SEEDS OF PROSPERITY

PUBLIC INVESTMENT IN SCIENCE AND TECHNOLOGY RESEARCH

A Study of the Economic Potential of Proposition 301 at Arizona State University
And a New Model for Assessing its Long-Term Value

Morrison Institute for Public Policy
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IN NOVEMBER 2000, ARIZONA VOTERS SAID "YES" TO NEW INVESTMENTS IN UNIVERSITY SCIENCE AND TECHNOLOGY RESEARCH WHEN THEY APPROVED PROPOSITION 301.

PROPOSITION 301 MONIES OFFER THE STATE AN EXTRAORDINARY OPPORTUNITY TO STRIDE AHEAD IN THE INTERNATIONAL RACE FOR BRAINPOWER, INNOVATION, AND COMPETITIVENESS.

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By Rob Melnick, Rick Heffernon, Nancy Welch, Morrison Institute for Public Policy

SEEDS OF PROSPERITY: PUBLIC INVESTMENT IN SCIENCE AND TECHNOLOGY RESEARCH

Return on investment in science and technology research will depend on Arizona becoming more competitive in developing and commercializing research, more recognized for innovation, and more attractive to knowledge workers.

EXECUTIVE SUMMARY

Nanotechnology, microscale medicine, virtual manufacturing — these rapidly expanding frontiers are proof positive that Arizona is competing in an era in which great wealth comes to those who innovate, especially in science and technology. Arizona's "traditional" industries — tourism, construction, and growth — will certainly continue to matter to the state's economy, but if we want to win our fair share of "new economy" prosperity and high-wage jobs, our economic portfolio must be reconfigured. It needs to feature brave new knowledge industries. This reconfiguration will require substantial public and private investment policies to seed new industries, as well as the patience to allow them to mature.

THE KNOWLEDGE ECONOMY: NOT BUSINESS AS USUAL

Economic development, now and in the future, will be anything but business as usual. To become more competitive and stay at the top of the knowledge economy game, Arizona must learn a new set of rules:

- Advances in science and technology will create enormous wealth, as they have done for the last half century, but changes will happen faster and faster.
- Innovation has joined natural resources, money, and people as the fourth critical ingredient for economic growth.
- Knowledge businesses will rely on universities to prepare, attract, and retain innovators and to develop new scientific products for commercialization; hence, a region's economic competitiveness increasingly will depend on the research strength and quality of its universities.

AN INVESTMENT IN SCIENCE AND TECHNOLOGY RESEARCH AT ARIZONA STATE UNIVERSITY

Approval of Proposition 301 by Arizona voters in November 2000 represented a significant step toward a new foundation for the state's economic future by providing a long-term funding stream for science and technology investments. This new sales tax enabled Arizona to create an economic development strategy appropriate for the knowledge economy.

For Fiscal Year 2002, Arizona State University used its "301" portion to complement the university's existing research base by conducting projects in six science and technology areas: biosciences/biotechnology, information science, advanced materials, manufacturing, access and workforce development, and technology transfer. Each area is linked to important knowledge economy industries and trends. These projects, however, represent only the startup phase of ASU's 301 research. Currently, the university has entered a consolidation phase that will integrate first-year research into interdisciplinary "mega-projects."

Early results from ASU's $15 million worth of projects have been positive. However, despite immediate benefits from knowledge gains, investment in scientific research typically takes decades to yield the full potential of its economic return. Thus, Arizona business, education, economic development, and government leaders who were interviewed for this analysis requested a creative set of metrics to gauge the lasting value of public investment in science and technology research.

CONNECTIONS, ATTENTION, AND TALENT TO ENHANCE ARIZONA'S COMPETITIVENESS

Seeds of Prosperity presents a new way of assessing the *long-term* economic impact of science and technology research as a supplement to the traditional annual measures the Arizona Board of Regents will track. This new paradigm — called the CAT measures — keeps "score" on science and technology research by means of:

- CONNECTIONS developed between university researchers and businesses that commercialize research.
- ATTENTION generated by university research, both locally and nationally, that helps attract investment and talent to the state.
- TALENT that Arizona recruits, retains, and develops because of its research, thereby providing the state with innovators and workers fit for the knowledge economy.

A CROSS-DISCIPLINARY FUTURE

ASU's first-year Proposition 301-funded projects provided numerous illustrations of how the CAT measures can be applied in the future to analyze the value of science and technology research. Some examples: ASU involvement in Project FORCE connected Arizona to 11 universities worldwide and to major businesses such as Advanced Microelectronics, Texas Instruments, and National Semiconductor. The Consortium for Embedded and Inter-Networking Technologies — which includes Intel, Motorola, and ASU — attracted the attention of the National Science Foundation. And ASU's Women's Health Research Forum attracted national attention to metro Phoenix's medical research, connected academics and businesspeople, and helped develop the state's research talent in this field.

For the future, Proposition 301 research activities will likely converge in even larger, more interdisciplinary collaborations that draw together research teams from many science and engineering fields. Such teams are now considered essential for producing the next generations of science and technology innovation.

THE MEASURE OF SUCCESS

Even a few years ago, Arizona's current commitment to university science and technology research could only be imagined. But Arizona is not alone in this type of investment. As every state moves aggressively to reap the rewards of the knowledge economy, Arizona leaders must remember:

- Public investment in science and technology research is a marathon, not a sprint.
- Arizona cannot rest on its laurels or claim economic victory after a few early successes in the knowledge economy — competition from other states will only increase over time.
- Return on investment in science and technology research will be a function of whether or not Arizona becomes more competitive in the development and commercialization of research, more recognized as a spawning ground for innovation, and more attractive to knowledge workers.

Attention generated by science and technology research in Arizona will help attract investment and talent to the state.

PUBLIC INVESTMENT IN SCIENCE AND TECHNOLOGY RESEARCH: PROPOSITION 301'S PROMISE FOR THE KNOWLEDGE ECONOMY

In November 2000, Arizona voters said "Yes" to new investments in university science and technology research when they approved Proposition 301, a 0.6 percent increase in state sales tax earmarked primarily for K-12 education and university research. In doing so, they demonstrated an understanding of the two most important fundamentals of today's knowledge economy:

- Research and innovation will drive Arizona's economy and prosperity.
- The ideas that lead to inventive companies and high-paying jobs come from creative people.

Since Proposition 301 went into effect, the tenets and realities of the knowledge economy have been confirmed time and again by examples both in Arizona and around the globe. Innovation has joined natural resources, people, and money as the fourth critical ingredient for economic growth. Therefore, the products and services that are likely to generate the greatest new wealth and high-wage jobs for our region and state will arise from advances in, and the convergence of, science and technology.

Arizona, however, will not be able to keep pace with national and global competition if it merely rests on its past economic laurels. Certainly tourism, construction, sunshine, and growth will remain important drivers of the state's economy for the near term. But to ensure long-term opportunity and prosperity, Arizona's portfolio must be reconfigured to feature knowledge industries.

Arizona's Technology and Research Initiative Fund

Proposition 301's approval set in motion the most substantial public investment in Arizona's economic future since the Central Arizona Project brought water to the state. For the next 20 years, this measure will provide the state's three major universities approximately $45 million annually. That funding will be dedicated to expanding cutting-edge research and education in science and technology as a means to foster sustained economic growth in Arizona. Leveraged with other public and private funding sources, Proposition 301 monies offer the state an extraordinary opportunity to stride ahead in the international race for brainpower, innovation, and competitiveness.

Passage of Proposition 301 led to the creation of the Technology and Research Initiative Fund (TRIF) as the repository for Proposition 301 sales taxes designated for universities. This fund is administered by the Arizona Board of Regents (ABOR) for the purpose of supporting university science and technology research that will nurture knowledge industries in the state. Working in conjunction with ABOR, each of the state's three public universities — Arizona State University, University of Arizona, and Northern Arizona University — selected specific research areas and support functions for its share of 301 funding.

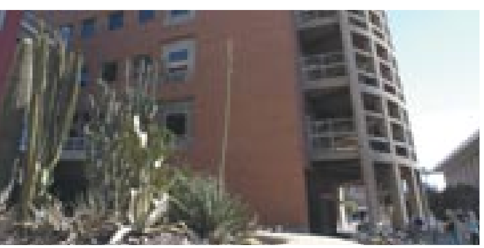
Not Business as Usual

The strategy of using university research as an economic development tool constitutes a dramatic departure from "business as usual" in Arizona. In the past, a university's economic contributions have been measured in terms of local expenditures on goods and services, and student "output" — the number and, to a lesser extent, the quality of its graduates. At the same time, public sector economic development has focused on tax incentives and the recruitment of companies, not on research investments.

Proposition 301 enhances those other economic development models with a strategy that is in tune with the basics of the knowledge economy. This new model recognizes that:

- **Universities are knowledge factories.** No other organization or institution in the state exists specifically to generate, teach, and transfer new knowledge.

- **Arizona's knowledge businesses depend on the state's universities for their future leaders and inventors.** Most graduates remain in Arizona, making state universities the primary source of the state's future knowledge workers.
- **The quality and the competitiveness of metropolitan regions increasingly stem from new economy activities at their universities.** Scholars from across the country including Richard Florida, Michael Porter, and Mary Walshok have shown that highly educated, innovative workers are attracted to regions that have excellence in higher education, reputations for abundant commercial opportunities, and people like themselves — a community of like-minded "knowledge entrepreneurs."



The promise of "301" for the state is powerful, and the first-year accomplishments have been notable as will be shown in the pages that follow. However, Arizona's leaders and voters cannot simply take on faith that the myriad of research and related activities supported by these dollars will automatically result in the desired economic impacts. The projects and initiatives must be monitored and evaluated in light of the way that economic development occurs in the knowledge economy.

Arizona State University and Proposition 301

This report covers the startup phase for ASU's 301-funded endeavors (Fiscal Year 2001-2002). Currently, ASU has entered a consolidation phase in which the university is integrating first-year efforts into large-scale interdisciplinary "mega-projects." (For more on this consolidation, see "Heading Into the Future" on page 37.)

To complement its existing expertise in scientific research, ASU proposed to apply first-year monies from the Technology and Research Initiative Fund to initiate or strengthen programs in six major areas:

- Biosciences/Biotechnology
- Information Science
- Advanced Materials
- Manufacturing
- Access and Workforce Development
- Technology Transfer

These initiatives were allocated $15.6 million in FY 2002.

The primary purpose of this report is to put the economic contributions of Arizona State University's TRIF research into context. It does *not* cover other uses of Proposition 301 monies at ASU — such as funds allocated for capital projects at ASU East and West — nor does it provide a cost-benefit analysis of all 301 dollars allocated to ASU. Instead, this report provides data on FY 2002 results for the first-year initiatives and presents a blueprint for long-term evaluation that augments the Arizona Board of Regents' oversight process.

From the outset, the Arizona Board of Regents recognized the need to hold universities accountable for expenditures and results. Before it could receive TRIF monies, each university had to present a set of goals and output measures for the activities it wanted to fund. Results for these "deliverables" will be collected and reviewed annually by ABOR to track progress.

Some of the ABOR-approved measures describe important aspects of economic impact, such as grants and patents. For example, if a TRIF activity enables a university to win a federal grant, that money will most likely be spent in Arizona. This is a classic example of "importing" wealth or "exporting" product, and is certainly a desirable way to grow the state's economy. Likewise, the patenting or licensing of a new product or process that results from a 301 research project can also produce an economic development impact.

However, the ABOR measures do not tell the whole story. They primarily count things rather than assess their value. And, as annual "snapshots," they are not designed to capture the nuances of the knowledge economy or the long view. But leading economic development practitioners and scholars caution us that creation of wealth in the 21st century will depend on taking this long view, primarily because prosperity will be based on sustained investment in developing talent, generating knowledge, and commercializing research. Moreover, experts emphasize that these factors must "work" and "think" together if they are going to profoundly affect local and regional economies.

Clearly then, the returns from TRIF activities cannot be analyzed as one would judge the effects of other public spending for economic development. To measure the value of a tourism promotion, for example, it would be appropriate to count how many people visited Arizona in a year as a result of a certain advertising campaign, and how much they spent. But this type of counting would not adequately measure the value provided by scientific research in Arizona. Discoveries made today may not reach commercial application for years to come, yet their implications could resonate for decades.

The complexity of analyzing the full economic impact of Proposition 301 research is clear to many of the state's leaders. People interviewed for this evaluation — leading Arizona policymakers, CEOs, media executives, and university officials — acknowledged the need to track ABOR's accountability measures, but they also emphasized the importance of supplementing these conventional measures with new types of assessment tools.

