ANNUAL REPORT 2024

SOUTHWEST RESEARCH INSTITUTE®

2024 BUILDING BOOM

In 2024, Southwest Research Institute continued a building boom, completing nearly $36 million worth of major facility projects, topping off nearly $165 million in investments over the last five years. Those projects included new buildings and research facilities, updates to the Slick Café and adding solar arrays to the Fitness Facility roof and new covered parking area. Another $195 million worth of projects are underway or approved to start in 2025, allowing us to continue to serve our clients, conduct research and solve problems from Deep Sea to Deep Space®.

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In 2024, SwRI broke ground on a new 21,000-square-foot Clinical Supply Facility that will support government and industry clients with integrated pharmaceutical and bioengineering services, including drug discovery, microencapsulation and production scale-up for clinical trials.

SwRI added solar panels to the Fitness Facility roof (not shown) and its new covered parking structures, providing 465 kW of power. This demonstration project will lead to additional use of photovoltaics across the Institute to help decrease SwRI's carbon footprint.

Demand for high-speed aerospace propulsion systems far exceeds the nation's industrial production capacity. SwRI broke ground on the Center for Accelerating Materials and Processes (CAMP), an onsite facility that will support research and development for manufacturing tomorrow's hypersonic aerospace engines.

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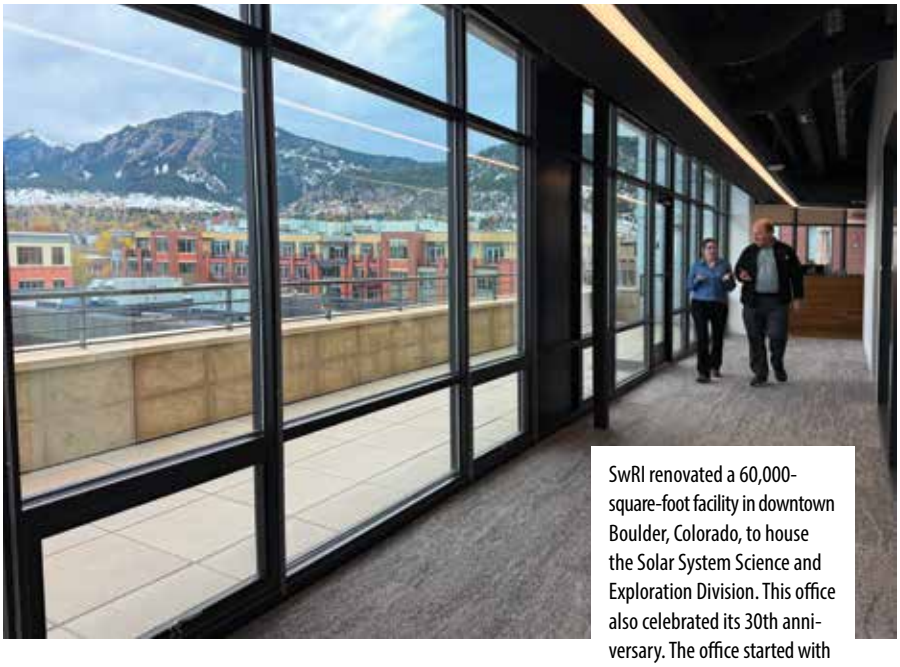
IMAGES COURTESY ALAMO ARCHITECTS AND PIEPER O'BRIEN HERR ARCHITECTS



SwRI renovated a 60,000-square-foot facility in downtown Boulder, Colorado, to house the Solar System Science and Exploration Division. This office also celebrated its 30th anniversary. The office started with three staff members in 1994 and now numbers more than 120.

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Construction of a new Intelligent Systems office building is underway. The 44,000-square-foot facility will include a 250-person-capacity conference center.

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The first SwRI-owned building outside of San Antonio, in Warner Robins, Georgia, will support our advanced electronic warfare work for the U.S. Air Force. The $18.5 million, 33,000-square-foot facility will open in mid-2025.

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In 2024 SwRI completed construction of a 1,260-square-foot indoor Spherical Near-Field Antenna Range, enhancing the Institute's antenna measurement capabilities for government and industry clients. Lined with radio frequency and microwave foam absorbers, the range finely samples the near field of an antenna, allowing engineers to mathematically transform the measurements into far-field data.

FROM THE PRESIDENT

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In 2024, SwRI continued solving some of humankind's most difficult technical challenges, from Deep Sea to Deep Space®, and practically everywhere in between. We continued adding staff members and new facilities while also supporting the communities where we live and work. In this 2024 Annual Report, we hope to provide you with some insights into our many different technical accomplishments, our continued mission-focused successes, our financial stewardship and the continued growth and development of our people and facilities.

Our Fiscal Year 2024 consolidated revenue and net assets grew to record levels while working to meet the growing needs of our clients. This past year, we completed $35 million in major facility projects, including the indoor Spherical Near-Field Antenna Range featured on the cover of this report. This specialized resource expands SwRI's antenna testing capabilities. We are also investing $195 million in other new facilities that are currently under construction, including the first SwRI-owned building outside of San Antonio (Warner Robins, Georgia) and the Center for Accelerating Materials and Processes, which will help advance the science, engineering and technologies needed for the production of high-speed aerospace propulsion systems.

In October of 2024, NASA's Europa Clipper mission launched with two SwRI-led instruments on board. The spacecraft is on its way to Jupiter's icy moon, Europa. Once there, our MAss Spectrometer for Planetary EXploration, or MASPEX, instrument will collect and identify gas molecules from Europa's surface with unparalleled precision. In addition, our Europa Ultraviolet Spectrograph, or Europa-UVS, will capture data used to determine the composition of Europa's gases and surface materials. But we'll have to be patient. The Europa Clipper doesn't reach Jupiter until 2030.

Meanwhile, we continued to make progress in decarbonizing the transportation industry. In 2024, we modified the internal combustion engine (ICE) of a semi-trailer truck to run on hydrogen (H_2) fuel while producing ultra-low emissions. Our H_2-ICE vehicle hit the road for the first time in 2024, demonstrating an option for heavy-duty applications with the potential to reduce tailpipe carbon dioxide emissions by a staggering 99%.

SwRI is also working to become a net-zero greenhouse gas campus. We have installed additional solar arrays and are recovering residual energy from many of our research programs to help power our operations. We are also developing plans to use condensates and recycled water to reduce our use of potable supplies. And we have installed an AI-powered fire detection system that provides continuous real-time outdoor fire detection for our campus and the surrounding parts of San Antonio.

Growth, expansion and a vision for the future guided SwRI's year. Please read on to learn more about our extraordinary staff, programs and progress in 2024.

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

As a nonprofit research and development organization, SwRI invests in innovation, using our robust internal research and development (IR&D) program to expand and enhance our expertise and encourage our staff's professional growth. In 2024, SwRI initiated 119 new IR&D projects, investing more than $11 million in internal research, including quick-look and focused research programs.

IR&D 2024

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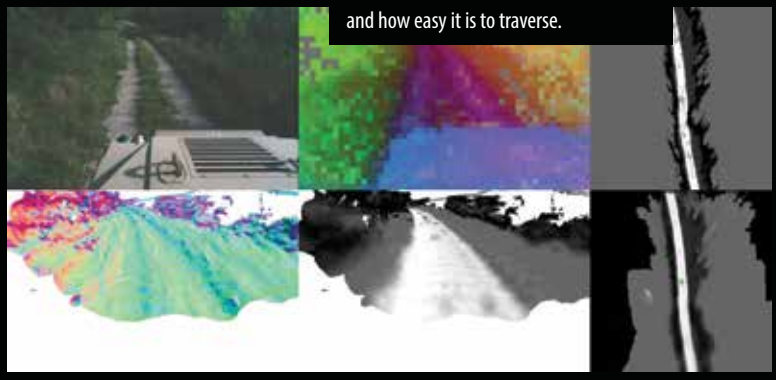
SwRI's internal research program supported the development of the Vision for Off-Road Autonomy (VORA™) suite of tools providing stealthy automated driving for off-road military vehicles. In 2024, we demonstrated how VORA could support exploration of the Moon in an environment that simulates the lunar surface (above). The image below illustrates how VORA color classifies an off-road environment and how easy it is to traverse.



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Our IR&D program helps us advance science, engineering and technology while also preparing for the future needs of our clients. The program also allows engineers and scientists to grow in their technical fields by providing freedom to explore innovative and unproven concepts without contractual restrictions and expectations. IR&D is frequently cited as a key enabling factor leading to new projects, new clients and completely new research arenas within the Institute.

IMAGE COURTESY ZERO-G

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SwRI engineers collaborated with Texas A&M to perform fluids engineering experiments aboard a series of parabolic flights, gathering data and observations at multiple gravity levels.

SwRI chemists integrated machine learning tools with Rhodium™ drug development software to screen DNA-targeting therapeutics, ranking 31 cancer-fighting drugs for their effectiveness against leukemia cells with 99.95% confidence.

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MILESTONES 2024

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Two SwRI instruments are among the nine launched aboard NASA's Europa Clipper spacecraft in October. The spacecraft is designed to conduct a detailed reconnaissance of Jupiter's moon Europa, investigating whether its vast subsurface ocean could harbor conditions suitable for life. SwRI developed the MAss Spectrometer for Planetary EXploration (MASPEX) and Ultraviolet Spectrograph (Europa-UVS) to explore Europa, Jupiter's fourth-largest moon and one of the most likely locations for potential life in our solar system.

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IMAGES COURTESY SPACEX/ NASA/JPL-CALTECH

AWARDS

Dr. Marc Janssens: National Fire Protection Association® DiNenno Prize Laureate

Dr. Kelly Miller: NASA Early Career Award

Kevin Shannon: ASTM Daniel H. Green Award

Dr. Alan Stern: Commercial Spaceflight Federation James Kuzima Public Communications Award & AIAA Fellow

Dr. Kristin Ulmer: Earthquake Engineering Research Institute Younger Member Award

Dr. Sergey Vinogradov: American Society for Nondestructive Testing Ward Rummel Engineering Excellence Award

For more than a decade, SwRI engineers have supported Shell Eco-Marathon events with technical inspections, design assessments and real-time fuel measurement for the ultra-energy-efficient vehicles designed, built and driven by student teams from around the world.

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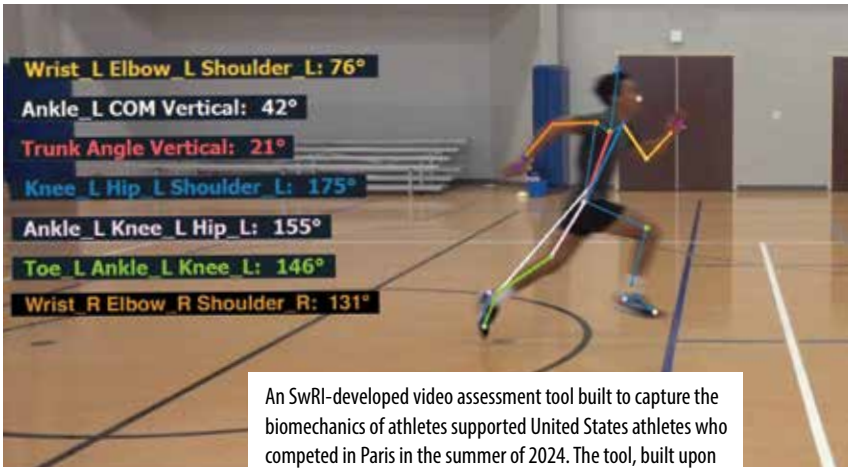
559 PAPERS PUBLISHED

PODCASTS **14**

22 WEBINARS

PRESENTATIONS GIVEN **714**

9 STREAMING MEDIA



An SwRI-developed video assessment tool built to capture the biomechanics of athletes supported United States athletes who competed in Paris in the summer of 2024. The tool, built upon SwRI's markerless biomechanics technology, uses video from a single cell phone camera to measure the mechanics of an athlete and provide feedback to the coaching staff.

