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Technology Today®

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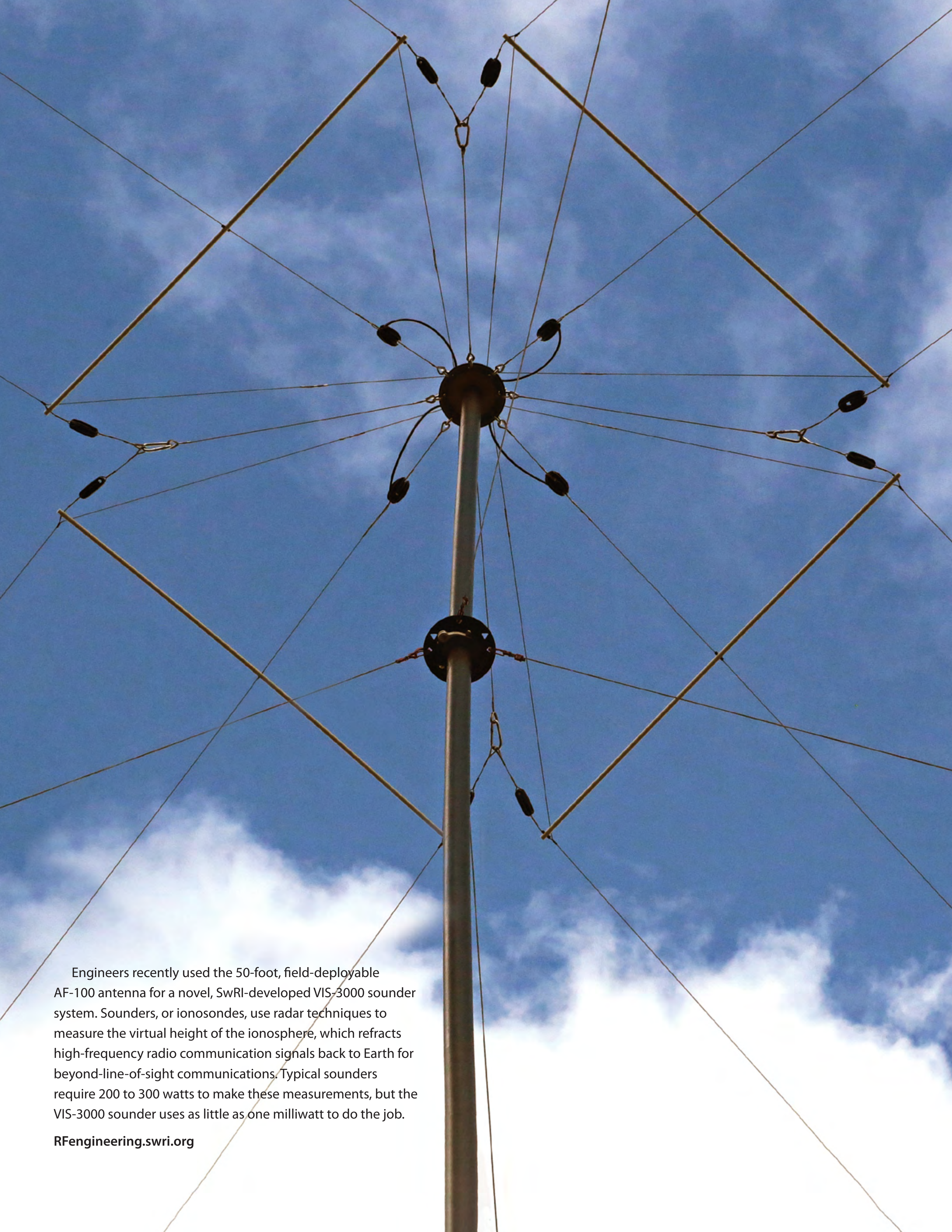

Engineers recently used the 50-foot, field-deployable AF-100 antenna for a novel, SwRI-developed VIS-3000 sounder system. Sounders, or ionosondes, use radar techniques to measure the virtual height of the ionosphere, which refracts high-frequency radio communication signals back to Earth for beyond-line-of-sight communications. Typical sounders require 200 to 300 watts to make these measurements, but the VIS-3000 sounder uses as little as one milliwatt to do the job.

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Southwest Research Institute 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.

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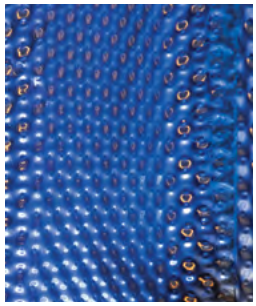

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ON THE COVER

SwRI has launched a new, dedicated Energy Storage Technology Center, 10 times larger than the previous facility. For the past 20 years, engineers have developed advanced techniques to cost-effectively evaluate battery power packs, shown here close up, under various conditions.

CONTENTS

EMPLOYMENT

Southwest Research Institute is an independent, nonprofit, applied research and development organization. The staff of more than 2,600 employees provide 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.

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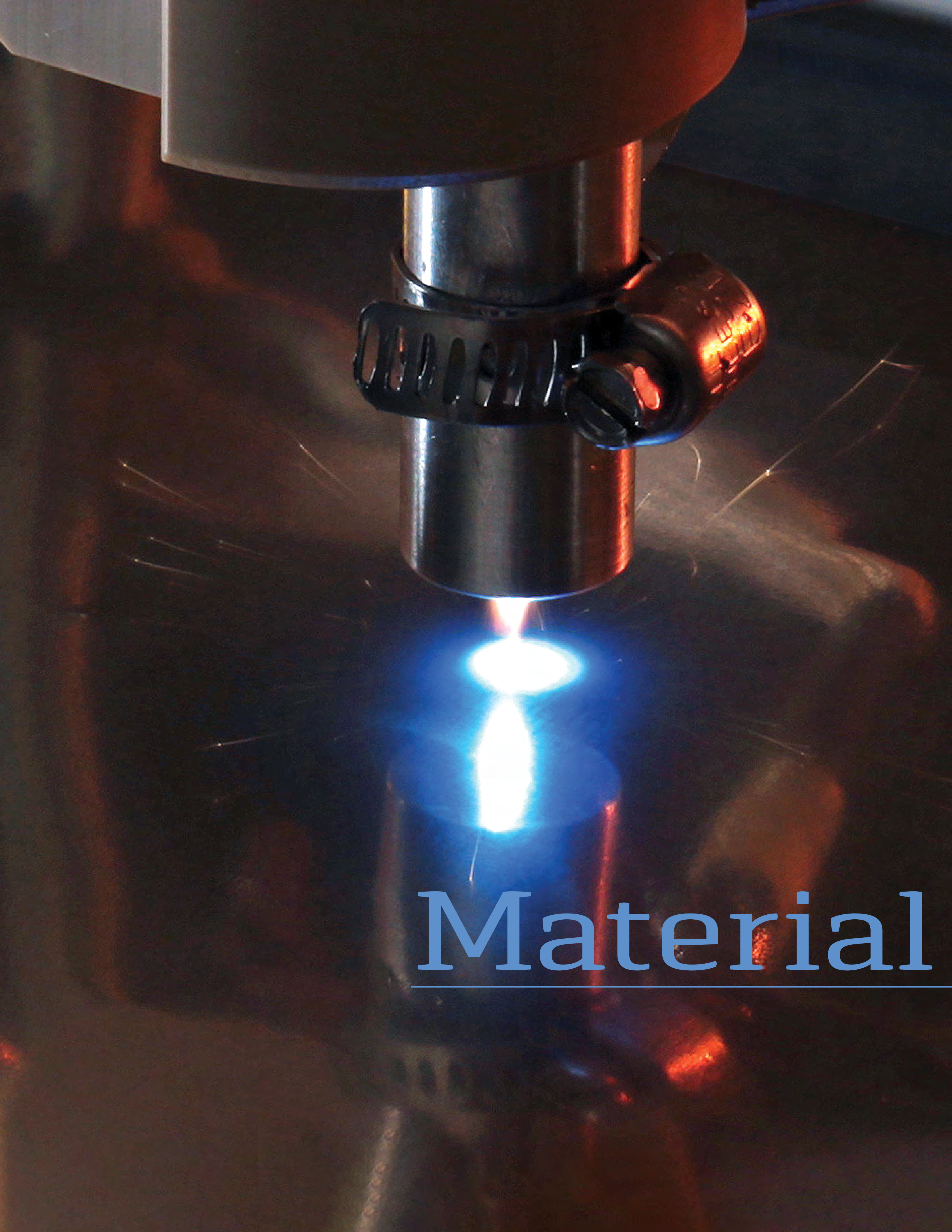

Material

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According to the preeminent international materials science organization, the economic effects of corrosion and wear cost the U.S. hundreds of billions of dollars a year and affect almost every industry, from transportation and energy to computers and textiles. A simple coat of paint can protect everyday objects from rusting, but today's specialized infrastructure, components and products require something more complex.

When developing these items, metals are a desirable material because they are very hard and tough, but they are also susceptible to wear, corrosion and corrosion-induced cracking. Ceramics are also hard and corrosion-resistant, but they are brittle and prone to fracture. Materials scientists look for ways to impart the best properties of one material onto another to improve a component's performance and durability. Some of this work has resulted in advanced coatings, thin films and engineered surfaces to enhance hardness, toughness and corrosion resistance of materials, and low-friction coatings to enhance motion, lower operating temperatures and reduce wear.

However, the traditional processes for applying these coatings can damage a material's substrate by subjecting it to very high temperatures and/or low pressures. Additionally, the list of objects that can benefit from these coatings is limited to those that fit in a vacuum chamber. That's why Southwest Research Institute has developed an innovative new process to apply coating under ambient conditions.

ON THE SURFACE

SwRI has been advancing surface modification technologies for more than 35 years. More than 4,000 square feet of materials science laboratory facilities house 20 vacuum chambers to deposit layers of material, atom-by-atom or molecule-by-molecule, onto a solid surface. Inside these chambers, protective materials called precursors are deposited onto the target material, or substrate, amid a vapor or plasma environment, where they condense onto the substrate as thin films.

SwRI specializes in ion beam and plasma-based modification and coating of advanced materials using vacuum-based technologies such as physical vapor deposition (PVD), plasma-enhanced deposition PVD and plasma-enhanced chemical vapor deposition. Using ion implantation and plasma-enhanced ion diffusion, engineers integrate charged particles into surface materials to impart new properties.

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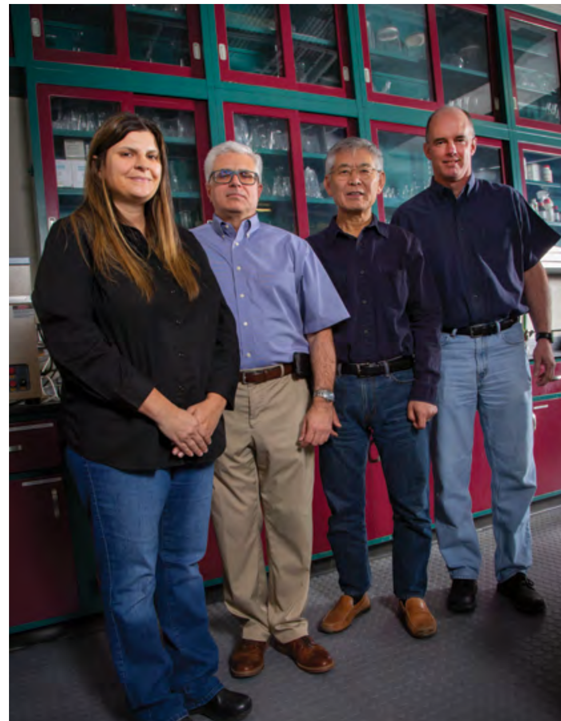

ABOUT THE AUTHORS

Dr. Vicky Poenitzsch, manager of SwRI's Surface Engineering and Chemistry Section, specializes in the synthesis and characterization of thin films, nanoparticles and nanocomposite materials. Dr. Michael A. Miller is an Institute scientist with more than 34 years of experience in materials science, surface science, molecular spectroscopy and solid-state chemistry and physics. Program Director Dr. Ronghua Wei has more than 35 years of experience in plasma science and engineering, materials science and engineering, surface engineering and tribology. Dr. Kent Coulter, a senior program manager, researches vacuum-coated thin films for optical, catalytic and advanced materials applications.

Benefits

Opening the "Vacuum" Door to New Surface Applications

By Dr. Vicky Z. Poenitzsch, Dr. Ronghua Wei, Dr. Michael A. Miller and Dr. Kent Coulter

D019204_2289

With more than 4,000 square feet of materials science laboratory facilities including 20 vacuum chambers, SwRI develops various techniques to deposit thin films on solid surfaces. These coatings increase the hardness and wear resistance of components to extend their service life.

DETAIL

Plasma — along with solid, liquid and gas — is one of the four fundamental states of matter. Plasmas are made up of charged or ionized particles and exhibit properties of both a liquid and a gas. They can be created by subjecting a neutral gas to heat, pressure and/or a strong electromagnetic field.

For example, SwRI scientists have studied diamond-like carbon (DLC) films using various processes including plasma immersion ion deposition (PIID) to create coatings that are both very hard and very durable. Material scientists also have studied nanocomposite films, which are deposited using a plasma-enhanced magnetron sputter (PEMS) process. Through these efforts, SwRI has established itself as a leader in surface engineering research by developing new coating technologies for government and industry clients.

Although vacuum-based coating processes can achieve high quality, performing the process inside a vacuum chamber is cumbersome and limiting. For example, vacuum deposition is impossible for large structures such as an aircraft wing or a ship impeller. In addition, some substrates, such as biological materials or soft polymers, are incompatible with vacuum conditions. These applications require a process that works in atmospheric pressures, outside a vacuum chamber.

Over the past five years, SwRI scientists have moved beyond the vacuum chamber, developing expertise in depositing coatings using plasmas at atmospheric pressure. For instance, the SwRI-developed High Power Impulse Plasma Source (HiPIPS) technique was recognized in 2017 by R&D Magazine as one of the top 100 inventions of the year. This process allows for enhanced surface modification and deposition of functional coatings without a vacuum. HiPIPS provides an unparalleled plasma processing space of very high density and flux — indicators of coating quality and efficiency — at low-temperature and atmospheric pressure conditions. HiPIPS' unique abilities open the door for new surface engineering applications and unprecedented coating / substrate combinations.

