

FISCAL YEAR 2020

TECHNOLOGY AND RESEARCH INITIATIVE FUND



ARIZONA BOARD OF
REGENTS
ASU ♦ NAU ♦ UA



ABOUT THIS REPORT

The fiscal year 2020 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.

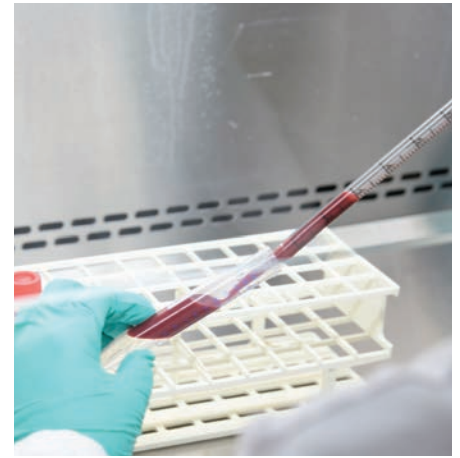
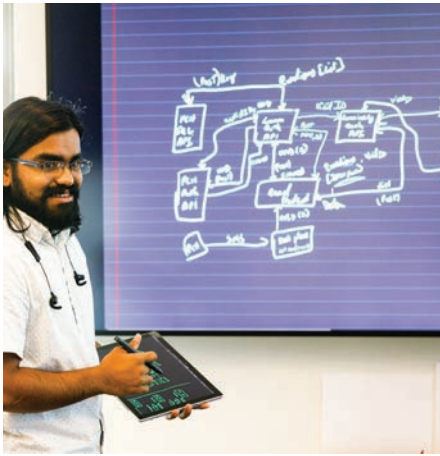
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TECHNOLOGY AND RESEARCH INITIATIVE FUND

TRIF BUDGET

Arizona's public universities received approximately \$81.4 million in TRIF revenue in fiscal year 2020. The universities leveraged that investment to attract outside research funding, resulting in \$465.7 million return on investment through TRIF-related research. Total TRIF revenue received to date since the inception of the program in June 2001 is over \$1.205 billion.

ABOR approves the TRIF budgets and project plans in five-year cycles. The fiscal year 2017-2021 project plans were approved by the board in June 2016 using the sales-tax forecast from the Joint Legislative Budget Committee (JLBC). 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.

MILKEN REPORT CITES TRIF'S IMPACT

In April of 2020, the Milken Institute published a new report, "Examining Arizona's Technology and Research Initiative Fund," that analyzes TRIF's significant impact on Arizona's public universities and the innovation economy in the state. The report, commissioned by the Flinn Foundation, stresses TRIF's importance to Arizona's continued success, citing it as a major reason for the growth of the biosciences in the state.







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TRAIL

ASU Arizona State University

ARIZONA STATE UNIVERSITY

TRIF-supported researchers at Arizona State University are providing innovative solutions to safeguard human health, security and prosperity in Arizona and around the world in the following focus areas:

During the TRIF cycle of fiscal year 2017 through fiscal year 2021, ASU is investing in four focus areas:

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

In fiscal year 2020, ASU leveraged TRIF investment to attract \$220 million in new funding. For example, the ASU-led, national Center for Bio-mediated and Bio-inspired Geotechnics (CBBG) Engineering Research Center was renewed for five years with \$16.4 million from the National Science Foundation. CBBG draws inspiration from nature to develop sustainable, resilient and cost-effective civil infrastructure systems.

The value of Arizona's long-term commitment to research and innovation has never been more apparent than during the coronavirus pandemic that began in early 2020. Researchers across ASU were able to quickly leverage TRIF-enabled technologies, expertise and infrastructure to assist in the global crisis.

For example, researchers in the Biodesign Institute pivoted automated diagnostic technology originally developed to detect radiation exposure. This technology now provides the capacity to process thousands of COVID-19 tests per day. The institute also launched the first saliva-based COVID-19 test in the western U.S., providing a safer and less invasive alternative to nasopharyngeal swabs.

TRIF-supported research also engaged 1,219 undergraduates, 2,426 graduate students and 398 post-doctoral appointees in the past fiscal year. Through innovative programs such as Practice Labs™, ASU is connecting students to companies, nonprofits and government organizations to help solve their critical business challenges while providing hands-on professional experience and exposing students to potential employers and career paths.

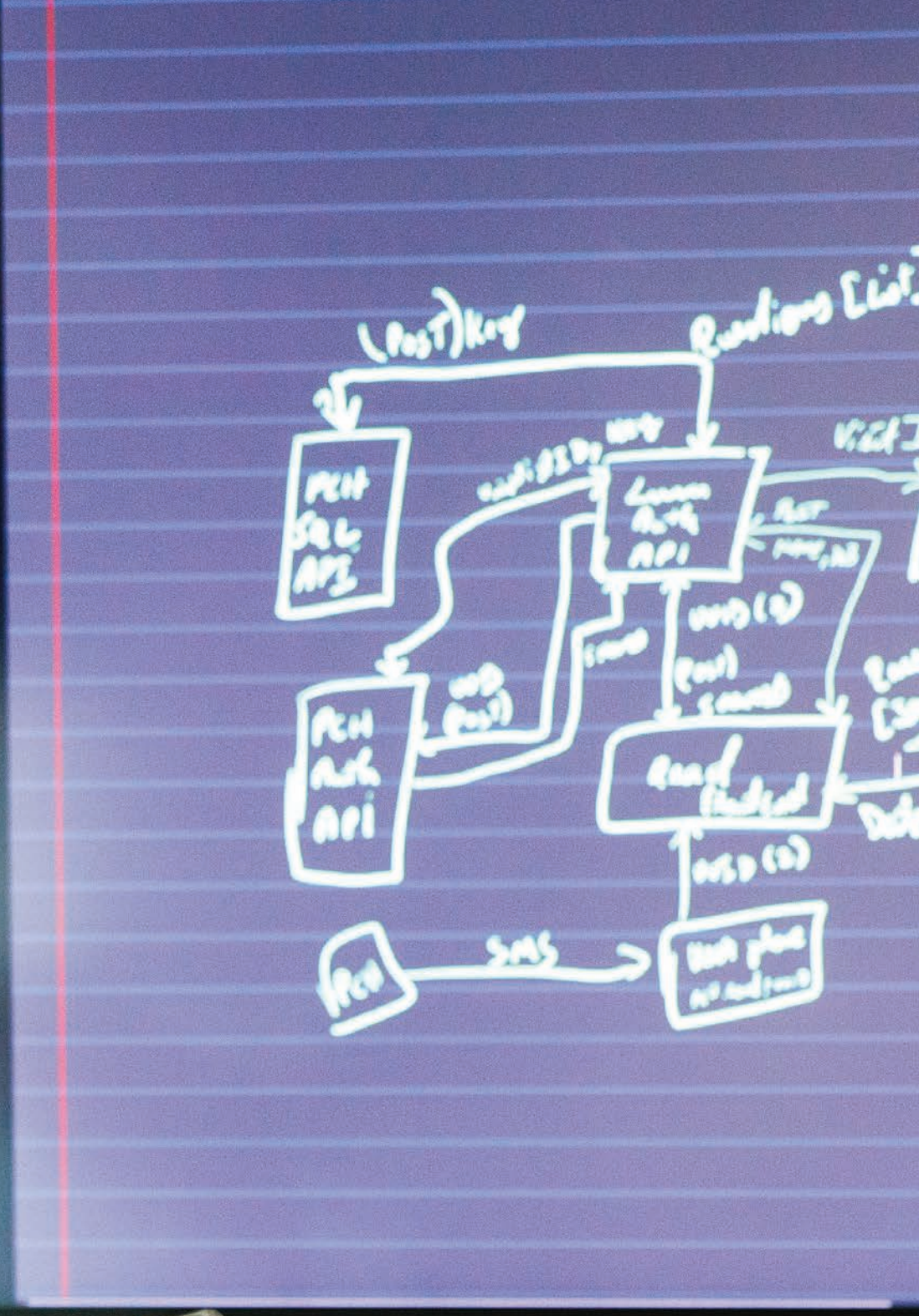
ASU's faculty and students are also translating their efforts into the marketplace. In fiscal year 2020, 111 patents were issued and 35 new startup companies were launched based on technology from TRIF-supported research. ASU ranks No. 12 among universities worldwide for U.S. patents issued, a testament to the university's capacity to bring new inventions to market.

In recognition of the university's rapid growth and societal impact, U.S. News & World Report named ASU the most innovative university in the country for five consecutive years. In 2020, Times Higher Education ranked ASU No. 1 in the U.S. and No. 5 in the world for impact based on the United Nations Sustainable Development Goals.



“Arizona State University is heavily invested in the communities we serve. The state’s reinvestment in us as an institution allows us to provide a substantial benefit to the local economy through the creation of an educated citizenry that supports the attraction of leading industries and the development of new, innovative businesses. Our focus on research, discovery and translation is fostering the creation of the kind of high-tech ecosystem in Arizona that provides high-paying jobs and external investment. We appreciate the vital infusion of TRIF funding, and are committed to being a good steward of these resources, returning benefit to the community in all possible ways.”

**— Neal Woodbury, Interim Executive Vice President,
ASU Knowledge Enterprise**



IMPROVING HEALTH

ASU's Improving Health efforts are anchored in the Biodesign Institute, which was launched with TRIF support in 2003 to create nature-inspired solutions for human health and well-being. The Biodesign Institute advances scientific discovery and accelerates commercialization to serve the public good in areas of pressing concern from the current coronavirus pandemic to cancer to Alzheimer's disease and more.

The institute's network of local and global collaborations — from Norway to South Korea to India — helps generate research synergy, significantly improving the pace and impact of scientific discovery. It draws on the interdisciplinary expertise of biologists and biochemists, geneticists and informaticians, physicians, engineers, epidemiologists and researchers in evolutionary theory, enabling multifaceted investigations of some of today's most urgent challenges.

In addition, TRIF investment contributes to programs and facilities that support this discovery 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 biosciences research 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 Biodesign Institute at ASU has been an invaluable partner in our response to the COVID-19 pandemic. We needed to move quickly to test our essential employees who are responsible for keeping the lights on and air conditioners running for our customers across the state of Arizona. The Biodesign Institute collaborated with APS to set up qPCR testing at multiple sites within just a few days, and has continued to work with us to improve the process so that we can sustain an effective testing program and maintain a healthy workforce."

— Pat Dinkel, Vice President of Strategy and Risk, APS






SUMMARY OF ACCOMPLISHMENTS

Since 2003, the Biodesign Institute has leveraged \$210 million in TRIF funding to attract over \$750 million in external awards, supporting research that saves lives. Biodesign scholars have also generated over 100 U.S. patents and more than 50 licensing agreements for the technologies they have created. TRIF also supports Biodesign's work in STEM education.

- One example of the multiplier effect of TRIF investment is Biodesign's Virginia G. Piper Center for Personalized Diagnostics, which has secured major contracts from the Biomedical Advanced Research and Development Authority and the Defense Advanced Research Projects Agency. That foundational research primed the center to rapidly spin up the ASU Biodesign Clinical Testing Lab (ABCTL) to fill the gap in COVID-19 testing in Arizona, with additional support from the Virginia G. Piper Charitable Trust.

This Clinical Laboratory Improvement Amendments-certified lab developed Arizona's first saliva-based COVID-19 test. Saliva testing is less invasive for patients, easier to run at scale, safer for testing staff and less resource intensive than commonly used nasopharyngeal swabs. ABCTL has conducted tens of thousands of tests, initially focusing on essential workers and vulnerable populations in partnership with over a dozen organizations. Now the lab is also partnering with the Arizona Department of Health Services (AZDHS) and Arizona Department of Administration (ADOA) to expand public testing across the state.

- TRIF investment also enabled the following efforts to address the coronavirus:
 - Researchers are working with AZDHS and ADOA to provide Arizonans the most up-to-date modeling information and predictions about the spread of the coronavirus.
 - The student-led PPE Response Network has crowdsourced 3D printing and sterilization capabilities in the community to provide tens of thousands of pieces of PPE for around 75 medical providers to date.
 - Students also invented two low-cost PPE sterilization devices and have applied for patents.
 - ASU is assisting the state with case investigations to identify individuals who may have been exposed.
- The coronavirus pandemic has highlighted the urgent need for better warning systems for infectious diseases, including influenza, which killed roughly 80,000 people last year in the U.S. With \$1.53 million in support from the National Library of Medicine, three Biodesign research teams are working to improve prediction of viral outbreaks. Their work has already enabled the discovery of over 3,000 new viruses, which helps researchers and clinicians prepare for outbreaks and design better defenses against them.
- Biodesign researchers are advancing efforts toward effective, pre-made cancer vaccines that combine common mutations occurring in RNA rather than DNA. Results in mice have already shown this approach to be as effective as complex therapies that are 1,000 times the cost. An ASU spinout company, Calviri, builds on these efforts and will eventually conduct human clinical trials.
- The ASU-Banner Neurological Disease Research Center is exploring new therapies for Alzheimer's and other devastating degenerative brain diseases. Researchers from the Biodesign Institute and the UArizona College of Pharmacy are exploring a small molecule drug known as DYR219. Rather than directly attacking visible hallmarks of Alzheimer's like plaques and tangles, the new drug inhibits an early pathway believed to be critical in the development of this devastating disease.



“The students helped us explore things and study things that we probably otherwise would not be able to do. Project Cities is an invaluable resource.”

— Rudy Esquivias, Planning Manager and Zoning Administrator, Apache Junction

WATER, ENVIRONMENTAL AND ENERGY SOLUTIONS

ASU’s Water, Energy and Environmental Solutions efforts are anchored in the Global Futures Laboratory, launched in 2019 as the next evolution of ASU’s longstanding leadership in sustainability activities. The laboratory is a bold new framework to organize and align ASU’s sustainability efforts, including the Julie Ann Wrigley Global Institute of Sustainability, which previously guided activities in this focus area.

ASU efforts in the Water, Energy and Environmental Solutions focus area build on the university’s foundational expertise in solar energy research and innovation, nanotechnology, and bio-inspired solutions, as well as strong interdisciplinary collaboration and partnerships with industry, nonprofits and governments.

In addition, TRIF investment contributes to programs and facilities that support these activities through infrastructure and instrumentation, technology transfer and strategic partnerships.

GOALS:

- Continue to advance ASU’s university-wide commitment to sustainability.
- Attract additional external funding to enable ASU units and their partners in the teaching, learning and discovery of sustainability and complex global systems.
- Implement, extend, share and promote sustainable 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 cities and businesses that will generate revenue and jobs in Arizona.
- The Center for Bio-mediated and Bio-inspired Geotechnics (CBBG) and the NanoEnabled Water Treatment Technologies (NEWT) center are National Science Foundation-supported Engineering Research Centers. ASU leads CBBG and is a partner in NEWT. These centers advance engineering research and design to tackle imminent sustainability issues by developing applied solutions for transportation, water, power, sanitation, and residential and commercial development.

SUMMARY OF ACCOMPLISHMENTS

- At the start of fiscal year 2020, ASU reached an important milestone in its commitment to sustainable operations, achieving full carbon neutrality six years ahead of its planned schedule. This action is one of many that have helped ASU earn the Sustainability Tracking, Assessment & Rating System (STARS) Platinum sustainability rating from the Association for the Advancement of Sustainability in Higher Education in March 2020 — a rating shared with only seven other institutions in the world.
- ASU engineers working in the Solar Power Lab have discovered how a microscopic alteration to industry-standard silicon wafers can boost the efficiency of solar panels. Increased solar efficiency reduces the cost of energy production, making solar power less expensive. The research group has repeatedly broken solar cell efficiency records in the past.
- Researchers with the Nanotechnology Enabled Water Treatment (NEWT) Engineering Research Center were awarded three patents related to the use of nanomaterials to purify drinking water, industrial wastewater, contaminated soils and sludges from municipal wastewater treatment plants.
- Future H2O is creating a future of water abundance through solutions-oriented research and implementation partnerships. Future H2O is training the next generation of water leaders through three new online education programs, including a 300-level ASU Online course; micro-learning modules for companies, utilities or teachers; and graduate hybrid specialty courses for water professionals in training.
- A team of four graduate students worked with Sun Power Puerto Rico to design a disaster-resilient solar electricity system that allows community leaders to safely remove and replace panels. The team completed installation in July 2019, right before hurricane season and a major earthquake that affected Puerto Rico's electricity grid. A wireless monitoring system was added in October 2019.
- Grasshoppers and locusts have substantial impact on agriculture and livelihoods worldwide. Researchers in ASU's Global Locust Initiative (GLI) discovered that soil amendments that increase crop nitrogen content can reduce locust damage and significantly boost crop yield. GLI is putting this research into action in West Africa with support from the U.S. Agency for International Development.
- The School of Sustainability's executive and professional education initiative designed an innovative online sustainability training for Wells Fargo's nearly 200,000 employees. A public version of the training reaches thousands of additional learners. The initiative is now working with Wells Fargo to develop five online professional training courses with micro-credentials for the Sustainable Earth portal.
- Project Cities successfully completed two semester-long partnerships with the City of Peoria and the Town of Clarkdale, and an extended project with the City of Glendale. The partnerships provided 224 students with hands-on learning opportunities while helping communities with sustainability challenges ranging from water conservation to transit to recycling management.
- Researchers in ASU's Center for Bio-mediated and Bio-inspired Geotechnics (CBBG) Engineering Research Center were issued three patents for enzyme-induced carbonate precipitation technology, which turns loose sand into cemented sand. The technology offers a wide variety of applications, such as controlling fugitive dust, strengthening building foundations, reducing the potential for ground failure during earthquakes and reducing soil erosion from runoff.



“As one of the most unique and exciting courses to take while at ASU, Space Business & Entrepreneurs ... is also one of the most instrumental for hopeful space professionals to get an intimate glimpse into the growing industry.”

— Jonathan Roll, ASU Master’s Student,
Science and Technology Policy



NATIONAL SECURITY SYSTEMS

ASU’s National Security Systems efforts are anchored in the Global Security Initiative. GSI addresses security challenges that are global in scale, borderless by nature, interdependent and often have no clear solutions. These threats require a novel, holistic approach centered on interdisciplinary research that spans the public, private and academic sectors. GSI develops practical, mission-relevant approaches and effective decision-oriented tools for policymakers and implementers, drawing upon faculty expertise and connections with the defense, security and diplomacy communities.

TRIF investment in National Security Systems at ASU also supports innovative efforts in space exploration. This includes NewSpace, which pairs ASU expertise with the commercial space industry, and the Interplanetary Initiative, which approaches critical questions about our space future that are neglected elsewhere.

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

GOALS:

- Attract significant additional external funding to advance research in emerging areas such as cybersecurity, resilience, health and human security, and resource security.
- Transfer scientific advancements from lab to marketplace through inventions, startups and licensing agreements.
- Create and strengthen private-sector collaborations to accelerate research and share resources and capabilities.
- Provide advanced education and training and accelerate the pipeline of highly trained researchers into the defense, intelligence and space industries.
- Inform and inspire the broader community through educational outreach efforts, including engagement and collaboration with K-12 educators and nonprofit organizations.

