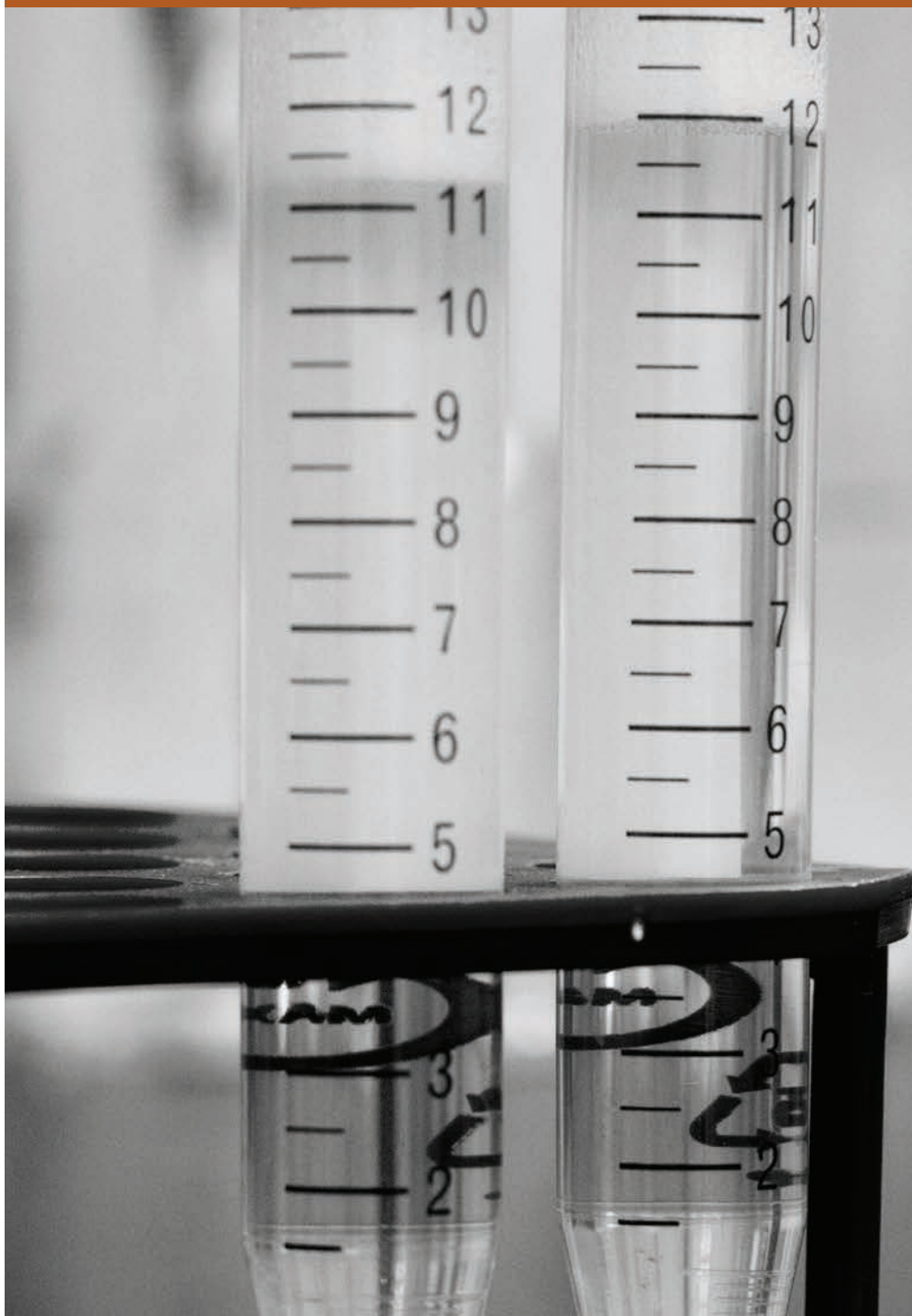


FISCAL YEAR 2021

TECHNOLOGY AND RESEARCH INITIATIVE FUND



ABOUT THIS REPORT

The fiscal year 2021 Arizona Board of Regents Technology and Research Initiative Fund filed in accordance with A.R.S. §15-1648(D) includes the prior year's TRIF expenditures. The board adopted TRIF five-year project plans, available on the ABOR website, detailing anticipated budgets and expected outcomes.

TRIF was established through Proposition 301 that increased the state's sales tax to be dedicated to K-12, community colleges and Arizona's public universities. Collection of the tax began on June 1, 2001, and the proposition was extended for another 20 years in 2018. Arizona law establishes TRIF using Proposition 301 sales tax revenue and gives the Arizona Board of Regents the responsibility to administer the fund. TRIF monies are continuously appropriated to ABOR and do not lapse at the end of the fiscal year.

The fiscal year 2020 TRIF report details research goals, accomplishments and highlights from the universities that address challenges to the state and society as well as detailed financial information on how the funds were utilized. Through TRIF funds, the institutions are able to accomplish advances in vital research, including COVID-19 research, virus biotech detection, water resources and more.

ABOUT THE ARIZONA BOARD OF REGENTS

The Arizona Board of Regents is committed to ensuring access for qualified residents of Arizona to undergraduate and graduate institutions; promoting the discovery, application, and dissemination of new knowledge; extending the benefits of university activities to Arizona's citizens outside the university; and maximizing the benefits derived from the state's investment in education.

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TECHNOLOGY AND RESEARCH INITIATIVE FUND

TRIF BUDGET

Arizona's public universities received approximately \$112.3 million in TRIF revenue in fiscal year 2021. Total TRIF revenue received to date since the inception of the program in June 2001 is well over a billion dollars.

ABOR approves the TRIF budgets and project plans in five-year cycles. The fiscal year 2021-2022 project plans were approved by the board in June 2016 using the sales-tax forecast from the Joint Legislative Budget Committee. These project plans are available on the ABOR web site at: <http://www.azregents.edu/reports-0>.

The TRIF statute includes a 20 percent limitation on the use of TRIF funds for capital projects expenditures.

TRIF INITIATIVES ADDRESS ISSUES CRITICAL TO STATE, SOCIETY

TRIF money is used to support initiatives and projects that meet one or more of the following categories established by the board.

Research investment areas:

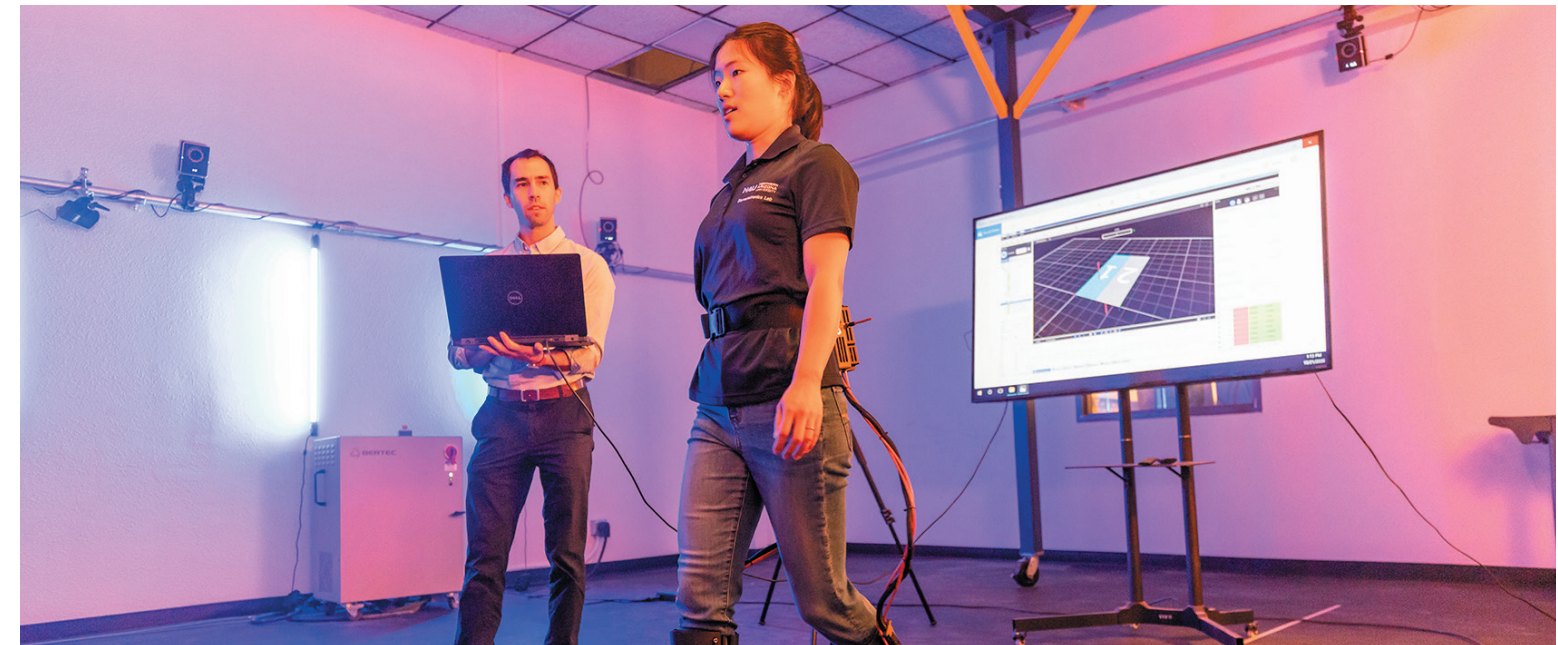
- Improving Health
- Water, Environmental, and Energy Solutions
- National Security Systems
- Space Exploration and Optical Solutions

Workforce development investment area:

- Higher Education Access for Workforce Development

Pursuant to A.R.S. §15-1648(C), TRIF funds will be used to support initiatives and projects that meet one or more of the following criteria:

- Promote university research, development and technology transfer related to the knowledge-based global economy.
- Expand access to baccalaureate or post-baccalaureate education for time-bound and place-bound students.
- Implement recommendations from the Governor's Task Force on Higher Education and/or the Arizona Partnership for the New Economy.
- Develop programs that will prepare students to contribute in high technology industries located in Arizona.
- These same criteria are used in considering tri-university awards of the Regents' Innovation Fund and grants.





ARIZONA STATE UNIVERSITY

TRIF-supported research at Arizona State University creates solutions that promote human health and well-being while advancing Arizona's economy and global competitiveness.

During the TRIF cycle of fiscal years 2017 through 2021, ASU invested in four focus areas:

- **Improving Health.**
- **Water, Environmental and Energy Solutions.**
- **National Security Systems.**
- **Access and Workforce Development.**

In fiscal year 2021, ASU leveraged TRIF investment to attract over \$349 million to support projects that address critical challenges — nearly a tenfold return on investment. For example, ASU's Global Security Initiative (GSI) is developing technologies to combat malicious disinformation through a collaboration with Kitware, Inc., funded by \$11.9 million from DARPA. And in October 2020, the Nanotechnology-Enabled Water Treatment (NEWT) Engineering Research Center was renewed to 2025 with \$16.5 million from the National Science Foundation.

In recognition of ASU's success in entrepreneurship experiential education and training, the Edson family provided an endowed gift to create the J. Orin Edson Entrepreneurship + Innovation Institute in 2020. This generous gift ensures ASU's ability to provide high-quality resources and support to university, youth and community entrepreneurs in perpetuity. In addition, the Edson Entrepreneurship + Innovation Institute was awarded over \$20 million in other gifts and grants in fiscal year 2021.

TRIF investment, and the return on investment it generates, translates to benefits for Arizona citizens. During the COVID-19 pandemic, ASU Biodesign Institute researchers quickly adapted to create a clinically certified diagnostic testing laboratory capable of processing up to 20,000 tests per day. Now, the institute is transforming the lab into a generalized platform for developing new ways to diagnose diseases and initiate engagement in clinical trials. In addition to offering valuable services to the community, the lab will provide students with numerous hands-on learning opportunities.

In fiscal year 2021, TRIF-supported research across the four focus areas engaged 1,339 undergraduates, 2,583 graduate students and 428 post-doctoral appointees. For example, 300 students worked with local communities to solve sustainability and planning challenges through ASU's Project Cities program, gaining valuable career experience while providing value to Arizona communities.

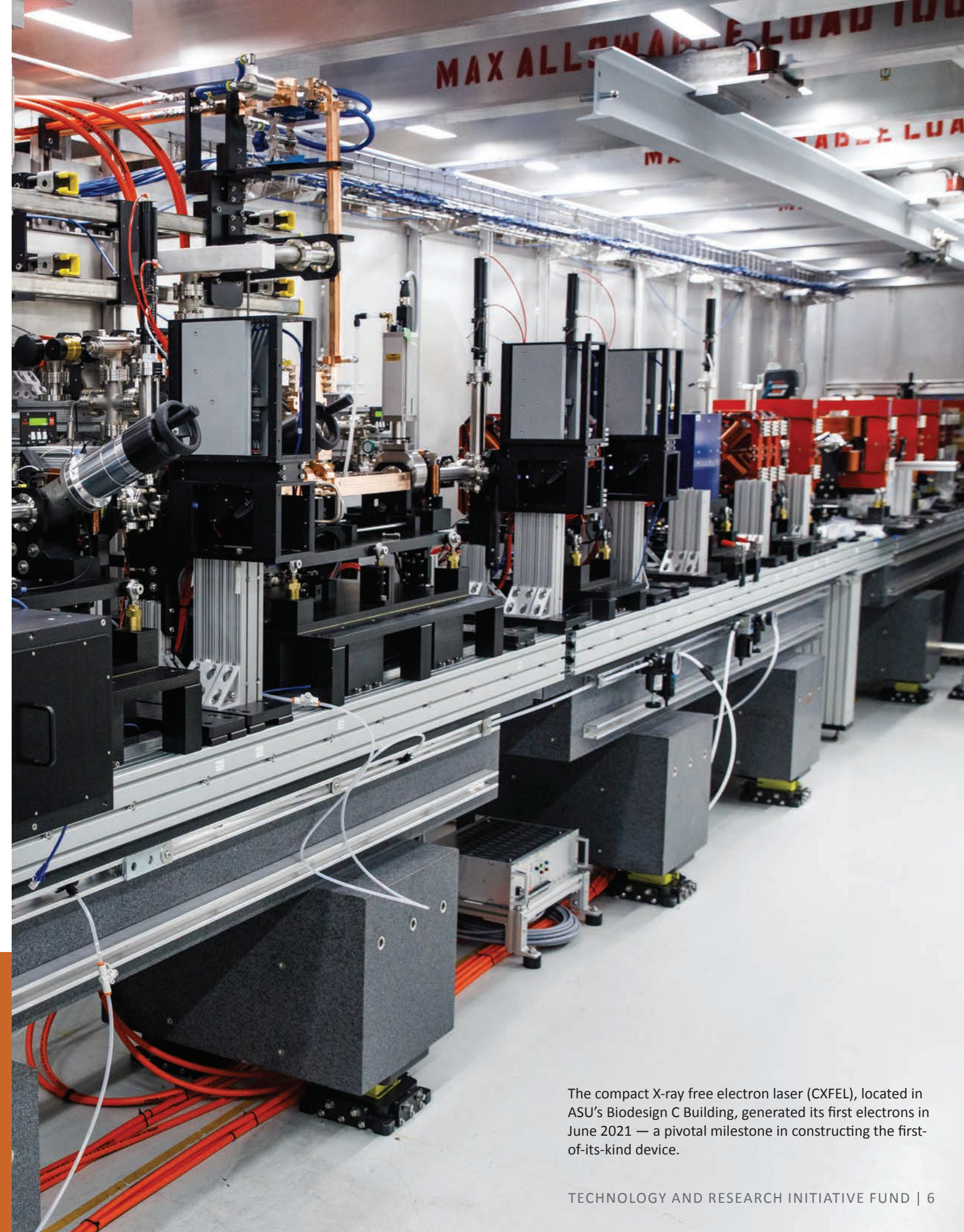
Additionally, TRIF-supported faculty and students were granted 129 patents and launched 40 new startup companies in fiscal year 2021. ASU now ranks No. 10 among universities in the U.S. and No. 11 worldwide for U.S. patents issued, according to the U.S. National Academy of Inventors and the Intellectual Property Owners Association.

For the sixth consecutive year, U.S. News & World Report named ASU the most innovative university in the country in 2021. Times Higher Education also ranked ASU No. 1 in the U.S. and No. 9 in the world for global impact, based on the United Nations Sustainable Development Goals. Arizona's investment in research and education through TRIF has served as an important catalyst for ASU's rapid growth and global leadership.



"TRIF investment in Arizona State University catalyzes impactful research, implements solutions in our communities, attracts business investment, creates high-paying jobs and stimulates our economy, thereby lifting all Arizona residents and creating value that far exceeds initial investment for generations to come. We appreciate this crucial support, which is allowing us to convert a COVID-19 testing facility into a platform for diagnosing many different diseases; collaborate with the U.S. Department of Defense to combat malicious disinformation; and develop carbon capture technology to sustain our planet. TRIF funding continues to lay the groundwork for Arizona to tackle any challenge, and all of us at ASU remain steadfastly committed to dedicating our time, talent and energy to growing Arizona's limitless potential."

— Sally C. Morton, Executive Vice President, ASU Knowledge Enterprise



The compact X-ray free electron laser (CXFEL), located in ASU's Biodesign C Building, generated its first electrons in June 2021 — a pivotal milestone in constructing the first-of-its-kind device.

IMPROVING HEALTH

ASU's efforts in Improving Health are primarily centered in the Biodesign Institute. Founded with TRIF support in 2003, Biodesign develops and discovers nature-inspired solutions for human health and well-being. For nearly 20 years, Biodesign has continued this mission, generating discoveries and commercializing medical technologies in service to Arizona and the world.

Biodesign's physical and research footprint has expanded across the globe with partner initiatives from Europe to Asia. Biodesign's interdisciplinary model leverages TRIF funding to connect biologists and geneticists, informaticians and physicians, epidemiologists and engineers, combining their shared expertise to answer challenging questions and create innovative solutions.

Another area supported by TRIF is the new Institute for Future Health (IFH), a joint venture between ASU and the University of Arizona to address emergent health challenges. IFH will serve as a research hub to employ biomedicine, engineering and computing to innovate disease diagnosis and treatment, enhance community wellness and create cost-effective solutions.

In addition, TRIF investment contributes to programs and facilities that support Improving Health efforts through infrastructure and instrumentation, technology transfer and external collaborations.

GOALS:

- Attract significant additional external funding to continue a trajectory of success in biosciences and health-related research.
- Transfer scientific advancements from lab to marketplace through inventions, startups and licensing agreements.
- Create and strengthen clinical partnerships and other private-sector collaborations to accelerate research and share resources and capabilities.
- Provide advanced education and training in state-of-the-art biosciences research and accelerate the pipeline of highly trained scientists critical to the state's economic development plan.
- Inform and inspire the broader community through educational outreach efforts, including engagement and collaboration with K-12 educators and nonprofit organizations.

"(The Diagnostic Commons) has been an invaluable resource to my team here and has helped inform our contributions to the pandemic policy response in the U.K. and the countries we directly support."

