolysis. Both processes have potential to create hydrogen with low carbon emissions, if implemented with carbon capture or renewable energy.

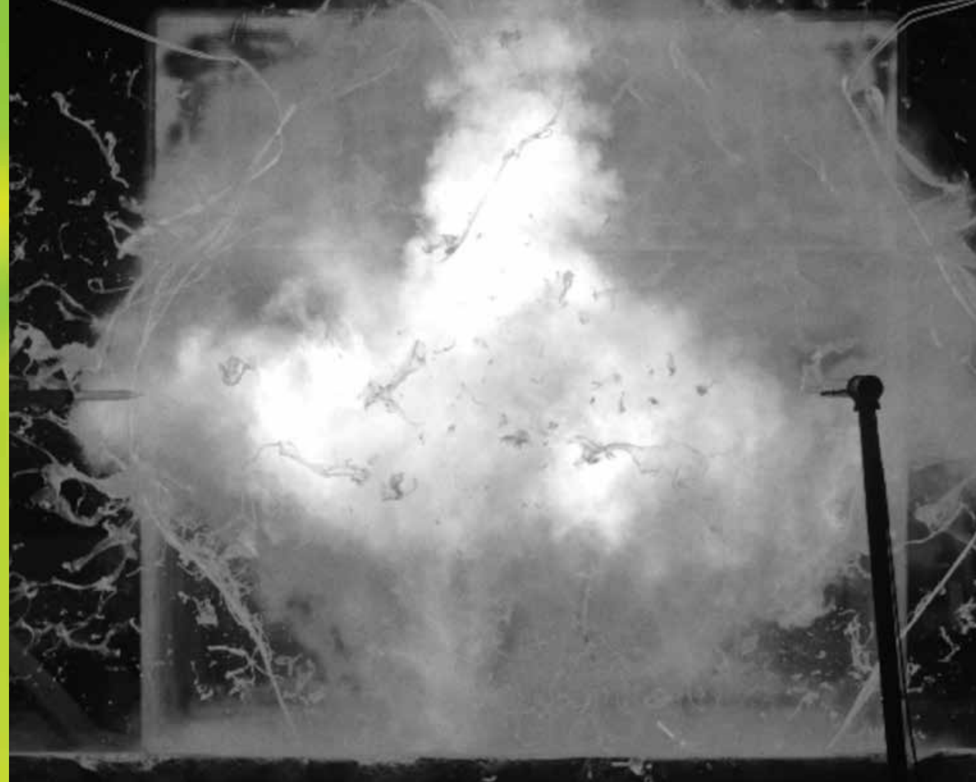
Industry traditionally uses SMR to produce hydrogen, combining methane and steam to produce hydrogen and carbon dioxide (CO_2). In 2018, the U.S. produced ten million metric tons of H_2 through SMR, producing about 90 million tons of CO_2 emissions. Because SMR produces most of the hydrogen used today, it offers a tremendous opportunity for reducing CO_2 emissions. SMR technology is fairly mature, so the challenges lie with decarbonizing that process to make clean "blue" hydrogen (see infographic about the hydrogen energy spectrum on p. 10). New carbon capture technologies have begun the transition from the laboratory into field application. As industry works to employ these emerging technologies, SwRI can provide expert assistance in scaling them up into pilot-scale and field-scale demonstrations.

Electrolysis produces hydrogen by splitting water into hydrogen and oxygen using electricity, special electrodes and membranes. Electrolysis typically requires a lot of power, but when the power comes from renewable sources, the resulting hydrogen has a minimal carbon footprint and is called "green" hydrogen. The downside of electrolysis is that it relies on certain exotic metals and traditionally high-cost membranes. SwRI is researching ways to lower the cost of electrolyzer construction and improve current efficiencies.

Methane pyrolysis produces a new "turquoise" hydrogen from natural gas without carbon dioxide emissions. The thermal process has been used commercially for years to create solid black carbon materials used in rubbers, tires, plastics and coatings. It breaks down the methane in the absence of an oxidizer, producing hydrogen gas and a solid carbon byproduct instead of gaseous emissions. Industry is now researching unique reactor designs or process conditions to reduce the energy penalty and carbon footprint associated with the thermal-based conversion process. Chemists are also designing a flexible process that can adjust to market demands for carbon products.

HYDROGEN SAFETY

Alexandra Schluneker



D025305

SwRI conducted experiments to characterize the hazards of hydrogen by filling bags with pressurized gas mixtures, igniting them and then imaging and measuring the detonation and shock propagation.

Hydrogen is a very small molecule. It is also one quarter the density of natural gas, which makes it difficult to contain. It can leak out of storage vessels and pipelines at a more rapid rate than natural gas, and when it escapes, it can ignite and/or explode over a wide range of concentrations. Hydrogen is a colorless, odorless and tasteless gas, and its flames are nearly invisible to the human eye, making the hazard harder to detect. So, how do we safely harness and use this energy resource?

As hydrogen becomes a larger part of the energy sector, the gas will be integrated into homes and businesses. Using modeling and testing, SwRI takes a holistic, multitiered approach to assess risk and consequences and develop mitigation techniques.

In particularly complex or hazardous environments such as a chemical plant, engineers can use custom computational fluid dynamics models to investigate incident scenarios. Using internal funding, SwRI developed a new computational capability to simulate gas-phase detonations for real-world scenarios that involve large-scale, complex domains and heterogeneous, multicomponent mixtures. SwRI researchers performed experiments to measure the overpressures that occur in a partially confined structure in the event of a detonation of hydrogen-air or methane-oxygen mixtures.

When models are not enough, SwRI performs large-scale experiments to gain a real-world understanding of the hazards of hydrogen gas. Engineers pressurize hydrogen vessels to their limit and test for weaknesses through scenarios such as bullet penetration and fire proximity. SwRI also collaborated with the National Institute of Standards and Technology (NIST) to conduct a series of experiments releasing hydrogen at various concentrations into full-scale residential garages — with and without an automobile present — that were then ignited. The findings helped create safety recommendations for the automotive industry.

D025231_1402

D025254_1942

Lead Engineer Alexandra Schluneker, a fire testing specialist, demonstrates one of the hazards of hydrogen. When burning, its flames are nearly invisible and require special equipment to detect as shown in the side-by-side comparison of standard and infrared images.

D025229_0219

Principal Engineer Buddy Broerman led the development of this novel compressor using custom materials and coatings to meet compression efficiency objectives. The LMRC device is undergoing further development in 2022.

HYDROGEN DISTRIBUTION

Eugene "Buddy" Broerman

D025229_0822

Senior Research Engineer Nathan Poerner performs maintenance on the hermetically sealed LMRC that SwRI designed for hydrogen compression.

Moving hydrogen from the point of distribution to the point of end use presents an array of technical challenges. The low density of hydrogen gas presents efficiency challenges for pressurizing the gas and pushing it around the country in pipelines. Hydrogen's associated small particle size also increases the potential for gas leaks in flow equipment. In addition, hydrogen is associated with increased fatigue crack growth rates, dramatically reducing the toughness of typical flow component steels and welds. This can lead to catastrophic failures in distribution equipment. SwRI is conducting research to address these challenges across the gas distribution industry.

Compressing hydrogen for pipeline distribution or as a transportation fuel is energy-intensive and challenging from a materials and reliability perspective. To address the need for faster and higher compression rates, SwRI designed, built and tested a novel hermetically sealed linear motor-driven reciprocating compressor (LMRC). This unique hydrogen compressor demonstrated enhanced reliability characteristices and leak-free performance for the transportation industry and beyond.

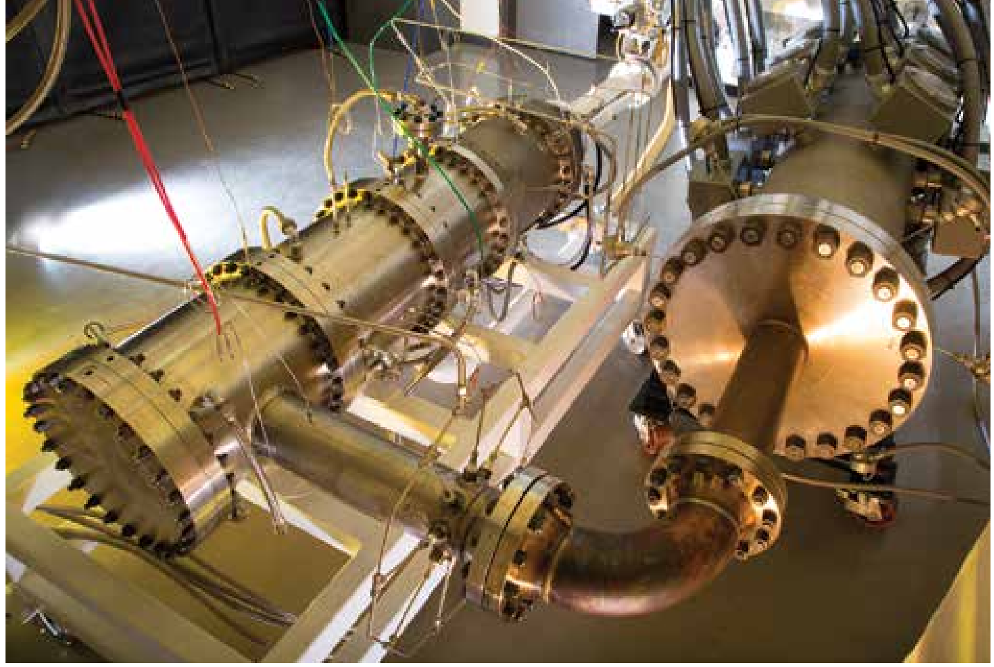
The U.S has approximately three million miles of natural gas pipelines but only about 1,600 miles dedicated to hydrogen. As a result, the industry is investigating using existing natural gas piping networks to transport cleaner blends of natural gas and hydrogen. SwRI is performing targeted research to understand potential impacts on pipeline operation, including relatively small volumes of hydrogen (up to 5%). Additional experiments and design activities will help industry address these challenges and include materials and leak detection testing for blended gases.

SwRI engineers are also characterizing how hydrogen blends affect the mechanical response of a variety of materials utilized in hydrogen gas transportation and integrating these results into integrity strategies. These fitness-for-service and engineering assessments are critical to determining safe operating conditions, minimum flaw sizes and inspection intervals.

SwRI performs mechanical testing in high-pressure hydrogen and blended-gas environments (up to 3,000 psi and 500° F) by coupling autoclaves to servo-hydraulic load frames. Engineers perform tensile, fracture toughness, fatigue crack growth rate, crack arrest threshold and strain-controlled and load-controlled fatigue tests per ASTM standards in relevant environments. This battery of tests is used to develop fitness-for-service analyses and ensure safe operation of structures and infrastructure. Additionally, SwRI supports the DOE HyBlend program to address pipeline material challenges caused by blending hydrogen with natural gas.

HYDROGEN for POWER GENERATION

Tim Allison and Tim Callahan



D021576_4187

SwRI developed and tested a micromix injector for gas turbines; this concept is capable of operating reliably at hydrogen's high flame speeds.

More than 40% of electricity in the U.S. is currently produced by burning natural gas in large combined-cycle power plants that often include both gas and steam turbines. Despite producing about half of the carbon dioxide emissions of a coal-based power plant, natural gas power plants still produce significant amounts of carbon dioxide. In contrast, hydrogen-based power shows the potential for zero-carbon emissions.

Like natural gas, hydrogen can be stored for extended periods in underground caverns, either as pure hydrogen, in hydrogen carrier compounds such as ammonia or through molecular adsorption into materials. SwRI's Sorption Science Laboratory evaluates the properties of potential hydrogen storage materials, measuring the performance of a variety of natural and synthetic adsorption materials. For instance, SwRI is part of a team working on the integration and techno-economic assessment of a high-density Cryogenic Flux Capacitor that stores hydrogen in an aerogel material at cryogenic temperatures. The team will integrate this technology into a 100-megawatt-hour system at a natural gas combined-cycle power plant for evaluation.

Hydrogen is not, however, a drop-in replacement for natural gas in a conventional power plant due to differences in combustion characteristics. Hydrogen has a much wider flammability range, lower autoignition temperature and faster flame speed than natural gas, which could result in damaging "flashback" conditions. SwRI is helping design and test next-generation gas turbine combustors that adapt the combustor geometry for hydrogen. These hydrogen-appropriate designs include "micromix" injectors with many small flow passages.

