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SUMMER 2017

TECHNOLOGY TODAY®

BLAZING A TRAIL FOR AGILE AUTOMATION

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ON THE COVER

Smarter Automation

SwRI has developed a robotic system incorporating machine vision to automate a package sorting system.

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EMPLOYMENT

Southwest Research Institute is an independent, nonprofit, applied research and development organization. The staff of nearly 2,700 employees pursues activities 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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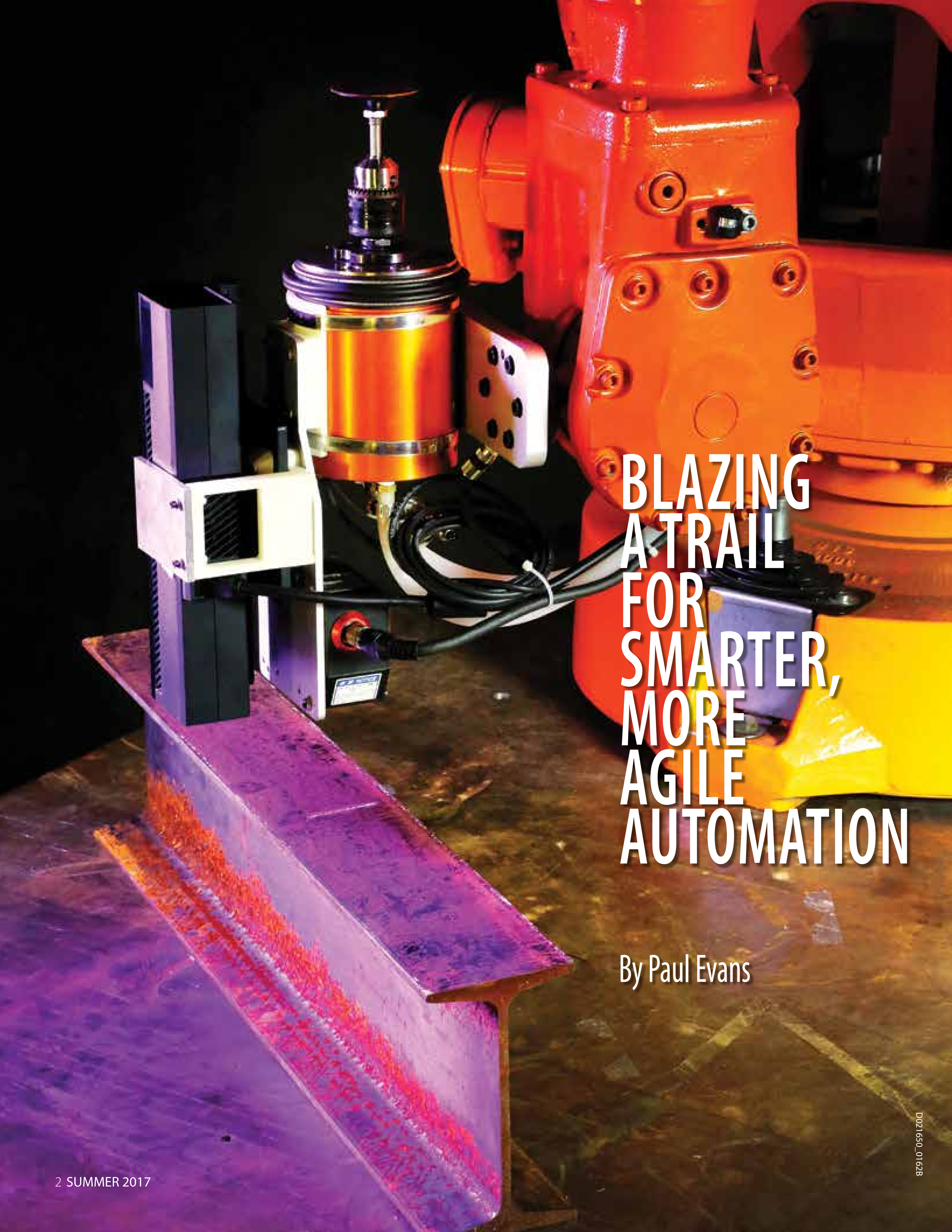

BLAZING A TRAIL FOR SMARTER, MORE AGILE AUTOMATION

By Paul Evans

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ABOUT THE AUTHOR

Paul Evans directs SwRI's Manufacturing Technologies Department. This group uses new technologies to enable advanced industrial applications, developing and implementing innovative electromechanical systems and adaptive software solutions. Evans has conducted robotics and automation programs for a variety of clients and industries, including food manufacturing, automotive, aerospace, material handling, and packaging.

Industrial robots usually call to mind the image of an articulated arm bolted to a factory floor, its end-effector "hand" pivoting to spot-weld automobile bodies as they slide past, one by one, on an assembly line.

That's nowhere near the image that the robotics community has in mind for future industrial automation. These robots will be mobile, agile, and adaptive. They're not rooted to a floor; on the contrary, these robots can navigate through their workspace. They use machine vision and GPS-like location to interact with objects and understand where they are within their environment. These robots understand tools and their capabilities and are able to apply them automatically to new tasks. And when the work is done, robots can be sent to do a different job, with different tools.

Robotics researchers also want their new machines to "speak" the same robot language as a host of other robots worldwide. Rather than being a trade secret, the language would be open-source and accessible to programmers of a broad range of robots, so everyone can benefit from that common language.

All of this isn't just a wish list or some far-off utopian vision: It's already in development today at Southwest Research Institute. In fact, researchers in the Intelligent Systems Division have spent nearly three decades developing software to make industrial robots smarter. SwRI also has been instrumental in developing, proliferating, and curating ROS-Industrial (ROS-I). This open-source framework is designed to build an international community around the advanced Robot Operating System known as ROS for industrial applications.

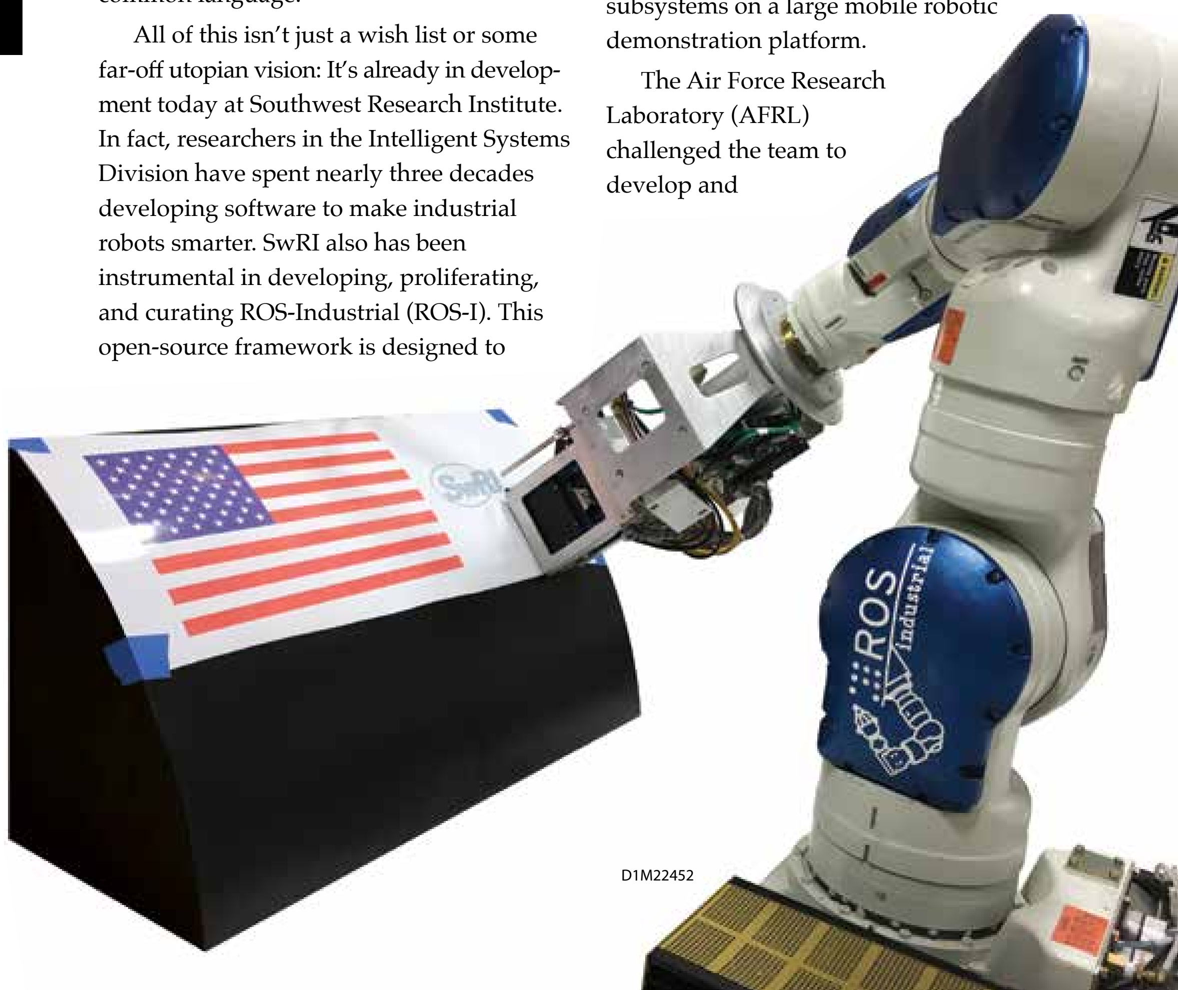
Over just five years, manufacturers and suppliers have adopted ROS-I for applications ranging from robots that dynamically sort cluttered objects, to ones that can paint arbitrary objects, to robots that move autonomously inside a warehouse or factory while avoiding obstacles.

MILITARY INTEREST IN ROBOTICS

The prospect of developing intelligent, multitasking robots has caught the interest of the military as well. The U.S. Air Force recently assembled a team of SwRI, the Boeing Company, and the National Center for Defense Manufacturing and Machining (NCDMM) to make advanced robotics reusable for aerospace maintenance and manufacturing. NCDMM is managing the four-year, $6.7 million contract. Boeing is providing process development and tooling expertise, while SwRI is developing a general-purpose software framework using ROS-I and will integrate all the subsystems on a large mobile robotic demonstration platform.

The Air Force Research Laboratory (AFRL) challenged the team to develop and

Left: The SwRI-led ROS-Industrial Consortium successfully reached a milestone in its "robotic blending" focused technical project. The robot application uses SwRI's "scan-n-plan" process to remove machine tool marks from metal parts, saving time and freeing workers from this repetitive task.



Right: SwRI has patented a large-scale robotic technique for inkjet printing intricate graphics on aircraft and other complicated surfaces, shown here in a laboratory-scale demonstration.

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demonstrate a mobile multiprocess robotic solution through the Advanced Automation for Agile Aerospace Applications (A5) program. The objective: Make it easier to use one piece of machinery to transition from one manufacturing or maintenance task to another, quickly and cost-effectively, without engineering or programming rework between tasks.

Traditional manufacturing automation tends to rely on purpose-built machines, typically dedicated to a specific aircraft or component. Those machines demand large initial capital outlays and significant operating expenses; adaptation is costly and innovation is slow.

The A5 program aims to upend that paradigm using ROS-Industrial to develop flexible technology that can be used across different manufacturing processes and environments. Phase 1 will develop adaptive robotic capabilities in aircraft sanding. Phase 2 will apply those capabilities to composite aircraft repair, and Phase 3 will develop nondestructive capabilities using the same mobile platform.

Using ROS-I, the team can dramatically reduce the amount of manual programming and intervention needed to implement advanced automation.

A HISTORY OF SMARTER ROBOTS

Using advanced automation to solve military maintenance challenges is nothing new at SwRI. The drive toward smarter industrial robots for military aerospace tasks began more than 30 years ago with an automated process to polish away scratches in the clear-composite cockpit canopies of F-16 fighter aircraft. Later, SwRI was active in developing robots to remove coatings from F-15 fighters. For modern aircraft and aerospace systems, it's important that the robot remove paint without damaging the underlying composite materials that make up large portions of today's aircraft. Such a system saves time and money while providing consistent quality, but perhaps most significantly, it can improve worker welfare by removing them from hazardous environments.

Continued research at SwRI has refined the robotic coating removal process itself, from blasting plastic particles onto a surface to vaporizing layers of coating material using precisely focused lasers. New, state-of-the-art laser coating removal (LCR) technology is being developed for a commercial client. The system combines a mobile robotic platform, laser scanning technology, and high-powered lasers for safe and efficient removal of paint and other aircraft coatings.

