

**Arizona Higher Education Enterprise
Technology and Research Initiative Fund (TRIF)**

**Five-Year Project Plan
July 1, 2016 through June 30, 2021**



ARIZONA STATE UNIVERSITY

TECHNOLOGY AND RESEARCH INITIATIVE FUND (TRIF)

Business Plan – Fiscal Years FY17-21

1.1 Executive summary

TRIF investments at ASU are strategically allocated to fuel research-driven solutions that grow Arizona's economy and workforce and maximize the return on investment for the Arizona taxpayer. Our five TRIF initiatives:

- Improving Health
- National Security Systems
- Water, Environmental and Energy Solutions
- Access and Workforce Development: Entrepreneurship and Innovation
- Access and Workforce Development: Advanced Manufacturing

represent a diverse portfolio of research-to-marketplace programs that promise significant benefits to the State of Arizona.

1.2 Outline of university mission/goals/values

ASU is a comprehensive public research university, measured not by whom we exclude, but rather by whom we include and how they succeed; advancing research and discovery of public value; and assuming fundamental responsibility for the economic, social, cultural and overall health of the communities it serves.

ASU has established the following goals for 2016 and beyond:

- **Demonstrate leadership in academic excellence and accessibility**
 - Maintain the fundamental principle of accessibility to all students qualified to study at a research university
 - Maintain university accessibility to match Arizona's socioeconomic diversity
 - Improve freshmen persistence to 90%
 - Enhance university graduation rate to 75%-80% and 25,000 graduates
 - Enhance quality while reducing the cost of a degree
 - Enroll 100,000 online and distance education degree seeking students
 - Enhance linkages with community colleges so as to expand baccalaureate degree production to national leadership levels
 - Enhance measured student development and individual student learning to national leadership levels

- **Establish national standing in academic quality and impact of colleges and schools in every field**
 - Attain national standing in academic quality for each college and school (top 5-10% for each college)
 - Attain national standing in the learning value added to our graduates in each college and school
 - Become the leading university academically (faculty, discovery, research, creativity) in at least one department or school within each college/school
- **Establish ASU as a global center for interdisciplinary research, discovery and development by 2020**
 - Become a leading global center for interdisciplinary scholarship, discovery and development
 - Become a leading American center for discovery and scholarship in the social sciences, arts and humanities
 - Enhance research competitiveness to more than \$700 million in annual research expenditures
 - Augment regional economic competitiveness through research and discovery and value-added programs
- **Enhance our local impact and social embeddedness**
 - Provide Arizona with an interactive network of teaching, learning and discovery resources that reflects the scope of ASU's comprehensive knowledge enterprise
 - Develop solutions to real-life challenges (ex. Reducing the Urban Heat Island Index and improving long-term air quality in metropolitan Phoenix)
 - Increase the number of qualified K-12 teachers by 25% and develop a tool for teachers and administrators to evaluate educational performance and outcomes
 - Establish, with Mayo Clinic, innovative health solutions pathways capable of educating 200 million people about health care, engaging 20 million people in online health care delivery and enhancing treatment for 2 million patients

1.3 Outcomes

We measure TRIF investment impact with the following metrics:

- **Return on investment.** New externally funded grant awards are a result of

strategic alignment of research with challenges that need to be solved and of strong partnerships with leading national and global organizations. This brings additional revenue to the state and creates jobs at the university and at our local partners.

- **Technology transfer.** Patents, licenses and options, and new startup companies represent the translation of research and innovation to the marketplace and workforce.
- **Industry engagement.** By partnering with industry leaders, we leverage our knowledge enterprise for maximal marketplace impact.
- **Workforce contributions.** University students who receive research training understand problem solving and are prepared for the high-tech industries driving our economy.
- **Educational outreach.** ASU leads numerous outreach efforts to spark discovery, learning and entrepreneurship in K-12 students and community members.
- **Government agency/community engagement.** Collaborations with government and community agencies connect our subject matter experts and innovative solutions with organizations working directly with populations in need.

1.4 Overall budget

ASU's proposed TRIF budget will remain concentrated on what are our largest and most well established TRIF funded initiatives, but will be expanded to include smaller investments in our two new Access and Workforce Development Initiatives in Entrepreneurship and Innovation, and Advanced Manufacturing.

Initiative Budgets	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
Improving Health	\$ 13,376,521	\$ 14,131,519	\$ 14,827,611	\$ 15,524,742	\$ 16,222,933
National Security Systems	\$ 3,561,613	\$ 3,769,612	\$ 3,977,610	\$ 4,185,609	\$ 4,393,608
Water Environmental and Energy Solutions	\$ 7,050,459	\$ 7,349,538	\$ 7,768,132	\$ 8,186,383	\$ 8,604,285
Access and Wrokforce Development					
Entrepreneurship & Innovation	\$ 1,369,851	\$ 1,449,851	\$ 1,529,850	\$ 1,609,850	\$ 1,689,849
Advanced Manufacturing	\$ 1,959,956	\$ 2,217,881	\$ 2,415,197	\$ 2,611,816	\$ 2,807,725
TOTAL	\$ 27,318,400	\$ 28,918,400	\$ 30,518,400	\$ 32,118,400	\$ 33,718,400

1.5 Marketing/communication overview

TRIF investment at ASU has enabled significant discovery, economic development and the attracting external funding awards. We communicate the impact of TRIF to audiences internal to ASU as well as those in the local community and throughout Arizona. The following key messages will be incorporated in ASU communications and presentations featuring TRIF-enabled research and impacts:

- TRIF investments are strategically leveraged to support established research with a track record of success as well as emerging high-potential research areas.
- The research and economic development enabled by TRIF has real impact on our community, our state and beyond.
- TRIF investments support the training and education of students, and contributing to a highly skilled workforce that can fulfill the high-tech jobs being created in Arizona and attract new business and industry to the state.

ASU's Office of Knowledge Enterprise Development (OKED) has a dedicated marketing and communication team with a mission of communicating the impact of ASU's research, innovation, entrepreneurship and economic development. The team works with partners throughout the university to implement marketing plans for key initiatives including those enabled through TRIF investment. ASU anticipates working closely with ABOR to ensure that we contribute materially to the public relations and media strategy surrounding this program.

1.6 University administration of TRIF

TRIF is administered through OKED with the following leadership:

- Sethuraman "Panch" Panchanathan, executive vice president and chief research and innovation officer
- Elizabeth Cantwell, vice president of research development
- Tamara Deuser, associate vice president and chief of staff

During the proposed FY2017 – FY2021 cycle, ASU will invest TRIF funds in five strategic initiatives. Each initiative is anchored by a flagship unit and may have supporting programs and facilities:

Improving Health

- Anchored by The Biodesign Institute led by Joshua LaBaer
- Supporting programs and facilities: Center for Healthy Outcomes in Aging, College of Health Solutions, Complex Adaptive Systems, Research Computing, DNASU and the Genomics Facility.

National Security Systems

- Anchored by the Global Security Initiative led by Nadya Bliss
- Supporting programs: Exploration, NewSpace

Water, Environmental and Energy Solutions

- Anchored by the Julie Ann Wrigley Global Institute of Sustainability led by Gary Dirks

- Supporting programs and facilities: LightWorks, Food Systems Transformation Initiative, ASU Leadership Academy, the Decision Theater, and chemical and environmental characterization and synthesis facilities

Access and Workforce Development: Entrepreneurship and Innovation

- Anchored by Entrepreneurship and Innovation (E+I) led by Ji Mi Choi

Access and Workforce Development: Advanced Manufacturing

- Anchored by the Flexible Electronics and Display Center led by Nicholas Colaneri
- Supporting programs and facilities: Center for Entrepreneurship, Generator Labs, Global Resolve, WP Carey Center for Entrepreneurship, Startup Mill, ASU NanoFab and Materials characterization and synthesis facilities

2 Improving Health

2.1 Investment description/rationale/justification

Improving Health has been the largest TRIF funded initiative at ASU for more than a decade. During this time, ASU successfully used TRIF funding not only to support substantial scientific advancements, but also to attract significant funding to the State, deliver cutting edge education and research training to our students and to successfully commercialize our research discoveries to create jobs in Arizona.

Since 2002, ASU has been the fourth fastest growing biosciences research enterprise among US universities that conducted more than \$40M in biosciences research annually. Moreover, ASU was the fastest growing biosciences research enterprise among universities without a medical school. While the national growth in university biosciences research since 2002 has totaled 77%, ASU's biosciences research funding grew by more than 220% from \$40.5M in 2002 to \$129.9M in 2014. As a result of this progress, ASU is now ranked among some of the nation's top biosciences research enterprises. For example, ASU is now ranked 10th in the nation for research expenditures in bioengineering.

Similarly, ASU has had tremendous success in the intense competition for NIH funding. While NIH awards grew by just 30% from 2002 to 2015, over the same period of time ASU grew its NIH funding by more than 130% - more than 4 times the national average. In total, ASU's success in winning NIH awards has brought \$190M more dollars of NIH funding to Arizona than would have been the case had ASU merely kept pace with the national average. This outstanding performance has resulted in ASU now ranking 9th among all US universities without a medical school in terms of HHS (including NIH) funded research expenditures.

The success of ASU's researchers in developing and advancing the novel and use-inspired research ideas that have attracted these funding increases over the last decade, have also provided world class educational opportunities and financial support for our students. Over the last decade, ASU's Improving Health Initiative has provided student employment opportunities and research fellowships for more than 1000 graduate and undergraduate students.

Finally, ASU's Improving Health Initiative has had a decade of success transferring its scientific knowledge and discoveries to the marketplace. Our Improving Health Initiative has produced hundreds of invention disclosures and dozens of US patents, attracted more than 100 technology licensing agreements and has served as the foundation for more than a dozen startup companies.

HealthTell is an illustrative example how ASU's Improving Health Initiative has successfully transferred its research to the market. HealthTell is an ASU startup based

on novel health diagnostic research conducted at ASU's Biodesign Institute with seed funding from TRIF. The research led to the creation of new technology that was patented, licensed and is the foundation of the spinout company. Since establishing the company in 2012, the HealthTell founders have grown their business to support more than 30 employees almost all of which work in their Chandler Arizona offices. The company has surpassed \$3M in revenues and recently raised more than \$25 million from investors to further expand their business. HealthTell has also integrated into the region's biosciences economic ecosystem, and now has partnerships with several institutions including the Barrow Neurological Institute and Dignity Health.

TRIF funding has been a critical resource in supporting ASU's ascendancy in biosciences research, in our ability to provide top tier educational opportunities and financial support to students, and in moving our scientific breakthroughs into the marketplace - bolstering the Arizona economy and improving the health and wellness of its citizens. For the proposed additional period of TRIF Funding, ASU will maintain Improving Health as its largest TRIF investment. Biosciences is and will continue to be the largest discipline for higher education research and development funding, accounting for more than half of all US university research expenditures, and continued TRIF support in this strategically important field will allow ASU to continue to increase its share of competitively awarded biosciences research funding.

As in the previous TRIF funding cycles, ASU's Improving Health Initiative focuses on the Biodesign Institute. Created on the premise that scientists can overcome complex societal challenges by re-imagining the "design rules" found in nature, the Biodesign Institute embodies ASU's New American University design aspirations to conduct use-inspired research, fuse intellectual disciplines and value entrepreneurship – principles that are increasingly important to federal agency, business and nonprofit sponsors.