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HONORS

Nathan Andrews: Associate Fellow American Institute of Aeronautics and Astronautics (AIAA)

Jessica Brysch: 2023 Empowering Women in Industry Conference – Mentor of the Year

Dr. Steve Dellenback: Appointed to the U.S. Department of Transportation Transforming Transportation Advisory Committee

Dr. Nick Mueschke: AIAA Associate Fellow

Matt Robinson: Manufacturing USA – 2024 Modern Makers

Dr. James Walker: President, International Ballistics Society & Distinguished Scientist of the Hypervelocity Impact Society

PATENTS & INVENTIONS

35 U.S. PATENTS AWARDED

U.S. PATENT APPLICATIONS FILED **54**

50 INVENTION DISCLOSURES SUBMITTED

3,237 EMPLOYEES

2,202 DEGREES

339 DOCTORATES

623 MASTERS

1,019 BACHELORS

221 ASSOCIATES

On Hydrogen Day, staff members from across the Institute gathered around SwRI's H_2-ICE demonstration vehicle, fuel-cell vehicle and onsite liquid hydrogen tank, just a few examples of our commitment to a wide range of clean hydrogen applications. Research includes clean hydrogen production, fuel blending, infrastructure embrittlement, safety and more.

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AUTOMOTIVE AND TRANSPORTATION

SwRI upgraded several emission test cells with new equipment in one of the most experienced emissions test laboratories in the country, which actually predates the creation of the Environmental Protection Agency.

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For more than 75 years, Southwest Research Institute has been involved in nearly every facet of automotive and transportation research from powertrains to fuels and lubricants to intelligent highways and connected and automated vehicles. In 2024, SwRI continued existing programs and launched new ones aimed at safe, energy-efficient, affordable, and low- and zero-emission modes of transport. For more than 30 years, SwRI has been a premier provider of intelligent transportation systems (ITS) and advanced traffic management systems (ATMS) while developing automated driving systems for vehicles designed to traverse urban roadways, off-road environments and military battlefields.

AUTOMOTIVE

This year, SwRI successfully developed and demonstrated a hydrogen-fueled Class 8 demonstration vehicle, offering energy efficiency above 40% while producing near-zero carbon emissions. The vehicle uses a hydrogen internal combustion engine (H_2-ICE) that produces ultra-low NOx and CO_2 emissions while still providing enough torque and power for most heavy-duty applications. Because NOx emissions affect air quality and pose other health risks, they are heavily regulated. Built in collaboration with the industry-supported H_2-ICE consortium, the completed demo vehicle toured the country, making a compelling case for this zero-greenhouse gas option for the difficult-to-decarbonize long-haul trucking market.

The energy opportunities that H_2-ICE and hydrogen can provide the commercial vehicle industry have led to questions about the infrastructure needed to support hydrogen-fueled commercial fleets in the long term. While hydrogen hubs along major traffic arteries would help ensure the viability of hydrogen-fueled fleets, many questions as to how to deploy this infrastructure remain. SwRI is launching the Refueling of Fleets consortium to help fleet owners, the federal government and original equipment manufacturers understand what this will entail.

Electrified powertrains are one approach to achieve net-zero emissions. In 2024, SwRI launched the newest phase of our

In conjunction with the Electrified Vehicle and Energy Storage Evaluation-II consortium, SwRI developed and evaluated a battery immersion cooling test rig that suppresses thermal runaway in EV batteries.

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SwRI's H_2-ICE demonstration vehicle is powered by a hydrogen-fueled internal combustion engine that produces ultra-low NOx and CO_2 emissions while providing torque and power for most heavy-duty applications.

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Advanced Fluids for Electrified Vehicles (AFEV) consortium, following a successful four-year consortium that included members of the automotive fuels and lubricants industries. Through AFEV 2, SwRI aims to advance the industry's understanding on the unique stresses placed on fluids for electric and hybrid vehicles, and to optimize these fluids for electric vehicles.

In 2024, SwRI launched the next phase of an electric vehicle (EV) battery consortium dedicated to understanding the performance of energy storage systems. The Electrified Vehicle and Energy Storage Evaluation-II consortium builds on more than a decade of SwRI-led, precompetitive research with companies across the mobility sector. While battery cell research focusing on test repeatability, aging and fast charging strategies will remain at the heart of the program, we are expanding module and pack research. We are also exploring emerging cell chemistries with increased energy capacities. Performance and abuse testing at various scales provides critical data and insights to improve thermal management and safety performance using new technologies. For instance, immersion cooling entails submerging battery cells or packs into a dielectric fluid to dissipate heat more effectively than air cooling.

In 2024, SwRI launched preparations for implementing new category specification changes for gas engine oils for passenger and commercial vehicles, requiring them to be more durable, economical, fuel efficient and environmentally friendly. This year, the American Petroleum Institute launched PC-12, a new heavy-duty engine oil category, and SwRI is leading the development of new tests to qualify these engine oils. Using internal funding, engineers developed tests to evaluate heavy-duty crankcase lubricants for their ability to reduce valvetrain wear under different conditions. The new MACK T-8 and MACK T-11 tests produced robust data while using a fuel-efficient engine and less expensive parts,

To test "vehicle-to-everything" connectivity technologies, SwRI built a new four-way traffic signal intersection on campus. The project allows SwRI to send digital messages between automated vehicles, traffic signals and roadway infrastructure, to improve mobility and safety.

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Working with the California Air Resources Board, SwRI designed an automated mobile hydraulic dynamometer (MoHyD) system to perform field-based emissions testing on a wide range of heavy-duty engines up to 400 horsepower.

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offering the industry potentially billions of dollars in savings. As the primary test development lab, SwRI is the expert in these new procedures, which have a projected lifespan of 20 years.

SwRI also developed a portable device to significantly reduce the time and costs associated with testing heavy equipment for emissions compliance in 2024. Working with the California Air Resources Board (CARB), SwRI designed and built an automated mobile hydraulic dynamometer (MoHyD) system compatible with a wide range of heavy-duty engines used in tractors and other off-road equipment up to 400 horsepower. Pronounced "mow-hide," the standalone instrument connects to the hydraulic systems of off-road equipment, allowing engine emissions testing in the field. MoHyD simulates engine operations over various cycles and conditions, replicating tests conducted in a lab.

Fuels and lubricants research is one of SwRI's original research and testing programs, so the Institute has continuously reinvested in its laboratories and facilities. In 2024, SwRI focused on upgrading, consolidating and maintaining a range of test facilities and laboratories to ensure that we remain our clients' first choice for standard fuel tests. Additionally, SwRI is streamlining and updating our client-facing portal, providing secure access to testing information, resources and data tailored to each client.

SwRI also upgraded several test cells in one of the most experienced emissions test laboratories in the country, which even predates the creation of the Environmental Protection Agency. The year-long effort to revamp the test cells will ensure quieter, cleaner, safer and more efficient operations for years to come. The upgrades include new AC dynamometers, emissions measurement technology and associated infrastructure to support longer, more efficient and robust testing. The AC dynamometers will also reduce the Institute's carbon footprint by generating power for the grid instead of sending waste heat to cooling towers that consume water.

Using internal funding, SwRI developed a new evaluation procedure for heavy-duty engine oils under PC-12. The test method is faster, cheaper and more environmentally friendly than previous procedures.

SwRI evaluated this novel electric vehicle fire-containment system designed to prevent fires from damaged electric vehicles spreading to nearby vehicles and structures at repair facilities.

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For over 10 years, SwRI has served as a Shell Eco-marathon sponsor, providing science, technology, engineering and math (STEM) outreach as well as evaluation of the latest efficient and automated driving technologies. These annual engineering competitions challenge student teams from around the globe to design, build, test and drive ultra-energy-efficient vehicles. SwRI staff provides technical and engineering support and presents one student team with an award recognizing innovation. In 2024, SwRI staff traveled to Indianapolis, Indiana; Nogaro, France; and Lombok, Indonesia, for regional Shell Eco-marathon events. The goal is to provide the next generation of engineers and scientists with the opportunity to collaborate as teams and explore current and future vehicles and energy that will shape a lower carbon future for all.

Fire technology specialists at the Institute routinely develop customized fire testing to evaluate new products and technologies not covered by existing standards. In 2024, SwRI designed and performed a custom fire test for an EV containment system designed to mitigate the risks associated with storing damaged EVs, which are at increased risk of spontaneously catching fire. Engineers exposed an EV inside the enclosure system to heat, monitoring temperature and air quality from a safe location. At its peak, interior temperatures reached nearly 2,000 degrees Fahrenheit, while the outside of the enclosure stayed below 350°F. Engineers also evaluated the system's watertight seal by flooding the enclosure with an extinguishing agent.

Through ARPA-E's NEXTCAR program, Institute engineers are reducing vehicular energy consumption using next-generation connected and automated vehicle (CAV) technology. Now in Phase II, SwRI's NEXTCAR project is using CAV technology and Level 4 automated driving systems to develop a specialized algorithm suite to provide 30% energy savings. Building on the success of its eco-routing, eco-driving and power-split optimization technologies, SwRI is exploring cooperative control, smart lane change/merge and dedicated CAV operations.

SwRI develops and manages software and hardware for digital signage used to provide travel time to motorists in San Antonio.

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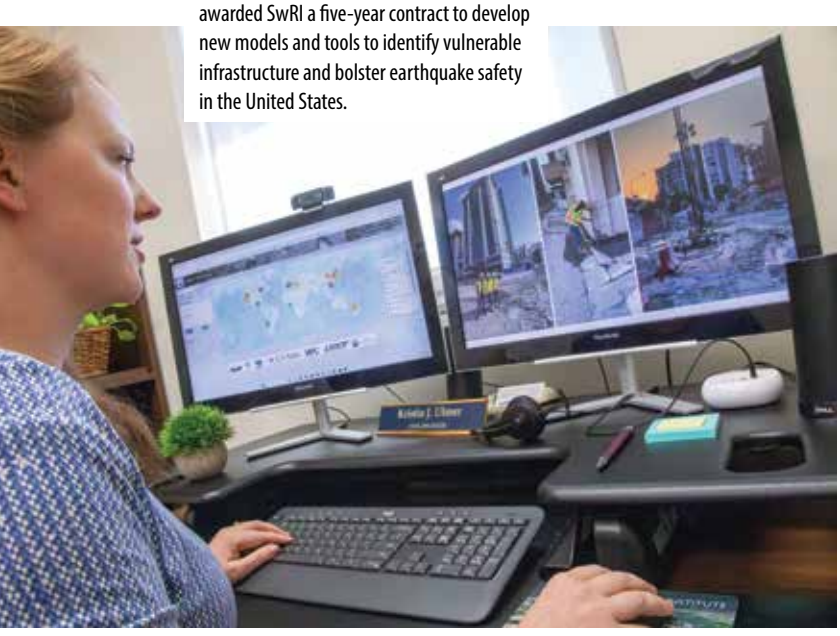

In 2024, the Federal Highway Administration awarded SwRI a five-year contract to develop new models and tools to identify vulnerable infrastructure and bolster earthquake safety in the United States.

