

# TECHNOLOGY AND RESEARCH INITIATIVE FUND

FY 2018

BOARD OF  
**Regents**  ARIZONA'S PUBLIC  
UNIVERSITIES

EDUCATE • DISCOVER • IMPACT

**ASU** Arizona State  
University

**NORTHERN  
ARIZONA**  
UNIVERSITY 

 THE UNIVERSITY  
OF ARIZONA



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# TRIF EXECUTIVE SUMMARY

## PROPOSITION 301 FUNDS TRIF

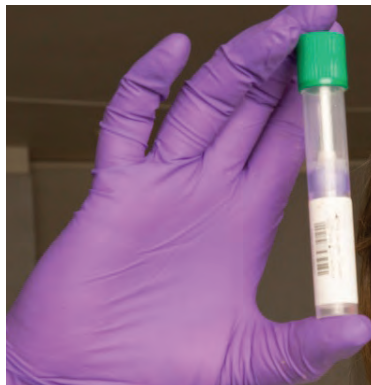
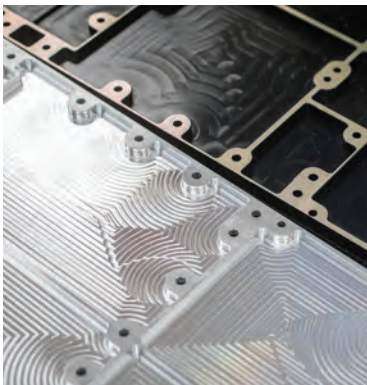
- Proposition 301 increased the state's sales tax to be dedicated to K-12, community colleges and Arizona's public universities. Collection of the tax began on June 1, 2001. In 2018, the proposition was extended for another 20 years.
- Arizona law establishes the Technology and Research Initiative Fund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

## TRIF BUDGET

- 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. These project plans are available on the ABOR web site at: <http://www.azregents.edu/reports/research-technology-transfer>.
- In fiscal year 2017-18, TRIF received approximately \$77.2 million in revenue. Total TRIF revenue received to date since the inception of the program in June 2001 is over \$1,041 billion.
- The TRIF statute includes a 20 percent limitation on use of TRIF funds for capital projects expenditures.

## 2018 FINANCIALS

This year the actual sales tax receipts were \$1,720,266 over budget projections. In September 2017, revised budget projections were approved by the board for the remaining four-year term of the program. Revised budgets are reflected in the financials and metrics sections of this report.



## TRIF INITIATIVES

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 monies 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.

## TRIF REPORTING

- A.R.S. §15-1648(D) requires the board to submit to the governor and the Legislature by Sept. 1 of each year a report of prior year TRIF expenditures.
- This fiscal year 2018 TRIF report, as well as previous reports, is available on the ABOR web site.
- The board-adopted TRIF five-year project plans detailing anticipated budgets and expected outcomes are also available on the ABOR website.









# ARIZONA STATE UNIVERSITY

Investment of Technology and Research Initiative Funds (TRIF) at Arizona State University advances research, entrepreneurship and economic development while fueling innovative solutions. These solutions provide a significant return on investment to the citizens of Arizona in the form of an accelerating economy, broad access to education and training, and better quality of life.

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

- **Improving Health** encompasses use-inspired, collaborative research that advances human health and quality of life.
- **Water, Environmental and Energy Solutions** integrates research efforts that create solutions to the challenges posed by urbanization and the increasing demands for energy, water, food and clean air.
- **National Security Systems** addresses the critical research and technology needs of the security, defense and aerospace sectors.
- **Access and Workforce Development** advances research and education to elevate and expand Arizona's highly skilled workforce.

In the past year, \$179 million in new funding from external sources has been awarded to TRIF-funded initiatives, such as efforts to advance a universal cancer vaccine and a project to develop flexible, resilient electrical systems for military and civilian needs. Across the four focus areas this year, 883 undergraduates, 1,414 graduate students and 255 post-doctoral appointees were involved in TRIF-supported research. In addition, TRIF research generates novel technology and new businesses. This year, 33 new startup companies were founded based on technology from TRIF-supported research and 72 new patents were issued.

Since 2002, ASU has leveraged TRIF investment in ways that are accelerating research, the resulting solutions and economic impacts. ASU exceeded \$600 million in research expenditures in fiscal year 2018, making it one of the fastest-growing research enterprises among U.S. institutions with more than \$100 million in research expenditures. In addition, ASU ranks No. 17 among all universities in the world for U.S. patents, ahead of Columbia, the University of Washington and Duke. In recognition of this growth and impact, ASU was named the most innovative university in the country by U.S. News and World Report for the third consecutive year, based on surveys of university presidents and leaders. This innovation allows us to educate and graduate more students while earning recognition for the increasing caliber of ASU's programs and graduates.







“TRIF has enabled substantial research progress at ASU, positioning the university as one of the nation’s premiere institutions, including being named the most innovative university in the country by U.S. News and World Report. As a direct result of TRIF investment, ASU researchers are creating significant economic, social and cultural impact in Arizona and beyond. For example, TRIF-enabled faculty have developed new strategies for diagnosing, treating and preventing cancer. They have created a low-cost test for Zika virus. They have secured three patents and launched a startup company focused on nanotechnology-enabled water treatment. In addition, we are enabling students to gain the hands-on experience that employers demand, including developing a medical technology workforce program in Maricopa County.”

— Sethuraman “Panch” Panchanathan, Executive Vice President, ASU Knowledge Enterprise, and Chief Research and Innovation Officer







“Decision Theater Network’s data translation and demonstration experience allows expert decision makers to explore disparate information sets and execute informed and impactful policies.”

— Jon Miller, Director, DTN

## IMPROVING HEALTH

TRIF-supported researchers in Improving Health initiatives are addressing the complex and critical challenges of health and health care. This focus area fuses biomedicine, engineering and computing through innovative approaches in partnership with leading institutions like Mayo Clinic.

### Programs supported in the Improving Health focus area and associated goals:

- The Biodesign Institute addresses today’s critical global challenges in health care, sustainability and security by developing solutions inspired by natural systems and translating those solutions into commercially viable products and clinical practices.
- The Decision Theater Network (DTN) engages researchers and leaders across the TRIF focus areas to visualize and identify solutions to complex problems. With locations in Tempe and in Washington, D.C., DTN facilities provide the latest expertise in collaborative computing and display technologies for data visualization, modeling and simulation.
- Research Computing provides high-performance computing resources across the TRIF focus areas. These resources are available to ASU researchers as well as industry and community partners, enabling the collection, management and analyses of vast and complex data sets.
- Complex Adaptive Systems (CAS) represent a unique framework for biomedicine. Initiatives led by CAS include the nonprofit National Biomarker Development Alliance, which is developing standards for the discovery and effective use of biomarkers in medicine.

# SUMMARY OF ACCOMPLISHMENTS

Each year TRIF investments in our Improving Health portfolio are leveraged to secure new external funding and to expand research and technology to generate maximum impact.

- During the past year, Biodesign researchers submitted \$349 million in proposals and secured \$39 million in new award obligations. These include \$8.6 million from the National Institutes of Health Cancer Systems Biology Consortium to explore how evolution and ecological processes affect the growth of tumors, and \$6.4 million from the Open Philanthropy Project to advance pursuit of a universal vaccine for cancer. During the past year, researchers identified a toxic protein that may be a clue to the cause of Alzheimer's; developed a low-cost, easily administered Zika diagnostic; created a nanobot that can seek and destroy tumors; and entered into a partnership with the city of Tempe to monitor the presence of opioids in wastewater.
- DTN currently enables 17 research projects across ASU. For example, ASU's School for the Science of Health Care Delivery and DTN secured funding from the Robert Wood Johnson Foundation to develop a seven-screen visualization to highlight the impact of the serious mental illness population on Arizona's public services and decrease fragmentation of the state's public health care. DT is also using PULSE, a social media scraping and analysis tool built through TRIF funding, to understand Twitter's role in Hurricane Harvey disaster relief and how social media can be used as a community organizing mechanism.
- Research Computing has supported more than \$120 million in research projects over the past three years. In fiscal year 2018, it supplied 37 million CPU hours of high-performance computing to 1,035 students and research associates working with 177 primary investigators from 12 colleges. This enabled scientific investigation of more than 150,000 different research questions. Research Computing also assisted researchers with the computing capacity needed to conceptualize computational questions before submitting competitive funding proposals.
- CAS co-director George Poste was selected as a member of the new National Academy of Medicine committee to develop a national strategy for cancer control in the U.S. CAS researchers were involved in development of new tests for better detection of drug resistance in cancer treatment.



“With support from the people of Arizona, the Biodesign Institute has become one of the nation’s most forward-thinking research centers, attracting the best and the brightest minds in our state, from across the nation and the world. For us, no challenge is too great. Every day, our scientists and students are in hot pursuit of new ways of detecting and treating disease that will result in a far better, healthier and happier life for all of us and for generations to follow.”

— Josh LaBaer, Director,  
Biodesign Institute





## WATER, ENVIRONMENTAL AND ENERGY SOLUTIONS

As our world becomes increasingly urbanized and resource constrained, we need creative, science-based solutions. Research advanced in the Water, Environmental and Energy Solutions focus area capitalizes on the key role that Arizona can play in the future of energy technology, education and commercial development.

**Programs supported in the Water, Environmental and Energy Solutions focus area and associated goals are:**

- The Julie Ann Wrigley Global Institute of Sustainability (ASU Wrigley Institute) advances research, education and business practices for an urbanizing world. Its four cornerstones of education; research; business practices and global partnerships; and transformation transcend disciplines, campuses and institutional boundaries.
- The LightWorks initiative envisions a resilient and equitable energy future supported by innovations in technology, policy, law and markets. LightWorks pulls light-inspired research at ASU under one strategic framework, leveraging the university's unique strengths in solar-electric energy, sustainable fuels and products, and energy and society.
- 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.
- Future H2O is changing the narrative about water from one of scarcity to one of abundance and creating opportunity for change at scale for regional, national and global water systems.

# SUMMARY OF ACCOMPLISHMENTS

Programs in the Water, Environmental and Energy Solutions portfolio operate at local and global scales to address sustainability issues.


- The ASU Wrigley Institute submitted nearly \$66 million in grant proposals in fiscal year 2018 — a 71 percent increase over last year — and leveraged TRIF funding to support several initiatives and research projects. For example, the School of Sustainability partnered with Major League Baseball to launch a scalable zero-waste initiative at Salt River Fields. The Sustainable Cities Network collaborated with 10 Maricopa County cities to create a regional Alternative Stormwater Management Guidance Handbook promoting green infrastructure and low-impact development. Project Cities completed its inaugural city partnership in Apache Junction, where students invested nearly 34,000 hours on sustainability projects to improve the city's quality of life.
- LightWorks has secured more than \$26.8 million in research awards in the past five years. In fiscal year 2018, the Office of Naval Research awarded LightWorks \$2 million to advance intelligent distributed electrical architectures with secure controls that enable more flexible and resilient solutions for naval, civilian and humanitarian needs. Through LightWorks, the Center for Negative Carbon Emissions has entered into a three-year research agreement with Shell's New Energy and Research Technology Group to fund research on carbon capture from the atmosphere. Additionally, LightWorks researchers are working with the Navajo Nation to provide education, tools for decision-making and energy-specific developments intended to retain highly skilled community members and to increase economic diversification and opportunity and cultural resiliency.
- TRIF investment in CBBG supported development of a one-of-a-kind rainfall simulator/erosion control test facility for use in evaluating innovative methods for controlling hillside soil erosion. It has also supported outreach to local K-12 schools and a summer Research Experience for Teachers program. Additionally, four graduate students and three faculty mentors participated in the NSF Innovation Corps program to accelerate commercialization of CBBG-developed technologies.
- NEWT was awarded three patents in the past year and launched a woman-owned startup company, H2O Insights, that will begin commercializing these technologies. ASU also leads the development of a MobileNEWT test bed that will deploy new technologies and evaluate their performance at different locations with different water sources. The facility will also be used for outreach and education to show how nanotechnology can improve our lives.
- Future H2O has established the "Working Watersheds" initiative, which helps companies transform watersheds into working ecosystems through interventions like wetland construction. The initiative was initially TRIF funded but is now nearly 90 percent externally funded. Future H2O has also developed curriculum for "The Global H2O Classroom," which celebrates the breadth of water – from hydrology to the humanities, engineering to economics and ecology – via blended pedagogy, including forthcoming online and in-country offerings in Southeast Asia and South America.

"Through TRIF support, we have established a center for drinking water treatment systems that use the unique properties of nanomaterials, which is leading to patents, papers, student support, outreach and education, and spin-off companies. TRIF funding is helping to bridge the gap between fundamental research and development, which is needed prior to commercialization by larger companies."

— Paul Westerhoff, Regents' Professor and Deputy Director, NEWT







“TRIF support is critical to ASU’s ability to address complex security challenges. It gives us the flexibility to build diverse teams of researchers who can take new approaches to issues that affect our state, like resource scarcity, cyberattacks or how humans can best utilize artificial intelligence. And it is working. DHS’s selection of ASU as the lead of its new Center of Excellence underscores the fact that we are increasingly viewed as a national leader in security research.”

— Nadya Bliss, Director, GSI

## NATIONAL SECURITY SYSTEMS

ASU takes a multifaceted approach to security research, including innovative public-private partnerships. As a result, the National Security Systems portfolio aligns with cutting-edge development in the security sector and research leads directly to implementable solutions.

### **Programs supported in the National Security Systems focus area and associated goals:**

- The Global Security Initiative (GSI) tackles “wicked problems” characterized by challenges with complex interdependencies that don’t have clear solutions. The hub of ASU’s security research, GSI explores issues that include health security, economic security, resource security and cybersecurity.
- The Space Technology and Science Initiative (NewSpace) leads the integration of academic and commercial space enterprises using ASU’s core strengths in space science, engineering and education. NewSpace is creating academic-commercial partnerships that bring together the most brilliant minds in the space industry sector for an unprecedented collaborative effort.
- The Interplanetary Initiative creates interdisciplinary projects that approach critical questions about our space future that are neglected elsewhere. Projects advanced by the initiative use a structured project management approach including planning outcomes and products from the start. In addition, all projects bring research into the classroom and track efforts in exploration learning.

# SUMMARY OF ACCOMPLISHMENTS

The National Security Systems focus area has created a portfolio of university research initiatives that partner with companies in the highly competitive security, defense and aerospace sectors. These efforts are creating new potential and markets for these industries in Arizona.

