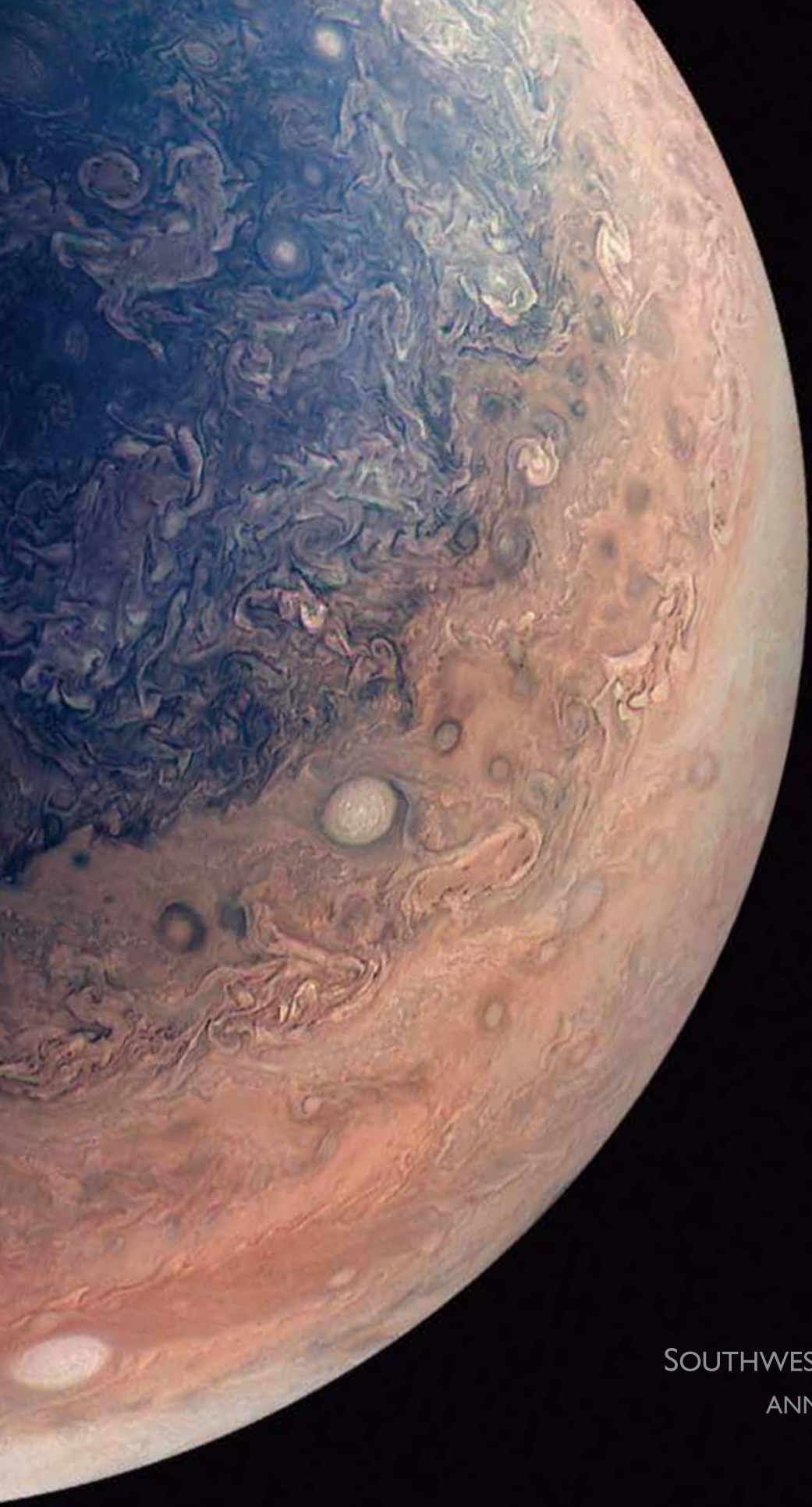


Southwest Research Institute

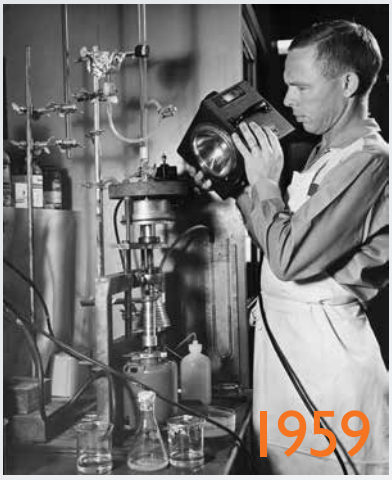
annual report 2017

SwRI TURNS 70

In 1947, oilman and philanthropist Tom Slick Jr. founded Southwest Research Institute as a nonprofit, contract research and development organization. Our mission then, as now, is to benefit government, industry and the public through innovative science and technology.

For 70 years, we have advanced knowledge in a broad range of fields while providing practical technical solutions for our government and industry clients. From developing deep sea technology to unlocking the secrets of the universe, SwRI uses advanced science and applied technology to spark human progress and scientific achievement.

Tom Slick signs the SwRI charter.



D007200

SwRI's chemists pioneered microencapsulation developments for pharmaceuticals and consumer products.

$ Reached $13 million
Reached 1,000
600

1947 — 1957 — 1967

$ Grew from <$100,000 to $4.5 million
Increased from <20 to 437
Grew from 64 to 600

$ Grew to $46 million
Reached 1,500
Grew in size, but remained at 600

DC6522

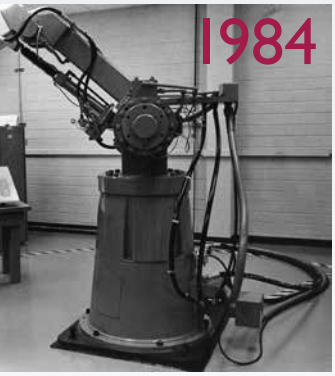
SwRI began operating the U.S. Army fuels and lubricants research lab located on our grounds.

SwRI evaluated direction finding systems for the U.S. Navy.

DE107063

$ BUDGET STAFF PROJECTS

We developed this advanced robotic system to remove rivets from aircraft wings.



DC54073

DE119468-2

SwRI offered clients the largest ion beam surface modification chamber in North America.

We designed and built the latest personnel sphere of the Alvin research submersible.

D018123_0175

1977

- $ Increased to $148 million
- Grew to 2,200
- Exceeded 1,000

1987

- $ Almost doubled to $260 million
- Reached 2,500
- Nearly 1,500

1997

- $ Grew to $501 million
- Reached 3,100
- Exceeded 2,000

2007

- $ Neared $600 million
- Nearly 2,600
- Exceeded 6,500

2017

D022859

D0000555

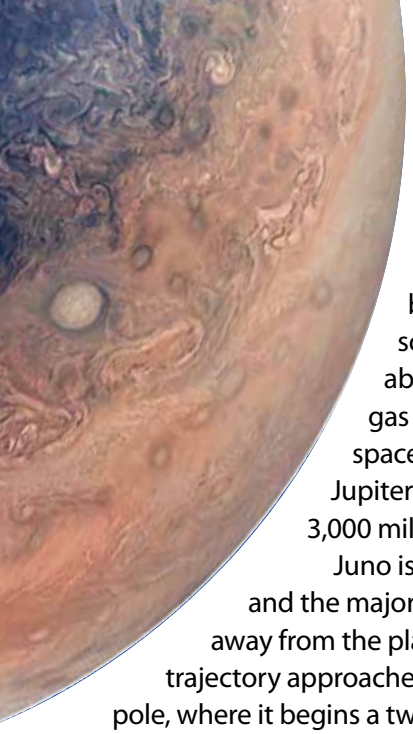
SwRI was selected to operate the Center for Nuclear Waste Regulatory Analyses to support licensing a repository facility at Yucca Mountain in Nevada.

IMAGE COURTESY NASA/JPL-CALTECH D022873

Using internal funding, we developed our first automated driving platform.

D015932_5206

SwRI leads NASA's Juno mission to Jupiter, currently in orbit around the gas giant.



About the cover: NASA's Juno mission, led by SwRI, is rewriting what scientists thought they knew about Jupiter specifically, and gas giants in general. The Juno spacecraft has been in orbit around Jupiter since July 2016, passing within 3,000 miles of the equatorial cloud tops. Juno is in a polar orbit around Jupiter, and the majority of each orbit is spent well away from the planet. But once every 53 days, its trajectory approaches Jupiter from above its north pole, where it begins a two-hour transit from pole to pole, flying north to south with its eight science instruments collecting data and its JunoCam public outreach camera capturing astounding images.