Spark-ignited, natural gas reciprocating engines widely used for power generation, as peak-shaving assets for power plants or for distributed power generation, can be adapted to natural gas/hydrogen blends or pure hydrogen. These power generation assets stabilize the grid as power demand fluctuates and provide backup power in the event of a supply disruption. Like gas turbines, reciprocating engines are sensitive to the combustion characteristics of hydrogen or hydrogen/natural gas blends that can contribute to abnormal combustion events resulting in engine damage. Through a combination of simulation, single-cylinder and multicylinder engine testing, SwRI is developing port- and direct-injection combustion systems and strategies to enable the use of hydrogen and hydrogen blends in these engines, while minimizing chances for abnormal combustion. SwRI has several specialized facilities to support the development of hydrogen engines up to 5 MW and can blend hydrogen with natural gas to facilitate engine testing.

The information, data, or work presented herein was funded in part by the U.S. Department of Energy, under award numbers DE-FE0032031, DE-EE0008415 and DE-EE0005805. The views and opinions of the authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

D025237_0651

Director Dr. Tim Allison, who specializes in energy production turbomachinery, is collaborating with Tim Callahan, a staff engineer focusing on engine development, on the hydrogen initiative. They are using SwRI's High-Energy Annex Test Facility to conduct large-scale testing of gas turbine combustor components, including single injectors or annular combustor tests, with fuel blends of up to 100% hydrogen fuel.

HYDROGEN in TRANSPORTATION

Graham Conway

D022750_6973

SwRI operates a medium-duty single-cylinder engine with 100% direct-injection hydrogen at 170 bar injection pressure to characterize hydrogen combustion.

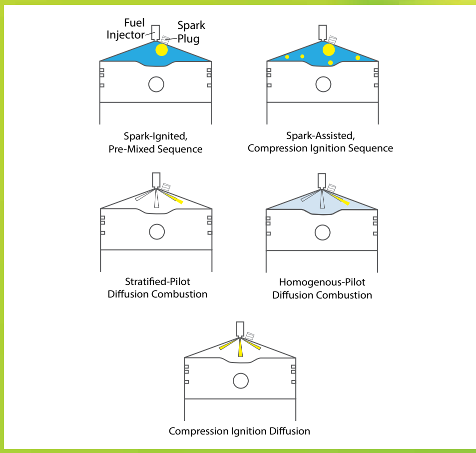
Transitioning the transportation industry to hydrogen fuel to lower tailpipe CO_2 emissions is a major technology and infrastructure development undertaking. Traditional internal combustion (IC) engines power today's ships, trains and automobiles (both highway and off-road), and there is no one-size-fits-all replacement technology. While battery power will likely be the ultimate low-emission solution for passenger vehicles, hydrogen shows promise for the remainder of the transportation industry. Hydrogen can either completely replace or supplement traditional fossil fuels in IC engines or can be used in fuel cell powertrains. Both solutions lower tailpipe CO_2; however, they also present unique technical challenges.

Hydrogen fuel cell electric vehicles (FCEVs) are on the cusp of maturity and an interesting alternative, particularly where battery power is not yet feasible, such as for large vehicles. However, fuel cells require a special high-purity hydrogen and are currently more expensive to produce and less durable than IC or battery powertrains. In contrast, the existing engineering, manufacturing and servicing infrastructure for IC engines is favorable for near-term transitioning to hydrogen IC engine solutions.

Using internal funding, SwRI is benchmarking one of the few commercially available FCEVs on the market, subjecting the vehicle to a barrage of tests and using the data to determine baseline characteristics. Benchmarking will allow SwRI to understand how current hydrogen-based FCEVs should perform and help establish a basis to compare future iterations and other FCEVs. Additionally, because fuel cells require different accessories than traditional internal combustion engines, the data may help material component suppliers and manufacturers prepare for future needs.

Hydrogen fuel can also decarbonize tailpipe emissions in IC engines. Spark-ignited IC engines burn gasoline and natural gas while diesel fuels compression-ignition engines. While properties of these fuels lend themselves to their respective combustion modes, hydrogen has unique properties supporting both spark-ignition and compression-ignition engines. For example, a high burn rate, low minimum ignition energy and wide flammability limits permit stable combustion under high-efficiency, dilute conditions. In spark-ignition engines, the low minimum ignition energy can also lead to challenges with controlling combustion, while high autoignition temperatures create challenges in compression ignition engines.

SwRI has developed a multimode combustion solution that takes advantage of positive fuel properties while minimizing the effects of negative properties associated with each combustion mode. Using internal funding, engineers are testing and modeling the globally patented multimode solution to optimize each strategy.



D025306

SwRI's patented multimode combustion approach for hydrogen IC engines takes advantage of properties that enhance combustion while mitigating attributes that negatively affect performance and safety. The combustion chamber shows ignition (yellow) will be spark-, compression- and spark-assisted compression in air-fuel mixtures, ranging from more air (lighter blues) to less air (darker blues).

D025243_1526

SwRI Principal Engineer Dr. Graham Conway, a leader in the Powertrain Engineering Division's Technical Planning and Roadmap Strategy steering group, is studying cleaner hydrogen-fuel engine applications.

EXPANDED VALVE TESTING, RESEARCH

SwRI has expanded its flow component testing facilities and capabilities to evaluate the performance and safety of valves, particularly those used in emerging carbon capture and hydrogen transport applications.

NITROGEN BLOWDOWN

SwRI's Blowdown Facility recreates the intense conditions of gas events, making it possible to test subsurface safety valve (SSSV) performance at high pressures to prevent injury, loss of life and environmental effects.

The facility recently recorded its highest-ever nitrogen flow rate of 310 million standard cubic feet per day (MMscfd) at 2,400 pounds per square inch gauge (psig). In addition to allowing more strenuous testing for SSSVs and other safety and pollution prevention equipment, SwRI is expanding its valve testing capabilities to evaluate existing SSSVs for carbon capture and storage (CCS) applications to support clean energy initiatives. Companies can reduce their carbon footprint by capturing and sequestering carbon dioxide (CO_2) in subsurface caverns, reservoirs or depleted oil wells. SSSVs can safeguard these storage applications.

"CO_2 storage is challenging, because the fluid can be very cold and solidify under certain conditions," said Nicole Lemon, a research engineer in SwRI's Fluids Engineering Department. "Increased safety measures are needed for CCS testing because CO_2 properties can change dramatically based on temperature and increased pressure. Increased safety measures are required for any testing program with CO_2 to avoid a gas event."

Investigating how existing SSSV designs perform at cold temperatures in CCS applications is critical prior to long-term service. SwRI's experience with cryogenic and extreme cold testing can help the energy industry evaluate existing SSSV designs and test newly developed hardware.

HYDROGEN

In seeking to decrease greenhouse gas emissions, the oil and gas industry is looking at blending hydrogen into natural gas streams that will ultimately be used for power generation or residential heating. This would require valve infrastructure to be less susceptible to hydrogen-related embrittlement and more leak-tight.

D025307

In addition to fire testing valves, SwRI offers a range of hydrogen safety evaluations and research, including evaluating valves for material compatibility and performance.

"Transitioning to hydrogen gas that works with existing infrastructure could offer a more natural progression away from carbon-based fuels," said SwRI's Angel Wileman, who heads the Institute's Thermofluids Section in the Mechanical Engineering Division. "Finding clean energy solutions using hydrogen comes with its own unique set of challenges, however. Challenges that SwRI can help evaluate and overcome." (see cover story, p. 2)

Hydrogen-specific valves must operate at either very low temperatures or high pressures to safely store hydrogen. SwRI offers nearly all testing methods for hydrogen valves, including fire testing and the international standard, ISO 19880-3. Test pressures can reach over 15,000 psig.

SwRI test facilities are accredited through the American Petroleum Institute (API) to perform validation testing on both surface and subsurface safety valves. The facilities accommodate safety testing of other flow components such as oilfield tools, pumping units and even fire hydrants. All testing is completed under an API Q1 and ISO 17025 quality management system.

D025302

SwRI's Flow Component Testing Facilities perform both standard and custom testing, including CO_2 SSSV testing.

The SPECTRUM of a Hydrogen Economy

In the quest for decarbonization, transitioning to a hydrogen-based economy could offer a realistic path to net zero emissions across the energy marketplace. Net zero refers to the balance between the amount of greenhouse gas produced and the amount removed from the atmosphere. Southwest Research Institute is investigating a palette of hydrogen technologies to develop clean, affordable and reliable

	GREY HYDROGEN	BLUE HYDROGEN
Process	SMR or gasification	SMR or gasification with carbon capture (85-95%)
Source	Methane or coal 	Methane or coal 

GREY HYDROGEN

Grey hydrogen (H_2), the most common form of H_2, is created using steam methane reformation (SMR) without sequestering the greenhouse gases made in the process. SMR, which emits 7 kg of carbon dioxide (CO_2) for every kg of H_2 produced, is only low carbon if CO_2 is captured and stored permanently.

BLUE HYDROGEN

Blue hydrogen is a low-carbon resource, also produced using steam reforming. The process uses natural gas to produce H_2 and CO_2, but the CO_2 is captured and stored. SwRI is investigating new carbon capture and storage techniques to decarbonize the process.

energy, reducing our dependence on fossil fuels and looking for greener alternatives.

When the oil and gas industry refers to the hues of hydrogen, it refers to the different processes used to produce each. While hydrogen is an invisible gas, color codes – green, blue, turquoise and grey hydrogen – highlight the environmental footprint associated with hydrogen production.

In addition to power production, SwRI is investigating using hydrogen in transportation activities including fuel cells in medium- and heavy-duty applications and as fuel for internal combustion engines. These applications could reduce carbon emissions, but the actual carbon footprint would largely be determined by the source or "color" of the hydrogen.

Other challenges to the hydrogen economy include hydrogen transport and safety. For example, hydrogen embrittlement could compromise existing natural gas pipeline infrastructure, and the low density of hydrogen gas makes it harder to pressurize and push around the pipeline network. Plus, small-size hydrogen molecules could increase leak risks and are flammable over a range of concentrations. Pressurized vessels containing compressed hydrogen are also subject to rupture if the vessel is compromised. SwRI is conducting research to characterize and mitigate these risks.

TURQUOISE HYDROGEN

Pyrolysis

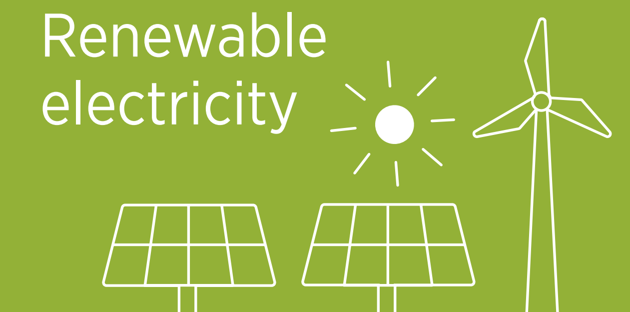
Methane

Turquoise hydrogen is an emerging resource, produced using methane pyrolysis without gaseous carbon emissions. The thermal process splits methane, producing H_2 and carbon solids. SwRI is researching unique reactor designs and process conditions to reduce the energy penalty and carbon emissions associated with the process and improve the utility of carbon solid byproducts.