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SwRI engineers demonstrated an adversary-in-the-middle device developed to evaluate the cyber resiliency of vehicle-to-grid charging systems. With the device, SwRI identified cybersecurity vulnerabilities with electric vehicles using direct current fast-charging systems.

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SwRI displayed its NEXTCAR vehicle outfitted with vehicle autonomy stack and eco-driving technology at the ARPA–E 2024 Innovation Summit. We demonstrated efficiency improvements offered by approaching a traffic signal without requiring a complete stop.

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SwRI developed and maintains San Antonio's TransGuide traffic management system, which allows operators to use ITS technology to improve mobility for the traveling public.

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TRANSPORTATION

SwRI has developed ATMS and ITS networks that integrate infrastructure, technology and software with vehicles to communicate with the traveling public. SwRI has generated more than 29 million lines of computer code to support the ITS technology we've deployed in more than 50 traffic management centers across 13 states and Puerto Rico.

SwRI's ActiveITS footprint continues to expand, managing traffic in three of the five most populous states in the U.S., with new deployments in Utah and New England. In 2024, SwRI deployed ActiveITS through the Utah Department of Transportation's cloud platform. Additionally, we integrated full-featured network-based capabilities into the New England Compass ATMS project that serves New Hampshire, Maine and Vermont.

SwRI won a subcontract to install our integrated corridor management technology for the Virginia Department of Transportation. This artificial-intelligence-based decision-support system aims to improve system reliability as well as safety and mobility for travelers in Northern Virginia.

In collaboration with Vanderbilt University, SwRI integrated a diversion route subsystem into the I-24 Smart Corridor project in Nashville for the Tennessee Department of Transportation. This software module helps ATMS operators coordinate diversion routes in response to major traffic incidents.

We are working on the largest vehicle-to-everything (V2X) deployment in the state of Texas — connectivity that enhances mobility, efficiency and safety while reducing environmental impacts. V2X technology enables vehicles to communicate with each other (V2V), pedestrians and cyclists (V2P) and roadside infrastructure (V2I) via communications devices that continuously exchange speed, position and other information. SwRI has installed roadside technology connected to the Texas Department of Transportation field network and to onboard units installed in a freight fleet.

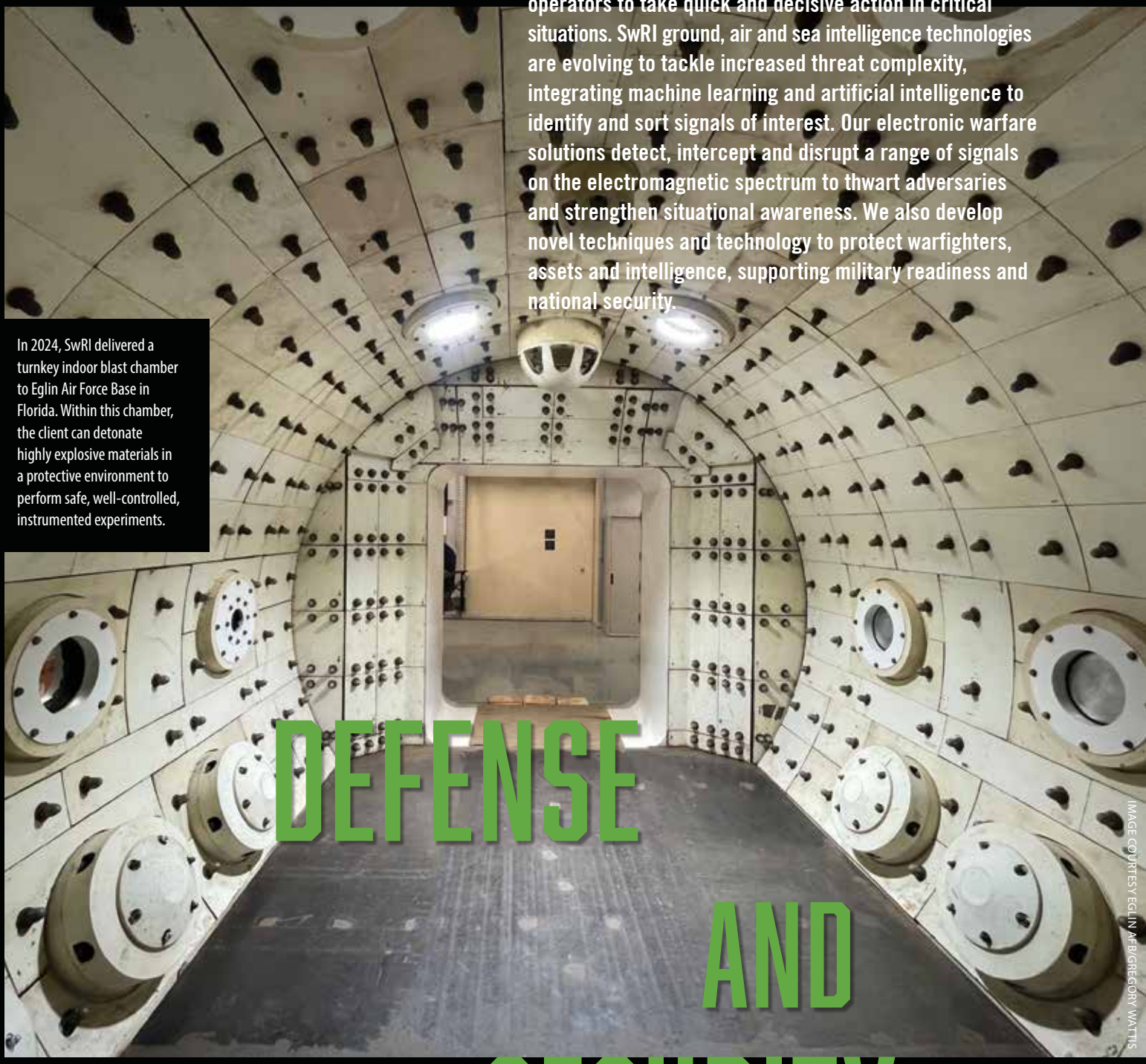
We developed off-road autonomous driving tools with a focus on stealth for military clients. Also relevant for agriculture and space operational agility applications, the Vision for Off-Road Autonomy (VORA) system passively perceives objects, models environments and simultaneously localizes and maps while navigating.

In 2024, SwRI began developing liquefaction models to evaluate America's roads, bridges and tunnels for vulnerability to earthquake damage under the Federal Highway Administration's Seismic and Multi-Hazard Resilience program. Expanding upon work performed for the Next Generation Liquefaction project, the Institute is collaborating with The University of California, Los Angeles, and Oregon State University to provide new modeling tools to help highway infrastructure owners identify assets that are vulnerable to earthquake-induced liquefaction. Liquefaction occurs when saturated soil behaves more like a fluid and becomes incapable of supporting a structure during an earthquake. The five-year project will increase public safety and improve the nation's earthquake readiness.

Using internal funding, we identified cybersecurity vulnerabilities in EVs, direct current fast-charging systems and other EV supply equipment. These findings laid the groundwork for identifying ways to bolster the security of the fast-charging infrastructure, leading to follow-up projects.

DEFENSE AND SECURITY

For more than 70 years, Southwest Research Institute has been on the forefront of capabilities to offer protection to military forces and assets. We develop secure and reliable communications intelligence (COMINT) technology, allowing operators to take quick and decisive action in critical situations. SwRI ground, air and sea intelligence technologies are evolving to tackle increased threat complexity, integrating machine learning and artificial intelligence to identify and sort signals of interest. Our electronic warfare solutions detect, intercept and disrupt a range of signals on the electromagnetic spectrum to thwart adversaries and strengthen situational awareness. We also develop novel techniques and technology to protect warfighters, assets and intelligence, supporting military readiness and national security.



In 2024, SwRI delivered a turnkey indoor blast chamber to Eglin Air Force Base in Florida. Within this chamber, the client can detonate highly explosive materials in a protective environment to perform safe, well-controlled, instrumented experiments.

IMAGE COURTESY EGLIN AFB/GREGORY WATTIS

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SwRI's new indoor Spherical Near-Field Antenna Range expands the Institute's antenna testing capabilities, characterizing larger antennas up to 10 feet in diameter and 1,000 pounds.

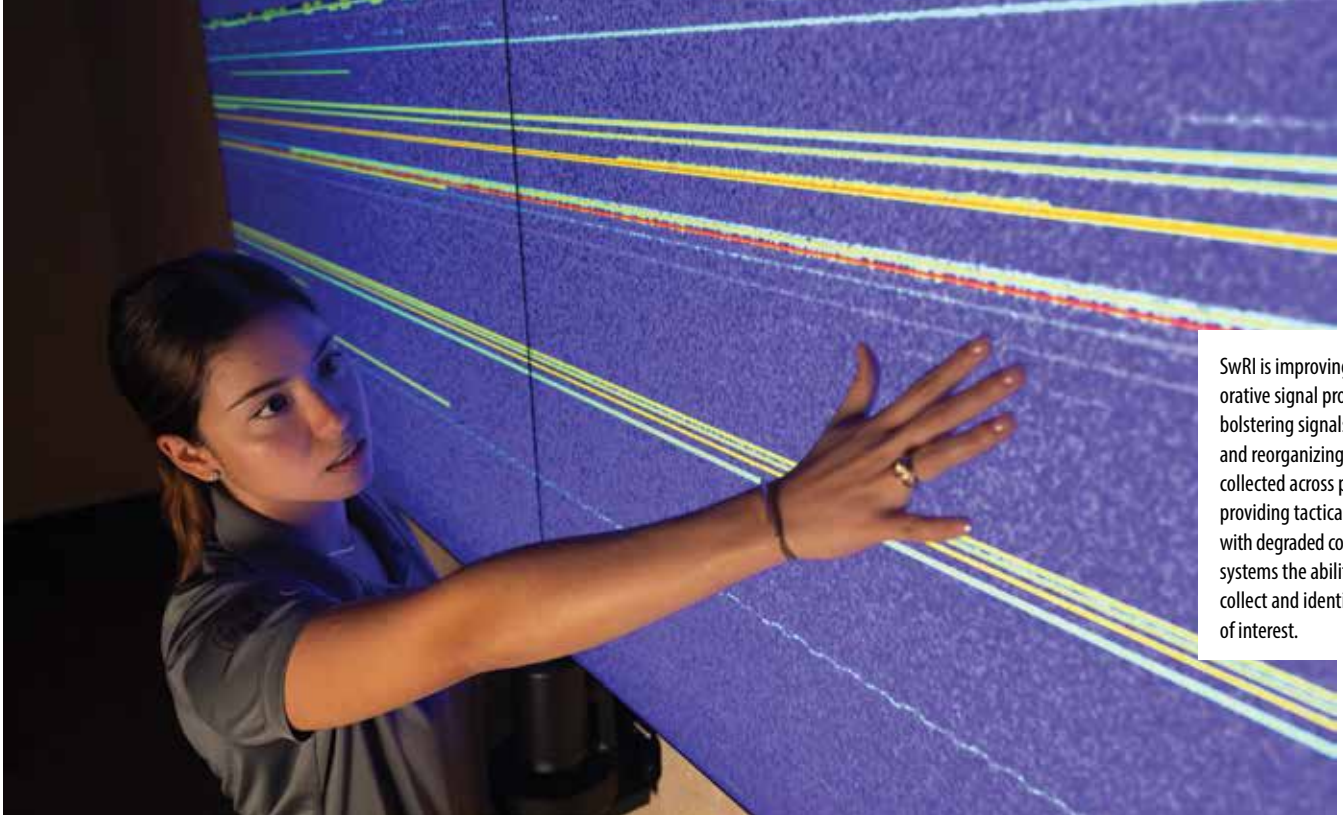
SwRI continues to develop powerful and precise antenna and signal technology tools for defense and intelligence applications. In 2024, software engineers improved collaborative signal prosecution, identifying signals by sorting and reorganizing data collected across platforms. The capability gives tactical users in the field, with limited communication systems, the ability to quickly collect and identify signals of interest. The system is operational and will soon be ready to support Department of Defense tactical operations.

