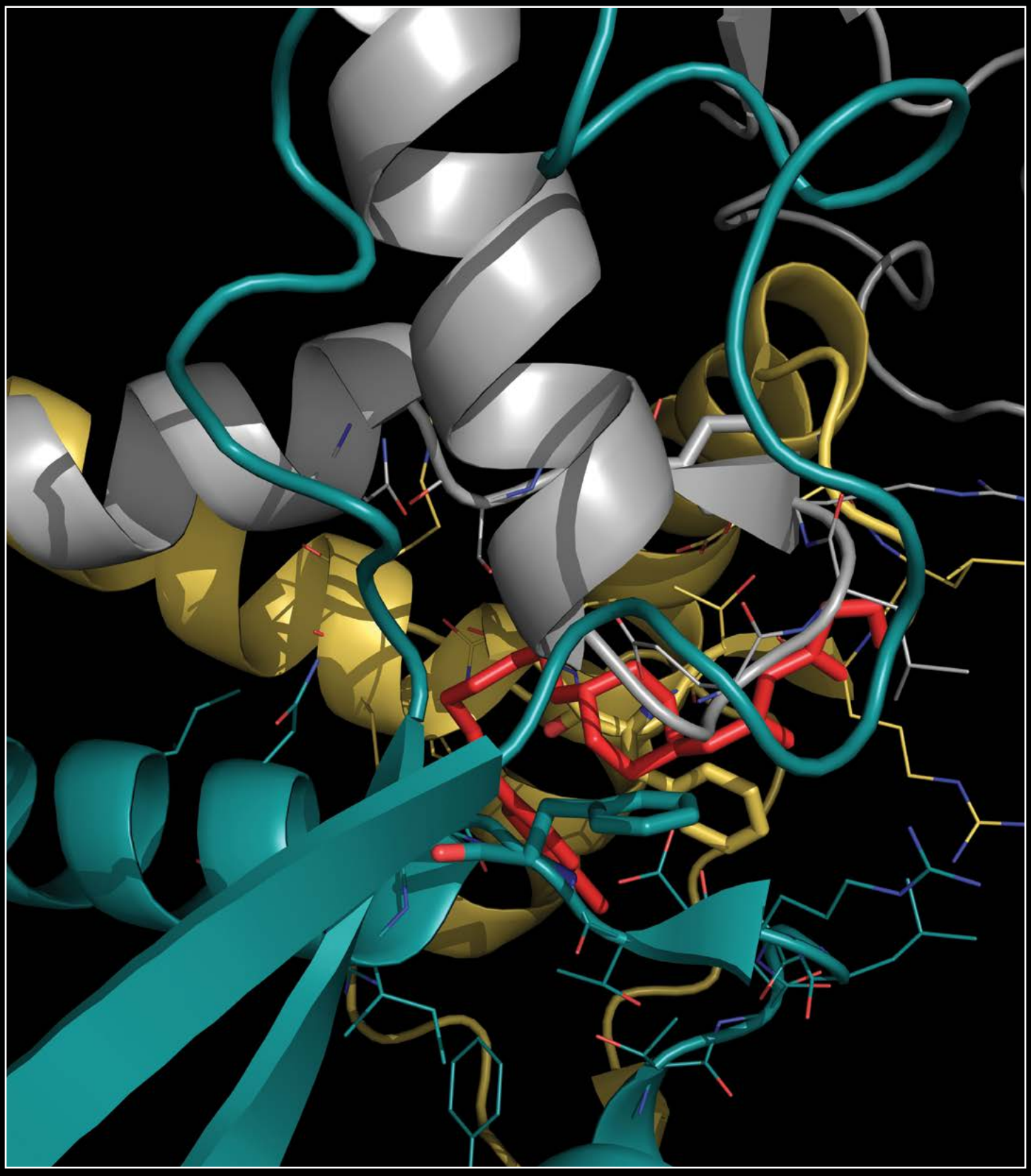
SOUTHWEST RESEARCH INSTITUTE®



2015
ANNUAL REPORT

NEW HORIZONS

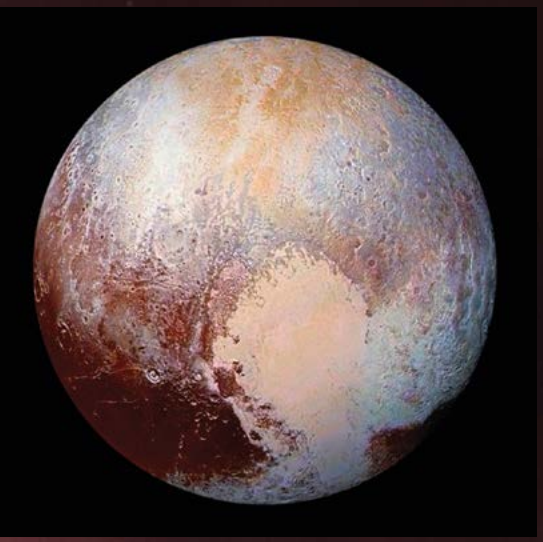
encountering PLUTO & CHARON

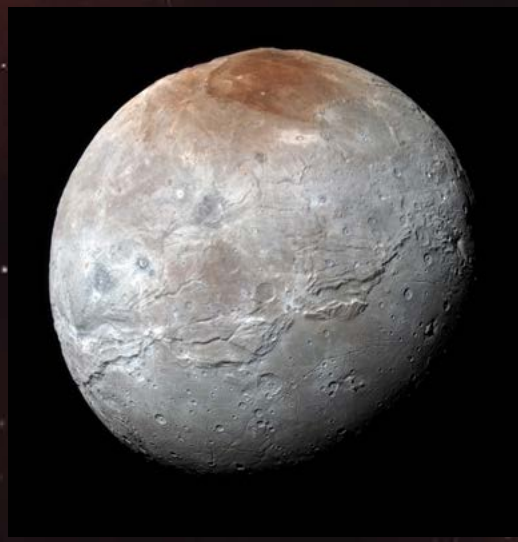
In 2015, Southwest Research Institute played a key role in arguably the science story of the year as the New Horizons spacecraft buzzed past Pluto, returning breathtaking photographs of an unexpectedly complex and geologically young surface. Images of Pluto's largest moon Charon also show evidence of a surprisingly varied and violent history. When New Horizons turned back to look at Pluto backlit by the sun, a layered hazy atmosphere was revealed. It will take a year for all the flyby data to be transmitted back to Earth, and scientists will probably spend the next decade unraveling what it all means. In association with this project, Southwest Research Institute was featured in thousands of international stories in newspapers, magazines, websites, and blogs, as well as on broadcast news. As a nonprofit research and development organization headquartered in San Antonio, Texas, we have spent the last 68 years helping government and industry clients solve their most challenging technical problems. While early efforts focused on automotive testing, environmental research, and radio direction finding, today SwRI scientists and engineers work on projects ranging from deep sea to deep space.

2015 ANNUAL REPORT

Message from the President 2
2015 Highlights 4
Internal Research & Development 5
Applied Physics 6
Automation & Data Systems 8
Automotive Engineering 10
Chemistry & Chemical Engineering 14
Geosciences & Engineering 16
Mechanical Engineering 18
Signal Exploitation & Geolocation 20
Space Science & Engineering 22
Financial Statements 24
Board of Directors, Officers & Vice Presidents 25
Advisory Trustees 26

On the cover: Southwest Research Institute chemists and high performance computer specialists joined forces to develop Rhodium™ Therapeutic Drug Development Software. This powerful new modeling and 3-D visualization tool accelerates the development of more effective treatments for diseases ranging from Alzheimer's to Ebola.





Far left: The New Horizons team informally named Pluto's heart-shaped feature "Tombaugh Regio" in honor of astronomer Clyde Tombaugh, who discovered the dwarf planet. The bright expanse of the western lobe of Pluto's "heart" is informally called Sputnik Planum. Above left: Pluto's surface sports a remarkable range of landforms that have their own distinct colors, telling a complex geological and climatological story. Above center: Pluto's high-altitude haze layer is blue and thought to be similar in nature to the haze seen at Saturn's moon Titan. Above right: Charon's color palette is not as diverse as Pluto's; the moon's most striking feature is the reddish north polar cap, informally named Mordor Macula.

Courtesy NASA / JHUAPL / SwRI.

The Institute's multidisciplinary, collaborative approach allows us to successfully solve our clients' most challenging problems.

Since our founding nearly seven decades ago, innovation in science and technology has been a hallmark of Southwest Research Institute. It's not hyperbole to say we are committed to advancing science and applying technology to benefit government, industry, and all of humankind. That is our mission. Our multidisciplinary, collaborative approach allows us to successfully solve our clients' most challenging problems. SwRI has a track record of success that is inculcated in our culture, and I am pleased to present this annual report, which provides highlights of select programs and achievements in 2015.

Our scientific and technical expertise was front and center this summer when NASA's New Horizons spacecraft reached its target — the Pluto system — at the far reaches of the solar system. SwRI led the New Horizons science mission gathering data and photographic images of the last classical planet (technically, a dwarf planet) in our solar system to be visited by a spacecraft. The closest encounter lasted just a few hours, but the mission was decades in the making and the transit from Earth took more than 9 years! The New Horizons Pluto mission so enthralled the world that *Discover* magazine selected it as the top science story of the year. Closer to home, our scientists are leading the science mission for the Magnetospheric Multiscale (MMS) mission. In 2015, NASA launched four MMS spacecraft into the Earth's magnetosphere to investigate one of the most basic and important physical processes in the universe — magnetic reconnection.

We continue developing and managing globally recognized multi-client cooperative research programs. For instance, we launched the seventh phase of the Clean High-Efficiency Diesel Engine consortium and the second phase of a program assessing onboard sensors to measure particles in engine emissions. Our Automotive Consortium for Embedded Security™ is addressing concerns about automotive cyber security. In addition to our consortia for the automotive industry, our Eagle Ford Joint Industry Project improves the understanding of how geologic formations affect petroleum production, and ROS-Industrial is advancing automation in the manufacturing arena. We also joined the Republic of Korea's Ulsan Consortium to help decommission aging nuclear power plants in Asia.

The Institute's science and technology programs continue to gain recognition for their innovation, with four of our technologies named as finalists for 2015 R&D 100 Awards. Two — Cased Pipeline Corrosion Model for evaluating corrosion conditions of cased pipeline sections, and RANGER, a vehicle localization technology that enables precise navigation for automated vehicles — were named among the 100 most significant innovations for 2015. Likewise, the Connected Automation to Enhance Work Zone Safety program was a finalist in the 2015 Best of Intelligent Transportation Systems Awards.

We are collaborating with universities and industry organizations working with The University of Texas at San Antonio on the CONNECT program, funding biofuels and pharmaceutical research programs. We also formalized a program with the University of Colorado at Boulder to allow graduate students to contribute to SwRI space science programs.

From the President

Locally, the Institute remains committed to helping our community through science, technology, engineering, and mathematics outreach and support. Employees regularly mentor students in and around San Antonio, supporting robotics and cyber security teams and sponsoring student engineer programs. For the third year in a row, the Northside Independent School District recognized the Institute with a 2015 Partner of the Year Award. More than 300 employees and their families participated in the annual SwRI Cares program and almost 80 percent of our employees participated in the 2015 United Way campaign; SwRI and its staff raised more than $800,000.

We continue to invest in our infrastructure and facilities, including $2.5 million in pollution abatement systems for our fire research facilities in 2015. We expanded our heavy article test facility to better support robotics and aerospace clients and completed a 1,200-square-foot small arms facility to evaluate small-caliber guns and ammunition as well as light armor materials. We also opened a new office in the Dayton, Ohio, suburb of Beavercreek, to support projects associated with nearby Wright-Patterson AFB.

We continue to invest in our vibrant internal research and development (IR&D) program that encourages scientists and engineers to explore innovative ideas and enhance our science and technology base. We initiated 88 new IR&D projects and spent more than $7.2 million on internal research in 2015. Many of these projects are described throughout this report.

Historically, Institute revenue sources are split at a nearly even ratio between government and industry clients, which allows us to maintain a balanced workload despite spending fluctuations. Each year we face fiscal challenges associated with government policies and industry variables. Despite these challenges in 2015, our technical programs generated revenues of $592 million, with net income of nearly $24 million. The Institute is a significant contributor to the overall South Texas economy as the seventh largest employer headquartered in San Antonio. Our payroll of more than $226 million and other associated business activities had a billion-dollar impact on the San Antonio and Bexar County area.

We remain committed to expanding our technical strengths and resources to meet strategic and fiscal goals, while continuing our history of growth and ability to provide rich career opportunities for our staff. A large backlog of contracts and proposals is an encouraging sign for a successful 2016. Programs include developing solar energy technologies, integrating a precision direction finding system, and managing an extensive new Environmental Protection Agency emissions program. New space science projects include building space instruments for a mission to Jupiter's moon Europa and developing a mission to Jupiter's Trojan asteroids.

I appreciate the support from the Board of Directors and look forward to working with them and the Advisory Trustees and Institute staff. Our vision is to be our clients' first choice for independent, advanced science and applied technology solutions for problems from deep sea to deep space, and everything in between.

Adam L. Hamilton, P.E.
President

SwRI offers a vibrant internal research and development program that encourages scientists and engineers to explore innovative ideas and enhance our science and technology base.

HIGHLIGHTS 2015

For the first time, Southwest Research Institute is building spacecraft — eight microsatellites — for NASA's **Cyclone Global Navigation Satellite System** (CYGNSS). We've led science missions, such as the mission to Pluto, and built instruments, including the Alice spectrometer and the SWAP particle detector aboard New Horizons. We've also developed other space hardware, such as an actuator control unit and flight control computers for a commercial space utility vehicle. But these are the first SwRI-constructed spacecraft. The CYGNSS microsatellites will launch in late 2016 to improve hurricane forecasting by monitoring changes in storm intensity.