SwRI developed this mobile manipulator platform to evaluate new robotic applications. The technology is applied to automate warehouse operations and to adapt navigation strategies for SwRI's large-scale aerospace robotics programs.

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This illustration depicts how a robotic arm commonly used in advanced manufacturing can be adapted to perform multiple functions such as under-wing sanding or composite repair on military aircraft.

Significantly, the LCR process uses a high-speed vision system to precisely control the coating removal. This provides the capability to remove the coating layer by layer, down to the base material, or leaving the primer intact. It's particularly well-suited to today's modern airframes constructed from sensitive substrate materials.

TEACHING A ROBOT NEW TRICKS

Responding to needs in the aerospace industry, SwRI researchers recently added yet another application for large-scale robots. They patented a technology for inkjet printing on rounded surfaces such as aircraft fuselages.

As aircraft decorative coatings have become increasingly complex, the aircraft manufacturing and maintenance communities are seeking more efficient ways to apply complex graphics. To fully leverage the potential efficiency and aesthetic advantages, the inkjet process must be able to print on a variety of complex geometries and in varied orientations, over large areas.

Inkjet printing provides the potential for superior performance compared to decals or appliqués, which are difficult to qualify due to adhesion and robustness issues over the wide range of speeds and environmental conditions associated with flight.

The inkjet system, developed with internal funding by SwRI, needed to overcome challenges associated with large, complex surfaces to be painted, as well as inaccuracies in robot positioning and vibration of robot structures. Inkjet, also known as direct printing, allows for digitally printing complex graphics on everything from textiles to billboards. The SwRI-developed system expands that capability to aircraft fuselages, wings, tail fins, and engine nacelles, replacing labor-intensive traditional painting techniques.

SwRI's research culminated in being awarded U.S. Patent No. 9,527,275, "High Accuracy Inkjet Printing." The patent covers hardware and software for precise application of multiple graphic swaths of color ink onto complex surfaces, creating a continuous graphic image. Each pass of color, or graphic swath, can be aligned over curved surfaces without spaces, gaps, or discontinuities.

A vision sensor will detect an encoded pattern to ensure accurate application of graphic images. The encoded pattern will be deposited on the surface in a known location with respect to the most recently deposited graphic swath. The printing system includes high-bandwidth servo actuators to locate the print head with respect to the encoder pattern to permit precise positioning for the next swath.

SwRI specializes in integrating unique sensor solutions into existing manufacturing processes and developing control methodologies to automate processes. Here, engineers have developed a robotic system incorporating machine vision to automate a package sorting system.

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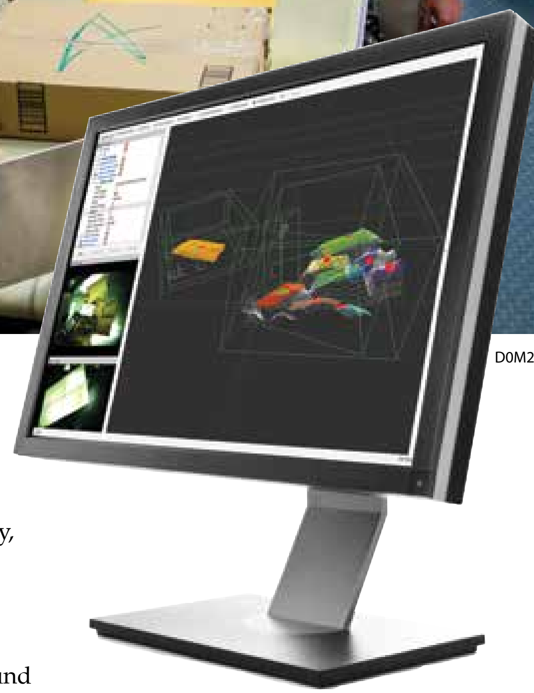

TAKING ROS-I TO THE WORLD

All of these initiatives draw upon the resources and ingenuity of the ROS-I community, a diverse group of experts in academia and industry that is advancing secure and open-source robotics.

SwRI maintains the ROS-I software repository and coordinates the ROS-Industrial Consortium (RIC), which has more than 50 members from academia and industry around the world. Launched in 2013, RIC has three branches, with SwRI leading RIC-Americas and Fraunhofer IPA in Stuttgart, Germany, leading RIC-Europe. In 2016, RIC expanded into the Asia-Pacific region with the Singapore-based Advanced Remanufacturing and Technology Centre and Nanyang Technological University launching RIC-Asia Pacific. RIC supports the ROS-I community and focuses on training, technical support, and setting the strategic roadmap for ROS-I.

ROS-I is revolutionizing robotics and their use in advanced manufacturing. Capabilities include collision-free and advanced path planning, software reuse across robot brands, and easy integration of the latest sensing technologies. ROS-I also allows rapid prototyping for new applications and provides a bridge to other frameworks such as PackML, MTConnect, and many others. SwRI is leading the charge, using ROS-I as a springboard to create tomorrow's smart, dexterous robots for applications from the factory floor to military maintenance depots and beyond.

This story was originally published in Industry Today, Volume 20, Issue 1.

Questions about this article? Contact Evans at (210) 522-2994 or paul.evans@swri.org.

In 2011, SwRI installed this largest-ever dual robot system to use plastic media blasting to remove coatings from Air Force fighter jets. Engineers also used the system to conduct a large-scale demonstration of a high-speed laser coating removal technology, a more environmentally friendly alternative to current chemical and blast removal methods. SwRI is currently developing a laser-based coating removal system deployed on a mobile robotic platform for a commercial client.

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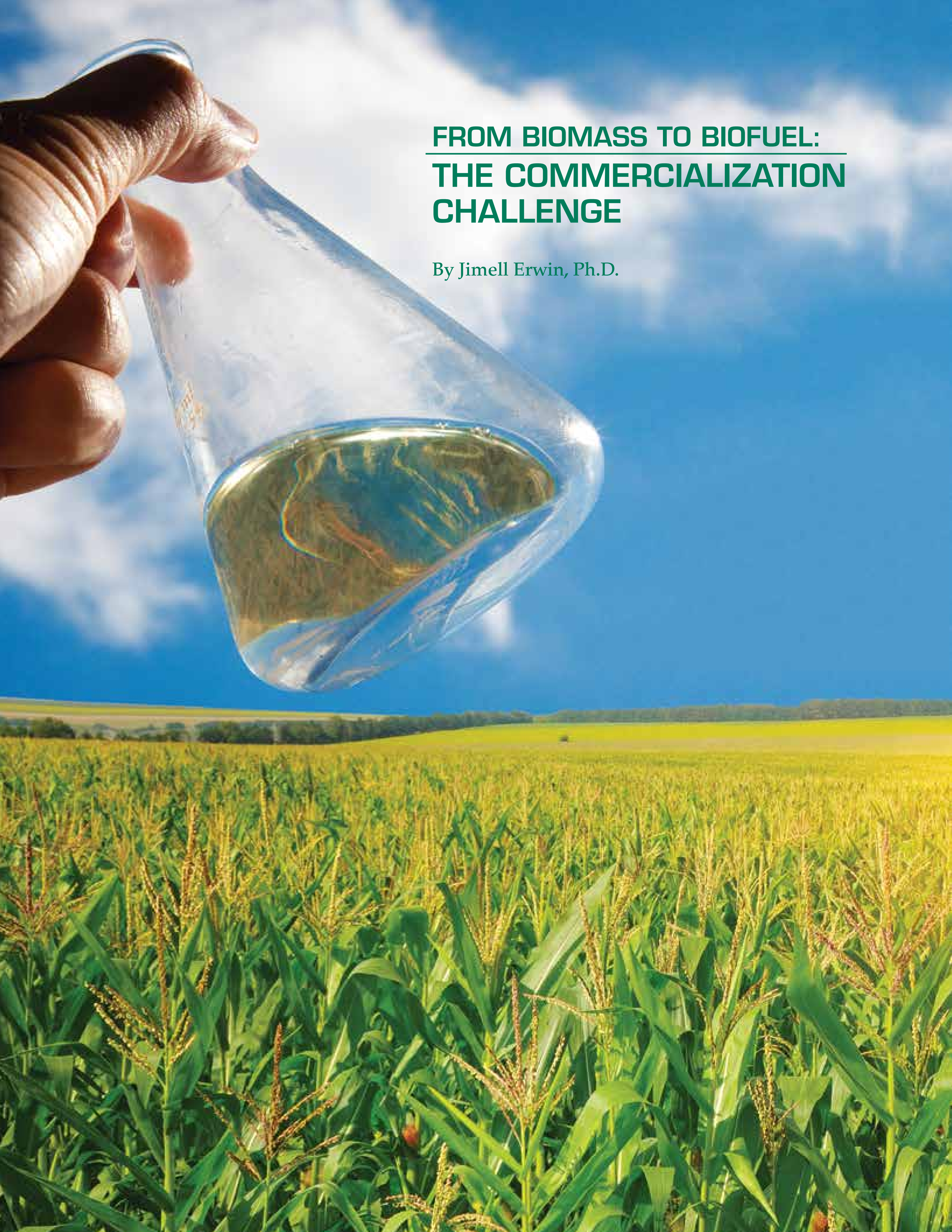


FROM BIOMASS TO BIOFUEL:

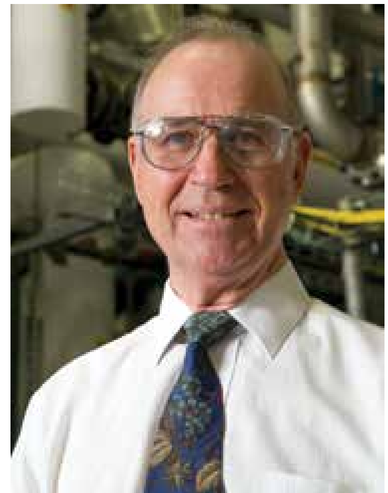
THE COMMERCIALIZATION CHALLENGE

By Jimell Erwin, Ph.D.

The promise of green, renewable fuels beckons many a would-be entrepreneur to develop biomass into cost-effective fuels, using crops grown for that purpose or recycled materials, such as agricultural waste or used cooking oil.

The chemistry to produce biofuels is fairly straightforward, if somewhat involved. It *can* be done, but advancing the refining process from the grease trap or the beaker to a profitable, commercial-level factory can be another story. Often, a processor labors long and hard to produce a crude biofuel, only to discover that there's still much work and expense ahead before the new crude can become a market-ready product that meets fuel specification standards.

Southwest Research Institute's chemical engineers have helped a number of clients meet their objectives and avoid expensive mistakes. With our pilot-scale laboratory equipment and development techniques, SwRI helps clients upgrade and refine crude biobased products more efficiently while meeting the needs of the marketplace.



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ABOUT THE AUTHOR

Dr. Jimell Erwin directs SwRI's Chemical Engineering Department, which specializes in processing and distilling chemical products, particularly fuels. Recent work includes developing ultraclean hydrocarbons, processing biofuels, and developing new refining technologies. He has led the development of olefin alkylation products, a new gas-to-liquids process, and catalytic gas-phase reactions.

WHAT'S A BIOFEEDSTOCK?

A biofeedstock or biomass is a renewable, biological material that can be used as or converted into a fuel or energy product. Biomass currently used to make hydrocarbon fuels includes plant-, animal-, and algae-based materials grown specifically for that purpose, or recycled materials such as cooking grease. These concentrated plant materials, combined with certain alcohols and crop oils, often enjoy some chemical advantages over crude oil. For example, they can contain a higher level of combustible hydrogen and a lower level of undesirable sulfur, while their boiling point is similar to that of most hydrocarbon fuels and intermediate products. All of this makes them desirable for conversion into fuel products such as diesel, jet fuel, and naphtha, an intermediate product similar to gasoline and benzene, often used as a solvent or fuel. The chemical similarity of converted biomass to crude oil has stimulated some oil refiners and catalyst manufacturers to adapt their oil-refinery processes and products to produce biofuels. So far, so good, but making new fuel sources is not the end of the story.

However they are derived, biofeedstocks tend to vary in makeup and uniformity, which complicates their suitability for commercial use. This variability can affect refinery operations and yield uneven product throughput and quality. Experience has shown that there is no one-size-fits-all approach to refining biofeedstocks. Consequently, biofuel processors need to recognize that a combination of processes may be needed to create commercial products, which can increase their production costs. The bottom line: Effective processing can be the difference between profit and loss, or between feasible and no-go.

And that's where SwRI's chemical engineering pilot-scale laboratories come in, where each proposed processing scheme can be examined individually and weighed for efficiency and profitability. Once the data are in and a viable process is chosen, engineering and design work can begin on an operating plant to refine the client's biofeedstock. Using this data in techno-economic analyses can predict the future costs of building and operating a biofeedstock refining plant. Such preliminary work can be a vital intermediate step for a company on the path to building a successful business operation. Three recent cases illustrate how pilot-plant development has taught some lessons and also helped clients achieve their biofuel objectives.

