

ANNUAL  
REPORT 2016

SOUTHWEST RESEARCH INSTITUTE

## 2016 ANNUAL REPORT

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In 2016, Southwest Research Institute's automated vehicle program celebrated its 10-year anniversary. Our annual report cover features an image of an intersection mapped by our award-winning Ranger technology. Ranger enables precise navigation for automated vehicles using commercially available hardware and sophisticated SwRI algorithms. We develop low-cost, high-performance perception, localization, path planning, and control technologies for intelligent vehicles ranging from golf carts to SUVs to tractor trailers. We also develop unmanned, cooperative vehicle, and active safety systems for commercial and military applications.

Vehicle automation is one of our most recent programs for the transportation and automotive industries. Since 1949, SwRI has dedicated extensive resources to serving the automotive industry, solving problems from headlights to tailpipes and evaluating the functional fluids that keep vehicles running. We are the world's largest independent engine, fuels, and lubricants research, development, and evaluation laboratory. SwRI maintains more than 200 engine and transmission dynamometer test cells to support these activities.

SwRI was among the pioneers of the vehicle emissions field, measuring and characterizing engine exhaust constituents and developing some of the first official emissions test and control strategies. Our staff provides a full range of automotive design and development services, including component upgrades and new engine designs for mass production. We design, develop, and evaluate engines and powertrain components to reduce emissions, improve efficiency and durability, and meet other new product requirements, such as power and torque.

DM02204\_9516







Pictured are five of the 20 vehicles in our unmanned systems research fleet.



DO22237\_9906

Today, around 800 SwRI employees work on automotive-related projects.



## FROM THE PRESIDENT

DM019740\_3554

As Southwest Research Institute enters its 70th year, our diverse project portfolio continues to serve us well, attracting clients and reinforcing our stature as a premier applied research and development organization. The programs outlined in this Annual Report highlight just some of the notable accomplishments our staff achieved this past year. From developing nanoparticle technology to probing the vastness of space, SwRI's 2016 program was highly successful in terms of technology advances and scientific achievement.

For the second consecutive year, our space science program made headlines worldwide when NASA's Juno spacecraft arrived at our solar system's largest planet, Jupiter. This SwRI-led mission will help scientists better understand the formation of the gas giant and the origin of the rest of the solar system, including Earth. The Juno orbit insertion came a year after the historic New Horizons encounter with Pluto. That mission, also led by SwRI, continued to return compelling flyby data.

Closer to Earth, the Magnetospheric Multiscale mission measured, for the first time, plasma physics associated with a phenomenon known as magnetic reconnection. In another Earth science program, we recently completed and delivered eight Cyclone Global Navigation Satellite System (CYGNSS) microsattellites to study how hurricanes intensify and improve storm forecasting and tracking.

Our clean energy program is also thriving. In 2016, the U.S. Department of Energy funded six projects, including a program to design, build, and operate a large-scale pilot plant at our San Antonio headquarters to demonstrate supercritical carbon dioxide power cycles. This promising technology could help meet energy goals for cleaner, more secure, and more affordable power. We are also designing a next-generation oxy-combustion pilot plant. This advanced clean coal technology has the potential to generate highly efficient, carbon-free electricity.

Recent advances in our chemistry program include nanosuspension formulas particularly applicable to our drug development and delivery program. This year, we began pharmaceutical research projects targeting both the Ebola and Zika viruses.

Our staff continues to engage with peers around the world on innovative projects and ideas, advancing technology and scientific discourse in practically every technical field as we solve problems in environments stretching from deep sea to deep space. For example, the Institute is a founding member of the San Antonio Bioscience Research Database, a collaborative resource of bioscience research projects. Globally, we are recognized for creating and leading multiclient consortia that bring together industry participants to develop precompetitive technology. We established the Aluminum Head Evaluation, Analysis, and Durability consortium to advance automotive cylinder head designs. We expanded initiatives to study reservoirs in Texas' Permian Basin and Austin Chalk, collecting geologic data to help the petroleum industry improve production. And the ROS-Industrial consortium, which supports factory automation, went global this year, expanding into the Asia-Pacific region.

We continue to be a good corporate citizen in the communities in which we operate. Our staff members volunteer at local schools and nonprofits, mentor students, and serve as judges for science and engineering competitions. The Institute supports engineering contests, offers student employment opportunities, and hosts programs such as the Young Engineers and Scientists Program. In 2016, almost 250 employees and their families participated in the annual SwRI Cares service day, and almost 80 percent of our employees participated in the United Way campaign, which raised more than \$806,000.

Our capital improvement program includes infrastructure projects to benefit current and future clients. We are nearing



DD21263

## IR&D 2016

completion of facilities to add capacity to deep-water, high-pressure ocean simulation chambers, and to house a two-stage, light-gas launch tube that can achieve hypervelocities close to 7 kilometers per second. We upgraded tracks at the Locomotive Technology Center, allowing us to conduct certification testing under the Environmental Protection Agency's new Tier 4 emissions standards. We finalized the Institute's air pollution abatement system for our fire testing facilities, completing a multi-year, \$5.4 million investment to provide safer, cleaner, and greener testing practices.

In addition to improving our facilities, we continue to invest in our future in other ways as well. Our internal research and development program provides Institute engineers and scientists the freedom to explore groundbreaking concepts. In 2016, we initiated 106 projects and spent more than \$7.4 million to develop innovative solutions to problems. A number of these projects are highlighted throughout this report.

Although an outstanding year in terms of our technical programs, 2016 was challenging in terms of financial performance. Institute revenue sources are split at a nearly even ratio between government and industry, and that diversity has historically helped the Institute. This year, however, industry variables and a fluctuating economic and political landscape created broad fiscal effects. Even in this environment, SwRI's technical program generated revenues of \$559 million, resulting in a net income of \$6.8 million. The Institute provides approximately \$1 billion of economic impact to the San Antonio and Bexar County areas annually, and provides significant positive economic influence for the other communities in which we operate.

Looking to next year, we are positioned to take advantage of a range of new business opportunities. Already, a large backlog of contracts and proposals points to a successful 2017. For example, we recently received a five-year, \$39 million contract to support the Naval Surface Warfare Center Dahlgren Division. We will continue to seek new ways to increase revenue and provide opportunities for our staff consistent with our mission.

With support of the Board of Directors, we continue to strive to be the first choice for clients seeking solutions for their most complex problems. I look forward to working with the Advisory Trustees and Institute staff to ensure our clients continue to receive the highest quality scientific and technical services in 2017 and beyond.



Adam L. Hamilton, P.E.  
President

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. In 2016, SwRI initiated 106 new projects, 20 percent over 2015, and spent more than \$7.4 million on internal research.

Some of this year's projects include:

Rhodium™ Therapeutic Drug Development Software:  
Generation II Performance Port

Exploration of Encapsulation Methods of  
Subunit Vaccines

Fuel Economy Effect of Advanced Vehicle Hardware

Low-Cost, Brake Mean Effective Pressure,  
High-Power-Density Diesel Engine

Transient Durability Analysis of Aluminum  
Cylinder Heads

Developing a New Polycyclic Aromatic Hydrocarbon  
Method for Process Oils

Robotic Product Singulation Testbed for  
Sorting Applications

Assessing the Feasibility of Ranger in Kit Form

Large-Scale Additive Manufacturing Using Concrete  
Composite Materials

Zero-Power Sensors for the Internet of Things and  
Other Applications

Stratospheric Compressor for Lighter-than-Air Vehicles

Modeling of Exotic Ice Glaciers on Pluto and Mars

Development of a Sensor for Use in Network  
Threat Awareness

Avionics Assessments

Development of Artificial Muscle Actuator for  
Physical Joint Simulator

Impact of Carbon-Fiber-Reinforced Composites

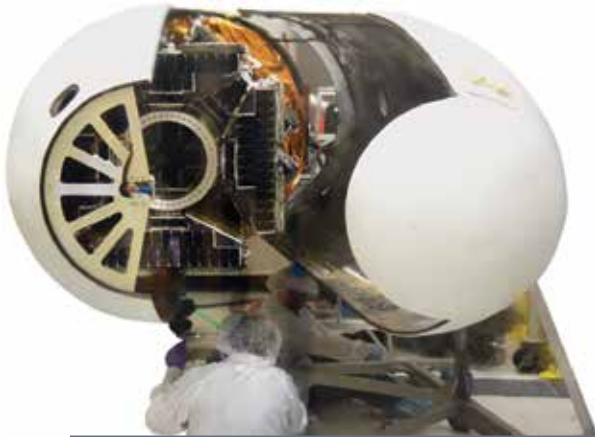
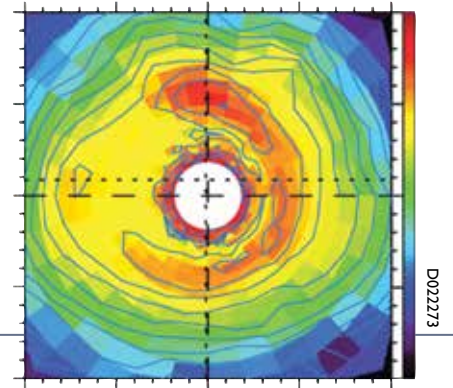
Developing an Integrated Methodology to Estimate  
Geologic Stress States

