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JUNO ARRIVES AT JUPITER

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TECHNOLOGY TODAY®

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ON THE COVER

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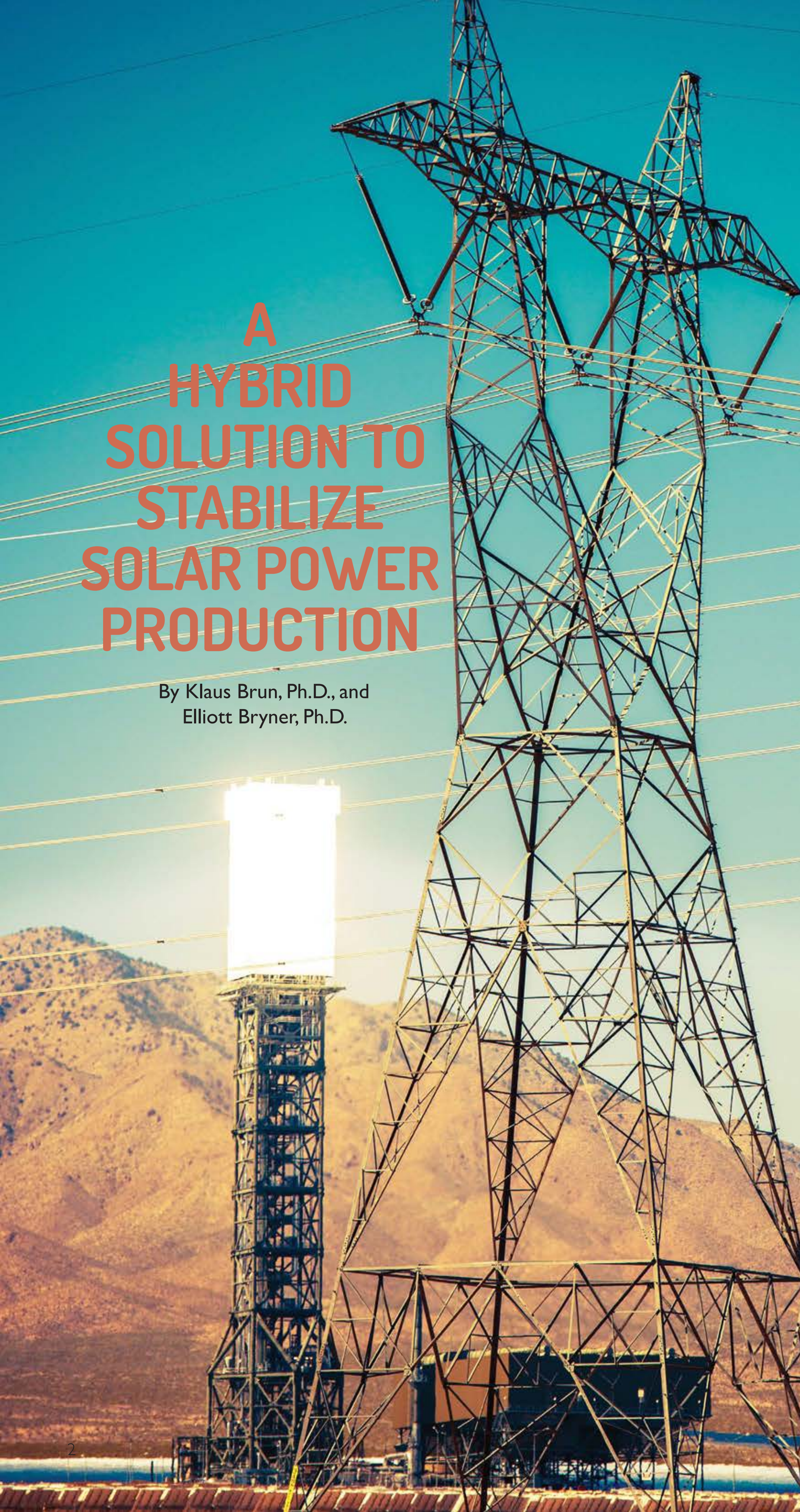

A HYBRID SOLUTION TO STABILIZE SOLAR POWER PRODUCTION

By Klaus Brun, Ph.D., and
Elliott Bryner, Ph.D.

SwRI CRANKS UP HEAT TO IMPROVE EFFICIENCY, COST EFFECTIVENESS

Electric grids maintain an instantaneous balance between supply and demand, with different resources making unique contributions to the power mix. Managing the balance between generation and load, while moving electricity from the source to the customer, is challenging.

As the world integrates more green, renewable resources, the complexities of balancing power generation with varying loads increase. Solar and wind are clean technologies, but they produce power that fluctuates with changes in wind and available sunlight.

To stabilize these fluctuations in solar applications, Southwest Research Institute engineers are developing critical technologies to combine renewables with natural gas-fueled energy to help make solar power a more cost-effective, dependable resource in the energy marketplace. Here's how they're doing it.

CSP-HYBRID'S GROWING ROLE

With funding from the U.S. Department of Energy's SunShot Initiative , SwRI is developing technology to supplement concentrated solar power (CSP) plants, or solar thermal plants, with natural gas burners. Solar thermal plants, much like traditional power plants, use heat to generate steam, which drives turbines to create electricity. SwRI's hybrid solar-natural gas solution is aimed at increasing efficiency and output consistency, while operating in a sweet spot that minimizes the production of pollutants during gas combustion.

This hybrid solution applies to CSP plants that collect concentrated sunlight from thousands of heliostats, sun-tracking mirrors that reflect and focus solar energy to the collector at the top of a tower. The dense heat collected by these "power towers" can generate temperatures up to 1,000 degrees Celsius. The higher temperatures allow efficiencies — and costs — to approach those of conventional power plants using fossil fuels.

A NEW INJECTOR FOR CSP COMBUSTORS

For peak power efficiency, the temperatures driving production turbines should remain constant. However, CSP plants provide variable levels of heat based on time of day, weather, and other conditions. To bridge this gap, SwRI engineers propose integrating a natural gas combustor to boost temperatures when sunlight input drops off. To produce the most efficient hybrid natural gas-CSP plant, SwRI needed to develop a natural gas combustor able to withstand inlet temperatures of 1,000 degrees C — about the melting point of gold.

Conventional combustors use a pre-mix injection system designed to minimize emissions of nitrous oxides (NOx). If temperatures get above 650 degrees C, current systems experience unwanted auto-ignition and flashback. Under these conditions, flammable

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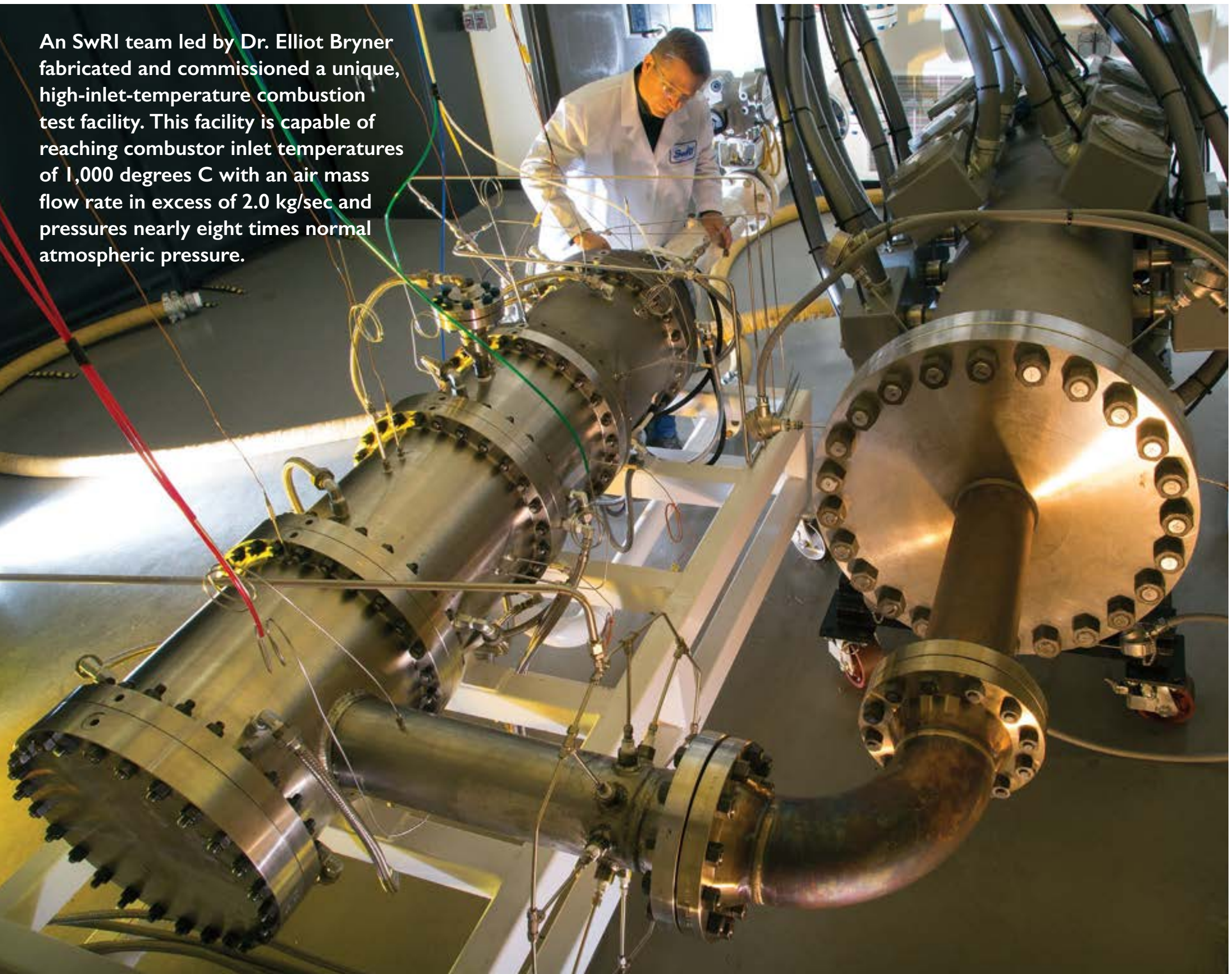
ABOUT THE AUTHORS

Dr. Klaus Brun (center) and Dr. Elliott Bryner (third from right) led a team of machinery experts, developing a unique, high-inlet-temperature combustion test facility at SwRI. The team included (from left) James Donnelly, Seth Cunningham, John Stubbs, Brun, Bryner, Nathan Poerner, and Shane Coogan.



An SwRI team led by Dr. Elliot Bryner fabricated and commissioned a unique, high-inlet-temperature combustion test facility. This facility is capable of reaching combustor inlet temperatures of 1,000 degrees C with an air mass flow rate in excess of 2.0 kg/sec and pressures nearly eight times normal atmospheric pressure.

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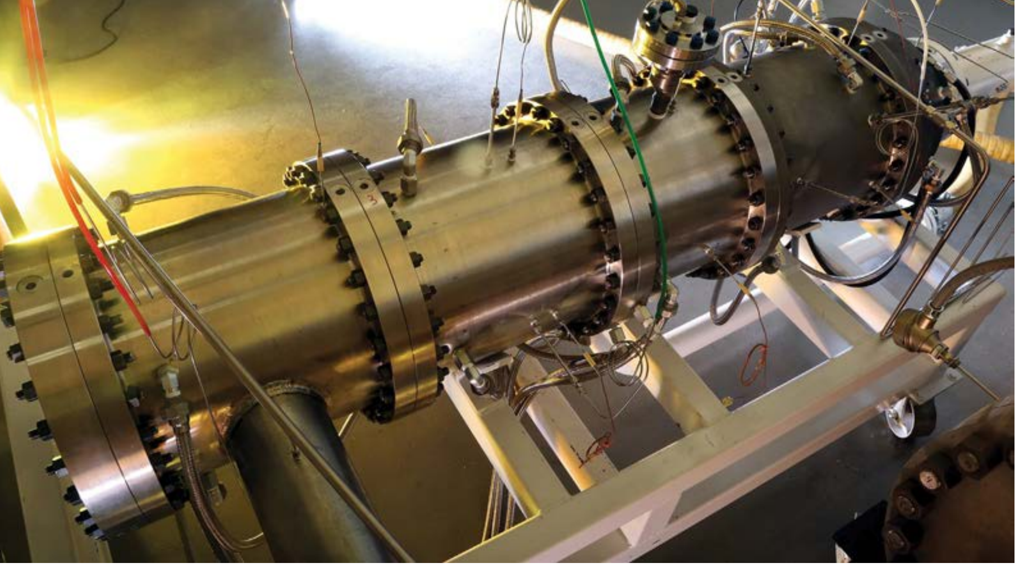
DETAIL

The SunShot Initiative is a national collaborative effort to make solar energy cost-competitive with other forms of electricity by the end of the decade.



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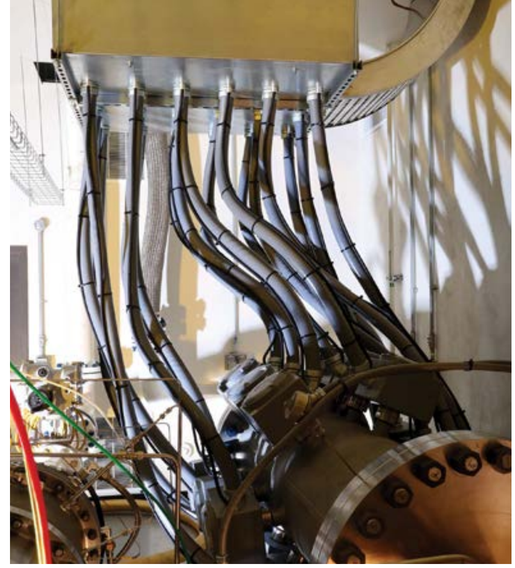

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The combustor (left) is made from a pressure vessel fabricated from a thick-walled high-temperature cast steel alloy, designed to withstand extreme inlet air,combustion, and exhaust gases. Without access to many square miles of heliostats to generate high air temperatures, SwRI needed to develop a test rig to simulate superheated solar inputs. A 2-megawatt electric heater (right) raises inlet air temperatures to 800 degrees C. Then, a secondary gas-fired heater bumps temperatures up to 1,000 degrees C.

mixtures ignite prematurely. The explosive results shorten combustor life and spew pollutants such as NOx.