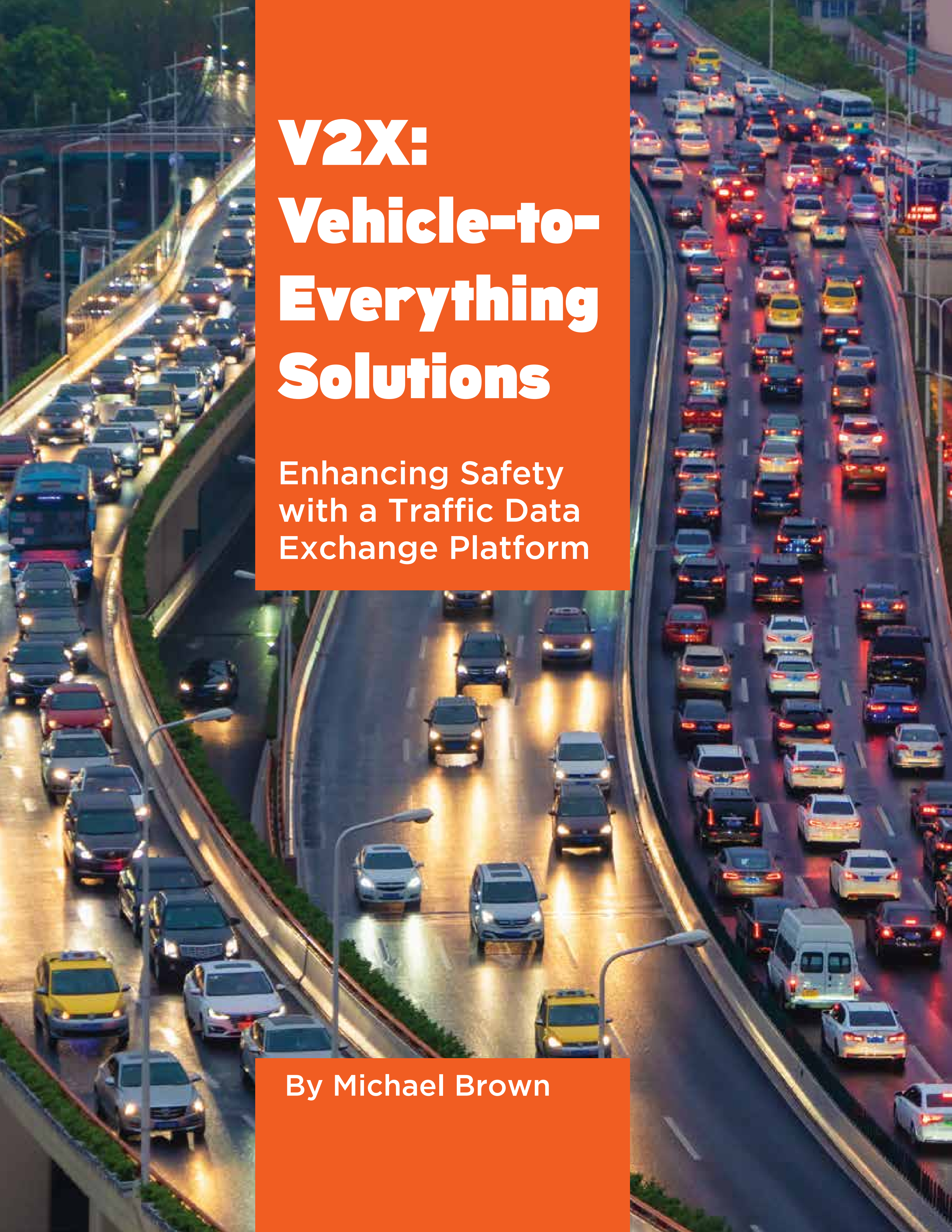
GREEN HYDROGEN

Electrolysis

Renewable electricity



Green H_2 is a zero-carbon resource, produced using electrolysis powered by surplus renewable energy from solar and wind resources. SwRI is studying the electrochemical reaction used to split water into hydrogen and oxygen, emitting no CO_2 in the process. Chemical engineers are researching ways to lower the cost of electrolyzer construction and improve current efficiencies.



V2X: Vehicle-to-Everything Solutions

Enhancing Safety with a Traffic Data Exchange Platform

By Michael Brown

Next time you are stuck in traffic amid a sea of tail lights and exhaust emissions, imagine a roadway where movement is fully and intelligently connected to prioritize mobility and safety. Vehicle-to-everything, or V2X, aims to integrate transportation offering near-real-time connectivity with other vehicles, networks, pedestrians, devices and roadway infrastructure. Millions of vehicles, people and transportation technology would be in constant communication, providing seamless interchanges, rerouting journeys away from congestion, dynamically updating traffic controls, efficiently allocating parking and so on.

DETAIL

What are V2X technologies? V2X (vehicle-to-everything) includes networks, devices and data shared via V2V (vehicle-to-vehicle), V2N (vehicle-to-network), V2P (vehicle-to-pedestrian), V2D (vehicle-to-device) and V2I (vehicle-to-infrastructure) connectivity.

ABOUT THE AUTHOR

Institute Engineer Michael Brown has been a leader in intelligent systems for more than 25 years. He has led multiple connected and automated vehicle programs for the U.S. Department of Transportation and is leading key activities for related programs for the U.S. Department of Energy. Brown has also led multiple programs for state DOTs including the Florida Department of Transportation Vehicle-to-Everything (V2X) Data Exchange Platform discussed in this article.

D025244_1707

According to one forecast, the automotive V2X market is slated to grow at an annual rate of 38%, from $619 million in 2021 to more than $2.2 billion in 2025. The numerous benefits of V2X implementation, however, face challenges, including requiring a secure system that ensures privacy, authenticity and security for all types of V2X communication. Deploying V2X requires coordinated action across the mobility marketplace, from individual automakers to federal, state and local transportation agencies to infrastructure technology and communications networks.

With more than two decades of leadership in intelligent transportation technology and applications, Southwest Research Institute is on the vanguard of V2X research, development and deployment. SwRI engineers are leading a project to develop a data exchange platform for the Florida Department of Transportation (FDOT).

This system will leverage cloud, fog and edge computing to analyze road conditions and communicate important information to the traveling public, state/local government entities, private sector partners and other stakeholders. The platform will archive data to allow long-term historic analyses to support data-driven infrastructure investments and research initiatives.

SAFETY CENTERED

No matter how it operates, V2X is all about safety. The U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) estimated that 31,720 people died in motor vehicle crashes from January through September 2021, an increase of approximately 12% from the 28,325 fatalities projected for the first nine months of 2020. These data represent the highest number of fatalities during the first nine months of any year since 2006, and the highest percentage increase during the first nine months in the Fatality Analysis Reporting System's history. Moving the needle to enhance roadway safety could not come soon enough.

NHTSA estimates vehicle-to-vehicle (V2V) alone could reduce crashes by 13%, resulting in over 600,000 fewer accidents each year. The U.S. Department of Transportation estimates that V2X technology could reduce unimpaired driver crashes by as much as 80%. With V2X, all traffic participants will be able to better perceive and predict each other's behavior on the road. That will reduce crashes, congestion and other inefficiencies.

The FDOT project will be among the first in the United States to develop a V2X data exchange, capturing data from thousands of devices across connected and automated vehicle (CAV) and infrastructure networks. A key objective of the project is to standardize the collection, analysis and sharing of data from several disparate systems, which have different coding and encryption methodologies, and to make additional considerations for privacy and safety. The primary goal is to save lives and move people more efficiently on roadways by sharing driving conditions. This data exchange will lay the foundation for FDOT to send alerts to drivers and traffic managers to coordinate routing, road closures and emergency responses.

Another important aspect of safety is security, including hardening the technology for cybersecurity. The exchange will capture anonymous data both from standardized onboard units communicating directly with FDOT-owned roadside units and from the proprietary data feeds of various car manufacturers and fleets.

This connected vehicle data will be fused with a breadth of other data both from FDOT-owned infrastructure and from third-party data feeds. This stream of enriched data will be the basis for alerts in the near term as well as analyses of long-term data to combine machine learning and traditional algorithms to understand trends and ultimately revolutionize how to manage traffic.

COMPLEX COLLABORATION

Perhaps the most significant aspect of this program is the team of players involved in its development, which highlights the level of cooperation needed to deploy V2X on a wider scale. The SwRI-led team includes tech companies, vehicle manufacturers, academia, cloud and network providers,

D025314

SwRI is leading the development of a statewide data exchange program for FDOT that ingests high-volume, high-velocity data from diverse sources. The platform will facilitate detection and notification of actionable conditions as well as historical analysis to support future initiatives.

original equipment manufacturers (OEMs) and fleet companies, as well as transportation agencies and the communications sector. The V2X Data Exchange Platform is intended to encompass FDOT's operational, in-development and planned CAV project corridors. The system will enable FDOT to disseminate CAV information to the automobile industry, logistics providers and other third parties to consume for their specific applications.

This V2X architecture takes advantage of a variety of computing and data storage resources, serving as different layers of an overall application. Generally speaking, the edge processes data locally to reduce network traffic and resources. The fog acts as a gateway, collecting, combining and processing relevant edge data, distributing some back to the edge and some back up to the larger cloud of data. The cloud then intelligently stores the information to provide access to data and archive long-term materials.

Some of the challenges facing V2X are similar to those faced in other internet of things (IoT) applications, where networks of disparate devices must learn to communicate and collaborate in near-real-time applications but in a cloud-based digital ecosystem. The key to the V2X applications is employing fog and edge computing. In this application, the fog processing is largely provided by the intelligent transportation systems whereas the edge is largely a function of increasingly intelligent, connected vehicles and roadside equipment.

EDGE

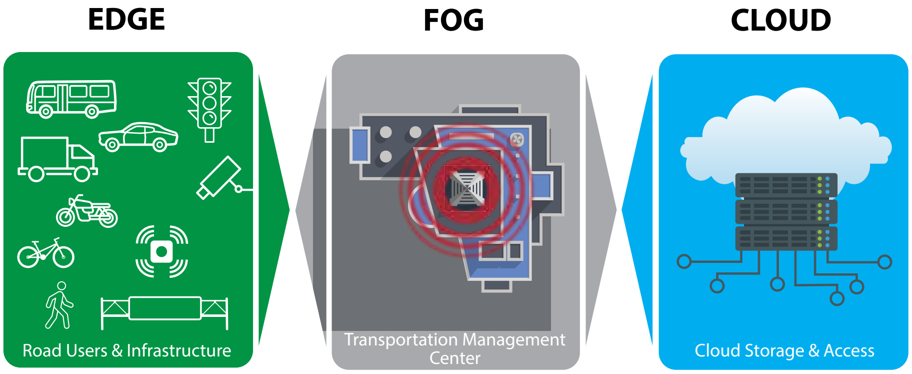
The vehicle edge is a critical component in V2X, so the automotive industry is undergoing a series of transitions, moving toward digitalization and connected mobility. While sales of traditional cars are decreasing, sales of connected cars are increasing, signaling changing consumer preferences.

Connected car adoption is accelerating from 35% in 2015 to around 98% of all cars sold through 2020. The shift from conventional to intelligent vehicles includes growing networks of digital technology and microprocessors within a vehicle powering performance, control and communication systems that can alert and assist drivers, helping to reduce crashes.

Through V2V technology, vehicles wirelessly exchange information about the speed and position of surrounding vehicles to help prevent crashes, ease traffic congestion and improve the environment. The greatest benefits will be achieved when all vehicles can communicate with each other, but in the interim, older vehicles will still benefit from V2X through existing Advanced Traffic Management Systems technology used in most urban areas.

Connected vehicles broadcast and receive omnidirectional messages, providing a 360-degree awareness of similarly equipped nearby vehicles. V2V messaging has a range of around 1,000 feet to assess speed, position and heading. Many vehicles offer driver-assist technologies like blind spot alerts to help prevent crashes, using sensors on the vehicles. Connected vehicles will share this information, for instance alerting a driver when an out-of-sight vehicle several cars ahead is braking.

Roadside infrastructure such as cameras, weather sensors and traffic signals is also



DETAIL

Cloud, fog and edge computing represents different layers in information technology. Cloud computing stores and accesses data and programs over the internet, rather than on a local computer. Fog computing pushes data processing down to a local area network, closer to relevant sensor technology. Edge computing processes data away from centralized nodes, at the edge of the network and individual sources of data.

Lead Computer Scientist Darin Parish and Assistant Program Manager Dan Rossiter are developing V2X software that will support communications between technology such as traffic signal controllers, roadside cameras and traffic management systems to improve communications and safety for the traveling public.

D025244_1776

D025315

At the edge and fog level, SwRI's Active-Vision™ systems track and share trajectory information of vehicles in the vicinity using V2X.

part of the edge system. Holding as much information within the vehicle/roadside edge lowers the requirement for expensive transmission capacity. Edge computing optimizes data flow to minimize operating costs, moving information out into the fog as trends develop across the larger traffic ecosystem. Edge systems support reflex-like actions such as detecting wrong-way drivers and immediately notifying surrounding vehicles.

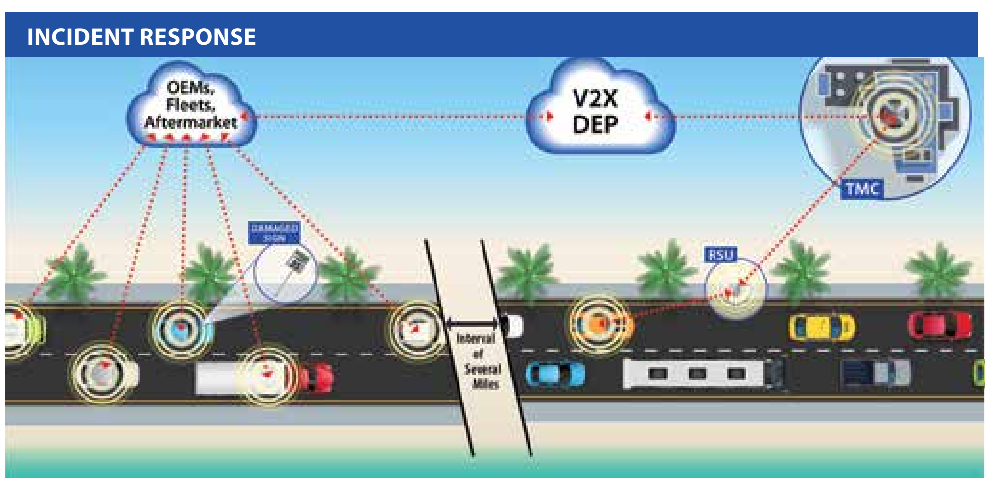
V2X information has been shared via a wireless protocol similar to Wi-Fi known as dedicated short-range communications (DSRC). However, the industry is quickly adapting a new protocol known as C-V2X, which complements cellular technology by offering a similar point-to-point communication mechanism while utilizing the mobile network for long-range applications.