Mechanical Stratigraphy and Natural Deformation in  
the Austin Chalk

[ird.swri.org](http://ird.swri.org)

# 2016 HIGHLIGHTS

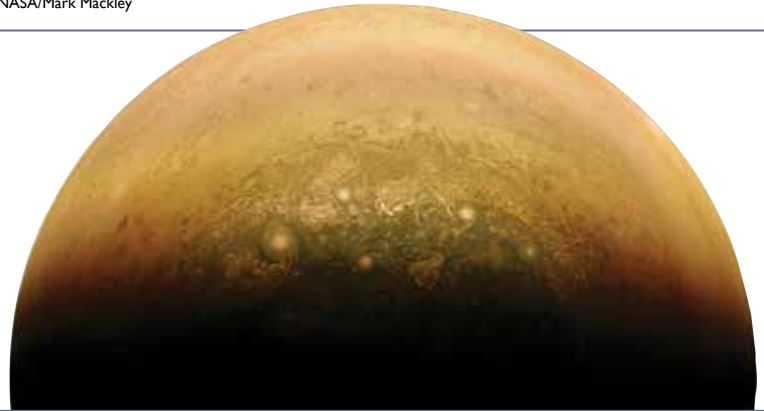
SwRI leads the science investigation for NASA's Magnetospheric Multiscale (MMS) mission, which recently made the first direct detection of the source of magnetic reconnection (at right), which originates in a narrow boundary layer between the Earth's magnetosphere and the solar wind. During reconnection, the magnetic field lines of the Earth break, then almost instantly reconnect with solar magnetic field lines allowing solar energy to flow unimpeded into the magnetosphere. This transfer of energy drives magnetic storms and dramatic auroral displays. The MMS Smart Instrument Suite Team received NASA's Robert H. Goddard Exceptional Achievement Award.



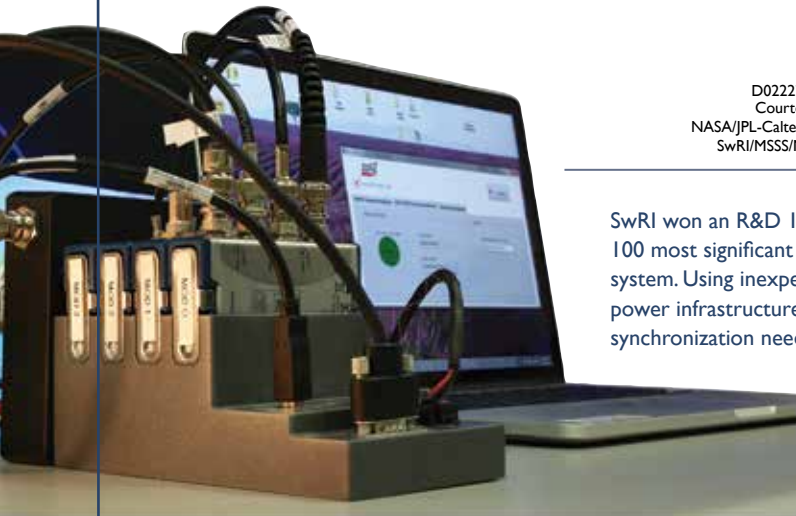
For the first time, SwRI designed and built spacecraft, eight microsattellites for NASA's Cyclone Global Navigation Satellite System (CYGNSS) mission. Here the satellites are enclosed in the launch vehicle fairing for the December 2016 launch. The CYGNSS mission is designed to measure the oceans beneath a hurricane to allow scientists to predict how strong a storm will be when it makes landfall.

D022274  
Courtesy NASA/Mark Mackley

In 2016, NASA's Juno spacecraft entered orbit around the king of the planets, Jupiter. The SwRI-led mission returned the first images of the Jovian poles, which are rife with swirling storms as large as Mars and towering 50 miles above the planet's cloud tops. A "citizen scientist" created this image of the sunlit side of Jupiter's south pole using data from JunoCam, a public outreach instrument.



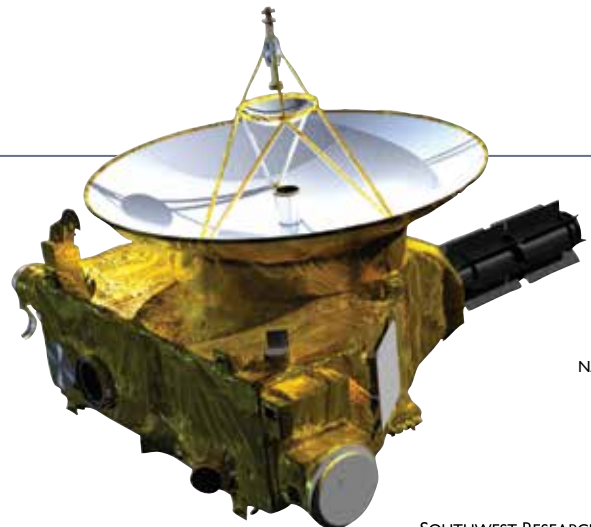
D022275  
Courtesy  
NASA/JPL-Caltech/  
SwRI/MSSS/Mai



SwRI won an R&D 100 Award for the Time REsilient System (TRES), named one of the 100 most significant innovations of 2016. We worked with a public utility to develop the system. Using inexpensive hardware and sophisticated software, TRES protects critical power infrastructure from GPS cyberattacks, maintaining the precise, GPS-based time synchronization needed for utility operations. SwRI has won 41 awards since 1971.

D022240\_0097

The New Horizons science team and Principal Investigator Dr. Alan Stern have been honored numerous times for their work leading the exploration of Pluto. Stern made the 2015 TIME 100 list (for the second time) and the team has earned more than 25 awards to date.



D022276  
Courtesy  
NASA/JHUAPL/SwRI



## ACTIVITIES



**663**  
PAPERS

**620**  
PRESENTATIONS



In 2016, our technical staff published 663 papers and gave 620 presentations. The staff also served technical societies, industry boards, and working committees in a variety of local, national, and international roles.

## ACHIEVEMENTS



### TECHNICAL SOCIETY FELLOWS

- Dr. James Walker**  
International Ballistics Society
- Dr. William Bottke**  
Meteoritical Society
- Dr. Kathryn A. Dannemann**  
ASM International



### AWARDS

- Dr. Darin George**  
Laurance S. Reid Award,  
International School of Hydrocarbon Measurement
- Dr. Klaus Brun**  
ASME Industrial Gas Turbine Award
- Dr. John Spencer**  
AGU Whipple Award
- Dr. Terry Alger**  
ASME Internal Combustion Engine Award



**40**  
**40**

### HONORS

- San Antonio Business Journal names staff members "40 Under 40" rising stars
- Paul Hvass**
- Eloy Flores**
- Ron McGinnis**



### MEDALS

- Dr. Stephen Fuselier**  
European Geosciences Union Hannes Alfvén Medal
- Dr. Christopher Freitas**  
ASME Fluids Engineering Division's 90th Anniversary Medal

## STAFF



**2,665**

BACHELOR'S  
  
**691**

MASTER'S  
  
**513**

DOCTORATE  
  
**275**

## PATENTS

AWARDED

**46**



U.S. Patents

FILED

**43**



Patent Applications

SUBMITTED

**60**



Invention Disclosures

# APPLIED PHYSICS

D022277

- 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
- Microelectromechanical Systems (MEMS)
- Robotic Vehicle Evaluations
- Failure Analysis
- Rapid Prototyping
- Flight Controls
- Miniaturization Technologies
- Turbine Engine Tests & Diagnostics
- Condition-Based Maintenance
- Gunship Controls & Simulation
- Automatic Test Systems
- Unmanned Aerial Vehicles

Southwest Research Institute pushes the boundaries of engineering and physics to create advanced technologies and systems to meet our clients' challenging demands. Our diverse staff and world-class expertise allow us to create innovative, cost-effective approaches to solve complex problems. SwRI develops and evaluates novel systems and software for a range of unique applications.