The planned TRIF investments at the Biodesign Institute will focus on specific resource needs including:

- Seed funding for scientific pursuits and collaborations to facilitate scientifically impactful projects
- Building and maintaining core facilities, shared instrumentation and infrastructure to accelerate research outcomes
- Providing sustainable research support services with improved efficiencies and reduced costs

These core investments at the Biodesign Institute will be reinforced by smaller investments in complementary health outcome-related research programs at ASU and supporting infrastructure investments.

2.1.1 Brief overview of industry or area being addressed by the initiative to include benefit to Arizona

The Biodesign Institute has long been recognized as a key driver in developing a robust bioscience economy in Arizona. As early as 2009, then Governor Janice Brewer recognized the Biodesign Institute with Arizona's "Excellence in Economic Development Award" for its innovative contributions to the state's economic growth.

More recently, a study by the Seidman Research Institute at ASU's W. P. Carey School of Business showed that the Biodesign Institute made an economic impact of \$1.5 billion over its first decade of operation. The annual direct economic impact is the highest for any single bioscience research institute in the state, according to the report. Annually, Biodesign Institute operations have contributed an average of \$135.5 million in direct impacts on Arizona's economy, created and supported more than 1,600 high-paying jobs, and generated \$10.5 million in state and local tax revenues.

The Biodesign Institute also figures prominently in Arizona's Bioscience Roadmap. The Biodesign Institute's contribution to this enterprise focuses on three important areas:

- capturing significant external funding for the generation of research output
- attracting and training premier scientific talent and high-wage jobs to Arizona
- spurring innovation that produces economic growth

Finally, the Biodesign Institute plays a significant role in the development of a highly trained biosciences workforce in Arizona. Currently the Biodesign Institutes employs and trains more than 50 postdoctoral researchers and 300 graduate and undergraduate students each year. The Biodesign Institute has also provided hands-on research experiences for undergraduates, high school students and high school teachers to advance Arizona's STEM education.

2.1.2 Discussion of mission, goals, values and vision

Today, we face threats from global pandemics, an aging population suffering a decline in quality of life due to chronic and acute diseases, poor health due to water quality issues, an over-reliance on fossil fuels as our primary energy source, an accumulation of nondegradable toxic chemicals in our environment, and the tragedies resulting from natural disaster and human conflict. Even as we face these threats, the Biodesign Institute recognizes that we live at a time of unprecedented knowledge and technology, and that effective and economical solutions to all of these pressing problems can be found.

The Biodesign Institute addresses today's critical global challenges in healthcare, sustainability and security by discovering solutions inspired from natural systems and by developing those solutions into commercially viable products and clinical practices.

To advance its research mission, the Biodesign Institute has established 15 interdisciplinary research centers that currently boast a portfolio of more than 200 active externally funded research projects.

Scientific, clinical and professional excellence is the foundation of the Biodesign Institute's world-class research. Its 65 faculty members, comprising both tenure line and research faculty, include one Nobel Prize winner and four National Academies members, who regularly publish in top-tier, high-impact scientific journals and collaborate with research and commercial enterprises around the world.

2.1.3 Description of programmatic investments

As stated, the Biodesign Institute will anchor the Improving Health focus area with the support of other health outcome-focused units and facilities:

- In response to the rapidly expanding population of older adults in the state of Arizona, the **Center for Healthy Outcomes in Aging** convenes investigators to develop and test interventions that promote the highest level of health and quality of life for individuals who are aging within a culturally diverse society. The center emphasizes multidisciplinary, theory-based interventions across a variety of clinical settings.
- Research conducted by the renowned faculty in the **College of Health Solutions** focuses on addressing society's most pressing problems related to health and health care. Students engaged in our multidisciplinary research will be on the front lines, testing innovations to improve the health of populations and communities, enhance health care delivery and patient-centered care, and improve function and reduce disability across the lifespan.
- **Complex Adaptive Systems (CAS)** represents a unique framework for biomedicine. The group collaborates broadly within ASU and with major institutions globally. Initiatives led by CAS include the National Biomarker Development Alliance (NBDA) and CAS Biomedicine, which works on models and analytics to integrate big data in biomedicine.
- The **Research Computing** center is a unique, high-performance computing resource leveraged across all TRIF initiatives. The Research Computing center provides the advanced computing and data processing capabilities that allows ASU researchers and its partners to collect, manage and analyze vast and complex data sets in order to rapidly discover strategies and produce real-world outcomes across research disciplines.
- The **DNASU** and **Genomics Facility** are two centralized repositories that served as an international bank of plasmid clones and genetic sequences critical to several large collaborative projects at ASU. These resources offer the worldwide

scientific community collaborative access to research components and expertise that our faculty have. Advances in genomics at these facilities will continue to impact the way human disease is diagnosed, prevented and treated.

2.2 Expected outcomes as a result of TRIF investments

2.2.1 Specific and realistic goals that are clearly measurable

As mentioned previously, Improving Health is ASU largest TRIF funded initiative and so it likewise accounts for the largest proportion of ASU's TRIF enabled sponsored awards, technology transfer activities, and workforce contributions. Over the proposed 5-year TRIF funding period, ASU's planned expansion of its Improving Health Initiative to additional health-related units and infrastructure investments will synergistically accelerate our ability to deliver economically important research outcomes.

2.2.1.1 Return on investment

For the proposed TRIF funding period from 2017 to 2021, ASU anticipates that it can continue its remarkable trajectory in the biosciences and health related fields. We expect that the proposed TRIF investments of \$75M will allow us to grow TRIF-enabled annual sponsored project funding from \$77.5M in 2017 to more than \$124M in 2021, a 60% increase. Over the 5-year period, our investments in the Improving Health Initiative will attract more than \$500M in sponsored project funding to the State. Furthermore, we expect that this funding will be complimented by almost \$10M dollars of research-focused gifts and royalty income.

2.2.1.2 Technology transfer

ASU Improving Health Initiative will continue is notable productivity in transferring scientific advancements from the lab to the marketplace. We expect that ASU's proposed TRIF investments will result in 287 new inventions, 32 US patents, 93 technology licensing agreements and the formation of 12 new startup companies.

2.2.1.3 Industry engagement (outreach, partnerships, collaboration)

ASU's TRIF-funded Improving Health Initiative has been notably successful in collaborating and creating successful partnership with the private sector. Over the last decade, BDI researchers have partnered with and attracted funding from 75 companies, the overwhelming majority of which are companies residing outside of Arizona, bringing in a total of \$23M dollars of external funding to the state.

We will continue to build on our existing industry engagements and will establish new federal, private sector, nonprofit and other strategic partnerships throughout the TRIF funding cycle. This includes, but is not limited to:

- Further development of clinical partnerships to accelerate the work of Biodesign

Institute researchers who are studying 96 diseases and 16 types of cancer

- Provide technical instruction, resources and development opportunities to form meaningful local, national and international collaborations
- Market the capabilities of our core facilities available to partners to establish new partnerships and encourage new research

2.2.1.4 Workforce contributions

TRIF investments in ASU's Improving Health Initiative have provided advanced education and training in state-of-the-art biosciences research for both graduate and undergraduates students for more than a decade. More than 1,000 students have had the opportunity to gain hands-on laboratory experience with the latest technologies, develop proficiencies in interdisciplinary research, and establish innovative scientific thinking that have prepared them for employment in healthcare, government, private sector and academia.

Looking ahead, ASU has ambitious plans to accelerate this pipeline of highly trained biosciences research critical to the state's economic development plan. We expect that over the next five years our Improving Health Initiative will engage and train more than 3,000 graduate and undergraduate students and will be able to attract and support more than 600 postdoctoral appointments.

2.2.1.5 Educational outreach

ASU's Improving Health Initiative has always focused on informing and inspiring the broader community, and the Biodesign Institute boasts a number of highly regarded educational outreach efforts.

The Biodesign Institute actively engages with Arizona's K-12 students. Each year, the Institute provides competitively earned internship opportunities to Arizona's high school students so that they may obtain hands-on laboratory experience to complement their classroom education. The Institute's graduate students are encouraged to interact with the local K-12 schools as part of their graduate educational requirements.

The Institute also broadly collaborates with non-profit organizations in educational outreach initiatives. For example, the Biodesign Institute annually collaborates with the Association for Women in Science (AWIS) in its efforts to provide career opportunities for young girls by participating in their hands-on science day. Similarly, the Institute partners with organizations such as ASU's Camp Sparky and the American Society for Civil Engineers to educate and inspire elementary school students.

Finally, Biodesign actively participates in ASU's Ask a Biologist by generating educational materials for K-12 teachers and students to use in their classrooms all over the world. The Institute also welcomes in the public to make science accessible to all by

providing hundreds of tours to showcase ASU science and research in our award-winning research institution.

2.2.1.6 Government agency/community engagement (outreach, partnerships, collaboration)

TRIF funding for ASU's Improving Health Initiative has allowed us to develop a broad federal funding portfolio that includes the US Department of Defense (DOD), National Institutes of Health (NIH), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), and other agencies. In total, ASU's Biodesign Institute has attracted more than \$400M of federal funding. Over the proposed five years of additional TRIF funding, ASU expects to attract an additional \$350M in federal funding to the State.

The Biodesign Institute actively seeks ways to be an embedded community member and leads our partners on numerous community engagement activities each year. This includes frequent public lectures and symposia offered in the Biodesign Institute auditorium, all of which are free to the public and allow our scientists to be accessible to the community. Our annual Night of the Open Door public open house, which had over 3,000 visitors in 2016, provides scientific demonstrations and activities for all ages. Other community engagement activities include the Institute's partnership with the annual United Way campaign, which brought in over \$15,000 in 2015 for charity.

2.2.2 Annual metrics table of expected outcomes and timeline for achievement

Expected Outcomes	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
TRIF EXPENDITURES					
Total	\$ 13,376,521	\$ 14,131,519	\$ 14,827,611	\$ 15,524,742	\$ 16,222,933
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 77,500,000	\$ 90,750,000	\$100,750,000	\$110,750,000	\$124,000,000
Gifts & Other Sources	1,100,000	1,130,000	1,160,000	1,190,000	1,220,000
Royalty Income	800,000	800,000	800,000	800,000	800,000
TOTAL	79,400,000	92,680,000	102,710,000	112,740,000	126,020,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	55	56	57	59	60
US Patents Issued	6	6	6	7	7
Licenses and Options Executed	16	17	18	20	22
Startup Companies	2	2	2	3	3
WORKFORCE CONTRIBUTION					
Postdoctoral Appointees	109	118	126	133	143
Graduate Students	343	372	394	416	445
Undergraduate Students	251	273	289	306	328

2.3 Initiative structure

2.3.1 Organizational structure

Joshua LaBaer leads the Biodesign Institute supported by an executive leadership team comprised of the institute's 15 research center directors. The Institute's operations staff provide institutional support in financial services, research infrastructure, human resources, research operations, IT and research advancement with the common purpose of advancing the ongoing mission of the Institute while improving efficiencies, reducing overhead and leveraging ASU and OKED resources to improve productivity and implement innovative best practices.