The solar-powered spacecraft's payload is designed to study Jupiter's interior structure, atmosphere and magnetosphere. Two instruments developed and led by SwRI are working in concert to study Jupiter's auroras, the greatest light show in the solar system.

COVER IMAGE COURTESY NASA/JPL-CALTECH/SwRI/MSSS/GABRIEL FISET D022868

IN 2017,

Southwest Research Institute celebrated 70 years of scientific and technical achievements. Our talented scientists and engineers have made innumerable contributions advancing the state of the art in research and development, ultimately benefiting all humankind. While we are proud of our past, our focus is on the future's projects to help solve our government and industry clients' most challenging technical problems. This Annual Report highlights some of the accomplishments of the past year and previews some of the challenges before us as we continue to advance scientific progress and human achievement.

Collaboration among our technical staff and with other organizations has been a hallmark of our success. We seek projects and programs that allow our staff to work with others for the greater good. Intelligent systems analysts work with automotive engineers to devise new models of mobility. Computer scientists work with chemists to turbocharge drug development technology. We introduced the Human Performance Initiative to better understand the complex biomechanical and physiological components of physical performance and health. We're part of a team designing, building and operating a 10 MWe pilot plant to demonstrate smaller, cleaner and more efficient power production technology. Our industry-specific consortia pool the resources of many to resolve problems for all. In 2017, we secured a patent to locate and mitigate corrosion damage on hard-to-inspect pipelines installed under surface features. The Cyclone Global Navigation Satellite System, the first Institute-designed and -built spacecraft, was launched, and the SwRI-led Juno mission continues to collect incredible images and data as it orbits Jupiter.

As our reputation continues to grow, it becomes more difficult each year to claim we are the best-kept secret in San Antonio. We launched a new corporate website to expand our marketing efforts and make it easier for clients to navigate our service offerings more efficiently. Our media outreach efforts are paying strong dividends with unprecedented coverage locally, nationally and internationally. Our science and technology programs make headlines around the world. Locally, the San Antonio Business Journal named us the 2016 Business of the Year, acknowledging our stature as a powerhouse in the R&D marketplace.

We are committed to continuously improving our research capabilities. The capital improvements and infrastructure program is an investment in our future. This year, we completed installation and testing of a hypervelocity light-gas launcher, the centerpiece of a new facility that expands our 65-year history of

impact dynamics research. We added laboratory facilities for fluid dynamics and flow components research and development. And we opened a new laboratory in Ann Arbor, Michigan, to expand our automotive research footprint.

We are also great corporate and community neighbors. Staff members contribute to and volunteer in the various communities where they work. They mentor students in science, technology, engineering and math (STEM) and serve as judges for science and engineering competitions. Professional organizations seek them out as speakers and to sit on boards and committees to help formulate industry standards and advance scientific innovation.

Historically, our diverse revenue sources are split between government and industry. Though the fluctuating political environment caused uncertainty and contributed to a financially challenging fiscal year for research and development, the Institute remains a major economic contributor in San Antonio, Bexar County and the other communities where we operate. SwRI contributed more than $1 billion to the local economy. Moving forward, a healthy backlog of contracts and proposals boosts our confidence for a successful 2018 and beyond.

Even as we face new challenges in the coming year, we see new opportunities to expand our science and technology base. We want to be the first choice for clients seeking solutions for their most complex problems. I look forward to working with the Advisory Trustees, Board of Directors and Institute staff to ensure our clients receive the highest quality scientific and technical services in 2018 and beyond.

Adam L. Hamilton, P.E.
PRESIDENT & CEO

D022833_9426

IR&D 2017

Our internal research and development program allows SwRI engineers and scientists the freedom to explore innovative, unproven concepts. The program often invests in technology our clients will need in the future. It also expands into completely new fields where collaborations among our diverse staff result in novel approaches or technology. In 2017, SwRI initiated 102 new projects and invested more than $7 million in internal research.

DM022328

Using internal research funding, a multidisciplinary team developed human performance expertise. One result was a patent-pending, low-cost "markerless" motion capture system that uses a biomechanical musculoskeletal model fused with deep learning algorithms to characterize physical motion. We are now positioned as one of the leaders in this field, working with professional sports teams and the tactical athlete community.

MILESTONES 2017

HONORS

Robin Canup:
Named a member of American Academy of Arts and Sciences

Ben Thacker:
Named Fellow of American Institute of Aeronautics and Astronautics

619 PAPERS published

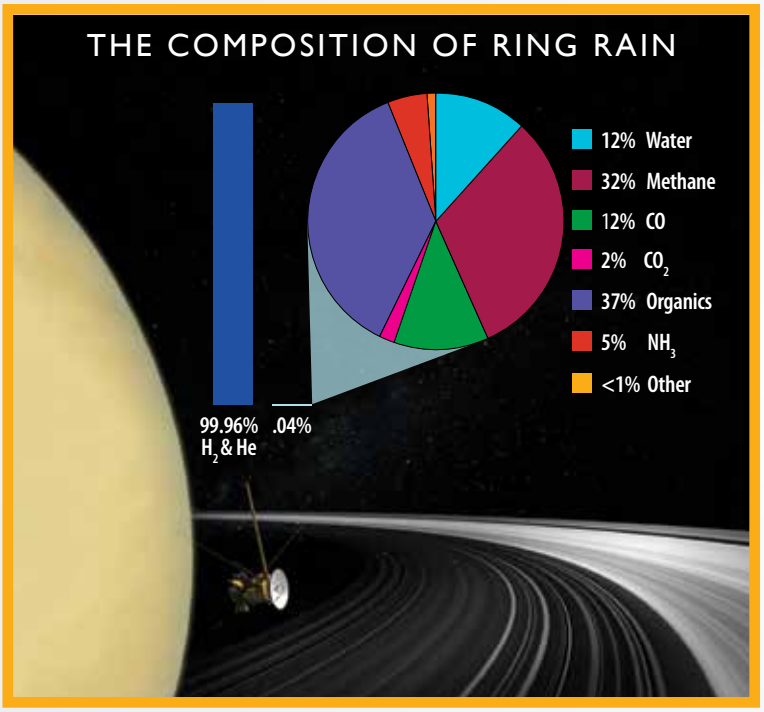
PRESENTATIONS GIVEN 600

PATENTS & inventions

50 U.S. PATENTS received

U.S. PATENT applications filed 33

60 INVENTION disclosures submitted



IMAGES COURTESY NASA/JHUAPL/JPL/SwRI/CARLOS HERNANDEZ D022865 D022867

In October, when the Cassini spacecraft completed its 13-year sojourn in the Saturn system, the SwRI-led Ion and Neutral Mass Spectrometer was one of the last instruments sending back data. As the spacecraft prepared for its terminal dive into the planet, INMS detected and quantified the first direct measurements of "ring rain," the interaction between the icy rings and the planet. Unexpectedly, the instrument detected significant amounts of methane and organic materials.

2,574 EMPLOYEES

- 264 DOCTORATES
- 502 MASTERS
- 693 BACHELORS
- 260 ASSOCIATES

AWARDS

Gary Bessee:
2017 IASH Lifetime Achievement Award
Steven Dellenback:
SAE International 2016 Delco Electronics ITS Award
Robert Fanick:
E. Ann Nalley ACS Southwest Region Award
Tony Magaro:
NILG Lifetime Achievement Award

D022179_8751

D022686__7655

As the SwRI-led New Horizons mission pursues its next flyby target, Kuiper Belt Object 2014 MU69, scientists needed to know more about this mysterious object, barely visible even with the Hubble Space Telescope. Teams of SwRI and other scientists armed with 25 portable telescopes searched the southern skies when MU69 blocked a star for a moment. Five of the teams recorded the brief occultation, providing critical information about MU69's shape, size and brightness — important data to plan the January 1, 2019, flyby. As shown in this artist's concept, MU69 may actually be a binary pair orbiting close together or perhaps two like-sized bodies fused together.

In 2017, SwRI won two R&D 100 awards, which recognize the 100 most significant innovations of the year. SwRI's Smart Leak Detection system uses optical sensor fusion and machine learning to reliably and autonomously detect small liquid pipeline leaks of hazardous chemicals. High Power Impulse Plasma Source (HiPIPS) technology was first developed under a DARPA program. It generates high-density, high-flux plasmas efficiently, at low temperatures and atmospheric pressures, applying durable coatings to materials and products to improve functionality and performance.