SUMMARY OF ACCOMPLISHMENTS

- GSI's Center for Cybersecurity and Digital Forensics is engaging the next generation of Arizona's technical workforce, providing hands-on research experience working with government and industry on complex cybersecurity challenges. More than 45 students are gaining the advanced skills Arizona needs to continue to thrive as a technological hub through CDF's \$28 million research portfolio on binary analysis, phishing, scams and other topics.
- In November, GSI's Cybersecurity Education Consortium (CEC) partnered with IBM to host a CyberDay4Girls learning event that introduced cybersecurity concepts and skills to more than 200 middle school girls. CEC also created a curriculum on cybersecurity to help local teachers introduce the topic in their classrooms.
- GSI provided upskilling courses on management and business techniques to information security experts at PayPal, giving participants the skills needed to advance in the company. GSI also helped organize the annual National Initiative for Cybersecurity Education Conference in Phoenix in November, which brought more than 800 people from around the country together to discuss the changes needed to develop the cybersecurity workforce of the future.
- Supported by a \$3 million award from the Department of Defense, GSI's Center for Human, Artificial Intelligence, and Robot Teaming is working with industry, universities and other organizations to incorporate team science into the next generation of AI technology — critical for the use of AI not only in national security missions, but any situation where teamwork and trust are vital to successful outcomes. This research is applicable to the future of work, particularly in technology hubs like the greater Phoenix area.
- ASU has been selected by the U.S. Defense Advanced Research Projects Agency (DARPA) to create an epigenetic tool to fight against weapons of mass destruction. This field-deployable, point-of-care device will determine in 30 minutes or less if a person has been exposed to weapons of mass destruction or their precursors. The DARPA award, worth up to \$38.8 million over four years, will build on the university's growing capabilities in developing molecular diagnostics for applications in defense and human health.
- The Flexible Electronics and Display Center has completed its U.S. Army flexible X-ray detector project, developing and testing the world's first fully flexible X-ray detector backplane and flexible scintillator. X-ray panels were previously built on glass substrates, which were heavy and easily broken, making them unsuitable to deploy in the field to inspect suspected IEDs. FEDC's flexible technology can be draped across an object to be inspected and rolled into a two-inch tube for easy transport.
- In August 2020, The Interplanetary Initiative will launch its three-year Bachelor of Science in Technological Leadership degree program. Between July 2019 and March 2020, the initiative's public events have reached 700 people in person and 13,000 people via livestream.
- ASU NewSpace supported the Space Business & Entrepreneurs course with 16 speakers from across the commercial space industry. As part of the class, 16 students developed teams and created their own business pitches to support a space-related startup.



ACCESS AND WORKFORCE DEVELOPMENT

Programs supported through the Access and Workforce Development focus area are working to upskill today's workforce, educate and train the leaders of tomorrow, support entrepreneurs and small businesses, and advance critical and emerging industries.

As the most innovative university in the country, ASU is continually seeking new ways to partner with businesses, nonprofits, governments and others to provide accessible lifelong learning and support a thriving, sustainable economy in Arizona and beyond. For example, ASU brings together interdisciplinary teams of students — mentored by faculty members — to collaborate with outside organizations to help solve key challenges. Partners get to work with a problem-solving team selected to provide the optimal skill set, while students gain valuable hands-on career experience.

GOALS:

- Attract additional external funding and stimulate new funding opportunities by effectively communicating to potential sponsors the outcome-focused nature of programming.
- Guide the launch of new startup companies, particularly among student entrepreneurs.
- Create and strengthen partnerships with corporations, 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.



“With its student-led design, (the ShipShape) project not only brings fresh thinking to our work, but also provides students with a window into international development work and the work of our agency, which many do not know about. It’s a win-win!”

– Sharmila Raj, USAID Health Development Officer



SUMMARY OF ACCOMPLISHMENTS

- ASU Corporate Engagement and Strategic Partnerships (CESP) created a public-private partnership with Infosys, a global leader in next-generation digital services and consulting. The partnership is creating over 1,000 jobs for Arizonans through the opening of the Technology Innovation Center at SkySong, the ASU-Scottsdale Innovation Center. ASU will continue accelerating the Infosys workforce when they move to the Novus Innovation Corridor.
- ASU Practice Labs™ offer a custom approach to identifying, addressing and solving complex business issues. Practice Labs mobilize student teams, with oversight from faculty members or project managers, to work on pressing industry partner needs. To date, the program has involved more than 50 students and over \$600,000 in funding from 10 local, national and international partners.
- ASU Entrepreneurship + Innovation supports the development of a circular economy, a sustainable approach that includes designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. From January 2017 to December 2019, 19 circular economy ventures participated in the RISN Incubator, a business accelerator offered by ASU and the City of Phoenix. These ventures raised \$3.72 million in capital and \$4.14 million in revenues, filed 14 patents and launched 25 products.
- MacroTechnology Works is advancing Arizona’s semiconductor industry, creating a regional ecosystem of innovation to develop and manufacture new technologies. Industry partners have the unique opportunity to lease space at MTW and to utilize ASU’s Advanced Electronics and Photonics facility while engaging in collaborative research with ASU faculty and students. In FY 2020, two industry partners — Applied Materials and Von Ardenne North America — signed lease agreements. Several startup companies, including Cactus Materials, NuevoGen, SwiftCoat and Amberwave, have also established presence on site.
- ShipShape is a free, offline mobile education game that teaches basic supply chain skills to health care workers. The app was developed by ASU students with funding from the U.S. Agency for International Development. It combines a user-friendly interface with curriculum designed specifically for the developing world. The app is currently being implemented in Ghana in partnership with the Kwame Nkrumah University of Science and Technology (KNUST), with plans to expand to Nigeria, Kenya and other developing countries in the future.
- 450 employees of Chemonics, a leading international development firm, have participated in a fully online MiniMaster’s in supply chain management taught by ASU business faculty. Ten MiniMaster’s students have matriculated into ASU and are currently completing master’s degrees.
- SciHub is an integrated research, teaching, outreach and product development lab. SciHub’s Clubes de Ciencia summer program engages students in hands-on, intensive, one-week science workshops. In 2019, 166 high school students from Arizona and Mexico participated. In the 2019-2020 school year, 60 high school students also participated in SciHub’s SCIENCE and ENgineering Experience (SCENE), which provides science research experience in state-of-the-art labs at ASU.
- ASU’s Center for Wireless Information Systems and Computational Architectures (WISCA) is spinning out two companies. One will advance ASU-developed small-scale radars for contactless heart rate monitoring. Another is based on technologies developed through a \$20 million DARPA award for the Domain-Specific System on Chip program.

HIGHLIGHTS

In fiscal year 2020, ASU continued its trajectory of rapid growth and impact. The university reached \$640 million in research expenditures and submitted a record \$2.4 billion in proposals, largely based on TRIF-enabled activities. ASU researchers address the most pressing challenges in each of the TRIF focus areas in order to benefit the citizens of Arizona and beyond.

The coronavirus crisis is far from over, and ASU is mobilizing efforts not only toward testing, tracking and treating the disease, but also understanding and mitigating its effect on our economy and society. For example, GSI's Center for Accelerating Operational Efficiency, a Department of Homeland Security Center of Excellence, is leveraging its ongoing research in disaster preparation and response to address logistics and supply chain challenges related to the pandemic. In addition, ASU's Research Development team is assisting more than 240 faculty and staff members interested in developing collaborative proposals in response to COVID-19 in areas ranging from immigration policy to disinformation to how people use data visualizations.

The Biodesign Institute's compact X-ray free electron laser (CXFEL) is poised to increase our understanding of viruses and other pathogens, as well as countless other molecules and materials. The CXFEL took a major leap forward this year with a comprehensive design study, supported by a \$4.7 million grant from the National Science Foundation. In November, ASU hosted a Nature conference focused on XFEL technology, attended by top scientists in the field. Conference attendees, as well as senior leadership from the National Institutes of Health, toured the CXFEL facility and learned about the potential for research projects and collaborations.

New technologies are revolutionizing industries and transforming the workplace. ASU has leveraged TRIF investment to secure funding that will advance critical industries and train tomorrow's workforce to meet the demands of the future.

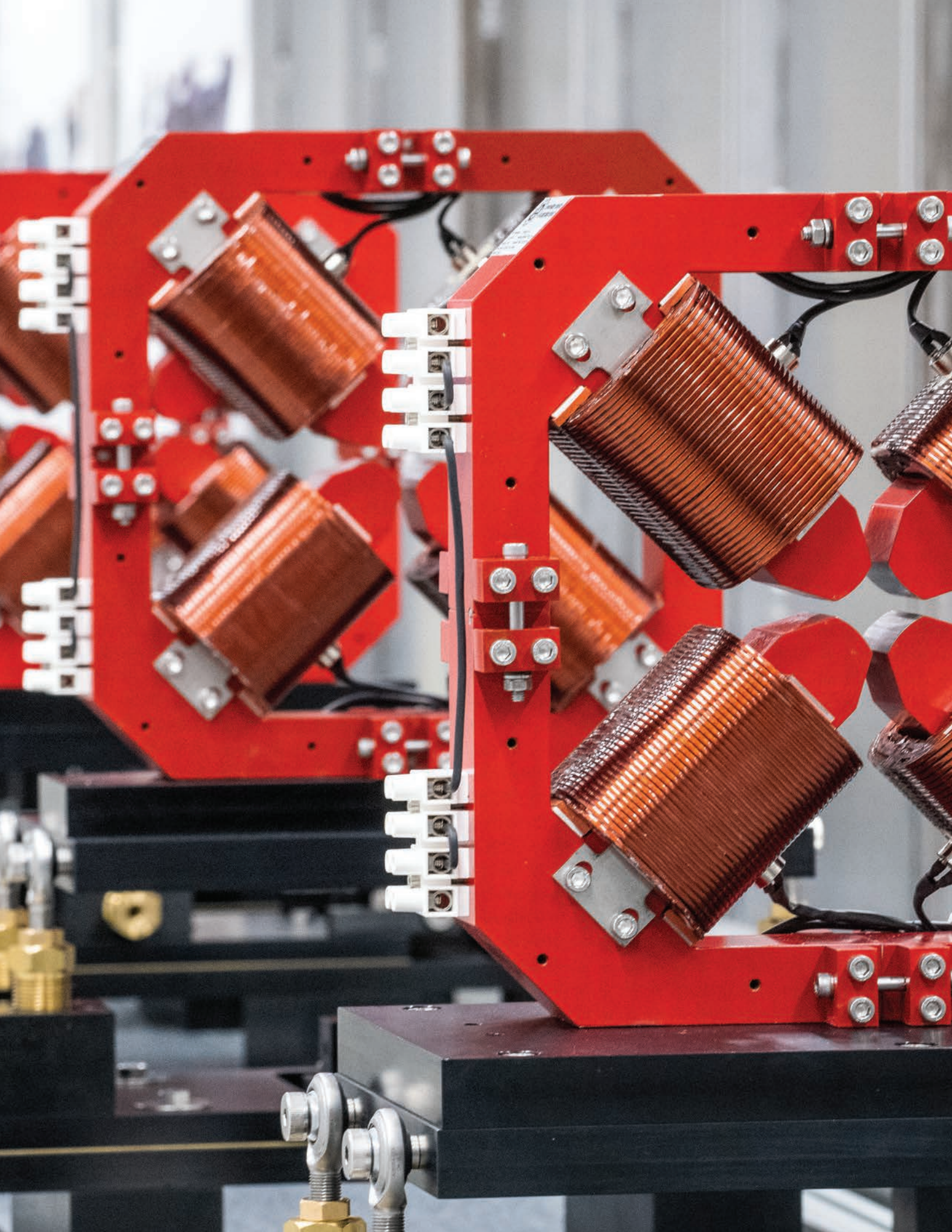
Corporate Engagement and Strategic Partnerships (CESP) secured a \$30 million gift from State Farm to drive a new education and career development program that targets high school and transfer students, as well as working adults. This program creates connections between students, faculty, mentors and employers that enable lifelong learning, providing learners the knowledge necessary for life and work in the 21st century.

CESP also won a \$2 million Department of Labor grant focused on public-private partnerships to address the acute need for a skilled information technology workforce. This program targets 1,600 ASU students and new learners over a four-year timeframe, promoting the large-scale expansion of apprenticeships across the nation to a range of employers, including small and medium-sized businesses.

The Navrotsky Eyring Center for Materials of the Universe is uniting interdisciplinary teams of scientists to help design next-generation materials for space exploration. Initial TRIF investment in the center has attracted nearly \$5 million in grant funding and infrastructure development, in addition to a \$1 million endowment for expanding and sustaining the center.

These are just a few of the ways that ASU is building on its foundation of TRIF-enabled impact. As the university's research enterprise grows, ASU accelerates discoveries and technologies that provide real solutions for health, sustainability, security and economic well-being. ASU provides valuable opportunities for hands-on learning to graduate, undergraduate and K-12 students. And, ASU shares knowledge broadly, reinvesting in Arizona to help communities prosper and thrive.









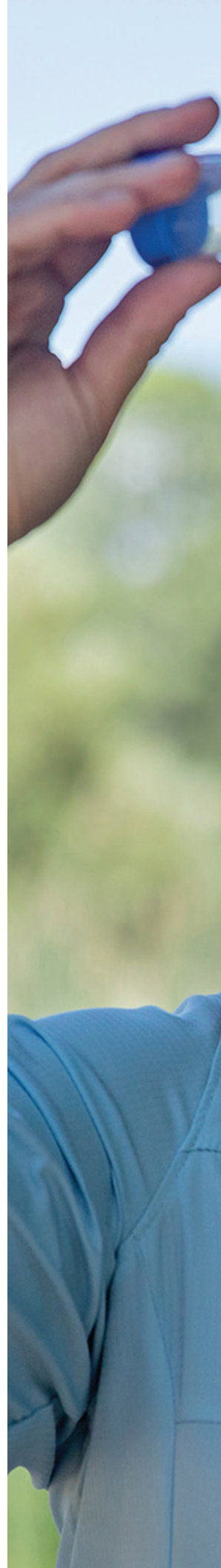
NORTHERN ARIZONA UNIVERSITY

Northern Arizona University's capacity to invest in areas of strategic research growth was significantly expanded in 2016 when the Arizona Board of Regents approved NAU's bold five-year plan for fiscal years 2017-21 TRIF. NAU's TRIF financial investments have had a meaningful impact throughout Arizona, producing economic benefits through scientific advancements, workforce training and access to higher education. In fiscal year 2020, TRIF funding has enabled NAU faculty to attract a total of \$23,685,184 in 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 the 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 19 patents. In addition, NAU filed 41 new patent applications and submitted 43 new invention disclosures.

One of the most compelling examples of NAU's successful research partnerships is the response to the COVID-19 pandemic. In April 2020, NAU's Pathogen and Microbiome Institute (PMI) launched the COVID-19 Testing Service Center (CTSC). 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 COVID-19 pandemic, enabling both industry and nonprofit partners to test potential vaccines and treatments against the coronavirus.

- 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, in clinical settings and in the public health arena — in ways that elevate translational research capabilities to new heights. This has become even more evident as NAU researchers have catalyzed their efforts around the COVID-19 pandemic.
- The NSS initiative has driven investment in research-intensive hires and in high-tech laboratories, and as a result, NAU has already become a leader in the critical area of cybersecurity, developing new technologies to protect Arizona's businesses and consumers while spurring its economy. This discipline is a core national security priority that will affect all Arizonans in the years ahead and NAU is committed to developing the highly qualified workforce 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, particularly focused on serving communities throughout Arizona.
- The WEES initiative, based on regional research that is one of NAU's historic strengths, has driven the university to explore and discover on a global scale, enhancing the university's leadership position in this discipline.
- The SPACE initiative capitalizes on the recent recruitment of research-intensive faculty in the areas of astronomy and planetary science, while leveraging the wealth of astronomical resources found throughout Arizona at partner institutions, to prepare a workforce that will strengthen Arizona's stature as a worldwide leader in this rapidly growing area of research.





“Ongoing funding from the Technology and Research Initiative Fund (TRIF) has enabled Northern Arizona University to significantly increase its research productivity, becoming globally recognized for achievements in a wide range of disciplines.


“NAU’s research enterprise is a vital growth engine for Arizona’s economy. As our researchers and research centers work to carry out their missions, they actively collaborate with state and community agencies, foundations, nonprofit organizations and initiatives and a host of other partners.

“Our success in research has a significant impact on the quality of Arizona’s education system. Through our public service and outreach initiatives, we influence curricula in K-12 classrooms throughout the state. Our dedicated faculty researchers, who serve as both educators and mentors, provide meaningful hands-on experiences to our students, preparing the next generation for the challenges of the future.

“NAU’s public service and outreach initiatives are making our state a better place for every Arizonan by increasing access to healthcare, quality education and social support services for underserved populations in our region.

“Research thrives at NAU, and with funding from TRIF, we continue to build our capacity for research in a broad range of disciplines that will help improve health, the environment, the economy — and quality of life — for all.”

– Rita Hartung Cheng, 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

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

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 established the Center for Health Equity Research (CHER) to address the health care disparities of the state's underserved populations, including Native Americans, Hispanics and rural communities. This initiative has resulted in millions of dollars in new grant funding — most notably, the Southwest Health Equity Research Collaborative, a five-year, grant-funded initiative supported by more than \$21.4 million in funding from the National Institute on Minority Health and Health Disparities of the National Institutes of Health.

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. This expansion and investment in PMI has led to increased extramural research funding as well as startup companies formed to commercialize its discoveries. 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. In fiscal year 2020, NAU launched the COVID-19 Testing Service Center (CTSC) to grow the SARS-CoV-2 virus and test new drugs against it, giving Arizona an edge in responding to the crisis.