- GSI is establishing ASU as a leader in global security and bringing significant external funding to the state. For example, the Department of Homeland Security awarded ASU \$20 million to establish the national Center for Accelerating Operational Efficiency. CAOE works with government agencies to improve disaster response planning, identify indicators of potential lone-wolf style attacks and make airport security checkpoints safer and more efficient — particularly relevant to Arizona as a border state with one of the busiest airports in the nation. In fiscal year 2018, GSI researchers submitted \$85 million in new proposals and supported a defense sector portfolio that received nearly \$30 million in new awards.
- NewSpace introduced Blue Origin to the ASU campus and co-sponsored an inaugural sub-orbital payload competition. More than 30 students participated in a culminating pitch event that advanced three teams to launch their projects into low Earth orbit in fall 2018. Additionally, NewSpace partnered with ASU's Interplanetary Initiative to promote NASA's Small Innovative Missions for Planetary Exploration (SIMPLEx) funding opportunity to faculty and local industry, resulting in three mission proposals requesting \$15-55 million each.
- Nine pilot projects of the Interplanetary Initiative completed their first year in fiscal year 2018, with active involvement from 85 people (including 30 students) representing 25 ASU units and 14 external groups. Pilot teams have secured more than \$600,000 in grants and donations. Five additional pilots will begin in fiscal year 2019. In addition, 20 ASU classes from 11 units have incorporated Interplanetary Initiative questions and knowledge creation. These classes total over 700 students.

“Involving students in knowledge creation is a challenge in a large university, unless we bring research into the classroom and the classroom into the research lab. Exploration learning skills are critical to the concept of ‘master learners’ — students must learn the skills and processes needed for answering tomorrow’s questions, not just absorb the content discovered to date.”

— Lindy Elkins-Tanton,  
Professor and Director,  
School of Earth and  
Space Exploration





# ACCESS AND WORKFORCE DEVELOPMENT

The Access and Workforce Development focus area addresses the need for training and education required to drive Arizona's economy. ASU is leveraging its award-winning programs to advance this focus area on two fronts – entrepreneurship and advanced manufacturing. The research and programs supporting these efforts work synergistically to marry innovative thinking with cutting-edge, applied technology.

## Programs supported in the Access and Workforce Development focus area and associated goals:

- ASU Entrepreneurship and Innovation (E+I) provides educational opportunities, training and mentoring to students, faculty and the community. E+I is a connecting resource that opens the university's research and development capabilities, experience in innovation, and facilities to the broader community with an eye toward stimulating new ventures and improving economic outcomes.
- The Advanced Materials Initiative (AMI) enables the materials research community to accelerate the pace of innovation through strategic teaming, infrastructure development and operational analytics. It seeks to identify and nurture opportunities of high impact, especially those related to the university's priority application areas of transportation, health, energy, sustainability, construction and space exploration.
- The Flexible Electronics and Display Center (FEDC) is a global leader in flexible electronics manufacturing. This public-private partnership demonstrates ASU's manufacturing capabilities and has created a powerful innovation infrastructure to drive economic growth. Together with the MacroTechnology Works (MTW) Initiative, ASU is advancing fundamentally new manufacturing capabilities for emerging transformational technologies.
- ASU is a partner in the Advanced Regenerative Manufacturing Institute (ARMI), a member-driven nonprofit organization. The institute's mission is to make practical the large-scale manufacturing of engineered tissues and tissue-related technologies to benefit existing industries and grow new ones.

"The success of entrepreneurs leads to more jobs, more revenues and more substantial pathways to individual and societal economic growth."

— Ji Mi Choi,  
Associate Vice President,  
Entrepreneurship  
and Innovation



“The new MC-IDA project will develop and enhance a medtech workforce in Maricopa County that links employers to vulnerable and underserved worker populations and links higher-paying jobs to citizens in the county. In addition, new innovative and viable medtech startups will be established.”

— Gregory Raupp, Director, MacroTechnology Works



## SUMMARY OF ACCOMPLISHMENTS

The initiatives in the Access and Workforce Development focus area are activating and accelerating Arizona’s economy. This includes programs supporting entrepreneurs and businesses from idea to market and a targeted focus on developing Arizona’s advanced materials sector with its skilled workforce requirements.

- E+I supports the development of new ventures around a sustainable circular economy through the RISN Incubator, a partnership with the Walton Sustainability Solutions Initiative and the City of Phoenix. The initial 10 pilot companies have raised over \$1.3 million in capital with a resulting \$3.15 million in business sales. E+I also supported the pilot of the Inno-Nations incubator for Native American business owners and enterprises, providing community training and a two-semester course in American Indian Studies, with a minor certificate program forthcoming.
- AMI identified and seeded innovative projects in new materials and began planning materials applications for ASU’s future high-intensity compact X-ray free electron laser. The initiative made several key equipment investments, including a modern X-ray fluorescence analyzer for rapidly determining the elemental composition of bulk materials. In addition, AMI collaborated with startup companies such as Cactus Materials, which won a NASA SBIR phase I grant for developing 3D integrated electronic devices that incorporate ASU technology.
- The MTW site, which houses FEDC, continues to drive semiconductor and materials technology developments. TRIF seed funding for collaborative efforts between FEDC and faculty at the Biodesign Institute has led to the creation of a new diagnostic technology. This work was awarded a \$3.5 million grant from the National Cancer Institute, which will include a clinical trial in India. MTW was also awarded \$2 million from the Maricopa County Industrial Development Authority (MC-IDA) to develop a skilled workforce program for medical technologies that accelerates innovation, grows the ecosystem and enhances Maricopa County’s global competitiveness.
- ARMI awarded ASU an Education Workforce Development “quick start” program to address the need for workforce training in regenerative medicine (RM)-based biomanufacturing, technologies and therapies. In summer 2018, ASU is piloting development of a comprehensive online curriculum in RM and biomanufacturing for undergraduates, graduates, veterans and non-college-bound youth. The pilot program will include six weeks of lectures and two weeks of hands-on sessions followed by internships, with full two-year and four-year programs anticipated within the next five years.



## HIGHLIGHTS

ASU's thriving knowledge enterprise reflects the spirit of ASU's charter, focused on access, excellence and impact. Success is demonstrated by the robust growth of ASU's research expenditures, which have nearly quintupled to \$600 million since TRIF began in 2002. It is demonstrated through ASU's tech transfer, which led the university to leap ahead 13 spots in the world ranking for U.S. patents in the past year. And it is demonstrated in the recognition ASU receives through academic rankings and the attraction of external partners — including many Fortune 500 companies. The strategic investment of TRIF has been instrumental in catalyzing and driving this success.

For the FY17–FY21 TRIF funding cycle, ASU has identified targeted research thrusts that are poised for large project acquisition and that leverage ASU expertise while providing strong return on investment for Arizona taxpayers. These research thrusts translate directly to the projected needs of the Arizona employment sectors and include:

- **Health and well-being**
- **Food/energy/water nexus**
- **Earth and space exploration**
- **Industrial transformation, including advanced manufacturing, advanced materials and future transportation**
- **Smart cities and urban resilience**
- **Internet of things and cybersecurity**

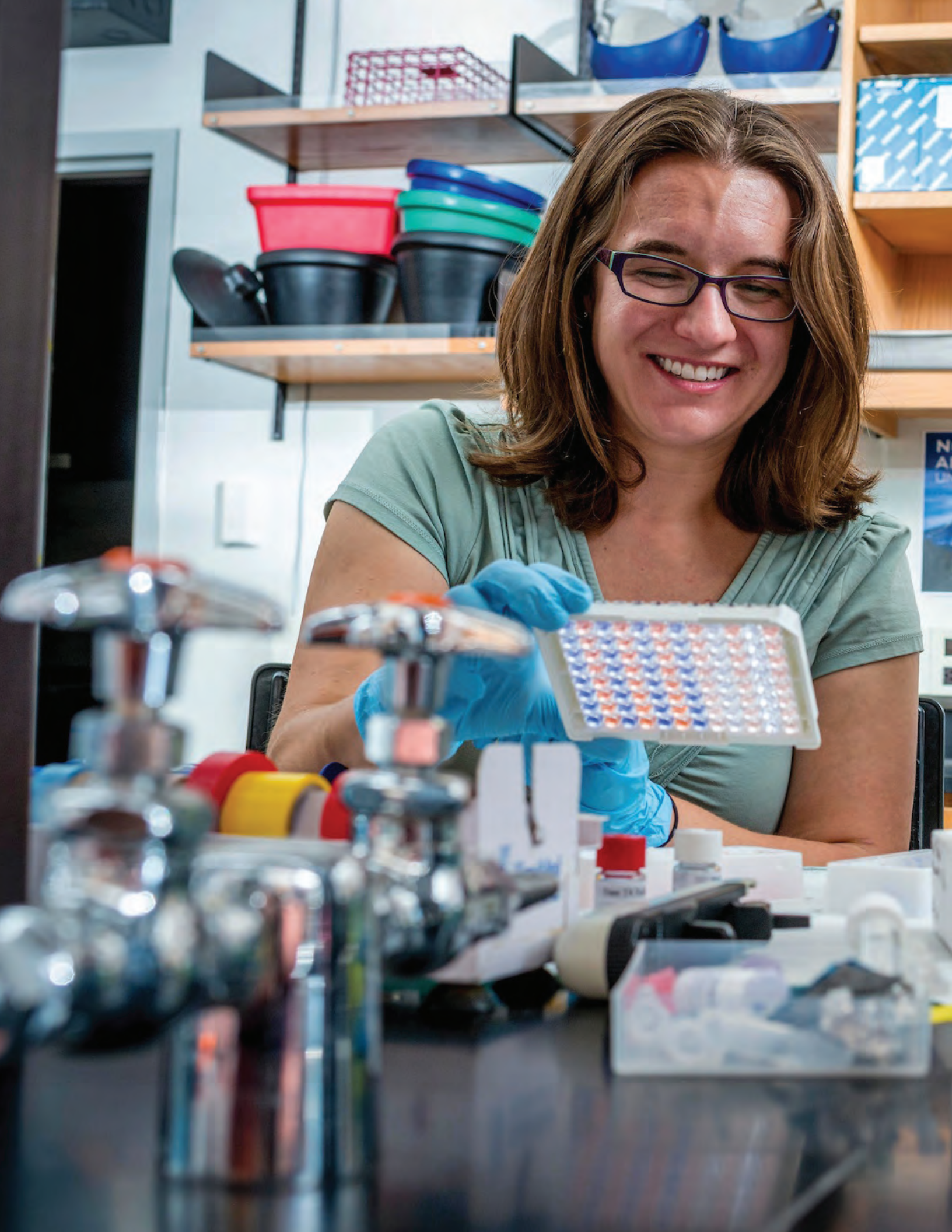
TRIF funding has enabled ASU researchers to pilot innovative programs that go on to secure large external awards. This year, there has been solid advancement in the area of health and well-being, with awards of more than \$8.5 million to ASU over five years from the National Cancer Institute to establish the Arizona Cancer and Evolution Center. This grant establishes ASU as the hub of an international network of research scientists who are dedicated to understanding cancer in an entirely new way, and opens the door to new partnerships and investment in the future.

The Department of Homeland Security (DHS) also turned to ASU researchers for help developing advanced tools to improve operations in DHS organizations, including the Transportation Security Administration, U.S. Coast Guard, Federal Emergency Management Agency, and U.S. Customs and Border Protection. The new center brings \$20 million to ASU over the next five years with potential to extend for another five years. It also provides opportunities for students to conduct research and complete internships, giving ASU an opportunity to broaden its work in preparing the next generation of security practitioners.

To stay abreast of emerging trends, challenges and opportunities, ASU established the Global Futures Initiative, led by Peter Schlosser, one of the world's leading earth scientists. The initiative will use knowledge and innovation across all of the thrust areas to ensure a sustainable future for humanity.

The world is rapidly changing and as a society we face great challenges, many acutely apparent to Arizona citizens. Through research efforts supported by TRIF, ASU is playing a significant role in creating a bright future for Arizona, one in which the state is widely recognized as an outstanding place to work, study and live — while preparing a new generation to continue a tradition of excellence.









**NORTHERN  
ARIZONA  
UNIVERSITY** 



# NORTHERN ARIZONA UNIVERSITY

Since the Arizona Board of Regents approved Northern Arizona University's bold five-year plan for the fiscal year 2017-21 Technology and Research Initiative Fund (TRIF) in spring 2016, expanding NAU's capacity to invest in areas of strategic research growth, NAU's TRIF investments continue to have a significant impact throughout Arizona, producing economic benefits through scientific advancements, workforce training and access to higher education.

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

The WEES and iHealth initiatives have driven NAU to innovate and discover while enhancing our leadership position in these disciplines. AWD supports the state's economic growth through the development and delivery of courses and degree programs that support workforce needs in high demand areas such as health, teacher education and business and nonprofit management, particularly focused on serving communities throughout Arizona. SPACE capitalizes on our recent recruitment of research-intensive faculty in the areas of astronomy and planetary science, while leveraging the wealth of astronomical resources found throughout Arizona to prepare a workforce that will strengthen Arizona's stature as a worldwide leader in this rapidly growing area of research. The growing need for cutting-edge research in the critical area of cybersecurity is driving our investment in NSS, an area in which NAU has already positioned itself as a leader through a number of new research-intensive hires and investment in high-tech laboratories. NAU sees this as a core national security priority that will affect thousands of Arizona businesses in the coming decade, and a highly qualified workforce will be needed to meet these challenges.



“Research at NAU is vital to our mission of providing a high quality education and service to our region. The discoveries of our expert faculty researchers inspire our students to reach further and achieve more. Our solutions to regional issues focus on providing public service in

critical areas. Funding from TRIF has enabled NAU to leverage additional external resources resulting in the accomplishments highlighted in this report.”

– Rita Hartung Cheng, President







The National Institutes of Health awarded NAU a total of \$21.4 million for a five-year initiative to establish the Southwest Health Equity Research Collaborative (SHERC), with \$4.8 million awarded in fiscal year 2018. SHERC will recruit and support a new cadre of researchers to grow the university's capacity for basic biomedical, clinical and behavioral research under the umbrella of health equity. Professor Julie Baldwin, director of the Center for Health Equity Research, and professor Diane Stearns are co-leaders of the project.

## IMPROVING HEALTH

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

**Bioengineering/Biotechnology:** Investments in the NAU Center for Bioengineering Innovation (CBI) will catalyze 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. CBI's research 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.

**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. In fiscal year 2017, NAU established the Center for Health Equity Research to address the healthcare disparities of the state's underserved populations, including Native Americans, Hispanics and rural communities, and this initiative has resulted in millions of dollars in new grant funding.

**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 will lead 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 bacteria from hospital-acquired infections to anthrax, plague and biological warfare agents.