40/40 SAN ANTONIO Business Journal 40-UNDER-40

Maria Araujo
Maher Dayeh

LEADERSHIP

Sidney Chocron: President of the International Ballistics Society
Walt Downing: Chairman of BioMed SA
Chris Freitas: Associate Editor of the ASME Journal of Verification and Validation
Ron Green: Chair of National Cave and Karst Research Institute
Xihua He: Chair for the NACE Corrosion in Nuclear Systems Symposium
Mary Massey: International Journal of Microencapsulation Editorial Board
Jamie Oxley: Secretary for the Controlled Release Society Board of Directors

APPLIED PHYSICS

D001934

- 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
- Nonlethal 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

D015617_3860

We upgraded our anechoic chambers to test noise emissions of high-flow inert gases to help a client reduce industrial noise. New microphones and accelerometers measure air- and structure-borne noise.

Inset: In the 1960s, SwRI developed nuclear magnetic resonance technology to measure and test materials.

As part of its condition-based maintenance program, SwRI uses its n-Variable Statistical Process Control Tool (nSPCT™) to identify anomalous water usage, assess system performance and prevent waste.

SwRI is helping the Army overhaul its helicopter maintenance facilities in Corpus Christi, Texas. Engineers are designing flexible manufacturing layouts for efficient work flows.

Southwest Research Institute pushes the boundaries of physics and engineering to create advanced technologies and systems that meet our clients' challenging demands. Our diverse staff and world-class expertise result in innovative, cost-effective approaches that solve complex problems. Research and development ranges from novel defense technology to materials, electronics, acoustics and more.

In 2017, we received a 5-year, $39 million follow-on contract to support the Naval Surface Warfare Center – Dahlgren Division. This contract vehicle allows us to address emerging needs associated with homeland security, anti-terrorism, mission assurance, force protection, unmanned systems and related programs. For example, we are continuing to refine a device that projects an eye-safe laser beam to serve as a nonlethal deterrent system.

We continued upgrades to the Engine Tracking Database System, which helps friendly foreign militaries around the world support and maintain F-15 and F-16 engines. The ETDS program facilitates tracking and management of parts, maintenance, usage and inspection data for the F110 family of engines. Five allies currently use the system, with additional countries coming online next year.

In another program supporting our military allies, SwRI developed a filter test stand to evaluate both air and liquid filtration technologies critical to protecting engines from contamination and damage. The stand's differential pressure mode evaluates both liquid and air filters, capturing measurements across the filter element to accurately assess effectiveness and efficiency. For liquid filters, the bubble point pressure test determines the air pressure when bubbles first escape a wetted filter, indicating the largest pore size in the filter. Test stand software captures data and determines whether a filter meets specifications.

In a recent NASA program, we evaluated materials exposed to the acoustic pressure of a rocket launch to ensure they could withstand extreme sound pressure levels without breaking apart. We used our reverberant chamber to simulate the acoustic profile of a rocket launch across the entire audible spectrum, and we tuned the sound output to match custom launch profiles. We monitored and recorded sound levels before, during and after the launch simulation to ensure materials were rugged enough to withstand extreme noise.

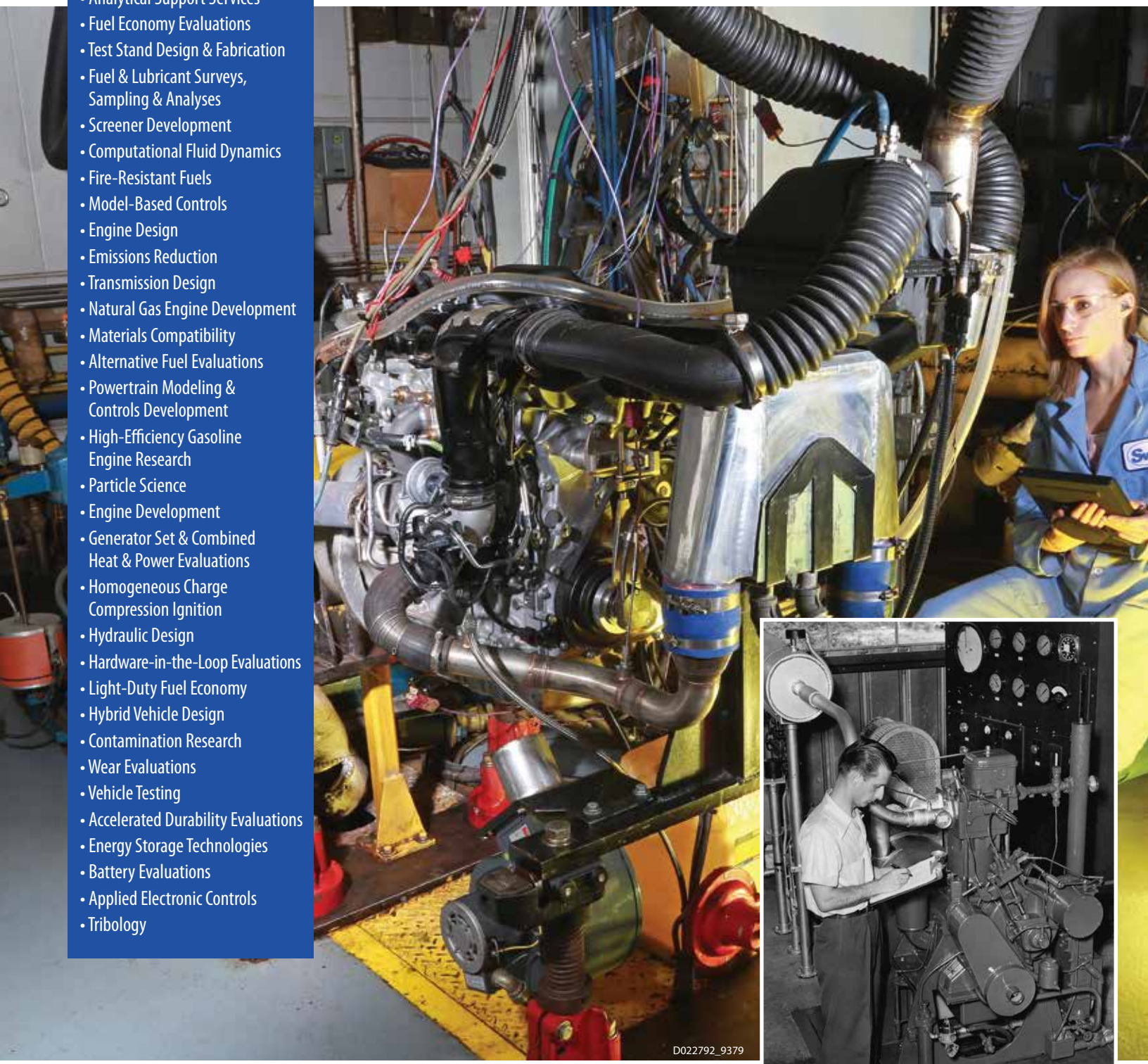
SwRI has conducted failure and construction analyses of electronic and electrical components for nearly 40 years. We recently investigated explosions in electrical switchgear cabinets for a manufacturing plant. Failure analysis specialists worked with the client to determine that overloaded fuses degraded over time, resulting in catastrophic failure.

In an internal research program, SwRI engineers investigated large-scale, 3-D printing techniques for concrete construction projects. Layer-by-layer additive manufacturing methods used both a fixed gantry system and mobile robotics to deposit mortar-based material. We developed a patent-pending reinforcement system that may enhance physical connection and formed strength between successive layers of additively printed material. We tested this interlocking layer design and compared its shear strength to traditionally molded concrete samples using the same mortar-based composition.

For more information visit **applied-physics.swri.org** or contact Vice President Ken Bennett at 210.522.5242 or kenneth.bennett@swri.org.

AUTOMOTIVE ENGINEERING

- 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



D022792_9379

D022849

Low-speed pre-ignition (LSPI) is the premature ignition of gasoline in the combustion chamber, which can damage engines. Our researchers led the development of a new industry standard LSPI test for engine oils.

Inset: SwRI has used engine test stands to conduct fuel and lubricant research and testing since the 1950s.

We have expanded our automotive research footprint in Ann Arbor, Michigan, to offer Detroit-area clients convenient local resources for powertrain control and emissions research.

We tested a 50,000-gallon collapsible tank filled with aviation fuel. Our double-lined tank farm can accommodate collapsible tanks that hold up to 210,000 gallons.

As the drive for cleaner, more efficient vehicles continues, Southwest Research Institute remains on the vanguard. Combining our expertise in powertrain technology with our longstanding fuels and lubricants research allows SwRI to provide innovative solutions to automotive challenges from headlights to tailpipes.