SwRI's Mechanical Engineering Division has overcome these challenges with a novel combustor design that uses a patent-pending arrangement of injectors. This computer-controlled system adjusts fuel injection rates to meet the precise heat addition requirements needed to maintain a constant turbine input temperature, despite fluctuating solar inputs. When the CSP-heated air is delivered to the combustor, the system determines how much natural gas is needed to heat up the air to reach peak efficiencies. The combustion process takes place in cylinders, better known as "cans." When this air-gas mixture is ignited, it spins electricity-generating turbines.

CAN DESIGN, MULTI-BANK MICRO-MIX INJECTOR

For this project, the SwRI team had to deal with problems associated with air heated above 650 degrees C, at which point air and fuel will burn immediately when they are mixed together without an external source of ignition. Instead of using conventional lean pre-mixing injection schemes to reduce NOx, the SwRI technology uses a series of injectors that introduce the fuel and air into the combustion chamber to reduce emissions.

To avoid triggering auto-ignition, SwRI engineers created a novel process for injecting, mixing, and burning the hot air and natural gas. For added durability, the combustor is made from a pressure vessel fabricated from a thick-walled, high-temperature cast steel alloy, designed to withstand hot inlet air, combustion, and exhaust gases.

To keep it simple, this project looked at only a single combustor can. The prototype was developed at one-eighth scale for compatibility with a prototype gas turbine. The design can be scaled up for commercialization and modified for multi-can turbines.

To manage the airflow from the high-temperature air inlet to the combustion chamber, SwRI designed a multi-bank, micro-mix injector. This design regulates fuel injection in such a way that combustion of the air-fuel mixture is delayed until it reaches the combustion chamber. The circular injector, which looks a little like a shower head, uses a series of metal plates pierced with dozens of small holes. The holes create a uniform lean mixture of air and natural gas to counter the effects of premature auto-ignition and flashback. When flame speeds propel combustion back into the injector, this "flashback" causes damage, greatly reducing injector service life. Because moving parts are problematic at high temperatures, the team used injection ports fed by multiple banks to manage airflow without a high-temperature valve.

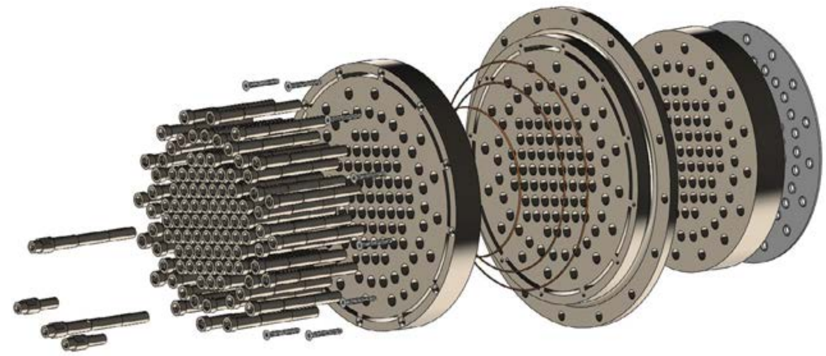
TESTING AND EVALUATION

To develop and evaluate this design, SwRI developed a sophisticated test rig in its Turbomachinery Research Facility. Without access to many square miles of heliostats to generate high air temperatures, engineers needed to simulate the superheated solar inputs. A 2-megawatt (MW) electric heater raises inlet air temperatures to 800 degrees C. Then, a secondary gas-fired heater bumps temperatures up to 1,000 degrees C. During testing, SwRI monitored the combustor rig with a suite of instrumentation. Thermocouples measured air and metal temperatures. Steady-state pressure transducers and a gas sampling system determined the composition of combustion products. A centrifugal compressor, designed by SwRI engineers as part of a previous Department of Energy project, delivered the pressurized air.

During proof-of-concept testing in 2015, the SwRI technology mixed record-high temperatures of heated air with natural gas in a combustion chamber.

CONCLUSIONS

The project has produced a number of valuable results. The SwRI team fabricated and commissioned a unique, high-inlet-temperature combustion test facility. This facility is capable of reaching combustor inlet temperatures of 1,000 degrees C with an air mass flow rate in excess of 2.0 kg/sec and pressures of nearly



SwRI designed this novel multi-bank, micro-mix injector to regulate natural gas injection. The air-fuel mixing is delayed until it reaches the combustion chamber. This expanded engineering drawing shows the internal complexity of the finished component.

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eight times normal atmospheric pressure. The facility is equipped with a flexible and extensible instrumentation and data acquisition system for measuring temperatures, air flow, species concentrations, and static and dynamic pressures. This facility has demonstrated operation over the full temperature range and up to near-real-world turbine inlet pressures.

Using this facility, SwRI conducted preliminary flow, combustion, acceptance, endurance, and stability testing on the high-temperature combustor. The team conducted more than 50 hours of testing for this clean sheet injector design under very harsh and destructive conditions. These tests provided considerable insight to the current design as well as direction for improving the service life in future generations of the injector design. In the next phase, the team will combine a cutting-edge additive manufacturing process with advanced materials to address more challenges and meet operational standards, including a service life of 30,000 hours.

WHAT'S NEXT?

SwRI engineers are working with industry partners to develop a commercialization path for the technology to be ready to hit the market by 2020.

SwRI analysis indicates that CSP-hybrid systems with temperatures reaching 1,000 degrees C can dramatically lower the leveled cost of energy (LCOE) while increasing solar energy production. LCOE weighs everything that affects energy costs, from installation to maintenance, including facility costs, electricity prices, and government subsidies. Furthermore, combining natural gas and renewables in a single hybrid power plant is more economical than having two completely separate plants.

Questions about this article? Contact Brun at (210) 522-5449 or klaus.brun@swri.org.

In the U.S. alone, total solar capacity exceeded 20 gigawatts (GW) in 2015.[1] Most of that power is associated with photovoltaic solar, but five CSP projects totaling 1,250 MW of capacity were installed in 2014 in the desert regions of Arizona, California, and Nevada. And more are on the way.

Rapid deployment of CSP has created demand for improvements to address the unique technical challenges to operation. This has created many opportunities for SwRI scientists and engineers.

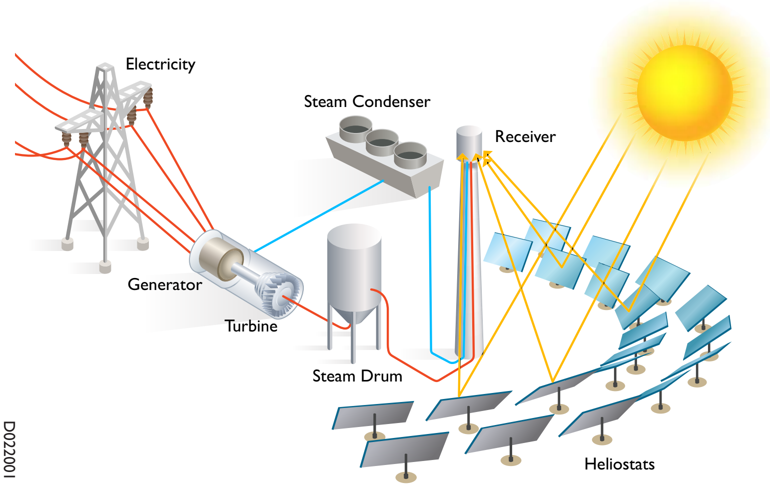
SwRI is also developing a turboexpander for supercritical CO_2 power cycles in CSP plants for the DOE. Supercritical is a state of matter that puts gases and liquids under a combination of high temperature and pressure to create a working medium ideal for power-generating systems. For a commercial client, SwRI has also developed encapsulated phase-change chemicals as an energy storage solution. Tanks of encapsulated salts alternately melt and solidify to efficiently store and distribute energy from parabolic mirror-based solar plants.

[1]Solar Energy Industries Association

DETAIL

Solar power tower plants use a large array of mirrors (called heliostats) focused on a central tower that contains heat-transfer materials. The transfer materials are pumped into tanks to store the heat for up to a day. The material is then passed through a heat exchanger, where it produces steam that drives the generators.

SOLAR POWER TOWER PLANT



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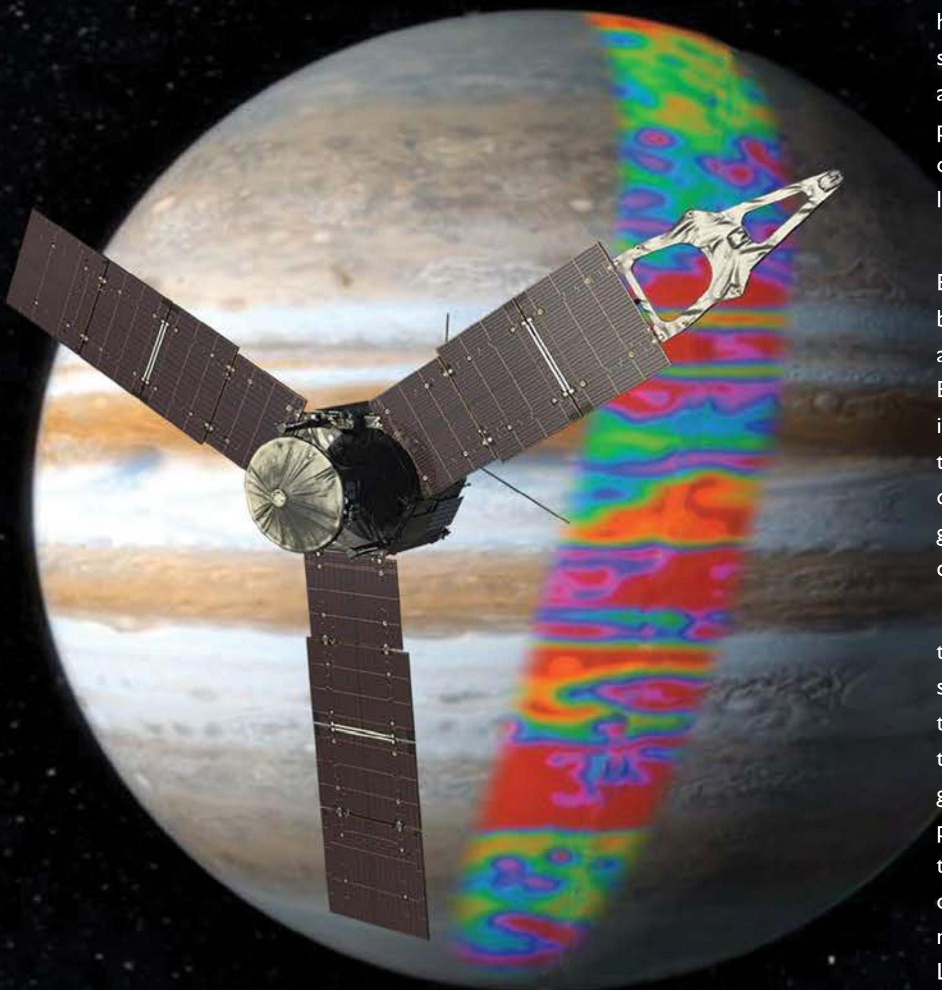
JUNO'S JOURNEY ENDS, JUPITER SCIENCE BEGINS



Over 20 months, Juno will orbit Jupiter 37 times to measure global water abundance in the gas giant. The spacecraft will measure magnetic and gravitational fields to understand what lies at its core.

SwRI's Bolton leads NASA mission to gas giant

After a 5-year journey, NASA's Juno spacecraft has arrived at Jupiter, the largest planet in our solar system. The spacecraft entered a novel polar orbit around the gas giant on July 4. From this vantage point, Juno is poised to improve our understanding of Jupiter's formation and, in turn, the processes that led to formation of our solar system.

"NASA's done it again," said SwRI's Dr. Scott Bolton at the post orbit insertion NASA press briefing. Bolton (shown third from left below) is an associate vice president in SwRI's Space Science and Engineering Division and serves as the principal investigator for the Juno mission. "This is the one time I don't mind being stuck in a windowless room on the night of the 4th of July. The mission team did great. The spacecraft did great. We're in orbit. We conquered Jupiter."

On its journey to Jupiter, Juno became both the most distant solar-powered and the fastest spacecraft in history. To achieve orbit, the spacecraft turned and executed a 35-minute main engine burn to slow down enough to be captured by the gas giant. Soon after the burn, Juno turned once again to point the 18,698 individual solar cells that power the spacecraft back at the Sun. When a simple series of tones signaled Juno's success, the team in the mission control room at the Jet Propulsion Laboratory in Pasadena, Calif., erupted into cheers, applause, high-fives, and hugs.

"Tonight, through tones, Juno sang to us, and it was a song of perfection. The spacecraft worked perfectly, which is always nice when you're driving a vehicle with 1.7 million miles on the odometer," said Rick Nybakken, Juno project manager from JPL. "We hit our burn targets within one second, on a

D021002 COURTESY NASA/AUBREY GEMIGNANI

target that was just tens of kilometers large. Isn't that incredible?"