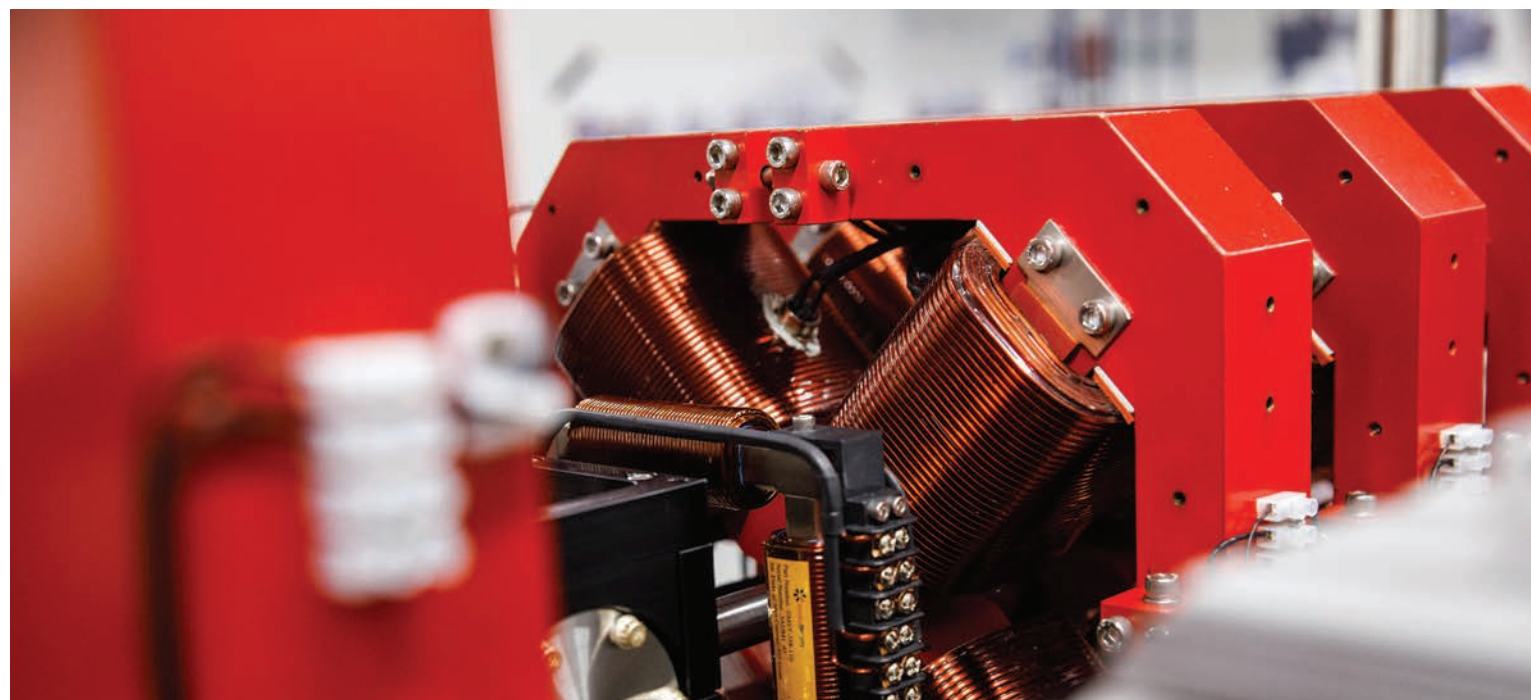
— Tony Blair, Former U.K. Prime Minister and the Founder and Executive Chairman of the Tony Blair Institute for Global Change



A staff member in the ASU Biodesign Clinical Testing Lab examines a saliva sample being tested for COVID-19.

SUMMARY OF ACCOMPLISHMENTS

- In June, ASU's compact X-ray free electron laser (CXFEL) program reached a pivotal milestone — generation of its first electrons. The achievement marks a major operational step for the CXFEL, which will advance our understanding of biology, medicine and materials. The instrument has already attracted more than \$14 million in external funding.
- In 2020, the ASU Biodesign Clinical Testing Laboratory (ABCTL) was established to meet the urgent need for COVID-19 testing in Arizona. The lab processed over 800,000 tests by the end of fiscal year 2021, returning results within 48 hours. Building on this tremendous success, ABCTL is transforming into a generalized platform for developing new ways to rapidly diagnose and detect disease. This effort represents Biodesign's first direct link to patients and has resulted in \$80 million in external funding to date.
- Biodesign researchers, working with the University of Arizona and Northern Arizona University, have genetically sequenced more than 6,000 samples of SARS-CoV-2, the virus that causes COVID-19. Their work provides insights into variants that are circulating in Arizona, including delta. Some of these variants are more transmissible, affect treatments or cause more severe disease. Working closely with the Arizona Department of Health Services (ADHS) and Centers for Disease Control and Prevention, the researchers are helping to inform state and federal public health policies.
- ASU's epidemiological modeling team has provided accurate projections of COVID-19 hospitalizations, deaths and infections in Arizona based on different scenarios. The team merged their findings with analyses from UArizona and NAU to make informed recommendations at regular meetings with ADHS.
- The Biodesign Institute recruited Jeffrey Kordower, a leader in neurodegenerative disease research and pioneer in the field of neural transplantation techniques, as founding director of the ASU-Banner Neurodegenerative Disease Research Center.
- The newly launched Institute for Future Health's growing research portfolio includes:
 - Leading the multi-institution Arizona Coalition for Comprehensive Evaluation of Long-COVID (ACCEL) to study the long-term effects of COVID-19 infection. IFH has submitted a \$99 million proposal to the National Institutes of Health for this statewide consortium.
 - Designing new sensors and telemedicine technologies for remote monitoring of patients with a high risk of rehospitalization. A focus is on patients with congestive heart failure, pediatric asthma and mental illness, three ailments that make up the largest share of rehospitalizations and cost to health care systems.
 - Creating novel, interactive clinical systems to remotely monitor the health of veterans in rural Arizona in partnership with the Veterans Administration and health care company, Philips. Expansion of VA telemedicine will improve the quality of life and care for rural veterans, a frequently underserved population.
- ASU's Decision Theater created Diagnostic Commons in partnership with the College of Health Solutions and funded by the Rockefeller Foundation. This web-based interactive platform collects COVID-19 data to arm decision-makers with the information required to operate safely, access testing and develop best practices in a pandemic.





“We expect this project to be an important step for the commercialization of a technology that can be scaled to help balance the world’s carbon budget. The [DOE] award will demonstrate how this technology can contribute to the CO₂ drawdown that will be needed to keep global warming in check.”

— Pól Ó Móráin, CEO, Carbon Collect

WATER, ENVIRONMENTAL AND ENERGY SOLUTIONS

ASU’s Water, Environmental and Energy Solutions efforts are anchored in the Julie Ann Wrigley Global Futures Laboratory, which is committed to ensuring a habitable planet and a future in which well-being is attainable for all. The laboratory draws on ASU’s legacy of excellence in sustainability-related research, education and service, leveraging tools and expertise from across ASU to advance its ambitious mission.

The Global Futures Laboratory encompasses the Global Institute of Sustainability and Innovation and the College of Global Futures, which includes three schools — the School of Sustainability, the School for the Future of Innovation in Society and the School of Complex Adaptive Systems.

TRIF investment in this focus area also contributes to two national Engineering Research Centers focused on sustainability challenges — the Center for Bio-mediated and Bio-inspired Geotechnics (CBBG) and the Nanotechnology-Enabled Water Treatment (NEWT) center. In addition, TRIF investment enables programs and facilities that support Water, Environmental and Energy Solutions efforts through infrastructure and instrumentation, technology transfer and external collaborations.

GOALS:

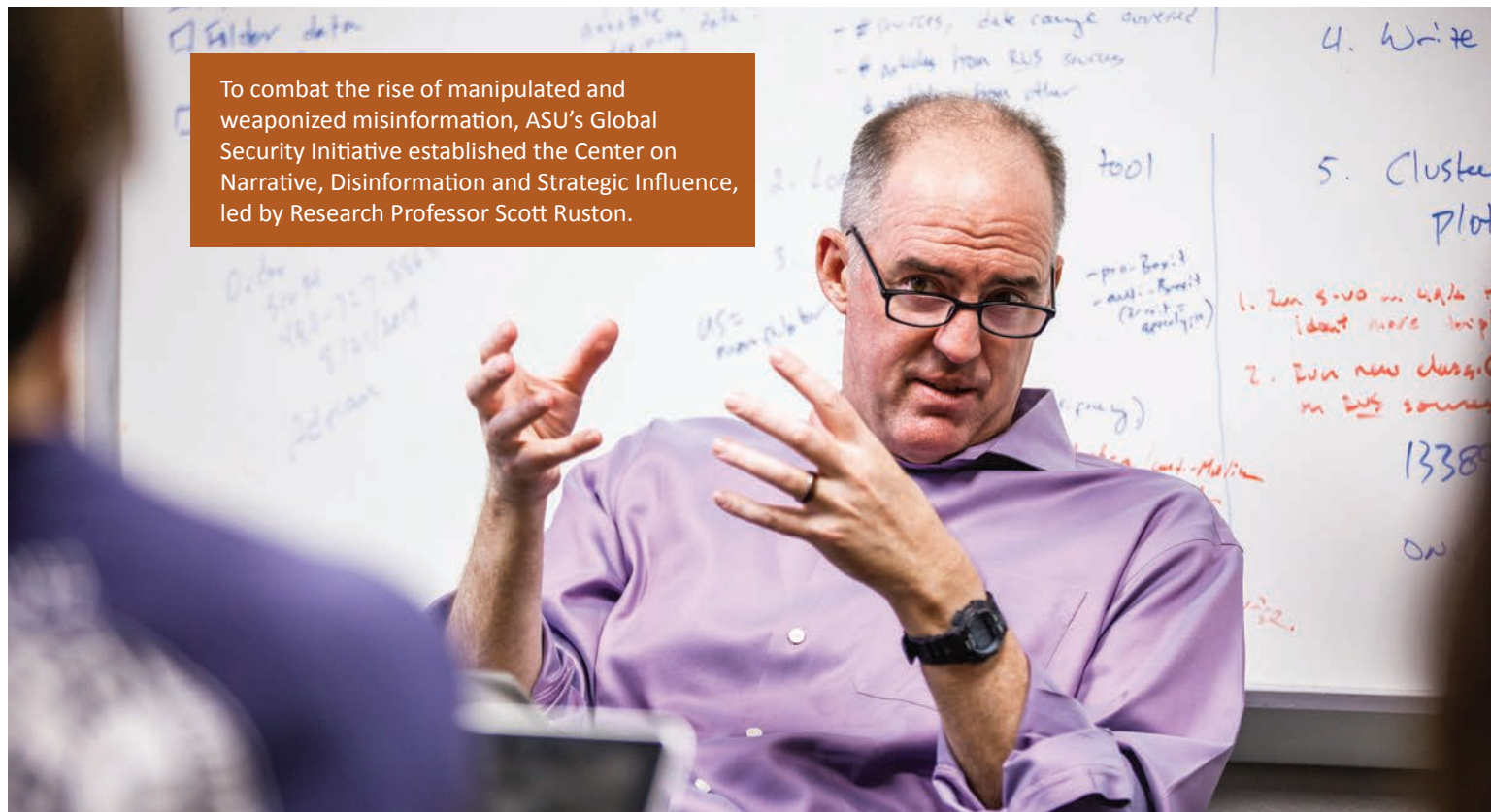
- Attract additional external funding to support ASU units and their partners in the teaching, learning, discovery and solutions-based application of planetary systems, sustainability, complex systems, and ethical innovation and technology development.
- In the mold of a “medical center for the planet,” educate the next generation of sustainability scientists and scholars, and train leaders and stakeholders in every field to implement best practices that empower a thriving future for all of Earth’s inhabitants.
- Engage with broad and diverse publics to implement, extend, share and promote sustainable and ethical practices locally, nationally and globally.
- Connect scientists, scholars, humanists, engineers, technologists, policymakers, business leaders, students and communities to enhance the capacity to address global challenges.
- Support research and development in technologies and systems used by governments, non-governmental organizations and businesses that will generate revenue and jobs in Arizona.

SUMMARY OF ACCOMPLISHMENTS

- Fugitive dust is a major air quality problem in Maricopa County and around the world. It can cause respiratory illnesses and permanent lung damage. The CBBG Engineering Research Center completed an initial field trial on its innovative technology for fugitive dust control at a landfill in Apache Junction, in partnership with Freeport McMoran, Republic Waste Services and the Salt River Landfill. On the basis of this trial, the U.S. Bureau of Reclamation granted CBBG \$187,000 to evaluate the technology for mitigating fugitive dust associated with the drying up of California’s Salton Sea.
- ASU’s Future H2O launched two spinout companies in fiscal year 2021. GELF Sciences, Inc. is commercializing ASU-developed technology for producing transportation-grade hydrogen gas from agriculture, food processing and sewage. Future H2O-B is a B corp that provides consulting services on water stewardship to clients ranging from Fortune 500 companies to water resource commissions in developing countries.
- Since 2019, a locust plague has been devastating crops in East Africa and India. ASU’s Global Locust Initiative is one of the top resources for locust information and has been featured in Newsweek, the New York Times, NPR, Forbes, Science Magazine and Science News, among other news outlets. GLI houses the world’s largest living collection of locusts and grasshoppers and serves as a recharge center, selling locusts and related services to support research at institutions across the U.S.
- ASU LightWorks was instrumental in brokering a deal with Carbon Collect (formerly Silicon Kingdom Holdings) to commercialize ASU-developed technology for capturing CO₂ from the air. In early 2021, the Department of Energy awarded \$2.5 million to the ASU-Carbon Collect effort to design three commercial-scale “carbon farms” that can capture 1,000 tons of CO₂ per day.
- PFAS are manmade chemicals that accumulate in the human body, and research suggests they cause a variety of health problems. Researchers with the NEWT Engineering Research Center have discovered new, cost-effective ways to destroy PFAS that contaminate groundwater. Over the past year, this technology has been deployed in a mobile pilot plant at a central Arizona groundwater wellsite. It offers the potential to make freshwater more readily available to Arizonans while creating new business opportunities for commercializing the technology.
- Since 2017, ASU’s Project Cities program has involved over 860 students in 57 class projects helping local communities solve challenges related to sustainability, planning, water conservation, public engagement, historic preservation, smart technology and recreation, among others. This includes over 300 students involved in the most recent program year, working on 20 applied projects.
- The College of Global Futures Executive and Professional Education initiative launched seven new courses on the Sustainable Earth portal, a partnership with the Wells Fargo Foundation. These self-paced micro-credential courses are available to individuals and organizations seeking to advance their sustainability goals. The initiative also provided training on the use of digital technology to spur international development. More than 360 USAID staff as well as scholars from universities around the world have participated in the training, with support from a USAID grant.
- LightWorks is engaged with Southwest Gas, SRP and APS in thinking about and planning for the energy transition, including grid stability, long-term energy storage and renewable hydrogen production.



CBBG’s fugitive dust control technology is deployed at Apache Junction Landfill. Photo by ASU Assistant Professor Nasser Hamdan.



To combat the rise of manipulated and weaponized misinformation, ASU's Global Security Initiative established the Center on Narrative, Disinformation and Strategic Influence, led by Research Professor Scott Ruston.

NATIONAL SECURITY SYSTEMS

The Global Security Initiative (GSI) serves as the hub for ASU's National Security Systems efforts. GSI pioneers unconventional approaches to wide-ranging, interconnected security challenges by leveraging ASU's expert faculty; research engine; and connections in defense, international development and diplomacy communities. To meet these challenges, GSI creates practical tools, technologies and systems that deliver impact for policymakers through interdisciplinary collaboration across the public, private and academic sectors.

In fiscal year 2021, TRIF investment also began supporting engagement with the U.S. Department of Defense through the National Security Innovation Network (NSIN), a platform that connects defense, academic and venture capital communities to solve national security challenges.

TRIF investment in National Security Systems also supports ASU space exploration efforts through NewSpace and the Interplanetary Initiative. NewSpace keeps ASU competitive in an evolving space industry by linking university researchers with commercial spaceflight companies for awards and opportunities. The Interplanetary Initiative promotes humanity's future as an interplanetary species by answering vital questions about how humanity will govern, coexist and collaborate among the stars through interdisciplinary research and education.

In addition, TRIF investment contributes to programs and facilities that support National Security Systems efforts through infrastructure and instrumentation, technology transfer and external collaborations.

GOALS:

- Address emerging national security needs with unique, advanced capabilities and grow externally funded defense and aerospace research by 2024.
- Advance research and discovery in relevant areas such as cybersecurity, disinformation, human/AI/robot teaming, and advanced communication and analytic systems.
- Build state and national cyber-readiness by providing hands-on cybersecurity learning programs for all skill levels and age groups.
- Provide advanced education and training to accelerate the pipeline of highly trained researchers into the defense, intelligence and aerospace industries, and enable the current workforce to upskill in emerging areas.
- Create and strengthen relevant private-sector collaborations, support technology transition, accelerate adoption of advanced research, and share resources and capabilities with our partners.

SUMMARY OF ACCOMPLISHMENTS

- In response to the growing threat of manipulated and weaponized information for geopolitical influence, GSI established the Center on Narrative, Disinformation and Strategic Influence. The new center is already undertaking two Department of Defense projects. One effort is focused on Chinese propaganda in East Asia, funded at \$1.8 million. The second is an \$11.9 million federal contract with Kitware Inc., an international software research and development company, to produce new technology to characterize malicious disinformation and to detect falsified media and its origin.
- Partnering with PayPal, Google and Samsung, GSI researchers conducted a large-scale study of the full life cycle of phishing attacks. Tracking nearly 4.8 million phishing victims over the course of a year, researchers found about half of victims were scammed before internet browsers were able to detect and block malicious activity. This work is helping companies proactively protect user accounts. The resulting research paper was awarded second place in the Internet Defense Prize competition led by Facebook and USENIX.
- GSI's Center for Human, Artificial Intelligence, and Robot Teaming secured a \$200,000 award from the Air Force Office of Scientific Research to study human-robot teaming in space. Using testbeds representing the International Space Station, future Martian bases and NASA's Johnson Space Center, the effort seeks to determine how humans and artificial intelligences can best collaborate during space operations.
- To improve national and state cyber-readiness, GSI provided and supported hands-on learning resources for diverse skill levels and age groups. Efforts included:
 - Free cybersecurity curricula for Arizona middle and high school teachers, including access to the U.S. Cyber Range, a virtual environment where students can practice cybersecurity and online privacy skills.
 - pwn.college, a free education platform that delivers increasingly sophisticated learning modules and exercises to develop cybersecurity skills sought by employers.
 - Helping to organize and lead the "Olympics" of ethical hacking — the annual DEF CON Capture the Flag Tournament. The virtual event saw more than 1,300 teams from around the world competing to solve complex cybersecurity challenges.
- The Interplanetary Initiative launched its three-year, workforce-facing Bachelor of Science in Technological Leadership in 2021 with 45 students enrolled. The initiative also provided seed funding for eight pilot research projects in 2021. In partnership with XPRIZE, the Interplanetary Initiative will help drive the next generation of space-related XPRIZE competitions, launching in fall 2021.
- In fiscal year 2021, NewSpace enabled \$2.1 million in awards, including a prestigious NASA Early Career Award of \$600,000 and a \$450,000 NASA Flight Opportunities Program award. The latter connected an ASU researcher to Tucson-based company Worldview to test a new instrument. One of the first NewSpace-enabled projects, the Lunar Polar Hydrogen Mapper, was delivered to NASA's Kennedy Space Center in Florida in June. Constructed by an ASU-led team, the small satellite is expected to launch later this year and begin its mission mapping water on the moon's south pole.
- In partnership with NSIN, ASU launched the inaugural National Security Academic Accelerator (NSA2), which provides training, support and funding to advance ASU technology to startups that serve national security needs. NSA2 also connects burgeoning startups with potential Defense Department customers to speed tech transfer.