## 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 healthcare 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 healthcare providers, research institutions and tribal communities, NAU researchers are generating discoveries and innovations 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 \$11 million in external grant funds in fiscal year 2018.
- NAU and TGen were jointly awarded two U.S. patents relating to novel assays, one for the detection of Cryptococcosis, a potentially fatal fungal disease, and the other for determining Staphylococcus strain antibiotic resistance for selecting the best treatments for MRSA.
- Regents' Professor Paul Keim, executive director of PMI, received \$474,883 from the Defense Threat Reduction Agency to seek a comprehensive understanding of drug resistance and susceptibility mechanisms across a large and diverse collection of burkholderia pseudomallei, a potential bioterror agent. Mechanisms that are identified will be developed into tools for more rapid and effective testing, diagnosis and treatment.
- The National Institutes of Health awarded assistant professor Bridget Barker of PMI \$217,600 for a project to define an entirely new life cycle stage of Coccidioides, which causes Valley Fever.
- NAU received a \$3.6 million RO1 renewal grant to continue working on a long-term research project studying the link between high levels of persistent organic pollutants on St. Lawrence Island in Arctic Alaska and the health of the residents there. Professor Frank von Hippel is the project's principal investigator. Von Hippel is also applying his expertise in this area to a study of the effects of water contamination on residents of Yuma in partnership with the Yuma medical community.
- A new doctoral degree program in interdisciplinary health was launched in fiscal year 2018. This cross-disciplinary collaborative program is designed to educate and train the next generation of health researchers, advocates and educators with emphasis on health equity, disability and psychosocial health. Students will work with faculty on important theoretical and practical issues related to population health, health care and well-being. Graduates will be uniquely qualified to lead interdisciplinary research that yields new insights about health.

NAU received \$224,998 from the Arizona Department of Health Services to evaluate the novel use of a wearable exoskeleton to improve balance and walking economy for children with movement disorders. Assistant Professor Zachary Lerner is the project's principal investigator. NAU also filed for four patents on Lerner's innovative robotic exoskeleton research aimed at assisting children with cerebral palsy, research which offers promising new means to increase the quality of treatments through assisted rehabilitation.





## 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 new School of Informatics, Computing and Cyber Systems (SICCS).

Cybersolutions addresses key challenges for secure computing. The most obvious challenge is the need for cybersecurity and encryption that cannot be easily defeated. Novel approaches 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. Cyber-physical 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. This will be accomplished largely through NAU's new 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. (As a whole, NAU SICCS faculty received \$3.89 million in external grant awards in fiscal year 2018.)

- NAU faculty who received TRIF funds through the NSS initiative received more than \$919,700 in external grant awards in fiscal year 2018.
- NAU received \$463,681 from the National Science Foundation to engage community leaders in the resilient management of their food, energy and water systems to prepare them for disaster relief and recovery. The project will focus on developing a nationally scalable protocol for public participation in STEM research that leverages data science and visualization tools from the FEWSION mapping project. Associate professor Benjamin Ruddell, who leads FEWSION, is also the principal investigator on this project.
- Professor of practice Bertrand Cambou received a \$195,700 grant from Alion Science and Technology Corporation to study how ternary computing (which is based on ternary logic, more complex than binary logic) can enhance information assurance and cybersecurity. Also, two patents were awarded to NAU in fiscal year 2018 for Dr. Cambou's novel cybersecurity methods, which provide new approaches to strengthen authentication channels and prevent side-channel attacks by hackers.

The Department of Defense Air Force Research Laboratory awarded assistant professor Fatemeh Afghah a \$65,000 grant to develop tools and protocols for secure spectrum sharing between military systems and other communication technologies. The results of this project will expand the United States' leadership in wireless innovation by opening the Department of Defense spectrum to other services while enabling access of military systems to other spectrum parts if needed.





## ACCESS AND WORKFORCE DEVELOPMENT

Northern Arizona University continues to leverage over two decades of success in providing affordable pathways to degree completion through innovative programming and delivery options. NAU's TRIF initiative, Access and Workforce Development (AWD) supports statewide efforts to connect community members to degrees in the health sciences and education. By integrating technology and advanced learning design, these programs meet both employer and student needs in their communities throughout the state. A growing number of Arizonans, including under-represented populations, have achieved a higher education degree and career success through NAU's flexible, alternative learning models.

Education and health services are among the fastest growing industries in Arizona, with healthcare having the highest overall gain in jobs. NAU has continued expansion of nursing program offerings to meet a variety of new and practicing nurse employment and career progression needs. Teacher education continues to be a central pillar of NAU's legacy, and this initiative supports programming throughout Arizona and online.

Providing consistent service toward student success and degree completion are achieved by integrated, on-demand services, informed by the best practices in student 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, including the establishment of the NAU Teachers Academy.**
- **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.**



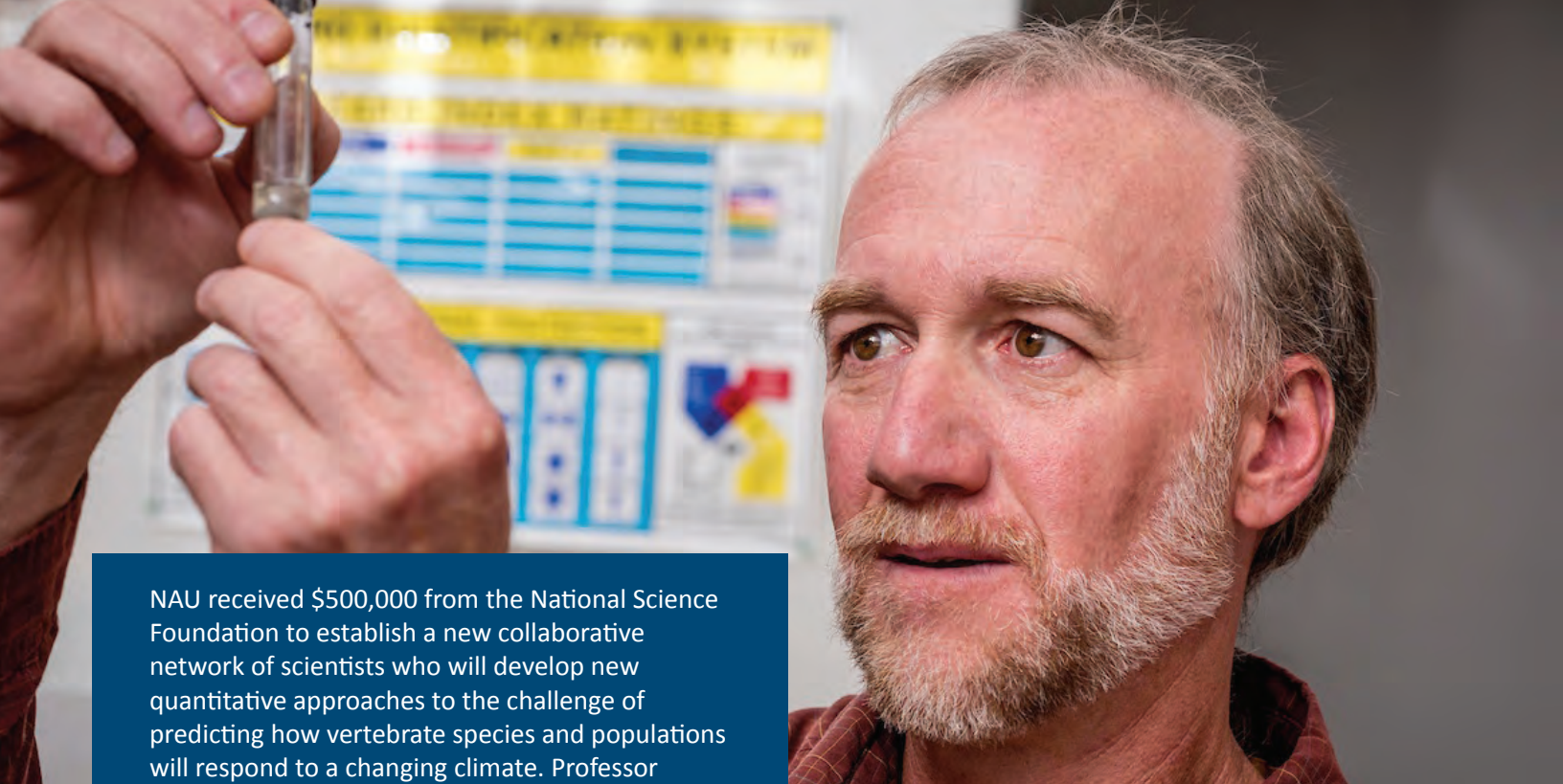
## SUMMARY OF ACCOMPLISHMENTS

A key value of Northern Arizona University is to provide all qualified students with access to higher education, regardless of their ability to attend the residential campus in Flagstaff. NAU offers several programs across the state in partnership with local community colleges, as well as private and public organizations to meet workforce needs. As Arizona strives to increase postsecondary education certificates and degrees among its citizens, it is vital that access to higher education is available in delivery models that meet student needs in achieving their goals.

- NAU's competency-based education (CBE) program, Personalized Learning, the first CBE program at a public institution, is an innovative approach to the traditional learning experience. Students' progress through the curriculum by demonstrating competency in the subject matter. Because Personalized Learning offers full access to all course content during a flat-rate, six-month subscription, the cost of degree completion for motivated students can be quite low. On average, Personalized Learning students complete a bachelor's degree in two subscriptions. In fiscal year 2018, TRIF funds supported the launch of a Master of Nursing degree in May 2018 in Personalized Learning.
- NAU continues to leverage its strengths in individualized learning, service and student success as the university's enrollment increases and provide access to Arizona's first-generation and underrepresented populations. Efforts in student retention and success, including applying technology to alert faculty and academic advisors to struggling students, have positively influenced the student experience. Other continuing efforts in the adaptive courseware program allows effective remediation to increase student success. These innovative learning and support strategies have positive impacts for all Arizona students.







NAU received \$500,000 from the National Science Foundation to establish a new collaborative network of scientists who will develop new quantitative approaches to the challenge of predicting how vertebrate species and populations will respond to a changing climate. Professor Loren Buck, associate director of the Center for Bioengineering Innovation, is leading this project.

## 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 environmental sciences have created two research centers at NAU - the Center for Ecosystem Science and Society (Ecos) and the Merriam Powell Center for Environmental Research (MPCER). Researchers in Ecos study the interactions of biological communities to determine how they respond to and influence environmental change. Ecos prioritizes the training of future scientists and disseminating information about their discoveries to the public. MPCER has been instrumental in advancing cross-disciplinary environmental research and training at NAU with a focus on the Colorado Plateau.

NAU's Forest and Land Management program invests in two research centers: the long-standing Ecological Restoration Institute (ERI) and Landscape Conservation Initiative (LCI). 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. Investments in LCI support 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.

## 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 increased external funding and enhanced capacity for addressing complex issues in environmental variability and ecosystem science as well as forest and land management. This enhanced capacity has also enabled NAU researchers 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 more than \$7 million in external grant awards in fiscal year 2018.
- Professor Scott Goetz was awarded nearly \$2 million by the U.S. Department of Defense (DoD) to lead a team of NAU researchers in a multi-year project to assess the resiliency and vulnerability of the boreal forest on DoD lands across central Alaska.
- Professor Michelle Mack received \$255,681 from the National Science Foundation to reduce uncertainties associated with post-fire carbon dynamics in boreal forests by unraveling the ecological mechanisms by which fire severity and reduced soil organic layer depth could influence ground carbon accumulation and storage through changes in soil insulation and larch recruitment. Mack also received \$274,270 from the U.S. Department of Defense to collect, analyze and synthesize long-term data from a previous project in the Alaskan boreal forest exploring the mechanistic connections among vegetation, the soil organic layer, and permafrost ground stability, which influence the sustainability of black spruce forests.
- NAU received \$499,791 from the National Science Foundation for a project to determine whether tree growth is carbon limited in order to better understand not only how trees will respond to rising levels of atmospheric CO<sub>2</sub>, but also the role of vegetation in the global carbon cycle and the impacts of environmental change on plants. Professor Andrew Richardson is the principal investigator on this project.



The National Science Foundation awarded Professor Andrew Richardson \$1,015,095 to use imagery from a network of digital cameras as well as computer simulations to track vegetation phenology (the study of seasonal natural phenomena relating to plant/animal life) across North America in order to better manage and sustain healthy ecosystems.

# 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 Arizona's 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.**

Professor Nadine Barlow received a \$59,081 grant from Central Connecticut State University to identify and characterize a set of physical properties that can be used to define pristine Martian ejecta morphologies and determine how these deposits are modified.







The Space Telescope Science Institute awarded associate professor David Trilling \$53,818 for a project that will use 150 pure parallel orbits of the Hubble Space Telescope to discover and measure the colors of faint Kuiper Belt objects. The results will help constrain the history of the outer Solar System.

## 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, the Flagstaff Robotic Survey Telescope and the UKIRT Infrared Telescope in Hawaii under a partnership with the University of Arizona. 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 more than \$882,000 in external grant awards in fiscal year 2018.
- The National Science Foundation awarded assistant professor Mark Salvatore a \$167,228 grant to understand the biological, geological and hydrological functions of the polar regions at spatial scales previously beyond the reach of individuals, and to develop tools for imagery-enabled science for global applications.
- Assistant professor Christopher Edwards was awarded a \$107,306 grant by the Space Science Institute to improve understanding of the spatial and temporal distribution of water on the lunar surface. To accomplish this, Edwards and his team will develop a robust correction for thermal emission in infrared spectral datasets.
- The NASA Goddard Institute for Space Studies awarded assistant professor Cristina Thomas a \$71,497 grant for a project that will use near-infrared spectra obtained by NASA's Infrared Telescope Facility to characterize the compositions of near-Earth and main belt asteroids.
- Assistant professor Tyler Robinson received a \$57,520 grant from NASA to produce a community database of super-Earth and mini-Neptune transit, reflectance and emission spectra relevant to the James Webb Space Telescope and future direct imaging missions.
- In fiscal year 2017, NAU used TRIF funding of \$37,000 to jointly purchase the Ramen Spectrometer with Lowell Observatory. The primary users of this spectrometer are researchers in the Astrophysical Ice Lab in NAU's Department of Physics and Astronomy. Here, the spectrometer is used for assessing the compositions and phases in icy mixtures that are relevant to extraterrestrial settings such as lakes on Saturn's moon Titan and glaciers on Pluto. Results from this device have already been presented in nine conference abstracts, included in papers published in peer-reviewed journals and helped NAU astronomers secure external funding for projects.

## HIGHLIGHTS

At 7,000 feet and beyond, Northern Arizona University's researchers are expanding our quest for knowledge — now more than ever. 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; 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 health care, defense and security, land and water management, and space exploration issues facing the world today. 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, 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 research.

NAU's TRIF initiative in Access and Workforce Development is aligned with 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. Attaining 140 percent of the 2021 TRIF goal in this area is reflective of NAU's successful efforts. NAU graduated 1,388 nurses and teachers at locations other than Flagstaff, throughout Arizona and online in the 2017-18 academic year. These graduates meet critical workforce needs and represent the opportunity to transform education and health care in communities where they live and work.