2.3.2 Advisory board

The Biodesign Institute seeks external and internal feedback and input to achieve strategic outcomes. A national external advisory board comprised of 12 members provides counsel to the leadership team, as appropriate, and convenes annually to review the ongoing research activities and strategic priorities of the Biodesign Institute. Members of this board are respected experts in their fields and offer thought leadership from various institutions around the country including Purdue University, Lawrence Berkeley National Lab, Oregon Health & Science University, University of North Carolina at Chapel Hill, Stanford University School of Medicine, Texas A & M Health Science Center, Johns Hopkins, Medgenics Inc., Sanford-Burnham Medical Research Institute and the Santa Fe Institute.

Additionally, an internal advisory committee from ASU comprises over 20 members who advise and offer ongoing, networked resources and rich expertise in a variety of disciplines represented by colleges and programs across all ASU campuses.

2.3.3 Infrastructure

The Biodesign Institute is housed in a 350,000 square-foot, award winning, purpose built, LEED-certified building. The Biodesign Institute's building is Arizona's single largest research infrastructure investment in the biosciences.

2.3.4 Description of investment mechanisms

The Biodesign Institute's commitment to research excellence, impact and innovation will allow us to achieve the following goals from FY2017 to 2021:

Enhance productivity and alignment of existing Biodesign Centers:

- Reinvigorate the Center for Infectious Diseases and Vaccinology with a new center director and leadership vision
- Further develop inventive and innovative informatics approaches to solving

some of society's grand challenges

- Enhance collaboration between centers for novel programs with additional funding potential
- Establish a strong presence in pan-university initiatives in key research areas that have the potential for large external investment

Launch and anchor new scientific research centers during the next five years:

- Launch a world-class Neurodegenerative Disease Research Center in alliance with Banner Health, one of our strategic clinical partners
- Establish the Biodesign Center for Fundamental and Applied Microbiomics for improved health and environmental sustainability
- Develop three new Biodesign Institute centers of research in topic areas relevant to our mission of improving the health and well-being of our planet and its people. Strategic topic areas under consideration include synthetic biology, cybersecurity and others.

2.4 Initiative budget table

Initiative Budget	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
Improving Health	\$ 13,376,521	\$ 14,131,519	\$ 14,827,611	\$ 15,524,742	\$ 16,222,933

2.5 Plan for sustainability

2.5.1 Anticipated funding sources for ongoing support

As described above, the Biodesign Institute and ASU companion TRIF Funded investments in the Improving Health Initiative are well positioned to build on ASU's impressive funding record. ASU expects to continue attract funding from federal agencies, business and nonprofit sponsors. In addition to continued increases in sponsored awards, research gifts and technology transfer revenues will also both contribute to the ongoing support of ASU's Improving Health Initiative.

2.5.2 Timeline for transitioning away from TRIF support

ASU's Improving Health Initiative plans transition from TRIF support to indirect cost recovery from their externally funded projects at the end of the proposed 5-year investment period.

3 National Security Systems

3.1 Investment description/rationale/justification

Since 2012, ASU's National Security Systems Initiative has allocated just over \$10 million of TRIF funding to stimulate its research activities in defense and security related areas. Over the same period, ASU's National Security Systems initiative has enabled more than \$100 million in sponsored research projects primarily funded from the Department of Defense, the Intelligence Community and companies that serve these organizations. Our success in this area has propelled ASU to rank 34th in the nation in terms of DOD funding. In addition to bringing external research money to the state, ASU's National Security Systems Initiative is contributing to Arizona's economic development by leveraging research and development efforts to form new spinoff companies, providing relevant and effective postgraduate pathways to entrepreneurial development that is keeping money and talent in state.

ASU's National Security Systems Initiative is spearhead by its Global Security Initiative (GSI), a university-wide interdisciplinary hub for global security research that focuses on openness, inclusiveness and connections to the global defense, development and diplomacy communities. The Global Security Initiative and its associated programs address emerging global challenges characterized by complex interdependencies and conflicting objectives, where there may not be obvious solutions. GSI serves as ASU's primary interface to the Department of Defense (DOD) and intelligence community (IC), positioning Arizona for industry, government and philanthropic investments. Research efforts at GSI also provide insights on new learning approaches to create and sustain the national security workforce needed for Arizona and the U.S. to maintain a competitive edge in the global economy.

3.1.1 Brief overview of industry or area being addressed by the initiative to include benefit to Arizona

GSI's work, by exploring and addressing challenges that are directly relevant to Arizona, will serve to benefit Arizona citizens. For example, the State of Arizona has targeted the aerospace and defense industry as a primary focus area for building sustained technology-related economic growth in the state. GSI's work, and that of the NewSpace initiative, will help to solidify Arizona as a prime location for aerospace defense-related research.

Arizona's citizens also directly benefit from GSI's Center for Cybersecurity and Digital Forensics (CDF). Cybersecurity has become a significant concern for the business community, and this center partners closely with Security Canyon, Arizona's cybersecurity public-private coalition, to better understand and support Arizona's needs. Cybersecurity has been identified by Security Canyon as an "industrial cornerstone for

Arizona's economy" and the CDF's will serve Arizona as center of excellence for research and development in this important field and an source of highly trained graduates.

Additionally, Arizona has witnessed considerable growth in the Information and Communications Technology (ICT) sector in recent years, with "nearly 70,000 people currently employed in ICT industries across more than 3,770 establishments, contributing an excess of \$11 billion to the Gross Regional Product in 2014," according to the Greater Phoenix Economic Council. The research and insights produced by GSI's CDF will help Arizona businesses ensure the security of their technologies and operations and help foster innovation and entrepreneurship, providing talent pipelines directly to local companies. The center also brings highly visible international conferences to Arizona on a regular basis.

GSI's research into the challenges posed by urbanization, extreme weather events and resource scarcity are challenges that will continue to impact the state and its residents into the future. Finding solutions to these challenges will be essential for ensuring the resilience of the state's people, from urban to rural communities. Resilience is a multi-dimensional concept, ranging from infrastructure to utility management, from resources in the physical world to protection of personal data online. GSI's work in energy and infrastructure resilience, in partnership with several national laboratories, will inform policymakers and urban planners on how to best protect the health and welfare of all Arizona residents. GSI's partnerships with national labs are a particularly important resource because they serve as a means for GSI to share and further develop its talent base. GSI also partners with health providers like Mayo Clinic and Banner Health, searching for ways to increase health resilience.

3.1.2 Discussion of mission, goals, values and vision

GSI leverages the interdisciplinary capabilities of the university to solve problems of local, state, national and global security. Our vision is a security and intelligence landscape, transformed through interdisciplinary research and discovery, in which defense, development and diplomacy operate collaboratively to drive positive outcomes for complex global challenges.

The business model for GSI is based on a blended approach, taking best practices from the business sector and combining them with the strengths of the university to pursue and execute research funding in the security and defense arenas.

3.1.3 Description of programmatic investments

GSI's primary strategic areas of focus are:

- **Cybersecurity.** We live in an increasingly connected world. While technologies serve to strengthen our ability to share and store information, they also present

society with challenges that can threaten personal privacy and national security. GSI's CDF brings together leading faculty in engineering, social sciences, law and business to conduct sponsored research focused on identity management, privacy issues, malware attribution, secure mobile devices, predictive analytics/adversarial dynamics and digital forensics. CDF's capacity to study and address these challenges is strengthened by its partnerships with Arizona businesses like GoDaddy, Intel and Aetna, as well as national companies and organizations like the U.S. Army Research Office, the U.S. Department of Justice, National Security Agency, National Science Foundation, Microsoft, Google, the U.S. Department of Energy, CISCO and Bank of America.

- **Urban security.** The number of people living in urban areas worldwide is accelerating at an unprecedented rate. Cities, including those in Arizona, will need to find new ways to accommodate this growth and the numerous challenges that urbanization presents. GSI will address these challenges through a proposed Urban Security Research Center that will draw upon the university's expertise in interdisciplinary research and its national partnerships to produce world-class research and novel insights into these challenges and approaches for addressing them. Among the areas being explored by GSI researchers is the development and use of innovative technologies that will enable policymakers and public officials to anticipate and prevent, rather than react to, potential threats posed by a variety of natural and manmade phenomena, many of which are unique to the state.
- **Extreme weather events and infrastructure and resource security.** The degradation of natural resources due to population growth, economic development, and changes in built and natural landscapes poses challenges for communities worldwide. Extreme weather events (droughts, floods, temperature extremes, etc.) can further limit resources and intensify conflicts to control them. This can lead to social and political effects such as migration, disease outbreak and spread, and political instability. Each of these could have significant impact on our national security. GSI addresses these issues by developing research products, tools and processes for decision-making in the context of changing resources and national security dynamics at local, regional and global scales. For instance, by examining the impact of environmental change on water, food and energy and associated social dynamics at multiple scales, conflict may be anticipated and mitigated or avoided. GSI is also working to understand and address the vulnerability of individuals and communities to extreme heat and water scarcity, two issues that are of particular concern to Arizonans. GSI's capacity to study and address these challenges is strengthened by its research partnerships with local institutions, such as Arizona Public Service and Salt River Project, as well as major research institutions throughout the country, including

Pacific Northwest National Laboratory, Oak Ridge National Laboratory and Argonne National Laboratory.

- **Human health and human security.** Increased connectivity (both virtual and physical), urbanization and environmental change will all have important implications for human health and well-being. Current and future climate variability is expected to significantly impact ecosystems, water, energy and food security, as well as human health. A critical impacted area of human health is that of vector-borne infectious diseases. GSI contributes to the understanding of how these diseases spread, as well as the timely decision-making necessary in a pandemic or epidemic situation. Our work on extreme heat and water scarcity and the impact on vulnerable communities is also relevant to this area, particularly in relation to their potential effect on Arizona's aging population.

The following programs complement GSI in support of ASU's National Security Systems Initiative:

- An **Exploration Initiative** focused on the intersection of an Exploration paradigm with successful developments in education, space technology, global security and entrepreneurship. This initiative leverages the New American University focus on simultaneous pursuit of excellence, broad access to quality education, and meaningful societal impact through exploration - the act of searching for the purpose of discovering new knowledge through information, resources and people.
- The **NewSpace Initiative** leverages ASU's expertise in space-related science, technology and operations to build the future of America's commercialized space programs. NewSpace is developing partnerships with companies in Arizona and the Southwest, where private commercial spaceports and rocket factories are increasingly becoming an integral part of the space landscape.

3.2 Expected outcomes as a result of TRIF investments

The creation of interdisciplinary research centers will represent significant milestones for GSI. Centers will be created around the focus areas of cybersecurity, resilience, health and human security, and urban security. Each center will capture significant external funds, based on subject matter projections developed through a formal strategic planning exercise over a five-year time span.

3.2.1 Specific and realistic goals that are clearly measurable

3.2.1.1 Return on investment

Over the proposed 5-year period, an intensified focus and greater campus-wide coordination on defense and security research promises to accelerate ASU's funding

growth in this competitive area. Under GSI's leadership, ASU expects to increase its research funding from \$36 million to \$60 million annually – a 65% increase over the five year period. In total, the expected research funding attracted to Arizona in this economically important sector is expected to total \$240 million.