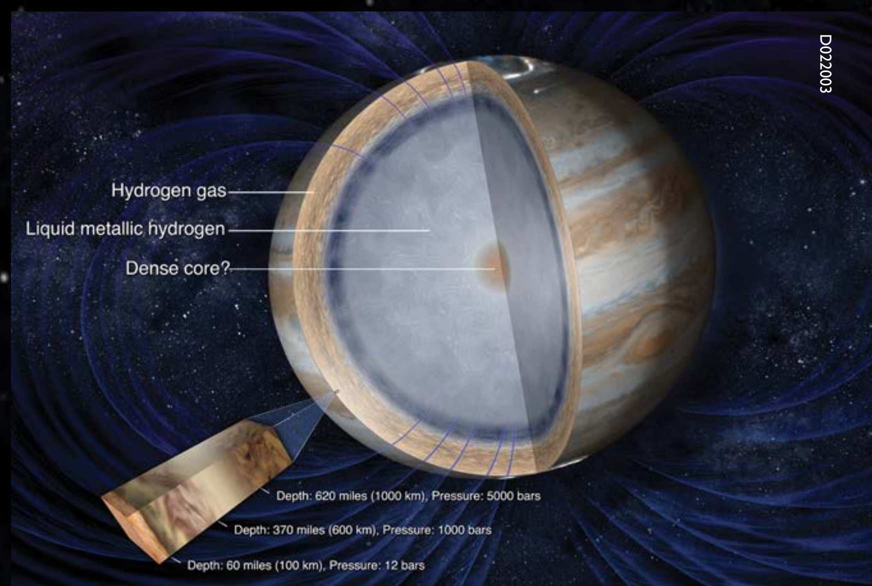
And now the incredible science begins. "Our science collection phase begins in November, but we are collecting data a lot earlier than that," said Bolton, "which, when you're talking about the single biggest planetary body in the solar system, is a really good thing. There is a lot to see and do here."

The Juno spacecraft is designed to unmask the mysteries that lie beneath the swirling clouds on Jupiter's visible facade. Over the course of the mission, Juno will orbit Jupiter 37 times. With a suite of nine instruments, scientists will look at the internal composition of Jupiter to determine how deep the colorful surface features persist, mapping the atmosphere's composition, temperature, clouds, and patterns of movement to unprecedented depths. Juno will measure the amount of water and ammonia in Jupiter's atmosphere and help determine if the planet has a core of heavy elements, constraining models on the origin of this giant planet and thereby the solar system.

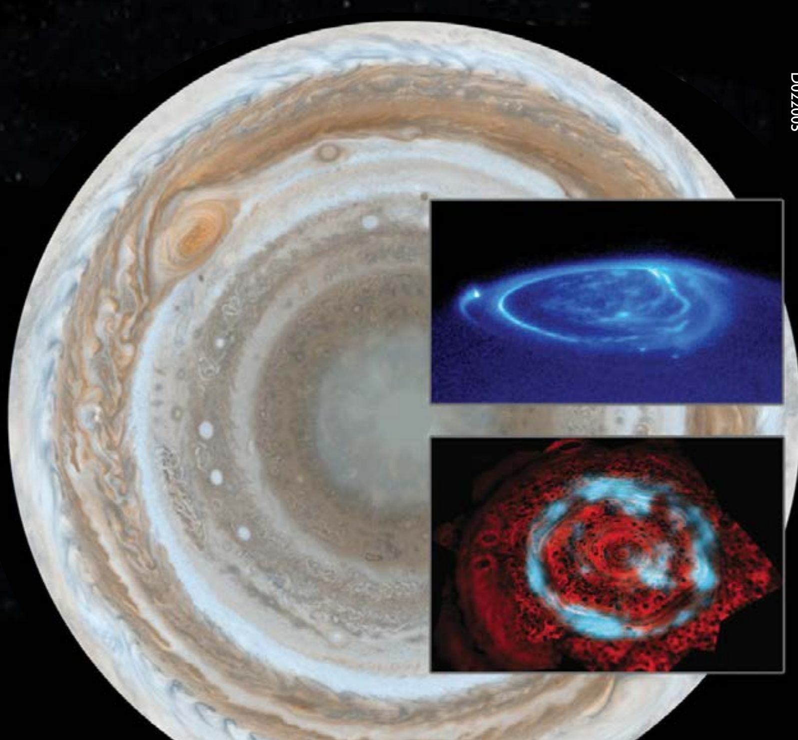
Scientists are also looking for evidence of pressurized hydrogen that is believed to generate Jupiter's magnetic field, creating a powerful magnetosphere that sparks the brightest aurora in our solar system. SwRI built two science instruments aboard the spacecraft critical to understanding these phenomena. The Jovian Auroral Distributions Experiment (JADE), led by SwRI's Dr. Phil Valek, will measure the auroral electron and ion populations along the planet's magnetic field lines to determine which particle populations create the Jovian aurora. The Juno Ultraviolet Spectrograph (UVS), led by SwRI's Dr. Randy Gladstone, will image ultraviolet emissions from the Jovian aurora, allowing space scientists to correlate auroral observations with JADE measurements.

The Juno mission is the second planetary mission flown as part of NASA's New Frontiers Program. NASA's Jet Propulsion Lab manages the Juno mission for the principal investigator. Lockheed Martin of Denver built the spacecraft. The Italian Space Agency contributed an infrared spectrometer instrument and a portion of the radio science experiment.

Just before orbit insertion, JunoCam relayed back to Earth images shot during approach. In this image, you can see Jupiter's giant red spot and three of the four largest moons. The Juno team put together a unique time-lapse movie of these Galilean satellites in motion about Jupiter, available at: https://youtu.be/XpsQimYhNkA



Juno has the technology to measure, for the first time, the atmosphere below Jupiter's cloudy façade. Instruments will map variations in composition, temperature, cloud opacity, and dynamics to depths greater than 100 bars at all latitudes.



The SwRI-built UVS and JADE instruments are designed to characterize and explore the three-dimensional structure of Jupiter's polar magnetosphere and auroras.

JUPITER IMAGES COURTESY NASA/JPL-CALTECH/SWRI/MSSS

LEAVE THE DRIVING TO US

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SwRI's automated vehicle program celebrates 10-year anniversary

By Ryan D. Lamm

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ABOUT THE AUTHOR

Ryan D. Lamm, director of SwRI's Applied Sensing Department, climbs aboard the largest vehicle in SwRI's unmanned fleet. With over 19 years of experience, Lamm leads the department in its development of intelligent network systems, cooperative systems, embedded sensing networks, and unmanned systems.

In a 1967 article titled "The Art of Directed Opportunism," Martin Goland proclaimed that "once the decision has been made to move ahead in a particular direction, the effort cannot be half-hearted." The words of SwRI's second president still ring true 50 years later and are the driving force for a team of engineers who launched the Institute's unmanned systems program a decade ago.

The Mobile Autonomous Robotics Technology Initiative (MARTI) — its acronym a nod to Martin Goland — began in 2006 with a $4 million investment from SwRI's internal research program. It sought to develop unmanned ground vehicle (UGV) technology for the autonomous control of tactical and combat military ground vehicles, passenger cars, commercial trucks, industrial tractors, and mobile robots.

Far from half-hearted, the MARTI program has strategically positioned the Institute as a leader in unmanned systems technology. Now approaching $60 million in external project funding, the program has resulted in a vibrant, sustainable business for the Institute. By weaving together SwRI's vast capabilities into a "mosaic of grander design," the Institute is now an internationally recognized solutions provider of active safety, automated driving systems, and UGVs.

MARTI began as a collaborative effort among five technical divisions. More than 100 SwRI staff spent more than 32,000 project hours during its startup years from 2006 to 2011. In all, SwRI has automated 15 types of vehicles, ranging from golf carts and SUVs to Class 8 tractor trailers. Automated driving systems have been deployed in seven countries on four continents, including two UGVs in Afghanistan in 2014.

The program began with a handful of engineers tinkering with a used sport utility vehicle in a corner of a small lab at SwRI's San Antonio headquarters. The program has since grown to a fleet of over 20 automated vehicles piloting themselves around SwRI facilities, both on and off road. This bustle of activity involves multidisciplinary teams of engineers and analysts performing leading-edge research and development in a 20,000-square-foot facility. SwRI serves a full range of clients, including original equipment manufacturers as well as other automotive, agriculture, construction, and defense companies. The program is continually expanding, to encompass the U.S. Army, Navy, and Marine Corps as well as foreign ministries of defense. Plans are underway to add more labs and vehicle bays to support future growth.

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In November 2008, SwRI demonstrated its first automated vehicle, known as MARTI, on the streets of New York City as part of the ITS World Congress.

ADAPTING TO ECONOMIC REALITIES

The MARTI program initially researched the current state of the art in automated vehicle technology in the commercial vehicle realm. Within the first six months, engineers identified and installed a set of prototype sensors and computational hardware, developed extensive vehicle dynamic models to optimize control, established rudimentary software to drive the vehicle, and optimized near-real-time control algorithms. This technology allowed research vehicles to follow a dense set of waypoints, traveling at over 30 miles an hour around a test track without human intervention.

Within its first year, SwRI's automated vehicle could avoid obstacles — both static and dynamic — without human intervention. Within 18 months, the vehicle could negotiate intersections in mixed traffic, obeying general traffic laws. And in November 2008, SwRI publicly demonstrated MARTI technology on the streets of New York City. During its Big Apple debut, SwRI's first automated vehicle successfully negotiated intersections, interacted with other manned and unmanned vehicles, avoided dynamic obstacles such as vehicles and pedestrians, and coordinated maneuvers with other vehicles and roadway infrastructure such as traffic signals. Simultaneous to the technology development, SwRI formed relationships with the commercial auto industry. Unfortunately, just as SwRI unveiled the technology in New York City, an automotive industry crisis began as part of a global financial downturn.

MILITARY RESEARCH, DEPLOYMENT

During the downturn, with the help of the Institute's Business Development Office, SwRI pivoted emphasis from commercial to military systems. Engineers also looked for ways to combine the MARTI technology with connected vehicle technology being developed to support intelligent transportation systems on public roads. At the 2009 Robotics Rodeo — a showcase of military robotics technology at Fort Hood in Killeen, Texas — SwRI used the MARTI vehicle platform to demonstrate how a UGV can reliably support military multi-vehicle convoy operations.

SwRI's UGV technology is modular, which allowed engineers to rapidly adapt it for military applications. For example, a convoy could instruct a UGV to "lead upon command" and "follow where appropriate." The UGV could operate in various formations, navigate an urban environment, lead the convoy, and fall back into formation upon command. The UGV could also rapidly be switched from human operation to fully autonomous modes.

As a result of the demonstration, SwRI began a project with the U.S. Navy to develop unmanned vehicle algorithms and platforms using low-cost vision technology. The Small Unit Mobility Enhancement Technology (SUMET) program, funded by the Office of Naval Research, implemented all-terrain navigation using a vehicle outfitted with only camera-based sensors. The SUMET program achieved reliable automated vehicle operation in austere, harsh, off-road environments without depending on global

In cooperation with the U.S. military, SwRI deployed two fully automated tactical vehicles to Afghanistan to assess how this technology could support ground troops in the battlefield.

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Connecting unmanned aerial systems — drones — with unmanned ground vehicles provides more global information about the surrounding environment. This sort of unmanned technology can help remove humans from particularly hazardous duties.

THE 5 LEVELS OF AUTOMATED DRIVING

Automated driving systems have a way to go before people can literally sleep at the wheel while a fully automated minivan shuttles the family to a soccer game. The Society of Automotive Engineers (SAE) has identified five levels of automation, based on the need for humans to steer, accelerate/decelerate, and monitor overall driving conditions.

The majority of today's vehicles are at Levels 0-3, with Level 0 offering no automation. Levels 1 and 2 allow for system-assisted acceleration/deceleration (cruise control) and steering. Some Level 3 "conditional automation" systems are currently available on high-end vehicles. "Adaptive cruise control" automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead, while "lane keep assist" technology alerts the driver when a vehicle is about to deviate from a traffic lane.

Level 4 "high automation" is a few years away. At Level 4, a human is no longer needed to be a fallback operator in certain environments. However, this level could be here sooner than you think as automobile manufacturers race to see who can get there first. Level 4 is the "hands-off, feet-off" scenario where humans can doze off in their moving vehicles, in certain scenarios. It's also a huge technological step that SwRI is helping to achieve. True Level 5 "full automation" or automated driving anywhere, anytime is many more years away.

Over the past decade, SwRI has developed technologies that can enable Level 3 through Level 5. Our technologies include perception (detection of terrain and obstacles), localization (techniques that operate with and without GPS), and navigation (path-planning algorithms).

SwRI has also focused on scenarios where the dynamic driving task needs to be done in all roadways and environmental conditions, on and off public roads. Approximately 35 percent of U.S. roadways are not paved. Known as the "last mile" problem, getting vehicles from public roadways to the final destination down an unmarked road or drive will require a new generation of solutions to achieve Levels 4 and 5 automation. SwRI's research is key to solving the last mile problem and essential for widespread use of automated driving systems in the years to come.

positioning system (GPS) technology. SUMET achieved this by using multi-spectral electro-optical perception and advanced path-planning algorithms. SwRI demonstrated the SUMET platform multiple times in various off-road scenarios. The UGV could detect and avoid pedestrians and natural and man-made obstacles. The sensor suite could distinguish between different terrains, such as dirt, rock, asphalt, grass, wood, and foliage.