In 2016, SwRI made a fourth update to the Digital Automotive Image System (DAIS). Fifteen thousand law enforcement organizations across the U.S. and Canada use this software tool to investigate crimes involving motor vehicles. Using unique, SwRI-developed search algorithms, DAIS helps identify vehicles seen by witnesses or captured by video cameras at a crime scene.

To support U.S. Army CH-47F helicopter maintenance, SwRI evaluated a cockpit digital indicator of the aircraft's hydraulic system to assess failure trends and develop depot support capabilities. By reverse engineering indicator components, we were able to develop a test system and technical data package for the Corpus Christi Army Depot.

This year, we developed procedures to perform noise and vibration testing for gas-handling equipment to help a client meet sound restrictions. Using our anechoic chamber, engineers measured acoustic and structural noise emitted by an equipment assembly handling high-pressure nitrogen gas. We modified the chamber to accommodate delivery of large volumes of gas, expanding our acoustic evaluation capabilities.

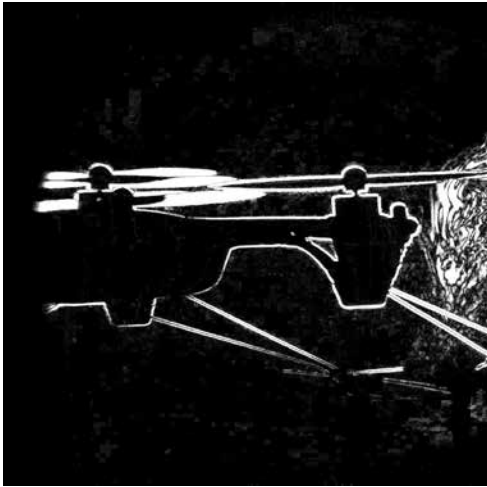
Caves and other underground voids pose potential hazards to construction activities, but surveying these features is challenging and labor-intensive. GPS does not function underground and these voids are often too small for conventional surveying equipment. SwRI has developed and delivered a prototype cave mapping system for the city of Austin that safely surveys these features without requiring a person to enter the cave. Using a compact rotating LIDAR scanner on the end of a telescoping pole, the system can generate

In some regions, discovering limestone caverns can delay construction activities while the potential collapse hazard is mapped. SwRI developed this prototype cave mapping system to safely survey voids without requiring a person to enter.

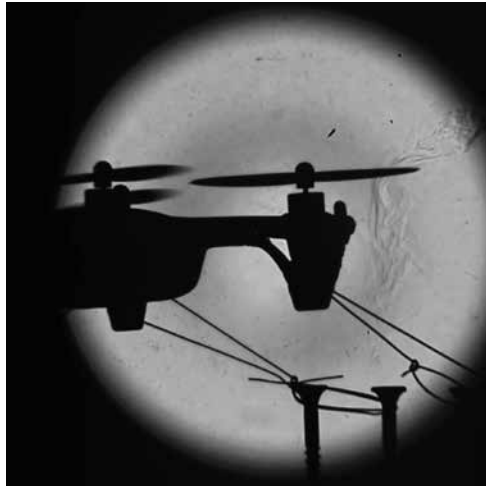


D022278





D022279



D022280

We are building a 2-foot parabolic mirror to visualize airflow around a quadcopter using advanced imaging techniques. Engineers want to characterize the “flow bubble” that keeps a drone aloft to understand how it interacts with objects in the environment.

3-D maps of voids. The pole can extend 25 feet and LIDAR can scan up to 65 feet.

In the human health arena, our microbiology labs evaluated a new ultrafiltration method for a nationwide Environmental Protection Agency study. The method is designed to detect coliphages, harmful contaminants associated with *E. coli*, in local water supplies. Microbiologists also supported an internal research initiative to address antibiotic-resistant bacteria. SwRI-developed Rhodium™ molecular modeling software identified compounds that could inhibit beta-lactamase, an enzyme that helps bacteria develop resistance to antibiotics. Numerous biological assays determined how the compounds affected bacterial growth and whether they increased the effectiveness of antibiotics.

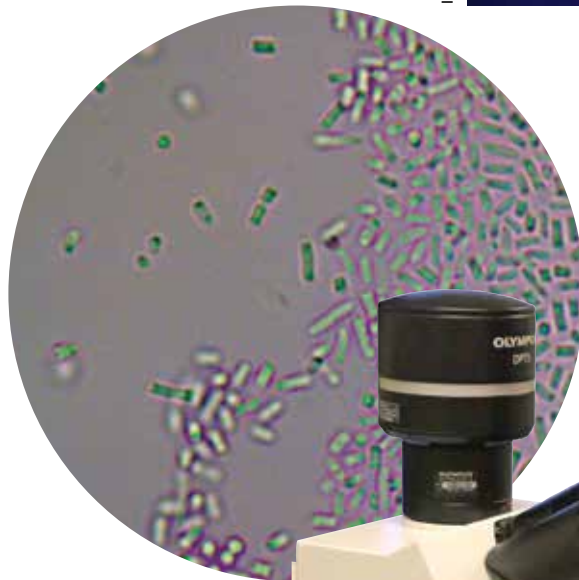
To support an upcoming NASA mission to Jupiter’s moon Europa, engineers are assessing components of an ultra-sensitive spectrometer. SwRI space scientists designed this instrument to characterize the composition of geyser-like plumes erupting from the moon. The analyses will verify that the spectroscopic signal remains strong as it is transformed from flowing ions into an electronic signature that can be transmitted back to Earth. Scientists will be looking at the data for signs that the water beneath Europa’s icy crust could support life.

For more information visit [applied-physics.swri.org](http://applied-physics.swri.org) or contact Vice President Ken Bennett at 210.522.5242 or [kenneth.bennett@swri.org](mailto:kenneth.bennett@swri.org).

SwRI developed a sensor-based autonomous device to discourage and ultimately deny entry to sensitive locations. We evaluated system performance using instrumented mobile mannequins (left) to measure what would be seen, heard, and felt by a human (right).



D022281



Microbiologists supported an internally funded project to model bacterial transport for applications in tumor targeting and bacteria-based corrosion. Experiments included studying bacteria in confined spaces to compare movement patterns and trajectories, particularly when chemical attractants were present.

D022282 /  
D022209\_5615



# AUTOMOTIVE ENGINEERING

DE138079

- 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

As the drive toward clean-burning, more efficient vehicles continues, Southwest Research Institute is at the forefront, combining expertise in powertrain technology with a long-standing program in fuels and lubricants research.

Automotive fuel economy remains an important factor for both commercial users and consumers. The SwRI-developed Direct Electronic Vehicle Control (DEVCon) system, combined with a high-precision chassis dynamometer, is helping industry meet Corporate Average Fuel Economy (CAFE) standards by providing highly repeatable fuel economy measurements. Even small improvements in fuel economy in today's advanced engines can be validated using this system. This past year, we expanded DEVCon's use by adding auto-shift capabilities for vehicles with manual transmissions.

We are pioneering dual-fuel technologies that enable large, high-horsepower engines used in the rail and mining industries to use a combination of diesel fuel and natural gas to reduce operating costs and harmful emissions. We are in our fifth year of a contract with a large engine manufacturer to develop and put into production a dual-fuel conversion kit for locomotives. The kit allows liquefied natural gas to provide up to 80 percent of the fuel. These engines meet U.S. Environmental Protection Agency Tier 3 locomotive emissions requirements while retaining the ability to run on 100 percent diesel fuel.

We developed an innovative approach to dramatically increase natural gas use in mining trucks. The method replaces stock diesel



D022102\_1738

We're extending RPECS<sup>®</sup>, a unique powertrain control system developed at SwRI, to acquire crank-angle-based measurements. Every sensor and actuator is sampled each engine cycle, allowing researchers to rapidly and cost-effectively map, evaluate, and modify engines under development.



injectors with optimized common rail injectors that offer industry a lower-cost alternative to more complex technologies under consideration. Initial results show a possible path to meeting U.S. EPA Tier 4 non-road emissions requirements without NO<sub>x</sub> aftertreatment or exhaust gas recirculation systems.

For the California Air Resources Board, we developed natural gas- and diesel-fueled proof-of-concept engines that demonstrate a 90 percent reduction in NO<sub>x</sub> emissions compared to current heavy-duty engines. These new engines will allow industry to pursue next-level technologies for lowering emissions to ultimately meet stricter regulations in the future.

Under our High-Efficiency Dilute Gasoline Engine 3 (HEDGE3) and Advanced Combustion Catalyst and Aftertreatment Technologies (AC<sup>2</sup>AT) consortia, we developed new methods to analyze engine combustion system performance and deposits. We developed a technique to predict flame speed and auto-ignition in highly dilute rich fuel-air mixtures. Another SwRI-developed process allows scientists to predict deposit formation in engines that use selective catalytic reduction to control NO<sub>x</sub> emissions. We validated both methods using high-speed optical measurements.