What this means is that evaluating 301-driven economic impacts over the next two decades will require fresh thinking. The impact of research on the state's pool of knowledge workers cannot be determined simply by tracking university graduation rates. Nor can the value of research be judged by the number of patents filed every year — commercial adoption of newly patented products and processes depends on their appeal to entrepreneurs and venture capitalists. Thus, the economic impact of Arizona's 301 investments will have to be assessed in relation to a variety of interrelated factors.

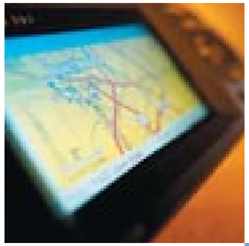
As San Diego expert Mary Walshok says, "Economic development in knowledge-driven economies arises out of a confluence of technical, sociological, economic, and political forces."[1] The report that follows takes all of those forces into account to help Arizona's leaders and voters understand the nature and potential economic impact of ASU's six TRIF initiatives.

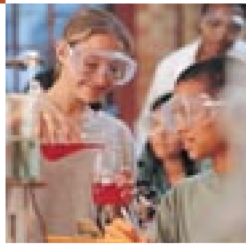
Guide for a New Journey

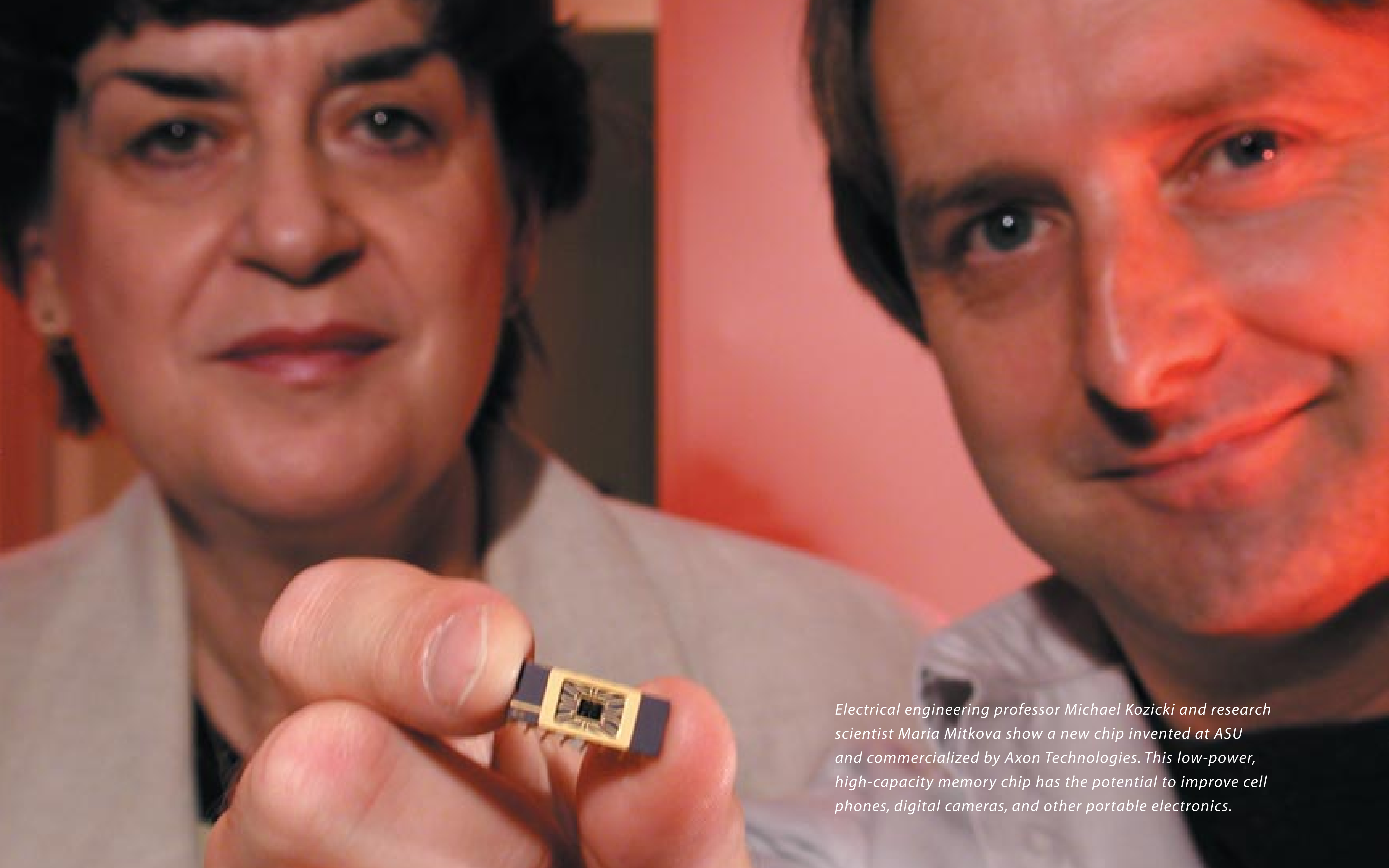
Author Douglas Adams' imaginary *Hitchhiker's Guide to the Galaxy* steered countless readers through extraordinary worlds and unusual situations. Because ASU's real-life, right-now TRIF activities may seem as incredible as science fiction to many readers, this report provides a guide to the research and ideas at the heart of the six initiatives.

The report's next section presents the economic context for each of ASU's research initiatives, explaining in lay terms what this science and technology is about and providing examples of potential commercial applications. The third section describes each of the six initiatives and their goals, and reassembles the ABOR data in new categories, displaying the initiatives side-by-side for better comparison. The report's fourth section presents another way of thinking about, and ultimately measuring, the economic value of TRIF research in consideration of how the knowledge economy works. It also provides several examples from ASU to help illustrate how research creates products, affects people, and relates to the world beyond the university. And the fifth section of the report plots the "trajectory" of ASU's six initiatives to let Arizonans know how each research area is expected to develop over time.

It may seem extravagant to refer to the Proposition 301 initiatives as a journey into new worlds, but it is accurate. By providing an opportunity for the state's best scientists and students to work together on tomorrow's products — and supplying them with new resources, clear directives, and enlightened oversight — Arizona is on a path that a few years ago could only be imagined. From such a path, the next transforming technology or visionary business leader could emerge in Arizona. With that prospect a real possibility, no journey is likely to be more important for this state.







Electrical engineering professor Michael Kozicki and research scientist Maria Mitkova show a new chip invented at ASU and commercialized by Axon Technologies. This low-power, high-capacity memory chip has the potential to improve cell phones, digital cameras, and other portable electronics.

THE ECONOMIC CONTEXT: ASU'S RESEARCH IN PERSPECTIVE

ASU's six TRIF initiatives do not stand alone. Four of the initiatives — Biosciences/Biotechnology, Information Science, Advanced Materials, and Manufacturing — carve out promising niches in much larger research and development ventures. Two others — Access and Workforce Development, and Technology Transfer — provide support functions for science and technology research. To put each of the projects in perspective, the following six accounts briefly describe the economic context for Proposition 301-sponsored activities in bioindustry, information technology, nanotechnology, modern manufacturing, workforce development, and university technology transfer.

BIOINDUSTRY: PRODUCTS AND POTENTIAL

The companies that comprise bioindustry utilize breakthroughs from bioscience research and transform them into commercially viable products, such as cancer fighting drugs, oil-devouring microbes, or brain-scanning imagers. Often referred to as biotech, life sciences, or simply "bio," this industry encompasses a broad array of disciplines that increasingly have become interrelated. For example, it includes aspects of biology, chemistry, medicine, and agriculture, among others. Definitions of the current categories and terms used to describe bio activities remain elastic as the industry continues to expand at a brisk pace, but most research and product development occur within two main arenas: 1) biotechnology and life sciences, and 2) medical devices and other biotech-related advanced equipment.

Products of Biotechnology and Life Sciences

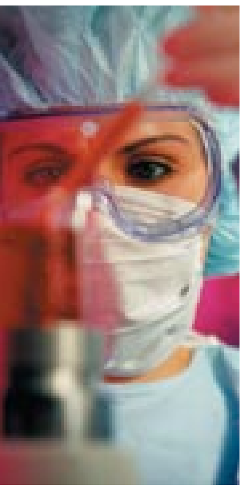
Research in biotechnology and life sciences focuses on using biological molecules, genetic material, and manipulated cells to produce new types of products for medicine, agriculture, and an expanding number of diverse industries such as forensics, environmental remediation, and biomanufacturing. Some examples of the many products in use or under development include:

- Diagnostics, such as genetic coding, that will customize cancer treatments for individual patients.
- Drugs and vaccines to treat infectious diseases such as AIDS, hepatitis, anthrax, and cholera.
- Genetically altered plants and animals that can grow faster, resist diseases, provide more nutrition, or produce drugs and vaccines to treat human maladies.
- Enzymes, biological agents, and cultured microorganisms that neutralize hazardous waste, manufacture pharmaceuticals, or refine valuable minerals from low-grade ores and waste materials.
- Tissues that can be grown to create replacement blood vessels, bones, nerve cells, skin, and other organs.

Types of Medical Devices and Advanced Biotech-Related Equipment

Medical devices include instruments, machines, implants, and other equipment used to diagnose or treat disease, loss of function, and other conditions. Advanced biotech-related equipment consists primarily of computerized laboratory devices used by biotech researchers. Among the many devices and equipment in use or under development are:

- Implantable devices such as cardiac pacemakers, mechanical hearts, and cochlear or ocular implants.
- Microscale diagnostic devices and probes that can run multiple tests from a pinprick of blood.
- Implantable sensors and telemetry, such as nanoscale "labs on a chip" or pill-sized video cameras that can be swallowed, implanted, or injected into the blood stream for minimally invasive monitoring of chronic conditions such as heart disease, epilepsy, and diabetes.
- Programmable devices on or in the body that can respond to biosensors or other commands to deliver precise amounts of drugs, stimulate optic or auditory nerves, or control muscles and artificial limbs.
- Laboratory apparatus such as automated DNA sequencers, cell sorters, and molecule synthesizers.



The Potential of Bioindustry

The United States is considered a world leader in bioscience products and, accordingly, its bioindustry cluster has grown rapidly. Recent reports have concluded that the U.S. biotechnology sector alone more than doubled in size from 1993 to 1999. As of 2001, the industry consisted of nearly 2,000 companies that produced $39 billion in revenues and directly employed 157,000 people. The momentum of bioindustry is clearly building.

Biomedical research investment has increased sevenfold since 1985 and patents have increased tenfold. With a strong aging trend evident among the U.S. population, and a concomitant increase in demand for health care and related products, the industry's growth is likely to continue for the foreseeable future.

Research and development has always been key to driving innovation in bioindustry due to the unusually close linkages that exist between university-based research and private sector commercialization of new products. By far the greatest amount of funding for bioresearch comes from federal government sources — particularly the National Institutes of Health (NIH), which has been slated to receive $27 billion for FY 2003, a 15.7 percent increase over FY 2002. Among the areas targeted for increases in NIH research funding are bioterrorism, cancer, diabetes, allergy and infectious diseases, minority health, Parkinson's disease, and Alzheimer's disease.

Federal research funding typically flows to regions that already boast strong research talent, infrastructure, and facilities. Higher local investment, therefore, tends to lead to higher growth in federal funding. Historically, the Greater Phoenix area has made a large investment in clinical facilities related to health care, but a relatively small investment in the type of research facilities that attract federal grants. Consequently, the Greater Phoenix area receives a much lower level of federal research funding for bio than would be expected for its size — considerably less, for example, than metropolitan Boston or Minneapolis. ■

INFORMATION TECHNOLOGY: SIGNIFICANCE TO THE NEW ECONOMY

Over the last decade, the U.S. economy has experienced a profound transformation in the way business is transacted — moving, for example, from handwritten factory orders to intelligent digital supply networks. At the heart of this transformation has been the explosive growth of information technology (IT), which has permeated almost every facet of daily life. The rise of IT has changed how people communicate with each other, conduct research, design new products, engage in commerce, and teach the next generation. In coming decades, information technology is likely to produce an even greater impact on the economy as advances and new discoveries continue to accelerate change.