PROCESSING UNCHAMBERED

By breaking free of the vacuum chamber, HiPIPS offers virtually unlimited surface engineering applications. It not only outperforms other ambient pressure plasma processes, but also rivals the effectiveness of vacuum plasma systems. The SwRI team developed techniques to discharge a dense plasma with increased ionization for advanced surface modification and coating deposition. To do this, HiPIPS uses high-power pulsed direct current (DC) generators. The high-power pulses control ionization and fragmentation of chemical precursors in the plasma phase. Enhancing ionization and dissociation enables new precursor chemistries, which could improve the functionality of coatings.

Plasma-enhanced chemical vapor deposition (PECVD) is a common method for materials synthesis, surface engineering and thin film deposition. In conventional CVD, electrical energy (such as microwave or radio frequency) excites a gaseous feedstock under vacuum conditions to create a stable mixture of reactive species, such as radicals, ions, electrons and neutrals. The electron and radical/ion temperatures in these hot plasmas are in equilibrium and typically exceed 1,500 degrees C. Although PECVD is widely used, its temperature extremes, combined with the vacuum environment, dramatically limit the type, shape and size of substrate candidates.

Over the past two decades, several atmospheric-pressure plasma discharge schemes have addressed these limitations. So-called cold plasmas are characterized by electron temperatures much greater than that of the ions, neutrals and gas. While these systems have expanded the plasma toolkit, they too are limited in terms of practical application. For example, some small-scale academic studies have demonstrated thin film deposition with these systems, but most atmospheric-pressure plasma jets are used to clean surfaces or modify surface wettability. Despite some successes in this field, significant technical challenges remain, including precursor non-homogeneity, electrical arcing and/or extinguishing. As a result, ambient pressure plasmas are typically run with a predominantly inert feedstock gas and relatively low fractions of simple reactive gases, at fluxes several orders of magnitude lower than conventional hot vacuum plasmas.

BREAKING UP IS HARD TO DO

To overcome these challenges, SwRI recognized and exploited recent innovations in high-power pulsed DC power supplies, commonly used with magnetrons, to develop an advanced atmospheric-pressure plasma jet. This application

DETAIL

Wettability describes properties of printing inks associated with resistance to bleeding, discoloring, fading, etc., upon exposure to moisture. Inks are formulated to increase the printed ink's water resistance. The term wettability also refers to how readily an ink pigment absorbs water.

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Using the plasma-enhanced magnetron sputtering (PEMS) process in a vacuum chamber, SwRI deposits nanocomposite coatings on turbine blades.

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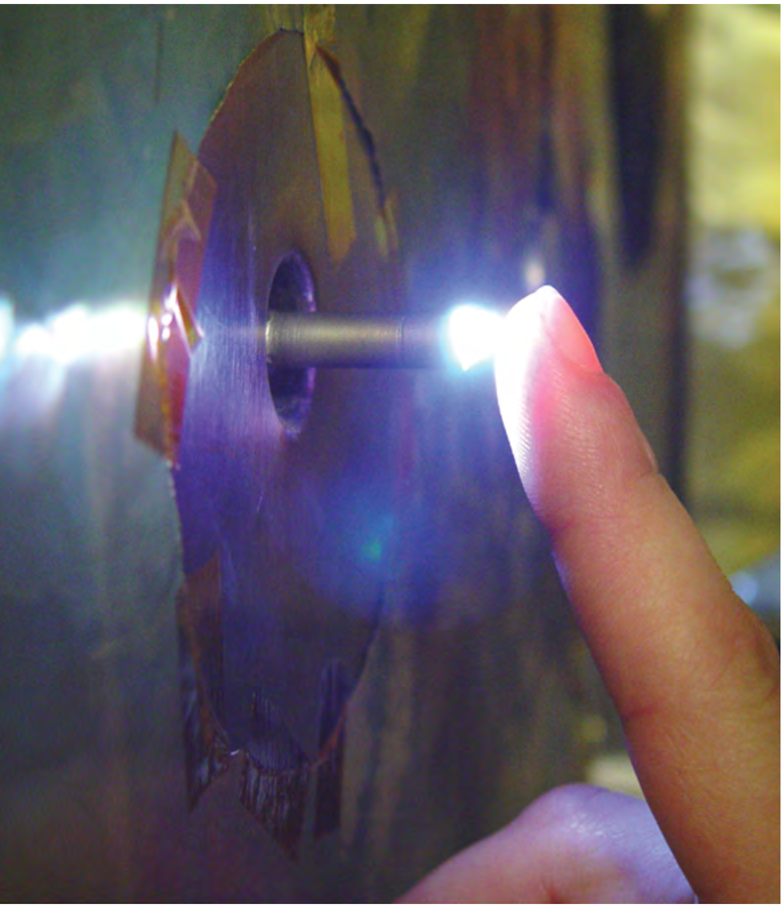

This photo of HiPIPS' argon plasma jet illustrates the low temperatures and atmospheric pressures used.

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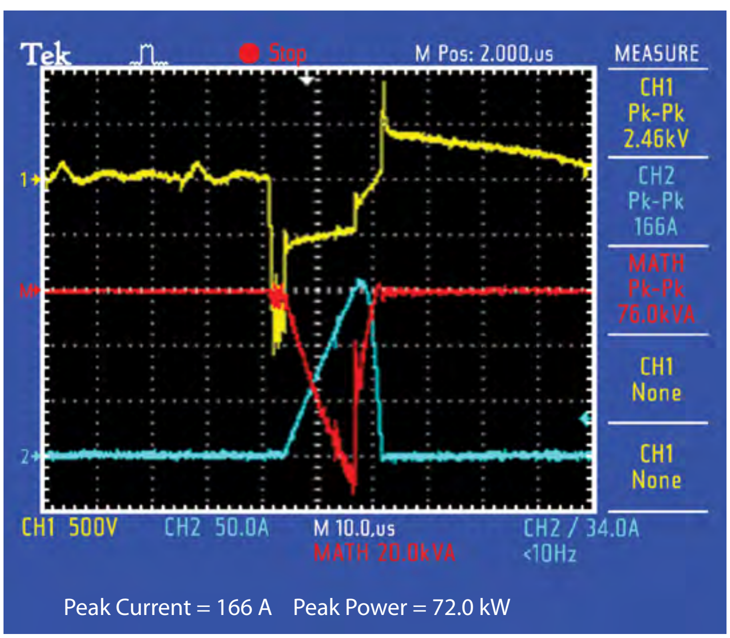


This screenshot of oscilloscope voltage, current and power traces demonstrates HiPIPS' high-density, high-flux plasmas at low temperature and atmospheric pressure conditions.

creates peak power densities and currents that are two to three orders of magnitude higher than cold-plasma jets driven by radio-frequency or AC electricity sources. HiPIPS uses variable-pressure plasma jets with high-power pulsed DC generators that supply extremely high power density in short pulses. When gas precursors are fed into the plasma source and a negative, high-voltage DC pulse is applied to the electrode, the electric current flows through the gaseous medium as electrons. The free electrons are accelerated and collide with gas molecules, breaking them up to create reactive species. As the DC pulse continues, the electric current increases dramatically. Because of the high current capability of the advanced power supply design, extremely high power quickly excites the plasma. This high-power discharge produces highly ionized gases as well as an abundance of radicals. While the pulsed discharge quickly approaches an arc state, controlling the pulse length dampens arcing, allowing for continuous stable operation.

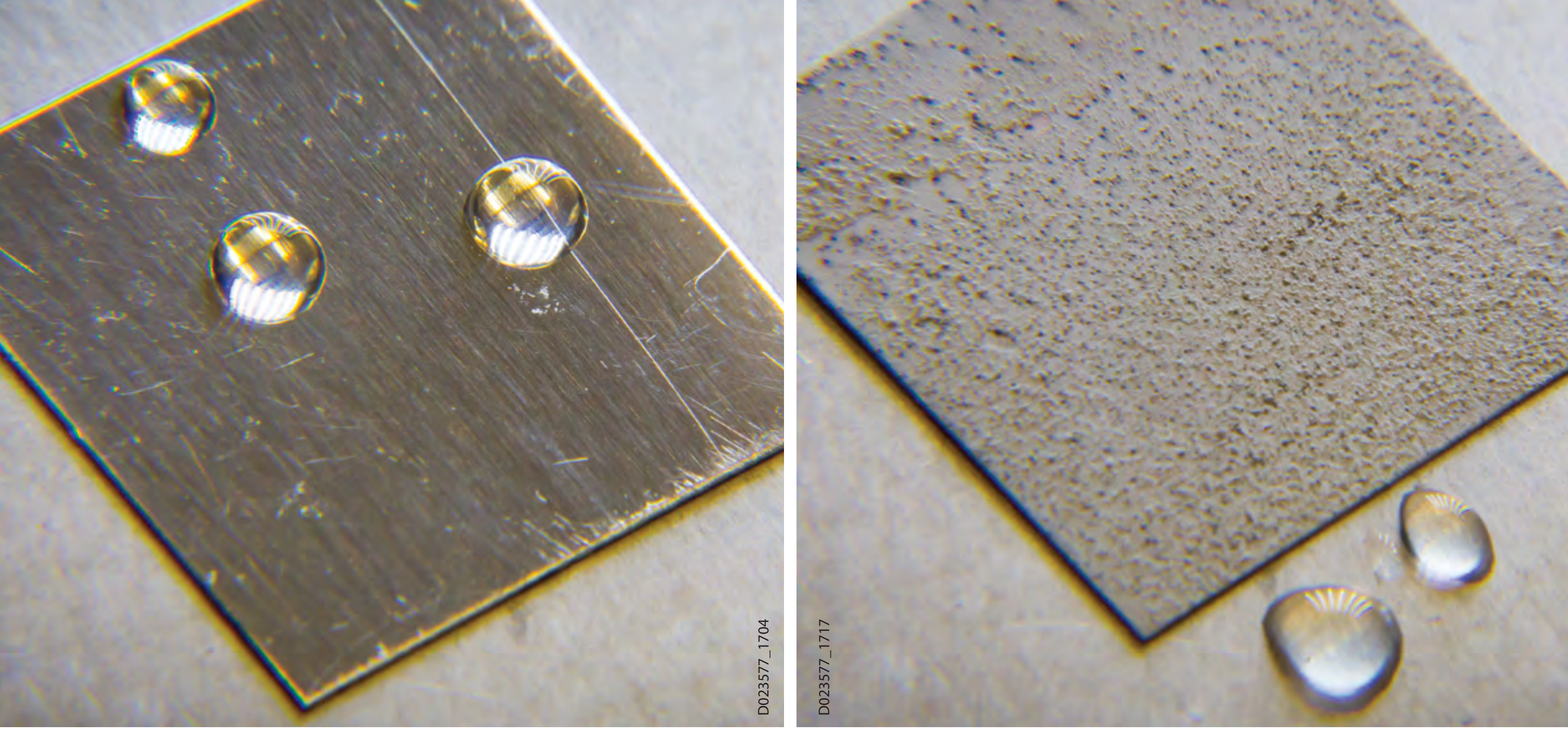
SwRI further expanded HiPIPS' applicability to include new precursors and processing conditions. When it comes to depositing functional coatings, HiPIPS technology holds a critical advantage in its ability to provide plasma treatments unsuitable for conventional atmospheric plasma processes. Its controlled high-impulse power determines how chemical precursors are ionized and fragmented in the plasma phase. This control allows engineers to tailor the process chemistry involved to produce the desired coating property. SwRI has used HiPIPS precursors ranging from inert gases and molecular gases to liquids and solids, including methane, hydrogen, nitrogen, oxygen, carbon monoxide and organosilicon compounds. These precursors can be used alone or in combination with each other and/or with inert gases such as argon. SwRI designed a variation of HiPIPS that uses two concentric electrodes and a wire feedstock to deposit metallic coatings at ambient conditions.

CURRENT, FUTURE APPLICATIONS

SwRI is investigating HiPIPS applications ranging from surface cleaning to the activation of polymer surfaces for improved ink wettability. Engineers also are studying how surface-modified alumina platelets and carbon fibers could improve adhesion between layered composite materials. SwRI has developed durable, superhydrophobic (water repelling) coatings for aircraft drag-reduction for the aerospace industry.

HiPIPS has also contributed to environmentally friendly alternatives to chrome electroplating. For this, SwRI developed a proof-of-concept technique to deposit cobalt-chrome, titanium alloy and ceramic protective coatings instead of electroplated chrome. SwRI characterized HiPIPS plasma properties using current-voltage probes and optical emission spectroscopy. Scanning electron microscopy, energy-dispersive X-ray spectroscopy and X-ray diffraction characterized the microstructure and elemental composition of resulting coatings and surface treatments.

While HiPIPS is still in the demonstration phase, the potential



Using HiPIPS, SwRI has developed durable, superhydrophobic (water repelling) coatings to reduce drag on aerospace materials and components. The left image is uncoated, while the right image has been treated with the hydrophobic coating.

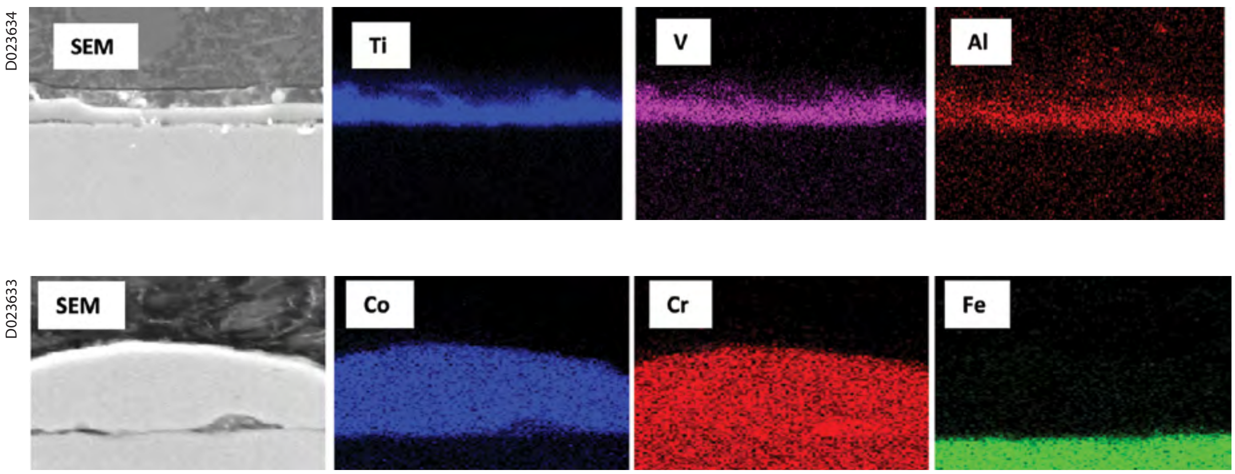
DETAIL

In surface engineering applications, a magnetron excites electrons to produce ionized precursor materials.