We designed a dynamometer test to evaluate how engine oils affect fuel economy in heavy-duty engines. This test identifies lubricants that provide fuel economy benefits, which will help reduce carbon dioxide emissions to conform to EPA greenhouse gas rules. While EPA certification testing captures precise emissions information, the procedures are not designed to address how lubricants affect fuel economy. Based on EPA dynamometer procedures, we developed a test to assess how different lubricants affect heavy-duty engine fuel economy.

The U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) Fuels and Lubricants Research Facility is located at and operated by SwRI. At TARDEC, we are evaluating gear oils designed to improve the overall fuel efficiency



DM1017373\_9053

Since 1949, SwRI has performed a wide variety of fuels and fluid-related research, evaluating engine oils, gasolines, additives, and transmission fluids.



An SwRI-developed dual-fuel conversion kit allows locomotives to use a combination of diesel fuel and natural gas.

D022283  
Courtesy  
GE Transportation  
Systems





# AUTOMOTIVE ENGINEERING

DE138079



DO22131\_9442

We expanded the test range of DEVCon, our electronic control system, by adding an auto-shift capability to evaluate vehicles with manual transmissions.

of military ground vehicles. Correlating stationary axle efficiency testing with the SAE J1321 vehicle testing standard showed that these gear oils could reduce fuel consumption by up to two percent. We designed and built a gear oil efficiency test stand that represents the military's light-, medium-, and heavy-duty tactical vehicles. The goal is to develop a Federal Test Method for conducting stationary axle testing of fuel-efficient gear oils for military equipment. The method would be the first to standardize procedures



DO22222\_5762

We designed this dual-fuel test stand to evaluate combining diesel fuel and natural gas in large, high-horsepower engines to reduce costs and lower emissions.

to assess the efficiency associated with different gear oils. The U.S. Army TARDEC plans to include this method in their approval process for new axle gear lubricants.

We are developing gasoline engine oil tests for the new GF-6 performance category. These oils will help automobile manufacturers meet CAFE standards while maintaining acceptable durability when used in today's advanced technology engines. SwRI formed the Pre-ignition Prevention Program to address low-speed



pre-ignition (LSPI) problems that can cause severe knocking in turbocharged engines with direct fuel injection systems. This consortium identified three main contributors to pre-ignition: lubricant formulation, fuel, and engine design and calibration. As a result, automobile manufacturers requested that the GF-6 performance category include a test to measure LSPI.

We also helped develop test protocols for a new diesel engine lubricant category, PC-11. These engine oils offer lower viscosities to help truck manufacturers meet EPA greenhouse gas regulations by reducing fuel consumption in heavy-duty trucks. The products will be introduced in the market in December 2016 as API® Category CK-4 and FA-4.

We developed a water mapping protocol to understand how additives affect water separation in aviation fuels. As diesel fuel passes through a pipeline, additives adsorbed onto pipeline walls can contaminate jet fuel. The additive can potentially affect how well filtration systems remove water from the fuel. SwRI conducts the water mapping protocol in its aviation filtration test facility, which uses an industry-standard two-stage aviation filter. For the test, 15,000 gallons of aviation fuel are treated with a diesel fuel additive and water is injected. Starting at low flow rates, we incrementally increase flow rates and monitor the downstream water content. If a test concludes at the maximum flow rate with minimal downstream free water, the candidate additive is likely to have minimal to no impact on the water separation characteristics of jet fuel.

For more information visit [automotiveengineering.swri.org](http://automotiveengineering.swri.org) or contact Vice President Daniel W. Stewart, P.E., at 210.522.3657 or [daniel.stewart@swri.org](mailto:daniel.stewart@swri.org), or Vice President Steven D. Marty, P.E., at 210.522.5929 or [steven.marty@swri.org](mailto:steven.marty@swri.org).



D021130\_9395

We developed a specialized axle test stand for evaluating gear oils used in military vehicles.



D021864\_7901

Our water mapping test rig evaluates how additives affect aviation fuels and how effectively filtration systems can remove water from the fuel.



# CHEMISTRY & CHEMICAL ENGINEERING

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

DM02215\_5388



Chemists are developing a mobile treatment unit to destroy chemical agents using the SwRI-designed Dedicated EGR<sup>®</sup> engine. After the agents are destroyed, exhaust gases are passed through soil-based fluidized bed and scrubber columns to remove combustion byproducts.

D022284

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 solutions for homeland security threats.

We continue to expand our integrated pharmaceutical activities, applying nearly 70 years of experience in microencapsulation technology. As a pioneer in this field, SwRI offers an onsite "introduction to microencapsulation" workshop for our clients. We are a preferred pharmaceutical research and development organization, providing comprehensive Current Good Manufacturing Practice services from drug discovery to production of clinical supplies of drugs for our clients.

We continue to make advances in drug delivery technologies, such as highly stable therapeutics based on novel nanosuspension formulations. We have recently enhanced our capabilities and capacity for drug formulations with new milling and fluid bed coater equipment.

In 2016, an implant we helped develop to treat opiate addiction was approved by the U.S. Food and Drug Administration. We are now modifying this platform for other diseases, such as Parkinson's and malaria. SwRI also is researching potential treatments for Ebola, a vaccine for a sexually transmitted disease, and antidotes for cyanide and other toxic chemicals.

For the energy industry, SwRI engineers and scientists develop novel processes for the oil, gas, and petrochemical sectors while developing new techniques for exploiting alternative sources of energy, such as biomass. Using state-of-the-art catalysts and processing techniques, SwRI is working with the University of Texas at San Antonio to use biofeedstocks from nonfood crop resources and create sustainable biofuels and other products. SwRI is developing a prototype process to upgrade biomass using a new lab-scale simulation of a high-pressure fluidized bed reactor, collecting data to ultimately scale the process for a larger bioenterprise.



D002174\_2375



SwRI engineers heat a high-temperature circulating fluidized bed pilot plant to 650 degrees C for pyrolysis and catalytic conversion to upgrade biomass, coal, and natural gas into fuels and desirable chemical products.

To support wood-framed, mid-rise architecture, SwRI developed fire tests to evaluate “green” wooden construction assemblies.



D072285

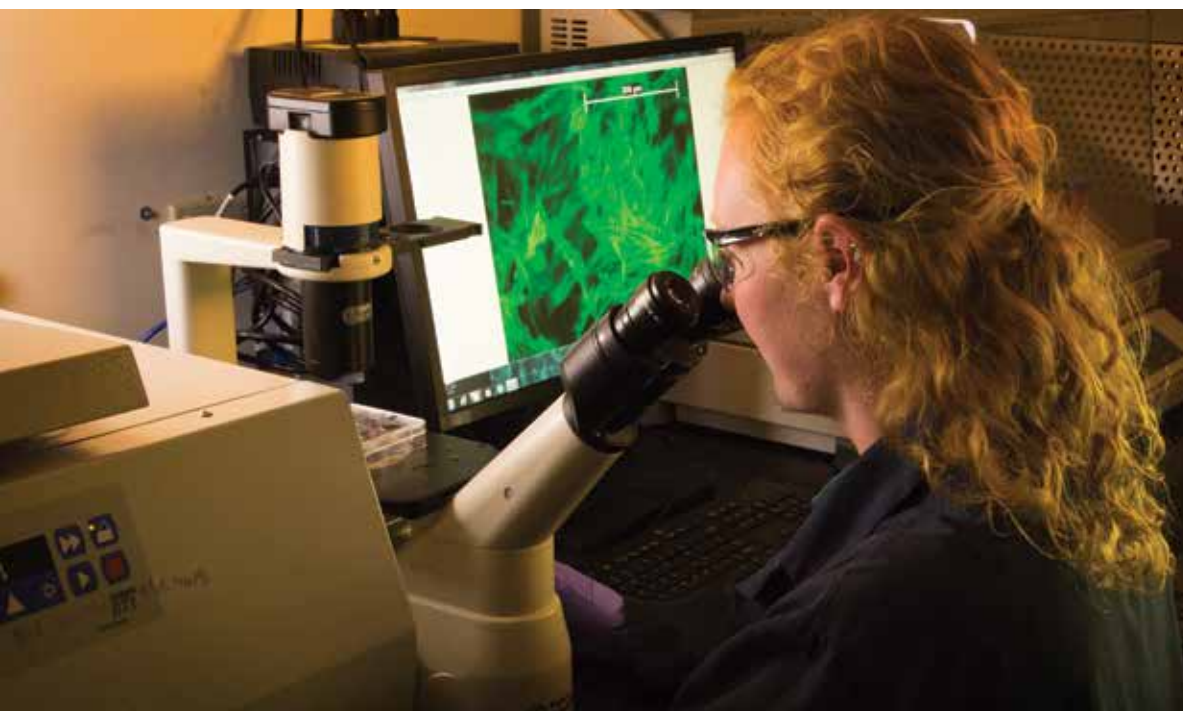
In a collaborative, multidisciplinary effort, chemists and chemical engineers are leading a three-year project with the Defense Advanced Research Projects Agency (DARPA) to create a mobile system to destroy chemical warfare agents and other hazardous materials close to where these threats may be found. This concept integrates our chemical engineering process development experience with our automotive engineering expertise, using a novel SwRI-designed Dedicated EGR® engine as a thermal treatment device. The byproducts of combustion are then captured using a novel soil-based pollution abatement system.