In 2015, SwRI was awarded a contract to continue operating the **Texas Manufacturing Assistance Center** (South Central Region). For more than 20 years, TMAC has offered local manufacturers technical expertise to decrease lead times, increase throughput, reduce costs, and improve quality.

SwRI took home two prestigious **R&D 100 Awards** from ceremonies held in Las Vegas. *R&D Magazine* recognized SwRI's CAsed Pipeline COrrosion Model (CAPCOM) and RANGER localization technology as being among the 100 most significant innovations for 2015. Two other SwRI research initiatives were among the finalists, the FOCAS® Hot Gas Transient Reactor and the Dynamic Crevice Sampling System.

We invested $2.5 million in **pollution abatement systems** for fire research facilities and received a $500,000 grant from the Texas Commission on Environmental Quality to offset some of the costs of this new technology.

For the second year in a row, the **Alliance for Work-Life Progress** awarded SwRI with a Seal of Distinction in 2015. The Institute was one of only five companies headquartered in Texas to receive this recognition.

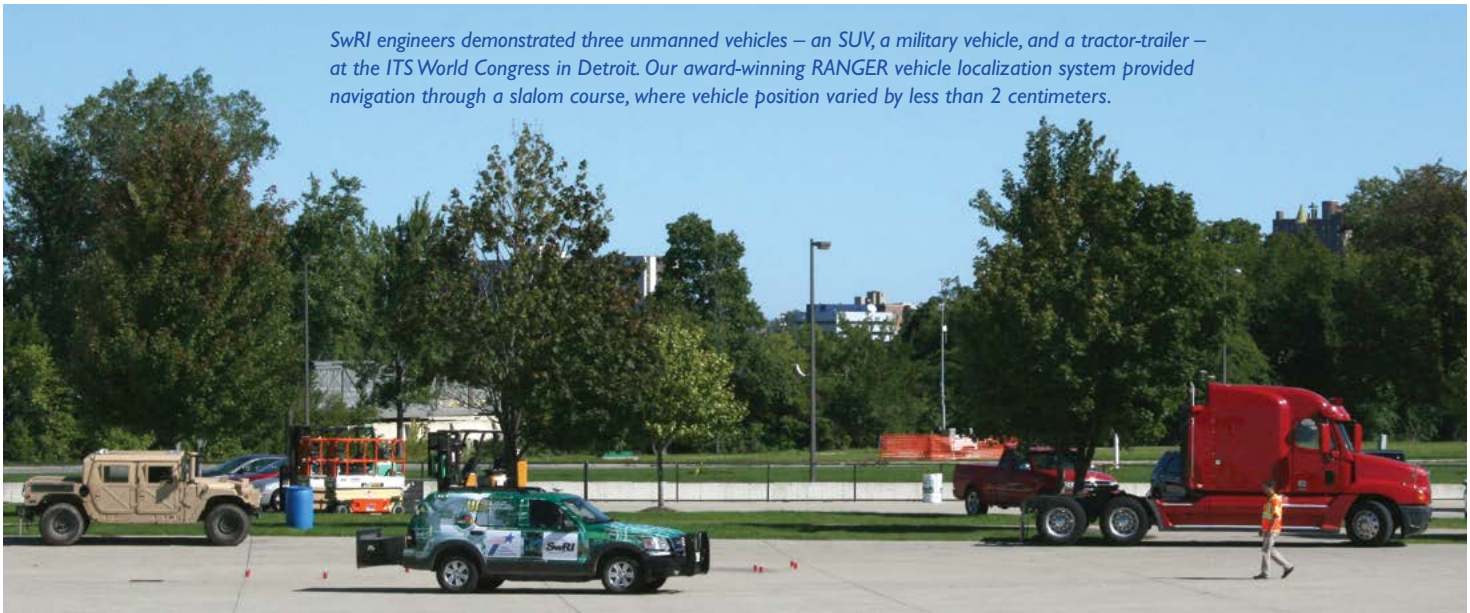
In 2015, numerous staff members received recognition for **professional accomplishments**, including President Adam L. Hamilton, who was named to the Board of Directors of the San Antonio Chamber of Commerce. **Award winners** included Dr. Daniel D. Durda, who received the American Astronomical Society Carl Sagan Medal; Dr. David McComas, who received NASA's Exceptional Public Service Medal; Mike Birke, who received the ASTM International Daniel H. Green Award; and Dr. Richard Garcia, who received the Society of Automotive Engineers' Forest R. McFarland Award.

Staff members honored as **Fellows** include Dr. James Walker for the American Institute of Aeronautics and Astronautics; Dr. Charles Anderson and Dr. Gordon Johnson for the International Ballistics Society; Dr. Nathaniel Putzig as a NASA Planetary Science Early Career Fellow; and Dr. Alan Stern, who was named an Honorary Fellow of the Royal Astronomical Society. Dr. Kathryn Dannemann was elected a trustee of ASM International. Miriam Juckett and Bill Ryan were among the *San Antonio Business Journal*'s "40 Under 40" rising stars.

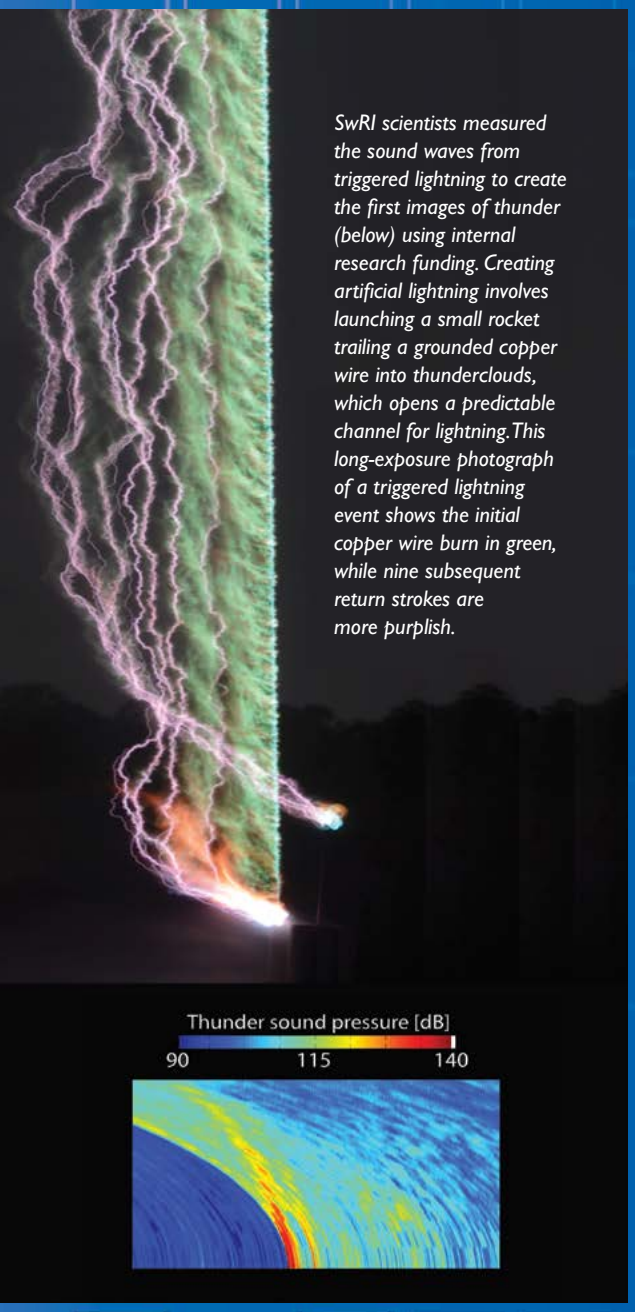
The **SwRI staff** numbered **2,708** employees. Of those, 280 hold doctorates, 497 hold master's degrees and 676 hold bachelor's degrees. The Institute received 51 U.S. patent awards, filed 39 patent applications, and submitted 66 invention disclosures. The technical staff published 603 papers and gave 495 presentations.

Two staff members were invited to speak at **congressional events** in 2015. On behalf of the American Geophysical Union, Dr. Cynthia Dinwiddie spoke at an inaugural congressional geoscience reception on Capitol Hill. Dr. Alan Stern testified to the U.S. House of Representatives' Subcommittee on Space.

D021661



SwRI engineers demonstrated three unmanned vehicles – an SUV, a military vehicle, and a tractor-trailer – at the ITS World Congress in Detroit. Our award-winning RANGER vehicle localization system provided navigation through a slalom course, where vehicle position varied by less than 2 centimeters.



D021662/CourtesyUF/FIT/ICLRT

SwRI scientists measured the sound waves from triggered lightning to create the first images of thunder (below) using internal research funding. Creating artificial lightning involves launching a small rocket trailing a grounded copper wire into thunderclouds, which opens a predictable channel for lightning. This long-exposure photograph of a triggered lightning event shows the initial copper wire burn in green, while nine subsequent return strokes are more purplish.

IR&D 2015

Our internal research and development program allows SwRI engineers and scientists the freedom to explore innovative, unproven concepts. The program, which bridges new ideas with advanced concepts, invests in technology our clients will need in the future.

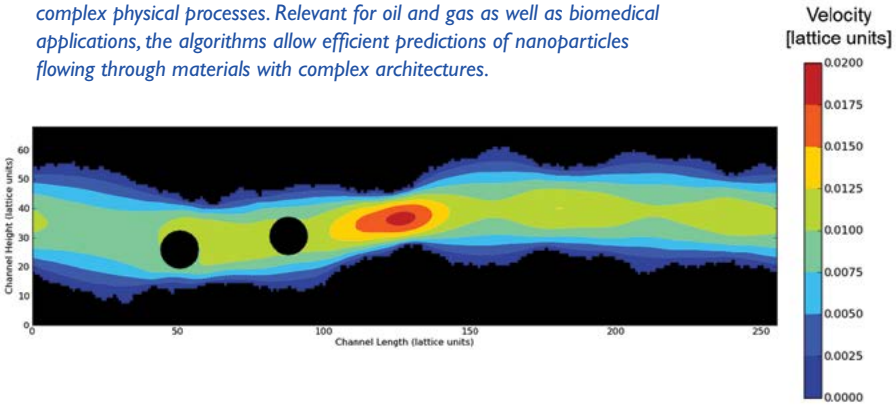
This year, we launched a Computational Optimization Focused Internal Research Program to evaluate advanced computational methods and their application to our project needs. Solving complicated problems often requires long computational runs that can be quite costly. The goal of the program is twofold: to identify ways to solve problems more cost effectively and efficiently as well as to promote collaboration among researchers across our technical divisions.

In 2015, SwRI initiated 88 new projects and spent more than $7.2 million on internal research. Some of this year's projects include:

- Detecting distracted drivers using vehicle data
- Lubricant impact on fuel economy
- Supernova modeling
- Detecting explosions from balloon-borne platforms
- Enhancing indoor geolocation
- Bone scaffolding for facial repair
- Novel antibacterial formulation targeting Lyme disease
- Catalysts to reduce low-temperature NOx emissions
- Robotic product singulation techniques
- Energy-efficient GPS processing methods
- Wrong-way driver detection
- Low-cost, robust particle counter for space applications
- Algorithms to detect GPS spoofing
- Geologic evaluation of stratigraphy and deformation in the Southwest
- Correlating bat guano core samples to drought history in South Texas
- Traffic profile predictions
- Automated detection of liquid pipeline leaks
- Dynamic characterization of soft biological tissues
- Low-friction, low-wear coatings for valvetrains
- Combustion chamber optimization
- Characterizing internal deposits on diesel injectors
- Feasibility study for satellite ground station
- Enhancing subunit vaccine through encapsulation
- Compressor for lighter-than-air stratospheric vehicles
- Geophysical instrument for Mars InSight mission
- Deep learning system for automated picking
- Development of beta-lactamase inhibitors

D021663_18-R8541

As part of the Computational Optimization Focused Internal Research Program, SwRI staff developed algorithms that dramatically increase modeling speed for complex physical processes. Relevant for oil and gas as well as biomedical applications, the algorithms allow efficient predictions of nanoparticles flowing through materials with complex architectures.