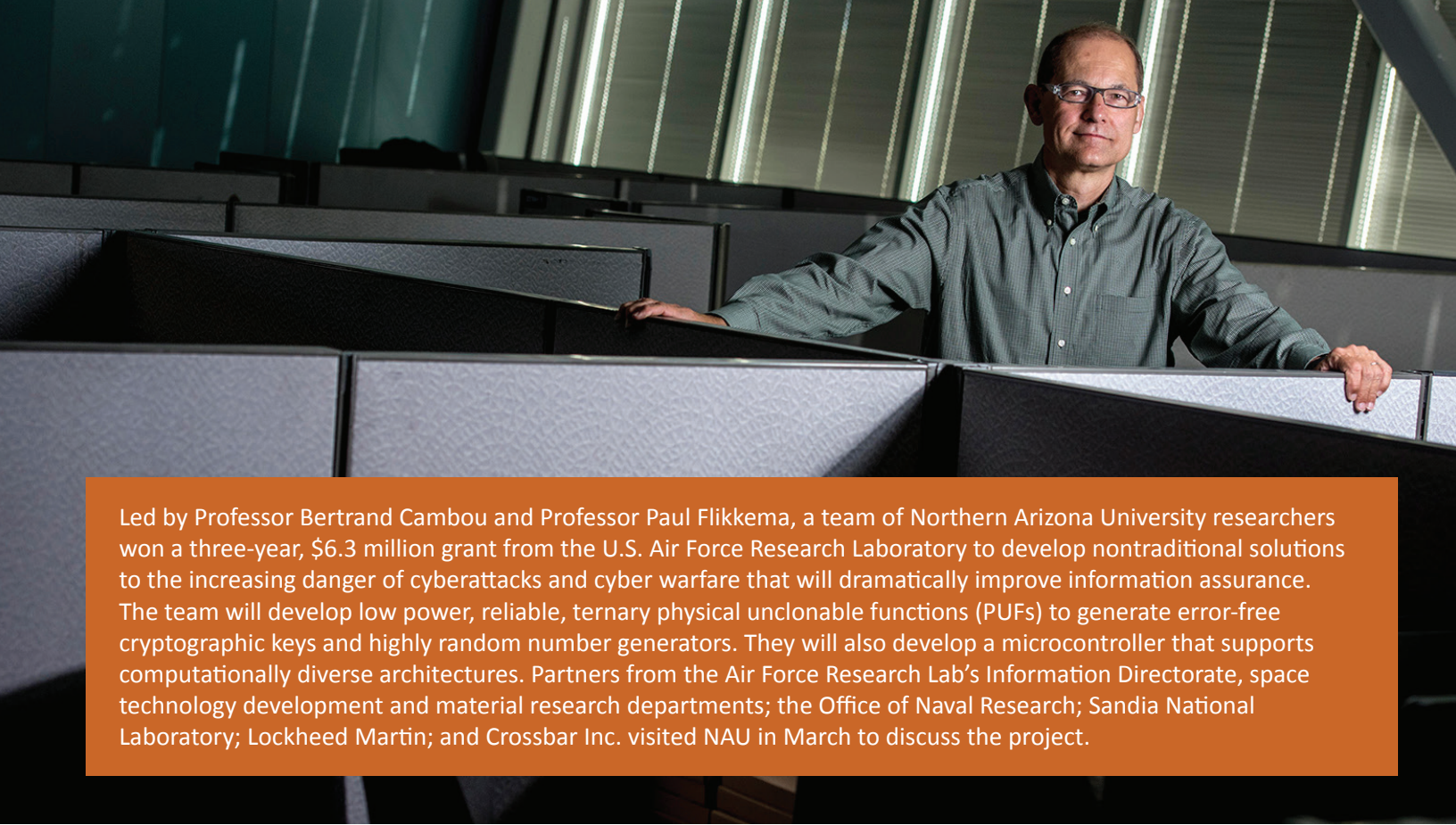
Bioengineering/Biotechnology: Investments in NAU's strengths in bioengineering and biotechnology are catalyzing discoveries that improve lives, foster economic growth in Arizona and beyond and provide cutting-edge training in bioengineering research for undergraduates and graduate students who will join the biotechnology workforce. Research in this field focuses on a wide range of areas, including personal bionics and wearable robotics, rehabilitation, hearing improvement and materials and devices for biocompatible implants and sensors. In fiscal year 2019, NAU established the Center for Materials Interfaces for Research and Applications (iMIRA!). Through basic and applied science discoveries in materials interfaces, NAU will impact health, energy and the environment, and these new technological applications can improve lives and enhance economic potential. NAU launched a new Ph.D. program in Applied Physics and Materials Science in fiscal year 2020, positioning NAU to attract students to a unique state program: a research-intensive Ph.D. program that prepares graduates for meaningful and fulfilling careers in the application of physics or materials science to critical areas of national need.

GOALS:

- **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 and strengthen partnerships with health care providers in Northern Arizona.**
- **Generate new biotechnology startup enterprises and jobs in the region.**

SUMMARY OF ACCOMPLISHMENTS

- Northern Arizona University'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 Improving Health initiative received \$6,234,337 in external grant funds in fiscal year 2020.
- The U.S. Army Contracting Command awarded Regents Professor Paul Keim, executive director of PMI, \$2.8 million to develop prototype Bartonella hensalae and Chikungunya virus biothreat detectors. Keim also received a \$214,493 award to collaborate with Arizona State University on a major project for the Defense Advanced Research Projects Agency to develop a field deployable diagnostic test that can quickly detect an individual's history of exposure to weapons of mass destruction.
- Assistant Professor Jason Ladner, assistant director of PMI, was awarded \$781,269 to collaborate with TGen on a project for the National Institutes of Health (NIH). The researchers will develop a technology that enables antibodies against hundreds of thousands of selectable targets to be measured simultaneously in a small drop of blood, with a focus on antibodies that recognize any of the more than 300 viruses capable of infecting humans.
- Associate Professor Jeffrey Foster, assistant director of PMI, received a \$563,784 award from the National Science Foundation (NSF) and the National Natural Science Foundation of China to collaborate on a major genetic study of white-nose syndrome in bats.
- The NSF awarded Regents Professor Kiisa Nishikawa \$551,792 to develop a novel approach for investigating the neuromechanics of in vivo muscle function.
- Professor David Wagner, director of PMI's Biodefense and Disease Ecology Center, received \$500,000 from the U.S. Defense Threat Reduction Agency (DTRA) to study the human plague in Madagascar.
- The NIH awarded Assistant Professor Emily Cope, assistant director of PMI, \$468,472 to seek a microbial link between chronic rhinosinusitis and asthma, both serious and costly diseases. She was also awarded \$50,000 by the Arizona Alzheimer's Consortium to study the causality of the gut microbiome via the gut-brain axis in Alzheimer's disease.
- Assistant Professor Zachary Lerner received a \$423,876 award from the NIH to evaluate the novel use of powered ankle assistance from a wearable exoskeleton to improve walking economy across varied terrain in children with cerebral palsy.
- The DTRA awarded Assistant Professor C. Todd French \$374,656 to explore how environmental factors affect the presence and virulence of Burkholderia pseudomallei. He also received \$55,112 from the NIH to develop vault nanoparticles as a delivery platform for Burkholderia pseudomallei and Burkholderia mallei antigens.
- Regents Professor Julie Baldwin, director of NAU's Center for Health Equity Research, received a \$250,000 grant from the NIH to study the unique needs of caregivers of persons with Alzheimer's disease and related dementias, identifying how family caregivers are coping with current COVID-19-related demands. She was also awarded \$75,000 by the Flinn Foundation to develop mathematical models describing the spread of SARS-CoV-2 that are fine-tuned to the rural communities of northern Arizona.
- Assistant Professor Crystal Hepp, assistant director of PMI, was awarded a \$225,000 New Investigator Award grant by the Arizona Biomedical Research Centre to investigate the circulation and source locations of West Nile virus in the state.
- Professor Miguel José Yacamán received \$200,000 from the NSF to develop a new physics-based test technology for COVID-19.
- Assistant Professor Amirhossein Arzani was awarded \$174,999 by the NSF to develop a computational framework to predict cardiovascular disease progression.
- Assistant Professor Matt Salanga is leading a project funded through \$100,000 from the Flinn Foundation to determine the most effective combination of cancer-fighting drugs to fight melanoma, the most lethal type of skin cancer.
- PMI has executed service agreements with two industry partners to leverage its new COVID-19 Testing Service Center (CTSC) capabilities. Assistant Professor French, who leads the CTSC, is working with scientists at Vault Pharma and Oncology Venture to test the effectiveness of their drugs on COVID-19. The Flinn Foundation awarded PMI \$100,000 to accelerate the CTSC's ramp-up to begin this work; the grant will also support the work of Associate Professor Bridget Barker, associate director of PMI.
- NAU was jointly awarded U.S. patents for technologies co-invented by Regents Professor Paul Keim: Systems and Methods for Universal Tail-based Indexing Strategies for Amplicon Sequencing; Single Molecule-Overlapping Read Analysis for Minor Variant Mutation Detection in Pathogen Samples (which was also awarded a European Union patent); and Isolated Genes and Transgenic Organisms for Producing Biofuels. NAU was jointly awarded a U.S. patent and a Japanese patent for Ionic Liquids for Transdermal Drug Delivery, co-invented by Associate Professor Andrew Koppisch.
- In fiscal year 2020, TRIF funds strengthened resources in NAU's core facilities serving health research communities via NAU's Research Equipment Acquisition Program, including the Imaging and Histology Core Facility and Environmental Genetics and Genomics Lab.



Led by Professor Bertrand Cambou and Professor Paul Flikkema, a team of Northern Arizona University researchers won a three-year, \$6.3 million grant from the U.S. Air Force Research Laboratory to develop nontraditional solutions to the increasing danger of cyberattacks and cyber warfare that will dramatically improve information assurance. The team will develop low power, reliable, ternary physical unclonable functions (PUFs) to generate error-free cryptographic keys and highly random number generators. They will also develop a microcontroller that supports computationally diverse architectures. Partners from the Air Force Research Lab's Information Directorate, space technology development and material research departments; the Office of Naval Research; Sandia National Laboratory; Lockheed Martin; and Crossbar Inc. visited NAU in March to discuss the project.

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. Under the fiscal year 2017-2021 business plan, Northern Arizona University's investments in the National Security initiative focus on cybersolutions, which are being delivered through NAU's School of Informatics, Computing and Cyber Systems (SICCS). Because of these investments, NAU is successfully attracting major funding from a variety of government agencies responsible for national security, including the U.S. Air Force and the U.S. Navy.

Cybersolutions 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 will include both software designs and embedded encryption in hardware. Reconfigurable computing represents major challenges for cybersecurity due to a need for computing programs that are adaptable and often less secure, e.g. machine learning. 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.

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.**
- **Emphasize scholarly productivity and extramural funding by creating a culture that centers on high expectations and high-impact interdisciplinary research.**
- **Provide cutting-edge training and learning opportunities to students by integrating research into existing curricular programs and building new programs that support 21st-century technological challenges.**

SUMMARY OF ACCOMPLISHMENTS

Northern Arizona University's National Security Systems initiative leverages research, discovery and training to develop and disseminate innovative and secure applications in informatics, computing and cyber systems. The university will accomplish its goals largely through NAU's School of Informatics, Computing and Cyber Systems (SICCS), which was formed to meet the need for advanced interdisciplinary computational and data sciences, and to enable NAU to successfully compete for major external research grants in informatics, cyber systems development and cybersecurity.

- NAU faculty who received TRIF funds through the NSS initiative received \$6,445,205 in external grant awards in fiscal year 2020.
- Associate Professor Fatemeh Afghah was awarded \$349,149 by the National Science Foundation to develop transformative changes to the way challenges and responses to physical unclonable functions (PUF) are corrected.
- Assistant Professor Ryan Behunin was awarded \$150,000 by the Defense Advanced Research Projects Agency to collaborate with Honeywell Aerospace Advanced Technology, which is leading a team of world-class universities and industry-leading technology partners, to make the first truly compact optical frequency standard-based clock. With short- and long-term stability more than 1,000 times better than any existing portable clock technology, the results of this project could dramatically improve real-world timing and navigation systems.
- Professor Bertrand Cambou received \$49,526 from industry partner Sawblade Ventures for a project to develop and deploy a set of technologies strengthening Sawblade's product offering. The researchers will build on the portfolio of cyber technologies developed by NAU, as well as those jointly developed with Sawblade, to select those that are synergistic with an advanced electronic design automation environment.
- NAU was awarded patents for five new technologies invented by Cambou:
 - Encoding Ternary Data for PUF Environments (two separate patents)
 - Systems Implementing Hierarchical Levels of Security
 - PUF Hardware Arrangement for Increased Throughput (two separate patents)
- NAU was awarded three separate patents for new technologies co-invented by Cambou and Afghah, Multi-State Unclonable Functions and Related Systems.
- NAU was awarded a patent for Authentication of Images Extracted from Unclonable Objects, a new technology co-invented by Cambou and Assistant Professor Abolfazl Razi.
- NAU was awarded a patent for False Alarm Suppression in Intensive Care Units, a new technology co-invented by Afghah and Razi.
- NAU launched three new online programs in cybersecurity — a Bachelor of Science, Master of Science and a graduate certificate. These programs prepare students with the technical skills to analyze and understand cybersecurity exploits and to design hardened computational systems.



Associate Professor Fatemeh Afghah was one of only 40 researchers nationwide — and the only one in Arizona — recognized with the Air Force Young Investigator Award, a three-year, \$450,000 grant intended to foster creative basic research in science and engineering, enhance career development and provide opportunities for engineers to address military challenges in science and engineering. Through this project, Afghah is developing an algorithm to enable an unmanned aerial vehicle — a UAV or drone — to monitor disaster-impacted areas. The fully autonomous system should be able to monitor the area, send pictures, develop a task list and a task allocation mechanism to assign work to other UAVs.



ACCESS AND WORKFORCE DEVELOPMENT

Northern Arizona University continues to expand upon more than three decades of success providing flexible, affordable, market-driven degree programs across Arizona. NAU's TRIF initiative, Access and Workforce Development (AWD), supports statewide and online efforts to connect community members to degrees in the health sciences and education. By integrating cutting-edge pedagogy and instructional technology, these programs meet both student and employer needs throughout the state. Whether through concurrent enrollment at local community colleges or through robust transfer articulation agreements, a growing number of Arizonans have achieved a higher education degree and career success through NAU's workforce-driven programs.

Health services and education remain high demand workforce industries in Arizona. NAU continues to expand nursing program offerings to meet a variety of new and practicing nurse employment and advancement needs. In the spring of 2020, NAU launched its first for credit microcredential for nurses with a master's degree to gain prescriptive authority. NAU's heritage as a teacher's college is honored by this initiative through support of teacher education programming throughout Arizona and online.

Student success and degree completion are supported through integrated, on-demand services, informed by the best practices in student onboarding, retention and coaching, and through the application of adaptive learning technologies.

GOALS

- **Advanced training for high demand health professions, including expanded concurrent programs with community colleges and a new competency-based nursing program.**
- **Continuing education and advanced degree offerings in teacher education.**
- **Expansion of student success and retention efforts through engaged academic coaching and advising for online and statewide students.**
- **Design and coordination of a coherent and comprehensive teaching and learning support structure for university-wide application.**
- **Applying e-Learning strategies to increase degree productivity; transform how faculty teach; and improve how and how much students learn while preparing students with life-long skills for learning through technology.**
- **Intentional course design for student success with a focus on blended delivery modes and application of adaptive learning technologies for individuation of learning.**

SUMMARY OF ACCOMPLISHMENTS

A vital component of the mission and strategic plan of Northern Arizona University is to provide access to higher education and create opportunities for Arizonans. In addition to the residential campus in Flagstaff, NAU offers over 100 programs online and across the state in partnership with local community colleges 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 are available when needed, at a price Arizonians can afford. Equally important is the ability for all students to receive the same high-quality services, regardless of their learning modality or location.

- Nursing and other skilled health professionals are in high demand. Health care and social assistance remain in the top six section of industry in Arizona by job volume, and are expected to continue to grow into the next decade (U.S. Bureau of Labor Statistics). NAU offers seven health sciences bachelor's degree completion programs in addition to a concurrent RN-BSN nursing program to provide flexibility to working health professionals. These programs are offered online and around the state with our community colleges partners.
- The College of Education expanded its initiatives in serving the behavioral health needs of Arizona. Specifically, program capacities were doubled to admit twice the number of students in school counseling, school psychology and clinical mental health counseling.
- The university was able to respond to the needs of students who were displaced as a result of university (Argosy) closures in Arizona. NAU expanded the reach of teacher education programs across Arizona, with the support of the Arizona Teachers Academy scholarship, and especially in rural Arizona.
- NAU Online continues to support and build web-enhanced, blended, hybrid and fully online (both traditional and competency-based) courses through its e-Learning unit, with an emphasis on course consistency, quality and student success.
- NAU Online piloted a continuing education unit in the fall that was supported by e-Learning in the development of non-credit education microcredentials. In the spring, an Entrepreneurship series and a group of virtual summer camps including Meaning Making in a Pandemic, Introduction to Brewing Science and The World of Olympians were highlights of this effort.
- NAU Online's e-Learning unit has been pivotal in preparations for the delivery of NAUFlex courses in anticipation of enrollment challenges related to COVID-19, where live synchronous remote instruction via Zoom and Collaborate Ultra is backed up by asynchronous content. This included the delivery of dozens of well-attended webinars on effective instruction and technology tools.
- NAU continues to leverage its strengths in individualized learning and student support as the university provides access to Arizonans who choose to learn away from the main campus. Aligning services for nontraditional 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.
- TRIF dollars provided not just academic programming for Arizona students, but also ensured professional advising and support services for statewide and online students, including fieldwork placements for health professionals.





Professor Kevin Gurney received \$683,065 from the National Institute of Standards and Technology to continue his research on the Hestia fossil fuels carbon dioxide emissions output to inform policy and decision support. He was also awarded \$101,403 by the National Oceanic and Atmospheric Administration to build on his previous work to undertake a similar analysis of U.S. monthly fossil fuel emissions for observations spanning 2010-2019.

WATER, ENVIRONMENTAL AND ENERGY SOLUTIONS

Under the fiscal year 2017-2021 Business Plan, Northern Arizona University'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 NAU's historical strengths in environmental and ecosystem sciences. Investments in these areas have created several important research centers at NAU:

- **Center for Ecosystem Science and Society (EcoSS):** Researchers in EcoSS 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.
- In fiscal year 2020, NAU established the **Center for Adaptable Western Landscapes (CAWL)**. CAWL will capitalize on the ongoing success and the great legacy of achievement of the Merriam-Powell Center for Environmental Research (MPCER), which has been instrumental in advancing cross-disciplinary environmental research and training at NAU, and the Land Conservation Initiative (LCI), which has supported applied biological research, collaborative planning and field-based educational experiences to forge new solutions to landscape-scale environmental challenges, bringing strong scientific support to public deliberation and land-management efforts across Arizona. CAWL will synthesize these two streams of success, preserving much of the very best of both, and creating new synergy to achieve even more. NAU has great expectations for CAWL to have robust 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

- **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

Northern Arizona University'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 been able to develop solutions to some of the unique environmental challenges of the southwestern United States.