Edge computing can allow traffic management centers to efficiently derive meaningful information from CAV and roadside sensor data.

FOG

Traffic management systems are the mission control or nerve center for an urban area's road system. In V2X applications, they serve in a fog capacity, collecting, combining, analyzing and sharing information both back to the traveling public and to the cloud network for archiving and analysis.

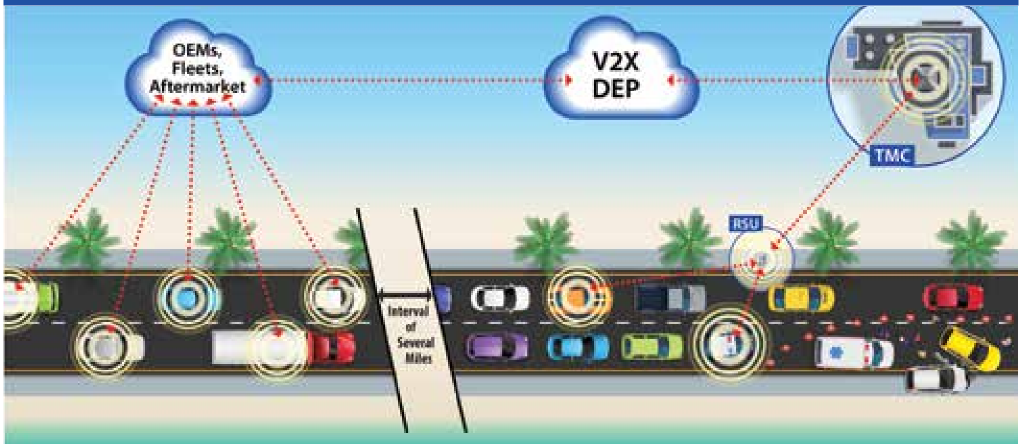
Most of today's intelligent transportation systems use a variety of roadside devices to monitor traffic, identify incidents and communicate with drivers. Cameras can identify and relay events causing backups to a traffic management system, which can then use dynamic messaging signs to communicate with the public, even recommending alternative routes. Advances are now allowing the vehicles themselves to directly communicate with infrastructure,



D025298

V2X applications will facilitate actionable communications while also archiving historical information in the cloud for traffic trends analysis.

V2X CHARACTERISTICS



D025299

Intelligent infrastructure uses various techniques to monitor traffic, identify incidents and communicate with drivers.

and the infrastructure can also communicate directly with drivers through messages to increasingly ubiquitous infotainment systems. The vehicles themselves are becoming sensors providing data to the intelligent traffic infrastructure.

SwRI is developing the scalable FDOT platform-based cost-saving serverless architecture, building and running services without having to manage the underlying infrastructure. Software developers will write and deploy code, while a cloud provider allows servers to run their applications, databases and storage systems at any scale.

CLOUD

The V2X platform will connect entire networks that will include other devices such as smart phones. Eventually, the vehicle computer vision systems could help identify potential bicycle and pedestrian safety concerns to serve these more vulnerable road users.

The FDOT V2X Data Exchange Platform's cloud-fog-edge-based architecture will make it easier to adapt, maintain and scale. The team is integrating fog and edge data, intelligence and processing capabilities closer to where the data originates — at the network edge. The low-latency system will be optimized to process a very high volume of data with minimal delay. Ultimately data will be archived in the cloud to provide both route-level visualization and historical views of traffic data and events, including daily heat maps for the speeds along a specified route.

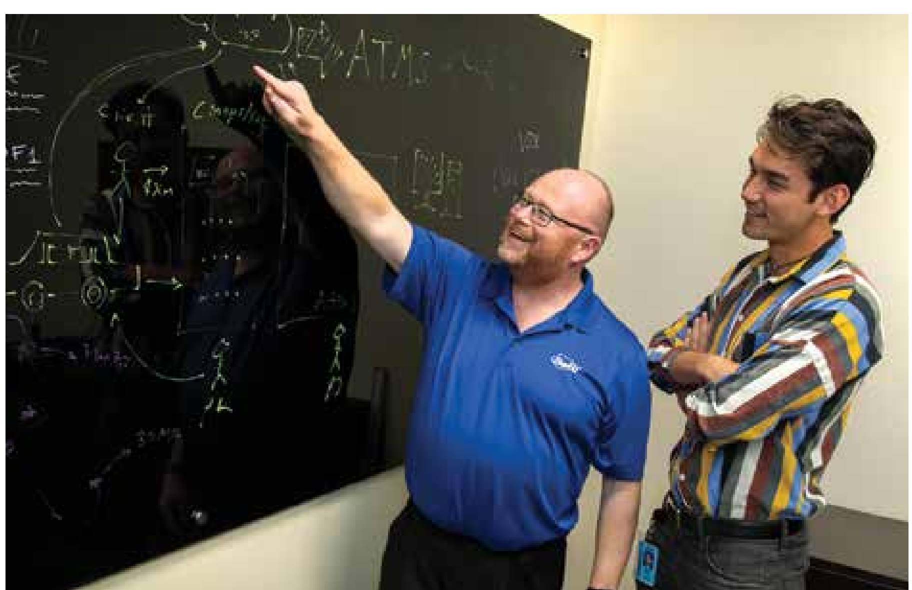
Various data warehouse services will intelligently store the data, distributed over several layers to provide rapid access while maintaining long-term data at minimal costs. Preprocessed data will be stored in three components. One data warehouse component will be optimized for quick queries and visualizing data. The "middle" component will support ad hoc and historical queries, and the long-term component will store data that is infrequently accessed. Decision support and data analytics will combine status information with static and historical data to provide actionable information to FDOT.

V2X REALIZED

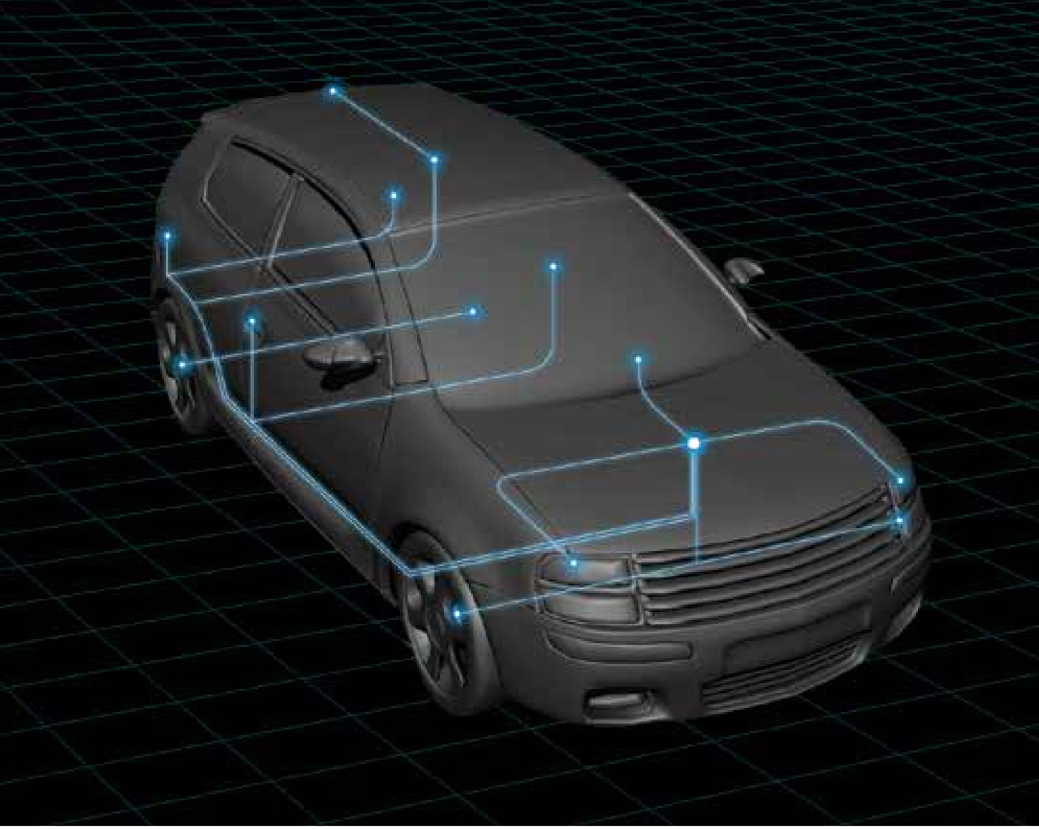
For more than 25 years, SwRI has been a leader in the development of intelligent transportation systems and machine learning technologies with software deployments at transportation agencies across the United States. SwRI's ActiveITS™ is used in 18 states and territories, which combined have more than 50% of the U.S. population. With this extensive experience, SwRI is developing the FDOT V2X platform to ingest high-volume, high-velocity data from diverse transit sources to enhance safety and mobility on Florida's roads.

Participants in this V2X program include Ford Mobility, which will supply V2X data from its connected vehicle platform; Iteris, a smart mobility company based in California; Florida International University; Amazon Web Services; Google; and several OEMs and logistics and fleet companies.

Institute Engineer Michael Brown explains how a cloud-fog-edge-based architecture will make the FDOT V2X Data Exchange Platform easier to adapt, maintain and scale to new staff member, Computer Scientist Jason Raiti.



D025244_1790



VEHICLE CYBERSECURITY, INTRUSION DETECTION

SwRI engineers have developed an intrusion detection system (IDS) to protect military ground vehicles against cyberthreats to embedded systems and connected vehicle networks.

Developed in collaboration with the U.S. Army Ground Vehicle Systems Center (GVSC) Ground System Cyber Engineering (GSCE) Directorate, the IDS technology uses digital fingerprinting and algorithms to identify communications anomalies across automotive systems and components.

Military, passenger and commercial vehicles use the standard Controller Area Network (CAN) bus protocol to enable communications across various microprocessor nodes or electronic control units. The CAN protocol, for example, informs a dashboard display when a sensor detects low oil pressure or when headlights are turned on. It also relays operational communications for systems such as transmissions and other critical automotive technology.

"A cyberattack could potentially send erroneous information across the CAN protocol to alter or impede a vehicle's operations," said SwRI's Jonathan Wolford, who co-authored a paper on the subject. "An attack on several connected vehicles could have disastrous effects."

Since 1986, CAN has been a standard automotive protocol, providing a reliable and flexible platform to transmit information. However, it was not designed with cybersecurity protections in mind. As modern vehicles become increasingly connected via external networks, the CAN system is more vulnerable to potential cyberattacks from bad actors sending false messages.

SwRI's new algorithms digitally fingerprint messages on nodes that transmit information via the CAN bus protocol. Digital fingerprinting allows SwRI's intrusion detection systems to identify when an unknown/invalid node or computer is connected to the vehicle network. These algorithms use the CAN transceiver's message transmission to track low-level physical layer characteristics — such as the minimum and maximum voltages as well as the voltage transition rates for each CAN frame — to create these digital fingerprints.

The researchers trained the system with baseline data to build a fingerprint of each node, understand characteristics and better identify anomalies. With digital fingerprinting, the intrusion system accurately identifies messages sent from unauthorized nodes or when a valid node is sending spurious messages indicative of a "masquerade attack."

After training the system, SwRI engineers injected false data, and the algorithms flagged them instantly. The system is capable of both identifying threats and defending against them.

"These attacks are theoretically easier for bad actors who have physical access to a vehicle, but vehicles are also vulnerable to wireless attacks," said SwRI's Peter Moldenhauer, who co-authored the research paper. "Our system is designed to build cyber resiliency into the CAN protocol as we move to more connected and automated vehicle networks."

While developed for military vehicles, the system can also be used to identify anomalies in passenger cars and commercial vehicles.

The research team won the Best Paper Award for the Cyber Technical Session at the 2022 Ground Vehicle Systems Engineering & Technology Symposium (GVSETS) conference. The paper is titled "Cyberattack Defense through Digital Fingerprinting, Detection Algorithms, and Bus Segmentation in Ground Vehicles."

Recent studies led by graduates of SwRI's joint graduate program in physics and astronomy with The University of Texas at San Antonio demonstrate new techniques to understand the composition of lunar surfaces.