IT Products and Processes

Information technology encompasses the development and management of computer hardware, computer software, and related services. The primary purpose of IT is to turn massive volumes of data into useful, accessible information. Today, IT is most prominently embodied by the nearly ubiquitous personal computers found in homes, offices, and shirt pockets across the country, as well as by the application software that allows computer users to create and work with word processing documents, spreadsheets, and graphics files.

Information technology, however, also includes other fields. Notable among these is embedded technology, the design of tiny, low-power computers-on-a-chip that, along with their dedicated software, make just about every new appliance and electronic device "smart." Embedded computers now run cellular telephones, refrigerators, digital cameras, toasters, GPS units, and air conditioners, to name a few. New automobiles contain up to 35 embedded computers.

Bioinformatics forms yet another branch of information technology. It has developed at the nexus of computer science and biology. This rapidly growing field is the result of recent trends in biotechnology — such as the study of the human genome — that are beginning to generate vast amounts of data for describing complex organisms and their processes. The purpose of bioinformatics is to develop the new tools necessary for archiving and annotating this data so that it can be accessible and meaningful to scientists.

Due to the effects of "digital convergence," information technology has also become increasingly linked with telecommunications. One example of digital convergence is the routine use of telecom networks — for example, cable, telephone, and wireless — to connect IT products such as personal computers and servers via the Internet. This cross of different technologies has recently become one of the main consumer interests driving sales for both sectors. It is leading to a new generation of hand-held devices with multiple functions built in that will seamlessly bridge the divide between IT and telecom by placing telephone calls, surfing the Internet, fixing a GPS reading, recording digital images, sending e-mail, and maintaining a personal calendar. The result is that recent economic descriptions have begun to refer to IT and telecom as the "information and communications technology" industry, or ICT.

Economic Impacts

Whether categorized as IT or ICT, this industry plays a major role in both the world and domestic economy. The U.S. currently ranks first in the world for producing information and communications technology products and services, and is also one of the world leaders for spending on ICT with a total of approximately $762 billion in 1999 — about 35 percent of the global market. Among all industry sectors, financial services is the largest consumer of information technology ($70 billion in 1999) followed by communications services, manufacturing, wholesale, and business services. IT also ranks as the largest export sector in the U.S., with a 29 percent share of the market.

IT has had a powerful impact on U.S. job and economic growth in the last decade. While comprising only 8 percent of the total economy, the IT sector accounted for almost 30 percent of real growth in the country's GDP from 1994 to 2000. Furthermore, several studies show that IT was responsible for half to three-quarters of the acceleration in productivity growth between the early 1990s and the late 1990s. All told, approximately 10 million people in the U.S. are employed in IT jobs, many of them working for companies engaged in business outside the IT industry, such as financial services and manufacturing. In Arizona, IT accounted for approximately 4,000 business establishments in 1999 that directly employed over 100,000 workers. Adding in all IT-related jobs at non-IT businesses, the number of Arizona IT workers would easily exceed 150,000. ■

ADVANCED MATERIALS: THE PROMISE OF NANOTECHNOLOGY

The latest big trend in materials research is to think small — very, very small. In this tiny world, red blood cells loom as large as stadiums and individual carbon atoms seem to be the size of baseballs. That is the realm of nanotechnology, a world where things are measured in billionths of a meter — a nanometer — and where the main building blocks of advanced materials are small collections of atoms. This will be the future: a world of "small tech."

Working directly with individual atoms is a relatively new skill for humans, but it is an age-old "technology" for nature. Over billions of years, nature has employed enzymes and catalysts to organize different kinds of atoms into organic molecules and other complex microscopic structures that make life possible. These natural products can have impressive capabilities, such as the power to harvest solar energy, convert minerals and water into living cells, and store massive amounts of memory in both nerve cells and DNA proteins.

Scientists, however, have only recently devised tools that allow them to see the surfaces of atoms and manipulate them directly. This has occurred due to significant advances in electron microscopy and scanning probes over the last two decades. As nanotech tools become ever more precise and powerful in the future, scientists expect to develop atomic-level processes that will fundamentally change the way advanced materials are created, affecting everything from medicine to aerospace to computing. Already, a nanoscale "molecular" computer circuit has been demonstrated that is two or three orders of magnitude smaller than the most sophisticated computer chips currently in production. And while this chip remains invisible to the naked eye, it nevertheless was hailed as the biggest breakthrough of the year for 2001 by the prestigious journal *Science*.

Why Nanotechnology?

Using the processes of nanotechnology, basic industrial production is expected to veer dramatically from the course of the past. Raw materials will come from the atoms of abundant substances such as carbon, hydrogen, or silicon. These atoms will be manipulated into precise configurations to create new materials that exhibit exactly the right properties for each application. Carbon atoms, for example, could be bonded in a number of different geometries that create a fiber, a tube, a molecular coating, or a wire, all with the superior strength-to-weight ratio of diamonds. Moreover, this material processing will not require smokestacks, power-hungry industrial machinery, or intensive human labor, but instead may be accomplished either by "growing" new structures through some combination of chemical catalysts and synthetic enzymes, or by building them through new techniques based on self-assembly of nanoscale materials into useful predetermined designs. In theory, nanotechnology will allow people to fabricate almost any type of material or product allowable under the laws of physics.

Products Now and for the Future

The potential impact of nanotechnology processes and products is expected to be far-reaching, affecting nearly every conceivable electronic component, energy source, agricultural product, medical device, pharmaceutical, and material used in manufacturing. Already, a number of nanomaterial-enhanced products are on the market and growing in use. Nanomaterials woven into fabrics give clothing resistance to stains. Nanopowders of titanium dioxide help sunscreens invisibly reflect ultraviolet light. Nanocrystals of silver embedded in bandages kill bacteria and prevent infection. Nanoparticles of clay added to plastic make it possible for brewing companies to bottle beer in plastic containers. And nanopigments used in computer printers produce brighter images on paper.

In addition to existing products, scientists envision a vast number of world-changing devices and materials for the future. Among them:

- Microscopic machines that can be implanted in the body to restore sight, hunt down cancer cells, or release drugs to treat life-threatening diseases.
- Catalytic filtration systems that will remove and neutralize any toxins contaminating water and air.
- Solar cells as cheap as wrapping paper that will reduce our dependency on fossil fuels.
- Super-conducting cables that will transmit energy with near-zero losses.
- Microscopic memory storage devices that can store millions of gigabytes of data.
- Diamond-fiber airplane hulls impregnated with nano-sensors and micro-actuators that will make it possible to produce a Boeing 747-size airplane at one-fiftieth the weight and with features such as the ability to maneuver without flaps, and the capacity to detect, report, and even "heal" structural defects.

Economic Prospects

Many public and private entities see vast potential in the enterprises that could spin off from nanotechnology research. Japan and Europe have been investing heavily in nanotech and its potential applications in microscale systems for several years in order to position themselves for the global economy of the 21st century. In the U.S., federal funding for nanotech research has been rising of late, from $116 million in 1997 to over $600 million in 2002 — a fivefold increase. Most of the research activity typically clusters around strong research institutions and the region's related private sector companies. *Small Times* magazine recently ranked the top six regions for nanotech and microtech R&D as Silicon Valley, Southern California, Boston, New York-New Jersey area, Dallas-Houston-Austin, and Chicago. Other places to watch according to the magazine were Albuquerque, Michigan, New York state, Ohio, North Carolina, and Washington.

Currently, nanotech businesses produce an estimated $45.5 billion in annual sales, according to an industry group. This group also predicts sales to reach $700 billion by 2008. A National Science Foundation study, meanwhile, forecasts the nanotech market to reach $1 trillion by 2015.

MODERN MANUFACTURING: IMPACT ON U.S. ECONOMIC GROWTH

During the 1990s, the U.S. enjoyed unprecedented economic growth and prosperity. A primary force behind that growth was America's retooled and technology-wise manufacturing industry, which grew rapidly during that period. Overall, manufacturing accounted for the largest portion of GDP growth from 1992 to 1997 — contributing a 29 percent share compared to 19 percent and 16 percent respectively for services and retail, the next closest sectors. Manufacturing also posted substantial productivity gains during the late 1990s — more than twice the gains for all other nonfarm industries. In addition, manufacturing continues to rank as one of the country's largest employers and producers, with 20 million workers and a total contribution of $1.5 trillion annually to GDP.

Components of Manufacturing

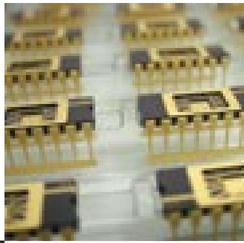
Manufacturing is a broadly diversified industry comprised of two main categories: 1) "durable goods," such as lumber products, electronic equipment, and motor vehicles, and 2) "nondurable goods," such as food products, textiles, and chemicals. While the majority of businesses involved in manufacturing appear to be "old economy" in nature, manufacturers as a group actually spend more on cutting-edge information technology and Internet capabilities than any other industry sector. This technology bent has allowed them in recent years to become more productive and competitive in the global market.

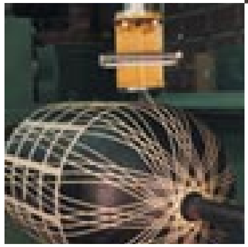
One measure of manufacturing's technology emphasis is its commitment to research and development (R&D). Currently, manufacturing supplies more than 70 percent of all private R&D dollars in the country, and more than half of all R&D spending inclusive of government sources. The fruits of that research often spill over into other areas of the economy, such that manufacturing acts as the de facto provider of new technology for many sectors, particularly retail, services, government, and finance. For example, the technology behind banking's ATM machines was originally developed for use in equipment on the factory floor. In addition, manufacturing's creation of new materials, chemicals, and electronic sensors often translates into new products and applications for health care facilities, public utilities, motion picture producers, government offices, and many others, including private households. Furthermore, American high tech manufacturers — such as Intel, Motorola, and IBM — directly produce the multitude of advanced tools and products that are currently fueling the information age and driving continued long-term economic growth.

Trends in Modern Manufacturing

The look of a modern manufacturing firm has changed radically in the last decade. On the leading edge of this corporate makeover are companies like Cisco Systems, the top manufacturer of components and systems for the Internet. With a relatively small employee base and no factories in its inventory, Cisco relies on a "virtual" manufacturing division of independent, Internet-connected partners — a total of 37 different entities in 2000. These strategic partners coordinate with Cisco to make all of the company's components and also to complete the majority of final assembly work. The result is that more than half of Cisco's product line ships directly to the customer having never been touched or inspected by a Cisco employee.

Even major old economy manufacturers have taken up new strategies similar to Cisco's. Increasingly, they are employing a network of "horizontally integrated" suppliers (*i.e.*, independent manufacturing partners) rather than maintaining a "vertically integrated" supply chain consisting only of wholly-owned subsidiaries. The difference is that horizontal integration promises to reduce risk and streamline employment for the lead manufacturer, while allowing each partner in the supply chain to concentrate on its core competencies. All this can save money. But hidden "interoperability costs" — the price in time and money for figuring out how to securely transmit design specifications, inventory data, and other essential information across a multitude of proprietary computer systems at independent supply partners — can take a big bite out of this savings. A 1999 study, for example, calculated interoperability costs in the U.S. auto industry to be in excess of $1 billion annually. Because of the cross-cutting nature of this problem, many analysts argue that a single, standardized technology infrastructure is needed that can securely transmit sensitive data at all levels of the supply chain across all industries.





Factory and supply network management has changed dramatically in the information age. Advances in telecommunications and networking now allow corporate executives sitting at their computers at corporate headquarters to look at the real-time flow of raw materials and rate of factory production occurring at any number of subsidiary or partner installations half a world away. With good information and the right tools for decision-making, these executives should be able to fine tune manufacturing supplies and outputs to closely match incoming orders. In this way they could achieve "just in time" delivery of products to customers, thereby eliminating inventory costs and reducing risk that products will become obsolete before they are sold. This is a major consideration. If such strategies had been perfected in 2001, the semiconductor industry might not have had to write off an estimated $18 billion in unwanted inventory.

WORKFORCE: TRENDS FOR THE NEW ECONOMY

The nature of work in America has undergone a dramatic change in the last two decades. With both the Internet and information technology (IT) driving global business, firms across the spectrum have turned to innovative uses of digital technology to stay competitive. In this economic climate, most of industry's better-paid workers are now assumed to be computer literate, whether they are engaged in traditional high tech jobs in engineering, science, or computers, or whether they are involved in non-IT fields such as law, education, or health care. In the future, nearly all college graduates will need to possess some IT skills in order to function in their chosen careers. Making sure that current and future workers are up-to-date on their skills is one of the missions of public universities.