ACCESS AND WORKFORCE DEVELOPMENT

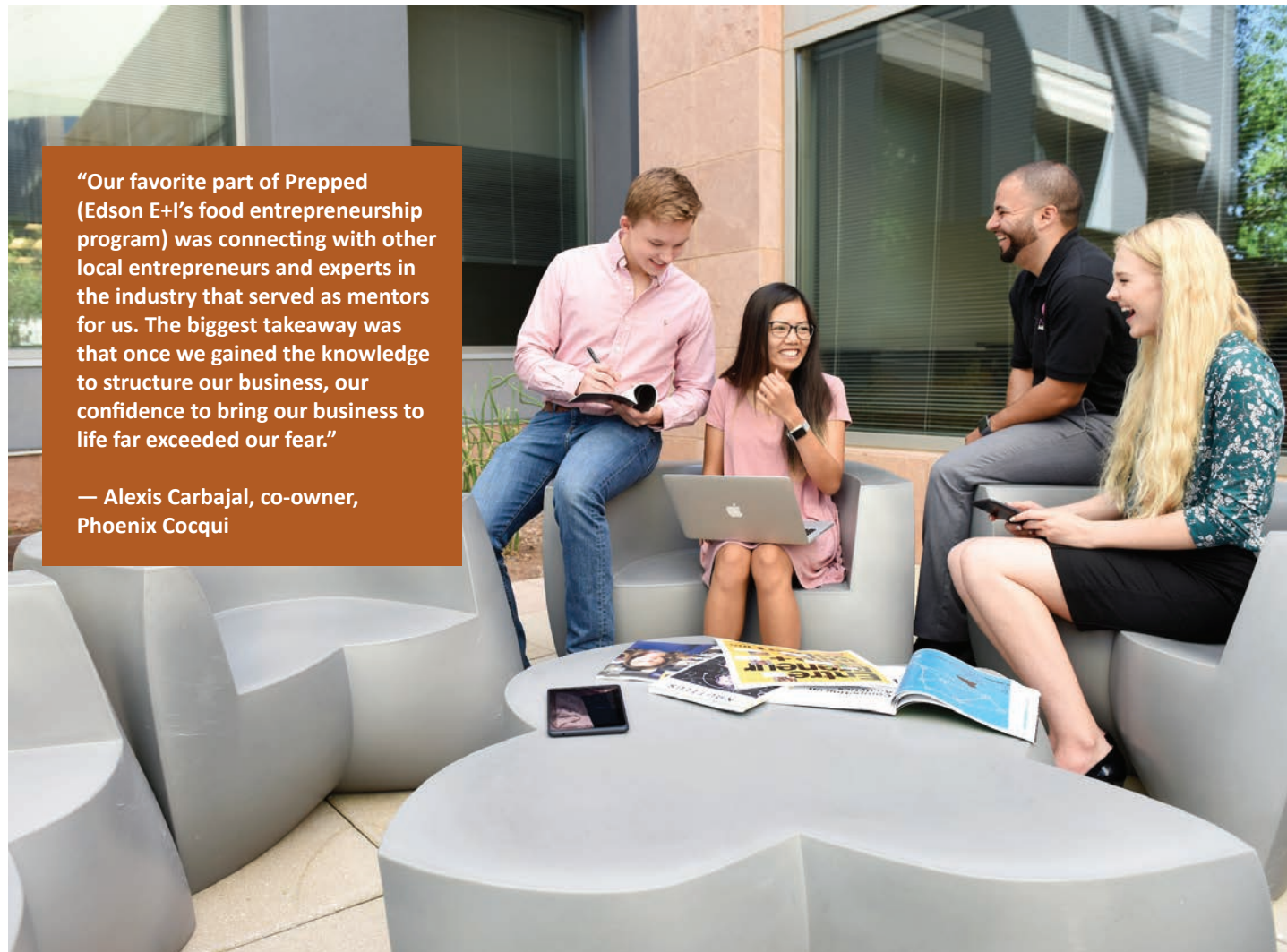
Programs supported through the Access and Workforce Development focus area ensure a thriving economy powered by a highly trained workforce. ASU provides educational and experiential opportunities for learners from kindergarten through doctoral levels, as well as continuing education and upskilling for current employees.

Small businesses account for 64 percent of new jobs created in the U.S. ASU provides support and resources to entrepreneurs at all stages — from ideation to growing an existing venture. ASU also partners with established companies to accelerate their impact in a variety of ways, from partnerships with faculty experts, access to core facilities for research and development efforts, developing student teams to help solve critical problems and more.

In addition, TRIF investment contributes to programs and facilities that support Access and Workforce Development efforts through infrastructure and instrumentation, technology transfer and external collaborations.

GOALS:

- Attract businesses to Arizona and advance high-growth industries in the state.
- Secure external funding and stimulate new funding opportunities.
- Guide the launch of new startup companies, particularly among students and entrepreneurs in underserved communities.
- Create and strengthen partnerships with private companies, municipal and state governments, regional economic development organizations and chambers of commerce, and local community members, including entrepreneurs.
- Provide educational opportunities throughout the community, such as teacher trainings, apprenticeships, conference presentations, curriculum development and dissemination, maker camps and classes, and community engagement.



“Our favorite part of Prepped (Edson E+I’s food entrepreneurship program) was connecting with other local entrepreneurs and experts in the industry that served as mentors for us. The biggest takeaway was that once we gained the knowledge to structure our business, our confidence to bring our business to life far exceeded our fear.”

— Alexis Carbajal, co-owner, Phoenix Cocqui



ASU’s Advanced Electronics and Photonics (AEP) core facility supports Arizona’s semiconductor and microelectronics industry with specialized equipment and consultation.

SUMMARY OF ACCOMPLISHMENTS

- ASU transitioned the Flexible Electronics and Display Center into the Advanced Electronics and Photonics (AEP) core facility, which provides access to unique semiconductor processing facilities to companies of all sizes. FEDC traditionally operated on substrates that are orders of magnitude larger than most university research labs and more aligned with industry needs. Applied Materials, the largest semiconductor equipment manufacturer in the world, signed a \$3.75 million research contract with ASU and is leasing space at the ASU Research Park. Numerous startup companies also leverage AEP to avoid capital costs and collaborate with ASU faculty and students on research. These include Swift Coat, Sunflex Solar, Advent Diamond, NeuvoGen, Cactus Materials, Regher Solar, AmberWave and Automera.
- ASU Corporate Engagement and Strategic Partnerships (CESP) helped secure key corporate partners to participate in the \$8 million AZNext program funded by the Department of Labor. The program is designed to address the acute talent shortages for mid- to high-skilled workforce in IT, cybersecurity and advanced manufacturing.
- CESP also helped develop a collaboration with PepsiCo to create a ten-module water management training for its global employees in partnership with ASU’s Future H2O, ASU’s Learning Enterprise and The Nature Conservancy. PepsiCo also invested \$460,000 into the TRIF-supported Nanotechnology Enabled Water Treatment (NEWT) center to continue three sponsored research projects.
- In September 2020, the J. Orin Edson Entrepreneurship + Innovation Institute was established with an endowed gift from the Edson family. The institute advances and expands on highly successful programming that supports entrepreneurship among ASU students, faculty, youths and the broader community. With additional grant funding from Verizon, Edson E+I’s work with the Verizon Innovative Learning Lab Program has expanded its middle school youth entrepreneurship program to nearly 400 schools, working with hundreds of educators and thousands of students.
- Luminosity Lab is a student-driven research and development lab where interdisciplinary teams design and build solutions to some of the world’s most pressing challenges. In December 2020, a Luminosity team beat nearly 1,000 competitors from around the world to win the XPRIZE Next-Gen Mask Challenge with their fog-free mask for preventing the spread of COVID-19. The team received \$500,000 to advance their invention.
- The Biodesign Institute launched the Center for Sustainable Macromolecular Materials and Manufacturing with support from ASU’s Advanced Materials Initiative. The center addresses the plastic pollution problem by innovating materials through green chemistry and sustainable engineering practices. ASU recruited leading polymer chemist Timothy Long to direct the center, which is part of a larger ASU effort involving more than 70 companies spanning the full supply chain from raw materials to packaging to recycling. The effort has received funding from the Department of Energy, Honeywell, Intel and NSF.
- SciHub is an integrated research, teaching, outreach and product development lab where interdisciplinary teams collaborate in an entrepreneurial environment. SciHub teams have developed a variety of products, such as a portable optical spectrometer with a range of uses including food quality analysis, plant health assessment, identification of allergens and paint color matching. The spectrometer has been distributed to over 50 high school and college students and won the grand prize at the 2021 Arizona Science and Engineering Fair.

HIGHLIGHTS

ASU leverages TRIF investment to transform innovative ideas into world-class institutes, centers and programs that provide tangible benefits to Arizona, the nation and the world.

For example, TRIF was instrumental to launching the Biodesign Institute, a bold idea for using nature's design tools to create solutions in health, sustainability and security. Today, Biodesign is a premier global research institute that has attracted more than \$800 million in sponsored funding, secured more than 230 patents and launched 41 spinout companies. Each year, the institute employs and trains more than 550 students and nearly 50 postdoctoral researchers.

ASU is strategically positioning TRIF-supported programs to continue this trajectory of growth. For example, the Advanced Electronics and Photonics core is expanding its capabilities to support future research and industry translation needs. AEP's ecosystem-based model is key to the National Network for Microelectronics research and development, defined in the current National Defense Authorization Act as a core and hub model to advance microelectronics research and development within the U.S. Funding is expected at \$2 billion over five years, with ASU positioned to compete as a core site and a network leader.

The newest addition to ASU's TRIF portfolio, the Institute for Future Health (IFH), promises to deliver additional impact. Quickly adapting to address emerging challenges, IFH has already submitted a \$99 million proposal to the National Institutes of Health for a statewide consortium to study the long-term effects of COVID-19 infection.

The new Biodesign Center for Sustainable Macromolecular Materials and Manufacturing is addressing the challenge of medical plastic waste by launching a program to upcycle used medical plastics into 3D printing filament. The project is starting with ASU's own COVID-19 testing lab as well as partnering with Mayo Clinic.

ASU is expanding its footprint to empower Arizona's high-growth, high-wage industries. This year, ASU and Mayo Clinic opened the 150,000-square-foot Health Futures Center next to the Mayo Clinic Phoenix Campus. The center is home to the Mayo Clinic and ASU Alliance for Health Care and the MedTech Accelerator, which accelerates early-stage medical technology companies. The facility includes wet and dry labs, a movement research lab, a demonstration kitchen and a simulation lab for training medical practitioners.

The university also opened 850 PBC on the downtown Phoenix Biomedical Campus. The LEED-Gold-certified building features 240,000 square feet of wet and dry labs, offices and retail space. ASU units lease half the building, while the other half houses private-sector companies, including three Biodesign-based spinout companies.

The Global Futures Laboratory is scheduled to move into the new Interdisciplinary Science and Technology Building 7 in January 2022. Located on the northeastern corner of ASU's Tempe campus, the 280,000-square-foot building will embody the ethos of the laboratory. Designed to meet LEED Platinum standards, the building will capture and reuse 100 percent of rainfall to support a diverse selection of native plant species. It will also integrate ideas and technologies from past cultures, including a functioning canal that dates to the ancient Hohokam peoples.

These are just a few examples of ASU's successful model for advancing big ideas and key infrastructure that generate high-impact, high-return enterprises. ASU has a proven ability to quickly spin up new efforts as challenges emerge (such as a global pandemic) and evolve (such as long COVID and medical plastics waste). Arizona's long-term commitment to research, innovation and workforce development through TRIF is essential to this agility and provides tremendous returns to the people of Arizona, now and into the future.





NORTHERN ARIZONA UNIVERSITY

Northern Arizona University's capacity to invest in its historical research strengths and areas of strategic research growth was significantly expanded in 2016 when the Arizona Board of Regents approved NAU's bold five-year TRIF plan for fiscal years 2017-2021. NAU's TRIF financial investments have had a meaningful impact throughout Arizona, producing economic benefits through scientific advancements, workforce training and enabling access to higher education. In fiscal year 2021, TRIF funding has enabled NAU faculty to attract a total of \$11.5 million in new external funding through all five initiatives.

Beyond their economic benefits, NAU's investments have also increased the university's capacity to form successful research partnerships, strengthened its capability to commercialize new technologies and capitalized on the intellectual talent of faculty to achieve the university's mission of enriching lives and creating opportunities for students and the communities NAU serves. This year, NAU was issued eight patents, filed 31 new patent applications and submitted 51 new invention disclosures.

One of the most compelling examples of successful partnerships is NAU's response to the COVID-19 pandemic. In April 2020, NAU's Pathogen and Microbiome Institute (PMI) launched the COVID-19 Testing Service Center. By quickly repurposing its existing biodefense research infrastructure for the new testing facility — labs rated at Biosafety Level 3 (BSL-3), one of the highest levels of biocontainment — PMI dedicated much of its significant research capacity to fight the pandemic, enabling both industry and nonprofit partners to test potential vaccines and treatments against the coronavirus. As the pandemic progressed, PMI has launched efforts to track COVID-19 variants throughout the state, working in partnership with UArizona and TGen, and has also collaborated in multidisciplinary research across NAU, such as monitoring community outbreaks through wastewater testing.

Through its five TRIF initiatives - Improving Health (iHealth), National Security Systems (NSS), Access and Workforce Development (AWD), Water, Environmental and Energy Solutions (WEES) and Space Exploration and Optical Solutions (SPACE) - NAU has consistently generated a positive return on TRIF investments.

- The iHealth initiative has propelled NAU to innovate and discover - in the lab, clinical settings and the public health arena - in ways that elevate translational research capabilities, enabling NAU researchers to contain and mitigate the impacts of the COVID-19 pandemic in the state.
- The NSS initiative has driven investment in research-intensive faculty and in high-tech laboratories. NAU has established itself as a leader in the critical areas of cybersecurity and cyber solutions, developing new technologies to protect Arizona's businesses and consumers while spurring its economy. A core national security priority that will affect all Arizonans in the years ahead, NAU is developing both the highly qualified workforce and the technological advances needed to meet these challenges.
- AWD supports the state's economic growth through the development and delivery of degree and certificate programs that support workforce needs in high-demand areas such as health and teacher education, serving communities throughout Arizona.
- The WEES initiative, based on regional research of the environment, land management and sustainability initiatives that is one of NAU's historic strengths, has driven the university to explore and discover on a global scale, enhancing its leadership position in this discipline.
- The SPACE initiative capitalizes on the recruitment of research-intensive faculty in the areas of astronomy and planetary science while leveraging the wealth of astronomical resources in Northern Arizona and throughout the state at partner institutions to prepare a workforce that will strengthen Arizona's stature as a worldwide leader in this burgeoning area of research.



As we look back at all the discoveries that have been made in fiscal year 2021, the innovative solutions that have been developed, the workforce development programs that have been expanded, and the students whose lives have been changed through a culture of research and learning excellence, we can all be very proud of what we've accomplished at Northern Arizona University. The residents of our state can be just as proud, because they played a substantial part in our achievements by funding Arizona's Technology and Research Initiative Fund (TRIF), and we are sincerely grateful for their ongoing support.

Looking ahead to fiscal year 2022 - which is already showing significant promise for our research enterprise - we are preparing the next TRIF Three-Year Project Plan, in which we will use TRIF funding to invest in strategic projects that will yield the greatest impact on Arizona that also build on our historic areas of greatest strength.

— José Luis Cruz Rivera, President



As the principal investigator for the Partnership for Native American Cancer Prevention, Professor Jani Ingram has been awarded \$6.83 million by the National Cancer Institute (NCI) for NAU to continue its efforts in cancer research, training and outreach programs serving Native American communities for the next five years. Since 2002, NAU and the University of Arizona Cancer Center have received funding from NCI, working in partnership to alleviate the unequal burden of cancer among Native Americans.

IMPROVING HEALTH

NAU's investments in the iHealth initiative focus on three areas: pathogen genomics, health research initiatives and bioengineering/biotechnology.

- **Pathogen Genomics:** Investments in NAU's world-renowned Pathogen and Microbiome Institute (PMI) have led to the creation of intellectual property and national recognition in biosecurity - resulting in increased extramural research funding as well as active engagement with industry partners through the COVID-19 Testing Service Center. PMI's research focuses on the evolution, ecology and epidemiology of some of the most threatening disease-causing viruses, bacteria and fungi from COVID-19 to hospital-acquired infections, anthrax, plague, Valley Fever and biological warfare agents.
- **Health Research Initiatives:** NAU is expanding its capacity to produce nationally recognized translational health research and to make discoveries in personalized medicine, infectious disease control and clinical research around a wide range of chronic health conditions. NAU's Center for Health Equity Research addresses health care disparities affecting the state's underserved populations, including Native Americans, Hispanics and rural communities – resulting in millions of dollars in new funding, most notably the Southwest Health Equity Research Collaborative, a five-year, grant-funded initiative supported by more than \$21.4 million from the National Institutes of Health.
- **Bioengineering/Biotechnology:** Investments in bioengineering and biotechnology are catalyzing discoveries that improve lives, foster economic growth and provide cutting-edge training for a diverse population of students who will join Arizona's workforce. Research in this field includes personal bionics and wearable robotics, rehabilitation, hearing improvement and biocompatible implants and sensors.

GOALS:

- **Develop solutions for critical areas of health care with an emphasis on addressing health disparities.**
- **Leverage NAU's existing research and intellectual assets to generate external funds.**
- **Expand health-care programs, delivery modalities and locations to meet workforce needs in the state and region.**
- **Catalyze an entrepreneurial spirit among university faculty and students to address the need for new health-care technologies and innovations today and in the future.**
- **Build and strengthen partnerships with health-care providers in Northern Arizona.**
- **Generate new biotechnology startup enterprises and jobs in the region.**

SUMMARY OF ACCOMPLISHMENTS

NAU's TRIF investments under the Improving Health initiative range from basic, applied and translational research in human biology, bioengineering and microbiology/genomics to clinical, community and behavioral health sciences. By building valuable partnerships with local and regional health-care providers, research institutions and tribal communities, NAU researchers continue to make discoveries and invent new technologies that have an immediate and long lasting impact on the health and well-being of the diverse populations of Arizona.

- NAU faculty who received TRIF funds through the iHealth initiative achieved \$5.5 million in new external grant funds in fiscal year 2021.

Pathogen and Microbiome Institute

- Regents Professor and PMI Executive Director Paul Keim led the Arizona COVID-19 Genomics Union (ACGU), in a study tracking SARS-CoV-2, the causative agent of COVID-19. ACGU scientists Associate Professor Greg Caporaso, Assistant Professor Crystal Hepp and Assistant Professor Jason Ladner sequenced the genomes in virus-positive patient samples, contributing to statewide efforts to test patients and provide guidance for public policymakers.
- Assistant Professor Todd French and Regents Professor Keim partnered with Danish pharmaceutical manufacturer Allarity to test the drug stenoparib as a potential antiviral treatment against the British variant of SARS-CoV-2 at NAU's COVID-19 Testing Service Center.
- Associate Professor Caporaso was awarded \$3.75 million by the National Cancer Institute to build software capable of analyzing and archiving data focused on the interplay between the human microbiome and cancer.
- Associate Professor Jeff Foster received \$3 million from the Defense Threat Reduction Agency to lead an international effort to combat brucellosis, one of the most pervasive infectious diseases worldwide, infecting an estimated 500,000 people and millions of animals annually.
- Patents were issued to NAU for Regents Professor Keim's novel assay for genotyping *Cryptococcus gattii*, which causes a potentially fatal fungal disease, and for his low-cost, high-throughput assay for assessing efficacy of drugs against *Coccidioides* spores, which cause Valley Fever (co-invented by Associate Professor Bridget Barker).

Center for Health Equity Research

- Regents Professor Julie Baldwin, Center for Health Equity Research (CHER) director, and Professor Ramona Mellott, dean of NAU's College of Education, were awarded \$1.4 million to create an innovative graduate certificate training program for clinicians and doctoral students in health professions that addresses substance use disorders in underserved populations.
- Regents Professor Baldwin and other CHER researchers were awarded \$1.2 million from the NIH to support projects addressing health inequities that have become more evident due to COVID-19 throughout Arizona.
- Associate Professor Samantha Sabo, Assistant Professor Heather Williamson and Professor Nicolette Teufel-Shone conducted a regional survey with 200 leaders from five Arizona counties. The results will inform strategic planning to address health equity issues through collaboration among Arizona's top community leaders.

Bioengineering/Biotechnology

- Assistant Professor Zach Lerner launched NAU's most successful commercial spin-off based on his bioengineering research and patent-pending technologies, which optimize human mobility through the development of exoskeletons, particularly for children with cerebral palsy.
- Associate Professor Michael Shafer and Professor Heidi Feigenbaum developed a high-performance artificial muscle technology that enables more human-like motion, outperforming human muscle when applied to robots with future applications in assistive technologies such as exoskeletons and prostheses.



With funding from the Fliin Foundation's Translational Research in Precision Medicine Seed Grant Initiative, Assistant Professor Emily Cope is looking for a novel therapeutic for asthma among economically disadvantaged populations, studying low-cost fiber supplements as a way to help improve symptoms.