DETAIL

Pilot plants are precommercial production systems that evaluate new raw materials and techniques while producing small amounts of products for assessment. Pilot plants also identify additional research objectives, such as how to accelerate processes or whether any useful or harmful byproducts are produced. The knowledge gained from pilot projects is used to design full-scale production systems and commercial products.

ALGAE OIL

Oils derived from algae grown in water offer some distinct advantages: They are easily renewable. And, because they grow in a "flowable" medium, they can be easily transported, extracted, and processed. Other traits are not so desirable: High oxygen content in the fatty acids of algae oil can reduce engine peak power, and paraffins produced during processing

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According to the U.S. Department of Energy, algae could potentially produce up to 60 times more oil per acre than land-based plants. SwRI is working with clients to develop cost-effective processing techniques for algal fuel.

have a higher freezing point than many fuels do. This can complicate matters, as is the case for jet fuel, which is exposed to frigid temperatures at high altitudes. One client who wished to use algae oil as a feedstock planned to use a commercial catalyst to deoxygenate the oil and lower its freezing point before distilling it to reach the targeted flash-point and end-point temperatures needed for commercial products. Preparing the commercial catalyst was relatively easy, but SwRI's 8-liter reactor pilot plant wasn't efficient at exploring the best processing conditions. For that, we used a 0.1-liter pilot plant that could quickly change the conditions and would require less feedstock per test. We determined the best conditions of pressure, temperature, and flowrate for production while saving the client valuable time.

When the process was switched to the 8-liter pilot plant for larger-scale production, we discovered that a rapid increase in gas pressure revealed a plugged preheat segment of the reactor bed packed with seemingly inert aluminum oxide. The chemical compounds of these "inerts" are made up of aluminum and oxygen and are commonly called alumina. Changing the alumina didn't stop the clog, and we found that alumina itself could react to deoxygenate the fatty acids during preheating. Meanwhile, the presence of unfilterable cellular material from the algae also contributed to obstructions.

Ultimately, we discovered that it was necessary to dilute the feedstock and to tap the reactor frequently to dislodge the alumina at the top of the reactor bed for the processing to be successful. Using these approaches, we were able to produce a trial batch of oil that met specification, providing essential information for the client.

DETAIL

An ethanol processing project had some unintended consequences. To handle the large quantities of nondenatured ethanol needed, SwRI had to conduct a new hazardous operations review and upgrade its federal license to possess and dispense large quantities of ethanol. All this was accomplished quickly to meet the client's schedule.

ETHANOL BIOFUELS

Ethanol from fermented or hydrolyzed cellulose is a versatile and sustainable feedstock. Cellulose, the fibrous component of plants, is mostly inedible to humans and animals, except for cud-chewing animals such as cows and sheep, which have special digestive systems.

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SwRI uses this second-generation pilot plant to scale up and evaluate biofuel processing methods.

Hydrolysis breaks down the fibrous cellulose by adding water and using enzymes to convert complex cellulose into simple sugars such as glucose, which are then fermented and distilled into ethanol or grain alcohol.

Ethanol serves as a component of gasoline and can be converted into jet fuel as well as a source of other commercial products. This alcohol burns easily, which makes it an attractive green feedstock. However, it also tends to absorb moisture and can contribute to corrosion. And like algae oil, it has a relatively high oxygen content.

To create jet fuel, a client was using a proprietary catalyst to build complex organic molecules, or polymers, from simpler ethanol molecules. This technique, called oligomerization, is a fairly short polymerization process. Catalysts are materials used with reactive substances that increase the rate of a chemical reaction without undergoing any permanent chemical change themselves. The particular catalyst for this oligomerization was effective in creating the right chemical reactions, but was ultrasensitive to metals and sulfur, which deactivated or "poisoned" the catalyst. This sensitivity required feedstocks to be pretreated, adding complexity to the overall process. This particular process also required another complicated step to isolate byproduct water produced during synthesis, something seldom required for petroleum hydrocarbons. SwRI used its 8-liter pilot plant, separating its three reactor beds to create different phases for removing metals and the sulfur before performing the oligomerization process. Other modifications allowed online sampling and water removal; all this was done rapidly, saving the client months of time.

Processing the ethanol went well, but sampling and analyzing the selectivity of the catalyst were challenging. Selectivity is the ability of a particular catalyst to favor the intended reactions rather than undesirable side-reactions leading to byproducts. In

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Above: SwRI can accurately determine the product properties of novel liquids, such as viscosity measurements at unusual temperatures or with reactive liquids. Algae slurries can be particularly challenging.

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Left: The composition of materials produced during pilot plant operations can be rapidly assessed using instruments such this carbon-hydrogen analyzer. Chemists can then adjust the process "on the fly" with timely, accurate data.

addition, the oxygenated compounds in different samples reacted with the lines used to draw samples from the pilot plant. Ultimately, we installed new fluorocarbon sample lines that were heated to prevent oxygenate separation so we could efficiently characterize samples and deliver accurate data about the process.

CONTINUOUS BIODIESEL PRODUCTION

Biodiesel is often made by chemically reacting lipids — vegetable oil, soybean oil, and animal fats — with an alcohol to create fatty acid esters that are easily mixed with conventional diesel fuel. These chemical compounds have physical characteristics closer to those of fossil fuels than those of raw vegetable oil.

Chemists typically use batch-processing techniques to produce esters for blending into diesel fuel. The usual process combines methyl alcohol with a strong base, typically sodium hydroxide or lye, to produce the desirable esters. Industry uses whole crop oils and restaurant waste oils as the raw material. The main byproduct is "wet" glycerol, which is produced in a watery layer. The primary ester product floats on top of the wet layer. While this process consumes mostly food crop oils, other crops, particularly plants that grow on arid land, produce oils suitable for making biodiesel. What was missing was a more efficient way to make the esters.

An Institute client improved on the batch technology using a proprietary catalyst that SwRI developed with internal funds, which performs the reaction normally provided by sodium hydroxide. This catalyst not only allows continuous ester production, with high selectivity for methyl esters when converting the crop oils with methanol, but also eliminates the sodium hydroxide liquid waste.

In a serendipitous development, a baseline test using excess methanol yielded no glycerol byproduct at all. Instead, the process produced a variety of oxygenates, including abundant amounts of commodity chemicals of commercial value. In today's marketplace, the widespread batch-production of biodiesel has drastically reduced the commercial value of "wet" glycerol, so this continuous process is not only more efficient but produces more valuable secondary products as well.

PILOTING FOR THE FUTURE

Computer simulations and semi-empirical methods help determine the limitations of pilot-scale systems, such as the three examples cited in this article. Traditionally, pilot plant data provide the basis for the design of commercial plants. Process modeling has matured to the point that small- or even pilot-scale studies are routinely accepted by industry for whole-plant performance and economics, without the intermediate step of further validation. Frequently, business models move toward commercialization without even budgeting for intermediate-scale testing.

Pilot-scale testing not only serves as an insurance policy for commercialization; it also provides an early opportunity to discover the peculiarities of a new technology or how to enhance an existing process to provide added value.

SwRI has extensive facilities and capabilities for designing, fabricating, and operating chemical processes from the test tube to commercial plant scale-up. As these three case studies show, our pilot plants help bridge the gap between a promising laboratory experiment and the development of commercial products and processes, a path that is often challenging for clients to navigate successfully.

Questions about this article? Contact Erwin at (210) 522-2389 or jimell.erwin@swri.org.

DETAIL

Polymers are long chains of monomers, which are much simpler, building-block molecules. A polymer can be made up of thousands of monomer units. The long chains give polymers their unique properties. Consider ethane, CH_3-CH_3, which is a gas molecule at room temperature. Doubling the chain length or the total number of carbons to four creates butane, CH_3-CH_2-CH_2-CH_3, a liquid product, and the common fuel in lighters. Increasing the chain length sixfold can create a longer paraffin, $CH_3(CH_2CH_2)10CH_3$, a waxy substance. Add enough units, and you get the paraffin used in wax candles.

SwRI develops catalyst-based techniques to process biofeedstocks into fuels and other products. This versatile catalyst tester allows chemists to compare yields, temperatures, and pressures of up to four scenarios simultaneously.

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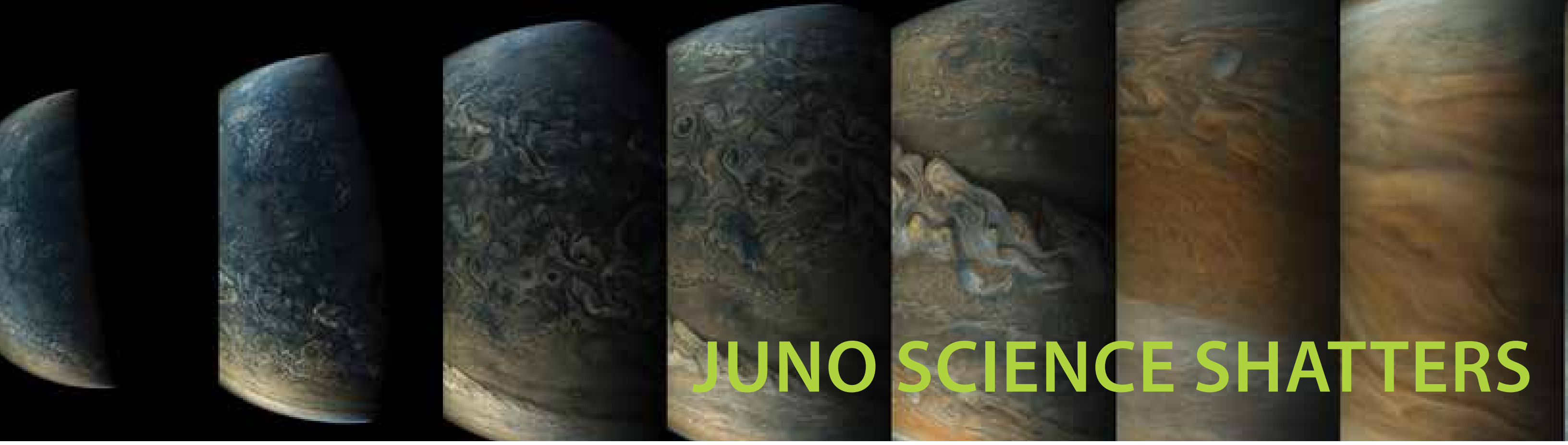

JUNO SCIENCE SHATTERS

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NASA's Juno mission, led by SwRI's Dr. Scott Bolton, is rewriting what scientists thought they knew about Jupiter specifically, and gas giants in general. The Juno spacecraft has been in orbit around Jupiter since July 2016, passing within 3,000 miles of the equatorial cloudtops.

"We knew going in that Jupiter would throw us some curves," said Bolton, Juno principal investigator. "But now that we are here we are finding that Jupiter can throw the heat, as well as knuckleballs and sliders. There is so much going on here that we didn't expect, that we have had to take a step back and begin to rethink of this as a whole new Jupiter."

Juno is in a polar orbit around Jupiter, and the majority of each orbit is spent well away from the gas giant. But once every 53 days, its trajectory approaches Jupiter from above its north pole, where it begins a two-hour transit (from pole to pole) flying north to south with its eight science instruments collecting data and its JunoCam public outreach camera snapping pictures. Downloading the six megabytes of data collected during the transit can take 1.5 days.

The solar-powered spacecraft's payload is designed to study Jupiter's interior structure, atmosphere, and magnetosphere. Two instruments developed and led by SwRI are working in concert to study Jupiter's auroras, the greatest light show in the solar system. The Jovian Auroral Distributions Experiment (JADE) is a set of sensors detecting the electrons and ions associated with Jupiter's auroras. The Ultraviolet Imaging Spectrograph (UVS) examines the auroras in UV light to study Jupiter's upper atmosphere and the particles that collide with it. Scientists expected to find similarities to Earth's auroras, but Jovian auroral processes are proving puzzling.

"Although many of the observations have terrestrial analogs, it appears that different processes are at work creating the auroras," said SwRI's Dr. Phil Valek, JADE instrument lead. "With JADE we've observed plasmas upwelling from the upper atmosphere to help populate Jupiter's magnetosphere. However, the energetic particles associated with Jovian auroras are very different from those that power the most intense auroral emissions at Earth."

Also surprising, Jupiter's signature bands

Waves of clouds at 37.8 degrees latitude dominate this three-dimensional Jovian image from May 19, 2017. Details as small as 4 miles across can be identified in this enhanced color JunoCam image. Small bright high clouds, likely composed of water and/or ammonia ice, are about 16 miles across and in some areas appear to form "squall lines" that could be snowing on Jupiter.