3.2.1.2 Technology transfer

While ASU's approach to defense and security related research is unique in its multi-disciplinarity, it nevertheless has strong connection to the applied research conducted in the engineering and computer science disciplines. As a result, we expect significant technology creations and transfer activities over the proposed 5-year funding period. ASU's National Security Systems Initiative expects to produce 124 invention disclosures, to receive 14 US patents and to enter 22 licensing and options agreements.

3.2.1.3 Industry engagement (outreach, partnerships, collaboration)

Private sector partners will be important to support Arizona's economic development in GSI's research areas. CDF, launched in August 2015, has established a membership plan crafted to fit the needs of business and industry. Arizona-based companies will be prioritized, with a second tier of companies that are likely to move to Arizona from the Bay Area and Pacific Northwest. Partnerships with utility companies, namely Salt River Project and Arizona Public Service, will be expanded to address the topics of infrastructure and resilience.

GSI expects \$10 million annually in private sector funding by 2021, and expects to establish 8 strategic corporate partnerships by 2017 and to grow this number to more than 40 by 2021. These strategic partnerships would reflect a greater degree of coordination and engagement beyond a sponsored research agreement, and would complement the funding ASU already receives in Defense and Security research from its more than 30 corporate sponsors.

3.2.1.4 Workforce contributions

As an initiative that spans the university and includes all ASU's DOD and IC related research efforts, ASU's National Security Systems Initiative expects to support research opportunities for a large number of both graduate and undergraduate students. In 2017, the Initiative expects to provide research engagements for 227 graduate and 115 undergraduate students. By 2021, we expect both of these numbers to increase by 30 percent to 303 graduate and 153 undergraduates. Additionally, ASU's National Security Systems Initiative expects to attract and support 159 postdoctoral appointments.

3.2.1.5 Government agency/community engagement (outreach, partnerships, collaboration)

While the expected DOD/IC funding in GSI's primary strategic areas cybersecurity,

urban security, and infrastructure resilience will be the core of ASU's National Security Systems Initiative funding portfolio. GSI also expects to attract additional funding for resilience and health from organizations such as USAID, NIH, DTRA, DOE and others. GSI collaborates with The ASU Foundation on an outreach plan to foundations for funding primarily in health, human security and resilience and expect these efforts to result in \$4 million of funding by 2020. Lastly, the Exploration and NewSpace programs will be a key source of continued growth in NASA funding and will be the catalyst to advance our position of national leadership as the 12th ranked US university in NASA funded research expenditures.

In addition to these funding engagements with government and nonprofits, GSI will also create formal joint-effort partnerships with eight national laboratories by 2021, marked by significant co-funded research.

3.2.2 Annual metrics table of expected outcomes and timeline for achievement

Expected Outcomes	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
TRIF EXPENDITURES					
Total	\$ 3,561,613	\$ 3,769,612	\$ 3,977,610	\$ 4,185,609	\$ 4,393,608
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 36,000,000	\$ 43,000,000	\$ 48,000,000	\$ 53,000,000	\$ 60,000,000
Gifts & Other Sources	-	-	-	-	-
Royalty Income	50,000	50,000	50,000	50,000	50,000
TOTAL	36,050,000	43,050,000	48,050,000	53,050,000	60,050,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	20	22	25	27	30
US Patents Issued	2	2	3	3	4
Licenses and Options Executed	4	4	4	5	5
Startup Companies	0	0	0	0	0
WORKFORCE CONTRIBUTION					
Postdoctoral Appointees	27	30	32	34	36
Graduate Students	227	249	265	281	303
Undergraduate Students	115	126	134	142	153

3.3 Initiative structure

3.3.1 Organizational structure

The GSI leadership team has extensive experience in research, defense-related industry experience and a successful record of accomplishment with academic and defense-related industry organizations. The GSI leadership team includes:

- Nadya Bliss, director

- Gail-Joon Ahn, director of the Center for Cybersecurity & Digital Forensics
- Jaqueline Wernimont, co-director of the Human Security Collaboratory
- Jessica Rajko, co-director of the Human Security Collaboratory

3.3.2 Advisory board

GSI is convening an external strategic advisory board to assist in identifying opportunities for impact, relationship building and funding. This board will include past representatives from the DOD and IC, as well as leading researchers with significant security and defense research and research leadership experience.

3.3.3 Infrastructure

University infrastructure supporting the National Security Systems Initiative includes CDF and the ASU Research Enterprise (ASURE), the not-for-profit applied research, development, and consulting affiliate of Arizona State University. CDF brings together leading faculty in engineering, social sciences, law and business to:

- conduct sponsored research focused on identity management, privacy issues, malware attribution, secure mobile devices, predictive analytics/adversarial, dynamics and digital forensics
- create custom education, internship and training platforms
- support entrepreneurial activities in partnership with ASU SkySong

ASURE specializes in conducting classified and midrange technology readiness level (TRL) services for the defense and security industry. ASURE connects the defense and security industry with the unsurpassed intellectual resources of America's fastest growing research university. We develop outcome-driven, customer-focused, real-world solutions designed to meet near- and longer-term security and defense needs.

3.3.4 Description of investment mechanisms

GSI has been formally in operation since February 1, 2015. Its launch was preceded by a six-month effort to redesign and reconceptualize ASU's approach to working with the DOD and IC, aligning ASU's unique strengths with key local, national and global research and development needs across the security and defense space.

During this conceptualization phase, we held discussions with a wide range of relevant government agencies to identify key areas of interest in security and defense, as well as the best methods of collaboration with these entities. Coordination with government agencies, foundations and industry partners will continue to ensure the alignment of ASU capability with funding sources.

GSI coordinates closely and continuously with existing ASU institutes, centers and

academic units to maximize the impact of TRIF investment and avoid duplicating effort. GSI provides formal mechanisms, such as the Defense Advanced Research Projects Agency (DARPA) working group and collaborative research centers, to engage faculty and provide guidance in securing defense-related funding. GSI also provides informal mentoring, proposal coordination and review, and relationship building to any interested faculty member or university entity.

GSI's deep understanding of the funding landscape as well as the capabilities that exist across the university informs its use of TRIF funding to make strategic investments in research centers and to provide seed funding for high potential research programs.

3.4 Initiative budget table

Initiative Budget	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
National Security Systems	\$ 3,561,613	\$ 3,769,612	\$ 3,977,610	\$ 4,185,609	\$ 4,393,608

3.5 Plan for sustainability

3.5.1 Anticipated funding sources for ongoing support

GSI's development activities and demonstrated success will elevate ASU on the DOD and intelligence community stage, leading to an overall capture of \$60 million by 2021 across the university. GSI has a three-pronged approach to capturing external funding, based on government, industry and non-profit sources.

3.5.2 Timeline for transitioning away from TRIF support

GSI expects to generate significant funding from external sources in the form of industry memberships and external research funding from DOD and other agencies such as USAID, NIH, DTRA and DOE.

4 Water, Environmental and Energy Solutions

4.1 Investment description/rationale/justification

The Julie Ann Wrigley Global Institute of Sustainability (Wrigley Institute) is the hub of ASU's sustainability initiatives, advancing research, education and business practices for an urbanizing world. Its School of Sustainability, the first of its kind in the country and celebrating its tenth anniversary, offers transdisciplinary degree programs focused on finding practical solutions to the most pressing social, economic and environmental challenges of our times.

The proposed TRIF investment in the Wrigley Institute will enable the institute to:

- continue to advance ASU's university-wide commitment to sustainability
- enable ASU units and their partners in the teaching, learning and discovery of sustainability
- implement, extend, share and promote sustainable practices locally, nationally and globally
- connect scientists, scholars, humanists, engineers, technologists, policymakers, business leaders, students and communities to enhance the capacity to address sustainability challenges
- support research and development in sustainable technologies and sustainable systems used by cities and businesses that will generate revenue and jobs in Arizona

The Wrigley Institute programs and other initiatives supporting the TRIF focus area related to specific sustainability challenges in local, national, and global communities including renewable energy, food systems, community well-being and urban resilience.

4.1.1 Brief overview of industry or area being addressed by the initiative to include benefit to Arizona

The Wrigley Institute emphasizes investigation of real-world problems that require the development and application of practical solutions. Greater Phoenix is a "laboratory" where solutions to water, energy, transportation and livability problems can be developed by ASU, tested and refined. In many cases, translation of university research can be transformed into commercial products and services that simultaneously "do well and do good"; that is, that solve serious problems for Arizona and beyond while also creating economic value.

Wrigley Institute projects have already demonstrated the ability to create Arizona-based jobs and businesses and attract a highly educated and trained workforce. Our enterprise-funding model has promoted collaborations with industry partners and other

valued institutions.

The LightWorks initiative within the Wrigley Institute is an example of this investment model. LightWorks fosters economic growth by providing advanced technologies, supporting local firms and enhancing the attractiveness of Arizona to outside investors. Expanded programs at LightWorks serve to create high-quality jobs in manufacturing, services, research and development. These support increased tax revenues and enhance the reputation of Arizona as the leader in developing and deploying sustainable energy solutions, especially solar energy.

For example, two startup companies founded on ASU technology were developed with LightWorks TRIF investments:

- Fluidic Energy is estimated to generate over \$15 million in annual revenue and employs 35 people. The company has raised \$150 million in equity financing from investors.
- Heliae had sales of \$4.2 million in 2014 and employs 105 people.

4.1.2 Discussion of mission, goals, values and vision

ASU is a leader in the global movement to help solve enduring challenges of sustainability, promoting human prosperity and well-being for all while protecting and enhancing Earth's life support systems. The overarching goal of the proposed TRIF investment in the Wrigley Institute and other initiatives is to enable the institute to focus select ASU talent on the development of solutions to sustainability challenges.

The measure of the number of people affected is the best measure of a project's impacts. For example, developing a technology designed for hot, arid environments that has a real value proposition in the market has the potential to impact 1–2 billion people worldwide.

The impacts of convening stakeholders will be examined across all activities to quantify the number of events and the level of potential influence within the respective stakeholder group. For example, local stakeholders and international experts studying desalination would examine the tradeoffs of having desalinated water become a fourth source of water for the Phoenix metro area.

We can measure, in a semi-qualitative/quantitative way, how often and where our experts have brought their perspectives to bear upon relevant issues where decision makers could take action. An example would be hosting a webinar where sustainability scientists offer varying perspectives on the future of sustainable transportation fuels and attendees from funding and regulatory agencies act to create a funding opportunity focused on emerging technologies.

4.1.3 Description of programmatic investments

TRIF funding will provide the institute with the resources to invest in multidisciplinary initiatives and the mechanism for teams to organize around research challenge areas, create proof-of-concept technologies and systems, and leverage the pursuit of additional funding from federal and private agencies, as well as from charitable foundations. TRIF investment at ASU will support activities in the following five Water, Environmental and Energy Solutions challenge areas and associated programs:

- **Novel sources of renewable energy: ASU LightWorks** is designed to address anticipated shortages of conventional energy. The world's energy system is patently unsustainable, and research and development from LightWorks-funded scientists is creating a more sustainable energy future. As economies expand and personal income rises, the world's energy demand will grow. Filling that growing demand with clean, renewable electricity and fuel, implementing energy efficiency measures, and transitioning Arizona and the nation from fossil fuels is an economic and social imperative.