With nearly \$2 million in funding, NAU joined a major new initiative to establish the Center for Quantum Networks (CQN). Associate Professor Inès Montañó and Professor Stephanie Hurst will collaborate with the University of Arizona, the lead institution on this five-year project, which represents NAU's first participation in an NSF-designated Engineering Research Center. CQN will lay the foundations of the quantum internet, revolutionizing how humankind computes, communicates and senses the world.

NATIONAL SECURITY SYSTEMS

According to the U.S. Department of Homeland Security, the country's economic vitality and national security depend on a stable, safe and resilient cyberspace. NAU's investments in the National Security initiative focus on cyber solutions, which are being delivered through NAU's School of Informatics, Computing and Cyber Systems that was formed in 2016 to meet the need for advanced interdisciplinary computational and data sciences, and to successfully compete for major external research grants in informatics, cyber systems development and cybersecurity. Because of these investments, NAU is successfully attracting increased funding from a variety of government agencies responsible for national security, including the U.S. Air Force and the U.S. Navy.

Cyber solutions address key challenges for secure computing. The most obvious challenge is the need for cybersecurity and encryption that cannot be easily defeated. Novel approaches and solutions include both software designs and embedded encryption in hardware. Cyberphysical systems will require security to ensure that computers talking to other computers are not corrupted and harm entire systems of machine-to-machine communications. The same concern can be extended to remote sensing data and smart infrastructure systems such as smart cities, smart buildings and even smart cars. Investments from the NSS initiative also support NAU's efforts in the management of foundational supply chains and the development of innovative functional materials, concurrent with providing exceptional training opportunities for students to meet the needs of industry within the state.

GOALS

- **Develop new secure applications of computing and computer-systems design.**
- **Collaborate with technology-driven industry partners.**
- **Generate nationally recognized science and scholarship by integrating emerging research domains with NAU's areas of strength, including biological and environmental research.**
- **Provide cutting-edge training and learning opportunities for students to apply in the workforce.**

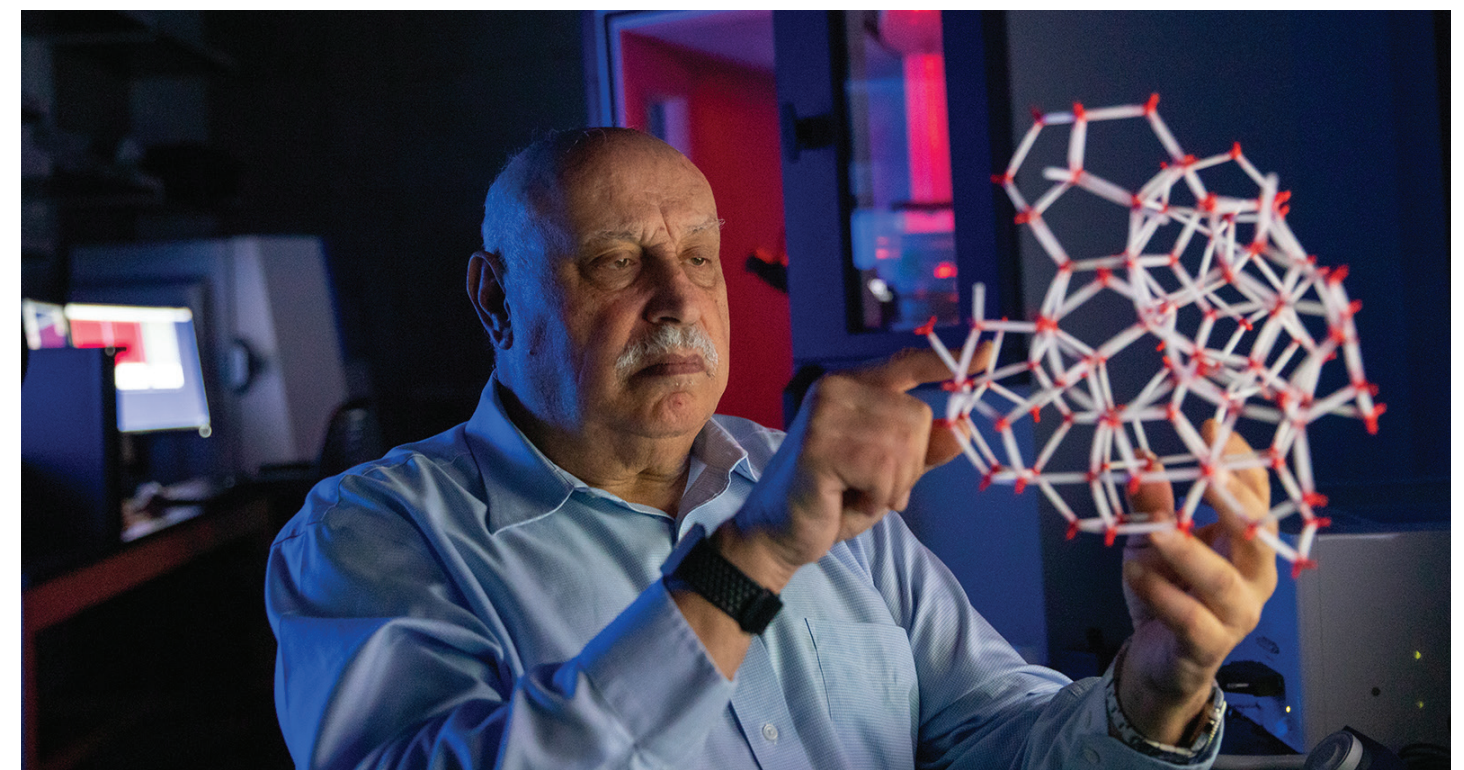
SUMMARY OF ACCOMPLISHMENTS

NAU's National Security Systems initiative leverages research, discovery and training to develop and disseminate innovative and secure applications in informatics, computing and cyber systems - goals that are largely accomplished through NAU's School of Informatics, Computing and Cyber Systems.

- NAU faculty who received TRIF funds through the NSS initiative achieved \$1.1 million in external grant awards in fiscal year 2021.
- Funded through a National Science Foundation (NSF) grant of more than \$4 million over five years, Associate Professor Inès Montañó, Professor Gabriel Montañó and Regents Professor Miguel José Yacamán are teaming up with Arizona State University and other regional partners in a five-year effort to expand the reach of the Nanotechnology Collaborative Infrastructure Southwest to the communities of northern Arizona and the Four Corners region.
- Associate Professor Fatemeh Afghah, Regents Professor Peter Fulé and Assistant Professor Abolfazl Razi won a \$1.2 million NSF grant to study the use of drones in responding to forest fires in collaboration with Georgia Tech, the Desert Research Institute and the National Center for Atmospheric Research. The project will explore ways to use unmanned autonomous vehicles in tracking forest fires, with the goal of giving firefighters a better situational awareness about the fire environment, provide up-to-date information on where the fire is and help fire responders form reliable predictions about the fire activity.
- Associate Professor Afghah also received a \$550,000 grant through the NSF's Faculty Early Career Development Program, one of the foundation's most prestigious awards. The funding will support a project developing algorithms that will enable a fleet of smart and autonomous drones to assess situations, change course, stand up against environmental factors like wind, communicate with other drones and coordinate a strategy together, all with limited support from humans.

Patents Issued

- NAU was awarded patents for four new technologies:
- Professor Bertrand Cambou's cybersecurity method for password management using addressable physical unclonable function (PUF) generators.
- A method for strengthening quantum key distribution using addressable PUFs and ternary state logic, invented by Professor Cambou.
- Professor Cambou's enhanced computer architecture, which utilizes dynamic hybridized positional notation to increase cybersecurity.
- A nanomaterial-based system using PUFs co-invented by Professor Cambou and Associate Professor John Gibbs.





SUMMARY OF ACCOMPLISHMENTS

Providing access to higher education for all Arizonians, regardless of where or how they chose to learn, is a vital component of NAU's mission and strategic plan. NAU offers over 100 programs online and across the state in partnership with local community colleges and businesses to meet current and emerging workforce needs. As workforce and market priorities evolve, especially during these unprecedented times, it is imperative that access to relevant higher education programs is available to respond to individual and workforce needs in a delivery format flexible to a variety of life situations that is financially accessible. Nursing and other skilled health professionals continue to be in high demand with an 18 percent growth expected by 2026 (source: Economicmodeling.com). NAU graduated nearly 500 nurses and allied health program students this year.

- The College of Education expanded to meet the behavioral health needs of Arizona by doubling capacity in its programs in school counseling, school psychology and clinical mental health counseling. Enrollment in the Master of Education, School Counseling program grew by 30 percent in fiscal year 2021 and 24 students completed this degree.
- NAU expanded the reach of teacher education programs across Arizona with the support of the Arizona Teachers Academy scholarship and especially in rural Arizona. Enrollment in Early Childhood and Elementary Education programs grew by 5 percent in fiscal year 2021.
- The e-Learning unit was pivotal in the critical transition to the delivery of NAUFlex courses in response to the COVID-19 pandemic. Twenty-seven faculty-focused live workshops were hosted with more than 200 participants.
- NAU continues to leverage its strengths in individualized learning and student support as the university provides access to Arizonians who choose to learn away from the main campus. Aligning services for non-traditional learners, such as expanded advising hours, access to Cline Library 24/7, writing support and career development, have reinforced NAU's commitment to the success of all students, regardless of their learning modality.

ACCESS AND WORKFORCE DEVELOPMENT

NAU continues to build upon more than three decades providing market-driven, high-demand degree programs across Arizona. NAU's TRIF initiative Access and Workforce Development (AWD) supports statewide and online efforts to connect community members to flexible and affordable degrees in the health sciences and education. By infusing cutting-edge instructional technology, adaptive learning and pedagogy, these programs meet both student and employer needs throughout the state. By offering programming tailored for working adults, as well as programs developed in partnership with local community colleges, a growing number of Arizonians have achieved a higher education degree and career success through NAU's workforce-driven programs.

Education and health services remain high demand workforce industries in Arizona. NAU's long history as a teacher's college is honored by this initiative supporting teacher education programming throughout Arizona and online. NAU's nursing programs continue to thrive through Concurrent Enrollment Programs with six community colleges, online and through competency-based programs. AWD also supports the online Health Sciences - Allied Health program with seven focus areas.

GOALS

- Provide affordable quality programs to reach new populations of students through an alignment of workforce needs with academic programming, including an expansion of the pipeline for new health-care professionals and concurrent enrollment programs with community colleges that meet the surrounding needs of the community, region and state.
- Expand competency-based programs and advanced training for high demand health professions.
- Programs to expand the new teacher pipeline for K-12 in local communities throughout the state and continuing education and advanced degree offerings in teacher education.
- Apply e-Learning strategies to increase student access to postsecondary education; transform how faculty teach in this modality; and expand degree offerings.
- Intentional course design for student success with a focus on blended delivery modes and application of adaptive learning technologies for individualization of learning.





Associate Professor Clare Aslan, co-director of the Center for Adaptable Western Landscapes (CAWL), was awarded a \$379,177 grant from the Electric Power Research Institute to study improvements in pollinator habitat and biodiversity in the rights-of-way of Arizona utilities.

WATER, ENVIRONMENTAL AND ENERGY SOLUTIONS

NAU's investments in the WEES initiative focus on two areas: Adapting to a Changing Environment (environmental sciences) and Forest Health and Land Management (forest and land). These programs build on the university's historical strengths in environmental and ecosystem sciences. Investments in these areas have created several important research centers:

- **Center for Ecosystem Science and Society (EcoSS):** EcoSS researchers study the interactions of biological communities to determine how they respond to and influence environmental change. EcoSS prioritizes the training of future scientists and disseminating information about their discoveries to the public.
- **Ecological Restoration Institute (ERI):** Investments in ERI support the development of solutions to the costly environmental problems of degraded forest health and unnatural wildfire. Losses of revenue from decreased tourism, short-term job losses and damage to water supplies and water quality are just a few of the economic impacts that ERI's work seeks to alleviate.
- **Center for Adaptable Western Landscapes (CAWL):** CAWL extends the great legacy of achievement of the Merriam-Powell Center for Environmental Research (MPCER), which was instrumental in advancing cross-disciplinary environmental research and training and the Landscape Conservation Initiative (LCI), which supported applied biological research, collaborative planning and field-based educational experiences to forge new solutions to landscape-scale environmental challenges. CAWL researchers provide strong scientific support to public deliberation and land-management efforts across Arizona. CAWL is positioned for continued success in scientific achievement, collateral benefit for the training and mentoring of students, success in attracting and maintaining significant sponsored projects, producing broad societal benefit and serving western communities.

GOALS

- Advance research to protect one of Arizona's most vital resources – its land – to inform policies and provide tools to support land management, forest health, and environmental and ecosystem sciences.
- Leverage NAU's existing research and intellectual assets to generate external funds.
- Create curricular innovations related to key workforce needs in the state and region.
- Catalyze an entrepreneurial spirit among university faculty and students.
- Build/strengthen partnerships with Arizona environmental and land-management groups.
- Generate new environmental business opportunities and jobs in the region.

SUMMARY OF ACCOMPLISHMENTS

NAU's investments under the TRIF WEES initiative have generated a significant increase in external funding and enhanced capacity for addressing complex issues in environmental variability and ecosystem science as well as forest restoration and land management. Because of this enhanced capacity, NAU researchers have developed innovative solutions to some of the unique environmental challenges of the southwestern United States and beyond.

- NAU faculty who received TRIF funds through the WEES initiative achieved \$3.9 million in new external grant awards in fiscal year 2021.
- Professor Gery Allan was awarded \$1.5 million by the National Science Foundation (NSF) to examine survival strategies that natural systems might use to respond to the combined effects of environmental change and invasive species. The project effort is a collaboration with the Desert Botanical Garden and Arizona State University.
- Regents Professor Michelle Mack received \$850,000 from the NSF to investigate the impacts of wildfire on long-term carbon locked away in Arctic soils.
- Funded through a \$456,652 NSF grant, Regents Professor Ted Schuur installed IonPlus automated radiocarbon instrumentation in NAU's new Arizona Climate and Ecosystems Isotope Lab - one of the only facilities in the world with this instrumentation.
- As part of a five-year agreement, Phoenix-based Salt River Project (SRP) supported several NAU projects through \$446,125 in funding to investigate forest health and restoration, renewable energy sources and increasing diversity in STEM fields:
 - Associate Professor Temuulen "Teki" Sankey is using sensors to measure moisture in the soil as a function of forest thinning and other forest restoration practices.
 - David Huffman, director of research and development at ERI and Professor Andrew Sánchez Meador, executive director of ERI, are testing the effectiveness of mobile laser screening in southwestern forests.
 - Professor Tom Acker, Lecturer Carson Pete and Senior Lecturer Fethiye Ozis are developing a science course focusing on the basics of energy, designed to enroll students from underrepresented minorities and attract them to the energy industry.
 - Associate Professor Sánchez Meador, Huffman and postdoc Jonathon Donager are using laser scanning systems as well as field-based sample designs to assess the loading of coarse woody debris, which contributes to the biodiversity of forest ecosystems.
- Professor Han-Sup Han, ERI director of forest operations and biomass utilization, received \$350,000 from the U.S. Department of Commerce to create the Forest Operations Training Center, which will provide training opportunities for forest equipment operators, log truck drivers and heavy equipment mechanics.

Scholarly Publications

- WEES researchers are highly regarded in their field, as evidenced by significant publications in some of the most prestigious journals in science, including Nature, Science, Proceedings of the National Academy of Sciences, Nature Communications, Environmental Research Letters and Nature Ecology and Evolution.



SPACE EXPLORATION AND OPTICAL SOLUTIONS

NAU's investments in the SPACE initiative focus on three areas - solar system origins, Mars and exoplanets. These programs build on NAU's historical strengths in astronomy and planetary science, leveraging partnerships with institutions across Arizona and beyond that provide access to an abundance of world-class telescopes, observatories and state-of-the-art imaging systems.

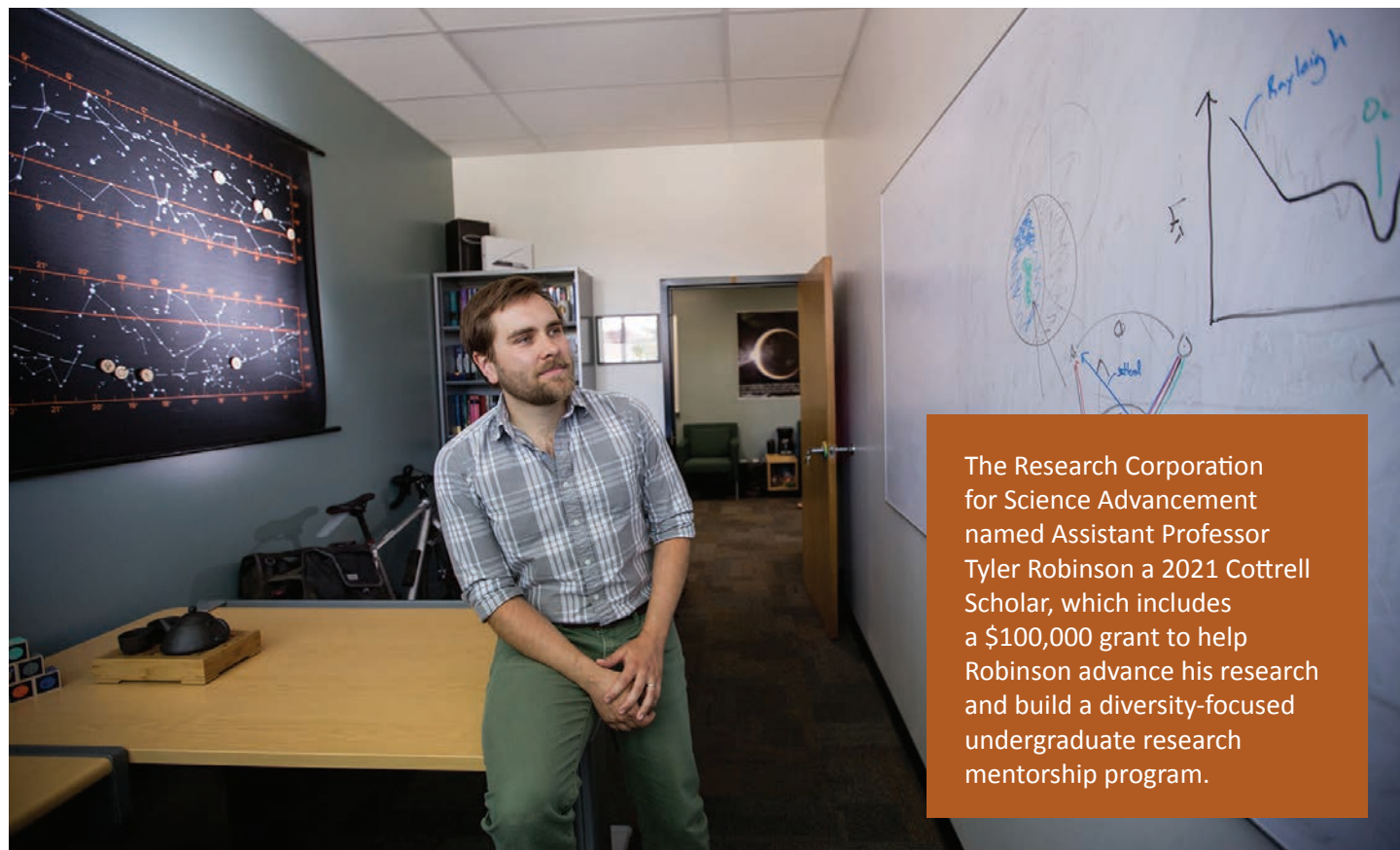
Solar system origins: Thrust area researchers study the formation and evolution of the solar system, detecting and characterizing the properties of rocky asteroids that could potentially impact the Earth. They are looking for the elusive "Planet X," a large undiscovered planet in the most distant regions of the solar system, and are studying objects in the Kuiper Belt, a vast region of comets and other icy objects beyond the orbit of Neptune.