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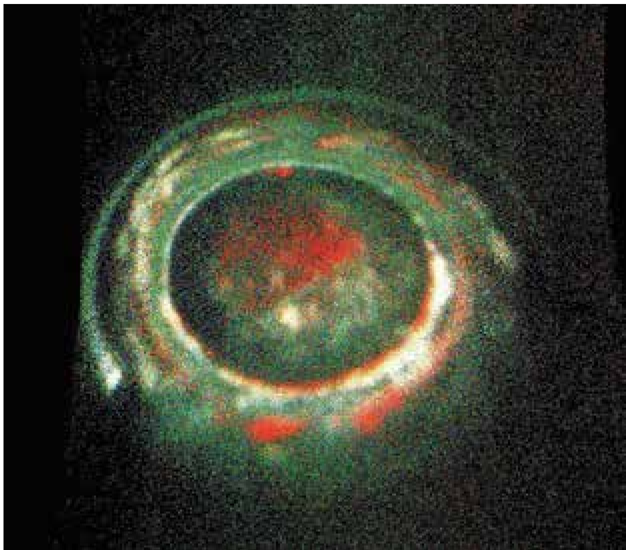
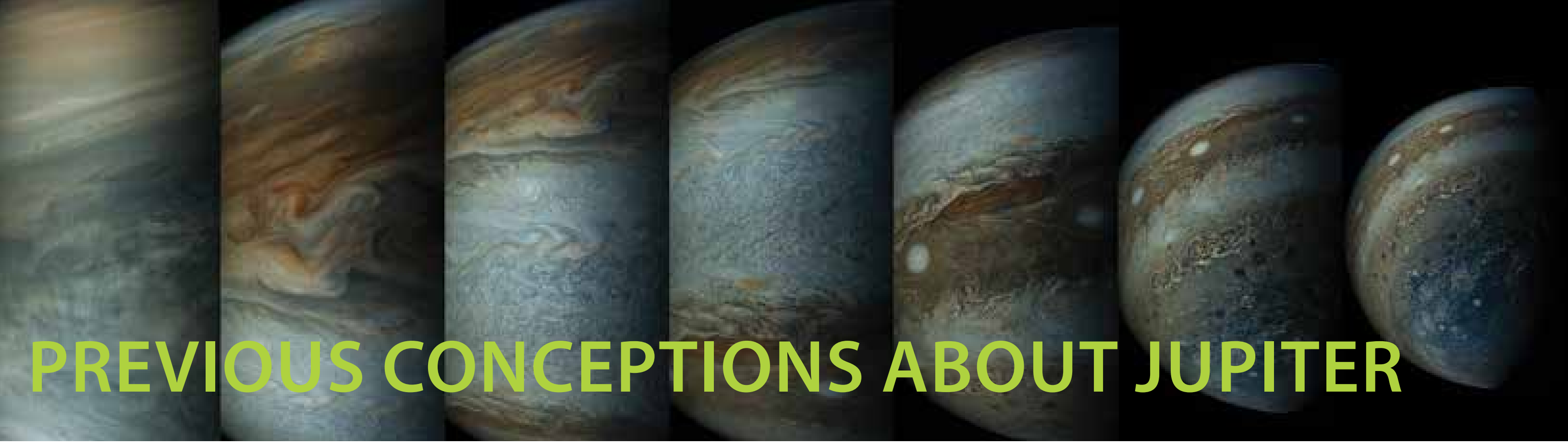


The complexity and richness of Jupiter's "southern lights" or auroras are on display in this false-color image from Juno's Ultraviolet Spectrograph. The red coloring of some of the features indicates that those emissions came from deeper in Jupiter's atmosphere, a surprising source based on Earth's auroras, which are fed by the solar wind. The green and white features indicate emissions from higher up in the atmosphere.



PREVIOUS CONCEPTIONS ABOUT JUPITER

disappear near its poles. JunoCam images show a chaotic scene of enormous swirling storms towering above a bluish backdrop. Since the first observations of these belts and zones many decades ago, scientists have wondered how far beneath the gas giant's swirling façade these features persist. Juno's microwave sounding instrument reveals that topical weather phenomena extend deep below the cloud tops, to pressures of 100 bars, 100 times Earth's air pressure at sea level.

"However, there's a north-south asymmetry. The depths of the bands are distributed unequally," Bolton said. "We've observed a narrow, ammonia-rich plume at the equator. It resembles a deeper, wider version of the air currents that rise from Earth's equator and generate the trade winds."

Juno is mapping Jupiter's gravitational and magnetic fields to better understand the planet's interior structure and measure the mass of a core. Scientists think a dynamo — a rotating, convecting, electrically conducting fluid in a planet's outer core — is the mechanism for generating the planetary magnetic fields.

"Juno's gravity field measurements differ significantly from what we expected, which has implications for the distribution of heavy elements in the interior, including the existence and mass of Jupiter's core," Bolton said.

The magnitude of the observed magnetic field was 7.766 Gauss, significantly stronger than expected. But the real surprise was the dramatic spatial variation in the field, which was significantly higher than expected in some locations, and markedly lower in others.

"We characterized the field to estimate the depth of the dynamo region, suggesting that it may occur in a molecular hydrogen layer above the pressure-induced transition to the metallic state."

One of the central questions Juno was designed to answer was what was at the giant planet's core. Most scientists expected to find either a small, compact core or no core at all. Based on gravity experiment data, scientists have coined the phrase "fuzzy core" to describe what the Juno data may mean.

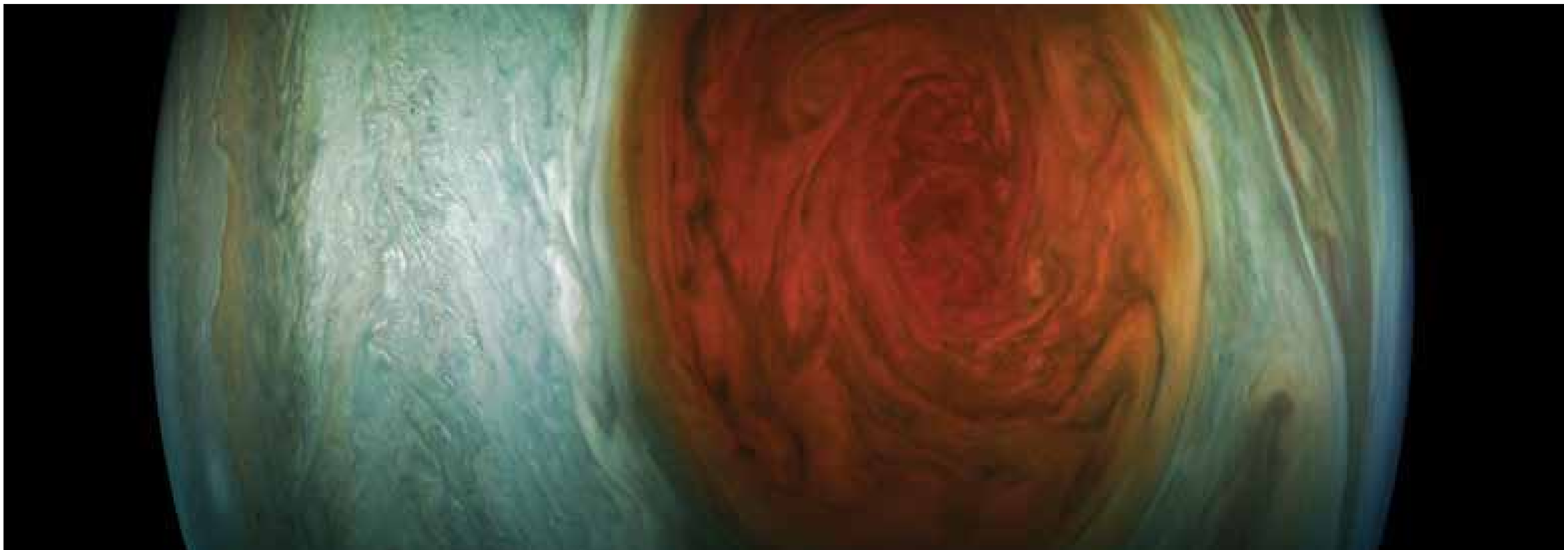
"There may be a little compact core but most think there may be layers there," Bolton said. "There seems to be a fuzzy core that may be much larger than anybody had anticipated. There may be a core there, but it's very big and it may be partially dissolved."

The Juno mission also has a campaign to inspire and motivate the connections between science, art, and music. The JunoCam instrument has been incredibly successful engaging the public with Juno's mission, where amateur astronomers are the driving force behind the incredible images of Jupiter.

Juno is the second mission developed under NASA's New Frontiers Program. The first was the SwRI-led New Horizons mission, which provided the first historic look at the Pluto system in July 2015 and is now on its way to a new target in the Kuiper Belt. NASA's Jet Propulsion Laboratory in Pasadena, Calif., manages the Juno mission for the principal investigator, SwRI's Bolton. Lockheed Martin of Denver built the spacecraft. The Italian Space Agency contributed an infrared spectrometer instrument and a portion of the radio science experiment.

IMAGES COURTESY NASA/JPL-CALTECH/SwRI/MSSS/GERALD EICHSTÄDT /SEÁN DORAN

Citizen scientists created this amazing close-up of Jupiter's Great Red Spot using JunoCam data from Juno's flyby on July 10, 2107.



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AUTOMATING A CONSCIENCE

Q&A about ethics and the automated driving system industry

Technology Today sat down with Dr. Steve Dellenback, vice president of SwRI's Intelligent Systems Division and a leader in the automated vehicle field. We discussed this rapidly evolving industry and the next big barrier: How do we program a car's decision-making system to weigh the ethical implications of its actions?

Technology Today: There's a lot of automated vehicle hype out there. When do you think we will see automated vehicles on streets and highways?

Steve Dellenback: I think we'll have automated driving systems in constrained areas in the next two to five years. These environments could include mining operations, farms, freight yards, or possibly places like retirement communities where there isn't a lot of traffic. I think we're probably 10 to 20 years out for full mixed-mode, with human-driven cars and trucks interacting with vehicles equipped with automated driving systems. If there were managed "technology lanes" set out on highways where only vehicles with certain technologies could drive — similar to toll lanes — I think we could deploy it a lot sooner.

TT: What keeps automated vehicles, or AVs, from being adopted more quickly?

SD: One reason is cost; the enabling technologies are not cheap. The average price of a vehicle in the U.S. is now about $34,000, but you're looking at tens of thousands of dollars more for the hardware that enables automated driving operations. Another reason is perception. People sometimes don't understand how capable the human eyeball and brain are. You look out at the road and you can easily identify hundreds of objects. The crossing over of information between your eye and your brain is truly astounding. Trying to recreate the same fidelity as the human eye for automation — frankly, we're still not there. Now there's a third aspect on the horizon: cyber security. Since its invention, the car has been a stand-alone device, unconnected to the outside world. The addition of communications integrated into the vehicle introduces another whole set of issues, including how do you prevent people from hacking into cars? But perhaps the most serious hurdle is the societal issue, psychological acceptance. Will people trust a vehicle equipped with an automated driving system with their life?

TT: How do you balance cost-effectiveness and performance?

SD: Perception-based behaviors are challenging. There's a big tradeoff in the capability of sensors. You could buy a very expensive camera and have fantastic resolution at a long distance. But the typical commercial car can't absorb adding thousand-dollar sensors, so manufacturers are looking at cameras in the $30 to $100 range. To make good driving decisions, you need to see about 80 meters in front of the car. But if you look at a traffic light at that range through a very low-end camera, you may only have two to four pixels of camera resolution from that light. How does the computer know it's a traffic light and not just a light alongside the road? That's the real issue: How do you get enough resolution to discriminate? That's where the human eye has amazing resolution and where the human brain has the ability to understand context.

Cameras are just one kind of sensor. You've heard about LIDAR; that's the spinning-light laser. LIDAR is very good for detecting large objects — a car, a house, or a tree. It identifies the edges of that object. But if you have LIDAR and you're in tall grass, it's going to think the grass is a solid object. While 65 percent of the roadways in this country are paved, that means 35 percent are not.

That's why you have to start fusing technologies, such as adding radar. Higher-end cars have been adding advanced driver assistance systems, or ADAS, for a number of years. Adaptive cruise control uses sensors to measure the distance to the car in front. Some cars have little infrared sensors along the bumper. They're good from two to eight feet, and that's how you sense distance when you are auto-parking or when you're pulling into your garage and it beeps when you are too close to the pillars next to the door. The trick is to fuse these different sensor technologies at as low level as possible.