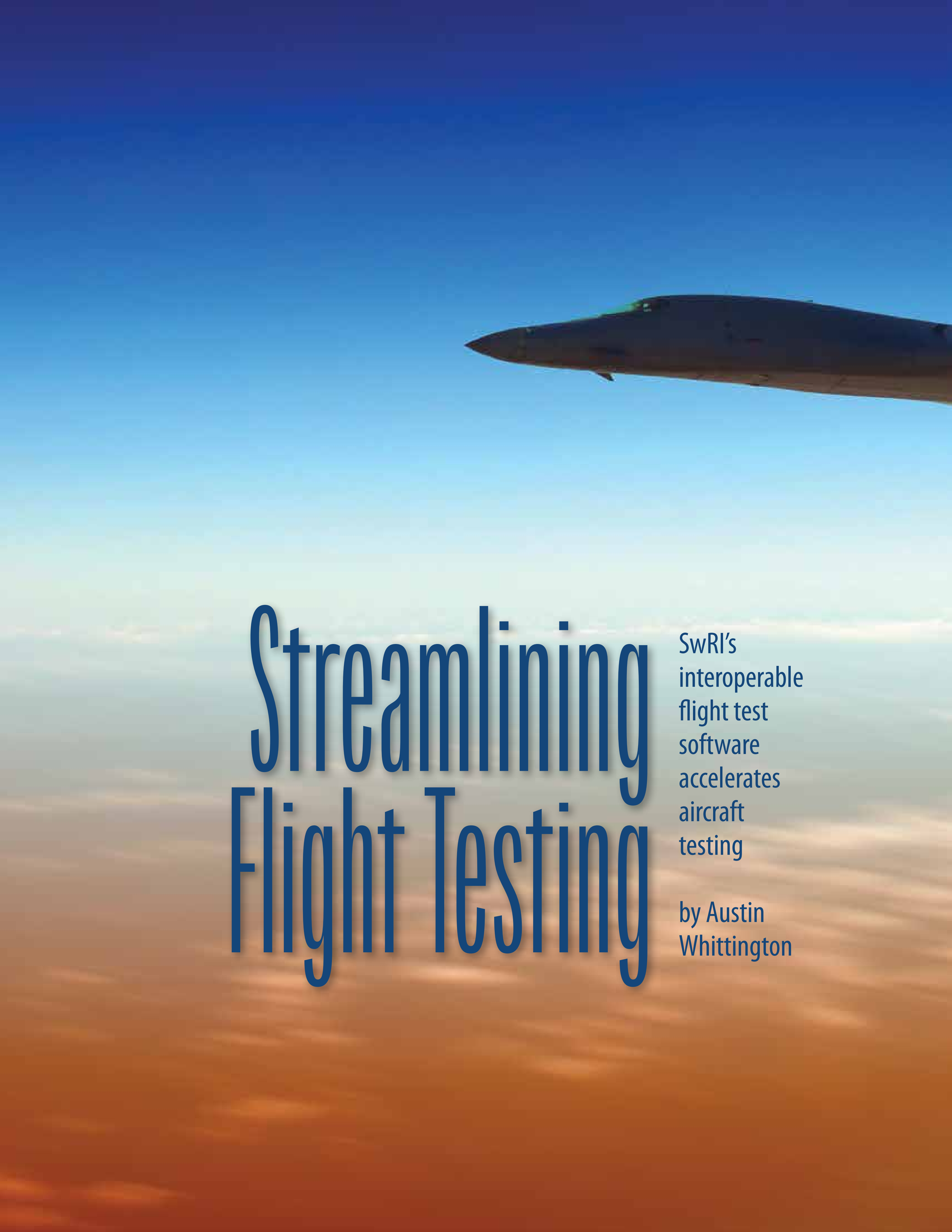
range of applications for the technology is practically unlimited. The technology is currently undergoing further development for optimization and scale-up.HiPIPS deposits a variety of films and performs various surface treatments, including surface modification, cleaning and etching.

The HiPIPs system is portable and versatile, deployable in a a range of locations. SwRI is designing a miniaturized HiPIPS system for use on the International Space Station's crystallization module to create ultra-pure materials with novel properties. SwRI is also conducting a paper feasibility study with the National Energy Technology Laboratory to evaluate using HiPIPS technology to create a conductive fluid for magnetohydro-dynamic power generation technology. The technique would eliminate the need for potentially hazardous reactive seed alkali metals. Altogether, HiPIPS is poised to revolutionize the surface engineering field, creating environmentally friendly techniques to protect equipment, large and small, affecting nearly every industry and individual.

Questions about this article? Contact Poenitzsch at vicky.poenitzsch@swri.org or 210.522.3755.



SwRI evaluates the quality of HiPIPS applications, examining a cross section of steel coated with titanium alloys (top) and cobalt chrome alloys (bottom) using a scanning electron microscope. Corresponding energy-dispersive X-ray spectroscopy maps of HiPIPS coatings reveals uniform distribution and high amounts of alloy elements.



Streamlining Flight Testing

SwRI's interoperable flight test software accelerates aircraft testing

by Austin Whittington

Aerospace technology is incredibly complex and safety critical.

Ground tests validate designs and engineering while flight testing ensures that systems meet government and industry standards. Flight test evaluations range from a single new system for an existing vehicle to the overall development and certification of a new aircraft. As such, testing can take a few weeks to many years and demands extensive resources. As the complexity and interoperability of aircraft systems have increased, so too has the complexity of flight testing and instrumentation and their associated costs.

Southwest Research Institute supports the commercial and military aerospace industries with flight test solutions that span structural engineering and aeronautical telemetry. SwRI plays an important role in developing and testing embedded software and integrated test solutions to streamline and lower the costs of flight testing commercial and military aircraft systems.

Flight test instruments are typically small orange boxes that process data from sensors attached throughout the aircraft. A flight test instrumentation (FTI) program can track more than 100,000 parameters, ranging from gyroscope performance on autopilot to wing pressure at top speed.

To maximize the value of costly flight time, engineers often synchronize multiple test goals. When testing several articles per flight, any number of problems can affect not only the aircraft, but also flight test instrumentation. A problem on one test can trigger costly delays in subsequent tests. These challenges are exacerbated when flight test instruments operate on separate proprietary platforms, slowing the time it takes to switch test goals in real time.

FLIGHT TEST INTEROPERABILITY

In light of these challenges, a seamless standard would benefit the entire industry. SwRI is working with the commercial aerospace industry and government agencies to address these challenges by developing standardized FTI software. Housed at SwRI's Flight Test Technologies Laboratory in San Antonio, our team draws on years of experience helping instrument vendors and aircraft manufacturers develop flight test solutions.

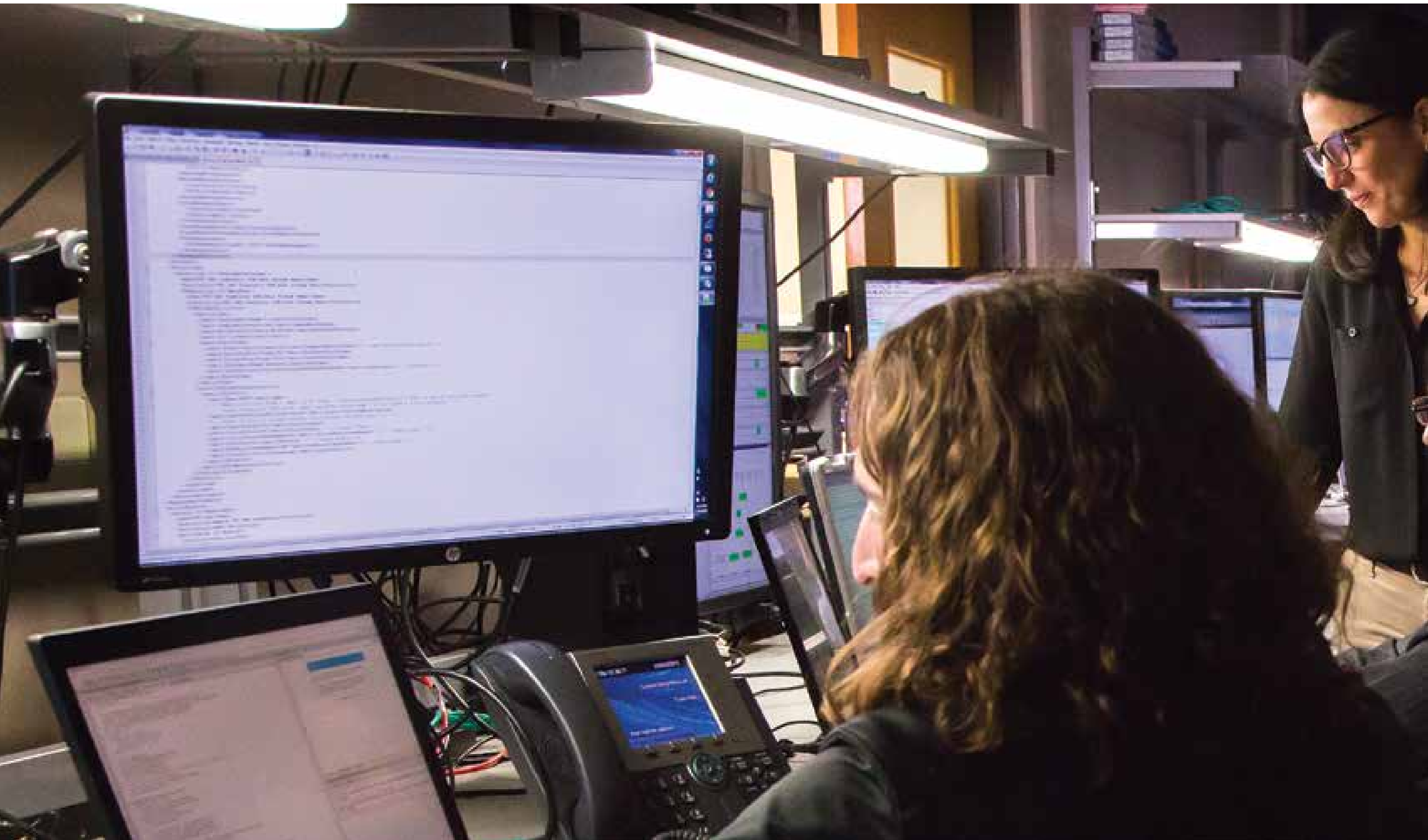
SwRI's unique expertise in this sector led it to become the lead integrator for the U.S. Department of Defense integrated Network Enhanced Telemetry program, or iNET. As iNET's lead integrator, SwRI works with the DOD and aerospace stakeholders to develop a Metadata Description Language (MDL) that allows for standard configuration of all vendor hardware. A standard language helps test engineers work across multiple vendor devices, paving the way for flexibility in flight testing to adapt to changing conditions, such as inclement weather or equipment failures.

The iNET program focuses on improving vendor interoperability and enabling two-way telemetry to better manage numerous flight tests on multiple aircraft simultaneously. Scheduling flight tests at an Air Force base, for example, can be particularly challenging when as many as 30 aircraft are testing several systems at the same time.

With two-way communications and interoperable instruments, iNET enables real-time data gathering and dynamic scheduling, allowing engineers to switch a flight test goal if an instrument fails or extra flight time becomes available when another flight test is cancelled. If a flight encounters a problem with a test instrument or sensor, it may need to land for troubleshooting, causing delays from several hours to several days. Or suppose an aircraft is scheduled to fly over mountains to experience ice buildup on its wings to evaluate the system response. If the weather does not create the desired conditions, a normal plan would be to abort the test, land the plane and try again later. Under either of these scenarios, iNET could

DETAIL

The DOD's integrated Network-Enhanced Telemetry program, or iNET, aims to produce simpler, more cost-effective, vendor-agnostic equipment interfaces. Increasingly complex aircraft and DOD spectrum reductions resulted in gaps in real-time data flight test collection. With iNET, the test community has unprecedented ground control of instrumentation and test articles in real time.



reconfigure the instrumentation in real time to perform a different set of tests or allow other flights to access extra flight time or telemetry bandwidth.

More recently, SwRI has leveraged its iNET work on a series of contracts with the Defense Advanced Research Projects Agency (DARPA) and the Air Force Research Laboratory. The project incorporates DARPA's Building Resource Adaptive Software Systems (BRASS) technology to facilitate adaptations to technology changes and security updates over the next several decades.

By integrating BRASS into the standardized iNET configuration, SwRI engineers hope to develop a lasting solution to deal with rapid advances in technology affecting the commercial and military aerospace industries. In late 2018, SwRI received a second BRASS contract to integrate flight test standardization with the Army's ground vehicle interoperability goals (See VICTORY sidebar on p. 13). If the BRASS techniques prove to be adaptable and sustainable to match the comprehensive goals of flight test programs, their applicability and effectiveness for commercial aerospace and the military will be significant and lasting.

INTEGRATING BRASS WITH iNET

The DARPA BRASS project builds on iNET's interoperability solutions using algorithms that allow test engineers to use complex computational techniques to solve a range of difficult problems in real time.

Broken hardware is a common problem that affects flight test scheduling. For instance, if a data acquisition unit (DAU) needs to be replaced but inventory stock is low, installing it could deprive concurrent programs. Ordering a new DAU from the vendor adds cost and delays. However, another type of DAU, even from a different vendor, might meet requirements and be available immediately.

Using requirements analysis techniques, the BRASS-powered system can track inventory of old or unused instruments, determining that a secondary DAU will satisfy the original requirements, saving money and time for the original test while

DETAIL

Vehicular Integration for C4ISR/EW Interoperability (VICTORY) standard specifications provide a foundation for interoperability among onboard sensors and weapon systems, enabling a level of situational awareness not previously possible and resulting in increased soldier survivability and effectiveness.