Mars: Researchers use spacecraft data to study the geology of the Red Planet while hunting for water and life on its surface. Faculty and students direct the path and daily tasks of the NASA Curiosity Rover on the surface of Mars, build flight instruments for spacecraft bound for Mars and make important contributions to spaceflight missions.

Exoplanets: Thrust researchers study planets orbiting distant stars using telescopes and computer simulations to characterize their physical and chemical properties with the goal of identifying which of the thousands of known exoplanets are the best candidates to harbor life and therefore merit further study.

GOALS

- Double external research funding in astronomy and planetary science.
- Partner with Arizona companies to develop instrumentation for shoebox sized spacecraft (CubeSats).
- Fly a CubeSat to an extraterrestrial object, such as an asteroid.
- Expand partnerships with private observatories such as Lowell Observatory, FROST, UKIRT and ATLAS.
- Build and/or operate small telescopes such as FROST and ATLAS to detect potentially hazardous near-Earth asteroids.
- Continue to operate and expand the capabilities of the Astrophysical Ice Laboratory on the NAU campus.



The Research Corporation for Science Advancement named Assistant Professor Tyler Robinson a 2021 Cottrell Scholar, which includes a \$100,000 grant to help Robinson advance his research and build a diversity-focused undergraduate research mentorship program.



SUMMARY OF ACCOMPLISHMENTS

At 7,000 feet above sea level, Flagstaff is the world's first International Dark Sky City, a natural location for studying astronomy and planetary sciences. Through TRIF investment in the Exploring Planetary Systems research initiative, NAU is developing unique and cutting-edge research and academic programs in solar system origins, Mars and exoplanet research. TRIF investment enables NAU to expand its partnerships with Lowell Observatory and the U.S. Naval Observatory, and provides access to highly sought-after telescopes such as the Discovery Channel Telescope and the Flagstaff Robotic Survey Telescope. NAU researchers leverage TRIF support with external funding to discover new ways of exploring space, contribute to a new understanding of our place in the universe and seek opportunities to translate research into economically productive innovations with commercial applications.

- NAU faculty who received TRIF funds through the SPACE initiative achieved \$1 million in new external grant awards in fiscal year 2021.
- Assistant Professor Cristina Thomas was awarded grants totaling \$431,000 by NASA to study two different types of asteroids, which will help scientists better understand the origins of asteroids.
- Through \$349,000 in funding from NASA, Associate Professor Gerrick Lindberg is collaborating with Lowell Observatory on a study of Saturn's moon Titan in preparation for the 2026 Dragonfly mission.
- NASA recognized Assistant Research Professor Alicia Rutledge as one of only five early-career scientists in the country to receive funding through its Planetary Science Early Career Award. Assistant Research Professor Rutledge will use the \$200,000 award for a portable field laboratory.
- Anna Engle, Ari Koeppel and Anthony Maue, students in NAU's Astronomy and Planetary Science doctoral program, were awarded grants through the Future Investigators in NASA Earth and Space Science and Technology program. The funding—up to \$135,000 total per student for up to three years - supports graduate student-designed research projects in Earth sciences, heliophysics, planetary science and astrophysics.
- Associate Professor Chad Trujillo is on a team of astronomers confirming the orbit of a planetoid that is almost four times farther from the Sun than Pluto, making it the most distant object ever observed in our solar system. The Minor Planet Center has now given it the official designation of 2018 AG37.
- Associate Professor Christopher Edwards collaborated on the first mission ever launched by the Arab world into our solar system, a space probe to Mars that carried an instrument he co-designed in collaboration with engineers from the United Arab Emirates Mohammed bin Rashid Space Centre and Arizona State University.

HIGHLIGHTS

Students bring their aspirations to NAU to learn, grow and achieve academic success that will ultimately lead to fulfilling lives. Faculty researchers are always aspiring, too — to solve the most compelling problems, to meet the most complex challenges, and to boldly explore the next frontiers of knowledge. NAU continues to generate impressive research outcomes, and TRIF funding is a strong mainstay, enabling NAU to make strategic investments that promise to sustain this growth well into the future.

TRIF funding has provided the foundation for NAU to attract new external research funding, increase capability to develop inventions with high potential for technology transfer and strategically invest in workforce development. These accomplishments enhance Arizona's research enterprise and reputation while addressing critical issues facing the world today in the areas of health care, defense and security, land and water management, and space exploration. Strategic investments in high research faculty, laboratory infrastructure, research centers and new graduate programs have enabled NAU to make significant financial impact progress, generating technology transfer activity that includes invention disclosures, patents issued, and licenses and options.

TRIF resources have enhanced NAU's educational infrastructure and capability to prepare its students to be complex problem solvers, addressing the workforce needs of today and an increasingly diversified workforce for the future. These investments develop new talent as demonstrated by the increasing number of NAU graduates who are staying in Arizona to live and work after graduation, as well as the attraction of new talent to Arizona to study, teach and conduct research.

NAU is expanding its student-centered educational mission to better serve Arizona, increasing its outreach and commitment to welcome a quickly growing and more diverse population by offering more targeted opportunities for first-generation students as well as Hispanic and Native American students, even while improving retention and graduation rates among all students. Through competitive, externally funded grants, research remains a significant growth engine for NAU that supports the university's mission. At the same time, the research projects faculty lead continue to offer a significant pathway for intellectual growth of students, providing learning opportunities that enable students to secure better jobs, generating economic growth for communities and improving the lives of Arizona's citizens.

NAU's TRIF initiative in Access and Workforce Development supports high demand degree delivery online and in-person across Arizona. By providing alternatives to time- and place-bound adult students who are unable to attend the residential campus, this initiative provides access to degree programs, certificates and continuing education programs that meet workforce needs within local communities. NAU advanced this effort in-person in partnership across Arizona at community colleges, online and through the competency-based Personalized Learning program. The COVID-19 pandemic impacted instructional delivery for nearly every course offered by NAU during fiscal year 2021. NAU faculty worked closely with the university's TRIF-funded team of instructional designers to adapt and deliver courses from traditional in-person classes to synchronous or asynchronous learning experiences to support student progression throughout the pandemic.





UNIVERSITY OF ARIZONA

As the state's oldest Research 1 institution and its designated land-grant university, the University of Arizona prepares students to be leaders in tomorrow's workforce, contributes as one of the largest economic engines in Arizona and creates impactful solutions to complex, regional and global challenges. With more than \$760 million in research expenditures in fiscal year 2020, UArizona pursues and produces results that drive innovation and transform lives for people in the university's backyard and around the world.

UArizona does this first and foremost by enabling cutting-edge research and development, including the provision of support for infrastructure, facilities and computing; producing results that leverage the university's unparalleled expertise; and attracting outside resources and talent to the state. UArizona is meeting the challenges of the future with bold thinking under the visionary framework of the Fourth Industrial Revolution.

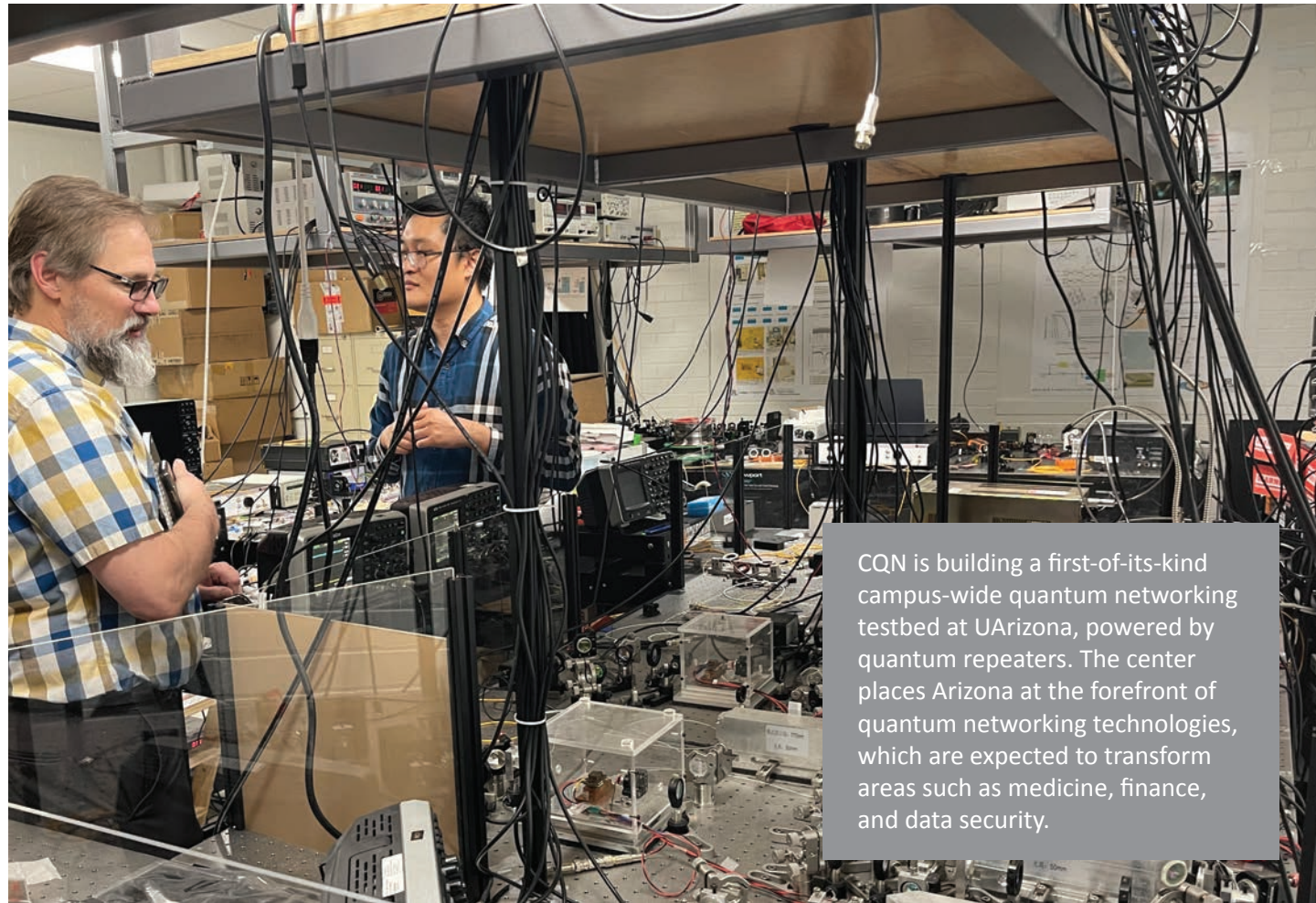
UArizona participates in the following TRIF initiatives:

- **Improving Health:** The global pandemic has accelerated the need for multidisciplinary solutions and nimble thinkers. UArizona has in place expansive infrastructure, state-of-the-art technology and world-renowned faculty to meet today's challenges. TRIF investments allow the BIO5 Institute — which aims to harness the power of its five disciplines (agriculture, engineering, medicine, pharmacy and science) — to connect and mobilize hundreds of world-class plant, animal and human bioscientists, engineers, physicians and computational researchers to develop creative solutions for complex challenges such as disease, hunger, water and food safety, and other environmental issues facing Arizona in both rural and urban areas.
- **Water, Environmental and Energy Solutions:** UArizona is ranked as the nation's No. 1 program in water resources by the Shanghai Academic Ranking of World Universities, recognizing outstanding leadership in water research. WEES leverages TRIF investments to spur transdisciplinary food, energy and water research and innovative public and private partnerships that promote effective mitigation strategies and resilience necessary to sustain a swelling global population. By investing in robust, leading-edge research programs, including wastewater-based epidemiology and identification of emerging contaminants in groundwater, UArizona makes the state a safer, healthier place to live, now and in the future.
- **National Security Systems:** Located near defense installations and industry partners such as Raytheon and Lockheed Martin, researchers at UArizona seek effective, efficient solutions to national security challenges. UArizona's National Security Systems initiative comprises a range of technology and research at the university — from advanced optical technologies for creating highly sensitive sensors to hypersonic systems, to the emerging and increasingly critical area of space domain awareness — and promotes collaboration, innovation, and research and development to support Arizona's high-tech economy.
- **Space Exploration and Optical Solutions:** UArizona continues as an international research powerhouse in both space science and optics. Not only does the campus sit at the center of "Optics Valley" — a high concentration of optics companies and research in Southern Arizona — but it also has led space system development since the inception of the U.S. space program in 1958. UArizona recently leveraged the university's expertise by forming the University of Arizona Space Institute and continue to fund new programs, establish new facilities and launch successful start-up companies in the areas of SEOS.
- **Access and Workforce Development:** Through efforts to develop the technically skilled and innovative workforce necessary to meet the state's growing industry demands, UArizona is creating clear pathways for students to gain research opportunities and other relevant experiences to become field experts and future leaders. Through this initiative, UArizona is prioritizing the opportunities and experiences of students who have historically had limited access, seeking to create a more diverse, inclusive workforce.



"At the University of Arizona, our researchers are resilient, entrepreneurial and solution-focused, translating knowledge and discovery into real, tangible benefits for Arizonans and people across the globe. With a focus on the health and prosperity of the state, TRIF enables our faculty and students to tackle increasingly complex challenges that require adaptive problem solving, and TRIF has helped position UArizona as a critical resource for novel ideas in times of normality as well as crisis. With the addition of the Access and Workforce Development initiative, we are taking investment in a capable, flourishing workforce to the next level, exposing students — particularly those who have had limited access — to the highest quality research and career training."

— Dr. Elizabeth Cantwell, Senior Vice President, Research and Innovation, The University of Arizona



CQN is building a first-of-its-kind campus-wide quantum networking testbed at UArizona, powered by quantum repeaters. The center places Arizona at the forefront of quantum networking technologies, which are expected to transform areas such as medicine, finance, and data security.

SPACE EXPLORATION AND OPTICAL SOLUTIONS

TRIF funding has been critical in building and maintaining UArizona’s excellence in space exploration and optical sciences. The Space Exploration and Optical Sciences initiative leverages the university’s expertise and resources to catalyze innovative, high-impact research; drive regional economic development and entrepreneurship; and provide experiential learning to students to expand the state’s high-tech workforce.

SEOS has been successful in creating newly funded “big science and engineering” programs, establishing new research facilities, stimulating innovation and initiating successful startup companies, employing intellectual property, and enhancing outreach to underrepresented populations in Arizona and technology transfer to local companies.

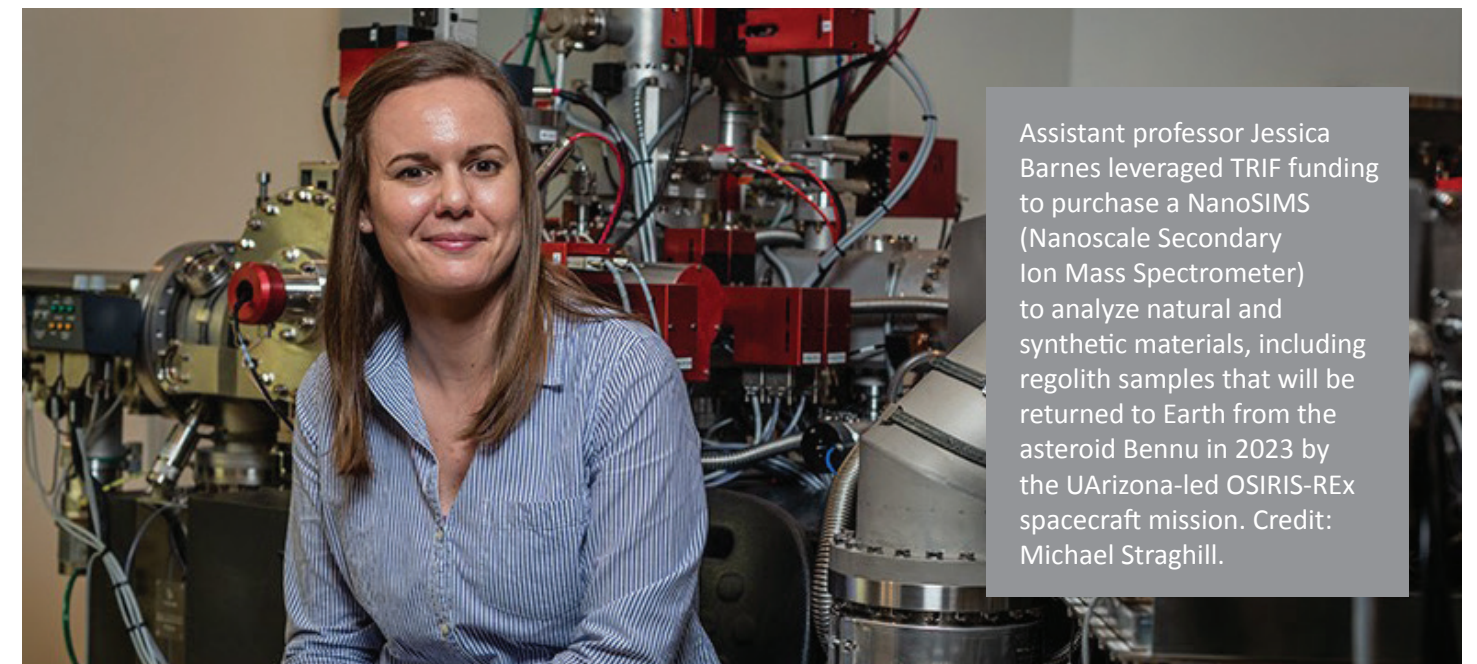
The university has led the nation’s universities in space sciences each year for the past two decades with TRIF. For example, TRIF enables projects to analyze a sample from asteroid Bennu upon its return to Earth. Additionally, TRIF investments empowered both the university and the state into a leadership role in the exploding field and future economy of Quantum Information Science & Engineering (QISE).

GOALS

- Leveraging TRIF funds to obtain more than a ten-fold return on investment through increased external research funding, directly impacting Arizona’s economy.
- Making key faculty hires in optics, engineering and space to support new research areas and more students.
- Creating new photonics and imaging infrastructure and facilities to support defense/security, medical and industrial research to help the U.S. remain competitive.
- Enhancing Arizona’s diverse workforce development directly through increased student support as well as outreach to companies and underrepresented populations in Arizona.
- Encouraging technology transfer and innovation activities, creating new Arizona startup companies with UArizona developed intellectual property to directly impact Arizona’s economy.

SELECTED ACCOMPLISHMENTS

- Based on groundwork laid with TRIF funding, UArizona received an initial, five-year, \$26 million grant from the National Science Foundation with an additional five-year, \$24.6 million option to establish and lead a new National Science Foundation Engineering Research Center — the Center for Quantum Networks (CQN) — with core partners - Harvard University, the Massachusetts Institute of Technology and Yale University. CQN aims to lay the foundations of the quantum internet, which will revolutionize how humankind computes, communicates and senses the world.
- NASA selected for further study the \$20 million Aspera mission, led by a postdoctoral researcher and his UArizona team, several of whom were funded by TRIF. The mission would launch an ultraviolet telescope to study processes in galaxies that can’t be seen from the ground when observing through Earth’s atmosphere.
- UArizona established the University of Arizona Space Institute (UASI), in part with funding from TRIF, to support design development and proposal preparation for spacecraft missions and instruments and to diversify the university’s roster of potential leaders of such projects. In its first year, UASI supported efforts led by 14 individuals, including four women and two underrepresented minorities, resulting in proposals that would bring at least \$10 million of work each to UArizona. Four such proposals, including the aforementioned Aspera, have been submitted.
- TRIF-leveraged funding led to a \$2.4 million grant from the Gordon and Betty Moore Foundation and a \$1.5 million gift from a private donor to purchase a Nanoscale Secondary Ion Mass Spectrometer (NanoSIMS). The NanoSIMS will be used to analyze natural and synthetic materials, including regolith samples that will be returned to Earth from the asteroid Bennu in 2023 by the UArizona-led OSIRIS-REx spacecraft mission. In addition, the NanoSIMS will be a training ground for the next generation of aspiring sample scientists at UArizona.
- The James C. Wyant College of Optical Sciences leveraged funding in fiscal years 2017-2021 from AIM Photonics for matching support that has totaled nearly \$5 million, supporting research in advanced photonic integrated circuit manufacturing technology and applications needed to maintain and build the companies in Southern Arizona that lead to its reputation as “Optics Valley.”
- A TRIF award for “Sustainable Growth of the Cloud” (jointly funded by both SEOS and WEES) in 2018 was critical for establishing a relationship with Microsoft Corporation Cloud Infrastructure that has led to further funding in fiscal year 2021. Data centers — centralized locations for storing servers and computing and networking equipment — make cloud computing possible but require water and energy to operate. This partnership with Microsoft has led to a multidisciplinary group designed to tackle solar-powered water purification and other solutions to make data centers more efficient and less energy reliant.
- Two TRIF-supported astrobiology researchers led teams that each obtained a NASA grant of approximately \$6 million in the initial competition for Interdisciplinary Consortia for Astrobiology Research. UArizona is the only institution to lead more than one of the eight consortia selected. The two teams aim to advance our fundamental understanding of early Earth biology and biogeochemistry and explore which nearby planets outside our solar system may be suitable for hosting life.
- TRIF continues to provide a significant fraction of the support for the world-class telescopes that UArizona operates or partners in, such as the Giant Magellan Telescope, and has supported dozens of undergraduate and graduate students in laboratories, as well as opportunities for community college and high school students.