And then there's weather. It's one thing when there are blue skies, but let's consider how rain affects sensor performance. Then turn the rain into snow. And then let's turn the lights out and be in total darkness. With a $100 camera in the dark with no streetlights, you can't see anything. Sure, there are night-vision cameras, but those run in the thousands to tens of thousands of dollars. This whole sensor fusion concept is necessary and complex if you truly want automated vehicles to work in all operating modes, especially when you consider the need for sensor redundancy.

TT: But even with the right technology package onboard, that won't necessarily solve all the problems.

SD: Right. Consider the "Trolley Problem." This classic, 100-year-old ethics problem, where a trolley is coming down a hill out of control, and you're standing next to a switch. You can choose for it to go left or right. On the left-hand track there are four people, and on the right-hand track there's one person. The ethical question is,

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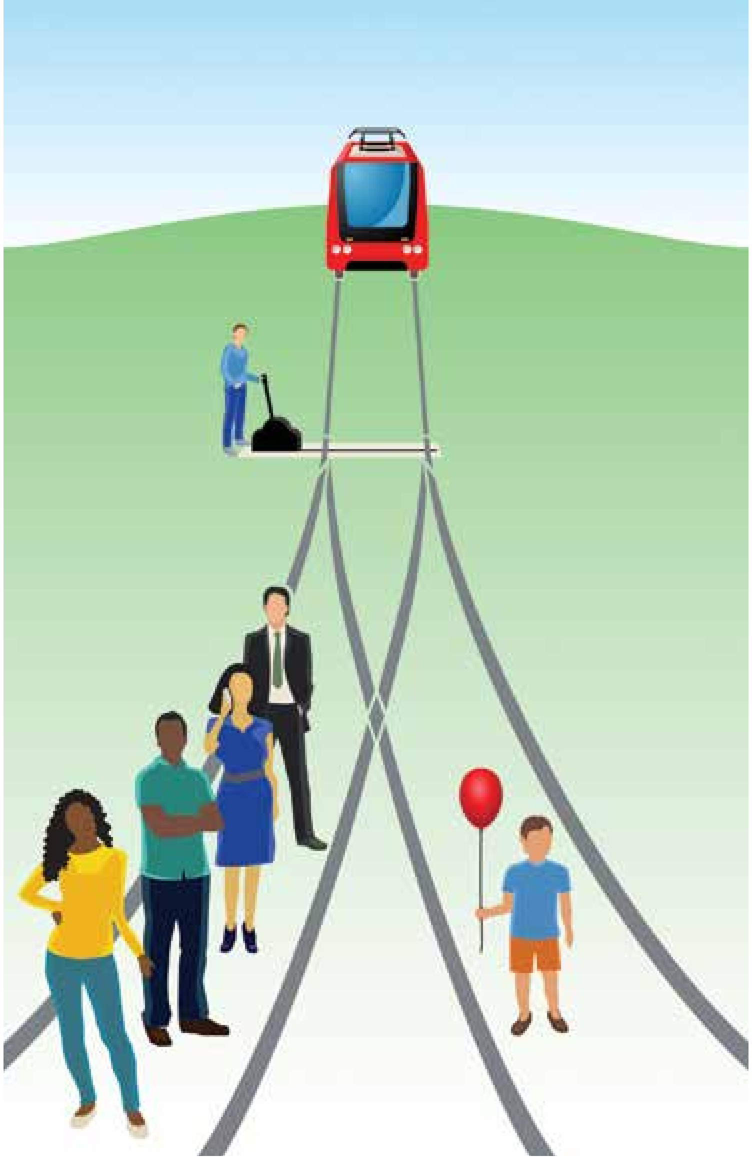
Dr. Dellenback has over 32 years of research and development experience in a variety of areas ranging from microprocessor assembly language, to large integrated factory floor automation, statewide integrated transportation systems, and automated vehicles. He discussed SwRI's program in automated driving and how complicated the development process remains.



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The Trolley Problem: An out-of-control trolley is racing downhill. Would you send it left or right?

which way do you throw the switch? Most people quickly say they'd choose the right track, with just one person. But I forgot to tell you — that one person is your child or an important political figure, which further complicates the value question.

TT: How do you build ethics into an autonomous system?

SD: In my mind, ethics entails creating a "value proposition." At some point, you have to start putting values on things — minor crashes, major crashes, what kinds of objects you can hit. You have to figure out what the system can do, and see us do, in our everyday driving that we didn't really know we were doing. For instance, when you see an object in the road you make a decision: You might put two wheels off on the side of the road and go around it. The real question is whether to build that response into the program. That's somewhat new ground in this industry, and I don't think many people are really working on building in ethics. Ethics are relative to personal values, and personal values vary by geographic region, upbringing, a myriad of things. Do you want the vehicle to adapt to the consumer's values, or do you impose the same values/ethics on all robots? We are still trying to figure out how to get them to fundamentally drive, to fundamentally prove themselves to be a safe and reliable product. That's why I think we are still not just three years out, because of the ethical implications.

TT: Can an automated car be given a conscience?

SD: We all make value decisions related to driving. But driving styles and driving conditions vary. As humans, we sense that in certain conditions we should slow down, and that plays into how we make decisions. If you're driving through a neighborhood and you know there's a bunch of kids there, most people will drive a little slower. How do you build something like that into a vehicle? Human drivers are making decisions based on our environment and our values and our understanding of the consequences of pain. Robots don't yet feel, or react to the concept of pain. And even if they did, what would their pain threshold be? Some people simply won't slow down. They'll say, "I'm going to drive full speed through this neighborhood because it's my right to drive 30 miles an hour." Someone else who is a parent or a grandparent might say, "I'm going to drive 20 miles an hour because that's the safer thing to do." At a different time of day, say 11 p.m., maybe it's fine to go 30. But where does that point break? And then you throw in things like holidays. Let's say it's Halloween. That requires a change of driving style, because typically, children are smart enough not to run out in front of cars. But on Halloween, all bets are off. So there's that whole aspect of changing styles based on environments.

TT: So the automated driving system must not only learn the rules of the road but also quantify the risks of complex scenarios and make financial and/or life-or-death decisions?

SD: AVs are going to have to decide if and when they should brake or swerve off the road. Let's say there's a moose in the road: You and I both know logically that if you hit a moose, you're in a lot of trouble. The question is, should you veer off the road to miss it? If you veer one way you may enter the path of an oncoming car; if you veer the other way, you could end up in a ditch. Your software, your systems have to be smart enough to compare the risk of hitting a moose or swerving. If you're on the Bonneville Salt Flats, it's easy to veer off. But if you're about to hit a moose, you could be in the Grand Tetons on a mountain road. If you veer off the side, you could plunge 1,000 feet.

Consider another scenario: You are in the middle of a crowded highway or on an icy road and a dog wanders onto the road. Braking or evasive maneuvers would be dangerous, and many of us know that in some situations you probably should stay the course. But what if it isn't a dog? What if it's a child crawling? Should we trust our computers to distinguish that? It looks like it has four legs; it could look like a dog to the computer, but with the human eye that's a nonissue. So how are we going to get a computer to do that? Frankly, that's beyond my programming skills.

TT: How do you get computers to learn how to drive when there are so many variables involved?

SD: We are using an advanced machine learning technique known as deep learning. You essentially teach patterns to the computer, and the computer eventually starts extrapolating those patterns. A simple example is, you teach a computer what a human walking toward you looks like, and then you teach the computer what a car looks like. So then, what if there is a person walking behind a car, where you only see part of the body? With deep learning, you don't have to program into the computer what a body looks like when it's behind a car. You've already taught it what a car and a body both look like, so the computer will infer that the human is behind a car. Computing power has finally gotten to the point that it can support real-time deep learning implementations. In past years, deep learning was very much an offline, post-processing activity. With the dynamic driving task, response times have to be in the milliseconds. When a car is driving 70 miles an hour, you can't think about it for a half-second; you have to act very quickly. So that's why deep learning is now coming into its own in this field. Actually, the Institute is applying deep learning to many different aspects of its research, in a number of divisions and a number of technology areas. Keep in mind, machine learning is not the end solution to every problem. It is just one tool that is popular right now. As technology continues to evolve, we believe deep learning will be part of a solution but not necessarily the end solution.

TT: How will deep learning affect the next phase of automated driving implementations?

SD: Deep learning is basically thinking. You're trying to get the computer to draw conclusions. That's scary, because if you talk to an auto company or a Tier 1 supplier, they tell you that they normally want about 300 million miles worth of data on a vehicle or a new system to declare it safe and ready for production. When we build these deep-learning systems in the laboratory development environment, we train them using a significant database of images so the computer can "learn" what components it is looking for in a scene. When these systems operate on a vehicle, they are analyzing sensor data to look for patterns they were previously taught to recognize. So, you put them in a car and they start learning, conceivably becoming better and better drivers. However, the question is, who is doing the teaching? Is the vehicle learning how

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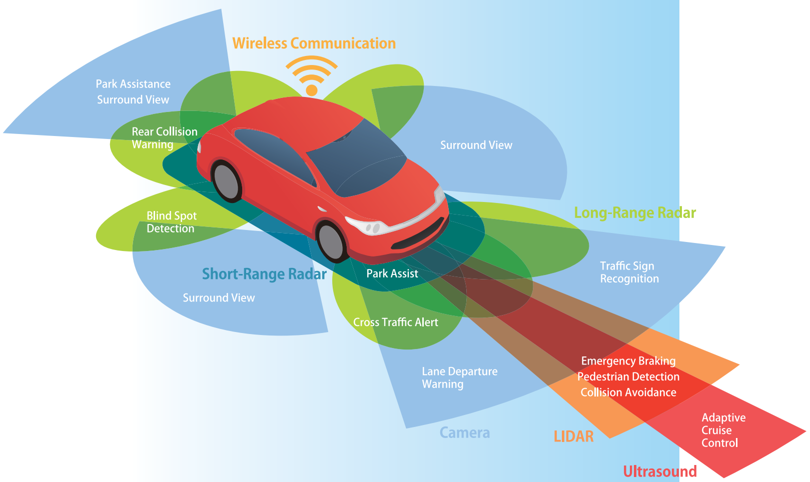
In 2016, SwRI's automated vehicle program celebrated its 10-year anniversary. Pictured are five of the 30 vehicles in our unmanned systems research fleet. We develop low-cost, high-performance perception, localization, path planning, and control technologies for intelligent vehicles ranging from golf carts to SUVs to Class 8 tractor trailers.

you drive, which is probably fairly safe? Or how your teenage son drives? So how do you make sure that your system is learning right? We are trying to come up with a technique for validating these deep-learning networks. How do we know that it is doing the right thing, repeatedly?

By **2050**, the penetration of automated vehicles could **reduce traffic fatalities** in the U.S. by as much as **90%**, saving almost **300,000 lives** every decade and **$190 billion** a year in medical costs associated with accidents.*



* according to a 2015 report by McKinsey & Company, a U.S. consulting firm

TT: What do you think is the most important automated driving system goal?

SD: We talk about a crash-free society as the ultimate goal. If you look at traffic deaths, last year they rose by approximately 5,000 people. For the first time in many years, 40,000 Americans perished in auto accidents, and 93 percent of the unimpaired crashes were categorized as human error. But can you get to a crashless society? I think the idea that automated cars will never crash is unrealistic. Recent events in the news suggest that's a very difficult thing to do. As an engineer, I think it's a myth to say they will never crash. But I think we can get very close to crash-free using driverless technology. But we still have many hurdles.

TT: Where are we today in implementing automated driving systems?

SD: Lots of cars currently have some automated functions right now, but they are not fully automated. With automated driving systems, how long does it take to get your attention back on the wheel? How long does it take for your mind to get the situational awareness to know what's going on? Now take it a step further: The car sees a moose in the road and says, "I need your help." Chances are, by the time you put your hands on the wheel and look up, the moose is going to be in your windshield and the situation is going to be in the past. Researchers are looking at how much time it takes to transition back and forth between highly automated or partially automated driving, and fully manual driving. We've discovered that it takes a surprising number of seconds for a driver to become engaged after not being focused on the task.

TT: What's the next new development at SwRI in automated driving research?

SD: We've developed more than 15 unique automated vehicles platforms so far. The thing that distinguishes us from the competition is our ability to work in an unstructured environment. Others involved in automated vehicle research have heavily funded their research programs and they do an excellent job of driving down the freeways and down well-marked interior roads. But if only 65 percent of the roadways in this country are paved, how are you going to get a delivery down that last mile on an unpaved road? From a technical perspective, that's a very different problem. Since 2008 we've been working in the military environment. There, we don't drive on paved roads. We've also been successful working for the agricultural equipment and related industries. They've got some of the same problems as the military. For example, vineyards aren't well-defined with pavement between the rows. We don't have the programs that look for striping on roadways because we're driving on unstructured environments that have high grass, dirt, and mud. I see us continuing to move some of the capability we developed for the military into the structured environment.