In another “green” application, engineers are helping industry assess the fire performance of wood-based components for midrise buildings 10 to 15 stories high. All-wood construction has many advantages: it uses a renewable resource, has seismic advantages,

and supports prefabrication into easy-to-assemble components. We designed and built a one-of-a-kind test system for prefabricated components and evaluated the fire performance of vertical beam floor joist connections using our small horizontal furnace.

We continue to develop quick, cost-effective analytical and radiochemistry techniques to screen foods, materials, water, and other complex matrices to assess contamination and assure purity. We also provide high-level irradiation services to verify the radiation hardness of materials and devices used in the nuclear industry.

For more information visit [chemistry.swri.org](http://chemistry.swri.org) or contact Vice President Dr. Michael MacNaughton, P.E., at 210.522.5162 or [michael.macnaughton@swri.org](mailto:michael.macnaughton@swri.org).



Scientists image live stem cells cultured in a perfused bioreactor. The stem cells will be used in regenerative medicine to seed advanced collagen matrices to treat diabetic skin wounds in animal trials.

DM021983\_9986

# DEFENSE & INTELLIGENCE SOLUTIONS

D022286

- Condition-Based Maintenance
- Aircraft Component Testing
- Flight Controls
- Information Assurance
- Automatic Test Systems
- Flightline Testers
- Aircraft Systems & Engineering
- Analysis, Analytics, Visualization & Reporting
- Antennas & Propagation
- Avionics-Based Open Systems
- Cloud Computing
- Signal Analysis & Processing
- Electromagnetic Modeling
- Deep Learning
- Data Visualization
- Electronic Warfare
- Intelligence Networking
- GPS Engineering
- Geolocation
- Information Operations
- Life-Cycle Support
- Signals Intelligence
- Surveillance Systems
- Tagging, Tracking & Locating Solutions
- Situational Awareness
- Intelligence, Surveillance & Reconnaissance
- RF/Microwave Design
- Tactical Networking
- Multi-INT Processing, Exploitation & Dissemination
- Multimodal Sensing/Targeting
- Radar Simulation
- Software-Defined Radios
- Smart Sensors
- Weapon System Integration & Sustainment

With terrorism and unstable nations an ever-present danger in the near term, locating and identifying potential threats provides important defense intelligence. Southwest Research Institute is supporting the United States and its allies through state-of-the-art research in direction finding, surveillance, geolocation, and tracking. We also are working with the military to advance avionics and electronics for aircraft and ground vehicles.

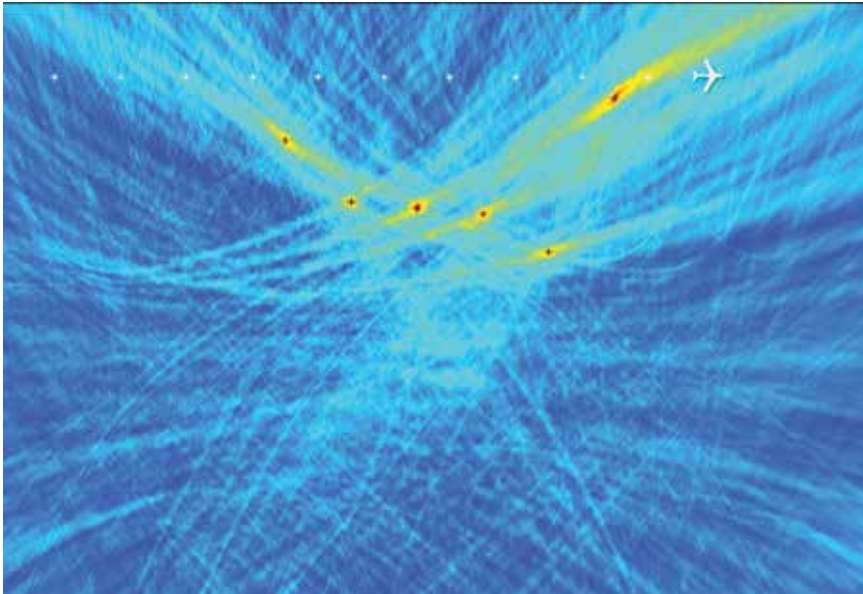
Radar and electronic countermeasure systems have specific requirements for signal generation. For example, radar systems generate signal pulses of a specific width that are transmitted at specific time intervals. We completed an electronic warfare test system that automatically validates signal requirements for radar and electronic countermeasure systems. For radar systems, the system measures and validates transmitted pulse patterns. For electronic countermeasure systems, the system simultaneously measures and associates radar and electronic countermeasures for complex scenarios involving multiple radar signals and multiple false targets. The system uses this information to validate difficult-to-measure characteristics such as range, velocity, and angle. Most recently, we used the test system to validate U.S. Air Force electronic countermeasure systems.

We developed and produced a new technology for measuring the height of ionospheric layers. This instrument, called a vertical incidence (VI) sounder, has a very low-power radio transmission capability that uses 1,000 times less power than currently available technology. Ionospheric sounders are useful for scientific research, military systems, and high-frequency signal propagation. For instance, over-the-horizon radar systems use VI sounders and associated real-time ionospheric models to select the most effective transmission frequency.

We continue to upgrade and expand the capabilities of Scout™, an SwRI-developed

SwRI is developing micro-tags, tiny devices that emit radio frequency signals that can be detected when hidden or at long distances.





The SwRI-developed time-variant spatial correlation algorithm enables geolocation of many coincident RF transmitters from just a few sensors. This image shows the estimated emitter locations for six independent RF transmitters operating simultaneously.

D021539\_2940



The National Science Foundation is revamping a mothballed A-10 “Warthog” to serve as a weather research plane. We designed this dual independent power system to support the “Weatherhog’s” scientific payload.

DM021413\_0642



To help protect our warfighters, we delivered very high frequency/ultra high frequency signal intelligence direction finding systems that identify and locate sources of combatant communications. The systems are integrated into electric assembly housings on military aircraft.

wideband radio frequency survey and monitoring system. In 2016, we used internal research funds to develop software supporting time- and frequency-difference-of-arrival radio location to augment Scout’s direction finding capabilities. These new features use standard U.S. government interfaces, enabling Scout to operate with U.S. and allied radio geolocation networks to locate enemy forces.

Under contract to the Office of Naval Research, we are developing an automated shared information system that will be repeatable and extendable to other intelligence domains. We also are creating a multi-intelligence domain that will enable real-time fusion of data collected from many different sensors and intelligent sources.

We are creating “micro-tags,” devices about the size of a sunflower seed that send signals using radio frequency backscatter techniques. This innovative technology highlights our design expertise with small antennas, low-power RF circuits, and very low energy communication techniques. Unlike barcodes, which require a clear line-of-sight, the RF micro-tags can be detected even when concealed or at long distances. The technology will allow development of a variety of new devices for tracking assets.

In support of the U.S. Air Force A-10 fleet, we are providing field- and depot-level engineering assistance to return grounded aircraft to operational status. For example, we successfully identified faulty wiring in a flight computer that caused an A-10 to yaw mid-flight. Our analysis allowed Air Force maintenance crews to repair and return the aircraft to combat-ready status.

For more information visit [defense.swri.org](http://defense.swri.org) or contact Vice President Nils Smith, P.E., at 210.522.3685 or [nilsmith@swri.org](mailto:nilsmith@swri.org).





# GEOSCIENCES & ENGINEERING

D0M21246

- 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

D022288



For nearly 30 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. Our program focuses on energy, water resources, and planetary geology.

In 2016, we continued operating the Center for Nuclear Waste Regulatory Analyses. The Center supports the Nuclear Regulatory Commission (NRC) in its regulatory responsibilities related to radioactive waste storage, transportation, and disposal. We provide support across the entire nuclear power cycle, from uranium production and enrichment through electrical power production to interim storage and ultimate disposal of waste. We also continue to export our waste management expertise, completing technical analyses for proposed radioactive waste repositories around the world.