Assistant professor Jessica Barnes leveraged TRIF funding to purchase a NanoSIMS (Nanoscale Secondary Ion Mass Spectrometer) to analyze natural and synthetic materials, including regolith samples that will be returned to Earth from the asteroid Bennu in 2023 by the UArizona-led OSIRIS-REx spacecraft mission. Credit: Michael Straghill.

The TRIF-seeded WEST center initiated the UA2020 Wastewater-Based Epidemiology program that monitored campus dormitory wastewater for SARS-CoV-2 during the coronavirus pandemic.



SELECTED ACCOMPLISHMENTS

- The TRIF-seeded Water & Energy Sustainable Technology (WEST) center initiated the UA2020 Wastewater-Based Epidemiology program that monitored campus dormitory wastewater for SARS-CoV-2 during the coronavirus pandemic. Clinical testing of students in dormitories where the virus was detected in wastewater enabled early detection of symptomatic and asymptomatic cases, reducing exponential spread of COVID-19.
- TRIF funding led to a \$700,000 Department of Energy (DOE) grant that will develop a new technique for fabricating or printing perovskite solar cells that could lead to significantly reduced costs for solar energy. A related \$750,000 Office of Naval Research grant will launch a new program to mentor and train students from underrepresented backgrounds in the field of printable electronics.
- TRIF supported a partnership between UArizona and Sixth-World Solutions (SWS), a Navajo-owned company, to install water collection systems in remote areas of the Navajo Nation. To date, the partners have trained SWS technicians in solar-nanofiltration system design and construction, constructed four household-scale systems, and organized a program to increase resident acceptance of such systems based on community participation. UArizona researchers are training the SWS team to be fully capable of replicating designs and operating/maintaining built systems in the field, furthering water security and resilience in remote areas.
- UArizona researchers developed and published the first mathematical model for quantifying poly- and perfluoroalkyl substances (PFAS), environmentally durable chemicals that leach through soils to groundwater aquifers. Some studies in humans have shown that certain PFAS may affect growth, learning and behavior of infants and children, interfere with the body's natural hormones and increase the risk of cancer, among other potential effects. The model will allow stakeholders, including Tucson Water partners, to better characterize, manage and mitigate PFAS contamination risks to groundwater resources. Results from the TRIF-funded work led to a \$1.3 million grant from the Department of Defense to study PFAS contamination in soils at the Davis Monthan Air Force Base with applications for other military sites.
- An interdisciplinary team investigated the overlapping impacts of the COVID-19 pandemic and climate events on local food producers, distributors, processors and restaurants in southern Arizona's food system, as well as their responses to these impacts. The results shed light on how local food systems pivot in moments of crisis and identify the factors and best practices that can strengthen this system into the future.
- Researchers identified concentrated sources of dust pollution along Interstate 10 that can immediately inform Arizona agencies on future investments in early warning dust systems and dust mitigation. The new index of dust risk will allow the National Resources Conservation Service, Arizona Department of Transportation, Arizona State Land Department and other partners to quickly identify hot spots of dust pollution and dust storms that can present significant health and transportation hazards. The researchers also developed a new combination of microbes and native plant seeds to rapidly colonize and stabilize the dust-prone soils, providing a long-lasting solution for dust reduction.
- In partnership with DOE and the BHP mining company, the Center for Environmentally Sustainable Mining filed a provisional patent for a new technology to tackle increasing amounts of naturally occurring but harmful uranium in groundwater. This technology enables the remediation of contaminated resources to benefit and expand Arizona's economy by providing clean water and generating metals critical to national security and clean energy technology.
- A \$113,000 TRIF investment resulted in \$1.8 million in new funding to date from NASA, the U.S. Department of Agriculture and DOE, supporting the development of a combination of satellite observations, field data and ecosystem process models to understand and predict how the productivity of dry lands and other ecosystems may change under rising atmospheric carbon dioxide and climate and land use changes. These findings will help farmers, ranchers and land managers prepare for and adapt to future conditions.

WATER, ENVIRONMENTAL AND ENERGY SOLUTIONS

The Water, Environmental and Energy Solutions TRIF initiative is developing innovative, practical solutions for water, environmental and energy sustainability in Arizona. Research findings are applied globally, as many other semiarid regions face increasing natural resource demands and uncertainties related to drought and extreme events. Strategic investment shapes innovative research and brings federal dollars to Arizona, and projects help secure adequate supplies of clean water for the state, optimize sustainable stewardship of the state's lands, create resiliency in the face of climate variability and advance Arizona's leadership in the renewable energy industry.

GOALS

- **Build on UArizona's world-renowned expertise in water and climate variability and its emerging excellence in the renewable energy sector to enhance multidisciplinary collaboration for science, technology and resource management.**
- **Focus on use-inspired research performed by multidisciplinary teams that will result in innovative, practical solutions for Arizona and beyond.**
- **Leverage TRIF investment in strategic areas to increase public and private funding and commercialization of research results in technology and industry.**
- **Train a new generation of scientists, engineers and other professionals to meet state and national needs.**



UArizona and Sixth-World Solutions (SWS), a Navajo-owned company, partnered to install water collection systems in remote areas of the Navajo Nation.

IMPROVING HEALTH

The Improving Health TRIF funding, which helped launch the BIO5 Institute in 2001, continues to drive scientific discovery and innovation 20 years later. Research and education focus on advancing basic biology, developing technology, translating research outcomes to the clinic and marketplace, and facilitating engaged training to prepare our future workforce.

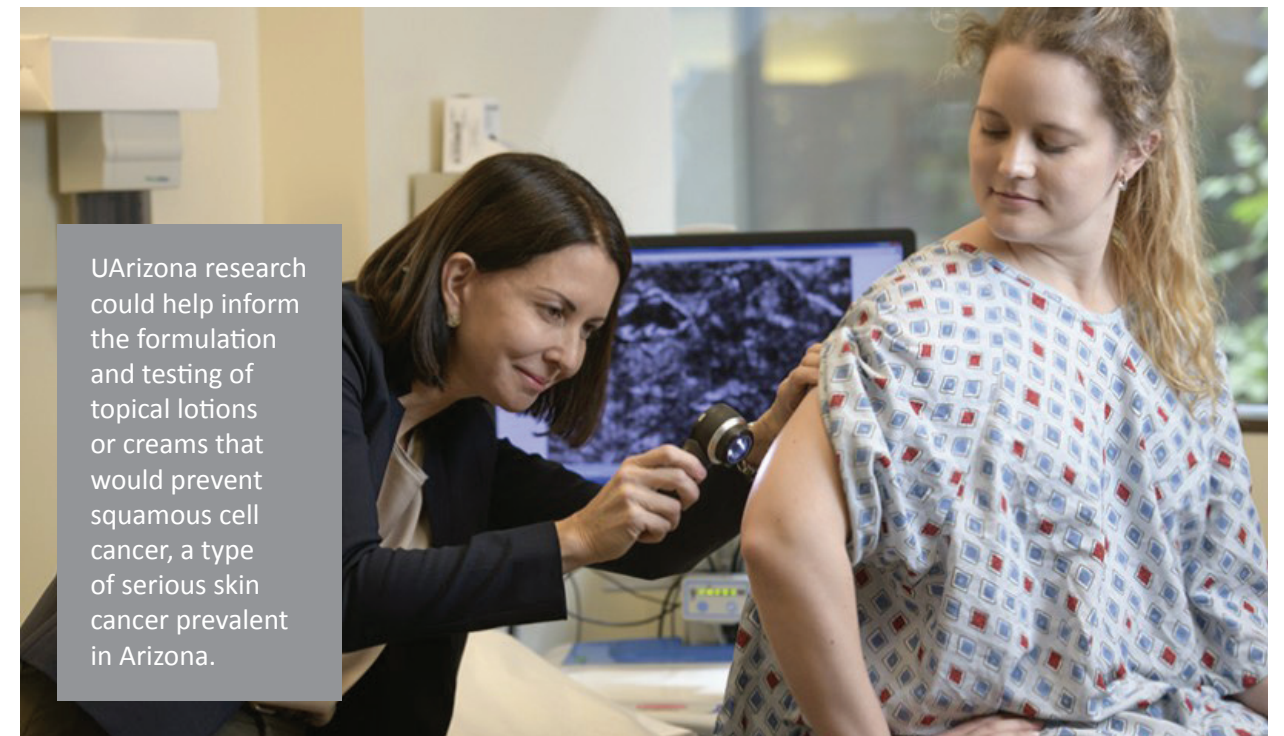
BIO5 connects and mobilizes top scientific minds from disciplines across campus to develop bold solutions for complex biological challenges, including aging, disease, hunger, and water and food sustainability. This approach has enabled promising scientific advancements related to Alzheimer's disease and dementia; progress in preventing and curing asthma and other lung diseases; novel sensing technology that helps inform precision medicine; one-of-a-kind programs to train the next generation of bioscientists; and economic opportunity, all of which impact the lives and resiliency of Arizonans.

GOALS

- Foster collaborative projects that address major challenges in the biosciences, biomedicine and biotechnology, and forge significant progress on novel solutions for asthma, cancer, Valley Fever, diabetes, sudden cardiac death, malnutrition, infectious disease, Alzheimer's and other age-related brain diseases, and other public health crises.
- Strengthen and expand translational research by recruiting, retaining and supporting innovative faculty and teams with world-class facilities, equipment, support resources, grants and other financial assistance. This includes an innovative seed grant program that fosters creativity and high risk, high reward research for interdisciplinary teams. The results of these grants lead to external grant dollars to Arizona, intellectual property and continued improved health for Arizonans.
- Engage and train future generations of scientists by maintaining successful outreach and internship programs to promote experiential learning and STEM proficiency, contributing to the Arizona economy through workforce development.
- Promote an entrepreneurial culture in which scientists contribute to the economy of Arizona through workforce development, technology transfer, partnerships with industry, and the creation of new services and companies in Arizona.



Researchers received a \$5.7M grant to prepare for clinical trials of a novel peptide therapy to treat vascular cognitive impairment and dementia, the second most common form of dementia after Alzheimer's disease.



UArizona research could help inform the formulation and testing of topical lotions or creams that would prevent squamous cell cancer, a type of serious skin cancer prevalent in Arizona.

SELECTED ACCOMPLISHMENTS

- TRIF funding enabled numerous efforts to tackle COVID-19, including contributions to the Arizona COVID-19 Genomics Union statewide collaboration to sequence and analyze SARS-CoV-2 genomes from across Arizona, and the rolling out of the saline gargle direct PCR test (requiring no lengthy and costly RNA extraction step) as the main, highly successful testing modality at UArizona with tens of thousands of tests completed.
- A cross-disciplinary UArizona team determined the role for a biomarker of obstructive lung diseases like asthma and COPD, leading to a \$2.5 million National Institutes of Health (NIH) R01 grant and the publication of their field-shifting findings. This work will contribute to the development of novel therapeutics to help prevent and mediate these diseases, which affect more than 47,000 children and one million adults in Arizona.
- TRIF support led to a \$5.7 million grant from the National Institute on Aging to prepare for clinical trials of a novel peptide therapy to treat vascular cognitive impairment and dementia, the second most common form of dementia after Alzheimer's disease. To date, the U.S. Food and Drug Administration has not approved any drugs that specifically treat vascular dementia, which involves cognitive impairment caused by injuries - often stroke related - to the vessels supplying blood to the brain.
- A UArizona researcher was named one of 11 lead investigators for the National Institutes of Health Community Engagement Alliance Against COVID-19 Disparities. American Indian, African American, Hispanic and Latino people are disproportionately affected by COVID-19, experiencing higher rates of illness and death. The Community Engagement Alliance program aims to build trust, increase awareness and education, and promote clinical trial inclusion among these vulnerable populations to ultimately reduce their disease burden.
- UArizona research found that a novel, genetically engineered T cell can target and attack pathogenic T cells that cause Type 1 diabetes with potential for new immunotherapy treatments. More than 10 percent of Arizonans were diagnosed with diabetes in 2020, and an estimated one in three adults in the state has pre-diabetes.
- Graduates of the inaugural and interdisciplinary class, Designing Drugs: From Chemistry to Cure, conceived and launched the startup, Cliacept, Inc., after learning about both the science that powers drug discovery and the business side that keeps it afloat. The company aims to develop an antibody to treat Alzheimer's disease by mitigating neuroinflammation in the brain.
- A UArizona research lab received a \$1.8 million award from the National Institute of General Medical Sciences to advance a one-of-a-kind device that senses tiny amounts - down to a single molecule - of everything from doping agents to biomarkers for cancer, Alzheimer's disease, Lyme disease and COVID-19. The technology has several advantages over prevailing sensing methods, and the research team is working to miniaturize the system so it's portable and easier to use; for example, detect contaminants in water, find trace amounts of disease, and test air quality.
- TRIF support led to a \$6.9 million grant from the National Cancer Institute to study TLR4, a cellular receptor of the immune system that could help inform the formulation and testing of topical lotions or creams that would prevent squamous cell cancer, a type of serious skin cancer prevalent in Arizona.



UArizona undergraduate students built telescopes now deployed at Biosphere 2 to track satellites and space junk. Undergraduate and graduate students operate the SDA observatory complex at Biosphere 2, gaining extensive hands-on training.

NATIONAL SECURITY SYSTEMS

The TRIF National Security Systems initiative aims to advance access and workforce development opportunities for Arizona defense industries; provide experiential learning and research opportunities to students seeking careers in the defense industry; expand Arizona's deep contributions to the national security sector; enhance partnerships with appropriate defense industrial base companies in the state; support regional economic development; and create and maintain advanced research and development infrastructure to provide fundamental research capabilities for national security.

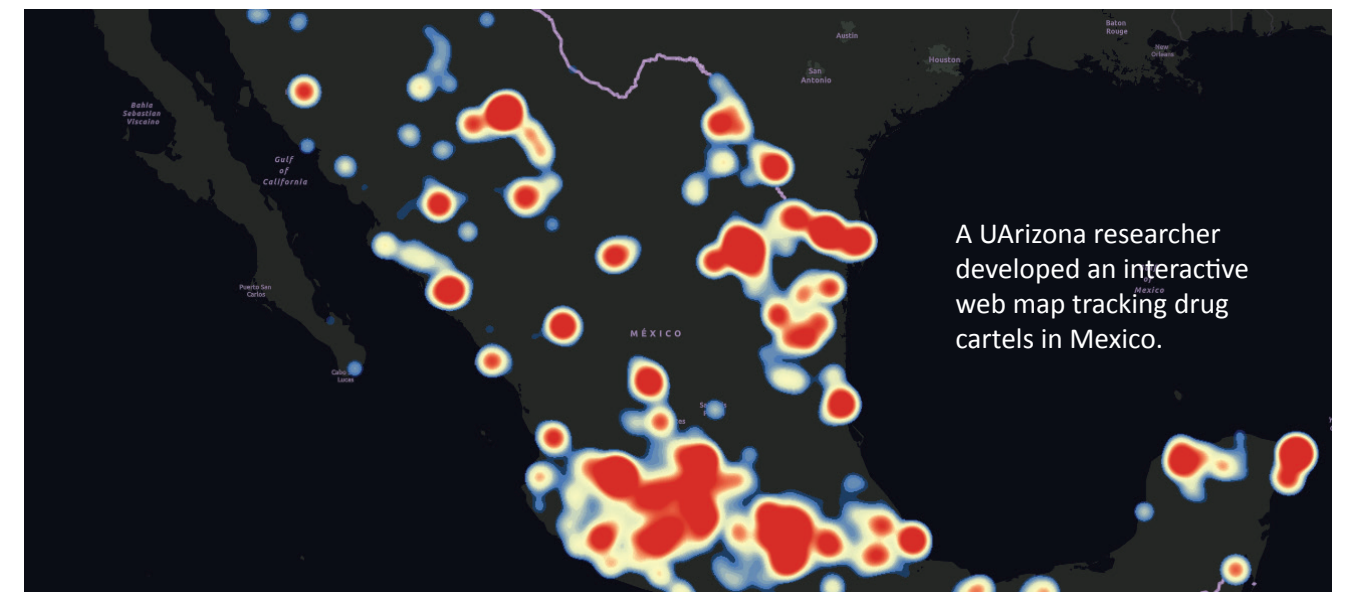
NSS delivers innovative concepts, broadens the technical agility of the defense sector, stimulates technology transfer particularly in dual use technologies, and creates new intellectual property for the university. While engaging in cutting-edge, strategic research, faculty are proving themselves thought leaders in the national security realm, winning awards and honors, publishing widely, training students and forging partnerships that help spur Arizona's economy and technology standing.

GOALS

- Increase external U.S. Department of Defense and private-sector research and development funding to scale capacity.
- Strengthen and expand defense- and security-related research by recruiting the best and brightest faculty to Arizona and supporting projects that will advance the development of new technologies and products to aid in securing our national interest.
- Support workforce development directly through student research teaming experiences in partnership with defense agencies, UArizona and industry.
- Set the stage for innovation and commercialization of research results by spawning invention disclosures that will support future licensing and spinout companies.

SELECTED ACCOMPLISHMENTS

- Orbital space around Earth is congested, contested and competitive with space debris posing a potential threat to spacecraft. Space Domain Awareness (SDA) involves detecting, tracking, cataloging and identifying objects in orbit, including satellites and other artificial objects. TRIF investment has supported UArizona expertise in this national security area, helping to position the SDA research program toward winning a \$7.5 million award from the U.S. Air Force Research Laboratory (AFRL).
 - The new SDA observatory complex at Biosphere 2 — the largest run by an academic institution in the U.S. — includes the Stingray network, which will perform persistent measurements of astronomical objects in the Geostationary belt, home to communications, weather and navigation satellites. UArizona researchers have deployed cyberinfrastructure specifically designed for SDA and are connecting it to the observatory at Biosphere 2.
 - Researchers are developing the first academic catalog for XGEO (the area between geostationary orbit, around 22,000 miles above Earth's equator and the moon) and are currently tracking 168 objects in this cislunar space. The cislunar area is poorly cataloged and important to better understand lunar conditions and activity around the moon.
 - Researchers are working with the U.S. Air Force and the U.S. Space Force to develop short executive courses designed to train their personnel using the SDA observatory, with potential to bring direct economic benefit to Pinal County.
 - SDA researchers worked with high school students from Catalina High School, with support from local Tucson small businesses, which provide industrial and small business experiences. One student from Oro Valley High School also is participating in SDA work at UArizona.
- A \$200,000 grant from Raytheon and a \$1.5 million grant from the University Consortium for Hypersonics, in partnership with Raytheon, are enabling research to investigate cooling mechanisms for hypersonic vehicles and multi-fidelity approaches for hypersonics, respectively.
- TRIF support helped researchers obtain a \$185,000 National Science Foundation award to advance work on industrial control systems security and 5G network security. This NSF award recognizes the need to protect and preserve the societal and economic benefits of cyber systems while ensuring our security and privacy.
- TRIF support resulted in an interactive web map tracking drug cartels in Mexico and improved interactive web maps tracking different types of armed actors in Colombia.
- The NSS initiative supported a number of other undergraduate students — including community college transfers who are now studying cutting-edge techniques in hypersonics — and graduate students through mentoring opportunities such as the Women in Science and Engineering program and the N2Women program. Another student was awarded a GEM Fellowship, which supports underrepresented groups at the master's and doctoral levels in engineering and science. The student also was selected for an internship at Lawrence Livermore National Laboratory.
- Presenting on research to support 3D printing of moon dust, a UArizona doctoral student won first place in the ASCEND Propel Pitch Competition organized by Lockheed Martin at the 2020 American Institute of Aeronautics and Astronautics ASCEND conference. Related to that work, an undergraduate student engaged in diverse research skills, including materials formulation and preparation, 3D printing process operation and control, and manufacturing of viable components out of lunar materials.