- NAU faculty who received TRIF funds through the WEES initiative received \$8,910,904 in external grant awards in fiscal year 2020.
- Regents Professor Bruce Hungate, director of NAU's Center for Ecosystem Science and Society (EcoSS), received a \$2.24 million grant from the U.S. Department of Energy to investigate and describe the microbial ecology of nutrient feedbacks to climate warming, conducting experiments in arctic, boreal, temperate and tropical biomes.
- Professor Edward Schuur, who leads the global Permafrost Carbon Network (PCN), was awarded \$1 million by the National Science Foundation to provide a platform for collaborative research and networking activities that will give scientists and decision makers an annually updated view of changing Arctic carbon emissions into the atmosphere. Results of this research will inform the Intergovernmental Panel on Climate Change. He also received \$456,652 from the NSF to acquire IonPlus automated radiocarbon instrumentation, which will enable researchers to produce an integrated gas analysis and labeling radiocarbon system with a focus on Arctic carbon and geochronology. Schuur received \$1 million from the U.S. Department of Energy to continue his research into changing environmental conditions in high latitude arctic and boreal ecosystems as a result of permafrost thaw.
- The NSF awarded Associate Professor Nicholas McKay four grants totaling \$1.34 million:
 - \$527,906 to compare the rate of Arctic system response to past warming events with similar rate and duration to that of modern warming, providing a better understanding of the potential response to future warming.
 - \$453,466 to build on his previous work to develop PRESto: A Paleoclimate Reconstruction Storehouse to Broaden Access and Accelerate Scientific Inference, which will make paleoclimate information vastly more accessible beyond academia.
 - \$209,116 to build on previous work to support a hybrid-federated annotation system within the geosciences.
 - \$152,451 to launch a data mobilization campaign designed to bring Earth systems data into community-curated scientific that allow users to detect, map and investigate abrupt change in Earth systems.
- The NSF awarded Assistant Professor Rebecca Best \$882,310 to conduct a study to investigate the magnitude, evolution and community consequences of phenotypic plasticity in a widespread foundation tree, *Populus fremontii*.
- Assistant Professor Christopher Doughty was awarded \$273,453 by NASA to validate the effects of climate change on plant water use efficiency in the tropical regions of South America and Western Africa.
- Professor Han-Sup Han, director of forest operations and biomass utilization for NAU's Ecological Restoration Institute, was awarded \$260,000 by the U.S. Forest Service for a project designed to reduce wildfire risk, develop the wood products market, invest in rural economies and increase forest restoration treatments across Arizona, New Mexico and Colorado.



John & Pit Lucking Family
Professor Catherine Gehring,
co-director of the new Center for
Adaptable Western Landscapes,
received \$217,380 from the U.S.
Geological Survey to evaluate
strategies for managing and
restoring dryland ecosystems
degraded by drought.

SPACE EXPLORATION AND OPTICAL SOLUTIONS

Under the fiscal year 2017-2021 Business Plan, Northern Arizona University'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, while 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 researchers study the formation and evolution of the solar system, detecting and characterizing the physical and chemical properties of rocky asteroids that could potentially impact the Earth. They are looking for the elusive "Planet X," a large and undiscovered planet in the most distant regions of the solar system. They are also 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 members and their students direct the path and daily tasks of the NASA Curiosity Rover on the surface of Mars from the NAU campus; they also build flight instruments for spacecraft bound for Mars.

Exoplanets researchers study planets orbiting distant stars using telescopes and computer simulations to characterize their physical and chemical properties. The researchers' goal is to identify which of the thousands of known exoplanets are the best candidates to harbor life and are therefore worthy of further study.

GOALS

- **Double external research funding in astronomy and planetary science.**
- **Partner with Arizona companies to develop instrumentation for shoe-box sized spacecraft (CubeSats).**
- **Fly a CubeSat to an extraterrestrial object, such as an asteroid.**
- **Expand partnerships with private observatories such as Lowell Observatory, FRoST 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.**



Assistant Professor Mark Salvatore was awarded \$167,000 by the National Science Foundation to develop a protocol to analyze a massive amount of data — more than 60,000 images — across the frozen landscape of Antarctica. Ultimately, Salvatore aims to build the cyberinfrastructure required to make the most of satellite imagery for geosciences, starting with researchers working in polar areas and branching out to the larger non-polar community.



Professor David Trilling received \$341,275 from the National Science Foundation to continue NAU's long-running Research Experiences for Undergraduates program in Astronomy and Planetary Science. Students carry out individual research projects with mentors from NAU, Lowell Observatory and the U.S. Geological Survey, and develop their professional skills and networks. NAU has a particular emphasis on recruiting female students and students from diverse backgrounds, the latter through collaborations with minority serving institutions in California and New Mexico.

SUMMARY OF ACCOMPLISHMENTS

As the first International Dark Sky City, Flagstaff — at 7,000 feet above sea level — is a natural location for studying astronomy and planetary sciences. Through TRIF investment in the Exploring Planetary Systems research initiative, Northern Arizona University 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, to contribute to a new understanding of our place in the universe and to seek opportunities to translate research into economically productive innovations with commercial applications.

- NAU faculty who received TRIF funds through the SPACE initiative received \$2,094,738 in external grant awards in fiscal year 2020.
- Professor David Trilling was awarded \$792,164 by NASA to support a large-scale telescope survey in Chile he is leading with a multi-institution team. The project's overall science goals are to measure the properties of faint bodies in the outer Solar System to help understand the formation and evolution of our Solar System.
- NASA awarded Associate Professor Joshua Emery four grants totaling \$781,298:
 - \$320,717 for a project to search for the presence of water on Near Earth Objects (NEOs) and asteroids in the Main Asteroid Belt in collaboration with scientists at the University of Arizona.
 - \$261,907 for his work on the OSIRIS-REx Asteroid Sample Return Mission, whose primary objective is to send a spacecraft to the asteroid Bennu and return with a pristine sample from its surface. Scientists will study the sample in depth to address some of NASA's (and humanity's) fundamental questions: How did the Solar System form? How did life evolve in the Solar System? Are asteroids harbingers of life or death, or both?
 - \$160,904 to investigate the origin of CO₂ ice and dark, spectrally red material on the surfaces of the regular satellites of Uranus.
 - \$37,770 to collaborate with the Southwest Research Institute on the Lucy mission, the first reconnaissance of the Jupiter Trojan asteroids — objects that hold vital clues to deciphering the history of the Solar System.
- Professor Devon Burr received \$198,730 from NASA to investigate the source(s) of dark sand in the western medusae fossae formation on Mars. He also received \$64,976 from NASA to collaborate with Colgate University to investigate endmember sedimentological processes on Titan, the largest moon of Saturn and the second-largest natural satellite in the Solar System.
- In fiscal year 2020, TRIF funds were used to strengthen partnerships with telescope facilities used by NAU astronomers and planetary scientists, including the Discovery Telescope Partnership with Lowell Observatory.

HIGHLIGHTS

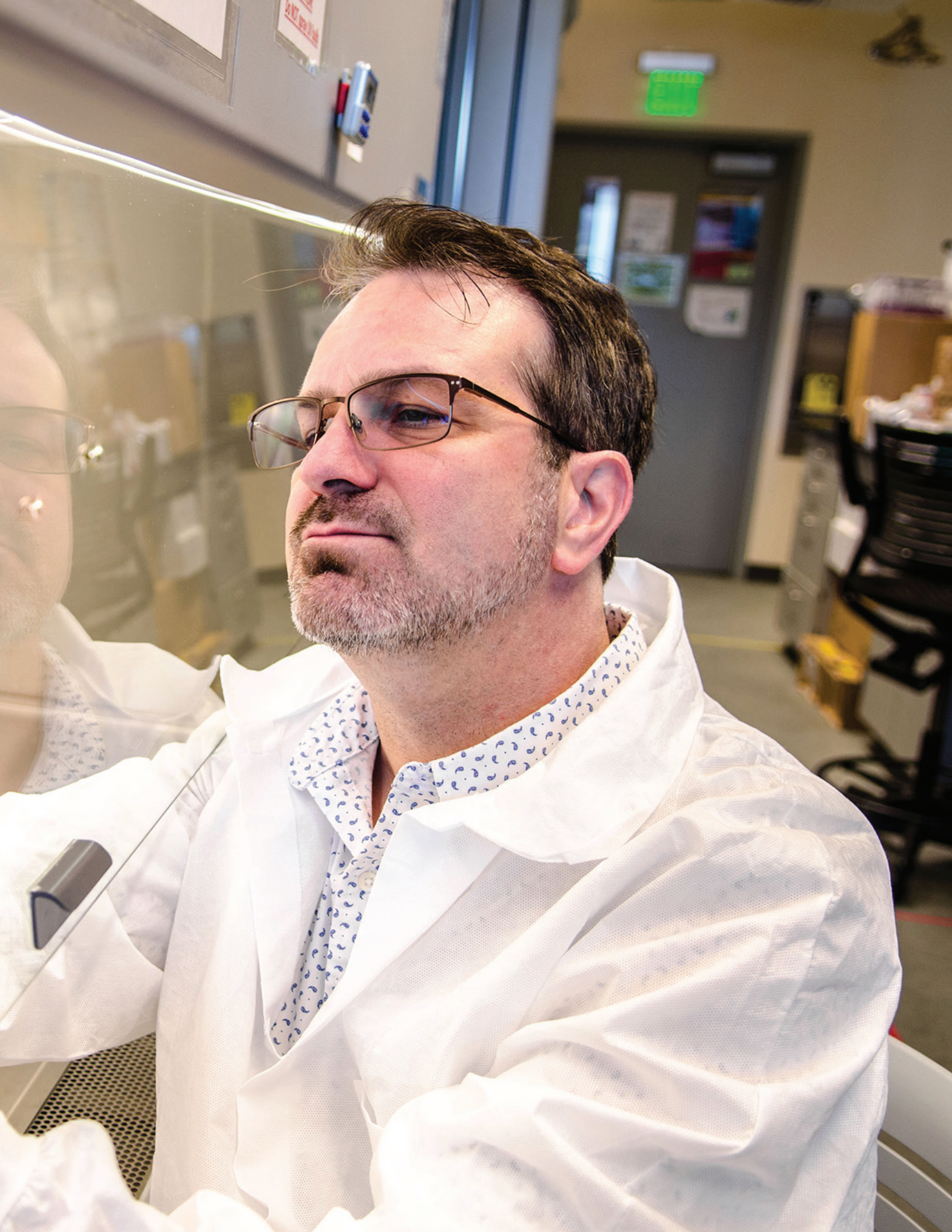
At NAU, aspirations are at the heart of everything the university does. Students bring their aspirations to NAU to learn, grow and achieve academic success that will ultimately lead to fulfilling lives. Faculty researchers are always aspiring, too — to solve the most compelling problems, to meet the most complex challenges, 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, research centers and new graduate programs have enabled NAU to make significant financial impact progress, generating technology transfer activity, including 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's TRIF initiative in Access and Workforce Development complements NAU's mission to serve the state of Arizona through accessible education delivery models. This initiative includes the integration of technology and advanced learning designs to increase student engagement across all of NAU's campuses. The primary focus of this effort is to provide educational alternatives to attending a residential campus in order to meet both student demands for a degree and workforce needs in local communities. NAU has advanced this effort through community campuses, in partnership with community colleges, online learning and the competency-based Personalized Learning program.









THE UNIVERSITY
OF ARIZONA

UNIVERSITY OF ARIZONA

As the largest research university in the state, with nearly \$690 million in research expenditures, the University of Arizona is producing results that are creating impactful solutions to many global problems, preparing students for the workforce of tomorrow and contributing as one of the largest economic engines for Arizona.

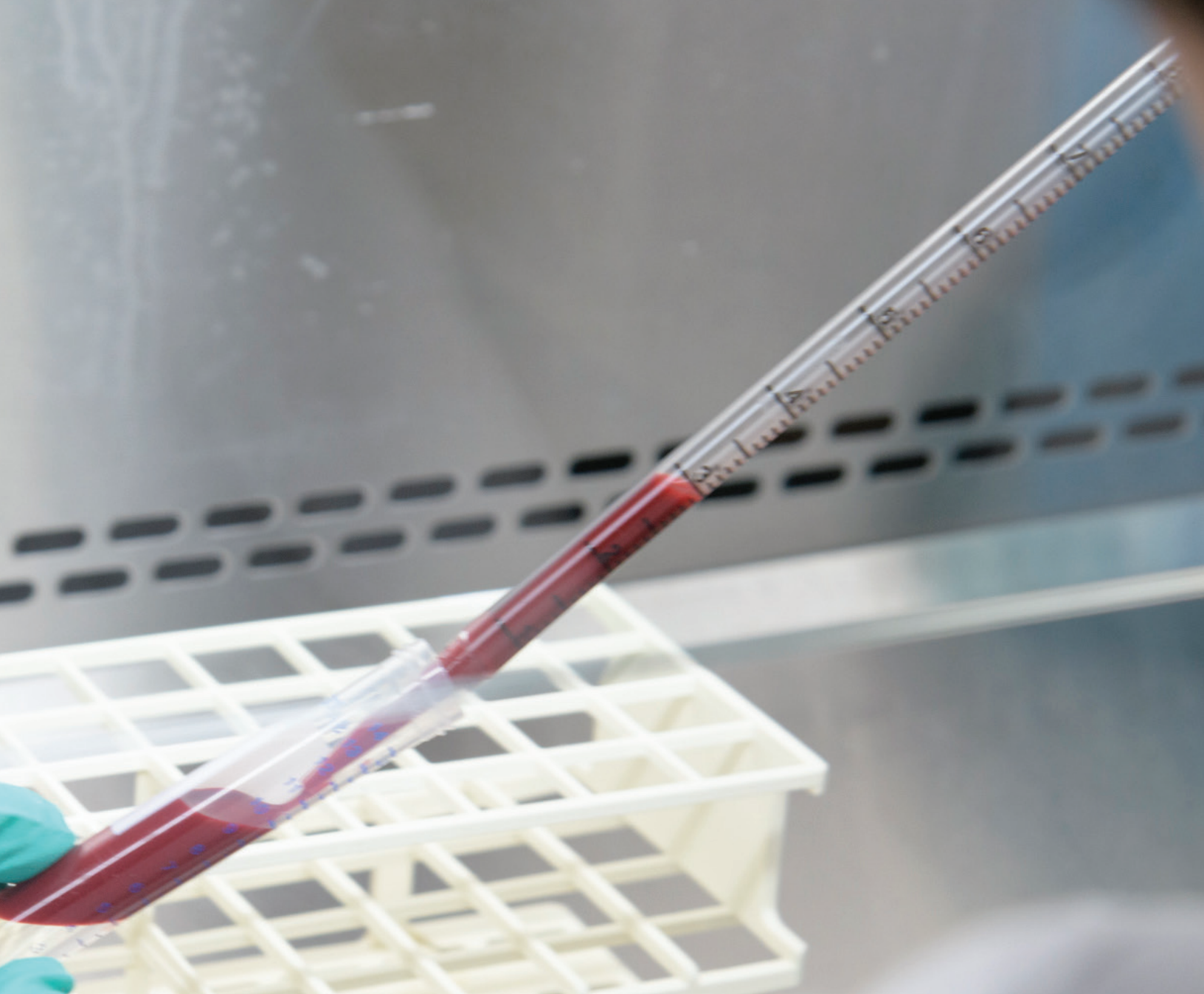
The philosophy of UArizona's TRIF program is to advance economic development opportunities and benefit Arizonans. The university does this by catalyzing research and development; supporting the infrastructure, facilities and computing that enables cutting-edge research and development; producing results that leverage UArizona's expertise; and attracting outside resources to the state.

UArizona is combining that philosophy with the newly approved Strategic Plan, inspired by the Fourth Industrial Revolution – a time of augmented intelligence and the fusion of digital, physical and biological worlds. UArizona's plan is bold and distinctive with 90+ initiatives organized under five pillars.

UArizona participates in the following TRIF initiatives:

- **Improving Health:** Health care is changing, and UArizona is at the forefront of the precision health movement — finding individual solutions to medical problems by taking into account individual variation in genes, environments and lifestyles. TRIF investments in Improving Health 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.
- **Water, Environmental and Energy Solutions:** UArizona has been recognized as the world's No. 1 program in water resources by the Shanghai Academic Ranking of World Universities for the second consecutive year, recognizing outstanding leadership in water research. The WEES initiative invests TRIF dollars in cutting-edge food, energy and water research, cross-campus collaborations and innovative partnerships that promote fresh ideas, technologies and effective resource management practices necessary to help sustain a swelling global population. UArizona's decision-support tools that integrate rainfall data into transportation and agricultural scenario planning as well as research on how groundwater pumping affects rivers, makes Arizona a safer and healthier place to live, now and in the future.
- **National Security Systems:** Harnessed by UArizona's Defense and Security Research Institute, researchers are finding effective and practical solutions in one of the most critical areas of research today — national security. UArizona's National Security Systems initiative impacts a range of technology and research at the university — from optics to high-temperature materials to hypersonics.
- **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. Given these strengths, it's no surprise that SEOS is the most lucrative of UArizona's TRIF initiatives, with an almost eight-fold return on investment. Strategies in this area will help the university continue to reach farther, faster, in this age of information and space exploration.





“TRIF funding enables the University of Arizona to advance knowledge and its applications by investing across our institution so that we not only stimulate the highest quality thought leadership, research and scholarship, but also allow our faculty, students and staff to translate knowledge into impact. Now — perhaps more than ever — we have seen just how truly transformative and impactful TRIF has been in enabling our researchers to give Arizonans significant returns on their investment as our research enterprise collectively pivoted to address COVID-19 swiftly, head on and statewide. No matter what complex challenges come our way in the years ahead, we look forward to continuing to leverage our TRIF dollars to provide an even greater economic and societal benefit to our state for generations to come.”

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



Optical sciences professor and inventor Hong Hua demonstrates the eSight system with Kennedy Nyairo, Tech Launch Arizona licensing manager for the College of Optical Sciences. Hua is a leading researcher of augmented reality systems.

Paul Tumarkin/Tech Launch Arizona

SPACE EXPLORATION AND OPTICAL SOLUTIONS

The Space Exploration and Optical Solutions (SEOS) TRIF initiative seeks to provide real-world learning for Arizona students in optics, astronomy and space sciences; expand Arizona dominance and leadership in optics and space research to support regional economic development; enhance partnerships with industry, community groups and governments; and create and maintain an infrastructure to advance distinctiveness and diversity with business practices that are effective, efficient and entrepreneurial.

SEOS has been very successful in creating newly funded “big science and engineering” programs, establishing new research facilities, stimulating innovation and initiating successful start-up companies, employing intellectual property (IP), and enhancing outreach to under-represented populations in Arizona and technology transfer to local companies.