An SwRI team is developing standardized language for FTI to synchronize and improve flight test agility in real time.

avoiding putting other tests at risk. And these BRASS adaptations will typically explore beyond what an engineer would consider because a solution does not have to seem likely for BRASS to explore the possibility. These types of exploratory optimizations and adaptations are generally done by humans with significant domain experience, who use "intuition" as guidance. A BRASS-powered system can explore further and faster, looking for a more "objective" satisfaction of the requirements.

Another advantage of future BRASS-powered systems is the possibility for real-time adaptations. A BRASS-based system could consider the environment of the whole test range and decide to adapt a single test to avoid impacts to concurrent tests, or trigger adaptations to maximize the value or minimize the cost of the entire test range under its control.

In the BRASS realm, several classes of problems can be solved or addressed adaptively. For instance, to assemble a flight test data acquisition system, an engineer needs to know what measurements and data rates are needed. A future BRASS-powered system would have these parameters built into the program, limiting the number of options available. For example, engineers typically assemble a system and validate its capabilities, including system redundancies to ensure access to safety-critical information. A BRASS-powered system can assemble configuration possibilities, based on available equipment, while minimizing hardware requirements.

FRAMING FUTURE CHALLENGES

Recent flight test telemetry advances provide adaptability. Consider that a test article encountering strange vibrations might require more safety-of-flight data to continue the test. Using traditional telemetry, the test article's fixed transmission schedule would force the flight test to abort. However, an iNET system could grant the bandwidth rights needed to transmit the test data without any reconfiguration.

Consider the scenario for a test article undergoing flight testing when a test scheduled to run in parallel has been grounded. A grounded test means significantly more bandwidth is available for data download. An iNET telemetry network system could grant access to the additional bandwidth to other tests. Without iNET, the guidelines for adapting to a beneficial situation do not exist, so a traditional system would move forward as if no change had occurred, missing the cost and value advantage associated with the grounded test. A BRASS-powered system would have access to all the relevant parameters, allowing it to take advantage of the situation. The system could recommend anything from simply transmitting more data for the existing test, to suspending it to do a more "lucrative" test, and thereby maximizing overall value. Making these types of complex adaptations lies in the future, but the technology's potential is significant.

Ignoring some of the practical limitations of letting a computer create and modify test plans, the sky is literally the limit for how these systems adapt. Consider the earlier example of the icing flight test delayed by weather conditions. Armed with information about instrumentation, equipment and tests for unrelated tasks, a BRASS system could recommend reconfigurations to perform other tests. Going further, a BRASS system could plan for that possibility, evaluating other testing scenarios or

SwRI has developed a new network-based telemetry system to expand and enhance flight test capabilities for the Department of Defense's iNET program.

The SwRI-led VICTORY architecture and open standards have revolutionized and streamlined how the military adds critical systems to its tactical vehicles.

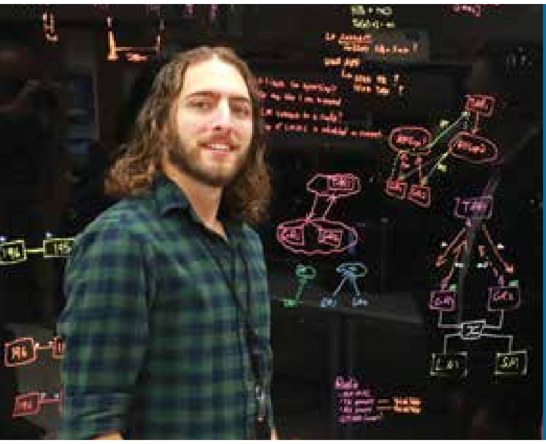
monitoring the weather en route, allowing a cost-effective transition to alternative tasks if test parameters are not met.

Consider that NASA uses computer-designed antennas to maximize radiation patterns in ways humans would not have envisioned. Similarly, a BRASS system could recommend exotic test shapes and plans that end up saving tens of thousands of dollars and weeks of testing. The system could improve designs even as standards and test platforms evolve over time.

While these advanced applications are still years away, using our modeling techniques brings groundbreaking adaptive technology and expertise to this domain today. The scenarios discussed provide reasonable opportunities for BRASS adaptive technologies to prove their worth, not only solving the problem but also building credibility for the technology. Combining all the techniques into the model will dramatically increase the quality and capabilities of adaptive systems for flight tests and beyond.

For more information, visit swri.org/flight-test-technologies.

Questions about this article? Contact Whittington at austin.whittington@swri.org or 210.522.2847.



ABOUT THE AUTHOR

Flight test researcher Austin Whittington is the principal investigator of the DARPA BRASS project. He has particular experience in constraints modeling and knowledge representation and is a research analyst in SwRI's Intelligent Systems Division.

VICTORY

Through a 13-month contract valued at $1.5 million, SwRI is applying technology developed in flight test research to standardize software systems used in U.S. Army ground vehicles.

The U.S. military faces many challenges in making hardware and software interoperable and long-lasting in aircraft and ground vehicles. SwRI's DARPA contract will create opportunities to connect interoperability initiatives across the DOD to improve efficiency and adoption of new technologies for decades to come.

DARPA's BRASS program is designed to make software last a century through standardization and adaptation to changes in technology. The Army is addressing interoperability concerns in ground vehicles through the VICTORY program.

The Army created the VICTORY initiative to help correct problems created by the "bolt on" approach for integrating Army ground vehicle electronics. VICTORY is necessary to minimize the amount of redundant hardware associated with current capabilities and to reduce the cycle time and cost necessary to develop, integrate, test, maintain and upgrade vehicles throughout their lifecycles.

Previously, SwRI explored using DARPA BRASS to adapt to complex flight test environments using a universal flight test Metadata Description Language (MDL) in military and civilian aircraft. The new contract continues the flight test research while expanding the project scope to identify problems and scenarios in ground vehicles and model software solutions.

QUALIFYING DRILLING SENSOR SYSTEMS

SwRI is helping lead the first phase of a joint industry program (JIP) to verify and validate oil and gas drilling sensor systems. The Independent Verification and Validation (IV&V) of Sensors and Systems in Drilling JIP will develop techniques to classify sensor abilities affecting drilling data and impacting operations, analytics and automation.

"SwRI has significant experience in areas relevant to the development of recommended practices for sensors and systems IV&V used in drilling," said Maria Araujo, a manager in SwRI's Intelligent Systems Division who is co-chairing the program. "SwRI has decades of IV&V expertise in analysis, control and automation sensors used in many high-technology industries, including oil and gas. SwRI will work with drilling industry experts to identify and rank critical sensor systems."

Some critical drilling equipment and sensors have proven insufficient for specific tasks, particularly as the industry employs more data analytics and automation. Technology is often inadequately calibrated or maintained or is used in applications outside its operational parameters. In addition, data transfer channels and time stamping are susceptible to reliability problems. In Phase 1, the program will classify sensors and systems used throughout the drilling operation to prioritize IV&V standard setting and identify a critical system for a pilot study.

"Formal industry-accepted verification and validation of sensors, equipment and systems will benefit both suppliers and customers," Araujo said. "Suppliers can verify their products, and customers will have access to validated attributes and capabilities. Suppliers can accelerate market readiness using a standardized test rather than conducting minimal or arbitrary tests for each new installation. Similarly, customers will have faster access to certified sensors and systems. And importantly, poor sensors and systems will not pass evaluations, avoiding safety risks and costly consequences associated with using inferior systems."

The Society of Petroleum Engineers (SPE) Drilling Systems Automation Technical Section (DSATS) is administering the program. Drilling industry expert John de Wardt will co-chair the JIP with Araujo. JIP membership is open to petroleum companies, drilling contractors, service companies and equipment suppliers. International participants are welcome.

The Institute is uniquely positioned to support this initiative, with more than 25 years participating in collaborative programs. The approach allows clients to pool their R&D dollars for precompetitive research, offering a more cost-effective approach to solving problems. JIP participants have full rights to the intellectual property developed during the course of their membership, and the results are planned for release as a Drilling Industry Recommended Practice.

CANCER CHALLENGE CHAMPS

SwRI joined forces with UT Health San Antonio pathologists to place first in an international challenge to develop automated methods to detect breast cancer tumor cells. They trained a computer algorithm previously used for automotive, robotics and defense applications to identify cancer cells for the BreastPathQ: Cancer Cellularity Challenge.

"Adapting an autonomous robotics algorithm to solve a health diagnostics problem shows that we really have state-of-the-art techniques," said Hakima Ibaroudene, the SwRI engineer who led the winning effort. "Our method has the potential to improve medical imaging diagnostics, ultimately bolstering healthcare for cancer patients."

Developing the cancer-detecting algorithm began with UT Health San Antonio pathologists teaching SwRI engineers to recognize breast cancer tumor cells. The engineers then trained the computer algorithm to analyze cell images, looking for defining characteristics that distinguish cancerous cells from normal ones. Once trained, the SwRI algorithm scanned images provided for the challenge, matching the findings of human pathologists at the highest rate, making it the top-performing algorithm out of 100 competing submissions.

"The results demonstrated the importance of understanding network design and training the algorithm versus using an 'out-of-the-box' model," said David Chambers, SwRI engineer. "Our approach was driven by subject matter expertise."

Challenge organizers provided two collections of images: one to train the algorithms, the other to test them. The team analyzed images extracted from breast cancer patients and assigned a score based on the number of cancer cells in each image. Pathologists track tumor response to therapy by determining the percentage of tumorous cells in the area. Currently, this task is performed manually and relies on experts to interpret complex tissue structures. A reliable automated method could produce more consistent results and avoid potential human error.

"Artificial intelligence and machine learning approaches to medical image analysis will provide pathologists with a powerful tool to more rapidly identify and quantify important image features," said Dr. Bradley Brimhall, UT Health San Antonio pathologist and challenge participant. "In doing so, additional diagnostic and prognostic information will be available for providers to guide cancer treatment."

The challenge team also included Donald Poole, SwRI engineer, and Dr. Edward Medina, UT Health San Antonio pathologist. The American Association of Physicists in Medicine, the National Cancer Institute and SPIE, the international society for optics and photonics, sponsored the challenge. The team presented their winning algorithm at the 2019 SPIE Medical Imaging Conference in San Diego.

SwRI engineers David Chambers and Donald Poole trained a detection algorithm, using breast cancer tumor cell images, to win the BreastPathQ: Cancer Cellularity Challenge. Out of 100 submissions, their algorithm placed first in the international challenge to develop an automated method to detect breast cancer tumor cells.

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FARM TO FORK


30
years
testing food
40+
scientists, chemists
& techs
>100
nutrients
characterized
Includes:
• Fatty acids
• Amino acids
• Vitamins
• Minerals

Fueling Tomorrow's

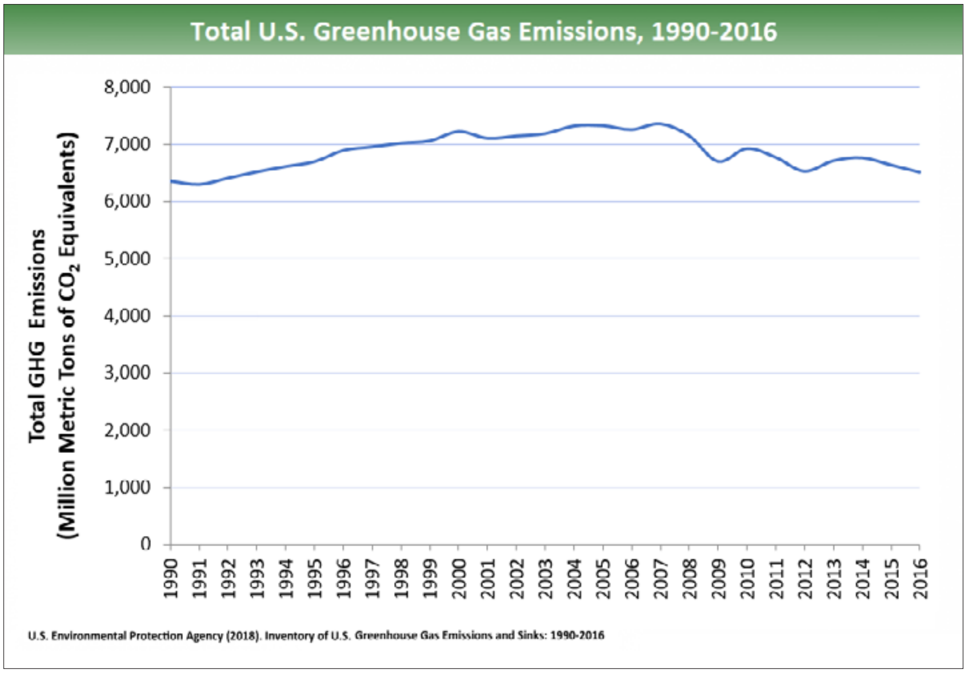
Transportation

Improving electrification & storage technology

By Dr. Terry Alger

When most people hear “CAFE standards,” they think about the kitchen cops and health inspections for local eateries and the food they offer. At Southwest Research Institute, we think about another form of fuel, and more specifically, vehicle fuel efficiency. Corporate Average Fuel Economy — CAFE — standards set the bar for the average new vehicle fuel economy, as weighted by sales, that a manufacturer’s fleet must achieve.

Congress initially enacted CAFE standards in 1975 in response to the 1973 oil embargo that quadrupled the price of oil. Almost overnight, the cost of gasoline became a major concern among auto manufacturers and the public alike. These CAFE standards aimed to double the average fuel economy of the new car fleet to 27.5 miles per gallon by 1985. Recognizing the challenges facing heavier vehicles, the U.S. Department of Transportation set a second standard for light trucks with the same overall goal but with a 22.2 mpg target.



The United States has successfully reduced CO_2 emissions since 2000.

IMAGE COURTESY EPA.GOV

These standards remained fixed until the price shocks of 2007. Then economic factors, combined with growing concern about carbon dioxide emissions and the availability of oil, led to a new round of fuel economy agreements in 2009. SwRI is working with the auto industry to meet these requirements and simultaneously achieve acceptable safety, emissions and performance standards, all while keeping vehicles affordable for the average consumer.

As the transportation industry strives to improve efficiency, the electric power generation industry is also attempting to reduce CO_2 emissions. And it's working. The United States has reduced its CO_2 emissions by nearly 20 percent since 2000. Most of this change is associated with the transition from coal to natural gas for power generation, although renewable energy sources and more efficient vehicles have also contributed. At SwRI, we work with both the transportation and electric power industries to improve energy storage technology.