Our San Antonio headquarters offers one of the largest independent engine, fuels and lubricants research facilities in the world, and we test virtually every engine oil and fluid available on the market. SwRI now offers engine development facilities in Ann Arbor, Michigan, augmenting more than 200 research dynamometers at our headquarters. In addition to expanding our capabilities in high-efficiency powertrain development and emissions research, these facilities provide local resources in the Detroit area.

To support next-generation engine technology, we have designed single-cylinder research engines to study everything from knock and combustion stability to real-time wear under challenging operating conditions. These research engines are available for purchase, and we have three variations available in our labs, two for light- and medium-duty applications and one for heavy-duty applications. These research engines can be configured for spark- or compression-ignition research for alternative fuel, wear, optical, crank offset and bore-to-stroke relationship studies. The custom design accommodates multi-cylinder or single-cylinder heads. Unique patent-pending features include mechanisms to adjust compression ratio and crankshaft offset without engine disassembly.

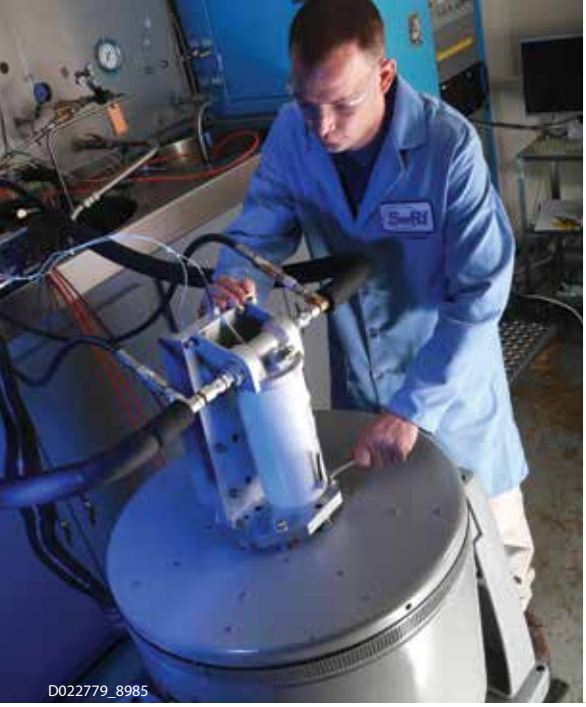
This year, we doubled the capacity of our Exhaust Composition Transient Operation Laboratory while expanding catalyst and aftertreatment research capabilities. Additions include an automated universal synthetic gas reactor to test catalyst core samples and three systems for accelerated aging and evaluation of emission control system performance.

To support the growing electric and hybrid vehicle market, our Energy Storage Technology Center® is moving into new facilities. With the additional space, we will expand our battery research, develop new energy storage and management systems, and increase our evaluation capacity for lithium ion, advanced lead acid and ultracapacitors for automotive, consumer products and grid storage systems.

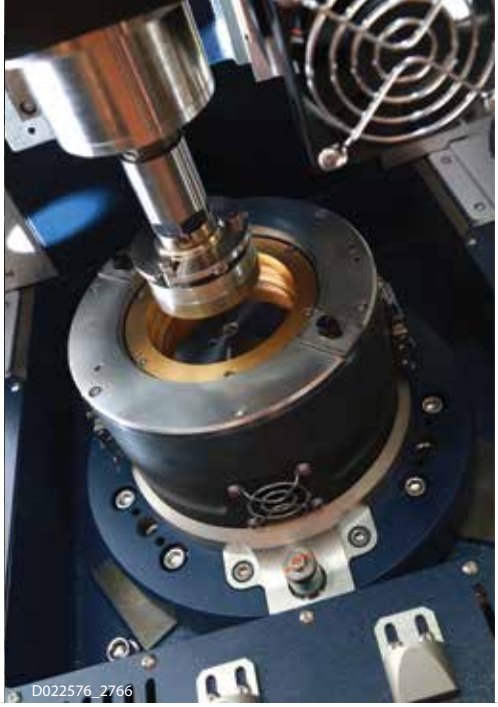
For the U.S. Department of Energy, we are integrating connected and automated vehicle technologies with the goal of improving the energy efficiency of a hybrid vehicle by more than 20 percent. We are using connected vehicle technologies to "preview" roadways and optimize route, speed profile and power flows from the hybrid system. The project will ultimately help define future powertrain performance requirements.

SwRI also has developed high-horsepower off-road dual-fuel engines that easily meet the Environmental Protection Agency's prior Tier 2 regulations. More recently, SwRI engineers demonstrated how dual-fuel engine designs could potentially meet the latest Tier 4f regulations without the need for catalysts, exhaust gas recirculation or particulate filters. These technologies not only add to the initial cost of the vehicles but also can increase fuel consumption, reduce engine performance and add operational and maintenance costs. The goal was to design and demonstrate a dual-fuel engine that meets Tier 4f without active aftertreatment systems.

In other large engine work, SwRI operates a locomotive technology center near downtown San Antonio, where engineers are testing new locomotive engines for exhaust emissions compliance. We are also evaluating "end of useful life" exhaust emissions, testing engines just before they are overhauled to determine if locomotives meet applicable EPA emissions standards throughout their service life.



We developed a procedure to evaluate diesel fuel filters under cyclic fluid flow rates and controlled structural vibration. This method simulates actual service conditions better than traditional filter efficiency tests.



To understand ring liner scuffing in engines, our tribologists extract lubricant from different regions of the piston assembly to determine what processes cause the damage.

SwRI conducts 100,000-mile engine dynamometer studies for electric vehicles. Every 10,000 miles, we evaluate how aging affects battery range, pack performance, pulse power and charging strategies.

In addition, we are developing tests to evaluate automotive engine oils to the International Lubricants Standardization and Approval Committee's GF-6 performance specifications. Oils meeting the specification should increase fuel economy, enhance oil robustness and reduce engine oil aeration. Our researchers led the development of a new engine oil oxidation test and helped define specifications for new fuel economy and low-speed pre-ignition tests.

Through internal funding, SwRI tribologists are developing a screening technique to better understand scuffing between a piston ring face and cylinder liner in engines. The technique will evaluate how lubricant chemistry, viscosity and frictional response affect this unpredictable, hard-to-reproduce phenomenon. We also designed a novel high-frequency reciprocating rig to evaluate the lubricity of highly volatile fuels such as gasoline, liquefied petroleum gas and dimethyl ether.

Recently, we developed a method to map dynamic performance of elastomer O-ring seals in real time and built a dynamic seal tester to investigate how fuels and lubricants affect elastomer seals in operating environments. For the U.S. Army, we are developing concepts for a federal test method to compare the performance of fuel lubricity additives.

For the past 60 years, SwRI has operated the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) Fuels and Lubricants Research Facility. Located at SwRI, TARDEC is a government-owned facility providing advanced research, development and engineering services to the U.S. Army and other agencies. In 2017, engineers evaluated a 50,000-gallon collapsible fuel tank filled with aviation fuel at a new SwRI tank farm. These portable tanks, which range from 3,000 to 210,000 gallons, store fuel for military field operations. Qualification testing previously used water as the testing medium because a safe and environmentally secure facility to test with fuel was unavailable. Now, our dedicated, double-lined tank farm, which accommodates tanks of all sizes, allows SwRI to perform qualification testing using fuel.

In 2017, we established a new method to evaluate diesel fuel filter performance under real-world conditions. Diesel fuel filters mounted to engines or other machinery typically experience vibration and variable fuel flow. Using cyclic fluid flow rates and controlled structural vibration, this new method not only evaluates the filters but also demonstrates how dynamic events affect performance.

SwRI is a leader in developing and managing consortia that allow clients to pool their resources for pre-competitive research. Eight automotive consortia are currently active. Our Clean High-Efficiency Diesel Engine consortium has been making diesel engines cleaner for more than a quarter of a century and recently developed a modular heavy-duty single-cylinder engine to support research activities. Our High-Efficiency Dilute Gasoline Engine consortium has spent more than a decade pursuing lower emissions and higher fuel efficiency. The Advanced Engine Fluids group studies how fuel and lubricant chemistry affect engine durability and performance, while the Advanced Combustion Catalyst and Aftertreatment Technology consortium focuses on emission control technologies. The Aluminum Head Evaluation, Analysis and Durability consortium is developing lighter, more durable engine components to help meet tighter fuel economy and emissions regulations.

For more information visit **automotiveengineering.swri.org** 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.

Our single-cylinder engine is a cost-effective platform to validate innovative engine design and advance combustion research strategies. It is available for contract use or purchase.