TT: So, what's next?

SD: Within the industry, across all the companies that are working in the automated vehicle area, we need to integrate ethical algorithms into our programs. The reality of automated vehicles is that it's not just the technology of how do I turn the steering wheel, how do I accelerate, how do I brake. And I think we've got to find a way to introduce it to industry and to the public. Frankly, the other thing that's needed is some legislation and standardization. How will an automated vehicle work in large-scale applications? What are people's expectations? Like all technologies, these systems are not fail-safe; problems are going to occur. What's going to happen? Can a company live past that first incident?

RAISE THE BAR ON SOLAR SPECTROGRAPHS

The Rapid Acquisition Imaging Spectrograph Experiment (RAISE), designed and built by SwRI, collected 1,500 images of the Sun during its 5-minute flight May 5. RAISE, the prototype for NASA's next generation of space-based solar spectrographs, took its third suborbital space flight onboard a sounding rocket.

"Using sounding rockets to get out of Earth's atmosphere provides us with fantastic data at a relatively low cost," said SwRI's Dr. Don Hassler, RAISE principal investigator. Flight objectives include studying small-scale dynamics of coronal loops, high-frequency waves in the solar atmosphere, and transient brightenings in the solar network. "This flight provided some of the highest cadence spectral observations of the Sun at these wavelengths ever taken."

After launch from White Sands, N.M., the RAISE instrument aimed its ultraviolet imaging spectrograph at an active region of the Sun to better understand the dynamics that cause solar eruptions.

Observations were coordinated with three orbiting satellites — the Solar Dynamics Observatory (SDO), the Hinode Solar Observatory, and the Interface Region Imaging Spectrograph (IRIS) — to gather multiple perspectives of the same solar activity. Despite brief flight times, sounding rocket missions play a vital role in NASA's mission to advance new technologies and instrumentation and qualify them for space in a low-cost, rapid turnaround environment.

IMAGE COURTESY: AMIR CASPI, SwRI/JOY NG, NASA'S GODDARD SPACE FLIGHT CENTER

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MAPPING GEOLOGY IN SHALE FORMATIONS

SwRI has launched the Permian Basin Joint Industry Project (JIP). Kickoff meetings in May included field trips to study geology in the eastern, southern, and western parts of the basin.

In the first phase, SwRI will expand its initial investigations of deformation and mechanical stratigraphy in exposed strata in and around the Permian Basin. Over the next two years, the consortium will combine new geological outcrop data with subsurface investigations, allowing members to make better informed decisions for oil production.

"With burgeoning activity focused on unconventional reservoirs, our investigations will provide data to help producers plan for the many complications in shale oil plays," said SwRI Institute Scientist Dr. David Ferrill.

Natural fractures in reservoirs can improve extraction by providing permeability to and connectivity within the reservoir. However, fractures can also have detrimental effects as "thief zones" that may have leaked hydrocarbons from the reservoir. Permeable pathways to aquifers can also lead to excess water production or can siphon off drilling mud.

By studying outcrops and the tectonic events that formed and shaped the region, the Permian Basin JIP will help operators determine the likelihood and type of deformation expected in a given reservoir, which can allow operators to optimize well drilling plans.

At the kickoff meeting, JIP members discussed data contributions and project tasks to support geomechanical modeling and improve understanding of the geological variation across the Permian Basin. A suite of tasks was discussed and agreed upon that spans outcrop and core investigations, geomechanical analyses, and regional mapping of geologic structures to understand how rock layering can affect tectonic events.

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SwRI's Permian Basin Joint Industry Project kickoff meeting included field trips to geologic exposures in the region. This roadside exposure of a fault zone includes horsts and grabens, which are upthrown and downthrown blocks between faults that have slipped, offsetting and extending the rock layers.

SWRI SCIENTISTS DISCOVER HYDROGEN IN ENCELADUS' PLUME — AND POSSIBLE SOURCES FOR IT

This microbial food supply could potentially support an underwater ecosystem in icy worlds

Enceladus' sea floor likely has hydrothermal vents like ours

Scientists from SwRI have discovered hydrogen gas in the plume of material erupting from Saturn's moon Enceladus. Analysis of data from NASA's Cassini spacecraft indicates that the hydrogen is best explained by chemical reactions between the moon's rocky core and warm water from its subsurface ocean. The SwRI-led team's discovery suggests that Enceladus' ocean floor could include features analogous to hydrothermal vents on Earth, which are known to support life on the seafloor.

"Hydrogen is a source of chemical energy for microbes that live in the Earth's oceans near hydrothermal vents," said SwRI's Dr. Hunter Waite, principal investigator of Cassini's Ion Neutral Mass Spectrometer (INMS). "Our results indicate the same chemical energy source is present in the ocean of Enceladus. We have not found evidence of the presence of microbial life in the ocean of Enceladus, but the discovery of hydrogen gas and the evidence for ongoing hydrothermal activity offer a tantalizing suggestion that habitable conditions could exist beneath the moon's icy crust."

On the Earth's ocean floor, hydrothermal vents emit hot, mineral-laden fluid, allowing unique ecosystems teeming with unusual creatures to thrive. Microbes that convert mineral-laden fluid into metabolic energy make these ecosystems possible.

"The amount of molecular hydrogen we detected is high enough to support microbes similar to those that live near hydrothermal vents on Earth," said SwRI's Dr. Christopher Glein, a coauthor on the paper and a pioneer of extraterrestrial chemical oceanography. "If similar organisms are present in Enceladus, they could 'burn' the hydrogen to obtain energy for chemosynthesis, which could conceivably serve as a foundation for a larger ecosystem."

During Cassini's close flyby of Enceladus on Oct. 28, 2015, INMS detected molecular hydrogen as the spacecraft flew through the plume of gas and ice grains spewing from cracks on the surface. Previous flybys provided evidence for a global subsurface ocean residing above a rocky core. Molecular hydrogen in the plumes could serve as a marker for hydrothermal processes, which could provide the chemical energy necessary to support life. To search for hydrogen specifically native to Enceladus, the spacecraft flew particularly close to the surface and operated INMS in a specific mode to minimize and quantify any spurious sources.

"We developed new operations methods for INMS for Cassini's final flight through Enceladus' plume," said SwRI's Rebecca Perryman, the INMS operations technical lead. "We conducted extensive simulations, data analyses, and laboratory tests to identify background sources of hydrogen, allowing us to quantify just how much molecular hydrogen was truly originating from Enceladus itself."

"Everything indicates that the hydrogen originates with hydrothermal activity at the boundary between the inner ocean and the moon's rocky core," Waite said.

Waite is the lead author of "Cassini Finds Molecular Hydrogen in the Enceladus Plume: Evidence for Hydrothermal Processes," published in the April 14, 2017, issue of the journal Science.

INMS, built by NASA's Goddard Space Flight Center, is operated by an international team of scientists headed by Waite. The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency and the Italian Space Agency. NASA's Jet Propulsion Laboratory, Pasadena, California, a division of Caltech, manages the mission for NASA's Science Mission Directorate in Washington, D.C. The Cassini orbiter was designed, developed, and assembled at JPL.

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This illustration shows NASA's Cassini spacecraft diving through the plumes of Saturn's moon Enceladus.

Joint SwRI-UTSA study shows how radioactive decay could create hydrogen

In the icy bodies around our solar system, radiation emitted from rocky cores could break up water molecules and support hydrogen-eating microbes.

To address this cosmic possibility, a joint University of Texas at San Antonio (UTSA) and SwRI team modeled a natural water-cracking process called radiolysis. They then applied the model to several worlds with known or suspected interior oceans, starting with Saturn's moon Enceladus. While radiolysis does not produce adequate hydrogen for conditions at that moon, the team then applied the model to Jupiter's moon Europa, Pluto and its moon Charon, and the dwarf planet Ceres.

"We found that the physical and chemical processes that follow radiolysis release molecular hydrogen," said Alexis Bouquet, a student in the joint doctoral program between UTSA's Department of Physics and Astronomy and SwRI's Space Science and Engineering Division. Radioactive isotopes of elements such as uranium, potassium, and thorium are found in a class of rocky meteorites known as chondrites. The rocky cores of the worlds studied by Bouquet and his coauthors are thought to have similar compositions.

Subsurface oceans permeating these cores could be exposed to ionizing radiation, undergo radiolysis, and produce molecular hydrogen and reactive oxygen compounds.

Bouquet explained that microbial communities sustained by molecular hydrogen have been found in extreme environments on Earth, including a groundwater sample found nearly 2 miles deep in a South African gold mine as well as hydrothermal vents on the ocean floor. That raises interesting possibilities for the potential existence of analogous microbes at the water-rock interfaces of ocean worlds such as Enceladus or Europa.

The most frequently considered source of molecular hydrogen on ocean worlds is serpentinization, a chemical reaction between rock and water that occurs around hydrothermal vents. While hydrothermal activity can produce considerable quantities of hydrogen, in porous rocks typically found under seafloors radiolysis could also produce copious amounts. And unlike serpentinization, radiolysis could also produce a sulfate food source for microorganisms.

"Radiolysis in an ocean world's outer core could be fundamental in supporting life. Because mixtures of water and rock are everywhere in the outer solar system, this insight increases the odds of abundant habitable real estate out there," Bouquet said.

Bouquet is lead author of the study published in the May edition of Astrophysical Journal Letters. Coauthors of the article, "Alternative Energy: Production of H_2 by Radiolysis of Water in the Rocky Cores of Icy Bodies," are SwRI's Glein, Dr. Danielle Wyrick, and Waite, who also serves as a UTSA adjoint professor.

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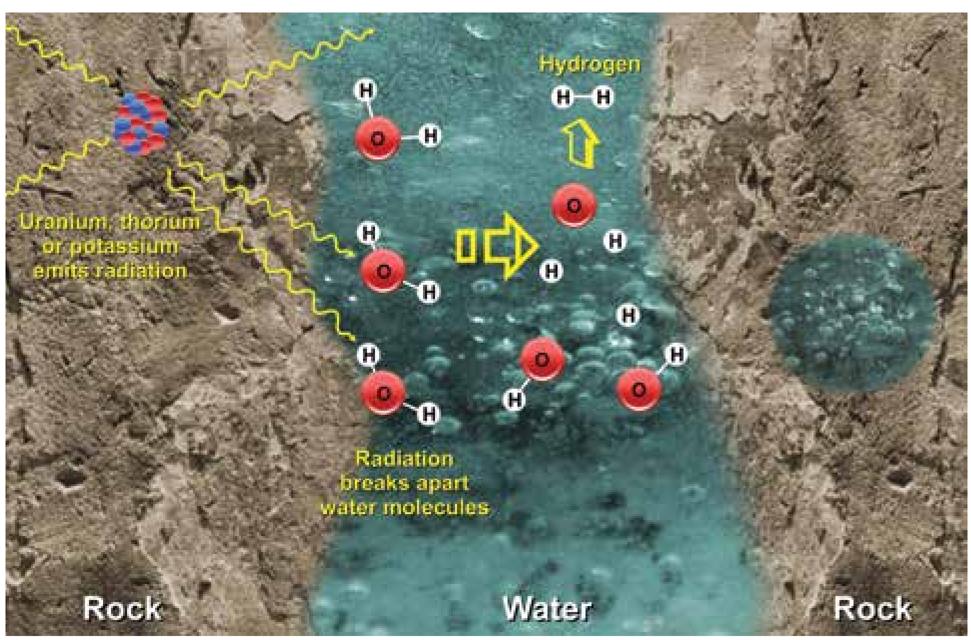

The UTSA-SwRI team modeled a natural water-cracking process called radiolysis. They applied the model to the icy bodies around our solar system to show how radiation emitted from rocky cores could break up water molecules and support hydrogen-eating microbes.

IMAGE COURTESY NASA/JPL-CALTECH /SETI INSTITUTE

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DRONE RECONNAISSANCE

SwRI has secured a patent for technology that allows unmanned aerial systems to cooperate with unmanned ground vehicles, providing more information about the surrounding environment and enabling safer maneuvers.

"We developed this capability to support defense clients seeking solutions to the challenges of unmanned ground vehicles navigating in extreme environments," said SwRI's Ryan Lamm. The system also is helping SwRI develop future commercial solutions for remote inspection systems.

U.S. Patent No. 9,625,904 for "Unmanned ground/aerial vehicle system having autonomous ground vehicle that remotely controls one or more aerial vehicles" covers on-board, in-sky perception sensors that can detect a path to be followed by the ground vehicle.

MOBILE DESTRUCTION UNIT

SwRI recently completed initial testing of a prototype system to destroy chemical warfare agents on location, using available resources.