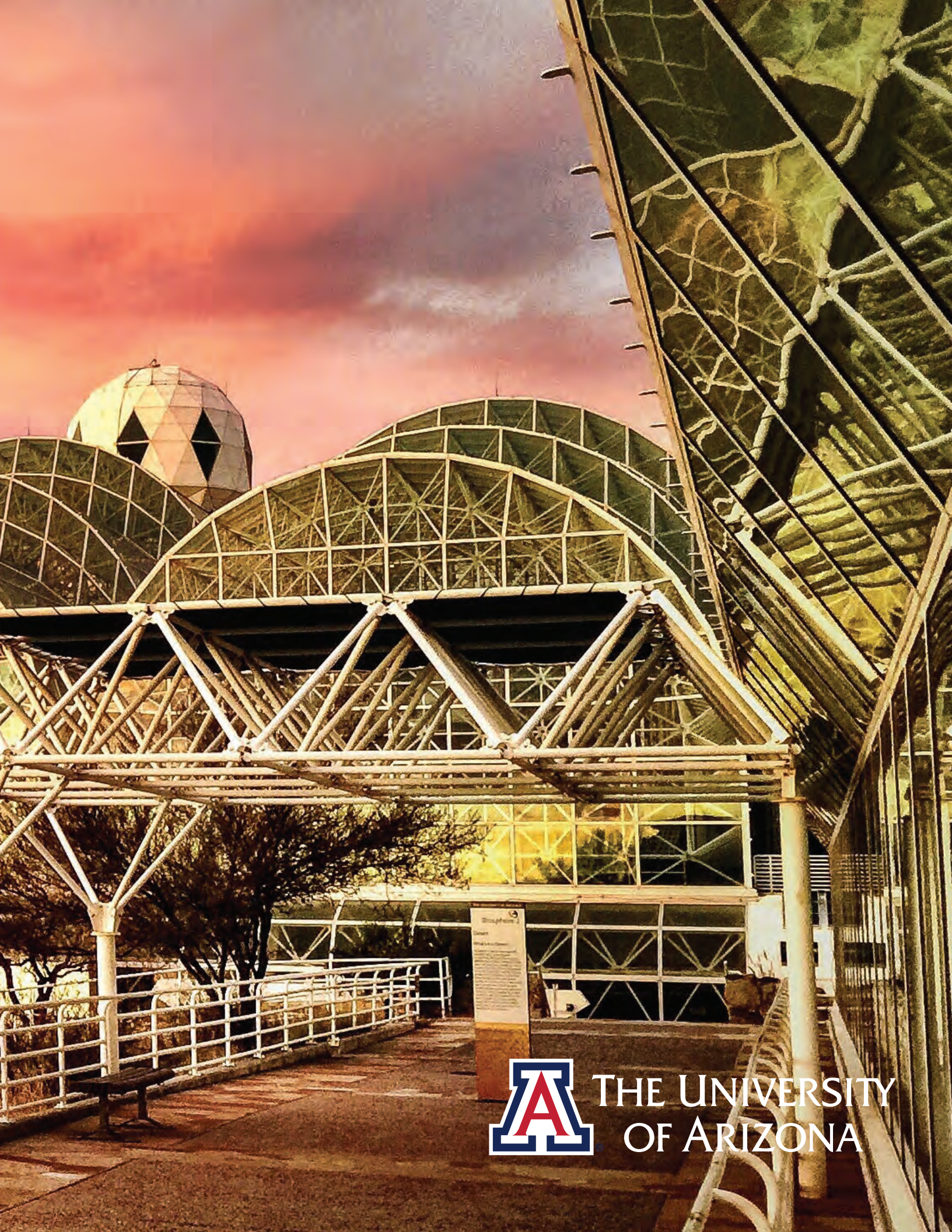












THE UNIVERSITY  
OF ARIZONA





# UNIVERSITY OF ARIZONA

Research at the University of Arizona is focused on producing results that benefit society, address grand challenges and prepare students for the workforce. UA is accelerating innovation in Arizona by bringing research out of the laboratories to create new ideas, products, technologies and services.

The philosophy of UA's Technology and Research Initiative Fund (TRIF) program is to advance economic development opportunities and benefit Arizonans by catalyzing research and development; supporting the infrastructure, facilities and computing that enables cutting-edge research and development; producing results that leverage UA's expertise and attract outside resources to our state; and providing real-world, advanced training to develop next-generation leaders.

## UA participates in the following TRIF initiatives:

- **Improving Health:** According to the Arizona Commerce Authority (ACA), bioscience and health care currently account for more than 300,000 jobs across the state. The future of health care isn't a blanket "cure all," but rather it will be personalized treatment that takes into account individual variation in genes, environment and lifestyle. The UA's Improving Health TRIF initiative is focused on delivering research results — from bench to bedside — that will improve the lives and health of our citizens, create high-quality jobs within the state and engage students in science to grow the STEM workforce. Linking UA's two medical schools and leveraging the university's clinical partnership with Banner Health, the UA has secured a historic \$64 million grant in precision medicine awarded by the National Institutes of Health.
- **Water, Environmental and Energy Solutions:** Arizona is a "living laboratory," and the UA has a depth of experience utilizing abundant sun energy and limited water resources to grow a wide diversity of crops. UA researchers are at the forefront of studying the nexus of food, energy and water — all essential components to help sustain a global population expected to swell to 9.7 billion by 2050. WEES successes include a five-year, \$3 million grant from the National Science Foundation to train UA graduate students in STEM fields with a focus on improving food, energy and water security in the Navajo Nation.
- **National Security Systems:** The nation's security is among one of the most critical areas of research today, and Arizona plays a large role with a robust aerospace and defense enterprise. UA's National Security Systems initiative impacts a range of technology and research at the university and will stimulate and promote collaboration, innovation, and research and development to support Arizona's high-tech economy.
- **Space Exploration and Optical Solutions:** Space and optics are two of the deepest and historic strengths at the UA. Southern Arizona is known as "Optics Valley" and UA is at the center of it. The axiom "faster, better, cheaper" has never been truer in today's information age. UA's strong international reputation and talent base in this area support growth in literally every industry sector identified by the ACA. UA's space exploration is equally as renowned, considering that the university has been involved in every major NASA mission since the agencies inception.

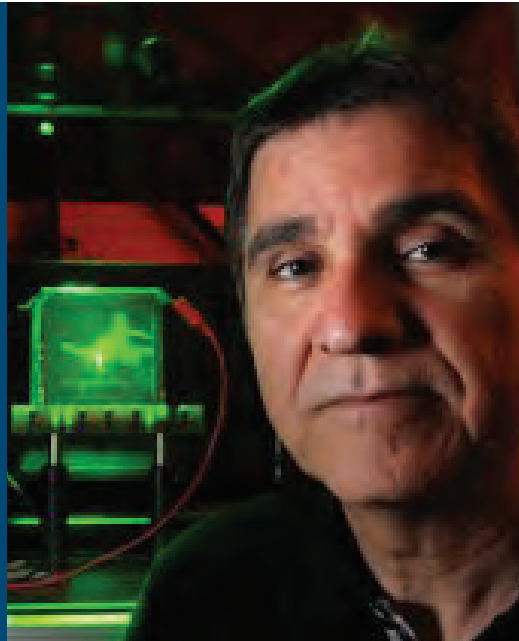




“Our growth is directly tied to innovative, cutting-edge research taking place every day on campus by our researchers. The success of our enterprise relies on the talent of UA researchers and their innovative ideas, team work and productivity that drives us forward.”

– Kimberly Ogden, Interim Vice President for Research

The photonics effort at the College of Optical Sciences is expanding on its success in the TRIF enabled, 10-year Center for Integrated Access Networks (CIAN) Engineering Research Center that is funded by the National Science Foundation and led by Nasser Peyghambarian. The quantum properties of light are a key element of photonics, positioning the UA to be an influential leader in the rapidly growing national focus on quantum information sciences.



## SPACE EXPLORATION AND OPTICAL SOLUTIONS

Through TRIF investments in the Space Exploration and Optical Solutions (SEOS) initiative, the University of Arizona is expanding educational opportunities for Arizona students in optics, astronomy and space sciences; incubating novel, high-impact research directions; and supporting regional economic development by leveraging the university's world-renowned optics education and research resources.

TRIF funding for the SEOS initiative is instrumental to faculty and student success in advancing objectives that will be central to the UA's emerging strategic plan. TRIF investment also is critical for developing a quantum optical network on campus and fostering student engagement and research for underserved students.

## GOALS

- **Leveraging TRIF funds to obtain at least a ten-fold return on investment through increased external research funding to support and educate more students.**
- **Identifying and supporting key optics faculty hires for strategic areas of Arizona need and/or opportunity across the UA campus.**
- **Creating new shared imaging and photonics infrastructure and facilities that broadly benefit the UA's research and education mission.**
- **Supporting Arizona workforce development directly through increased student fellowships and enhancing the UA's outreach to companies and underrepresented populations in the state to help increase the number of trained minority students.**
- **Encouraging technology transfer, helping the creation of new Arizona startup companies and expanding innovation activities.**
- **Encourage the commercialization of research results, helping the creation of new Arizona startup companies and expanding innovation activities.**



## SELECTED ACCOMPLISHMENTS

- Enabling the rapid acquisition of critical equipment. Jared Males in the Steward Observatory expanded his program in corona graphic exoplanet imaging, which will allow astronomers to image exoplanets closer to their bright host stars than ever before, to more than \$2.8 million in funding from the National Science Foundation and other sources, contributing to the UA's continued national leadership in observational astronomy.
- Increasing the UA's footprint in photonics. In just his first nine months at the UA, recently hired theoretician Saikat Guha secured \$1 million in contract support toward a powerful, cross-campus effort in quantum optical networking, computation and sensing.
- Spanning interdisciplinary skills. Blending photonics and biomedical applications, Judith Su developed remarkable chip-scale optical sensors capable of detecting single biomolecules, generating strong interest from both the medical community and national security for biothreat monitoring. Seed programs advanced with TRIF support have blossomed into \$685,000 in grants from the National Institutes of Health and the Partnership for Clean Competition, and recently a \$1.9 million grant with UA researcher Euan McLeod from the Defense Threat Reduction Agency.
- Enabling the next generation and working with students. The Center for Integrated Access Networks in the UA College of Optical Sciences held its annual Integrated Optics for Undergraduate Native Americans program. The 10-week summer program offers undergraduate Native American students hands-on research opportunities in optics and photonics, as well as hydrology, soil sciences, atmospheric sciences or environmental sciences. The students also attend Native American focused workshops, the culturally relevant Optics Research Workshop and presentations given by Native American STEM graduate students and faculty.







## WATER, ENVIRONMENTAL AND ENERGY SOLUTIONS

University of Arizona research supported by TRIF in the Water, Environmental and Energy Solutions initiative is developing innovative, practical solutions for water and environmental and energy sustainability in Arizona with results that will provide insights on how to live on a planet with limited resources. Research findings are applied globally, because many other semiarid regions face increasing natural resource demands and uncertainties related to drought and extreme events. Projects in this initiative are helping to secure adequate supplies of clean water for Arizona's economic vitality, optimize sustainable stewardship of Arizona's lands, create resiliency in the face of climate variability and advance Arizona's leadership in the renewable energy industry.

### GOALS

- **Building on the UA'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.**
- **Focusing on use-inspired research performed by multidisciplinary teams that will result in innovative, practical solutions for Arizona and beyond.**
- **Leveraging investment in strategic areas to increase public and private funding and commercialization of research results in technology and industry.**
- **Training a new generation of scientists, engineers and other professionals to meet state and national needs.**



## SELECTED ACCOMPLISHMENTS

- Supporting water, food and energy innovations for Arizona's future. Research by Peiwen Li on novel solar thermal-driven desalination is producing technologies that reduce the environmental impacts of desalination by generating clean water and dry salts instead of brines. Raymond Kostuk is developing new solar energy applications through tools that evaluate energy yields and a new method for fabricating holographic optical elements that diffract light to vertically mounted solar panels for increased energy capture. The UA decision-support tool, SnowView, is interactively modeling the effect of environmental conditions on snowpack in the Salt and Verde river basins, helping Arizona water managers plan water availability for hydropower, agriculture and human consumption.
- Working with students to find water management strategies. Robert Lynch, a student in the McLain laboratory, used molecular techniques to examine how toxic algal blooms occur in Arizona surface waters — research that can lead to water management strategies to avoid toxin production. Faculty hires in fiscal year 2018 are researching diverse topics, including crop adaptation to environmental stresses, membrane technologies for water reuse and desalination, and trade/food policy for increased drought resilience.
- Addressing global grand challenges. Biosphere 2 (B2) is preparing to become home to the largest reef research tank in the world. B2 Ocean will offer the structural and trophic complexity of a functioning ecosystem, propelling UA research on the science and practice of reef restoration. Additionally, research is underway on new high-yield foods, and innovative production technologies are needed to sustainably meet global food resource demands. Barry Pryor and his colleagues at the UA Controlled Environment Agriculture Center are studying mushrooms that have extraordinarily high protein levels and unique pharmaceutical properties, and they are demonstrating how production environments can be optimized to enhance the properties of this valuable food resource.
- Boosting engagement with industry and stakeholders. UA research made headlines when National Public Radio's Science Friday presented a film and story featuring Karletta Chief's research on river water quality and tribal concerns associated with the 2015 Gold King Mine spill. The Water Resources Research Center is continuing to raise water literacy through efforts such as its annual conference, The Business of Water, Arizona Project Wet and an Osher Lifelong Learning Institute lecture series. In addition, by bringing multiple mining companies together to work with UA researchers, the UA Mining Industry Academic Research Cooperative is targeting industry relevant research and is providing technology transfer that is critical to the mining industry.



In a unique partnership with Tucson-area schools, Greg Barron-Gafford and students installed and are evaluating agrivoltaics-solar canopies shading gardens. Panels showed a 5 percent increase in power production and crops needed only half the water and had a longer growing season.

## IMPROVING HEALTH

TRIF investments in Improving Health allow the BIO5 Institute to bring together world-class plant, animal and human bioscientists, engineers, physicians and computational researchers to develop bold solutions for complex challenges such as disease, hunger, water and food safety, and other environmental issues facing Arizona.

Improving Health areas for investment are carefully chosen to align with areas of state and national need and for which University of Arizona faculty already have significant expertise. This strategy catalyzes the capacity to expand impact, economic opportunity and external funding opportunities when supported by this initiative.

## GOALS

- **Fostering 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, degenerative eye disorders, and Alzheimer’s and other age-related brain diseases.**
- **Strengthening and expanding translational research by recruiting the best and brightest faculty to Arizona and supporting projects that will advance the development of new medicines, devices, diagnostics and nutritional and therapeutic strategies.**
- **Engaging and training our future generations of scientists by maintaining successful outreach and internship programs to promote experiential learning and STEM literacy in the state.**
- **Expanding 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.**
- **Promoting an entrepreneurial culture in which scientists work across disciplines to accelerate commercial translation of research breakthroughs.**



Local startup Regulonix LLC has licensed a newly invented class of non-opioid painkillers that are non-addictive, non-toxic at high doses and more effective than morphine. While chronic pain and opioid misuse and overdose are widely prevalent, the discovery could provide viable options to combat these major public health crises. The company’s co-founders, who also are the inventors, include researchers May Khanna, Rajesh Khanna and Vijay Gokhale (not pictured).