LightWorks seeks to create a resilient and equitable energy future by stimulating innovations in technology, policy, law and markets. These innovations have at their core an "enterprise mentality." This means that LightWorks invests in scientists who can develop and scale new energy systems that have viable, commercial applications. This investment policy not only addresses the energy challenge but it also creates jobs and revenue for Arizona in the process.

- **Food systems: the Food Systems Transformation Initiative (FSTI)** will make food systems more equitable, diverse and resilient. Adapting local and global food systems to evolving uncertainties in an unstable world will make cities and states more resilient. In addition, food and agribusiness are enormous markets and demand will remain high as world population grows largely unabated. Thus, transforming food systems and enabling food production methods to meet the needs of a 21st-century Earth has the potential to create jobs, generate revenue and position Arizona—a state with a rich economic heritage in food and fiber production—as a world leader.
- **Leadership: the ASU Leadership Academy** trains faculty and staff who are emerging leaders, focusing on communication, team building, securing resources and building a culture of excellence. The academy aims to create the next generation of Arizona-based leaders with the capacities and capabilities to compete for, and oversee, the complex, large-scale, pan-university and interdisciplinary projects, necessary to address the complex problems sponsors are increasingly focused on. In the recent past, Arizona has received

considerable criticism for its lack of leaders, and a TRIF investment in the ASU leadership academy will help change that image by developing leadership-capable workforce required for Arizona to succeed in an increasingly competitive world economy. In addition, faculty and staff trained in the leadership academy will develop the skills to start and new private sector companies.

- **Education and Training:** This initiative is designed as an enterprise, seeking clients (businesses, federal agencies, non-governmental organizations) that want to increase their employees' understanding of sustainability. Our market research shows there is a demand for this type of education/training, especially if it is associated with a well-known, highly regarded institution such as ASU. This initiative is a "small business-like," non-credit activity that custom-designs short sustainability education programs to meet specific demands for which a client will pay. To date, the initiative has engaged the World Bank, Arizona Green Chamber of Commerce, Intel and USAA. TRIF funds will be invested to start up and accelerate this activity, which will contribute out-of-state revenue.
- **Cities: the Sustainable Cities Network** helps Arizona cities address their sustainability challenges. In the absence of having solutions to challenges such as water supply and quality, waste management, energy and others, an economic and social core of Arizona—its cities—will be at risk of failure. The Network is a vehicle for communities to share knowledge and coordinate efforts to understand and solve sustainability problems. It is designed to foster partnerships, identify best practices, provide training and information, and create a bridge between ASU's research and the front-line challenges facing local communities. An example of ASU's research being applied to addressing the real challenges facing Arizona's cities, is our efforts to reducing the Urban Heat Island Index and to improve long-term air quality in metropolitan Phoenix.

In addition to the these research challenge areas, TRIF funding will also be used to support the following:

- **Decision Theater.** The Decision Theater Network (DTN) engages researchers and leaders 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. The network addresses cross-disciplinary issues by drawing on ASU's diverse academic and research capabilities.
- **Chemical and environmental characterization and synthesis.** Capabilities include magnetic resonance, mass spectroscopies, chromatography and physical property measurement systems. These can be applied to clean technology,

renewable energy, advanced manufacturing and processing.

4.2 Expected outcomes as a result of TRIF investments

4.2.1 Specific and realistic goals that are clearly measurable

4.2.1.1 Return on investment

The Water, Environmental and Energy Solutions (WEES) initiative is a key interdisciplinary ASU TRIF-funded initiative that has been instrumental to ASU's emergence as one of the nation's leading research universities in this multidisciplinary field. One example of ASU's prominence in this broad discipline comes from the National Science Foundation (NSF), which currently ranks ASU as 5th nationally in Earth Sciences total research expenditures and 22th nationally in Environmental Sciences total research expenditures. These impressive national rankings reflect the university's ability to turn TRIF investments into research projects and programs that have attracted substantial funding to the State of Arizona.

Over the last five years, the \$20M in TRIF funding ASU has invested in its WEES initiative have resulted in the competitive acquisition of more than \$60M in sponsored projects dollars and more than \$15M in research gifts.

Looking forward, ASU aims to grow capabilities in this area substantially as these efforts will have a direct and certain benefit for the citizens in the State of Arizona. With increased TRIF investments totaling \$35M over the five year period from 2017 to 2021, ASU's WEES initiative intends to attract more than \$140M in sponsored projects funding and an additional \$22.5M in research gifts.

4.2.1.2 Technology transfer

ASU's Water, Environmental and Energy Solutions initiative has increasingly focused its efforts on applied solutions to the grand challenges in sustainability. These efforts have manifested in substantially increased technology development. Whereas in 2012 and 2013 ASU's WEES initiative produced just one invention disclosure, in 2015 the initiative produced a record number of 28 invention disclosures. Over the proposed additional funding period, ASU expects this trend to continue due to its use-inspired research efforts and will generate more than 60 invention disclosures, 11 US patents, and create 24 licensing and options agreements to translate its research into the marketplace.

4.2.1.3 Industry engagement (outreach, partnerships, collaboration)

Programs funded in the Water, Environmental and Energy Solutions focus area will engage with industry in various ways to leverage the impact of TRIF funding. Examples of industry engagements will include but are not limited to: joint research, collaborations

on proposal development, student internships, guest speakers, joint fora, co-authorship of research reports and executives-in-residence. We expect to establish at least 140 industry engagements during this TRIF funding cycle:

	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
Industry Engagements	20	25	30	30	35

4.2.1.4 Workforce contributions

At the core of ASU's WEES initiatives lies the Julie Ann Wrigley Global Institute of Sustainability and its pioneering School of Sustainability, which is the first of its kind in the US. As our WEES related research has grown, the educational focus of the School has been paramount and has driven an initiative-wide focus on student engagement. Over the last 5 years, the WEES initiative has provided advanced research training in this emergent interdisciplinary field to hundreds of graduate and undergraduate students and been the choice of more than 60 postdoctoral appointees and research professionals to continue their education in. Over the proposed period of continued TRIF funding, the WEES initiative plans to broadly expand this engagement by providing research opportunities to more than 1,800 graduate and undergraduate students. Additionally, we expect that continued TRIF funding would allow us to attract and support 161 postdoctoral appointments.

4.2.1.5 Educational outreach

ASU is committed to sustainability education at all grade levels and our planned WEES initiative activities reflect this promise. Our National Sustainability Teacher's Academy supports ASU's commitment to making high quality education accessible to all of Arizona's students by bringing sustainability into middle school classrooms. Another award-winning program, the Ecology Explorers program, has brought over 2,000 K-12 students in 75 schools across the Phoenix metro area together with university researchers and public school science teachers to bring scientific discovery into the lives of young students.

Other important examples of educational outreach include but are not limited to: K-12 teacher trainings, conference presentations, public speaking, community fora, curriculum development and dissemination. During this TRIF funding cycle the Wrigley Institute will establish, partner and support 50 distinct educational outreach events:

	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
Education Outreach Events	5	8	10	12	15

4.2.1.6 Government agency/community engagement (outreach, partnerships, collaboration)

Over the last decade, the Julie Ann Wrigley Global Institute of Sustainability has

attracted more than \$80M in federal research funding for its innovative, solutions-focused research. Over the proposed five year TRIF funding cycle, the WEES initiative will expand on the institute’s success by attracting more than \$100M in new federal funding to Arizona.

The Institute’s scientists, along with other WEES initiative faculty, are partnering with the community by being actively involved in the public discussions and policy formation as we strive to design a more sustainable society and way of life. One key example is the Sustainability Solutions Festival, which convenes for one week each year in Arizona and brings together business leaders, students and the community to talk about the world’s toughest sustainability issues. In 2016, this event included major industry leaders such as Dell, SRP, and APS, as well as local community organizations such as the AZ Science Center and the City of Phoenix to bring over 7,000 people together.

Other examples of government and community engagement include but are not limited to: hosting government meetings, public presentations, student internships in government agencies, proposal fund matching and convening. Over the proposed five years of additional TRIF funding, the WEES initiative expects to host, partner or otherwise participate in 50 government and community engagements.

	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
Government and Community Engagements	5	8	10	12	15

4.2.2 Annual metrics table of expected outcomes and timeline for achievement

Expected Outcomes	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
TRIF EXPENDITURES					
Total	\$ 7,050,459	\$ 7,349,538	\$ 7,768,132	\$ 8,186,383	\$ 8,604,285
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 23,000,000	\$ 26,000,000	\$ 28,500,000	\$ 30,100,000	\$ 34,000,000
Gifts & Other Sources	4,250,000	4,380,000	4,510,000	4,650,000	4,790,000
Royalty Income	100,000	100,000	100,000	100,000	100,000
TOTAL	27,350,000	30,480,000	33,110,000	34,850,000	38,890,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	12	12	12	13	13
US Patents Issued	2	2	2	2	3
Licenses and Options Executed	4	5	5	5	5
Startup Companies	0	0	0	0	0
WORKFORCE CONTRIBUTION					
Postdoctoral Appointees	29	31	32	33	36
Graduate Students	148	158	166	171	183
Undergraduate Students	179	190	200	206	221

4.3 Initiative structure

4.3.1 Organizational structure

The Wrigley Institute is governed by a directorate that has established an ambitious agenda for our enterprise to become a leader in providing sustainable solutions for a rapidly urbanizing planet. Their combined expertise provides comprehensive oversight for TRIF-directed projects residing within the institute.

The Wrigley Institute directorate includes:

- Gary Dirks, director
- Rob Melnick, executive director and chief operating officer
- Christopher Boone, School of Sustainability dean

Each TRIF activity will have a program lead who will provide expertise and oversight on project expenses, milestones and external funding opportunities. We will identify program leads through the institute's established network of sustainability scientists and scholars. Lead scientists will be chosen based on their expertise and ability to manage cross-disciplinary teams and their entrepreneurial instincts and/or experience.

4.3.2 Advisory board

Primary advisory oversight of the TRIF investment in the Wrigley Institute is assigned to the institute's directorate. In addition, the Board of Directors for Sustainability at ASU, composed of representatives from business, government, nonprofit and academic organizations, actively advises the institute and the directorate on a regular basis.

4.3.3 Infrastructure

Infrastructure investments in the WEES initiative include resources such as The Arizona Center for Algae Technology and Innovation (AzCATI), which serves as a national testbed for research, testing, and commercialization of algae-based products such as biofuels, pharmaceuticals, nutraceuticals, and other algae biomass co-products. AzCATI provides open test and evaluation facilities for the algae industry and research community. Since its inception in 2010 with a grant from Science Foundation Arizona, AzCATI has grown its research portfolio to more than \$35 million. AzCATI currently leads the following sponsored projects:

- Department of Energy: Algae Testbed Public-Private Partnership
- US Department of Agriculture: best management practices for algal crop protection
- Salt River Project: microalgae carbon capture at the Coronado Generating Station

4.3.4 Description of investment mechanisms

As described above, investments in the WEES initiative range from the Wrigley Institute level which provides a hub for sustainability activity at ASU to specific programs like the Leadership Academy and Cities initiative. This provides for flexibility in this rapidly emerging area to ensure that the University programs remain nimble and responsive.