In 2012, the U.S. Army TARDEC (Tank Automotive Research, Development and Engineering Center) used the SUMET code to initiate its Dismounted Soldier Autonomy Tools (DSAT) program. For DSAT, SwRI worked with TARDEC engineers to add new sensing modalities and a more modular framework. With these advances, engineers could create, implement, and share new fully automated behaviors on multiple tactical vehicle platforms. Since DSAT was deployed in Afghanistan in spring 2014, the Army has used DSAT code in its Robotics Technology Kernel (RTK) and to develop new automated capabilities

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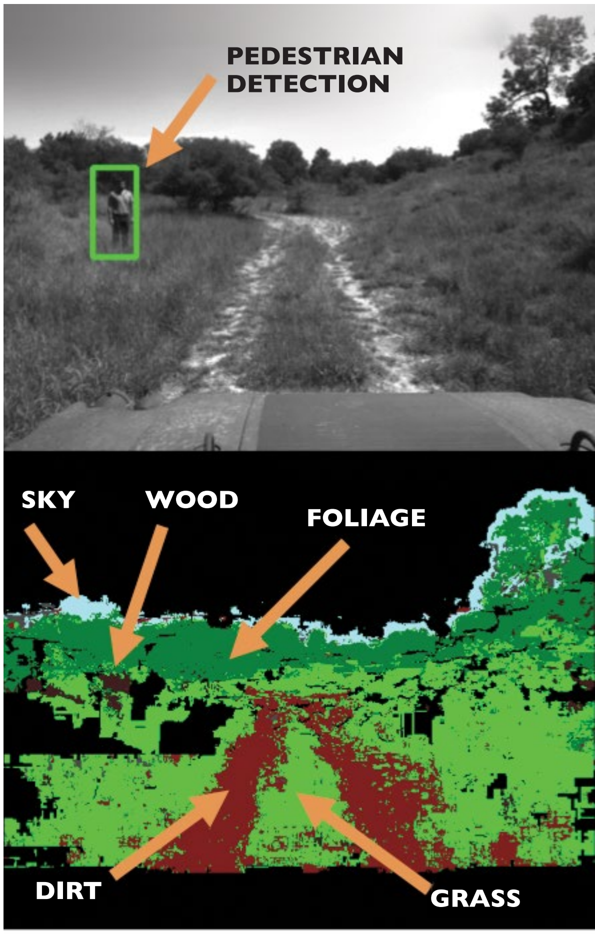


SwRI's unmanned vehicles use a low-cost sensor suite and sophisticated software to identify pedestrians and distinguish between terrains, such as dirt, roadway, grass, and sky.

REVISITING COMMERCIAL, INDUSTRIAL OPPORTUNITIES

As the automotive industry started recovering in 2010, SwRI began working with the commercial entities, road operators, and various departments of transportation as well as agriculture and mining companies. Engineers began to see how modular MARTI algorithms such as road curvature detection, automated truck- mounted attenuators, and human identification and tracking safety systems could be adapted for various mobile tractors and equipment.

Commercial companies in Japan and Europe were among the first to recognize the benefits of the SwRI-developed component technology.

SwRI developed gesture recognition capabilities for unmanned vehicles used in military, highway work convoy, and other applications. Image-processing algorithms identify and distinguish different arm gestures from a designated pedestrian to give commands that allow more natural, efficient interaction with an automated vehicle.

Today, various automotive manufacturers and tier one suppliers are using SwRI algorithms and technology in their automation research and development programs. This technology includes the 2015 R&D100 award-winning Ranger localization system (see story on p.13) as well as state-of-the-art environment classification and object detection systems.

DOWN THE ROAD

The Institute has delivered its automated vehicle technology around the world. Both SwRI's capabilities and its business focus have evolved in the decade since MARTI began. Engineers continue to specialize in a variety of technical solutions that give unmanned systems the ability to understand their environment, localize their position to within centimeters, navigate roadways and off-road terrain, and perform a full range of specialized applications.

Now more than ever, the media and public are fascinated by automated driving systems. While the technology is making its way from industrial and military applications to consumer vehicles, it still will be some time before all of us will be driven to and from work by an automated vehicle. See sidebar "The 5 Levels of Automated Driving" on p.11.

In the meantime, SwRI will be at the forefront of this technology, developing state-of-the-art solutions for industrial, commercial, and government clients.

Questions about this article? Contact Lamm at (210) 522-5350 or ryan.lamm@swri.org.

In 2016, a team of more than 25 analysts and engineers are engaged in SwRI's automated vehicle program, working on driverless technology for a wide range of military and commercial applications.

'Fresh' lunar craters discovered

An SwRI-led team of scientists discovered two geologically young craters — one 16 million, the other between 75 and 420 million, years old — in the Moon's deep, dark regions.

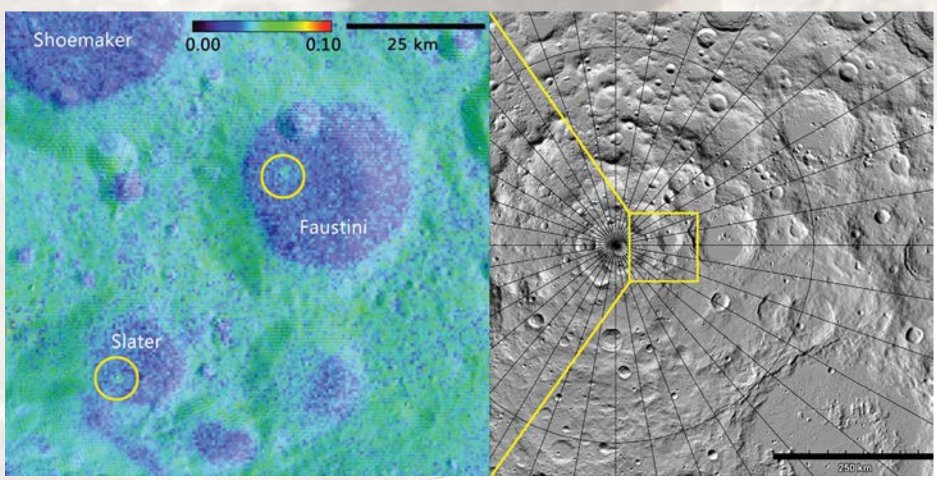
"These 'young' impact craters are a really exciting discovery," said Dr. Kathleen Mandt, who outlined the findings in a paper recently published by the journal Icarus. "Finding geologically young craters and honing in on their age helps us understand the collision history in the solar system."

Key to this discovery was the SwRI-developed Lyman-Alpha Mapping Project (LAMP) instrument aboard NASA's Lunar Reconnaissance Orbiter (LRO). LAMP uses the far-ultraviolet Lyman-alpha band skyglow and light from ultraviolet-bright stars to "see" in the dark and image permanently shaded regions of the Moon. Using LAMP and LRO's Mini-RF radar data, the team mapped the floors of very large, deep craters near the lunar south pole.

When a small object collides with a larger object, such as the Moon, the impact creates a crater on the larger body. During the impact, the ejected material blankets the area surrounding the crater. The ejecta blankets of "fresh," relatively young craters have rough surfaces of rubble and a sprinkling of condensed, bright dust. Over millions of years, these features undergo weathering and become covered with layers of fluffy, dark dust.

The areas around the two craters are brighter and rougher than the surrounding landscape. The team estimated the age of one crater at about 16 million years. The other crater's ejecta blanket had faded, showing that this crater must be at least 75 million years old. But fluffy dust would have completely covered the ejecta blanket within 420 million years, providing an upper limit on its age.

NASA's Lunar Reconnaissance Orbiter project funded this research.



D022024 COURTESY NASA GSFC AND NASA GSFC/ASU JMOON

SwRI scientists discovered these two geologically young craters within some of the deepest craters in the Moon's darkest regions. The one on the left lies within Slater Crater, named for the late Dr. David C. Slater, a former SwRI space scientist who designed and built the LAMP instrument.

RANGER RESEARCH KIT

SwRI recently showcased a kit-based version of its award-winning, patented Ranger precision vehicle localization solution. SwRI's system enables precise navigation for automated vehicles using commercially available hardware in combination with novel algorithms. The Ranger kit enables automated driving, valet parking in garages and structures, freight distribution, and docking of buses and large trucks when integrated into commercial vehicles.

"We are excited to make the latest version of this technology available to potential clients who want to integrate these systems into automated vehicles for a variety of applications," said Dr. Kristopher Kozak, who led Ranger's development. "We have made this technology smaller, faster, and more robust for real-world use at a relatively low cost."

Ranger uses a ground-facing camera, illumination, and localization algorithms to provide precise position and orientation measurements. Ranger images the unique "fingerprint" of road surfaces by matching thousands of distinguishing ground features, such as aggregate, cracks, and road markings, to corresponding features collected and stored in a map.

"GPS is ubiquitous, everybody has GPS on their phones, but it's not always as accurate as you need it to be for automated vehicle localization," Kozak added. "Ranger is a low-cost, high-precision localization system that overcomes a lot of problems affecting GPS systems."

D022025

This research vehicle is equipped with SwRI's Ranger localization technology for automated vehicles. Using a ground-facing camera, illumination, and algorithms, Ranger allows for precise automated driving, accurate to within 2 centimeters.

HIGHER TEMPS *ACCELERATING* ROCK GLACIER MOVEMENTS

National Science Foundation-funded research combines high-resolution optical and radar satellite data analyses with field studies

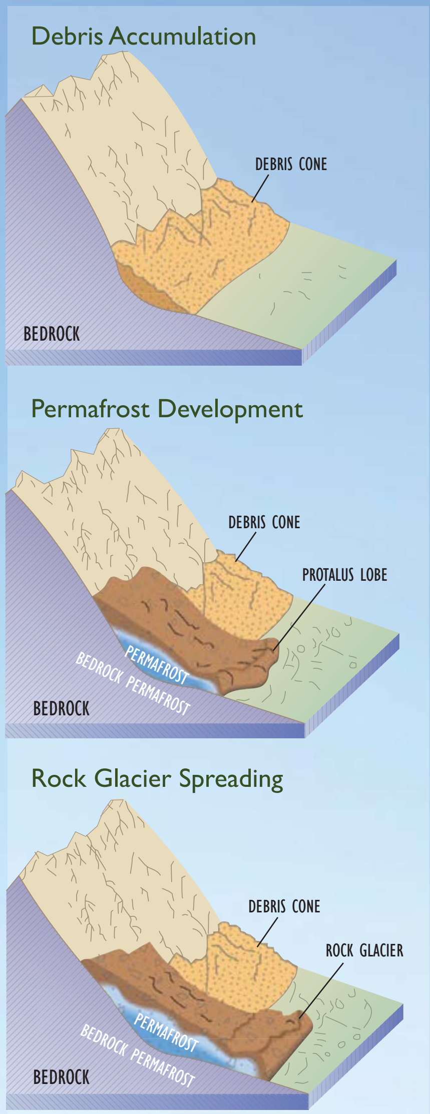
By Marius Necsoiu, Ph.D.

Rock glaciers can be observed in various stages of activity in places such as Rocky Mountain ski resorts and the Andes of South America. Like landslides moving at a glacial pace, these geomorphological formations consist of jagged rock fragments insulating a core of ice or ice-debris mixture that travels down steep mountains over thousands of years.

As temperatures rise in the world's high-elevation regions much faster than elsewhere, scientists are hoping to better understand the effects on rock glacier movement and the potential impacts on everything from the hydrology of alpine lakes to roadway safety near recreation areas.

Two studies published in early 2016 highlight how remote sensing methodologies developed by Southwest Research Institute can now measure rock glacier movement down to centimeters and lake surface changes at a detailed scale of analysis. Funded by a National Science Foundation grant, the research combined high-resolution optical and radar satellite imagery with ground observations and historical climate data. The data fusion also helped correlate rock glacier movements with changes in glacial lake levels in Romania's medium-altitude Carpathian Mountains over a 47-year period.

The SwRI team collaborated with geography researchers from Romania's West University of



D022012

DETAIL

Rock glaciers generally occur above the tree line. They form when perennially frozen debris containing a significant amount of ice slowly moves downslope. The ice core may originate from a glacier or buried snow banks. Coarse debris from rock falls accumulates and becomes "cemented" by water percolating up through the rubble and refreezing.

Timișoara to conduct the investigation and publish the results in papers in Elsevier's Remote Sensing of Environment and Elsevier's Quaternary International journals.

TECHNOLOGY AND METHODOLOGY

For both the rock glacier and lake studies, the team used complementary sets of optical and radar satellite images. Optical imagery included a stereo panchromatic dataset from a Corona KH-4B satellite reconnaissance mission, a SPOT 5 satellite image, and a set of Pléiades satellite stereo pair images. The dates for the Pléiades dataset coincided with field investigations, allowing scientists to develop a 4-meter-resolution digital terrain model. This model allows orthorectification and co-registration of optical and radar data, to remove image perspective (tilt) and relief distortions. The corrected images have a constant scale, displaying features in their true positions.

Romanian researchers assisted with both field research and geophysical expertise. They conducted two field surveys in 2014 using global positioning system (GPS) instruments, recording measurements at 15 locations with field accuracies of 20 to 150 centimeters. Post-processing improved the accuracies to between 12 and 65 centimeters, which ultimately helped improve the displacement estimates for both the rock glacier and alpine lake shoreline change analyses.

ROCK GLACIERS

In the rock glacier study, the team used synthetic aperture radar (SAR) satellite and radar interferometry (InSAR) techniques to successfully capture short-term and seasonal rock glacier movements. Developed initially by the U.S.