## SELECTED ACCOMPLISHMENTS

- Helping to prevent and cure disease in our state's most vulnerable. The University of Arizona-Banner Health All of Us research program has been awarded grants that will total \$64 million over five years, the largest award from the National Institutes of Health in Arizona history. The program seeks to enroll one million or more participants across the nation to improve treatment and prevention strategies based on people's individual differences in lifestyle, environment and genetics. A research team led by Monica Kraft is investigating the genetic mediators that help control lung inflammation and attacks in asthma patients with the goal to develop a better understanding of those mechanisms and refine novel therapies to moderate or eliminate asthma attacks.
- Enabling novel solutions to health and environmental challenges. Sustainable agriculture is ever more important as global leaders try to answer the question of how to feed a world population approaching 10 billion by mid-century. Joel Cuello and his team are looking for answers in the form of vertical farming, which will enable more efficient food production with fewer resources. As researchers improve the technology needed to make this concept viable on a large scale, private companies are starting to enter the vertical farming space commercially and will serve as partners to advance a sustainable business model.
- Leading hands-on education and workforce development programs that prepare students to thrive in a rapidly changing world. Flagship training programs like the Keep Engaging Youth in Science (KEYS) Research Internship have garnered increased visibility and will expand to a physical sciences pilot this year. KEYS began with nine interns in 2007. The program has now seen 428 Arizona teens — at least half of them from backgrounds traditionally underrepresented in science careers — complete internships in bioscience, biomedicine, engineering, environmental health and biostatistics and contribute to ongoing research projects across the UA. Many KEYS interns decide to continue their studies as undergraduates at one of Arizona's public universities: 61 percent selected the UA and 10 percent attended other in-state colleges. Eighty-three percent of KEYS alumni at the UA are pursuing STEM-related degrees.
- A research team led by Esther Sternberg and Perry Skeath is developing the next generation of wearable devices. The technology can keep tabs on a person's health status by measuring biomarkers — particular biochemicals in blood, saliva, urine or sweat that indicate how a body system is functioning. Combined with other sensors that keep tabs on additional vitals, such technology could be advanced further to ensure the long-term health of astronauts on deep-space missions. Possibilities abound for earthly applications as well, such as monitoring patients who are at risk of stroke or heart attack.



## NATIONAL SECURITY SYSTEMS

With TRIF funding for the National Security Systems initiative, the University of Arizona is bringing new resources — grants, contracts and connections — to Arizona, advancing the state’s economy through public-private partnerships in the defense and aerospace industries and developing new technologies to solve complex security challenges. These efforts, facilitated through the UA’s Defense and Security Research Institute (DSRI), are expanding the nation’s defense and security interests as well as opportunity for further market growth in these sectors throughout the state. Evidence of the success of our approach includes nearly \$9 million in awarded defense contracts and agreements.

The National Security Systems areas for investment are designed to unite the tremendous expertise at the UA in satellite technology, cybersecurity, optics and photonics with the strength of security, aerospace and defense partners.

## GOALS

- **Increasing external federal Department of Defense and private-sector research and development funding to scale capacity.**
- **Strengthening and expanding 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.**
- **Creating new shared infrastructure and facilities that broadly benefit the National Security Systems focus area.**
- **Supporting workforce development directly through student research teaming experiences in partnership with defense agencies, the UA and industry.**
- **Setting the stage for innovation and commercialization of research results by spawning new invention disclosures that will support future licensing and spinout companies.**



## SELECTED ACCOMPLISHMENTS

- Increasing UA research opportunities. UA faculty and cluster hires for the UA's Space Situational Awareness (SSA) initiative obtained multiple Department of Defense contracts for algorithm, software development, simulations/analysis and hardware development that will help researchers monitor the skies and help assess any threats. Headed by Roberto Furfaro, SSA-Arizona forms the foundation for the UA's SSA efforts and is helping to bring researchers together for funding opportunities. Research opportunities span diverse audiences — from industry to government — and SSA-Arizona helped bring in \$6.5 million in new funding, including a \$3.3 million cooperative agreement with the Air Force Research Laboratory, \$350,000 award from the Defense Advanced Research Projects Agency and a \$3 million sub-award from Lockheed Martin.
- Bolstering National Security Systems capacity to meet a global need. Christopher Walker developed inflatable spherical reflector technology for use in space, stratospheric and ground-based telecommunication and imaging systems. Walker, who is also processing data from the Stratospheric TeraHertz Observatory mission, is preparing for the recently selected \$40 million Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory (GUSTO) follow-on mission to study the interstellar medium in our Milky Way and beyond. He also furthered the development of a space-based inflatable telecommunications antenna that can cut the cost of both global and deep space communication networks. This technology is of great interest to both commercial and Department of Defense sectors.
- Establishing expertise and innovation. Startup faculty support and an Accelerate for Success grant helped establish a foundation of technical expertise and astronomical measurement capabilities to support space situational awareness at the UA's Steward Observatory. This includes work by UA researcher Eric Pearce on the Chimera photometer, which is already contributing significantly to both astronomy at the observatory and satellite surveillance.
- Giving students real-world experience. With UA industry partner Honeywell and a TRIF Industry Engagement Award, optical sciences student Colton Bigler is working on a heads-up display using holography and waveguide optics to give airplane pilots a larger field of view and improve their vision comfort. The experience will help deliver knowledge from the lab to the marketplace and Bigler will have a job with Honeywell upon completing his research.



## HIGHLIGHTS

The University of Arizona has made substantial progress toward 2021 goals. With overall Technology and Research Initiative Fund expenditures of \$28.6 million, the UA's calculated financial impact (sponsored awards, gifts and other sources and royalty income) of these investments was \$253 million, well over the budget of \$165 million and already exceeding fiscal year 2021 goals.

Technology transfer activity also beat projections. Fiscal year 2018 invention disclosures and patents were approximately 15 percent above expectations, and the number of university startups were triple the projections.

The mission of the UA's Technology and Research Initiative Fund will continue to deliver economic value and public benefit to the state of Arizona by:

- **Generating new dollars from outside the state to grow research and development activity in Arizona.**
- **Expanding economic opportunity for Arizonans.**
- **Benefiting the well-being of our citizens through new technologies and innovation that positively impact quality of life.**

Looking ahead, the UA is currently undergoing a strategic planning process in which the university is road mapping our future. One of the emerging themes that UA President Robert C. Robbins has talked about is the importance of the UA tapping into the Fourth Industrial Revolution — the convergence of the physical, biological and digital sciences. UA believes that these four areas position the university well as we look toward the next decade.

UA will be aligning TRIF initiatives to marry the pillars of the strategic plan with the needs of Arizona — with an eye on leveraging those dollars with external funding. The university is poised to lead innovations in health, big data, the environment and more. UA is in a position to enable more dynamic and democratic human interaction in an increasingly digital world.

The UA has a history of maximizing the dollars it receives through the TRIF initiative, and that trend is expected to continue. The university is confident that strategies — aligned closely with the Arizona Commerce Authority's key sectors of growth for our state — will continue to show forward progress and bring benefits to Arizona.













BOARD OF  
**Regents**  ARIZONA'S PUBLIC  
UNIVERSITIES

EDUCATE · DISCOVER · IMPACT

# ARIZONA BOARD OF REGENTS

## TRIF FUNDS

Technology and Research Initiative funds allocated to the board office support projects that advance Arizona's public universities in accordance with Arizona law and board guidelines. Each funded project is intended to further the goals outlined in the board's strategic plan and strengthen the ability to provide oversight of the universities' research and Arizona's workforce development.

ABOR TRIF funds support initiatives in these general areas - data resources and technological support, STEM and innovation projects, and the Regents' Innovation Fund.

## DATA/RESOURCES/TECHNOLOGY

Included in the data, resources and technology category are investments in the National Student Clearinghouse and K-12 pipeline student-data systems. A portion of TRIF funding provides access to expertise from faculty at Arizona's public universities through the Elsevier Pure Experts searchable database, a tool that is searchable by topics such as research units, journal articles, patent descriptions and business plans. Funding also supports the board office's business intelligence and database projects, which use Tableau's software and server to compile, analyze and visualize data. The Tableau server also supports university researchers across the system in their efforts to report and visualize data. These projects have allowed the board office to respond to regent, policymaker and other stakeholder requests for data and analysis regarding higher education and the K-12 pipeline.

## STEM/INNOVATION PROJECTS

ABOR TRIF funds continue to support the Arizona Technology Council's SciTech Festival that engages citizens of Arizona in hands-on experiences with STEM education in their community.

Through the board's continued funding of the Arizona SciTech Festival and its work across the state, over 2,000 STEM events occurred in 80 Arizona towns and cities during the two-month festival season alone this year, ranging from workshops for kids to presentations for adults and region-wide STEM festivals.

Arizona's three public universities showcased STEM and innovation projects through events that welcomed the public onto university campuses. Students, faculty, staff and researchers shared their knowledge through a broad range of innovative learning experiences in subjects such as science, math, engineering, ethnic studies and fine arts. These activities and events are purposeful in their intent to increase enrollment in STEM fields to prepare Arizonans to work in the state's high-technology industries.





## REGENTS' INNOVATION FUND

Regents' Innovation Fund (RIF) grants are instrumental in supporting universities' research and contribute to collaborative efforts among the universities and with community partners. Regents approved in June of 2017 funding for two RIF projects designed and submitted through a tri-university collaborative effort. Funding continued for both the Arizona Tri-University Transportation Research Collaboration and Exploiting Nanomaterials for End-to-End Cybersecurity Solutions for the second consecutive year.

## ARIZONA TRI-UNIVERSITY TRANSPORTATION RESEARCH COLLABORATION

**Year two of this project features five primary areas of interest:**

- Understanding the distributional effects of urban goods movement activities is examined through the implication of urban goods movement on traffic distribution and neighborhood quality within a megaregional economy.
- Structural inputs to transportation infrastructure resilience in the Phoenix-Tucson-Flagstaff megaregion consists of analyzing confounding and additive factors in the environment such as how the combination of increased stream flow, extreme heat and excessive loading impacts the structural integrity of a bridge.
- Operational safety and efficiency at a megaregion scale includes investigating traffic safety issues within the megaregion, reviewing non-freight related crashes and investigating locations for truck parking facilities.
- Roadway weather prediction and warning system includes providing a more integrative and comprehensive risk assessment for dust storm impacts on freight transportation; improving operational weather forecasting tools; mapping the recurrence and intensity of dust storms; analyzing archived Arizona Department of Transportation weather forecast reports; and building statistical models of key risk factors.
- Geodesign workshops for truck rest areas and compressed natural gas (CNG) refueling entails reviewing the shortage of truck rest stops and prioritizing station locations for the CNG truck-stop network.



## EXPLOITING NANOMATERIALS FOR END-TO-END CYBERSECURITY SOLUTIONS

This project focuses on the universities collaborating in an emerging cybersecurity area through initiatives and research such as new partnerships, technology transfer and developing new devices for cybersecurity. During the second year of the project, the research will focus on capitalizing the project's most promising areas and increasing chances to secure long-term funding from government agencies and industry. Two specific areas will be addressed - copper silica-based devices for cybersecurity and optical physical unclonable functions. This program will increase opportunities to work with agencies such as the Department of Homeland Security and the Department of Defense.

## DECISION THEATER

The Decision Theater Network helps researchers and leaders visualize solutions to complex problems, providing the latest expertise in collaborative computing and display technologies for data visualization, modeling and simulation.

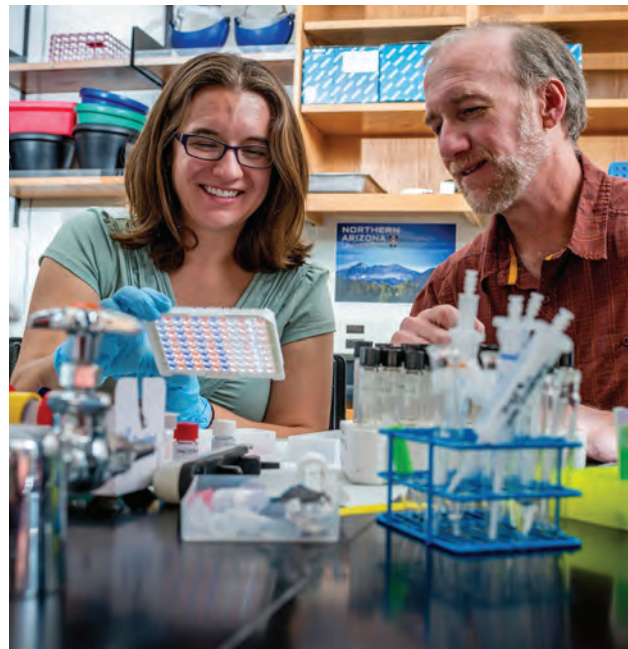
Capitalizing on Decision Theater's unique expertise, ABOR is developing an attainment visualization and forecasting model to be used as a tool for the board, policymakers, philanthropists, researchers, educators and others to increase Arizona's postsecondary attainment. Data modeling will allow for better discussion and decision making on how to best prepare Arizona residents for the "new economy" and Arizona's high-technology industries.