- Digital & Analog Electronics
- RF Systems
- Electromechanical Systems
- Micro-Power Circuitry
- Sensors
- Microbiology
- Virology
- Cell Biology
- Metamaterials
- Nanomaterials
- Lasers, Optics & Electro-Optics
- Acoustics & Ultrasonics
- Biometric Systems
- Non-Lethal Weapons
- MEMS
- Robotic Vehicle Evaluations
- Failure Analysis
- Rapid Prototyping
- Miniaturization Technologies
- Turbine Engine Tests & Diagnostics
- Condition-Based Maintenance
- Flight Controls
- Gunship Controls & Simulation
- Automatic Test Systems
- Unmanned Aerial Vehicles

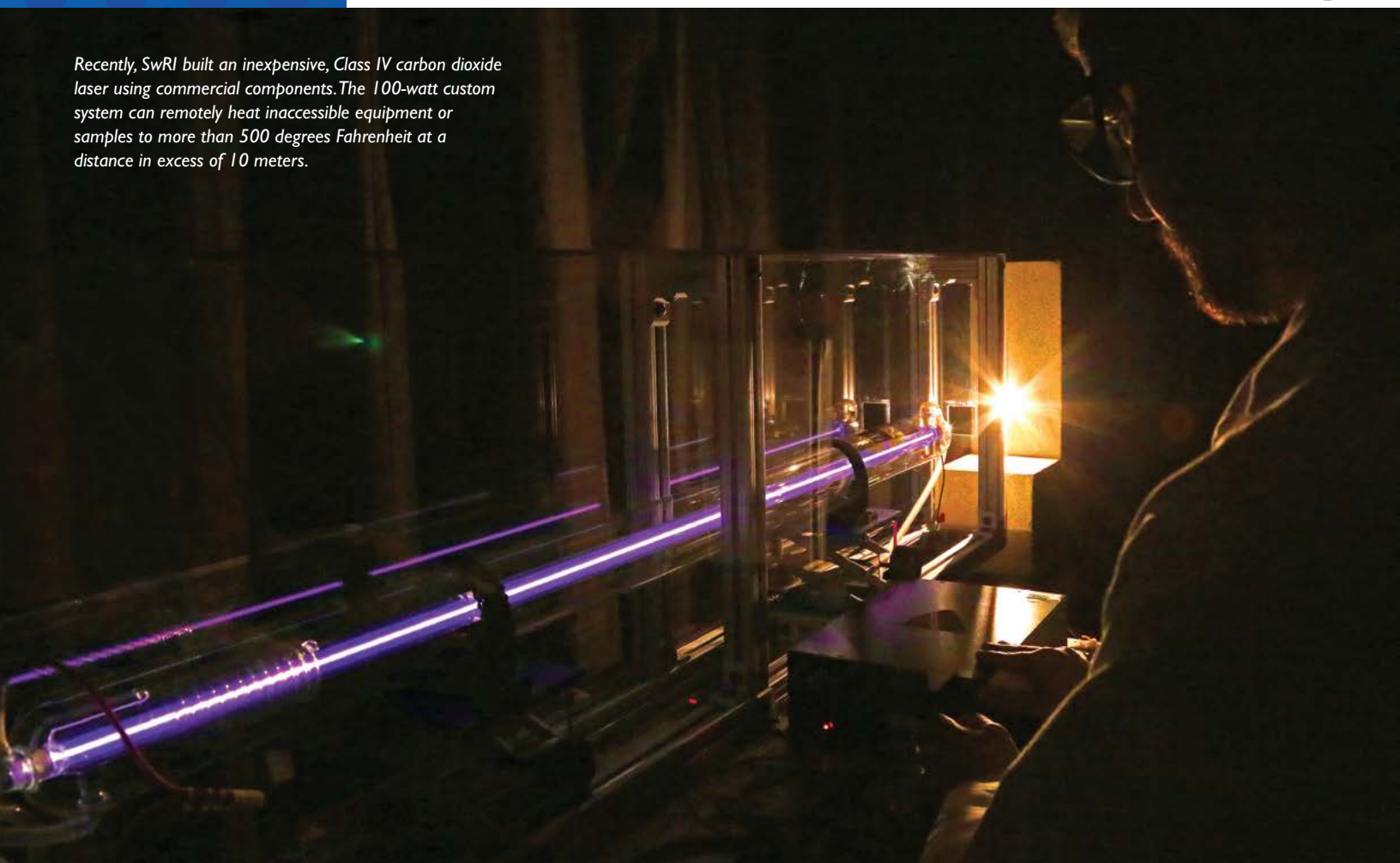
Applied Physics

With a diverse staff and world-class expertise, Southwest Research Institute pushes the boundaries of engineering and physics to create advanced technologies and systems to meet our clients' challenging demands. New approaches allow us to address persistent problems cost-effectively. SwRI develops, builds, and evaluates novel materials and systems for applications ranging from human health, to energy, to defense and law enforcement.

Our engineers provide critical upgrades to modernize aerospace systems for military and commercial aircraft, including a full spectrum of turbine engine test technologies. To improve reliability and supportability, SwRI uses commercial off-the-shelf equipment to upgrade existing facilities or develop new designs. We have developed test cell, control room, data acquisition, throttle control, load system, data analysis, leak detection, diagnostic, and condition-based maintenance tools. This technology supports the T-53, T-55, T-700, F-110, and TF-34 engines that power numerous rotary and fixed-wing aircraft.

For more than a decade, our engineers have been working in photonics, developing optical systems for novel light-delivery applications. SwRI engineers have developed a non-lethal personnel deterrent system known as the Long-Range Ocular Interrupter (LROI) for the U.S. Navy. This system has an array of visible lasers that projects a beam up to several kilometers, to either warn or suppress potentially hostile targets. Using laser ranging technology, LROI detects the distance to the target and adjusts the beam size to create the desired effect, while maintaining eye safety.

DM021581_4480



Recently, SwRI built an inexpensive, Class IV carbon dioxide laser using commercial components. The 100-watt custom system can remotely heat inaccessible equipment or samples to more than 500 degrees Fahrenheit at a distance in excess of 10 meters.

D021664

Both flash and continuous operating modes are available. A removable high-sensitivity electronic viewfinder scope can zoom in on a potential target, providing distance and other critical system information. LROI can be handheld or mounted in a variety of configurations and operates for more than an hour on a single battery pack.

In another application for defense or law enforcement, our engineers worked with the National Institute of Standards and Technology (NIST) to set up the 2015 Raven's Challenge, where bomb squads train and compete in realistic threat scenarios. SwRI and NIST built a training facility to allow robot operators to test their skills and compare the performance of different bomb disposal robot designs.

Working with NIST, SwRI engineers designed a bomb squad training suite to allow robot operators to practice mobility, manipulation, inspection, and search functions using various bomb disposal robots. The facility allows operators to compare different robot designs and test their skills.

DM021489_0176

To support a foreign aircraft maintenance depot, SwRI designed and built an automated test system to evaluate an advanced engine control system used on the F-15.

For the energy distribution industry, SwRI designed and built a laboratory rig to test high voltage power lines under realistic operating conditions. To understand how environmental factors affect operations at different conditions, we evaluate operating power lines under tension, at high voltage, and at various temperatures, all while controlling and measuring these parameters.

SwRI's microbiology laboratories help clients evaluate and improve disinfectants, sterilants, and biocides through a repertoire of standard and customized methods using good laboratory practices. In 2015, we evaluated various germicidal spray products to Environmental Protection Agency disinfectant standards. We demonstrated product effectiveness against a broad spectrum of microorganisms for general disinfection as well as for specific hospital, fungal, and resistant bacteria scenarios.

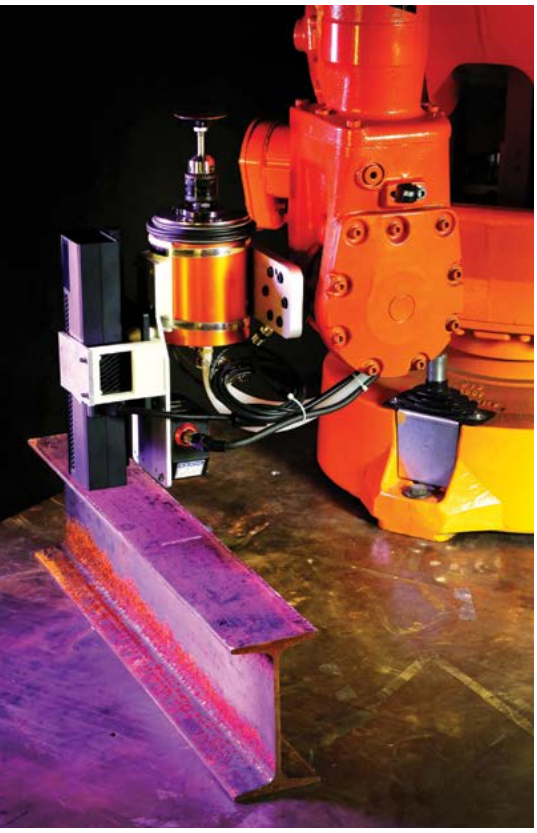
*Visit **applied-physics.swri.org** for more information or contact Vice President Ken Bennett at (210) 522-5242 or kenneth.bennett@swri.org.*

D021482_9611

SwRI engineers produced a non-lethal laser dazzler for the U.S. Navy to either warn or suppress adversarial targets. The Long-Range Ocular Interrupter uses an array of visible lasers to project an eye-safe beam up to several kilometers, temporarily blinding a potential adversary.

Automation & Data Systems

- Unmanned Systems
- Robotics
- Active Safety Systems
- Intelligent Transportation Systems
- Embedded Systems
- 3-D Sensing & Perception
- Tactical Networks
- Process Improvement
- Situational Awareness
- Automated Inspection
- Aerospace Networks
- Process Re-Engineering
- Control Center Software
- Image & Signal Processing
- High-Reliability Software
- Machine Vision
- ROS-Industrial
- Tactical Communications
- Specialized Sensing Systems
- Automated Vehicles
- Connected Vehicles
- Perception Systems
- Lean Manufacturing
- Network-Centric Systems
- Advanced Manufacturing
- Energy Efficiency
- Predictive Analytics
- Smart Energy Technologies
- Data Mining & Analytics
- Automotive Cybersecurity
- Penetration Testing
- Computational Optimization
- Training Simulators
- Instructional Design
- Texas Manufacturing Assistance Center



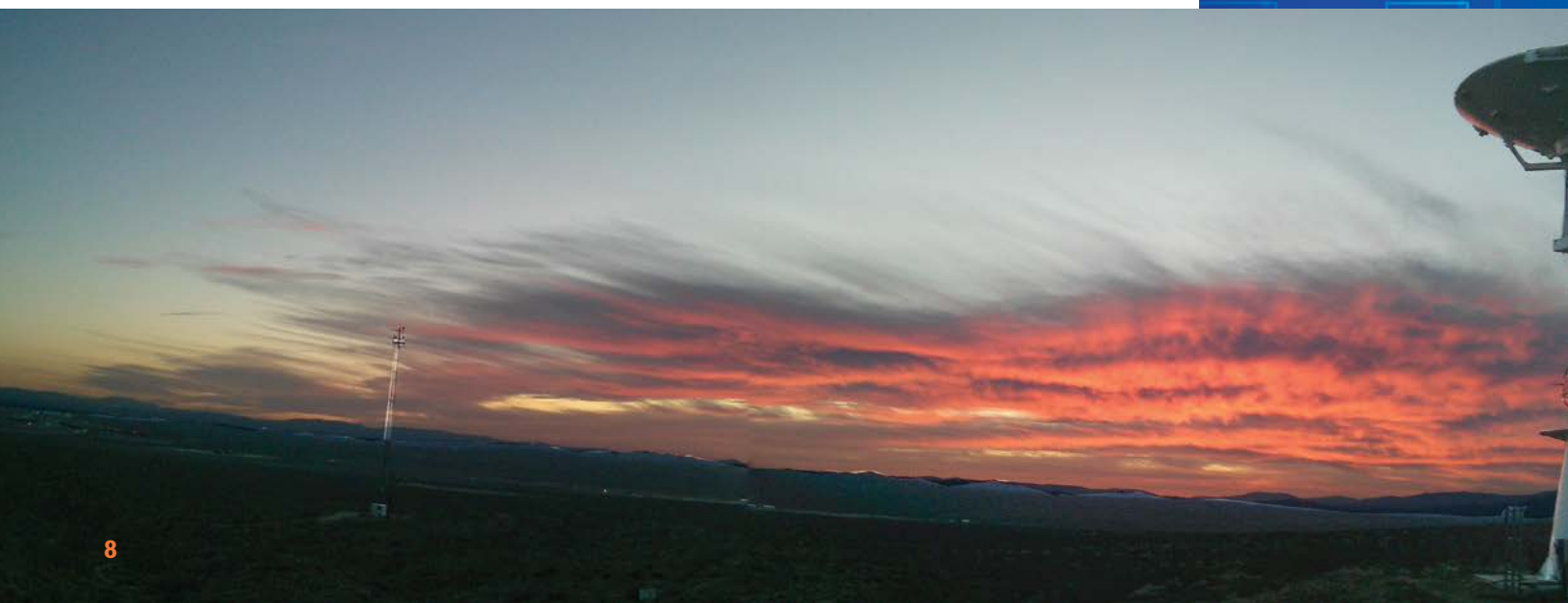
D021650_0192B

In 2015, the SwRI-led Robot Operating System Industrial (ROS-I) 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.

As the world becomes increasingly connected, Southwest Research Institute engineers and analysts are harnessing the evolving power of computers, networks, and automation to create software systems and robotic technologies that solve real-world problems.

Increased connectivity comes with increased vulnerability. To safeguard networks, our analysts perform penetration testing, sometimes called ethical hacking, to identify cybersecurity risks. We recently began a project assessing the security of LTE networks, identifying rogue base stations that can intercept cell phone traffic. In a related area, SwRI leads the Automotive Consortium for Embedded Security™ (ACES) to perform pre-competitive research in the area of automotive cyber security. ACES membership includes automotive manufacturers as well as Tier-1 suppliers.

In the intelligent highway and connected vehicle arena, SwRI is working with the U.S. Department of Transportation and various state agencies to realize the promise of a fully connected highway system. Connected vehicle and automated vehicle technologies can potentially resolve many problems before they occur. For example, in 2015 we automated an 18-wheeler to stop if it's too tall to clear an upcoming bridge, avoiding an accident and any resulting traffic congestion and secondary incidents. Under contract to the Federal Highway Administration, we are establishing a Connected Vehicle Certification Program to address short-term needs associated with pilot programs as well as the long-term needs of the



connected vehicle industry. As an industry leader, we assess standards, interoperability, security, and system certification, independently evaluating how vehicle manufacturers, device manufacturers, and system integrators can effectively implement standards and architecture.