GOALS


- **Leveraging TRIF funds to obtain more than a ten-fold return on investment (ROI) 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 IP to directly impact Arizona’s economy.**

SELECTED ACCOMPLISHMENTS

- With TRIF support and through several years of strategic planning and execution, UArizona established a strong team to put the university in a unique position to compete for the multi-billion dollar National Quantum Initiative Act. The university leveraged a multi-college collaboration, which includes five new TRIF faculty hires, and its world-renowned strengths in optics and photonics to compete for this award on the national stage.
- TRIF funding enabled the preparation of five proposals to NASA, one of which has already resulted in a contract to Alfred McEwen for the Phase A of a Discovery mission, Io Volcanic Observer (IVO). IVO was one of four proposals selected for Phase A studies, and NASA has announced that it hopes to select two of them to fly. This award is \$361,000 for 13 months, but if IVO is chosen for a full mission, it will cost more than \$500 million and will travel to Io, one of Jupiter's moons and the most volcanically active body in the solar system.
- In fiscal year 2020, TRIF supported 47 undergraduate students, 117 graduate students and 46 post-docs.
- TRIF funds contributed to new collaborative opportunities with Sandia National Labs, Universities Space Research Association, NASA, Jet Propulsion Laboratory and Oak Ridge National Laboratory of the U.S. Department of Energy. SEOS faculty are cultivating a program with the Department of Energy to establish a new center in Quantum Science Technologies. Faculty from the Lunar and Planetary Laboratory (LPL) and Steward Observatory have initiated programs with NASA, potentially resulting in several hundred-million dollar programs.
- TRIF support enabled UArizona researchers to compete for several Multi-University Research Initiative (MURI) Department of Defense projects, each at \$7.5 million over five years. UArizona has been working on two winning MURIs and currently has pending MURI proposals.
- SEOS faculty established 10 startup companies, six of them during fiscal year 2020. All six secured venture capital funds for their UArizona-generated IP. Four of the startups focus on manufacturing and commercializing lasers at wavelengths ranging from ultraviolet to mid-infrared for medical, defense and material processing applications.
- Partnerships with industry resulted in working with 30 companies generating industrial support of more than \$4 million in fiscal year 2020 alone. For example, projects funded by companies such as Facebook, Magic Leap and Microsoft resulted in state-of-the-art advances in augmented reality, autonomous systems and low-energy consumption data center networks with multi-million dollar budgets over several years.
- TRIF contributions to Native Nation communities in Arizona include supporting undergraduate students who are either Native American by citizenship or are attending an American Indian serving college or university by allowing them to gain research experience in laboratories at the Colleges of Optical Sciences, Engineering, and Science and participating in Native-American focused workshops.



A UArizona-led mission proposal to one of Jupiter's moons is among four finalists for the next \$500 million NASA Discovery. If selected, the Io Volcano Observer, or IVO, will investigate whether a magma ocean lies beneath the surface of the volcanically active moon.



Graduate students Olivia Hoch and Alex Gorr work with Arizona Geological Survey researcher Ann Youberg to measure soil infiltration in the Pinaleno Mountains burned by the 2017 Frye Fire. Debris flows in recently burned landscapes pose a serious threat to human life and infrastructure.

WATER, ENVIRONMENTAL AND ENERGY SOLUTIONS

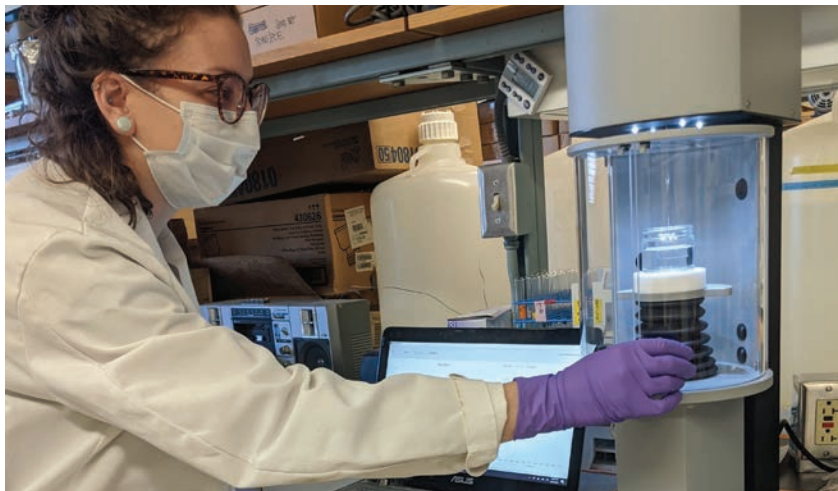
The Water, Environmental and Energy Solutions (WEES) TRIF initiative is developing innovative, practical solutions for water, environmental and energy sustainability in Arizona. Research findings are applied globally, as many other semiarid regions face increasing natural resource demands and uncertainties 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 Arizona, 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 investment in strategic areas to increase public and private funding and commercialization of research results in tech and industry.**
- **Train a new generation of scientists, engineers and other professionals to meet state and national needs.**

SELECTED ACCOMPLISHMENTS

- UArizona has been ranked No. 1 in the U.S. and No. 2 globally in the area of water resources in the 2020 Academic Ranking of World Universities by academic subjects. Faculty across campus have leveraged the university's natural surroundings to generate influence in water studies that goes well beyond the Southwest to benefit other regions. For example, TRIF-supported work on computationally intensive modeling at continental scales is generating new insights about the relationships between atmospheric, ground and surface waters with implications for long-term resilience in the eastern U.S.
- As Arizona wildfires become more frequent and disruptive, debris flows in recently burned landscapes pose a serious threat to human life and infrastructure. With TRIF support, UArizona researchers who study mechanisms that trigger post-fire debris flows defined rainfall intensity thresholds specific to Arizona conditions, thereby helping Arizona communities and land managers mitigate danger and damage.
- Throughout the COVID-19 pandemic, Charles Gerba at the Water and Energy Sustainable Technology (WEST) Center addressed public concerns by providing understanding of the survival of the novel coronavirus in wastewater treatment systems. Gerba also collaborates with industry partners to manufacture antimicrobial surface coatings that kill and reduce the spread of the virus.
- The Earth's critical zone, where most terrestrial life flourishes, extends from the top of the vegetation canopy to the base of weathered bedrock. Last year, UArizona led multi-institution workshops, generating fresh ideas that resulted in \$1.1 million in critical zone National Science Foundation funding with two additional large grants still pending.
- UArizona researchers are conducting landmark research into the chemical properties and transport of per- and poly-fluoroalkyl substances (PFAS), environmentally durable chemicals used to manufacture items like fire retardants, nonstick pans and rainproof clothing. By 2016, PFAS and related pollutants had affected 16 million people in the U.S. and have been found in numerous locations in Arizona. 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 researchers hope to identify the pollutant so that water treatment experts can help reduce exposure.
- Reliance on energy-consuming data centers is increasing dramatically as the world becomes more dependent on robust networking and connectivity. UArizona researchers from the School of Architecture are collaborating and contracting with Arizona data centers, utilities and international companies such as Microsoft and Google to evaluate how systems can be optimized to reduce both energy and water consumption.
- Following the spring 2018 E. Coli contamination of Yuma-grown romaine lettuce, Cooperative Extension scientists began a multi-year study looking at environmental factors for bacterial persistence and distribution. Their work helps growers mitigate risks, ultimately enhancing the safety of produce grown in the region and strengthening the economy of the state's agriculture sector.
- Over the past six years, Erin Ratcliff competed for and received five WEES grants to support her nationally acclaimed work in material sciences research on superconductors and energy storage. She leveraged less than \$200,000 in WEES funding to bring in nearly \$1.9 million in federal dollars, with an additional \$1.2 million in pending funding for a 16:1 return on investment.
- TRIF funds supported three startups - Auxilium Technology Group, SaiOx, Inc. and Throohealth.
- TRIF funding enabled assistantships, employment, scholarships, grants and research experiences for 159 graduate students, 140 undergraduate students and 35 post-docs, preparing them to enter the workforce through education and experiential learning.



PhD candidate Sarah Van Glubt measures the impact of PFAS (per- and poly-fluoroalkyl substances) contamination on the surface tension of water as part of landmark research into the properties and transport of these environmentally durable chemicals.

IMPROVING HEALTH

The Improving Health TRIF funding that helped launch the BIO5 Institute in 2001 continues to catalyze and mobilize a highly effective, cross-disciplinary research and translational bio/health sciences hub at the University of Arizona. Initiatives and projects are carefully chosen to align with areas of state and national need and with existing faculty expertise.

BIO5 connects almost 400 world-class plant, animal and human bioscientists, engineers, physicians and computational researchers to develop creative solutions to disease, hunger, water and food safety, and other complex health challenges facing Arizona and the world. This approach has resulted in, and will continue to produce, disease prevention strategies and promising new therapies, innovative diagnostics and devices, and improved food crops.

Because of TRIF, BIO5 is able to help quickly connect, facilitate and deploy people, resources and funding to expedite the university's community impact related to COVID-19 and other large-scale crises. This strategy expands impact, economic opportunity and external funding opportunities.

GOALS

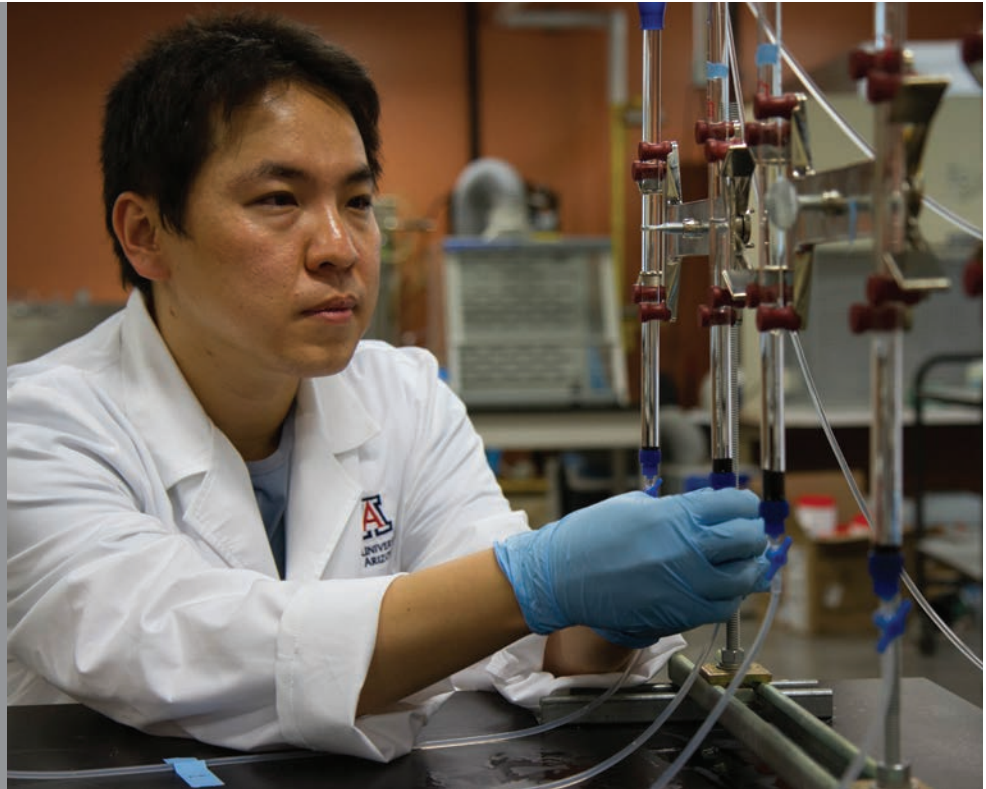
- **Foster collaborative projects that address major challenges in the biosciences, biomedicine and biotechnology and forge significant progress on novel treatments for asthma, cancer, valley fever, diabetes, sudden cardiac death, malnutrition, infectious disease, Alzheimer's and other age-related brain diseases, and other public health crises.**
- **Strengthen and expand translational research by supporting innovative faculty and teams that will advance the development of new medicines, devices, diagnostics, and nutritional and therapeutic strategies.**
- **Engage and train future generations of scientists by maintaining successful outreach and internship programs to promote experiential learning and STEM proficiency in the state.**
- **Expand shared resources in computational biology, imaging, high throughput screening, genomics, proteomics and cell analysis across all life science disciplines to expedite large-scale, team science grants that will boost federal research funding, serve as a resource for local industry, and create new services and companies in Arizona.**
- **Promote an entrepreneurial culture in which scientists work across disciplines to accelerate commercial translation of research breakthroughs.**
- **Promoting an entrepreneurial culture in which scientists work across disciplines to accelerate commercial translation of research breakthroughs.**



Nicole Swinteck


This year, the BIO5 KEYS Research Internship Program – a unique, seven-week summer research opportunity offered since 2007 – has taken a new form this summer, as 49 students engage in computational projects from the safety of their homes. Nearly 500 Arizona high school students have participated in the program since 2007.

UArizona researchers conduct bench- and larger-scale experiments at the UArizona Water and Energy Sustainable Technology (WEST) Center. A group of researchers at the WEST Center received TRIF support to study the risk of COVID-19 to facility worker health.



SELECTED ACCOMPLISHMENTS

- Through TRIF funding, UArizona awarded 43 pilot/seed/equipment grants totaling \$1.9 million to support catalytic early stage research. Additionally, in quick response to COVID-19, 13 research teams comprised of BIO5 members from seven UArizona colleges received a total of \$500,000 in rapid-turnaround seed grants to combat the global pandemic. Projects include understanding the lifecycle of the novel coronavirus, identifying potential treatments, and creating technology and patient databases to expand knowledge of how the disease spreads and who is most vulnerable.
- Because of TRIF support over the past 19 years, UArizona was able to mobilize labs to produce 15,615 COVID-19 diagnostic collection kits and ship these statewide, including to the Navajo Nation; print 3D masks for health care workers and first responders, produce hand sanitizer for health workers, invent a respiratory-assist device, launch a texting system to gather and provide COVID-19 information, and partner with the state to begin antibody testing.
- With support from a \$1.8M National Institute on Aging grant, a UArizona-led research team is testing a novel intervention using near-infrared light treatments that could help enhance cognition and reduce Alzheimer's disease risk in older adults.
- TRIF funding enabled assistantships, employment, scholarships, grants and research experiences for 535 graduate students, 557 undergraduate students, 126 post-docs and 49 high schoolers, preparing them to enter the workforce through education and experiential learning. In addition, Michael Marty has developed the Arizona Science, Engineering and Math Scholars Veterans Program to support veteran students who are pursuing STEM degrees at UArizona and bring their skills into research labs.
- The National Institutes of Health awarded Ying-hui Chou a \$3.4 million grant to combine her expertise in transcranial magnetic stimulation technology with brain imaging techniques to learn more about how to prevent memory loss and enhance brain function in patients experiencing mild cognitive impairment.
- TRIF funds supported three startup companies in fiscal year 2020, including ElectroSonix. Russell Witte developed patented acoustoelectric imaging technology that has the potential to improve the accuracy of cardiac ablation procedures in treating cardiac arrhythmias. Now the chief science officer at ElectroSonix, Witte is bringing the new heart imaging technique to market. The company licensed UArizona patents for acoustoelectric imaging for both the heart and brain.



UArizona aerospace and mechanical engineers will use elevated wind tunnel capacity to expand experiments on vehicles traveling at the speed of sound - and much faster.

NATIONAL SECURITY SYSTEMS

The TRIF National Security Systems (NSS) Initiative strategic plan is intended to advance access and workforce development opportunities for Arizona defense industries; provide experiential learning and research opportunities to strengthen 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.

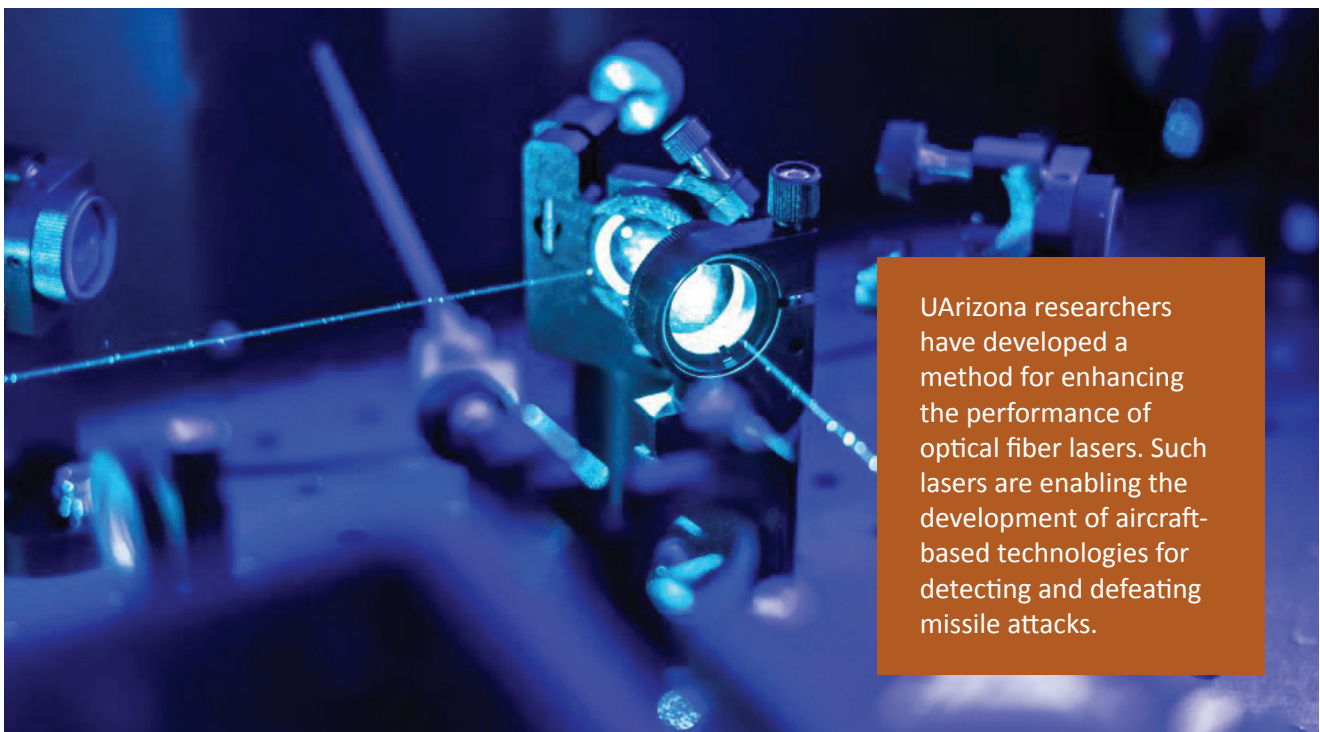
NSS delivers innovative concepts, broadens the technical agility of the defense sector, stimulates technology transfer, particularly in dual use technologies, and creates new intellectual property for the university. While engaging in cutting-edge, strategic research, faculty are proving themselves thought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

- Thirty-seven faculty researchers were supported through TRIF NSS this year, proposing more than \$145 million in research activities and winning millions in awards from various Department of Defense sponsors, NASA and defense industrial base companies such as Ball Aerospace, Raytheon and General Dynamics.
- Faculty made six invention disclosures to advance quantum technologies for sensing, computing and communications. These efforts are contributing to a revolution in military navigation, imaging and secure communications.
- Bio-marker specific wearable sensors are the target of a new joint effort between researchers in the colleges of engineering and medicine to develop low-cost human performance-monitoring capabilities with the Air Force Research Laboratory and the Nano Bio Manufacturing Consortium, a group of high-tech industries affiliated with the U.S. Air Force.
- Faculty developed the highest fidelity modeling capability to understand the plasma properties around hypersonic vehicles, allowing Raytheon and other defense industrial base firms to better integrate mission capabilities and deliver capabilities that leverage the plasma properties for higher performance systems.
- TRIF enabled the purchase of a Quantum Design Physical Property Measurement System, which covers a temperature range of 50 milli Kelvins to 400 Kelvins. This is the first instrument of this type available at UArizona. The access to extremely low temperatures allows researchers to probe into quantum phenomenon in upcoming funded research.
- A diverse cadre of students contributed directly to research focused on implantable carbon nanofiber sensors for biological sample interrogation, the placement of the fuel injector in a scramjet engine to reduce engine failures, and other experiences that helped prepare for future endeavors. In total, TRIF enabled 42 undergraduate students in the NSS focus area.
- TRIF funding also enabled research and professional development experiences for 49 graduate students and five post-docs who made contributions to national security, delivering papers advancing quantum technologies and optics, and more.
- With NSS support, faculty worked with two local 11th grade students to explore the flow of chemical reactions in computational fluid dynamic models for re-entry into the Martian atmosphere and to improve data interpolation within UArizona computational fluid dynamic modeling code, CFDWARP.