SwRI's novel airborne ultra high frequency (UHF) direction finding (DF) antenna enables government and military users to detect and geolocate terrestrial and airborne radio frequency (RF) sources in flight. The antenna array offers wide frequency coverage, with an upper operational frequency 10 times higher than its lower operating frequency. Embedded electronics filter, amplify, mix and condition RF signals to optimize system performance, while maintaining low size, weight and power (SWaP) requirements. The novel antenna integrates onto legacy aircraft using existing radome and RF distribution infrastructure and can be deployed in ground-based mobile and fixed-site applications.

SwRI's JUPITER Advanced Electronic Warfare System bolsters U.S. Air Force dominance over the electromagnetic spectrum with a suite of hardware and software that rapidly detects and responds to enemy radar threats. JUPITER utilizes the Modular Open System Approach, which allows easy expansion, removal or replacement of components. Sensor Open System Architecture (SOSA™) and commercial off-the-shelf products facilitate the modular design and support interoperability, while minimizing costs.

SwRI is advancing wideband signal detection capabilities. In 2024, engineers developed automatic detection of next-generation wideband signals for COMINT operations, including 5G, spread spectrum and frequency-hopped protocols. The capability supports airborne, naval and ground missions for military and government applications. The SOSA-compliant design meets industry standards, using embedded processing on field programmable gate arrays and single board computers to minimize SWaP.

SwRI builds custom, comprehensive defense systems for the United States military and ally countries to safeguard the communications intelligence pipeline. We continue to expand our facilities and staff to support surveillance of the electromagnetic



SwRI is improving collaborative signal prosecution, bolstering signals by sorting and reorganizing data collected across platforms, providing tactical field users with degraded communication systems the ability to quickly collect and identify signals of interest.

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environment and arm our warfighters with advanced technology to outmaneuver adversaries and protect their battlespace.

New facilities are expanding our defense and intelligence capabilities. SwRI's indoor Spherical Near-Field Antenna Range, built in 2024, is enhancing the Institute's antenna measurement capabilities for government and industry clients. The 1,260-square-foot range, lined with RF and microwave foam absorbers, can finely sample the near field of an antenna, which engineers can mathematically transform into far-field measurement data.

The new range overcomes prior limitations, servicing antennas up to 10 feet in diameter and 1,000 pounds, characterizing full 3D radiation patterns. The range includes a built-in, overhead, half-ton hoist to position large, heavy antennas.

In addition to the antenna range, SwRI built a temperature- and access-controlled lab and warehouse for defense electronics assembly and government property storage. We broke ground on the first SwRI-owned building outside of San Antonio in Warner Robins, Georgia. The $18.5 million, 33,000- square-foot facility will

SwRI is developing wideband signal detection software, installed on this software-defined radio housed in a development chassis.

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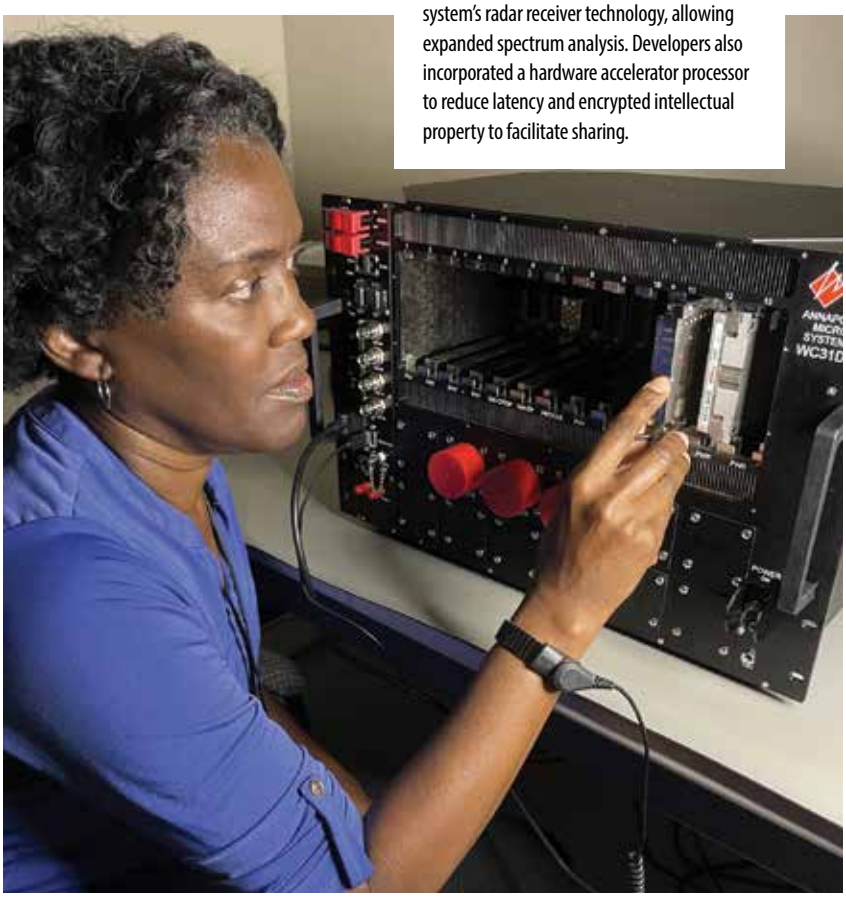

In 2024, SwRI engineers increased the instantaneous bandwidth of the JUPITER system's radar receiver technology, allowing expanded spectrum analysis. Developers also incorporated a hardware accelerator processor to reduce latency and encrypted intellectual property to facilitate sharing.

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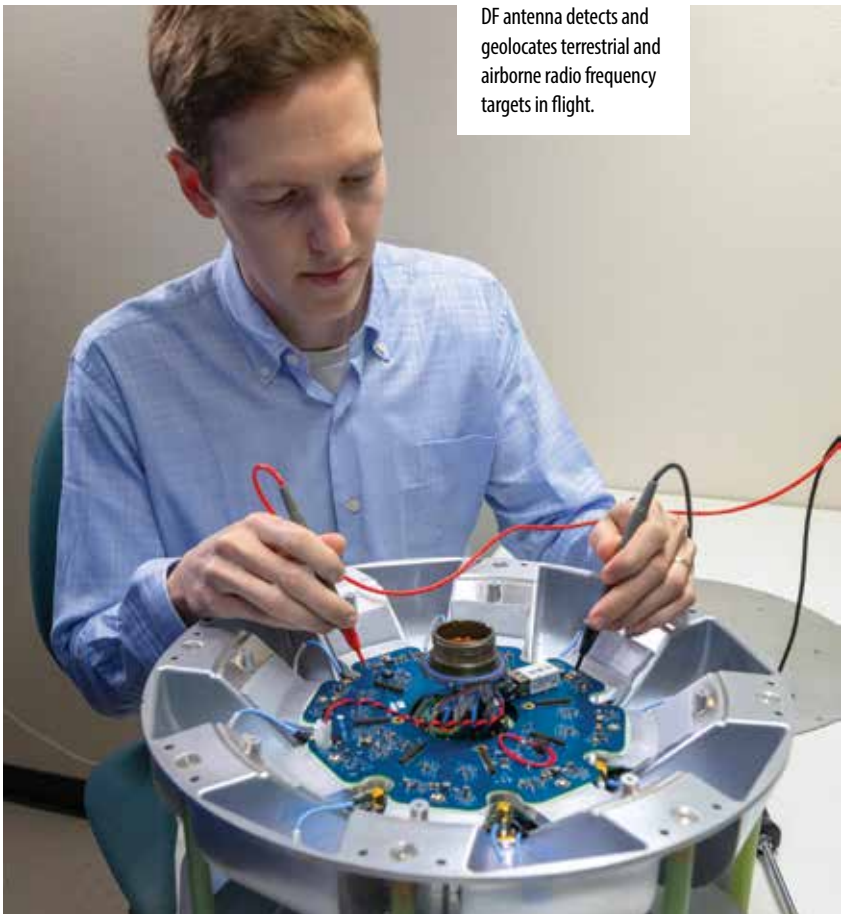
open in mid-2025 and support our advanced electronic warfare work for the U.S. Air Force.

To protect assets and information, SwRI is testing nonlethal ways to impair adversaries, particularly those who have infiltrated a secure facility. We studied how a combination of dense smoke and strobe lights affected test subjects, working with psychologists to conduct behavioral analyses of the results. Using a custom-developed test chamber, we study how these distractions affect the fine and gross motor skills as well as the memory, balance and visual acuity of subjects performing representative tasks.

Thousands of active-duty personnel suffer tibial stress fractures each year, resulting in lost duty days that impact military readiness. SwRI is applying its digital twin technology, a virtual model of the human body, to develop human-in-the-loop technology to optimize rehabilitation. By reducing the load on the affected bone during recovery, this technology can help injured service members return to duty faster, ultimately improving military readiness.



SwRI's novel airborne UHF DF antenna detects and geolocates terrestrial and airborne radio frequency targets in flight.