EFFICIENCY LIMITS

The fundamental efficiency of today's automotive engines is actually quite high, which means it is difficult to make further significant improvements. Some can be made with new technologies (see "Clean and Cool" in the Summer 2010 issue of Technology Today). Other solutions involve waste heat recovery or adjusting the engine to operate more consistently in the efficiency zone. For power generation, the challenge of balancing the supply with demand can lead to inefficient operations. In both applications, adding an energy storage device — such as a battery — can significantly improve the efficiency of a system.

Batteries convert electrical energy into chemical energy for safe and efficient storage. In automobiles, braking is a huge waste of energy. For a typical car with friction brakes, the vehicle's kinetic energy is converted into thermal energy when its brake pads rub on rotors. That thermal energy is then released as heat into the environment, so that, effectively, all the energy that went into speeding the car up is turned into wasted heat. By using an energy storage system and a generator connected to the axles, a hybrid vehicle converts kinetic energy into electrical energy during a braking event, which is stored in a battery. In this manner, some of the energy that went into accelerating the car can be recovered for use later. In addition, having an electric motor and battery that can power the vehicle allows the engine to be used more efficiently, saving fuel. Finally, batteries in plug-in hybrids can be charged when the car is not in use, supplying the vehicle with energy generated by cleaner, more efficient sources.

For the power industry, batteries can help balance the load on the grid. They are more responsive than generators to sudden demands for power and can also absorb energy for use later, depending on demand. Plus, a major challenge preventing the country from getting all the benefits from solar and wind energy is timing. Peak wind and solar production periods often occur when energy demand is low. Integrating batteries into the system allows utilities to capture the excess energy and send it to the grid later when demand might outstrip supply. And greening energy production makes electric vehicles even more attractive.

STORAGE SYNERGY

Despite their potential benefits, widespread adoption of advanced energy storage systems has been stymied by challenges in cost, reliability, safety and energy density. SwRI has spent the last two decades addressing these issues to encourage more widespread adoption of advanced storage technology.

For the automotive sector, SwRI has worked on many different hybrid systems over the past 20-plus years. In the early 2000s, we evaluated the durability of a powertrain for a groundbreaking electric vehicle and contributed to a hydraulic hybrid system for delivery trucks. Then in 2011, SwRI launched its first major battery effort for the transportation sector, initiating the Energy storage system Evaluation and safety (EssEs) consortium to study and benchmark lithium-ion batteries for the emerging hybrid vehicle market.

DETAIL

SwRI manages more than a dozen multiclient projects, including seven automotive consortia, allowing organizations to pool their research and development dollars for pre-competitive research.

SwRI purchases one electric vehicle per year, benchmarking its performance before disassembling the battery pack and benchmarking individual cells.

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EssEs, now in its seventh year, has tested over 40 different types of lithium-ion cells, the building blocks of battery packs in today's hybrid and electric vehicles. The consortium also buys one electric vehicle per year, benchmarking its performance before disassembling the battery pack and benchmarking individual cells.

Our early battery test work was a grassroots effort, with SwRI repurposing engine test cells as battery test facilities. Outfitted with thermal chambers to keep the test articles at a consistent temperature, these test cells characterize batteries operating over a range of ambient temperatures. A cycler charges and discharges batteries in a prescribed manner, depending on the test.

Initially, the EssEs consortium focused on performance, life and abuse-tolerance testing of lithium-ion cells. Activities expanded beyond the consortium to include testing batteries for individual clients as a part of their product development process.

STORAGE SAFETY

As more electric vehicles took to the roads, several highly publicized accidents occurred, where batteries caught fire or exploded. To address these safety hazards, battery abuse testing became an important component of the electric vehicle product development process. Batteries in cars, cell phones and even medical devices must pass abuse tests while meeting performance requirements.

To meet these demands, the EssEs team built devices to crush, puncture and otherwise damage battery cells to characterize safety, creating a core capability to perform all required battery abuse testing to various U.S., European Union and United Nations standards.

Battery abuse testing takes several forms. The first is electrical abuse.

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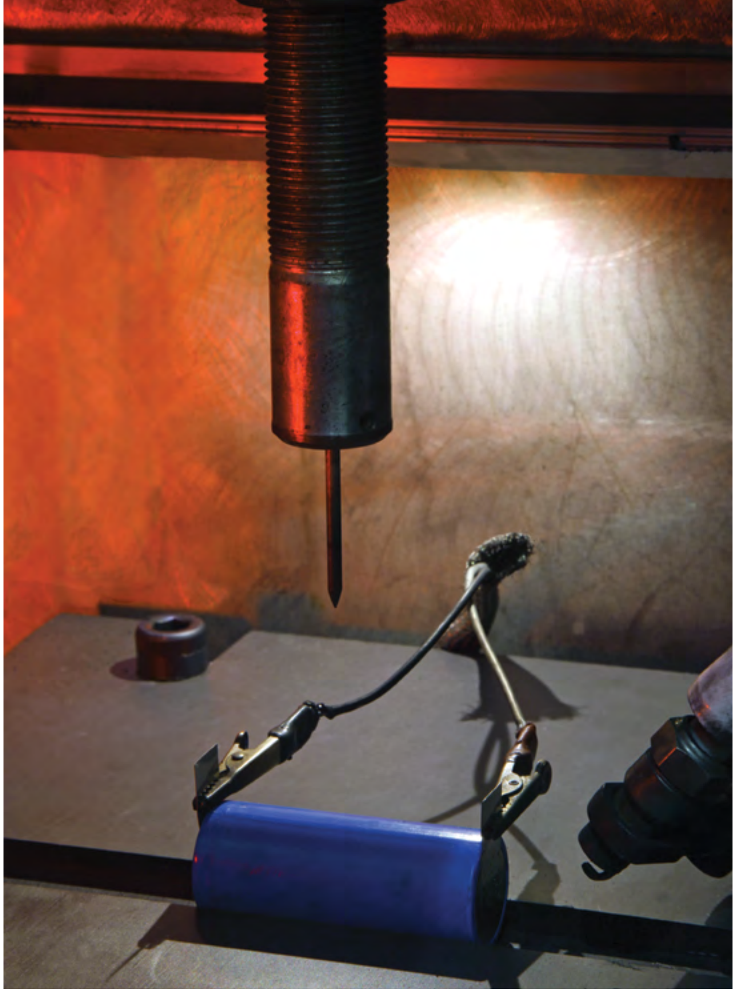
Fire specialists expose fully charged electric vehicle batteries to gasoline pool fires. Engineers monitor 60 sensors measuring temperatures up to 800 degrees C in this 2-minute test to characterize resistance to fire and explosion.



Among the battery of storage cell tests SwRI conducts is penetration testing to simulate damage from road hazards.

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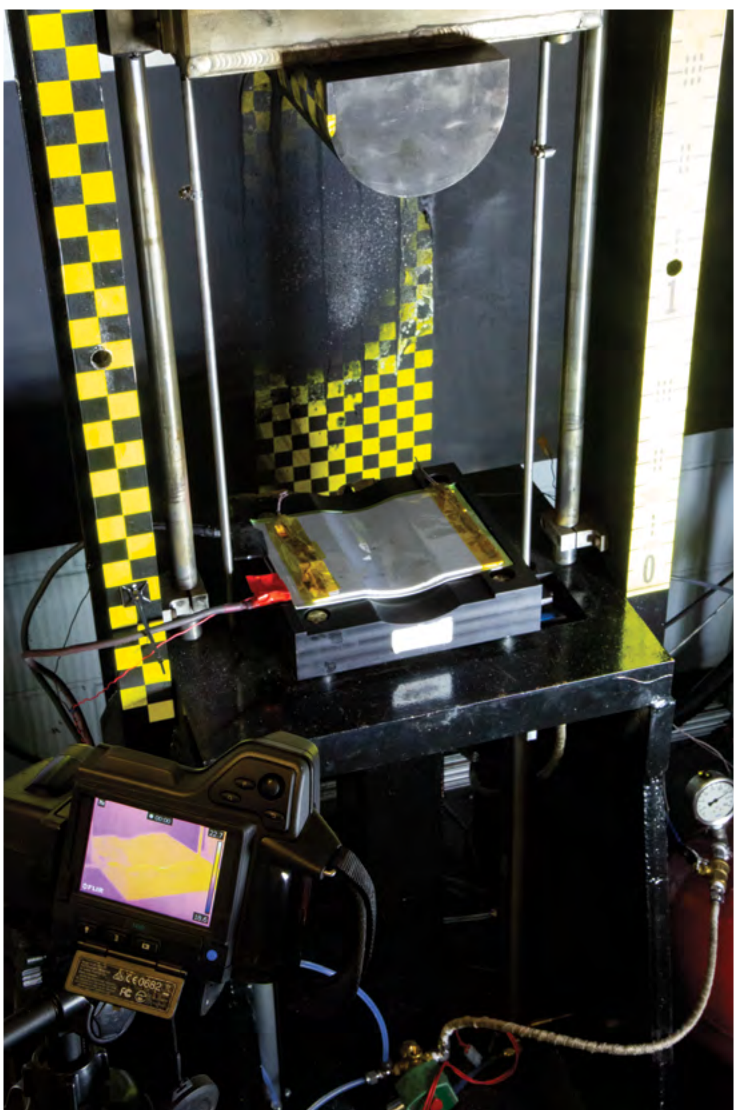

SwRI has developed a unique crush test fixture that uses sensors and video to characterize what could happen to a battery in an accident.

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Although modern battery management systems are extremely robust, overcharging or overdischarging can still potentially occur. To minimize this risk, SwRI evaluates how batteries deal with these situations, charging or discharging the units at different rates until they fail or a specified testing period ends.

The second form of abuse, physical abuse, comes in many forms. Teams from across the Institute use their capabilities to accomplish the work. SwRI performs all required physical abuse tests, from crushing cells, modules and packs to drop testing and simulating crash damage. Penetration tests mimic damage from road debris, and salt fog simulates corrosive environmental conditions. Fully charged batteries are exposed to pool fires to assess resistance to fire and explosion. As battery technology has matured, abuse testing has become less dramatic. Five years ago, abuse testing almost always resulted in a fire or some kind of dramatic event. Today, those incidents rarely happen. While the team might miss the excitement, it is nice to know that as batteries have proliferated, they've become much, much safer.

STORAGE SPECS

Characterization and performance testing round out our battery test work. SwRI evaluates manufacturers' ability to make consistent cells for both the EssEs consortium and individual clients. Size, weight and electrical properties are measured for a statistically representative sample of cells to evaluate the production quality of different cell types. Once characterized, we test cells under standard and custom charge and discharge cycles to measure their response to changes in temperature, charge/discharge rate and starting energy levels. As a part of this testing, a subset of cells are aged and tested at intervals to establish the response of the cell. It is common knowledge in the industry that batteries function different-


D023598_9993

The ESTC team includes, from left, Technician Mike Taylor, Research Engineer Kevin Jones, Assistant Manager Mickey Argo, Staff Engineer Dr. Bapi Surampudi, Senior Research Engineer Ian Smith, Manager Mark Walls, Principal Technician Mario Guillen, Staff Technician Doug Czaja and Engineer Christopher Kelly.

ly as they get older, so an important part of our work is establishing how aging affects different cell chemistries.

ELECTRIFICATION EXPANSION

As this work continued to expand, testing activities soon outgrew their space, so SwRI developed a dedicated facility completed in March 2018. SwRI's new Energy Storage Technology Center (ESTC) is 10 times larger than the previous lab, providing plenty of room for thermal chambers and space for several electric vehicles. The new facility has two dedicated "abuse rooms" with separate ventilation systems and scrubbers, ensuring that no toxic materials escape, and that battery abuse testing can be done safely.

SwRI is now one of the few one-stop shops in the United States that performs all regulatory battery safety tests on cells, modules and even complete battery packs. And, thanks to the emissions scrubbing system installed at the fire technology laboratory in 2014, even pack-level tests can be done safely and without impacting the environment.

The new lab offers more opportunities for vehicle benchmark testing, calibration and validation services for power electronics and technology in electrified vehicles. The team has completed internally funded research programs to develop new algorithms to predict battery life and improve fast charging. In addition, engineers are using existing SwRI intellectual property to investigate and improve battery coolants.

In a future project, the team will also work with CPS Energy, San Antonio's electric utility, on a grid storage experiment. CPS is building 5 MW of solar generation capacity and grid storage batteries at SwRI. Our engineers will participate in the operation of the system, performing experiments on the batteries and collecting data on the system for use in future applications.

TOMORROW'S CAFE MENU

Contrary to some reports in the popular press, the internal combustion engine is not dead, nor is it about to be replaced as the prime mover for the majority of the country's transportation needs. Nonetheless, electrified vehicles are destined to be a big part of future mobility solutions. SwRI's new Energy Storage Technology Center offers a full menu of innovative solutions for electric vehicles, which will play an increasing role in helping the automotive industry meet CAFE standards. Figuring out the safest, cleanest and most efficient means to fuel our way of life benefits all of us, no matter where we live or what we do.

Questions about this article? Contact Alger at terry.alger@swri.org or 210.522.5505.

SwRI TOOL TARGETS OIL SPILLS

SwRI engineers have created an interactive decision tree designed to find the best mitigation methods for specific oil spill scenarios. Numerous chemical dispersant technologies are available, and countless variables and conditions affect the performance of any given dispersant. SwRI's decision-making tool helps users understand how a dispersant technology will perform under different spill scenarios.

Led by SwRI Research Engineer Dr. Amy McCleney, the team designed the decision tree for the U.S. Department of Interior's Bureau of Safety and Environmental Enforcement to train individuals who respond to oil spill incidents.

"When an oil spill occurs, chemical dispersants, distributed by boat or airplane, enhance the breakup of spilled oil on water into small droplets, which dissipate in the surrounding ocean," McCleney said. "Microorganisms then degrade the small oil droplets to remove the harmful pollutants from the water."

Choosing the best technology for oil spill cleanup is extremely challenging due to numerous spill scenario combinations that can affect the overall response outcome. The SwRI tool supports hundreds of scenario combinations. Users select certain environmental and oil conditions, and the tool determines the most efficient dispersant and delivery approach to clean up the spill. For example, the thickness of an oil slick is a major variable affecting how much dispersant is needed to break up the spill.