A UArizona researcher developed an interactive web map tracking drug cartels in Mexico.

HIGHLIGHTS

Researchers and innovators at UArizona are determined to make a difference, bringing continued action and impact to the state in fiscal year 2021 and setting the stage for further growth. With overall TRIF expenditures of \$29.2 million, UArizona's calculated financial impact (sponsored awards, gifts and other sources and royalty income) of these investments was more than \$226 million, well over the expected projections of \$193.6 million.

During fiscal year 2021, a year of continuing COVID-19 crisis, TRIF investment in cutting-edge research and novel ideas propelled the well-being of society forward.

TRIF-funded COVID-19 response seed grants through the BIOS Institute enabled teams of multidisciplinary researchers to tackle the coronavirus crisis. Just one of those grants, for example, allowed Michael Worobey and his collaborators to sequence the complete genomes of more than 30 SARS-CoV-2 viruses, illuminating what viral variants were circulating on the UArizona campus, and contributed to UArizona's innovation of the saline gargle PCR testing method, which was found to be more sensitive than the gold standard nasopharyngeal-swab PCR test and saliva testing — and much more tolerable to those tested — among other advances.

The Water & Energy Sustainable Technology Center monitored campus dormitory wastewater for novel coronavirus during the pandemic. This work contributed to efforts to keep campus open throughout the fall semester and resulted in Yuma County implementing a similar testing program in 2021.

Working within COVID-19 health and safety guidelines, UArizona faculty continued to combine their TRIF-supported expertise with specialized student training. Vishnu Reddy and Roberto Furfaro - world-renowned researchers in space domain awareness who identify, catalog and characterize objects in space, including those that may pose a threat to spacecraft - have finished the construction and commissioning of the nation's largest SDA observatory complex operated by an academic institution. Undergraduate and graduate students operate the facility at Biosphere 2, and students have gained extensive hands-on training on SDA and artificial intelligence applied to space systems for real-life problems.


While all of the TRIF initiatives incorporate strong student training and workforce development components, UArizona made a targeted TRIF investment in fiscal year 2021 to support students, particularly those who are underrepresented, in entering a high-tech, research workforce pipeline. Under this new Access and Workforce Development initiative, UArizona is developing a course-based undergraduate research (CURE) curriculum in introductory STEM lab classes and general education CURE courses to increase success rates of Hispanic and other low-income students in STEM majors.

Tech Launch Arizona, UArizona's commercialization arm, received 148 invention disclosures in fiscal year 2021, 26 more than the previous year. TLA also executed 46 licenses and options for university inventions (more than in fiscal year 2020) and saw 73 patents issued (30 more than the previous year). Additionally, the university launched four TRIF-supported startups, bringing inventions to the world for public benefit, creating jobs and growing economic impact.

One invention — a trifocal intraocular lens developed by James Schwiegerling — earned \$6 million in royalties in fiscal year 2021. Working with TLA, the university licensed the innovative technology to global medical device company Alcon. The novel lens, PanOptix, is now helping over 500,000 cataract patients worldwide see better, including Schwiegerling himself.

UArizona continued to benefit from other forms of TRIF investment over the years, with personnel and infrastructure in place to rapidly address the evolving pandemic. The dynamic Research Restart Plan, designed by the Office of Research, Innovation and Impact in March 2020, enabled the smooth ramp up of laboratory research and activity amid COVID-19.

Looking forward, the next cycle of TRIF investment will enable the university to position Arizona as "The Resilient State," capable of dealing with any threat and successfully operating through any challenge. Through TRIF, UArizona will help create an agile state economy; produce a workforce that stays in Arizona; support a healthy entrepreneurial ecosystem; and continue to develop the technical prowess, innovation and discovery contained within UArizona to deliver positive impacts and solutions for the well-being of Arizonans.



An intraocular lens (shown above) offers a solution to cataracts, which cloud vision with aging. However, it doesn't allow recipients to see at all distances. Trifocal intraocular lenses, on the other hand, provide vision at near, far and in-between distances, eliminating some people's need to wear glasses.



ARIZONA BOARD OF REGENTS

ABOR TRIF FUNDS

The Arizona Board of Regents retains a small portion of TRIF funds in support of projects that advance Arizona's public universities in accordance with Arizona laws and board guidelines. Each project funded through TRIF is intended to further goals outlined in the board's strategic enterprise metrics, and strengthen research at the universities and Arizona's workforce development.

ABOR TRIF funds support initiatives in these general areas - data resources and technological support; science, technology, engineering and math (STEM) and innovation projects.

INVESTING IN DATA, RESOURCES AND TECHNOLOGY

Strategic investments in data, resources and technology through TRIF provide data and analysis for stakeholders, including regents and legislators. Investing in the National Student Clearinghouse and data sharing with the Arizona Department of Education provides enhanced data mining resources. A portion of TRIF funding provides access to expertise from faculty at Arizona's public universities through the Elsevier Pure Experts (SciVal) searchable database. Funding also supports the board's business intelligence and database projects, which use Tableau's software and server to compile, analyze and visualize data. Tableau also supports university researchers across the system in their efforts to report data. Development of a central database management system allows the board office to respond to requests regarding Arizona's workforce, higher education and the K-12 pipeline.

PROMOTING STEM AND INNOVATION PROJECTS FOR ARIZONA'S FUTURE

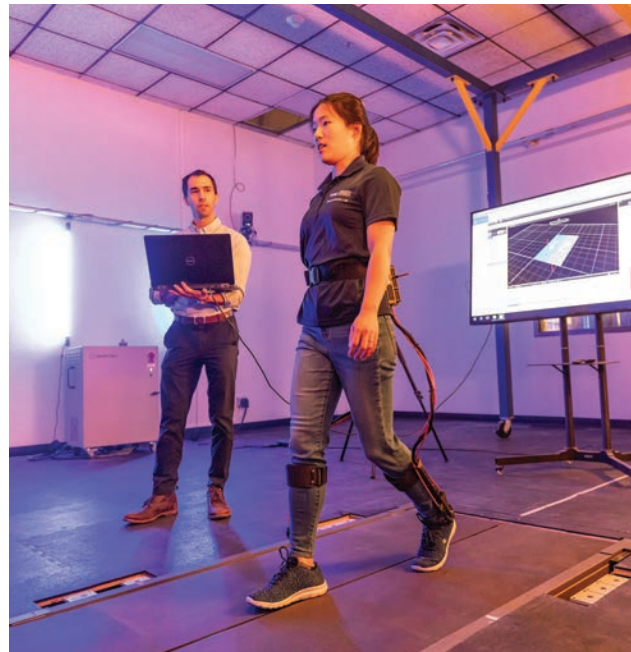
In fiscal year 2020, TRIF funds were invested in two projects promoting STEM and innovation - Arizona Tech Council's SciTech Festival and the ASU Innovation Open (ASUio).

The Arizona SciTech Festival is an annual statewide celebration of STEM. As a foundational gold sponsor, funding through the board and TRIF supports the administration and operation of the festivals that are held in various locations across Arizona. The SciTech Festival leverages Arizona's STEM ecosystem to excite and inform Arizonans of all ages about STEM and how it is driving the state forward.

TRIF funding supported ASUio that is designed to challenge and advance collegiate startups that harness the power of entrepreneurship to tackle the world's most challenging problems. Sponsors and supporters provided funding and mentorship for student competitors on their ventures, and technology innovators from universities around the world gathered to pitch their ideas for cash prizes during the event.



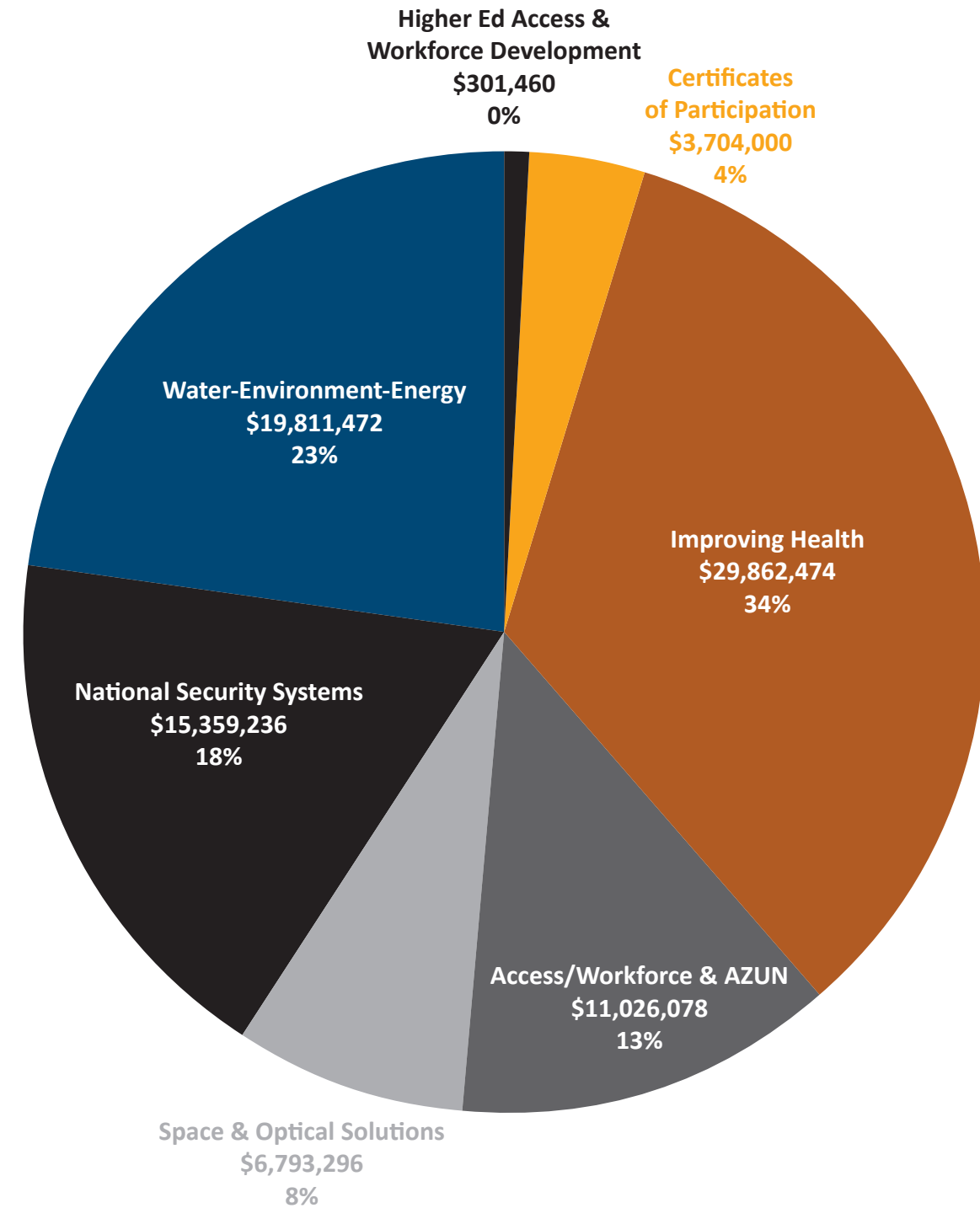
FINANCIALS & METRICS



**FY 2018 - 2021
ARIZONA UNIVERSITY SYSTEM
TECHNOLOGY AND RESEARCH INITIATIVE FUND**

	FY 2018 ACTUAL	FY 2019 ACTUAL	FY 2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
REVENUE					
Carry Forward	8,684,576	10,634,673	15,378,549	12,006,483	12,006,483
TRIF Revenue	77,211,240	83,610,510	81,456,038	110,836,061	85,569,000
TOTAL REVENUE	\$ 85,895,816	\$ 94,245,183	\$ 96,834,587	\$ 122,842,544	\$ 97,575,483
EXPENDITURES					
OPERATING	61,995,953	66,671,410	70,307,328	77,053,150	72,170,400
CAPITAL	9,896,688	8,830,438	10,835,801	11,057,144	9,694,600
ASU Polytechnic/West COPs	3,704,000	3,704,000	3,704,000	3,704,000	3,704,000
TOTAL CAPITAL	13,600,688	12,534,438	14,539,801	14,761,144	13,398,600
TOTAL EXPENDITURES	\$ 75,596,641	\$ 79,205,848	\$ 84,847,129	\$ 91,814,295	\$ 85,569,000
SUMMARY BY PROGRAM AREA					
Improving Health	\$ 29,424,142	\$ 28,687,340	\$ 26,431,233	\$ 29,862,474	\$ 29,368,089
Water, Environment, Energy Solutions	14,911,510	18,363,047	18,972,325	19,811,472	20,139,762
National Security Systems	9,852,316	12,555,957	12,756,544	15,359,236	12,331,426
Space Exploration and Optical Solutions	7,172,981	4,266,589	9,577,737	6,793,296	9,042,423
Access & Workforce Development	8,054,570	9,152,394	11,151,698	10,506,078	8,463,300
ASU Poly/ASU West COPs	3,704,000	3,704,000	3,704,000	3,704,000	3,704,000
AZUN	505,000	510,000	515,000	520,000	520,000
Higher Ed Access & Workforce Development	-	-	-	301,460	-
ABOR Other	1,514,620	1,823,578	1,395,000	4,542,895	2,000,000
PROGRAM AREA TOTAL	75,139,139	79,062,905	84,503,537	91,400,913	85,569,000
TOTAL EXPENDITURES	\$ 75,139,139	\$ 79,062,905	\$ 84,503,537	\$ 91,400,913	\$ 85,569,000

**FY 2021
SYSTEM ACTUAL TRIF EXPENDITURES**





**FY 2018 - 2021
ARIZONA STATE UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND**

	FY 2018 ACTUAL	FY 2019 ACTUAL	FY 2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
REVENUE					
Carry forward	555,600	\$ 335,500	\$ 545,396	19,024	19,024
TRIF Revenue	32,306,900	34,866,604	33,886,275	35,650,000	35,650,000
TOTAL REVENUE	\$ 32,862,500	\$ 35,202,104	\$ 34,431,671	\$ 35,669,024	\$ 35,669,024
EXPENDITURES					
OPERATING	25,658,500	27,744,500	27,227,671	28,446,000	28,446,000
CAPITAL	3,500,000	3,546,400	3,500,000	3,500,000	3,500,000
ASU Poly/ASU West COPs	3,704,000	3,704,000	3,704,000	3,704,000	3,704,000
TOTAL EXPENDITURES	\$ 32,862,500	\$ 34,994,900	\$ 34,431,671	\$ 35,650,000	\$ 35,650,000
SUMMARY BY INITIATIVE					
Improving Health	\$ 14,744,400	\$ 14,964,300	\$ 11,917,391	\$ 13,242,427	\$ 14,991,300
Water, Environment and Energy Solutions	6,071,800	7,533,200	8,262,701	7,407,855	8,246,800
National Security Systems	3,942,300	3,450,400	3,083,927	4,445,884	4,229,800
Access & Workforce Development					
Entrepreneurship & Innovation	732,500	1,328,800	725,118	1,589,174	1,601,700
Advanced Manufacturing	3,332,000	4,014,200	6,719,510	5,232,901	2,876,400
TOTAL	28,823,000	31,290,900	30,708,647	31,918,241	31,946,000
ASU Poly/ASU West COPS	3,704,000	3,704,000	3,704,000	3,704,000	3,704,000
TOTAL EXPENDITURES	\$ 32,527,000	\$ 34,994,900	\$ 34,412,647	\$ 35,622,241	\$ 35,650,000

**ARIZONA STATE UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
IMPROVING HEALTH**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY 2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 14,744,400	\$ 14,964,300	\$ 11,917,391	\$ 13,242,427	\$ 14,991,400
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 92,909,977	\$ 102,240,048	\$ 111,380,066	\$ 174,635,300	\$ 124,000,000
Gifts & Other Sources	1,399,722	1,890,337	2,477,429	2,793,653	1,220,000
Royalty Income	196,261	371,958	316,904	296,363	800,000
TOTAL	94,505,960	104,502,343	114,174,399	177,725,316	126,020,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	97	86	91	107	60
US Patents Issued	32	27	32	40	7
Licenses and Options Executed	15	14	21	23	22
Startup Companies	5	5	7	8	3
WORKFORCE CONTRIBUTION					
Academic and Postdoctoral Appointees	145	154	187	182	143
Graduate Students	630	749	1,070	1,034	445
Undergraduate Students	230	264	359	351	328

**ARIZONA STATE UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
NATIONAL SECURITY SYSTEMS**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY 2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 3,942,300	\$ 3,450,400	\$ 3,083,927	\$ 4,445,884	\$ 4,229,800
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 33,292,653	\$ 48,532,922	\$ 53,113,731	\$ 61,007,841	\$ 60,000,000
Gifts & Other Sources	-	-	-	-	-
Royalty Income	76,305	14,898	118,013	50,281	50,000
TOTAL	33,368,958	48,547,820	53,231,744	61,058,122	60,050,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	52	40	39	48	30
US Patents Issued	9	11	26	25	4
Licenses and Options Executed	8	2	5	5	5
Startup Companies	2	2	2	2	0
WORKFORCE CONTRIBUTION					
Academic and Postdoctoral Appointees	50	79	82	84	36
Graduate Students	366	479	594	588	303
Undergraduate Students	176	247	243	255	153

**ARIZONA STATE UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
WATER, ENVIRONMENTAL, ENERGY SOLUTIONS**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY 2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 6,071,800	\$ 7,533,200	\$ 8,262,701	\$ 7,407,855	\$ 8,246,800
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 26,139,847	\$ 28,545,795	\$ 30,121,498	\$ 34,593,495	\$ 34,000,000
Gifts & Other Sources	3,196,485	1,213,249	546,272	208,528	4,790,000
Royalty Income	2,000	117,016	25,005	306,864	100,000
TOTAL	29,338,332	29,876,060	30,692,775	35,108,887	38,890,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	13	24	30	49	13
US Patents Issued	13	27	25	27	3
Licenses and Options Executed	5	3	6	6	5
Startup Companies	2	2	4	5	0
WORKFORCE CONTRIBUTION					
Academic and Postdoctoral Appointees	35	80	73	84	36
Graduate Students	147	400	345	459	183
Undergraduate Students	104	190	121	193	221

**ARIZONA STATE UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
ACCESS & WORKFORCE DEVELOPMENT:
ADVANCED MANUFACTURING**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY 2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 3,332,000	\$ 4,014,200	\$ 6,719,510	\$ 5,232,901	\$ 2,876,400
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 22,677,335	\$ 18,810,146	\$ 21,305,970	\$ 68,836,073	\$ 25,000,000
Gifts & Other Sources	138,791	158,936	456,603	494,821	100,000
Royalty Income	91,800	75,000	67,011	303,907	50,000
TOTAL	22,907,926	19,044,082	21,829,584	69,634,801	25,150,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	44	28	42	51	12
US Patents Issued	18	26	28	37	2
Licenses and Options Executed	4	2	4	4	4
Startup Companies	2	3	3	4	1
WORKFORCE CONTRIBUTION					
Academic and Postdoctoral Appointees	25	59	44	60	14
Graduate Students	98	323	272	268	69
Undergraduate Students	27	89	58	87	77