"It is in our national interest to have a field-operable unit to safely dispose of chemical warfare agents and other dangerous chemicals on the front lines, in a timely manner," said SwRI's Darrel Johnston.

Because current chemical destruction methods produce hazardous byproducts, the Defense Advanced Research Projects Agency (DARPA) issued a call for innovative systems that can neutralize chemicals or dangerous materials without creating hazardous waste. SwRI responded with a dry pollution control process, ideal for arid or remote regions, using its Dedicated EGR® engine to burn the agents as fuel. Once the chemicals are destroyed, exhaust gases pass through a soil-based scrubber bed to remove acid gases. The goal is for the soil to be completely nonhazardous at the end of the process.

"In 2016, we developed a proof-of-concept system using the soil scrubber backend, without the engine," Johnston said. "We evaluated the prototype solid scrubber system with simulants, using a plasma torch in place of the engine. The testing was successful, and gave us good scrubber data that we can couple to the D-EGR engine module."

The modular unit under development is designed to fit into a large shipping container for easy transport. The resulting modular mobile unit can be transported easily and deployed in a field setting close to where hazardous chemicals may be stored.

Project ESPRESSO

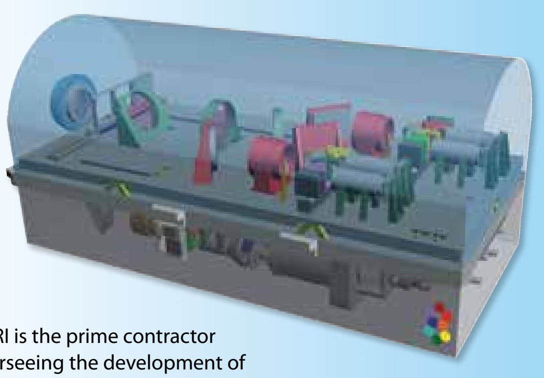
NASA recently selected Project ESPRESSO, the Exploration Science Pathfinder Research for Enhancing Solar System Observations initiative, as part of its Solar System Exploration Research Virtual Institute (SSERVI). Led by SwRI, ESPRESSO is a consortium of seven research institutions, two industry partners, and international institutions dedicated to advancing future human exploration of the solar system.

ESPRESSO will pursue pathfinding research, techniques, and technologies that will enable safe, effective exploration by a future generation of astronauts. The project is particularly focused on operational safety on and near the surfaces of airless bodies, such as asteroids and moons. ESPRESSO will develop target selection, characterization, and analysis capabilities as well as techniques to evaluate the in-situ resource utilization potential of potential targets.

"Scientific endeavors have always benefited from the courage of those who risk their safety to provide a glimpse of the unknown," said ESPRESSO Principal Investigator Dr. Alex Parker. "It is our responsibility in the scientific community to do everything in our power to support future explorers through dedicated efforts to ensure that any endeavor we ask of them can be conducted as safely as possible."

ESPRESSO's progress can be followed at the project's website, espresso.institute. SwRI's partner institutions are Johns Hopkins University, SETI Institute, Lowell Observatory, University of Maryland, NASA Johnson Space Center, and the Planetary Science Institute. ESPRESSO's industry partners are Planetary Resources and Integrated Spaceflight Services, and the collaborative institutions are the University of Colorado, Stony Brook University, Mount Holyoke College, University of Central Florida, JHU Applied Physics Laboratory, the University of Strathclyde (Scotland), and the University of British Columbia (Canada).

SSERVI is a virtual institute headquartered at NASA's Ames Research Center in Mountain View, Calif. Its members are distributed among universities and research institutes across the United States and around the world.



SwRI is the prime contractor overseeing the development of OCTOCAM, an astronomical workhorse housing eight detectors within the refrigerator-sized instrument.

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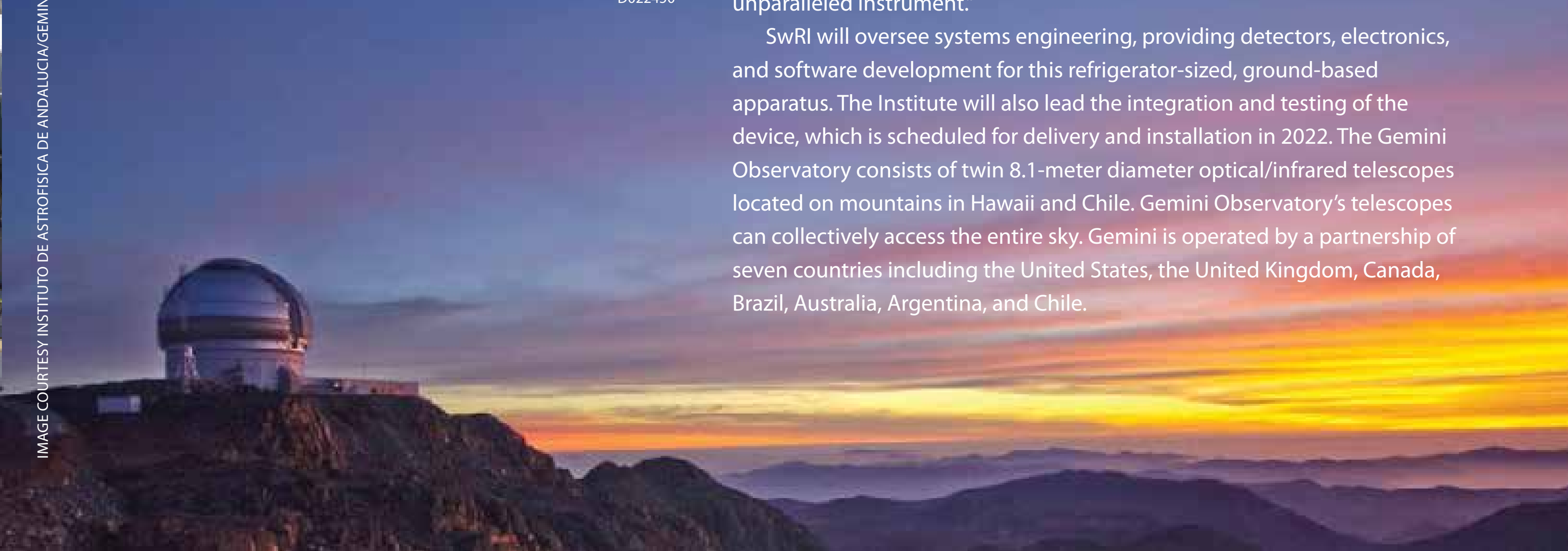


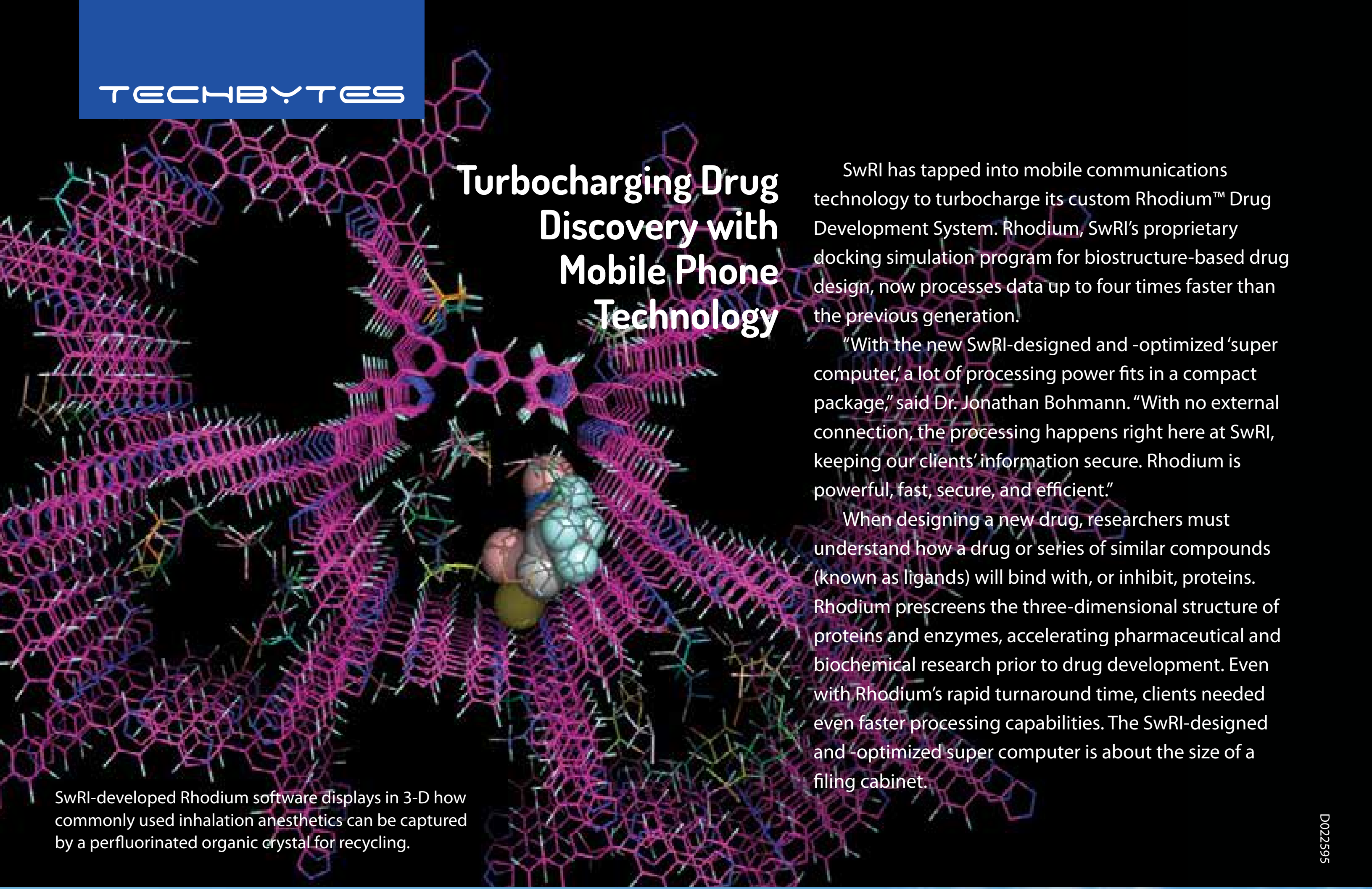
IMAGE COURTESY INSTITUTO DE ASTROFISICA DE ANDALUCIA/GEMINI OBSERVATORY D022596

SwRI managing OCTOCAM development

The Gemini Observatory has named SwRI as prime contractor to develop OCTOCAM, a next-generation astronomical instrument to complement the 8-meter Gemini South telescope in Chile. OCTOCAM is a unique, fast multichannel imager and spectrograph, providing rapid exposures of high-resolution images and color spectra from ultraviolet to infrared wavelengths.

"Using eight state-of-the-art detectors, OCTOCAM will simultaneously observe visible and invisible light spectra almost instantaneously, in tens of milliseconds," said SwRI's Dr. Peter Roming, project manager and co-principal investigator. "The imaging, spectral analysis, and temporal resolution combined with exceptional sensitivity make OCTOCAM a unique, unparalleled instrument."

SwRI will oversee systems engineering, providing detectors, electronics, and software development for this refrigerator-sized, ground-based apparatus. The Institute will also lead the integration and testing of the device, which is scheduled for delivery and installation in 2022. The Gemini Observatory consists of twin 8.1-meter diameter optical/infrared telescopes located on mountains in Hawaii and Chile. Gemini Observatory's telescopes can collectively access the entire sky. Gemini is operated by a partnership of seven countries including the United States, the United Kingdom, Canada, Brazil, Australia, Argentina, and Chile.



Turbocharging Drug Discovery with Mobile Phone Technology

SwRI has tapped into mobile communications technology to turbocharge its custom Rhodium™ Drug Development System. Rhodium, SwRI's proprietary docking simulation program for biostructure-based drug design, now processes data up to four times faster than the previous generation.

"With the new SwRI-designed and -optimized 'super computer,' a lot of processing power fits in a compact package," said Dr. Jonathan Bohmann. "With no external connection, the processing happens right here at SwRI, keeping our clients' information secure. Rhodium is powerful, fast, secure, and efficient."

When designing a new drug, researchers must understand how a drug or series of similar compounds (known as ligands) will bind with, or inhibit, proteins. Rhodium prescreens the three-dimensional structure of proteins and enzymes, accelerating pharmaceutical and biochemical research prior to drug development. Even with Rhodium's rapid turnaround time, clients needed even faster processing capabilities. The SwRI-designed and -optimized super computer is about the size of a filing cabinet.

SwRI-developed Rhodium software displays in 3-D how commonly used inhalation anesthetics can be captured by a perfluorinated organic crystal for recycling.