15:53 ..  
2015 bin -> usr/bin  
09:31 boot  
15:50 dev  
09:32 etc  
15:52 home  
2015 lib -> usr/lib  
2015 lib64 -> usr/lib  
10:01 lost+found  
Aug 22:45 mnt  
Sep 2015 opt  
Sep 15:52 private -> /home  
Sep 08:15 proc  
Aug 15:37 root  
Sep 15:50 run  
Sep 2015 sbin -> usr/bin  
Sep 2015 srv  
Sep 15:51 sys  
Sep 15:45 tmp  
2. Aug 15:39 usr  
23. Jul 10:25 var  
21. Sep 15:00

# FINANCIALS & METRICS





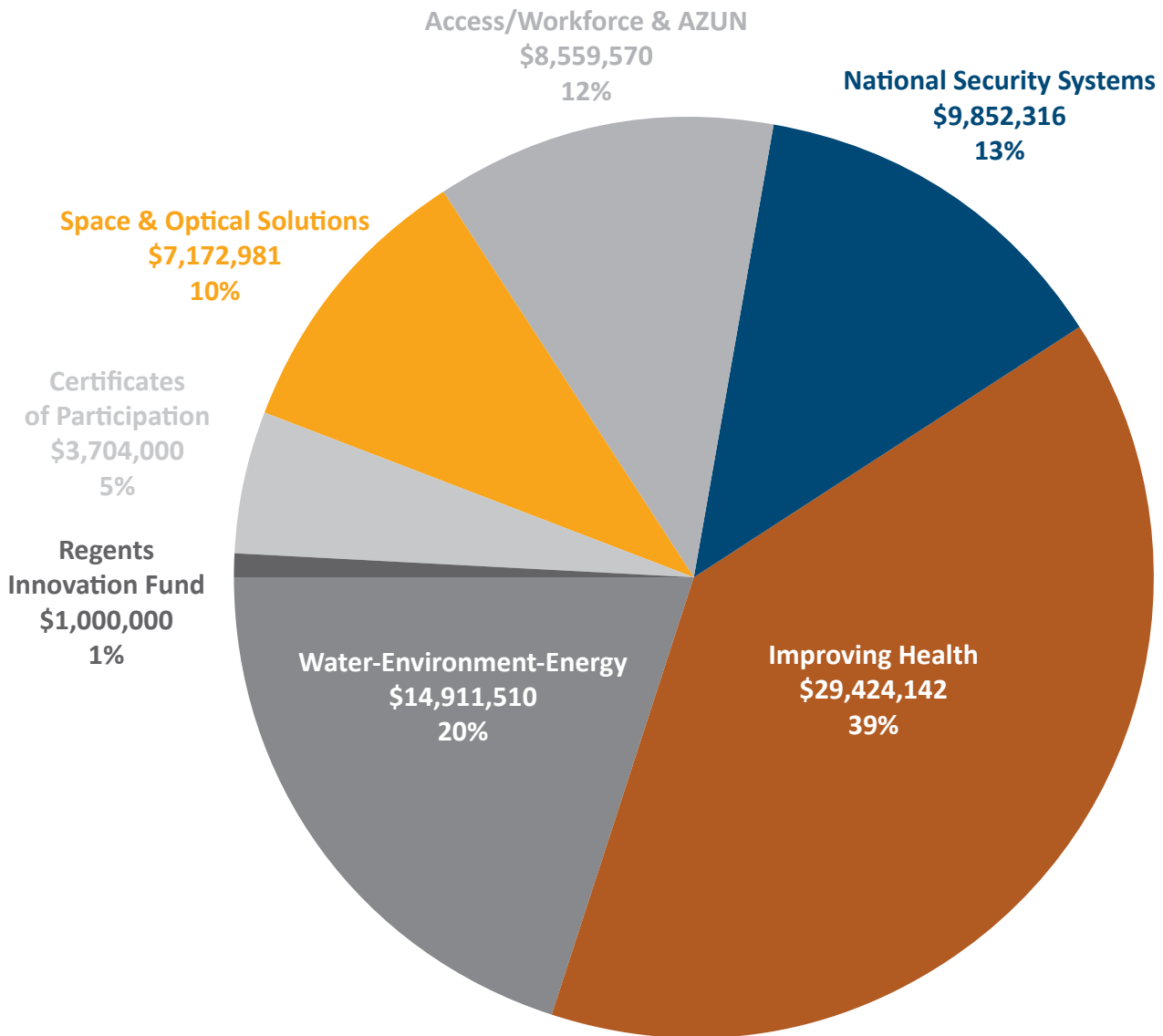


# FY 2017 - 2021 ARIZONA UNIVERSITY SYSTEM TECHNOLOGY AND RESEARCH INITIATIVE FUND

	<i>FY 2017 ACTUAL</i>	<i>FY 2018 ACTUAL</i>	<i>FY 2018 BUDGET</i>	<i>FY 2019 BUDGET</i>	<i>FY 2020 BUDGET</i>	<i>FY 2021 BUDGET</i>
<b>REVENUE</b>						
Carry Forward	4,322,940	8,684,576	8,684,576	10,634,674	-	-
TRIF Revenue	72,797,470	77,211,240	75,490,980	78,208,460	81,806,000	85,569,000
<b>TOTAL REVENUE</b>	<b>\$ 77,120,410</b>	<b>\$ 85,895,816</b>	<b>\$ 84,175,556</b>	<b>\$ 88,843,134</b>	<b>\$ 81,806,000</b>	<b>\$ 85,569,000</b>
<b>EXPENDITURES</b>						
OPERATING	56,555,913	61,995,953	68,172,210	69,323,311	66,820,123	72,170,400
CAPITAL	8,088,491	9,896,688	10,483,607	10,165,157	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
<b>TOTAL CAPITAL</b>	<b>11,795,991</b>	<b>13,600,688</b>	<b>14,187,607</b>	<b>13,869,157</b>	<b>14,985,877</b>	<b>13,398,600</b>
<b>TOTAL EXPENDITURES</b>	<b>\$ 68,351,904</b>	<b>\$ 75,596,641</b>	<b>\$ 82,359,817</b>	<b>\$ 83,192,468</b>	<b>\$ 81,806,000</b>	<b>\$ 85,569,000</b>
<b>SUMMARY BY PROGRAM AREA</b>						
Improving Health	\$ 26,074,280	\$ 29,424,142	\$ 28,162,448	\$ 27,614,557	\$ 29,212,812	\$ 29,368,089
Water, Environment, Energy Solutions	11,646,602	14,911,510	17,451,555	18,499,214	17,668,180	20,139,762
National Security Systems	9,566,065	9,852,316	14,983,383	14,389,314	13,749,295	12,331,426
Space Exploration and Optical Solutions	5,850,345	7,172,981	6,226,386	8,390,520	6,721,289	9,042,423
Access & Workforce Development	7,656,193	8,054,570	7,720,931	8,084,964	8,235,424	8,463,300
Regents Innovation Fund	1,200,000	1,000,000	1,000,000	1,000,000	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	505,000	510,000	515,000	520,000
ABOR Other	2,150,919	518,310	1,000,000	1,000,000	1,000,000	1,000,000
<b>PROGRAM AREA TOTAL</b>	<b>68,351,904</b>	<b>75,142,829</b>	<b>80,753,703</b>	<b>83,192,569</b>	<b>81,806,000</b>	<b>85,569,000</b>
<b>TOTAL EXPENDITURES</b>	<b>\$ 68,351,904</b>	<b>\$ 75,142,829</b>	<b>\$ 80,753,703</b>	<b>\$ 83,192,569</b>	<b>\$ 81,806,000</b>	<b>\$ 85,569,000</b>

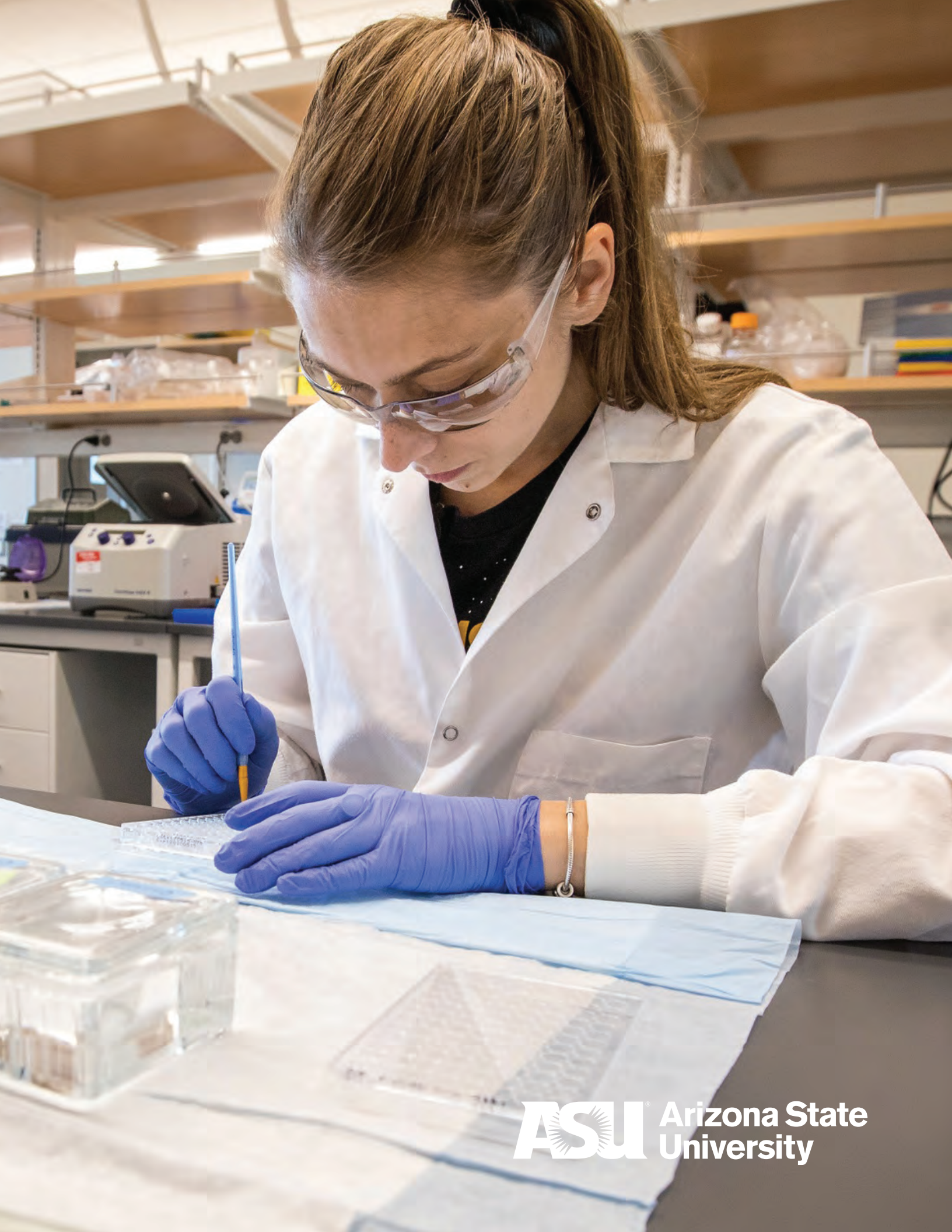


# FY 2017 ACTUAL TRIF EXPENDITURES









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

	<i>FY 2017 ACTUAL</i>	<i>FY 2018 ACTUAL</i>	<i>FY 2018 BUDGET</i>	<i>FY2019 BUDGET</i>	<i>FY 2020 BUDGET</i>	<i>FY 2021 BUDGET</i>
<b>REVENUE</b>						
Carry Forward		\$ 555,600	\$ 555,600	\$ 335,500		
TRIF Revenue	30,543,500	32,306,900	31,618,800	32,705,700	34,144,800	35,650,000
<b>TOTAL REVENUE</b>	<b>\$ 30,543,500</b>	<b>\$ 32,862,500</b>	<b>\$ 32,174,400</b>	<b>\$ 33,041,200</b>	<b>\$ 34,144,800</b>	<b>\$ 35,650,000</b>
<b>EXPENDITURES</b>						
OPERATING	24,876,300	25,658,500	24,970,400	25,837,200	26,940,800	28,446,000
CAPITAL	1,404,100	3,500,000	3,500,000	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
<b>TOTAL CAPITAL</b>	<b>5,111,600</b>	<b>7,204,000</b>	<b>7,204,000</b>	<b>7,204,000</b>	<b>7,204,000</b>	<b>7,204,000</b>
<b>TOTAL EXPENDITURES</b>	<b>\$ 29,987,900</b>	<b>\$ 32,862,500</b>	<b>\$ 32,174,400</b>	<b>\$ 33,041,200</b>	<b>\$ 34,144,800</b>	<b>\$ 35,650,000</b>
<b>SUMMARY BY INITIATIVE</b>						
Improving Health	\$ 13,541,800	\$ 14,744,400	\$ 13,360,400	\$ 13,767,200	\$ 14,285,000	\$ 14,991,300
Water, Environment and Energy Solutions	6,572,000	6,071,800	7,349,500	7,573,300	7,858,200	8,246,800
National Security Systems	3,671,700	3,942,300	3,769,600	3,884,400	4,030,500	4,229,800
Access & Workforce Development						
Entrepreneurship & Innovation	614,200	732,500	1,427,400	1,470,900	1,526,200	1,601,700
Advanced Manufacturing	1,880,700	3,332,000	2,563,500	2,641,500	2,740,900	2,876,400
<b>TOTAL</b>	<b>26,280,400</b>	<b>28,823,000</b>	<b>28,470,400</b>	<b>29,337,300</b>	<b>30,440,800</b>	<b>31,946,000</b>
ASU Poly/ASU West COPs	3,707,500	3,704,000	3,704,000	3,704,000	3,704,000	3,704,000
<b>TOTAL EXPENDITURES</b>	<b>\$ 29,987,900</b>	<b>\$ 32,527,000</b>	<b>\$ 32,174,400</b>	<b>\$ 33,041,300</b>	<b>\$ 34,144,800</b>	<b>\$ 35,650,000</b>



# ARIZONA STATE UNIVERSITY TECHNOLOGY AND RESEARCH INITIATIVE FUND IMPROVING HEALTH

<b>PERFORMANCE ANALYSIS</b>	<b>FY 2017 ACTUAL</b>	<b>FY 2018 ACTUAL</b>	<b>FY 2018 BUDGET</b>	<b>FY2019 BUDGET</b>	<b>FY 2020 BUDGET</b>	<b>FY 2021 BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	\$ 13,541,800	\$ 14,744,400	\$ 13,360,400	\$ 13,767,200	\$ 14,285,000	\$ 14,991,300
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	\$ 82,409,681	\$ 92,909,977	\$ 90,750,000	\$ 100,750,000	\$ 110,750,000	\$ 124,000,000
Gifts & Other Sources	723,874	1,399,722	1,130,000	1,160,000	1,190,000	1,220,000
Royalty Income	157,454	196,261	800,000	800,000	800,000	800,000
<b>TOTAL</b>	<b>83,291,009</b>	<b>94,505,960</b>	<b>92,680,000</b>	<b>102,710,000</b>	<b>112,740,000</b>	<b>126,020,000</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	81	97	56	57	59	60
US Patents Issued	31	32	6	6	7	7
Licenses and Options Executed	37	15	17	18	20	22
Startup Companies	5	5	2	2	3	3
<b>WORKFORCE CONTRIBUTION</b>						
Academic and Postdoctoral Appointees	145	145	118	126	133	143
Graduate Students	542	630	372	394	416	445
Undergraduate Students	267	230	273	289	306	328

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

<b>PERFORMANCE ANALYSIS</b>	<b>FY 2017 ACTUAL</b>	<b>FY 2018 ACTUAL</b>	<b>FY 2018 BUDGET</b>	<b>FY2019 BUDGET</b>	<b>FY 2020 BUDGET</b>	<b>FY 2021 BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	\$ 3,671,700	\$ 3,942,300	\$ 3,769,600	\$ 3,884,400	\$ 4,030,500	\$ 4,229,800
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	\$ 39,063,761	\$ 33,292,653	\$ 43,000,000	\$ 48,000,000	\$ 53,000,000	\$ 60,000,000
Gifts & Other Sources	-	-				
Royalty Income		76,305	50,000	50,000	50,000	50,000
<b>TOTAL</b>	<b>39,063,761</b>	<b>33,368,958</b>	<b>43,050,000</b>	<b>48,050,000</b>	<b>53,050,000</b>	<b>60,050,000</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	35	52	22	25	27	30
US Patents Issued	9	9	2	3	3	4
Licenses and Options Executed	4	8	4	4	5	5
Startup Companies	4	2	0	0	0	0
<b>WORKFORCE CONTRIBUTION</b>						
Academic and Postdoctoral Appointees	43	50	30	32	34	36
Graduate Students	338	366	249	265	281	303
Undergraduate Students	190	176	126	134	142	153