Forecasts for Growth

The U.S. civilian labor force is projected to grow by 17 million jobs in the first decade of the 21st century, reaching a total of 158 million in 2010. While certain low-skill, low-pay sectors are expected to hold large shares of overall employment, the *fastest growing* occupations will be those that demand greater skills and education — and also tend to be among the most high-paying. Job categories that usually involve a college degree, for example, are projected to account for 42 percent of new job growth between 2000 and 2010, while professional occupations overall are expected to add the most new jobs to the economy — about 7 million. In Arizona, a similar trend is anticipated. Among those occupations forecast to experience rapid growth for the period 1998 to 2008, the top four are computer-related: computer scientists, computer support specialists, computer engineers, and systems analysts. Moreover, the top paying occupations in Arizona — such as physicians, lawyers, engineers, and top executives — all increasingly need IT skills to perform their functions.

IT Skills Required Throughout the Economy

High tech firms currently have the greatest concentration of formally trained IT personnel (*e.g.*, computer scientists and systems analysts). The highest overall demand for these workers, however, comes from non-IT firms with fewer than 100 employees — the same small firms that also report the most difficulty in finding qualified, skilled candidates to fill their positions. According to employers of IT workers, the three most important skills they look for in new employees are knowledge relevant to the position, hands-on experience, and good *nontechnical* skills such as communication, problem-solving, analysis, and the ability to learn quickly. In many cases, a strong business background is as important as strong technical skill.

Looking forward, most observers agree that solid IT literacy will be a requirement for almost every profession. Already this is coming true: most office workers and professionals interact with computers on a daily basis, police officers routinely carry laptop computers and other digital equipment in their patrol vehicles, medical technicians work with sophisticated computer imaging systems and other computer-based diagnostics, warehouse workers keep detailed digital databases on computer to track supplies and shipments, and many factory workers operate digitally controlled tools and testing equipment. These are just to name a few.

Moreover, not all IT jobs — such as help desk positions and web site maintenance — are currently filled by workers who have formal IT education. In many companies it is common for these positions to be handled by secretaries and clerical staff who have shown an aptitude for computers or application software and have demonstrated good communication skills. Even in most person-to-person "helping" professions — such as health care, social work, and counseling — computers and the Internet are frequently employed to document case work, research problems and treatment, and communicate with colleagues. Thus, the technical sophistication of the American workforce is an economy-wide competitiveness issue.

It is also a career-long issue. Most workers of the future will need to retrain and reposition themselves for new career tracks several times during their lives. To accomplish this they will need access to a variety of college degree and non-degree programs that feature cutting-edge information, convenient modes of delivery, and expedient time to completion of coursework.

TECHNOLOGY TRANSFER: THE VALUE OF UNIVERSITY RESEARCH

World War II's Manhattan Project demonstrated the national importance of universities in providing science and engineering expertise. Since that time, federal funding has played an integral role in supporting basic research at many of the country's top universities. This funding has spawned many new innovations and scholarly papers through the years, but until the 1980s relatively few research results were developed commercially. Two main reasons account for this lack of technology transfer. First, businesses viewed the discoveries from basic research as too "early stage" and risky to develop on their own; second, research universities were discouraged from developing these discoveries themselves because existing federal and state laws prevented them from profiting on new inventions that evolved out of federally funded research.

Passage of the Bayh-Dole Act in 1980 eliminated major federal impediments to technology transfer. It allowed universities to file and retain patent rights to their inventions, enter into exclusive licensing agreements with businesses, and collaborate with industry to promote commercialization of university innovations. As a result, patents issued to U.S. universities jumped from fewer than 250 per year prior to Bayh-Dole to more than 3,200 in FY 2000.

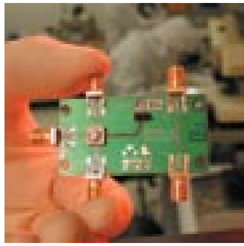
Currently, most federal research dollars for universities flow through such agencies as the Department of Defense, the National Institutes of Health, NASA, the Department of Energy, the National Science Foundation, and the Department of Agriculture. Other sources of sponsored university research include state and local governments, private industry, nonprofit organizations, and individuals. For FY 2000, more than $25 billion were allocated to sponsored research at U.S. universities, according to the Association of University Technology Managers (AUTM).

Tech Transfer Activity

More than 200 universities in the United States currently engage in the formal promotion of technology transfer. They do so for a number of reasons, including to:

- Expedite development of new innovations for the public good
- Reward, retain, and recruit faculty
- Develop closer ties with industry
- Generate income for the university
- Promote economic growth

Technology transfer activity and revenues tend to rise as the level of sponsored research rises. According to recent surveys, the range of sponsored research funding varies widely across the U.S., from $2.1 billion for the combined University of California system down to $1.8 million for the University of Northern Iowa. For 2000, Arizona State University received $67 million in sponsored research funding, which ranked it 96th out of 142 reporting universities.



One of the main goals of tech transfer offices at public universities is to link technology transfer activities with local and state economic development efforts. Overall, technology transfer annually accounts for more than $40 billion in economic activity that supports an estimated 280,000 jobs in the U.S. and Canada. One university alone — MIT — holds more than 1,000 U.S. patents, which generated over $30 million in licensing revenues for FY 2000. MIT also spun off 31 new startup companies in FY 2000.

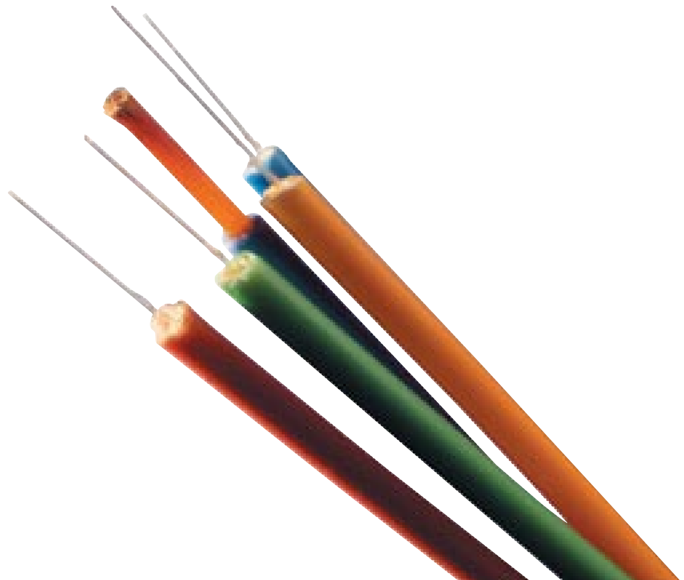
ASU student Minerva Romero is a senior studying biology and physiology. She expects to pursue a career as a doctor after graduation.

ASU'S TECHNOLOGY AND RESEARCH INITIATIVES: STARTING POINTS AND STEPS AHEAD

The Arizona Board of Regents approved six distinct initiatives for Arizona State University — Biosciences/Biotechnology, Information Science, Advanced Materials, Manufacturing, Access and Workforce Development, and Technology Transfer. These six comprise the vast majority of Proposition 301 funding for the university, and they are the sole subject of this analysis.

Each initiative was launched during FY 2002, which began July 1, 2001 and ended June 30, 2002. Two sets of tables on the following pages describe the initiatives and their results during FY 2002:

- **Starting Points** presents the description, goals, and monetary allocation for each initiative. These starting points are particularly important because they were used to track whether the ABOR-approved first-year outcomes were achieved, and also to develop an evaluation framework for future years.
- **Steps Ahead** shows the major results and accomplishments during the first year of the two-decade-long journey. These are summarized under five headings: new hires, new money, new ventures, new programs, and new skills.



ASU's six major program areas under Proposition 301:

Biosciences/ Biotechnology

Information Science

Advanced Materials

Manufacturing

Access & Workforce Development

Technology Transfer

STARTING POINTS

Each initiative embarked with specific goals and objectives that guided their activities, results, and accomplishments. Descriptions of each initiative and their starting points are summarized in the following two tables.

2002 DESCRIPTION

BIOSCIENCES/ BIOTECHNOLOGY Allocated FY02: $6,876,400 Spent FY02: $3,406,400*	INFORMATION SCIENCE Allocated FY02: $4,031,500 Spent FY02: $1,487,600*	ADVANCED MATERIALS Allocated FY02: $1,512,900 Spent FY02: $1,242,300*	MANUFACTURING Allocated FY02: $479,200 Spent FY02: $133,200*	ACCESS & WORKFORCE DEVELOPMENT Allocated FY02: $2,200,000 Spent FY02: $1,050,200*	TECHNOLOGY TRANSFER Allocated FY02: $500,000 Spent FY02: $335,700*
ASU will expand its interests in integrative biomedical research with basic and applied research in five thematic areas: medical bioengineering, pharmaceuticals and nutraceuticals, stress and disease prevention, genomics and genomic medicine, and health policy and public health. This initiative will link 301-funded projects and other research to develop a biomedical research program with the Arizona Biomedical Institute (AzBio) as its centerpiece. AzBio expects to help make metropolitan Phoenix competitive in the biotechnology industry.	ASU will use basic, interdisciplinary, and applied research as well as workforce development to connect with the public and private sectors for advances in embedded and networked systems, knowledge systems, wireless technologies, and multimedia systems. This initiative also will support the information technology needs of other ASU initiatives. Fundamental knowledge in information technology and leading-edge "embedded" systems and microcomputers will make many types of devices "smarter." Research on knowledge networks, wireless connectivity, multimedia, and bioinformatics will result in new products and stimulate formation of new companies, attract new industries, and retain and expand established firms.	ASU will extend its participation in nanotechnology research for advances in microscale and nanoscale systems by integrating physical, molecular, materials, and biological sciences with engineering. Interdisciplinary research will produce revolutionary nanoengineered devices including many types of sensors, semiconductors, and memory devices. Linkages will be made with private firms for research and, ultimately, commercialization of new applications in industries such as health care, threat detection, transportation, processing, and manufacturing.	ASU will enhance its capacity for manufacturing research in the semiconductor field and other industries by working with academic and industry partners to develop a research agenda for high tech manufacturing supply networks. Research on supply networks will enhance the efficiency and effectiveness of Arizona's many existing high technology manufacturers, especially in semiconductors and related components. Improvements are anticipated in capacity, production speed, and profitability of private sector manufacturers and their supply networks.	ASU will help ensure that its students and all Arizonans have skills to prosper in and enhance the state's knowledge economy. Access and Workforce Development seeks to extend tech skills among students in all disciplines, increase the number of teachers and learners in math, science, and technology fields, and raise retention and graduation rates. Projects include infusing technology across the curriculum, enhancing ASU's e-learning and distance education programs, extending pre-service and in-service work with secondary math and science teachers, supporting an applied computing degree, and partnering with private sector firms to develop a microelectronics "teaching factory."	ASU will further its tech transfer program through technology marketing, licensing, and business development and planning. This initiative will integrate technology transfer with local economic development. The initiative will increase the speed with which ASU can market new developments in science and technology, including 301-funded research and other research from throughout the university. Activities cover patent licensing, liaison to entrepreneurs, business development, and integration of tech transfer with the full range of public economic development efforts.

Source: Morrison Institute for Public Policy, 2003.

Data: Arizona State University report: *Prop 301/Technology & Research Initiative Fund* – FY 2002 Results, July 2002.

* Due to the startup status of the six initiatives, not all allocated funding was spent by the end of FY 2002. The residual remained as a carry-forward, consistent with ABOR policy.