We helped the NRC evaluate potential groundwater flow patterns, geochemical interactions, and potential ecological and radiological impacts for a required supplement to the Department of Energy’s environmental impact statement for a permanent disposal site. SwRI also looks at the environmental impact of current and proposed nuclear facilities and evaluates fire, seismic, and other natural hazards. In addition, we address material aging processes for dry storage casks in interim storage facilities.

One of the most complicated waste sites SwRI investigated in 2016 was Jefferson Proving Ground. This legacy Army testing facility near Madison, Indiana, contains depleted uranium as well as a million rounds of unexploded ordnance. We addressed extensive technical challenges and regulatory complexities associated with the variety of contaminants and activities in the surrounding area.

SwRI’s petroleum exploration and development program continues to provide in-depth structural geology and geomechanical analyses and training for the oil and gas industry.

We continue to improve our award-winning 3DStress® software, applying it to a wide range of geological conditions and extending its use to evaluate geothermal reservoirs. New functionality includes simulating the stages of hydraulic fracture production, as fluids are pumped underground to

In 2016, we helped the NRC prepare a draft environmental impact statement for a proposed in-situ uranium recovery facility. An environmental review includes a range of activities, such as the site evaluation shown here.



fracture the rock and improve well production, as well as to evaluate earthquake risks associated with deep-well injection.

We used a new high-end computational cluster to conduct two- and three-dimensional finite element simulations of hydraulic fracturing, studying in detail the mechanical layers within the Eagle Ford Formation in South Texas. The new cluster supports more realistic models analyzed in dramatically shorter timeframes.

Building on the success of our 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.

Water quality and availability remains an important global — and local — concern. We are applying hydrological expertise to meet the needs

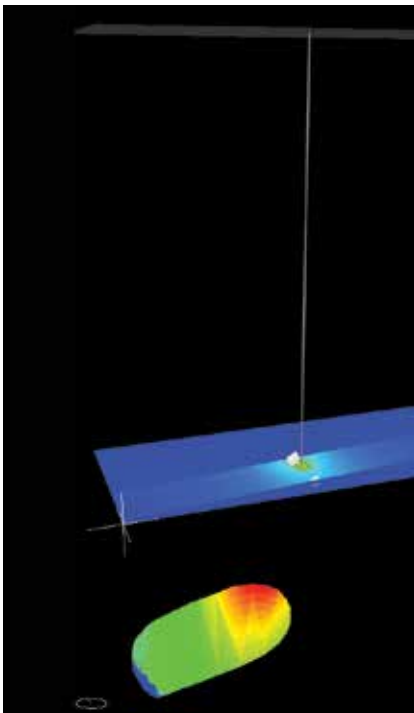
of government agencies, as well as municipal and commercial organizations. We develop advanced groundwater models to understand underground aquifers across Texas. In 2016, we expanded our research to include surface water and how these resources affect groundwater reservoirs.

For NASA, we apply expertise in Earth science to other planetary bodies. Using terrestrial analogs to understand conditions on Mars, scientists studied isolated liquid water reservoirs in subfreezing environments on Earth. Combining field studies with laboratory experiments and computer modeling, we discovered a mechanism that allows liquid water to exist in bitterly cold conditions. Trends in the volume of reservoirs could point to climate change at high latitudes on Earth.

For more information visit [geosciences-engineering.swri.org](http://geosciences-engineering.swri.org) or contact Vice President Dr. Wesley Patrick at 210.522.5158 or [wesley.patrick@swri.org](mailto:wesley.patrick@swri.org).

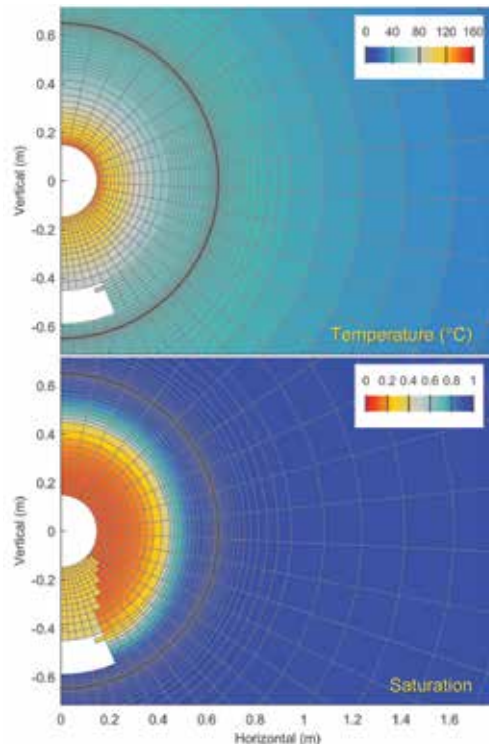
SwRI hydrologists test water quality parameters — such as pH, temperature, and conductivity — in a South Texas stream. These measurements provide insight into the interactions between surface water and groundwater in the region.

D022289



Our 3DStress® software simulates how a wastewater injection well could have activated a fault, causing a series of earthquakes in Youngstown, Ohio. The colors show pressure on basement rock (blue) and potential slipping of an underlying fault; red indicates the highest risk of earthquake occurrence.

D022290



As part of an international team, SwRI developed software to model complex thermal (top), hydrological (bottom), and mechanical processes in the strata surrounding potential underground radioactive waste repositories (white half-circle).



D022173\_9562





# INTELLIGENT SYSTEMS

DIM018755\_9279

- Unmanned Systems
- Robotics
- Active Safety Systems
- Intelligent Transportation Systems
- Embedded Systems
- 3-D Sensing & Perception
- Process Improvement
- Situational Awareness
- Automated Inspection
- Aerospace Networks
- Process Re-Engineering
- Control Center Software
- Image & Signal Processing
- High-Reliability Software
- Machine Vision
- ROS-Industrial
- 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 (TMAC)
- Collaborative Robotics
- Laser Coating Removal
- Human Performance

Engineers developed an autonomous system that detects hydrocarbon leaks in real time using mobile or stationary sensors. Using machine learning techniques, the system analyzes sensor data and reliably determines the chemical fingerprint of liquid spills.



DO22203\_9160

Southwest Research Institute engineers and analysts apply computer, network, and automation technologies to create advanced software and robotic systems that solve a wide range of real-world problems.

We continue to be a national leader in advanced traffic management systems, adapting technology initially developed for state-wide systems in Florida and Texas for new applications. In 2016, we successfully deployed the New England Compass Traffic Management System across New Hampshire, Vermont, and Maine, providing traffic operations automation, data hub, and traveler information applications. We customized SwRI-developed ActiveITS software to provide rural and winter traffic management capabilities from a cloud-hosted platform.

SwRI's automated vehicle program celebrated its 10-year anniversary this year. We now have more than 20 diverse vehicles in our unmanned research fleet. Multidisciplinary teams of engineers and analysts are continually advancing technology, giving unmanned systems the ability to understand their environment, localize their position to within centimeters, and navigate roadways and off-road terrain. SwRI serves a full range of clients, including original equipment manufacturers as well as other automotive, agriculture, construction, defense, and industrial organizations.

In 2016, we customized our intelligent transportation technology to create the New England Compass Traffic Management System across New Hampshire, Vermont, and Maine.



D022291



SwRI engineers have applied deep learning techniques and advanced neural networks to create high-performance image processing systems. These advances include object detection software using fully convolutional neural networks to recognize emerging patterns. When used for automation applications like unmanned vehicles, these networks can be trained using large databases of examples and then deployed to run in real time on low-cost, low-power platforms. The system can identify pedestrians, cyclists, vehicles, traffic signs, and more using an approach that detects objects of varying sizes at longer ranges.

We are leading the U.S. in applied research and development for industrial robotics, with particular expertise in developing large-scale systems. Over the last 25 years we have developed a series of aircraft paint-stripping robots, including a laser-based system now in development. We are experts in integrating unique sensor solutions into existing manufacturing processes and developing control methodologies to automate processes. For instance, we are developing a robotic system to automate a complex, labor-intensive process used in the oil and gas industry.

In addition, SwRI curates the open-source ROS-Industrial framework, applying the Robot Operating System to manufacturing. The ROS-I consortium went global this year, expanding into the Asia-Pacific region. One notable technical accomplishment was our application of ROS-I and 3-D sensing/perception expertise to a singulation solution called the "Pick 1 Perception System." Pick 1 uses innovative software and algorithms to robotically sort piles of objects, such as parcels and packages, for warehousing and logistics applications.