D022750_6975

CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

- Geophysical & Geological Investigations
- Groundwater Resource Evaluations
- Chemical & Radiological Contaminant Transport
- Laboratory, Field & Numerical Analyses
- Corrosion
- Materials Life Prediction
- Risk & Performance Assessments
- Environmental Impact Assessments
- Geoscience Processes
- Climate Change Impact Assessment
- Structural Integrity Analyses
- Reliability & Operational Safety Analyses
- Regulatory Analyses & Guidance
- Fire Protection & Forensic Analyses
- Material Aging & Degradation
- Natural & Human-Induced Hazard Assessments
- Structure, System & Component Fragility Analyses
- Pipeline Failure Analyses
- Probabilistic Risk Assessment

D022863

D022872

This year, we completed major environmental evaluations of the Jane Dough uranium recovery project and Reno Creek uranium facility sites.

Inset: Since the late 1980s, SwRI has conducted research to support underground radioactive waste disposal in the U.S. and abroad.

The integrity of energy infrastructure is critical to the safety, security and economy of the nation. SwRI scientists study materials used in nuclear facilities, assessing both internal and external corrosion processes.

In response to the incident at Fukushima, Japan, SwRI helped NRC update seismic hazards for western United States nuclear power plants, such as the Diablo Canyon Power Plant shown here.

In 2017, the Southwest Research Institute contract to operate the Center for Nuclear Waste Regulatory Analyses was renewed. Sponsored by the Nuclear Regulatory Commission, the Center has supported the agency in fulfilling its regulatory responsibilities related to radioactive waste storage, transportation and disposal for the last 30 years.

This year, CNWRA® completed seven knowledge management reports that document decades of field studies, laboratory experiments and computer simulations associated with radioactive waste management. While the work was conducted in the context of a proposed geologic repository, the results have led to broad overall advances in earth sciences and engineering.

We continue to export our long-term storage and disposal expertise, completing technical analyses for proposed radioactive waste repositories around the world. CNWRA met the quality assurance requirements of the International Organization for Standardization to enable it to conduct work in Canada and Europe.

We also provide support across the entire nuclear power cycle, from uranium production to interim waste storage and ultimate disposal. We continue conducting environmental evaluations of nuclear facility sites, assessing the impact of proposed activities and communicating with stakeholders. Now, we are transitioning expertise developed for these facilities to nonnuclear applications. In particular, our public outreach skills are vital to many regulatory agencies and industries working to develop various types of safety-critical facilities.

As the industry matures, commercial nuclear power plants are seeking to operate beyond the original licensing period. CNWRA developed the Generic Aging Lessons Learned report to outline approaches to identify and manage plant aging effects. The standard review plan guides the NRC staff when performing safety reviews of license extension applications. We also developed computational modeling techniques to support transitioning nuclear power plants to probabilistic fire protection standards that more adequately reflect possible scenarios.

Building on our experience in seismic and volcanic hazards analyses, we are expanding into other natural hazard arenas for nuclear and nonnuclear infrastructure. Additional hazards include tornadoes, sinkhole formation, mine collapse and earthquake-induced liquefaction.

Instability and strength loss from soil liquefaction, when silty ground acts like a liquid during seismic events, cause significant damage to critical facilities during earthquakes. In 2017, we initiated contract work and held a workshop, laying the groundwork for a Next Generation Liquefaction Consortium. The consortium will conduct research to develop practical, consensus-based probabilistic models to understand and predict liquefaction triggering and consequences.

We continue to use our corrosion expertise for the nuclear industry. In 2017, we began applying this expertise to the 2.6 million miles of pipelines and over a million storage tanks used by the oil and gas industry. SwRI is one of few organizations with expertise characterizing both external and internal corrosion processes. We can assess, for example, site-specific soil conditions outside, and corrosive chemicals flowing inside, pipes to locate areas of corrosion susceptibility and recommend remediation. We also patented technology to assess and determine how to mitigate damage to pipelines, particularly those installed using horizontal directional drilling. This technique is often used to install pipelines under features like rivers, roads or railways, but can damage protective coatings.

For more information visit **cnwra.swri.org** or contact Executive Director Dr. Wesley Patrick at 210.522.5158 or wesley.patrick@swri.org.

CHEMISTRY & CHEMICAL ENGINEERING

D022850

- 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

D022713_5660

Using pilot-scale facilities, SwRI is helping clients develop novel processing techniques to cost-effectively produce a common feedstock for today's consumer products.

Inset: Since the 1950s, SwRI chemistry labs have supported petroleum, microencapsulation, pharmaceutical and environmental research.

Our chemists are part of a team developing a therapeutic implant for controlled release of an antimalarial medication. Developed for the Walter Reed Army Institute of Research, the implant is undergoing early nonclinical trials.

We exposed a liquefied natural gas tank to an external fire to understand how the tank's pressure relief safety system would perform in a fire scenario.

SwRI has developed a rapid analytical method to characterize chemicals in consumer products. In the first 350 evaluations, analysis yielded 4,000 chemical signatures, 1,400 of which were unknowns with potential human health risks.

Southwest Research Institute chemists and chemical engineers work with our clients to develop and commercialize new fuel and chemical technologies, provide solutions for homeland security threats and address emerging challenges to human health and safety. Our scientists verify the purity of and identify trace toxins in consumer products and develop novel drug formulations and products that enhance the nutrition, appearance and taste of foods.

In 2017, SwRI completed testing of a prototype system that would allow soldiers to destroy chemical warfare agents in remote arid locations without the logistics burden of providing water. The SwRI-developed destruction process uses a vehicle engine to burn the agents as fuel and a soil-based dry process to remove acid gases from the exhaust.

For the energy industry, SwRI engineers and scientists develop and validate novel processes to upgrade and refine hydrocarbon products from bio-based feedstocks and other alternative sources, using our large-scale pilot plants and extensive laboratory facilities. Presently, we are developing innovative processes to produce olefins, a critical raw material for many plastic and chemical products. These processes provide a market advantage by allowing our clients to benefit from the low cost and ready availability of light hydrocarbons.

We have enhanced our integrated Current Good Manufacturing Practices pharmaceutical and bioengineering facilities to expand our production of pharmaceuticals for clinical trials and commercial sales. These include controlled-release formulations for vaccines, anti-inflammatory medications, high-potency cancer therapeutics and tamper- and abuse-resistant pain medications.

We have taken advantage of new mobile communications technology to accelerate the processing speed of SwRI's custom Rhodium™ drug discovery software. Rhodium is now up to four times faster, greatly increasing its capacity to screen drug candidates. Our drug design and optimization process successfully developed leading candidates to treat Ebola and antidotes to reverse effects of pesticide or nerve agent exposures.

We are leveraging our 70 years of experience in microencapsulation to meet client needs in pharmaceutical, veterinary, food, nutraceutical, agricultural and consumer products, as well as oil and gas applications. The U.S. Food and Drug Administration recently approved the first and only extended-release, intra-articular injection for osteoarthritis-related knee pain, which was formulated at SwRI. In addition, we are using novel FDA-approved implant technology to protect against HIV and to treat opioid addiction, Parkinson's disease and thyroid imbalances.

In the fire safety arena, engineers are studying how relatively small fuel leaks can have catastrophic effects when fumes create explosive atmospheres. We are conducting experiments evaluating how gas mixtures, ignition sources and confinement affect the detonation process and are using this data to develop computational techniques to model risks and impacts to surrounding structures.

Fire retardants common in household appliances, furnishings and insulation remain controversial, in terms of both efficacy and toxicity. In 2017, we evaluated the relative toxicity of smoke produced by materials with and without fire retardants to provide critical information on how combustion by-products might affect human health. This research is particularly relevant for firefighters, who are repeatedly exposed to these particular hazards.

For more information visit **chemistry.swri.org** or contact Vice President Dr. Michael MacNaughton at 210.522.5162 or michael.macnaughton@swri.org.

DEFENSE & INTELLIGENCE SOLUTIONS

D022853

- Condition & Trigger-Based Maintenance & Management
- Information Assurance
- Automatic Test Program/ Set Development
- Analysis, Analytics, Visualization & Reporting
- Avionics-Based Open Systems
- Signal Analysis & Processing
- Deep Learning
- Electronic Warfare
- Intelligence & Tactical Networking
- GPS Engineering
- Geolocation
- Signals Intelligence
- Tagging, Tracking & Locating Solutions
- Situational Awareness
- Intelligence, Surveillance & Reconnaissance
- Multi-INT Processing, Exploitation & Dissemination
- Multimodal Sensing/Targeting
- RADAR Simulation
- Software-Defined Radios
- Weapon System Integration & Sustainment
- Aircraft Data Recorders
- Autonomous Sensors/Sensing Platforms
- Communications Solutions

D022710_6072

We continue to modify and improve our Electronic Warfare Test System, which automatically validates signal requirements for radar and electronic countermeasure systems.