2002 MAJOR GOALS

BIOSCIENCES/ BIOTECHNOLOGY	INFORMATION SCIENCE	ADVANCED MATERIALS	MANUFACTURING	ACCESS & WORKFORCE DEVELOPMENT	TECHNOLOGY TRANSFER
Advance breakthroughs in biomedicine and target high priority biomedical specialties with significant promise for future development. Strengthen the Arizona bio industry. Focus research in areas with long-term collaborative potential in current and emerging priority areas for the National Institutes of Health, National Science Foundation, other federal agencies, and possible research partners. Combine research efforts between departments and colleges at ASU and the outside medical community. Establish and strengthen partnerships with institutions in the Phoenix area through shared facilities and joint faculty appointments. Develop state-of-the-art laboratory facilities through new equipment and multidisciplinary core facilities. Identify and develop technology transfer opportunities for all major biosciences/ biotechnology programs. Recruit and hire faculty in areas targeted by AzBio.	Equip ASU to partner with technology users in Arizona, including the computer hardware, software, and IT industries. Establish ASU as a partner in leading-edge research by creating collaborative partnerships with technology companies. Expand the supply of graduates qualified to work in Arizona's computing industries by providing opportunities for students to interact with employers and engage in research and leadership development activities. Enhance the value of undergraduate and graduate programs for the software, information science, knowledge systems, and e-commerce industries. Provide internationally recognized research to attract a larger proportion of computer hardware, software, and network technology R&D to Arizona. Attract nationally competitive research faculty for embedded systems, bioinformatics, and knowledge systems. Establish interdisciplinary faculty research teams where ASU strengths align with national needs and research agendas. Attract $2 million in external funding. Establish 20 student internships in embedded tech and software. Develop and pilot a high school software engineering course with at least 25 students.	Expand external funding in nanotechnology and wide bandgap semiconductors. Develop new nanosystems for high value-added applications and transfer to the commercial sector. Engage science and engineering students in nanotechnology and materials research. Provide state-of-the-art equipment and upgrades for interdisciplinary use. Acquire staff for joint use facilities. Attract $3 million in external funds for specific initiative areas. Bring in 10 new graduate students. Provide 12 undergraduates with research experience. Develop 3 new external partnerships. Hire at least 1 interdisciplinary faculty member. Enhance interdisciplinary collaborative research between departments and across colleges.	Submit major proposal to the National Science Foundation for research in semiconductor manufacturing operations. Create research agenda for high technology manufacturing supply networks. Identify and generate external research funds. Assess needs in the manufacturing curricula for undergraduates and graduates. Establish 10 undergraduate student internships in high technology firms. Establish a test bed for a laboratory in high technology manufacturing supply research.	Strengthen technology support for undergraduate and graduate instruction. Conduct faculty and support staff searches. Fund classrooms and laboratories to support technology-enhanced instruction. Identify new e-learning programs to be developed. Develop strategies for improved recruitment, training, and retention of secondary school math and science teachers. Host a conference for college and university faculty responsible for science, math, engineering, and technology disciplines. Support development of an applied computing B.S. program at ASU West. Partner with Intel and Motorola on a microelectronics teaching factory at ASU East.	Encourage more invention disclosures among ASU researchers. Increase evaluation of discoveries for technical viability and commercial potential. Invest in selected inventions with commercial potential. Assist ASU start-up companies with business plans. Increase awareness among Arizona's private sector of investment and technology transfer opportunities at ASU. Create a campus environment that fosters entrepreneurship. Employ a team of consultants to evaluate and assess ASU technologies and help take them to market. Fund "proof of concept" grants and develop early-stage university technologies. Promote technology marketing efforts through an "electronic forum." Increase business development services to ASU inventors. Increase outreach to the business and economic development communities.

Source: Morrison Institute for Public Policy, 2003.

Data: Arizona State University report: *Prop 301/Technology & Research Initiative Fund* – FY 2002 Results, July 2002.

STEPS AHEAD: OVERVIEW OF FY 2002 RESULTS AND ACCOMPLISHMENTS

A journey of a thousand miles begins with a single step. From hiring faculty members and research staff to updating equipment and sponsoring conferences to conducting research and winning grants, the six TRIF initiatives achieved most of their objectives and took many steps toward building the foundation on which future research and economic development will be based.

New Hires — Initiative leaders searched for and selected the faculty, researchers, and support staff needed to carry out their projects. These people also collaborated with professionals in the community and at ASU, prompted future developments, and supervised or supported graduate and undergraduate students.

NEW HIRES

BIOSCIENCES/ BIOTECHNOLOGY	INFORMATION SCIENCE	ADVANCED MATERIALS	MANUFACTURING	ACCESS & WORKFORCE DEVELOPMENT	TECHNOLOGY TRANSFER
1 faculty in bioengineering. 2 faculty in nutraceuticals and pharmaceuticals.	2 faculty in computer science/embedded systems. 1 faculty in information systems/knowledge systems. 1 faculty in bioinformatics.	1 faculty in computational materials. 2 process engineers for Center for Solid State Electronics Research. 1 support staff for Center for Solid State Science.	1 senior research associate for research support.	6 faculty in nursing, education, law, engineering/fine arts, English, and languages and literature to further teaching tech skills in all disciplines. 1 director of training operations for ASU East microelectronics teaching factory. 2 info-tech specialists in instructional support. 2 info-tech specialists in extended education. 1 info-tech specialist in data analysis. 1 info-tech specialist in Center for Learning and Teaching Excellence.	N/A

Source: Morrison Institute for Public Policy, 2003.

Data: Arizona State University report: *Prop 301/Technology & Research Initiative Fund* – FY 2002 Results, July 2002.

New Money — TRIF dollars attracted new funds to ASU and sharpened the focus of some ongoing efforts. For example, some initiatives leveraged TRIF money, adding more "external" dollars to university research efforts. Others redirected existing funds to initiative research. This category presents the total money generated by each initiative and provides examples of the new funds' sources and purposes.

NEW MONEY

BIOSCIENCES/ BIOTECHNOLOGY	INFORMATION SCIENCE	ADVANCED MATERIALS	MANUFACTURING	ACCESS & WORKFORCE DEVELOPMENT	TECHNOLOGY TRANSFER
$4.7 million received in new federal and industry awards, contracts, and donations. 56% increase shown in total value of ASU grant proposals written in biosciences — to $78 million.	$2.1 million received, including $1 million from Motorola and Intel for Consortium for Embedded and Inter-Networking Technologies; $715,000 in NSF funds to match ASU research seed funds, curriculum development, and internships; $300,000 industry funding for Connection One; $63,000 from Intel for Center for Advancing Business Through Information Technology.	$7.26 million received in federal and industry awards, including workforce development and NSF Integrative Graduate Education and Research Traineeship.	Over $550,000 awarded in new external funds, including $150,000 from Intel, $108,000 from Semiconductor Research Corporation, and $300,000 from National Science Foundation for studies of semiconductor supply networks.	N/A	$472,000 generated for ASU from value of all products and startups campus-wide.

Source: Morrison Institute for Public Policy, 2003.

Data: Arizona State University report: *Prop 301/Technology & Research Initiative Fund* – FY 2002 Results, July 2002.

New Ventures — New partnerships among ASU departments and between ASU and public and private sector entities began in the past year. Various research consortia, businesses, and alliances also resulted from the initiatives' activities.

NEW VENTURES					
BIOSCIENCES/ BIOTECHNOLOGY	**INFORMATION SCIENCE**	**ADVANCED MATERIALS**	**MANUFACTURING**	**ACCESS & WORKFORCE DEVELOPMENT**	**TECHNOLOGY TRANSFER****
Established partnership with U.S. Veterans Administration and National Institute of Diabetes and Digestive and Kidney Diseases for new research. Established partnerships for collaborative research with Mayo Clinic, Sunhealth, Barrow Neurological Institute, Scottsdale Healthcare, Bannerhealth, Arizona Health Sciences Dental School, Advanced Bionics, Medtronics, CreaAgri, and Intel. Helped establish consortium that attracted TGen to Phoenix. Signed agreements for joint projects with other TRIF initiatives, including Information Science and Advanced Materials.	Developed College of Business Center for Advancing Business through Information Technology. Established Consortium for Embedded and Internetworking Technologies with Motorola and Intel. Developed Connection One, a consortium of 6 firms and ASU for wireless technologies research.	Signed agreement with Sandia National Labs for participation in 3 interdisciplinary grants, 2 graduate fellowships, and 6 research projects. Developed National Science Foundation Industrial Partnership with Motorola. Subcontracted with Lockheed Martin on grant from Defense Advanced Research Project Agency. Formed SJT Micropower, Inc., a new startup.	Expanded projects to model semiconductor manufacturing supply networks.	N/A	5 new products entered market. 3 startup companies formed. 97 inventions disclosed. 108 patent applications made. 11 patents acquired. 9 licenses or options for industry adoption signed. Contracted for tech commercialization assistance. Contracted with High Tech MBA Partnership with W. P. Carey School of Business. Contracted with Master's Consulting Group. Formed alliances with The Indus Entrepreneur and Arizona Venture Capital Conference. Joined International Innovation Initiative, an academic consortium to bundle related technologies for marketplace. Contracted with Patent and Licensing Exchange for online marketing and licensing services.

Source: Morrison Institute for Public Policy, 2003.

Data: Arizona State University report: *Prop 301/Technology & Research Initiative Fund* – FY 2002 Results, July 2002.

** Invention disclosures, patent applications, patents, and startup companies for all initiatives are reported under Technology Transfer.

New Programs — Many activities for ASU students, faculty, or others in the community related to TRIF goals. This category also includes equipment and software purchased for specific research areas and throughout ASU, as well as awards and notable publicity received relative to the initiative.

NEW PROGRAMS

BIOSCIENCES/ BIOTECHNOLOGY	INFORMATION SCIENCE	ADVANCED MATERIALS	MANUFACTURING	ACCESS & WORKFORCE DEVELOPMENT	TECHNOLOGY TRANSFER
Upgraded lab facilities for the Health Assessment Core Facility to provide more research options and improve competitiveness for national grants.	Tested software engineering curriculum in 4 Phoenix-area high schools with 88 students. Established ASU Software Factory to provide professional software development for students and sponsored projects. Consortium for Embedded and Inter-Networking Technologies covered by *Electronic Times* and American Society for Engineering Education. 6 courses introduced or revised. ASU Information Systems graduate program ranked 10th nationally by *U.S. News and World Report*.	Won 5-year National Science Foundation Integrative Graduate Education and Research Traineeship grant for workforce development. Upgraded nanoscience joint use facilities with electron beam lithography system. Upgraded advanced materials/ microsystems joint use facilities with two new high density plasma deep etch systems.	Purchased test bed equipment for high technology manufacturing supply network research. Developed agenda for new research in high technology manufacturing supply network.	Upgraded technology in 8 classrooms and labs in College of Engineering and Applied Sciences, and Biology Department. Purchased server equipment and developed a portable module to provide technology support for classrooms campus-wide. Customized retention and graduation tracking software. Funded e-learning program development in technical communication, semiconductor manufacturing, fire service management, security engineering technology, environmental technology management, special ed, and Connect-MBA. Supported activities in applied computing at ASU West. Offered 72 new distance and online courses and 1 new online degree program. Established microelectronics teaching factory at ASU East. Developed "Intro to Information Technology" course for all students.	Provided business development services to ASU entrepreneurs.

Source: Morrison Institute for Public Policy, 2003.

Data: Arizona State University report: *Prop 301/Technology & Research Initiative Fund* – FY 2002 Results, July 2002.

New Skills — The initiatives worked to enhance skills among ASU graduate and undergraduate students, faculty and professionals, and others in the community. This was accomplished through 301-inspired projects, internship programs, seminars, workshops, and new curricula. Many meetings and conferences were also held to further understanding of ASU research and private sector business opportunities.

NEW SKILLS

BIOSCIENCES/ BIOTECHNOLOGY	INFORMATION SCIENCE	ADVANCED MATERIALS	MANUFACTURING	ACCESS & WORKFORCE DEVELOPMENT	TECHNOLOGY TRANSFER
16 graduate/postdoctorate students enrolled in 301-related programs. 11 undergraduates were given research experience on 301 projects. 5 interdisciplinary research workshops in neuroscience, environment and ecology of human and animal populations, musculoskeletal disease, immunology, and stress research. Hosted *Women's Health Forum* for ASU researchers and local health leaders.	32 internships gave students work experience in industry or ASU Software Factory. Hosted workshops, web sites, and meetings to develop interdisciplinary research and performance measures.	13 new graduate students enrolled in 301-related research programs. 28 undergraduates were given research experience on 301 projects.	1 postdoctorate student gained work experience in research support role. 8 research assistantships provided experience on 301 projects.	Hosted *Technology and Visualization in the College Classroom* for ASU faculty, community college faculty, and K-12 teachers. 96 faculty trained in technology course design.	Hosted individual and group conferences among ASU researchers and investors. Facilitated mentoring relationships between researchers and investors. Held joint activities with ASU entrepreneurial student organizations. Hosted more than 150 meetings and conferences on technology, research, and economic development. Hosted entrepreneurial education workshops with The Indus Entrepreneur and Arizona Venture Capital Conference for ASU constituents.

Source: Morrison Institute for Public Policy, 2003.

Data: Arizona State University report: *Prop 301/Technology & Research Initiative Fund* – FY 2002 Results, July 2002.