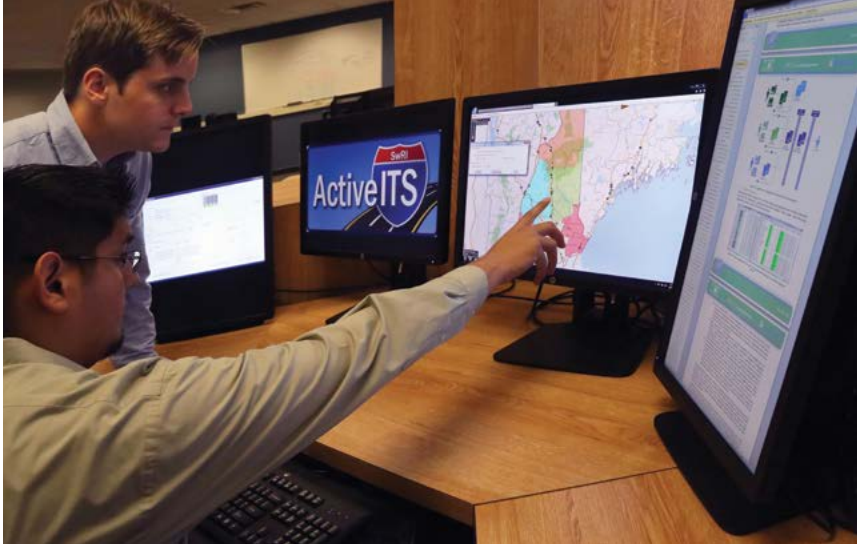
Over the last three years, SwRI has helped the Army develop a suite of autonomy tools as part of the Robotics Technology Kernel to allow mounted and dismounted soldiers to operate and interact with unmanned vehicles. As part of the Army program, SwRI engineers and analysts have developed hardware and software deployed on three types of vehicles (six total vehicles), allowing a variety of autonomous and semiautonomous behaviors. In 2015, we demonstrated new capabilities to improve troop effectiveness, situational awareness, robustness, and reliability. Reusing code in multiple vehicles and applications has accelerated the development of higher levels of automated operation while increasing the reliability and safety of systems.

In another program to support the military, our training specialists revised a familiarization program for towed decoy devices. These lifesaving devices are deployed behind military aircraft to attract and absorb attacks from radar-guided missiles, sparing the aircraft and its crew. This browser-based interactive program uses text, narration, animation, and two-dimensional graphics to allow Air Force personnel to practice maintenance and engineering procedures.

For the electric utility industry, SwRI is developing an active monitoring system to detect high impedance faults in power lines. These faults occur when a tree branch or other semiconductive material comes in contact with the wire, or the wire falls to the ground, allowing electricity to discharge. The loss of current is too low to trip circuits but does represent a serious public safety hazard that can cause fire or electrocution. Using internal funding, SwRI developed a radar-based technique to continuously monitor a power distribution network, looking for anomalies. Based on this technique, SwRI is developing a system to identify and locate where these high-impedance faults occur to allow energy providers to quickly fix these problems.

*Visit **autodata.swri.org** for more information or contact Vice President Susan Crumrine at (210) 522-2089 or susan.crumrine@swri.org.*

DM021571_4053-2



SwRI analysts are developing transportation systems in six states across the country. More than 40 traffic management centers use SwRI-developed software to monitor in excess of 10,000 miles of roadways in both metropolitan areas and rural environments.

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

D021269_6941

D021665

SwRI developed a new network-based telemetry system to expand and enhance flight test capabilities for the Department of Defense's iNET program. The system achieved various flight test milestones this year.

- Gasoline & Diesel Engine Lubricant Evaluations
- Driveline Fluids Evaluations
- Filtration Evaluations
- Fuel Performance & Qualifications
- Analytical Support Services
- Fuel Economy Evaluations
- Test Stand Design & Fabrication
- Fuel & Lubricant Surveys, Sampling & Analyses
- Screener Development
- Computational Fluid Dynamics
- Fire-Resistant Fuels
- Model-Based Controls
- Engine Design
- Emissions Reduction
- Transmission Design
- Natural Gas Engine Development
- Materials Compatibility
- Alternative Fuel Evaluations
- Powertrain Modeling & Controls Development
- High-Efficiency Gasoline Engine Research
- Particle Science
- Engine Development
- Generator Set & Combined Heat & Power Evaluations
- Homogeneous Charge Compression Ignition
- Hydraulic Design
- Hardware-in-the-Loop Evaluations
- Light-Duty Fuel Economy
- Hybrid Vehicle Design
- Contamination Research
- Wear Evaluations
- Vehicle Testing
- Accelerated Durability Evaluations
- Energy Storage Technologies
- Battery Evaluations
- Applied Electronic Controls
- Tribology

We are transferring our award-winning Dedicated Exhaust Gas Recirculation engine technology, developed for gasoline-powered cars, to new areas by exploring its application to medium-duty trucks and off-road equipment.

Automotive Engineering

Evaluating on- and off-road engines — and the fuels that power them — has been a core program of Southwest Research Institute since its founding in 1947. We combine our expertise in fuels, lubricants, and emissions research with our internationally recognized work in engine and transmission technologies to serve clients around the world.

We have the largest independent fuels and lubricants laboratory in the world, and we test virtually every engine oil and fluid available on the market.

SwRI researchers are evaluating oil samples collected domestically and around the globe for the American Petroleum Institute (API™) Aftermarket Audit Program. The program, underway at SwRI since 2009, involves independent contractors procuring currently manufactured oils from retailers. Samples are then sent to SwRI, blind coded, and laboratory tested to ensure that they meet the advertised API specifications.

We are developing and implementing six new gasoline engine tests for the International Lubricants Standardization and Approval Committee. These GF-6 specification tests will govern passenger car motor oil performance. The tests will gauge engine lubricant performance as it relates to wear, deposits, sludge, low-speed pre-ignition, and fuel economy. The development process typically takes several years and involves a joint effort between automotive manufacturers, test laboratories, and oil additive companies. Expected to go online in early 2018, the GF-6 specification will be in effect for a minimum of five years.

We also are developing test protocols for new API diesel specifications, expected to be implemented in December 2016. API CK-4 is for oils used in high-speed, four-stroke diesel

DM19375_4871

We evaluate engine oil samples to ensure they meet international specifications set by the American Petroleum Institute (API) and the International Lubricant Standardization and Approval Committee (ILSAC).

D021619_5394

A new baghouse system draws exhaust from our engine test cells. The system filters out particulate matter and discharges it to a waste container for safe disposal.

D021670

D021651_8275

engines to meet 2017 model year on-highway and non-road emissions standards. API FA-4 is for 30-weight oils specifically formulated for use in high-speed, four-stroke diesel engines, to meet 2017 model year on-highway greenhouse gas emission standards.

Fuel economy improvements remain the prime driver for both of these new lubricant specifications. As new engine designs account for lower lubricant viscosities, increased fuel economy can be achieved. However, older engines that were not designed for the thinner and more robust lubricants may not have proper lubrication if thinner oils are used in them. This potential lack of "backwards compatibility" has become a new industry concern.

SwRI is one of two organizations chosen globally by a major automotive manufacturer to conduct a vehicle fuel economy test as part of its revised engine oil specification. This high-precision test is conducted with passenger cars operating on chassis dynamometers to demonstrate fuel economy gains of at least 0.5 percent for the next generation of efficient motor oils.

Since 1956, SwRI has operated the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) Fuels and Lubricants Research Facility. TARDEC, located on the grounds of SwRI, is a government-owned facility that provides advanced research, development, and engineering services to the U.S. Army and other government agencies. The Army continues to invest in this legacy program. Recent upgrades include a new axle test stand for evaluating the effects of lubricants for light-, medium-, and heavy-duty applications.

SwRI is committed to protecting the environment. We installed a baghouse system to reduce particulate emissions generated by our engine test cells. The system filters out particulate materials, primarily soot, for safe disposal.

Our researchers continue to develop innovative engines and components to increase efficiency and lower emissions. Under our internal research program, we developed the Hot Gas Transient Reactor (HGTR®), a system that simulates diesel engine exhaust. Using HGTR, engineers can develop and test catalysts and

Leveraging research conducted for our High-Efficiency Dilute Gasoline Engine consortium, we developed an engine combustion and air handling system with cooled EGR to significantly improve fuel consumption and meet regulated emissions standards for a passenger car application.

Automotive Engineering

aftertreatment systems without an actual engine, cutting fuel costs in half. The capability also allows aftertreatment systems to be developed in parallel with new engine systems.

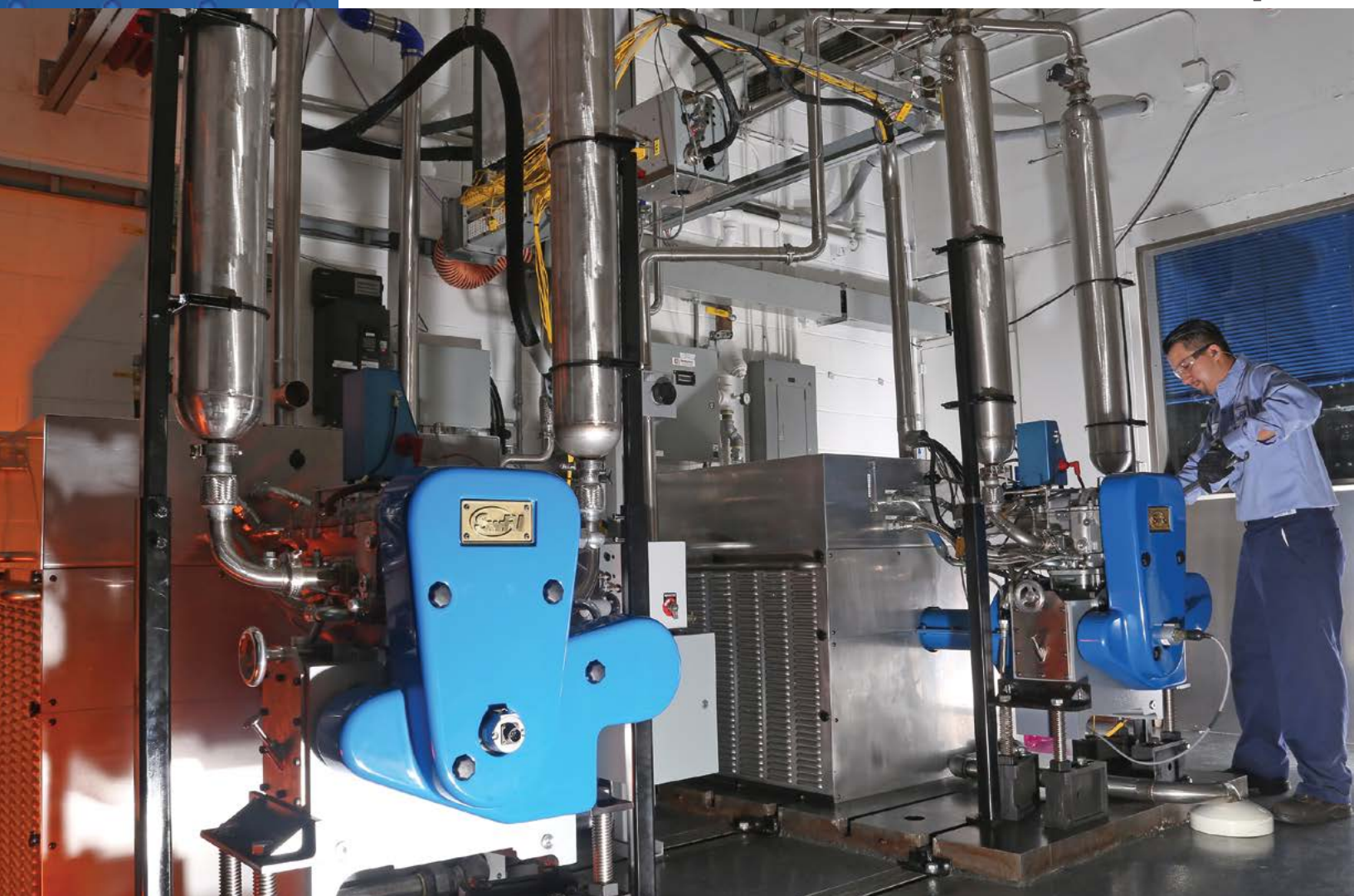
We are exploring applications for our award-winning Dedicated Exhaust Gas Recirculation (D-EGR®) engine technology, which significantly improves gasoline vehicle economy. Through our internal research program, we are evaluating using D-EGR technology in applications that traditionally use diesel engines, such as medium trucks and small off-highway equipment. Also using internal funding, we designed and built a single-cylinder research engine. Drawing on this development, we are seeking external sources to develop a heavy-duty version of our engine.

We are the leader in developing and managing automotive consortia. Our Clean High-Efficiency Diesel Engine (CHEDE) consortium completed its 24th year of activity, and our High-Efficiency Dilute Gasoline Engine (HEDGE®) consortium marked 10 years. This year we added two more: the Advanced Engine Fluids (AEF) and Advanced Combustion Catalyst and Aftertreatment Technology (AC^2AT) consortia. AEF studies the effects of fuels and lubricants chemistry on engines, while AC^2AT focuses on catalyst and emissions control technologies.

As electric and hybrid automobiles become

Using internal research funding, we designed state-of-the-art, single-cylinder engines to perform advanced combustion research. The customizable engines are offered to clients in heavy-, medium-, and light-duty variants.

D021650_9399



D019502_9594

SwRI designed and built six identical test stands to support development of the new Sequence IVB engine oil test for the lubricant industry. The test stands are designed to operate a 1.5-liter gasoline engine with a 250-horsepower eddy current dynamometer.

more commonplace, the need for small, effective, safe battery designs is increasing. To address this need, SwRI established an Energy Storage Technology Center (ESTC) that brings together multidisciplinary expertise in automotive technology, electronics, chemistry, advanced materials, and product assurance to help solve problems associated with energy storage. ESTC complements the efforts of our Energy Storage System Evaluation and Safety (EssEs) consortium, which completed its fourth year in 2015.

SwRI was one of six global "Partners in Innovation" for the annual Shell Eco-marathon, a university student competition held annually in the Americas, Asia, and Europe. As part of the event, we sponsored the Technical Innovation Award, given for outstanding initiative and technical ingenuity. This is the fifth year SwRI has participated in the Eco-marathon.