"This is a game changer for oil spill preparedness, because oil spill cleanup thus far has been a relatively subjective process," she said. "This tool can help transition spill response operations into a more objective, systematic and measurable approach."

McCleney and fellow SwRI engineers Maria Cortes, Jacqueline Manders and Kevin Supak based the tool on an existing equipment efficiency system developed at SwRI. The team spent a year researching literature and interviewing industry experts, identifying the most efficient oil spill cleanup practices from across the industry to incorporate into the singular decision tree.

"In the end, this is all about protecting our coastlines and the public from oil," McCleney said. "This tool can train responders to select the best oil cleanup method before an event such as the Deepwater Horizon oil spill occurs, to implement more effective and timely responses."

IMAGE COURTESY STEPHEN LEHMAN, US COAST GUARD

D023628

An airplane sprays chemical dispersants on an oil slick in the Gulf of Mexico during the 2010 Deepwater Horizon oil spill.

ENERGY STORAGE SOLUTIONS

SwRI has received a $2 million grant from the United States Department of Energy's Advanced Research Projects Agency–Energy to develop an advanced pumped heat electricity storage system. This system offers twice the energy density of a lithium ion battery using an innovative thermodynamic cycle to store energy in hot and cold fluids.

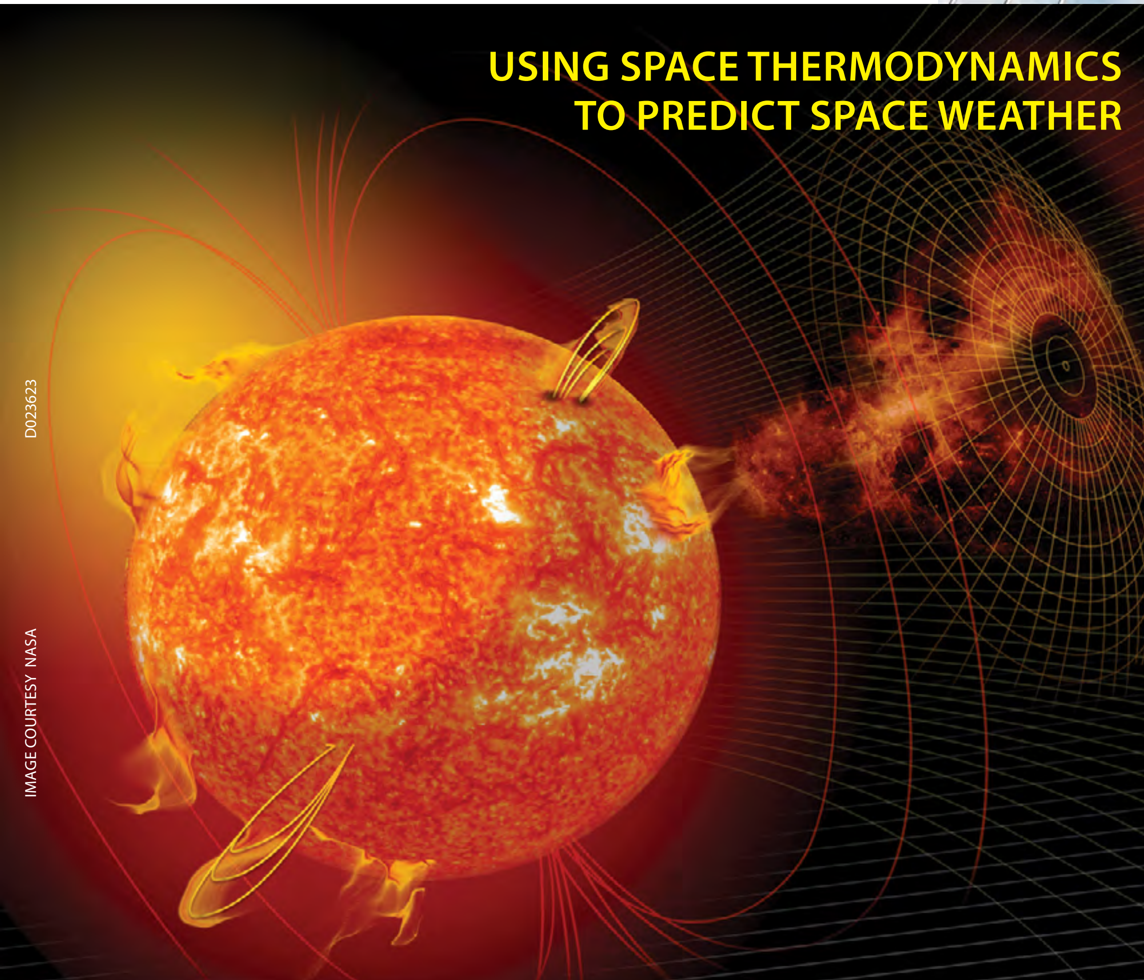
"It's important, now more than ever, to invest in innovative solutions that can help deliver on the promise of effective, renewable energy," said Danny Deffenbaugh, vice president of SwRI's Mechanical Engineering Division. "This new energy storage system is a wonderful example of research that benefits the world we live in, which SwRI engineers are committed to pursuing."

To implement renewables such as solar or wind energy on a larger scale, new energy storage technology is critical to match intermittent supplies with customer demand. The SwRI team, led by research engineer Brittany Tom, plans to build the new kW-scale energy storage demonstration system over the next two years.

"Grid-scale energy storage technologies like this one address a critical need for renewables on electricity grids worldwide," Tom said.

In this new system, electric energy from the grid is converted into thermal energy and stored as a thermal potential. At full capacity, the system could store energy for hours or up to several weeks before converting it back to electrical energy. The capacity of the system can be easily extended by increasing the volume of the storage tanks. The technology offers a low-cost solution when compared to "peaker" plants, which generate and provide electricity during the peak demand hours of the morning, later afternoon and evening.

USING SPACE THERMODYNAMICS TO PREDICT SPACE WEATHER



D023623

IMAGE COURTESY NASA

Research conducted by SwRI's Dr. George Livadiotis has shed new light on predicting the thermodynamics of the solar wind and "space weather" events. Solar flares and coronal mass ejections release hot, fast-moving plasmas that transmit magnetic fields from the solar corona, as depicted in this illustration. He calculated the distribution of particle velocities at thermal equilibrium when streams of particles are moving en masse, behavior typical of space and astrophysical plasmas. By measuring the macroscopic properties of plasmas, we can now understand and predict the microphysics of these plasmas. The new results are published in Astrophysical Journal.

iopscience.iop.org/article/10.3847/1538-4357/ab05b7/pdf

SPACE-OPTIMIZED OPTOCOUPLER

SwRI has developed a high-reliability, high-voltage optocoupler for spaceflight applications. NASA has selected the device as a power interface between the Europa Clipper spacecraft and three onboard instruments bound for Jupiter's moon Europa in the next five years. The power converter, developed with internal funding, overcomes reliability problems similar systems have had operating in space.

An optocoupler, also known as an opto-isolator, transfers electrical signals between two isolated circuits using light, in this case an array of LED sources. The SwRI device enables 15 kilovolts of isolated, low-voltage control for space instruments operating at up to 10.5 kV.

"Operating in conditions from -40 to 100 degrees Celsius, our power converter is ruggedized to withstand the rigors of launch and adverse radiation conditions in space," said SwRI's Carlos Urdiales. "In addition to withstanding the radiation environment around Jupiter, our optocoupler is fast, stepping from 0 to 10 kilovolts in 23.4 microseconds. The half-inch package weighs less than 4 grams and has a radiation tolerance in excess of 100 kilorads."

The high-quality device offers high reliability and long life in a relatively small footprint, which is critical for space applications. The optocoupler is being integrated into the MAss SPectrometer for Planetary EXploration (MASPEX), the Plasma Instrument for Magnetic Sounding (PIMS) and the SUrface Dust Analyser (SUDA) instruments for the Europa Clipper mission. SwRI's optocoupler will help power astrobiology examinations to understand the moon's subsurface sea and potential habitability as well as characterization of its atmosphere, ionosphere and magnetosphere.

"SwRI's SW1001502 octocoupler is a highly reliable choice for high-voltage electrostatic analyzers, deflectors, bias and custom stepping power systems," said Senior Engineering Technologist Dennis Guerrero. "It can also be used as a high-voltage linear control element, a current source or an operational amplifier output stage."

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SwRI is integrating its optocoupler power conversion technology into three instruments bound for Jupiter's moon Europa. The radiation-hardened, high-reliability device overcomes problems similar systems have had operating in space.

D018190_6259

SwRI designed Strofio, a basketball-sized instrument weighing just over 7 pounds, to measure particles in Mercury's sparse exosphere.

SAMPLING MERCURY'S EXOSPHERE

On October 20, the European Space Agency's BepiColombo spacecraft launched for Mercury carrying a unique payload designed and built at SwRI: an instrument called Strofio, designed to study Mercury's tenuous exosphere. Part of the SERENA suite of instruments, Strofio's measurements will help us better understand the planet's surface and the history of the smallest rocky planet orbiting close to the Sun.

"An exosphere is different from an atmosphere," said Dr. Stefano Livi, the Institute scientist who leads the Strofio experiment, funded by NASA's Discovery Mission of Opportunity program. "Mercury doesn't have enough gravity to hold onto a permanent atmosphere. Instead, it is surrounded by a thin, collision-free particle environment. Several mechanisms act on the surface of Mercury that can free particles from the soil. As atoms leave the surface they briefly populate this exosphere before they return to the surface or drift away into interplanetary space."

Mercury's proximity to the Sun makes it difficult to observe from Earth. It is also challenging for spacecraft to reach the planet and to survive in its harsh environment. The BepiColombo mission includes two spacecraft — ESA's Mercury Planetary Orbiter (MPO) and the Japan Aerospace Exploration Agency's Mercury Magnetospheric Orbiter. From aboard MPO, Strofio will study how Mercury's exosphere and magnetosphere interact with each other and with the planet's surface.

"Strofio is novel in its ability to detect the rare, static particle population in Mercury's exosphere," Livi said. "We had to rethink and retool typical spectrometer designs."

To understand these interactions, Strofio must identify the particles escaping from Mercury's surface. Because the exosphere is so thin, sampling particles is particularly challenging — in fact, the particle density is so low that the instrument had to be commissioned in specialized facilities at the University of Bern. Every particle captured is analyzed in a rotating field. When and where each particle gets to the detector determines the mass of each particle. Strofio uses detection algorithm tools to enhance the instrument's sensitivity and improve identification.

GREEN SKIES

Since 2008, SwRI has supported environment management activities for the U.S. Air Force and other federal agencies to improve energy efficiency and reduce greenhouse gas emissions. Our engineers are helping the Department of Defense develop gas leak detection, capture and reuse technologies.

One target is sulfur hexafluoride (SF_6), a colorless, odorless, nonflammable gas used as an electrical insulator in the E-3 aircraft's communications equipment. The E-3 airborne warning and control system (AWACS) conducts surveillance, command, control and communications functions for tactical and air defense around the world. According to the U.S. Environmental Protection Agency, SF_6 is a potent greenhouse gas. Its global warming potential is 23,000 times that of CO_2 over 100 years, and it remains in the atmosphere for up to 3,200 years.

SwRI has studied the feasibility of reclaiming, recycling, replacing and potentially reducing the use of gaseous SF_6 in the AWACS platform. Engineers conducted an extensive search for replacement candidates that provide equal or better performance and meet safety guidelines for health, flammability and instability hazards in a flight application.

Using a custom-designed test cell, SwRI evaluated the high-voltage negative DC electrical breakdown of potential gas candidates over the range of pressures and conditions experienced by AWACS equipment. Working with Texas Tech University's Center for Pulsed Power and Power Electronics, engineers measured S-band RF power using several promising gas admixtures that potentially satisfy technical and safety requirements for the aircraft's antenna and waveguide components. The Air Force is currently evaluating research results.

IMAGE COURTESY USAF/ AIRMAN 1ST CLASS CHRIS MASSEY D023627

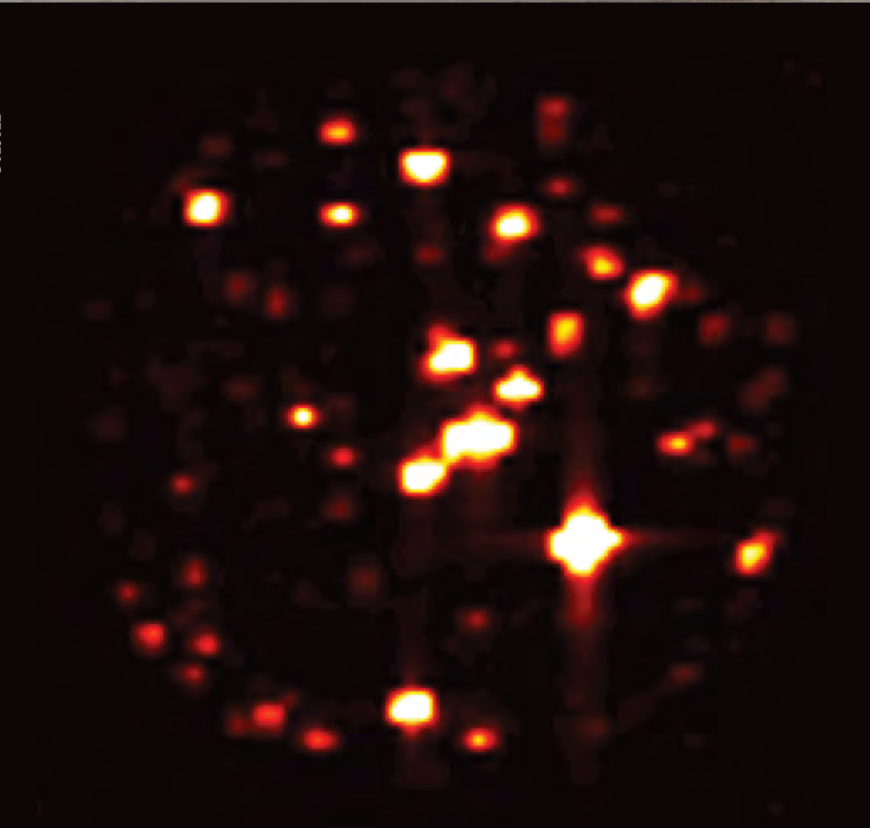


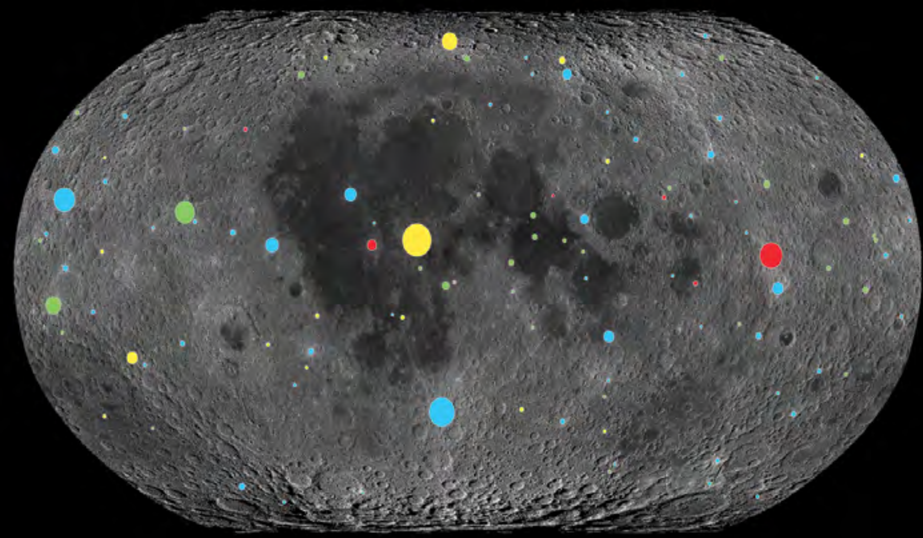
IMAGE COURTESY NASA/JPL-CALTECH/SWRI/INAF D023622

VOLCANIC ERUPTION LIGHTS UP IO ON EARTH'S DARKEST NIGHT

A team of space scientists has captured new images of a volcanic plume on Jupiter's moon Io during the Juno mission's 17th flyby of the gas giant. On Dec. 21, during Earth's winter solstice, four of Juno's cameras captured images of the moon's polar regions as well as evidence of an active eruption.