SwRI also entered a new area of research: optimizing human physical performance. The military special forces and professional sports communities are interested in 3-D motion capture analysis for biomechanical assessments. However, current practices and technologies do not meet cost and accuracy demands. The SwRI team is combining expertise in biomechanics, image processing, neural networks, sensor fusion, and systems engineering to explore a new 3-D motion capture system that aligns with the needs of the human performance community.



SwRI is developing the largest mobile robotics system in the world. The system combines a high-power laser with a mobile robotic platform and a laser scanner to efficiently and safely remove paint from aircraft and other large structures.

For more information visit [intelligentsystems.swri.org](http://intelligentsystems.swri.org) or contact Vice President Dr. Steve Dellenback at 210.522.3914 or [steve.dellenback@swri.org](mailto:steve.dellenback@swri.org).



SwRI applied deep learning techniques and neural networks to help unmanned vehicles identify objects. Trained to identify pedestrians, cyclists, vehicles, traffic signs, and more, the system can detect objects of varying sizes at longer ranges.





## MECHANICAL ENGINEERING

D015674\_1986

- 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
- Supercritical CO<sub>2</sub> Power Cycles

Southwest Research Institute's mechanical engineering program serves clients in the energy, aerospace, and defense industries. We apply expertise in materials engineering, structural engineering, fluids, machinery, nondestructive inspection, and blast and impact studies to solve a range of problems and create advanced technologies.

Our researchers are involved in advanced manufacturing to improve products and processes. We are part of a national initiative to develop advanced manufacturing technology to increase innovation and enhance industrial competitiveness. This effort spans a number of federal agencies and a range of industries. For the Defense Advanced Research Projects Agency, we are modeling a fabrication process to predict the strength of bonded composite materials. We are conducting materials studies to evaluate parts produced using additive manufacturing, a process that builds objects by adding layer-upon-layer of material. We also are investigating a modeling approach that will be a

For the DOE SunShot program, SwRI is developing novel, high-efficiency turbo expanders and heat exchangers for an sCO<sub>2</sub> power generation system. The high-temperature, high-pressure technology will enable more cost-effective operations for concentrating solar plants.

D022193\_3944







SwRI built this high-viscosity flow loop to test pumps, filtering elements, electrostatic separation systems, oil and water mixers, and other flow components under three-phase (oil, water, and gas) conditions.

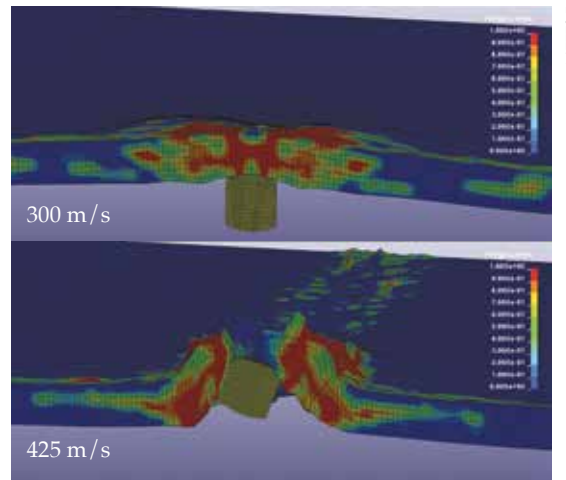
faster and less expensive alternative to the classic “build and break” approach used to qualify new materials and manufacturing processes.

On the energy front, we are a technology leader in developing novel supercritical carbon dioxide (sCO<sub>2</sub>) power technology. Under high pressures and temperatures, sCO<sub>2</sub> behaves as very dense gas. Power cycles using sCO<sub>2</sub> can reach higher thermal efficiencies using smaller equipment, thus lowering plant costs. For the U.S. Department of Energy (DOE), we are developing an sCO<sub>2</sub> 1-MW facility that will serve as the primary test bed for several DOE projects. We also completed two 3-MW utility-scale facilities to test turbomachinery components, instrumentation, valves, and other flow components needed for sCO<sub>2</sub> power applications.

SwRI has also been selected to host DOE’s Supercritical Transformational Electric Power (STEP) sCO<sub>2</sub> demonstration plant. This 10-MW plant will be the principal test bed to qualify equipment. The next generation of sCO<sub>2</sub> power — oxy-fuel combustion — will



We acquired a large-format industrial coating system to complement our existing surface modification equipment. Using the SwRI-developed plasma enhanced magnetron sputtering process, engineers harden the surfaces of machine tools and other devices by applying specialized coatings.



We developed a new model that simulates the effects of ballistic impact on armors and other materials. These images show a 30-caliber projectile impacting a 6.23-mm-thick glass composite at 300 meters per second (top) and at 425 meters per second (bottom). Color contours represent damage.

use pure oxygen instead of air in the combustion process. We are developing several test stands that will allow us to design the hardware needed for this promising energy technology.

In the U.S., many pipelines, bridges, and power distribution grids have surpassed their design life. Using expertise developed during our long-standing aircraft structural integrity program, we are addressing problems associated with aging infrastructure. We are applying a range of techniques — from finite element analysis to full- and large-scale structural testing — to evaluate the structural integrity of railroad tank cars and pressure vessels. Recently we also evaluated the U.S. Navy’s submarine rescue launch and recovery system.

For more information visit [mechanicalengineering.swri.org](http://mechanicalengineering.swri.org) or contact Vice President Danny Deffenbaugh at 210.522.2384 or [danny.deffenbaugh@swri.org](mailto:danny.deffenbaugh@swri.org).

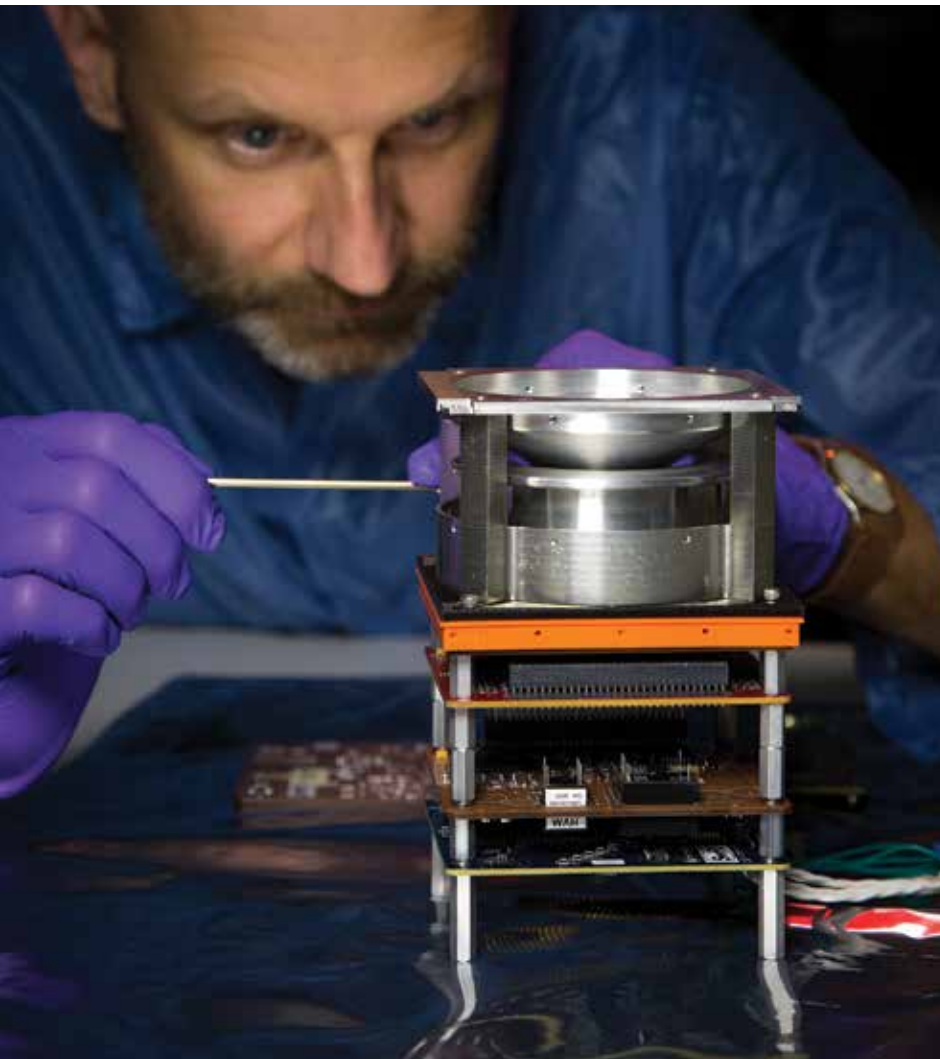
## SPACE SCIENCE & ENGINEERING

Courtesy NASA

D022295

- Planetary Science
- Magnetospheric Physics
- Solar & Heliospheric Physics
- Spacecraft Science Instruments
- Spacecraft Avionics
- Electromechanical Systems
- Power Systems
- Small Satellite Design, Development & Fabrication
- Spacecraft Management
- Data Analysis & Science Support
- Science & Mission Operations
- Lighter-than-Air Systems

D022202\_9121



SwRI built this novel, miniaturized suprathermal ion spectrograph (SIS) to measure ions associated with solar and interplanetary energetic particle events. SIS is one of three instruments to be carried by CuSP, a shoe-box-sized CubeSat developed at SwRI.