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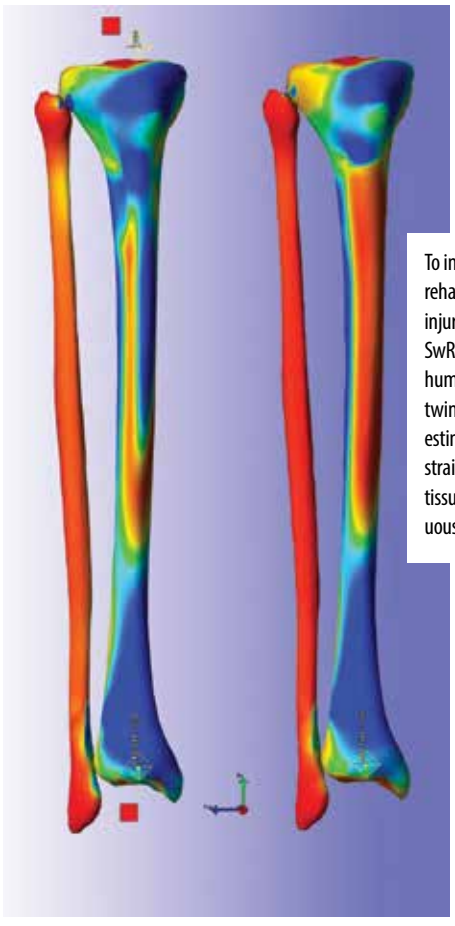

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To improve the rehabilitation of injured soldiers, SwRI is developing human digital twin technology to estimate internal strain on tibia bone tissue during strenuous activities.

EARTH AND SPACE

IMAGE COURTESY NASA/JOHNS HOPKINS UNIVERSITY APL/PRINCETON/ED WHITMAN

SwRI plays a key role in instrument design, fabrication, evaluation and integration for the Interstellar Mapping and Acceleration Probe spacecraft, shown at Johns Hopkins University Applied Physics Laboratory.

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Southwest Research Institute is home to one of the nation's leading space science and engineering programs, conducting fundamental and applied research and developing innovative technology for commercial companies and government agencies worldwide. The Institute's strong Earth science expertise complements our space research.

In addition to investigating space phenomena and developing payload instruments, electronics and spacecraft, SwRI continues its work in solar physics, conducting research to understand how the solar wind and solar events create space weather, which can impact space technology and astronaut safety. SwRI staff are leading two heliophysics missions, including the Magnetospheric Multiscale (MMS) mission, which continues studying magnetic reconnection in Earth's magnetosphere. We are also leading the Polarimeter to UNify the Corona and Heliosphere (PUNCH) mission, which will explore connections between the solar corona and solar wind. In 2024, SwRI built, integrated and tested the four suitcase-sized satellites scheduled to launch into a polar orbit in February 2025. PUNCH is designed to expand our knowledge on how the mass and energy of the Sun's corona becomes the solar wind that fills the the solar system.

SwRI manages the payload for NASA's Interstellar Mapping and Acceleration Probe (IMAP) mission, providing the Compact Dual Ion Composition Experiment instrument and participating on other instrument teams. Also scheduled to launch in 2025, IMAP will investigate fundamental physical processes that control our solar system's evolving space environment. SwRI is also managing spacecraft procurement and has developed two analyzer for cusp ions (ACI) instruments for NASA's Tandem Reconnection and Cusp Electrodynamics Reconnaissance Satellites (TRACERS) mission. The spacecraft is on track to launch in spring 2025 for a one-year mission to study magnetic reconnection and cusp dynamics in Earth's magnetopause. Both TRACERS spacecraft have undergone mechanical and electrical integration, with environmental testing underway.

TRACERS IMAGE COURTESY ANDY KALE

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All instruments for the TRACERS mission, including the SwRI-led ACI, have been built, tested and delivered. A successful system integration review confirmed readiness for the spacecraft and payload merger and a 2025 launch.

In 2024, SwRI delivered the Solar Wind Plasma Sensor (SWiPS), which will measure the properties of solar ions, for a National Oceanic and Atmospheric Administration satellite dedicated to tracking space weather.

106888

Teams led by SwRI also successfully executed two ground-breaking experiments — by land and air — collecting unique solar data from the total eclipse that cast a shadow from Texas to Maine on April 8, 2024. The Citizen Continental-America Telescopic Eclipse (CATE) 2024 experiment engaged more than 200 community participants in a broad, approachable and inclusive effort to make a continuous 60-minute, high-resolution movie of this exciting event. A nearly simultaneous investigation used unique equipment installed in NASA's WB-57F research aircraft to chase the eclipse shadow, making observations possible only when "chasing" the eclipse shadow by air.

SwRI also delivered the Solar Wind Plasma Sensor (SWiPS) and the magnetometer (MAG), which have been integrated into a National Oceanic and Atmospheric Administration (NOAA) satellite dedicated to tracking space weather. SWiPS will measure the properties of ions originating from the Sun, including the very fast ions associated with coronal mass ejections that interact with Earth's magnetic environment.

SwRI scientists are also leading three missions to explore the full range of objects in our solar system, from planets to dwarf planets, asteroids and comets. The Juno mission continues its extended mission to understand Jupiter and its moons, while New Horizons proceeds through the Kuiper Belt, exploring the outer reaches of our solar system. The Lucy mission to Jupiter's Trojan asteroids is preparing for its next main belt asteroid encounter in 2025, following the successful flyby of Dinkinesh and its satellite Selam. Lucy plans to explore nine additional asteroids over its 12-year journey.

In October, two SwRI instruments, MASPEX and Europa-UVS, launched aboard NASA's Europa Clipper spacecraft from the agency's Kennedy Space Center (see p. 4). The spacecraft is designed to conduct a detailed reconnaissance of Jupiter's moon Europa, investigating whether its subsurface ocean has conditions suitable for life.

In 2024, NASA selected SwRI to lead the development of a lunar lander/rover instrument suite — Dating an Irregular Mare Patch with a Lunar Explorer, or DIMPLE — designed to understand if the Moon has been volcanically active in the geologically recent past. DIMPLE will use radioisotope-based dating, a rover and cameras to determine the age and composition of an anomalously young-looking patch of basalt named Ina. The payload includes the first-ever purpose-built rock dating instrument for use in space, developed by SwRI.

Two additional SwRI instruments are preparing for lunar launch in 2025. The Lunar Magnetotelluric Sounder (LMS) has been integrated into a lander to measure the electrical conductivity of the lunar subsurface. The Institute's Magnetic Anomaly Plasma Spectrometer for NASA's Lunar Vertex mission will study how the solar wind interacts with the Moon's surface materials in anomalous regions of magnetic rocks.

In 2024, several scientists were awarded observation time on NASA's premier James Webb Space Telescope. One team discovered hydrothermal activity on the icy dwarf planets Eris and Makemake, located in the Kuiper Belt. Another found evidence of hydration on the metallic asteroid Psyche in the main belt. A third detected carbon dioxide and hydrogen peroxide for the first time on the frozen

Since launching in 2016, the CYGNSS satellite constellation has made history, penetrating thick clouds and heavy rains to better understand hurricane intensification. A model of a CYGNSS smallsat will be displayed in the Smithsonian's National Air and Space Museum.

106878

SwRI's new electromagnetic compatibility and interference (EMC/EMI) test chamber is evaluating this PUNCH spacecraft in advance of its 2025 launch.

106907

IMAGE COURTESY CATE 2024 R PATEL DAN SEATON

106910

SwRI led two projects during the April 8 eclipse, including Citizen CATE 2024, which engaged 35 teams and more than 200 citizen scientists across the U.S. collecting 47,000 images of totality from the Mexican to the Canadian borders.

surface of Pluto's largest moon, Charon. Experiments conducted in SwRI laboratories demonstrated that these compounds could form under conditions analogous to those at Charon.

SwRI is studying samples returned from the asteroid Bennu by NASA's OSIRIS-REx mission, using laboratory infrared measurements of Bennu materials to confirm measurements made by the spacecraft's thermal emission spectrometer on orbit. While the samples have confirmed many predictions about their composition, unexpected minerals, such as hydrated phosphates, have also been identified. Teams have also found abundant organic compounds present, providing an opportunity to study the building blocks essential for life, uncontaminated by Earth's environment.

SwRI is developing QuickSounder, the first in a new generation of NOAA low-Earth-orbit environmental satellites. In early 2024, NASA and NOAA selected SwRI to design and build QuickSounder and operate it for three years to study physical properties of the Earth that affect weather patterns.

For the U.S. Space Force, SwRI is building a small demonstration spacecraft designed to refuel compatible vehicles in geostationary

BENNU IMAGE COURTESY J. DWORKIN/GSFC AND LUCY IMAGE COURTESY NASA/SwRI/JHUAPL/NOIRLAB

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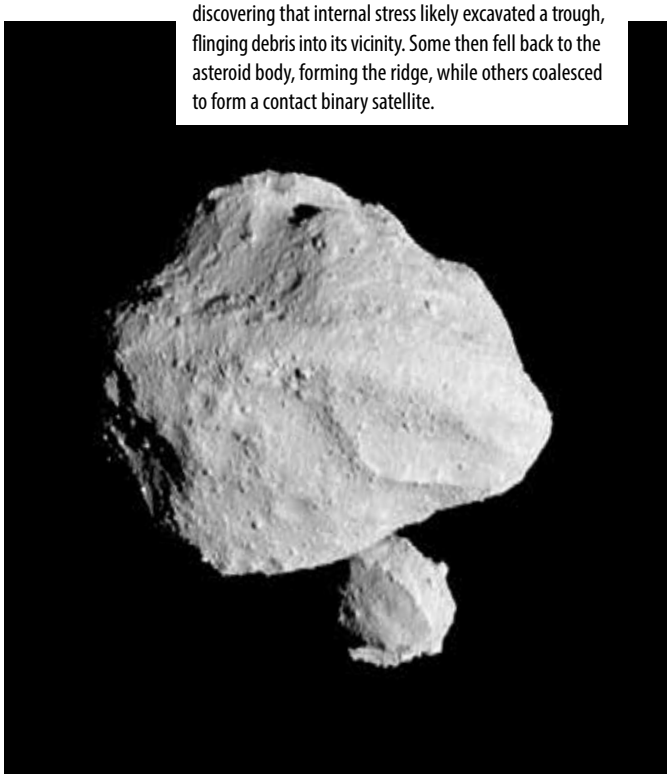
An SwRI scientist (left) serves on the OSIRIS-REx sample analysis team, which categorized specimens from asteroid Bennu in a clean room at the NASA Johnson Space Center.



NASA's Lucy spacecraft flew past the asteroid Dinkinesh, discovering that internal stress likely excavated a trough, flinging debris into its vicinity. Some then fell back to the asteroid body, forming the ridge, while others coalesced to form a contact binary satellite.