Inset: SwRI has been involved in radio direction finding for the U.S. Navy continuously since 1951.

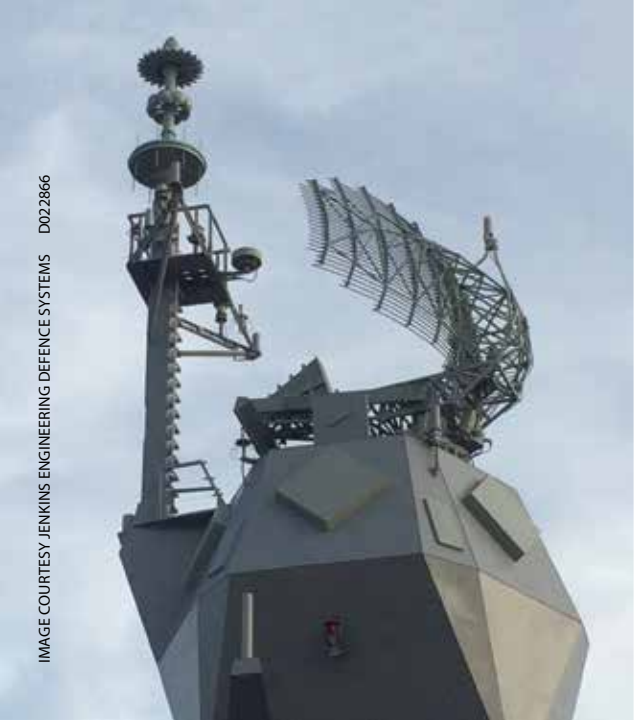
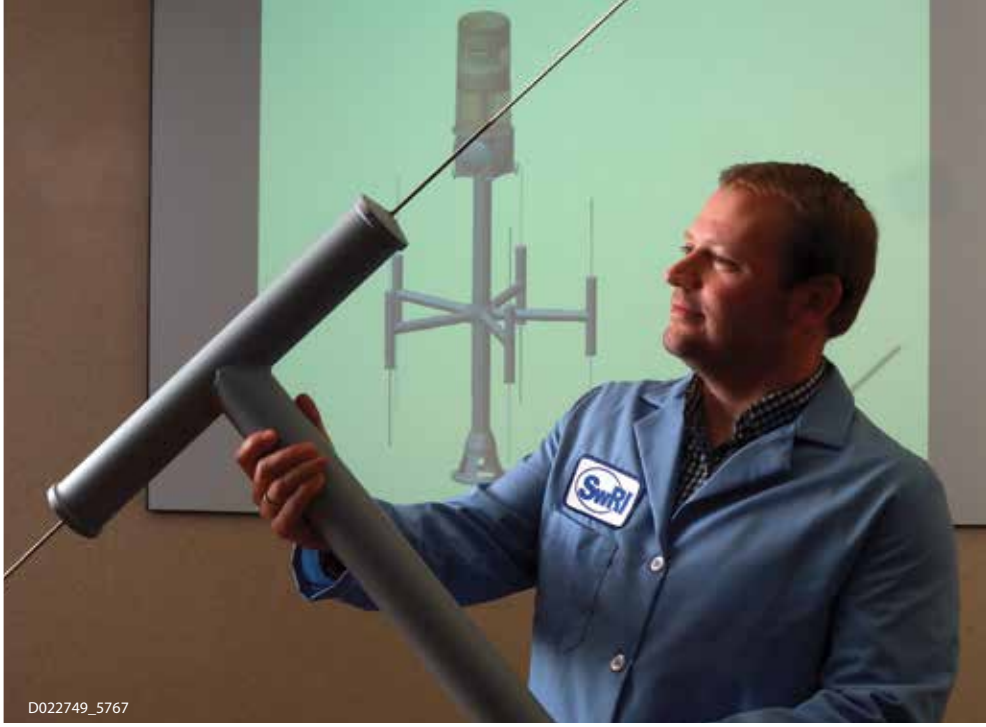


IMAGE COURTESY JENKINS ENGINEERING DEFENCE SYSTEMS D022866

Our work in shipboard direction finding antennas spans decades. Most recently we began a multi-year plan to install SwRI-designed antennas on Anzac class frigates for the Royal Australian Navy.



We are designing components for a fixed-site, low-cost direction finding antenna that will enhance the capabilities of Scout™, an SwRI-developed radio frequency survey and monitoring system.

For 66 years, Southwest Research Institute electronics engineers have conducted research in direction finding, surveillance, geolocation and tracking, supporting the United States and its allies in these important defense areas. We also support the military with our work in cyber technology, electronics integration and avionics systems.

We are developing the Advanced Electronic Warfare Laboratory, a first-of-its-kind system used to evaluate and improve modern and future radio systems. The AEWL supports signals intelligence, electronic intelligence, communications, radar warning, electronic attack and electronic countermeasures missions. The laboratory simulates a realistic electromagnetic environment — cluttered with a variety of signals from radio devices — that allows technology developers to assess the effectiveness of new capabilities in a repeatable, real-time, closed-loop setting. The system will save both time and money by reducing the need for live test exercises.

Our Electronic Warfare Test System, developed last year, automatically validates signal requirements for electronic countermeasure systems. This year, the system discovered three possible problems in aircraft attack pods that could not be detected with previous test systems. We confirmed and documented two of the problems and are investigating the third. Modifications and improvements to the system will enable it to determine if a problem is software- or hardware-related.

For the Commonwealth of Australia, we completed the initial design review for the Anzac communication electronic support replacement program. This step completes Phase 1 of a multimillion-dollar, multi-year program to install our communications intelligence equipment aboard Anzac-class frigates operated by the Royal Australian Navy.

We are leading an effort for the National Spectrum Consortium to prototype dynamic spectrum access architecture to enable Department of Defense radio communications to coexist within the same frequency band used by commercial broadcast services. Television and radio stations use this band to transmit mobile video, audio and text news stories from remote locations to their broadcast facilities. A key objective of this effort is for military radios to never interfere with these operations.

In 2017, we redesigned the threat timing generator card for the Multiple Threat Emitter System (MUTES) and Mini-MUTES. These systems simulate enemy radar to train U.S. Air Force flight crews. In related work, we also are redesigning computer assemblies for both systems and repairing Mini-MUTES equipment.

Using internal funding, we continued to refine Scout™, an SwRI-developed, portable, wideband radio frequency survey and monitoring system that has aided the intelligence community for over five years. This past year, we created several novel designs for a fixed-site, low-cost VHF/UHF direction finding antenna. This antenna will augment Scout's signal intelligence collection capabilities.

For more information visit **defense.swri.org** or contact Vice President Nils Smith, P.E., at 210.522.3685 or nils.smith@swri.org.

- Unmanned Systems
- Robotics
- Active Safety Systems
- Intelligent Transportation Systems
- Process Improvement
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- Human Performance
- Machine Vision
- ROS-Industrial
- Connected Vehicles
- Perception Systems
- Localization Technologies
- High-Reliability Systems
- Flight Test Technologies
- Advanced Manufacturing Technologies
- Automated Driving
- Energy Inspection Technologies
- Big Data & Analytics
- Cybersecurity
- Penetration Testing
- Weapon Detection
- Leak Detection Systems
- Advanced Transportation Management Systems