After traveling five years and 1.7 billion miles, NASA's Juno spacecraft began orbiting Jupiter on July 4, 2016. The first spacecraft to study the giant planet from polar orbit, Juno flies as close as 2,600 miles above Jupiter's cloud tops. Southwest Research Institute leads the Juno mission, which is expected to provide clues to the formation of our solar system as well as new discoveries about the gas giant's origin, interior, atmosphere, and magnetosphere. We also built two of the instruments onboard to study Jupiter's powerful auroras.

Another milestone in July was the extension of the SwRI-led New Horizons mission. Following the historic flyby of Pluto in summer 2015, New Horizons is now on course for a 2019 encounter with Kuiper Belt Object (KBO) 2014 MU69. KBOs are small, primitive, icy bodies beyond the orbit of Neptune, thought to be leftovers from the formation of the solar system. In the meantime, SwRI scientists and other members of the New Horizons team continued to discover new features in the Pluto-Charon system, as the final flyby data were delivered in late 2016.

Both of these missions will help scientists understand more about the formation and early history of the solar system. We also use sophisticated computer simulations to model interactions among early solar system bodies. For example, recent computer models indicate that collisions among the building blocks of the planets may explain why Mars is considerably smaller than Earth and Venus.

SwRI is leading the science investigation for NASA's Magnetospheric Multiscale mission, a four-spacecraft mission currently surveying the boundary between the solar wind and Earth's magnetosphere. For the first time, MMS successfully measured the elusive electron physics that allow the magnetic field carried by the solar wind to merge with Earth's magnetic field. This phenomenon is the primary driver of space weather in Earth's magnetosphere.

Eight microsatellites developed by SwRI for NASA's Cyclone Global Navigation Satellite System (CYGNSS) mission were delivered to Vandenberg Air Force Base for integration with the Pegasus



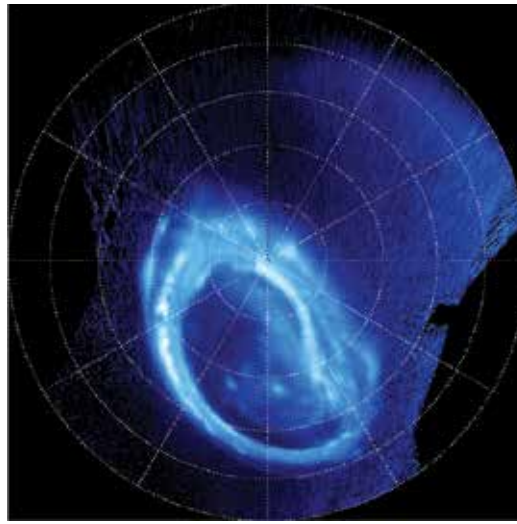
launch vehicle. The CYGNSS microsattellites were successfully launched in December 2016 and will provide measurements needed to understand and predict how hurricanes and cyclones intensify.

Also in the area of small satellite development and applications, we delivered CYGNSS-based flight avionics for several small satellite programs and were selected to develop CuSP, the CubeSat for Solar Particles. This satellite is one of 13 CubeSats that will hitch a ride on NASA's giant new Space Launch System during its first unmanned test flight in 2018.

In our solar physics program, scientists made the most precise measurements to date of surface flows on the Sun. We also imaged the solar corona transitioning into the solar wind and developed a new understanding of how coronal mass ejections form.

Our space systems program is a leading provider of computers for diverse commercial and government spaceflight applications. For instance, we are supplying a mass memory storage system for the Joint Polar Satellite System 2, a weather satellite scheduled to launch in 2021. We also delivered flight computer engineering units for the Dream Chaser flight test vehicle, scheduled for glide testing in 2017. Dream Chaser is a reusable spacecraft designed to deliver cargo to the International Space Station.

For more information visit [spacescience.swri.org](http://spacescience.swri.org) or contact Vice President Dr. James L. Burch at 210.522.2526 or [jim.burch@swri.org](mailto:jim.burch@swri.org).



SwRI's Ultraviolet Spectrograph (UVS) onboard the Juno spacecraft observed Jupiter's aurora in August 2016, shown in this ultraviolet brightness map of the north polar region. Data from UVS and Juno's particle instruments will help scientists understand the processes responsible for Jovian auroras.

D022296  
Courtesy NASA

In September 2016, scientists and engineers prepared the SwRI Solar Instrument Pointing Platform (SSIPP) for a five-hour stratospheric balloon flight. SSIPP is a miniature, high-precision solar observatory designed to lower costs for solar research from the near-space environment.



D022297  
Courtesy World View

D021879\_9732



SwRI designed, integrated, and evaluated a constellation of microsattellites for a NASA mission. Engineers conducted thermal vacuum tests for the eight CYGNSS satellites in a new, larger chamber that accommodated four satellites at a time.

# CONSOLIDATED FINANCIAL STATEMENTS

For the years ended September 30, 2016, and September 25, 2015

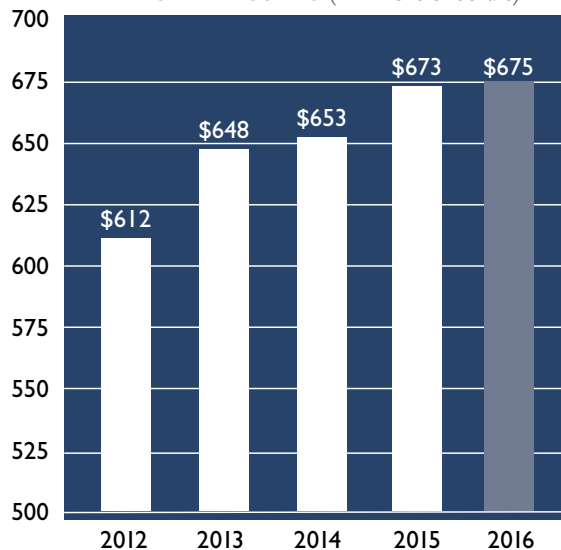
## INCOME STATEMENTS (in thousands of dollars)

	2016	2015
Revenue	\$559,823	\$592,364
Direct Project Costs	322,782	338,937
Operating Income	237,041	253,427
Division Operating Expenses	146,888	141,294
General Overhead	63,112	61,014
Depreciation — General Facilities	16,486	15,389
Internal Research	7,457	7,220
Realized/Unrealized (Gain) Loss on Postretirement Medical Funds	(5,048)	3,576
Income Before Federal Income Tax Expense	8,146	24,934
Federal Income Tax Expense	1,280	1,139
Net Income	<u>\$6,866</u>	<u>\$23,795</u>

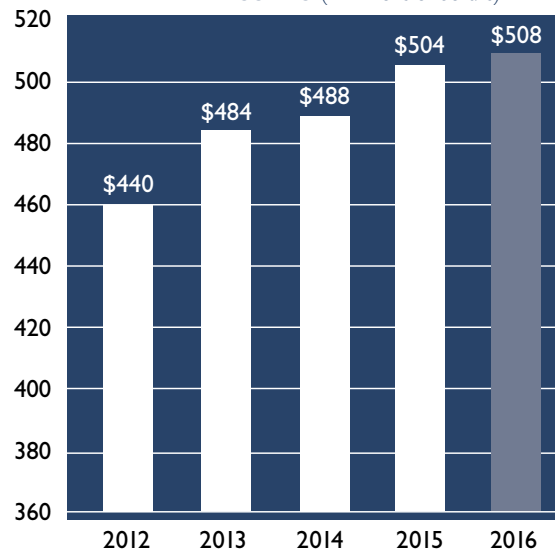
## BALANCE SHEETS (in thousands of dollars)

	2016	2015
Current Assets	\$261,887	\$254,197
Property and Equipment, Net	294,825	294,905
Other Assets	118,197	123,959
Total Assets	<u>\$674,909</u>	<u>\$673,061</u>
Current Liabilities	\$99,891	\$108,371
Noncurrent Liabilities	67,088	61,184
Net Assets	507,930	503,506
Total Liabilities and Net Assets	<u>\$674,909</u>	<u>\$673,061</u>

## TOTAL ASSETS (in millions of dollars)



## NET ASSETS (in millions of dollars)





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