UArizona researchers have developed a method for enhancing the performance of optical fiber lasers. Such lasers are enabling the development of aircraft-based technologies for detecting and defeating missile attacks.

HIGHLIGHTS

Navigating an unprecedented viral pandemic during fiscal year 2020 required the University of Arizona's research enterprise to quickly yet prudently pivot to keep essential lab and facility activities operational and maintain productivity to the extent possible, while prioritizing and protecting the health and safety of researchers and student workers.

Researchers and staff, in response, showed remarkable resiliency to these unprecedented circumstances, and UArizona continued to make substantial progress toward fiscal year 2021 goals, even after ramping down activity in March with the governor's stay-at-home order. With overall TRIF expenditures of \$35.6 million, UArizona's calculated financial impact (sponsored awards, gifts and other sources and royalty income) of these investments was \$227 million, well over the expected projections of \$184.5 million.

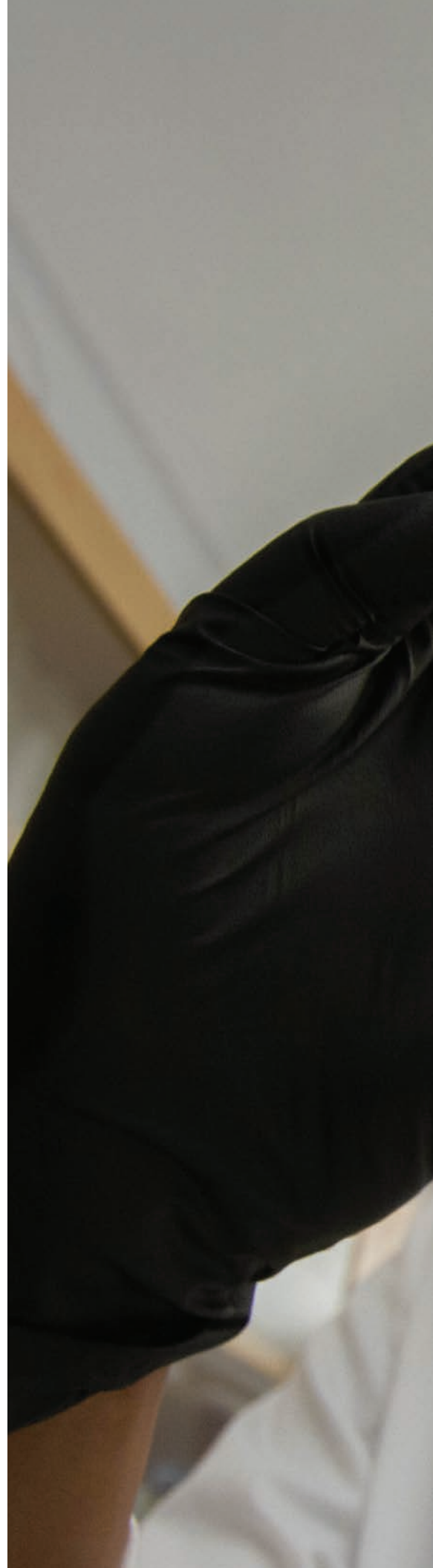
Technology transfer exceeded previous years totals, despite the pandemic. The university launched a record-breaking 19 startups, nearly doubling the previous year's total and surpassing the previous record of 16. With these nascent companies, UArizona also reached a significant milestone in bringing the total number of UArizona startups since Tech Launch Arizona's inception to over 100.

As we head into fiscal year 2021, challenges center around COVID-19, with disruptions to the global supply chain as well as productivity potentially resulting in lower higher education research and development numbers and less facilities and administrative expense recovery for the year. And, while the U.S. Office of Management and Budget has continued to provide exceptions and administrative relief to awards in response to COVID-19, such allowances might not continue even if high numbers of COVID-19 cases persist. This risk is shared by all research universities, not just UArizona.

Nevertheless, the university's research enterprise is as well positioned as any in the nation. In March, the Office of Research, Innovation and Impact (RII) formed a campus-wide Research Coordination Group, now totaling more than 200 faculty, to promote and support research initiatives on coronavirus and assist with state and local community efforts to prevent, contain and/or surveil COVID-19. RII also developed a waiver process for the smooth ramp down and ramp up of laboratory research and designed a dynamic Research Restart Plan that includes six phases for safe re-entry.

UArizona also has, thanks to TRIF investment over the years, the personnel and infrastructure in place to redeploy resources quickly to address a pandemic like COVID-19 and other crises. The world saw this this spring, when some of the university's core facilities and laboratories were able to rapidly pivot from their main functions to develop testing, PPE and other essential responses to the pandemic statewide.

The university will continue to maximize the dollars received through the TRIF initiative to enable economic vibrancy, speedy innovation and deliver public benefit. Even as COVID-19 presents obstacles for research continuity, the university will continue applying its values — integrity, exploration, inclusion, adaptation, determination and compassion — to TRIF focus areas to deliver ever-greater impact and solutions for Arizonans.









ARIZONA BOARD OF
REGENTS

ASU ♦ NAU ♦ UA



ARIZONA BOARD OF REGENTS

ABOR TRIF FUNDS

The regents retain a small amount of funds in support of projects that advance Arizona's public universities in accordance with Arizona law and board guidelines. Each project funded through TRIF is intended to further goals outlined in the board's strategic plan 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; and the Regents' Innovation Fund.

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 and Arizona State University's Decision Theater to visualize and forecast educational attainment in Arizona. 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 continues to be 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 educate them on how it is driving the state forward. Drawing more than 560,000 attendees in 2019, the goal of the festival is to inspire Arizonans to pursue careers in STEM and related fields of study.

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. Technology innovators from universities around the world gathered to pitch their ideas for cash prizes during the event held in January of 2020 at ASU's Sun Devil Stadium.

REGENTS' INNOVATION FUND SUPPORTS RESEARCH

Regents' Innovation Fund (RIF) grants are instrumental in supporting research at the universities, and contribute toward collaborative efforts among the universities and community partners. During the board's June 2019 meeting, regents approved funding for three RIF projects designed and submitted through a tri-university collaborative effort:

Center for Complex System Safety: The Center for Complex System Safety (CCSS) is an ASU-led initiative focused on a single critical element that cuts across many engineering and natural systems - safety. The multi-university CCSS will leverage multiple disciplines (e.g., big data analytics, physics-based learning, risk-based assessment, environmental science and aerodynamics, among others) to create an innovative educational, training and knowledge hub unique to Arizona and the nation on safety assurance and risk management of complex systems. The center will develop new programs and enhance existing ones that will prepare students to contribute to Arizona's high-tech industries, as well as to the safety of its citizens. It will focus on systems such as the traffic management system for Urban Air Mobility (UAM); and the U.S. national gas pipeline.

Benefits of the grant include enhancing Arizona's leadership position on the automated transportation system with Urban Air Mobility; improving safety awareness and risk management of aging infrastructure, especially gas and water pipeline systems in Arizona; advancing risk assessment and mitigation of forests in Arizona; and promoting close collaboration between local aerospace industries and university research teams.

Developing an Event Broker for Time-Domain Astronomy: Funding through this grant that is led by Northern Arizona University will support development of an event broker to detect and filter interesting events in the solar system and beyond. It will enable active monitoring of objects in the solar system and the classification of static sources. The project will generate alerts for objects whose observable properties change, indicating the occurrence of dynamic processes. Alerts generated by the event broker will allow for rapid follow-up by other telescope facilities. This data-driven discovery process will lead to insights into the nature of bodies in the solar system and beyond. The project will develop and employ an ensemble of techniques to be used to detect interesting astrophysical events that exploit new parallel and high performance computing technologies.

Students involved in this work will be trained with skills that are in high demand in Arizona, helping to bolster Arizona's economy, particularly in space exploration and industries requiring expertise in computer science, software engineering, systems analysis and other computational fields.

Advancing Additive Manufacturing Frontiers on Earth and Beyond: The team on this project led by the University of Arizona is focused on 3D printing technologies that use indigenous resources - native soil, minerals, water, flora and energy - under extreme conditions that include extraterrestrial - lunar, Martian, asteroid and meteoritic materials - and isolated and depleted earth-bound environments. Goals include: developing new capabilities in materials chemistry, advanced manufacturing machine design and manufacturing processes that better position Arizona's universities for aerospace, medical, and defense funding; immersion of students in additive manufacturing curriculum and industry internships; and creating a certificate program to future proof workforce-ready students.

The project will reinforce university strengths in aerospace and defense-related research and development where excellence in additive manufacturing has become a critical precursor for success. Arizona's manufacturing workforce capabilities will also be strengthened to support the wide base of companies that contribute to Arizona's gross domestic product.

FINANCIALS & METRICS





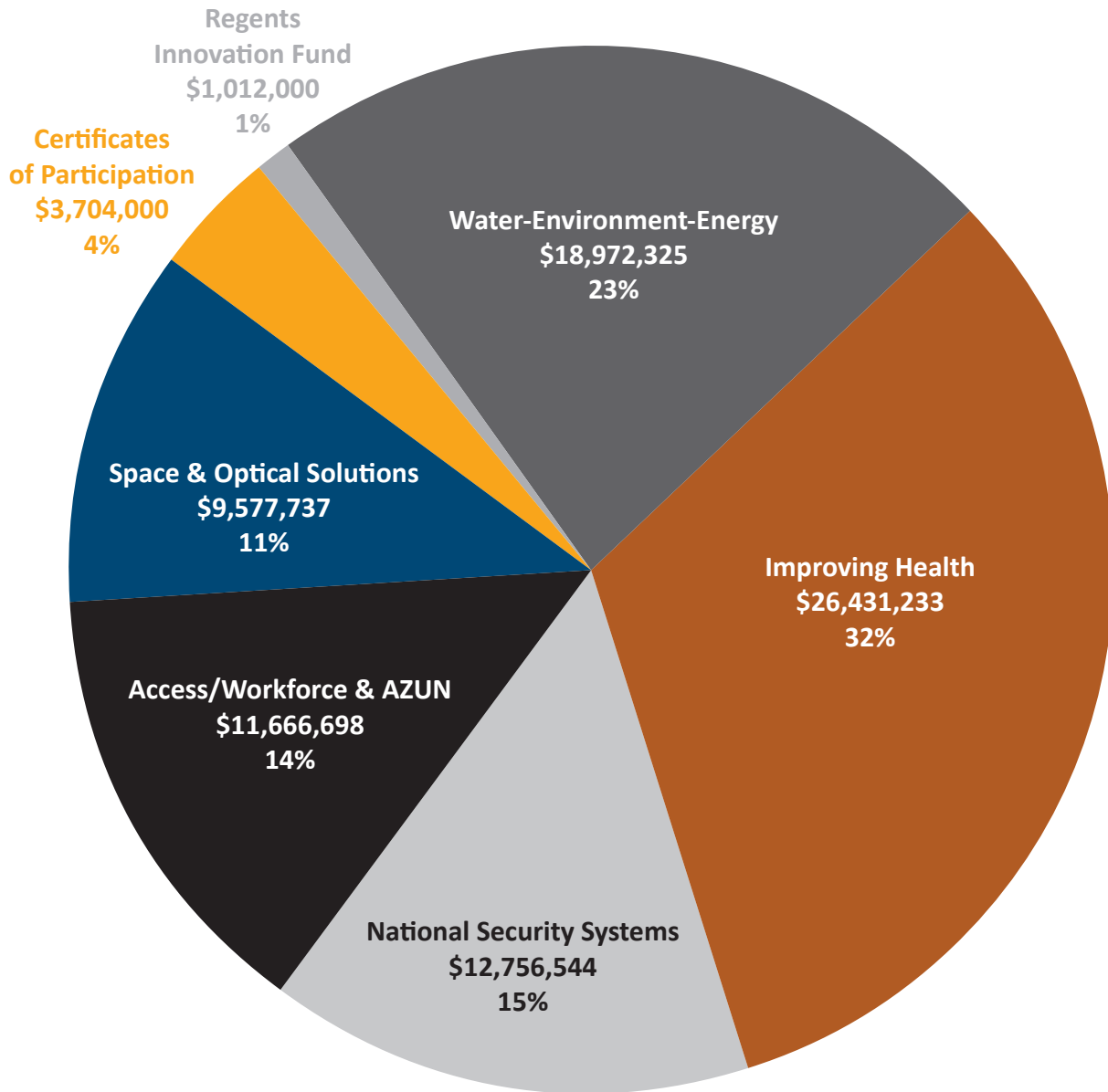
FY 2017 - 2021

ARIZONA UNIVERSITY SYSTEM

TECHNOLOGY AND RESEARCH INITIATIVE FUND

	<i>FY 2017</i> ACTUAL	<i>FY 2018</i> ACTUAL	<i>FY 2019</i> ACTUAL	<i>FY 2020</i> ACTUAL	<i>FY 2020</i> BUDGET	<i>FY 2021</i> BUDGET
REVENUE						
Carry Forward	4,322,940	8,684,576	10,634,673	15,378,549	6,431,213	-
TRIF Revenue	72,797,470	77,211,240	83,610,510	81,456,038	81,806,000	85,569,000
TOTAL REVENUE	\$ 77,120,410	\$ 85,895,816	\$ 94,245,183	\$ 96,834,587	\$ 88,237,213	\$ 85,569,000
EXPENDITURES						
OPERATING	56,555,913	61,995,953	66,671,410	70,283,534	66,820,123	72,170,400
CAPITAL	8,088,491	9,896,688	8,830,438	10,835,801	11,281,877	9,694,600
ASU Polytechnic/West COPs	3,707,500	3,704,000	3,704,000	3,704,000	3,704,000	3,704,000
TOTAL CAPITAL	11,795,991	13,600,688	12,534,438	14,539,801	14,985,877	13,398,600
TOTAL EXPENDITURES	\$ 68,351,904	\$ 75,596,641	\$ 79,205,848	\$ 84,823,335	\$ 81,806,000	\$ 85,569,000
SUMMARY BY PROGRAM AREA						
Improving Health	\$ 26,074,280	\$ 29,424,142	\$ 28,687,340	\$ 26,431,233	\$ 29,310,112	\$ 29,368,089
Water, Environment, Energy Solutions	11,646,602	14,911,510	18,363,047	18,972,325	17,721,680	20,139,762
National Security Systems	9,566,065	9,852,316	12,555,957	12,756,544	13,776,695	12,331,426
Space Exploration and Optical Solutions	5,850,345	7,172,981	4,266,589	9,577,737	6,721,289	9,042,423
Access & Workforce Development	7,656,193	8,054,570	9,152,394	11,151,698	8,264,424	8,463,300
Regents' Innovation Fund	1,200,000	1,000,000	1,200,000	1,012,000	1,000,000	1,000,000
ASU Poly/ASU West COPs	3,707,500	3,704,000	3,704,000	3,704,000	3,704,000	3,704,000
AZUN	500,000	505,000	510,000	515,000	515,000	520,000
ABOR Other	2,150,919	514,620	623,578	383,000	1,000,000	1,000,000
PROGRAM AREA TOTAL	68,351,904	75,139,139	79,062,905	84,503,537	82,013,200	85,569,000
TOTAL EXPENDITURES	\$ 68,351,904	\$ 75,139,139	\$ 79,062,905	\$ 84,503,537	\$ 82,013,200	\$ 85,569,000

**FY 2020
SYSTEM ACTUAL TRIF EXPENDITURES**







FY 2017 - 2021
ARIZONA STATE UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND

	<i>FY 2017</i> <i>ACTUAL</i>	<i>FY 2018</i> <i>ACTUAL</i>	<i>FY 2019</i> <i>ACTUAL</i>	<i>FY2020</i> <i>ACTUAL</i>	<i>FY 2020</i> <i>BUDGET</i>	<i>FY 2021</i> <i>BUDGET</i>
REVENUE						
Carryforward		\$ 555,600	\$ 335,500	\$ 545,396	\$ 207,204	\$ 19,024
TRIF Revenue	30,543,500	32,306,900	34,866,604	33,886,275	34,144,800	35,650,000
TOTAL REVENUE	\$ 30,543,500	\$ 32,862,500	\$ 35,202,104	\$ 34,431,671	\$ 34,352,004	\$ 35,669,024
EXPENDITURES						
OPERATING	24,876,300	25,658,500	27,744,500	27,227,671	26,940,800	28,446,000
CAPITAL	1,404,100	3,500,000	3,546,400	3,500,000	3,500,000	3,500,000
ASU Poly/ASU West COPS	3,707,500	3,704,000	3,704,000	3,704,000	3,704,000	3,704,000
TOTAL CAPITAL	5,111,600	7,204,000	7,250,400	7,204,000	7,204,000	7,204,000
TOTAL EXPENDITURES	\$ 29,987,900	\$ 32,862,500	\$ 34,994,900	\$ 34,431,671	\$ 34,144,800	\$ 35,650,000
SUMMARY BY INITIATIVE						
Improving Health	\$ 13,541,800	\$ 14,744,400	\$ 14,964,300	\$ 11,917,391	\$ 14,382,300	\$ 13,009,417
Water, Environment and Energy Solutions	6,572,000	6,071,800	7,533,200	8,262,701	7,911,700	9,096,560
National Security Systems	3,671,700	3,942,300	3,450,400	3,083,927	4,057,900	3,807,063
Access & Workforce Development						
Entrepreneurship & Innovation	614,200	732,500	1,328,800	725,118	1,536,600	768,000
Advanced Manufacturing	1,880,700	3,332,000	4,014,200	6,719,510	2,759,500	5,264,960
TOTAL	26,280,400	28,823,000	31,290,900	30,708,646	30,648,000	31,946,000
ASU Poly/ASU West COPS	3,707,500	3,704,000	3,704,000	3,704,000	3,704,000	3,704,000
TOTAL EXPENDITURES	\$ 29,987,900	\$ 32,527,000	\$ 34,994,900	\$ 34,412,646	\$ 34,352,000	\$ 35,650,000