4.4 Initiative budget table

Initiative Budget	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
Water Environmental and Energy Solutions	\$ 7,050,459	\$ 7,349,538	\$ 7,768,132	\$ 8,186,383	\$ 8,604,285

4.5 Plan for sustainability

4.5.1 Anticipated funding sources for ongoing support

We expect to increase partnerships and sponsored support so we can sustain the individual programs by the close of FY2021. We will accomplish this self-sustaining model through business opportunities that expand the impacts of our research, facilitating and convening stakeholders, and influencing the narrative around critical issues.

During the five years of TRIF investment, the Wrigley Institute will continue to secure external funding from Federal agencies such as the National Science Foundation

(NSF), U.S Department of Defense (DOD), National Aeronautics and Space Administration (NASA), Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), World Bank/IFC, and the U.S. Agency for International Development (USAID). Additional investment from corporations such as Wells Fargo Bank, Intel Corporation, Archer-Daniels Midland and Starbucks will also contribute to ongoing support for the Institute and initiatives.

4.5.2 Timeline for transitioning away from TRIF support

We will transition funding from TRIF to external research support, with a goal of becoming self-sustaining by the end of FY2021.

5 Access and Workforce Development: Entrepreneurship and Innovation

5.1 Investment description/rationale/justification

ASU is known for its unique and effective approach to growing an entrepreneurial enterprise within a public university system. At ASU entrepreneurship is not confined to a single college or school, nor is it housed in one center or institute. Valuing entrepreneurship means that it is more than just a class or a program; it is a mindset that is woven into the fabric of the university, permeating every activity. ASU students, faculty and staff in every discipline and at every level work to identify local and global needs, articulate how to meet them and implement entrepreneurial solutions.

By creating a new Access and Workforce Development Initiative in Entrepreneurship and Innovation, ASU will greatly enhance and expand its award-winning programs to reach an even greater number of students and faculty, and more deeply engage with the community outside the university.

At its core, ASU's Access and Workforce Development Initiative in Entrepreneurship and Innovation is being launched to advance as broadly as possible the idea that creating a job is a real alternative to seeking one, and to then provide the necessary training, mentoring, support and resources to those who are inspired to do so. By providing Arizona with a steady stream of graduates prepared and ready to create, we are confident that we will have a real impact on the Arizona economy.

5.1.1 Brief overview of industry or area being addressed by the initiative to include benefit to Arizona

On a national scale, small businesses are driving contributors to the U.S. economy. Small businesses employ nearly half of the private sector labor force and pay 44% of the total U.S. private payroll. Small businesses created 65% of net new jobs in the U.S. over the past 17 years.

At the local level, entrepreneurs provide numerous benefits to their communities. In addition to creating jobs and generating wealth, they spend within the community. For every dollar spent at a local business, 73 cents stays local (in terms of taxes, supplies and local spending of employee wages). Entrepreneurship also leads to wealth creation in low-income communities.

Entrepreneurship and innovation have been at the forefront of the transformation of ASU, and entrepreneurship is valued as a critical objective. ASU's Office of Entrepreneurship and Innovation (E+I) anchors these initiatives but entrepreneurship and innovation are demonstrated in curriculum across all ASU programs of study to expand entrepreneurial thought and education.

Our impact on the community and marketplace is profound. Startup companies that have licensed ASU intellectual property have attracted over \$500 million in funding from venture capital firms and other investors, with much of this financing achieved during the last five years. Overall, ASU's venture development activities have led to the formation and assistance of more than 80 companies based on ASU discoveries. Many of these companies currently operate in Arizona and employ ASU graduates; in Arizona, four companies alone represent over 350 jobs created in Arizona.

SkySong, the ASU Scottsdale Innovation Center, is a prime example of ASU's commitment to be socially and economically embedded in the communities we serve. The university is leading the transition of the McDowell Corridor from a former "motor mile" of car dealerships to a major innovation hub for the greater Phoenix Region. These activities include company and community engagement, the development of a 20-year strategic plan to guide the SkySong development and the implementation of a business acceleration space.

Since opening in early 2008, SkySong has been a linchpin for the revitalization of the McDowell Corridor with over \$588 million in economic output and a projected output of \$32.17 billion by 2046. In addition, SkySong tenants employ over 1,500 people on a site that had been vacant since the mid-1990s. Overall, SkySong represents a major public-private partnership with 450,000 square feet of office space completed, which will grow to 1.2 million square feet at total buildout. In the last two years, four companies have grown from the acceleration space into their own affiliate space within SkySong and two affiliates have since become commercial tenants.

5.1.2 Discussion of mission, goals, values and vision

The Office of Entrepreneurship and Innovation provides educational opportunities, training and mentorship in entrepreneurship to students, faculty, and the broader community. It also serves as a connecting and collaborating resource across ASU and the greater Phoenix community that opens the university's research and development capabilities, experience in innovation and its facilities to the broader community with an eye towards stimulating new ventures and improving economic outcomes. The office's success in these efforts is evidenced by ASU's national and international reputation as an entrepreneurial institution of higher education.

5.1.3 Description of programmatic investments

We ensure key collaboration between students, faculty, staff, the private sector and other community partners to commercialization research discoveries. TRIF funding will be used to enhance our entrepreneurship programs that support these constituencies in the creation of new products, services and companies including:

- **ASU Mentor Network** supports student, faculty and community-led startups in

an ASU accelerator program. ASU faculty with experience in entrepreneurship can participate as mentors and faculty who want to start a venture benefit from this valuable network of area professionals.

- **ASU Startup Bootcamp** provides a structured approach to starting a new company. The summer Startup Bootcamp provides a balanced approach of self-guided training, mentorship and regular consultation with an E+I venture manager to assist faculty in launching their ventures. Faculty startups are embedded with other high-potential startups comprised of ASU alumni- and community-based companies.
- **ASU Startup Mill** is an exclusive program jointly run by E+I and Arizona Technology Enterprises (AzTE). Startup Mill invites the highest-potential student- and faculty-led startups within the university as well as select startups from outside the university to receive top-tier entrepreneurship support from ASU. Participants receive incubation, acceleration and strategic investment from the university. The program also matches participating startups with seasoned venture capitalists and executives who provide mentoring and direction to the ventures, may serve in an administrative capacity, and help identify high-potential intellectual property within the university. Startup Mill aims to retain high-performing startups in Arizona that will create jobs and contribute significantly to regional economic development as they scale.
- **ASU Startup School** is a series of facilitated workshops in which entrepreneurs learn how to develop a successful venture. Offered online and in person, ASU Startup School is available to anyone, anywhere. Faculty can access this resource on their own time or participate in facilitated sessions. Faculty can also become certified ASU Startup School instructors to deploy this resource in their respective colleges.

In addition to the core entrepreneurship focused programs, ASU is redefining innovative economic engagement while having a large-scale impact on the local economy by engaging with corporate partners, municipal and state partners, regional economic development organizations and chambers of commerce, and local community members, including entrepreneurs. Additional services provide by the Office of entrepreneurship and Innovations include:

- Expanding strategic industry collaboration to increase the university's accessibility to businesses and identify opportunities to increase the university's economic impact, both locally and globally
- Developing and launching new centers in collaboration with interested companies
- Introducing faculty to companies that are considering locating in the region

- Providing introductions to research and development organizations in the region
- Supporting and hosting public or internal conferences, summits, meetings and events at SkySong, the ASU Scottsdale Innovation Center

5.2 Expected outcomes as a result of TRIF investments

5.2.1 Specific and realistic goals that are clearly measureable

5.2.1.1 Return on investment

ASU's Access and Workforce Development Initiative in Entrepreneurship and Innovation expects to generate nearly \$20M in funding over the course of the proposed 5-year investment period – nearly three times the planned investment. Funding for entrepreneurial education and programming typically comes from the businesses and nonprofits that focus on improving economic welfare. While this is a comparatively small market compared to the federal funding available for scientific research and development, we expect to capture a notable market share of the competitively awarded funding available. Furthermore, we intend to stimulate new funding opportunities by effectively communicating to potential sponsors the outcome-focused nature of our programming and the broad societal impact entrepreneurial and innovation programs deliver.

5.2.1.2 Technology transfer

While ASU's Access and Workforce Development Initiative in Entrepreneurship and Innovation does not itself produce invention disclosures, patents or licensing agreements, it is heavily focused on helping student entrepreneurs launch their businesses. Over the proposed five-year period of TRIF funding we expect to be able to guide the launch of 111 student startups.

5.2.1.3 Industry engagement (outreach, partnerships, collaboration)

ASU partners with corporations, municipal and state governments, regional economic development organizations and chambers of commerce, and local community members including entrepreneurs. Some partners include:

- Arizona Commerce Authority
- AZ TechStars
- Greater Phoenix Economic Council
- Greater Phoenix Leadership Council
- Economic development managers and offices throughout the Greater Phoenix region

- Invest Southwest
- National Advisory Council on Innovation and Entrepreneurship (NACIE)
- Startup AZ
- University Economic Development Association (UEDA)

ASU also works with many corporations around the world, aided by a pan-university Corporate Engagement Council and Corporate Relations Task Force, with over 60 administrators across the university working together to coordinate relationships, projects and responses to new engagements.

Corporate partners serve as critical sponsors of ASU's entrepreneurship and innovation programs, including four projects through a Cisco-advised Silicon Valley Community Foundation award, support of women's entrepreneurship through JP Morgan Chase and significant support of youth entrepreneurship programs through the Verizon Foundation.

Through the ASU Entrepreneurship Outreach Network, ASU works with 14 libraries providing resources and support to enable them to be robust sources of entrepreneurship information to their communities.

5.2.1.4 Workforce contributions

Each year, through the various Innovation Challenges, we see over 500 applications, representing a body of nearly 2,000 students, who are actively building ventures. Across the university, our Entrepreneurship and Innovation educational programs have engaged over 1,500 students pursuing entrepreneurship-based degrees and certificates. Lastly, our Launch Days programming exposes more than 20,000 students to Entrepreneurship and Innovation opportunities.

Our methodology for measuring the workforce contribution from our TRIF Funded Entrepreneurship and Innovation efforts however, will be the number of graduate and undergraduate students that participate in one of our established venture development programs. In total, we expect to provide this intensive training and mentorship to more than 800 students over the proposed five-year period of TRIF funding.

5.2.1.5 Educational outreach

ASU's Access and Workforce Development Initiative in Entrepreneurship and Innovation's has two primary outreach programs which will be enhanced over the proposed five-year TRIF funding period.

ASU's Entrepreneurship Challenges engage students from well over half of the 290 undergraduate majors. The Teaching Innovation Fellows (TIF) program provides training for high school educators on embedding innovation, entrepreneurship and science, technology, engineering and math (STEM) concepts into curricula through

applied community-based projects. The program provides a framework for educators of a variety of disciplines, educational settings and grade levels to learn applied project methodologies. The TIF program uses a blended learning approach, combining face-to-face workshops with virtual learning experiences.