INTELLIGENT SYSTEMS

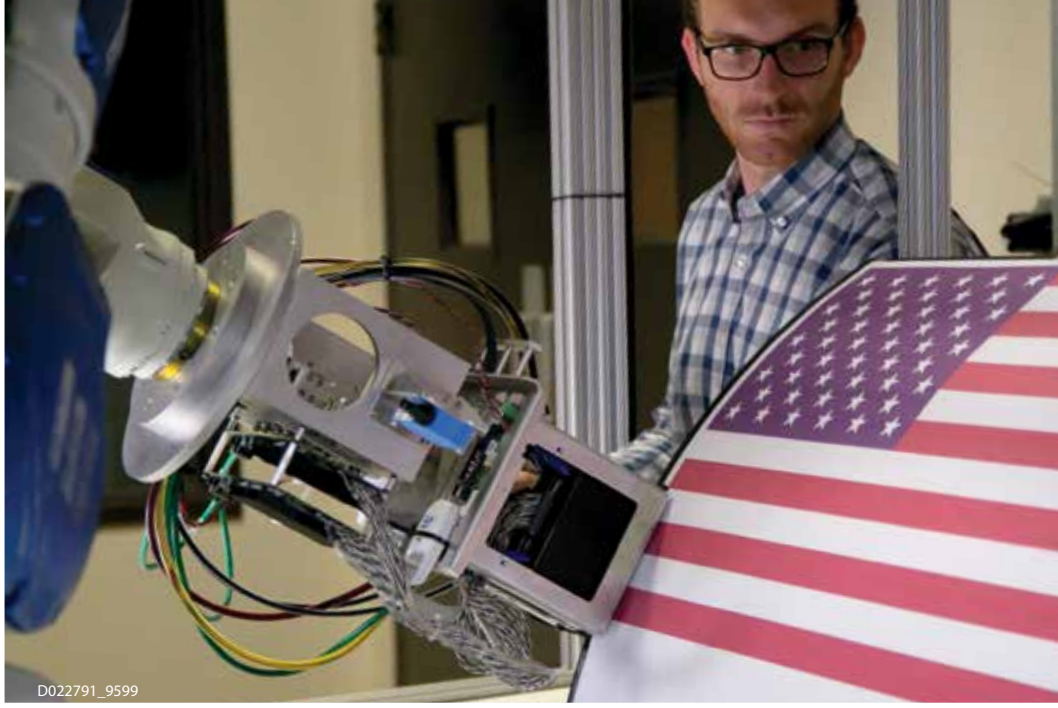
D022756_0560

D022851

We are applying unmanned aerial systems, or drones, for challenging inspection applications that involve detecting and assessing small deformations, cracks and other defects in materials.

Inset: In the 1980s, SwRI automated the inspection and repair of damaged aircraft canopies for the U.S. Air Force.

Engineers adapted SwRI's Ranger localization technology for convoy applications. As the lead vehicle maps the route surface, it transmits the data to the rest of the convoy, which autonomously follows its route to within 3 cm.



SwRI has patented an automated inkjet technique that could revolutionize how aircraft and other industries apply complicated graphics to complex surfaces.

Southwest Research Institute applies the most advanced digital technology to create sophisticated 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, expanding to 10 states in 2017. We recently signed follow-on contracts to continue managing state-wide systems in Florida and California, two of the largest states, in both population and miles of road. For Florida, we are developing an integrated corridor management system to manage a locality's entire transportation network holistically instead of as individual components, such as freeways or surface streets. The objective is to balance traffic across the network by actively recommending alternative routes, modifying signal timing and using other methods.

In 2017, SwRI revitalized its cyber security program, with a focus on the transportation and automotive security arenas. Today's highly computerized vehicles are increasingly connected, making them possible targets for hackers. We are collaborating with academia on award-winning security software designed to make it extremely difficult to install malware on a vehicle system. Our analysts also expanded capabilities that look for vulnerabilities in digital systems including geographically dispersed advanced transportation networks.

Multidisciplinary teams are continually advancing SwRI's automated driving technology, giving unmanned systems the ability to understand their environment, localize their position and navigate roadways and off-road terrain. This year, SwRI automated a tracked combat vehicle and applied our Ranger localization and navigation technology to military convoys.

We are also adapting our smart leak detection system, originally developed to identify small liquid pipeline spills, to detect gaseous leaks. We apply deep learning techniques to an infrared video stream to automatically detect methane plumes in real time for the Department of Energy.

In the field of automation, SwRI patented a potentially disruptive technology to cost-effectively print intricate graphics on aircraft and other complex surfaces using inkjet systems. Building on a series of paint stripping systems, the large-scale robot-based technique overcomes obstacles associated with applying artwork to large complex surfaces, as well as the need to adjust for inaccuracies in robot positioning and vibration.

This year, we established a collaborative robotics laboratory, which includes multiple robots designed to work alongside human operators. The lab will deliver next-generation advanced automation technology needed by manufacturers.

SwRI continues to curate the open-source ROS-Industrial framework, applying the Robot Operating System for advanced manufacturing applications on an international scale. In the military arena, SwRI is part of a team developing a new generation of robots for the Air Force. The goal is to develop a multi-process mobile system that can support a variety of aerospace manufacturing and maintenance processes. Analysts are using ROS-I to create programs that automatically perceive the aircraft, plan tasks, determine robot motions and reliably execute processes.

Closer to our home base in San Antonio, SwRI has helped small and medium manufacturers become more competitive in the global economy through a branch of the Texas Manufacturing Assistance Center we've operated for more than 20 years.

Visit **intelligentsystems.swri.org** for more information or contact Vice President Dr. Steve Dellenback at 210.522.3914 or steve.dellenback@swri.org.

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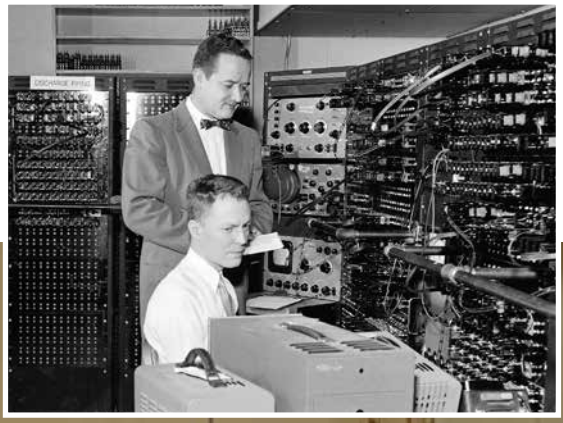


MECHANICAL ENGINEERING

- 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_2 Power Cycles

D022555_1028

In 2017, we added a 7,050-square-foot facility for launching projectiles at high speeds. The centerpiece of the facility is a two-stage light-gas launcher that can achieve hypervelocities close to 7 kilometers per second (15,660 miles per hour).

Inset: SwRI developed a unique electro-acoustic analog of a gas compressor station in the 1950s.

Our recently completed high-pressure high-temperature facility adds infrastructure for testing and evaluating subsea equipment and systems. Our test chambers can reach pressures to 30,000 psig and temperatures up to 650 degrees F.

SwRI researchers developed a fuel mixing facility to allow combustion testing of many different, non-traditional fuel mixtures in a gas turbine.

Since 1947, Southwest Research Institute's mechanical engineering program has provided a range of research, development and evaluation services to both government and industry clients. Core research areas include electric power generation, underwater systems, space systems hardware, armored vehicles, aircraft structural integrity, and oil and gas production and transmission.

In collaboration with the U.S. Department of Energy and a major oil service company, we are developing a hydraulic fracturing process that uses natural gas as the primary fracturing fluid. This technology uses natural gas to generate a foam suitable for fracture treatments, reducing water usage by as much as 80 percent over conventional water-based techniques. This year, we evaluated liquefied natural gas and compression cycles to identify the best process for preparing the foam. We also investigated the foam's properties at field conditions using a pilot-scale facility designed, built and operated by our engineers. These data are now available to the oil and gas industry.

We are developing advanced technology to inspect aging infrastructure, such as 50-year-old nuclear waste storage tanks located at the Hanford Site in Washington. In 2012, a leak was discovered in a region not inspected because of access challenges. Combining internal research and client funding, we adapted an existing system developed for nuclear power plant inspection that uses low-frequency sound waves to detect flaws. In a test on a mock-up tank, the technique detected nearly 80 percent of the flaws. Plans are underway to integrate the technology into a robotic system.

Our aircraft structural integrity program continues to help the U.S. Air Force and other military branches maintain the airworthiness of their fleets. To address promising processes for extending the structural service life of aging aircraft, we formed the Engineered Residual Stress Implementation Working Group. Now in its second year, this international group comprises 23 member organizations, with experts from U.S. defense agencies, major aircraft companies, educational institutions and other organizations. ERSI is developing, validating and qualifying critical analytical methods and quality assurance tools that will affect current maintenance inspection requirements.

Our support for the U.S. military also extends to ground-based equipment. For the U.S. Army Tank Automotive Research, Development and Engineering Center, we designed and fabricated hulls and floors for a heavy armored personnel carrier. Using both computational analysis and experimental blast testing, we validated that these components would improve vehicle safety and occupant survivability.

Today's advanced manufacturing processes need a method to capture the relationship between key manufacturing parameters such as microstructure, defects, material properties, inspection and damage tolerance, and the final product. We recently integrated our fracture mechanics and reliability assessment software, DARWIN® (Design Assessment of Reliability with INspection), with a commercial X-ray simulation software to improve fracture risk assessments. DARWIN also provides information to the X-ray software about location-specific defects that could ultimately fail during the service life of a product.

Visit **mechanicalengineering.swri.org** for more information or contact Vice President Danny Deffenbaugh at 210.522.2384 or danny.deffenbaugh@swri.org.