The studies used data from the SwRI-developed and -led Lyman Alpha Mapping Project (LAMP) instrument aboard NASA's Lunar Reconnaissance Orbiter (LRO), a robotic mission launched in 2009 to study the surface of the Moon and investigate potential future landing sites.

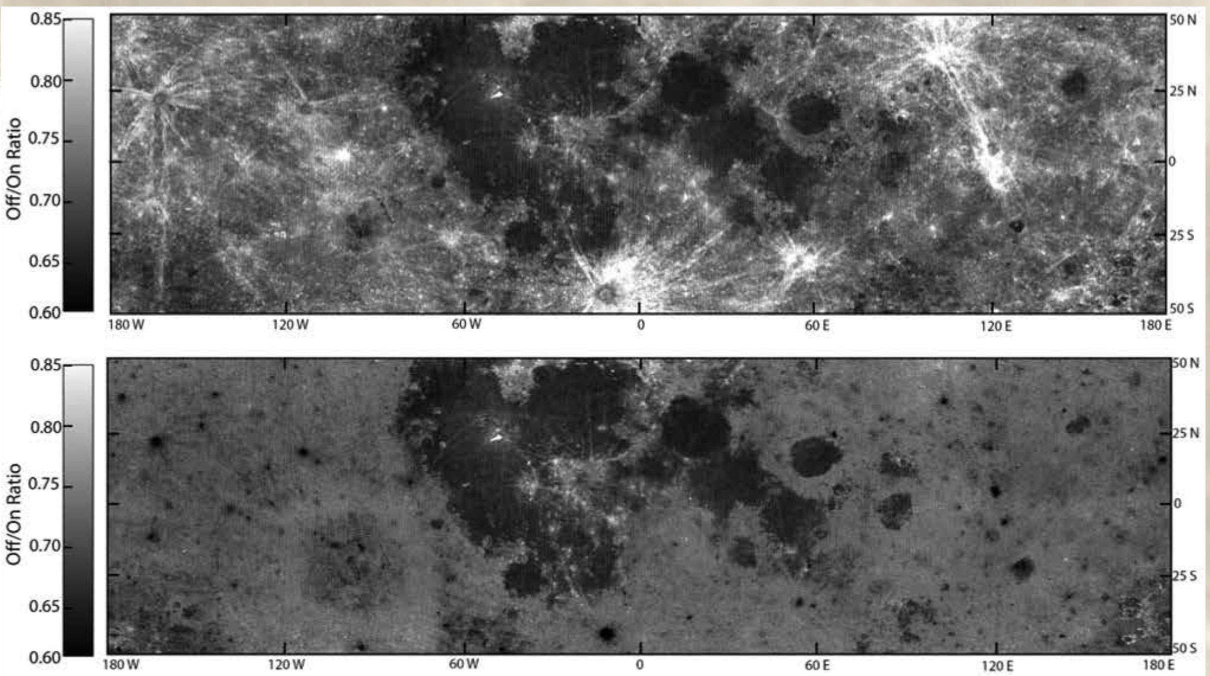
LAMP's primary purpose is to find water ice in deep polar craters using background ultraviolet light generated by stars. However, scientists are finding expanded uses for LAMP data.

NEW INSIGHTS FROM LUNAR INSTRUMENT

COMPOSITION, EVOLUTION OF LUNAR SURFACES

A study led by Dr. Benjamin Byron, a post-doctoral researcher at NASA's Jet Propulsion Laboratory, focused on measuring reflections of far-ultraviolet (FUV) light to understand the composition of lunar surfaces. LAMP's FUV observations indicate that the lunar surface reflectance in the ultraviolet wavelength is sensitive to changes in both composition and maturity. This can lead to uncertainties in the interpretation of the composition of features because space weathering over time dims older surfaces, while fresh impact craters are more reflective.

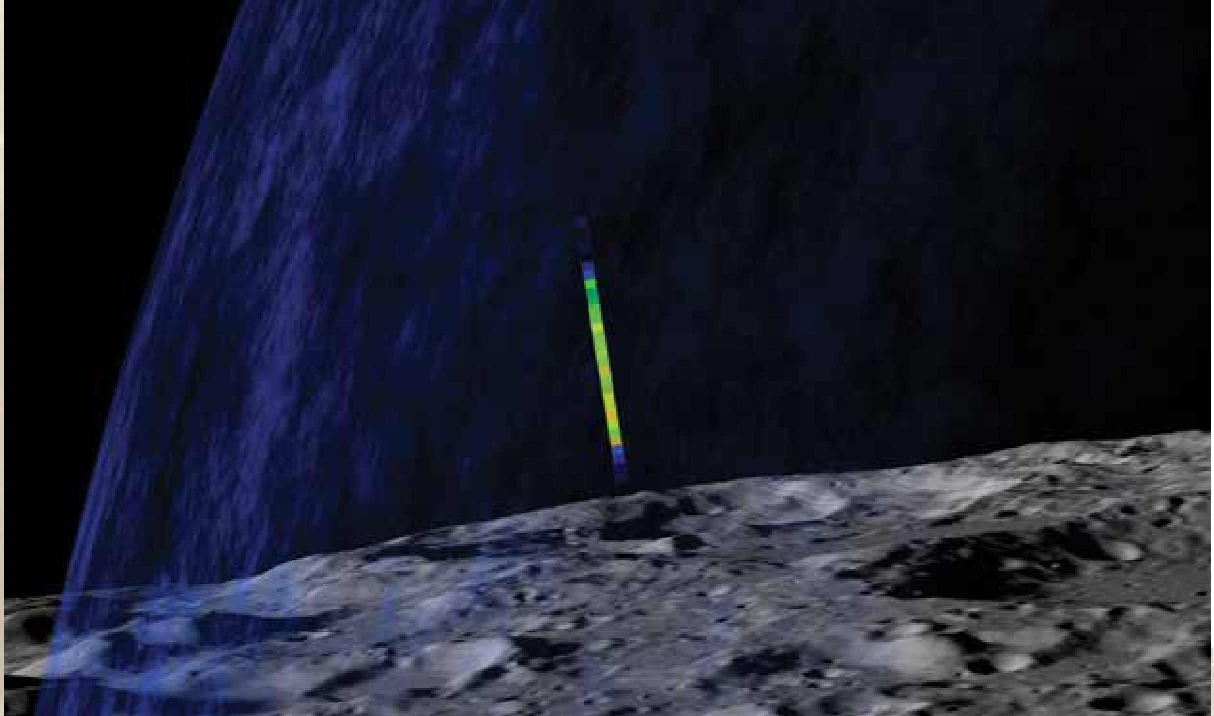
"We are using the optical maturity parameter to normalize these younger features in our maps of the lunar surface," said Byron, who conducted the research during his SwRI-UTSA graduate program. "This method had previously been used for other regions of the spectrum, but we've shown for the first time that it can be used for the far UV as well."



A new study used LAMP data to determine the composition of areas on the lunar surface by measuring the reflectance of far-ultraviolet light. The top image shows younger, less mature features such as impact craters while the bottom image removed these features to isolate the composition of lunar surfaces.

IMAGE COURTESY NASA/SwRI

D025325



D025326

SwRI scientists joined a team that reanalyzed and modeled decade-old data about materials ejected by an impact, shown here passing through LAMP's field of view. The new findings suggest that volatile materials in the permanently shaded region near the lunar south pole were likely delivered by a comet.

IMAGE COURTESY NASA/GSFC SCIENTIFIC VISUALIZATION STUDIO

The team used existing observations that characterized the surface maturity at visible wavelengths to apply an index called the optical maturity parameter. Byron removed maturity-related features from far-UV maps of the lunar surface so that only data about the surface's composition remained.

"What we see in our far-UV maps is a close correlation with composition maps from other regions of the electromagnetic spectrum," Byron said. "We're seeing these composition-related trends stand out in our maps more clearly than they had before, which allows us to have a global view of composition in the far-UV. It just goes to show that far-UV instruments such as LAMP are useful in performing compositional mapping for the Moon and for other bodies as well."

While far-UV spectrographs have been used to study the atmosphere and exosphere of other planetary bodies before, LAMP is the first to measure the composition of the lunar surface using reflected light in these wavelengths.

"I think this work shows how important it is to include instruments like these on future missions to asteroids and other planetary bodies without atmospheres," Byron said.

COMET DELIVERY TO MOON

SwRI scientists joined a team that reanalyzed and modeled data from a planned lunar impact more than a decade ago. The findings suggest that volatiles present in a crater near the Moon's south pole were likely delivered by a comet. Volatiles are chemical elements and compounds that can be readily vaporized and, in this case, were stabilized in ice lurking in this permanently shaded region (PSR).

LAMP had a bird's eye view when its launch vehicle's spent upper stage intentionally struck the Moon's Cabeus crater in 2009. LRO and the Lunar CRater Observation and Sensing Satellite (LCROSS) launched together and monitored the plumes of materials ejected into the atmosphere in this planned experiment to excavate and understand the origin and evolution of volatiles in this inky crater.

"The new research indicates that the crater materials are not volcanic in origin and are best explained by cometary impact delivery," said SwRI's Dr. Kurt Retherford, LAMP principal investigator. "Ruling out volcanic sources could mean that the top three meters of regolith in the Cabeus crater are younger than previously thought, probably less than a billion years old."

The most likely sources of the volatiles investigated were volcanic outgassing, comet or micrometeoroid impacts, and surface chemistry initiated by solar wind particles. For this research, the team looked at plumes of materials measured by LCROSS and LAMP and what they revealed about the composition of volatiles in the regolith. To simplify the analysis and eliminate as many influences as possible, the team compared the elemental composition of the volatiles to that of the potential sources, evaluating abundances of four elements — hydrogen, nitrogen, oxygen and sulfur — as they relate to carbon.

"Based on the ratios measured and the composition of comets, such as Rosetta spacecraft measurements of Comet 67P, comets are likely the primary source of these volatiles," said Dr. Lizeth Magaña, a recent graduate of the SwRI-UTSA program who recently joined the Johns Hopkins University's Applied Physics Laboratory.

"Studying these potential lunar resources not only supports expanded human exploration, but also helps us to understand the history of the Earth-Moon system," said JHUAPL's Dr. Kathleen Mandt, the lead author of a paper published in Nature Communications about this research. Mandt, a LAMP coinvestigator, was also a UTSA graduate and SwRI researcher prior to joining JHUAPL in 2017.

Present UTSA-SwRI graduate students continuing lunar studies with the LAMP team are Elizabeth Czajka, Caleb Gimar, Joanna Wedemeyer, Bereket Mamo, Mikhail Sharov and Patrice Smith.

When Pluto passed in front of a star, an SwRI-led team of astronomers measured the abundance of Pluto's atmosphere, shown here in New Horizons 2015 flyby data, and determined that it is dwindling.

D025300

PLUTO'S ATMOSPHERE DECREASING, FREEZING ONTO ITS SURFACE

When Pluto passed in front of a star on the night of August 15, 2018, an SwRI-led team of astronomers was watching. Numerous telescopes deployed at sites across the U.S. and Mexico observed Pluto's atmosphere as it was briefly backlit by the well-placed star. Scientists used this occultation event to measure the overall abundance of Pluto's tenuous atmosphere. The team found compelling evidence that Pluto's atmosphere is beginning to disappear, refreezing back onto its surface as it moves farther away from the Sun.

The occultation took about two minutes, during which time the star faded from view as Pluto's atmosphere and solid body passed in front of it. The rate at which the star disappeared and reappeared determined the density profile of Pluto's atmosphere.

"Scientists have used occultations to monitor changes in Pluto's atmosphere since 1988," said Dr. Eliot Young, a senior program manager in SwRI's Space Science and Engineering Division. "The New Horizons mission obtained an excellent density profile from its 2015 flyby, consistent with Pluto's bulk atmosphere doubling every decade, but our 2018 observations do not show that trend continuing from 2015."

Like Earth, Pluto's atmosphere is predominantly nitrogen. Unlike Earth, Pluto's atmosphere is supported by the vapor pressure of its surface ices, which means that small changes in surface ice temperatures would result in large changes in the bulk density of its atmosphere.

Pluto takes 248 Earth years to complete one full orbit around the Sun, and its distance varies from its closest point, about 30 astronomical units from the Sun (1 AU is the distance from the Earth to the Sun), to 50 AU from the Sun. For the past quarter century, Pluto has been receiving less and less sunlight as it moves farther away from the Sun, but until 2018 its surface pressure and atmospheric density continued to increase. Scientists attributed this to a phenomenon known as thermal inertia.