"We knew we were breaking new ground with a multi-spectral campaign to view Io's polar region, but no one expected we would get so lucky as to see an active volcanic plume shooting material off the moon's surface," said Dr. Scott Bolton, principal investigator of the Juno mission and an associate vice president of SwRI's Space Science and Engineering Division. "This was quite a New Year's present showing us that Juno has the ability to clearly see plumes."

JunoCam, the Stellar Reference Unit (SRU), the Jovian Infrared Auroral Mapper (JIRAM) and the Ultraviolet Imaging Spectrograph (UVS) observed Io for over an hour, providing unprecedented images of the most volcanic body in the solar system.



SwRI was part of a team that used Lunar Reconnaissance Orbiter data to study the Moon's craters, scaled by size and color-coded by age here, to understand the impact history of the Earth. This illustration shows a lunar surface dominated by blue craters less than 290 million years old, which is consistent with those on Earth, indicating that bombardments on both bodies have increased since that time.

IMAGE COURTESY NASA / LRO / USGS / UNIVERSITY OF TORONTO

D023621

ASTEROID ASSAULT ACCELERATED IN PAST 300 MILLION YEARS

SwRI scientists recently looked to the Moon to better understand the impact history of the Earth. The research, published January 18 in the journal *Science*, discovered that the rate of sizable asteroid collisions has increased by a factor of two to three on both bodies over the past 290 million years.

Earth has fewer older craters than expected compared to other bodies in the solar system, making it difficult to find an accurate impact rate and to determine if it has changed over time. Many experts assumed that the earliest Earth craters may have been worn away by wind, storms and geologic processes, mechanisms not present on the Moon.

Lunar craters experience little erosion over billions of years, but scientists could not pinpoint their ages until NASA's Lunar Reconnaissance Orbiter (LRO) started circling the Moon a decade ago. Using images and thermal data collected by LRO, SwRI scientists and collaborators calculated the ages of large lunar craters across the Moon.

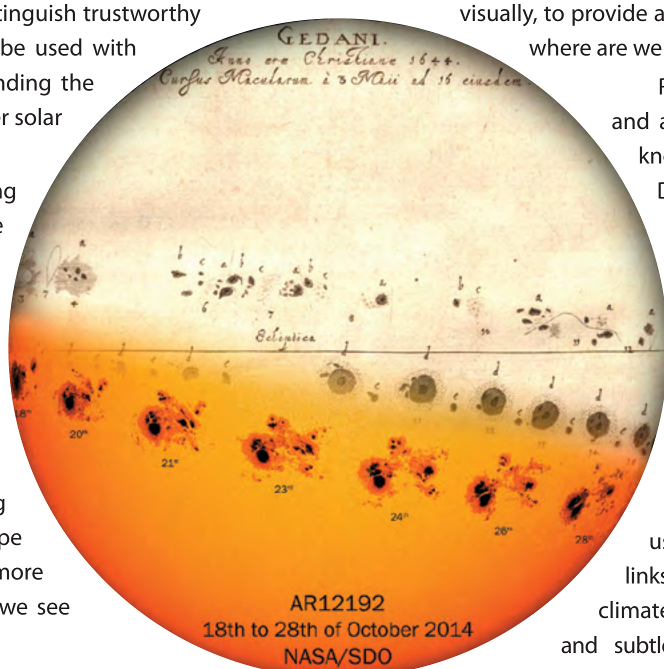
"What this research uncovered is that the Earth has fewer older craters on stable terrains, not because of erosion, but because the impact rate was lower prior to 290 million years ago," said SwRI's Dr. William Bottke. "The Moon is like a time capsule, helping us understand the Earth. We found that the Moon shared a similar bombardment history, which meant the answer to Earth's impact rate was staring everyone right in the face."

D023620

PUTTING SOLAR ACTIVITY IN PERSPECTIVE

An international team led by SwRI has developed a new technique for looking at historic solar data to distinguish trustworthy observations from those that should be used with care. This work is critical to understanding the Sun's past and future as well as whether solar activity plays a role in climate change.

"Scientists have been monitoring solar activity since Galileo made the first drawings in 1612 by counting sunspots and groups of sunspots," said SwRI's Andrés Muñoz-Jaramillo, a senior research scientist who is lead author of a paper in Nature Astronomy outlining the research. "However, putting all observations in perspective is quite challenging due to wide-ranging observation techniques and telescope magnifications used. We see much more now and our understanding of what we see changes the way we count spots."



The team, which included José Manuel Vaquero of the University of Extremadura (Spain), created a technique that takes all historic data gathered and digitized thus far and combines them visually, to provide a complete picture of the data we have and where are we missing information.

Roughly every 11 years, the magnetic structure and activity of the Sun cycle between periods known as solar minimum and solar maximum. During solar maximum, the Sun emits high levels of solar radiation, ejects large amounts of solar material and displays large numbers of intense sunspots, flares and other phenomena. During solar minimum, this activity is muted. Changes on the Sun cause effects in space, in the atmosphere and on Earth's surface. The Sun also experiences longer variations.

"One has to be very careful when using historic sunspot data to study potential links between the Sun and changes in terrestrial climate, given that these effects would be complex and subtle," Muñoz-Jaramillo said. "Our work uses historical data to provide context to users of these estimates who may not be aware of their limitations."

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NEXT-GEN MST TECHNOLOGY

A new, more powerful generation of SwRI's patented MagnetoStrictive Sensor can withstand extreme temperatures, automatically adjusts frequencies and incorporates a stronger magnet. The compact magnetostrictive transducer (MsT™) more accurately detects potential problems in oil, gas and chemical industry structures such as pipelines, storage tanks and anchor rods.

"The MsT system offers the next level of signal strength. This user-friendly technology more precisely locates structural issues," said Dr. Sergey Vinogradov, the SwRI staff engineer who led the upgrade initiative. "It is an extremely reliable, state-of-the-art, durable sensor that you can install just about anywhere."

The circular, hard-shell MsT sensor clamps around pipes and other structures and is available in circumferences ranging from one-half inch to 70 inches. It detects material flaws, corrosion and areas at risk of developing cracks and leaks. At just 1.1 inches wide, MsT uses less shear-wave couplant, a gel that aids energy transmission, and requires less clamping force when dry coupled. The MsT sensor can be permanently installed on a structure to provide ongoing monitoring.

"The MsT is compact and easy to install, but it's also more convenient," Vinogradov said. "With this improved sensor, the operator does not change hardware to change frequencies. And this function is automated, which reduces human error. This feature is especially useful when the sensors need to be installed at multiple, hard-to-access locations."

High temperatures accelerate corrosion in metal structures. For that reason, MsT is designed to withstand up to 500 degrees Celsius. It can be installed on extremely hot structures to detect weaknesses and can also withstand temperatures significantly below freezing.

SEEING THROUGH TITAN'S ENIGMATIC ATMOSPHERE

SwRI scientists recently tackled one of the greatest mysteries about Titan, one of Saturn's moons: the origin of its thick, nitrogen-rich atmosphere. A new study published online in *The Astrophysical Journal* posits that Titan's murky atmosphere comes, at least in part, from organic material "cooked" in the moon's interior.

"Titan has this very thick atmosphere, which makes it unique among moons in our solar system," said Dr. Kelly Miller, lead author of the study. "It is also the only body in the solar system, other than Earth, that has large quantities of liquid on its surface. Titan, however, has liquid hydrocarbons instead of water. A lot of organic chemistry is no doubt happening on Titan, so it's an undeniable source of curiosity."

The atmosphere of Saturn's largest moon is extremely dense, even thicker than Earth's atmosphere, and mostly nitrogen. It's also about 5 percent methane, which reacts quickly (by astrophysical standards) to form organics that gradually fall to its surface. This means atmospheric methane would either need to be replenished or that current conditions are transient and unique.

"The leading hypothesis has been that ammonia ice from comets was converted, by impacts or photochemistry, into nitrogen to form Titan's atmosphere," Miller said. "While that may still be an important process, it does not account for what we now know is a very substantial portion of comets: complex organic material."

To study the Titan mystery, Miller combined existing data from organic material found in meteorites, which is similar to but less abundant than cometary organics, with previous thermal models of the moon's interior. Miller found that "cooking" organics from Titan's formation in its interior could produce about half the nitrogen, and potentially all the methane, in the moon's enigmatic atmosphere.

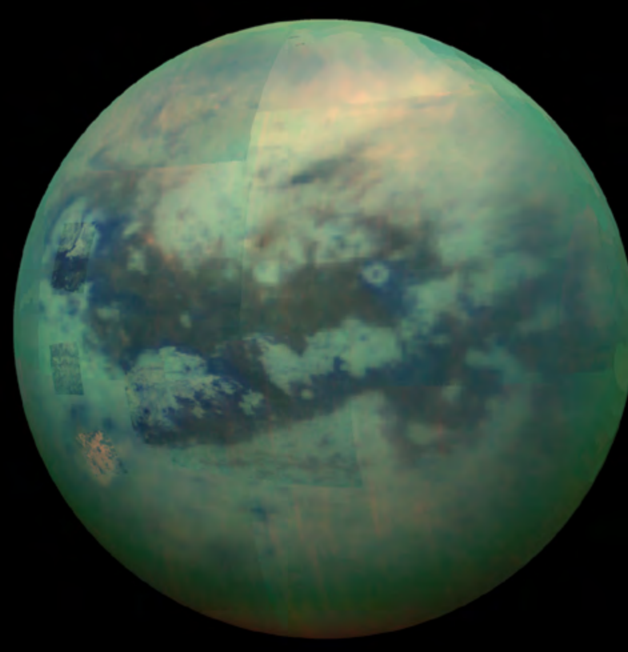
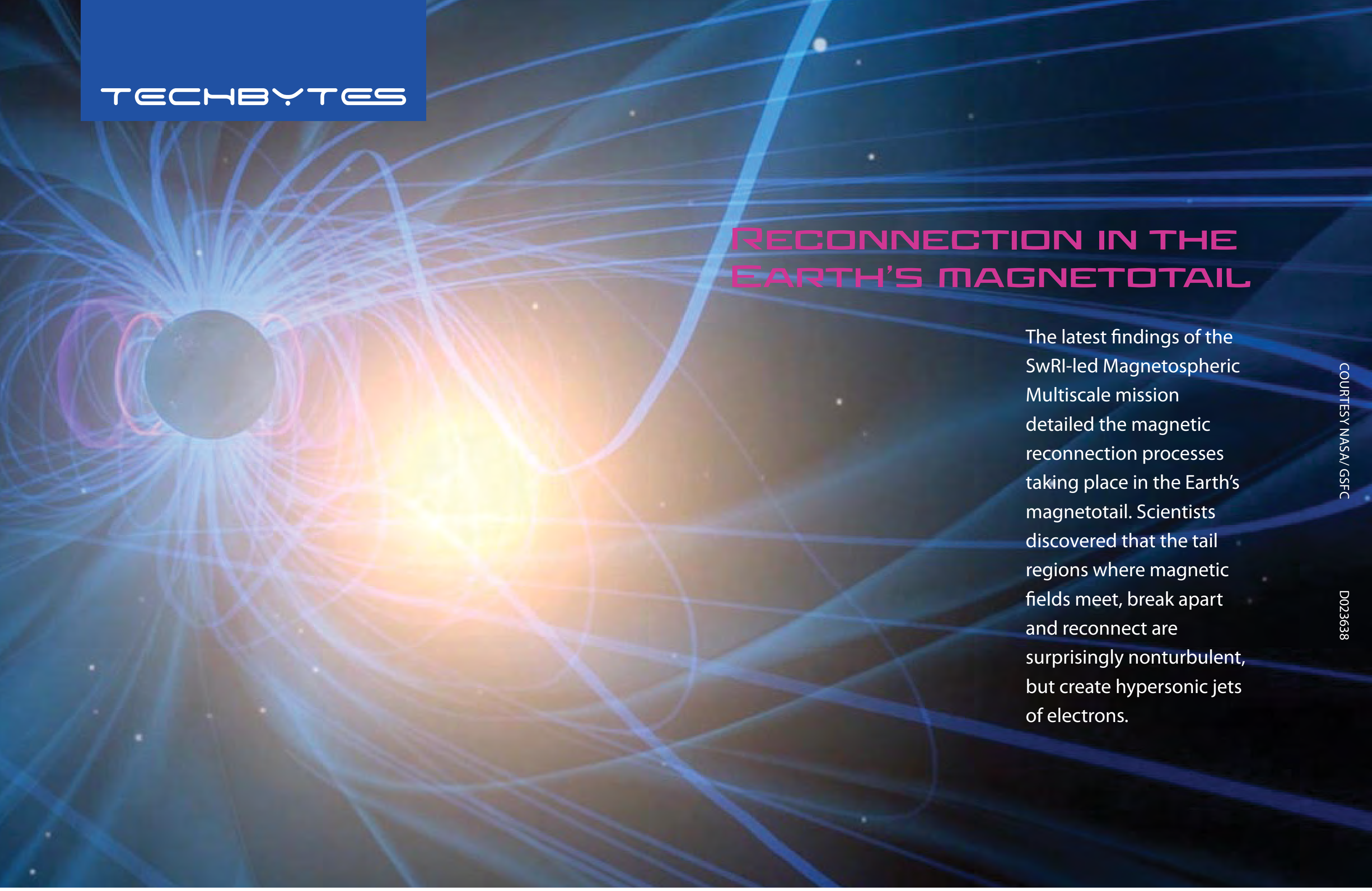