D022011

COURTESY MÎNDRESCU MARCEL, STEFAN CEL MARE UNIVERSITY OF SUCEAVA

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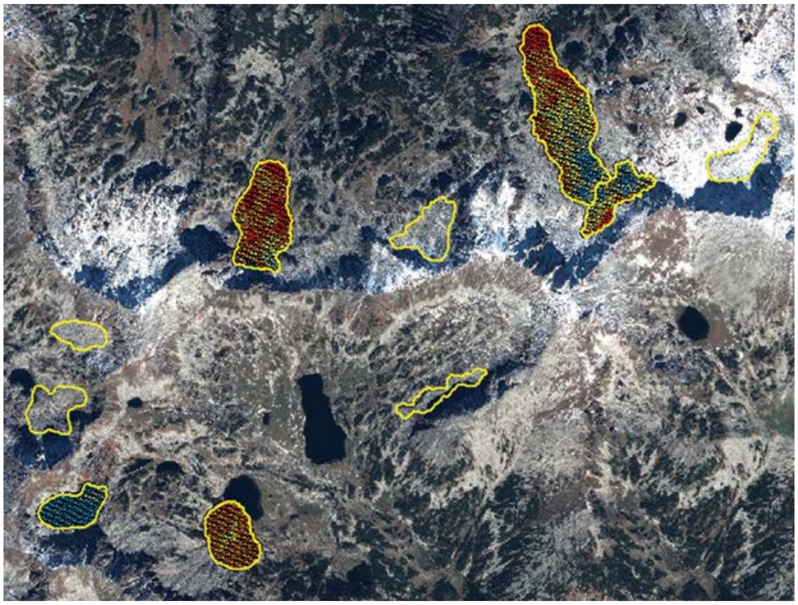
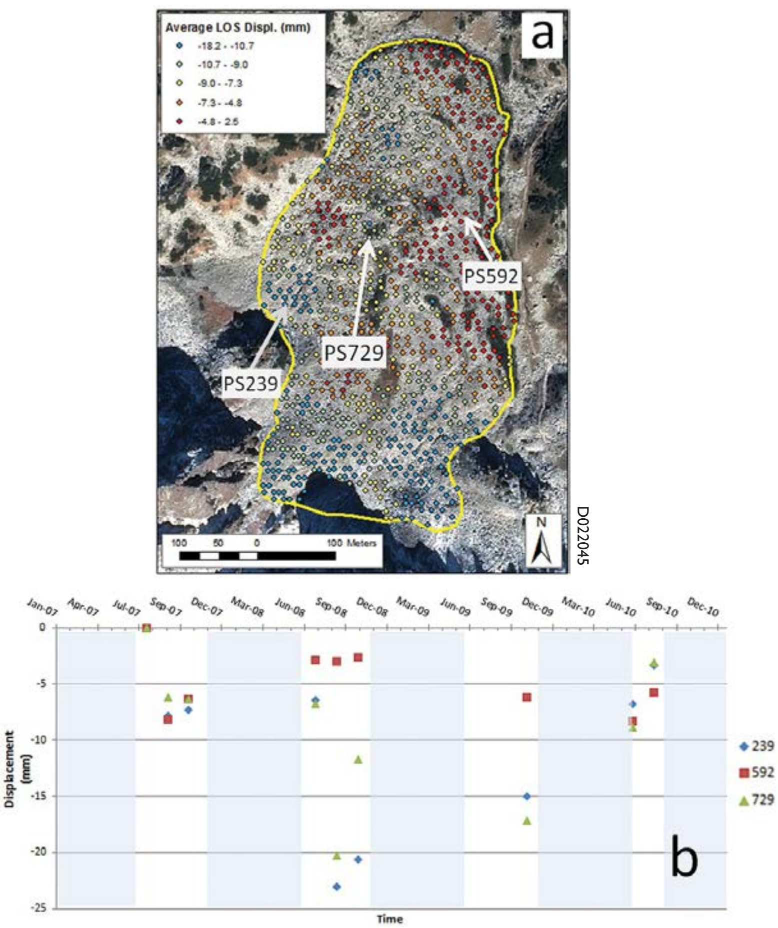


The team used satellite radar imagery and Interferometric Synthetic Aperture Radar (InSAR) techniques to help measure seasonal line-of-sight displacements of rock glaciers in the Carpathian Mountains. Colors denote rock glacier activity; the blue and light green markers indicate activity, while red and orange areas are inactive.



The InSAR result (a) from one of the studied rock glaciers indicates average line-of-sight displacements at individual point targets. The graph (b) shows displacement trends of three representative InSAR point targets over time.

D022016

military and NASA's Jet Propulsion Laboratory in the 1980s, InSAR enables topographic and ground deformation mapping using two or more radar images of the Earth's surface collected by orbiting satellites or aircraft. The team employed a variety of InSAR processing techniques to detect, monitor, and evaluate subtle landscape changes. The Japan Aerospace Exploration Agency Earth Observation Research Center provided the Advanced Land Observing Satellite (ALOS) data.

Using multi-temporal analyses of high-resolution optical satellite imagery, the study revealed the small-scale dynamic nature and slow geomorphologic evolution of rock glaciers between 1968 and 2014. The study concluded that the Carpathian rock glaciers moved very slowly — only a few centimeters per year — compared to other rock glaciers around the world. The slow movement is likely due to a thin permafrost layer beneath their surface. However, these movements have slightly accelerated during warmer periods since 2007.

GLACIAL LAKES

The second study, published in Quaternary International, examined surface area change in lakes near the same rock glaciers in the Retezat Mountains. The study area was selected because the Southern Carpathians host most of the alpine lakes in Romania, including both the widest and deepest glacial lakes.

The team analyzed the surface area of 27 lakes in the region and found that their areas fluctuated over the 47-year observation period. While the total surface area increased by only 1 percent between 1968 and 2014, over half of that growth occurred during the last seven years of the study period. The growth was 1.4 times larger from 2007 to 2014 than from 1968 to 2007, changing 7.9 times faster during the last seven years of the study period.

This study shows that lake size fluctuated in correlation with several key variables: lake elevation, lake depth, and land cover as well as catchment size and aspect, which are associated with rainfall collecting capacity.

A recent climatological analysis in the Carpathian region suggests temperatures are increasing, particularly during the last three decades. Wind speed decreased in every season, while precipitation showed no significant changes. The team posits that the relatively stable behavior of the glacial lakes may be caused by small precipitation variations. That is, seasonal snow-melt and rainfall control the water levels of the alpine lakes more than permafrost thaws.

The study also found that the intensity of the geomorphological processes is mainly controlled by the catchment aspect, which is significantly influenced by rainfall.

CONCLUSIONS

In the Southern Carpathian Mountains, rock glaciers and alpine lakes are changing slowly. But the SwRI-developed methodology determined that these small, slow changes have been accelerating slightly in the past decade or so as temperatures warm. The slow but accelerating pace of both changes should be substantiated by longer-term studies.

This multidisciplinary approach establishes a new methodology that has broad applications around the world. SwRI sees immediate applications in the United States to better understand a range of safety hazards associated with climate change, including rockslides and avalanches occurring in Colorado's Front Range and Utah's La Sal Mountains. These techniques can also be used for similar studies in further investigations around the globe. Focusing on areas where temperature changes are relatively large will support making shorter-term predictions of hazards.

Questions about this article? Contact Necsoiu at (210) 522-5541 or marius.necsoiu@swri.org.

Source: Information contained in this story can be found in "Rock Glacier Dynamics in Southern Carpathian Mountains from High-Resolution Optical and Multi-Temporal SAR Satellite Imagery," Necsoiu M., A. Onaca, S. Wigginton and P. Urdea. DOI: 10.1016/j.rse.2016.02.025, Remote Sensing of Environment. Vol. 177, pp. 21-36. 2016 and "Recent Morphodynamics of Alpine Lakes in Southern Carpathian Mountains using High-Resolution Optical Imagery," Necsoiu M., M. Mindrescu, A. Onaca, and S. Wigginton. DOI: 10.1016/j.quaint.2015.12.032, Quaternary International. in production. 2016

D022014

ABOUT THE AUTHOR

Dr. Marius Necsoiu, a remote sensing specialist at SwRI, makes GPS-based field measurements with Brigitte Magori, a Romanian student who served on the international project team. Skilled in developing collaborative and interdisciplinary solutions to Earth and planetary sciences problems, Necsoiu has also written or collaborated on more than 70 technical papers and reports.

Graduate students from Romania's West University of Timișoara assist SwRI scientists in gathering field data on rock glaciers with geophysics instruments.

D022015

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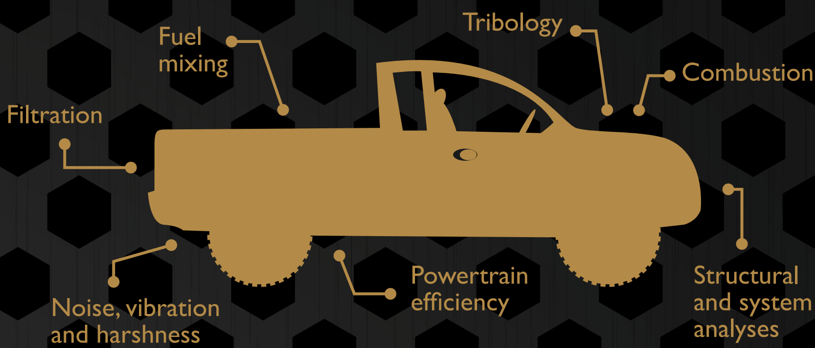
Since its inception in 1947, SwRI has dedicated extensive resources toward serving the automotive industry. Today, more than 1,000 SwRI employees work on automotive-related projects. We provide expertise in vehicles, engines, fuels, and lubricants for light-, medium-, and heavy-duty applications as well as off-road, rail, and marine systems.

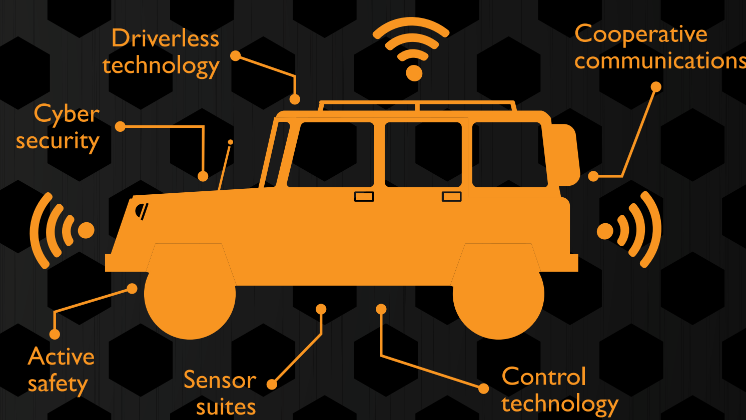


ENGINES & COMPONENTS

SwRI experience ranges from design and development of component and system upgrades to "clean sheet" full-engine designs to meet new product requirements, improve exhaust emissions, increase fuel economy, and gain higher power output.

INTELLIGENT VEHICLES & CYBER SECURITY

SwRI has automated 15 types of vehicles, ranging from golf carts and SUVs to Class 8 tractor trailers, using low-cost, high-performance perception, path planning, and control technologies for commercial and military vehicles. As vehicles become increasingly dependent on computers for systems such as engine timing and anti-lock brakes, SwRI works to safeguard vehicles from cyber threats.



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NEW HORIZONS SURVEYS SOLAR WIND

In addition to collecting stunning images and science in the Pluto system, NASA's New Horizons spacecraft also measured properties of the solar wind in the outer solar system. Measuring how the wind evolves as it travels billions of miles from the Sun, scientists made breakthrough discoveries about how solar wind interacts with Pluto's tenuous atmosphere after traveling billions of miles from the Sun.

SwRI operates the Solar Wind Around Pluto (SWAP) instrument, which measures the flow of charged particles emitted by the Sun. Data show that the tumultuous flow of solar particles calms and becomes more uniform by the time it reaches Pluto's orbit. In the inner solar system, the solar wind is more variable and consists of a mixture of episodic eruptive solar events and regular fast and slow wind streams that interact with one another.

"Differences in speed and density average together as the solar wind moves out," said SwRI's Dr. Heather Elliott, a member of the SWAP team. "But the wind is still being heated as it travels and faster wind runs into slower wind, so you see evidence of the Sun's rotation pattern in the temperatures even in the outer solar system."

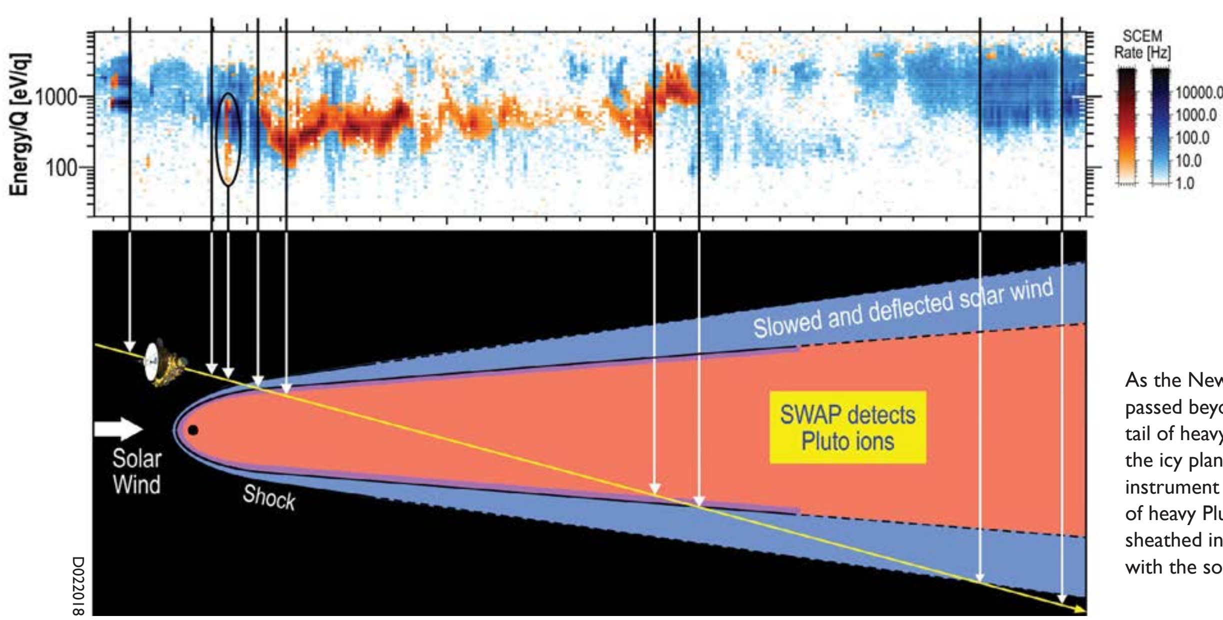
SWAP also provided a unique set of observations allowing scientists to characterize the novel nature of the Pluto/solar wind interaction, while charting the structure of the interaction region. Unlike Earth, whose atmosphere is shielded from the solar wind by a strong magnetic field, Pluto has a very weak field. As such, its atmosphere interacts directly with the solar wind.

"SWAP cannot make detailed composition measurements," Elliott said. "However, the instrument responds differently to light ions like those in the solar wind than it does to heavier ions. We were able to use this difference to distinguish between the light solar wind ions and heavy ions originating in Pluto's atmosphere."