"An analogy to this is the way the Sun heats up sand on a beach," said SwRI Staff Scientist Dr. Leslie Young, who specializes in modeling the interaction between the surfaces and atmospheres of icy bodies in the outer solar system. "Sunlight is most intense at high noon, but the sand then continues soaking up heat over the course of the afternoon, so it is hottest in late afternoon. The continued persistence of Pluto's atmosphere suggests that nitrogen ice reservoirs on Pluto's surface were kept warm by stored heat under the surface. The new data suggest they are starting to cool."

The largest known nitrogen reservoir is Sputnik Planitia, a bright glacier that makes up the western lobe of the heart-shaped Tombaugh Regio. The 2018 data will help atmospheric modelers improve their understanding of Pluto's subsurface layers, particularly regarding compositions that are compatible with the observed limits on heat transfer.

SWRI STUDIES HYPERSONIC SEPARATION SYSTEMS

SwRI is collaborating with The University of Texas at San Antonio to advance hypersonics research under a three-year, $1.5 million grant through the University Consortium for Applied Hypersonics. As a subcontractor to UTSA, SwRI will design experiments to push the envelope on hypersonic system designs and provide methods to better model complex system behavior.

Hypersonic speeds are faster than five times the speed of sound, or greater than Mach 5. When something is flying that fast, the air around the flying object becomes superheated by shockwaves. Depending upon the speed, some points behind the shockwave are hotter than the surface of the Sun, causing the air to chemically decompose. This strange chemical environment can cause these flight bodies to heat up, melt and chemically react with the air, which poses a unique challenge for aerospace applications that require a separation event to occur.

Separation events happen when two or more parts of a vehicle intentionally come apart. SwRI's Dr. Nicholas Mueschke, program manager of SwRI's Computational Mechanics Section, is leading hypersonic separation experiments that aim to better understand the driving factors that must be considered to achieve successful separation.

Separation events are commonplace in many aerospace applications. For example, rocket boosters are ejected during space launches, including some that now return to the launch pad after separation. Military aircraft require safe separation of payloads carried underwing or within storage bays. Some rocket nose cones are designed to protect launch packages, such as satellites, which split open and separate from the vehicle in flight.

"Flying at hypersonic speeds within the atmosphere makes the aerodynamics and loads experienced by separating structures more difficult to predict and harder to safely design around, because the time-scales of these events are squeezed into milliseconds," Mueschke said.

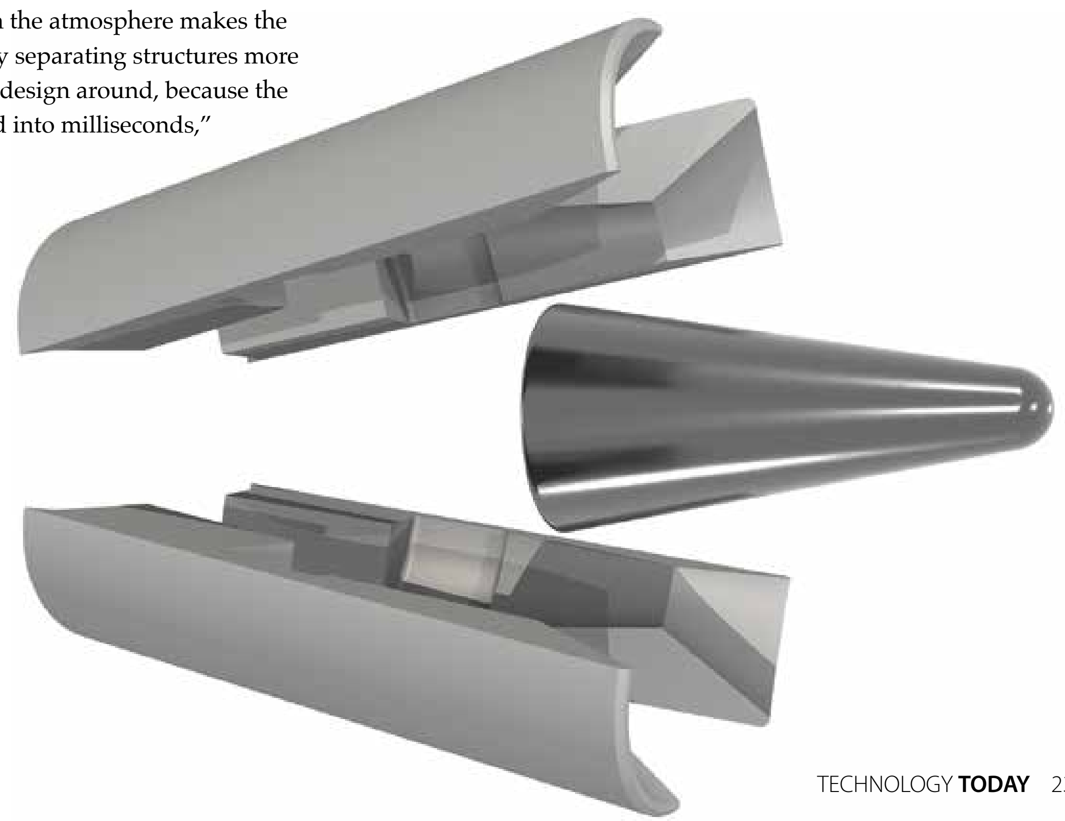
As next-generation hypersonic technology progresses, the ability to support separating components must also advance. A booster that separates from a vehicle, for example, allows for extended range and novel flight corridors. The challenge is designing components that can separate easily to avoid damaging or upsetting the primary vehicle, while withstanding the extreme aerodynamics and thermal environment associated with traveling at hypersonic speeds.

SwRI is designing novel experiments to evaluate hypersonic system designs while also providing methods to better model complex system behavior during separation events. The team is using the Institute's two-stage light-gas gun and ballistic testing facilities to simulate hypersonic flight conditions, which allows researchers to image objects in hypersonic flight.

"The goal is to generate aerodynamic and kinematic data that will anchor high-fidelity simulation models," Mueschke said. "We will also leverage some of our advanced simulation capabilities to design these experiments and evaluate how simulation models can improve future vehicle designs."

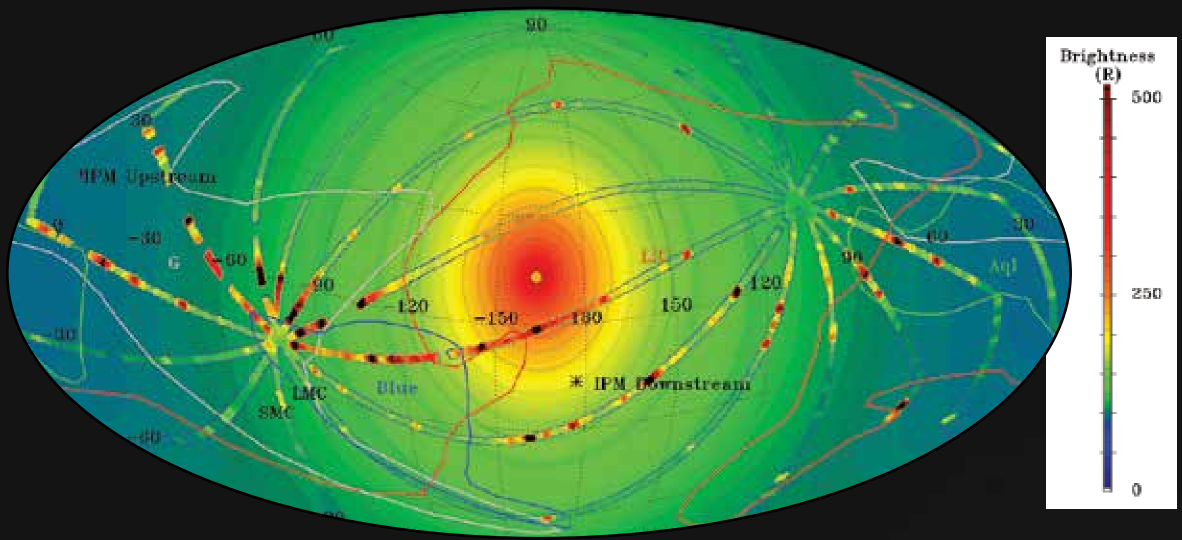
Ultimately, said Mueschke, this work is part of the broader effort to leverage hypersonic technology to deliver operational capability and options to combatant commanders that otherwise do not exist today.

The University Consortium for Applied Hypersonics is an inclusive, collaborative network of universities working with government, industry, national laboratories, federally funded research centers and existing university-affiliated research centers. It aims to deliver the innovation and workforce needed to advance modern hypersonic flight systems in support of national defense.



This image of hypersonic separation illustrates a conical flight body separating from a sabot after leaving the launch tube of the light-gas gun. Sabots encase projectiles to keep them aligned in the center of the barrel when fired.

D025303



From its vantage point aboard the New Horizons spacecraft traveling near the edge of the solar system, the SwRI-led Alice UV spectrograph characterized the subtle galactic component of the Lyman-alpha background UV glow. This false-color map illustrates the Sun-dominated Lyman-alpha component in orange as it fades to reveal the faint background UV light emitted by the Milky Way.

D025327/8

NASA's New Horizons Probe Measures UV Brightness of the Milky Way

A new study has determined the brightness of the galactic Lyman-alpha background light using an SwRI-developed instrument aboard NASA's Kuiper Belt space probe New Horizons.

The Lyman-alpha ultraviolet background, first detected in space in the 1960s and confirmed in 1971, bathes space in an ultraviolet glow. In most of our solar system, the background is dominated by Lyman-alpha photons emitted by the Sun and scattered by interstellar hydrogen atoms passing through. In the outer solar system, however, the scattered sunlight component of the Lyman-alpha signal wanes, making it easier to distinguish fainter components from the Milky Way.

"The galactic Lyman-alpha background comes from hot regions around massive stars that ionize all nearby matter, primarily hydrogen, the most abundant element in the universe," said SwRI's Dr. Randy Gladstone, the study's lead author. "When the electrons and protons eventually get back together, or recombine, they nearly always emit Lyman-alpha photons."

Hydrogen atoms between the stars scatter these photons into a roughly uniform glow throughout space. They are detectable, but only at the Lyman-alpha wavelength, which is not visible to human eyes. Because the solar component is so bright near the Earth, scientists could not tell how much light from the Milky Way galaxy contributed to its overall brightness.

"It's like standing near a streetlamp on a foggy night," Gladstone said. "The fog scatters the lamp's light, making it hard to see anything else. New Horizons has been flying away from the Sun for more than 15 years now. The farther we moved away from the Sun, the less we were blinded by the solar component of the Lyman-alpha background."

With the SwRI-led Alice UV imaging spectrograph aboard New Horizons, Gladstone was able to accurately measure the brightness of the galactic component of the Lyman-alpha background for the first time. New Horizons is now far beyond Pluto, allowing Gladstone to determine that the glow is 20 times dimmer than the Lyman-alpha background is near Earth.

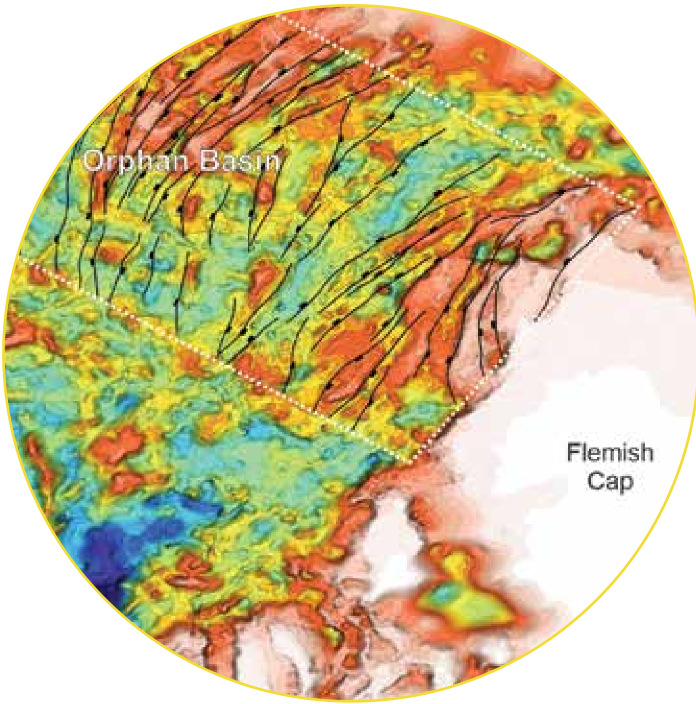
"This has been something that's been guessed at by astronomers for decades," Gladstone said. "Now we have a much more precise number."

Gladstone hopes that this discovery will help astronomers better understand the nearby regions of the Milky Way galaxy.