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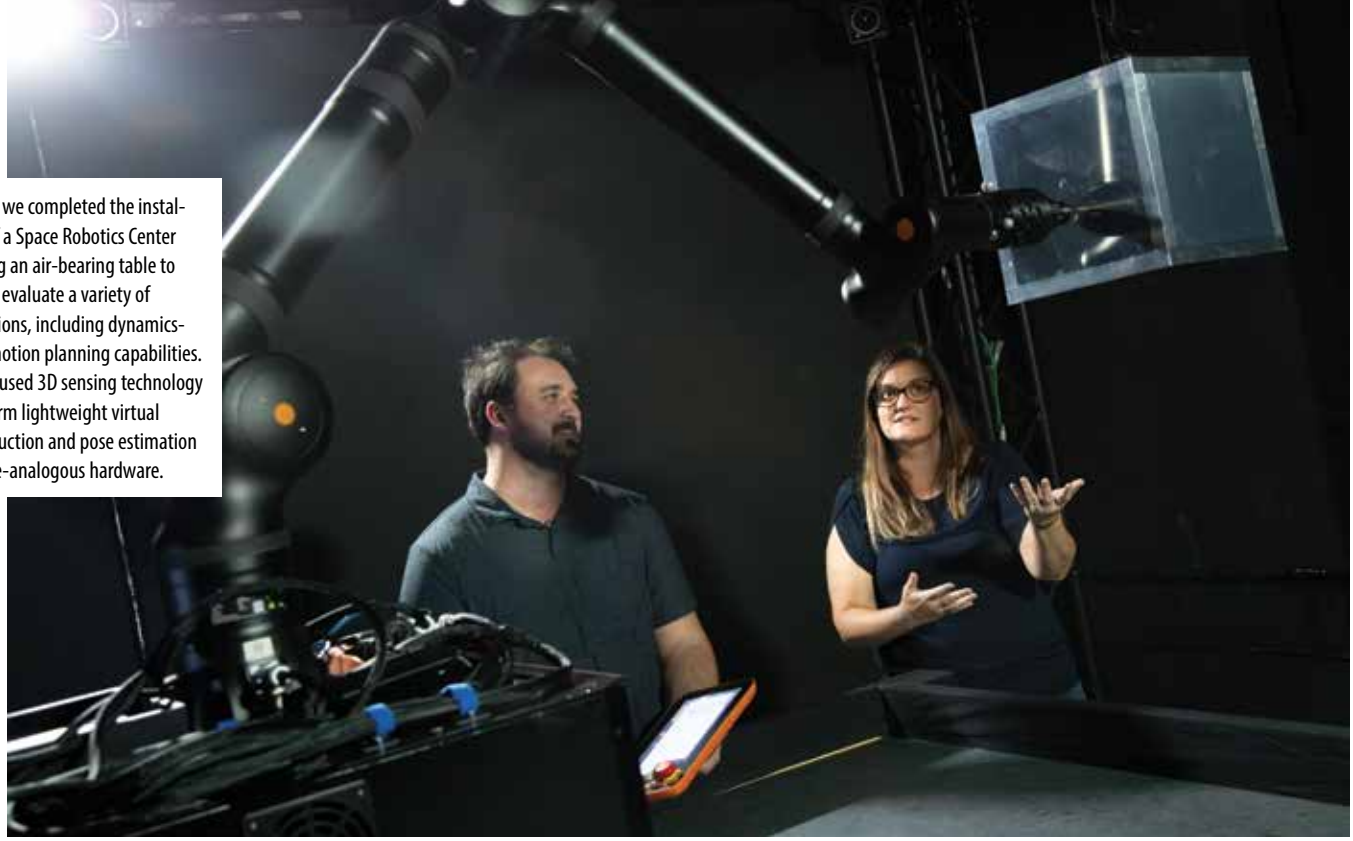

In 2024, we completed the installation of a Space Robotics Center featuring an air-bearing table to test and evaluate a variety of applications, including dynamics-aware motion planning capabilities. We also used 3D sensing technology to perform lightweight virtual reconstruction and pose estimation on space-analogous hardware.

106878

orbit. When the host spacecraft is ready, SwRI will integrate the payload and perform system-level environmental testing to prepare the vehicle for launch. The planned launch date for the integrated spacecraft is June 2026.

Using internal funding, SwRI is developing the Parallelogram Synchronized Truss Assembly (PaSTA), a mechanism designed for on-orbit service and refueling spacecraft. Tight pointing and positioning control require these spacecraft to be rigid during maneuvers. PaSTA will serve as a structural backbone to the deployed solar panels, stiffening the structure for better spacecraft control.

This year, SwRI produced a design concept for NASA's Jet Propulsion Laboratory to develop technology to detect wildfires from space before they spread. The resulting concept is based on our Pleaides instrument, developed using SwRI internal funding, hosted on eight small satellites to continuously search for signs of wildfires in the U.S.

To evaluate how to improve processing capabilities for space technology, we evaluated an advanced RISC machine (ARM) processor configuration to assess its suitability for current and future spaceflight missions. The ARM processor demonstrated significant advantages in performance and power consumption, making it a strong candidate for spaceflight applications requiring enhanced or flexible computing capabilities.

SwRI prioritizes advancing spaceflight safety as commercial space travel increases and the industry prepares for longer journeys. In 2024, Institute scientists performed structural vibration testing of propellant-filled cryogenic tanks in preparation for the delivery of NASA

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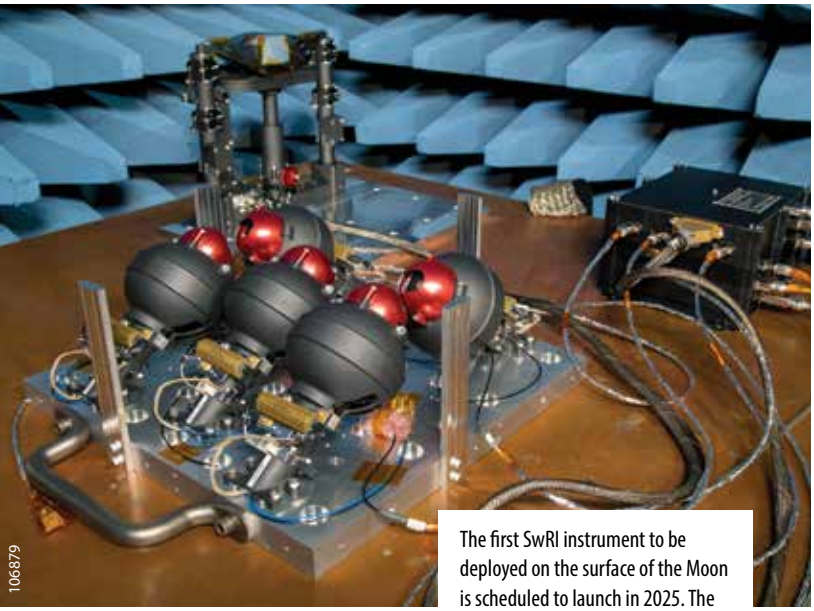
The PaSTA mechanism is designed to act as a structural backbone for refueling and life-extension spacecraft.



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The first SwRI instrument to be deployed on the surface of the Moon is scheduled to launch in 2025. The Lunar Magnetotelluric Sounder will characterize the lunar interior.

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SwRI evaluates the durability of composite tanks filled with cryogenic propellant to ensure that the tanks can store and transport fuel safely under conditions associated with lunar missions.

payloads to the Moon's south pole. These tests confirmed tank durability during and after vibration tests simulating rocket launch.

Additionally, Institute researchers are performing full-scale static and fatigue laboratory testing to validate the analytical and computational design of the next generation of commercial launch vehicles. This structural testing is essential to protect passengers' lives and increase consumer accessibility to suborbital flights.

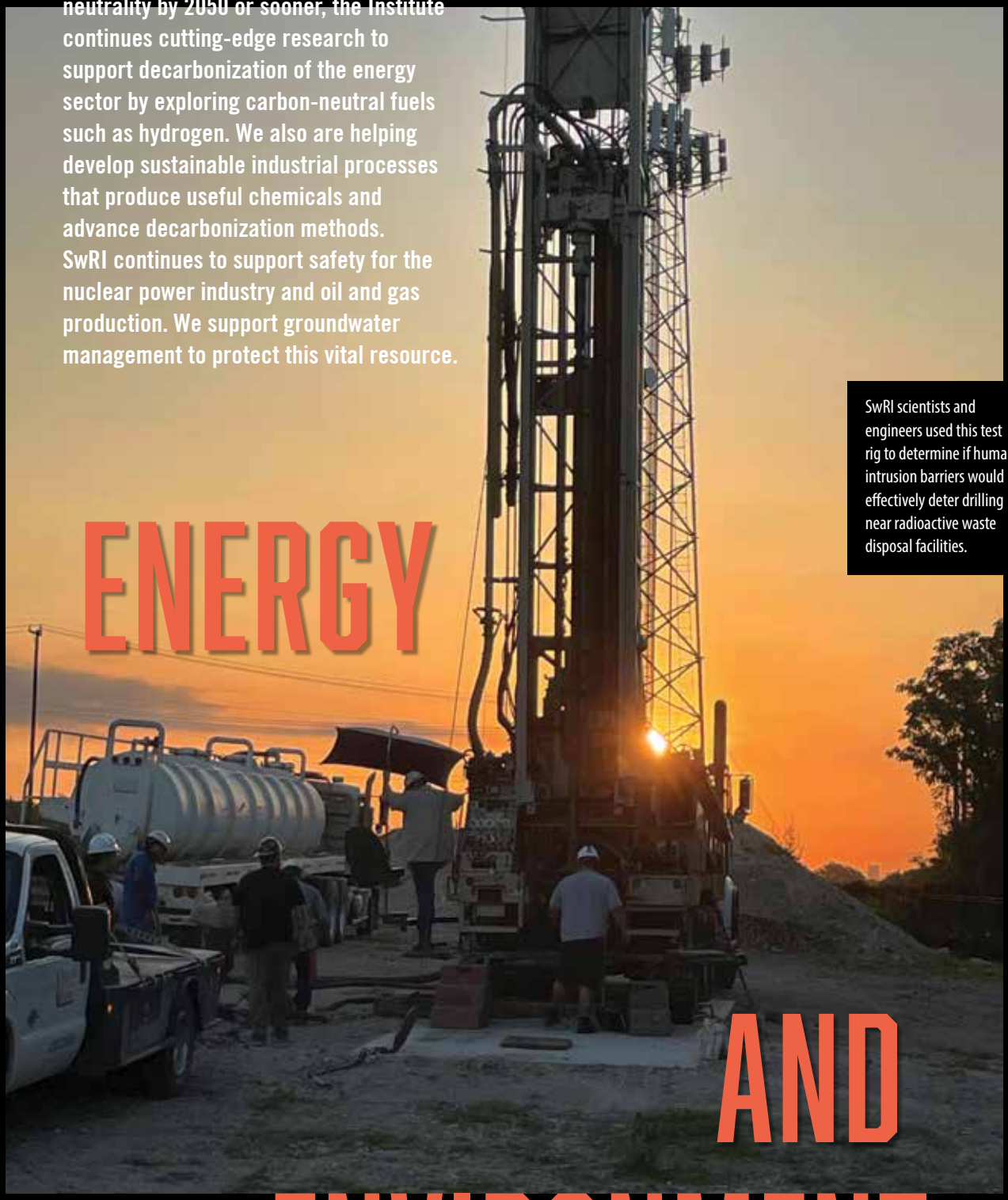
SwRI successfully flew three reduced-gravity payloads in 2024, advancing our understanding of bubble dynamics and heat transfer in fluids, essential for life support and propellant management in space and on the Moon. Additional experiments evaluated a lunar surface sensor and how impact cratering affected the evolution of asteroid Bennu's cobble-strewn surface.

And in collaboration with NASA's Marshall Space Center, SwRI is developing a series of inspection protocols designed to ensure the safety and structural integrity of future space and lunar habitats. These nondestructive inspection techniques are critical to constructing space habitats.

106855

SwRI's CLASSE (Center for Laboratory Astrophysics and Space Science Experiments) equipment simulates extra-terrestrial conditions. In 2024, experiments demonstrated that hydrogen peroxide can form under conditions analogous to those at Pluto's moon Charon.