**ARIZONA STATE UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
ACCESS & WORKFORCE DEVELOPMENT:
ENTREPRENEURSHIP & INNOVATION**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY 2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 732,500	\$ 1,328,800	\$ 725,118	\$ 1,589,174	\$ 1,601,700
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 4,021,094	\$ 5,527,000	\$ 0	\$ 5,531,150	\$ 5,000,000
Gifts & Other Sources					
Royalty Income					
TOTAL	4,021,094	5,527,000	-	5,531,150	5,000,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted					
US Patents Issued					
Licenses and Options Executed					
Startup Companies	17	18	19	21	23
WORKFORCE CONTRIBUTION					
Academic and Postdoctoral Appointees	0	6	12	18	0
Graduate Students	173	143	145	234	30
Undergraduate Students	346	342	438	453	152



**FY 2017 - 2021
NORTHERN ARIZONA UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND**

	FY 2018 ACTUAL	FY 2019 ACTUAL	FY 2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
REVENUE					
Carry forward	1,815,739	3,681,174	6,397,949	8,582,291	8,582,291
TRIF Revenue	14,301,433	15,581,302	15,245,475	15,973,000	15,973,000
TOTAL REVENUE	\$ 16,117,172	\$ 19,262,476	\$ 21,643,424	\$ 24,555,291	\$ 24,555,291
EXPENDITURES					
OPERATING	11,619,310	11,780,490	12,010,332	16,060,537	12,778,400
CAPITAL	816,688	1,084,038	1,050,801	5,964,954	3,194,600
TOTAL EXPENDITURES	\$ 12,435,998	\$ 12,864,528	\$ 13,061,133	\$ 22,025,491	\$ 15,973,000
SUMMARY BY INITIATIVE					
Improving Health	\$ 2,287,367	\$ 2,498,001	\$ 2,203,645	\$ 6,094,949	\$ 2,876,838
Water, Environment and Energy Solutions	3,336,334	3,275,370	3,073,482	5,313,265	3,311,473
National Security Systems	2,068,714	1,765,557	2,394,433	3,723,309	837,660
Space Exploration & Optical Solutions	248,513	1,006,205	1,167,503	2,689,965	4,441,829
Access & Workforce Development	3,990,070	3,809,394	3,707,070	3,684,003	3,985,200
AZUN	505,000	510,000	515,000	520,000	520,000
TOTAL EXPENDITURES	\$ 12,435,998	\$ 12,864,528	\$ 13,061,133	\$ 22,025,491	\$ 15,973,000

**NORTHERN ARIZONA UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
IMPROVING HEALTH**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 2,287,367	\$ 2,498,001	\$ 2,203,645	\$ 6,094,949	\$ 2,876,838
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 11,421,671	\$ 11,799,528	\$ 6,234,337	\$ 9,621,419	\$ 3,868,878
Gifts & Other Sources	200,000	-	-	-	193,444
Royalty Income	10,000	10,000	-	49,013	35,156
TOTAL	11,631,671	11,809,528	6,234,337	9,670,432	4,097,478
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	19	18	19	22	29
US Patents Issued	5	6	7	4	1
Licenses and Options Executed	0	3	3	2	1
Startup Companies	0	0	1	0	0
WORKFORCE CONTRIBUTION					
Academic and Postdoctoral Appointees	10	26	23	16	4
Graduate Students	45	52	43	126	35
Undergraduate Students	129	125	121	139	50

**NORTHERN ARIZONA UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
WATER, ENVIRONMENTAL, ENERGY SOLUTIONS**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 3,336,334	\$ 3,275,370	\$ 3,073,482	\$ 5,313,265	\$ 3,311,473
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 8,262,452	\$ 4,490,896	\$ 8,910,904	\$ 5,796,235	\$ 3,374,568
Gifts & Other Sources	-	-	-	-	168,728
Royalty Income	-	-	-	-	-
TOTAL	8,262,452	4,490,896	8,910,904	5,796,235	3,543,296
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	11	2	2	1	12
US Patents Issued	2	0	1	0	2
Licenses and Options Executed	0	0	0	0	0
Startup Companies	0	0	0	0	0
WORKFORCE CONTRIBUTION					
Academic and Postdoctoral Appointees	20	30	28	22	4
Graduate Students	63	77	65	85	35
Undergraduate Students	127	124	119	89	200

**NORTHERN ARIZONA UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
NATIONAL SECURITY SYSTEMS**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 2,068,714	\$ 1,765,557	\$ 2,394,433	\$ 3,723,309	\$ 837,660
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 1,193,274	\$ 1,306,649	\$ 6,445,205	\$ 7,018,802	\$ 1,330,197
Gifts & Other Sources	-	-	-	-	66,510
Royalty Income	30,500	500	5,000	17,250	35,156
TOTAL	1,223,774	1,307,149	6,450,205	7,036,052	1,431,863
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	14	13	5	10	7
US Patents Issued	2	4	12	4	2
Licenses and Options Executed	1	1	0	1	1
Startup Companies	0	0	0	0	1
WORKFORCE CONTRIBUTION					
Academic and Postdoctoral Appointees	2	3	4	1	4
Graduate Students	4	8	6	7	15
Undergraduate Students	17	14	16	12	25

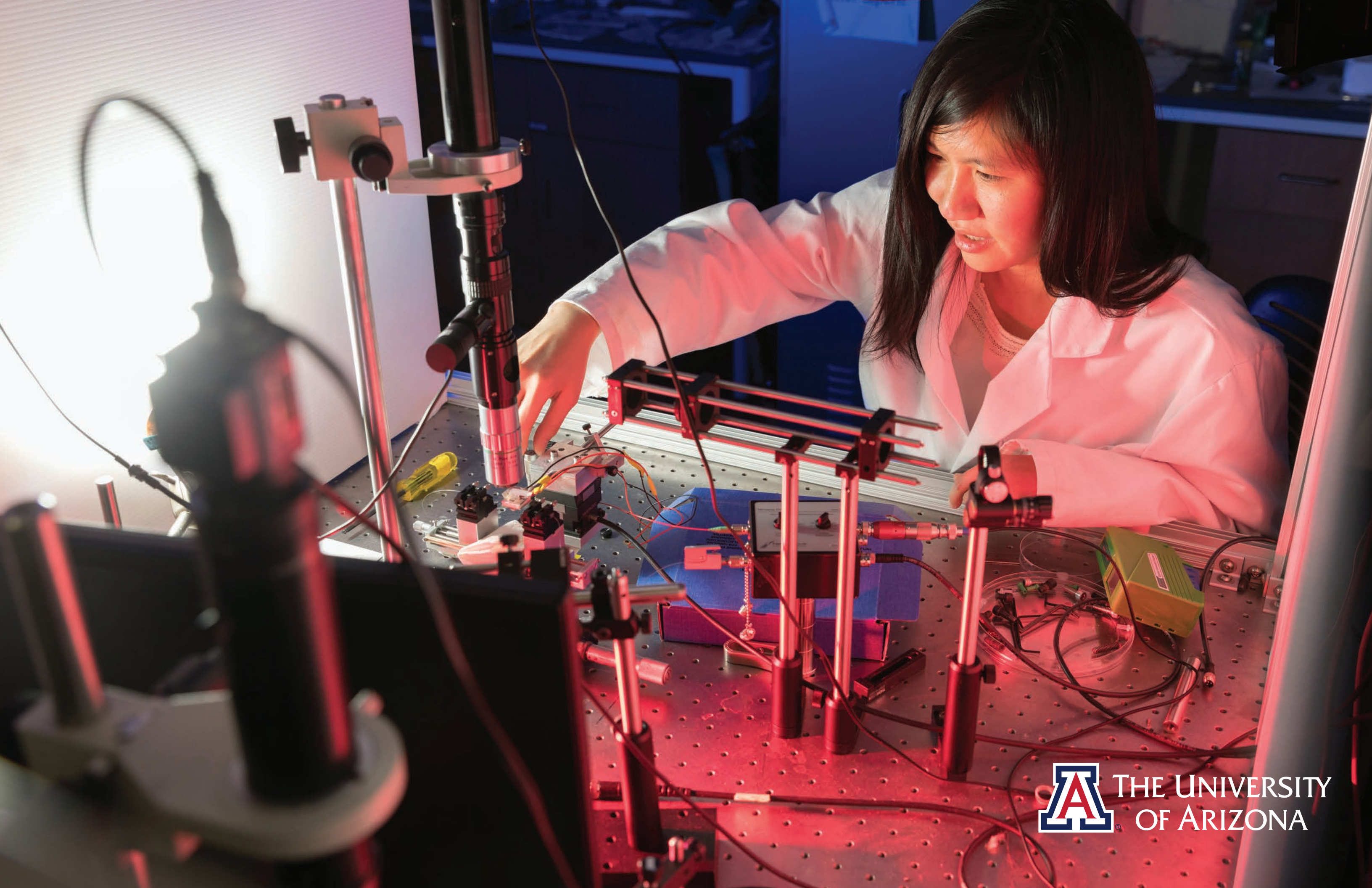
**NORTHERN ARIZONA UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
SPACE EXPLORATION AND OPTICAL SOLUTIONS**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 248,513	\$ 1,006,205	\$ 1,167,503	\$ 2,689,965	\$ 4,441,829
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 882,075	\$ 1,907,771	\$ 2,094,739	\$ 2,338,321	\$ 3,836,157
Gifts & Other Sources	-	-	-	-	191,808
Royalty Income	-	-	-	-	35,156
TOTAL	882,075	1,907,771	2,094,739	2,338,321	4,063,121
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	0	2	1	0	2
US Patents Issued	0	0	0	0	2
Licenses and Options Executed	0	0	0	0	1
Startup Companies	0	0	0	0	0
WORKFORCE CONTRIBUTION					
Academic and Postdoctoral Appointees	0	7	4	0	4
Graduate Students	3	7	9	7	15
Undergraduate Students	7	7	7	6	50

**NORTHERN ARIZONA UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
ACCESS & WORKFORCE DEVELOPMENT**

PERFORMANCE ANALYSIS	FY 2017 ACTUAL	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY2021 ACTUAL
TRIF EXPENDITURES					
AWD	\$ 5,161,293	\$ 3,990,070	\$ 3,809,394	\$ 3,707,070	\$ 3,684,003
AZUN	\$ 500,000	\$ 505,000	\$ 510,000	\$ 515,000	\$ 520,000
Total	\$ 5,661,293	\$ 4,495,070	\$ 4,319,394	\$ 4,222,070	\$ 4,204,003
FINANCIAL IMPACT OF TRIF INVESTMENT					
Annual Impact of Graduates on Economy ¹	\$ 15,990,000	\$ 15,626,000	\$ 14,235,000	\$ 14,950,000	\$ 18,278,000
Degree/Certificate Programs Offered ²	92	84	89	64	77
Business/Nonprofit Collaborations ³	211	374	522	516	441
Number of Students Served by A/WD ⁴	4,482	4,405	4,220	3,932	3,794
TOTAL	\$ 15,990,000	\$ 15,626,000	\$ 14,235,000	\$ 14,950,000	\$ 18,278,000
WORKFORCE CONTRIBUTION					
Web/Hybrid/Enhanced Courses Developed ⁵	191	287	243	260	197
Faculty Developing Courses ⁶	405	304	312	450	128
Increase in Student Technology Literacy ⁷	4,310	4,555	4,425	4,650	5,700
Individual Faculty Trained in Teaching Technologies ⁸	376	307	316	637	420
Faculty Support Incidents Resolved Technologies ⁹	13,590	11,734	12,721	19,904	17,573
Faculty using Adaptive Courseware	16	32	36	22	25
PROGRESS TOWARD 2021 GOALS					
ACCESS & WORKFORCE DEVELOPMENT: ONLINE & BLENDED DEGREE PROGRAMS					
EXPECTED OUTCOMES					
Workforce ready college graduates 5-Year Projection 2,000	1,405	1,388	1,455	1,348	1,240

¹ Estimated based on U. S. Census Bureau Data for annual increase in earnings by a baccalaureate-trained worker compared to high school degree
² Number of degrees supported by A/WD funding
³ Organizations (business, industry, nonprofits, school districts) with formal/informal relationships with NAU related to TRIF A/WD activities
⁴ Reporting based on number of students eligible to enroll in programs supported by A/WD funding.
⁵ Includes Web, hybrid, IT-enhanced, redesigns and quality review process compliance.
⁶ Number of faculty participating in course development, design and redesign.
⁷ Number of students completing a course with significant or advanced technical fluency skills.
⁸ Number of faculty completing core eLearning training.
⁹ The number of faculty eLearning help desk problems resolved



**FY 2017 - 2021
UNIVERSITY OF ARIZONA
TECHNOLOGY AND RESEARCH INITIATIVE FUND**

	<i>FY 2018 ACTUAL</i>	<i>FY 2019 ACTUAL</i>	<i>FY 2020 ACTUAL</i>	<i>FY 2021 ACTUAL</i>	<i>FY 2021 BUDGET</i>
REVENUE					
Carry forward	4,707,123	4,648,508	6,431,170	1,287,363	1,287,363
TRIF Revenue	28,602,907	31,162,604	30,490,949	31,946,000	31,946,000
TOTAL REVENUE	\$ 33,310,030	\$ 35,811,112	\$ 36,922,119	\$ 33,233,363	\$ 33,233,363
EXPENDITURES					
OPERATING	23,081,521	25,179,899	30,744,757	27,618,096	28,946,000
CAPITAL	5,580,000	4,200,000	4,890,000	1,592,190	3,000,000
TOTAL EXPENDITURES	\$ 28,661,521	\$ 29,379,899	\$ 35,634,757	\$ 29,210,286	\$ 31,946,000
SUMMARY BY INITIATIVE					
Improving Health	\$ 12,392,375	\$ 11,225,039	\$ 12,310,197	\$ 10,525,099	\$ 11,499,951
Space Exploration & Optical Solutions	6,924,468	7,554,476	8,410,234	7,090,353	8,581,489
Water, Environment and Energy Solutions	5,503,376	7,340,000	7,636,142	7,190,043	7,263,966
National Security Systems	3,841,302	3,260,384	7,278,184	4,103,331	4,600,594
Higher Ed Access & Workforce Development	-	-	-	301,460	-
TOTAL EXPENDITURES	\$ 28,661,521	\$ 29,379,899	\$ 35,634,757	\$ 29,210,286	\$ 31,946,000

**UNIVERSITY OF ARIZONA
TECHNOLOGY AND RESEARCH INITIATIVE FUND
IMPROVING HEALTH**

PERFORMANCE ANALYSIS	<i>FY 2018 ACTUAL</i>	<i>FY2019 ACTUAL</i>	<i>FY2020 ACTUAL</i>	<i>FY 2021 ACTUAL</i>	<i>FY 2021 BUDGET</i>
TRIF EXPENDITURES					
Total	12,392,375	11,225,039	12,310,197	10,525,099	11,499,951
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	89,142,292	78,544,924	111,287,819	127,573,005	70,191,514
Gifts & Other Sources	465,399	804,222	565,001	661,094	701,915
Royalty Income	200	55,000	46,000	367,996	58,493
TOTAL	89,607,891	79,404,146	111,898,820	128,602,095	70,951,922
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	38	35	67	61	55
US Patents Issued	2	21	18	29	5
Licenses and Options Executed	8	9	13	16	13
Startup Companies	4	1	3	3	2
WORKFORCE CONTRIBUTION					
Postdoctoral Appointees	184	218	126	109	122
Graduate Students	479	643	535	241	365
Undergraduate Students	539	659	557	284	389

**UNIVERSITY OF ARIZONA
TECHNOLOGY AND RESEARCH INITIATIVE FUND
WATER, ENVIRONMENTAL AND
ENERGY SOLUTIONS**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 5,503,376	\$ 7,340,000	\$ 7,636,142	\$ 7,190,043	\$ 7,263,966
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	34,978,098	37,230,355	28,666,051	40,912,168	36,265,615
Gifts & Other Sources	31,228,311	2,470,875	2,434,298	3,098,843	3,977,519
Royalty Income	5,145	3,785	2,583	66,913	877,394
TOTAL	\$ 66,211,554	\$ 39,705,015	\$ 31,102,932	\$ 44,077,924	\$ 41,120,528
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	16	12	11	17	27
US Patents Issued	1	0	3	5	5
Licenses and Options Executed	2	4	4	7	9
Startup Companies	0	0	0	0	1
WORKFORCE CONTRIBUTION					
Postdoctoral Appointees	29	55	35	21	103
Graduate Students	175	182	159	164	328
Undergraduate Students	109	123	140	148	134

**UNIVERSITY OF ARIZONA
TECHNOLOGY AND RESEARCH INITIATIVE FUND
SPACE EXPLORATION AND OPTICAL SOLUTIONS**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 6,924,468	\$ 7,554,476	\$ 8,410,234	\$ 7,090,353	\$ 8,581,489
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	93,922,125	86,349,520	69,863,665	29,286,218	70,191,514
Gifts & Other Sources	597,340	488,660	2,800,000	1,500,000	1,000,000
Royalty Income	1,438,529	1,932,029	4,393,115	6,889,218	140,383
TOTAL	\$ 95,957,994	\$ 88,770,209	\$ 77,056,781	\$ 37,675,436	\$ 71,331,897
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	62	69	44	54	55
US Patents Issued	11	17	22	30	5
Licenses and Options Executed	26	18	22	17	22
Startup Companies	6	4	8	-	2
WORKFORCE CONTRIBUTION					
Postdoctoral Appointees	20	25	46	26	18
Graduate Students	115	114	117	85	49
Undergraduate Students	47	57	47	80	10

**UNIVERSITY OF ARIZONA
TECHNOLOGY AND RESEARCH INITIATIVE FUND
NATIONAL SECURITY SYSTEMS**

PERFORMANCE ANALYSIS	FY 2018 ACTUAL	FY19 ACTUAL	FY2020 ACTUAL	FY 2021 ACTUAL	FY 2021 BUDGET
TRIF EXPENDITURES					
Total	\$ 3,841,302	\$ 3,260,384	\$ 7,278,184	\$ 4,103,331	\$ 4,600,594
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	1,281,873	1,343,532	6,984,106	15,644,555	10,000,000
Gifts & Other Sources	0	0	0	0	175,000
Royalty Income	0	0	0	0	0
TOTAL	\$ 1,281,873	\$ 1,343,532	\$ 6,984,106	\$ 15,644,555	\$ 10,175,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	6	8	0	16	5
US Patents Issued	0	0	0	9	0
Licenses and Options Executed	0	0	6	6	0
Startup Companies	0	0	1	1	0
WORKFORCE CONTRIBUTION					
Postdoctoral Appointees	10	10	5	10	6
Graduate Students	38	37	49	84	12
Undergraduate Students	49	13	42	43	12



FY 2017-2021
ARIZONA BOARD OF REGENTS
TECHNOLOGY AND RESEARCH INITIATIVE FUND

	<i>FY 2018</i> <i>ACTUAL</i>	<i>FY 2019</i> <i>ACTUAL</i>	<i>FY 2020</i> <i>ACTUAL</i>	<i>FY 2021</i> <i>ACTUAL</i>	<i>FY 2021</i> <i>BUDGET</i>
REVENUE					
Carry Forward	\$ 1,606,114	\$ 1,969,491	\$ 2,004,034	\$ 2,117,805	\$ 2,117,805
TRIF Revenue	2,000,000	2,000,000	1,833,339	27,267,061	2,000,000
TOTAL REVENUE	\$ 3,606,114	\$ 3,969,491	\$ 3,837,373	\$ 29,384,866	\$ 4,117,805
EXPENDITURES					
OPERATING	122,002	142,943	324,568	385,622	150,000
GRANTS/PROJECTS	1,514,620	1,823,578	1,395,000	4,542,895	1,850,000
TOTAL EXPENDITURES	\$ 1,636,622	\$ 1,966,521	\$ 1,719,568	\$ 4,928,517	\$ 2,000,000
SUMMARY BY INITIATIVE					
Data/Resources/Technology	1,464,620	1,773,578	1,345,000	4,492,895	1,900,000
STEM/Innovation Projects	50,000	50,000	50,000	50,000	100,000
TOTAL EXPENDITURES	\$ 1,514,620	\$ 1,823,578	\$ 1,395,000	\$ 4,542,895	\$ 2,000,000