"The unique position of New Horizons in the faraway Kuiper Belt allows it to make discoveries like this that no other spacecraft can," said SwRI Associate Vice President Dr. Alan Stern, New Horizons principal investigator. "What a great resource New Horizons is, not just for the exploration of the Kuiper Belt, but also to understand more about our galaxy and even the universe beyond our galaxy through this and other observations by our scientific instrument payload."

IMAGES COURTESY NASA/JHU APL/SwRI

D025322



Characterizing Offshore Oil Fields

SwRI geologists completed research characterizing the complex geological evolution of the Orphan Basin, located off the eastern coast of Newfoundland and Labrador. Using an extensive database of new 2D and 3D broadband seismic reflection data, geologists were able to visualize and understand the area's subsurface.

"By incorporating seismic interpretations of rock structures and layers, along with regional gravity and magnetic data and estimates of crustal thicknesses, we were able to generate structural interpretations of the Earth's crust," said SwRI's Dr. Adam Cawood, who led the research and is lead author of two recent papers on the subject. "Integrating multiple datasets is critical for understanding complex structural development in frontier oil and gas exploration regions."

The Orphan Basin and Flemish Pass region on the Newfoundland continental margin is a frontier area for oil and gas exploration. The region has historically been poorly understood in terms of structural and tectonic evolution, with few exploration wells and, until recently, sparse seismic data coverage.

"We characterized the region using 2D and 3D seismic data, interpreting structural geometries and basin evolution through time," said SwRI's Dr. David Ferrill, who co-authored the papers. "These analyses provide the context for upcoming assessments of location and distribution of source rock, reservoir and seal strata for exploration in the area."

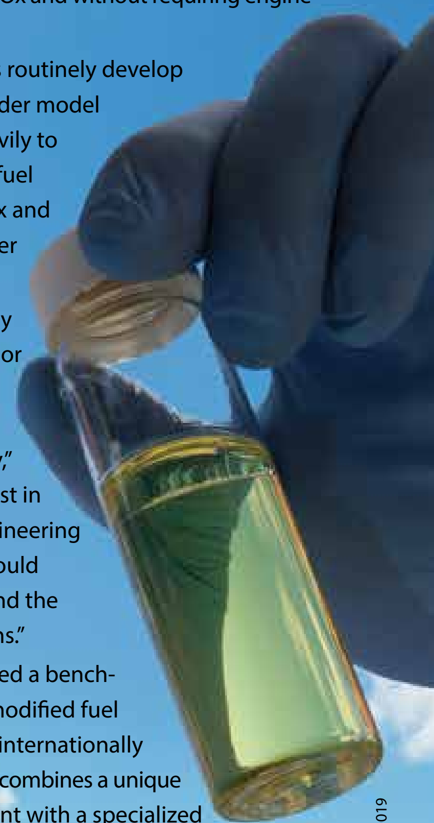
The team used defined protocols for cross-section construction and restoration, testing multiple scenarios and generating robust models for the geologic evolution of the Orphan Basin, Flemish Pass and Flemish Cap region.

"By doing this, we can better understand the tectonic evolution and related sediment accumulation during the formation of the North Atlantic, when the supercontinent of Pangea broke up and land masses drifted apart," Cawood said. "These results are important for interpreting the oil and gas potential in this frontier area."

CLEANER DIESEL FUELS

SwRI worked with a client to develop a post-refinery fuel treatment process that reduces exhaust emissions from diesel engines. The result is a modified fuel that could potentially replace today's ultra-low sulfur diesel, biodiesel and other renewable diesel fuels.

When burning a fuel-air mixture, internal combustion engines produce harmful pollutants such as soot and nitrogen oxides (NOx). Engineers design and calibrate engines to decrease emissions but have been stymied by the soot/NOx trade-off. Attempts to reduce soot with increased temperatures result in higher NOx, while lowering the temperature has the opposite effect. The modified fuel produces less soot emissions without increasing NOx and without requiring engine design or calibration changes.



Although engine manufacturers routinely develop cleaner engines for new vehicles, older model vehicles continue to contribute heavily to pollution levels. This new modified fuel could potentially lower exhaust NOx and particulates for both older and newer model diesel engine vehicles.

"While fossil fuels eventually may be replaced by electric powertrains or noncarbon fuels in our lifetime, the process developed with our client could be implemented immediately," said James Wood, a principal scientist in SwRI's Chemistry and Chemical Engineering Division. "Reducing soot and NOx could potentially protect human health and the environment from harmful emissions."

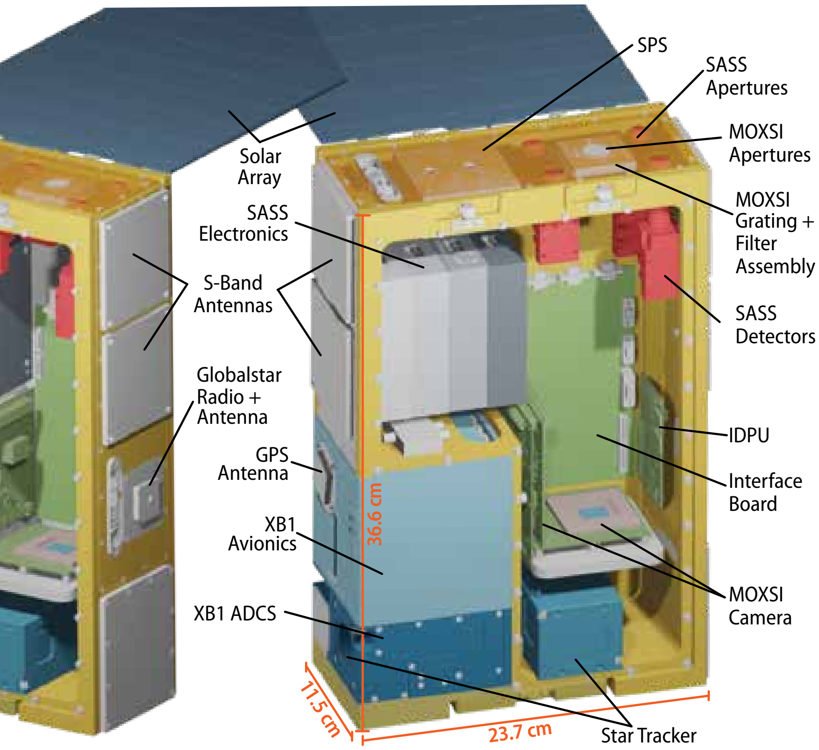
SwRI designed, built and operated a bench-scale processing plant to produce modified fuel samples for laboratory testing. This internationally patented breakthrough technology combines a unique low-concentration chemical treatment with a specialized mechanical mixing system to produce a stable diesel fuel.

SwRI's Powertrain Engineering Division evaluated the fuels during steady-state and transient engine emissions testing according to Environmental Protection Agency test procedures.

"The modified fuel resulted in a substantial reduction in soot mass emissions compared to the baseline ultra-low sulfur diesel," said Dr. Imad Khalek, a senior program manager who operates SwRI's particulate laboratory.

Based on the bench-scale plant, SwRI helped design a production-scale facility that meets ASTM International and ANSI (American National Standards Institute) standards and is capable of processing 12,000 barrels per day (150 million gallons per year). Production of the modified fuel is ready for commercial development.

NASA Selects SwRI-Led CubeSat Mission



NASA has selected the SwRI-designed CubIXSS as a secondary payload for an upcoming satellite launch. The shoebox-sized CubeSat includes multiple spectrometers to quantify elements in the Sun's corona and tease out the origin of hot plasmas in active regions that spawn explosive events such as solar flares.

D025318

NASA has selected the SwRI-led CubeSat Imaging X-Ray Solar Spectrometer (CubIXSS) as a secondary payload on an upcoming satellite launch. The nanosatellite will measure the composition of multimillion-degree plasmas in the solar corona — its outermost atmosphere — to characterize the origins of hot ionized gases in active regions of the Sun.

The Sun's active regions are characterized by disturbances in its magnetic fields. These regions spawn explosive solar events such as solar flares and coronal mass ejections (CMEs).

"As a magnetic field in an active region becomes increasingly twisted and tangled, it basically 'snaps' back into a less tangled shape," said SwRI Principal Scientist Dr. Amir Caspi, the mission's leader. "That snap releases a lot of energy and creates events such as solar flares."

The solar flare heats the Sun's plasma in that region to tens of millions of degrees Celsius, considerably hotter than the rest of the solar corona.

"We don't know how much plasma in solar flares is heated directly in the corona and how much is heated in the Sun's lower atmosphere and then transported up to the corona," Caspi said. "CubIXSS will measure X-rays from these phenomena to help us unravel this mystery."

CubIXSS is a larger CubeSat, about the size of a shoebox. It will carry multiple spectrometers to measure different wavelengths or "colors" of solar X-rays, including a new instrument that will quantify certain ions that only exist in a specific range of temperatures. Measuring the abundance of these elements at each temperature will provide insight into where heated plasmas originate.

"Studying the Sun is very important for people living on Earth," Caspi said. "CMEs and solar flares can disrupt satellite and ground-based communications. Understanding how these things happen will help us understand why they happen, which will help us predict these events and mitigate their effects."

INSPECTING AIRCRAFT ENGINE MATERIALS

The dark regions in this image show the "dirty white spots" sometimes found in nickel alloy engine components, anomalies that can lead to catastrophic failures. Under a new FAA contract, SwRI will develop new inspection methods to ensure anomalies like these are detected during the material manufacturing process.

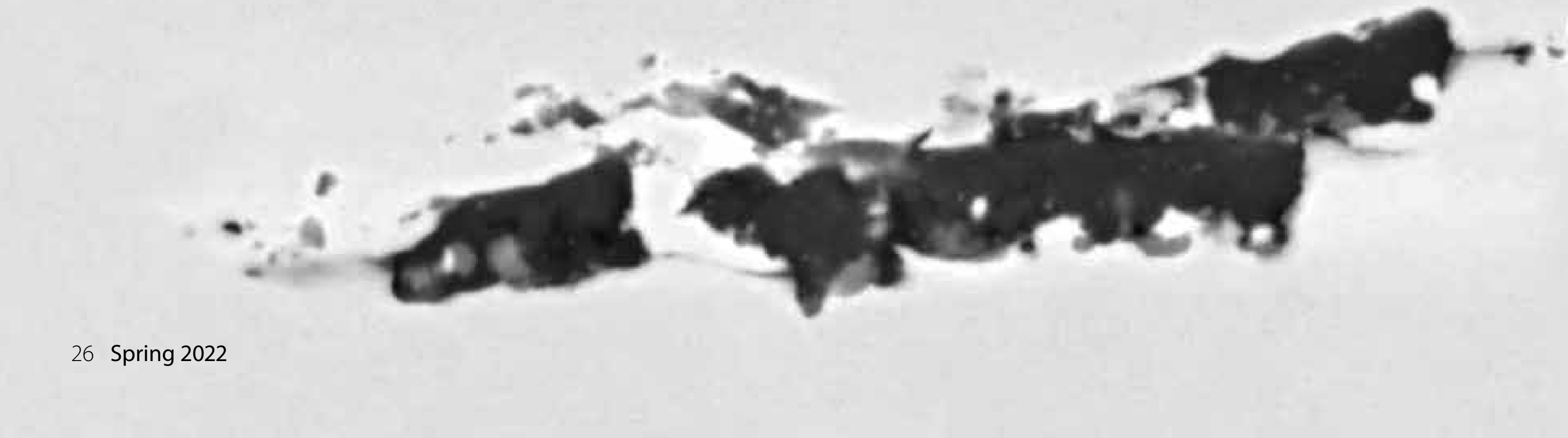


IMAGE COURTESY FAA D025321

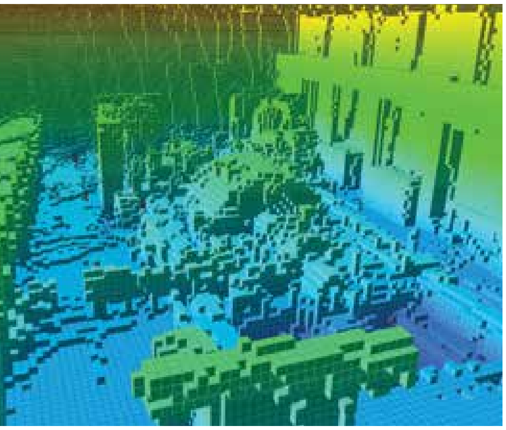
WEST TEXAS SPRING STUDY

SwRI hydrologists are conducting a two-year investigation of West Texas spring systems to improve water resource management for semiarid regions. Funded by a WaterSMART Applied Science Grant from the U.S. Bureau of Reclamation, the project is studying vital water systems at potential risk, including San Solomon Springs.