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

<b>PERFORMANCE ANALYSIS</b>	<b>FY 2017 ACTUAL</b>	<b>FY 2018 ACTUAL</b>	<b>FY 2018 BUDGET</b>	<b>FY2019 BUDGET</b>	<b>FY 2020 BUDGET</b>	<b>FY 2021 BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	\$ 6,572,000	\$ 6,071,800	\$ 7,349,500	\$ 7,573,300	\$ 7,858,200	\$ 8,246,800
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	\$ 27,874,447	\$ 26,139,847	\$ 26,000,000	\$ 28,500,000	\$ 30,100,000	\$ 34,000,000
Gifts & Other Sources	4,248,699	3,196,485	4,380,000	4,510,000	4,650,000	4,790,000
Royalty Income	2,000	2,000	100,000	100,000	100,000	100,000
<b>TOTAL</b>	<b>32,125,146</b>	<b>29,338,332</b>	<b>30,480,000</b>	<b>33,110,000</b>	<b>34,850,000</b>	<b>38,890,000</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	22	13	12	12	13	13
US Patents Issued	3	13	2	2	2	3
Licenses and Options Executed	3	5	5	5	5	5
Startup Companies	1	2	0	0	0	0
<b>WORKFORCE CONTRIBUTION</b>						
Academic and Postdoctoral Appointees	60	35	31	32	33	36
Graduate Students	210	147	158	166	171	183
Undergraduate Students	241	104	190	200	206	221

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

<b>PERFORMANCE ANALYSIS</b>	<b>FY 2017 ACTUAL</b>	<b>FY 2018 ACTUAL</b>	<b>FY 2018 BUDGET</b>	<b>FY2019 BUDGET</b>	<b>FY 2020 BUDGET</b>	<b>FY 2021 BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	\$ 1,880,700	\$ 3,332,000	\$ 2,563,500	\$ 2,641,500	\$ 2,740,900	\$ 2,876,400
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	\$ 13,047,918	\$ 22,677,335	\$ 16,100,000	\$ 18,750,000	\$ 21,250,000	\$ 25,000,000
Gifts & Other Sources	112,652	138,791	100,000	100,000	100,000	100,000
Royalty Income	16,000	91,800	50,000	50,000	50,000	50,000
<b>TOTAL</b>	<b>13,176,570</b>	<b>22,907,926</b>	<b>16,250,000</b>	<b>18,900,000</b>	<b>21,400,000</b>	<b>25,150,000</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	27	44	8	9	10	12
US Patents Issued	5	18	1	1	2	2
Licenses and Options Executed	8	4	3	3	3	4
Startup Companies	3	2	1	1	1	1
<b>WORKFORCE CONTRIBUTION</b>						
Academic and Postdoctoral Appointees	33	25	11	12	13	14
Graduate Students	155	98	53	57	62	69
Undergraduate Students	75	27	58	64	69	77



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

<b>PERFORMANCE ANALYSIS</b>	<b>FY 2017 ACTUAL</b>	<b>FY 2018 ACTUAL</b>	<b>FY 2018 BUDGET</b>	<b>FY2019 BUDGET</b>	<b>FY 2020 BUDGET</b>	<b>FY 2021 BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	\$ 614,200	\$ 732,500	\$ 1,427,400	\$ 1,470,900	\$ 1,526,200	\$ 1,601,700
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	\$ 2,960,137	\$ 4,021,094	\$ 2,750,000	\$ 3,500,000	\$ 4,100,000	\$ 5,000,000
Gifts & Other Sources						
Royalty Income						
<b>TOTAL</b>	<b>2,960,137</b>	<b>4,021,094</b>	<b>2,750,000</b>	<b>3,500,000</b>	<b>4,100,000</b>	<b>5,000,000</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted						
US Patents Issued						
Licenses and Options Executed						
Startup Companies	26	22	21	22	23	24
<b>WORKFORCE CONTRIBUTION</b>						
Academic and Postdoctoral Appointees	1	0	0	0	0	0
Graduate Students	99	173	26	28	29	30
Undergraduate Students	246	346	131	138	145	152







**NORTHERN  
ARIZONA**  
UNIVERSITY



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

	<i>FY 2017 ACTUAL</i>	<i>FY 2018 ACTUAL</i>	<i>FY 2018 BUDGET</i>	<i>FY2019 BUDGET</i>	<i>FY 2020 BUDGET</i>	<i>FY 2021 BUDGET</i>
<b>REVENUE</b>						
Carry Forward	\$ 1,281,965	\$ 1,815,739	\$ 1,815,739	\$ 2,864,487		
TRIF Revenue	13,417,994	13,957,380	13,957,380	14,500,920	15,220,400	15,973,000
<b>TOTAL REVENUE</b>	<b>\$ 14,699,959</b>	<b>\$ 15,773,119</b>	<b>\$ 15,773,119</b>	<b>\$ 17,365,407</b>	<b>\$ 15,220,400</b>	<b>\$ 15,973,000</b>
<b>EXPENDITURES</b>						
OPERATING	11,089,829	12,435,998	11,863,773	12,035,763	12,328,523	12,778,400
CAPITAL	1,794,391	816,688	2,093,607	2,465,157	2,891,877	3,194,600
<b>TOTAL EXPENDITURES</b>	<b>\$ 12,884,220</b>	<b>\$ 13,252,685</b>	<b>\$ 13,957,380</b>	<b>\$ 14,500,920</b>	<b>\$ 15,220,400</b>	<b>\$ 15,973,000</b>
<b>SUMMARY BY INITIATIVE</b>						
Improving Health	\$ 1,987,146	\$ 2,287,367	\$ 3,018,327	\$ 2,778,248	\$ 2,660,594	\$ 2,876,838
Water, Environment and Energy Solutions	1,547,695	3,336,334	1,826,753	2,059,984	2,127,794	3,311,473
National Security Systems	3,305,425	2,068,714	3,475,607	2,388,299	3,330,615	837,660
Space Exploration & Optical Solutions	382,661	248,513	1,401,662	2,791,825	2,618,073	4,441,829
Access & Workforce Development	5,161,293	3,990,070	3,730,031	3,972,564	3,968,324	3,985,200
<b>TOTAL</b>	<b>12,384,220</b>	<b>11,930,998</b>	<b>13,452,380</b>	<b>13,990,920</b>	<b>14,705,400</b>	<b>15,453,000</b>
AZUN	500,000	505,000	505,000	510,000	515,000	520,000
<b>TOTAL EXPENDITURES</b>	<b>\$ 12,884,220</b>	<b>\$ 12,435,998</b>	<b>\$ 13,957,380</b>	<b>\$ 14,500,920</b>	<b>\$ 15,220,400</b>	<b>\$ 15,973,000</b>



# NORTHERN ARIZONA UNIVERSITY TECHNOLOGY AND RESEARCH INITIATIVE FUND IMPROVING HEALTH

<b>PERFORMANCE ANALYSIS</b>	<b>FY 2017 ACTUAL</b>	<b>FY 2018 ACTUAL</b>	<b>FY 2018 BUDGET</b>	<b>FY2019 BUDGET</b>	<b>FY 2020 BUDGET</b>	<b>FY 2021 BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	\$ 1,658,683	\$ 2,287,367	\$ 3,018,327	\$ 2,778,248	\$ 2,660,594	\$ 2,876,838
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	\$ 9,823,529	\$ 11,421,671	\$ 2,451,753	\$ 2,326,065	\$ 2,878,568	\$ 3,868,878
Gifts & Other Sources	200,000	200,000	122,588	116,303	143,928	193,444
Royalty Income	24,070	10,000	9,375	-	-	35,156
<b>TOTAL</b>	<b>10,047,599</b>	<b>11,631,671</b>	<b>2,583,716</b>	<b>2,442,368</b>	<b>3,022,496</b>	<b>4,097,478</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	27	19	20	23	26	29
US Patents Issued	3	5	1	1	1	1
Licenses and Options Executed	2	0	1	0	0	1
Startup Companies	1	0	0	0	1	0
<b>WORKFORCE CONTRIBUTION</b>						
Academic and Postdoctoral Appointees	13	10	4	5	5	4
Graduate Students	29	45	20	25	30	35
Undergraduate Students	75	129	20	50	50	50

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

<b>PERFORMANCE ANALYSIS</b>	<i>FY 2017</i>	<i>FY 2018</i>	<i>FY 2018</i>	<i>FY2019</i>	<i>FY 2020</i>	<i>FY 2021</i>
	<i>ACTUAL</i>	<i>ACTUAL</i>	<i>BUDGET</i>	<i>BUDGET</i>	<i>BUDGET</i>	<i>BUDGET</i>
<b>TRIF EXPENDITURES</b>						
Total	\$ 1,547,695	\$ 3,336,334	\$ 1,826,753	\$ 2,059,984	\$ 2,127,794	\$ 3,311,473
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	\$ 11,241,109	\$ 8,262,452	\$ 2,022,251	\$ 2,304,498	\$ 4,108,358	\$ 3,374,568
Gifts & Other Sources	0	-	101,113	115,225	205,418	168,728
Royalty Income	0	-	9,375	23,438	-	-
<b>TOTAL</b>	<b>11,241,109</b>	<b>8,262,452</b>	<b>2,132,739</b>	<b>2,443,161</b>	<b>4,313,776</b>	<b>3,543,296</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	5	11	9	10	12	12
US Patents Issued	2	2	0	2	2	2
Licenses and Options Executed	0	0	1	1	0	0
Startup Companies	0	0	0	0	0	0
<b>WORKFORCE CONTRIBUTION</b>						
Academic and Postdoctoral Appointees	17	20	4	5	5	4
Graduate Students	50	63	20	25	30	35
Undergraduate Students	136	127	150	200	200	200



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

<b>PERFORMANCE ANALYSIS</b>	<i>FY 2017</i> <b>ACTUAL</b>	<i>FY 2018</i> <b>ACTUAL</b>	<i>FY 2018</i> <b>BUDGET</b>	<i>FY2019</i> <b>BUDGET</b>	<i>FY 2020</i> <b>BUDGET</b>	<i>FY 2021</i> <b>BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	\$ 1,839,497	\$ 2,068,714	\$ 3,475,607	\$ 2,388,299	\$ 3,330,615	\$ 837,660
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	\$ 5,493,136	\$ 1,193,274	\$ 4,466,045	\$ 4,355,925	\$ 1,811,342	\$ 1,330,197
Gifts & Other Sources	0	-	223,302	217,796	90,567	66,510
Royalty Income	6,000	30,500	18,750	23,438	46,875	35,156
<b>TOTAL</b>	<b>5,499,136</b>	<b>1,223,774</b>	<b>4,708,097</b>	<b>4,597,159</b>	<b>1,948,784</b>	<b>1,431,863</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
			<i>PROJECTED</i>	<i>PROJECTED</i>	<i>PROJECTED</i>	<i>PROJECTED</i>
Invention Disclosures Transacted	9	14	5	5	6	7
US Patents Issued	0	2	0	1	2	2
Licenses and Options Executed	1	1	2	1	2	1
Startup Companies	0	0	0	1	0	1
<b>WORKFORCE CONTRIBUTION</b>						
Academic and Postdoctoral Appointees	5	2	4	5	5	4
Graduate Students	3	4	10	10	10	15
Undergraduate Students	10	17	20	20	25	25

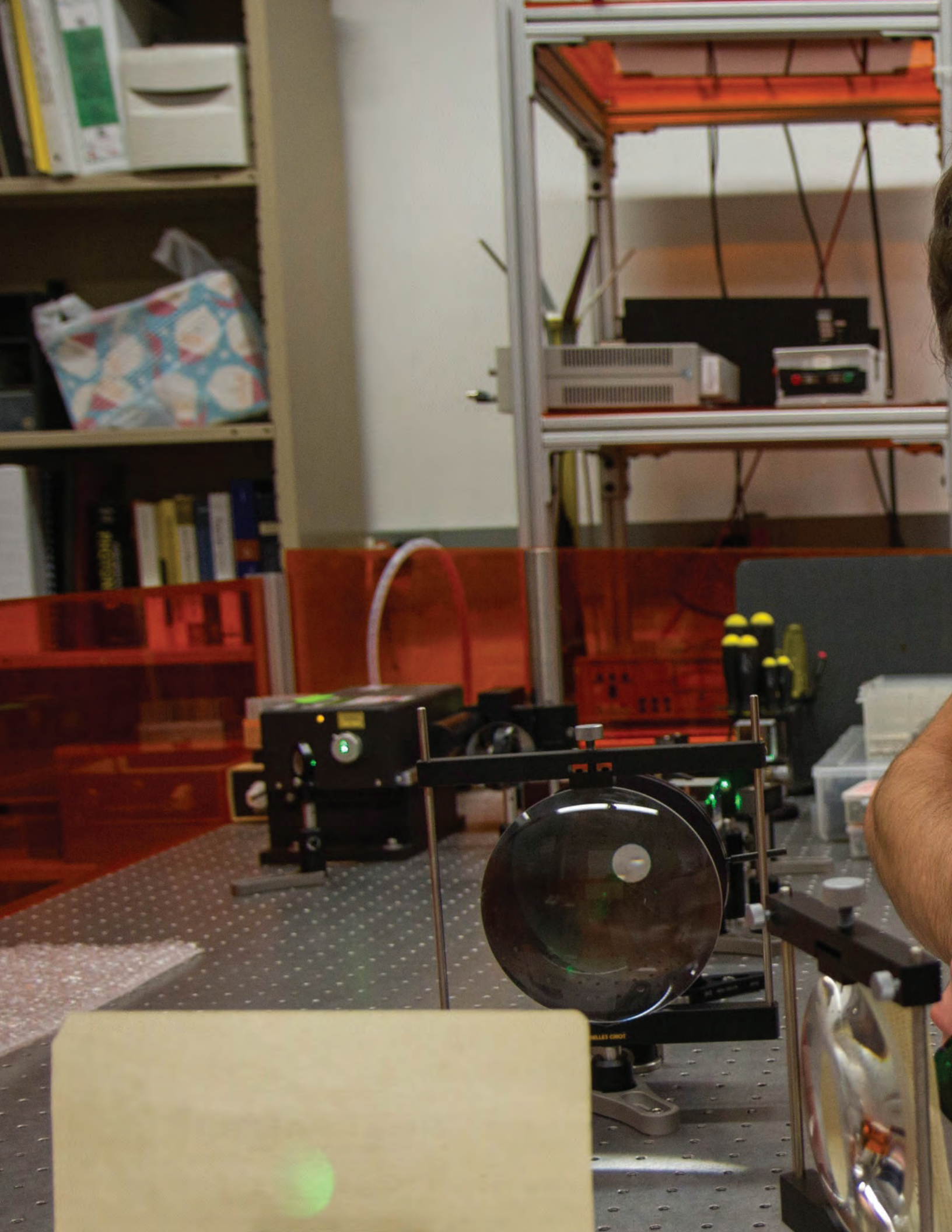
# NORTHERN ARIZONA UNIVERSITY TECHNOLOGY AND RESEARCH INITIATIVE FUND SPACE EXPLORATION AND OPTICAL SOLUTIONS