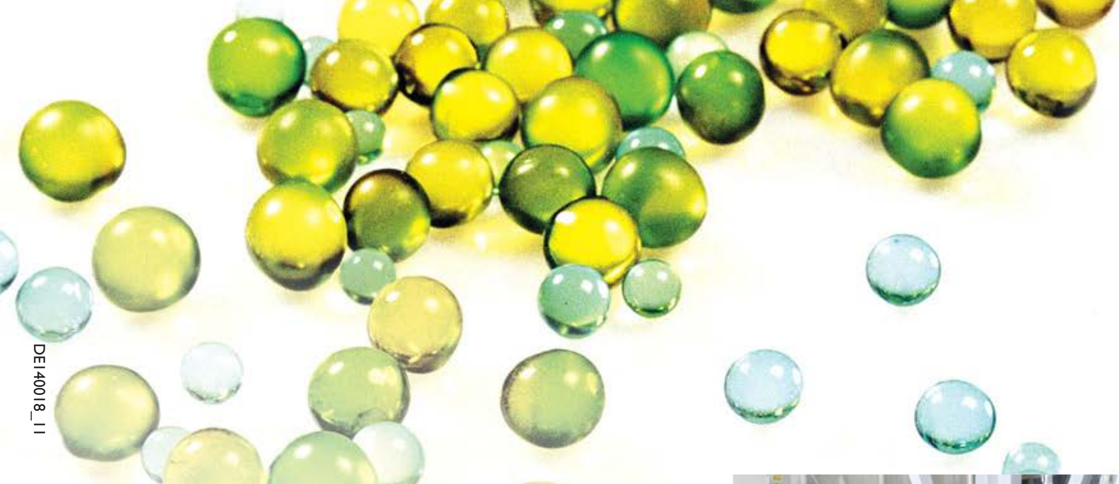
As the solar wind flows around objects in the solar system, it pushes on the Sun-facing side and pulls the opposite regions into an elongated tail structure. After closest approach, New Horizons traveled through Pluto's tail as it left the system. SWAP found that the tail region was dominated by heavy Plutogenic ions and surrounded by a sheath of solar wind ions.

SWAP also measures how neutral interstellar material becomes ionized and is "picked up" by the solar wind. These interstellar pickup ions can have up to twice the speed and four times the energy of the solar wind. Farther out in space, these ions may be the seeds of extremely fast energetic particles. Known as anomalous cosmic rays, these phenomena pose a radiation threat to astronauts closer to Earth. These ions also play an important role in shaping the boundary where the solar wind hits interstellar space.

New Horizons, the only operating spacecraft in the outer solar system, is the first mission in NASA's New Frontiers program, managed by the agency's Marshall Space Flight Center in Huntsville, Ala. The Johns Hopkins University Applied Physics Laboratory designed, built, and operates the New Horizons spacecraft and manages the mission under Principal Investigator Dr. Alan Stern's direction. SwRI leads the science mission, payload operations, and encounter science planning for NASA's Science Mission Directorate. The NASA Heliophysics program also supported the analysis of these observations.



As the New Horizons spacecraft passed beyond Pluto, it traversed a tail of heavy ions emanating from the icy planet. The SWAP instrument measured a population of heavy Plutogenic ions (in red) sheathed in lighter ions associated with the solar wind (in blue).



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Producing the Perfect Particle

THREE NEW MILLS MULTIPLY CAPABILITIES, CAPACITY

When developing new compounds, milling allows chemists to control particle size, stability, and uniformity to meet specific needs for food, cosmetics, biofuel, and pharmaceutical applications. SwRI now has five different mills to meet a variety of chemical extraction and particle mixing and sizing needs.

"Controlling particle size and morphology is critical, so it is extraordinary to have this variety of milling services available," said SwRI's Dr. Hong Dixon, who specializes in biomaterials and drug development. "And all these mills are Current Good Manufacturing Practice compliant."

SwRI offers a full range of services for formulation development and drug discovery, from modeling and synthesis to encapsulation, analytical support, and pilot-scale production. The Institute specializes in controlled release strategies, using a range of particle processes such as coating and surface modification to address clients' needs.

"With five mills at our disposal, we can break a substance down in one instrument and use another to reduce it further," Dixon said. "We offer additional particle processes, such as spray drying or fluidized bed coating, to encapsulate compounds for taste/smell masking, targeted or triggered release, and other needs."

Since 1949, SwRI scientists have worked with clients around the world to develop new encapsulation technologies. As a pioneer in the field of microencapsulation, SwRI provides contract research and development for pharmaceutical, nutraceutical, food, consumer product, agricultural, oil and gas, and other industries seeking formulation development.

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Above left: SwRI's pin mill works like a high-tech blender, breaking up substances through repeated impacts, to produce particles on a micrometer scale.
Above right: This ball mill produces extremely fine, well-mixed particles.
At right: Using this high-shear mixer, chemists emulsify compounds to reduce or disperse particles or create uniform sizing.
Below: This bead mill breaks down particles by agitating beads in a chamber to grind compounds down to nanometer size.

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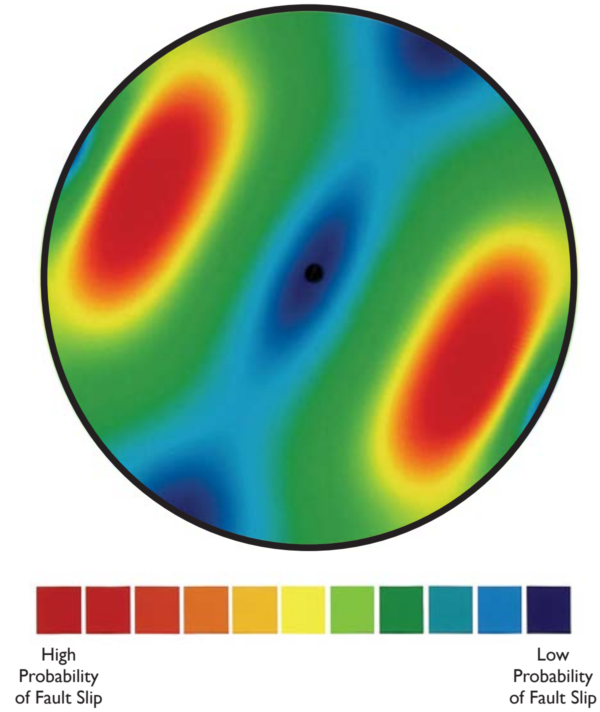
Predicting man-made earthquakes



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In the late 1990s, SwRI geologists developed 3DStress® software to identify the likelihood of a damaging earthquake within the vicinity of a potential high-level nuclear waste repository. This award-winning software has since been used extensively to evaluate oil and gas production and characterize geothermal reservoirs.

The latest version will offer new tools to help mitigate the frequency and distribution of induced, or "man-made," earthquakes associated with injecting wastewater into deep disposal wells. Within the past decade, otherwise seismically stable areas in Oklahoma, Texas, Ohio, and Kansas have seen increasing earthquake activity associated with injection wells. States are starting to introduce regulations mandating a seismic analysis before drilling new wells.

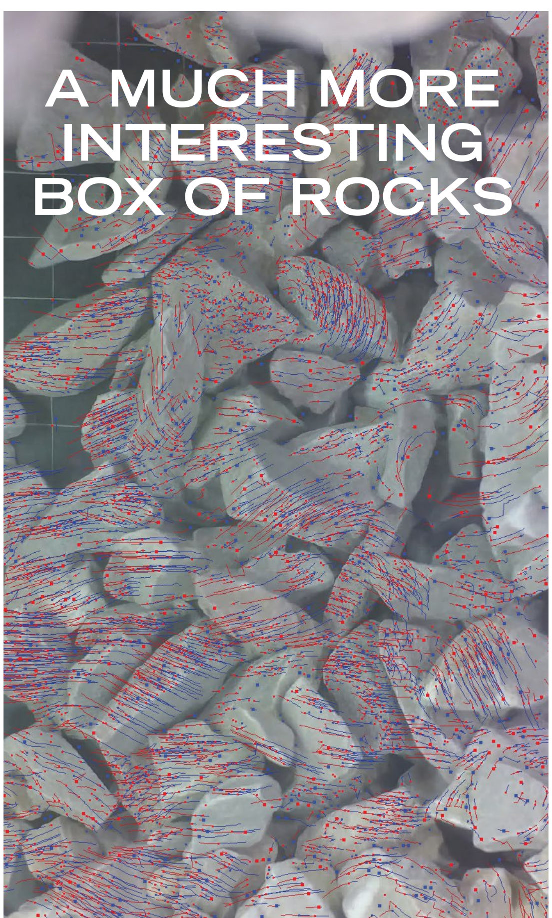
"If you plan to inject a large volume of water at a certain rate in an area that has known faults, 3DStress can assess the earthquake risk and predict magnitude," said Dr. Alan Morris, an SwRI geoscientist who led the current software updates.

Most petroleum wells produce a substantial amount of water along with the oil and gas. Managing this so-called "produced water" is an important issue. Primarily, that water is reinjected into producing reservoirs to enhance oil and gas recovery or into deep wells for disposal. It is the disposal wells that seem to increase seismic activity.

Earthquakes happen when an underground geologic fault slips. During injection, as fluid pressure increases, a previously stable fault can become unstable and slip, producing an earthquake. Man-made earthquakes are not a new phenomenon. Numerous documented examples have occurred since the 1930s from dam construction, reservoir filling, and underground fluid injection.

Using well hydraulics along with slip tendency analysis, the new version of 3DStress provides tools that can quickly evaluate fault reactivation and induced seismicity.

A MUCH MORE INTERESTING BOX OF ROCKS



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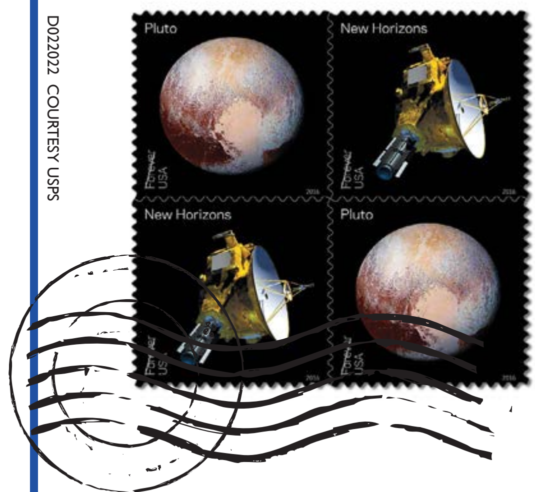
To better understand the surface of near-Earth asteroids, SwRI conducted an autonomous microgravity experiment aboard a recent Blue Origin space vehicle test flight. The Box Of Rocks Experiment (BORE) used transparent boxes to hold two types of rocks that simulate an asteroid's regolith — the layer of loose, heterogeneous material covering small asteroids. Video cameras recorded the piles of rocks through the entire flight. Researchers tracked the rocks' movements from frame to frame to better understand the dynamics involved in the formation and evolution of coarse regolith on small asteroids.

"BORE was designed as a simple, no-moving-parts experiment to study the settling effects of regolith," said SwRI's Dr. Dan Durda, BORE principal investigator. "We know very little about the low-gravity geological processes on the surfaces of these small bodies. Even watching the jostling behavior during low-speed collisions as these regolith simulants settle in microgravity can teach us a lot about what to expect as we set off to explore them."

BORE is one of three experiment payloads designed and developed for eventual human-tended suborbital spaceflight under SwRI's suborbital science program, led by SwRI Associate Vice President Dr. Alan Stern.

"This is an exciting time," said Stern. "Congratulations to Blue Origin and the BORE team. We are looking forward to many more flights and many more kinds of experiments in the coming era of commercial suborbital space flight."

Moments before re-entry, BORE experienced an asteroid-like gravity field allowing rocks to settle the way they would on a small asteroid. The red and blue tracking "blips" are used for data analysis.



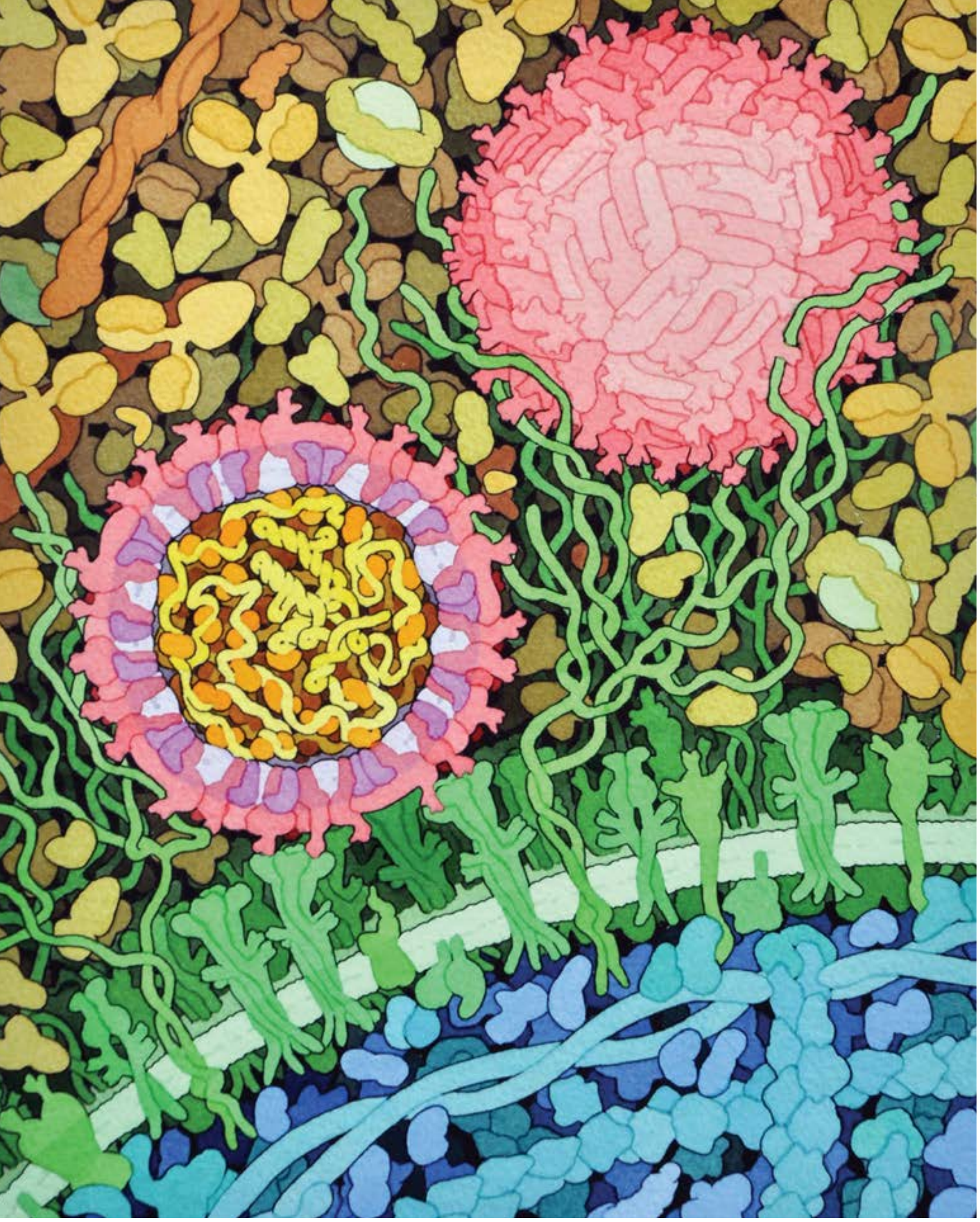
D022022 COURTESY USPS

Special delivery: Earth to Pluto

In 2006, NASA placed a now-obsolete 29-cent "Pluto: Not Yet Explored" stamp in the New Horizons spacecraft and sent it on the history-making mission to Pluto and beyond. On May 31, the Postal Service released the "Pluto—Explored!" stamp, recognizing the first reconnaissance of Pluto in 2015 by NASA's New Horizons mission.