On the international front, we assisted China's Ministry of Environmental Protection in establishing the Beijing 6 automotive emissions standards for non-road diesel engines. Using cooled EGR technology developed as part of our HEDGE consortium, we completed design and development programs for two light-duty, spark-ignited engines for the Chinese market.

We completed an expansion of our large engine test facility, which increased our test capability from 5,000 to 7,000 horsepower and added two test cells. SwRI will use these cells to develop and certify large locomotive, marine, and off-highway engines.

*Visit **automotiveengineering.swri.org** for more information or contact Vice President Daniel W. Stewart, P.E., at (210) 522-3657 or daniel.stewart@swri.org, or Vice President Steven D. Marty, P.E., at (210) 522-5929 or steven.marty@swri.org.*

D019751_6099

Our Hot Gas Transient Reactor (HGTR®), developed using internal funding, simulates diesel engine exhaust. The HGTR system allows researchers to evaluate catalysts without using an engine.

Chemistry & Chemical Engineering

- Drug Discovery
- Medicinal Chemistry
- Microencapsulation
- Biomaterials Engineering
- Materials Chemistry
- Chemical Process Engineering
- Alternative Fuels Development
- Homeland Security
- Analytical & Environmental Chemistry
- Environmental Monitoring
- Chemical Forensics
- Radiation Services
- Risk & Hazard Analysis Engineering
- Fire Protection Engineering
- Fire Testing & Research

At Southwest Research Institute, we apply advanced chemistry and chemical engineering technology to help our clients address challenges in areas ranging from alternative energy to human health and fire safety. We develop novel pharmaceutical formulations and product additives and verify the purity of foods and products. Our engineers and scientists also develop new hydrocarbon processing technologies and develop solutions to homeland security threats.

In 2015, we continued to expand our integrated pharmaceutical capabilities, particularly in the area of drug discovery. Our proprietary Rhodium™ modeling software uses advanced computational techniques to accelerate drug development by rapidly and cost-effectively identifying effective compounds from tens of thousands of potential candidates. Working with partners in academic, government, and commercial entities, we have used Rhodium to develop emerging medical countermeasures for chemical warfare agents and deadly viruses such as Ebola.

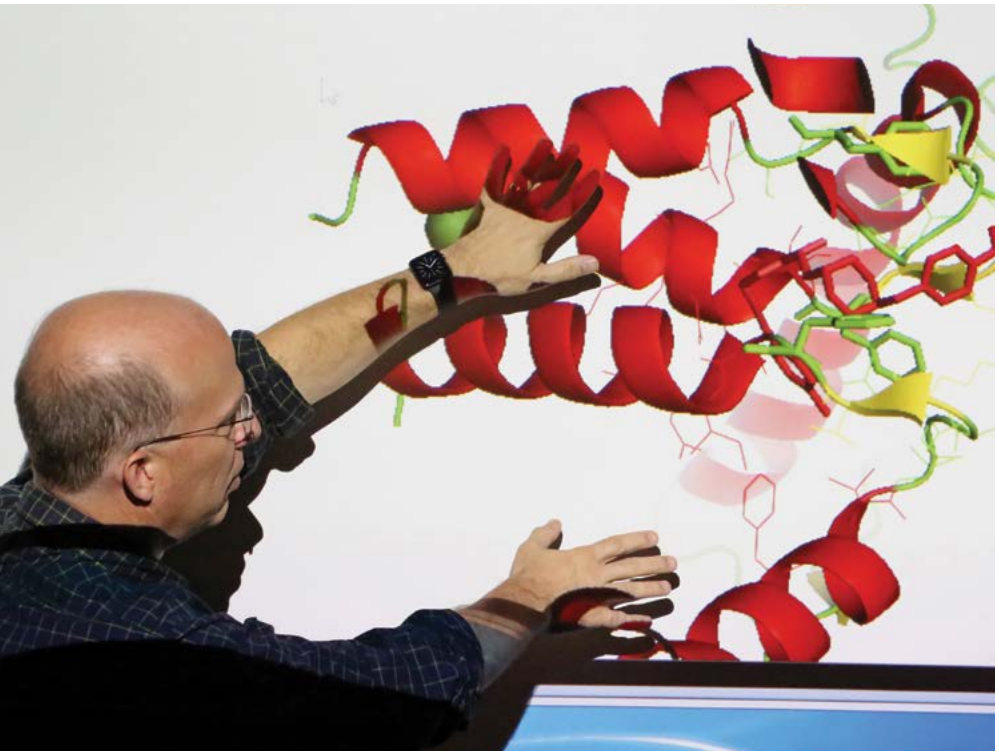
With 60 years of experience in microencapsulation technology, we continue to make advances in delivery technologies such as highly stable therapeutics based on novel nanosuspension formulations. We have enhanced our Current Good Manufacturing Practice facilities for pharmaceutical production by adding new clean rooms and increasing our production capacity to 200 liters.

SwRI engineers and scientists focus on creating novel energy solutions from conventional and unconventional sources. Using state-of-the-art catalysts and processing techniques, we efficiently upgraded natural gas hydrocarbons into diesel fuel and other functional fluids, such as cutting oil or hydraulic fluid. In 2015, we developed a carbon-neutral process to recycle used lubricants into new specification-grade products, indistinguishable from the original.

In other work, we are converting wood chips into valuable chemicals, while producing high-quality solid fuel as a byproduct. In complementary clean-coal research, we used fluidized bed reactor technology to upgrade common solid hydrocarbons, such as lignite, removing impurities and low-BTU components, to create cleaner, higher-quality, and more environmentally acceptable fuels. SwRI is also developing integrated systems that offset the cost of carbon capture from industrial operations, such as energy and cement production, by producing marketable commercial byproducts.

D021646_7678

For an industrial client, SwRI is developing a second-generation pilot plant that uses regenerable inorganic salts to capture carbon dioxide while producing marketable chemicals such as calcium carbonate and hydrochloric acid.



D021567_3878

Using Rhodium™ molecular modeling software, SwRI chemists are creating more effective treatments for Ebola and other diseases.

Tens of thousands of chemicals are currently in consumer products, and thousands of new materials and chemicals are introduced every year. The Environmental Protection Agency selected SwRI to develop advanced, high-throughput analytical methods to determine the chemical properties of commercial products and populate a national toxicological database.

Concerns about the safety of brominated fire retardants are driving the development of new formulations for treating in-home furnishings, electronics, and building insulation. SwRI staff members are evaluating new formulations and providing support to national scientific advisory committees and professional associations in the pursuit of more environmentally friendly fire retardants and extinguishing media.

We also enhanced our jet-fire and pool fire testing capabilities to support the petroleum production and transportation industries. On a smaller scale, we performed an in-depth study of flat-panel televisions, examining the flammability of the casing and measuring heat release rates and toxic off-gassing during combustion.

*Visit **chemistry.swri.org** for more information or contact Vice President Dr. Michael MacNaughton, P.E., at (210) 522-5162 or michael.macnaughton@swri.org.*

D021666

For the construction materials industry, our fire technology specialists evaluated new gypsum- and wood-based building components for use in buildings up to 10 stories high.

Working with the U.S. Department of Agriculture, SwRI developed new microencapsulated veterinary formulations to protect chickens against a parasitic disease. Chicks that eat the green microspheres mixed with their feed are protected against coccidiosis.

DM021572_4287

Geosciences & Engineering

For more than 25 years, Southwest Research Institute has conducted field studies, laboratory experiments, and computer simulations to advance the state of the art in Earth sciences and engineering, with a focus on energy, water resources, and planetary geology. We continue operating the Center for Nuclear Waste Regulatory Analyses (CNWRA®), supporting the Nuclear Regulatory Commission (NRC) in its regulatory responsibilities related to radioactive waste storage, transportation, and disposal, as well as other aspects of commercial uses of radioactive materials.

In 2015, we completed safety evaluation reports and conducted advanced modeling studies associated with a range of waste storage systems. The CNWRA also assisted the NRC in evaluating risks, hazards, and emergency and control systems for nuclear facility operations. Our engineers and scientists are collaborating with the NRC to develop a generic performance assessment model called SOAR, for Scoping of Options and Analyzing Risk. The model will provide timely risk and performance insights on a wide variety of potential geologic disposal options.

Through licensing and license renewals, nuclear power plants are permitted to operate for up to 60 years. As technology advances over decades of operation, modifying equipment and processes is essential to safely generating clean energy. SwRI analysts assist the NRC, reviewing plant license amendment and license renewal requests, to safely improve nuclear power production, reduce power generation interruptions and reactor shutdowns, and extend the operational life of these base-load sources of electricity.

We continue to export our expertise, completing probabilistic flow, transport modeling, and sensitivity analyses for a proposed nuclear waste repository in France. We are also supporting repository investigations for various entities in Canada, Finland, and Sweden. We performed

DM021586_4902

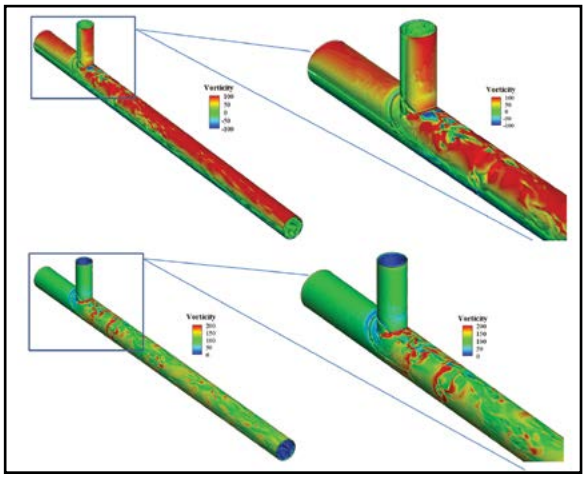
The U.S. Department of Energy is physically and chemically stabilizing residual radioactive waste inside underground tanks by filling them with grout. To address performance issues, SwRI scientists investigate grout characteristics using bench-scale and larger experiments.

- Geophysical & Geological Investigations
- Groundwater Resource Evaluations
- Geological Structure Analyses
- Energy Exploration
- Chemical & Radiological Contaminant Transport
- Laboratory, Field & Numerical Analyses
- Corrosion & Materials Life Prediction
- Risk & Performance Assessments
- Environmental Impact Assessments
- Geoscience Processes
- Cold Region Investigations
- Climate Change Impact Assessment
- Remote Sensing
- Structural Integrity Analyses
- Computational Fluid Dynamics
- Reliability & Operational Safety Analyses
- Planetary Science
- Regulatory Analysis & Guidance
- Fire Protection & Forensic Analyses
- Material Aging & Degradation
- Natural & Human-Induced Hazard Assessments
- Pipeline Failure Analysis
- Probabilistic Risk Assessment

With funding from the National Science Foundation, SwRI used satellite-based remote-sensing studies to measure rock glacier movement. Field measurements confirmed movement of these permafrost formations, providing key information about changing climate conditions.

D021667

SwRI geologists study faulting in the foothills of the Guadalupe Mountains to better understand the terrain in and around Texas' Permian Basin and how it affects petroleum production.



D021668

When hot and cold flows mix, temperature fluctuations in piping systems can cause thermal fatigue, a serious safety concern in nuclear power plants. SwRI scientists used high-fidelity numerical simulations to understand the swirling mixtures, identifying the vorticity magnitude and dominant temperature oscillation frequencies near a piping T-junction. This image illustrates the results from numerical simulations.

D021669 / Courtesy Florina Ardelean/West University of Timisoara

full-scale fire tests and developed advanced computer-based fire modeling technology to help the Japanese nuclear industry meet new fire safety requirements.

SwRI's petroleum exploration and development program continues to provide in-depth structural geology and geomechanical analyses and training for the petroleum industry. A new high-performance computer cluster allows large, three-dimensional geomechanical simulations of induced hydraulic fracturing.

We continue to improve our award-winning 3DStress® software, most recently adding an ability to simulate 3-D pore-fluid pressure changes associated with well injection or production activities. Of particular interest is induced seismicity, the minor earthquakes associated with wastewater injection, geothermal reservoir exploitation, and fracking. Using 3DStress, we analyze pore-pressure-related changes in the slip tendency of faults and fractures to assess and mitigate the potential for induced seismicity.

As SwRI began the second phase of the Eagle Ford Joint Industry Project, geologists focused on subsurface reservoir properties, studying seismic, well, and core data. Understanding the correlation between surface and subsurface geology is critical to successful production of fuels from unconventional reservoirs, such as Eagle Ford.

As global and local concerns about groundwater availability and quality grow, we continue to expand our expertise to meet the needs of government agencies, as well as municipal and commercial organizations. In 2015, we completed a major project, developing and applying a detailed groundwater model for the Edwards Aquifer. Our hydrologists support groundwater districts in South Central and West Texas, providing modeling, analysis, and field expertise.

For NASA, we apply expertise in Earth science to other planetary bodies, studying debris flows formed in subfreezing environments on Earth as terrestrial analogs to those formed on polar sand dunes on Mars. In cold-climate dune fields, relatively dark sand lying on bright snow can produce highly localized warm spots, melting the snowpack. Despite subfreezing air temperatures, we have concluded that this meltwater can cause alluvial processes and debris flows on Martian dune slopes.

*Visit **geosciences-engineering.swri.org** for more information or contact Vice President Dr. Wesley Patrick at (210) 522-5158 or wesley.patrick@swri.org.*

- Computational Fluid Dynamics
- Deep Ocean Simulations
- Fracture Mechanics
- Flow Measurement
- Multiphase Flow
- Probabilistic Failure Analysis
- Environmental Testing
- Surface Engineering & Coatings
- Telecommunications Evaluations
- Structural Mechanics
- Failure Analysis
- Eddy Current Modeling
- Diagnostic Software
- Thermal & Corrosion Analysis
- Nondestructive Evaluation
- Pipeline Compression
- Acoustics
- Biomechanics & Biomaterials
- Magnetostrictive Sensors
- Materials Integrity & Life Prediction
- Terminal Ballistics
- Guided Wave Inspection
- Aerodynamics
- Propellant Dynamics

Mechanical Engineering

Southwest Research Institute's mechanical engineering program serves the defense, aerospace, and energy sectors, applying expertise in materials, structures, nondestructive evaluation, sensor technology, energetic systems, and fluids and machinery dynamics.