A JOURNEY OF A THOUSAND MILES BEGINS WITH A SINGLE STEP.

FROM HIRING FACULTY MEMBERS AND RESEARCH STAFF
TO UPDATING EQUIPMENT AND SPONSORING CONFERENCES
TO CONDUCTING RESEARCH AND WINNING GRANTS,
THE SIX TRIF INITIATIVES ACHIEVED MOST OF THEIR OBJECTIVES
AND TOOK MANY STEPS TOWARD BUILDING THE FOUNDATION
ON WHICH FUTURE RESEARCH AND ECONOMIC DEVELOPMENT WILL BE BASED.

Technology at ASU allows students to stay connected to their professors, their classmates, and the world. This access helps provide ASU graduates with the skills and experience necessary for success in the knowledge economy.

CONNECTIONS, ATTENTION, AND TALENT: A NEW FRAMEWORK FOR MEASURING THE LASTING VALUE OF SCIENCE AND TECHNOLOGY RESEARCH

The Steps Ahead tables presented in the previous section help to answer many traditional auditing questions necessary for tracking public programs. These tables reveal that a large number of constructive activities took place within ASU's 301-funded initiatives during FY 2002. But just as there is a qualitative difference between the person who possesses a lot of facts and the person who can organize such facts into problem-solving information or innovative products, the TRIF initiatives should add up to something more than just a tally of grants, activities, and personnel.

To help define what that "something more" should be for these diverse fields, Morrison Institute for Public Policy conducted a series of interviews with Arizona business, political, civic, and media leaders. What emerged from these conversations was a remarkable consensus and confidence that 301-funded research would result in the development of exciting new products and processes. More importantly, these leaders also felt that, as necessary as the ABOR-approved measures are for tracking how Proposition 301's TRIF monies are spent, these measures must be complemented by additional criteria that gauge the lasting value of TRIF spending for Arizona's economy. More than anything else, these leaders said they wanted to know:

- Did ASU and the business community become more closely tied because of TRIF spending, and are their fortunes now more mutually dependent?
- Did ASU's 301 projects bring acclaim to the state from those who can influence or contribute to Arizona's prosperity?
- Did the ASU initiatives help keep our state's best and brightest minds here and attract more like them?

Such questions, when considered in light of the best thinking about economic development and the new economy, strongly suggest that Arizona should develop an additional yardstick for measuring the value of its investment in university research — one that goes beyond simple auditing. Therefore, this section presents a new set of criteria to frame such an analysis.

Research projects expected to add value to the state's economy should be evaluated on the extent to which they:

Make CONNECTIONS among ASU researchers and external communities, especially individuals and businesses that could partner with ASU to commercialize its research

Attract ATTENTION to ASU's research, particularly at the national level and from people and organizations that can enhance Arizona's economy

Recruit, retain, and develop TALENT who will provide Arizona with the innovations, workforce, entrepreneurship, networks, and distinction it needs to compete

These new criteria — henceforth called the CAT measures — represent a means of "keeping score" on ASU's 301-related activities and outcomes. Growing evidence suggests that measuring up on these would place Arizona in a favorable position to compete in the new economy.

Success according to the CAT measures should enable the state to become a leader in creating and applying the knowledge that will produce a substantial economic impact. In short, the CAT measures provide Arizona with a truly original way to evaluate the long-term economic development contribution of public investment in university research.

WHAT'S THE VALUE-ADDED? SAMPLE CAT INDICATORS

CONNECTIONS

University researchers on boards of companies

Private sector participation in university lab work and events

Joint presentations by university and private sector

Licenses and joint ventures inspired by research

Interactions and personal relationships between university researchers and peers

ATTENTION

University exposure in national, state, and local media

Presentations by university researchers

Research information disseminated by the university

Hits on university research web sites

Industry recruitment of science and technology students

TALENT

Successful hiring and retention of top research faculty

Science and technology grad students attracted and retained

Private sector individuals trained through research projects

"Visitors-in-residence" associated with university research projects

K-12 outreach by university research projects

Source: Morrison Institute for Public Policy, 2003.

MEASURING CONNECTIONS

For purposes of analyzing ASU's Proposition 301 projects, the concept of "connections" focuses on research activities and interactions that link 301-funded research and researchers with individuals and organizations that can enhance, publicize, or commercialize this work.

Thus, measuring Proposition 301-inspired connections is one way of determining if ASU's research in science and technology is sufficiently networked to move it from the campus to the business community — in other words, from basic research to commercial product. Some indicators of connection include:

- ASU 301 researchers on boards of companies
- Private sector participants in 301-related lab work, discussions, and special events
- Joint presentations by 301 researchers and private sector
- Licenses and joint ventures inspired by 301 research
- Interactions and personal relationships between 301 researchers and peers at ASU and other universities

MEASURING ATTENTION

The National Governors Association has stated, "Although knowledge creation is a critical first step in the wealth-creation process, knowledge creates no wealth unless it is used."[1] In other words, good research, in isolation, is not enough to create long-term economic impact — someone outside the university must be aware of ASU's research breakthroughs for them to take effect. This is an obvious, yet easily overlooked, factor in analyzing the likelihood that a research investment will yield a return.

The power of this "attention factor" is illustrated by the recent opening of a University of Wisconsin technology transfer office...*in San Diego*. At first blush, this may sound like a boondoggle, but actually it is a smart move. After years of hard work, the San Diego region — particularly UCSD — has established itself as a leader in science and technology research, and earned an international reputation that draws venture capitalists and entrepreneurs. This success in new economy businesses is now widely acknowledged both in the press and by word-of-mouth, hence others, like the University of Wisconsin, have a legitimate reason for wanting to get in on the action.

When it comes to attracting attention, more is usually better. Therefore "getting the word out" on what 301 researchers are working on and the products they intend to create will increase the TRIF investment's economic potential. Measures of attention include:

- Exposure of ASU's 301 research or researchers in national, state, and local media
- Presentations by ASU 301 researchers, especially to large groups that include the private sector
- Information distributed by ASU 301 projects
- Hits on 301 research project web sites
- Targeted recruiting of ASU science and technology students

MEASURING TALENT

Attention and connections indicators are inextricably linked to the final CAT measure, talent — the pool of educated, creative, motivated workers in the state. In order for economic development to occur, university-based science and technology talent not only must be connected to external communities, but also must be recognized by the rest of the country. According to Bill Breen, writing in the magazine *Fast Company*, "Top talent isn't just found at Berkeley, MIT, and Stanford. There are plenty of great people hidden away."[2] One of economic development's challenges is to bring these people to light.

Not long ago, the keys for a region to attract business location and expansion decisions were low taxes, limited government regulation, and proximity to markets. Now, the main ingredient for attracting and retaining businesses has become talent. The National Governors Association, working with Harvard University's Michael Porter and the Council on Competitiveness, determined that an abundant, creative, scientifically literate work force will likely make the difference between winners and losers in the new economy. According to the NGA, "CEOs report that the availability of technically trained talent is their top priority — one that often determines where they locate high-value investments."[3]

Consequently, the degree to which ASU's 301 projects enhance Arizona's talent pool in science and technology represents an important measure of their contribution to the state's economy. Arizona, however, is not known as a state that attracts business development on the quality of its talent. Quite the contrary, Arizona is better known for its low standardized test scores among K-12 students and its relatively unremarkable percentage of residents with college degrees, especially among younger workers. This helps explain why a recent national study conducted by the Greater Phoenix Economic Council shows that business site selection consultants, national business writers, and top-level executives primarily identify the state with tourism and retirement industries. While these industries remain valuable assets, they must be complemented by a workforce that is scientifically and technically capable if the state is to benefit from the powerful wealth creation forces such people can unleash.

For now, Arizona does not trade on the attractiveness of its talent pool. Over time, the TRIF-sponsored initiatives could help change that. To gauge their success, they should be measured on the degree to which they help attract, develop, and retain the kind of talented labor pool that economic development professionals use to "sell" a state nowadays. Such talent in Arizona could produce a major downstream impact on the economy if it were to influence local business startups or add value to existing firms.

Ways to measure 301's contributions to the state's talent pool include:

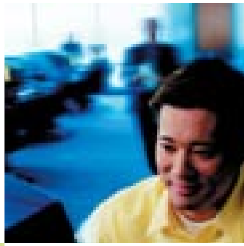
- Successful recruitment and retention of top faculty and staff researchers for 301 research
- Science and technology graduate students attracted and retained by 301 research projects
- Private sector individuals trained through ASU 301 projects
- "Visitors-in-residence" from universities and businesses working with ASU 301 projects
- K-12 outreach by ASU 301 projects

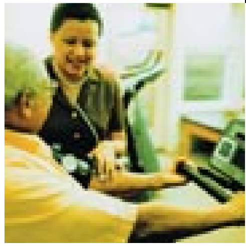
ANALYSIS OF VALUE-ADDED AT ASU

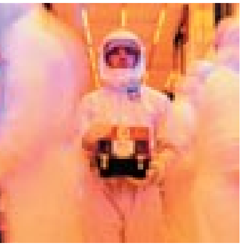
The CAT measures were developed to complement, not replace, outcome measures approved by ABOR. They are both a framework for thinking about long-term, big-picture economic development issues, and a set of indicators that, through systematic analysis, can be used to measure progress and tangible contributions to the state's economy.

ASU's six TRIF initiatives made accomplishments that fit the CAT paradigm during year one of the 20-year research program. But in fairness to the initiatives' first year — during which a great deal of time must be spent on organizing and staffing — and in recognition of the many activities that took place before this model was established, no attempt was made to compile a full accounting for FY 2002 using CAT indicators. Future analysis of 301 projects, however, as well as public investments in university research in the larger sense, should — and will — make this approach a useful yardstick for determining value-added.

As noted earlier, many Proposition 301-inspired activities at ASU have already helped Arizona establish new connections, gain attention, and begin to attract or develop new talent. Six examples are presented on the following pages to provide anecdotal evidence of how such indicators of success can be identified and how they can contribute economic value.







Building Capacity for Connections

Innovation takes place in trust networks that link university researchers, entrepreneurs, financiers, lawyers, and accountants to markets. The unit of innovation has become the network.

— Doug Henton
Collaboration and Innovation: the State of American Regions

FORCE PROJECT CONNECTS ASU RESEARCH TO INDUSTRY AND UNIVERSITIES

The Factory Operations Research Center (FORCe) is a program sponsored jointly by the Semiconductor Research Corporation (SRC) and International SEMATECH, two research consortia of semiconductor manufacturers. SRC and SEMATECH represent most of the major semiconductor companies operating in the world today. ASU is a major participant in the FORCe program.

FORCe coordinates five individual research projects for the two consortia. Each of these projects is aimed at a different strategy for improving the efficiency of wafer fabrication. In the semiconductor industry, wafer fabrication is the most costly manufacturing step, both in terms of *dollars* — a new fabrication factory, or "fab," costs $3 billion to build — and in terms of *time* — it often takes two months to complete the fabrication process, compared to only two weeks for all other manufacturing operations.

The goal of the FORCe program is to develop software tools and techniques that will allow consortium members to complete the fabrication process faster and cheaper with the same level of quality.

ASU professor John Fowler serves as the center director of FORCe. Two of the five research projects are also led by ASU faculty — each project involving collaboration with researchers at other universities. In addition, Fowler and the ASU team leaders serve on FORCe's "Core Team" made up of high-level representatives of selected consortium companies. The Core Team meets regularly to provide direction to the projects.

Proposition 301 funds help support several aspects of this research, including faculty salaries and graduate student stipends. Approximately seven ASU industrial engineering students are funded to work on high tech factory modeling. Upon completion of their degrees, these students are likely to be hired by sponsoring companies, thereby transferring university technology directly to the manufacturers. Faculty, also, are expected to interact with manufacturers and suppliers by visiting fabs and taking sabbaticals at member company plants.

Through FORCe and its research projects, ASU has established formal research connections with 11 universities around the country and the world, including Cornell University, University of California – Berkeley, University of Arkansas, Fraunhofer Institute (Germany), and National Taiwan University. In addition, ASU faculty and students have been connected with many of the world's semiconductor giants, including Advanced Micro Devices, IBM, Infineon Technologies, Intel, Motorola, ST Microelectronics, National Semiconductor, and Texas Instruments.