SPACE SCIENCE & ENGINEERING

D003255 1999

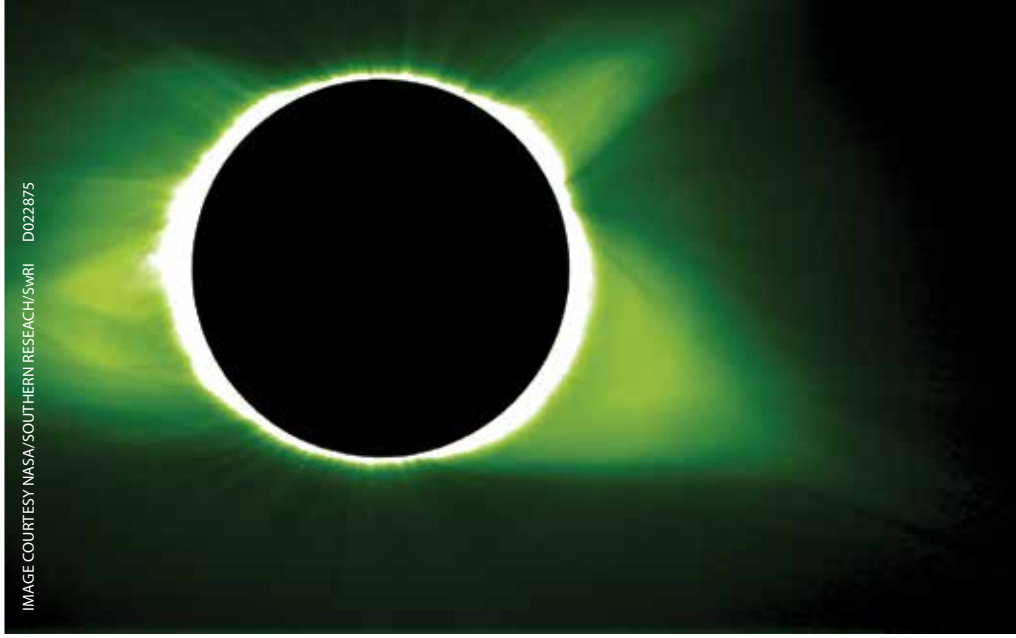
- Planetary Science
- Magnetospheric Physics
- Solar & Heliospheric Physics
- Spaceflight Science Instruments
- Spacecraft Avionics
- Electromechanical Systems
- Power Systems
- Small Satellite Design, Development & Fabrication
- Spacecraft Management
- Data Analysis & Science Support
- Science & Mission Operations
- Lighter-Than-Air Systems
- Water Resource Management
- Geological Structural Analyses
- Energy Exploration & Production Support

D022855

In addition to building the eight microsatellites in the CYGNSS constellation, SwRI runs the mission operations center from our Boulder, Colorado, location. We manage its mission planning, flight dynamics and command and control tasks.

Inset: In the 1990s, SwRI led the development of NASA's IMAGE spacecraft, which imaged the Earth's magnetosphere for the first time.

SwRI scientists and engineers developed the Heavy Ion Sensor, which will measure particles in the solar wind from aboard ESA's Solar Orbiter. When completely assembled, the instrument will be sheathed in thermal material for its close approach to the Sun.



An SwRI-led mission imaged the Sun's corona from aboard two NASA research aircraft, using the summer's solar eclipse to block the intense glare of the Sun and visualize more detail in the weaker coronal emissions.

Southwest Research Institute is home to one of the nation's leading space science and engineering programs, emphasizing both fundamental research and innovative technology. For more than 30 years, our program has advanced from conducting research to building payload instruments and electronics, to eventually leading entire NASA missions and now building spacecraft.

This year marked success in a new facet of our program: seeing the first SwRI-built spacecraft return important new Earth science data. The Cyclone Global Navigation Satellite System (CYGNSS), a constellation of eight microsatellites, is now collecting data that allow us to infer hurricane wind speeds at the ocean surface. The data will be integrated into models to better understand and predict how hurricanes intensify, a critical factor that has lagged behind landfall predictions.

A new heliophysics mission based on the CYGNSS microsatellite array is under conceptual design. SwRI's "Polarimeter to Unify the Corona and Heliosphere," known as PUNCH, employs a constellation of four desk-sized satellites that will orbit the Earth in formation to study how the Sun's atmosphere, or corona, connects with the interplanetary medium.

In its third year of operations, the SwRI-led Magnetospheric Multiscale (MMS) mission continues making a steady stream of discoveries about magnetic reconnection, a powerful process seen throughout the universe. In the first two years, MMS observations have been published in over 400 peer-reviewed publications.

Even as New Horizons hurtles toward its Kuiper Belt flyby in 2019, SwRI was selected to lead Lucy, NASA's first mission to the Trojan asteroids. The spacecraft, scheduled to launch in 2021, will study six of these primitive objects orbiting in tandem with Jupiter.

The SwRI-led Juno mission is making new discoveries from its first-ever polar orbit about the largest planet in the solar system. Every 53 days, Juno swings in close to the gas giant, collecting science about Jupiter's interior structure, atmosphere and magnetosphere. Two SwRI-led instruments are working in concert to study the Jovian auroras, the most spectacular in the solar system.

Space facilities under construction include a state-of-the-art laboratory that simulates planetary surfaces and the "COSMIC" calibration chamber. The first will investigate why Pluto's moon Charon has a red pole and how Jupiter's moon Europa forms its tenuous atmosphere. Engineers will use COSMIC to calibrate the SwRI-developed MASPEX™ instrument, the most precise space-borne mass spectrometer to date, scheduled to fly on NASA's Europa Clipper mission. SwRI is also the prime contractor developing OCTOCAM, a next-generation astronomical instrument to improve data collected by the 8-meter Gemini South telescope in Chile.

In 2017, NASA funded the Exploration Science Pathfinder Research for Enhancing Solar System Observations consortium. The second "virtual institute" led by SwRI, Project ESPRESSO will pursue research, techniques and technologies that will enable safe, effective exploration by a future generation of astronauts.

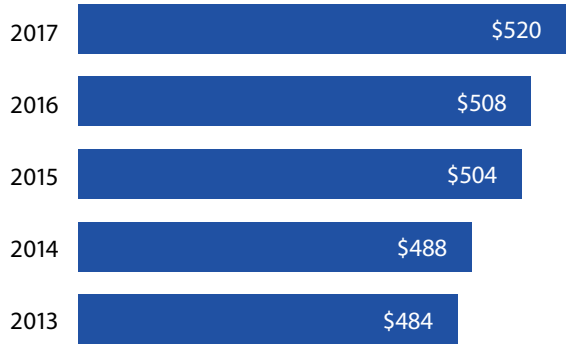
Closer to home, Earth scientists expand our understanding of critical natural resources, including petroleum and water. This year, SwRI launched a new joint industry project focused on enhancing production in Permian Basin shale oil reservoirs. Water quality and availability remains an important global and local concern. Our latest research linked groundwater in a Texas aquifer to the surface flows in one of the state's most pristine rivers.

For more information visit **spacescience.swri.org** or contact Vice President Dr. James L. Burch at 210.522.2526 or jim.burch@swri.org.

CONSOLIDATED STATEMENT OF ACTIVITIES in thousands of dollars

For the year ended September 29, 2017

Commercial Revenue	$215,842
Government Revenue	312,010
Contract underruns, net	843
Total revenue	528,695
Direct project costs	305,611
Operating income	223,084
Division operating expenses	129,944
Depreciation – research equipment	10,092
General overhead	61,969
Depreciation – general facilities	16,687
Internal research	7,057
Income (loss) from operations before federal income tax expense	(2,665)
Federal income tax expense	339
Income (loss) from operations before postemployment benefits activity	(3,004)
Realized/unrealized gain from postretirement medical benefits fund	7,027
Postemployment benefits liability actuarial adjustments	7,622
Change in unrestricted net assets	11,645
Net assets at beginning of year	507,930
Net assets at end of year	$519,575



NET ASSETS | in millions of dollars

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On September 14, the SwRI staff — in San Antonio and our satellite offices — gathered to celebrate the Institute's 70th anniversary. Timelines of SwRI's research activities detailed our research by decades, as President and CEO Adam Hamilton and Executive Vice President and COO Walt Downing recognized our past while setting our sites on an exciting future. Former president Dan Bates and many other retirees also came out to recognize this milestone. At our headquarters, we acknowledged our founder Tom Slick with various fun photo opportunities, including a nod to Slick's expedition to look for the legendary Yeti.


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