ARIZONA STATE UNIVERSITY TECHNOLOGY AND RESEARCH INITIATIVE FUND IMPROVING HEALTH

PERFORMANCE ANALYSIS	<i>FY 2017</i> ACTUAL	<i>FY 2018</i> ACTUAL	<i>FY 2019</i> ACTUAL	<i>FY2020</i> ACTUAL	<i>FY 2020</i> BUDGET	<i>FY 2021</i> BUDGET
TRIF EXPENDITURES						
Total	\$ 13,541,800	\$ 14,744,400	\$ 14,964,300	\$ 11,917,391	\$ 14,382,300	\$ 13,009,417
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	\$ 82,409,681	\$ 92,909,977	\$ 102,240,048	\$ 111,380,066	\$ 110,750,000	\$ 124,000,000
Gifts & Other Sources	723,874	1,399,722	1,890,337	2,477,429	1,190,000	1,220,000
Royalty Income	157,454	196,261	371,958	316,904	800,000	800,000
TOTAL	83,291,009	94,505,960	104,502,343	114,174,399	112,740,000	126,020,000
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	81	97	86	91	59	60
US Patents Issued	31	32	27	32	7	7
Licenses and Options Executed	37	15	14	21	20	22
Startup Companies	5	5	5	7	3	3
WORKFORCE CONTRIBUTION						
Academic and Postdoctoral Appointees	145	145	154	187	133	143
Graduate Students	542	630	749	1,070	416	445
Undergraduate Students	267	230	264	359	306	328

ARIZONA STATE UNIVERSITY TECHNOLOGY AND RESEARCH INITIATIVE FUND NATIONAL SECURITY SYSTEMS

PERFORMANCE ANALYSIS	<i>FY 2017</i> ACTUAL	<i>FY 2018</i> ACTUAL	<i>FY 2019</i> ACTUAL	<i>FY2020</i> ACTUAL	<i>FY 2020</i> BUDGET	<i>FY 2021</i> BUDGET
TRIF EXPENDITURES						
Total	\$ 3,671,700	\$ 3,942,300	\$ 3,450,400	\$ 3,083,927	\$ 4,057,900	\$ 3,807,063
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	\$ 39,063,761	\$ 33,292,653	\$ 48,532,922	\$ 53,113,731	\$ 53,000,000	\$ 60,000,000
Gifts & Other Sources	-	-	-	-	-	-
Royalty Income	-	76,305	14,898	118,013	50,000	50,000
TOTAL	39,063,761	33,368,958	48,547,820	53,231,744	53,050,000	60,050,000
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	35	52	40	39	27	30
US Patents Issued	9	9	11	26	3	4
Licenses and Options Executed	4	8	2	5	5	5
Startup Companies	4	2	2	2	0	0
WORKFORCE CONTRIBUTION						
Academic and Postdoctoral Appointees	43	50	79	82	34	36
Graduate Students	338	366	479	594	281	303
Undergraduate Students	190	176	247	243	142	153

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

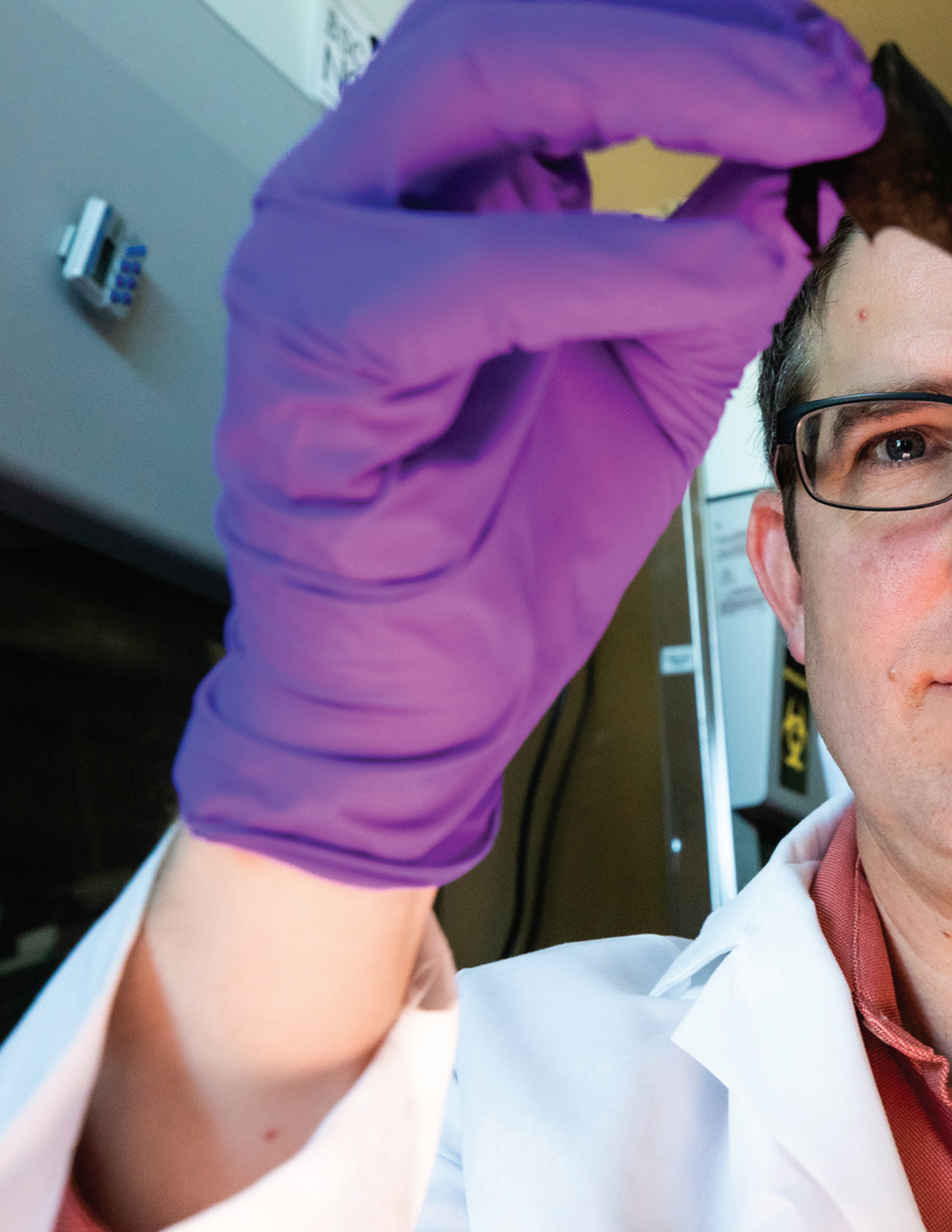
PERFORMANCE ANALYSIS	FY 2017 ACTUAL	FY 2018 ACTUAL	FY 2019 ACTUAL	FY2020 ACTUAL	FY 2020 BUDGET	FY 2021 BUDGET
TRIF EXPENDITURES						
Total	\$ 6,572,000	\$ 6,071,800	\$ 7,533,200	\$ 8,262,701	\$ 7,911,700	\$ 9,096,560
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	\$ 27,874,447	\$ 26,139,847	\$ 28,545,795	\$ 30,121,498	\$ 30,100,000	\$ 34,000,000
Gifts & Other Sources	4,248,699	3,196,485	1,213,249	546,272	4,650,000	4,790,000
Royalty Income	2,000	2,000	117,016	25,005	100,000	100,000
TOTAL	32,125,146	29,338,332	29,876,060	30,692,775	34,850,000	38,890,000
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	22	13	24	30	13	13
US Patents Issued	3	13	27	25	2	3
Licenses and Options Executed	3	5	3	6	5	5
Startup Companies	1	2	2	4	0	0
WORKFORCE CONTRIBUTION						
Academic and Postdoctoral Appointees	60	35	80	73	33	36
Graduate Students	210	147	400	345	171	183
Undergraduate Students	241	104	190	121	206	221

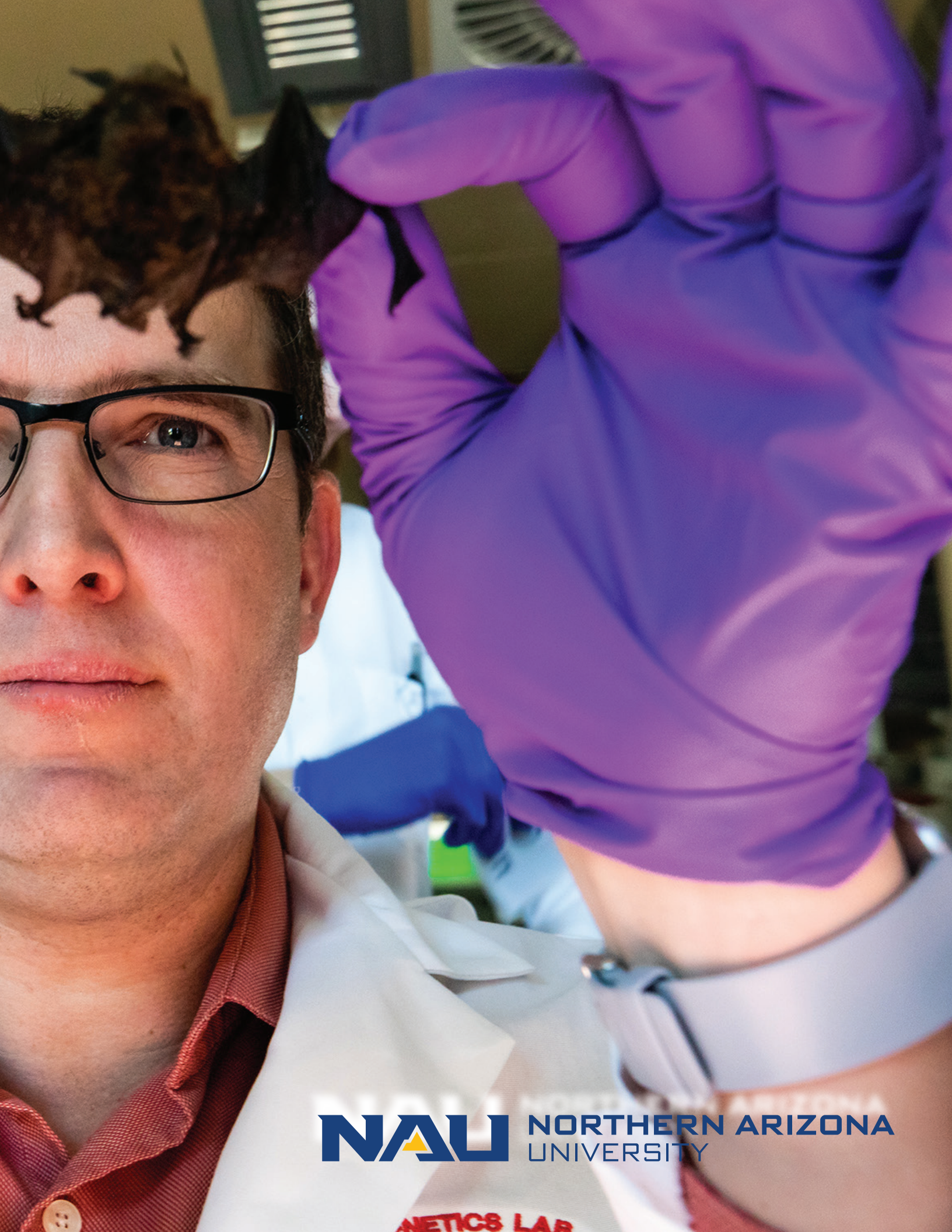
**ARIZONA STATE UNIVERSITY
TECHNOLOGY AND RESEARCH INITIATIVE FUND
ACCESS & WORKFORCE DEVELOPMENT:
ADVANCED MANUFACTURING**

PERFORMANCE ANALYSIS	FY 2017 ACTUAL	FY 2018 ACTUAL	FY 2019 ACTUAL	FY2020 ACTUAL	FY 2020 BUDGET	FY 2021 BUDGET
TRIF EXPENDITURES						
Total	\$ 1,880,700	\$ 3,332,000	\$ 4,014,200	\$ 6,719,510	\$ 2,759,500	\$ 5,264,960
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	\$ 13,047,918	\$ 22,677,335	\$ 18,810,146	\$ 21,305,970	\$ 21,250,000	\$ 25,000,000
Gifts & Other Sources	112,652	138,791	158,936	456,603	100,000	100,000
Royalty Income	16,000	91,800	75,000	67,011	50,000	50,000
TOTAL	13,176,570	22,907,926	19,044,082	21,829,584	21,400,000	25,150,000
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	27	44	28	42	10	12
US Patents Issued	5	18	26	28	2	2
Licenses and Options Executed	8	4	2	4	3	4
Startup Companies	3	2	3	3	1	1
WORKFORCE CONTRIBUTION						
Academic and Postdoctoral Appointees	33	25	59	44	13	14
Graduate Students	155	98	323	272	62	69
Undergraduate Students	75	27	89	58	69	77

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

PERFORMANCE ANALYSIS	FY 2017 ACTUAL	FY 2018 ACTUAL	FY 2019 ACTUAL	FY2020 ACTUAL	FY 2020 BUDGET	FY 2021 BUDGET
TRIF EXPENDITURES						
Total	\$ 614,200	\$ 732,500	\$ 1,328,800	\$ 725,118	\$ 1,536,600	\$ 768,000
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	\$ 2,960,137	\$ 4,021,094	\$ 5,527,000	\$0	\$ 4,100,000	\$ 5,000,000
Gifts & Other Sources						
Royalty Income						
TOTAL	2,960,137	4,021,094	5,527,000	-	4,100,000	5,000,000
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted						
US Patents Issued						
Licenses and Options Executed						
Startup Companies	15	17	18	19	21	23
WORKFORCE CONTRIBUTION						
Academic and Postdoctoral Appointees	1	0	6	12	0	0
Graduate Students	99	173	143	145	29	30
Undergraduate Students	246	346	342	438	145	152





NAU NORTHERN ARIZONA
UNIVERSITY

GENETICS LAB

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

	<i>FY 2017</i>	<i>FY 2018</i>	<i>FY2019</i>	<i>FY2020</i>	<i>FY 2020</i>	<i>FY 2021</i>
	<i>ACTUAL</i>	<i>ACTUAL</i>	<i>ACTUAL</i>	<i>ACTUAL</i>	<i>BUDGET</i>	<i>BUDGET</i>
REVENUE						
Carryforward	\$ 1,281,965	\$ 1,815,739	\$ 3,681,174	\$ 6,397,949	\$ 6,397,949	\$ 8,582,291
TRIF Revenue	13,417,994	13,957,380	15,581,302	15,245,475	15,220,400	15,973,000
TOTAL REVENUE	\$ 14,699,959	\$ 15,773,119	\$ 19,262,476	\$ 21,643,424	\$ 21,618,349	\$ 24,555,291
EXPENDITURES						
OPERATING	11,089,829	11,619,310	11,780,490	12,010,332	12,328,523	12,778,400
CAPITAL	1,794,391	816,688	1,084,038	1,050,801	2,891,877	3,194,600
TOTAL EXPENDITURES	\$ 12,884,220	\$ 12,435,998	\$ 12,864,528	\$ 13,061,133	\$ 15,220,400	\$ 15,973,000
SUMMARY BY INITIATIVE						
Improving Health	\$ 1,987,146	\$ 2,287,367	\$ 2,498,001	\$ 2,203,645	\$ 2,660,594	\$ 2,876,838
Water, Environment and Energy Solutions	1,547,695	3,336,334	3,275,370	3,073,482	2,127,794	3,311,473
National Security Systems	3,305,425	2,068,714	1,765,557	2,394,433	3,330,615	837,660
Space Exploration & Optical Solutions	382,661	248,513	1,006,205	1,167,503	2,618,073	4,441,829
Access & Workforce Development	5,161,293	3,990,070	3,809,394	3,707,070	3,968,324	3,985,200
TOTAL	12,384,220	11,930,998	12,354,528	12,546,133	14,705,400	15,453,000
AZUN	500,000	505,000	510,000	515,000	515,000	520,000
TOTAL EXPENDITURES	\$ 12,884,220	\$ 12,435,998	\$ 12,864,528	\$ 13,061,133	\$ 15,220,400	\$ 15,973,000

NORTHERN ARIZONA UNIVERSITY TECHNOLOGY AND RESEARCH INITIATIVE FUND IMPROVING HEALTH

PERFORMANCE ANALYSIS	<i>FY 2017 ACTUAL</i>	<i>FY 2018 ACTUAL</i>	<i>FY2019 ACTUAL</i>	<i>FY2020 ACTUAL</i>	<i>FY 2020 BUDGET</i>	<i>FY 2021 BUDGET</i>
TRIF EXPENDITURES						
Total	\$ 1,658,683	\$ 2,287,367	\$ 2,498,001	\$ 2,203,645	\$ 2,660,594	\$ 2,876,838
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	\$ 9,823,529	\$ 11,421,671	\$ 11,799,528	\$ 6,234,337	\$ 2,878,568	\$ 3,868,878
Gifts & Other Sources	200,000	200,000	-	-	143,928	193,444
Royalty Income	24,070	10,000	10,000	-	-	35,156
TOTAL	10,047,599	11,631,671	11,809,528	6,234,337	3,022,496	4,097,478
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	27	19	18	19	26	29
US Patents Issued	3	5	6	7	1	1
Licenses and Options Executed	2	0	3	3	0	1
Startup Companies	1	0	0	1	1	0
WORKFORCE CONTRIBUTION						
Academic and Postdoctoral Appointees	13	10	26	23	5	4
Graduate Students	29	45	52	43	30	35
Undergraduate Students	75	129	125	121	50	50

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

PERFORMANCE ANALYSIS	FY 2017 ACTUAL	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY 2020 BUDGET	FY 2021 BUDGET
TRIF EXPENDITURES						
Total	\$ 1,547,695	\$ 3,336,334	\$ 3,275,370	\$ 3,073,482	\$ 2,127,794	\$ 3,311,473
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	\$ 11,241,109	\$ 8,262,452	\$ 4,490,896	\$ 8,910,904	\$ 4,108,358	\$ 3,374,568
Gifts & Other Sources	0	-	-	-	205,418	168,728
Royalty Income	0	-	-	-	-	-
TOTAL	11,241,109	8,262,452	4,490,896	8,910,904	4,313,776	3,543,296
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	5	11	2	2	12	12
US Patents Issued	2	2	0	1	2	2
Licenses and Options Executed	0	0	0	0	0	0
Startup Companies	0	0	0	0	0	0
WORKFORCE CONTRIBUTION						
Academic and Postdoctoral Appointees	17	20	30	28	5	4
Graduate Students	50	63	77	65	30	35
Undergraduate Students	136	127	124	119	200	200