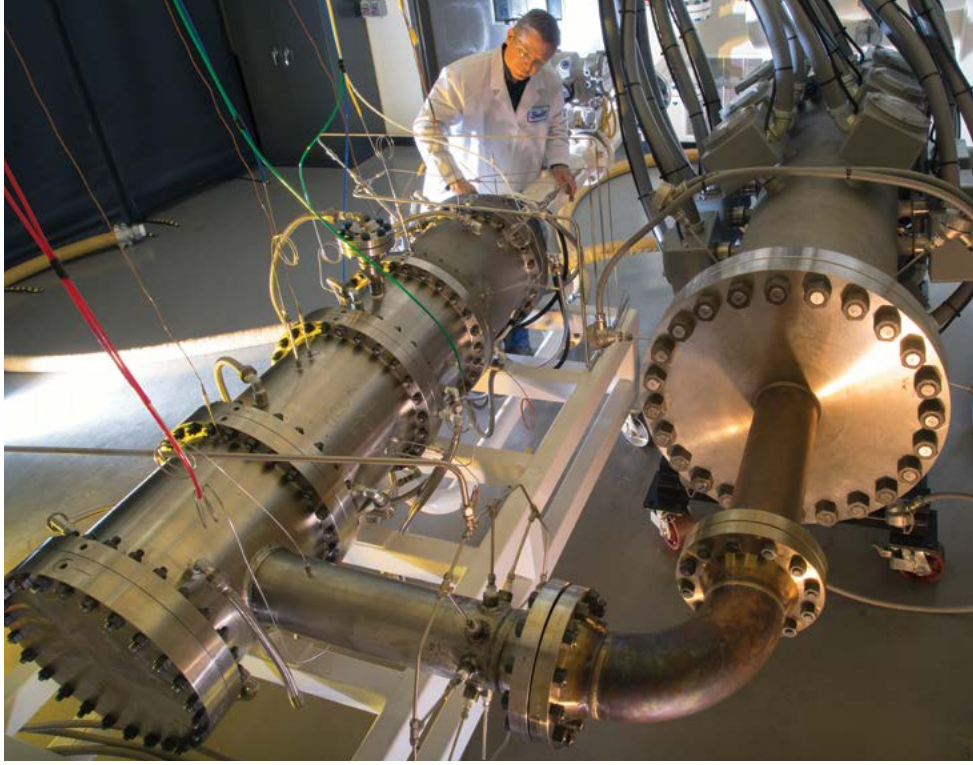
Our defense program extends to all branches of the military and involves ballistics, explosives, survivability, and light- and heavy-armor analyses. For the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC), we developed and delivered the Dynamic Deformation Instrumentation System for measuring the effects of landmines and improvised explosive devices on ground vehicles. The system comprises hardened miniature high-speed cameras combined with digital image correlation software to measure the transient motion and deformation of a vehicle's floor and hull during underbody blast. The system performed successfully during field testing, resulting in additional blast survivability research for TARDEC.

Our aerospace program encompasses aircraft structural life extension, jet engine performance and reliability, and launch vehicle structural dynamics and propulsion systems. DARWIN®, an SwRI-developed fatigue crack growth software program that determines the probability of fracture of jet aircraft engine rotors, completed its 20th year of continuous funding. The Federal Aviation Administration is extending this important research program through 2019. DARWIN is also being used for advanced military applications. For the U.S. Air Force Research Laboratory, we are linking DARWIN to third-party software to address complex crack and component geometries, and to simulate X-ray inspection methods and advanced manufacturing processes for aircraft engine rotors.

Our work in support of aircraft structural integrity for extending the service life of the U.S. Air Force fleet continues. This year, we completed full-scale wing tests that achieved a new benchmark for the expected structural life of T-38 wings. Our A-10 team was selected as

D021534_3073

This past year, SwRI built a new facility for testing small-caliber guns, ammunition, and light armor materials. The 1,200-square-foot facility includes state-of-the-art instrumentation and high-speed video for measuring and recording ballistic impact events.



We designed and built this combustor rig to evaluate a novel SwRI-developed concept to maximize the efficiency of solar power plants.

D021576_4200

the USAF Team of the Year under the Department of Defense Value Engineering Award program for developing innovative approaches to efficiently manage airframe structural inspection requirements for the A-10 fleet.

Evaluating roadside safety structures remains a core program. Our program is ISO-accredited and approved by the Federal Highway Administration to provide crash testing services to evaluate guardrails, end terminals, security barriers, and other structures. For one project, SwRI conducted full-scale crash testing of a pickup truck traveling at 62 mph to evaluate the performance of a high-tension cable barrier used in the median of a divided highway. We also are assisting the industry's transition to the American Association of State Highway and Transportation Officials crash test standard.

D021569_3653

SwRI researchers are performing F-16 wing component durability evaluations. Test results will be used to help extend the service life of the aircraft.

Our energy program includes oil and gas production and transportation, renewable energy, clean coal, and nuclear power. To help ensure the safety of offshore oil production, we develop sensor systems to independently validate the industry's pipe weld inspection systems.

We are developing clean energy technology for the U.S. Department of Energy to address factors associated with climate change. This year, we completed a major, six-year carbon dioxide compression project that led to the design of advanced inter-cooling compression technology. This technology will significantly increase compressor efficiencies and lower the cost of electricity in carbon separation and sequestration power plant applications.

We initiated the Separation Technology Research (STAR) program to advance research for better oil and gas separation equipment and test protocols. Now in its second year, the multimillion-dollar joint industry program has grown to 20 member companies. The first project for the STAR program, testing oilfield production scrubber devices offered by seven manufacturers under field conditions, is underway at our recently upgraded onsite Multiphase Flow Facility.

*Visit **mechanicalengineering.swri.org** for more information or contact Vice President Danny Deffenbaugh at (210) 522-2384 or danny.deffenbaugh@swri.org.*

DO21671

We conducted full-scale testing of a pickup truck impacting a highway median cable barrier to evaluate the barrier's performance.

Signal Exploitation & Geolocation

D021703

SwRI direction finding equipment and software were featured prominently at a successful multinational intelligence collection exercise.

For nearly seven decades, Southwest Research Institute engineers and scientists have conducted research in direction finding, surveillance, geolocation, and tracking, supporting the United States and its allies in these important areas. Last year we consolidated our defense industry-related electronics expertise by combining our geolocation and signal technology research with avionics and support systems, electronics integration, and cyber technology expertise.

We are continuing our role as a major provider of geolocation network data sensors and control and management solutions. This past year, an SwRI-developed network became operational, replacing a worldwide geolocation management system that had been in operation for decades. The new network supports defense-related initiatives for the U.S. government.

To protect our warfighters in all branches of the military, we develop systems that can locate threats, identify friendly forces, or interfere with enemy radar signals. Under contract to the Naval Air Systems Command, we are developing enhanced tactical technology as part of an electronics instrumentation package for military aircraft. We successfully delivered four models for flight testing, with the first test flight completed this past June on a rotary-wing platform. The electronics package represents a new tactical capability that allows air crews to change their missions midflight.

We have multiple projects for the U.S. Air Force's ALQ-131, an electronics suite that jams radar signals to prevent an aircraft from being tracked by enemy forces or targeted by a missile. We perform software maintenance and independent verification and validation of the ALQ-131 operation flight programs, mission data generators, and automated test stations.

- Signals Intelligence
- Aircraft Data Recorders
- Cyber Exploitation
- Information Operations
- Analysis, Analytics, Visualization & Reporting
- GPS Engineering
- Array Processing
- Intelligence, Surveillance & Reconnaissance
- Autonomous Sensing
- Cloud Computing
- RF Design
- Condition-Based Maintenance
- Tactical Networking
- Aircraft Simulation
- Electromagnetic Modeling
- Electronic Warfare
- Flight Controls
- Flight-Line Testers
- Geolocation
- Antennas & Propagation
- Software-Defined Radios
- Information Exploitation
- Aircraft Systems Engineering
- Aircraft Component Testing
- Intelligence Networking
- Automatic Test Program/ Set Development
- Life-Cycle Support
- Multi-INT Processing & Exploitation
- Communications Solutions
- Signal Processing
- Situational Awareness
- Information Assurance
- Surveillance Systems
- Cross-Domain Solutions
- Tagging, Tracking & Locating Solutions
- Trigger-Based Management

We successfully completed acceptance testing for the video processor assembly, identification friend or foe (IFF) interface, and threat-timing generator circuit card assemblies for the Mini-Multiple Threat Emitter System (Mini-MUTES). Mini-MUTES simulates an enemy's air defense radar system and is used to train U.S. Air Force flight crews. We completed site testing to certify that Mini-MUTES properly generated threat signals and could accurately track aircraft using the IFF system.

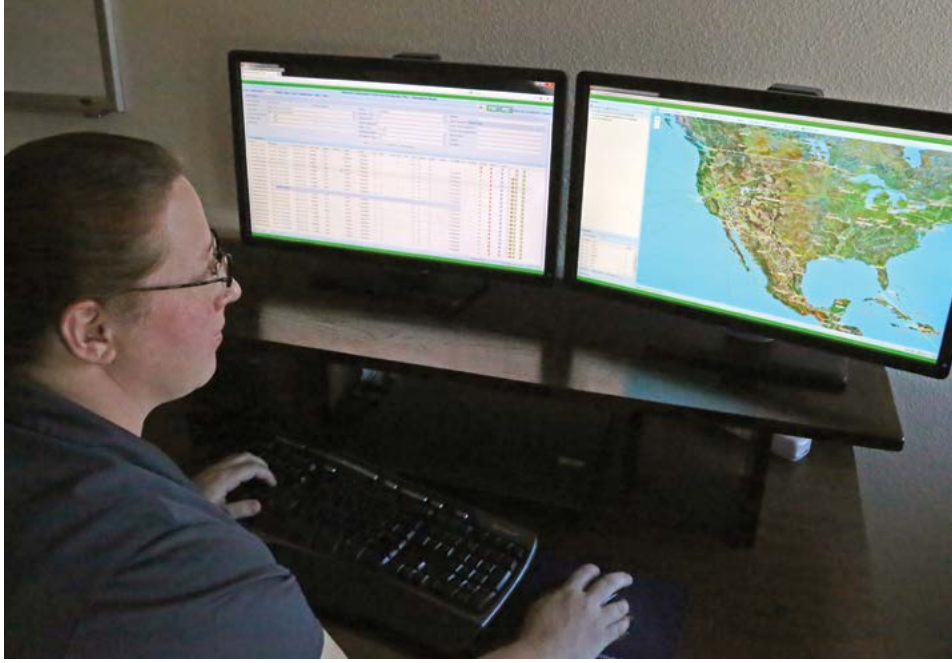
Using internal research funding, we enhanced the capabilities of Scout™, an SwRI-developed man-portable system for locating signal sources. We also used internal funding to develop our Frontier tactical networking interfaces, allowing SwRI systems to collaborate with various wireless signal location technologies.

We upgraded our in-house data collection systems to improve client support. The new systems can now collect data five times faster. In addition, we upgraded our transmitter and rotary test facilities with advanced technology.

To leverage our expertise in avionics and related support systems, we established an office near Wright-Patterson Air Force Base, Ohio, home of the Air Force Research Laboratory. Currently the office staff is collaborating with the General Services Administration and Air Force major commands to set up contract vehicles for future research efforts.

Signal Exploitation and Geolocation is being renamed Defense and Intelligence Solutions, effective Fiscal Year 2016. Visit ***defense.swri.org*** *for more information or contact Vice President Nils Smith, P.E., at (210) 522-3685 or nils.smith@swri.org.*

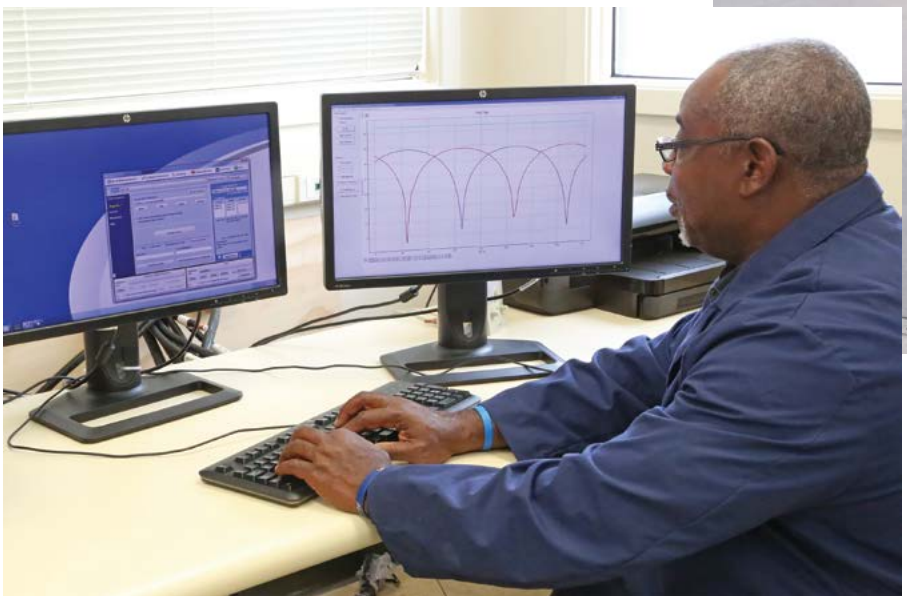
D021587_5018



A new SwRI-developed geolocation network supports defense-related initiatives for the U.S. government.