"Since the early 1990s the old, 'Pluto: Not Yet Explored' stamp served as a rallying cry for many who wanted to mount this historic mission of space exploration," said SwRI's Dr. Alan Stern, New Horizons lead scientist. Stern unveiled the new stamps at the first-day-of-issue ceremony at the World Stamp Show in New York City. And in July, the stamp aboard the spacecraft received a Guinness World Record for the furthest distance traveled by a postage stamp, having traveled more than 3 billion miles to Pluto and beyond.

The souvenir sheet of four stamps contains two new stamps appearing twice — an artist's rendering of the New Horizons spacecraft and an image of Pluto taken by the spacecraft.



D022021 COURTESY DAVID GOODSELL ©

The outside of one Zika virus particle, and a cross section of another, interacts with a cell.

RHODIUM SOFTWARE TARGETS ZIKA

The rapid spread of the mosquito-borne Zika virus is emerging as a global health threat. Zika symptoms are generally mild; however, the virus can cause serious birth defects when pregnant women are infected. SwRI is applying its proprietary Rhodium™ Therapeutic Drug Development Software to accelerate drug discovery for Zika.

Currently, there are no vaccines or medicines to prevent or fight the infection. SwRI is working with the U.S. Army Medical Research Institute of Infectious Diseases to find compounds to target Zika. SwRI scientists used computer modeling and 3-D visualization to screen 50,000 potential candidates in just two days. With Rhodium, chemists identified the top eight contenders for further evaluation.

"Zika is tricky," said Dr. Jonathan Bohmann, who led the development of Rhodium. "Symptoms are mild. Individuals may not know they are sick, which can spur infection rates. Rhodium rapidly reveals new possibilities to address rampant devastating diseases like Zika."

This work also will be valuable for addressing mosquito-borne Dengue fever, which is similar to Zika but with more severe symptoms. Chemists also have performed similar research for the Ebola virus. SwRI offers Rhodium drug discovery as a service.

Comet ice crystals

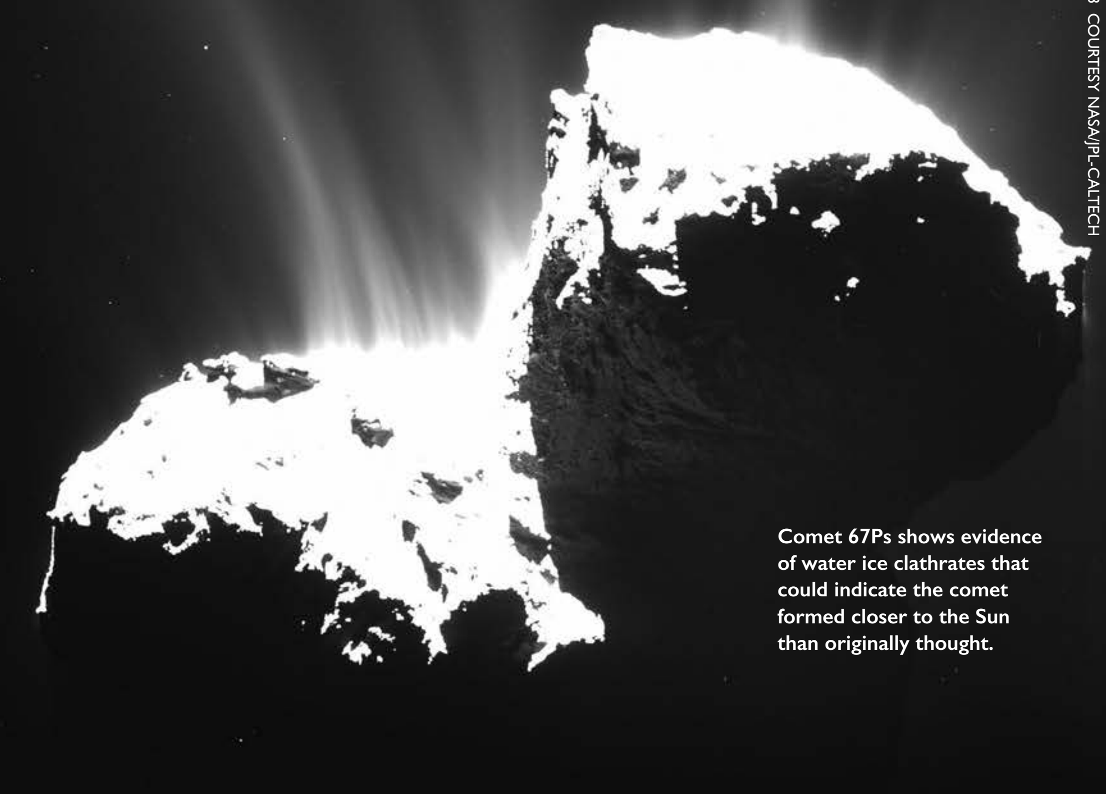
For decades, scientists have agreed that comets are mostly water ice. But what kind of ice — amorphous or crystalline — is still up for debate. Looking at data obtained by ESA's Rosetta spacecraft in the atmosphere, or coma, around comet 67P/Churyumov-Gerasimenko, SwRI scientists are seeing evidence of a crystalline form of ice called clathrates.

"The structure and phase of the ice is important because it tells us a lot about how and where the comet may have formed," says Dr. Adrienn Luspay-Kuti, lead author of a paper published in the journal Science Advances. "If the building blocks of 67P were predominantly crystalline ices and clathrates, then 67P likely agglomerated from chunks of ice closer to the Sun. The protosolar nebula closer to the Sun experienced higher temperatures and more turbulence where crystalline ices could form as the nebula cooled. More pristine amorphous ices likely dominated the colder outskirts of a developing solar system."

Amorphous water ice efficiently traps large amounts of volatile compounds, which are released simultaneously upon warming. Water clathrates are crystalline structures containing gas molecules. The volatiles locked inside the water ice actually create the stable clathrate structure. These structures release gases at characteristic temperatures, depending on the gas-phase volatile within. Luspay-Kuti led an international team of cometary experts that interpreted Rosetta spacecraft data, and found that the observed outgassing pattern indicates the nucleus of 67P contains clathrates.

"Without direct sampling of the nucleus interior, evaluating the composition of the coma provides the best clues about the ice structure and, as a result, the possible origin of cometary nuclei," said Luspay-Kuti.

This research was supported by NASA's Jet Propulsion Laboratory, Cornell University, the French National Research Agency, Centre National d'Études Spatiales, and the James Webb Space Telescope project.



D02023 COURTESY NASA/JPL-CALTECH

Comet 67Ps shows evidence of water ice clathrates that could indicate the comet formed closer to the Sun than originally thought.

D021981

SwRI Director Josh Johnson welcomes student essay winner Pranamesh Chakraborty to the ITS America 2016 conference in San Jose.

DOCTORAL CANDIDATE WINS SwRI-SPONSORED ESSAY CONTEST

Pranamesh Chakraborty, a doctoral candidate at Iowa State University, won the ITS America 2016 San Jose student essay competition sponsored by SwRI. The contest encourages engineering students to help advance transportation technologies by sharing ideas and concepts in an original essay.

Chakraborty won for his essay on "Big Data Analytics and its Role in Freeway Incident Detection." This was the fifth year that SwRI has sponsored the essay contest.

"We received many outstanding essays that presented some innovative ways students are looking at transportation issues and how to address them," said Josh Johnson, a director in the Intelligent Systems Division.

In addition to a $1,000 cash award, Chakraborty received complimentary registration to ITS America 2016 in San Jose, June 12-16, including air and hotel expenses.

SwRI ENGINEERS PLAY INTEGRAL ROLE IN Shell Eco-marathon

D022008

SwRI vice presidents Steve Marty (left) and Daniel Stewart (right) celebrate with Team Prometheus, which won the SwRI-sponsored Technical Innovation Award at SEM Europe.

SwRI mechanical and automotive engineers have provided integral technical services and mentorship at Shell Eco-marathon (SEM) events in the Americas, Europe, and Asia.

SwRI's Mark Walls monitors fuel usage.
D022009

SEM events challenge student teams from around the world in three venues to design, build, test, and drive ultra-energy-efficient vehicles. The competition is based on a simple idea: which car can cover a set distance on a test track using the least amount of fuel. SwRI has supported SEM events for the past six years as a Global Partner in Innovation.

SwRI engineers conduct technical inspections, vehicle design assessments, and fuel metering to ensure that the student vehicles compete on a level playing field.

"These events force students to think outside the box," said Rebecca Warden, an assistant manager in SwRI's Fuels and Lubricants Research Division. "They encourage high school students to pursue careers in STEM (science, technology, engineering, and mathematics). College-level engineering students gain a practical way to further their engineering education."

In March, more than 120 teams from 16 Asian countries competed in Manila, Philippines; in April, more than 120 teams from seven countries in the Americas competed in Detroit; and in July, more than 200 teams from Europe competed in London.

SwRI also sponsors the Technical Innovation Awards at each of the events. Team Tatonkatoo from the University of Colorado Boulder won the award at SEM Americas; Team Nanyang E-Drive from Nanyang Technological University in Singapore won SEM Asia; and Team Prometheus from the National Technical University of Athens, Greece, won at SEM Europe. Each team received a $2,000 prize. SwRI also sponsored a scholarship awarded at SEM Americas. Huy Nguyen, a freshman mechanical engineering student at California Polytechnic State University, was chosen from nearly 50 applicants to receive the $2,000 scholarship.

SwRI automotive engineers also helped develop the Drivers' World Championship (DWC) concept, a new component at this year's Europe event. The winning Urban Concept vehicles from the Asia and Americas events joined winning teams from Europe in a 24-lap race to determine the fastest and most energy-efficient vehicle.

The goal was to cross the finish line first while only consuming a certain amount of fuel. Race officials monitored fuel usage in real time through a system spearheaded by SwRI's Mark Walls.

The technology allowed SEM to acquire live, instantaneous measurements of liquid fuels in-vehicle. It also provided an onboard transponder that cut the energy source when the vehicle had consumed the allotted amount of fuel.

"My role in particular was to bring in the real-time precise fuel measurement," Walls said. "We assigned each team a fuel energy amount, and they had to complete the race in normal race fashion (first across the finish line) without running out of fuel. Once they hit their assigned energy amount, we shut them down remotely."

Each vehicle was provided a certain percentage of fuel above their best official regular SEM event result. "This additional amount allowed them to go a little faster than they could during the regular SEM event," Walls said. "But they could only go so much faster or else they'd run out of energy before making the required number of laps. So driving strategy can become a very important factor."

D022010 COURTESY SHELL

FLEXING SOME RESEARCH MUSCLE

Anatomical sciences have come a long way in the five centuries since Leonardo da Vinci used cadavers to sketch human physiology. More recently, biomechanical engineers have begun pairing cadavers with mechatronics to study the causes of orthopedic disease. But even state-of-the-art robotic technology cannot fully simulate the fluid movement of living muscles and tendons.

SwRI researchers hope to overcome these challenges using twisted polymer artificial muscles (TPAMs) to more accurately simulate joint movements. Using internal research funding, SwRI is developing TPAM-based actuators, up to 100 times stronger than human muscle, to study joint physiology.

"We want to create an artificial bicep and make it behave like a real muscle to study how it works in the body," said Andrew Moore, who specializes in robot testing and evaluation. "Our past research created a single muscle fiber. Now we will need to coordinate hundreds of muscle fibers to simulate an entire bicep."

For the next stage, Moore will collaborate with Travis Eliason, who specializes in musculoskeletal biomechanics at SwRI. Eliason's field often relies on joint simulators that use robotic actuators to study joint disease in cadavers. However, these hydraulic joints create rigid, linear movements. Actual human movements are more fluid, thanks to muscles that wrap around joints to soften movements and absorb shocks.