Furthermore, the FORCe projects continue to create new connections for ASU. For example, the ongoing FORCe research enabled ASU to win a prestigious NSF grant for the purpose of investigating related aspects of manufacturing modeling. This effort, led by ASU's Gerald Mackulak, is a joint project with researchers at Northwestern University, thereby connecting another institution to its network of universities interested in manufacturing systems research.

I-CUBED CONNECTS UNIVERSITIES THROUGH TECHNOLOGY TRANSFER

The International Innovation Initiative (I-cubed) provides a platform for connecting the technology transfer efforts of member universities throughout the world. Initiated under the leadership of Columbia University, I-cubed membership includes institutions from the United States, Canada, Great Britain, Sweden, and Taiwan.

The purpose of I-cubed is to bundle related research discoveries from member universities so that their combined technologies become more marketable. To accomplish this task, technology transfer offices at member institutions exchange patent lists and engage in presentations and analyses of their research technologies to identify areas that might form the basis for synergistic collaborations.

Arizona State University's first I-cubed collaboration matched Ig Tsong at ASU and Asif Khan at the University of South Carolina. The goal of these two research scientists is to build an economical light-emitting diode (LED) based on wide bandgap materials integrated onto a silicon wafer. Wide bandgap materials are characterized by their ability to operate at high temperature and emit light at the blue and ultraviolet end of the spectrum.

Tsong's contribution to this collaboration is the development of a new substrate material that allows wide bandgap semiconductors such as gallium nitride to bond to silicon wafers, and may enable LED fabrication at substantially lower cost than alternative approaches. This research has been supported by Proposition 301 funds. Khan's contribution is to use the substrate provided by Tsong and coworkers at ASU to create a new LED device.

If the collaboration between Tsong and Khan is successful, it will not only demonstrate the viability of Tsong's new substrate, but also could make a significant impact on the development of LED light sources for consumer applications, such as high-efficiency home lighting. Thus, a cross-university connection fostered by I-cubed will greatly increase the likelihood that these two researchers can speed their technical breakthroughs to the market and also attract licensing revenue for their work.

WOMEN'S HEALTH RESEARCH DRAWS ATTENTION OF KEY AGENCIES AND SCIENTISTS

The primary goal of AZBio is to foster interdisciplinary collaborative health research in the Phoenix metro area. Collaborative-minded health researchers, however, often have trouble finding one another in Arizona's largest metropolis. While the region is home to plenty of bioscience expertise, the talent pool is fragmented due to a decentralized system of independent hospitals, university science departments, private biotech firms, and other health care businesses and government agencies. This system tends to isolate people by distance, security issues, and in many cases, market competition.

AzBio's Kathy Matt, therefore, came up with a strategy to overcome some of the effects of this isolation. In May 2002, she teamed AzBio up with the governor's office to host the "Women's Health Research Forum." The idea was to pull together the region's best women's health researchers in a non-competitive setting at ASU so they could develop new cooperative research relationships. The forum was backed by ASU's Proposition 301 monies.

The day-long format of the forum was straightforward. A number of top women's health researchers made presentations describing their fields of work. Where interests overlapped, presenters and other participants had the opportunity to meet and discuss possible collaborations.

One of the morning sessions featured a hospital oncologist who reported on her clinical work involving breast cancer. Later, AzBio's Matt explained her research on the effects of stress on the body.

Something clicked for the oncologist — she told Matt that her patients frequently wanted to know how stress affects both their cancer and their treatment. The two researchers quickly joined forces to tackle this question, and they subsequently developed an interdisciplinary collaborative research proposal that has been submitted to NIH for funding.

The forum, however, did not only inspire new interdisciplinary collaborations; it also attracted significant attention on three levels: local, state, and national. First, in the regional domain of health research, it established ASU as a neutral venue for open discussion of bioscience research ideas — something not always available in the competitive, often secretive, atmosphere of the private sector. Second, it briefed representatives of state agencies on the value of ongoing research in the region, as well as the opportunities that may lie ahead. This bolsters policy arguments for expanding such research both for its medical and its economic potential. Third, the forum raised the Phoenix metro area's national profile in bioscience research by demonstrating to keynote speaker Dr. Wanda Jones — assistant deputy director of the Office of Women's Health, U.S. Office of Health and Human Services — that the region has a critical mass of research talent that should be further supported and funded. She has since "talked up" ASU to other women's health researchers in the country.

In addition, numerous radio and newspaper outlets publicized the forum, and a prominent news personality moderated the culminating lecture and discussion. In all, about 100 researchers, agency representatives, and policymakers attended the forum's events.

EMBEDDED SYSTEMS WORK ATTRACTS ATTENTION OF INDUSTRY AND NSF

The Consortium for Embedded and Inter-Networking Technologies (CEINT) was founded by ASU, Intel Corporation, and Motorola. The intent of the consortium is to increase knowledge and markets in the area of embedded technology — the tiny computer chips and their software that make modern appliances, networks, and other equipment appear to be "smart."

Proposition 301 funding pays for ASU's membership in the consortium, and also supports two faculty hired especially to augment embedded research and applications at the university.

A major goal of the consortium is to develop and strengthen ASU's curriculum in embedded technology so graduates are better prepared to work in this emerging field. To date the consortium has made direct awards of over $1million for research and curriculum development. This investment will eventually save the industry substantial time and money that would otherwise go to training new employees.

Associated with the curriculum thrust is an internship program in which graduate and undergraduate students work on faculty-supervised embedded technology projects at sponsoring companies. The internships give students real-world job experience while earning them course credits toward their degrees.

Another major goal of the consortium is to attract significant attention to both the university and the region as a global center for cutting-edge embedded systems research and manufacturing.

The consortium has managed to gain some important notice during its first year. For example:

- News articles on the consortium have appeared in local and national news media, as well as in national trade journals.
- Consortium members made presentations at national conferences, including an entire session on "embedded ecosystems" at the annual International Phoenix Conference on Computers and Communications (IPC3), and poster sessions on ASU's embedded technology curriculum at the annual conference of the American Society of Engineering Educators (ASEE).
- Motorola named ASU one of only five universities in the nation to receive targeted recruitment of its computer science and engineering graduates. Other targeted universities include MIT, Georgia Tech, and University of California, Berkeley.

In addition, the National Science Foundation saw enough promise in ASU's embedded technology curriculum project to award two major grants totaling $780,000 to support and expand curriculum development. At the same time, the consortium has been working actively to expand its base of industry and university members.

As a side benefit of the growing "buzz" surrounding consortium activities, ASU's Computer Science and Engineering (CSE) department has been able to attract highly regarded young talent in its latest faculty searches. Altogether, CSE has successfully filled five new positions in this competitive field in the past year.

Building Capacity for Attention

Promoting and marketing a region's industrial and research results serve to link the region's intellectual power to practical applications… the process attracts investments, venture capital, and talented workers.

— Ross Devol
America's High Tech Economy: Growth, Development and Risks for Metropolitan Areas,
Milken Institute

Building Capacity for Talent

The sine qua non of a modern economy is a well-educated, versatile work force able to conduct R&D and to convert its results into innovative products, processes, and services.

— A Governor's Guide to Building State Science and Technology Capacity, National Governors Association

BIO-NANO CURRICULUM CREATES INTERDISCIPLINARY TALENT

ASU's biomolecular nanotechnology graduate program links eight diverse research disciplines in engineering and the physical and life sciences through a Ph.D. program that promotes interdisciplinary teamwork. Among the research disciplines are chemical and materials engineering, molecular and cellular biology, physics, and plant biology. The goal of the program is to develop collaborative-minded researchers who can work effectively with their counterparts in other fields. Such teams are needed to perform cutting-edge research in many high tech companies.

Motorola, for example, is currently interested in developing molecular electronics. Lockheed/Martin is looking into ways to create living biosensors. And Kodak is investigating organic molecules that respond to and communicate with light. These types of research require the combined talents of scientists and engineers who understand the most advanced aspects of biotechnology, nanofabrication, materials science, nanoelectronics, biochemistry, and biophysics. To be successful, these researchers must also understand how to work together.

For ASU's bio-nano graduate students, the first research task has been to pool their individual talents to develop a nanoscale chemical delivery system. The finished device will employ a molecular motor that can "drive" to a specific position, burst open, and deposit the chemical on its intended target.

To accomplish their task, the bio-nano graduate students have had to learn chip fabrication techniques in a joint-use "clean room" facility located at ASU's Center for Solid State Electronics Research (CSSER). In this clean room, the students work under the guidance of a process technician funded by Proposition 301 monies. Additional support for the CSSER clean room has come from Intel, which donated the tools, and Motorola, which provided the installation expertise. Based on this support, plus the talent-building promise of the interdisciplinary curriculum, the bio-nano program won a prestigious IGERT (Integrative Graduate Education and Research Traineeship) grant from NSF in 2001.

The IGERT grant will support up to 10 new Ph.D. students each year — for a total of about 40 funded students in the program after four years. The IGERT students will also be eligible for internships at Arizona high tech companies to acquire work experience and become acquainted with potential employers.

The benefits of ASU's bio-nano program may reverberate in Arizona for years to come. Large high tech companies like Intel and Motorola often report that one of their most critical workforce challenges is finding the talent for interdisciplinary teams involved in advanced research projects. Now, however, the bio-nano program is training just such talent.

If past experience holds true, most of these students will be hired by local companies and remain in the state after graduation. These new leaders of science and engineering research will then provide the basis for attracting and mentoring the next generations of talented researchers for Arizona.

TECH-ORIENTED FACULTY AND COURSES STRENGTHEN FUTURE WORKFORCE TALENT

Technological advances have altered the landscape of the American work place and changed the way basic research is conducted in nearly every academic discipline. But while most students enter college with basic computer skills, they have not yet learned to apply these skills to their chosen fields. Therefore, Information Technology Across the Curriculum (ITATC) was conceived to better integrate technological changes into ASU's educational program. ITATC provides a campus-wide approach for upgrading the technology skills of all ASU students so they are better equipped to contribute to their professions upon graduation.

The main thrust of ITATC is to hire technology-oriented faculty in nontechnical academic departments across campus. ITATC facilitates these new hires by funding approximately half of their salary costs. The new faculty under ITATC are then held to the same discipline-specific standards as other members of their departments but, in addition, they are expected to model the use of their technology skills in the design and delivery of their classes. Their presence is intended to jump-start or accelerate the pace of technological change within their departments. The ITATC hires are also expected to assist colleagues in utilizing technology for their classrooms and research.

In its first year, ITATC helped fund six new faculty appointments involving seven disciplines: nursing, education, law, English, engineering/fine arts (a joint hire), and languages and literatures. More ITATC hires are anticipated for the future, including one each for psychology, political science, and justice studies. Proposition 301 monies support ITATC by providing the funds for shared salary costs of new tech-oriented faculty.

Languages and literatures professor Dan Gilfillan is one of the new faculty appointments resulting from an ITATC search conducted in FY 2002. For his spring 2003 course — "Digital Texts and Print Experiments" — students will examine the recent transition from print to digital technology and the impacts this transition has had on publishing, literary content, intellectual property rights, and the author-reader relationship. As part of their studies, the students will learn how to use the Internet to conduct research, and how to create electronic publications stemming from the results of their investigations.

New ITATC faculty, such as Gilfillan, will also assist in developing an interdisciplinary IT program for nontechnical majors. The introductory courses in this program are intended to provide a core competency in IT skills; however, each course will also be tailored to an individual academic discipline so it is relevant to a student's major. Subsequent courses will offer greater depth in computing and IT within the framework of nontechnical disciplines, leading to a total of six courses that can be taken as electives or as a minor in IT.

With greater technical skills, ASU graduates will be able to contribute to their employers more quickly in their new careers. This should strengthen Arizona's workforce and support continued economic development in the state.

ASU research specialist Jeffrey Thresher assists with studies of peptides and proteins in the Department of Kinesiology. The equipment he is using measures and analyzes how muscles relax, providing knowledge that may help treat heart disease in humans.

HEADING INTO THE FUTURE: NEW FOCUS FOR PROPOSITION 301-FUNDED RESEARCH

When ASU's TRIF projects were first conceived, they were structured as six discrete initiatives consisting of multiple individual components. This structure served as the setting for FY 2002 activities of the Proposition 301 initiatives and represents the startup phase of ASU's 301 research.

For FY 2003 and beyond, ASU's 301 research has entered a consolidation phase in which the nature of ASU's TRIF investments will be substantially reshaped. Components from different initiatives will be combined into one or more major integrated projects in order to foster large-scale interdisciplinary collaboration, a strategy considered necessary for conducting the next generations of science and technology research. At the same time, some investments will be redirected to other areas or to new projects altogether.