D021618_5471

D021618_5551



Our Rotary Test Facility includes a six-meter turntable (above) to evaluate antenna assemblies. Recent additions to the facility include a permanent control room building (above, in background) with new hardware and software that measure and display antenna patterns quickly and easily (left).

Space Science & Engineering

- Planetary Science
- Terrestrial & Planetary Magnetospheric Physics
- Solar & Heliospheric Physics
- Spacecraft Instrumentation
- Spacecraft Avionics
- Electromechanical Systems
- Power Systems
- Microsatellite Design, Development & Fabrication
- Spacecraft Management
- Data Analysis & Science Support
- Science & Mission Operations
- Lighter-Than-Air Systems

In 2015, Southwest Research Institute made history with NASA's New Horizons Pluto encounter and the launch of the Magnetospheric Multiscale (MMS) mission. SwRI leads the New Horizons science mission and built two of the instruments aboard the spacecraft. After a 9.5-year, 3-billion-mile journey, New Horizons became the first spacecraft to fly past Pluto, acquiring high-resolution images of the planet's surface and its moons, as well as measuring its atmosphere and space environment. New Horizons is now heading deeper into the Kuiper Belt and, with a mission extension, may encounter another object in this zone of primitive icy bodies, relics of the formation of the solar system.

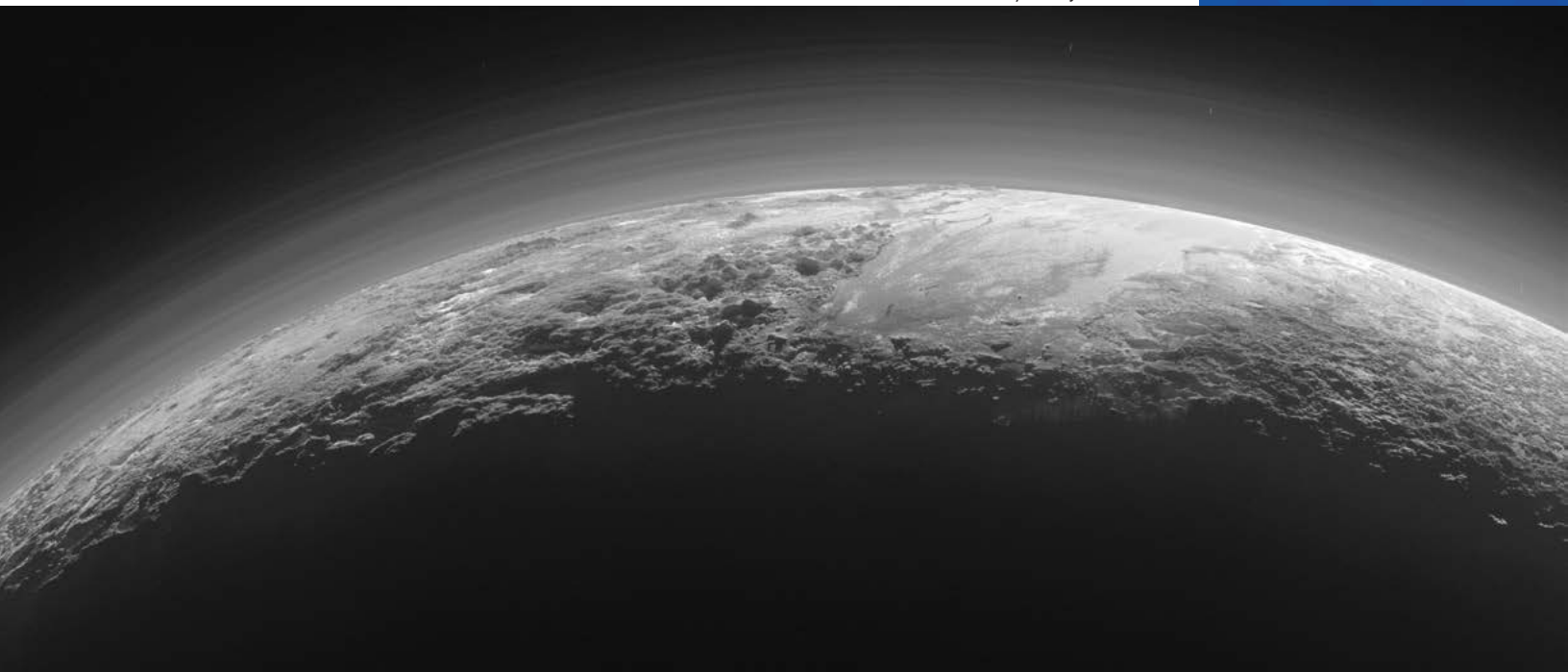
SwRI leads the MMS science investigation and built the plasma composition instruments and payload computers for the four MMS spacecraft. Following a successful launch and on-orbit commissioning, the MMS spacecraft are studying how the Sun's magnetic field, carried by the solar wind, can merge with the Earth's. Using MMS data, scientists will unravel the microphysics of "magnetic reconnection" — a fundamental, but poorly understood, physical process that transforms magnetic energy into kinetic energy and heat. Reconnection is at the heart of the phenomena referred to as "space weather."

Our space engineering program continued growth this year with completion of several new spacecraft control systems. We also realized a 20-fold increase in solid-state recorder performance and established an instrument interface test bed for early evaluation of payload interoperability. Engineers are developing technology to meet challenging thermal and radiation environments, such as required by ESA's Solar Orbiter mission. With our central role in NASA's Cyclone Global Navigation Satellite System (CYGNSS), we are expanding our capabilities in the increasingly important area of microsatellite design, fabrication, and integration.

The Institute's planetary science program is known for developing computer models to simulate and understand the formation of the planets and other solar system bodies. In 2015, new models helped SwRI scientists determine how Jupiter and Saturn likely formed in the solar system's protoplanetary disk. These new calculations show that the cores of these gas giants formed by gradually accumulating a

This image, captured by New Horizons 15 minutes after its closest approach on July 14, shows Pluto's mountains, thought to consist of water ice, and in the upper right, a smooth plain of frozen nitrogen, methane, and carbon monoxide. Also visible in the image are multiple layers of hydrocarbon haze.

D021674 / Courtesy NASA/JHUAPL/SwRI



D021672 / Courtesy ULA

SwRI leads the science investigation for NASA's Magnetospheric Multiscale (MMS) mission. Launched from Cape Canaveral in March, the four MMS spacecraft have achieved the tightest flying formation ever flown in Earth orbit as they probe the boundary of the magnetosphere.

D021529_1511

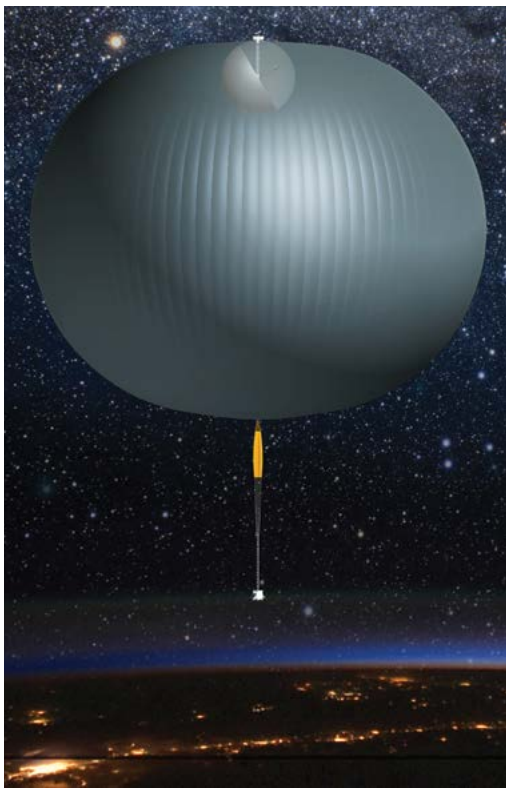
For a future mission to Europa, Jupiter's fourth largest moon, NASA has selected SwRI's MAss Spectrometer for Planetary EXploration (MASPEX™) instrument to measure trace chemicals in the moon's atmosphere. MASPEX will probe Europa's thin atmosphere, especially any plumes venting from an ocean thought to lurk below the moon's icy surface, looking for elements that point to the possibility of life.

population of planetary pebbles — icy objects about a foot in diameter. In another study, SwRI researchers combined numerical simulations with the analysis of stony meteorites to calculate that the giant impact that formed the Moon occurred roughly 4.47 billion years ago.

As we look to the future, two SwRI-developed instruments — MASPEX (MAss Spectrometer for Planetary EXploration) and UVS (Ultraviolet Spectrograph) — have been selected for a NASA mission to probe Jupiter's icy moon Europa. The two instruments will work in tandem to search for specific chemical compounds in Europa's atmosphere to determine if the icy moon could host life. MASPEX, developed with NASA and SwRI funding, is by far the most sensitive, highest resolution mass spectrometer ever flown in space. UVS belongs to a family of UV instruments SwRI developed for various planetary missions, including ESA's JUICE (JUpiter ICy moon Explorer) mission and the Juno mission.

Next year promises more excitement with the launch of CYGNSS' constellation of eight microsatellites and the arrival of the SwRI-led Juno spacecraft at Jupiter. Juno will spend a year in polar orbit studying the origin and evolution of the solar system's largest planet.

*Visit **spacescience.swri.org** for more information or contact Vice President Dr. James L. Burch at (210) 522-2526 or jim.burch@swri.org.*



D021673

Working with the University of Arizona, SwRI developed, built, and is testing a scale-model large balloon reflector (LBR) telescope, which features an inflatable, spherical reflector deployed within a much larger carrier balloon. The LBR telescope will float to the edge of space, well above most of the Earth's atmosphere, which can absorb and distort high-energy electromagnetic signals.

CONSOLIDATED FINANCIAL STATEMENTS

For the years ended September 25, 2015, and September 26, 2014

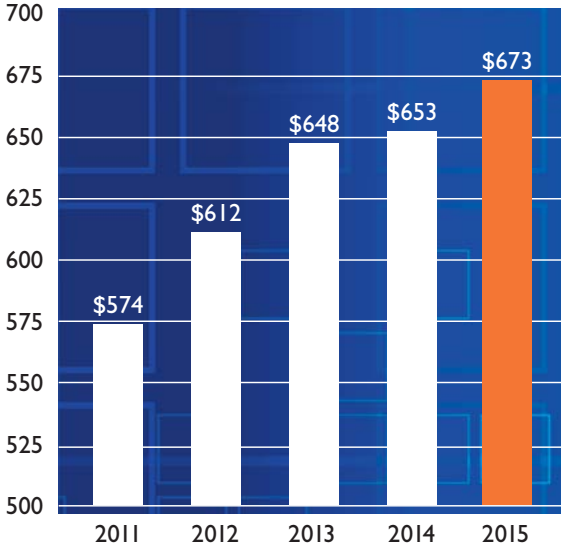
INCOME STATEMENTS (in thousands of dollars)

	2015	2014
Revenue	$592,364	$548,783
Direct Project Costs	338,937	331,037
Operating Income	253,427	217,746
Division Operating Expenses	141,294	139,184
General Overhead	61,014	53,407
Depreciation — General Facilities	15,389	15,945
Internal Research	7,220	6,861
Realized/Unrealized Loss (Gain) on Postretirement Medical Funds	3,576	(4,213)
Income Before Federal Income Tax Expense	24,934	6,562
Federal Income Tax Expense (Credit)	1,139	(1,335)
Net Income	$23,795	$7,897

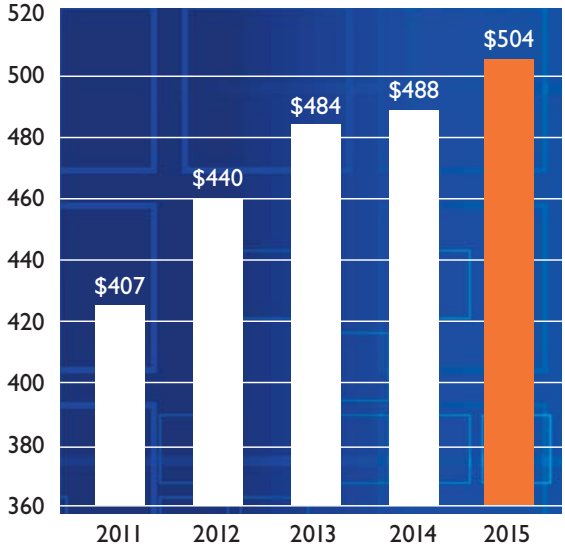
BALANCE SHEETS (in thousands of dollars)

	2015	2014
Current Assets	$254,197	$246,751
Property and Equipment, Net	294,905	292,540
Other Assets	123,959	114,038
Total Assets	$673,061	$653,329
Current Liabilities	$108,371	$104,634
Noncurrent Liabilities	61,184	60,982
Net Assets	503,506	487,713
Total Liabilities and Net Assets	$673,061	$653,329

TOTAL ASSETS (in millions of dollars)



NET ASSETS (in millions of dollars)



BOARD OF DIRECTORS

Chairman
Dr. Ricardo Romo
President
The University of Texas at San Antonio
San Antonio, Texas

Vice Chairman
Mr. Milton B. Lee
General Manager and CEO (Retired)
CPS Energy
San Antonio, Texas

Mr. Wayne S. Alexander
President (Retired)
SBC Southwestern Bell
San Antonio, Texas

Mr. Gene Ames
Ames Minerals
San Antonio, Texas

Mr. J. Dan Bates
President Emeritus
Southwest Research Institute
Shavano Park, Texas

Mr. Walter D. Downing, P.E.
Executive Vice President
Southwest Research Institute
San Antonio, Texas