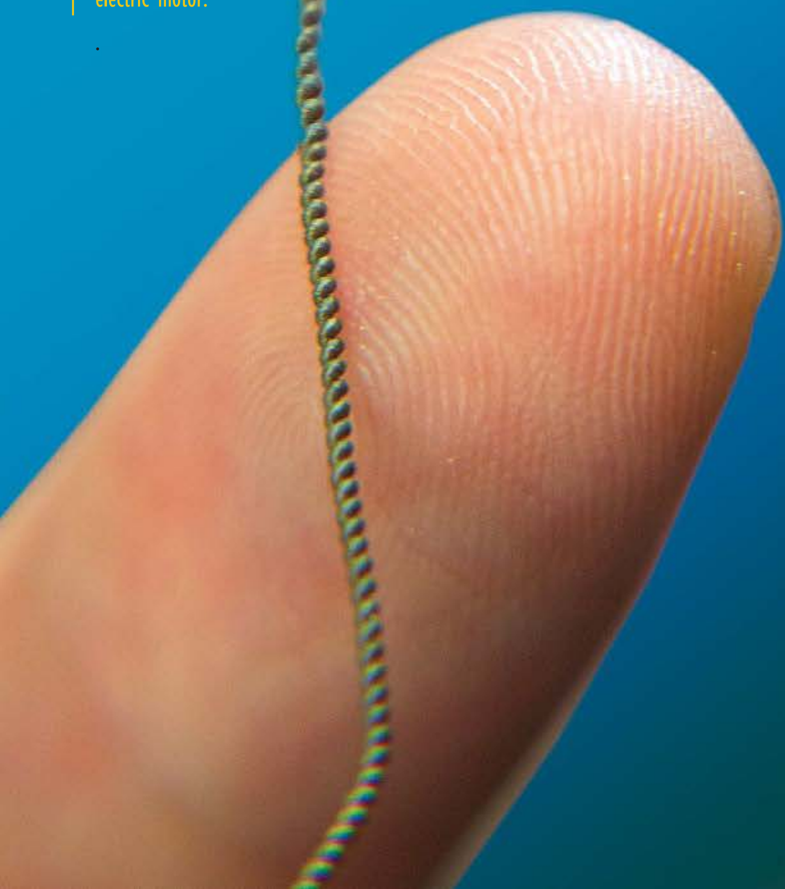
"Our idea is to make artificial muscles that simulate the action of natural muscles and allow these joint simulators to create more realistic movements," Eliason said.

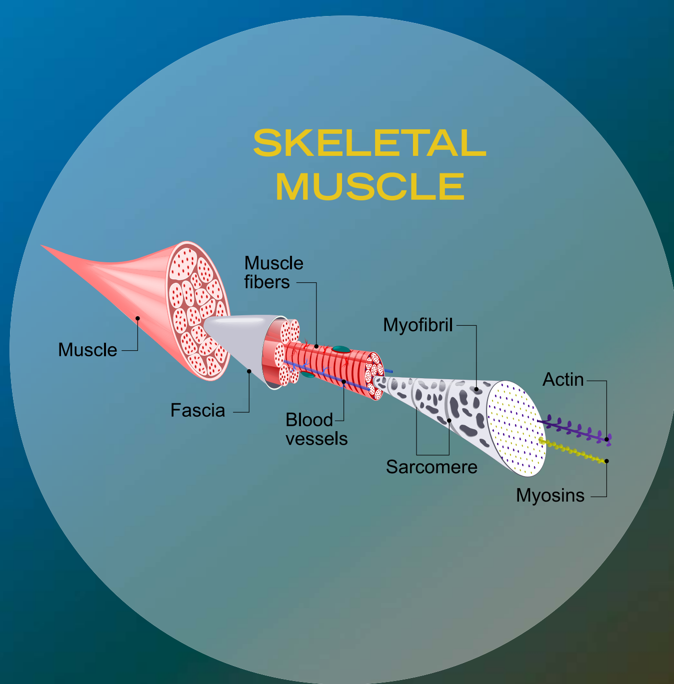
Using these devices, scientists could measure the complex internal mechanics of joints that may cause orthopedic disease. Long-term wear and tear on joints breaks down cartilage that cushions bones, causing osteoarthritis and debilitating pain, especially in knees.

"If we can determine the mechanics of a healthy joint, we can better understand how a disease changes those mechanics and, more importantly, how to put it back to normal," Eliason said.

DETAIL

Artificial muscles are estimated to be 100 times stronger than human muscles. SwRI's first TPAM weighed less than one gram while generating more than 200 grams of force. When integrated into a model aircraft, the artificial muscle successfully actuated the rudder, replacing an electric motor.





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RED PLANET ICE AGE

Using radar data collected by NASA's Mars Reconnaissance Orbiter, an SwRI-led team found evidence of an ice age recorded in the polar deposits of Mars. Ice ages on Mars are driven by processes similar to those responsible for ice ages on Earth; that is, long-term cyclical changes in the planet's orbit and tilt, which affect the amount of solar radiation it receives at each latitude.

"We found an accelerated accumulation rate of ice in the uppermost 100 to 300 meters of the polar cap," said Dr. Isaac Smith, a postdoctoral researcher at SwRI and lead author of a paper published in the May 27 issue of Science. "Radar observations of the ice cap provide a detailed history of ice accumulation and erosion associated with climate change."

Like Earth, modern-day Mars experiences annual rotation and seasonal cycles, as well as longer cycles, that influence the distribution of ice. However, the longer cycles might be more pronounced on Mars. That's because Mars' tilt changes substantially — by as much as 60 degrees — on timescales of hundreds of thousands to millions of years. By comparison, the Earth's tilt varies by only about 2 degrees over the same period.

"Because Mars has no oceans at present, it represents a simplified 'laboratory' for understanding climate science on Earth," Smith said. "Studying ice on Mars also is important to the future of human exploration of the Red Planet. Water will be a critical resource for a martian outpost."

This image, produced with the High Resolution Stereo Camera (HRSC) onboard ESA's Mars Express (MEx) spacecraft and specially processed by Dominik Neu and Patrick C. McGuire from the Freie Universität Berlin and the MEx/HRSC teams, shows spiral features signaling ice age advancement and retreat.

D022027 COURTESY ESA/DLR/FU-BERLIN/RALF JAUMANN ©

NEW VIEWS ON PERMIAN BASIN AND AUSTIN CHALK

D021667

Building on the success of the Eagle Ford Joint Industry Project, SwRI is developing similar initiatives for the Permian Basin in West Texas and the Austin Chalk in South Texas. These programs will develop mechanical stratigraphic and structural geologic results that industry can apply to improve oil and gas production in these areas.

In 2015, SwRI conducted field investigations in Permian strata in West Texas to characterize mechanical properties, tectonic settings, and deformation mechanisms such as fracture types and orientations. Results include regional maps showing fractures, faults, and folds, as well as the tectonic framework important to well planning and performance. These will help the oil and gas industry plan horizontal drilling and hydraulic fracturing to tap shale formations,

"We help the energy industry understand geology to improve the likelihood of success before investing millions of dollars into drilling thousands of feet of lateral wells," said Dr. David A. Ferrill, a director in SwRI's Geosciences and Engineering Division. "The conventional wisdom is that you can drill anywhere in the Permian and it will produce oil, but that's not the case with drilling in unconventional reservoirs. Natural fractures and other structures vary significantly throughout the basin, which influences the effectiveness of the lateral wells."

SwRI has begun a similar effort to study the geological formation known as the Austin Chalk, which overlies the Eagle Ford Formation. Historically, Austin Chalk has been exploited as a conventional fractured reservoir, producing oil and gas using horizontal drilling. Producers are starting to use hydraulic fracturing technology to exploit the Austin Chalk as a hybrid unconventional reservoir.

SwRI is investing internal resources to conduct field investigations of Austin Chalk outcrops to improve understanding of mechanical layering and natural deformation. Using this research, SwRI will develop training courses and industry-funded research to help energy companies understand the Austin Chalk and optimize well placement and stimulation programs.

BY THE NUMBERS

100 presentations given in

11 COUNTRIES

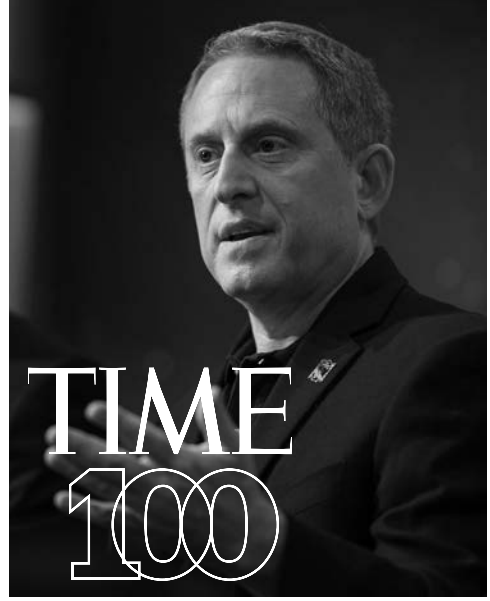
and **15** states

7 patents awarded between March and July 2016

76 articles published in

31 DIFFERENT PUBLICATIONS

COURTESY NASA



D022028 COURTESY NASA/BILL INGALLS

TIME has named Dr. Alan Stern one of the 100 most influential people of 2015. Stern, associate vice president of SwRI's Space Science and Engineering Division, serves as principal investigator of NASA's New Horizons mission to Pluto. The flyby made worldwide headlines when the spacecraft returned the first high-resolution images ever taken of Pluto and its moons. Stern was previously named to the TIME 100 in 2007 after taking over as NASA's Science Mission Directorate administrator.

"I am particularly honored to be named to the TIME 100 for a second time," Stern said. "This is an honor for the entire New Horizons team, which succeeded in exploring the Pluto system for the first time and, in doing so, made history by completing the first era of reconnaissance of the planets."

"Alan and the New Horizons team have tremendously advanced our understanding of Pluto, its moons, and the outer reaches of our solar system," said Dr. Jim Burch, vice president of SwRI's Space Science and Engineering Division.

Stern and the New Horizons team have received more than two dozen awards. Aviation Week & Space Technology bestowed on the team its 2016 Laureate Award for space exploration. The American Astronomical Society presented its Neil Armstrong Space Flight Achievement Award; AAS separately awarded Stern its Carl Sagan Memorial Award. The NASA mission also was named among the top science news stories of 2015 by Discover Magazine and Science News.

The Pluto flyby culminated July 14, 2015, when the spacecraft came to within 8,500 miles of the planet. NASA recently extended the New Horizons mission. The spacecraft will fly nearly a billion miles beyond Pluto to pass a Kuiper Belt object known as 2014 MU69.

The TIME 100, now in its 13th year, recognizes the activism, innovation, and achievements of the world's most influential individuals. The full list and related tributes appeared in the May 2 issue of TIME.

COMING UP

AWARDS

Dr. William Bottke, a planetary scientist in SwRI's Planetary Science Directorate in Boulder, Colo., was recently named a Fellow of the Meteoritical Society, recognizing his contributions to meteoritics and related endeavors. Bottke studies how meteorites, asteroids, and comets are delivered to Earth and how evidence from collisions across the solar system helps piece together its history.

Dr. Klaus Brun, a program director in SwRI's Mechanical Engineering Division, received the 2016 Industrial Gas Turbine Award given by the American Society of Mechanical Engineers International Gas Turbine Institute (ASME-IGTI). The award "recognizes sustained personal creative scientific or technological contributions unique to electric power or mechanical drive industrial gas turbine technology."

Dr. Stephen Fuselier, an executive director in SwRI's Space Science and Engineering Division, received the European Geosciences Union (EGU) Hannes Alfvén Medal for outstanding scientific contributions to understanding plasma processes in the solar system and other cosmic environments. He received the award at the EGU General Assembly in Vienna, where he also presented a one-hour lecture.

Dr. Darin L. George, a principal engineer in SwRI's Mechanical Engineering Division, received the 2016 Laurance S. Reid Award given by the International School of Hydrocarbon Measurement (ISHM). The acknowledgment is presented annually to recognize an outstanding individual who has made significant contributions to hydrocarbon measurement and/or control.

Dr. James D. Walker, director of SwRI's Engineering Dynamics Department, has been named a Ballistics Science Fellow by the International Ballistics Society (IBS). This is the highest honor within the IBS, awarded by its members "to individuals who have distinguished themselves within the ballistics community through outstanding and numerous significant contributions."

TRADE SHOWS

30th Annual AIAA/USU Small Satellite Conference, Logan, Utah; August 6-11, 2016

Tinker and the Primes, Midwest City, Okla.; August 22-24, 2016, Booth No. 39

Texas Groundwater Summit, San Marcos, Texas; August 23-25, 2016

Specialty & Agro Chemicals America; Charleston, S. C., September 7-9, 2016, Booth No. 7

45th Turbomachinery Symposium & 32nd International Pump Symposia, Houston, Texas; September 12-15, 2016

IEEE AUTOTESTCON, Anaheim, Calif.; September 12-16, 2016

American School of Gas Measurement Technology (ASGMT), Houston, Texas; September 19-22, 2016

ROSCon, Seoul, South Korea; October 8-9, 2016

5th Opportunity Crudes Conference, Houston, Texas; October 10-11, 2016, Booth No. D

High Horsepower (HHP) Summit, Chicago, Ill.; October 11-13, 2016

ASNT Annual Meeting, Long Beach, Calif. October 24-27, 2016, Booth No. 300

Automotive Testing Expo North America, Novi, Mich.; October 25-27, 2016, Booth No. 2015

International Telemetering Conference, Glendale, Ariz.; November 7-10, 2016, Booth No. 815

ExxonMobil Process Development Symposium Vendor Fair, The Woodlands, Texas; January 31, 2017

Technology & Maintenance Council (TMC), Nashville, Tenn.; February 27-March 3, 2017

SATELLITE, Washington, D.C.; March 7-10, 2017, Booth No. 123

Dixie Crow Symposium, Warner Robins, Ga.; March 20-24, 2017

Space Symposium, Colorado Springs, Colo.; April 3-6, 2017

Automate, Chicago, Ill.; April 3-6, 2017

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