Lastly, ASU's Access and Workforce Development Initiative in Entrepreneurship and Innovation advances the university's Access mission in supporting a diversity of programming for minorities, veterans and other underserved populations

5.2.2 Annual metrics table of expected outcomes and timeline for achievement

Expected Outcomes	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
TRIF EXPENDITURES					
Total	\$ 1,369,851	\$ 1,449,851	\$ 1,529,850	\$ 1,609,850	\$ 1,689,849
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 2,000,000	\$ 2,750,000	\$ 3,500,000	\$ 4,100,000	\$ 5,000,000
Gifts & Other Sources	-	-	-	-	-
Royalty Income	-	-	-	-	-
TOTAL	2,000,000	2,750,000	3,500,000	4,100,000	5,000,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	0	0	0	0	0
US Patents Issued	0	0	0	0	0
Licenses and Options Executed	0	0	0	0	0
Startup Companies	20	21	22	23	24
WORKFORCE CONTRIBUTION					
Postdoctoral Appointees	0	0	0	0	0
Graduate Students	25	26	28	29	30
Undergraduate Students	125	131	138	145	152

5.3 Initiative structure

5.3.1 Organizational structure

ASU believes in operating at speed, scale and complexity, and one way we achieve this is through a team of teams approach with a collaboration mindset. By deploying an agile and connected team approach, the collective efforts are harnessed to greater effect.

Economic development leadership includes:

- Sethuraman “Panch” Panchanathan, executive vice president and chief research and innovation officer of ASU's Knowledge Enterprise
- Todd Hardy, vice president of assets from the ASU Foundation
- Janice Kleinwort, executive director of economic affairs

- Keith Walton, vice president of strategic industry collaborations
- Ji Mi Choi, associate vice president of strategic partnerships and programs

This team, a small core staff and an additional group of university partners across various functional areas of expertise work to implement the variety of services in support of entrepreneurship and economic development through innovation.

5.3.2 Infrastructure

The leadership team above as well as student employees working on SkySong company engagement support the economic development team. The Office of Entrepreneurship and Innovation employs 12 full-time employees and additional grant-funded personnel marshalling ASU entrepreneurship resources from across the university and serving as a resource to all ASU programs and schools.

ASU supports the following facilities and resources for students, faculty, staff and the community:

- ASU Chandler Innovation Center, including 17,000 square feet of makerspace in partnership with TechShop, along with classroom, seminar and event space
- Changemaker Central – dedicated student social entrepreneurship spaces on each campus
- Cronkite School of Journalism and Mass Communications' Digital Innovation and Entrepreneurship Lab
- Edson Student Entrepreneur Initiative, funded by a \$5 million endowment, provides space at SkySong, capital and mentorship to student startups
- Ira A. Fulton Schools of Engineering Startup Center and Generator Labs
- Herberger Institute for Design and the Arts Pave Program in Arts Entrepreneurship, including an Arts Venture Incubator and InnovationSpace
- SkySong includes 16 conference rooms used by on-site companies and the broader community, hosting approximately 500 meetings on-site per month with roughly 5,000 monthly attendees
- W. P Carey School of Business Center for Entrepreneurship
- 14 libraries from around the region participating in the Entrepreneurship Outreach Network

5.3.3 Description of investment mechanisms

The Entrepreneurship and Innovation team seeks to expand the number of people who may participate in its programs to increase access to entrepreneurship training and

support. By enhancing communications, we endeavor to make programming and resources more accessible. In addition, the team aims to better support underserved populations: minority entrepreneurs, women entrepreneurs and veterans. By investing in better supporting and focusing on underserved populations, ASU aims to increase access to social mobility, create and foster a more dynamic and diverse economic development engine, and diversify areas of growth.

Simultaneously, the economic development team will seek to strengthen our corporate engagement strategies, enhance communications channels, and expand business attraction and retention activities.

5.4 Initiative budget table

Initiative Budget	FY 17	FY 18	FY 19	FY 20	FY 21
Access and Workforce Development: Entrepreneurship & Innovation	\$ 1,369,851	\$ 1,449,851	\$ 1,529,850	\$ 1,609,850	\$ 1,689,849

5.5 Plan for sustainability

As a department in service to university-wide entrepreneurship initiatives, the Office of Entrepreneurship and Innovation seeks external funding, particularly philanthropic funding, in support of the students and communities we serve. As part of the ASU Foundation's philanthropic campaign, Entrepreneurship and Innovation initiatives in particular figure prominently in seeking long-term sustainable funding solutions. An example of this is the Edson Student Entrepreneur Initiative that enables ASU to support student entrepreneurship with \$450,000 in startup grants annually, in addition to working space and mentorship. The student startups in the Edson Student Entrepreneur Initiative are tremendously successful in their own right. Edson cohorts from the last three years have raised a total of more than \$5 million in external funding, filed over 30 patents and hired more than 150 employees.

Additionally, many of the programs the Office of Entrepreneurship and Innovation supports is through external agencies which allows for the hiring and management of program personnel to design and deliver services. Through core funding, including TRIF investments, ASU is able to seek out those external funding opportunities in service to promoting entrepreneurship.

5.5.1 Anticipated funding sources for ongoing support

The Office of Entrepreneurship and Innovation has successfully garnered financial support from diverse external sources such as the National Science Foundation, a Cisco-advised fund at the Silicon Valley Community Foundation, JP Morgan Chase, and the Verizon Foundation. These supporters have enabled ASU to offer technology commercialization support to faculty, run youth and minority-supportive entrepreneurship programs, support for women's entrepreneurship programs, and

professional development enabling design thinking and infusion of entrepreneurship in high school classrooms across the country.

ASU anticipates continuing to seek external funding in support of the critical programs that allow for local, regional, and national economic growth in addition to an enriching experience for our students, faculty, and community.

5.5.2 Timeline for transitioning away from TRIF support

Over the next five years, as ASU increases the intensity of its philanthropic campaigns, and as the Office of Entrepreneurship and Innovation continues seeking out external support, we anticipate building on the success of our programs to the point of needing less core support, including TRIF investments.

Support of entrepreneurship, particularly university-based entrepreneurship continues to grow and as the most innovative university in the country, ASU plans on building on the momentum and gains we have realized, especially in recent years.

6 Access and Workforce Development: Advanced Manufacturing

6.1 Investment description/rationale/justification

The meaning of the term “manufacturing” is undergoing a historic transformation. Several important technological trends are revolutionizing the way things are made in America. These include:

- fabrication techniques like additive manufacturing
- novel materials that enable advances in electronics and life sciences applications
- the “democratized” process tooling that is driving the “maker” movement

ASU is already investing in several of these strategic areas through research activities conducted by faculty across a number of disciplines. In order to build on this foundation and accelerate the university’s participation in an important new area of applied research, we have established an Advanced Manufacturing Initiative that will anchor a TRIF focus in advanced manufacturing. The initiative will seek to coordinate efforts across programs in natural sciences and the Ira A. Fulton Schools of Engineering, and to create center-level research programs involving interdisciplinary clusters of faculty. It will be a central goal of the initiative to establish strategic partnerships with industry to help shape the research agenda and provide a stream of well graduates ready to matriculate to careers as leaders in this field.

A large fraction of the nation’s manufacturing innovation has traditionally come from a captive corporate research enterprise. Although the apparent overseas migration of many traditional manufacturing activities has been a focus of public attention in recent years, the erosion of our private-sector research capacity has not been so widely noticed. The DuPont Corporation’s recent decision to shutter its century-old Experimental Station is just the most recent example. The Bell Telephone Laboratories and Hewlett-Packard Laboratories are other prominent examples of preeminent private research laboratories that have disappeared.

Closer to home, Motorola once employed over 20,000 people in Arizona, about 10% of which were engaged in research and development. These jobs are now gone. As U.S. research and development capacity has withered, domestic companies have increasingly turned to academic institutions for their innovation pipeline needs. Together with venture-funded startups, these are rapidly becoming the principal source of new commercial technologies. This has attracted the attention of federal agencies, which have begun to develop and introduce programs to support the creation of public-private partnerships dedicated to advanced manufacturing technologies. The most prominent example is the National Network of Manufacturing Innovation Institutes established by the Advanced Manufacturing Program Office of the U.S. Department of Commerce, in which the U.S. Department of Defense (DOD) and U.S. Department of Energy (DOE)

actively participate. We believe these trends represent an opportunity underexploited by universities. ASU, with its focus on use-inspired research and well-developed corporate engagement activities, has many of the tools in place to become a leader in the targeted development of science and technology that is tightly coupled to economic development activities.

TRIF investments will support key personnel in establishing initiative operations, to fund seed research, and to conduct outreach to prospective corporate and federal agency sponsors. The end goal will be to catalyze and support the advanced manufacturing industry in Arizona by building world-class research and development capabilities, educational and research training opportunities, and a steady stream of graduates well prepared to enter and advance the industry.

6.1.1 Brief overview of industry or area being addressed by the initiative to include benefit to Arizona

Manufacturing is an important component of any healthy economy, and the economy of Arizona is no exception. According to statistics assembled by the Arizona Commerce Authority, Arizona's total manufacturing output (contribution to State Real Gross Domestic Product) in 2014 was \$23.12 billion, or nearly 9% of the state's Real GDP. Moreover, according to the Bureau of Labor Statistics, the average wage for a manufacturing position in 2014 was \$69,054, more than 50% higher than the average wage for all positions in Arizona. These are also high economic leverage jobs; each of the state's 157,000 manufacturing jobs supported about 202,000 additional jobs.

Today, manufacturing is the third-largest private sector contributor to overall economic output in Arizona, after rental and leasing, and professional and business services. As indicated above, however, several trends indicate that the maintenance of this level of activity in the manufacturing sector will depend on robust participation in emerging innovations. This is confirmed by preliminary planning that is under way for a potential state investment in the Velocity Initiative, supported by Phoenix IDA and the Greater Phoenix Economic Council. As part of this process, interviews have been conducted with a variety of regional companies engaged in manufacturing, along with community stakeholder groups. The results indicate substantial desire for investment to increase innovation, as well as specific interest in technology areas in which ASU has already begun to build capacity. These include flexible electronics, additive manufacturing, wearable robotics, renewable energy and cybersecurity.

In addition to technical innovation, Arizona's manufacturing sector also looks to the state's universities to meet its skilled labor force needs. Existing manufacturing reaches across a broad spectrum of industries, with the largest sectors being electrical machinery, aircraft, spacecraft, machinery and optics. As of 2014, Arizona was home to more than 4,600 manufacturers, about 95% of which have fewer than 100 employees.

Employers of every size consistently express intense interest in working more closely with ASU to tailor curricula to their needs, and to develop new methods for enhancing engagement between potential employers and students during their education. The university has begun to experiment with some of these ideas at its Polytechnic campus with its iProjects program, which pairs ASU student teams and their faculty mentors with industry project sponsors to develop real world solutions to a problem faced by the company. With the Access and Workforce Development Initiative in Advanced Manufacturing, we will build on this foundation to engage more actively with industry in workforce development.

6.1.2 Discussion of mission, goals, values and vision

Several ASU programs will support the Access and Workforce Development Initiative in Advanced Manufacturing to reach the following overall goals:

- Participate as a principal team member in bids for programs under the National Network of Manufacturing Institutes program
- Develop strategic partnerships with the state's principal manufacturers with the intention of expanding this activity beyond the state's borders in future years
- Adapt existing faculty recruitment programs to supplement capacity in targeted advanced manufacturing disciplines and establish ASU research excellence in those areas
- Develop a strategic plan for engagement with federal agencies to promote the development of large-scale programs to promote national manufacturing
- Broadly engage graduate and undergraduate students across disciplines in research and development projects in advanced manufacturing to supply the well-trained workforce and thought leadership this Arizona industry needs

6.1.3 Description of programmatic investments

During the proposed TRIF investment period, we will focus on four technical areas:

- **Flexible electronics.** Over the past decade, ASU has become a global leader in the emerging field of flexible electronics. This research excellence was enabled by a ten-year, \$100 million cooperative agreement with the U.S. Army, which funded the creation of a dedicated world-class pilot manufacturing facility. The Flexible Electronics and Display Center (FEDC), based in the former Motorola Flat Panel manufacturing facility in the ASU Research Park, served as the focus of an international consortium of more than 50 companies. These companies, in collaboration with a team of ASU scientists and engineers, achieved a long record of innovation milestones that were widely reported in national and international media.