Mr. A. Baker Duncan
Chairman
Duncan-Smith Investments Inc.
San Antonio, Texas

Mr. Adam L. Hamilton, P.E.
President
Southwest Research Institute
San Antonio, Texas

Mr. Roger R. Hemminghaus
Chairman and CEO (Retired)
Ultramar Diamond Shamrock Corporation
San Antonio, Texas

Mr. John C. Korbell
Managing Director
Morgan Stanley
San Antonio, Texas

Mr. Philip J. Pfeiffer
Of Counsel, Retired Senior Partner
Norton Rose Fulbright US LLP
San Antonio, Texas

Dr. Mary Ann Rankin
Senior Vice President and Provost
University of Maryland
College Park, Maryland

Mr. David S. Zachry
CEO
Zachry Corporation
San Antonio, Texas

OFFICERS

Mr. Adam L. Hamilton, P.E.
President

Mr. Walter D. Downing, P.E.
Executive Vice President

Mrs. Beth Ann Rafferty, C.P.A.
Chief Financial Officer
Vice President — Finance
Institute Secretary

Ms. Linda M. Boehme, C.P.A.
Treasurer
Assistant Institute Secretary

VICE PRESIDENTS

Mr. Kenneth H. Bennett Jr.
Applied Physics

Ms. Mary Massey, P.E.
Applied Power

Mrs. Susan B. Crumrine
Automation and Data Systems

Dr. Michael G. MacNaughton, P.E.
Chemistry and Chemical Engineering

Mr. Daniel W. Stewart, P.E.
Engine, Emissions, and Vehicle Research

Mr. Steven D. Marty, P.E.
Fuels and Lubricants Research

Dr. Wesley C. Patrick
Geosciences and Engineering

Mr. Danny M. Deffenbaugh
Mechanical Engineering

Mr. C. Nils Smith, P.E.
Signal Exploitation and Geolocation

Dr. James L. Burch
Space Science and Engineering

Mr. Paul Easley
Facilities and General Services

Mr. John W. McLeod
Vice President and General Counsel
Legal and Patent Office

ADVISORY TRUSTEES

Mr. James "Jim" R. Adams
Chairman of the Board (Retired)
Texas Instruments
San Antonio, Texas

Dr. C. Mauli Agrawal
Vice President for Research
The University of Texas at San Antonio
San Antonio, Texas

Dr. Dennis A. Ahlburg
Former President
Trinity University
San Antonio, Texas

Mr. Jack R. Allender
Partner
Fulbright & Jaworski LLP
Houston, Texas

Mr. Curtis "Curt" V. Anastasio
President and CEO (Retired)
GasLog Partners LP
NuStar Energy LP
San Antonio, Texas

Mr. Henry "Hank" Arendt, P.E.
Director of Technology (Retired)
Halliburton Energy Services
Dallas, Texas

Mr. Kenneth "Ken" E. Arnold, P.E., NAE
Senior Technical Advisor
WorleyParsons
Houston, Texas

Dr. M. Katherine Banks, P.E.
Vice Chancellor and Dean of Engineering
Director, Texas A&M Engineering Experiment Station
College Station, Texas

Mr. James R. Berg
President
MatsonCreative.com
San Antonio, Texas

Mr. David W. Biegler
Chairman
Southcross Energy Partners GP, LLC
Dallas, Texas

Dr. John R. Brazil
President Emeritus
Trinity University
Boerne, Texas

Dr. JoAnn Browning
Dean, College of Engineering
The University of Texas at San Antonio
San Antonio, Texas

Mrs. Phyllis Browning
Owner and CEO
The Phyllis Browning Company
San Antonio, Texas

Mr. J. Fred Bucy Jr.
President and CEO (Retired)
Texas Instruments Inc.
Dallas, Texas

Mr. Richard "Dick" L. Burdick
Retired Chairman
Thurmon Industries
New Braunfels, Texas

Mr. Michael D. Burke
Chair and Founder
San Antonio Clean Technology Forum
San Antonio, Texas

Dr. Ronald K. Calgaard
Chairman
Ray Ellison Grandchildren Trust
San Antonio, Texas

Mr. Richard W. Calvert
San Antonio, Texas

Mr. Tobin "Toby" Calvert
Investment Counselor
Luther King Capital Management
San Antonio, Texas

Mr. Trent Campbell Jr.
President
Campbell Industrial Sales Inc.
Houston, Texas

Dr. Donald M. Carlton
CEO (Retired)
Radian International
Austin, Texas

Dr. Francisco G. Cigarroa
Professor of Surgery
Transplant Center
The University of Texas Health Science Center at San Antonio
San Antonio, Texas

Dr. Alfred C. Coats
Managing Partner
AlphaQuest Consulting
Houston, Texas

Ms. Lila M. Cockrell
President (Retired)
San Antonio Parks Foundation
San Antonio, Texas

Gen. Donald "Don" G. Cook, USAF (Ret.)
San Antonio, Texas

Mr. Richard "Rich" B. Curtin
Executive Vice President — Operations (Retired)
Southwest Research Institute
San Antonio, Texas

Dr. Stuart Dorsey
President
Texas Lutheran University
Seguin, Texas

Mr. John W. Feik
President and COO
DFB Pharmaceuticals Inc.
San Antonio, Texas

Dr. Gregory L. Fenves
President
The University of Texas at Austin
Austin, Texas

Dr. William "Bill" L. Fisher
Professor, Geological Sciences
Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas

Dr. Peter T. Flawn
President Emeritus
The University of Texas at Austin
Austin, Texas

Dr. Robert "Bob" R. Fossum
President
San Juan Southwest
Dallas, Texas

Mr. James B. Francis Jr.
President
Francis Enterprises Ltd.
Dallas, Texas

Mr. Tom C. Frost
Chairman Emeritus
Frost
San Antonio, Texas

Mr. Robert K. Garrison
Executive Vice President and
General Manager
San Antonio Division
EOG Resources
San Antonio, Texas

Mr. Martyn C. Glen
Senior Managing Director
Integra Realty Resources — San Antonio
San Antonio, Texas

Dr. Earnest "Ernie" F. Gloyna
Dean Emeritus
Cockrell School of Engineering
The University of Texas at Austin
Austin, Texas

Mr. Christopher "Kit" Goldsbury Jr.
President and CEO
Silver Ventures
San Antonio, Texas

Ms. Paula Gold-Williams
Group Executive Vice President
Financial and Administrative Services
CFO and Treasurer
CPS Energy
San Antonio, Texas

Mr. James D. Goudge
Chairman and CEO
Broadway Bank
San Antonio, Texas

Dr. Joseph "Jody" M. Grant
Chairman Emeritus
Texas Capital Bancshares
Dallas, Texas

Mr. William "Bill" E. Greehey
Chairman of the Board
NuStar Energy LP
San Antonio, Texas

Mr. Mike Grubb
President and CEO
Southern Gas Association
Dallas, Texas

Dr. Rolf R. Haberecht
Chairman of the Board
VLSIP Technologies Inc.
Richardson, Texas

Mr. John "Jack" A. Hammack
Owner
Hammack Oil & Gas
Dallas, Texas

Mr. George A. Helland Jr., P.E.
Retired Executive
Houston, Texas

Dr. William L. Henrich, MACP
President
The University of Texas Health Science
Center at San Antonio
San Antonio, Texas

Mr. Mario Hernandez
President
San Antonio Economic Development
Foundation
San Antonio, Texas

Dr. John P. Howe III
President and CEO
Project HOPE
Millwood, Virginia

Mr. Benny H. Hughes
Of Counsel
Orgain, Bell & Tucker LLP
Beaumont, Texas

Dr. Anthony J. Infante
Professor of Pediatrics
The University of Texas Health Science
Center at San Antonio
San Antonio, Texas

Mr. Mark M. Johnson
Vice Chairman
Texas Capital Bank
San Antonio, Texas

Dr. Dale E. Klein
Associate Vice Chancellor for Research
The University of Texas System
Austin, Texas

Mr. William "Bill" R. Klesse
CEO and Chairman of the Board
(Retired)
Valero Energy Corporation
San Antonio, Texas

Mr. Jeffrey "Jeff" Kodosky
Co-Founder and Fellow
National Instruments
Austin, Texas

Mr. Joseph "Joe" R. Krier
Councilman District 9
San Antonio, Texas

Mrs. Carolyn Labatt
CEO
Computer Solutions
San Antonio, Texas

Lt. Gen. Frank F. Ledford Jr., USA (Ret.)
Former Surgeon General of the Army
President (Retired)
Texas Biomedical Research Institute
San Antonio, Texas

Dr. Adena Williams Loston
President
St. Philips College
San Antonio, Texas

Ms. Kimberly S. Lubel
Chairman and CEO
CST Brands Inc.
San Antonio, Texas

Mr. Julian G. Martin
Austin, Texas

Mr. L. Lowry Mays
President
Mays Family Enterprises LLC
San Antonio, Texas

Gen. William V. McBride, USAF (Ret.)
San Antonio, Texas

Mr. Robert S. McClane
President
McClane Partners LLC
San Antonio, Texas

Dr. Henry C. McGill Jr.
Senior Scientist Emeritus
Texas Biomedical Research Institute
Canyon Lake, Texas

Mr. Thomas M. Mengler, J.D.
President
St. Mary's University
San Antonio, Texas

Mr. John "Jack" K. Meyer
Senior Partner
South Texas Syndicate
San Antonio, Texas

ADVISORY TRUSTEES

Mr. Palmer Moe
Managing Director (Retired)
Kronkosky Charitable Foundation
Sunrise Beach, Texas

Dr. Jon N. Moline
President Emeritus
Texas Lutheran University
Seguin, Texas

Mr. Joe F. Moore
CEO (Retired)
Bonner & Moore Associates
Houston, Texas

Dr. Sharon Mosher
Dean, Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas

Mr. Robert "Bob" G. Newman
Partner (Retired)
Fulbright & Jaworski LLP
San Antonio, Texas

Ms. Jan Newton
President (Retired)
AT&T Texas
Boerne, Texas

Dr. Gabriele Niederauer
CEO and President
Bluegrass Vascular Technologies
San Antonio, Texas

Dr. John M. Niedzwecki
Cain Chair Professor and Regents Professor
Zachry Department of Civil Engineering
Texas A&M University
College Station, Texas

Dr. Richard "Rusty" E. Phillips
Vice President, Technology
BioStable Science & Engineering Inc.
Austin, Texas

Dr. David M. Pierce, P.E.
President
D.M. Pierce & Associates
Houston, Texas

Dr. Tessa Martinez Pollack
San Antonio, Texas

Mr. Chester N. Posey
Chairman
Orbix Corporation
Clifton, Texas

Dr. Carl F. Raba Jr., P.E.
Chairman Emeritus
Raba Kistner Inc.
San Antonio, Texas

Mr. Christopher T. Rice
Executive Vice President — Shared Services (Retired)
AT&T
Dallas, Texas

Dr. Herbert "Herb" H. Richardson
Director Emeritus
Texas A&M Transportation Institute
College Station, Texas

Mr. John B. Roberts
Chairman of the Board and CEO (Retired)
Anheuser-Busch Theme Parks
Austin, Texas

Mr. Richard T. Schlosberg III
Chairman
Texas Biomedical Research Institute
San Antonio, Texas

Mr. Jack M. Spinks
Owner
Spinks & Associates
Claremore, Oklahoma

Mr. H. Leighton Steward
Chairman
Plants Need CO2.org
Boerne, Texas

Dr. Ben G. Streetman
Dean Emeritus
Cockrell School of Engineering
The University of Texas at Austin
Austin, Texas

Dr. Edwin "Ned" L. Thomas
Dean of Engineering
Rice University
Houston, Texas

Dr. Ian M. Thompson
Director
Cancer Therapy & Research Center
CTRC — The University of Texas Health Science Center at San Antonio
San Antonio, Texas

Dr. Scott Tinker
Director, Bureau of Economic Geology
The University of Texas at Austin
Austin, Texas

Dr. Denise M. Trauth
President
Texas State University — San Marcos
San Marcos, Texas

Mr. Thomas L. Travis
President and CEO
Bank 7
Oklahoma City, Oklahoma

Mr. Kenneth P. Trevett
President Emeritus
Texas Biomedical Research Institute
San Antonio, Texas

Mr. Curtis T. Vaughan III
Chairman of the Board and CEO
Vaughan & Sons Inc.
San Antonio, Texas

Mr. Edward E. Whitacre Jr.
Chairman of the Board and CEO (Retired)
General Motors Company
Chairman Emeritus
AT&T Inc.
San Antonio, Texas

Col. Clarence R. "Reggie" Williams, USAF (Ret.)
President and CEO (Retired)
San Antonio Area Foundation
San Antonio, Texas

Mr. John "Jack" H. Willome
President (Retired)
Rayco
Boerne, Texas

The Honorable Nelson W. Wolff
Bexar County Judge
Commissioners Court
San Antonio, Texas

Mr. Gary V. Woods
President
McCombs Enterprises
San Antonio, Texas

Mrs. Jeanie R. Wyatt, CFA
CEO and Chief Investment Officer
South Texas Money Management Ltd.
San Antonio, Texas

Mr. H. Bartell Zachry Jr.
President and CEO
Zachry Interests Inc.
San Antonio, Texas

All inquiries should be addressed to:
Communications Department
Southwest Research Institute
P.O. Drawer 28510
San Antonio, Texas 78228-0510
Phone (210) 522-2257, Fax (210) 522-3547 or
e-mail action67@swri.org.

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

Southwest Research Institute
6220 Culebra Road
P.O. Drawer 28510
San Antonio, Texas 78228-0510
United States

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

SOUTHWEST RESEARCH INSTITUTE

Business Development
(210) 522-2122
Fax (210) 522-3496

bd@swri.org

swri.org

Advanced science. Applied technology.