IMAGE COURTESY NASA D022748

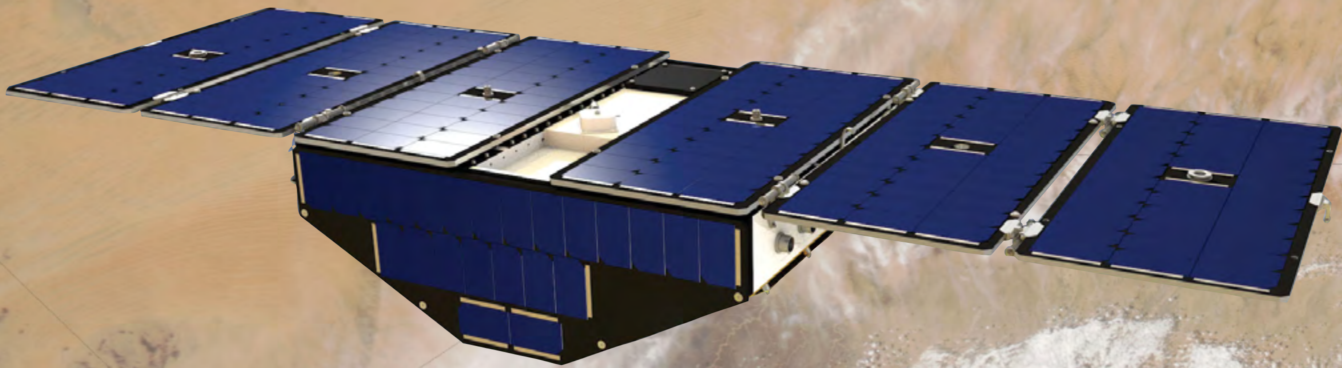


COURTESY NASA/ GSFC

D023638

RECONNECTION IN THE EARTH'S MAGNETOTAIL

The latest findings of the SwRI-led Magnetospheric Multiscale mission detailed the magnetic reconnection processes taking place in the Earth's magnetotail. Scientists discovered that the tail regions where magnetic fields meet, break apart and reconnect are surprisingly nonturbulent, but create hypersonic jets of electrons.



CYGNSS EXTENDED

NASA has extended the Cyclone Global Navigation Satellite System (CYGNSS) mission for an additional year and a half. The constellation of microsatellites designed and built at Southwest Research Institute has made history over the last two years, penetrating thick clouds and heavy rains to accurately assess wind speeds and better understand hurricane intensification. Assessments confirmed that all eight spacecraft and their subsystems are healthy and ready to support two more years of operations.

The microsatellites — each roughly the size of carry-on luggage — make frequent measurements of ocean surface winds to monitor the location, intensity, size and development of tropical cyclones. Flying in formation, the spacecraft cover an orbital swath that passes over most of the Earth's hurricane-producing zone, up to 35 degrees north and south of the Equator.

"Launched in late 2016, the spacecraft have provided round-the-clock surface wind speed measurements to help improve intensity forecasting of tropical cyclones," said SwRI's William Wells, CYGNSS operations phase systems engineer. "The extended mission opens the door for many new science opportunities, in addition to continuing the primary mission objectives. We are making some engineering and operational changes to enable new types of science while maximizing science returns in this second phase."

This science is critical because, over the last few decades, forecasters have improved hurricane path prediction significantly, but the ability to predict the intensity of storms has lagged behind. Collecting data in the midst of a storm is difficult and dangerous, but conventional space technology could not provide accurate measurements. GPS signals penetrate intense rainstorms, and CYGNSS uses these signals, reflected off the ocean surface, to calculate wind speeds.

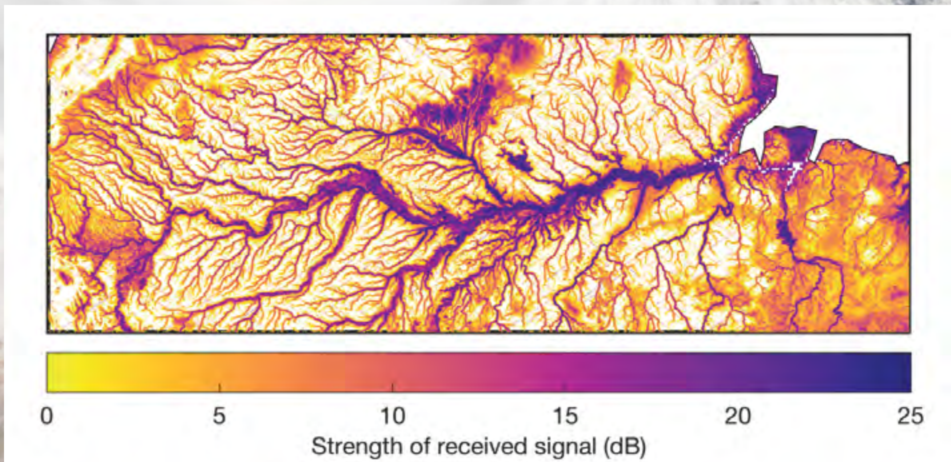
"For the extended mission, we are ramping up for four new investigations related to tropical cyclones, six in other oceanography disciplines, six that use CYGNSS data in groundbreaking land science applications and many others," said SwRI's Jillian Redfern, CYGNSS project manager and mission operations manager. "We are adjusting payload operations to support the new science applications while maintaining production of the core data products already in use by the science community."

During the prime mission phase, CYGNSS science has led to 72 refereed journal publications and 158 conference proceedings publications in atmospheric, ocean and terrestrial science as well as space systems engineering.

"We have made extensive observations of inner core winds and demonstrated that assimilating these data into numerical weather prediction models has a significant positive impact on their ability to forecast a storm's track, intensity and structure," said Dr. Chris Ruf, CYGNSS principal investigator from The University of Michigan in Ann Arbor, Michigan. "In addition, bonus observations over land have uncovered a wealth of new science applications related to imaging of flood inundation and measuring subsurface soil moisture. I look forward personally to many more years supporting these efforts and helping to expand the community of our data users."

SwRI led the engineering development and manages the operation of the constellation. The University of Michigan Climate and Space Sciences and Engineering Department leads the science investigation, and the Earth Science Division of NASA's Science Mission Directorate oversees the mission. SwRI's office in Boulder, Colorado, hosts the mission operations center, which commands the spacecraft, collects the telemetry and transmits the data to the science operations center at the University of Michigan.

In the second phase, the CYGNSS mission has expanded to include land-based studies. In the prime mission, a surprising capability emerged — CYGNSS can characterize flooded landscapes and measure subsurface soil moisture, as seen in this CYGNSS map of the Amazon basin.



COURTESY NASA/UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH/UNIVERSITY OF MICHIGAN

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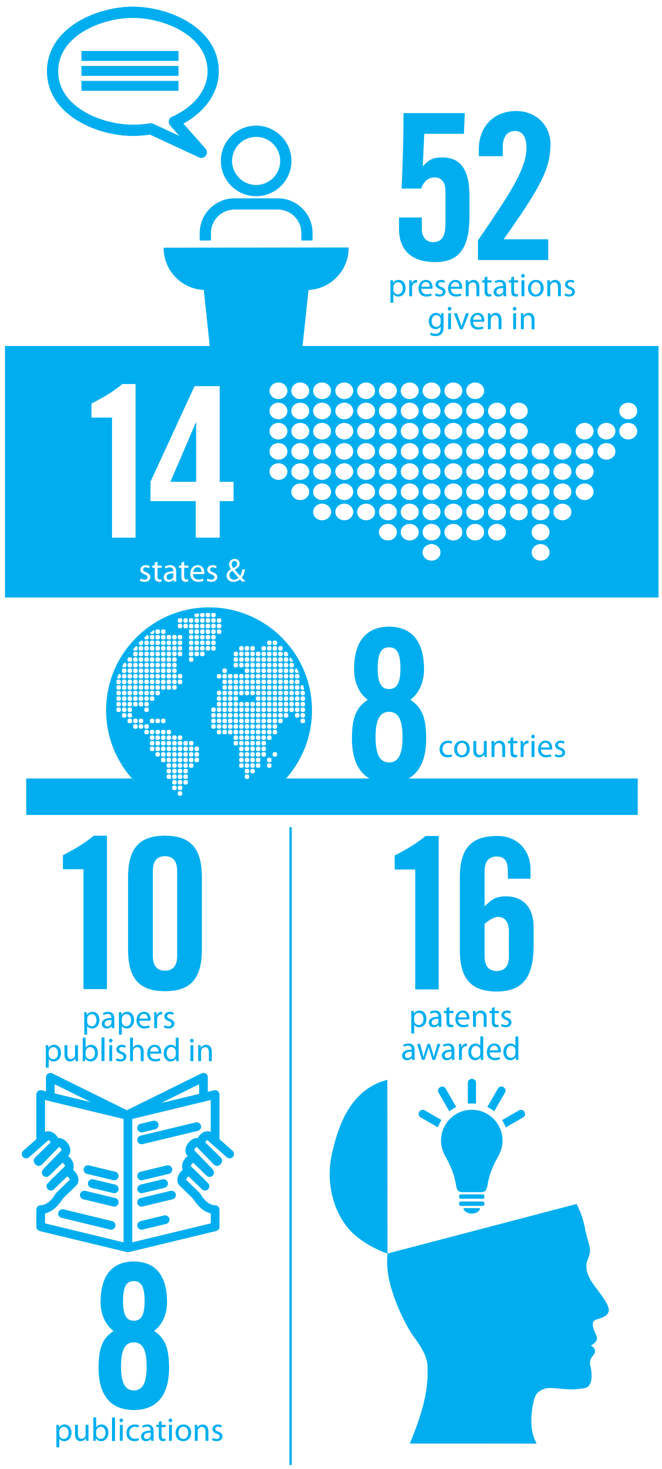
BY THE NUMBERS Fall 2018 – Spring 2019



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SwRI played a key role in the International Powertrains, Fuels and Lubricants Meeting held in San Antonio in January. The event included a tour of Institute facilities, including automotive, robotics and fire technology laboratories. SwRI president and CEO Adam L. Hamilton gave the meeting's keynote address and we hosted a "fiesta" party for attendees.

D023629

Dr. Terry Alger, a director in SwRI's Powertrain Engineering Division, has received the 2019 Edith and Peter O'Donnell Award in Technology Innovation. Presented by The Academy of Medicine, Engineering and Science of Texas (TAMEST), the honor recognizes Alger for his role in developing vehicle engine technologies that lower pollution levels and improve fuel economy.

D021434

Dr. Scott Bolton, associate vice president of SwRI's Space Science and Engineering Division, was honored with a 2018 American Ingenuity Award from Smithsonian Magazine. The award recognizes Bolton's contributions to the physical sciences as principal investigator of NASA's Juno mission to Jupiter, now about halfway through its prime mission.

D021434

Dr. Graham Conway, a principal engineer in the Powertrain Engineering Division, received an SAE Outstanding Oral Presentation Award for a talk titled "Alternative Fluids Injection for Knock Mitigation and Efficiency." Presented at the SAE Powertrains, Fuels and Lubricants Meeting in January, the talk focused on research funded by SwRI's HEDGE consortium.

D022395

James Dante, a manager in SwRI's Mechanical Engineering Division, has received a Strategic Environmental Research and Development Program award. The Weapons Systems and Platforms Project of the Year Award recognizes work that introduces new technology to reduce the military's environmental footprint.

D018561_0922

Dr. Peter Lee, a staff engineer in SwRI's tribology section, has been elected a Fellow of the Institution of Mechanical Engineers, which is the highest level of membership within the organization. Founded in 1847, the Institution of Mechanical Engineers is a United Kingdom-based organization of more than 120,000 engineers in 140 countries.

D022170_8395

Dr. Alan Stern, associate vice president of SwRI's Space Science and Engineering Division, has been appointed to the National Science Board by the Trump Administration. The National Science Board is the governing body of the National Science Foundation (NSF) and is jointly led by its own board president and the NSF director.

COMING UP

TRAINING

SwRI is hosting these short courses:

Cybersecurity Workshop, San Antonio, May 14, 2019

Fugitive Emissions Research Best Practices Webinar, San Antonio, May 14, 2019

ISO Internal Auditor Training, Austin, Texas, May 16, 2019

ISO Internal Auditor Training, San Antonio, June 20, 2019

Lean Six Sigma Yellow Belt Training, Austin, Texas, June 25, 2019

CONFERENCES

Offshore Technology Conference, Houston, May 6-9, 2019, Booth 2201

International School of Hydrocarbon Measurement (ISHM), Oklahoma City, May 14-15, 2019

National Association of Environmental Professions Annual Conference, Baltimore, May 19-23, 2019

AAPG Annual Convention & Exhibition, San Antonio, May 19-22, 2019, Booth 617

IFT Food Expo, New Orleans, June 3-5, 2019, Booth 2305

ITS America Annual Meeting, Washington, D.C., June 4-7, 2019, Booth 431

29th CIMAC World Congress, Vancouver, Canada, June 10-14, 2019, Booth 400

National Fire Protection Association (NFPA) Conference, San Antonio, June 17-20, 2019, Booth 1184

ASME Turbo Expo, Phoenix, June 17-21, 2019, Booth 311

Valve World Americas Expo & Conference, Houston, June 19-20, 2019, Booth 1701

For more information, visit **swri.org/events**.

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