The successful results of the FEDC program are now being transitioned to prototype applications by firms in the private sector. The technology and infrastructure developed to produce these prototypes give ASU a unique capability to fabricate thin-film electronics on flexible substrates. This capability is now being used as a platform to explore emerging application areas such as the interface between biology and electronics. For example, FEDC engineers have worked with researchers at the Biodesign Institute to create novel conformable biosensors that can be wrapped around a limb to monitor patient vital signs. More advanced concepts will combine biomolecules with flexible inorganic thin-film electronics to create diagnostic devices. We anticipate that seed funding in this area can be leveraged to establish a significant research initiative.

- **Additive manufacturing.** Over the past decade, the use of software-controlled deposition tools to “print” three-dimensional objects has emerged as an important new manufacturing technique. It is employed in industries such as aerospace to build complex shapes one layer at a time, yielding parts that cannot be produced by traditional machining methods. This technology has involved coordinated developments in a number of disciplines, including materials science, mechanical engineering and computational fluid dynamics. ASU has established expertise in all of these areas, making it well positioned to participate actively in this new field. In addition, many industries already located in Arizona are exploring additive manufacturing and have expressed interest in collaborating with ASU. Together with companies like Honeywell, the university has invested in a number of advanced 3-D printing tools at the Polytechnic campus in Mesa. A strategic hiring plan is being developed to add faculty with expertise in additive manufacturing, and specialized curricula are under development in consultation with potential industry partners. TRIF funding will be used to organize these activities into a focused initiative.
- **Materials science.** Many of America’s continuing technology advances are driven by the discovery and exploitation of new properties of novel materials. For example, despite the migration of electronics manufacturing to countries in the eastern Pacific, the industry continues to source its most advanced materials technology from the U.S. ASU is well positioned to participate in this space. The university employs a number of faculty whose research interests focus on the synthesis of new materials and materials structures, on the modelling and characterization of these materials and structures, and on their integration into useful devices. In particular, the Advanced Manufacturing Initiative will seek to develop a program of research on materials interfaces and their exploitation in

near two-dimensional structures. The initiative will develop a program of research and a strategy for engaging industry and federal agency funding sources.

- **Water technologies.** ASU is establishing itself as a global leader in the study of water and sustainability issues, and we are exploring the potential application of this work in manufacturing. ASU faculty have expertise in traditional water engineering and in ancillary technologies, such as sensors and data informatics, which are of direct relevance to the use of water in manufacturing.

In addition to these technical areas, TRIF funds will also be used to support the related facilities in the following areas:

- **Nanofabrication and cleanroom.** ASU NanoFab is a flexible nano-processing facility that offers state-of-the-art device processing and characterization tools for university research and for external company prototype development. Established companies and innovative startups benefit from using this advanced facility to accelerate their prototype development. We provide the facility, equipment and resources for a full range of operations—from the wet world of biosystems and chemistry to the dry world of inorganic materials, as well as the hybrid structures in between.
- **Materials characterization and synthesis.** Capabilities include high-resolution electron microscopy, structural/chemical/optical/surface/thermal analysis, synthesis and defect analysis. These capabilities benefit the local and regional community by providing open access to world-class instruments and techniques for materials characterization to industrial partners for new product development and process engineering.

6.2 Expected outcomes as a result of TRIF investments

6.2.1 Specific and realistic goals that are clearly measurable

6.2.1.1 Return on investment

The creation of focal initiatives around sustainable manufacturing, advanced materials, flexible electronics and additive manufacturing will enable the capture of significant external funds. Based on subject-matter projections developed through a formal strategic planning exercise, ASU expects to be able to secure more than \$90 million in sponsored funding over the proposed five-year period.

6.2.1.2 Technology transfer

Adaption of smart manufacturing by businesses has ramifications across all aspects of the economy, as well as national security. Our goals in technology transfer focus on the

economic ramifications of advanced manufacturing advancements for Arizona. As examples, the semiconductor and electronics industries will undergo significant transformation as new applications are developed to embed sensors and processors into products in virtually every area, from new materials and manufacturing techniques to medical devices and other health care technologies, communications, and clean energy.

Currently, there is a global manufacturing restructuring and a resurgence of U.S.-based manufacturing, expanding and enhancing the Southwest region's capacity to take advantage of opportunities. Technology transfer, licensing and startup encouragement will renew and protect its established production base and open new avenues for growth.

6.2.1.3 Industry engagement (outreach, partnerships, collaboration)

A critical component of regional advanced manufacturing strategy is conducting an annual cycle of strategic technology gap identification in the capabilities of the existing manufacturing companies in the region. This gap identification allows the initiative to develop industrial engagements that target real needs, and to plan technology developments that enhance Arizona's competitiveness. We plan:

- \$5 million per year in public-private partnership engagements in advanced manufacturing by 2021
- A formal commercial partnerships framework with 25 partners by 2021
- Development of an external advisory council made up of industrial collaborators

6.2.1.4 Workforce contributions

ASU expects to be able to provide highly specialized educational experiences and research and development training in advanced manufacturing focus areas to more than 600 graduate and undergraduate students over the proposed five-year funding period.

6.2.1.5 Educational outreach

ASU will deliver education outreach at all levels, with a particular focus on high school and community colleges. Examples of educational outreach include but are not limited to teacher trainings, apprenticeships, conference presentations, curriculum development and dissemination, maker camps and classes and community engagement via speaking, workshops and meetings. ASU will work with community colleges across Arizona to create certificate, on-line and apprenticeship programs in advanced manufacturing that lead to jobs, four-year college and advanced degrees.

6.2.1.6 Government agency/community engagement (outreach, partnerships, collaboration)

Through the Access and Workforce Development Initiative in Advanced Manufacturing, ASU will create formal joint-effort with National Laboratories, companies and NGOs. Traditional federal funding will be secured through DoD, DOE and NIST. Additional funding will be pursued through organizations such as USAID, NIH, DTRA, and others. Collectively, we expect \$15M in Federal partnerships and \$10M in commercial partnerships by 2021.

6.2.2 Annual metrics table of expected outcomes and timeline for achievement

Expected Outcomes	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
TRIF EXPENDITURES					
Total	\$ 1,959,956	\$ 2,217,881	\$ 2,415,197	\$ 2,611,816	\$ 2,807,725
FINANCIAL IMPACT OF TRIF INVESTMENT					
Sponsored Awards	\$ 12,500,000	\$ 16,100,000	\$ 18,750,000	\$ 21,250,000	\$ 25,000,000
Gifts & Other Sources	100,000	100,000	100,000	100,000	100,000
Royalty Income	50,000	50,000	50,000	50,000	50,000
TOTAL	12,650,000	16,250,000	18,900,000	21,400,000	25,150,000
TECHNOLOGY TRANSFER ACTIVITY					
Invention Disclosures Transacted	6	8	9	10	12
US Patents Issued	1	1	1	2	2
Licenses and Options Executed	2	3	3	3	4
Startup Companies	1	1	1	1	1
WORKFORCE CONTRIBUTION					
Postdoctoral Appointees	9	11	12	13	14
Graduate Students	46	53	57	62	69
Undergraduate Students	51	58	64	69	77

6.3 Initiative structure

6.3.1 Organizational structure

A director whose purview spans engineering, design, the physical and life sciences, and STEM pedagogy will lead this new initiative. Through the first several years, the initiative will incorporate an operations lead and a program development lead, and will utilize management resources from across the institution, such as financial services, research computing and human resources. The goals for organizational structure for this initiative focus on efficiencies and lowest costs to achieve the goals of the initiative.

Each activity funded through this initiative will have a program lead who will provide expertise and oversight on project expenses, milestones and external funding opportunities. These leads will be chosen based on their expertise and ability to

manage cross-disciplinary teams and their entrepreneurial instincts and/or experience.

6.3.2 Advisory board

Primary advisory oversight of the TRIF investment in the Access and Workforce Development Initiative in Advanced Manufacturing will be assigned to the internal advisory board of the Ira A. Fulton Schools of Engineering. In addition, the board of directors for research development at ASU, composed of representatives from business, government, nonprofit and academic organizations, will actively advise the initiative on a regular basis.

6.3.3 Infrastructure

The Flexible Electronics & Displays Center (FEDC) includes fabrication clean rooms, wet/dry laboratories, and a manufacturing pilot line originally constructed for industry use. FEDC was built through \$100 million in US Army investments over 10 years and achieved its goal of delivering flexible displays to support DOD missions. In the process, FEDC produced several processes and technologies that are in testing or have been adopted by commercial entities and DOD (Figure 4.1). FEDC successfully collaborates with more than 40 industry partners and previously facilitated the commercialization of a half dozen enabling technologies for manufacturing (e.g., materials, processes, manufacturing tools, software).

FEDC is housed in the Macro Technologies Works (MTW) building, which seeks a larger scale role for ASU manufacturing research at scale and in commercial world time frames with strategic industry and government partners

6.3.4 Description of investment mechanisms

ASU faculty conduct research in a number of areas that are relevant to emerging manufacturing paradigms through a variety of corporate engagements that are currently largely uncoordinated. Under the Access and Workforce Development Initiative in Advanced Manufacturing, we will employ a formal strategic planning process to organize these existing activities into coordinated campaigns that will provide clear research opportunities for both graduate and undergraduate students.

6.4 Initiative budget table

Initiative Budget	Projected FY 17	Projected FY 18	Projected FY 19	Projected FY 20	Projected FY 21
Access and Workforce Development:	\$ 1,639,104	\$ 1,735,104	\$ 1,831,104	\$ 1,927,104	\$ 2,023,104
Advanced Manufacturing					

6.5 Plan for sustainability

6.5.1 Anticipated funding sources for ongoing support

TRIF-funded manufacturing activities will be led by faculty and staff with proven track records of successful and impactful research, industry engagement, partnership creation, company building and commercialization.

We will transition funding from TRIF to external support in the form of grant funds, contracts and public-private partnerships, with a goal of sustaining the advanced manufacturing capability at ASU at the level of \$5 million in annual expenditures by the end of FY2021.

During the five years of TRIF investment, we will work to secure external funding from Federal agencies (DOD, NASA, DOE, EPA, Department of Commerce and NSF), as well as corporations such as Intel Corporation, Raytheon, Honeywell, Boeing and Medtronics.

6.5.2 Timeline for transitioning away from TRIF support

It is anticipated that by 2021, Advanced Manufacturing at ASU will be supported by external investments, particularly partnerships with companies. TRIF investments that were used to support capital and infrastructure investment plans will have yielded sufficient capacity that companies will be willing to use ASU as a key partner in new development activities. Other revenue sources (such as formal Public-Private Partnerships) are planned for ongoing expenses.