With this reshaping, boundaries between initiatives will tend to disappear, and focused, interdisciplinary "mega-projects" will dominate the research agenda. These mega-projects will align research efforts across a number of fields, spawning new research centers to draw together the best and most ambitious research faculty already at ASU. Areas of need will be shored up through recruitment of strategic new hires and graduate students.

As before, Proposition 301 investment dollars are expected to be leveraged by attracting grants and funding from corporations, consortia, federal agencies, and other institutions. The integrated nature of the mega-projects should provide additional opportunities for funding and collaborative relationships with such entities. ASU's mega-projects are also expected to increase the potential for research discoveries that create significant economic impact.

FIRST MEGA-PROJECT: ARIZONA BIODESIGN INSTITUTE

The first mega-project is an expansion of the biosciences initiative. This is signaled by a name change from the Arizona *Biomedical* Institute to the Arizona *Biodesign* Institute (AzBio). Under this reorganization, the scope of AzBio will be broadened considerably to include not only the biosciences, but also key aspects of materials science, information technology, and possibly manufacturing. AzBio will also be supported by targeted Proposition 301 investments in other areas, particularly workforce development and technology transfer.

The primary goal of AzBio will be to conduct research that can directly advance biomedicine, thereby bringing recognition to the Phoenix metro area as a biotech hub. AzBio will focus on two main areas:

1) *Biologics and Therapeutics by Design* will investigate vaccine production, new classes of pharmaceuticals from proteins and peptides, and rehabilitation engineering based on interfacing microelectronic systems with the central nervous system.

2) *Nano-Bio Systems by Design* will concentrate on ways to manipulate living systems at the molecular level to create nanoscale bio-optical (light activated) technologies, flexible microneural probes, "lab on a chip" biosystems, and other new sensing, analytical, or treatment technologies for human health.

Cross-cutting research on genomics and informatics will bridge these two areas. In addition, AzBio will house on-site technology transfer staff who will assist research teams in connecting their research discoveries to commercial enterprises.

To accommodate AzBio, a new 170,000-square-foot research facility has been approved for ASU's main campus. Construction is scheduled to begin in early 2003, with completion anticipated for 2004. This building will consist primarily of state-of-the-art laboratory and office space for bioscience and bioengineering, nanotechnology, and informatics. It will be designed to facilitate interactions and collaborations among researchers, and to have flexible space that can easily be reorganized to accommodate new research thrusts in coming years.

A portion of the new AzBio facility will be made available to other bioscience research organizations. Carl Hayden Veterans Administration Medical Center, for example, plans to lease space in the building to accommodate the hiring of at least a dozen new biomedical and bioengineering researchers. These researchers are expected to receive joint appointments at ASU. As more or different space is needed — possibly in three to five years — a second AzBio building is envisioned. Beyond that, a total of four AzBio facilities could eventually stand on the site.

CONTINUING INVESTMENTS: INDIVIDUAL PROJECTS

Several current research activities outside AzBio will continue to receive 301 funding. Some of these may, at some future date, be wrapped together in another mega-project. One proposal under consideration is for a large interdisciplinary project focusing on "cognitive ubiquitous computing" (CubiC) for improved human performance applications. This project would incorporate research on wireless nanotechnology for advanced-generation communication devices, interactive guidance systems for the blind and blind-deaf, networked sensors for environmental and security applications, and intelligent information fusion. Among the continuing projects and their parent initiatives are the following:

Information Science

The Consortium for Embedded and Inter-Networking Technologies (CEINT) is a research partnership with Intel and Motorola, created to increase knowledge and markets in the area of embedded technology. CEINT has already attracted substantial NSF funding and is working to enlist additional partners for its continued research.

Connection One (C-1) is a consortium comprised of ASU and six high tech companies, plus the National Science Foundation. The purpose is to conduct research on mixed-signal processing and wireless technologies. C-1 is actively recruiting new partners to expand its research.

The Center for Advancing Business through Information Technology (CABIT) conducts research on the implications of information technology for business. CABIT has formed a research relationship with Intel to conduct a number of projects, and it is currently developing new research relationships with public and private sector organizations.

Advanced Materials

Two related centers operate in conjunction with the Advanced Materials initiative. The Center for Solid State Science (CSSS) provides support for interdisciplinary research in solid state physics and chemistry, earth and planetary sciences, and materials research. The Center for Solid State Electronics Research (CSSER) provides support facilities for solid state electronics research across a wide range of disciplines including electrical, chemical, mechanical, and industrial engineering; materials science; and bioengineering. Both centers attract industry partnerships and federal grants. An NSF-funded IGERT program in biomolecular photonics makes use of CSSER facilities.

For 2003 and beyond, the two centers intend to provide staff support and equipment upgrades for cleanroom and other joint-use facilities. The IGERT program in biomolecular photonics will also continue, and will serve as a model for other new interdisciplinary graduate-level programs.

Manufacturing
This initiative will continue to focus on basic research related to manufacturing supply networks, with an emphasis on semiconductor manufacturing operations. Proposition 301 funding will support ongoing projects that involve partnership with Intel, two major semiconductor research consortia, and other universities both in the U.S. and abroad. In addition, the initiative intends to create new curricula and graduate programs to support the manufacturing industry's workforce, and also to form a nationwide university research consortium that includes MIT, Stanford, and University of Pennsylvania.

Workforce
Information Technology Across the Curriculum (ITATC) will continue its program for upgrading student IT skills campus-wide by helping to hire tech-oriented faculty in nontechnical majors. For 2003, ITATC intends to conduct 10 new searches for tenure-track faculty in liberal arts, justice studies, and other areas to be determined by a competitive process. These 10 new hires, when made, will fulfill ITATC's goal of helping fund a total of 16 new tech-oriented faculty by 2004.

The activities of AzBio will also be supported by investments of Proposition 301 funds in targeted workforce development strategies. These will take place in three areas:

- A proposed School of Life Sciences at ASU will offer interdisciplinary life science curricula for undergraduate students. The goal is to prepare students to engage in the type of graduate programs that are the basis for research at AzBio and other advanced research facilities.
- The Center for Research on Education in Science, Mathematics, Engineering, and Technology (CRESMET)—an alliance of ASU colleges of Education, Engineering and Applied Sciences, and Liberal Arts and Sciences—is intended to improve education for students in the areas of math, science, engineering, and technology. Proposition 301 funds will help expand the program to provide outreach to K-12 schools, with one of the goals of this outreach to establish a link with AzBio that will bring new research knowledge directly to the classroom
- The math and science honors program of the Institute for Strengthening Understanding of Math and Science (SUMS) currently works with gifted, disadvantaged K-12 students who might be interested in careers that require math and science. Proposition 301 funding will expand its focus to include both undergraduate and graduate students.

Technology Transfer
Technology Transfer staff will provide on-site support for AzBio, and will also continue to work with interested faculty to patent and license their research discoveries. In addition, ASU plans to introduce a comprehensive "technology venturing" program that will work directly with researchers, entrepreneurs, industry associations, economic development professionals, and service providers to build an "entrepreneurial infrastructure" that will help speed commercialization of new ASU technologies. The technology venturing program is expected to guide researchers and entrepreneurs from research discovery to startup company or business alliance, and will offer business development assistance that includes business plan writing, introductions to advisors and investors, and the services of a technology commercialization firm to assess the potential of new ASU technologies.

The chart on the following page summarizes continuing and anticipated activities for all six initiatives.

LOOKING BEYOND: WHERE THE INITIATIVES ARE HEADED

BIOSCIENCES/ BIOTECHNOLOGY	INFORMATION SCIENCE	ADVANCED MATERIALS	MANUFACTURING	ACCESS & WORKFORCE DEVELOPMENT	TECHNOLOGY TRANSFER
AZBio has been renamed the Arizona Biodesign Institute and has been broadened considerably to include aspects of materials science, information technology, and manufacturing. The initiative will concentrate on "Biologics and Therapeutics by Design," and "Nano-Bio Systems by Design."	The Consortium for Embedded and Inter-Networking Technologies is working to attract new funding and enlist new partners for its research. Connection One is expected to add new partners for further capacity in mixed signal processing and wireless technologies. The Center for Advancing Business Through Information Technology is partnering with Intel on research projects and developing new research relationships with public and private sector entities.	Upgrades and staff support will continue for the Center for Solid State Science and the Center for Solid State Electronics Research cleanroom facilities. The Integrative Graduate Education and Research Traineeship curriculum in biomolecular photonics will serve as a model for other interdisciplinary graduate programs.	Research partnerships with Intel and two major semiconductor consortia will continue to focus on manufacturing supply networks. New curricula and graduate programs will target industry workforce needs. A university research consortium is planned with partners nationwide.	Workforce activities will support AzBio in the following areas: development of a School of Life Sciences; funding for the Center for Research on Education in Science, Mathematics, Engineering and Technology and funding for the SUMS Math and Science Honors program. IT Across The Curriculum will participate in hiring 10 additional tech-oriented faculty for non-technical academic departments.	This initiative will provide on-site tech transfer staff at the new AzBio facility, and will continue to work with faculty to patent and license their discoveries. A planned technology venturing program will build an "entrepreneurial infrastructure" to guide new ASU technologies through startup or business alliance, and will offer business development assistance to ASU entrepreneurs.

Source: Morrison Institute for Public Policy, 2003.

Data: Arizona State University report: *Prop 301/Technology & Research Initiative Fund* – FY 2002 Results, July 2002; Draft *Arizona Biodesign 301 Business Plan*; Interviews conducted as of December 2002 with ASU administrators and principal investigators for TRIF initiatives.

THE MEASURE OF SUCCESS

Today's especially difficult economic times have been severely challenging for Arizona businesses and governments. However, the long-term economic investment represented by Proposition 301's Technology and Research Initiative Fund offers new opportunities and hope for Arizona's economic future.

This report presents a broad first look at the accomplishments and potential economic impact of Arizona's 20-year TRIF investment in ASU research. The first-year activities that were documented for the Arizona Board of Regents indicate that ASU's six initiatives engaged in numerous important research projects and support activities, and seem to have accomplished a great deal.

One notable achievement is that ASU's six initiatives attracted over $14 million in external financing through grants and partnerships in FY 2002. This amount is almost double their TRIF spending for the fiscal year, and nearly matches their total allocation. Such leveraging of Proposition 301 dollars implies that, as individual projects move forward and their joint ventures and partnerships mature, many have the potential to become self-supporting. Consequently, future TRIF financing could then be reinvested in other promising new endeavors in line with ABOR's goals.

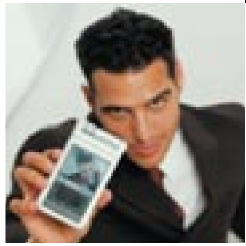
Ultimately, however, the measure of economic success for the Technology and Research Initiative will be the degree to which it contributes to Arizona's competitiveness in science and technology. In the knowledge economy, states with superior capacity to conduct and commercialize science and technology research will become the big wealth creators. The activities of a state's universities are an essential element for developing such capacity, and ASU has been engaged in this type of research for many years.

This report establishes a new framework for tracking the long-term, value-added contributions to the state from ASU's TRIF research projects. This framework goes beyond the traditional listing of activities and money generated. Instead, it describes new criteria called "CAT" measures (Connections, Attention and Talent) for determining the extent to which the TRIF projects yield lasting, productive economic connections for ASU, draw decision makers' attention to the state, and develop the creative talent and opportunities needed to make Arizona a competitive player in the knowledge economy. In combination, the traditional measures and CAT measures are a powerful means of analyzing both the annual and longer-term economic value of the TRIF investment.

At this very early stage, it appears that ASU's six initiatives are in a position to perform favorably under the new, value-added CAT framework. In fact, this report describes several ASU TRIF activities that illustrate important first-year accomplishments in line with the new measures. Yet these illustrations are anecdotal, not comprehensive evidence that ASU's projects will have the desired economic impact over the long haul. Those who judge the worth of 301's university investments must remember that TRIF is a marathon, not a sprint.

To determine whether the state's 301/TRIF research investment strategy is an economic development success, the initiatives will need to be regularly and systematically measured in terms of the research products they develop, the external funding they generate, and the connections, attention, and talent they produce for the university and the state. Collectively, these measures will enable Arizona to assess whether TRIF is a worthy investment of its public funds.

In the knowledge economy, states with superior capacity to conduct and commercialize science and technology research will become the big wealth creators.



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