D022595

PUSHING THE LIMIT

A new facility will enhance SwRI's capabilities in testing and evaluating subsea equipment and systems.

The new 5,000-square-foot Extreme High-Pressure High-Temperature facility houses a series of 13-inch diameter pressure chambers, accommodating up to 30,000 psig and temperatures up to 650 degrees F. The chambers can be configured for casing-pipe collapse testing to industry standards or for exposing other equipment to extreme conditions. Configurable test pits can be isolated and/or flooded as needed for special project requirements.

"This facility complements a wide variety of facilities and equipment dedicated to testing and evaluating a range of offshore and subsea components," said SwRI's Joseph Crouch.

Other features include 15-ton and 30-ton bridge cranes, two sample preparation areas, a dedicated control and observation room, and drive-through access for ease of loading and offloading test equipment.

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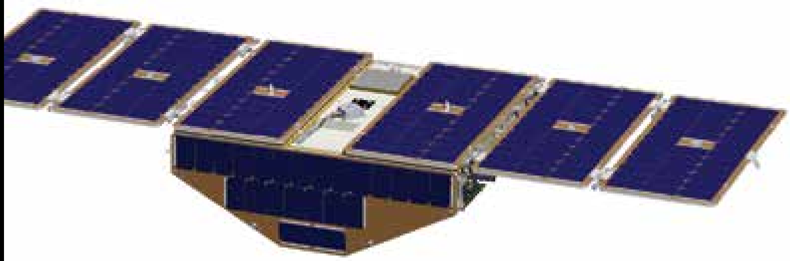
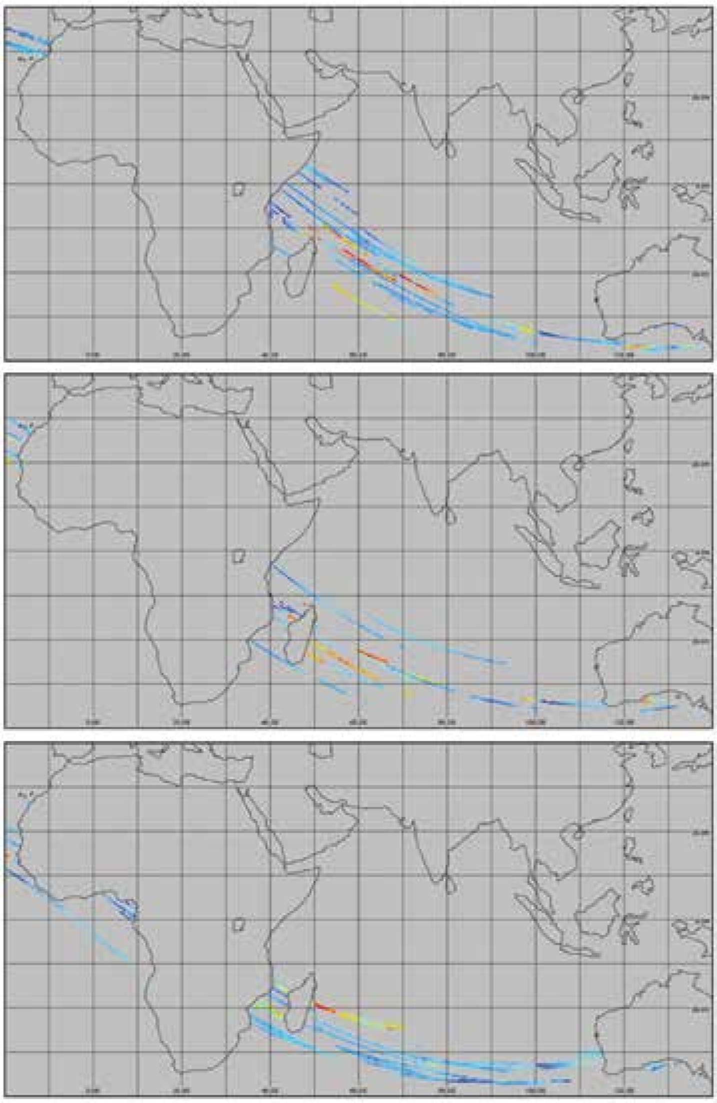
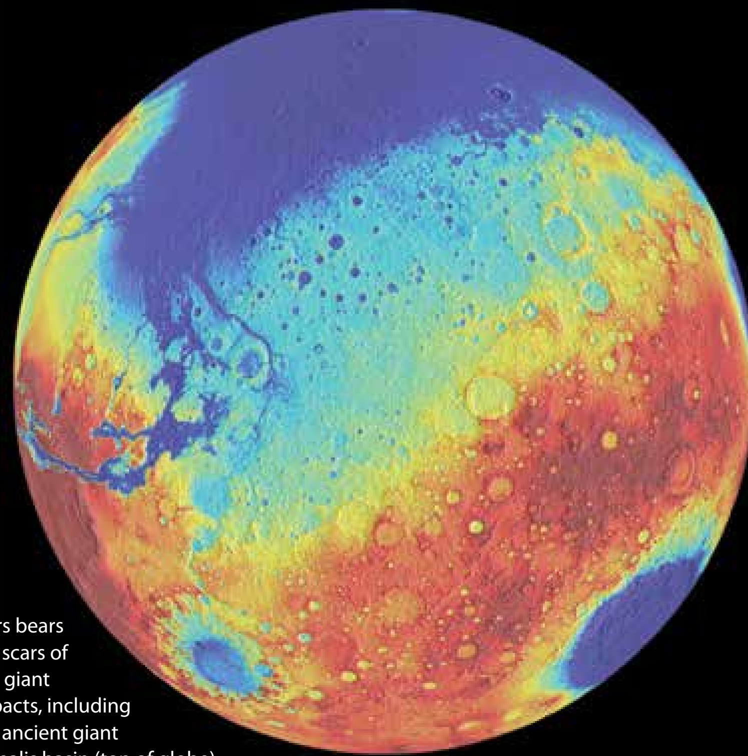


CYGNSS Satellites Sense Cyclone Wind Speeds



IMAGES COURTESY NASA/UNIVERSITY OF MICHIGAN D022147 D022589

Launched in December 2016, NASA's Cyclone Global Navigation Satellite System satellites — built and operated by SwRI — are now in science mode, studying how tropical storms intensify. These maps show ocean surface wind speeds (low to high, blue to red) measured by four of the eight spacecraft as Tropical Cyclone Enawo approached landfall on Madagascar. The measurements were made on March 6, 2017, (from top down) at 1:30 p.m., 2:30 p.m., and 3:30 p.m. EST.



D022590

Mars bears the scars of five giant impacts, including the ancient giant Borealis basin (top of globe), Hellas (bottom right), and Argyre (bottom left). An SwRI-led team discovered that Mars experienced a 400-million-year lull in impacts between the formation of Borealis and the younger basins.

MARTIAN DOLDRUMS

From the earliest days of our solar system's history, collisions between astronomical objects have shaped the planets and changed the course of their evolution. Studying the early bombardment history of Mars, scientists at SwRI and the University of Arizona have discovered a 400-million-year lull in large impacts early in Martian history.

"The new results reveal that Mars' impact history closely parallels the bombardment histories we've inferred for the Moon, the asteroid belt, and the planet Mercury," said SwRI's Dr. Bill Bottke. "We refer to the period for the later impacts as the 'Late Heavy Bombardment.' The new results add credence to this somewhat controversial theory. However, the lull itself is an important period in the evolution of Mars and other planets. We like to refer to this lull as the 'doldrums.'"

A giant impact carved out the northern lowlands 4.5 billion years ago, followed by a lull of approximately 400 million years. Then another period of bombardment produced giant impact basins between 4.1 and 3.8 billion years ago. The age of the impact basins requires two separate populations of objects striking Mars.

This discovery is published in the latest issue of Nature Geoscience in a paper titled "A post-accretionary lull in large impacts on early Mars." Bottke, who serves as principal investigator of the Institute for the Science of Exploration Targets (ISET) within NASA's Solar System Exploration Research Virtual Institute (SSERVI), is the lead author of the paper. Dr. Jeff Andrews-Hanna, from the Lunar and Planetary Laboratory in the University of Arizona, is the paper's coauthor.

BY THE NUMBERS
March – May 2017

198 presentations given in

16 states

and **10** COUNTRIES

58 papers published in

13 PUBLICATIONS

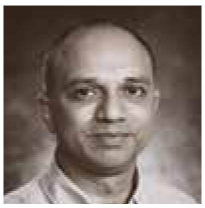
13 patents awarded

ACHIEVEMENTS

D1M22449

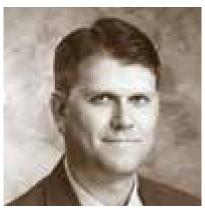
Dr. Robin Canup, associate vice president of SwRI's Space Science and Engineering Division, has been named a member of the American Academy of Arts and Sciences. The 2017 class of inductees includes leaders from academia, business, public affairs, the humanities, and the arts.

D021468



NASA has appointed **Dr. Mihir Desai**, director of SwRI's Space Research Department, to a one-year term on the Science Committee of its Advisory Council. This group provides assistance to the NASA administrator in addressing important program and policy matters.

D1M18202



The Optical Society has recognized **Thomas Moore**, a senior research engineer in SwRI's Mechanical Engineering Division, as a senior member. More than 180 were recognized for their experience and professional accomplishments within the field of optics and photonics.

D022598

The journal editors of the American Geophysical Union recognized **Dr. Kelsi Singer**, a postdoctoral researcher in SwRI's Boulder office, as an outstanding reviewer. In 2016, AGU received more than 13,500 submissions and published nearly 6,100 manuscripts requiring more than 30,000 reviews in all.

D022598

SCIENCE COVER REPRINTED WITH PERMISSION.
IMAGE COURTESY NASA/SWRI/MSSS/JPL-CALTECH/BETSY ASHER HALL, GERVASIO ROBLES, CANDY HANSEN, KOJI KURAMURA, ERIC DE JONG, SCOTT BOLTON

The first Juno science results were published in a special edition of Science. **Dr. Scott Bolton** is lead author of "Jupiter's interior and deep atmosphere: The initial pole-to-pole passes with the Juno spacecraft." SwRI's **Dr. Frederic Allegrini**, **Dr. Randy Gladstone**, and **Dr. Phil Valek** are coauthors of "Jupiter's magnetosphere and aurorae observed by the Juno spacecraft during its first polar orbits"; lead author is Dr. John Connerney of NASA's Goddard Space Flight Center.

COMING UP

31st Annual AIAA/USU Small Satellite Conference, Logan, UT; Aug. 5-10, 2017, Booth No. 57-58

Introduction to Propulsion Simulation Using NPSS, San Antonio; Aug. 22, 2017, SwRI is hosting this short course

Texas Groundwater Summit, San Marcos, TX; Aug. 29-31, 2017

Specialty & Agro Chemicals America, Charleston, SC; Sept. 6-8, 2017, Booth No. L-28

IASH Symposium, Rome, Italy; Sept. 10-14, 2017

Gas Turbine Performance and Introduction to Propulsion Simulation Using NPSS, Cranfield University, Bedfordshire, United Kingdom; Sept. 11, 2017, SwRI is hosting this one-week short course

AUTOTESTCON, Schaumburg, IL; Sept. 11-14, 2017, Booth No. 529

46th Turbomachinery Symposium & 33rd International Pump Users, Houston, TX; Sept. 11-14, 2017, Booth No. 2726

American School of Gas Measurement Technology (ASGMT), Houston, TX; Sept. 18-21

Introduction to Microencapsulation, San Antonio; Oct. 2-3, 2017, SwRI is hosting this two-day workshop

Pacific International Maritime Exposition, Sydney, Australia, Oct. 3-5, 2017

SPE Annual Technical Conference and Exhibition, San Antonio; Oct. 9-11, 2017, Booth No. 1683

International Telemetering Conference, Las Vegas, NV; Oct. 23-26, 2017, Booth No. 225

Automotive Testing Expo, Novi, MI; Oct. 24-26, 2017, Booth No. 2014

World Congress on Intelligent Transportation Systems, Montreal, Quebec, Canada; Oct. 29-Nov. 2, 2017, Booth No. 2115

ASNT Annual Meeting, Nashville, TN; Oct. 29-Nov. 2, 2017, Booth No. 1027

Natural Gas High Horsepower Summit, Jacksonville, FL; Nov. 6-9, 2017, Booth No. 234

Gas Turbine & Compressor Training Week, San Antonio; Nov. 13-17, 2017, SwRI is hosting this one-week training

ASIP Conference, Jacksonville, FL; Nov. 27-30, 2017, Booth No. 17

Lateral & Torsional Rotordynamics for Centrifugal & Reciprocating Machinery, San Antonio; Dec. 05, 2017, SwRI is hosting this short course

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