<b>PERFORMANCE ANALYSIS</b>	<i>FY 2017</i> <b>ACTUAL</b>	<i>FY 2018</i> <b>ACTUAL</b>	<i>FY 2018</i> <b>BUDGET</b>	<i>FY2019</i> <b>BUDGET</b>	<i>FY 2020</i> <b>BUDGET</b>	<i>FY 2021</i> <b>BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	\$ 382,661	\$ 248,513	\$ 1,401,662	\$ 2,791,825	\$ 2,618,073	\$ 4,441,829
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	\$ 1,256,431	\$ 882,075	\$ 2,121,252	\$ 2,343,311	\$ 2,969,534	\$ 3,836,157
Gifts & Other Sources	0	-	106,063	117,166	148,477	191,808
Royalty Income	0	-			23,438	35,156
<b>TOTAL</b>	<b>1,256,431</b>	<b>882,075</b>	<b>2,227,315</b>	<b>2,460,477</b>	<b>3,141,449</b>	<b>4,063,121</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	0	0	1	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
<b>WORKFORCE CONTRIBUTION</b>						
Academic and Postdoctoral Appointees	1	0	4	5	5	4
Graduate Students	3	3	10	10	10	15
Undergraduate Students	2	7	35	50	50	50



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

<b>PERFORMANCE ANALYSIS</b>	<b>FY 2017 ACTUAL</b>	<b>FY 2018 ACTUAL</b>	<b>FY 2018 BUDGET</b>	<b>FY2019 BUDGET</b>	<b>FY 2020 BUDGET</b>	<b>FY 2021 BUDGET</b>
<b>TRIF EXPENDITURES</b>						
AWD	\$ 5,161,293	\$ 3,990,070	\$ 3,984,573	\$ 3,972,564	\$ 3,968,324	\$ 3,985,200
AZUN	\$ 500,000	\$ 505,000	\$ 505,000	\$ 510,000	\$ 515,000	\$ 520,000
Total	\$ 5,661,293	\$ 4,495,070	\$ 4,489,573	\$ 4,482,564	\$ 4,483,324	\$ 4,505,200
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Annual Impact of Graduates on Economy <sup>1</sup>	\$ 5,147,000		\$ 7,279,220	\$ 9,389,097	\$ 11,503,769	\$ 13,623,383
Degree/Certificate Programs Offered <sup>2</sup>	92		77	79	81	83
Business/Nonprofit Collaborations <sup>3</sup>	211		175	190	205	220
Number of Students Served by A/WD <sup>4</sup>	4482		4,400	4,840	5,324	5,856
<b>TOTAL</b>	<b>5,147,000</b>		<b>7,279,220</b>	<b>9,389,097</b>	<b>11,503,769</b>	<b>13,623,383</b>
<b>WORKFORCE CONTRIBUTION</b>						
Web/Hybrid/Enhanced Courses Developed <sup>5</sup>	191		160	170	180	190
Faculty Developing Courses <sup>6</sup>	405		400	430	460	490
Increase in Student Technology Literacy <sup>7</sup>	4,310		4,425	4,550	4,675	480
Individual Faculty Trained in Teaching Technologies <sup>8</sup>	376		275	300	325	350
Faculty Support Incidents Resolved Technologies <sup>9</sup>	1,359		17,250	17,500	17,775	1,800
Faculty using Adaptive Courseware	16		10	15	25	40





# Photorefractive Polymers for Video-Rate Stereographic Display

William Lippert, Maria Alexandra Muehle, Rafael de Barros, & Poojitha Kumar  
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Photorefractive polymers (PRPs) are a class of materials that can be used to create waveguides for light. They are used in a variety of applications, including optical interconnects, optical sensors, and optical displays. In this work, we have developed a PRP that can be used to create waveguides for video-rate stereographic displays. The waveguides are created by exposing the PRP to a pattern of light, which creates a refractive index grating. This grating can be used to guide light from a video camera to a video display, allowing for the creation of a video-rate stereographic display.

Photorefractive polymers (PRPs) are a class of materials that can be used to create waveguides for light. They are used in a variety of applications, including optical interconnects, optical sensors, and optical displays. In this work, we have developed a PRP that can be used to create waveguides for video-rate stereographic displays. The waveguides are created by exposing the PRP to a pattern of light, which creates a refractive index grating. This grating can be used to guide light from a video camera to a video display, allowing for the creation of a video-rate stereographic display.

## Photorefractive Polymers



## Recent Advances



## References

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

	<b>FY 2017 ACTUAL</b>	<b>FY 2018 ACTUAL</b>	<b>FY 2018 BUDGET</b>	<b>FY2019 BUDGET</b>	<b>FY 2020 BUDGET</b>	<b>FY 2021 BUDGET</b>
<b>REVENUE</b>						
Carry Forward	\$ -	\$ 4,707,123	\$ 4,707,123	\$ 4,648,508	\$ -	\$ -
TRIF Revenue	26,835,988	28,602,907	27,914,800	29,001,840	30,440,800	31,946,000
<b>TOTAL REVENUE</b>	<b>\$ 26,835,988</b>	<b>\$ 33,310,030</b>	<b>\$ 32,621,923</b>	<b>\$ 33,650,348</b>	<b>\$ 30,440,800</b>	<b>\$ 31,946,000</b>
<b>EXPENDITURES</b>						
OPERATING	17,238,866	23,081,521	27,731,923	29,450,348	25,550,800	28,946,000
CAPITAL	4,890,000	5,580,000	4,890,000	4,200,000	4,890,000	3,000,000
<b>TOTAL EXPENDITURES</b>	<b>\$ 22,128,865</b>	<b>\$ 28,661,521</b>	<b>\$ 32,621,923</b>	<b>\$ 33,650,348</b>	<b>\$ 30,440,800</b>	<b>\$ 31,946,000</b>
<b>SUMMARY BY INITIATIVE</b>						
Improving Health	\$ 10,545,334	\$ 12,392,375	\$ 11,783,721	\$ 11,069,109	\$ 12,267,218	\$ 11,499,951
Space Exploration & Optical Solutions	5,467,685	6,924,468	8,275,302	8,865,930	7,682,186	8,581,489
Water, Environmental, Energy Solutions	3,526,907	5,503,376	7,738,176	8,116,615	6,388,180	7,263,966
National Security Systems	2,588,940	3,841,302	4,824,724	5,598,695	4,103,216	4,600,594
<b>TOTAL EXPENDITURES</b>	<b>\$ 22,128,865</b>	<b>\$ 28,661,521</b>	<b>\$ 32,621,923</b>	<b>\$ 33,650,348</b>	<b>\$ 30,440,800</b>	<b>\$ 31,946,000</b>



# UNIVERSITY OF ARIZONA TECHNOLOGY AND RESEARCH INITIATIVE FUND IMPROVING HEALTH

<b>PERFORMANCE ANALYSIS</b>	<b>FY 2017 ACTUAL</b>	<b>FY 2018 ACTUAL</b>	<b>FY 2018 BUDGET</b>	<b>FY2019 BUDGET</b>	<b>FY 2020 BUDGET</b>	<b>FY 2021 BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	10,545,334	12,392,375	11,783,721	11,069,109	12,267,218	11,499,951
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	74,499,075	89,142,292	62,400,000	64,896,000	67,491,840	70,191,514
Gifts & Other Sources	117,545	465,399	624,000	648,960	674,918	701,915
Royalty Income	16,000	200	52,000	54,080	56,243	58,493
<b>TOTAL</b>	<b>74,632,620</b>	<b>89,607,891</b>	<b>63,076,000</b>	<b>65,599,040</b>	<b>68,223,002</b>	<b>70,951,922</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	55	38	42	45	50	55
US Patents Issued	7	2	2	2	4	5
Licenses and Options Executed	6	8	10	11	12	13
Startup Companies	1	4	1	1	2	2
<b>WORKFORCE CONTRIBUTION</b>						
Postdoctoral Appointees	160	184	105	110	116	122
Graduate Students	439	479	315	331	347	365
Undergraduate Students	741	539	336	353	370	389

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

<b>PERFORMANCE ANALYSIS</b>	<b>FY 2017 ACTUAL</b>	<b>FY 2018 ACTUAL</b>	<b>FY 2018 BUDGET</b>	<b>FY2019 BUDGET</b>	<b>FY 2020 BUDGET</b>	<b>FY 2021 BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	\$ 3,526,907	\$ 5,503,376	\$ 7,738,176	\$ 8,116,615	\$ 6,388,180	\$ 7,263,966
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	28,190,149	34,978,098	32,240,000	33,529,600	34,870,784	36,265,615
Gifts & Other Sources	6,978,663	31,228,311	3,536,000	3,677,440	3,824,538	3,977,519
Royalty Income	8,250	5,145	780,000	811,200	843,648	877,394
<b>TOTAL</b>	<b>\$ 35,177,062</b>	<b>\$ 66,211,554</b>	<b>\$ 36,556,000</b>	<b>\$ 38,018,240</b>	<b>\$ 39,538,970</b>	<b>\$ 41,120,528</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	18	16	21	23	25	27
US Patents Issued	3	1	2	2	4	5
Licenses and Options Executed	4	2	7	7	8	9
Startup Companies	1	-	1	1	1	1
<b>WORKFORCE CONTRIBUTION</b>						
Postdoctoral Appointees	16	29	89	94	98	103
Graduate Students	152	175	284	298	313	328
Undergraduate Students	74	109	116	121	127	134



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

<b>PERFORMANCE ANALYSIS</b>	<i>FY 2017</i> <b>ACTUAL</b>	<i>FY 2018</i> <b>ACTUAL</b>	<i>FY 2018</i> <b>BUDGET</b>	<i>FY2019</i> <b>BUDGET</b>	<i>FY 2020</i> <b>BUDGET</b>	<i>FY 2021</i> <b>BUDGET</b>
<b>TRIF EXPENDITURES</b>						
Total	\$ 5,467,685	\$ 6,924,468	\$ 8,275,302	\$ 8,865,930	\$ 7,682,186	\$ 8,581,489
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	67,398,490	93,922,125	62,400,000	64,896,000	67,491,840	70,191,514
Gifts & Other Sources	525,123	597,340	1,000,000	11,000,000	1,000,000	1,000,000
Royalty Income	1,256,754	1,438,529	124,800	129,792	134,984	140,383
<b>TOTAL</b>	<b>\$ 69,180,367</b>	<b>\$ 95,957,994</b>	<b>\$ 63,524,800</b>	<b>\$ 76,025,792</b>	<b>\$ 68,626,824</b>	<b>\$ 71,331,897</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	50	62	42	45	50	55
US Patents Issued	14	11	2	2	4	5
Licenses and Options Executed	21	26	17	18	20	22
Startup Companies	5	6	1	1	2	2
<b>WORKFORCE CONTRIBUTION</b>						
Postdoctoral Appointees	2	20	16	17	17	18
Graduate Students	55	115	42	44	46	49
Undergraduate Students	29	47	8	9	9	10

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

<b>PERFORMANCE ANALYSIS</b>	<i>FY 2017</i>	<i>FY 2018</i>	<i>FY 2018</i>	<i>FY2019</i>	<i>FY 2020</i>	<i>FY 2021</i>
	<i>ACTUAL</i>	<i>ACTUAL</i>	<i>BUDGET</i>	<i>BUDGET</i>	<i>BUDGET</i>	<i>BUDGET</i>
<b>TRIF EXPENDITURES</b>						
Total	\$ 2,588,940	\$ 3,841,302	\$ 4,824,724	\$ 5,598,695	\$ 4,103,216	\$ 4,600,594
<b>FINANCIAL IMPACT OF TRIF INVESTMENT</b>						
Sponsored Awards	1,066,471	1,281,873	2,000,000	4,000,000	8,000,000	10,000,000
Gifts & Other Sources	0	0	100,000	125,000	150,000	175,000
Royalty Income	0	0	0	0	0	0
<b>TOTAL</b>	<b>\$ 1,066,471</b>	<b>\$ 1,281,873</b>	<b>\$ 2,100,000</b>	<b>\$ 4,125,000</b>	<b>\$ 8,150,000</b>	<b>\$ 10,175,000</b>
<b>TECHNOLOGY TRANSFER ACTIVITY</b>						
Invention Disclosures Transacted	0	6	0	0	3	5
US Patents Issued	0	0	0	0	0	0
Licenses and Options Executed	0	0	0	0	0	0
Startup Companies	0	0	0	0	0	0
<b>WORKFORCE CONTRIBUTION</b>						
Postdoctoral Appointees	5	10	5	5	6	6
Graduate Students	12	38	10	11	11	12
Undergraduate Students	10	49	10	11	11	12









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

	<i>FY 2017</i> <b>ACTUAL</b>	<i>FY 2018</i> <b>ACTUAL</b>	<i>FY 2018</i> <b>BUDGET</b>	<i>FY 2019</i> <b>BUDGET</b>	<i>FY 2020</i> <b>BUDGET</b>	<i>FY 2021</i> <b>BUDGET</b>
<b>REVENUE</b>						
Carry Forward	\$ 3,040,975	\$ 1,606,114	\$ 1,606,114	\$ 1,969,492		
TRIF Revenue	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
<b>TOTAL REVENUE</b>	<b>\$ 5,040,975</b>	<b>\$ 3,606,114</b>	<b>\$ 3,606,114</b>	<b>\$ 3,969,492</b>	<b>\$ 2,000,000</b>	<b>\$ 2,000,000</b>
<b>EXPENDITURES</b>						
OPERATING	83,944	118,312	128,209	130,000	140,000	150,000
GRANTS/PROJECTS	3,266,975	1,518,310	3,477,905	1,870,000	1,860,000	1,850,000
<b>TOTAL EXPENDITURES</b>	<b>\$ 3,350,919</b>	<b>\$ 1,636,622</b>	<b>\$ 3,606,114</b>	<b>\$ 2,000,000</b>	<b>\$ 2,000,000</b>	<b>\$ 2,000,000</b>
<b>SUMMARY BY INITIATIVE</b>						
Regents' Innovation Fund Grants	\$ 1,200,000	\$ 1,000,000	\$ 1,000,000	\$ 1,000,000	\$ 1,000,000	\$ 1,000,000
Data/Resources/Technology	200,919	468,310	850,000	900,000	900,000	900,000
STEM/Innovation Projects	50,000	50,000	150,000	100,000	100,000	100,000
Over realized funds to universities	1,900,000	-	-			
<b>TOTAL EXPENDITURES</b>	<b>\$ 3,350,919</b>	<b>\$ 1,518,310</b>	<b>\$ 2,000,000</b>	<b>\$ 2,000,000</b>	<b>\$ 2,000,000</b>	<b>\$ 2,000,000</b>