As the United States and many other countries have set goals to reach carbon neutrality by 2050 or sooner, the Institute continues cutting-edge research to support decarbonization of the energy sector by exploring carbon-neutral fuels such as hydrogen. We also are helping develop sustainable industrial processes that produce useful chemicals and advance decarbonization methods. SwRI continues to support safety for the nuclear power industry and oil and gas production. We support groundwater management to protect this vital resource.



SwRI scientists and engineers used this test rig to determine if human intrusion barriers would effectively deter drilling near radioactive waste disposal facilities.

ENERGY AND ENVIRONMENT

106894

The Supercritical Transformational Electric Power (STEP) Demo pilot plant at SwRI's headquarters in San Antonio achieved many important milestones in 2024. In January, the $169 million supercritical carbon dioxide (sCO_2) test facility made a new breakthrough for sCO_2 power generation — it achieved an industry first during commissioning, firing its natural gas heater and operating its turbine at an intermediate speed of 18,000 rpm. In May, the pilot plant generated electricity for the first time. Just a few months later it reached its full operational speed of 27,000 rpm, generating four megawatts of net power. In 2025, the facility will be reconfigured to undergo a new phase of testing to achieve its full capacity of 10 megawatts, enough to power 10,000 homes.

SwRI is also pursuing decarbonization of land-based electric power generation via gas turbines utilizing low- and zero-carbon fuels. This includes the expansion of its facilities to investigate the performance of a gas turbine combustion system using a variety of alternative fuels including hydrogen, propane, fuel oil and renewable diesel. To support this work, SwRI has installed a new air compressor triple the size of the previous equipment in its High Energy Annex Test (HEAT) combustion facility.

SwRI is creating a fuel reformer for large natural gas engines to cut emissions. If widely adopted, this technology could reduce carbon dioxide equivalent greenhouse gas emissions by 5 million tons a year. Additionally, Institute researchers are conducting validation testing of a full-scale turbomachine for hydrocarbon steam pyrolysis. This technology aims to decarbonize the production of high-value industrial chemicals — ethylene, propylene and hydrogen — currently produced using large fossil-fuel-fired furnaces.

SwRI is also developing a high-temperature tubular membrane that creates a chemical reaction to remove carbon dioxide gas during industrial processes. The CO_2 separator offers a "plug-and-play" carbon capture and sequestration tool that could offer businesses an opportunity to earn carbon credits. Developed over the last 10 years using internal funding, the current separator features a ceramic tube within a metal tube, operating at 650°C. In addition to researching carbon capture, SwRI's

The STEP Demo's sCO_2-powered turbine is a tenth the size of standard turbomachinery. STEP power cycles use sCO_2 instead of water as a thermal medium due to its favorable thermodynamic properties.

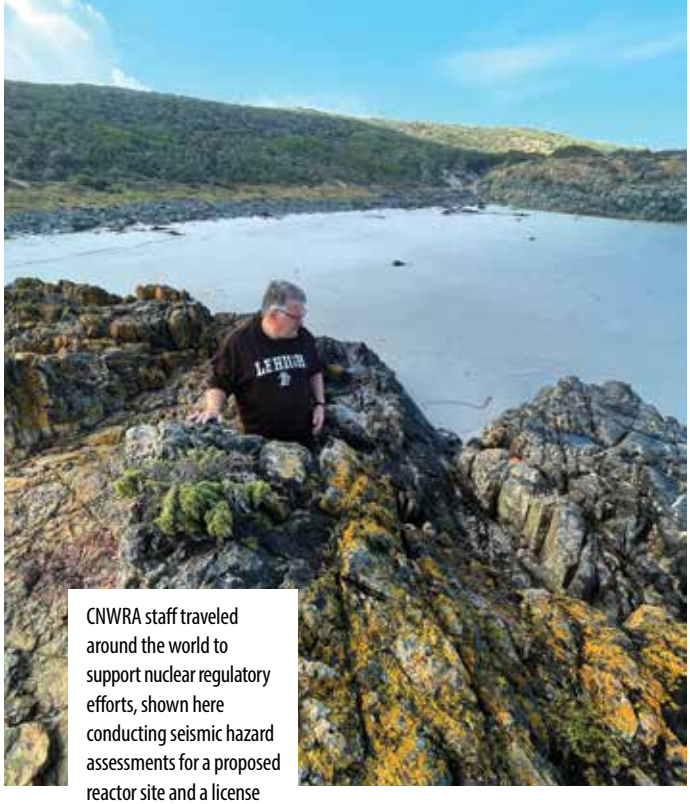
106854

multidisciplinary team is exploring ways to use carbon waste once it's sequestered.

In 2024, SwRI developed a fluidized bed pilot plant that can produce 2.3 tons of clean hydrogen a year. The facility demonstrated circulating and bubbling bed capabilities that ran continuously for thousands of hours. Operating at precommercial temperatures and scales, SwRI is identifying solutions for solids transport and tackling challenges related to equipment lifetime prior to scale-up. These advancements will help support sustainable practices in the chemical industry and address feasibility issues surrounding clean hydrogen and carbon capture.

SwRI tests advanced chemical recycling processes for post-consumer recyclable (PCR) plastics in a newly designed facility. Exploring a variety of feedstocks from multiple industries, engineers are focusing on new solutions for clients interested in turning waste and difficult-to-recycle PCRs into something useful. Through pyrolysis, which heats organic materials without oxygen, and catalysis, which uses a catalyst to spark a chemical reaction, engineers are exploring how PCRs respond to various temperatures and recycling methods. The new facility is booked through the end of 2025.

The SwRI Center for Nuclear Waste Regulatory Analyses (CNWRA®) continues to support the U.S. Nuclear Regulatory Commission (NRC). In 2024, the CNWRA provided expertise and guidance on seismic hazards and structural engineering for the NRC as the regulatory body reviewed license applications for advanced nuclear power reactors proposed for the United States. The CNWRA offers evaluation and regulatory guidance for storing, transporting, processing and recycling fuels for tomorrow's advanced nuclear reactors. The CNWRA also field-tested designs of intrusion barriers, including rolls of chain-link fence, granite boulders, tires embedded in grout, and five feet of reinforced concrete. The barriers are designed to deter near-surface drilling at



CNWRA staff traveled around the world to support nuclear regulatory efforts, shown here conducting seismic hazard assessments for a proposed reactor site and a license extension in South Africa.

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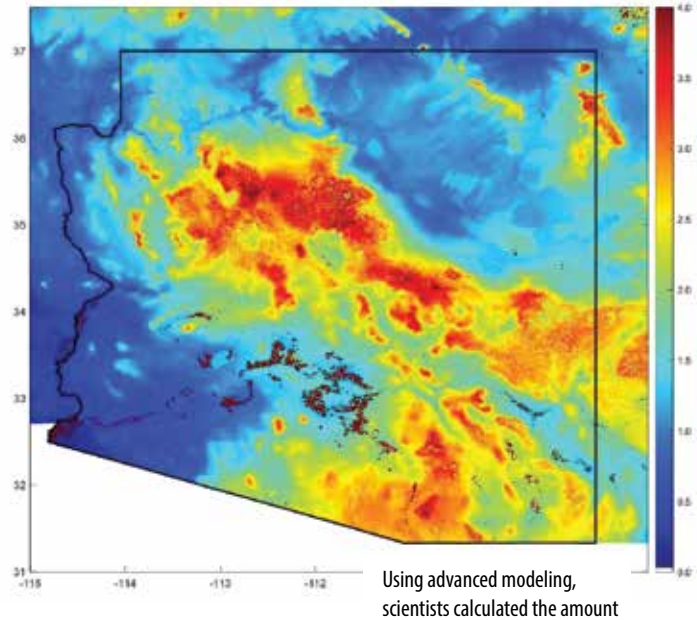
IMAGE COURTESY DR. HAYLEY CAWTHRA/COUNCIL FOR GEOSCIENCES OF SOUTH AFRICA



Using advanced modeling, scientists calculated the amount of water that new desalination techniques could produce from an artificial saltwater lake to develop drinking water for arid regions of the country.

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SwRI is developing novel technology to capture and sequester CO_2 during industrial processes. The membrane technology builds upon several iterations developed by SwRI staff over 10 years.

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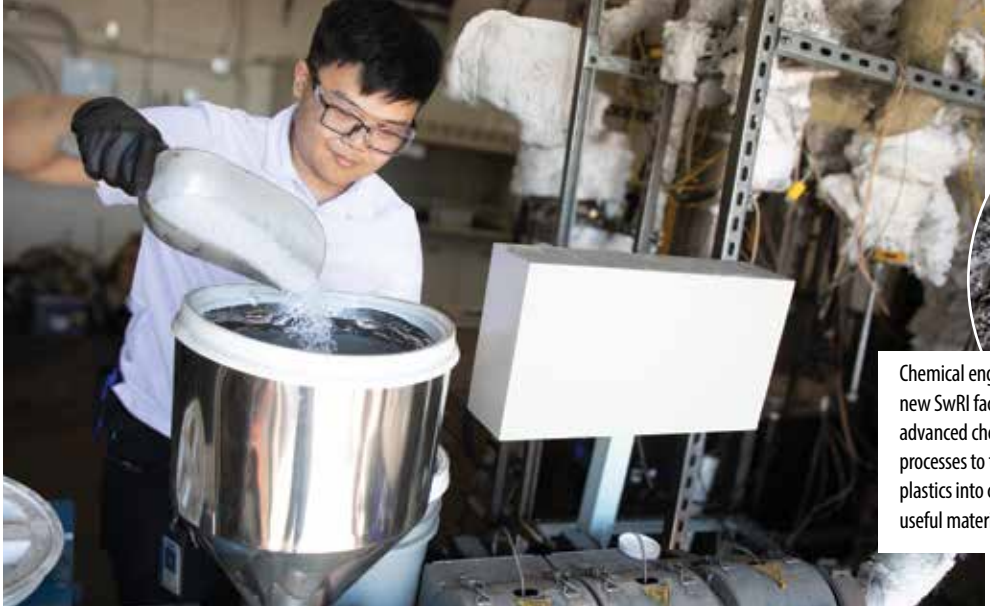

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Chemical engineers use a new SwRI facility to develop advanced chemical recycling processes to turn waste plastics into commercially useful materials.

low-level radioactive waste disposal facilities licensed to store waste with higher concentrations of radionuclides.

In international activities, SwRI-led seismic hazard assessments played a key role in the license extension process for the Koeberg Nuclear Power Station and a second proposed site in South Africa. SwRI staff served on safety review panels for the first-ever deep geologic repository of spent nuclear fuel, under construction in Finland. SwRI explored the chemical stability and effectiveness of barriers designed to isolate and contain nuclear waste over extended time frames for the Finnish Radiation and Nuclear Safety Authority.

SwRI is developing manufacturing processes for tri-structural isotropic (TRISO) nuclear fuel, small robust particles that are intrinsically safer because they resist melting at high temperatures. TRISO is the fuel of choice for tomorrow's advanced gas reactors. SwRI is conducting a comprehensive materials and process engineering study, considering state-of-the-art plant design and a production-ready rollout plan to provide a reliable TRISO supply chain to meet national and international demands.