NORTHERN ARIZONA UNIVERSITY TECHNOLOGY AND RESEARCH INITIATIVE FUND NATIONAL SECURITY SYSTEMS

PERFORMANCE ANALYSIS	<i>FY 2017</i> ACTUAL	<i>FY 2018</i> ACTUAL	<i>FY2019</i> ACTUAL	<i>FY2020</i> ACTUAL	<i>FY 2020</i> BUDGET	<i>FY 2021</i> BUDGET
TRIF EXPENDITURES						
Total	\$ 3,305,425	\$ 2,068,714	\$ 1,765,557	\$ 2,394,433	\$ 3,330,615	\$ 837,660
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	\$ 5,493,136	\$ 1,193,274	\$ 1,306,649	\$ 6,445,205	\$ 1,811,342	\$ 1,330,197
Gifts & Other Sources	-	-	-	-	90,567	66,510
Royalty Income	6,000	30,500	500	5,000	46,875	35,156
TOTAL	5,499,136	1,223,774	1,307,149	6,450,205	1,948,784	1,431,863
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	9	14	13	5	6	7
US Patents Issued	0	2	4	12	2	2
Licenses and Options Executed	1	1	1	0	2	1
Startup Companies	0	0	0	0	0	1
WORKFORCE CONTRIBUTION						
Academic and Postdoctoral Appointees	5	2	3	4	5	4
Graduate Students	3	4	8	6	10	15
Undergraduate Students	10	17	14	16	25	25

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

PERFORMANCE ANALYSIS	<i>FY 2017</i> <i>ACTUAL</i>	<i>FY 2018</i> <i>ACTUAL</i>	<i>FY2019</i> <i>ACTUAL</i>	<i>FY2020</i> <i>ACTUAL</i>	<i>FY 2020</i> <i>BUDGET</i>	<i>FY 2021</i> <i>BUDGET</i>
TRIF EXPENDITURES						
Total	\$ 382,661	\$ 248,513	\$ 1,006,205	\$ 1,167,503	\$ 2,618,073	\$ 4,441,829
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	\$ 1,256,431	\$ 882,075	\$ 1,907,771	\$ 2,094,739	\$ 2,969,534	\$ 3,836,157
Gifts & Other Sources	0	-	-	-	148,477	191,808
Royalty Income	0	-	-	-	23,438	35,156
TOTAL	1,256,431	882,075	1,907,771	2,094,739	3,141,449	4,063,121
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	0	0	2	1	2	2
US Patents Issued	0	0	0	0	2	2
Licenses and Options Executed	0	0	0	0	1	1
Startup Companies	0	0	0	0	0	0
WORKFORCE CONTRIBUTION						
Academic and Postdoctoral Appointees	1	0	7	4	5	4
Graduate Students	3	3	7	9	10	15
Undergraduate Students	2	7	7	7	50	50

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

PERFORMANCE ANALYSIS	FY 2017 ACTUAL	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY 2020 BUDGET	FY 2021 BUDGET
TRIF EXPENDITURES						
AWD	\$ 5,161,293	\$ 3,990,070	\$ 3,809,394	\$ 3,707,070	\$ 3,968,324	\$ 3,985,200
AZUN	\$ 500,000	\$ 505,000	\$ 510,000	\$ 515,000	\$ 515,000	\$ 520,000
Total	\$ 5,661,293	\$ 4,495,070	\$ 4,319,394	\$ 4,222,070	\$ 4,483,324	\$ 4,505,200
FINANCIAL IMPACT OF TRIF INVESTMENT						
Annual Impact of Graduates on Economy ¹	\$ 15,990,000	\$ 15,626,000	\$ 14,235,000	\$ 14,950,000	\$ 15,678,000	\$ 16,146,000
Degree/Certificate Programs Offered ²	92	84	89	64	81	83
Business/Nonprofit Collaborations ³	211	374	522	516	205	220
Number of Students Served by A/WD ⁴	4,482	4,405	4,220	3,932	5,324	5,856
TOTAL	\$ 15,990,000	\$ 15,626,000	\$ 14,235,000	\$ 14,950,000	\$ 15,678,000	\$ 16,146,000
WORKFORCE CONTRIBUTION						
Web/Hybrid/Enhanced Courses Developed ⁵	191	287	243	260	180	190
Faculty Developing Courses ⁶	405	304	312	450	460	490
Increase in Student Technology Literacy ⁷	4,310	4,555	4,425	4,650	4,675	4,800
Individual Faculty Trained in Teaching Technologies ⁸	376	307	316	637	325	350
Faculty Support Incidents Resolved Technologies ⁹	13,590	11,734	12,721	19,904	17,775	18,000
Faculty using Adaptive Courseware	16	32	36	22	25	40

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.

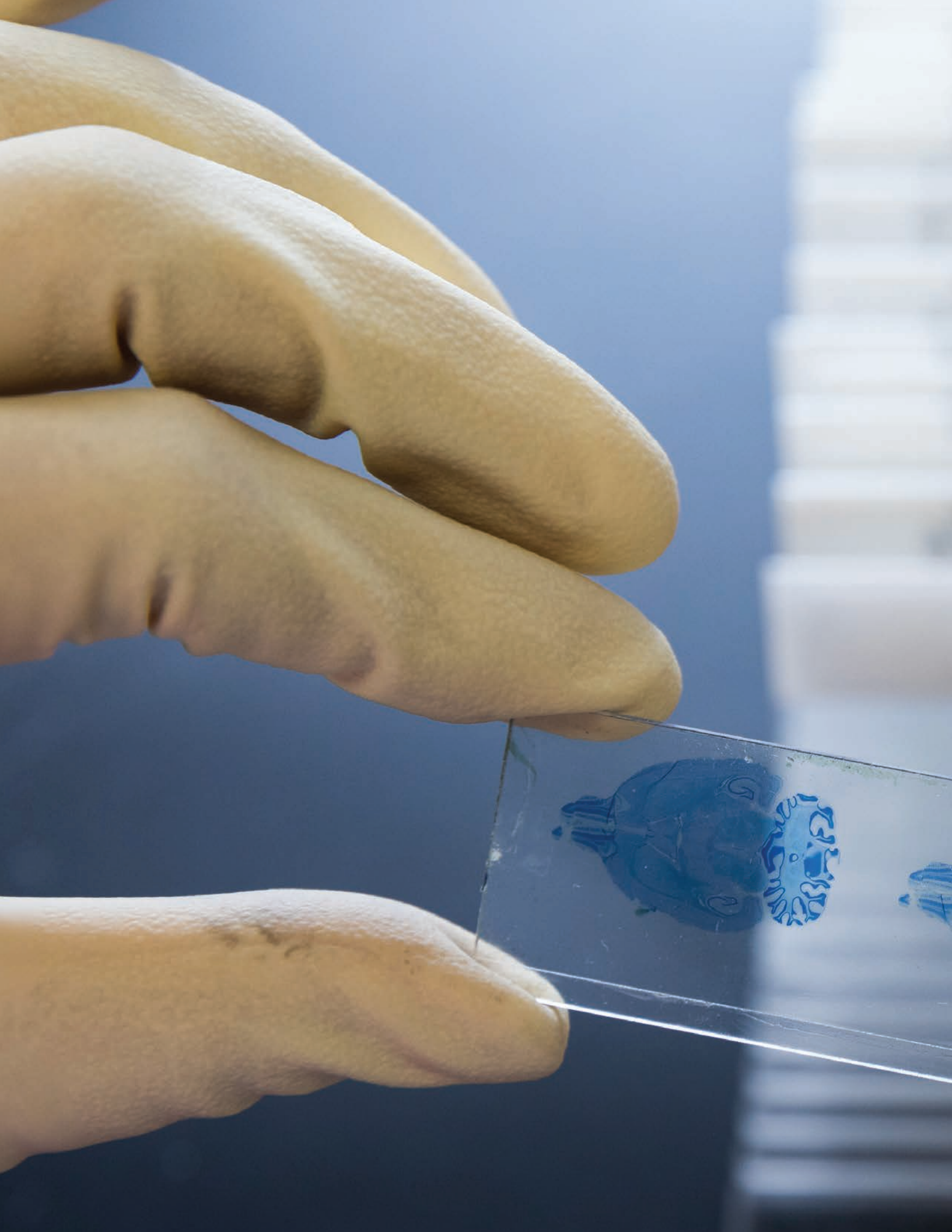
⁵ Includes Web, hybrid, IT-enhanced, redesigns and quality review process compliance.

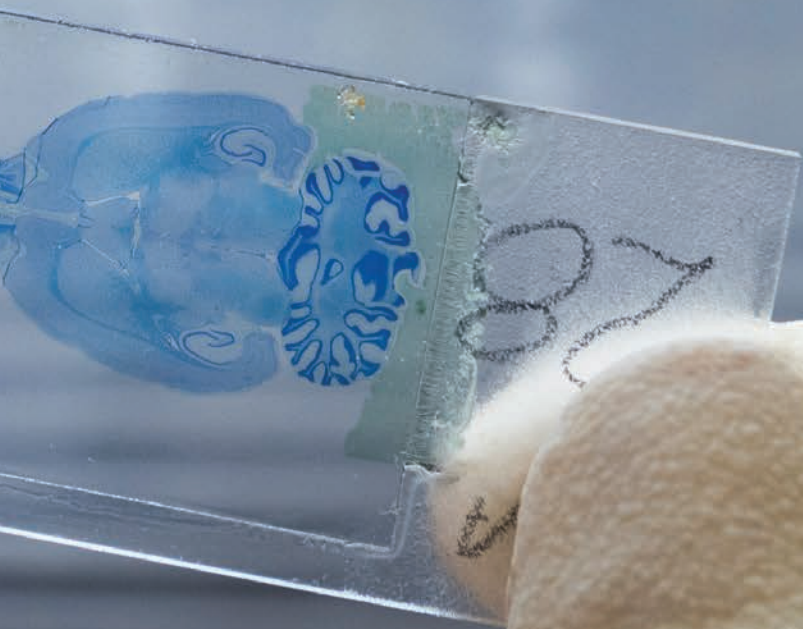
⁶ Number of faculty participating in course development, design and redesign.

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





THE UNIVERSITY
OF ARIZONA

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

	<i>FY 2017 ACTUAL</i>	<i>FY 2018 ACTUAL</i>	<i>FY2019 ACTUAL</i>	<i>FY2020 ACTUAL</i>	<i>FY 2020 BUDGET</i>	<i>FY 2021 BUDGET</i>
REVENUE						
Carryforward	-	4,707,123	4,648,508	6,431,170	6,431,213	1,287,363
TRIF Revenue	26,835,988	28,602,907	31,162,604	30,490,949	30,440,800	31,946,000
TOTAL	\$ 26,835,988	\$ 33,310,030	\$ 35,811,112	\$ 36,922,120	\$ 36,872,013	\$ 33,233,363
EXPENDITURES						
OPERATING	17,238,866	23,081,521	25,179,899	30,744,757	25,550,800	28,946,000
CAPITAL	4,890,000	5,580,000	4,200,000	4,890,000	4,890,000	3,000,000
TOTAL	\$ 22,128,865	\$ 28,661,521	\$ 29,379,899	\$ 35,634,757	\$ 30,440,800	\$ 31,946,000
SUMMARY BY INITIATIVE						
Improving Health	\$ 10,545,334	\$ 12,392,375	\$ 11,225,039	\$ 12,310,197	\$ 12,267,218	\$ 11,499,951
Space Exploration & Optical Solutions	5,467,685	6,924,468	7,554,476	8,410,234	7,682,186	8,581,489
Water, Environmental, Energy Solutions	3,526,907	5,503,376	7,340,000	7,636,142	6,388,180	7,263,966
National Security Systems	2,588,940	3,841,302	3,260,384	7,278,184	4,103,216	4,600,594
TOTAL	\$ 22,128,865	\$ 28,661,521	\$ 29,379,899	\$ 35,634,757	\$ 30,440,800	\$ 31,946,000

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

PERFORMANCE ANALYSIS	FY 2017 ACTUAL	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY 2020 BUDGET	FY 2021 BUDGET
TRIF EXPENDITURES						
Total	10,545,334	12,392,375	11,225,039	12,310,197	12,455,718	11,499,951
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	74,499,075	89,142,292	78,544,924	111,287,819	67,491,840	70,191,514
Gifts & Other Sources	117,545	465,399	804,222	565,001	674,918	701,915
Royalty Income	16,000	200	55,000	46,000	56,243	58,493
TOTAL	74,632,620	89,607,891	79,404,146	111,898,820	68,223,002	70,951,922
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	55	38	35	67	50	55
US Patents Issued	7	2	21	18	4	5
Licenses and Options Executed	6	8	9	13	12	13
Startup Companies	1	4	1	3	2	2
WORKFORCE CONTRIBUTION						
Postdoctoral Appointees	160	184	218	126	116	122
Graduate Students	439	479	643	535	347	365
Undergraduate Students	741	539	659	557	370	389

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

PERFORMANCE ANALYSIS	FY 2017 ACTUAL	FY 2018 ACTUAL	FY2019 ACTUAL	FY2020 ACTUAL	FY 2020 BUDGET	FY 2021 BUDGET
TRIF EXPENDITURES						
Total	\$ 3,526,907	\$ 5,503,376	\$ 7,340,000	\$ 7,636,142	\$ 7,867,984	\$ 7,263,966
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	28,190,149	34,978,098	37,230,355	28,666,051	34,870,784	36,265,615
Gifts & Other Sources	6,978,663	31,228,311	2,470,875	2,434,298	3,824,538	3,977,519
Royalty Income	8,250	5,145	3,785	2,583	843,648	877,394
TOTAL	\$ 35,177,062	\$ 66,211,554	\$ 39,705,015	\$ 31,102,932	\$ 39,538,970	\$ 41,120,528
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	18	16	12	11	25	27
US Patents Issued	3	1	0	3	4	5
Licenses and Options Executed	4	2	4	4	8	9
Startup Companies	1	0	0	0	1	1
WORKFORCE CONTRIBUTION						
Postdoctoral Appointees	16	29	55	35	98	103
Graduate Students	152	175	182	159	313	328
Undergraduate Students	74	109	123	140	127	134

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

PERFORMANCE ANALYSIS	<i>FY 2017</i> ACTUAL	<i>FY 2018</i> ACTUAL	<i>FY2019</i> ACTUAL	<i>FY2020</i> ACTUAL	<i>FY 2020</i> BUDGET	<i>FY 2021</i> BUDGET
TRIF EXPENDITURES						
Total	\$ 5,467,685	\$ 6,924,468	\$ 7,554,476	\$ 8,410,234	\$ 9,474,458	\$ 8,581,489
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	67,398,490	93,922,125	86,349,520	69,863,665	67,491,840	70,191,514
Gifts & Other Sources	525,123	597,340	488,660	2,800,000	1,000,000	
Royalty Income	1,256,754	1,438,529	1,932,029	4,393,115	134,984	140,383
TOTAL	\$ 69,180,367	\$ 95,957,994	\$ 88,770,209	\$ 77,056,781	\$ 68,626,824	\$ 70,331,897
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	50	62	69	44	50	55
US Patents Issued	14	11	17	22	4	5
Licenses and Options Executed	21	26	18	22	20	22
Startup Companies	5	6	4	8	2	2
WORKFORCE CONTRIBUTION						
Postdoctoral Appointees	2	20	25	46	17	18
Graduate Students	55	115	114	117	46	49
Undergraduate Students	29	47	57	47	9	10

UNIVERSITY OF ARIZONA TECHNOLOGY AND RESEARCH INITIATIVE FUND NATIONAL SECURITY SYSTEMS

PERFORMANCE ANALYSIS	<i>FY 2017</i> ACTUAL	<i>FY 2018</i> ACTUAL	<i>FY19</i> ACTUAL	<i>FY2020</i> ACTUAL	<i>FY 2020</i> BUDGET	<i>FY 2021</i> BUDGET
TRIF EXPENDITURES						
Total	\$ 2,588,940	\$ 3,841,302	\$ 3,260,384	\$ 7,278,184	\$ 4,756,524	\$ 4,600,594
FINANCIAL IMPACT OF TRIF INVESTMENT						
Sponsored Awards	1,066,471	1,281,873	1,343,532	6,984,106	8,000,000	10,000,000
Gifts & Other Sources	0	0	0	0	150,000	175,000
Royalty Income	0	0	0	0	0	0
TOTAL	\$ 1,066,471	\$ 1,281,873	\$ 1,343,532	\$ 6,984,106	\$ 8,150,000	\$ 10,175,000
TECHNOLOGY TRANSFER ACTIVITY						
Invention Disclosures Transacted	0	6	8	0	3	5
US Patents Issued	0	0	0	0	0	0
Licenses and Options Executed	0	0	0	6	0	0
Startup Companies	0	0	0	1	0	0
WORKFORCE CONTRIBUTION						
Postdoctoral Appointees	5	10	10	5	6	6
Graduate Students	12	38	37	49	11	12
Undergraduate Students	10	49	13	42	11	12





ARIZONA BOARD OF
REGENTS

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

	<i>FY 2017 ACTUAL</i>	<i>FY 2018 ACTUAL</i>	<i>FY 2019 ACTUAL</i>	<i>FY 2020 ACTUAL</i>	<i>FY 2020 BUDGET</i>	<i>FY 2021 BUDGET</i>
REVENUE						
Carry Forward	\$ 3,040,975	\$ 1,606,114	\$ 1,969,491	\$ 2,004,034		
TRIF Revenue	2,000,000	2,000,000	2,000,000	1,833,339	2,000,000	2,000,000
TOTAL REVENUE	\$ 5,040,975	\$ 3,606,114	\$ 3,969,491	\$ 3,837,373	\$ 2,000,000	\$ 2,000,000
EXPENDITURES						
OPERATING	83,944	122,002	142,943	300,774	140,000	150,000
GRANTS/PROJECTS	3,266,975	1,514,620	1,823,578	1,395,000	1,860,000	1,850,000
TOTAL EXPENDITURES	\$ 3,350,919	\$ 1,636,622	\$ 1,966,521	\$ 1,695,774	\$ 2,000,000	\$ 2,000,000
SUMMARY BY INITIATIVE						
Regents' Innovation Fund Grants	\$ 1,200,000	\$ 1,000,000	\$ 1,200,000	\$ 1,012,000	\$ 1,000,000	\$ 1,000,000
Data/Resources/Technology	200,919	464,620	573,578	333,000	900,000	900,000
STEM/Innovation Projects	50,000	50,000	50,000	50,000	100,000	100,000
Over realized funds to universities	1,900,000	-	-	-	-	-
TOTAL EXPENDITURES	\$ 3,350,919	\$ 1,514,620	\$ 1,823,578	\$ 1,395,000	\$ 2,000,000	\$ 2,000,000