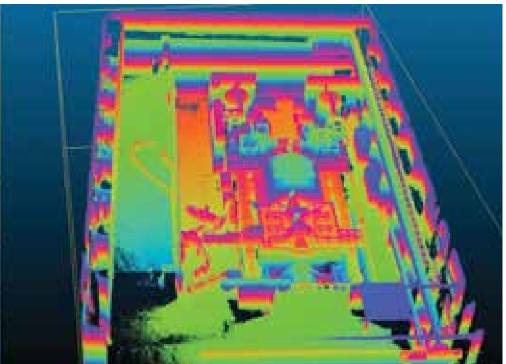
D025320

D025317

D025316



D025316



SwRI DEMONSTRATES DRONE AUTONOMY

During the European Robotics Hackathon (EnRicH) 2022, SwRI demonstrated an unmanned aerial system (UAS) that autonomously explored and mapped the interior of a nuclear power plant and detected radiation sources autonomously without the aid of a human pilot. The drone technology can potentially assist in life-saving search-and-rescue missions and hazardous inspections at industrial facilities and infrastructure following natural disasters and other incidents.

The event took place in Austria's Zwentendorf Nuclear Power Plant, the world's only nuclear facility to be completely built but never activated. The inoperable boiling water reactor plant serves as a training ground to prepare for radiological and nuclear incidents and disaster scenarios.

"Today's drones and ground robots typically require a lot of input and supervision from a human operator," said Dr. Eric Thorn, manager of SwRI's UAS research team. "The autonomy we've demonstrated has the potential to significantly reduce the burden on human operators, allowing robotic systems to operate independently."

Developed and tested through internally funded research, SwRI's technology combines new algorithms with computer vision sensors to allow drones to autonomously explore and map previously unknown environments.

SwRI's EnRicH entry featured a quadcopter equipped with several sensors – LIDAR, a time-of-flight camera and radiation detectors. The team utilized both on-drone processors and ground-based processing to perform sensing and perception, simultaneous localization and mapping (SLAM), exploration and other tasks.

"Our exploratory planner, which allows the system to navigate new spaces without the aid of human operators, performed well despite the challenging environment," said Chris Bang, an SwRI program manager in the Intelligent Systems Division. "The planner is very robust and flexible, adeptly operating in both man-made environments and natural locations such as caves."

During the EnRicH hackathon, the drone autonomously detected two sources of the radioisotope cobalt-60 hidden in separate locations as part of the challenge.

SwRI engineers used LIDAR point cloud data to reconstruct a high-resolution image of a facility that houses electric turbines at a nonoperational nuclear plant. These data visualizations can identify damage and potential hazards following accidents at nuclear power plants and other facilities.

WEBINARS, WORKSHOPS and TRAINING COURSES HOSTED by SwRI:

GD&T (Geometric Dimensioning and Tolerancing), April 25, 2022. Virtual training course.

Introduction to Propulsion Simulation using NPSS, May 3, 2022. Virtual training course.

NASGRO Training Course, May 3, 2022. Live virtual training course.

Purchasing and Supply Management, May 16, 2022. Virtual training course.

Pulsations and Vibrations, May 17, 2022. In-person training.

Tolerance Stack Analysis, May 23, 2022. Live online webinar.

CONFERENCES/MEETINGS:

ASNT Annual Conference, Phoenix, November 15, 2022. Booth No. 659.

BioFest Invest, University of Incarnate Word, San Antonio, March 30, 2022.

Space Symposium, Colorado Springs, Colorado, April 4, 2022, Booth No. 311.

AIChE Spring Meeting & 18th Global Congress on Process Safety, San Antonio, April 10, 2022, Booth No. 600.

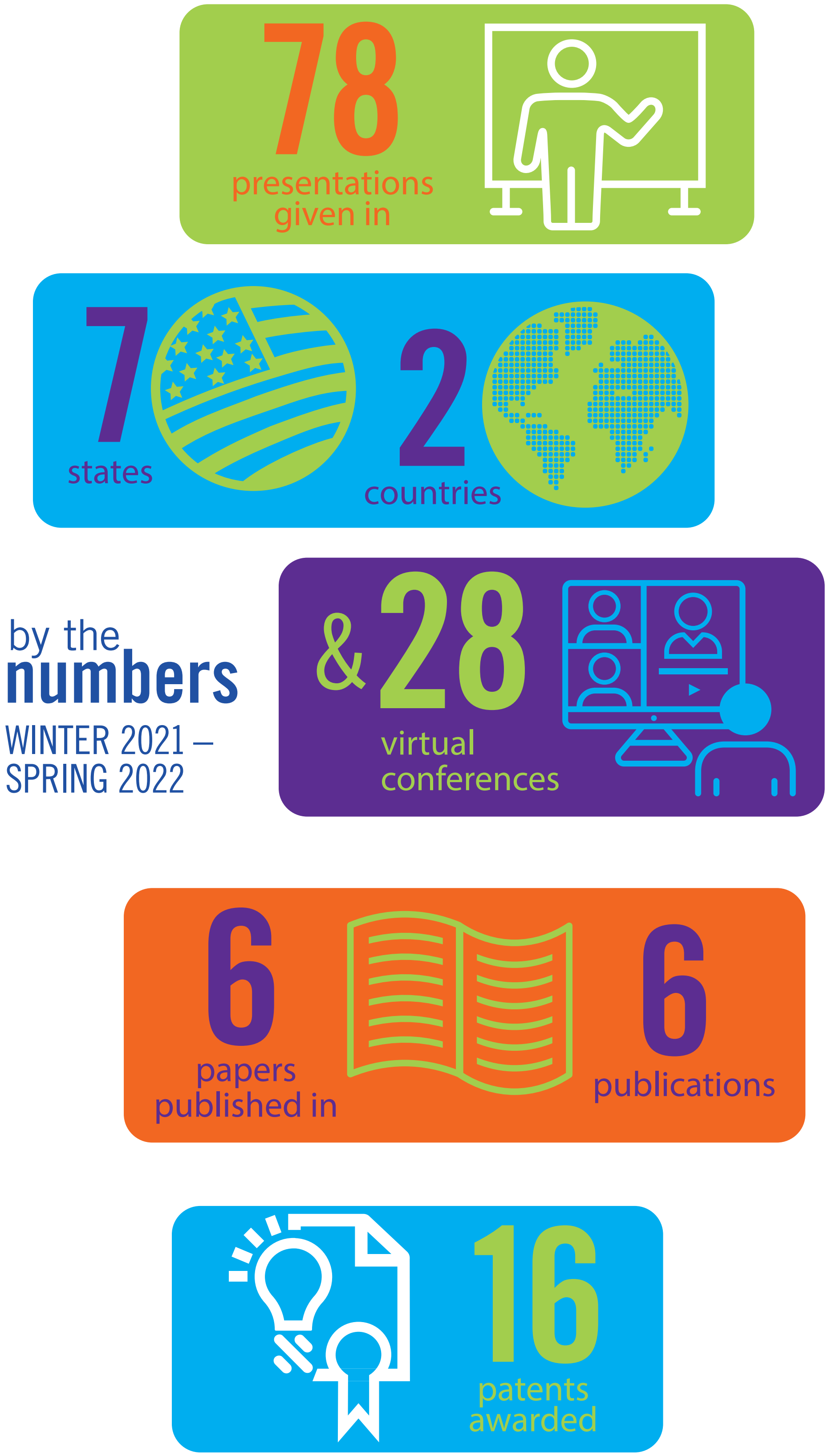
eChemExpo, Kingsport, Tennessee, April 20, 2022, Booth No. 406.

MRO Americas, Dallas, April 26, 2022, Booth No. 7010.

23rd Microencapsulation Industrial Convention (virtual), Rotterdam, Netherlands, May 2, 2022.

Offshore Technology Conference, Houston, May 2, 2022, Booth No. 1842.

Indo Pacific 2022 International Maritime Expo, Sydney, Australia, May 10, 2022.



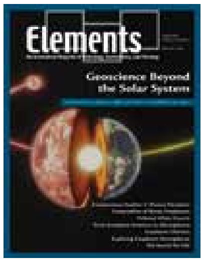
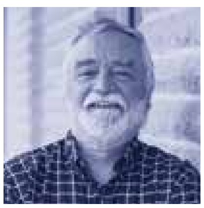


IMAGE COURTESY ELEMENTS MAGAZINE

SwRI Senior Research Scientist **Dr. Natalie Hinkel** and Research Scientist **Dr. Cayman Unterborn** were guest editors of a special issue of Elements Magazine exploring interdisciplinary views on exoplanets. The issue contains seven articles by 19 authors and gives a diverse overview of exoplanets, reviewing observations made about their geology, composition, atmosphere and potential to support life.

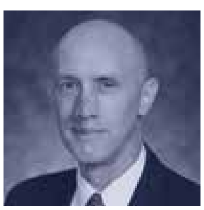
D025310

Dr. Imad A. Khalek, a senior program manager in SwRI's Powertrain Engineering Division, was elected a Fellow of the Society of Automotive Engineers (SAE). SAE awards fellowships to only about 20 members a year, recognizing those who have made significant impacts to the mobility industry through "leadership, research, publishing, innovation and volunteering."



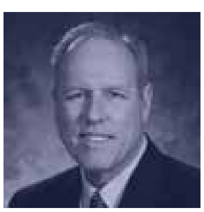
DM25223_0074

The Explorers Club — an international professional organization dedicated to the advancement of scientific exploration and field study — has selected SwRI's **Dr. Stefano Livi** (Space Science and Engineering Division) for membership in its Explorers Club 50 Class of 2022. The organization launched "The Explorers Club 50: Fifty People Changing the World that You Need Know About" initiative in 2021 to highlight "…trailblazing explorers, scientists, artists, and activists spanning the globe."



D025309

Dr. Peter W. A. Roming, director of SwRI's Department of Space Engineering, has been named a Fellow of the American Physical Society (APS). This distinction recognizes outstanding contributions to physics, particularly his ultraviolet observations of gamma ray bursts and supernovae as well as leadership of the UV/Optical Telescope on the Neil Gehrels Swift Observatory.



D025312

Dr. Ben Thacker, P.E., has been named vice president of Southwest Research Institute's Mechanical Engineering Division. Thacker previously served as executive director of the division's Materials and Fluids Engineering Departments. As vice president, Thacker will oversee a staff of more than 300, working in five research departments.

D025311

Dr. Elizabeth Trillo, a principal engineer in SwRI's Mechanical and Materials Section, has been named a National Association of Corrosion Engineers (NACE) Fellow. She was chosen as one of 13 fellows recognized in 2021 for their distinguished contributions in the field of corrosion and its prevention. Trillo was nominated for using her intellect and engineering skills to make the world a safer place.

SPRING 2022 • VOLUME 43, NO. 1

TECHNOLOGY **TODAY**

Executive Director of Communications
Tim Martin, Ph.D.

Editor
Deb Schmid

Contributors
Joanna Carver
Robert Crowe
Lisa Peña
Maria Stothoff
Tracey Whelan

Design
Jessica Vidal

Photography
Ian McKinney
Bryan Winter

Circulation
Stephanie Paredes

Address correspondence to the Editor,
Communications Department,
Southwest Research Institute,
6220 Culebra Road
San Antonio, Texas 78238-5166,
or e-mail **dschmid@swri.org**.
To be placed on the mailing list or to make address changes,
call 210.522.2257 or visit **update.swri.org**.

swri.org

INNOVATION | INTEGRITY
STEWARDSHIP | PEOPLE
SOUTHWEST RESEARCH INSTITUTE®

Southwest Research Institute
6220 Culebra Road
San Antonio, Texas 78238-5166
United States

Nonprofit Org.
U.S. POSTAGE
PAID
Permit No. 234
San Antonio, Texas

Deep Sea to Deep Space®

ABOUT THE INSTITUTE

Southwest Research Institute® (SwRI®) is a premier independent, nonprofit research and development organization. With nine technical divisions, we offer multidisciplinary services leveraging advanced science and applied technologies. Since 1947, we have provided solutions for some of the world's most challenging scientific and engineering problems.

Technology Today® (ISSN 1528-431X) is published three times each year and distributed free of charge. The publication discusses some of the more than 4,000 research and development projects under way at SwRI.

EMPLOYMENT

Southwest Research Institute's staff of more than 2,700 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**.

**An Equal Employment Opportunity/
Affirmative Action Employer
Race/Color/Religion/Sex/Sexual Orientation/
Gender Identity/National Origin/Disabled/Veteran
Committed to Diversity in the Workplace**

210.522.2122

ask@swri.org

swri.org

Like. Share. Follow. Listen.