We developed capabilities to install the Electric Power Research Institute's (EPRI's) radio frequency conductor monitors on power lines with a drone, which are presently installed by line crews, making the process more efficient and safer.

SwRI is collaborating with the University of Texas at Dallas (UTD) to search for new domestic lithium supplies, a critical resource for battery systems used in electric vehicles. The project is studying lithium deposit formation through fieldwork, geological mapping and subsurface interpretation in support of conceptual model development to help meet pressing needs.

To bolster drinking water reserves in the American Southwest, SwRI developed a proof-of-concept process to produce clean drinking water using solar condensers and the "lake effect." Researchers modeled the potential potable water that an artificial saltwater lake could yield, demonstrating the process at laboratory scales. Desert communities could one day utilize existing condenser technology and the evaporative effects of the Sun to desalinate brackish lake water as a potential source of drinking water.

106898

To search for new domestic lithium resources, SwRI collaborated with UTD, conducting reconnaissance field work in North America's only commercial production region for the raw material.

106889

SwRI's High Energy Annex Test (HEAT) combustion facility includes a new, powerful air compressor to explore how alternative fuels affect the performance of gas turbine combustion systems.

HEALTH AND BIOMEDICAL

SwRI chemists developed a screening method to test how drug compounds interact with the blood-brain barrier. The technique helps identify effective compounds and delivery methods to bypass this protective barrier and treat neurological diseases and conditions.

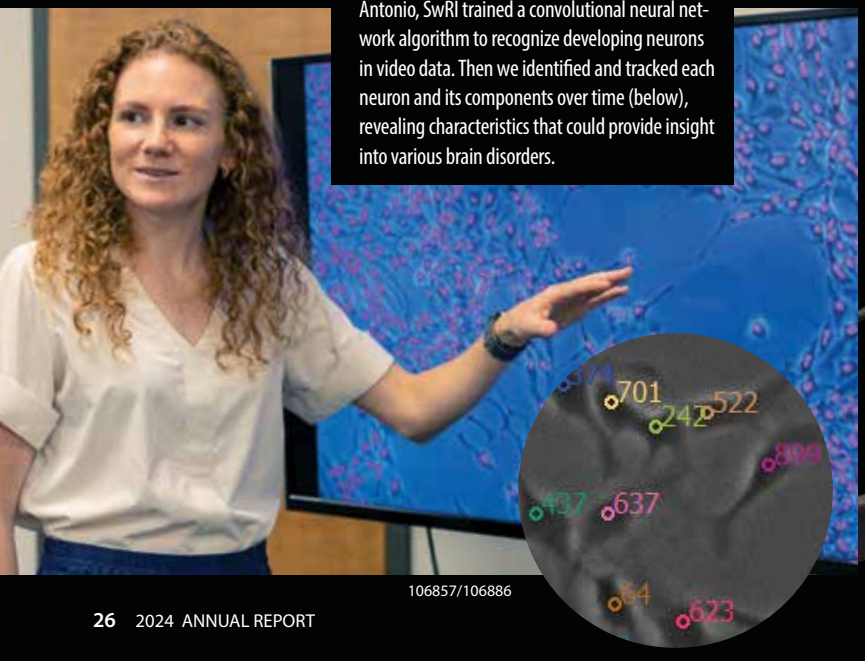
106848

Southwest Research Institute bolsters the biomedical and health care industry, developing biomaterials and pharmaceuticals while supporting human performance, community health and food safety initiatives.

The blood-brain barrier (BBB), which prevents potentially harmful substances in the bloodstream from reaching the brain and central nervous system, poses a challenge when trying to treat neurological diseases. A new in-vitro screening method developed at SwRI mimics the interaction of drug compounds with the cells that make up the BBB. The technique measures the permeation rates of molecules passing into the brain to identify effective pharmaceuticals along with the best delivery mechanisms to penetrate the BBB.

SwRI developed a set of algorithms to detect and track novel objects from multiple views. These algorithms estimate the full six-degrees-of-freedom pose of an object and how it moves through space. We are applying this research to improve our ENABLE™ markerless motion capture technology, which uses video to quantify and analyze biomechanical movement with practical applications for healthcare, the military and athletics.

SwRI collaborated with the city of San Antonio to create a data fusion tool designed to help understand and mitigate the effects of urban heat islands (UHIs). The tool integrates over 230 datasets collected from several city departments and public databases with the goal of helping the city protect populations particularly vulnerable to UHIs. The project demonstrated how the tool can help create targeted mitigation techniques to reduce the impacts of UHIs.



In collaboration with the University of Texas at San Antonio, SwRI trained a convolutional neural network algorithm to recognize developing neurons in video data. Then we identified and tracked each neuron and its components over time (below), revealing characteristics that could provide insight into various brain disorders.

106857/106886

SwRI has developed techniques to evaluate cognitive load, the amount of information that working memory can hold at one time. The psychophysiological measurement tools feature a camera and diode that record and track eye movement.

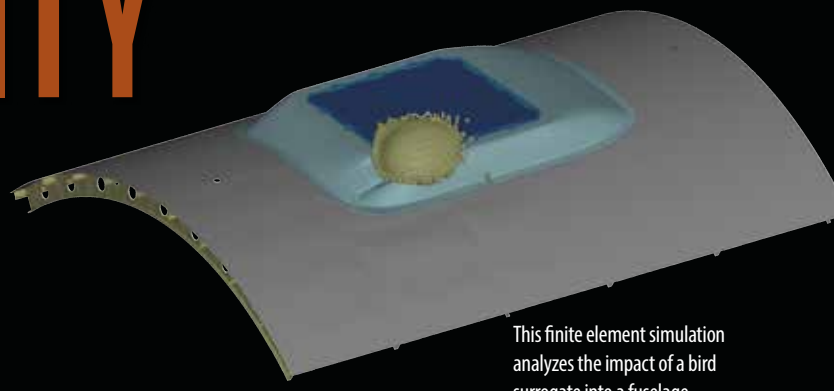
106874

Southwest Research Institute supports the manufacturing industry with advanced automation technology, creating adaptable tools and robot systems while providing workforce training. We also help ensure that aging infrastructure and new products meet or exceed standards for safety, durability and performance.

Sweeping flames reach heights of 30 feet during a standard jet fire resistance test that evaluates passive fire protection systems. Spraying the floor prevents moisture in the concrete from boiling and causing ruptures.

106850

MANUFACTURING AND RELIABILITY



This finite element simulation analyzes the impact of a bird surrogate into a fuselage-mounted antenna system.

107059

For air travel, conducting bird strike analysis and testing is crucial for aviation safety to identify and mitigate risks associated with inflight collisions with birds. By analyzing structural responses to bird impact, aircraft manufacturers can develop designs to withstand these events in compliance with Federal Aviation Administration regulations. Using detailed dynamic finite element analysis, SwRI helps manufacturers develop impact-resistant components, an approach designed to protect human lives and enhance the overall efficiency and reliability of air travel.

SwRI used Deep Neural Networks (DNNs) to predict the remaining useful lifetime of aircraft engines, significantly advancing predictive maintenance for the aviation industry. The system processes engine performance data, current operating conditions and maintenance records, allowing the system to learn and recognize subtle indicators of engine wear and other issues over time. Major airlines and aircraft manufacturers are adopting this technology to optimize maintenance schedules, reduce downtime and enhance safety. In 2024, improvements in DNN architectures and training algorithms increased prediction accuracy, making the technology more accessible and cost-effective for smaller operators.

To support industrial automation, SwRI used human-machine interactions to allow robots to blend and finish components in a metal foundry.

For 29 years, SwRI has operated the Texas Manufacturing Assistance Center, supporting small and medium manufacturers in South Central Texas with automation and process improvement solutions. Regional demand for manufacturing assistance continues to expand, to help defense contractors navigate cybersecurity compliance standards and growth in the automotive and semiconductor industries.

COMMUNITY CONTRIBUTIONS

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In 2024, Southwest Research Institute continued its long-standing support of the San Antonio community. SwRI's business activities injected more than $1.6 billion into the local economy last year.

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SwRI employees and their families, the Board of Directors, advisory trustees, retirees, contractors, Signature Science staff members and SwRI's corporate contributions raised a record-breaking $1.39 million for the United Way, exceeding the million-dollar mark for the fifth year in a row.

Many of SwRI's community outreach efforts emphasize supporting science, technology, engineering and math (STEM) education, particularly for underrepresented populations. In 2024, staff members volunteered for over 25 great American Eclipse outreach events, supplying 13,000 eclipse glasses and 100,000 mission-themed pinhole projectors. SwRI also led the 2024 Citizen CATE eclipse project, which involved more than 200 citizen scientists of all ages to continuously image the April 8 eclipse from Texas to Maine. SwRI also hired 181 undergrad and graduate students to get hands-on technical experience. Other STEM support included participating in career days, science fairs, STEM curriculum and student mentoring.

In addition, staff members volunteered with local agencies, logging more than 600 hours at the San Antonio Food Bank and delivering over 7,300 meals to homebound seniors through Meals on Wheels. The Research Recreation Association hosts monthly blood drives, which allowed employees to donate nearly 900 pints of blood in 2024. Other initiatives included volunteering for MathCounts, Special Olympics, MS Bike Ride and the Walk for Autism. SwRI staff collected large boxes of school supplies for San Antonio students and donated a room full of toys and bikes for the U.S. Marine Corps Reserve's Toys for Tots Program.

FINANCIAL HIGHLIGHTS 2024

STATEMENTS OF FINANCIAL POSITION | in millions of dollars

	For the year ended September 27, 2024	For the year ended September 29, 2023
Current Assets	$504	$474
Property & Equipment, Net	484	436
Other Assets	137	110
Total Assets	**$1,125**	**$1,020**
Current Liabilities	$206	$164
Noncurrent Liabilities	96	91
Net Assets	823	765
Total Liabilities and Net Assets	**$1,125**	**$1,020**

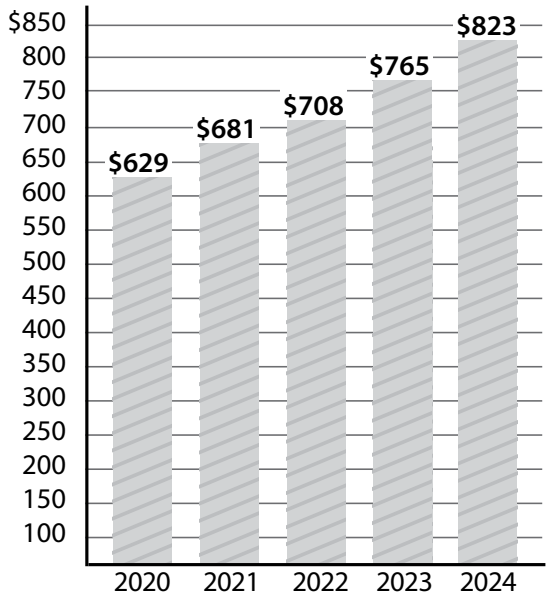
Consolidated revenues hit a record high of **$915** million

Consolidated net income from operations was **$22** million

Capital expenditures exceeded **$89** million

Internal research spending exceeded **$11** million

NET ASSETS | in millions of dollars



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Southwest Research Institute
6220 Culebra Road
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or solutions@swri.org

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